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1	/	Cog. Mgr.	<i>JG Field</i>	<i>10/25/96</i>	G1-11	1	/	J.S. Hutchings	<i>J.S. Hutchings</i>	<i>10/25/96</i>	
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1	/	RL Clawson	<i>RL Clawson</i>	<i>10-25-96</i>	G1-13						
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Safety Evaluation for Packaging (Onsite) for the Concrete-Shielded RH TRU Drum for the 327 Postirradiation Testing Laboratory

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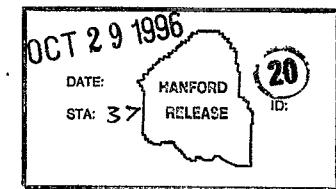
Key Words: transport, Type B quantities, Transuranic Waste Storage and Assay Facility, TRUSA, Solid Waste Storage Facility

Abstract: This safety evaluation for packaging authorizes onsite transport of Type B quantities of radioactive material in the Concrete-Shielded Remote-Handled Transuranic Waste (RH TRU) Drum per WHC-CM-2-14, *Hazardous Material Packaging and Shipping*. The drum will be used for transport of 327 Building legacy waste from the 300 Area to the Transuranic Waste Storage and Assay Facility in the 200 West Area and on to a Solid Waste Storage Facility, also in the 200 Area.

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LIST OF TERMS

ARF	airborne release fraction
ASTM	American Society for Testing and Materials
Bq	becquerel
Btu/h-ft-°F	British thermal units per hour-foot degree Fahrenheit
Ci	curie
cm	centimeter
dpm/cm ²	disintegrations per minute per square centimeter
EDE	effective dose equivalent
ECN	engineering change notice
IAEA	International Atomic Energy Agency
ID	inside diameter
in.	inch
ft	foot
ft-lb	foot-pound
g	gram
g/cm ³	grams per cubic centimeter
g/cm ²	grams per square centimeter
gal	gallon
J/kg-K	joules per kilogram kelvin
kg	kilogram
kg/m ³	kilograms per cubic meter
km	kilometer
km/h	kilometers per hour
ksi	1000-lb per square inch
lb	pound
lb/ft ³	pounds per cubic foot
m	meter
MeV	megaelectronvolt
μCi/cm ²	microcuries per square centimeter
mi	mile
MPa	megapascal
mph	miles per hour
mrem/h	millirem per hour
mSv/h	millisievert per hour
NCT	normal conditions of transport
PNNL	Pacific Northwest National Laboratory
psi	pounds per square inch
psia	pounds per square inch, absolute
rem/h	rem per hour
RH TRU	Remote-Handled Transuranic Waste
SARP	safety analysis report for packaging
SEP	safety evaluation for packaging
s/m ³	seconds per cubic meter
Sv	sievert
Sv/h	sievert per hour
TBq	terabecquerel
TCRP	total conditional release probability
TRU	transuranic (waste)
TRUSAF	Transuranic Waste Storage and Assay Facility
W/m ² -K	watts per square meter kelvin

SAFETY EVALUATION FOR PACKAGING (ONSITE) FOR
THE CONCRETE-SHIELDED RH TRU DRUM FOR THE
327 POSTIRRADIATION TESTING LABORATORY

PART A: DESCRIPTION OF OPERATIONS

1.0 INTRODUCTION

1.1 GENERAL INFORMATION

This safety evaluation for packaging (SEP) evaluates and documents the ability of the Concrete-Shielded Remote-Handled Transuranic Waste (RH TRU) Drum assembly to meet the packaging requirements of WHC-CM-2-14, *Hazardous Material Packaging and Shipping*, for the onsite transfer of Type B quantities of radioactive material. Onsite transfer is the transport of hazardous materials on controlled routes confined to established limited areas and to portions of federally owned roadways to which public access is prohibited during transfer.

This document shall be used by operations to ensure loading, tiedown of the packaging on the transport vehicle, and unloading are performed in agreement with WHC-CM-2-14. The analyses documented in this SEP demonstrate compliance of the Concrete-Shielded RH TRU Drum to the onsite transportation safety requirements.

The Concrete-Shielded RH TRU Drum will be used for transport of 327 Building legacy waste (hot cell debris) from the 300 Area to the Transuranic Waste Storage and Assay Facility (TRUSA) in 200 West Area and on to a Solid Waste Storage Facility, also in the 200 Area. The waste will remain in the drum for an indefinite period of storage at that facility.

This SEP demonstrates, by analysis or by reference to existing safety analysis reports for packaging (SARP), that the Concrete-Shielded RH TRU Waste Drum meets the onsite transportation safety requirements for Type B quantity packaging. Where possible, this SEP minimizes new analyses and draws upon the analyses, constraints, and logic of the *Safety Analysis Report for Packaging (Onsite) Internally Shielded 55-Gallon Drum* (SD-RE-SAP-043).

1.2 SYSTEM DESCRIPTION

The packaging consists of a 55-gal UN1A2 galvanized steel drum procured to U.S. Department of Transportation Specification 7A, Type A, and modified per Pacific Northwest National Laboratory (PNNL) drawing H-3-304541 and attached related engineering change notice (ECN) No. D01504-EDP01-FMP00-ECN01. Modifications include a steel inner cavity with concrete shielding on the sides and steel shielding on the top and bottom. The cavity has a steel shield plug and a gasketed and bolted steel cover. An impact-limiting foam

filler is provided between the shield plug and the cover. NucFil¹-013 filters are installed in the cavity cover and the drum lid to eliminate any possibility for pressure buildup. A removable sheet metal liner (H-3-304558 and attached related ECN No. D01504-EDP01-FMP00-ECN02) with a lifting bail provides a means of handling the waste containers (paint cans) during removal from the hot cell and insertion into the drum. It remains in the drum with the payload.

Tiedown of the package for transport will be accomplished using a modified application of standard techniques as specified in Section 4.2.

1.3 EXPIRATION

Use of this SEP is limited to a period of one year from the date of the first shipment. If it becomes desirable to maintain the packaging design for ongoing use, it will be necessary to prepare a SARP.

¹NucFil is a trademark of NFT Incorporated.

2.0 PACKAGING SYSTEM

2.1 CONFIGURATION AND DIMENSIONS

The Concrete-Shielded RH TRU Waste Drum has the external dimensions of a standard UNIA2 55-gal galvanized carbon steel drum. The inner cavity is 8-in. schedule 40 carbon steel pipe (7.891-in. inside diameter [ID] x 0.322-in. wall) with a usable inside height of 62.23 cm (24.5 in.). The removable sheet metal liner has an ID of approximately (17.58 cm [6.92 in.]). The upper section of the inner cavity is formed by an 8-x-10-in. schedule 40 concentric reducer fitted with a flange on the exterior of the 10-in. end. A 6.35-cm- (2.5-in.-) thick steel shield plug fits in the tapered transition of the reducer. A 1.9-cm- (0.75-in.-) thick steel cover and silicone gasket fit on the upper (10 in.) end of the reducer and is secured to the flange with 12, $\frac{1}{2}$ -in.-diameter steel bolts. A polyurethane foam impact limiter is placed between the shield plug and the bolted cover. The bottom end of the cavity is closed and shielded with a 6.35-cm- (2.5-in.-) thick steel plate welded to the 8-in. pipe. NucFil filters are installed in both the inner cavity cover plate and the drum lid. Concrete (20.68 MPa [3000 psi] minimum compressive strength with a density of 2,307 to 2,643 kg/m³ [144 to 165 lb/ft³]) fills the annulus between the sides of the inner cavity and the drum wall to provide radial shielding. The maximum weight of the drum, including contents, shall not exceed 657.7 kg (1,450 lb).

2.2 MATERIALS OF CONSTRUCTION

The inner cavity pipe is American Society for Testing and Materials (ASTM) A106, Grade B, carbon steel. The reducer is ASTM A234, Grade WPB, carbon steel. The cavity flange is ASTM A516 normalized carbon steel, and the cover plate is ASTM A516 carbon steel, normalized and produced to fine grain practice. The bottom plate is ASTM A516, any grade, carbon steel, normalized and produced to fine grain practice.

The gasket is solid silicone rubber ZZ-R-765 Class 2, 70 +/- 5 Durometer, or equivalent. The impact limiter is LAST-A-FOAM² FR-6704 polyurethane foam, 64 kg/m³ (4 lb/ft³) density.

The basic drum is 18-gage (or heavier) galvanized carbon steel with an 18-gage (or heavier) galvanized carbon steel lid, a standard gasket, and a standard bolted lock ring.

2.3 DESIGN AND FABRICATION METHODS

Design of the Concrete-Shielded RH TRU Waste Drum was performed for PNNL by ICF Kaiser Hanford Company with structural input from Westinghouse Hanford Company, Packaging Engineering. Fabrication will be performed in accordance with drawing H-3-304541 and ECN No. D01504-EDP01-FMPO0-ECN01 (drum) and with

²LAST-A-FOAM is a trademark of General Plastics Manufacturing Company.

drawing H-3-304558 and ECN No. D01504-EDP01-FMP00-ECN02 (removable liner). Materials of construction shall be as identified on the drawings.

2.4 WEIGHTS AND CENTER OF GRAVITY

The gross weight of the loaded Concrete-Shielded RH TRU Waste Drum shall not exceed 657.7 kg (1,450 lb). The maximum tare weight for the empty packaging is calculated as 630.5 kg (1,390 lb) when fabricated with concrete of the maximum density specified on the drawing. The maximum estimated payload weight is 13.6 kg (30 lb) (up to six paint cans at 2.3 kg [5 lb] each). The tare weight of each paint can is estimated at 0.34 kg (0.75 lb).

The center of gravity for the loaded container is calculated to be 43.7 cm (17.2 in.) from the bottom end with concrete of $2,403 \text{ kg/m}^3$ (150 lb/ft³). Center-of-gravity variations with concrete of other densities within the specified range are negligible.

2.5 CONTAINMENT BOUNDARY

Primary containment in this packaging is provided by the inner cavity structure, which has heavy walls and a substantial bolted cover. The drum provides a secondary containing function as well as structural support and strength to the concrete shielding. NucFil filters in both the inner container cover and the drum lid prevent pressure buildup while preventing radionuclide release.

This packaging provides markedly better containment of the payload than either the *Transuranic Radioactive Material in the 55-Gallon Drum*, HCS-042-002, *Safety Analysis Report for Packaging (Onsite)* (SD-RE-SAP-033) or the SD-RE-SAP-043 SARP. Both of these packagings rely on the drum itself for primary containment with additional containment provided by a 0.10-mm- (4-mil-) thick polyethylene liner, which is horsetailed and taped for closure.

2.6 CAVITY SIZE

The inner cavity of the Concrete-Shielded RH TRU Waste Drum is 20.27 cm (7.981 in.) ID by 62.23 cm (24.5 in.) usable depth. The removable liner reduces the usable diameter to approximately 17.58 cm (6.92 in.).

2.7 HEAT DISSIPATION

Decay heat within the Concrete-Shielded RH TRU Waste Drum is considered negligible because it is expected to be less than 1 W.

2.8 SHIELDING

Shielding on the sides of the drum is provided by approximately 17 cm (6.7 in.) of concrete plus approximately 0.9 cm (0.35 in.) of steel (pipe wall

plus drum wall). The concrete has a compressive strength of 20.68 MPa (3,000 psi) and a density of 2,307 to 2,643 kg/m³ (144 to 165 lb/ft³).

Shielding on the bottom is provided by 6.35 cm (2.5 in.) of steel plus the drum bottom thickness.

Top shielding consists of a 6.35-cm (2.5-in.) steel shield plug and a 0.34-cm. (0.75-in.) inner cavity cover, plus the drum lid (0.16 cm [0.062 in.]).

2.9 LIFTING DEVICES

Connection to the drum for lifting shall be with a lifting attachment designed for lifting 55-gal removable-head (but with the head installed) drums by the chime and having a rated load in excess of 657.7 kg (1,450 lb). The actual lift shall be by crane or other suitable means. No pick points are provided on the drum other than the standard drum chime.

2.10 TIEDOWN DEVICES

There are no tiedown devices that are a structural part of the package; therefore, the 10-5-2g requirement of 49 CFR 173 is not applicable.

Drums will be secured to the truck as specified in Part A, Section 4.2.

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3.0 PACKAGE CONTENTS

3.1 GENERAL DESCRIPTION

The Concrete-Shielded RH TRU Waste Drum contents consist of 327 Building legacy waste (hot cell debris), typically comprised of the following: paper towels, grinding disks, cloth wipes and towels, plastic bags and vials, steel and aluminum tools and fixturing, manipulator boots, stainless steel wool, and broken glass. There will be no chemicals, free liquids, or absorbed organic liquids. No fuel debris will be included other than that which may be in smearable form on other debris.

The material to be shipped (legacy waste) consists primarily of nonradioactive materials that have been contaminated with radioactive materials. Therefore, on either a volume or weight basis, the majority of the contents can be expected to be made up of nonradioactive materials.

The debris will be placed in 1-gal paint cans prior to loading into the removable inner liner of the drum. The paint cans will be punctured to preclude any pressure buildup. The available space will accommodate up to three uncrushed paint cans. Crushed paint cans may also be used with an expected quantity of up to six. The actual limit shall be dictated by the activity assay, which shall not exceed the limits of the source term specified in this section.

3.2 CONTENTS RESTRICTIONS

The activity of the contents shall not exceed the source term shown in Table A3-1 for either transuranic (TRU) or non-TRU materials. The total fissile material shall not exceed 15 g. The dose rate at the outside surface of the loaded drum shall not exceed 100 mrem/h. If a loaded drum is found to exceed this value, the contents shall be repackaged to reduce the dose rate to that level.

The contents shall not contain chemicals, free liquids, or absorbed organic liquids. There shall be no fuel debris other than that which may be in smearable form on other debris.

Table A3-1. Source Term for One Drum. (Bq)

Isotope	Ratio supplied by PNNL	Renormalized inventory	A_2 (TBq)	Fraction of A_2
^{235}U	2.09×10^3	5.26×10^2	Unlimited	0
^{238}U	1.04×10^6	2.62×10^5	Unlimited	0
^{238}Pu	9.10×10^8	2.29×10^8	2×10^{-4}	1.14
^{239}Pu	1.15×10^9	2.89×10^8	2×10^{-4}	1.44
^{240}Pu	1.14×10^9	2.87×10^8	2×10^{-4}	1.43
^{241}Pu	3.92×10^{10}	9.87×10^9	1×10^{-2}	0.988
^{242}Pu	4.18×10^5	1.05×10^5	2×10^{-4}	5.25×10^{-4}
^{241}Am	1.12×10^9	2.82×10^8	2×10^{-4}	1.41
^{244}Cm	9.62×10^7	2.42×10^7	4×10^{-4}	0.0606
^{134}Cs	4.33×10^9	1.09×10^9	0.5	2.18×10^{-3}
^{137}Cs	3.70×10^{10}	8.48×10^9	0.5	1.7×10^{-2}
$^{137m}\text{Ba*}$	3.50×10^{10}	8.81×10^9	0	0
^{90}Sr	1.42×10^{10}	3.57×10^9	0.1	3.57×10^{-2}
$^{90}\text{Y*}$	1.42×10^{10}	3.57×10^9	0	0
^{54}Mn	8.99×10^8	2.26×10^8	1	2.26×10^{-4}
^{60}Co	7.70×10^8	1.94×10^8	0.4	4.85×10^{-4}
^{125}Sb	2.01×10^9	5.06×10^8	0.9	5.63×10^{-4}
^{154}Eu	3.53×10^9	8.89×10^8	0.5	1.78×10^{-3}
Total	1.55×10^{11}	3.83×10^{10}		6.54

*Daughter product.
PNNL = Pacific Northwest National Laboratory.

4.0 TRANSPORTATION SYSTEM

4.1 TRANSPORTER

The transport vehicle shall consist of a flatbed truck or trailer, with a wooden deck, having sufficient capacity for the intended load. This SEP allows decks up to 238.8 cm (94 in.) wide. Significantly wider trucks, such as lowboys, will require increased tiedown tension and must be evaluated prior to use.

This is a deviation from SD-RE-SAP-043, which specifies either a closed or stake-bed truck for intra-area shipments and a closed truck for interarea shipments. A flatbed truck is acceptable in this case due to the significantly improved container design and tiedown requirements. The current container uses a substantial steel inner container with a bolted cover versus the plastic bag used in SD-RE-SAP-043. In addition, the inner container is the primary containment rather than the drum, as is the case in SD-RE-SAP-043.

The total number of drums allowed per shipment shall not exceed the following:

- 24 drums if of maximum allowable source inventory
- 30 drums if of less-than-maximum inventory and dose rates around the loaded truck do not exceed the limits of Part B, Section 5.4.2
- The rated capacity of the transporter.

4.2 TIEDOWN SYSTEM AND CARGO CONFIGURATION

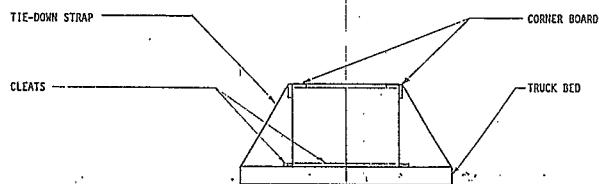
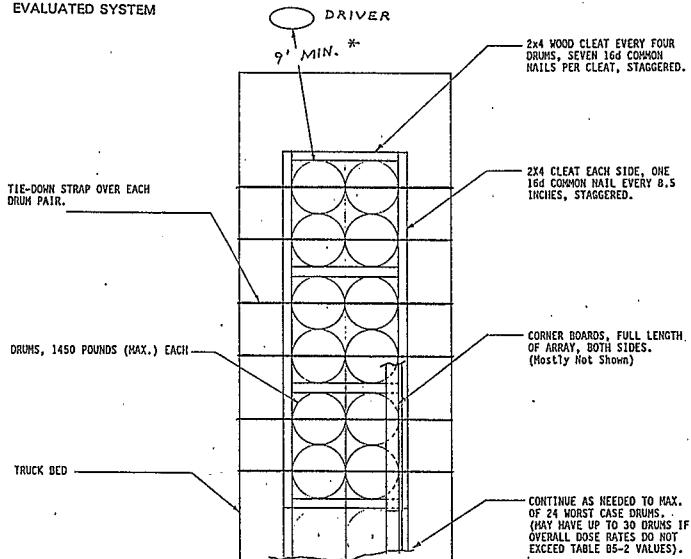
Drums shall be placed on the transport trailer in a double row down the longitudinal centerline. Stacking of drums is not permitted. The foremost pair must be positioned sufficiently far back from the front of the trailer to keep the front drums no less than 2.74 m (9 ft) from the driver if they are of maximum allowable activity. Drums of lesser activity may be closer, but in any event positioning shall not result in a dose rate greater than 0.02 mSv/h (2 mrem/h) in the occupied space of the cab. The drums shall be secured as specified in this section and as illustrated in Figure A4-1. The specified tiedown method meets all requirements of 49 CFR 393.100 through 393.104 and provides restraint sufficient for loadings of at least 0.62g forward and 0.5g to the sides or rear.

Drums may be positioned in two separate arrays if needed to balance axle loading: one group near the front axles and the other group over the rear axles.

Primary restraint is provided by 2x4-in. wooden cleats nailed to the trailer deck. Over-the-top tiedown straps are necessary to prevent tipping. A pair of 2x6-in., or larger, wooden corner boards shall be installed longitudinally along both top edges of the drum array to distribute strap loads and prevent straps from slipping off the drums. Each transverse pair of drums shall be secured by one strap, located on the centerline of the drums.

Figure A4-1. Truck Loading Arrangement and Details.

EVALUATED SYSTEM



NINE FOOT MINIMUM APPLIES IF THE FRONT DRUMS ARE AT MAXIMUM ALLOWABLE ACTIVITY. IF THEY ARE LESS THAN MAXIMUM, THE DISTANCE CAN BE REDUCED BUT SHALL NOT RESULT IN A DOSE RATE GREATER THAN 2 mrem/hr IN THE NORMALLY OCCUPIED SPACE OF THE CAB.

It should be noted that within the tiedown analysis contained in Part B, Section 10.0, a minimum strapping tension requirement of 3,366.7 kg (3,013 lb) is specified. In the event that no tension measuring equipment is available, standard rigging/securing tensioning practices shall be used.

All components of the tiedown assemblies, including the attachment points on the vehicle, shall have a working load limit of at least 1,366.7 kg (3,013 lb). Web straps shall be used due to the need for the tiedown to slip slightly on the corner boards during tightening. It may be helpful, during the tightening process, to rap the corner boards with a hammer adjacent to the strap to encourage the slip that must occur for the tension to equalize.

All tiedown hardware (straps, tighteners, and anchor points) shall be inspected prior to use to verify there is no damage or significant wear that could affect their satisfactory performance.

Wooden 2x4-in. cleats nailed to the truck deck provide the primary lateral and fore/aft restraint for normal conditions. Nailing requirements are shown in Figure A4-1.

Cleats shall be installed on both sides and in front and back of the drum array. In addition, cleats shall be installed between each group of four drums. These intermediate cleats limit the potential load on any one cleat to that due to four drums.

4.3 SPECIAL TRANSFER REQUIREMENTS

4.3.1 Routing and Access Control

Shipments shall be on Hanford Site roads between the 300 Area and the TRUSAf/Solid Waste facilities in 200 West Area. The route from the 300 Area to the Wye Barricade shall be by Route 4 South, and road closure is required for that segment. The route from the Wye Barricade to the 200 West Area shall be by Route 4 South and Route 3, and road closure is not required. Escort vehicles are required for the entire trip, including that portion beyond the Wye Barricade.

4.3.2 Radiological Limitations

For transportation purposes, the dose rate at the external surface of any individual Concrete-Shielded RH TRU Waste Drum is limited to 2 mSv/h (200 mrem/h) (49 CFR 173.441) without special provisions. However, the surface dose rate limit specified by *Hanford Site Solid Waste Acceptance Criteria* (Willis 1993), para. 5.4.2.2, is 1 mSv/h (100 mrem/h). This more restrictive limit will take precedence for the shipments covered by this SEP. The dose rate in the occupied space of the truck cab shall not exceed 0.02 mSv/h (2 mrem/h). The dose rate measured at a vertical plane projected from the outer edge of the vehicle is limited to 2 mSv/h (200 mrem/h), and the dose rate at any point 2 m from the plane described above is limited to 0.2 mSv/h (20 mrem/h). If further clarification is needed, see Part B, Section 5.4.2.

Surface contamination limits for the outside of the drum are specified in Table A4-1.

Table A4-1. External Container Contamination Limits.

Contaminant	Maximum permissible limits	
	$\mu\text{Ci}/\text{cm}^2$	dpm/cm^2
Beta-gamma emitting radionuclides; all radionuclides with half-lives less than ten days; natural uranium; natural thorium; uranium-235; uranium-238; thorium-232; thorium-228 and thorium-230 when contained in ores or physical concentrates	10^{-5}	22
All other alpha emitting radionuclides	10^{-6}	2.2

Source: 49 CFR 173.443, 1996, "Shippers-General Requirements for Shipments and Packagings," Code of Federal Regulations, as amended.

4.3.3 Speed Limitations

The risk evaluation does not impose a more restrictive speed limit than the normal highway speed of 88.5 km/h (55 mph). During intersection type turns, speed shall be limited to 8 km/h (5 mph) maximum.

4.3.4 Environmental Conditions

Loaded Concrete-Shielded RH TRU Waste Drums shall not be transported when there is snow or ice on the roadway or when the ambient temperature is below -12.2 °C (10 °F). This temperature limit is dictated by the steel used in the inner cavity.

4.3.5 Frequency of Use and Mileage Limitations

Within the confines of the current program, the packaging is a single-use container. It will be loaded, transported to TRUSA/AF/Solid Waste, and stored for an indefinite time. Any future movement or reuse of the packaging would have to be addressed at that time.

The risk analysis allows a maximum of seven shipments and a maximum of 30 drums per shipment, for an ultimate total of 210 drums. The shielding analysis limits the number of drums per shipment to 24 if all drums are of maximum allowable radiological inventory. The number of drums per shipment can be increased to a maximum of 30 if some of the drums are loaded with less than the maximum inventory and provided the radiological limits specified in Section 4.3.2 are met.

The mileage per trip shall not exceed 40.2 km (25 mi). This limits the route to that specified in Section 4.3.1.

Use of this SEP is limited to a period of one year from the date of the first shipment.

5.0 ACCEPTANCE OF PACKAGING FOR USE

5.1 NEW PACKAGING

New packagings shall be fabricated to the requirements of H-3-304541, Rev. 0, and ECN No. D01504-EDP01-FMP00-ECN01 (drum) and H-3-304558, Rev. 0, and ECN No. D01504-EDP01-FMP00-ECN02 (removable liner). Any changes to the drawings will require review by Packaging Engineering for effects on the SEP and could necessitate an engineering change notice to the SEP.

5.1.1 Acceptance Requirements

Newly fabricated Concrete-Shielded RH TRU Waste Drums shall be inspected for compliance to the requirements of the applicable drawings. The inspection may be performed by either the fabricator's or the user's Quality Assurance/Quality Control function. In either case, evidence of a satisfactory inspection shall be provided. As a minimum, acceptable verification shall be provided to assure that the procured drums (prior to modification and addition of shielding) are certified as U.S. Department of Transportation Type A packaging, that other materials meet the drawing requirements and that all welding meets ANSI/AWS D1.1-89 (AWS 1989) inspection requirements (as a minimum).

5.1.2 Inspection and Testing

The Concrete-Shielded RH TRU Waste Drum is a single-use item; therefore, every drum loaded will be a new drum. It will be loaded, transported to TRUSAF/Solid Waste, and placed in indefinite storage. Damage and deterioration associated with multiple usage will not occur. There are no testing requirements for this packaging.

The following pre-use checks are necessary to identify any damage or deterioration that might have occurred to new (empty) drums during storage or transit.

1. Visually verify that there is no damage to the drum, drum lid, gasket, closure ring, or sealing surface such as that which might be caused by dropping or other abuse.
2. Visually verify that there is no damage to the inner cavity cover gasket, sealing surface, or bolts.
3. Visually verify that the foam impact limiter is not missing.
4. Visually verify that the Nucfil filters are installed in both the inner cavity cover and the drum lid and that they are not damaged.

5.2 PACKAGING FOR REUSE

The packaging is not authorized for reuse.

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6.0 OPERATING REQUIREMENTS

6.1 GENERAL REQUIREMENTS

The following requirements apply to the use of the packaging. Specific operating procedures, with appropriate Quality Assurance/Quality Control hold points, shall be written by the user and approved by Packaging Engineering prior to use to ensure the requirements of the SEP are met.

For loading/unloading operations, the following shall be inspected or verified, as appropriate.

1. Visually inspect container exterior for damage.
2. Visually inspect the drum seal and sealing surfaces for damage.
3. Visually inspect the inner cavity gasket and sealing surfaces for damage.
4. Verify torquing of inner cavity closure bolts to a minimum of 25 ft-lb.
5. Verify torquing of the drum lid locking ring bolt to 40 ft-lb (nominal).
6. Visually inspect tiedown hardware for loose connections, cracks, or damage.
7. Verify proper positioning on, and tiedown to, the transporter per Figure A4-1.
8. Verify no more than seven shipments are made and no more than 30 drums per shipment.

6.2 LOADING PACKAGE

The following loading steps include some that are of concern only to laboratory operations and are subject to change by the laboratory with no effect on this SEP. Those steps identified with an * are pertinent to the SEP and may not be changed without review by Packaging Engineering.

1. Remove drum lid, inner cavity cover, foam impact limiter, steel shield plug, and removable liner.
- 2.* Perform pre-use inspection of drum per Section 5.1.2 and document inspection.

3.* Survey loaded paint cans for compliance with limits of this SEP (gamma scan, assay, dose rate, punctures, or other as applicable).

NOTE: Surveys and assays shall ensure the following requirements are satisfied.

- Dose rate at the drum surface shall not exceed 100 mrem/h.
- Contents shall be within the limits of the source term.
- Fissile content shall not exceed 15 g per drum.

4. Transfer drum liner into the cell per laboratory procedure.
5. Make arrangements with TRUSA/FSW to accomplish any advance waste certification steps that might preclude problems concerning acceptance of the waste at TRUSA. (The current understanding is that the drum weight prevents x-raying at TRUSA and that alternative means will be necessary to verify contents.)
6. Load cans into liner (maximum of three uncrushed or six crushed depending on the activity assay results [cannot exceed limits of the specified source term]).
7. Position the drum horizontally outside the cell port.
8. Transfer loaded liner out of the cell and into the drum per laboratory procedure.
9. Check dose rate at exterior surface of drum (< 100 mrem/h).
10. Rotate drum to partially or fully upright position (per laboratory procedure).
- 11.* Place steel shield plug in mouth of drum cavity.
12. Rotate drum to vertical (if not already).
- 13.* Install foam impact limiter on top of shield plug.
- 14.* Place inner cavity cover (with gasket) in position.
- 15.* Check dose rate at exterior surfaces of drum. If above acceptable limit of 100 mrem/h, return contents to the cell.
- 16.* Install inner cavity cover bolts and torque to 25 ft-lb minimum.
- 17.* Install drum lid and locking ring with bolt and lock nut. Position the lock nut between the locking ring lugs. Torque the locking ring bolt once to a nominal 40 ft-lb and tighten the lock nut.

- 18.* Check that external smearable contamination is within the limits of 49 CFR 173.443 (Table A4-1).
19. Transfer the loaded drum to holding area or to the transporter.

6.3 TRUCK LOADING AND TRANSPORTING

Those steps identified with an * are pertinent to the SEP and may not be changed without review by Packaging Engineering.

- 1.* Locate the first pair of drums a minimum of 2.74 m (9 ft) from the occupied space of the truck cab if the drums contain the maximum allowable activity. Drums of less than maximum activity may be placed closer than 2.74 m (9 ft), but shall be positioned to limit the dose rate in the cab to a maximum of 2 mrem/h.
- 2.* Position and secure the loaded drums on the transporter per Part A, Section 4.2, and Figure A4-1.
- 3.* Check that all requirements of Part A, Section 4.3, are met.
- 4.* Prepare shipping papers.

6.4 UNLOADING PACKAGE

The step identified with an * is pertinent to the SEP and may not be changed without review by Packaging Engineering.

1. Remove the transport tiedowns and corner boards.
2. Lift the drums individually with a crane or other lifting method in conjunction with a suitable drum lifting attachment. Place in required location.
- 3.* Receive shipment (complete shipping papers).

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7.0 QUALITY ASSURANCE REQUIREMENTS

7.1 GENERAL REQUIREMENTS

Quality assurance requirements related to design, procurement, fabrication, and use of the Concrete-Shielded RH TRU Waste Drum shall be based on PNNL's hazardous material shipping program as described in PNL-MA-81, *Hazardous Material Shipping Manual*, and to applicable portions of PNL-MA-70, *QA Manual*.

PNNL shall be responsible for fabrication of the Concrete-Shielded RH TRU Waste Drum to the requirements of drawings H-3-304541 (drum) and H-3-304558 (liner) and attached related ECNs (see Part A, Section 10.0). Inspection requirements shall be as required by PNL-MA-70.

The following features or operations are considered critical to fabrication:

- Materials for inner cavity fabrication
- Welding and weld inspection on the inner cavity
- Concrete density.

PNNL shall be responsible for packaging and shipping each drum in compliance with a PNNL-approved safe operating procedure, the requirements specified in this SEP, and those requirements contained in PNL-MA-81.

7.2 SEP CONTROL SYSTEM

The Concrete-Shielded RH TRU Waste Drum SEP shall be a supporting document to ensure that only an up-to-date SEP is used for transfer of radioactive materials. SEP changes shall be provided as engineering change notices and shall be provided to all holders of this SEP. SEP review records (comments) shall be retained by Packaging Engineering for the life of the system. These records are not considered quality assurance records, but provide historical evidence of SEP review and approval.

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8.0 MAINTENANCE

Due to the single-use nature of the Concrete-Shielded RH TRU Waste Drum and the one-year limit on this SEP, there are no maintenance requirements for either the container or associated tiedown hardware. Pre-use inspections for new containers are covered in Part A, Section 5.1. Pre-use inspections for tiedown hardware are covered in Part A, Section 4.2.

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9.0 REFERENCES

49 CFR 173, 1994, "Shippers-General Requirements for Shipments and Packagings," *Code of Federal Regulations*, as amended.

49 CFR 393, 1994, "Parts and Accessories Necessary for Safe Operation," *Code of Federal Regulations*, as amended.

AWS, 1989, *Structural Welding Code--Steel*, ANSI/AWS D1.1-89, American Welding Society, Miami, Florida.

PNL-MA-70, *QA Manual*, Pacific Northwest National Laboratory, Richland, Washington.

PNL-MA-81, *Hazardous Material Shipping Manual*, Pacific Northwest National Laboratory, Richland, Washington.

SD-RE-SAP-033, *Transuranic Radioactive Material in the 55-Gallon Drum, HCS-042-002, Safety Analysis Report for Packaging (Onsite)*, Westinghouse Hanford Company, Richland, Washington.

SD-RE-SAP-043, *Safety Analysis Report for Packaging (Onsite) Internally Shielded 55-Gallon Drum*, Westinghouse Hanford Company, Richland, Washington.

WHC-CM-2-14, *Hazardous Material Packaging and Shipping*, Westinghouse Hanford Company, Richland, Washington.

Willis, N. P., 1993, *Hanford Site Solid Waste Acceptance Criteria*, WHC-EP-0063-04, Westinghouse Hanford Company, Richland, Washington.

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10.0 APPENDIX: DRAWINGS AND RELATED ECNs

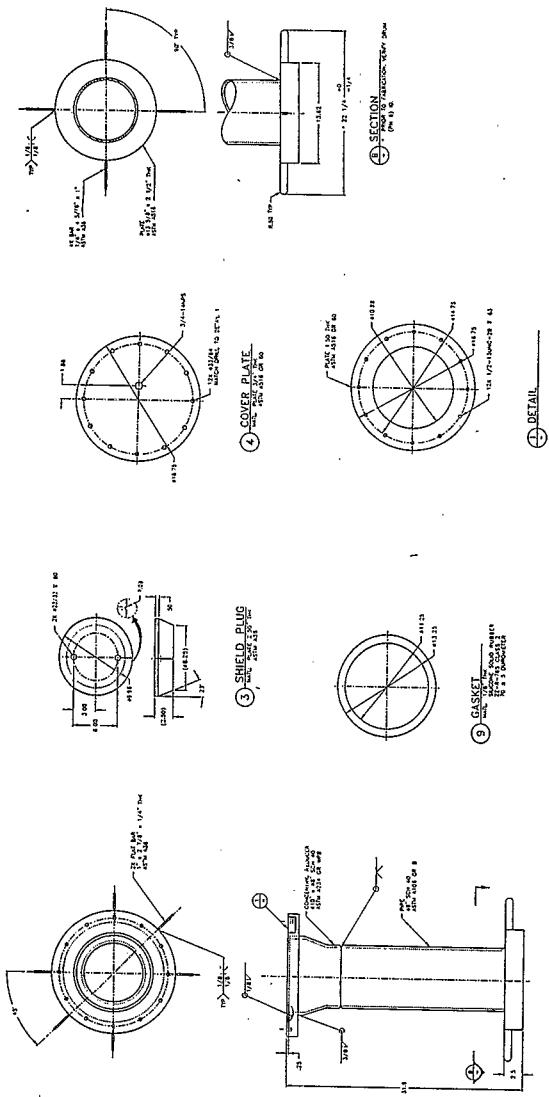
H-3-304541, Rev. 0, *Concrete-Lined Waste Package Assembly (Sheet 1 of 2) and Details (Sheet 2 of 2)*

ECN No. D01504-EDP01-FMP00-ECN01

H-3-304558, Rev. 0, *Concrete-Lined Waste Package Sleeve Assembly (Removable Liner)*

ECN No. D01504-EDP01-FMP00-ECN02

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ENGINEERING CHANGE NOTICE Pacific Northwest Laboratories (Reference FNL-MA-90)		1. CIN D01504	11P -01	R -0	IMP -00	LCR -01
		Page 1 of 9				
2. Project Title/Number/Work Order Number (See Page 2 for details) Concrete-Lined Waste Package/BE1257			3. Location 327	4. Date 10-10-96		
7. Facility Mod Yes <input type="checkbox"/> No <input checked="" type="checkbox"/>			8. Change Class N/A	9. Related PD No.(s) N/A	5. R&D Impact Level II	6. Safety Class Yes <input type="checkbox"/> No <input checked="" type="checkbox"/>
11. Title of Change Revision 1 to Concrete-Lined Drum Drawing			10. Related ECN No.(s) D01504-EDP01-FMP00-ECN02			12. NEPA Doc Req'd for changes Yes <input type="checkbox"/> No <input checked="" type="checkbox"/>
13. Documents Affected (Number, Sheet/Page, Index Number, Revision) H-3-304541, Sheets 1-2, Index 5010, Rev 0						
14. Cost Impact				15. Schedule Impact (days)		
ENGINEERING		CONSTRUCTION		DAYS		
Additional <input type="checkbox"/>	Additional <input type="checkbox"/>	Savings <input checked="" type="checkbox"/>	Savings <input checked="" type="checkbox"/>	Improvement <input type="checkbox"/>	Delay <input type="checkbox"/>	
None <input type="checkbox"/>	None <input type="checkbox"/>	Amount <input type="checkbox"/>	Amount <input type="checkbox"/>	None <input type="checkbox"/>	None <input type="checkbox"/>	
16. Originator JS Huisingsh		Phone 376-6226	MSIN H5-70	Organization Mechanisms Eng, FDNW		
17. Approvals						
ARCHITECT-ENGINEER PE JS Huisingsh (FDNW)	Signature S. Huisingsh	Date 10-14-96	31. PACIFIC NORTHWEST LABORATORY Signature Engnr. PE Moore <u>John Moore</u> Date 10-16-96			
QA	N/A		Bldg Mgr. WA Hooper <u>WA Hooper</u> 10/19/96			
Safety			CA <u>Barry Seale</u> 10-18-96			
Design			Safety N/A			
Environmental			Rad Waste Opr. JL Pierce <u>JL Pierce</u> 10-11-96			
RFSH Trans & Proj. Mgr. <u>John L. Field</u> 10/18/96			RCRA Fld. Svcs. KS Webster <u>KS Webster</u> 10-14-96			
18. Approved for Implementation						
20. Distribution (Include name, MSIN, and number of copies)						
JS Field (RFSH) G1-11 JS Henderson P8-24 JS Huisingsh (FDNW) H5-70 DR Jackson P8-24 JL Pierce P7-75 SS Shirega (RFSH) G1-11 RW Stevens P8-24 KS Webster P7-75						
19. Release Stamp PNL RELEASE 10-21-96 DATE Date						
Project Manager <u>J. L. Field</u> 10/21/96						

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ENGINNEERING CHANGE NOTICE Pacific Northwest Laboratories (Reference PNL-MA-90)	J. JDN 001504	LST -01	R -0	IMP -00	ECN -01
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21. Description of Change

Revise drawing H-3-304541, Sheet 1, Rev 0, "CONCRETE-LINED WASTE PACKAGE ASSEMBLY" per Items 1 through 5 identified below:

Item 1: Modify General Note 9 as follows:

From: PERFORM 100% VISUAL EXAMINATION OF ALL FINAL WELDS PER AWS D1.1-1994, SECTION 6, WITH ACCEPTANCE CRITERIA PER SECTION 8.15.1.
 To: PERFORM 100% VISUAL EXAMINATION OF ALL IDENTIFIED FINAL WELDS PER AWS D1.1-1994, SECTION 6, WITH ACCEPTANCE CRITERIA PER SECTION 8.15.1.

Item 2: Modify General Note 11 as follows:

From: STENCIL DRAWING NUMBER BETWEEN TOP TWO RIBS. CHARACTERS SHALL BE 1" TO 1.5" HIGH IN BLACK ENAMEL ON A YELLOW ENAMEL BACKGROUND. PAINT SHALL BE SIGN PAINTER ENAMEL APPLIED PER MANUFACTURER'S INSTRUCTIONS. ALSO IDENTIFY DRUM WITH A 3" X 6" X 16 GAUZE GALVANIZED STEEL TAG. LOCATE TAG IMMEDIATELY BELOW TOP-MOST RIB AND TACK WELD EACH CORNER. CLEAN AND RINSE EXPOSED CARBON STEEL AND COAT WITH MOISTURE CURING URETHANE CONTAINING ZINC. MARK TAG BY DIE STAMPING WITH 3/8" HIGH CHARACTERS. THE FOLLOWING WILL BE STAMPED: ...
 To: APPLY VINYL, ADHESIVE-BACKED, DRAWING NUMBER LABEL BETWEEN TOP TWO RIBS. CHARACTERS SHALL BE 1" TO 1.5" HIGH IN BLACK ON A YELLOW BACKGROUND. ALSO IDENTIFY DRUM WITH A 3" X 6" X 16 OR 14 GAUZE GALVANIZED STEEL TAG. LOCATE TAG IMMEDIATELY BELOW TOP-MOST RIB AND TACK WELD EACH CORNER. CLEAN AND RINSE EXPOSED CARBON STEEL AND COAT WITH MOISTURE CURING URETHANE CONTAINING ZINC. MARK TAG BY DIE STAMPING WITH 1/4" HIGH CHARACTERS. THE FOLLOWING WILL BE STAMPED: ...

Item 3: Modify General Note 11's flange bolt torque

From: 36 ± 2 IN-LB
 To: 25 ± 2 FT-LB

Item 4: Modify General Note 13 by replacing the word "WELDED" with "BRAZED WITH SILICONE BRONZE".

Item 5: Modify the welding symbol in zone F9-10

From: See sketch on page 4 (Rev 0 condition).
 To: See sketch on page 5 ("AS MODIFIED" condition).

Revise drawing H-3-304541, Sheet 2, Rev 0, "CONCRETE-LINED WASTE PACKAGE DETAILS" per Items 6 through 21 identified below:

Item 6: Modify zone G12 angle dimension (for PN 2)

From: 45°
 To: $45^\circ \pm 2^\circ$

Item 7: Modify the welding symbol in zone E12 (for PN 2)

From: See sketch on page 6 (Rev 0 condition).
 To: See sketch on page 7 ("AS MODIFIED" condition).

Item 8: Modify the welding symbol in zone D12-13 (for PN2)

From: See sketch on page 6 (Rev 0 condition).
 To: See sketch on page 7 ("AS MODIFIED" condition).

22. Justification

Revision incorporates red-line additions to the drawings, which will facilitate fabrication, reflect revised packaging requirements, improve fits of mating parts, relax unnecessarily tight tolerances and add flexibility to material selection for future waste packaging fabrication.

23. Other Affected Documents (List Document No., Title, Rev. No., and Date)

N/A

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24. Changes Completed

Date

25. As-Builts/Document Revs. Completed

Date

ENGINEERING CHANGE NOTICE Pacific Northwest Laboratories (Reference PWL-MA-80)	1. JCN 001504	EDP -01	R -0	IMP -00	ECN -01
Page 3 of 9					

21. Description of Change (cont.)

Item 9: Modify the welding symbol in zone D11 (for PW 2)
 From: See sketch on page 6 (Rev 0 condition).
 To: See sketch on page 7 ("AS MODIFIED" condition).

Item 10: Modify zone G8 machining dimensions (for PW 3)
 From: 2K c23/32 \mp .00
 To: 2K e0.75 \mp 1.06

Item 11: Modify zone F9 dimension (for PW 3)
 From: c9.96
 To: c9.60

Item 12: Modify zone F8 reference dimension (for PW 3)
 From: c8.25
 To: c8.55

Item 13: Modify zone F9 angle dimension (for PW 3)
 From: 23°
 To: 15°

Item 14: Modify zone E8 material call-out (for PW 3)
 From: ASTM A36
 To: ASTM A516 or A36

Item 15: Modify PW 10 as indicated below:
 From: See sketch on page 8 (Rev 0 condition).
 To: See sketch on page 9 ("AS MODIFIED" condition).

Item 16: Modify zone A8-9 notes (for PW 10)
 From: 2.0" THK
 POLYURETHANE FOAM
 LAST-A-FOAM FR-6704
 4 LBS PER CUBIC FT
 To: 2.0" THK (1.87" MIN)
 (SEE ASSEMBLY 1 NOTE)
 POLYURETHANE FOAM
 LAST-A-FOAM FR-6704
 4 LBS PER CUBIC FT

Item 17: Modify zone E8 material call-out (for PW 4)
 From: ASTM A516 GR 60
 To: ASTM A516 NORMALIZED, FINE GRAIN PRACTICE

Item 18: Modify zone G5 hole location dimension (for PW 4)
 From: 1.68 IN
 To: 1.9 IN

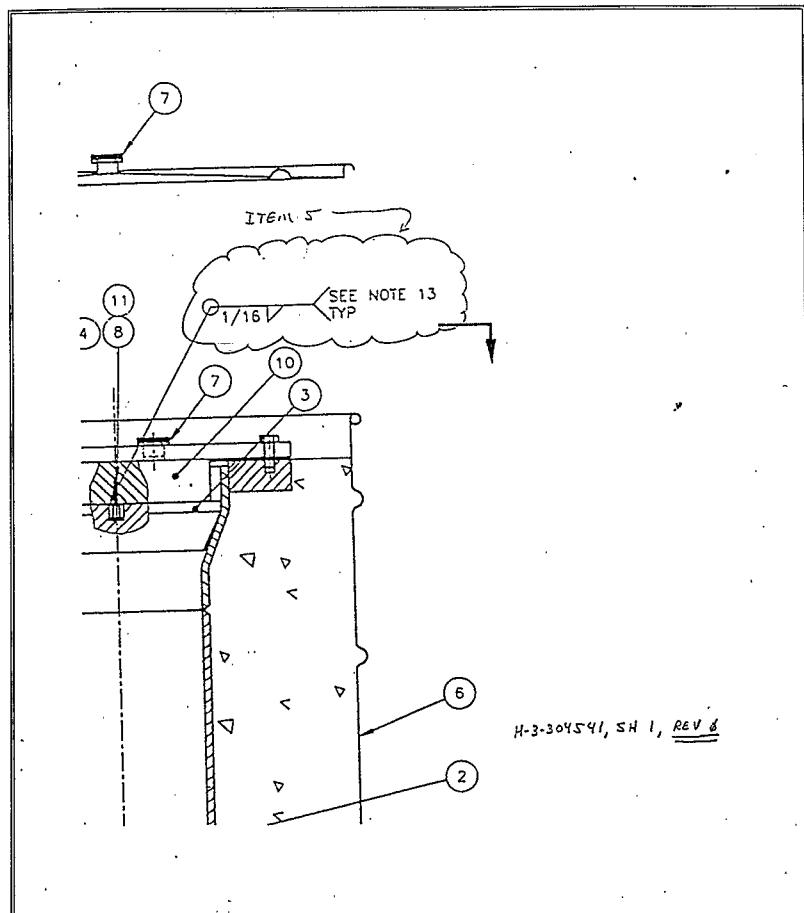
Item 19: Modify zone D-E5 plate description (for PW 1)
 From: PLATE 1.50 THK
 ASTM A516 GR 60
 To: PLATE 1.50 \pm .13 THK
 ASTM A516 NORMALIZED

Item 20: Modify zone F1 angle dimension (for SECTION B)
 From: 90°
 To: 90° \pm 2°

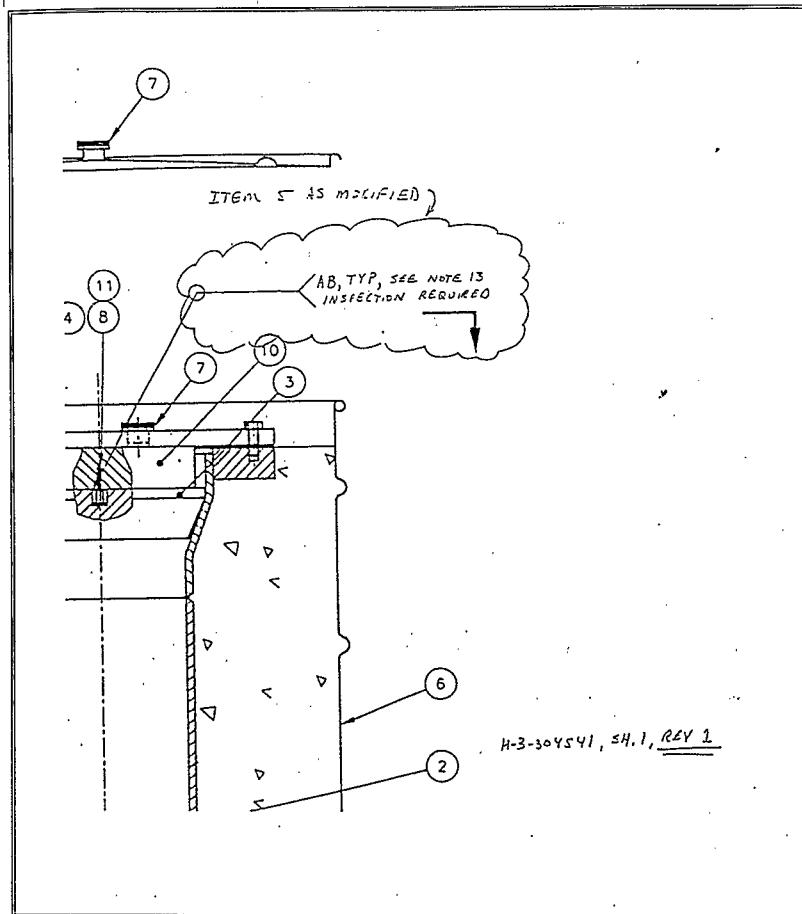
Item 21: Add tail and note in tail reading "INSPECTION REQUIRED" to zone EF1 weld symbol.

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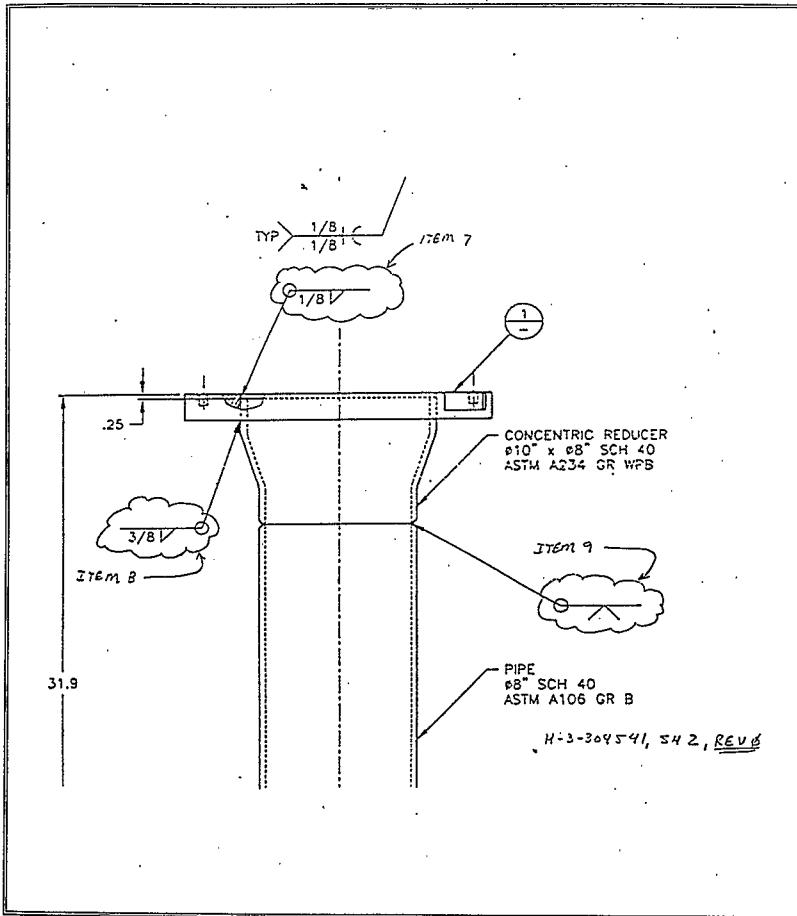
ENGINEERING CHANGE NOTICE Pacific Northwest Laboratories (Reference FNL-MA-90)	1. JCN D01504	ICP -01	R -0	IMP -00	LCN -01
					Page 4 of 9



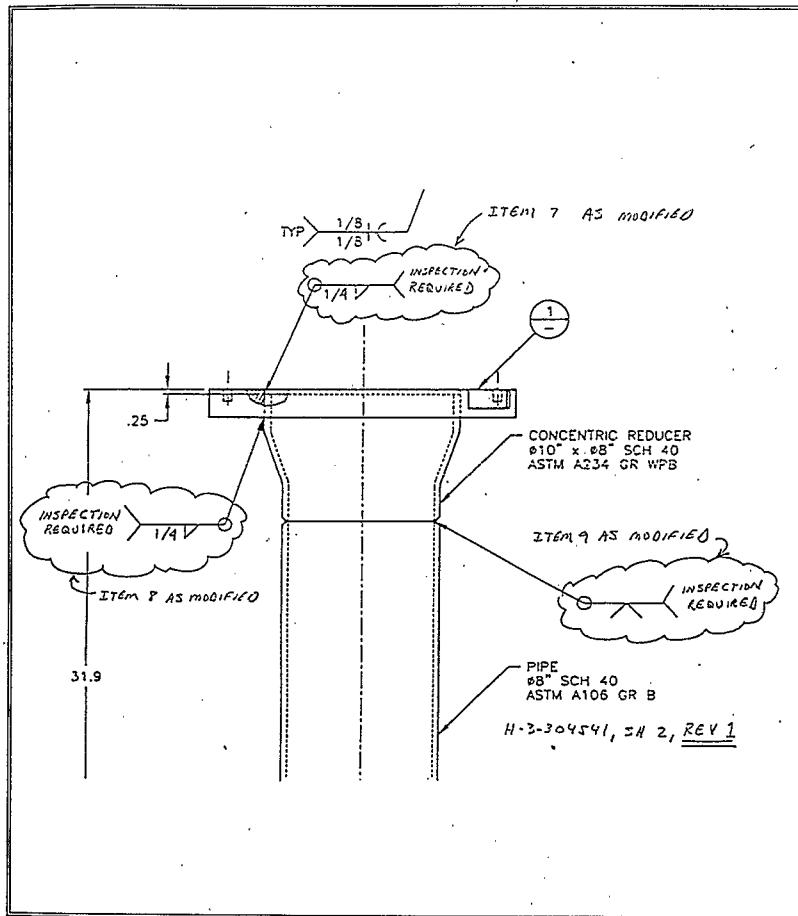
ENGINEERING CHANGE NOTICE Pacific Northwest Laboratories (Reference PNL-MA-90)	T. 214 001504	REV -01	IMP -00	ECN -01
Page 5 of 9				



ENGINEERING CHANGE NOTICE Pacific Northwest Laboratories (Reference PNL-MA-903)		1. JIN	EDP	R	IMP	ICN
		DE1504	-01	-0	-00	-01
		Page 6 of 9				

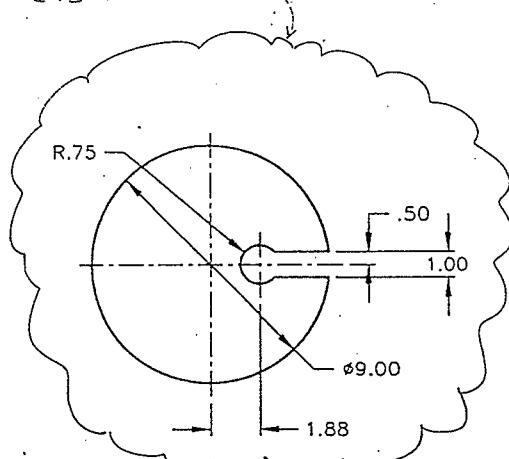


ENGINEERING CHANGE NOTICE Pacific Northwest Laboratories (Reference PNL-MA-90)	T. IIN P01504	IOP -01	R -0	IMP -00	LCW -01
					Page 7 of 9



ENGINEERING CHANGE NOTICE Pacific Northwest Laboratories (Reference PNL-MA-90)	1. 1.1N 007504	EDP -01	R -0	IMP -00	ECN -01
Page 8 of 9					

ITEM 15



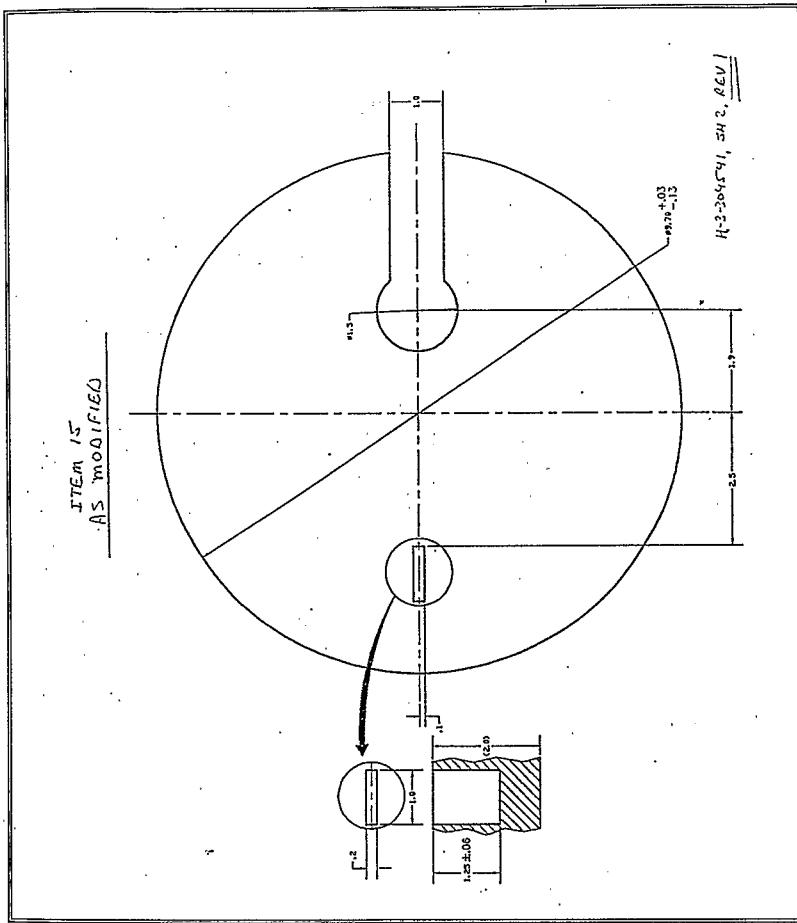
10

IMPACT LIMITER

MATL: 2.0" THK
POLYURETHANE FOAM
LAST-A-FOAM FR-6704
4 LBS PER CUBIC FT

H-3-264541, SH 2, REV C

ENGINEERING CHANGE NOTICE
Pacific Northwest Laboratories
(Reference FNL-MA-90)



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ENGINEERING CHANGE NOTICE Pacific Northwest Laboratories (Reference FNL-MA-90)			1. JIN D01504	EDP -01	R -0	FMP -00	ECN -02
Page 1 of 4							
2. Project Title/Number/Work Order Number (see Page 2 for details) Concrete-Lined Waste Package Sleeve/BE1297			3. Location 327	4. Date 10-10-96			
			5. R&D Impact Level III	6. Safety Class Yes <input type="checkbox"/> No <input checked="" type="checkbox"/>			
7. Facility Mod Yes <input type="checkbox"/> No <input checked="" type="checkbox"/>	8. Change Class N/A	9. Related PO No.(s) N/A	10. Related ECN No.(s) D01504-EDP01-FMP00-ECN01				
11. Title of Change Revision 1 to Concrete-Lined Drum Sleeve Drawing			12. NEPA Doc Req'd for changes: Yes <input type="checkbox"/> No <input checked="" type="checkbox"/>				
13. Documents Affected (Number, Sheet/Page, Index Number, Revision) H-3-304558, Sheet 1, Index 5010, Rev 0							
14. Cost Impact				15. Schedule Impact (days)			
ENGINEERING		CONSTRUCTION		DAYS			
Additional <input type="checkbox"/>	Savings <input checked="" type="checkbox"/>	Additional <input type="checkbox"/>	Savings <input checked="" type="checkbox"/>	Improvement <input type="checkbox"/>	Delay <input type="checkbox"/>	None <input type="checkbox"/>	
None <input type="checkbox"/>	Amount \$	None <input type="checkbox"/>	Amount \$	None <input type="checkbox"/>	None <input type="checkbox"/>		
16. Originator JS Huisingsh		Phone 376-6226	MSIN HS-70	Organization Mechanisms Eng., FDNW			
17. Approvals							
ARCHITECT-ENGINEER PE JS Huisingsh (FDNW)		Signature JS Huisingsh	Date 10-14-96	PACIFIC NORTHWEST LABORATORY Eng. PE Hoare		Signature PE Hoare	Date 10-14-96
OA		N/A		Bldg Mgr WA Hooper		WA Hooper	10-14-96
Safety				OA Barry Seehan		Barry Seehan	10-14-96
Design				Safety N/A			
Environmental		V		Rad Waste Ops JL Pierce		JL Pierce	10-14-96
RFSH PFS		<i>JS Huisingsh</i> 10-18-96		RCRA Fld. Svcs KS Webster		KS Webster	10-14-96
18. Approved for Implementation							
DEPARTMENT OF ENERGY				19. Release Stamp			
N/A				PNE RELEASE 10-21-96 DATE			
20. Distribution (include name, MSIN, and number of copies)							
JC Field (RFSH) G1-11 JF Henderson PB-24 JS Huisingsh (FDNW) HS-70 DR Jackson PB-24 JL Pierce P7-75 SS Shiraga (RFSH) G1-11 RV Stevens PB-24 KS Webster P7-75							
BEST AVAILABLE COPY							

ENGINEERING CHANGE NOTICE Pacific Northwest Laboratories (Reference PNL-HA-90)	1. JIN DD1504	EDP -01	R -0	FMP -00	ECN -02
Page 2 of 4					

21. Description of Change

Revise drawing N-3-304558, Sheet 1, Rev 0, "CONCRETE-LINED WASTE PACKAGE SLEEVE ASSEMBLY" per the items identified below:

Item 1: Remove the ϕ .13 hole and associated dimensions from the "DISK DETAIL" in zone EF7-8.
 From: See sketch on page 3 (Rev 0 condition).
 To: See sketch on page 4 ("AS MODIFIED" condition).

Item 2: Modify General Note 9 as follows:
 From: PERFORM 100% VISUAL EXAMINATION OF ALL SEAL WELDS AND BAIL TABS WITH CRITERIA PER AWS D9.1 - 1990,
 SECTION 6.
 To: PERFORM 100% VISUAL EXAMINATION OF ALL SEAL WELDS AND BAIL TAB WELDS. PERFORM 40% VISUAL EXAMINATION OF
 ALL REMAINING TAB WELDS. ACCEPTANCE CRITERIA PER AWS D9.1 - 1990, SECTION 6.

22. Justification

Vent hole in cover (disk) has been judged to be unnecessary in consideration of overall sleeve assembly's closure mechanism (tabs). Modified weld inspection requirements allow for inspection of a representative sampling of closure and handling tab welds.

23. Other Affected Documents (List Document No., Title, Rev. No., and Date)

N/A

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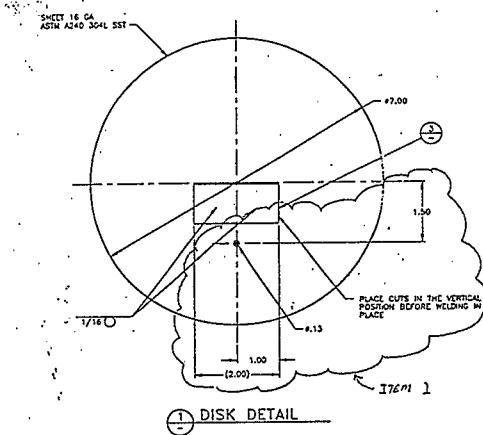
24. Changes Completed

Date

25. As-Builts/Document Revs. Completed

Date

ENGINEERING CHANGE NOTICE Pacific Northwest Laboratories (Reference PNL-MA-90)	I. JIN D01504	EDP -01	R -0	FHP -00	ECN -02
Page 3 of 4					

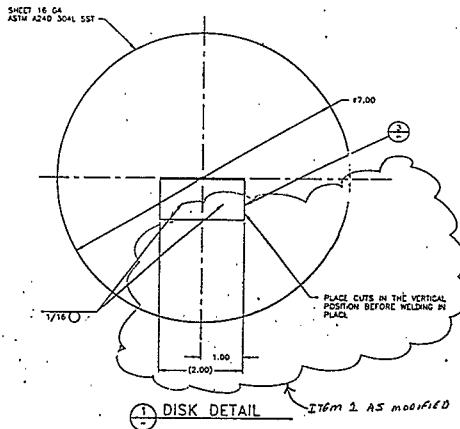


H-3-364558, SH. 1, REV A

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EA-1007-152 (5/93)

	ENGINEERING CHANGE NOTICE Pacific Northwest Laboratories (Reference PNL-MA-90)	T. JIN D01504	EDP -01	R -0	FHP -00	ECK -02
Page 4 of 4						



H-3-30455P, SH 2, REV. 1

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PART B: PACKAGE EVALUATION**1.0 INTRODUCTION****1.1 SAFETY EVALUATION METHODOLOGY**

This safety evaluation for packaging (SEP) for the Pacific Northwest National Laboratory (PNNL) Concrete-Shielded Remote-Handled Transuranic Waste (RH TRU) Drum used two existing safety analysis reports for packaging (SARP) for guidance. They are the *Transuranic Radioactive Material in the 55-Gallon Drum, Safety Analysis Report for Packaging (Onsite)* (SD-RE-SAP-033) and the *Safety Analysis Report for Packaging (Onsite) Internally Shielded 55-Gallon Drum* (SD-RE-SAP-043).

The initial PNNL design concept was for a drum very similar to that authorized by SD-RE-SAP-043. That drum utilized a nonsealed inner cavity and relied on the drum itself for primary containment. A plastic bag provided secondary containment. PNNL did, however, want to secure relief from the interarea restrictions imposed by that SARP (maximum of three 657.7-kg (1,450-lb) drums, closed vehicle) because the currently anticipated need is to ship 80 drums.

The final design included a stronger inner container that features a bolted gasketed cover. Primary containment is provided by this inner container rather than by the drum shell itself. A plastic bag is no longer required.

Because the new packaging is basically similar to, but improved over, the packaging evaluated and approved by SD-RE-SAP-043, Section 3.0, "Standards and Analysis," and Section 4.0, "Safety Controls," and supporting documents referenced therein, these sections are incorporated into this SEP by reference. They provide the documentation that approves the basic concrete-shielded drum as a Type A shipping container. The substantial inner container in the new design provides a very significant improvement over that original design. The inner container is evaluated in Section 7.0 of this SEP.

1.2 EVALUATION SUMMARY AND CONCLUSIONS

The PNNL Concrete-Shielded RH TRU Drum meets the established onsite transportation safety requirements through supplemental design improvements and administrative controls. The risk analysis supports shipment of up to 30, 657.7-kg (1,450-lb) drums per shipment, up to seven shipments total, and use of a flatbed truck. The shielding analysis, however, limits the maximum number of drums of maximum inventory to 24 in a 2x12 drum array. Up to 30 drums of lesser inventory may be transported provided the dose rate limits of Table B5-2 are not exceeded. Escort vehicles are required for the entire route while road closure is only necessary from the 327 Building to the Wye Barricade. Specific tiedown requirements are provided. Restrictions are imposed on road conditions, ambient temperature, speed, and package dose rates.

As shown in the Section 7.0, "Structural Evaluation," the Concrete-Shielded RH TRU Drum will maintain containment of the contents through all normal transfer conditions. Maintaining containment is demonstrated by comparing the evaluated stresses to ASME (1992) allowable stress values for the materials involved.

All evaluations have positive margins of safety with respect to the ASME (1992) allowables; therefore, this evaluation demonstrates that the Concrete-Shielded RH TRU Drum is safe for onsite transfers of 327 Building hot cell legacy waste within the limits of this SEP.

1.3 REFERENCES

ASME, 1992, *ASME Boiler and Pressure Vessel Code, Section VIII, Division 1*, American Society of Mechanical Engineers, New York, New York.

WHC-SD-SAP-033, *Transuranic Radioactive Material in the 55-Gallon Drum, HCS-042-002, Safety Analysis Report for Packaging (Onsite)*, Westinghouse Hanford Company, Richland, Washington.

WHC-SD-SAP-043, *Safety Analysis Report for Packaging (Onsite), Internally Shielded 55-Gallon Drum*, Westinghouse Hanford Company, Richland, Washington.

2.0 CONTENTS EVALUATION

2.1 CHARACTERIZATION

2.1.1 Radioactive Source Term

An estimate of the ratio of radionuclides contained in one drum was supplied by PNNL (see Part B, Section 2.6.1). It was estimated using the relative concentrations calculated from MFA-1 inventory ORIGEN2 runs and normalized to a ^{137}Cs activity of 3.7×10^{10} Bq (1 Ci). The surface dose rate on a drum is limited to 1.0 mSv/h (100 mrem/h); so, the inventory was renormalized to give this effective dose equivalent (EDE) using the computer code ISOSHLD (Engel et al. 1966, Simmons et al. 1967, and Rittman 1995). A copy of the ISOSHLD input/output file is contained in Part B, Section 5.8.2. The original ratio and the renormalized inventory for a single drum are presented in Table B2-1. The single-drum inventory contains 6.5 A₂s and is therefore a Type B quantity of radioactive material. There is less than 15 g fissile isotopes present in one drum (see Part B, Section 6.0), qualifying the inventory as fissile excepted.

2.1.2 Chemical Source Term

Specific chemical source term information is not available. The material is identified as hot cell legacy waste, which typically consists of the following: paper towels, grinding disks, cloth wipes and towels, plastic bags and vials, steel and aluminum tools and fixturing, manipulator boots, stainless steel wool, and broken glass. There will be no chemicals, free liquids, or absorbed organic liquids. No fuel debris will be included other than that which may be in smearable form on other debris.

2.2 RESTRICTIONS

The contents shall fall within the limits of the radiological source term and the chemical source term statement. Drum contents are limited to three uncrushed, or six crushed, 1-gal paint cans. Cans shall be punctured to preclude pressurization. Loaded drums shall exhibit an external surface dose rate no greater than 1 mSv/h (100 mrem/h).

2.3 SIZE AND WEIGHT

The maximum estimated payload weight is 13.6 kg (30 lb) (up to six paint cans at 2.3 kg [5 lb] each). The tare weight of each paint can is estimated at 0.34 kg (0.75 lb).

Table B2-1. Source Term for One Drum. (Bq)

Isotope	Ratio supplied by PNNL	Renormalized inventory	A_2 (TBq)	Fraction of A_2
^{235}U	2.09×10^3	5.26×10^2	Unlimited	0
^{238}U	1.04×10^6	2.62×10^5	Unlimited	0
^{238}Pu	9.10×10^8	2.29×10^8	2×10^{-4}	1.14
^{239}Pu	1.15×10^9	2.89×10^8	2×10^{-4}	1.44
^{240}Pu	1.14×10^9	2.87×10^8	2×10^{-4}	1.43
^{241}Pu	3.92×10^{10}	9.87×10^9	1×10^{-2}	0.988
^{242}Pu	4.18×10^5	1.05×10^5	2×10^{-4}	5.25×10^{-4}
^{241}Am	1.12×10^9	2.82×10^8	2×10^{-4}	1.41
^{244}Cm	9.62×10^7	2.42×10^7	4×10^{-4}	0.0606
^{134}Cs	4.33×10^9	1.09×10^9	0.5	2.18×10^{-3}
^{137}Cs	3.70×10^{10}	8.48×10^9	0.5	1.7×10^{-2}
$^{137m}\text{Ba}^*$	3.50×10^{10}	8.81×10^9	0	0
^{90}Sr	1.42×10^{10}	3.57×10^9	0.1	3.57×10^{-2}
$^{90}\text{Y}^*$	1.42×10^{10}	3.57×10^9	0	0
^{54}Mn	8.99×10^8	2.26×10^8	1	2.26×10^{-4}
^{60}Co	7.70×10^8	1.94×10^8	0.4	4.85×10^{-4}
^{125}Sb	2.01×10^9	5.06×10^8	0.9	5.63×10^{-4}
^{154}Eu	3.53×10^9	8.89×10^8	0.5	1.78×10^{-3}
Total	1.55×10^{11}	3.83×10^{10}		6.54

*Daughter product.

PNNL = Pacific Northwest National Laboratory.

2.4 CONCLUSIONS

As evaluated by the rest of this SEP, the radiological source term proposed by the customer (as renormalized to 1 mSv/h [100 mrem/h] at drum surface) is acceptable for the Concrete-Shielded RH TRU Drum.

2.5 REFERENCES

Engel, R. L., J. Greenborg, and M. M. Hendrickson, 1966, *ISOSHLD - A Computer Code for General Purpose Isotope Shielding Analysis*, BNWL-236, Battelle-Northwest Laboratories, Richland, Washington.

Rittman, P. D., 1995, *ISO-PC Version 1.98 - User's Guide*, WHC-SD-WM-030, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

Simmons, G. L., J. J. Regimbal, J. Greenborg, E. L. Kelly, Jr., and H. H. van Tuyl, 1967, *ISOSHLD-II: Code Revision to Include Calculation of Dose Rate from Shielded Bremsstrahlung Sources*, BNWL-236, Supplement 1, Battelle-Northwest Laboratories, Richland, Washington.

2.6 APPENDIX: SOURCE TERM RATIO DOCUMENTATION

Pacific Northwest National Laboratory
Operated by Battelle for the U.S. Department of Energy

August 23, 1996

J. G. Field
Westinghouse Hanford Co.
P. O. Box 1970
Richland, WA 99352

Dear, Mr. Field,

The source term information pertinent to the design of the RH-TRU Concrete-Lined Drum System is attached. This information is being transmitted to you for inclusion in the Safety Evaluation for Packing (SEP) which is being prepared by Dave Clem et al for PNNL. If any additional information is required, please contact me at the number below or Jeff Huisingsh at 376-6226.

Thank you.

Sincerely,


John F. Henderson, Group Leader
Postirradiation Testing Laboratory

cc: DK Clem,WHC
JR Green,WHC

cc: JD Huisingsh,ICF-K

cc: JE Mercado,WHC

cc: JM Seay,PNNL
RW Stevens,PNNL

JFH:jmr

Attachment

Battelle Boulevard ■ P.O. Box 999 ■ Richland, WA 99352

Telephone 376-7288 ■ Email jf_henderson@pnl.gov ■ Fax 376-5420

Pacific Northwest National Laboratory

Operated by Battelle for the U.S. Department of Energy

SOURCE TERM DATA FOR 327 BUILDING RH-TRU WASTE SHIPMENTS

Nuclide	Curies		
U235	5.66E-8		
U238	2.82E-5		
Pu238	2.46E-2		
Pu239	3.10E-2		
Pu240	3.08E-2		
Pu241	1.06E-0		
Pu242	1.13E-5		
Am241	3.04E-2		
Cm244	2.60E-3		
Cs134	1.17E-1		
Cs137	1.00E+0		
Sr90*	3.83E-1		
Mn54	2.43E-2		
Co60	2.08E-2		
Sb125	5.42E-2		
Eu154	9.53E-2		
Total	2.874		

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3.0 RADIOLOGICAL RISK EVALUATION

3.1 INTRODUCTION

The Concrete-Shielded RH TRU Drums will be used to ship Type B quantities of hot cell debris from the 327 Building to the 200 Area or to another Hanford Site storage location. The waste will be shipped in 55-gal steel drums, which have been modified to include a steel inner cavity and concrete shielding. The debris has been classified as transuranic (TRU) waste and contains miscellaneous discarded hot cell materials. Radiological risks are evaluated to determine compliance with onsite transportation safety requirements per WHC-CM-2-14, *Hazardous Material Packaging and Shipping*.

There will be approximately 24 to 30 drums per shipment with four expected shipments per year and seven maximum shipments within the time span of one year. The maximum mileage per shipment will be 40.23 km (25 mi). The assumptions for the radiological risk evaluation are the following:

- Highway mode
- 24 to 30 drums per shipment
- 4 to 7 shipments maximum
- 40.23 km (25 mi) per shipment.

The drums and liners are designed to withstand normal transportation conditions. For accident environments, the drums and liners must meet onsite transportation safety requirements as outlined in WHC-CM-2-14 and Mercado (1994). The requisite safety is determined by a radiological risk evaluation that uses dose consequences, risk acceptance criteria, failure threshold values, and Hanford Site accident frequencies. For the evaluation, accidents are categorized as impact, crush, puncture, and fire. Risk acceptance criteria are outlined in Section 3.2. The dose consequence analyses results are provided in Section 3.3. Failure thresholds are given in Section 3.4. The analysis of accident release frequencies for associated failure thresholds is given in Section 3.5. The accident frequencies, together with the dose values, provide the necessary input to provide an evaluation of acceptance of the risk related to the Concrete-Shielded RH TRU Drum shipping campaign as outlined.

3.1.1 Discussion and Results

The Concrete-Shielded RH TRU Drum failure thresholds were used to determine the total conditional probability of release for mechanical and thermal accident scenarios. The total conditional release probability was then multiplied by the Hanford Site annual accident rate to arrive at an annual accident release frequency. The annual release frequency was compared to the dose consequence results to determine acceptance. For the concrete-shielded drums a comparison of the annual release frequency with the criteria determined from the dose consequence study showed the risks to be greater than the required 10^{-6} . Therefore, additional administrative controls are necessary to reduce the risks to acceptable levels. For the drum shipments, vehicle escorts will lower the potential annual release frequency to below

10^{-6} and allow for seven shipments per year. Therefore, seven shipments per year of the Concrete-Shielded RH TRU Drums will comply with onsite transportation safety requirements provided all shipments are accompanied by escort vehicles.

3.2 RISK ACCEPTANCE CRITERIA

Graded dose limitations for probable, credible, and incredible accident frequencies ensure safety in radioactive material packaging and transportation (Mercado 1994). The dose limitations to the offsite and onsite individual for probable, credible, and incredible accident frequencies are presented in Table B3-1.

Table B3-1. Risk Acceptance Criteria Limits.

Description	Annual frequency	Onsite dose limit* Sv (rem)	Offsite dose limit* Sv (rem)
Incredible	$<10^{-7}$	None	None
Incredible	10^{-7} to $<10^{-6}$	None	.25 (25)
Credible	10^{-6} to 10^{-3}	.05/.15/.5 (5/15/50)	.005/.015/.05 (.5/1.5/5)
Probable	10^{-3} to 1	.002/.006/.02 (.2/.6/2)	.0001/.0003/.001 (.01/.03/.1)

*Effective dose equivalent/lens of eye/all other organs

3.3 DOSE CONSEQUENCE ANALYSIS RESULTS

The dose consequence study for the Concrete-Shielded RH TRU Drums is presented in Part B, Section 4.6. The analysis presents the results of an accident breaching a single drum and releasing 100% of the material at risk to the environment. The maximum number of drums in a single shipment is 30. No definitive analysis for the percentage of the inventory affected in accidents involving the transportation of 55-gal drums in open flatbed trucks has been made. Therefore, it is assumed that 25% of the material at risk in 30 drums containing the worst-case source term is released to the environment. The results shown in Table B4-3 are accordingly multiplied by factors of 0.25 and 30. The use of these multiplication factors is conservative for the following reasons. First, if all of the drums were to contain the worst-case inventory, only 24 could be shipped (see Part B, Section 5.0, "Shielding Evaluation"). Second, the failure thresholds on the drums are such that a catastrophic accident resulting in forces that would affect 25% of the entire cargo being shipped are much less than 10^{-6} , and an accident of this type has never occurred on the Hanford Site.

The material within the drums, which consists of hot cell debris, such as contaminated paper products and broken glassware, will act very differently in

a fire scenario versus a nonfire scenario. Therefore, dose consequences for both nonfire and fire scenarios are analyzed. The potential accident results are summarized in Table B3-2 for both scenarios. The assumption is made that a ground-level release occurs in the 300 Area and that the offsite receptor is only 100 m from the accident location. The doses given in Table B3-2 are the total committed EDEs, which are integrated over 50 years.

Table B3-2. Summary of Potential Dose Consequences for a Shipment of 30 Drums.

Exposure pathway	Onsite worker	Offsite receptor
Nonfire scenario doses in Sv (rem)		
Total EDE	0.46 (46)	0.017 (1.7)
Maximum organ	8.3 (830)	0.29 (29)
Fire scenario doses in Sv (rem)		
Total EDE	3.8 (380)	0.13 (13)
Maximum organ	69 (6,900)	2.3 (230)

EDE = Effective dose equivalent.

Both fire and nonfire scenarios result in doses to the public receptor greater than 0.005 Sv (0.5 rem) and less than 0.25 Sv (25 rem), which require accident release frequencies in the incredible range ($< 10^{-6}$).

3.4 PACKAGE FAILURE THRESHOLD ANALYSIS

The failure thresholds of the Concrete-Shielded RH TRU Drum have been determined for impact, puncture, crush, and fire as follows:

- Impact: 37 km/h (23 mph) velocity change on to a typical Hanford Site surface (see Part B, Section 7.13, for verification)
- Puncture: v/r ratio of 265 sec^{-1} (v/r = velocity for small package puncture failure divided by the radius of the puncturing probe)
- Crush: Survives 7,257.5-kg (16,000-lb) crush force in worst orientation (see Part B, Section 7.13, for verification)
- Fire: Fails any fire.

3.5 ACCIDENT FREQUENCY ASSESSMENT

3.5.1 Approach

The accident frequency assessment is based on the assumption that a single failure mode is appropriate for each of the different forces described as impact, puncture, crush, and fire. Package failure frequencies from different scenarios with similar consequences and the same type of force are summed to determine a composite failure mode for analysis. Fire and nonfire cases will be dealt with separately to determine compliance with Hanford Site criteria.

The frequency (F) of a truck accident is the product of the annual number of trips, the number of miles per trip, and the accident rate per mile.

$$F = \text{number of trips/yr} \times \text{mi/trip} \times \text{accidents/mi}$$

Hanford Site truck accidents have been compiled in a report using site-specific data (Green et al. 1996). The resulting accident rate for trucks is 2.0×10^{-7} accidents per mile. Therefore $F = 4 \times 25 \times 2.0 \times 10^{-7} = 2.0 \times 10^{-5}$. To allow for more flexibility in shipping configurations, the frequency for seven shipments was also found. It is $F = 7 \times 25 \times 2.0 \times 10^{-7} = 3.5 \times 10^{-5}$.

A risk management study performed by H&R Technical Associates (H&R 1995) has identified reduction factors that can be used to reduce the Hanford Site accident rate when administrative controls are enforced during shipment of radioactive material. These reduction factors are summarized below.

Reduction Factor	Administrative Control
4	Vehicle accompanied by escort vehicles
18.25	Shipment during nonpeak hours with escorts, emergency response notification, and road closure

If necessary, administrative controls can be used to mitigate higher-than-acceptable risks. The accident rate can then be reduced according to the reduction factor related to the level of controls enforced.

The frequency of truck accidents is multiplied by the sum of the conditional release probabilities of the specific failure modes to arrive at an annual accident release frequency. Conditional release probabilities for fire, crush, impact, and puncture are determined for highway from a Sandia National Laboratory study for accidents involving small packages (Clarke et al. 1976) and from a Hanford Site risk management study (H&R 1995). The conditional release probabilities are presented in the event trees shown in Figures B3-1 through B3-3.

3.5.2 Accident Release Frequency Analysis

An accident sequence analysis is developed for each failure type (impact, puncture, crush, and fire) and presented in the event trees shown in Figures B3-1 through B3-3. Information for the probability of occurrence and conditional probabilities of failure was taken from Clarke et al. (1976) and H&R (1995). Mechanical failure conditional probabilities are further subdivided into those affected by fire. The conditional probabilities are summed for comparison to the risk criteria. A summary of the conditional probabilities and summation are shown in Table B3-3.

Table B3-3. Accident Scenario Frequency Assessment Summary.

Accident scenario	Failure magnitude	Conditional probability	Conditional release probability
Impact failure	37 km/h (23 mph)	0.102	
• Fire affects impact failure • Impact failure only		0.0047 0.9953	4.283×10^{-4} 9.071×10^{-2}
Crush failure	>>7,257.5 kg (16,000 lb)	~0	~0
Puncture failure	265 sec ⁻¹	0.224 x 0.008	
• Fire affects puncture failure • Puncture failure only		0.0047 0.9953	7.525×10^{-6} 1.952×10^{-3}
Fire failure	Any fire		
• With mechanical force • Without mechanical force		0.0047 x 1.0 0.086 x 1.0	4.199×10^{-3} 9.159×10^{-3}
Total conditional release probability (TCRP)			0.1065
Annual release frequency (4 shipments) = TCRP x F = 2.1×10^{-6} y ⁻¹			
Annual release frequency (7 shipments) = TCRP x F = 3.7×10^{-6} y ⁻¹			
With escorts:			
Annual release frequency (4 shipments) = (TCRP x F)/4 = $2.1 \times 10^{-6}/4 = 5.3 \times 10^{-7}$ y ⁻¹			
Annual release frequency (7 shipments) = (TCRP x F)/4 = $3.7 \times 10^{-6}/4 = 9.3 \times 10^{-7}$ y ⁻¹			

The impact failure threshold was determined to be a 37-km/h (23-mph) change in velocity on to a typical Hanford Site surface (see Part B, Section 7.13, for verification). The probability of occurrence of a collision or overturn event is 0.8935 x F, and the conditional probability of impact failure is 0.102.

Puncture probabilities are determined by the v/r ratio, which is the puncture failure threshold velocity divided by the radius of the probe. The probability of occurrence of collision or overturn is 0.8935. This is multiplied by the probability of a puncture accident (0.224) and by the conditional failure probability for the 265 sec⁻¹ failure threshold, which is 0.0088.

Figure B3-1. Impact Accident Event Tree for Small Truck Package
With 37-km/h (23-mph) Failure Threshold.

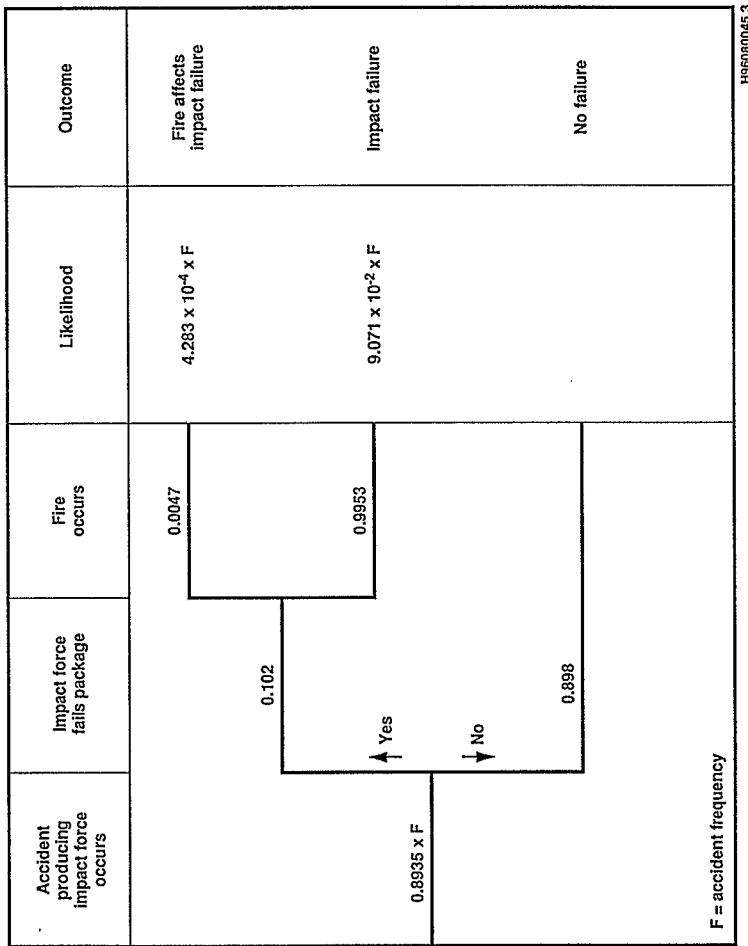


Figure B3-2. Puncture Accident Event Tree for Small Truck Packages.

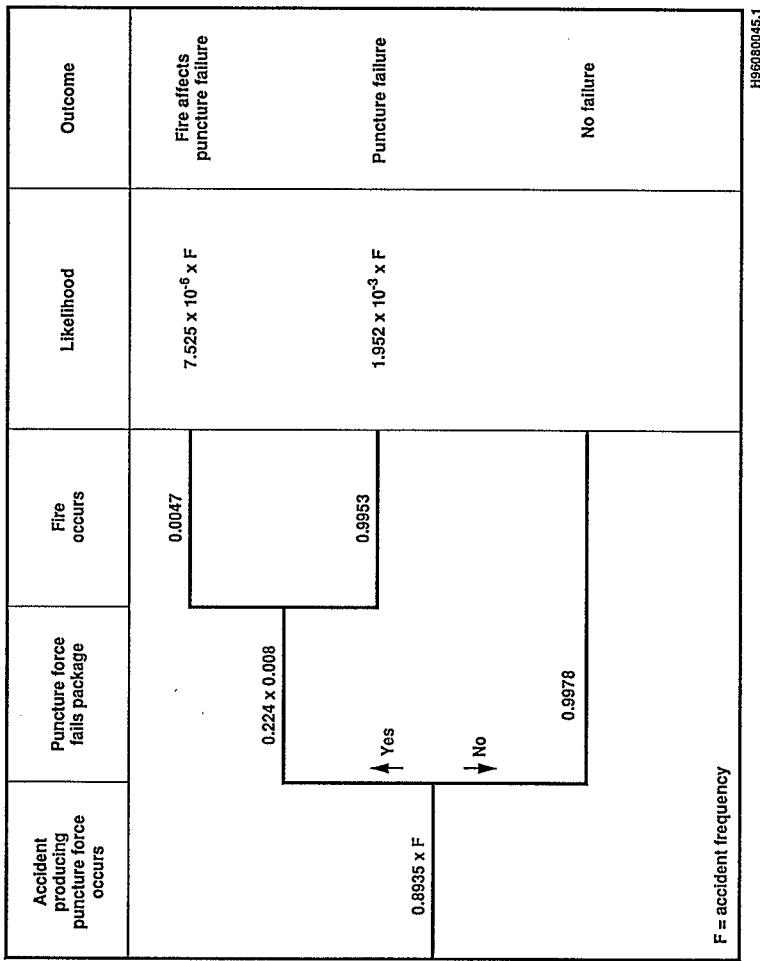
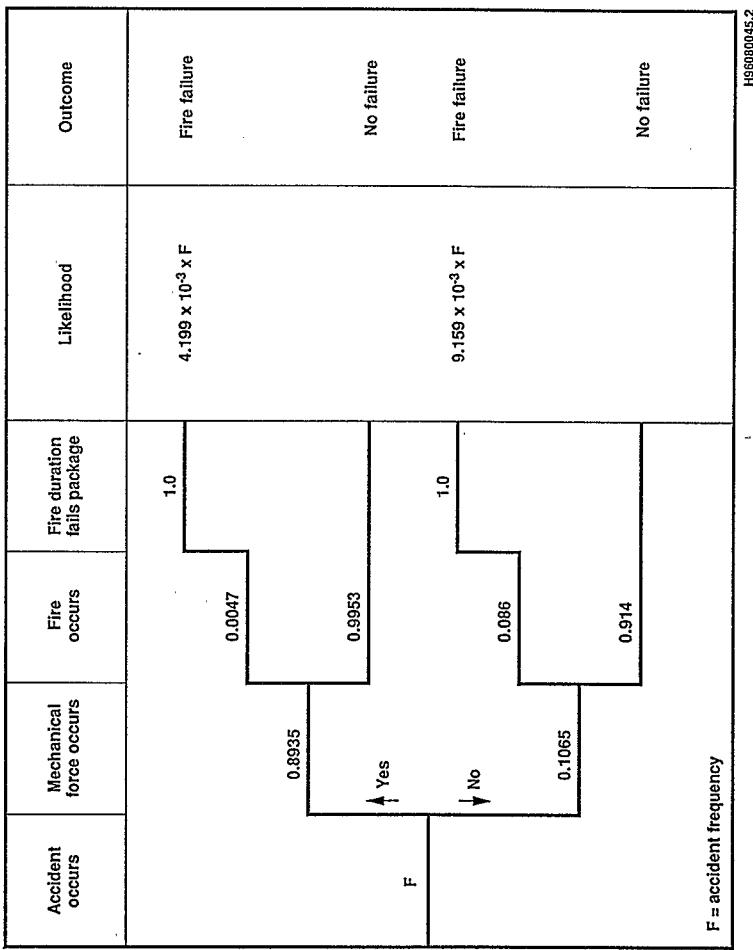


Figure B3-3. Fire Accident Event Tree for Small Truck Packages Without Mechanical Failure.



The failure threshold for crush is essentially zero; therefore, the conditional probability of failure due to crush is also approximately equal to zero.

The drums are assumed to fail in any fire event. The event tree shown in Figure B3-3 gives the probabilities of fire failing a small package with and without the presence of a mechanical force. The probability of a fire failing the package with a mechanical force present is $4.2 \times 10^{-3} \times F$, and the probability of fire failure with no mechanical force present is $9.159 \times 10^{-3} \times F$. Table B3.3 sums the event tree information and gives the total release frequency with and without additional administrative controls.

3.6 EVALUATION AND CONCLUSION

Table B3-3 shows the conditional release probabilities calculated for each scenario and sums them to give a total conditional release probability. The summed probability is then multiplied by F , the frequency, to arrive at an annual accident release frequency. The annual accident release frequency for four and seven shipments of drums in the normal operation highway mode is greater than the 1×10^{-6} required. If the shipments are escorted, however, the results may be reduced by a factor of four, and the annual release frequency for seven shipments becomes $9.3 \times 10^{-7} \text{ y}^{-1}$, which is less than the required amount. Therefore, the shipment campaign for up to seven shipments per year of the Concrete-Shielded RH TRU Drums meets transportation safety requirements provided the shipments are escorted.

3.7 REFERENCES

Clarke, R. K., J. T. Foley, W. F. Hartman, and D. W. Lawson, 1976, *Severities of Transportation Accidents Volume III--Motor Carriers*, SLA-74-0001, Sandia Laboratories, Albuquerque, New Mexico.

Green, J. R., B. D. Flanagan, and H. Harris, 1996, *Hanford Site Truck Accident Rate, 1990-1995*, WHC-SD-TP-RPT-021, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

H&R, 1995, *Recommended Onsite Transportation Risk Management Methodology, 522-1*, H&R Technical Associates, Inc., Oak Ridge, Tennessee.

Mercado, J. E., 1994, *Report on Equivalent Safety for Transportation and Packaging of Radioactive Materials*, WHC-SD-TP-RPT-001, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

WHC-CM-2-14, *Hazardous Material Packaging and Shipping*, Westinghouse Hanford Company, Richland, Washington.

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4.0 CONTAINMENT EVALUATION

4.1 INTRODUCTION

This evaluation shows that the Concrete-Shielded RH TRU Drum meets the normal and accident conditions criteria.

4.2 CONTAINMENT SOURCE SPECIFICATION

As described in Part B, Section 2.0.

4.3 NORMAL TRANSFER CONDITIONS

4.3.1 Conditions To Be Evaluated

The normal transfer condition tests evaluated or addressed are decreased external pressurization, penetration, 1.22-m (4-ft) drop, lifting, closure bolts and forces due to normal transport vibration.

4.3.2 Containment Acceptance Criteria

There shall be no leakage of waste material from the container under normal conditions. The containment vessel and drum shall be vented through a filtered vent.

4.3.3 Containment Calculations

As demonstrated in this Part, the waste will be contained within the inner cavity of the drum through all normal transport conditions. This is demonstrated by evaluating the container closure bolts and flange stresses created during a 1.22-m (4-ft) drop. The stresses are shown not to exceed ASME (1992) allowables for the materials involved. Analysis is provided in Section B-7.

4.4 ACCIDENT CONDITIONS

Accident conditions that result in excessive loading on the inner cavity flange or bolting could result in breach of containment.

Should an accident occur in which these loadings are exceeded, the dose consequences of such an accident are found to be acceptable, as described in Section 4.6.

4.5 CONTAINMENT EVALUATION AND CONCLUSIONS

The container will prevent any loss or dispersal of the radioactive contents when exposed to the normal transfer conditions.

4.6 DOSE CONSEQUENCE ANALYSIS (OF ACCIDENTS)

4.6.1 Introduction

The methodology used in this analysis is based on the International Atomic Energy Agency (IAEA) Q-system (IAEA 1990) as outlined in WHC (1993). The IAEA Q-system was developed as an all-encompassing generalized methodology using only the isotope as the defining variable. In this document, the specifics of the package are considered. Some of the pathways for dose may be considered as not credible, and although these pathways may be covered in the IAEA guide, they are disregarded in the analysis.

There are two receptors considered. The onsite receptor is considered to be 1 m from the spill for one-half hour, while the offsite receptor is located at the point of closest public approach to the spill. In the cases where the spill is assumed to take place in controlled areas, the offsite receptor is assumed to be at the Site boundary or the near bank of the Columbia River, whichever is closer. In the cases where the spill is assumed to take place in areas in which access is uncontrolled, the receptor is assumed to be 100 m away from the spill. The offsite receptor is assumed to inhale the airborne release only.

The source term used in this section is developed in Part B, Section 2.0, and repeated in Table B4-1. Table B4-1 is the source for one drum.

4.6.2 Results

4.6.2.1 Photon Dose. In the IAEA methodology the source is modeled as a point source. No credit is taken for any self-shielding by the source. The entire contents of the drum is assumed to be completely released from its steel enclosure. It is also generally assumed that the worker stands one meter from the accident for one half hour. In the fire scenario the conditions remain the same, despite the fact that the conflagration would tend to strongly discourage a worker from standing within one meter of the source for this amount of time.

The computer code ISOSHLD (Engel et al. 1966, Simmons et al. 1967, and Rittman 1995) was used to calculate the dose rate one meter from a point source consisting of a 100% release of one 55-gal drum. The ISOSHLD input file is contained in Part B, Section 5.8.1, an appendix of the shielding section. Bremsstrahlung from the β -particle-emitting radionuclides was accounted for. The fluence-to-dose conversion factors used in the calculation were the anterior-to-posterior irradiation pattern as presented in ANSI/ANS-6.1.1 (ANSI/ANS 1991). The EDE at 1 m from the source was calculated to be 9.3×10^{-4} Sv (9.3×10^2 rem).

Table B4-1. Source Term Based on
1.0 mSv/h on Contact. (Bq)

Isotope	Original	Renormalized
²³⁵ U	2.09×10^3	5.26×10^2
²³⁸ U	1.04×10^6	2.62×10^5
²³⁸ Pu	9.10×10^8	2.29×10^8
²³⁹ Pu	1.15×10^9	2.89×10^8
²⁴⁰ Pu	1.14×10^9	2.87×10^8
²⁴¹ Pu	3.92×10^{10}	9.87×10^9
²⁴² Pu	4.18×10^5	1.05×10^5
²⁴¹ Am	1.12×10^9	2.82×10^8
²⁴⁴ Cm	9.62×10^7	2.42×10^7
¹³⁴ Cs	4.33×10^9	1.09×10^9
¹³⁷ Cs	3.70×10^{10}	8.48×10^9
^{137m} Ba*	3.50×10^{10}	8.81×10^9
⁹⁰ Sr	1.42×10^{10}	3.57×10^9
⁹⁰ Y*	1.42×10^{10}	3.57×10^9
⁵⁴ Mn	8.99×10^8	2.26×10^8
⁶⁰ Co	7.70×10^8	1.94×10^8
¹²⁵ Sb	2.01×10^9	5.06×10^8
¹⁵⁴ Eu	3.53×10^9	8.89×10^8
Total	1.55×10^{11}	3.83×10^{10}

*Daughter product.

4.6.2.2 B-Particle Dose. The IAEA methodology (IAEA 1990) assumes a point source of the material for this case also. As with the photon analysis, it has been assumed in this case that the entire drum is completely released and forms a pile. Due to the limited range of β -particles as compared to photons, a shielding factor due to residual shielding from material such as package debris is used by the IAEA and is also adopted here. The variation of shielding factor as a function of the maximum energy of the β -particle is graphed in WHC (1993) IAEA (1990).

Except for this factor, no effort is made to account for either self shielding or shielding from an accurate model of the damaged package. This adds another conservative factor because the average distance from the source integrated over the pile is greater than 1 m for a point receptor 1 m above the ground at the edge. In effect, this assumption amounts to an assumption of infinite range of β -particles in air. A one-half-hour stay time is again assumed.

The two graphs in IAEA (1990) have been incorporated into a spreadsheet to facilitate the calculational process. The total β -ray dose was calculated as being 1.6×10^{-2} Sv (1.6×10^{-3} rem). Of course, this is a skin dose that by itself is counted as an organ dose and that when included in the EDE, is multiplied by the tissue weighting factor for skin (0.01). As expected, the majority of the β -ray dose was due to ^{90}Y .

4.6.2.3 Airborne Inhalation Dose. The computer code GXQ (Hey 1993) was used to calculate the Ψ/Q s for the distances and directions for the nearest Site boundary. The meteorological data used were the 1983 to 1991 averages for ground (actually 10-m) releases in the 200 Area. For the onsite receptor, a constant distance of 100 m between the release point and the receptor was used. The distance to the offsite receptor was taken as being equal to the distance from the solid waste burial ground to the site boundary or the near bank of the Columbia River, whichever was smaller. Because the shipment will originate in the 300 Area, which is an uncontrolled area, it was assumed that a member of the public would be able to approach the spill to within a distance of 100 m. A value for Ψ/Q was chosen, which was not exceeded more than 0.5% of the time using the U.S. Nuclear Regulatory Commission methodology.

The worst case of these was then chosen for each receptor and used in this analysis. The worst case for the onsite receptor was 100 m to the north of a release in the 300 Area, while the worst case for the offsite receptor was the same. Thus, the onsite and offsite Ψ/Q value used was 4.21×10^{-2} s/m³. The computer code GENII (Napier et al. 1988) was then used to calculate the dose to the affected individual. A copy of the input file is contained in Part B, Section 4.8. The following libraries were accessed:

- GENII Default Parameter Values (28-Mar-90 RAP)
- Radionuclide Library--Times < 100 years (23-July-93 PDR)
- External Dose Factors for GENII in Person Sv/yr per Bq/n (8-May-90 RAP)
- Worst-Case Solubilities, Yearly Dose Increments (23-Jul-93 PDR).

For the offsite receptor, the dose is due to the inhalation pathway alone as it is for the onsite receptor. However, for the onsite receptor, in order to compensate for the fact that this dose was calculated at a source-to-receptor distance of 100 m, the Ψ/Q was multiplied by a factor of 30 as recommended in IAEA (1990).

The analysis assumes that 100% of the inventory of one drum will be released in the accident. Of this a fraction will become airborne (airborne release fraction [ARF]), and a fraction of that will be in the respirable range. Mishima (1993) estimates that for a loss or dislodgment of surface contamination from solids of appreciable mass (e.g., glassware or tools), a free-fall and impaction will result in an ARF of 1×10^{-3} with all of that being in the respirable range.

However, for light materials with high surface-to-mass ratios (e.g., paper, cardboard, plastic, or rubber sheeting) very little force would be generated during impact with a surface. For these materials Mishima (1993) postulates that no significant dislodgment of surface contamination would result. On the other hand, a layer of dry contamination lying on a surface on the ground under nominal wind flow conditions has been assigned an aerodynamic release rate of $4 \times 10^{-6}/h$, which would result in an ARF of 2×10^{-6} in the half hour postulated for the accident. All of the contamination released is assumed to be respirable. These numbers are the bounding values culled from the literature. In this analysis, the ARF for the massive solids is used.

Mishima (1993) gives a bounding value of the ARF of 8×10^{-3} for burning to dryness of the nonvolatile elements and 1×10^{-2} for cesium. In the absence of particle size distributions, it has been assumed that these are all in the respirable range. Due to the closeness of the release fractions for cesium and the rest of the isotopes, and the fact that cesium's effect on the committed EDE is roughly three orders of magnitude below that of strontium, cesium was assumed to be released identically to the other isotopes.

Table B4-2 shows the results of these various terms being factored into the dose estimates. The limiting organ is the bone surfaces due to the dose from ^{241}Am .

Table B4-2. Expected Inhalation Doses in Sv. (rem)

	Offsite		Onsite	
	Fire	Nonfire	Fire	Nonfire
Committed effective dose equivalent	1.7×10^{-2} ($1.7 \times 10^{+0}$)	2.2×10^{-3} (2.2×10^{-1})	5.1×10^{-1} ($5.1 \times 10^{+1}$)	6.1×10^{-2} ($6.1 \times 10^{+0}$)
Organ dose	3.1×10^{-1} ($3.1 \times 10^{+1}$)	3.8×10^{-2} ($6.2 \times 10^{+0}$)	$9.2 \times 10^{+0}$ (9.2×10^{-2})	$1.2 \times 10^{+0}$ ($1.2 \times 10^{+2}$)

4.6.2.4 Skin Contamination and Ingestion Dose. In IAEA (1990) it is assumed that 1% of the package contents are spread over an area of 1 m² and that handling of the debris results in contamination of the hands to 10% of this level. It is also assumed that the person is not wearing gloves, but that a

recognition of the possibility of contamination results in a washing of the hands within a period of five hours. The EDE to the skin received by the individual is then taken from a graph in that guide.

The IAEA (1990) scenario for the uptake of activity due to ingestion of the material assumes that the person ingests all of the contamination from 10 cm² of skin over a 24-hour period. Because the dose per unit uptake via inhalation is generally the same order or larger than that via ingestion, the inhalation pathway will normally be limiting for internal contamination due to β -ray emitters. In particular, if the skin contamination dose is much larger than the inhalation dose, the ingestion pathway is not considered.

The shipments will be transported in a truck with all personnel being in the cab of the truck. All occupants of the cab are required by administrative procedure to be restrained by seat belts. Thus, the accepted scenario of the accident considered is that all personnel are restrained within the cab of the truck. It is considered unlikely that the driver or any other occupant of the cab will exit from the cab and approach close enough to the spill of radioactive material to become contaminated.

Also, being in the enclosed cab during the accident would render it extremely unlikely that the material would be spilled over them in the accident. However, if the above assumptions do not hold for any particular shipment, this route of exposure will have to be evaluated.

4.6.2.5 Gaseous Vapor Dose. This term is due to submersion in a cloud of gaseous isotopes that do not become incorporated into the body. A rapid 100% release of the contents of the package is assumed. The description of this pathway in the IAEA guide (IAEA 1990) concentrates entirely on releases within confining structures. No guidance is given for outside releases. However, since it has been assumed that the package considered in this document has nonexistent or negligible concentrations of these gases, the problem is moot.

This route for this particular package is not significant as there are no gaseous isotopes trapped in the material and the production rate is trivial.

4.6.2.6 Neutron Dose. The amount of TRU material is so low that neutron emissions are not of concern in this shipment. In addition to spontaneous and induced fission neutrons, neutrons from the (α, n) reaction are considered and dismissed as negligible.

4.6.2.7 Special Considerations. Alpha-particle emitters are not of significance in the material considered in this document, neither are tritium nor radon. The alpha-particle emitters are of a low concentration, and their effect will be through the mechanism of inhalation and ingestion. These effects have been considered separately. Bremsstrahlung has been included in the consideration of photon effects, and the effects of short-lived daughter products have been included in all of the calculations. Where these isotopes are significant they are assumed to be in equilibrium with their longer lived parent isotopes.

4.6.2.8 Total Dose. The total doses for a single drum are shown in Table B4-3. The peer review checklist is contained in Part B, Section 5.8.4.

Table B4-3. Total Dose in mSv (mrem) for a Single Drum.

	Offsite		Onsite	
	Fire	Nonfire	Fire	Nonfire
Total effective dose equivalent	1.7×10^{-1} (1.7×10^{-3})	2.2×10^{-1} (2.2×10^{-2})	5.1×10^{-2} (5.1×10^{-4})	6.1×10^{-1} (6.1×10^{-3})
Organ dose	3.1×10^{-2} (3.1×10^{-4})	3.8×10^{-1} (3.8×10^{-3})	9.2×10^{-3} (9.2×10^{-5})	1.1×10^{-3} (1.1×10^{-5})

4.7 REFERENCES

ANSI/ANS, 1991, *Neutron and Gamma-ray Fluence-to-dose Factors*, ANSI/ANS-6.1.1, American National Standards Institute/American Nuclear Society, New York, New York.

ASME, 1992, *ASME Boiler and Pressure Vessel Code*, Section VIII, Division 1, American Society of Mechanical Engineers, New York, New York.

Engel, R. L., J. Greenborg, and M. M. Hendrickson, 1966, *ISOSHLD - A Computer Code for General Purpose Isotope Shielding Analysis*, BNWL-236, Battelle-Northwest Laboratories, Richland, Washington.

Hey, B. E., 1993, *GXQ 3.1 Users' Guide*, WHC-SD-GN-SWD-30002, Rev. 0, Westinghouse Hanford Company, Richland, Washington, June 1993.

IAEA, 1990, *Explanatory Material for the IAEA Regulations for the Safe Transport of Radioactive Material*, IAEA Safety Series No. 7, 1985 Edition as amended in 1990, International Atomic Energy Agency, Vienna, Austria.

Mishima, J., 1993, *Recommended Values and Technical Bases for Airborne Release Fractions (ARFs), Airborne Release Rates (ARRs), and Respirable Fractions (RFs) at DOE Non-Reactor Nuclear Facilities*, Draft, DOE-HDBK-0013-93, U.S. Department of Energy, Washington, D.C.

Napier, B. A., D. L. Strenge, R. A. Peloquin, and J. V. Ramsdell, 1988, *GENII - The Hanford Environmental Dosimetry Software System*, PNL-6584, Pacific Northwest Laboratory, Richland, Washington, November 1988.

Rittman, P. D., 1995, *ISO-PC Version 1.98 - User's Guide*, WHC-SD-WM-UM-030, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

Simmons, G. L., J. J. Regimbal, J. Greenborg, E. L. Kelly, Jr., and H. H. van Tuyl, 1967, *ISOSHLD-II: Code Revision to Include Calculation of Dose Rate from Shielded Bremsstrahlung Sources*, BNWL-236, Supplement 1, Battelle-Northwest Laboratories, Richland, Washington.

WHC, 1993, *Report on Equivalent Safety for Transportation and Packaging of Radioactive Materials*, WHC-SD-TP-RPT-001, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

4.8 APPENDIX: GENII INPUT FILE

Program GENII Input File ##### 8 Jul 88 #####
 Title: Concrete Lined Waste Package Assembly - Cs - Inhalation
 \GENII\CLWPA2.w.in Created on 07-24-1996 at 14:39

OPTIONS===== Default =====

F Near-field scenario? (Far-field) NEAR-FIELD: narrowly-focused
 F Population dose? (Individual) release, single site
 T Acute release? (Chronic) FAR-FIELD: wide-scale release,
 Maximum Individual data set used multiple sites
 Complete Complete

TRANSPORT OPTIONS===== Section EXPOSURE PATHWAY OPTIONS===== Section

T Air Transport	1	F Finite plume, external	5
F Surface Water Transport	2	T Infinite plume, external	5
F Biotic Transport (near-field)	3,4	F Ground, external	5
F Waste Form Degradation (near)	3,4	F Recreation, external	5
		T Inhalation uptake	5,6
REPORT OPTIONS=====		F Drinking Water ingestion	7,8
T Report AEDe only		F Aquatic foods ingestion	7,8
F Report by radionuclide		F Terrestrial foods ingestion	7,9
F Report by exposure pathway		F Animal product ingestion	7,10
F Debug report on screen		F Inadvertent soil ingestion	

INVENTORY #####

4 Inventory input activity units: (1-pCi 2-uCi 3-mCi 4-Ci 5-Bq)

0 Surface soil source units (1- m² 2- m³ 3- kg)

Equilibrium question goes here

-----Release Terms-----		Basic Concentrations-----					
Use when	transport selected	near-field scenario, optionally					
Release	Surface Buried	Air	Surface Deep	Ground	Surface	Water	Water
Radio-nuclide	Air	Water	Waste	Air	Soil	Soil	Water
/yr	/yr		/m ³	/m ³	/unit	/m ³	/L
CS134	1.2E-01						
CS137	1.0E+00						

-----Derived Concentrations-----	
Use when	measured values are known
Release	Terres. Animal Drink Aquatic
Radio-nuclide	Plant Product Water Food

TIME #####

1 Intake ends after (yr)
 50 Dose calc. ends after (yr)
 0 Release ends after (yr)
 0 No. of years of air deposition prior to the intake period
 0 No. of years of irrigation water deposition prior to the intake period

FAR-FIELD SCENARIOS (IF POPULATION DOSE) #####

0 Definition option: 1-Use population grid in file POP.IN
 0 2-Use total entered on this line

NEAR-FIELD SCENARIOS #####

Prior to the beginning of the intake period: (yr)
 0 When was the inventory disposed? (Package degradation starts)
 0 When was LOIC? (Biotic transport starts)
 0 Fraction of roots in upper soil (top 15 cm)
 0 Fraction of roots in deep soil
 0 Manual redistribution: deep soil/surface soil dilution factor
 0 Source area for external dose modification factor (m²)

TRANSPORT #####

=====AIR TRANSPORT=====	=====SECTION 1=====
0-Calculate PM	10 Release type (0-3)
1 Option: 1-Use chi/Q or PM value	1 F Stack release (T/F)
2-Select MI dist & dir	10 Stack height (m)
3-Specify MI dist & dir	10 Stack flow (m ³ /sec)

1.0	Chi/Q or PM value	0	Stack radius (m)
0	MI sector index (1=S)	0	Effluent temp. (C)
0	MI distance from release point (m)	0	Building x-section (m2)
F	Use jf data, (T/F) else chi/Q grid	0	Building height (m)

=====SURFACE WATER TRANSPORT=====SECTION 2=====

0	Mixing ratio model: 0-use value, 1-river, 2-lake
0	Mixing ratio, dimensionless
0	Average river flow rate for: MIXFLG=0 (m3/s), MIXFLG=1,2 (m/s),
0	Transit time to irrigation withdrawal location (hr)
0	If mixing ratio model > 0:
0	Rate of effluent discharge to receiving water body (m3/s)
0	Longshore distance from release point to usage location (m)
0	Offshore distance to the water intake (m)
0	Average water depth in surface water body (m)
0	Average river width (m), MIXFLG=1 only
0	Depth of effluent discharge point to surface water (m), lake only

=====WASTE FORM AVAILABILITY=====SECTION 3=====

0	Waste form/package half life, (yr)
0	Waste thickness, (m)
0	Depth of soil overburden, m

=====BIOTIC TRANSPORT OF BURIED SOURCE=====SECTION 4=====

T	Consider during inventory decay/buildup period (T/F)?	
T	Consider during intake period (T/F)?	
0	Pre-Intake site condition.....	1-Arid non agricultural
		2-Humid non agricultural
		3-Agricultural

EXPOSURE

=====EXTERNAL EXPOSURE=====SECTION 5=====

0	Exposure time:	Residential irrigation:
0	Plume (hr)	T Consider: (T/F)
0	Soil contamination (hr)	0 Source: 1-ground water
0	Swimming (hr)	2-surface water
0	Boating (hr)	0 Application rate (in/yr)
0	Shoreline activities (hr)	0 Duration (mo/yr)
0	Shoreline type: (1-river, 2-lake, 3-ocean, 4-tidal basin)	
1.0	Transit time for release to reach aquatic recreation (hr)	
1.0	Average fraction of time submerged in acute cloud (hr/person hr)	

=====INHALATION=====SECTION 6=====

8766.0	Hours of exposure to contamination per year	
0	0-No resus- 1-Use Mass Loading	2-Use Anspaugh model
0	pension	Mass loading factor (g/m3)
		Top soil available (cm)

=====INGESTION POPULATION=====SECTION 7=====

1	Atmospheric production definition (select option):
0	0-Use food-weighted chi/Q, (food-sec/m3), enter value on this line
	1-Use population-weighted chi/Q
	2-Use uniform production
0	3-Use chi/Q and production grids (PRODUCTION will be overridden)
F	Population ingesting aquatic foods, 0 defaults to total (person)
	Population ingesting drinking water, 0 defaults to total (person)
	Consider dose from food exported out of region (default=F)

Note below: S* or Source: 0-none, 1-ground water, 2-surface water
 3-Derived concentration entered above

===== AQUATIC FOODS / DRINKING WATER INGESTION=====SECTION 8=====

F	Salt water? (default is fresh)					
	USE TRAN- PROD- -CONSUMPTION-					
	? FOOD SIT UCTION HOLDUP RATE					
	T/F TYPE hr kg/yr da kg/yr					
						DRINKING WATER
T	FISH 0.00	0.0E+00	1.00	40.0	0	Source (see above)
T	MOLLUS 0.00	0.0E+00	0.00	6.9	T	Treatment? T/F
T	CRUSTA 0.00	0.0E+00	0.00	6.9	1.0	Holdup/transit(da)
T	PLANTS 0.00	0.0E+00	0.00	6.9	730.0	Consumption (L/yr)

=====TERRESTRIAL FOOD INGESTION=====SECTION 9=====

USE	GROW	--IRRIGATION--	PROD-	--CONSUMPTION--				
?	FOOD	TIME	S RATE	TIME	YIELD	UCTION	HOLDUP	RATE

T/F	TYPE	da	*	in/yr	mo/yr	kg/m ²	kg/yr	da	kg/yr
T	LEAF	90.00	0	0.0	0.0	1.5	0.0E+00	1.0	30.0
T	ROOT	90.00	0	0.0	0.0	4.0	0.0E+00	5.0	220.0
T	FRUIT	90.00	0	0.0	0.0	2.0	0.0E+00	5.0	330.0
T	GRAIN	90.00	0	0.0	0.0	0.8	0.0E+00	180.0	80.0

=====ANIMAL PRODUCTION CONSUMPTION===== SECTION 10=====

USE T/F	--HUMAN--			DRINK WATER	--STORED FEED--			STOR- AGE kg/m ³		
	FOOD TYPE	CONSUMPTION kg/yr	PROD- HOLDUP kg		ACTION kg/yr	DIET CONTAN- FRACT.	GROW- TH RATE da		IRRIGATION TIME * in/yr	TIME mo/yr
T BEEF	80.0	15.0	0.00	0.00	0.00	90.0	0	0.00	0.80	0.00
T POULTR	18.0	1.0	0.00	0.00	0.00	90.0	0	0.00	0.80	0.00
T MILK	270.0	1.0	0.00	0.00	0.00	45.0	0	0.00	0.00	2.00
T EGG	30.0	1.0	0.00	0.00	0.00	90.0	0	0.00	0.80	0.00
									-FRESH FORAGE-	
BEEF					0.00	45.0	0	0.00	2.00	100.0
MILK					0.00	30.0	0	0.00	1.50	0.00

5.0 SHIELDING EVALUATION

5.1 INTRODUCTION

The Concrete-Shielded RH TRU Drums will be used to transport laboratory waste (e.g., chem-wipes, paper towels, rubber gloves, broken glassware) from the 300 Area to the solid waste burial ground in the 200 West Area. The package consists of a container constructed out of an 8-in. schedule 40 steel pipe fitted with a steel top and bottom. This container will be inserted into a 55-gal drum, and the annular space between the container and the drum will be filled with concrete. For purposes of the shielding model, it is assumed that 24 drums of maximum allowable inventory will be transported concurrently on a flatbed truck.

5.2 DIRECT RADIATION SOURCE SPECIFICATION

The source term used in this section is developed in Part B, Section 2.5, and is repeated in Table B5-1. Table B5-1 is the source for a single drum.

Table B5-1. Source Term for One Drum.

Isotope	Bq	Isotope	Bq
^{235}U	5.26×10^2	^{134}Cs	1.09×10^9
^{238}U	2.62×10^5	^{137}Cs	8.48×10^9
^{238}Pu	2.29×10^8	$^{137m}\text{Ba}^*$	8.81×10^9
^{239}Pu	2.89×10^8	^{90}Sr	3.57×10^9
^{240}Pu	2.87×10^8	$^{90}\gamma^*$	3.57×10^9
^{241}Pu	9.87×10^9	^{54}Mn	2.26×10^8
^{242}Pu	1.05×10^5	^{60}Co	1.94×10^8
^{241}Am	2.82×10^8	^{125}Sb	5.06×10^8
^{244}Cm	2.42×10^7	^{154}Eu	8.89×10^8
		Total	3.83×10^{10}

*Daughter product.

5.2.1 Photon Source

The photon source (γ -rays and Bremsstrahlung) is computed internally when the computer code ISOSHLD (Engel et al. 1966, Simmons et al. 1967, and Rittman 1995) is run for the shielding calculations. The isotopes and their activities are input into the code.

5.2.2 Beta Source

Eight of the isotopes in the source are β -particle emitters. The most energetic of these is the β -particle emitted by ^{90}Y of 2.27 MeV maximum energy. This particle will travel roughly 1.1 g/cm^2 , which is a distance of about 0.5 cm in concrete. Obviously, none of the β -particles will escape from the container. The radiative energy loss, converted into Bremsstrahlung, is accounted for by ISOSHLD (Engel et al. 1966, Simmons et al. 1967, and Rittman 1995).

5.2.3 Neutron Source

The concentration of neutron-emitting radionuclides indicates that the neutron dose is negligible.

5.3 SUMMARY OF SHIELDING PROPERTIES OF MATERIALS

The source is made up of steel paint cans filled with laboratory waste (chem-wipes, paper towels, rubber gloves, broken glass, etc.). Not more than six of these paint cans are placed in a steel container consisting of a 56.6-cm-long section of 8-in. schedule 40 pipe. A steel bottom is added, and a 10-in. to 8-in. schedule 40 pipe reducer is welded to the top. In the tapered section of the reducer is fitted a steel plug. The source density is calculated by dividing the assumed weight of the source (gross weight = $2.27 \times 10^3 \text{ g}/\text{can}$ and net weight = $1.81 \times 10^3 \text{ g}/\text{can}$) by the volume of the container.

This container is then placed inside a 55-gal steel drum, and the annular space between the container and the drum is filled with concrete of density equal to 2.31 g/cm^3 . Twenty-four of these drums will comprise one load of a 12.2-m (40-ft) flatbed truck. The drums will be loaded in units of four, held in place with a wooden lattice that will space each unit approximately 10.2 cm (4 in.) apart. Three units will be clustered together, and two of these clusters will comprise a load. The two clusters were modeled as 162.6 cm (64 in.) apart.

5.4 NORMAL TRANSFER CONDITIONS

5.4.1 Conditions To Be Evaluated

Dose rates are evaluated on the drum surface, on the vertical planes projected from the outer edge of the vehicle, 2 m from the vehicle, and in the driver's location.

5.4.2 Acceptance Criteria

The surface dose rate of a single drum is limited to 1 mSv/h (100 mrem/h). The dose rate measured at the vertical planes projected from the outer edges of the vehicle are limited to 2 mSv/h (200 mrem/h), and the

dose rate at any point 2 m from the vehicle edge is limited to 0.2 mSv/h (20 mrem/h). A maximum dose rate of 0.02 mSv/h (2 mrem/h) is allowed in any normally occupied space in the vehicle.

The surface dose rate limit is determined by the acceptance criteria for storage and disposal. The other limits are based on the exclusive use limits in 49 CFR 173.441 although the flatbed truck used for the shipment will not be an enclosed vehicle. The dose at 2 m was raised from 0.1 mSv/h (10 mrem/h) to 0.2 mSv/h (20 mrem/h) to allow for the unlikely event of a shipment of 24 containers each loaded with the worst-case maximum source term developed for a single drum. Because unloading and shipping the drums in separate vehicles in order to meet a 0.1-mSv/h (10-mrem/h) dose rate at 2 m may possibly cause higher exposures than shipment of the drums with the higher 2-m limit, as-low-as-reasonably-achievable considerations allow the dose rate limit to be raised for this limited campaign. Also, as shown in Table B5-2, the dose rate falls off quickly after 2 m. Allowing an increased 2-m dose rate is further justified by the requirement for road closure between the 300 Area and the Wye Barricade and the use of escorts for the entire route.

5.4.3 Shielding Calculations

The computer code ISOSHLD (Engel et al. 1966, Simmons et al. 1967, and Rittman 1995) was used on a desktop disk operating system-based personal computer. Input files are contained in Sections 5.8.1 and 5.8.2. This code performs a point kernel integration over the source region and sums the contributions of each of the point kernels to the dose at a point detector. The program also accounts for Bremsstrahlung produced by β -particles. The fluence-to-dose conversion factors used in the calculation were the anterior-to-posterior irradiation pattern as presented in ANSI/ANS-6.1.1 (ANSI/ANS 1991).

The surface dose rate limit of 0.1 mSv/h (100 mrem/h) is used in Part B, Section 2.0, in development of the source term. No drum will be loaded beyond this limit.

The dose rate at the position normally occupied by the driver is calculated as twice the dose rate from one drum at the same distance 2.74 m (9 ft) since there will be two unshielded drums on the end. No other contributions were added since the dose rate is reduced by a factor of roughly a thousand by having another drum between the source and the receptor. No credit was taken for shielding due to any backstop on the end of the flatbed or any cab between the driver and the load. If drums of less-than-maximum allowable activity are placed in the end position, they could be closer than 2.74 m (9 ft) provided the dose rate in the occupied space does not exceed 0.02 mSv (2 mrem/h).

The dose rate off the side of the truck is calculated at two different positions, at the center of a cluster and midway between the clusters. For the dose at the truck edge, the dose at the center of the cluster is the highest and is reported in the results. As the receptor point is moved away from the source, the two results tend to come together, although the point midway between the clusters is slightly higher for the distances from the truck edge (2 m and 6 m) that are used. Table B5-2 shows these results.

The ISOSHLD results are as follows.

Table B5-2. Dose Rates at Various Points Around the Truck.

Receptor location	Distance to drums	Dose rate mSv/h (mrem/h)
Cab	2.74 m (9 ft)	0.019 (1.9)
	Distance from edge of truck	
Side Edge	0 m	0.73 (7.3)
	2 m	0.14 (14)
	6 m	0.036 (3.6)

5.5 ACCIDENT CONDITIONS

With the top of the inner steel enclosure bolted down with 12 bolts and the concrete enclosed between two steel enclosures, the probable accident envisioned is that the lid of the 55-gal drum is removed by the force of the accident.

The top of the drum is 16-gauge steel. The computer code ISOSHLD (Engel et al. 1966, Simmons et al. 1967, and Rittman 1995) was run with and without this thickness of steel removed from the top shield. Under the condition of the removal of the top, the dose rate at a distance of 1 m from the top of one drum is 0.17 mSv/h (1.7 mrem/h). This dose rate is below the 49 CFR 173 limit for accidents of 0.01 Sv/h (1 rem/h) at 1 m.

5.6 SHIELDING EVALUATION AND CONCLUSIONS

Calculated dose rates on the surface of the drums and at various locations from the edge of the vehicle are within the limits set for shipment.

5.7 REFERENCES

49 CFR 173, 1994, "Shippers-General Requirements for Shipments and Packagings," *Code of Federal Regulations*, as amended.

ANSI/ANS, 1991, *Neutron and Gamma-ray Fluence-to-dose Factors*, ANSI/ANS-6.1.1, American National Standards Institute/American Nuclear Society, New York, New York.

Engel, R. L., J. Greenborg, and M. M. Hendrickson, 1966, *ISOSHLD - A Computer Code for General Purpose Isotope Shielding Analysis*, BNWL-236, Battelle-Northwest Laboratories, Richland, Washington.

Rittman, P. D., 1995, *ISO-PC Version 1.98 - User's Guide*, WHC-SD-WM-UM-030, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

Simmons, G. L., J. J. Regimbal, J. Greenborg, E. L. Kelly, Jr., and
 H. H. van Tuyl, 1967, *ISOSHLD-II: Code Revision to Include Calculation
 of Dose Rate from Shielded Bremsstrahlung Sources*, BNWL-236,
 Supplement 1, Battelle-Northwest Laboratories, Richland, Washington.

5.8 APPENDICES

5.8.1 Input Files for Normal Shipment of 30 Drums

POINT SOURCE DOSE AT ONE METER
 &INPUT NEXT=1, IGEOM=3, NSHLD=1, JBUF=1, IPRNT=0,
 X=100., T(1)=0.02, DUNIT=1, OPTION =1, SFACT=0.2517,
 WEIGHT(476)=5.66E-08, WEIGHT(252)=2.82E-05, WEIGHT(492)=2.46E-02,
 WEIGHT(493)=3.10E-02, WEIGHT(494)=3.08E-02, WEIGHT(495)=1.06E+00,
 WEIGHT(497)=1.13E-05, WEIGHT(496)=3.04E-02, WEIGHT(082)=3.83E-01,
 WEIGHT(084)=3.83E-01, WEIGHT(319)=1.17E-01, WEIGHT(335)=1.00E+00,
 WEIGHT(336)=9.46E-01, WEIGHT(456)=2.43E-02, WEIGHT(472)=2.08E-02,
 WEIGHT(269)=5.42E-02, WEIGHT(415)=9.53E-02, WEIGHT(500)=2.60E-03, &
 1 SOURCE 0.58

CASK DOSE FROM FIRST ROW AND EXPOSED SECOND ROW - SIDE- CONTACT
 &INPUT NEXT=1, IGEOM=7, NSHLD=4, JBUF=3, IPRNT=0,
 X=29., T(1)=10.14, T(2)=0.82, T(3)=17.62, TC4)=0.15,
 SLTH=69.62, Y=34.81, DUNIT=1, OPTION =0, SFACT=0.2517,
 NPSI=15, NHETA=19, DELR=0.5,
 WEIGHT(476)=5.66E-08, WEIGHT(526)=2.82E-05, WEIGHT(492)=2.46E-02,
 WEIGHT(493)=3.10E-02, WEIGHT(494)=3.08E-02, WEIGHT(495)=1.06E+00,
 WEIGHT(497)=1.13E-05, WEIGHT(496)=2.08E+00, WEIGHT(082)=3.83E-01,
 WEIGHT(084)=3.83E-01, WEIGHT(319)=1.17E-01, WEIGHT(335)=1.00E+00,
 WEIGHT(336)=9.46E-01, WEIGHT(456)=2.43E-02, WEIGHT(472)=2.08E-02,
 WEIGHT(269)=5.42E-02, WEIGHT(415)=9.53E-02, WEIGHT(500)=2.60E-03, &
 SOURCE 2 0.116
 SOURCE 9 0.469
 STEEL 9 7.85
 CONCR 16 2.31
 1 STEEL 9 7.85
 CASK DOSE AT TO DRIVER - SIDE
 &INPUT NEXT=4, OPTION=0, X=343.69, &
 CASK DOSE AT TO DRIVER - SIDE - +6'
 &INPUT NEXT=4, OPTION=0, X=358.93, &
 CASK DOSE AT TO DRIVER - SIDE - +1'
 &INPUT NEXT=4, OPTION=0, X=374.17 &
 CASK DOSE AT TO DRIVER - SIDE - +1.5'
 &INPUT NEXT=4, OPTION=0, X=398.68, &
 CASK DOSE AT TO DRIVER - SIDE - +2'
 &INPUT NEXT=4, OPTION=0, X=413.92, &
 CASK DOSE - MIDDLE OF CLUSTER C1-C - SIDE
 &INPUT NEXT=4, X=86.81, &
 CASK DOSE - MIDDLE OF CLUSTER C1-100 - SIDE
 &INPUT NEXT=4, X=183.82, &
 CASK DOSE - MIDDLE OF CLUSTER C1-200 - SIDE
 &INPUT NEXT=4, X=282.93, &
 CASK DOSE - MIDDLE OF CLUSTER C1-600 - SIDE
 &INPUT NEXT=4, X=681.96, &
 CASK DOSE - MIDDLE OF CLUSTER C2-C - SIDE
 &INPUT NEXT=4, X=130.11, &
 CASK DOSE - MIDDLE OF CLUSTER C2-100 - SIDE
 &INPUT NEXT=4, X=207.81, &
 CASK DOSE - MIDDLE OF CLUSTER C2-200 - SIDE
 &INPUT NEXT=4, X=299.07, &
 CASK DOSE - MIDDLE OF CLUSTER C2-600 - SIDE
 &INPUT NEXT=4, X=688.81, &
 CASK DOSE - MIDDLE OF CLUSTER C3-C - SIDE
 &INPUT NEXT=4, X=181.75, &
 CASK DOSE - MIDDLE OF CLUSTER C3-100 - SIDE
 &INPUT NEXT=4, X=243.49, &
 CASK DOSE - MIDDLE OF CLUSTER C3-200 - SIDE
 &INPUT NEXT=4, X=324.88, &
 CASK DOSE - MIDDLE OF CLUSTER C3-600 - SIDE
 &INPUT NEXT=4, X=700.41, &

CASK DOSE - MIDDLE OF CLUSTER C4-C - SIDE
 &INPUT NEXT=4, X=424.42, &
 CASK DOSE - MIDDLE OF CLUSTER C4-100 - SIDE
 &INPUT NEXT=4, X=454.30, &
 CASK DOSE - MIDDLE OF CLUSTER C4-200 - SIDE
 &INPUT NEXT=4, X=502.63, &
 CASK DOSE - MIDDLE OF CLUSTER C4-600 - SIDE
 &INPUT NEXT=4, X=798.54, &
 CASK DOSE - MIDDLE OF CLUSTER C5-C - SIDE
 &INPUT NEXT=4, X=484.39, &
 CASK DOSE - MIDDLE OF CLUSTER C5-100 - SIDE
 &INPUT NEXT=4, X=510.77, &
 CASK DOSE - MIDDLE OF CLUSTER C5-200 - SIDE
 &INPUT NEXT=4, X=554.21, &
 CASK DOSE - MIDDLE OF CLUSTER C5-600 - SIDE
 &INPUT NEXT=4, X=831.97, &
 CASK DOSE - MIDDLE OF CLUSTER C4-100 - SECOND ROW- SIDE
 &INPUT NEXT=4, X=481.87, &
 CASK DOSE - MIDDLE OF CLUSTER C4-200 - SECOND ROW - SIDE
 &INPUT NEXT=4, X=539.12, &
 CASK DOSE - MIDDLE OF CLUSTER C4-600 - SECOND ROW - SIDE
 &INPUT NEXT=4, X=851.14, &
 CASK DOSE FROM MIDDLE OF CLUSTER SHIELDED SECOND ROW C1-C - SIDE
 &INPUT NEXT=1, IGEOM=7, NSHLD=5, JBUF=4, IPRTN=0,
 X=145.47, T(1)=10.14, T(2)=20.28, T(3)=2.46, T(4)=52.86, T(5)=0.45,
 SLTH=69.62, Y=34.81, DUNIT=1, OPTION =0, SFACT=0.2517,
 NPSI=15, NTHTA=19, DELR=0.5,
 WEIGHT(476)=5.66E-08, WEIGHT(526)=2.82E-05, WEIGHT(492)=2.46E-02,
 WEIGHT(493)=3.10E-02, WEIGHT(494)=3.08E-02, WEIGHT(495)=1.06E+00,
 WEIGHT(497)=1.13E-05, WEIGHT(496)=2.08E+00, WEIGHT(082)=3.83E-01,
 WEIGHT(084)=3.83E-01, WEIGHT(319)=1.17E-01, WEIGHT(335)=1.00E+00,
 WEIGHT(336)=9.46E-01, WEIGHT(456)=2.43E-02, WEIGHT(472)=2.08E-02,
 WEIGHT(269)=5.42E-02, WEIGHT(415)=9.53E-02, WEIGHT(500)=2.60E-03, &
 SOURCE 2 0.116 0.116
 SOURCE 9 0.465 0.465
 STEEL 9 7.85
 CONCR 16 2.31
 1 STEEL 9 7.85
 CASK DOSE - MIDDLE OF CLUSTER C1-100 - SECOND ROW - SIDE
 &INPUT NEXT=4, X=244.15, &
 CASK DOSE - MIDDLE OF CLUSTER C1-200 - SECOND ROW - SIDE
 &INPUT NEXT=4, X=243.59, &
 CASK DOSE - MIDDLE OF CLUSTER C1-600 - SECOND ROW - SIDE
 &INPUT NEXT=4, X=742.87, &
 CASK DOSE - MIDDLE OF CLUSTER C2-C - SECOND ROW - SIDE
 &INPUT NEXT=4, X=174.80, &
 CASK DOSE - MIDDLE OF CLUSTER C2-100 - SECOND ROW - SIDE
 &INPUT NEXT=4, X=262.68, &
 CASK DOSE - MIDDLE OF CLUSTER C2-200 - SECOND ROW - SIDE
 &INPUT NEXT=4, X=357.00, &
 CASK DOSE - MIDDLE OF CLUSTER C2-600 - SECOND ROW - SIDE
 &INPUT NEXT=4, X=749.16, &
 CASK DOSE - MIDDLE OF CLUSTER C3-C - SECOND ROW - SIDE
 &INPUT NEXT=4, X=216.00, &
 CASK DOSE - MIDDLE OF CLUSTER C3-100 - SECOND ROW - SIDE
 &INPUT NEXT=4, X=218.32, &
 CASK DOSE - MIDDLE OF CLUSTER C3-200 - SECOND ROW - SIDE
 &INPUT NEXT=4, X=378.89, &
 CASK DOSE - MIDDLE OF CLUSTER C3-600 - SECOND ROW - SIDE
 &INPUT NEXT=4, X=759.83, &
 CASK DOSE - MIDDLE OF CLUSTER C4-C - SECOND ROW - SIDE
 &INPUT NEXT=4, X=440.18, &
 CASK DOSE - MIDDLE OF CLUSTER C5-C - SECOND ROW - SIDE
 &INPUT NEXT=4, X=498.25, &
 CASK DOSE - MIDDLE OF CLUSTER C5-100 - SECOND ROW - SIDE
 &INPUT NEXT=4, X=498.25, &
 CASK DOSE - MIDDLE OF CLUSTER C5-200 - SECOND ROW - SIDE
 &INPUT NEXT=4, X=587.50, &
 CASK DOSE - MIDDLE OF CLUSTER C5-600 - SECOND ROW - SIDE
 &INPUT NEXT=4, X=882.58, &
 CASK DOSE-BETWEEN CLUSTERS FIRST ROW AND EXPOSED SECOND-C1-C-SIDE
 &INPUT NEXT=1, IGEOM=7, NSHLD=4, JBUF=3, IPRTN=0,
 X=138.19, T(1)=10.14, T(2)=0.82, T(3)=17.62, T(4)=0.15,
 SLTH=69.62, Y=34.81, DUNIT=1, OPTION =0, SFACT=0.2517,
 NPSI=15, NTHTA=19, DELR=0.5,
 WEIGHT(476)=5.66E-08, WEIGHT(526)=2.82E-05, WEIGHT(492)=2.46E-02,

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WEIGHT(493)=3.10E-02, WEIGHT(494)=3.08E-02, WEIGHT(495)=1.06E+00,
WEIGHT(497)=1.13E-05, WEIGHT(496)=2.08E+00, WEIGHT(082)=3.83E-01,
WEIGHT(084)=3.83E-01, WEIGHT(319)=1.17E-01, WEIGHT(335)=1.00E+00,
WEIGHT(336)=9.46E-01, WEIGHT(456)=2.43E-02, WEIGHT(472)=2.08E-02,
WEIGHT(269)=5.42E-02, WEIGHT(415)=9.53E-02, WEIGHT(500)=2.60E-03,&
SOURCE 2 0.116 0.116
SOURCE 9 0.465 0.465
STEEL 9 7.85
CONCR 16 2.31
1 STEEL 9 7.85
CASK DOSE - BETWEEN CLUSTERS C1-100 - SIDE
&INPUT NEXT=4, X=212.96, &
CASK DOSE - BETWEEN CLUSTERS C1-200 - SIDE
&INPUT NEXT=4, X=302.67, &
CASK DOSE - BETWEEN CLUSTERS C1-600 - SIDE
&INPUT NEXT=4, X=690.39, &
CASK DOSE - BETWEEN CLUSTERS C2-C - SIDE
&INPUT NEXT=4, X=190.89, &
CASK DOSE - BETWEEN CLUSTERS C2-100 - SIDE
&INPUT NEXT=4, X=250.59, &
CASK DOSE - BETWEEN CLUSTERS C2-200 - SIDE
&INPUT NEXT=4, X=330.08, &
CASK DOSE - BETWEEN CLUSTERS C2-600 - SIDE
&INPUT NEXT=4, X=702.83, &
CASK DOSE - BETWEEN CLUSTERS C3-C - SIDE
&INPUT NEXT=4, X=257.03, &
CASK DOSE - BETWEEN CLUSTERS C3-100 - SIDE
&INPUT NEXT=4, X=303.84, &
CASK DOSE - BETWEEN CLUSTERS C3-200 - SIDE
&INPUT NEXT=4, X=372.26, &
CASK DOSE - BETWEEN CLUSTERS C3-600 - SIDE
&INPUT NEXT=4, X=723.60, &
CASK DOSE - BETWEEN CLUSTERS C4-C - SIDE
&INPUT NEXT=4, X=215.45, &
CASK DOSE - BETWEEN CLUSTERS C4-100 - SIDE
&INPUT NEXT=4, X=254.63, &
CASK DOSE - BETWEEN CLUSTERS C4-200 - SIDE
&INPUT NEXT=4, X=144.75, &
CASK DOSE - BETWEEN CLUSTERS C4-600 - SIDE
&INPUT NEXT=4, X=746.35, &
CASK DOSE - BETWEEN CLUSTERS C5-C - SIDE
&INPUT NEXT=4, X=384.61, &
CASK DOSE - BETWEEN CLUSTERS C5-100 - SIDE
&INPUT NEXT=4, X=417.35, &
CASK DOSE - BETWEEN CLUSTERS C5-200 - SIDE
&INPUT NEXT=4, X=469.50, &
CASK DOSE - BETWEEN CLUSTERS C5-600 - SIDE
&INPUT NEXT=4, X=778.11, &
CASK DOSE - BETWEEN CLUSTERS C6-C - SIDE
&INPUT NEXT=4, X=444.38, &
CASK DOSE - BETWEEN CLUSTERS C6-100 - SIDE
&INPUT NEXT=4, X=473.00, &
CASK DOSE - BETWEEN CLUSTERS C6-200 - SIDE
&INPUT NEXT=4, X=519.60, &
CASK DOSE - BETWEEN CLUSTERS C6-600 - SIDE
&INPUT NEXT=4, X=809.32, &
CASK DOSE - BETWEEN CLUSTERS C1-C - SECOND ROW- SIDE
&INPUT NEXT=4, X=180.89, &
CASK DOSE - BETWEEN CLUSTERS C1-100 - SECOND ROW - SIDE
&INPUT NEXT=4, X=266.78, &
CASK DOSE FROM SHIELDED SECOND ROW-BETWEEN CLUSTERS-C1-2- SIDE
&INPUT NEXT=1, IGEOM=7, NSHLD=5, JBUF=4, IPRNT=0,
X=560.03, T(1)=10.14, T(2)=20.28, T(3)=2.46, T(4)=52.86, T(5)=0.45,
SLTH=69.62, Y=54.81, DUNIT=1, OPTION=0, SFACT=0.2517,
NPST=15, NTHETA=19, DELR=0.5,
WEIGHT(476)=5.66E-08, WEIGHT(526)=2.82E-05, WEIGHT(492)=2.46E-02,
WEIGHT(084)=3.10E-02, WEIGHT(494)=3.08E-02, WEIGHT(495)=1.06E+00,
WEIGHT(497)=1.13E-05, WEIGHT(496)=2.08E+00, WEIGHT(082)=3.83E-01,
WEIGHT(336)=9.46E-01, WEIGHT(456)=2.43E-02, WEIGHT(472)=2.08E-02,
WEIGHT(269)=5.42E-02, WEIGHT(415)=9.53E-02, WEIGHT(500)=2.60E-03,&
SOURCE 2 0.116 0.116
SOURCE 9 0.465 0.465
STEEL 9 7.85
CONCR 16 2.31
1 STEEL 9 7.85

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CASK DOSE - BETWEEN CLUSTERS C1-600 - SECOND ROW - SIDE
 &INPUT NEXT=4, X=750.61, &
 CASK DOSE - BETWEEN CLUSTERS C2-C - SECOND ROW - SIDE
 &INPUT NEXT=4, X=223.75, &
 CASK DOSE - BETWEEN CLUSTERS C2-100 - SECOND ROW - SIDE
 &INPUT NEXT=4, X=297.51, &
 CASK DOSE - BETWEEN CLUSTERS C2-200 - SECOND ROW - SIDE
 &INPUT NEXT=4, X=383.35, &
 CASK DOSE - BETWEEN CLUSTERS C2-600 - SECOND ROW - SIDE
 &INPUT NEXT=4, X=762.07, &
 CASK DOSE - BETWEEN CLUSTERS C3-C - SECOND ROW - SIDE
 &INPUT NEXT=4, X=282.29, &
 CASK DOSE - BETWEEN CLUSTERS C3-100 - SECOND ROW - SIDE
 &INPUT NEXT=4, X=343.71, &
 CASK DOSE - BETWEEN CLUSTERS C3-200 - SECOND ROW - SIDE
 &INPUT NEXT=4, X=420.22, &
 CASK DOSE - BETWEEN CLUSTERS C3-600 - SECOND ROW - SIDE
 &INPUT NEXT=4, X=781.27, &
 CASK DOSE - BETWEEN CLUSTERS C4-C - SECOND ROW - SIDE
 &INPUT NEXT=4, X=336.36, &
 CASK DOSE - BETWEEN CLUSTERS C4-100 - SECOND ROW - SIDE
 &INPUT NEXT=4, X=389.34, &
 CASK DOSE - BETWEEN CLUSTERS C4-200 - SECOND ROW - SIDE
 &INPUT NEXT=4, X=458.29, &
 CASK DOSE - BETWEEN CLUSTERS C4-600 - SECOND ROW - SIDE
 &INPUT NEXT=4, X=802.39, &
 CASK DOSE - BETWEEN CLUSTERS C5-C - SECOND ROW - SIDE
 &INPUT NEXT=4, X=401.93, &
 CASK DOSE - BETWEEN CLUSTERS C5-100 - SECOND ROW - SIDE
 &INPUT NEXT=4, X=401.93, &
 CASK DOSE - BETWEEN CLUSTERS C5-200 - SECOND ROW - SIDE
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 CASK DOSE - BETWEEN CLUSTERS C6-C - SECOND ROW - SIDE
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 CASK DOSE - BETWEEN CLUSTERS C6-200 - SECOND ROW - SIDE
 &INPUT NEXT=4, X=554.97, &
 CASK DOSE - BETWEEN CLUSTERS C6-600 - SECOND ROW - SIDE
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 WEIGHT(269)=5.42E-02, WEIGHT(415)=9.53E-02, WEIGHT(500)=2.60E-03, &
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 SOURCE 9 0.465
 STEEL 9 7.85
 FOAM 2 0.064
 CONC 3 0.00129
 1 STEEL 9 7.85
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 &INPUT NEXT=4, OPTION=0, X=185., &
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 &INPUT NEXT=4, X=285., &
 CASK DOSE AT THREE METERS - END
 &INPUT NEXT=4, X=385., &
 CASK DOSE AT SIX METERS - END
 &INPUT NEXT=6, X=685., &
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 WEIGHT(493)=3.10E-02, WEIGHT(494)=3.08E-02, WEIGHT(495)=1.06E+00,
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 WEIGHT(084)=3.83E-01, WEIGHT(319)=1.17E-01, WEIGHT(335)=1.00E+00,

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WEIGHT(269)=5.42E-02, WEIGHT(415)=9.53E-02, WEIGHT(500)=2.60E-03, &
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1 SOURCE 9 0.465
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NTHETA=19, DELR=2.,
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WEIGHT(493)=3.10E-02, WEIGHT(494)=3.08E-02, WEIGHT(495)=1.06E+00,
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WEIGHT(269)=5.42E-02, WEIGHT(415)=9.53E-02, WEIGHT(500)=2.60E-03, &
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1 SOURCE 9 0.465
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DATS ALL PHOLQUES!!!!!!&
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```

5.8.2 Input File for Accident Case

```

0      2 CONCRETE LINED WASTE PACKAGE ASSEMBLY
CASK DOSE AT CONTACT - END
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WEIGHT(493)=3.10E-02, WEIGHT(494)=3.08E-02, WEIGHT(495)=1.06E-02,
WEIGHT(497)=1.13E-05, WEIGHT(496)=3.04E-02, WEIGHT(082)=3.83E-01,
WEIGHT(084)=3.83E-01, WEIGHT(319)=1.17E-01, WEIGHT(335)=1.00E+00,
WEIGHT(336)=9.46E-01, WEIGHT(465)=2.43E-02, WEIGHT(472)=2.08E-02,
WEIGHT(269)=5.42E-02, WEIGHT(415)=9.53E-02, WEIGHT(500)=2.60E-03, &
SOURCE 2 0.116
SOURCE 9 0.465
STEEL 9      7.85
FOAM 2          0.064
CONCR 3          0.00129
1 STEEL 9          7.85
CASK DOSE AT ONE METER - END
&INPUT NEXT=4, OPTION=0, X=185., &
CASK DOSE AT TWO METERS - END
&INPUT NEXT=4, X=285., &
CASK DOSE AT THREE METERS - END
&INPUT NEXT=4, X=385., &
CASK DOSE AT SIX METERS - END
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CASK DOSE AT CONTACT - END - ACCIDENT CASE
&INPUT NEXT=1, IGEOM=9 NSHLID=5 JBUF=5 IPRNT=0,
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NTHETA=19, DELR=2.,
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WEIGHT(493)=3.10E-02, WEIGHT(494)=3.08E-02, WEIGHT(495)=1.06E-02,
WEIGHT(497)=1.13E-05, WEIGHT(496)=3.04E-02, WEIGHT(082)=3.83E-01,
WEIGHT(084)=3.83E-01, WEIGHT(319)=1.17E-01, WEIGHT(335)=1.00E+00,
WEIGHT(336)=9.46E-01, WEIGHT(465)=2.43E-02, WEIGHT(472)=2.08E-02,
WEIGHT(269)=5.42E-02, WEIGHT(415)=9.53E-02, WEIGHT(500)=2.60E-03, &
SOURCE 2 0.116
SOURCE 9 0.465
STEEL 9      7.85
FOAM 2          0.064
CONCR 3          0.00129
1 STEEL 9          7.85
CASK DOSE AT ONE METER - END - ACCIDENT CASE
&INPUT NEXT=4, OPTION=0, X=185., &
CASK DOSE AT TWO METERS - END - ACCIDENT CASE
&INPUT NEXT=4, X=285., &
CASK DOSE AT THREE METERS - END - ACCIDENT CASE
&INPUT NEXT=4, X=385., &
CASK DOSE AT SIX METERS - END - ACCIDENT CASE
&INPUT NEXT=4,X=685., & DATS ALL PHOLQUES!!!!!!
&INPUT NEXT=6, &

```

5.8.3 HEDOP Review Checklist

HEDOP REVIEW CHECKLIST
 for
 Radiological and Nonradiological Release Calculations

Document Reviewed: SHIELDING AND ACCIDENT DOSE CONSEQUENCE ANALYSES FOR THE USE OF THE CONCRETE-LINED WASTE PACKAGE ASSEMBLY

Submitted by: H. J. Goldberg

Date Submitted: 13 August 1996

Scope of Review: Dose consequences due to accidents

YES NO* N/A

- [] [] 1. A detailed technical review and approval of the environmental transport and dose calculation portion of the analysis has been performed and documented.
- [] [] 2. Detailed technical review(s) and approval(s) of scenario and release determinations have been performed and documented.
- [] [] 3. HEDOP-approved code(s) were used.
- [] [] 4. Receptor locations were selected according to HEDOP recommendations.
- [] [] 5. All applicable environmental pathways and code options were included and are appropriate for the calculations.
- [] [] 6. Hanford site data were used.
- [] [] 7. Model adjustments external to the computer program were justified and performed correctly.
- [] [] 8. The analysis is consistent with HEDOP recommendations.
- [] [] 9. Supporting notes, calculations, comments, comment resolutions, or other information is attached. (Use the "Page 1 of X" page numbering format and sign and date each added page.)
- [] 10. Approval is granted on behalf of the Hanford Environmental Dose Overview Panel.

* All "NO" responses must be explained and use of nonstandard methods justified.

Reviewer Name: Paul D. Rittmann, B.A., M.S., Ph.D., CHP

(print or type)

Paul Rittmann
 HEDOP-Approved Reviewer (Signature)

9-18-96

Date

5.8.4 Checklist for Independent Technical Review

CHECKLIST FOR INDEPENDENT TECHNICAL REVIEW

DOCUMENT REVIEWED

NUMBER: 8M730-HJG-96-xxx

TITLE: SHIELDING AND ACCIDENT DOSE CONSEQUENCE ANALYSES FOR THE USE OF THE CONCRETE-LINED WASTE PACKAGE ASSEMBLY

AUTHOR(s): H. J. Goldberg

I. Method(s) of Review

- Input data checked for accuracy
- Independent calculation performed
- Hand calculation
- Alternate computer code: _____
- Comparison to experiment or previous results _____
- Alternate method (define) _____

II. Checklist (either check or enter NA if not applied)

- Task completely defined
- Activity consistent with task specification
- Necessary assumptions explicitly stated and supported
- Resources properly identified and referenced
- Resource documentation appropriate for this application
- Input data explicitly stated
- Input data verified to be consistent with original source
- Geometric model adequate representation of actual geometry
- Material properties appropriate and reasonable
- Mathematical derivations checked including dimensional consistency
- Hand calculations checked for errors
- Assumptions explicitly stated and justified
- Computer software appropriate for task and used within range of validity
- Use of resource outside range of established validity is justified
- Software runstreams correct and consistent with results
- Software output consistent with input
- Results consistent with applicable previous experimental or analytical findings
- Results and conclusions address all points and are consistent with task requirements and/or established limits or criteria
- Conclusions consistent with analytical results and established limits
- Uncertainty assessment appropriate and reasonable
- Other (define) _____

III. Comments: units for distance on Table 5.3.1
 should be cm rather than m

IV. REVIEWER: Paul Rittmann DATE: 9-18-96

6.0 CRITICALITY EVALUATION

Table B6-1 shows the calculations to determine the fissile content of the concrete-shielded drum. The activities for the radionuclides identified as fissile in 49 CFR 173.403(j) are included along with their specific activities from 49 CFR 173.435. These radionuclides are ^{233}U , ^{235}U , ^{238}Pu , ^{239}Pu , and ^{241}Pu .

The quantity (g) of each fissile radionuclide is shown in Table B6-1. These values were calculated by dividing the radionuclide activity (Ci) by its specific activity (Ci/g). Table B6-1 shows that the total quantity of fissile material contained in the concrete-shielded drum is 0.135 g. Because the total quantity of fissile material is less than 15 g, the concrete-shielded drum is fissile excepted per 49 CFR 173.453(a), and no further analysis is required to address criticality concerns.

Table B6-1. Onsite Transfer Cask Fissile Inventory.

Nuclide	Activity, Bq	Activity, Ci	Specific activity, Ci/g*	Quantity, g
^{233}U	0	0	NA	0
^{235}U	5.26×10^2	1.42×10^{-8}	2.20×10^{-6}	6.46×10^{-3}
^{238}Pu	2.29×10^8	6.19×10^{-3}	17	3.64×10^{-4}
^{239}Pu	2.89×10^8	7.81×10^{-3}	0.062	0.126
^{241}Pu	9.87×10^9	0.267	100	2.67×10^{-3}
Total		NA	NA	0.135

*Specific activities taken from 49 CFR 173.435, 1996, "Shippers--General Requirements for Shipments and Packagings," *Code of Federal Regulations*, as amended.

6.1 REFERENCE

49 CFR 173, 1996, "Shippers--General Requirements for Shipments and Packagings," *Code of Federal Regulations*, as amended.

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7.0 STRUCTURAL EVALUATION

The PNNL Concrete-Shielded RH TRU Drum packaging is essentially a carbon steel pipe encased in concrete and housed in a 55-gal drum. ICF Kaiser Hanford Company designed the package for PNNL to transport contaminated waste from the 327 Building to the Transuranic Waste Storage and Assay Facility (TRUSA) for storage. The contents of the package are contaminated hot cell wastes, which have been put into paint cans.

7.1 STRUCTURAL DESIGN AND FEATURES

The outer shell of the package is a UN1A2 55-gal galvanized drum with a removable gasketed head cover and bolted locking ring. The drum and head cover are manufactured from 18-gage American Society for Testing and Materials (ASTM) A 366 (ASTM 1989) galvanized steel. A NucFil¹-013 filter is provided on the head cover. Containing the contents within the drum is an inner shell consisting of a schedule 40 pipe with flanged ends encased in concrete. The inner shell is a pipe manufactured from 8-in. schedule 40 carbon steel pipe with a 10-in. x 8-in. schedule 40 concentric reducer welded to the top end. The reducer is welded to a 45.09-cm- (16.75-in.-) outside diameter by 3.8-cm- (1.5-in.-) thick circular flange, equipped with 12, $\frac{1}{2}$ -in. 13 UNC bolt holes. Closure is provided by 45.09-cm- (16.75-in.-) outside diameter by 1.91-cm- ($\frac{3}{8}$ -in.-) thick cover plate attached to the inner shell with 12, $\frac{1}{2}$ -in. 13 UNC ASTM A-449 (ASTM 1989) closure bolts. The cover plate is also provided with a NucFil-13 filter. Compressed by the closure bolts between the cover plate and inner shell assembly is a 0.32-cm- ($\frac{1}{8}$ -in.-) thick silicone rubber gasket. Installed inside the inner shell is a 6.4-cm (2 $\frac{1}{2}$ -in.) cone-shaped shield plug fabricated from ASTM A-36 (ASTM 1989) carbon steel. Between the inner shell and the cover plate is a rigid, close-cell polyurethane foam with a density of approximately 64.07 kg/m³ (4 lb/ft³). Bottom end closure is provided by a 34.59-cm- (13.62-in.-) diameter 6.4-cm- (2 $\frac{1}{2}$ -in.-) thick plate, which is welded to the inner shell. Welded to the bottom plate are 0.64-cm- ($\frac{1}{4}$ -in.-) thick outriggers for embedment into the concrete. Inner shell welds are performed in accordance with AWS/ANSI D1.1 (AWS/ANSI 1989). The specification and physical properties for the materials of construction are shown in Table B7-1.

The properties of the concrete are specified as having a density of 2,307 to 2643 kg/m³ (144 to 165 lb/ft³) with minimum strength of 21 MPa (3,000 psi) at 28 days.

7.2 CHEMICAL AND GALVANIC REACTIONS

The UN1A2 55-gal drum is manufactured from galvanized steel, which inhibits normal atmospheric corrosion for transportation. The carbon steel lid and hub flange are protected by the drum from direct exposure to the atmosphere for transportation. For those carbon steel components encased in

¹NucFil is a trademark of NFT Incorporated.

Table B7-1. Structural Materials of Construction at 93.3 °C (200 °F).

Item(s)	Specification	Ultimate strength MPa (ksi)	Yield strength MPa (ksi)	Allowable stress MPa (ksi)
Cover plate, hub flange, bottom end plate	ASTM A-516 Grade 60	414 (60)	221 (32)	103 (15)
Closure bolts	ASTM A-449	827 (120)	634 (92)	421 (61)
Concentric reducer	ASTM A-234 Grade WPB	414 (60)	241 (35)	103 (15)
8-in. schedule 40 pipe	ASTM A-106 Grade B	414 (60)	241 (35)	103 (15)

Source for all material properties: ASME, 1995, ASME Boiler and Pressure Vessel Code, Section II, Part D, American Society for Mechanical Engineers, New York, New York.

concrete, the alkaline nature of concrete ensures permanence of the steel. This has been confirmed by the examination of steel reinforcement in buildings that have been demolished (Baumeister and Marks 1967).

7.3 BRITTLE FRACTURE

Based on the requirements for low-temperature operations established in ASME (1995c) Section VIII, Division 1, critical packaging materials are acceptable for a minimum operating temperature of -12.2 °C (10 °F) without impact testing. The 55-gal drum, 8-in. schedule 40 pipe, and concentric reducer have thicknesses less than 1 cm (0.4 in.) thickness. Consequently these materials have a minimum operating temperature of less than -12.2 °C (10 °F). The heavy cover plate, hub flange, and bottom end flange are fabricated from normalized ASTM A-516 carbon steel and are under 10 cm (4 in.) in thickness. These components also have a minimum operating temperature of less than -12.2 °C (10 °F). The closure bolts are manufactured from ASTM A-449 (ASTM 1989) carbon steel and have a low temperature limit of -29 °C (-20 °F). This demonstrates the package materials are acceptable for transport for temperatures above -12.2 °C (10 °F).

7.4 SIZE OF PACKAGE AND CAVITY

The interior dimensions of the package are for a UN1A2 55-gal drum. The interior cavity dimensions for a 55-gal drum are for a right circular cylinder with a height of 86.1 cm (33.9 in.) and a diameter of 57.15 cm (22.50 in.). The inner shell assembly cavity is also a right circular cylinder. Clear dimensions of the cavity are 63.22 cm (24.89 in.) in height and 20.27 cm (7.98 in.) diameter.

7.5 WEIGHT AND CENTER OF GRAVITY

The maximum gross weight of the package is limited to 658 kg (1,450 lb). Estimated empty weight of the package is 619 kg (1,364 lb). The center of gravity is located at approximately the geometric center of the package.

7.6 TAMPER-INDICATING FEATURES

There are no tamper-indicating features provided on this package.

7.7 POSITIVE CLOSURE

Positive closure of the package is provided by 12, $\frac{1}{2}$ -in. 13 UNC hex head bolts on the cover plate and threaded into the inner shell assembly. An additional positive closure is provided by a bolted lock ring securing the lid onto the UNIA2 55-gal drum.

7.8 LIFTING AND TIEDOWN DEVICES

There are two stainless steel wire rope assemblies welded to the shield plug for lifting and handling of the shield plug. Each stainless steel wire rope has a rated capacity of 798 kg (1,760 lb). The McMaster-Carr SAFE-LINE (McMaster-Carr 1990) rope clips have a rated capacity of 90% of the wire rope capacity. The estimated weight of the shield plug is 23 kg (50 lb). Consequently, there is a large margin of safety for lifting and handling of the shield plug. No other lifting devices are provided on the package. There are no tiedown devices provided on the package.

7.9 NORMAL CONDITIONS OF TRANSPORT (NCT)

7.9.1 Conditions To Be Evaluated

The analytical NCT tests to be applied for this package are a 1.2-m (4.0-ft) flat top end drop onto a concrete surface and an external pressure reduction of 24.1 kPa (3.5 psia). Loadings from these two conditions are combined for determination of package performance. For conservatism, the NCT operating temperature of the package is assumed at 93.3 °C (200 °F). Due to the thickness of the inner shell and concrete, the package is not vulnerable to NCT penetration. Vibration performance of the package is not assessed since each package is for one-time transport.

7.9.2 Acceptance Criteria

Acceptance of the performance of the package design is based on the stresses induced by the loading remaining below the material specified allowable stresses. The allowable stresses are based on the stress intensity method for failure determination used by ASME in Section III, Subsection NB, for Service Level A conditions (ASME 1995b). Maintaining the contents within the package for the NCT evaluated is demonstrated by the stress intensities resulting from the applied loads remaining below the allowables.

7.9.3 Structural Model

The structural evaluation of this package is based on classical linear elastic analytical methods and techniques. Determination of impact loads are based on the pressure flow concept set forth by Oak Ridge National Laboratory (ORNL 1970). Within the evaluation only the critical components for maintaining the contents in the package are evaluated. The evaluated critical components for this package are defined as the cover plate and closure bolts.

7.10 STRUCTURAL EVALUATION AND CONCLUSIONS

Based on the Oak Ridge National Laboratory pressure flow concept of steel (ORNL 1970), the impact deceleration load factor for a 1.2-m (4.0-ft) flat top end drop onto a concrete surface was determined as 78g. As shown in Part B, Section 5.13, the deceleration load factor is a result of the deformation of the 55-gal drum and lid upon impact. This deceleration load factor multiplied by the weight of the cover plate is then applied as a uniform load on the upper closure system, which consists of the cover plate and hold-down bolts. An additional deceleration load factor is determined for the impact of the contents onto the cover plate. Determination of the deceleration load factor of the contents is based on deformation of the foam insert inside the inner shell. In this case the static crush stress and strain of the foam are used to determine the deceleration load factor. This factor times the weight of the contents is then applied as a uniform load on the upper closure system. These two loads are combined with the differential pressure load to determine the stresses on the closure bolts and cover plate.

The stress in the bolts are evaluated by the methods outlined in *Stress Analysis of Closure Bolts for Shipping Casks* (LLNL 1993). Results of the evaluation show the margins of safety for the average stress is 1.54, average shear stress is 3.99, and total stress is 1.11. Stresses on the cover plate are evaluated based on idealizing the plate as a simply supported circular plate under uniform loading. The maximum total stress on the plate occurs at the center of the plate. Based on the ASME allowable for ASTM A-516 (ASTM 1989) carbon steel, the margin of safety for total stress is 3.38. These large positive margins of safety demonstrate that the cover plate and closure bolts have sufficient structural integrity to maintain the contents in the package during NCT.

7.11 ACCIDENT FAILURE THRESHOLDS

The failure thresholds are the conditions at which the package fails to retain the contents. These parameters are used as inputs in developing the transportation risk assessment. Failure determination is based on exceeding ASME Section III, Subsection NB, allowables for Service Level D conditions (ASME 1995b). In Part B, Section 7.13, the failure thresholds for impact velocity change and puncture are determined. For this package based on the NCT drop evaluation, loading from a 1.2-m (4.0-ft) drop exceeds the 71,170-newton (16,000-lb) crush load failure threshold load for a small package. Consequently, it demonstrated that the package will not crush. In the evaluation in Part B, Section 7.13, the impact velocity change failure threshold is 37 km/h (23 mph) for the package. This failure threshold is

based on the orientation that causes the most damage. In this case, an oblique, over-the-center-of-gravity impact of the package causes the maximum damage to the packaging. The puncture failure threshold is based on the Sandia National Laboratory methodology (SNL 1976), which equates the ratio relative velocity of the package to a probe of a given diameter. For this package the puncture failure threshold is 265 sec¹.

7.12 REFERENCES

ASME, 1995a, *ASME Boiler and Pressure Vessel Code*, Section II, Part D, American Society of Mechanical Engineers, New York, New York.

ASME, 1995b, *ASME Boiler and Pressure Vessel Code*, Section III, Subsection NB, American Society of Mechanical Engineers, New York, New York, 1995.

ASME, 1995c, *ASME Boiler and Pressure Vessel Code*, Section VIII, Division 1, American Society of Mechanical Engineers, New York, New York.

AWS/ANSI, 1989, *Structural Welding Code-Steel*, AWS/ANSI D1.1-89, American Welding Society/American National Standards Institute, Miami, Florida.

ASTM, 1989, *Annual Book of ASTM Standards*, Vol. 1.01 and 1.04, American Society of Testing, Philadelphia, Pennsylvania.

Baumeister, T., and L. S. Marks, 1967, *Standard Handbook for Mechanical Engineers*, Seventh Edition, McGraw-Hill Book Company, New York, New York.

LLNL, 1993, *Stress Analysis of Closure Bolts for Shipping Casks*, NUREG/CR-6007, TI 006540, Lawrence Livermore National Laboratory, Livermore, California.

McMaster-Carr, 1990, *Catalog 90*, McMaster-Carr Supply Company, Los Angeles, California.

ORNL, 1970, *Cask Designer's Guide*, ORNL-NISC-68, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

SNL, 1976, *Severities of Transportation Accidents, Volume 1: Summary*, SLA-74-0001, Sandia National Laboratory, Albuquerque, New Mexico.

7.13 APPENDICES

7.13.1 Engineering Safety Evaluation--Failure Thresholds

ENGINEERING SAFETY EVALUATION

Subject	Pacific Northwest Concrete Waste Drum Failure Thresholds	Page	1 of 11
Originator	S. S. Shiraga	Date	08/01/96
Checker	J. J. Mahoney	Date	08/19/96

I. Objective:

The objective of this evaluation is to determine the Pacific Northwest Concrete Waste Drum impact velocity change and puncture failure thresholds.

II. References:

ASME, 1992, *Boiler and Pressure Vessel Code*, Section III, Service Level D, American Society of Mechanical Engineers, New York, New York.

ASME, 1992, *Boiler and Pressure Vessel Code*, Section VIII, American Society of Mechanical Engineers, New York, New York.

ASME, 1995, *Boiler and Pressure Vessel Code*, Section II, American Society of Mechanical Engineers, New York, New York.

DOD, 1994, *Military Handbook - Metallic Materials and Elements for Aerospace Vehicle Structures*, MIL-HDBK-5G, U.S. Department of Defense, Washington, D.C., November 1994.

General Plastics, 1996, *LAST-A-FOAM FR-6700 Product Data Sheet*, General Plastics, Tacoma, Washington, June 1996.

LLNL, 1993, *Stress Analysis of Closure Bolts for Shipping Casks*, NUREG/CR-6007, TI 006540, Lawrence Livermore National Laboratory, Livermore, California, January 1993.

ORNL, 1970, *Cask Designer's Guide*, ORNL-NISC-68, Oak Ridge National Laboratory, Oak Ridge, Tennessee, February 1970.

Pacific Northwest, 1996, *Concrete-Lined Waste Package*, drawing H-3-304541, Rev. 0, Pacific Northwest National Laboratory, Richland, Washington, July 1996.

SNL, 1976, *Severities of Transportation Accidents, Volume 1: Summary*, Sandia National Laboratory, Albuquerque, New Mexico, July 1976.

III. Results and Conclusions:

For this evaluation, the package velocity impact failure threshold is the impacting velocity at which the lid bolts fail and the contents are expelled from the package. The deceleration loading from the impact onto a concrete surface is determined by the pressure flow concept developed by ORNL (ORNL 1970) in the worst case orientation. However, since the outer packaging is sheet metal, the concrete acts as a hard unyielding surface. Package failure parameters are determined by classical methods. For conservatism, the NCT loading from pressure is combined with the drop loading. The puncture failure threshold is determined by the methods developed by SNL (SNL 1976), which is determined by the ratio of relative velocity of a package to a probe.

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Results of the evaluation show the package closure lid bolts fail at an impact velocity of 23 mph. The ratio of the relative velocity of the package to a probe is determined as 265 sec^{-1} .

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IV. Evaluation:**Failure Threshold Evaluation of Pacific Northwest Drum Design**

Dimensional values from Pacific Northwest Drawing H-3-304541 (Pacific Northwest 1996):

Assumed drum thickness: $t_d = 0.0516$ in. Lid thickness: $t_l = 0.0516$ in.

Drum ID: $id_d = 22.5$ in. Lid total depth: $d_{lid} = 0.75$ in.

Corner radius: $r_{cor} = 0.25$ in. Density of stainless steel: $\rho_{sst} = 0.29 \frac{\text{lb}}{\text{in}^3}$

Flow stress of drum material: $\sigma_{fs} = 50,000$ psi Assumed initial crush height: $h_{drc} = d_{lid} - 2 r_{cor}$

Outside diameter of drum: $od_d = id_d + 2 t_d$ ID of lid: $id_l = od_d - 2 t_d - 2 t_l$

Gross weight of drum: $W_{dr} = 1,450$ lb Assume drop height: $h_{drop} = 17$ ft

Weight determination:

Lid dimensions: $t_{pl} = 0.75$ in. Diameter: $d_{lid} = 16.75$ in.

Lid weight: $W_{lid} = \rho_{sst} = \frac{\pi d_{lid}^2}{4} t_{pl}$ $W_{lid} = 48$ lb

Weight of contents: $W_{cont} = 36$ lb

Plug dimensions: $bd_{plug} = 10.05$ in. $sd_{plug} = 8.25$ in.

$t_{land} = 0.5$ in. $h_{plug} = 2.5$ in.

Volume of plug, plate, and cone sections:

$$V_{plug} = \frac{\pi bd_{plug}^2}{4} t_{land} + \frac{1}{3} \pi (h_{plug} - t_{land}) \left[\left(\frac{bd_{plug}}{2} \right)^2 + \left(\frac{sd_{plug}}{2} \right)^2 + \frac{bd_{plug}}{2} \frac{sd_{plug}}{2} \right]$$

Weight of plug: $W_{plug} = \rho_{sst} V_{plug}$ $W_{plug} = 50$ lb

Weight of plug and contents: $W_{pc} = W_{cont} + W_{plug}$ $W_{pc} = 86$ lb

Energy of drop: $E_{dr} = W_{dr} h_{drop}$ $E_{dr} = 24,650$ ft-lb

Bolt loading from internal pressure:

Evaluate bolts per NUREG/CR-6007 (LLNL 1993). Determine required bolt torque per ASME Section VIII (ASME 1992).

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Assumed differential pressure: $p_f = 11.2 \text{ psi}$ Poisson's ratio: $\nu_t = 0.29$

Thickness of wall: $t_w = 0.322 \text{ in.}$

Elastic modulus of bolt: $E_{\text{bolt}} = 28.6 \times 10^6 \text{ psi}$ Elastic modulus of sst: $E_{\text{sst}} = 27.6 \times 10^6 \text{ psi}$

Bolts:

Number: $n_b = 12$ Nominal diameter: $D_b = 0.5 \text{ in.}$ Pitch: $13/\text{in.}$

Diameter of bolt circle: $D_{\text{bc}} = 14.75 \text{ in.}$ Inside diameter: $d_{\text{in}} = 10.75 \text{ in.}$

Bolt length between top and bottom of lid: $L_b = t_w + 0.251 \text{ in.}$ Flange thickness: $t_f = 1.5 \text{ in.}$

Assume worst case operating temperature of 200°F , values from ASME, Section II (ASME 1995) and temperature correction factors from *Military Handbook - Metallic Materials and Elements for Aerospace Vehicle Structures* (Military Handbook 1994):

Assume bolt yield (ASTM A449): $s_y = 0.95 \text{ (92 ksi)}$ $s_y = 87.4 \text{ ksi}$

Assume ultimate: $s_u = 0.98 \text{ (120 ksi)}$ $s_u = 117.6 \text{ ksi}$

Allowable: $s_m = 23 \text{ ksi}$

Assume gasket factors: $y_{\text{gas}} = 200 \text{ psi}$ $m = 1.0$

Location of gasket load reaction:

$$\text{Width of gasket: } b_o = \frac{1}{2} \frac{(13.25 - 11.25)}{2} \text{ in.} \quad b_o = 0.5 \text{ in.}$$

$$\text{Effective width of gasket: } b = 0.5 \sqrt{\frac{b_o}{\text{in.}}} \quad b = 0.35 \text{ in.}$$

$$\text{Location: } D_{lg} = 13.25 \text{ in.} - 2 b \quad D_{lg} = 12.54 \text{ in.}$$

$$\text{Minimum preload to seat gasket: } F_{\text{spmin}} = \frac{\pi D_{lg} b y_{\text{gas}}}{n_b} \quad F_{\text{spmin}} = 232 \text{ lb}$$

$$\text{Minimum operating gasket load: } F_{\text{opmin}} = \frac{2 \pi D_{lg} b m p_f}{n_b} \quad F_{\text{opmin}} = 26 \text{ lb}$$

Therefore, seating load is larger; however, to maintain bolt tightness, increase preload to:

$$T_{\text{pre}} = 25 \text{ lb-ft} \quad \text{Recommended torque for alloy steel bolts.}$$

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Non-prying tensile force on bolts due to preload:

Friction factor assuming use Never-Seez: $k_{\text{bolt}} = 0.18$

$$F_{\text{apre}} = \frac{T_{\text{pre}}}{k_{\text{bolt}} D_b} \quad F_{\text{apre}} = 3,333 \text{ lb}$$

Residual torque on bolt: $M_t = 0.5 T_{\text{pre}}$

Pressure load on bolt:

$$\text{Non-prying tensile force per bolt: } F_{\text{apress}} = \frac{\pi D_{\text{lg}}^2 P_f}{4 n_b} \quad F_{\text{apress}} = 115 \text{ lb}$$

$$\text{Shear force per bolt: } F_{\text{spress}} = \frac{\pi E_{\text{est}} t_{\text{pl}} P_f D_{\text{lg}}^2}{2 n_b E_{\text{est}} t_w (1 - v_s)} \quad F_{\text{spress}} = 1,046 \text{ lb}$$

$$\text{Fixed edge prying force: } F_{\text{fpres}} = \frac{D_{\text{lb}} P_f}{4} \quad F_{\text{fpres}} = 41 \frac{\text{lb}}{\text{in}}$$

$$\text{Fixed edge prying moment: } M_{\text{fpres}} = \frac{P_f D_{\text{lb}}^2}{32} \quad M_{\text{fpres}} = 76 \frac{\text{lb in}}{\text{in}}$$

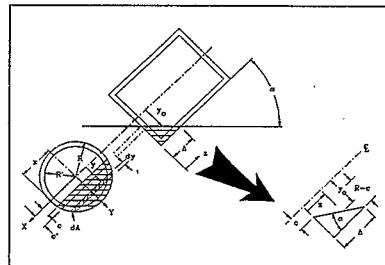
Oblique drop:

Using the concept of flow stress of steel, and idealizing the package as a hollow right angle cylinder, determine the deceleration loads.

Derivation of oblique crush equations:

CG of package assumed 6 in. from bottom of shield plug.

Distance from top of package to CG, scaled from Pacific Northwest drawing H-3-304541 (Pacific Northwest 1996):



$$s_{\text{top}} = 15 \text{ in.}$$

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$$\gamma = \tan \frac{id_4}{s_{\text{top}}} \quad \gamma = 56.31^\circ$$

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Assumed over CG corner drop angle: $\alpha = 90^\circ - \gamma$ $\alpha = 33.69^\circ$

Determined crushed volume of a solid cylindrical end:

By symmetry: $dA = 2x dy$ and for a circle: $r^2 = x^2 + y^2$

Therefore cross-sectional crush area: $A = \int_c^R 2 \sqrt{r^2 - y^2} dy$

Therefore volume of crush is: $V = \int_0^{\Delta} A dz = \int_0^{\Delta} \int_c^R 2 \sqrt{R_d^2 - y^2} dy dz$

By integrating with respect to y: $V = \int_0^{\Delta} \left(\frac{\pi R_d^2}{2} - y_o \sqrt{R_d^2 - y^2} - R_d^2 \sin \left(\frac{y_o}{R_d} \right) \right) dz$

Since by geometry: $\Delta = \frac{R_d - c}{\tan(\alpha)}$ and $y_o = c + z \tan(\alpha)$

The volume then becomes:

$$V = \int_0^{\Delta} \left[\frac{\pi R_d^2}{2} - (c + z \tan(\alpha)) \sqrt{R_d^2 - (c + z \tan(\alpha))^2} - R_d^2 \sin \frac{c + z \tan(\alpha)}{R_d} \right] dz$$

Integrating by parts:

$$V = \frac{R_d^2 \sqrt{R_d^2 - c^2} + c R_d^2 \sin \left(\frac{c}{R_d} \right) - \frac{\pi R_d^2 c}{2} - \frac{1}{3} (R_d^2 - c^2)^{\frac{3}{2}}}{\tan(\alpha)}$$

Idealize the drum as a hollow cylinder with closed ends. To determine total volume of deformation subtract volume of solid outer cylinder from volume of solid inner cylinder and solve for c.

Volume of outer solid cylinder:

$$V_{osc} = \frac{R_d^2 \sqrt{R_d^2 - c^2} + c R_d^2 \sin \left(\frac{c}{R_d} \right) - \frac{\pi R_d^2 c}{2} - \frac{1}{3} (R_d^2 - c^2)^{\frac{3}{2}}}{\tan(\alpha)}$$

Volume of inner solid cylinder:

$$V_{isc} = \frac{R'_d^2 \sqrt{R'_d^2 - c'^2} + c' R'_d^2 \sin \left(\frac{c'}{R'} \right) - \frac{\pi R'_d^2 c'}{2} - \frac{1}{3} (R'_d^2 - c'^2)^{\frac{3}{2}}}{\tan(\alpha)}$$

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By geometry: $R'_d = R_d - t_d$ and $c' = c + t_d \tan(\alpha)$

By substitution:

$$V_{fs} = \left[\begin{array}{l} (R_d - t_d)^2 - \sqrt{(R_d - t_d)^2 - (c + t_d \tan(\alpha))^2} \\ + (c + t_d \tan(\alpha))(R_d - t_d)^2 \arcsin \left(\frac{c + t_d \tan(\alpha)}{R_d - t_d} \right) \\ + \left[\frac{-\pi (R_d - t_d)^2 (c + t_d \tan(\alpha))}{2} - \frac{1}{3} [(R_d - t_d)^2 - (c + t_d \tan(\alpha))^2]^{\frac{3}{2}} \right] \end{array} \right] \tan(\alpha)$$

Define: $R_d = \frac{od_d}{2}$ $R_i = \frac{id_d}{2} - t_i$

Using the concept of flow stress (ORNL 1970):

By conservation of energy and assuming a coefficient of restitution of 0.

$$E_{dr} = \sigma_{fs} V_{fs}$$

Using Mathcad *Find* function to solve for c :

Given

$$\sigma_{fs} \left[\begin{array}{l} R_d^2 \sqrt{R_d^2 - c^2} + c R_d^2 \arcsin \frac{c}{R_d} - \frac{\pi R_d^2 c}{2} - \frac{1}{3} (R_d^2 - c^2)^{\frac{3}{2}} \\ \left[\begin{array}{l} R_i^2 \sqrt{R_i^2 - (c + t_d \tan(\alpha))^2} \\ + (c + t_d \tan(\alpha)) R_i^2 \arcsin \left(\frac{c + t_d \tan(\alpha)}{R_i} \right) \\ + \frac{-\pi R_i^2 (c + t_d \tan(\alpha))}{2} \\ + \left[\frac{-1}{3} [R_i^2 - (c + t_d \tan(\alpha))^2]^{\frac{3}{2}} \right] \end{array} \right] \\ - 1 \left[\begin{array}{l} \tan(\alpha) \end{array} \right] \end{array} \right] = E_{dr}$$

$c = 8.5$ in.

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Based on this estimate deformation, assume crushed area is an ellipse:

$$\text{Major axis: } a = \frac{R_d - c}{\sin(\alpha)} \quad a = 5.06 \text{ in.}$$

Minor axis:

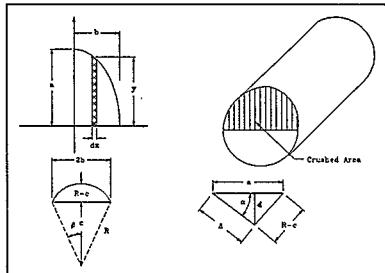
$$\beta = \arccos \frac{c}{R_d} \quad \beta = 41.27^\circ$$

$$b = \frac{R_d \sin(\beta)}{2} \quad b = 3.73 \text{ in.}$$

Ignore energy absorption contribution of localized concrete failure.

$$\text{Width of impact: } R_d - c = 2.81 \text{ in.}$$

$$\text{Depth of deformation: } d = b \sin(\alpha) \quad d = 2.07 \text{ in.}$$



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$$\text{Deceleration load based on deformation: } g_{dec} = \frac{h_{drop}}{d} \quad g_{dec} = 99$$

Assume uniform impact loading on bolts (LLNL 1993):

Assumed dynamic load factor: DLF = 1.5

$$\text{Non-prying force: } F_{simp} = \frac{1.34 (W_{pc} + W_{lid}) g_{dec} DLF}{n_b} \quad F_{simp} = 2,210 \text{ lb}$$

$$\text{Shear load on bolts: } F_{simp} = \frac{g_{dec} (W_{pc} + W_{lid}) \cos(\alpha) DLF}{n_b} \quad F_{simp} = 1,372 \text{ lb}$$

$$\text{Fixed edge forces: } F_{simp} = \frac{1.34 (W_{pc} + W_{lid}) g_{dec} DLF}{\pi D_{lb}} \quad F_{simp} = 572 \frac{\text{lb}}{\text{in}}$$

$$\text{Fixed edge moments: } M_{simp} = \frac{1.34 (W_{pc} + W_{lid}) g_{dec} DLF}{8 \pi} \quad M_{simp} = 1,055 \text{ lb} \frac{\text{in}}{\text{in}}$$

Ignore vibration and thermal loading.

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Preload per unit length of bolt circle: $P_{pre} = \frac{F_{pre}}{\pi D_{lb}}$ $P_{pre} = 72 \frac{\text{lb}}{\text{in}}$

Load combinations:

$$F_{pre} = 3,333 \text{ lb} \quad \text{and} \quad F_{al} = F_{pre} + F_{imp} \quad F_{al} = 2,325 \text{ lb}$$

$$F_{fc} = F_{press} + F_{imp} \quad F_{fc} = 614 \text{ lb/in}$$

$$M_{fc} = M_{press} + M_{imp} \quad M_{fc} = 1,131 \text{ lb in/in}$$

Additional tensile force due to prying:

$$\text{Factors:} \quad C1 = 1$$

$$C2 = \frac{8}{3(d_{ld} - d_{ln})^2} \left[\frac{E_{sat} t_{pl}^3}{(1 - v_s)} + \frac{(d_{ld} - d_{ln}) E_{sat} t_{lf}^3}{D_{lb}} \right] \frac{L_b}{n_b D_b^2 F_{bolt}}$$

$$K_{bb} = \frac{n_b}{L_b} \frac{E_{bolt}}{D_{lb}} \frac{D_b^4}{64} \quad K_1 = \frac{E_{sat} t_{pl}^3}{3 \left[(1 - v_s^2) + (1 - v_s)^2 \frac{D_{lb}^2}{d_{ld}^2} \right] D_{lb}}$$

$$\text{Prying tensile force:} \quad F_{sp} = \frac{\pi D_{lb}}{n_b} \left[\frac{2 M_{fc}}{(d_{ld} - D_{lb})} - C2 (F_{fc} - P_{pre}) \right] \quad F_{sp} = 4,220 \text{ lb}$$

$$\text{Bending moment:} \quad M_{bb} = \frac{\pi D_{lb}}{n_b} \frac{K_{bb}}{K_{bb} + K_1} M_{fc} \quad M_{bb} = 806 \text{ lb-in}$$

$$\text{Total force on bolts:} \quad F_{tot} = F_{al} + F_{sp} \quad F_{tot} = 6,545 \text{ lb}$$

$$\text{Effective bolt diameter:} \quad D_{ba} = D_b - 0.9743 \frac{1}{\text{pit}}$$

$$\text{Average tensile stress:} \quad s_{ba} = \frac{1.2732 F_{tot}}{D_{ba}^2} \quad s_{ba} = 46,125 \text{ psi}$$

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Average shear stress: $s_{bs} = \frac{1.2732 (F_{simp} + F_{spres})}{D_{ba}^2}$ $s_{bs} = 17,043 \text{ psi}$

Maximum bending stress: $s_{bb} = \frac{10.186 M_{bb}}{D_{ba}^3}$ $s_{bb} = 106,856 \text{ psi}$

Maximum shear by bolt torsion: $s_{bt} = \frac{5.093 M_t}{D_{ba}^3}$ $s_{bt} = 9,948 \text{ psi}$

Maximum stress intensity: $s_{bi} = \sqrt{(s_{bs} + s_{bb})^2 + 4 (s_{bs} + s_{bt})^2}$ $s_{bi} = 162,225 \text{ psi}$

Margin of safety based on ASME Section III, Service Level D (ASME 1992) criteria:

Average stress: $MS_1 = \frac{0.7 s_u}{s_{bs}} - 1$ $MS_1 = 0.78$

Average shear stress: $MS_2 = \frac{0.42 s_u}{s_{bs}} - 1$ $MS_2 = 2$

Ratio of average tensile stress to allowable and average shear stress to allowable must be less than 1:

$$\frac{s_{ba}}{0.7 s_u} + \frac{s_{bt}}{0.42 s_u} = 1$$

Bolt failure in shear and tensile.

Threshold velocity: $vel = \sqrt{2 g h_{drop}}$ $vel = 23 \text{ mph}$

Equivalent thickness of steel for puncture risk:

Approximate thickness of concrete: $t_{conc} = 7 \text{ in.}$

Pipe thickness: $t_{pipe} = 0.322 \text{ in.}$

Equivalent steel thickness: $t_{eq} = \frac{t_{conc}}{12} + t_d + t_{pipe}$ $t_{eq} = 0.96 \text{ in.}$

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Puncture failure threshold (SNL 1976):

Ratio of relative velocity between package and probe:

$$\text{ratio} = \sqrt{\frac{t_{eq} \pi s_y}{\left(\frac{W_{dr}}{g}\right)}} \quad \text{ratio} = 265 \text{ sec}^{-1}$$

7.13.2 Engineering Safety Evaluation--NCT Drop

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Originator S. S. Shiraga S. S. Shiraga Date 07/26/96
Checker J. J. Mahoney J. J. Mahoney Date 08/12/96

I. Objective:

The objective of this evaluation is to determine the NCT 4 ft drop performance of the Pacific Northwest designed concrete lined waste drum.

II. References:

ASME, 1992, *Boiler and Pressure Vessel Code*, Section VIII, American Society of Mechanical Engineers, New York, New York.

General Plastics, 1996, *LAST-A-FOAM FR-6700 Product Data Sheet*, General Plastics, Tacoma, Washington, June 1996.

LLNL, 1993, *Stress Analysis of Closure Bolts for Shipping Casks*, NUREG/CR-6007, TI 006540, Lawrence Livermore National Laboratory, Livermore, California, January 1993.

ORNL, 1970, *Cask Designer's Guide*, ORNL-NISC-68, Oak Ridge National Laboratory, Oak Ridge, Tennessee, February 1970.

Pacific Northwest, 1996, *Concrete-Lined Waste Package*, drawing H-3-304541, Rev. 0, Pacific Northwest National Laboratory, Richland, Washington, July 1996.

Young, W. C., 1989, *Roark's Formulas for Stress and Strain*, Sixth Edition, McGraw-Hill, Inc., New York, New York.

III. Results and Conclusions:

The Pacific Northwest package deceleration loading is determined by pressure flow concept developed by ORNL (ORNL 1970). Package performance is evaluated by classical methods. For this evaluation, it is assumed the worst case deceleration loads are generated from a top end drop onto a concrete surface. However, since the outer packaging is a 55-gallon drum comprised of sheet metal, the concrete acts as a hard unyielding surface. For conservatism, the NCT loading from pressure is combined with the drop loadings.

Results of the evaluation show the package 55-gallon drum outer housing deforms and the inner impact limiting foam crushes to decelerate the package during a 4 ft NCT drop. Deformation of the drum and crushing of the foam reduces the deceleration loading on the inner package. The evaluation shows that at these reduced deceleration levels, the contents are retained. This is demonstrated by the positive margins of safety on the closure bolts and lid from the combined loadings.

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IV. Evaluation:NCT Impact Evaluation of Pacific Northwest Drum Design

Assumed drum thickness (18 gage): $t_d = 0.0516$ in. Lid thickness (18 gage): $t_l = 0.0516$ in.

Drum ID: $id_d = 22.5$ in. Lid total depth: $h_{lid} = 0.75$ in.

Corner radius: $r_{cor} = 0.25$ in. Density of stainless steel: $\rho_{sst} = 0.29 \frac{\text{lb}}{\text{in}^3}$

Flow stress of drum material: $\sigma_{fs} = 50,000$ psi Assumed initial crush height: $h_{drc} = h_{lid} - 2 r_{cor}$

Outside diameter of drum: $od_d = id_d + 2 t_d$ ID of lid: $id_l = od_d - 2 t_d - 2 t_l$

Cross sectional area of drum: $A_{cr} = \frac{\pi}{4} (od_d^2 - id_l^2)$

Crush volume: $V_{cr} = \frac{\pi}{4} (od_d^2 - id_l^2) h_{drc}$

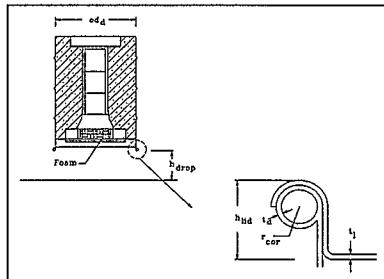
Gross weight of drum: $W_{dr} = 1,450$ lb

Drop height: $h_{drop} = 4$ ft

Weights:

Lid dimensions: $t_{pl} = 0.75$ in.

Diameter: $d_{lid} = 16.75$ in.



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Lid weight: $W_{lid} = \rho_{sst} \frac{\pi d_{lid}^2}{4} t_{pl}$ $W_{lid} = 48$ lb

Weight of contents: $W_{cont} = 36$ lb

Plug dimensions: $bd_{plug} = 10.05$ in. $sd_{plug} = 8.25$ in.

$t_{pland} = 0.5$ in. $h_{plug} = 2.5$ in.

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Volume of plug, plate, and cone sections:

$$V_{\text{plug}} = \frac{\pi b d_{\text{plug}}^2}{4} t_{\text{land}} + \frac{1}{3} \pi h_{\text{plug}} t_{\text{land}} \left[\left(\frac{b d_{\text{plug}}}{2} \right)^2 + \left(\frac{s d_{\text{plug}}}{2} \right)^2 + \frac{b d_{\text{plug}} s d_{\text{plug}}}{2} \right]$$

Weight of plug: $W_{\text{plug}} = \rho_{\text{st}} V_{\text{plug}}$ $W_{\text{plug}} = 50 \text{ lb}$

Weight of plug and contents: $W_{\text{pc}} = W_{\text{cont}} + W_{\text{plug}}$ $W_{\text{pc}} = 86 \text{ lb}$

Energy of drop: $E_{\text{dr}} = W_{\text{dr}} h_{\text{drop}}$ $E_{\text{dr}} = 5,800 \text{ ft-lb}$

Energy absorbed by crush of drum:

Drum rim radius: $r_{\text{cr}} = r_{\text{cor}} + t_d$ $r_{\text{cr}} = 0.3 \text{ in.}$

Assume rim ring crushes a full radius at first iteration: $\delta_{\text{cr}} = r_{\text{cr}}$

Energy absorbed in rim crush (ORNL 1970):

$$E_{\text{rima}} = \frac{\sigma_{\text{fs}} (t_d + t_b)^2 \pi \text{od}_d}{r_{\text{cr}}} \left(\delta_{\text{cr}} + 0.4 \frac{\delta_{\text{cr}}^2}{r_{\text{cr}}} \right) \quad E_{\text{rima}} = 4,412 \text{ ft-lb}$$

Energy absorbed in crush of drum top end: $E_{\text{drum}} = \frac{\frac{h_{\text{dr}} A_{\text{cr}} [\sigma_{\text{fs}} (t_d + t_b)]}{\text{od}_d}}{2} \quad E_{\text{drum}} = 69 \text{ ft-lb}$

Energy absorbed by drum lid: $E_{\text{rim}} = E_{\text{dr}} - E_{\text{drum}}$ $E_{\text{rim}} = 5,731 \text{ ft-lb}$

Determine deformation of rim after crush of drum top end:

Given:

$$\frac{\sigma_{\text{fs}} (t_d + t_b)^2 \pi \text{od}_d}{r_{\text{cr}}} \delta_{\text{cr}} + 0.4 \frac{\delta_{\text{cr}}^2}{r_{\text{cr}}} - E_{\text{rim}} = 0 \text{ lb-ft}$$

Deformation of rim: $\text{diff} = \text{find } \delta_{\text{cr}}$ $\text{diff} = 0.37 \text{ in.}$

Total deformation of drum: $\text{def} = \text{diff} + h_{\text{dr}}$ $\text{def} = 0.62 \text{ in.}$

Deceleration loading factor: $g_1 = \frac{h_{\text{drop}}}{\text{def}}$ $g_1 = 78$

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Inner foam parameters, LAST-A-FOAM, FR-6704, Density of 4 lb/cuft (General Plastics 1996):

Foam volume:

$$\text{Foam diameter: } d_{\text{foam}} = 9.0 \text{ in.} \quad \text{Height: } h_{\text{foam}} = 2.0 \text{ in.}$$

$$\text{Volume: } V_{\text{foam}} = \frac{\pi}{4} d_{\text{foam}}^2 h_{\text{foam}} \quad V_{\text{foam}} = 127 \text{ in}^3$$

$$\text{Crush: } A_{\text{foam}} = \frac{\pi}{4} d_{\text{foam}}^2 \quad A_{\text{foam}} = 64 \text{ in}^2$$

$$\text{Energy: } E_{\text{pc}} = W_{\text{pc}} h_{\text{drop}} \quad E_{\text{pc}} = 343 \text{ ft-lb}$$

Assume a stain and iterate with crush strength to match stain and stress for strain < 60%, and assumed temperature of 75 °F.

$$\text{Crush strength: } s_u = 94 \text{ psi}$$

$$\text{Deformation of foam: } \delta h = \frac{E_{\text{pc}}}{\pi \left(\frac{d_{\text{foam}}}{2} \right)^2 s_u} \quad \delta h = 0.69 \text{ in.}$$

$$\text{Strain of foam: } \frac{\delta h}{h_{\text{foam}}} = 0.34$$

$$\text{Deceleration loading factor: } g_{\text{foam}} = \frac{h_{\text{drop}}}{\delta h} \quad g_{\text{foam}} = 70$$

Bolt loading from internal pressure:

Evaluate bolts per NUREG/CR-6007 (LLNL 1993). Determine required bolt torque per ASME Section VIII (ASME 1992).

$$\text{Assumed differential pressure: } p_t = 11.2 \text{ psi} \quad \text{Poisson's ratio: } \nu_s = 0.29$$

$$\text{Thickness of wall: } t_w = 0.322 \text{ in.}$$

$$\text{Elastic modulus of bolt: } E_{\text{bol}} = 28.6 \times 10^6 \text{ psi} \quad \text{Elastic modulus of sst: } E_{\text{st}} = 27.6 \times 10^6 \text{ psi}$$

Bolts (1/2-13 UNC-2A):

$$\text{Number: } n_b = 12 \quad \text{Nominal diameter: } D_b = 0.5 \text{ in.} \quad \text{Pitch: } p_t = 13/\text{in.}$$

$$\text{Diameter of bolt circle: } D_{\text{bc}} = 14.75 \text{ in.} \quad \text{Inside diameter: } d_{\text{in}} = 10.42 \text{ in.}$$

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Bolt length between top and bottom of lid: $L_b = t_p$

Flange thickness: $t_f = 1.5$ in.

Assume worst case operating temperature of 200 °F:

Bolt yield (ASTM A449): $s_y = 92$ ksi Bolt ultimate: $s_u = 120$ ksi

Allowable: $s_a = \frac{2}{3} s_y$ $s_a = 61$ ksi

Assume gasket factors: $y_{ps} = 200$ psi $m = 1.0$

Location of gasket load reaction:

$$\text{Width of gasket: } b_o = \frac{1}{2} \frac{(13.25 - 11.25)}{2} \text{ in. } b_o = 0.5 \text{ in.}$$

$$\text{Effective width of gasket: } b = 0.5 \sqrt{\frac{b_o}{\text{in.}}} \text{ in. } b = 0.35 \text{ in.}$$

$$\text{Location: } D_{lg} = 13.25 \text{ in.} - 2b \quad D_{lg} = 12.54 \text{ in.}$$

$$\text{Minimum preload to seat gasket: } F_{apmin} = \frac{\pi D_{lg} b y_{ps}}{n_b} \quad F_{apmin} = 232 \text{ lb}$$

$$\text{Minimum operating gasket load: } F_{opmin} = \frac{2 \pi D_{lg} b m p_f}{n_b} \quad F_{opmin} = 26 \text{ lb}$$

Therefore, seating load is larger; however, to maintain bolt tightness, increase preload to:

$$T_{pre} = 25 \text{ lb-ft} \quad \text{Recommended torque for alloy steel bolts.}$$

Non-prying tensile force on bolts due to preload:

$$\text{Friction factor assuming use Never-Seez: } k_{bolt} = 0.18$$

$$F_{apro} = \frac{T_{pre}}{k_{bolt} D_b} \quad F_{apro} = 3,333 \text{ lb}$$

$$\text{Residual torque on bolt: } M_r = 0.5 T_{pre}$$

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Pressure load on bolt:

$$\text{Non-prying tensile force per bolt: } F_{\text{apress}} = \frac{\pi D_{\text{lb}}^2 P_f}{4 n_b} \quad F_{\text{apress}} = 115 \text{ lb}$$

$$\text{Shear force per bolt: } F_{\text{spress}} = \frac{\pi E_{\text{ext}} t_{\text{pl}} P_f D_{\text{lb}}^2}{2 n_b E_{\text{ext}} t_w (1 - v_s)} \quad F_{\text{spress}} = 1,046 \text{ lb}$$

$$\text{Fixed edge prying force: } F_{\text{fpress}} = \frac{D_{\text{lb}} P_f}{4} \quad F_{\text{fpress}} = 41 \frac{\text{lb}}{\text{in}}$$

$$\text{Fixed edge prying moment: } M_{\text{fpress}} = \frac{P_f D_{\text{lb}}^2}{32} \quad M_{\text{fpress}} = 76 \text{ lb } \frac{\text{in}}{\text{in}}$$

Uniform impact loading on bolts:

Assume flat bottom drop. Since design shows lid surrounded by concrete, assume lid is protected.

Assume dynamic load factor: DLF = 1

$$\text{Non-prying force: } F_{\text{imp}} = \frac{1.34 (g_{\text{foam}} W_{\text{pc}} + g_1 W_{\text{lid}}) \text{DLF}}{n_b} \quad F_{\text{imp}} = 1,083 \text{ lb}$$

$$\text{Fixed edge forces: } F_{\text{imp}} = \frac{1.34 (g_{\text{foam}} W_{\text{pc}} + g_1 W_{\text{lid}}) \text{DLF}}{\pi D_{\text{lb}}} \quad F_{\text{imp}} = 280 \frac{\text{lb}}{\text{in}}$$

$$\text{Fixed edge moments: } M_{\text{imp}} = \frac{1.34 (g_1 W_{\text{lid}} + g_{\text{foam}} W_{\text{pc}}) \text{DLF}}{8 \pi} \quad M_{\text{imp}} = 517 \text{ lb } \frac{\text{in}}{\text{in}}$$

Ignore vibration and thermal loading.

$$\text{Preload per unit length of bolt circle: } p_{\text{pre}} = \frac{F_{\text{pre}}}{\pi D_{\text{lb}}} \quad p_{\text{pre}} = 72 \frac{\text{lb}}{\text{in}}$$

Load combinations:

$$F_{\text{pre}} = 3,333 \text{ lb} \quad \text{and} \quad F_{\text{al}} = F_{\text{apress}} + F_{\text{imp}} \quad F_{\text{al}} = 1,198 \text{ lb}$$

$$F_{\text{fc}} = F_{\text{fpress}} + F_{\text{imp}} \quad F_{\text{fc}} = 322 \text{ lb/in}$$

$$M_{\text{fc}} = M_{\text{fpress}} + M_{\text{imp}} \quad M_{\text{fc}} = 593 \text{ lb in/in}$$

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Additional tensile force due to prying:

$$\text{Factors: } C_1 = 1$$

$$C_2 = \frac{8}{3(d_{ld} - d_{lb})^2} \left[\frac{E_{st} t_{pl}^3}{1 - v_s} + \frac{(d_{ld} - d_{lb}) E_{st} t_{lf}^3}{D_{lb}} \right] \frac{L_b}{n_b D_b^2 F_{bolt}}$$

$$K_{bb} = \frac{n_b}{L_b} \frac{E_{bolt}}{D_{lb}} \frac{D_b^4}{64} \quad K_1 = \frac{E_{st} t_{pl}^3}{3 \left[(1 - v_s^2) + (1 - v_s)^2 \frac{D_{lb}^2}{d_{ld}} \right] D_{lb}}$$

$$\text{Prying tensile force: } F_{sp} = \frac{\pi D_{lb}}{n_b} \left[\frac{\frac{2 M_{fc}}{(d_{ld} - D_{lb})} - C_2 (F_{fc} - p_{pre})}{C_1 + C_2} \right] \quad F_{sp} = 2,188 \text{ lb}$$

$$\text{Bending moment: } M_{bb} = \frac{\pi D_{lb}}{n_b} \frac{K_{bb}}{K_{bb} + K_1} M_{fc} \quad M_{bb} = 300 \text{ lb-in}$$

$$\text{Total force on bolts: } F_{tot} = F_{axl} + F_{sp} \quad F_{tot} = 3,386 \text{ lb}$$

$$\text{Effective bolt diameter: } D_{ba} = D_b - 0.9743 \frac{1}{\text{pit}}$$

$$\text{Average tensile stress: } s_{ba} = \frac{1.2732 F_{tot}}{D_{ba}^2} \quad s_{ba} = 23,863 \text{ psi}$$

$$\text{Average shear stress: } s_{bs} = \frac{1.2732 F_{sp}}{D_{ba}^2} \quad s_{bs} = 7,374 \text{ psi}$$

$$\text{Maximum bending stress: } s_{bb} = \frac{10.186 M_{bb}}{D_{ba}^3} \quad s_{bb} = 39,744 \text{ psi}$$

$$\text{Maximum shear by bolt torsion: } s_{bt} = \frac{5.093 M_1}{D_{ba}^3} \quad s_{bt} = 9,948 \text{ psi}$$

$$\text{Maximum stress intensity: } s_{bi} = \sqrt{(s_{ba} + s_{bb})^2 + 4 (s_{bs} + s_{bt})^2} \quad s_{bi} = 72,429 \text{ psi}$$

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Margin of safety:

$$\text{Average stress: } MS_1 = \frac{s_m}{s_{tu}} - 1 \quad MS_1 = 1.57$$

$$\text{Average shear stress: } MS_2 = \frac{0.6 s_m}{s_{tu}} - 1 \quad MS_2 = 3.99$$

$$\text{Total stress: } MS_3 = \frac{3 s_m}{s_{tu}} - 1 \quad MS_3 = 1.54$$

Stresses on closure lid:

Material of plate: ASTM A-516 Grade 60.

Material strength properties: $s_y = 32 \text{ ksi}$ $s_u = 60 \text{ ksi}$

ASME allowable at 200 °F: $s_m = 15 \text{ ksi}$

$$\text{Radius of plate: } r_{ls} = \frac{d_{in}}{2}$$

The system can be considered as a uniformly loaded flat plate which is simply supported (Young 1989, page 429).

$$\text{Loading: } q_f = \frac{g_{f,om} W_{pc} + g_l W_{ld}}{\pi r_{ls}^2}$$

$$\text{Moment at center: } M_c = \frac{q_f r_{ls}^2 (1 + v_s)}{16} \quad M_c = 635 \text{ lb in}$$

$$\text{Radial moment: } M_{rp} = M_c$$

$$\text{Tangential moment: } M_{tp} = M_c$$

$$\text{Radial bending stress at center: } \sigma_{r,2} = \frac{6 M_{rp}}{t_{pl}^2} \quad \sigma_{r,2} = 6,772 \text{ psi}$$

$$\text{Tangential bending stress at center: } \sigma_{t,2} = \frac{6 M_{tp}}{t_{pl}^2} \quad \sigma_{t,2} = 6,772 \text{ psi}$$

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Total stress at center: $\sigma_{\text{tot2}} = \sigma_{\text{rb2}} + \sigma_{\text{bs2}}$ $\sigma_{\text{tot2}} = 13,544 \text{ psi}$

Margin of safety: $MS_{\text{so}} = \frac{S_{\text{in}}}{\sigma_{\text{tot2}}} - 1$ $MS_{\text{so}} = 0.11$

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8.0 THERMAL EVALUATION

The Concrete-Shielded RH TRU Drum is a package used by PNNL to transport contaminated hot cell waste from the 327 Building to the TRUSA. The waste materials are contained in paint cans with the package. The package is designed by ICF Kaiser Hanford Company. The maximum decay heat from the contaminated waste contents is 1 W. This section evaluates the maximum external and internal temperatures of the package for the NCT. The hypothetical accident conditions are based on the fire failure threshold in the risk assessment, Part B, Section 3.4.

8.1 SUMMARY OF THERMAL PROPERTIES OF MATERIALS

The outer shell package is a right-angle cylinder manufactured from a UNIA2 55-gal drum. The drum is fabricated from ASTM A-366 (ASTM 1989) galvanized steel. Within the drum is an inner shell manufactured from 8-in. schedule 40 steel pipe, which is encased in concrete. The concrete is specified to have a maximum density of 2,643 kg/m³ (165 lb/ft³). Thermal properties of the materials of construction are listed in Table B8-1.

Table B8-1. Summary of Thermal Properties.

Material	Thermal conductivity W/m ² -K (Btu/h-ft-°F)	Specific heat J/kg-K (Btu/lb-°F)	Density kg/m ³ (lb/ft ³)	Emissivity/ absorptivity
Galvanized steel	0.00327 (0.0005767)	502 (0.120)	7,861 (491)	0.89/0.8
Hanford concrete	0.00012 (0.000021)	1042 (0.249)	2,643 (165)	0.73
Carbon steel	0.00327 (0.0005767)	502 (0.120)	7,861 (491)	0.45

Source for all material properties: WHC, 1996, *Thermal Analysis Methods for Safety Analysis Reports for Packaging*, WHC-SD-TP-RPT-005, Rev. 1, Westinghouse Hanford Company, Richland, Washington.

8.2 THERMAL EVALUATION FOR NCT

8.2.1 Conditions To Be Evaluated

Conditions for evaluation of package performance are based on the thermal requirements of 49 CFR 173.442 for an exclusive use package. These conditions are modified for site-specific conditions that are more extreme than for the conditions cited in 49 CFR 173.442. For onsite shipment evaluation, the package is assumed to be in an ambient temperature environment of 46.1 °C (115 °F) and in direct sunlight at the worst solar angle for 12 hours. The internal heat load from the assumed contents is 1 W.

8.2.2 Acceptance Criteria

The acceptance criteria for this package is an exterior surface temperature of no greater than 82 °C (180 °F) for the specified conditions.

Since the package is encased in concrete for shielding, the American Concrete Institute allowable temperature for nuclear applications of concrete (ACI 1989) is used as a limiting internal temperature. For this package, which is a concrete steel composite of relatively small size, the maximum allowable internal temperature of concrete is 93.3 °C (200 °F).

8.2.3 Thermal Model

The external surface temperature is determined by idealizing the package as a right-angle cylinder and evaluating the loadings using classical methods. The internal package temperature is determined by classical methods and idealizing the internals of the package as concentric shells.

8.3 THERMAL EVALUATION AND CONCLUSIONS

By conservative classical methods and idealizing of the package geometry, the evaluation presented in Part B, Section 8.6, demonstrates the package meets the above acceptance criteria. The external surface temperature is conservatively calculated based on assuming the package is exposed to solar heating for a 12-hour period with a worst-case solar declination angle of 30° from vertical with an ambient temperature of 46.1 °C (115 °F). Also, it is assumed the package is in still air and insulated on the bottom, therefore losing heat only from the top and around the circumference. Results of utilizing these worst-case assumptions show the maximum external surface temperature of the package is 63.9 °C (147 °F), which is well under the 82 °C (180 °F) allowable temperature. The calculated maximum internal package temperature, based on the above heat loading and external surface temperature, is 91.7 °C (197 °F). This conservative temperature estimate is below the American Concrete Institute maximum allowable concrete temperature. Consequently, the results of this evaluation show the package meets the thermal requirements for the NCT under conservatively extreme conditions.

8.4 ACCIDENT CONDITIONS

For this package, no thermal hypothetical accident conditions are evaluated. The risk assessment assumes the package fails in a 800 °C (1475 °F) fire.

8.5 REFERENCES

49 CFR 100-177, 1996, "Transportation," *Code of Federal Regulations*, as amended.

ACI, 1989, *ACI Manual of Concrete Practices 1989*, Part 4, American Concrete Institute, Detroit, Michigan.

ASTM, 1989, *Annual Book of ASTM Standards*, Vol. 1.04, American Society of Testing, Philadelphia, Pennsylvania.

WHC, 1996, *Thermal Analysis Methods for Safety Analysis Reports for Packaging*, WHC-SD-TP-RPT-005, Rev. 1, Westinghouse Hanford Company, Richland, Washington.

8.6 APPENDIX: ENGINEERING SAFETY EVALUATION--TEMPERATURES

ENGINEERING SAFETY EVALUATION

Subject Pacific Northwest Concrete Waste Drum Temperatures Page 1 of 5
Originator S. S. Shiraga Handwritten Date 07/31/96
Checker J. J. Mahoney Handwritten Date 08/15/96

I. Objective:

The objective of this evaluation is to determine steady state outside and inside surface temperatures of the package for normal conditions of transport.

II. References:

Jakob, M., and G. A. Hawkins, 1957, *Elements of Heat Transfer*, John Wiley & Sons, Inc., New York, New York.

ORNL, 1970, *Cask Designer's Guide*, ORNL-NISC-68, Oak Ridge National Laboratory, Oak Ridge, Tennessee, February 1970.

WHC, 1993, *Thermal Analysis Methods for Safety Analysis Reports for Packaging*, WHC-SD-TP-RPT-005, Rev. 1, Westinghouse Hanford Company, Richland, Washington, September 24, 1993.

III. Results and Conclusions:

This evaluation is based on classical steady state heat transfer methods. It also conservatively assumes that the solar angle of declination relative to vertical is at maximum for heat loading for a 12 hour period. Results of the evaluation show the exterior surface of the package reaches a temperature of 148 °F in that period. The interior surface of the package reaches a temperature of 197 °F. This evaluation shows the exterior of the package does not reach the 182 °F temperature limit specified by DOT for exclusive use shipments.

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IV. Evaluation:NCT Thermal Evaluation for Pacific Northwest Concrete Drum:

Idealize outside temperature determination on Pacific Northwest drum as a vertical cylinder with flat ends, subjected to direct solar heating in still air at the worst angle for 12 hours.

(Jakob and Hawkins 1957)

$$\text{Free convection coefficient for a vertical cylinder: } k_{hv} = 0.29 \frac{\text{BTU}}{\text{h ft}^2}$$

$$\text{Free convection coefficient for a horizontal plate: } k_{vp} = 0.27 \frac{\text{BTU}}{\text{ft}^2 \text{ h}}$$

$$\text{Length of cylinder: } L_t = 34.7 \text{ in.} \quad \text{OD of cylinder: } L_t = 22.6032 \text{ in.}$$

$$\text{Surface area of cylinder: } A_s = \pi L_t L_t \quad \text{Surface area of plate: } A_t = \frac{\pi}{4} L_t^2$$

$$\text{Total surface area of package: } A_{tot} = A_s + A_t \quad A_{tot} = 19.9 \text{ ft}^2$$

$$\text{Combined convection constant: } hd = \left[\frac{k_{hv} A_s}{\left(\frac{L_t}{\text{ft}} \right)^{\frac{1}{4}}} + \frac{k_{vp} A_t}{\left(\frac{L_t}{\text{ft}} \right)^{\frac{1}{4}}} \right] R^{-\frac{1}{4}} \quad hd = 5.09 \frac{\text{BTU}}{\text{h (R)}^{\frac{1}{4}}}$$

Radient heating constant:

$$\text{Stefan-Boltzman's natural constant: } \sigma_{sb} = 0.1714 \cdot 10^{-8} \frac{\text{BTU}}{\text{h ft}^2 \text{ R}^4}$$

$$\text{Emissivity of steel: } \epsilon_s = 0.89$$

$$K_1 = \sigma_{sb} \epsilon_s A_{tot} \quad K_1 = 3.04 \cdot 10^{-8} \frac{\text{BTU}}{\text{h R}^4}$$

Determination of Solar Loading (ORNL 1970):

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Solar angle of declination relative to vertical for maximum loading: $\theta_{sol} = 30^\circ$

Solar heat loading (WHC-SD-TP-RPT-005), hourly loading based on a 12 hour period:

Flat horizontal surfaces:

$$Q_s = 219 \frac{\text{BTU}}{\text{h ft}^2}$$

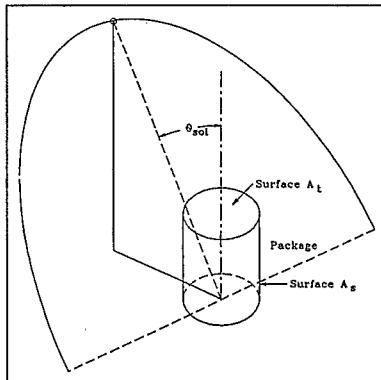
Curved surfaces:

$$Q_{s1} = 123 \frac{\text{BTU}}{\text{h ft}^2}$$

Internal heat load: $q_{int} = 1 \text{ W}$

Solar absorptivity, assume same as emissivity:

$$\alpha_{sol} = 0.8$$



Solar heat load: $q_{sol} = \alpha_{sol} Q_s A_t \cos \theta_{sol} + Q_{s1} \frac{A_s}{2} \sin \theta_{sol}$

Total heat load: $q_t = q_{sol} + q_{int} \quad q_t = 847 \frac{\text{BTU}}{\text{h}}$

Outside ambient temperature is 115 °F and in Rankine: $T_o = (115 + 459.7) \text{ R}$

Using conservation of energy: $q_{in} - q_{out} = 0$

Then by substitution: $q_t - q_{rad} - q_{con} = 0$

$$\text{or} \quad q_t - K_1 (T_f^4 - T_o^4) - hd (T_f - T_o)^{\frac{3}{4}} = 0$$

Solve for T_f which is temperature at the surface using roots of the equation solution:

$$T_{fl} = \text{root} \left[q_t - K_1 (T_f^4 - T_o^4) - hd (T_f - T_o)^{\frac{1}{4}}, T_f \right]$$

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External surface temperature: $T_{\text{fl}} = 608 \text{ R}$

Determine temperature in $^{\circ}\text{F}$: $T_{\text{ff}} = \left| \frac{T_{\text{fl}}}{R} - \frac{459.7 \text{ R}}{R} \right| \quad T_{\text{ff}} = 148 \text{ }^{\circ}\text{F}$

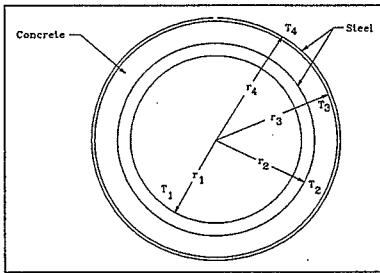
Heat transfer into the cask:

Cylindrical length of cask: $L_c = 34.7 \text{ in.}$

Assume one-dimensional heat transfer:

$$q_t = \frac{2 \pi L_c (T_1 - T_4)}{\frac{\ln \left(\frac{r_2}{r_1} \right)}{k_{\text{cst}}} + \frac{\ln \left(\frac{r_3}{r_2} \right)}{k_{\text{gr}}} + \frac{\ln \left(\frac{r_4}{r_3} \right)}{k_{\text{cst}}}}$$

Solve for T_1 :



$$T_1 = \left[\frac{q_t + \frac{2 \pi L_c}{\frac{\ln \left(\frac{r_2}{r_1} \right)}{k_{\text{cst}}} + \frac{\ln \left(\frac{r_3}{r_2} \right)}{k_{\text{gr}}} + \frac{\ln \left(\frac{r_4}{r_3} \right)}{k_{\text{cst}}}} T_4}{\frac{2 \pi L_c}{k_{\text{cst}}}} \right] \left[\frac{\ln \left(\frac{r_2}{r_1} \right)}{k_{\text{cst}}} + \frac{\ln \left(\frac{r_3}{r_2} \right)}{k_{\text{gr}}} + \frac{\ln \left(\frac{r_4}{r_3} \right)}{k_{\text{cst}}} \right]$$

Thermal properties of materials (WHC-SD-TP-RPT-005):

Grout: $k_{\text{gr}} = 0.000021 \frac{\text{BTU}}{\text{sec in.}}$

Steel: $k_{\text{cst}} = 0.0005767 \frac{\text{BTU}}{\text{sec in.}}$

Dimensional properties of package:

Thickness of steel: $t_w = 0.365 \text{ in.}$

Outer shell radius: $r_4 = \frac{L_t}{2}$

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 Checker J. J. Mahoney 1/11 Date 08/15/96

Thickness of drum: $t_{dr} = 0.0516$ in.

$$\text{Cavity radius: } r_1 = \frac{7.981 \text{ in.}}{2} \quad \text{Outer shell inner radius: } r_3 = r_4 - t_{dr}$$

$$\text{Inner shell outer radius: } r_2 = r_1 + t_w \quad \text{Outer shell temperature: } T_4 = T_{sf}$$

$$T_1 = \left[\frac{q_t + \frac{2 \pi L_c}{\frac{\ln(r_2)}{k_{csd}} + \frac{\ln(r_3)}{k_{gr}} + \frac{\ln(r_4)}{k_{csd}}} T_4}{\frac{2 \pi L_c}{k_{csd}}} \right] \left[\frac{\ln(r_2)}{k_{csd}} + \frac{\ln(r_3)}{k_{gr}} + \frac{\ln(r_4)}{k_{csd}} \right]$$

Temperature on the inner surface of the cask: $T_1 = 197$ °F

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9.0 PRESSURE AND GAS GENERATION EVALUATION

As indicated in Part B, Section 4.6, there are no trapped gaseous isotopes, and the gas generation rate is considered trivial. Because the paint cans are required to be punctured and there are NucFil filters in both the inner cavity cover and the drum lid, there is no potential for pressurization.

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10.0 PACKAGE TIEDOWN SYSTEM EVALUATION

10.1 SYSTEM DESIGN

Up to 30 drums may be positioned in a 2x(up to 15) array oriented axially on the trailer centerline. They shall be oriented on the trailer centerline. The array shall be surrounded by 2x4-in. wooden cleats nailed to the deck. In addition, a transverse cleat shall be located between each 2x2 group within the array and also nailed to the deck. The front pair of drums shall be no closer than 2.74 m (9 ft) from the normally occupied space of the cab if the drums are of maximum allowable activity. Drums of less-than-maximum allowable activity may be located closer than 2.74 m (9 ft), but shall not result in a dose rate greater than 0.02 mSv/h (2 mrem/h) in the normally occupied space of the cab. See Figure B10-1.

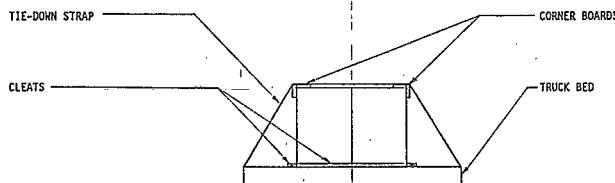
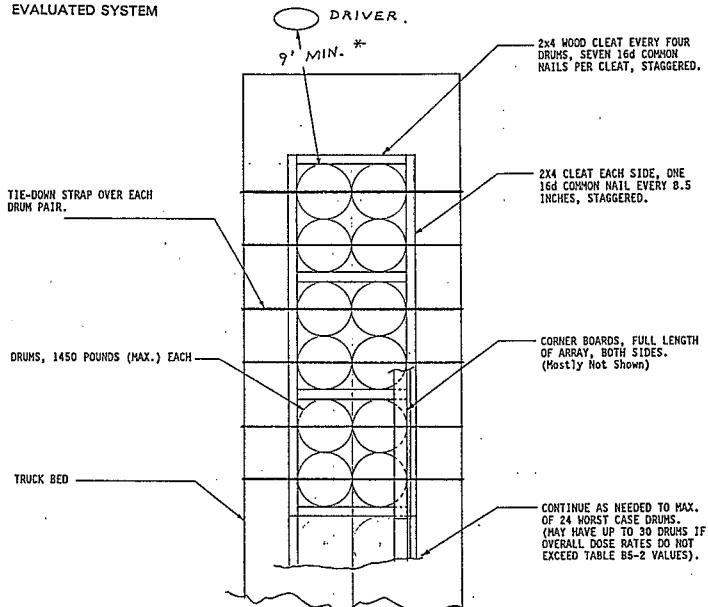
If necessary for load distribution, the load may be divided into two arrays, one forward and one aft, with a space between. They shall be two drums wide oriented on the trailer centerline.

10.2 ATTACHMENTS AND RATINGS

The cleat nailing must not be less than that shown in Figure B10-1. Each over-the-top strap must be tightened using standard rigging/security tensioning practices and using straps with minimum tensile load-rated capability of 1,366.7 kg (3,013 lb). Their working load limit and the trailer attachment points must be compatible with this tension requirement.

Figure B10-1. Truck Loading Arrangement and Details.

EVALUATED SYSTEM



* NINE FOOT MINIMUM APPLIES IF THE FRONT DRUMS ARE AT MAXIMUM ALLOWABLE ACTIVITY. IF THEY ARE LESS THAN MAXIMUM, THE DISTANCE CAN BE REDUCED BUT SHALL NOT RESULT IN A DOSE RATE GREATER THAN 2 mrem/hr IN THE NORMALLY OCCUPIED SPACE OF THE CAB.

10.3 APPENDIX: TIEDOWN CALCULATION

ENGINEERING SAFETY EVALUATION

Subject Tiedown Analysis for 1,450 lb, 55-Gallon Drums on a Flat Bed Truck Page 1 of 6
Originator D. K. Clem D. K. Clem Date 8-14-96
Checker R. S. Marlow R. S. Marlow Date 9/18/96

I. Objective:

The objective of this analysis is to evaluate the proposed drum arrangement and tiedown method with regard to the applicable requirements of 49 CFR 393.

II. References:

49 CFR 393, 1995, "Federal Motor Carrier Safety Regulations," *Code of Federal Regulations*, as amended.

Marks, L. S., 1951, *Mechanical Engineers Handbook*, Fifth Edition, McGraw Hill Book Company, New York, New York.

III. Results and Conclusions:

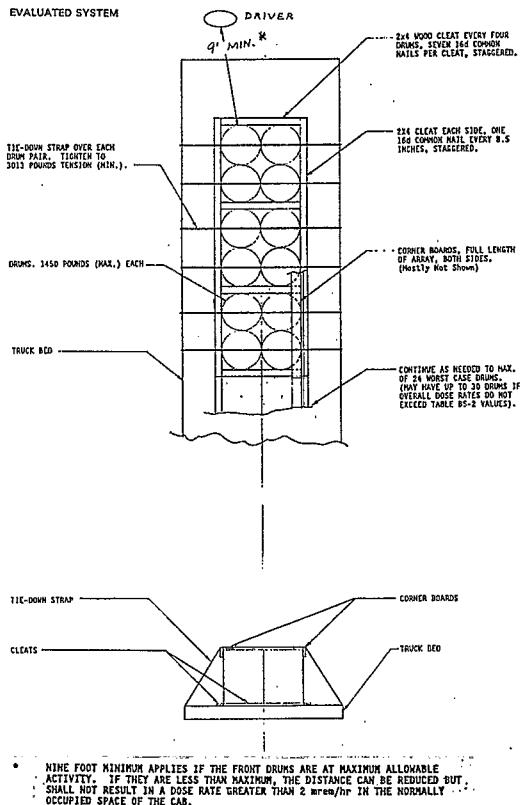
The analysis shows that the illustrated tiedown system is adequate for imposed loads of $0.62g$ longitudinal and $0.5g$ lateral on drums with a gross weight up to 1,450 lb/drum. No credit is taken for friction, but it is recognized that friction will exist and will provide an additional safety factor.

ENGINEERING SAFETY EVALUATION

Subject Tiedown Analysis for 1,450 lb. 55-Gallon Drums on a Flat Bed Truck Page 2 of 6
 Originator D. K. Clem Date 8-14-96
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IV. Evaluation:

Evaluated system:



ENGINEERING SAFETY EVALUATION

Subject Tiedown Analysis for 1,450 lb, 55-Gallon Drums on a Flat Bed Truck Page 3 of 6
 Originator D. K. Clem Date 5-14-96
 Checker R. S. Marlow Date 9/18/96

Longitudinal resistance:

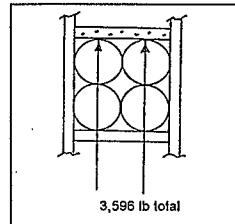
Assumptions:

- Resistance provided by cleats alone. No credit for friction.
- Nail strength value taken at ultimate for coastal fir.
(~540 lb/nail) (Marks 1951).
- Maximum load on a single cleat is four (4) drums at $0.62g$
 $= (4)(1,450)(0.62) = 3,596$ lb (49 CFR 393).

Nails required:

$$\frac{3,596}{540} = 6.7$$

Use seven (7) evenly spaced and staggered.



Lateral resistance:

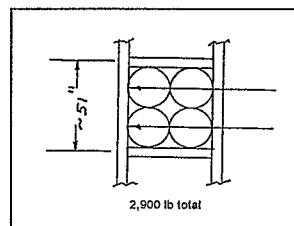
Assumption:

- Same as longitudinal case except maximum load/four (4) drums at $0.5g$ $= (4)(1,450)(0.5) = 2,900$ lb.

Nails required:

$$\frac{2,900}{540} = 5.37$$

Use six (6) 51 in. or one every 8.5 in., staggered.



Drum tipping (single drum, longitudinal):

Assumptions:

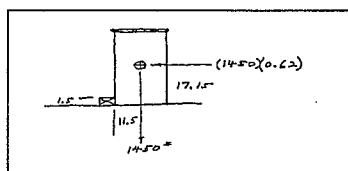
- Drum slides until it contacts cleats.

$$M_{\text{Tipping}} = (1,450)(0.62)(17.15) = 15,418 \text{ in-lb}$$

(ignore cleat)

$$M_{\text{Righting}} = (1,450)(11.5) = 16,675 \text{ in-lb}$$

$M_R > M_T \therefore$ Tipping will not occur at 0.62g.



Since lateral load of $0.5g$ is $< 0.62g$, tipping will not occur in lateral direction either.

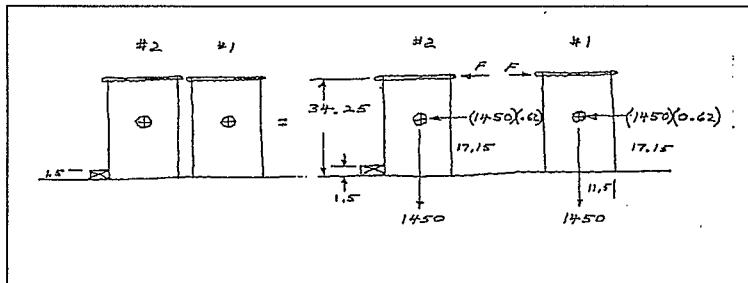
ENGINEERING SAFETY EVALUATION

Subject Tiedown Analysis for 1,450 lb. 55-Gallon Drums on a Flat Bed Truck Page 4 of 6
 Originator D. K. Clem Date 8/14/96
 Checker R. S. Marlow Date 9/18/96

Drum tipping (pairs, longitudinal):

Consider the case of two drums, one will slide until it contacts cleat. The other slides until it contacts the rim with the first drum.

Determine tipping situation from that point.



Drum #1:

$$F = (1450)(0.62) = 899 \text{ lb}$$

$$M_{(\text{Tipping})} = F (34.25 - 17.15) = 15,372 \text{ in-lb}$$

$$M_{(\text{Righting})} = (1450)(11.5) = 16,675 \text{ in-lb}$$

$M_R > M_T \therefore$ Drum #1 will not tip.

Drum #2:

$$M_{(\text{Tipping})} = (899)(34.25) + (1,450)(0.62)(17.15) = 46,209 \text{ in-lb}$$

(ignore cleat height)

$$M_{(\text{Righting})} = (1,450)(11.5) = 16,675 \text{ in-lb}$$

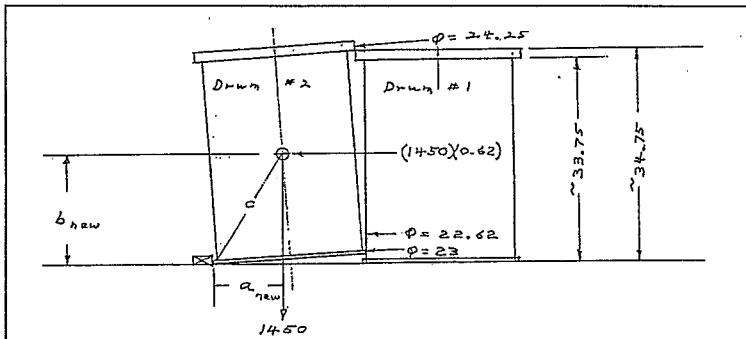
Net tipping moment: $46,209 - 16,675 = 29,534 \text{ in-lb}$

$M_T > > M_R \therefore$ Drum #2 will tip.

When the base of Drum #1 contacts the base of Drum #2, $F = 0$ and M_T is greatly reduced. However, shifting of the center of gravity due to the angle of the tip results in M_T still being slightly greater than M_R . The drum will fall over without additional restraint (calculation not shown).

ENGINEERING SAFETY EVALUATION

Subject Tiedown Analysis for 1,450 lb. 55-Gallon Drums on a Flat Bed Truck Page 5 of 6
Originator D. K. Clem Date 8/14/96
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Tiedowns:

With reference to the previous "pair tipping" case: It is desirable to apply sufficient force through tiedowns to prevent tipping of the leading drum (Drum #2) due to forces imposed in it by the following drum (Drum #1). The same tipping scenario is applicable to both lateral loads and longitudinal loads, but the loads and the action of the tiedowns is different for the two directions.

General assumptions:

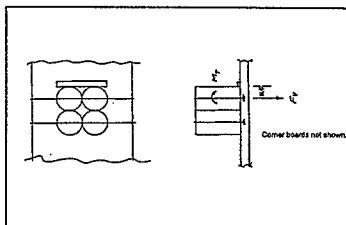
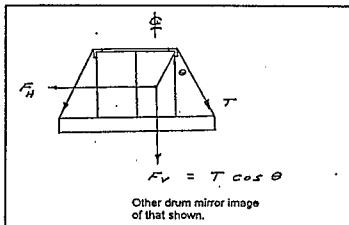
- Consider the case for tipping due to longitudinal loadings (loads of $0.62g$) as bounding both lateral and longitudinal loading conditions. Prescribed lateral loading is $0.5g$, so use of $0.62g$ is conservative.
- From the "pair tipping" case: A net righting moment of 29,534 in-lb is required to be considered by the tiedown.
- No credit is taken for friction. Drums are assumed to slide to the cleats or to the adjacent drum.
- One lateral strap crosses over the top centerline of each lateral pair of drums.
- Truck bed width is assumed to be within the range of 88 in. to 96 in. A significantly wide bed, such as a lowboy, would require increased strap tension.

Tiedowns for longitudinal loading:

- Tiedown tension is translated to its vertical component at drum centerline. The horizontal component does not contribute to the longitudinal tipping case.

ENGINEERING SAFETY EVALUATION

Subject Tiedown Analysis for 1,450 lb. 55-Gallon Drums on a Flat Bed Truck Page 6 of 6
 Originator D. K. Clem Date 8-14-96
 Checker R. S. Marlow Date 9/19/96



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Required that $F_v (11.5) = M_T$

$$F_v = \frac{29,534}{11.5} = 2,568 \text{ lb}$$

Check tension required for bed widths of 88 in. to 96 in. (θ 's of 26.72° to 31.54°)

$$T_{\text{required}} = \frac{F_v}{\cos \theta} = \frac{2,568}{\cos 31.54} = 3,013 \text{ lb}$$

for 96 in. width. This is worst case within range.

This is also the worst case between the lateral versus longitudinal loading conditions.

Therefore, tiedown tension of 3,013 lb or greater will prevent drum tipping in lateral or longitudinal direction up to 0.62g.

Operational constraints:

1. Truck shall have a wood deck.
2. Truck bed width shall be in range of 88 in. to 96 in. Tiedown tension must be increased for width exceeding 96 in.
3. One tiedown strap per lateral drum pair, tightened to 3,013 lb minimum.
4. Drum array shall be two drums wide, centered on the truck centerline. Maximum number of drums shall be limited by truck capacity or 30 drums, whichever is less.
5. Wooden cleats and nailing shall be as shown.
6. One or more arrays may be positioned along the length of the truck, if needed, to balance axle loading.

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Safety Evaluation for Packaging (Onsite) for the Concrete-Shielded RH TRU Drum for the 327 Postirradiation Testing Laboratory (WHC-SD-TP-SEP-051)		ECN No. N/A

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