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1	1	Cog. Eng. WA McCormick (RFS) 5/6/97 H1-15	1	1	JR Green (RFS) 5/6/97 H1-15
1	1	Cog. Mgr. JG Field (RFS) 5/7/97 H1-15	1	1	WS Josephson (RFSH) 5/6/97 R1-56
1	1	[redacted] PA Titzler (LMHC) 5-7-97 R1-56	1	1	ME McKinney (NHC) 5/7/97 S2-48
1	1	[redacted] EM Veith (LMHC) 5/7/97 R1-56	1	1	RL Schlosser (LMHC) 5/7/97 H6-06
1	1	QA CR Hoover (RFSH) 5/6/97 H1-15			
1	1	Safety DW McNally (FDH) 5/7/97 G1-15			
1	1	RL Clawson (RFS) 5-6-97 H1-14			
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18.	19.	20.	21. DOE APPROVAL (if required)
W. A. McCormick 5/7/97 Signature of EDT Originator / Date	P. A. Titzler 5-7-97 Authorized Representative for Receiving Organization / Date	J. G. Field 5/7/97 Design Authority/ Cognizant Manager / Date	Ctrl. No. [] Approved [] Approved w/comments [] Disapproved w/comments

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Safety Analysis Report for Packaging (Onsite) Long-Length Contaminated Equipment Transport System

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Rust Federal Services Inc. Northwest Operations, Richland, WA 99352
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Abstract: This safety analysis report for packaging describes the components of the long-length contaminated equipment (LLCE) transport system (TS) and provides the analyses, evaluations, and associated operational controls necessary for the safe use of the LLCE TS on the Hanford Site. The LLCE TS will provide a standardized, comprehensive approach for the disposal of approximately 98% of LLCE scheduled to be removed from the 200 Area waste tanks.

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LIST OF TERMS

ASME	American Society of Mechanical Engineers
atm	atmosphere
BC	burial container
Bq	becquerel
Ci	curie
Ci/g	curies per gram
cm	centimeter
cm^3/s	cubic centimeters per second
CoC	certificate of compliance
CWC	Central Waste Complex
DST	double-shell tank
ENDF/B-V	evaluated nuclear data file/B-version V
ft	foot
g	gram
in.	inch
kg	kilogram
kPa	kilopascal
km	kilometer
kN	kilonewton
L	liter
lb	pound
LFL	lower flammability limit
LLCE	long-length contaminated equipment
m	meter
MCNP	Monte Carlo N-Particle (computer code)
MeV	megaelectronvolt
mi	mile
mm	millimeter
mrem/h	millirem per hour
OD	outside diameter
PDC	packaging design criteria
photons/s	photons per second
PO	purchase order
psig	pounds per square inch, gauge
QA	quality assurance
QC	Quality Control
RMW	radioactive mixed waste
SARP	safety analysis report for packaging
SST	single-shell tank
std cm^3/s	standard cubic centimeters per second
Sv	sievert
TRU	transuranic
TS	transport system
W	watt
W/in.	watts per inch

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SAFETY ANALYSIS REPORT FOR PACKAGING (ONSITE) LONG-LENGTH CONTAMINATED EQUIPMENT TRANSPORT SYSTEM

PART A: DESCRIPTION AND OPERATIONS

1.0 INTRODUCTION

1.1 GENERAL INFORMATION

Tank farms has a large number of long-length contaminated equipment (LLCE) items installed in the risers of flammable, ferrocyanide, and organic watchlist single-shell tanks (SST); non-watchlist tanks; double-shell tanks (DST); vaults; and receivers. Most of the LLCE items will be classified as Type B (and possibly fissile) radioactive mixed waste (RMW). Examples of LLCE items include transfer pumps, instrument trees, air lift circulators, and air lances. There are approximately 1,900 LLCE items installed in the SSTs and DSTs at present. Of these 1,900 LLCE items, there are over 585 different types of LLCE, weighing from 181-9,072 kg (400-20,000 lb) and ranging in size from 10-152 cm (4-60 in.) in diameter by 10-19 m (32-62 ft) in length. The nominal radiation level of removed equipment is approximately 5 rem at contact, with a recorded maximum radiation level of 60 rem at contact.

The new debris rule has eliminated the previously acceptable practice of triple rinsing, bagging, and burying LLCE items removed from the SSTs and DSTs. The current regulatory interpretation of this rule is that the land disposal restriction treatment standard for equipment that has come in contact with tank waste requires that all contacted surfaces, including internal surfaces, be visually inspected. Implementation of this requirement is both difficult, impractical, and costly. Items previously removed from the tanks are currently stored within the Central Waste Complex (CWC) where weekly surveillance inspections are performed. A routine disposal method for LLCE items is not currently implemented onsite.

The past Tank Waste Remediation System's (TWRS) approach for retrieving and disposing of installed LLCE items required a newly engineered system to meet each individual program's requirements for a specific removal operation. This approach proved both costly and time consuming, as each removal activity required a new equipment and operations development effort. The LLCE transport system (TS) provides a standardized, comprehensive approach for the disposal of approximately 98% of LLCE scheduled to be removed from the 200 Area waste tanks. This approach provides a generic, cradle-to-grave system for retrieval, transport, and disposal or storage of LLCE items.

The purpose of this safety analysis report for packaging (SARP) is to describe the components of the LLCE TS and to provide the analyses, evaluations, and associated operational controls necessary for the safe use of the LLCE TS on the Hanford Site. Part A of this SARP will describe the system, payload, and controls for using the system during retrieval, transport, and unloading operations. Part B of this SARP provides the associated analyses to demonstrate that the LLCE can be safely handled and transported onsite.

1.2 SYSTEM DESCRIPTION

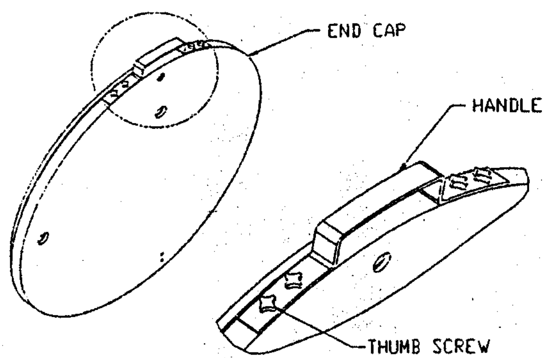
1.2.1 LLCE Burial Container

The primary component of the packaging is the LLCE burial container (BC), which consists of a long cylindrical pipe with one preinstalled end cap. The BC is provided with an additional end cap for sealing of the open end of the BC after insertion of the LLCE payload. These components are all constructed of high-density polyethylene (HDPE). Each end cap has a preinstalled, closed-cell, foam cushion glued to the inside to protect the end caps from excessive loads placed on them by the void fill or BC skid during differential thermal expansion/contraction caused by large environmental temperature transients. In addition there are penetrations in the end caps to allow for void filling, venting, and leak testing operations.

1.2.1.1 BC Ancillary Components. There are several subcomponents and features of the LLCE BC that are utilized with the major components of the packaging during lid sealing, void filling, and final closure seal operations. They are described in the following sections.

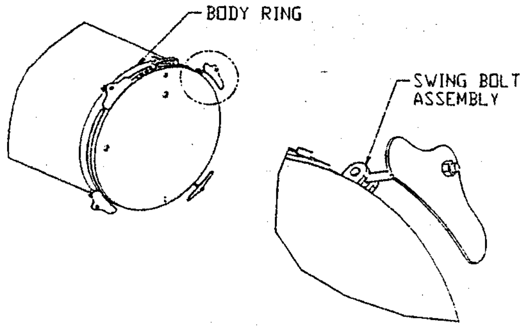
1.2.1.1.2 End Cap Handling Fixture. The BC lids are manipulated via a removable handling fixture that is installed in the 12 o'clock position of the outer diameter prior to being placed onto the BC. Figure A1-1 shows this feature.

Figure A1-1. End Cap Handling Fixture.



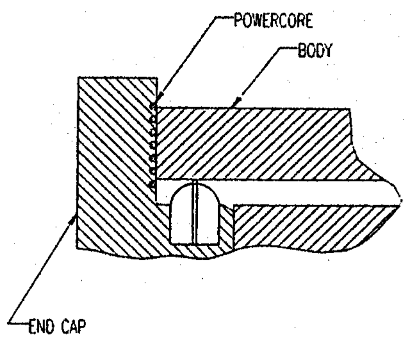
1.2.1.1.2 End Cap Welding Fixture. Once the end cap is installed on the BC, an end cap welding fixture is placed on the end of the BC to firmly fix the end cap during the fusion process. Figure A1-2 shows the end cap welding fixture.

Figure A1-2. End Cap Welding Fixture.



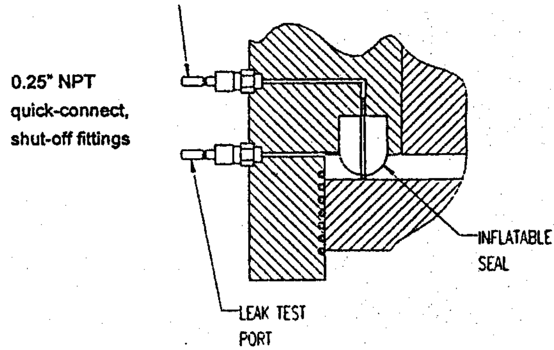
1.2.1.1.3 Powercore Weld. The end cap is fused to the BC by applying a current to the preinstalled powercore material in the end cap. The current causes the powercore to fuse the end cap and BC material together, thus creating a homogenous unit that retains approximately 90% of the HDPE original material properties and provides a leak-testable seal. Figure A1-3 shows the general configuration of this macroencapsulating weld.

Figure A1-3. Macroencapsulation Weld.



1.2.1.1.4 Leak Test Port and Inflatable Seal. After fusing the end cap to the container using the powercore, the seal is leak tested by means of an inflatable seal and leak test ports. The annulus around the inner cavity of the BC and end cap is pressurized, and the outer perimeter of the container weld zone is bubble leak checked. Figure A1-4 shows the basic leak test port configuration. The leak tests ports are plugged, sealed and leak tested using a vacuum bubble leak test once the major end cap seal has been tested.

Figure A1-4. Leak Test Port/Test Annulus.



1.2.1.1.5 **Void Fill Fixtures.** After the major end cap fusion zone is leak tested, the container is void filled with low-density (< 35 lb/ft^3) grout material, such as perlite cement. A primary fill port, secondary fill port, and a vent port are installed in the BC end cap to facilitate the void filling. Figures A1-5 and A1-6 show the void fill configuration and fittings that facilitate this process.

Figure A1-5. Void Fill Features.

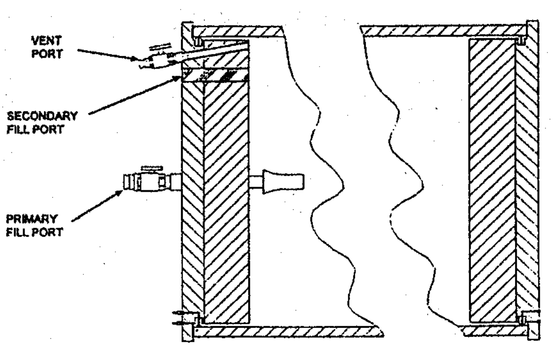
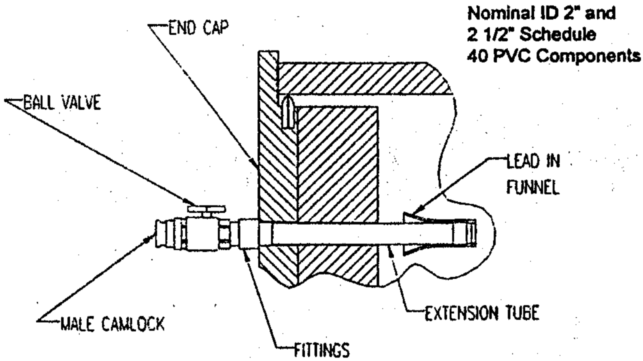


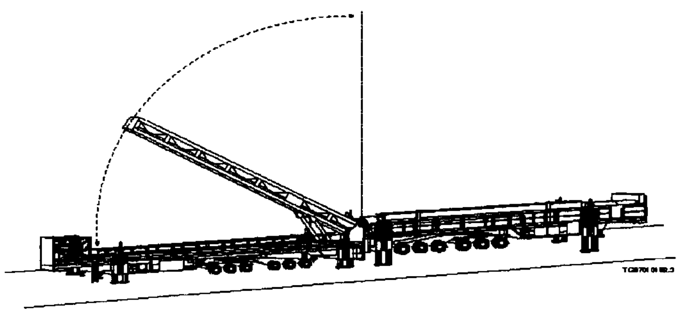
Figure A1-6. Fill Port/Trimmie Tube.



1.2.2 LLCE Trailers

The other major components of the LLCE TS are the receiver trailer, the transport trailer, and related components. Figure A1-7 shows the general layout of the system.

Figure A1-7. Transport System.



1.3 REVIEW AND UPDATE CYCLES

This SARP is subject to periodic reviews and updates. A review shall be performed every five years to ensure that all SARP evaluations and other included information meet new or revised regulatory and/or company requirements. The initial review and update of the SARP shall be midyear 2002.

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2.0 PACKAGING SYSTEM

2.1 CONFIGURATION AND DIMENSIONS

There are eight different sizes of BCs as shown in Table A2-1.

Table A2-1. Long-Length Contaminated Equipment Burial Container Sizes and Weights.

Container	Length m (ft)	Outside diameter cm (in.)	Wall thickness cm (in.)	Empty weight kg (lb)	Maximum gross weight kg (lb)
C1	17.07 (56)	70.6 (26)	2.24 (0.88)	735 (1,617)	5,127 (11,280)
C2	22.25 (73)	70.6 (26)	2.24 (0.88)	940 (2,066)	6,635 (14,597)
C3	17.34 (56.9)	91.4 (36)	3.10 (1.22)	1,430 (3,147)	9,264 (20,380)
C4	22.32 (73.2)	91.4 (36)	3.10 (1.22)	1,822 (4,008)	12,642 (27,812)
C5	22.37 (73.4)	137.8 (54.25)	4.65 (1.83)	4,214 (9,270)	27,335 (60,137)
C6	17.42 (57.1)	160.8 (63.32)	5.21 (2.05)	4,427 (9,740)	28,792 (63,342)
C7	22.39 (73.5)	160.8 (63.32)	5.21 (2.05)	5,589 (12,295)	43,208 (95,058)
C9	17.39 (57.1)	137.8 (54.25)	4.65 (1.83)	3,315 (7,292)	21,963 (46,118)

Drawings H-2-827807 through H-2-827845 provide fabrication and assembly details for the entire family of LLCE BCs and associated hardware. Drawing H-2-827806 provides the LLCE drawing index for all LLCE BC related drawings.

2.2 MATERIALS OF CONSTRUCTION

The LLCE BCs, BC lid, end cap, and lid penetration plugs are constructed entirely of HDPE. Pipe sizes are commercially available units that are butt-fused together and cut to length. The lids are machined from stock.

2.3 MECHANICAL PROPERTIES OF MATERIALS

The HDPE material used for the BC is Type III, Class C, Category 5, Grade P34 HDPE, meeting ASTM D1248, *Standard Specification for Polyethylene Plastics Molding and Extrusion Materials* (ASTM 1989). This material has a nominal density of 0.941 - 0.959 g/cm^3 and is weather resistant, containing greater than 2% carbon black. The yield strength, modulus of elasticity, and brittle fracture properties of the material are temperature dependent. Viscoelastic creep and the effect of irradiation are time dependent. The fatigue strength of the material is documented in Part B, Section 7.7.2.

Part B, Section 7.7.2, contains detailed data on the material properties associated with HDPE as described previously. The material is very suitable from a structural standpoint for its intended purpose.

2.4 DESIGN AND FABRICATION METHODS

Design and fabrication of the LLCE BCs and ancillary components shall be in accordance with the drawings listed in Part A, Section 10.0. In addition, the containers must be fabricated in accordance with HNF-SD-WM-SPP-002 (PHMC 1997), including use of the appropriate codes and standard identified in the document.

2.5 WEIGHTS AND CENTER OF GRAVITY

Tare and maximum gross weight for each size LLCE BC are shown in Table A2-1. The center of gravity for the empty BC will be found in the approximate geometric center. The center of gravity for a loaded container will vary, depending on the type of LLCE item installed and whether or not the BC is void filled. Weight distribution calculations will be required on a case-by-case basis to determine the proper distribution of lifting slings.

2.6 CONTAINMENT BOUNDARY

The LLCE BC provides the containment boundary for the LLCE items. Lid penetrations are sealed with HDPE plugs once void fill is complete.

2.7 CAVITY SIZE

Cavity size varies for each member of the LLCE BC family. Table A2-2 shows the internal volume for each container size.

Table A2-2. Long-Length Contaminated Equipment Burial Container Cavity Volumes.

Burial container	Cavity volume (ft^3)
C1	176
C2	229
C3	338
C4	438
C5	995
C6	1,050
C7	1,362
C9	767

2.8 HEAT DISSIPATION

Heat dissipation in the LLCE BCs is achieved through passive thermal conduction and radiation. There are no artificial cooling mechanisms employed to dissipate payload decay heat. The heat generation rate for the maximum curie content is 9.8 W, as can be seen in the RADCALC output in Part B, Section 9.0. When considered over a length of 30 ft, this results in a decay heat of 0.27 W/in., which is insignificant for the heat dissipation capabilities of the BC material.

2.9 SHIELDING

External shielding of the package is provided primarily by steel plates mounted on the front, back, and sides of the trailer carrying the LLCE package. There is minimal external shielding above and below the package. Some additional shielding is provided by the steel skid on the bottom half of the LLCE within the BC.

The source term used in the shielding analysis of the proposed LLCE shipments was based on a worst-case evaluation. The total activity of this source may be as high as 3110 Ci. This source strength combined with the limited external shielding of the package may result in high dose rates around the transportation trailer in the vicinity of the tractor cab. Extra shielding in the form of lead blankets around the tractor cab is required to keep the dose rate to the driver under the limit of 2 mrem/h. The amount of lead shielding required for the worst-case source was determined and is reported in Part B, Section 5.0.

A safety zone may have to be established during loading, transport, and unloading operations for workers to maintain exposure levels under limits specified by the radiological control personnel.

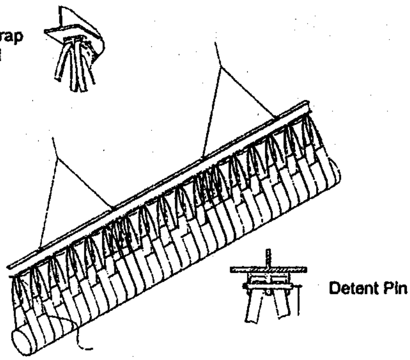
2.10 LIFTING DEVICES

The LLCE TS uses a dedicated set of lift beams and sacrificial slings to lift the unloaded and loaded LLCE BCs. The lift beams utilize remotely removable detent pins to attach the slings. Both lift beams, one for the short containers and one for the long containers, were load tested and American National Standards Institute certified by the manufacturer and meet Hanford Site hoisting and rigging requirements. Figure A2-1 shows the general configuration for a two-crane pick of a typical BC.

2.11 TIEDOWN DEVICES

The tiedown system is an integral part of the transport trailer. It consists of prestaged BC chalks, which attach to the trailer with Iso-lock fittings, forward blocking utilizing the shield wall, and tiedown straps integrated between the lifting straps. The tiedown system was evaluated for normal transfer conditions, including shock and vibration, to adequately restrain the BC without causing damage to the container as required by the WHC-SD-TP-PDC-020 (WHC 1995). There are no tiedown devices that are a structural part of the BC.

Figure A2-1. Lifting Beam and Slings.



3.0 PACKAGE CONTENTS

3.1 GENERAL DESCRIPTION

Package contents consist of a bagged LLCE, rigging, and RMW not removed by the rinsing system of the flexible receiver assembly. These articles are placed in a steel, cylindrical half-pipe (BC skid), which contains an integral steel trimmie tube for distribution of the void fill material. The BC skid is then placed inside the BC.

Table A3-1 lists the activity of the design basis contaminated equipment, which was taken from the packaging design criteria for the LLCE TS (WHC 1995).

3.2 CONTENT RESTRICTIONS

The contents authorized for transport of LLCE and associated RMW in the BCs are restricted to the bounding maximums described in the following sections. The determination of the authorized contents is given in Part B, Section 2.0.

3.2.1 Content Matrix

The content matrix consists of the BC skid and trimmie tube, the LLCE item with residual radioactive mixed waste contamination, and retrieval rigging contained within the flexible receiver bag. When the payload is characterized as nontransuranic, the waste matrix is also comprised of a low-density grout monolith surrounding the remaining constituents of the matrix within the BC. **Where the payload is determined to be transuranic waste, the BC must be shipped to a permitted storage facility without void fill.**

3.2.2 Radioactive Materials

The derivation of the maximum curie content listed in Table A3-1 is described in Part B, Section 2.0. Maximum curie contents were established for seven different container sizes. The maximum curie content corresponds to 378 A_2s as shown in Table A3-1. Therefore, the LLCE TS contains Type B quantities of radioactive material.

Table A3-2 contains the fissile content of the LLCE TS. The activities for the radionuclides identified as fissile in 49 CFR 173.403 (i.e, ^{238}Pu, ^{239}Pu, ^{241}Pu, ^{233}U, and ^{235}U) are included along with their specific activities from 49 CFR 173.435. The quantity (g) of each fissile radionuclide is also listed in Table A3-2.

Table A3-1. Maximum Curie Content. (2 sheets total)

Nuclide	Ci	A_2, Ci	A_2s
^{14}C	6.07 E-02	5.41 E+01	1.12 E-03
^{60}Co	3.32 E+01	1.08 E+01	3.07 E+00
^{63}Ni	9.81 E-01	8.11 E+02	1.21 E-03
^{79}Se	2.44 E-03	5.41 E+01	4.51 E-05
^{90}Sr	2.08 E+02	2.70 E+00	7.70 E+01
^{90}Y*	2.08 E+02	0.00	0.00
^{93m}Nb	6.01 E-03	1.62 E+02	3.71 E-05
^{93}Zr	8.77 E-03	5.41 E+00	1.62 E-03
^{95}Zr	7.57 E+00	2.43 E+01	3.12 E-01
^{99}Tc	1.37 E+00	2.43 E+01	5.64 E-02
^{106}Rh*	8.70 E+00	0.00	0.00
^{106}Ru	8.70 E+00	5.41 E+00	1.61 E+00
^{125}Sb	5.27 E+00	2.43 E+01	2.17 E-01
^{129}I	8.52 E-04	Unlimited	0.00
^{134}Cs	1.39 E+00	1.35 E+01	1.03 E-01
^{137}Cs	9.10 E+02	1.35 E+01	6.74 E+01
^{137m}Ba*	8.61 E+02	0.00	0.00
^{144}Ce	4.24 E+02	5.41 E+00	7.84 E+01
^{144}Pr*	4.24 E+02	0.00	0.00
^{147}Pm	1.58 E-01	2.43 E+01	6.50 E-03
^{151}Sm	1.68 E+00	1.08 E+02	1.56 E-02
^{154}Eu	1.13 E+00	1.35 E+01	8.37 E-02
^{155}Eu	1.13 E+00	5.41 E+01	2.09 E-02
^{233}U	2.58 E-04	2.70 E-02	9.56 E-03
^{234}U	2.32 E-07	2.70 E-02	8.59 E-06
^{235}U	6.98 E-05	Unlimited	0.00
^{237}Np	2.96 E-04	5.41 E-03	5.47 E-02
^{239}Np*	1.91 E-06	0.00	0.00
^{238}Pu	7.72 E-03	5.41 E-03	1.43 E+00
^{238}U	1.69 E-03	Unlimited	0.00

Table A3-1. Maximum Curie Content. (2 sheets total)

Nuclide	Ci	A_2, Ci	A_2s
^{239}Pu	4.00 E-01	5.41 E-03	7.39 E+01
^{240}Pu	1.86 E-02	5.41 E-03	3.44 E+00
^{241}Am	3.67 E-01	5.41 E-03	6.78 E+01
^{241}Pu	1.79 E-01	2.70 E-01	6.63 E-01
^{242}Am*	3.81 E-04	0.00	0.00
^{242}Cm	1.15 E-03	2.70 E-01	4.26 E-03
^{242m}Am	3.83 E-04	5.41 E-03	7.08 E-02
^{242}Pu	1.21 E-09	5.41 E-03	2.24 E-07
^{243}Am	1.09 E-02	5.41 E-03	2.01 E+00
^{244}Cm	1.58 E-03	1.08 E-02	1.46 E-01
Totals	3.11 E+03		3.78 E+02

*This radionuclide is a daughter as defined in 49 CFR 173.433; therefore, its activity was set to 0 for the A_2 calculations.

49 CFR 173, 1997, "Shippers--General Requirements for Shipments and Packagings," *Code of Federal Regulations*, as amended.

Table A3-2. Long-Length Contaminated Equipment Transport System Fissile Inventory.

Nuclide	Activity, Ci	Specific activity, Ci/g	Quantity, g
^{233}U	2.6 E-04	9.7 E-03	2.7 E-02
^{235}U	7.0 E-05	2.2 E-06	3.2 E+01
^{238}Pu	7.7 E-03	1.7 E+01	4.5 E-04
^{239}Pu	4.0 E-01	6.2 E-02	6.5 E+00
^{241}Pu	1.8 E-01	1.0 E+02	1.8 E-03
Totals	7.9 E+00		3.9 E+01

3.2.3 Nonradioactive Materials

Chemical wastes from various activities, including plutonium extraction from spent nuclear fuel, laboratory analyses, and other national defense support activities, were deposited in SSTs from 1944 to 1980. From 1980 to the present, chemical wastes from similar activities have been deposited in the

DSTs. The most recent comprehensive list of potential contaminants is available in WHC-SD-WM-TCP-007, *Disposal of Tank Farm Long-Length Contaminated Equipment: Radiological and Chemical Characterization Plan* (Roach 1995b). A thorough review of the chemical compatibility of HDPE with these chemicals is provided in Part B, Section 2.5. The majority of chemicals will be removed or diluted from the LLCE item by high-pressure wash during retrieval.

Sampling activities to characterize the waste in each tank will be performed on a case-by-case basis when a new LLCE item removal operation is identified.

4.0 TRANSPORT SYSTEM

4.1 TRANSPORTER

The LLCE BCs, when used in retrieval operations, are loaded with the payload and transported exclusively on the dedicated transport trailer (LLCE Transport Trailer HO-64-4280). No other trailer is authorized to transport a loaded LLCE BC.

4.2 TIEDOWN SYSTEM

An engineered tiedown system is provided for securing the LLCE to the transport trailer. During staging of the equipment, the BC is placed in a chock secured on the transport trailer, using a lift beam and rigging. The lift beam is then stowed with the rigging still attached on the transport trailer lift beam storage device. Straps are then placed between the lift beam rigging at predetermined intervals (dependent on the size of container used). Guidance for lift strap and tiedown attachment placement is given in the HNF-SD-WM-SPP-002 (PHMC 1997).

On one side of the BC, the tiedown straps are secured with remotely activated hydraulic pins. On the other side of the BC, the straps are tensioned with conventional load binders. The front end (driver end) of the transport trailer provides blocking for the BC via the shield wall, which is staked and restrained by a system of chains and load binders. The rear end of the trailer is not blocked. Features are available to provide aft restraint; however, it is not expected to be an operational requirement due to the extremely slow speeds and low accelerations anticipated during normal transport.

For unloading purposes, the hydraulic pins are remotely released, and the tiedown straps slide off of the container when it is lifted from the transport trailer chock.

4.3 SPECIAL TRANSFER REQUIREMENTS

Based on the results of the gas generation evaluation in Part B, Section 9.0, a gas generation analysis must be performed for each LLCE removal prior to loading the equipment into the burial container. Although the gas generation evaluation in this SARP is based on conservative source term, until such time as a reliable data base has been established, based on data from a general cross section of SST and DST characterizations, it is assumed that gas generation is a potential problem.

4.3.1 Route Access Control

Due to potential high radiation fields around the transport vehicle, a radiation work zone may be in place during transport operations. As such, it is required that route planning and in-transit access control be in place prior to each shipment. A safety zone shall be established, based on input from radiological personnel, and at no time during the transport operation shall unauthorized vehicles or persons be permitted within the zone. Part B, Section 5.0, provides information on potential radiation fields based on the worst-case payload source term.

4.3.2 Radiological Limitations

The transport trailer is design to be operated remotely via pendant control and/or infrared control. Some shielding is provided by shield panels on the trailer and by the trailer itself. However, given the worst-case source term there is a potential for radiation fields higher than normal, especially in the vicinity of the BC where the in-tank portion of the LLCE item is placed. This is normally at the front of the trailer near the driver. Safety zone distances shall be derived from the dose limits specified in the *Hanford Site Radiological Control Manual*, HSRCM-1, Revision 2 (WHC 1996). Potential zones can be established using the data provided in Part B, Section 5.8. This section provides tabulated dose/distance data for a variety of configurations, based on the limiting source term and varying amounts of shielding.

The primary dose limit of concern for the system is that the driver of the transport trailer tractor be exposed to less than 2 mrem/h. Based on input from radiological control personnel, shielding shall be added to the tractor, as required, to reduce exposure to this level. See Part B, Section 5.0, for information regarding potential exposure and requirements for dose reduction to the driver.

Permissible external contamination limits for the exterior of the LLCE BC are as shown in Table A4-1.

Table A4-1. External Container Contamination Limits.

Contaminant	Maximum permissible limits		
	Bq/cm^2	$\mu Ci/cm^2$	dpm/cm^2
Beta and gamma emitters and low toxicity alpha emitters	0.4	10^{-5}	22
All other alpha emitting radionuclides	0.04	10^{-6}	2.2

Source: 49 CFR 173.443, 1997, "Shippers--General Requirements for Shipments and Packagings, *Code of Federal Regulations*, as amended.

4.3.3 Environmental Conditions

If extreme fog, ice, or adverse snow conditions exist, as determined by the authorized shipper, the package shall not be transported.

5.0 ACCEPTANCE OF PACKAGING FOR USE

5.1 NEW PACKAGE ACCEPTANCE TESTING

Acceptance testing and inspections are performed to evaluate the performance of the LLCE BC per the requirements of this SARP. The acceptance inspections and tests are categorized as fabrication, performance, and prior to first use.

During fabrication of all LLCE BC components, the quality assurance (QA) plan or equivalent described in Part A, Section 7.0, shall be implemented.

The following are requirements for the inspection and testing of the packaging. Specific procedures with appropriate Quality Control (QC) hold points shall be written by the fabricator or user prior to use to ensure the packaging is not damaged during inspection and testing operations.

5.1.1 Acceptance Requirements

Acceptance criteria for the BC and related components dimensions must meet the tolerances provided on the appropriate drawings. An index of drawing numbers is provided in Part A, Section 10.0. In addition, new packagings or related components must meet the acceptance criteria in the *Long-Length Contaminated Equipment Burial Containers Fabrication Process Procedures*, HNF-SD-WM-SPP-002 (PHMC 1997).

5.1.2 Inspection and Testing

5.1.2.1 Fabrication Inspection and Testing.

5.1.2.1.1 Fabrication Inspection. The cask components shall be inspected after final assembly to verify compliance with the drawing dimensions given in Part A, Section 10.0. Visual or ultrasonic nondestructive examination shall be performed on the applicable welds per the drawing requirements.

5.1.2.1.2 Leakage Rate Testing. Each complete LLCE BC containment boundary shall be leakage rate tested upon completion of fabrication. The tests will be performed at ambient temperature after final assembly is completed. The leakage rate tests will be performed in accordance with ANSI N14.5 (ANSI 1987).

5.1.2.2 Prior to Use Inspections. Prior to use inspections shall be performed to ensure the BC meets the SARP requirements and can be assembled to meet the leak rate acceptance criteria. Also, before use, the packaging shall be labeled with its gross weight, tare weight, and drawing number. Each LLCE BC shall be inspected prior to use as described below. Each inspection shall be documented as stated in Part A, Section 5.1.3. The inspections shall be performed to ensure that the packaging has maintained the original as-fabricated configuration. These inspections shall, as a minimum, consist of the following steps.

1. Visually examine the LLCE BC, BC lid, and ancillary components for damage due to transport. Any defect exceeding the following guidelines in the BC weld zone areas must be repaired:

   - Internal Defect: flat bottom circular hole less than 3.2 mm (0.125 in.) equivalent spaced 1.3 cm (0.5 in.) apart

   - External Scratch: less than 50.8 cm (20 in.) long x (0.038 in.) deep spaced 3.8 cm (1.5 in.) apart

   - External Gouge: less than 6.4 mm (0.25 in.) long x (0.100 in.) deep spaced 3.8 cm (1.5 in.) apart.

2. Visually inspect the package tiedowns, lift beam, detent pins, and lifting straps to ensure they are in good working condition.

3. Visually inspect BC inflatable seal for damage.

4. Visually examine all components of the packaging system for cleanliness; ensure they are cleaned of any dirt or dust.

5.1.3 Documentation

Acceptance testing and inspection verification (including results therefrom) shall be documented with QC verification and maintained for the life of the package or five years, whichever is longer.

5.2 PACKAGING FOR REUSE

The LLCE BCs are considered nonreusable.

6.0 OPERATING REQUIREMENTS

6.1 GENERAL REQUIREMENTS

The following are minimum requirements for the use of the LLCE BC. Each facility shall prepare operating procedures based on the Fluor Daniel Hanford, Inc., safety requirements. Prior to use, the specific operating procedures with appropriate Quality Assurance/QC hold points shall be written by the user and approved in accordance with WHC-CM-2-14, *Hazardous Material Packaging and Shipping*.

For loading and transport operations, the following shall be performed.

1. Verify initial temperature conditions are between 0 and 37.8 °C (32 and 100 °F).
2. Perform gas generation analysis based on characterization data.
3. Establish a safety zone within worker radiological exposure limits.
4. Visually inspect the seals and sealing surfaces for damage.
5. Visually inspect the BC and components for cracks or damage.
6. Visually inspect the lifting attachments for cracks or damage.
7. Verify loading and closure of the BC.
8. Verify void fill requirements are met if applicable.
9. Verify dose rates to the driver are acceptable prior to shipment per Part A, Section 4.3.2. Add appropriate shielding to reduce driver exposure to less than 2 mrem/h.
10. Verify external contamination limits per Table A4-1 are met prior to transport.
11. Verify tiedown of the BC to the transporter.
12. Verify appropriate shipping paperwork is prepared and signed by a certified shipper.
13. Verify proper removal from the transporter.

Prior to void fill or transport, the BC lid seal shall be leakage rate tested per HNF-SD-WM-SPP-002 (PHMC 1997).

6.2 LOADING PACKAGE

The following describes the general operations for loading an LLCE BC. Detailed operating procedures, as described above, shall be developed by the TS user prior to all operations.

1. The proper size chock for the BC to be used is attached to the transport trailer.
2. The BC is placed on the transport trailer chock with the open end facing the rear of the trailer. The lift beam is stowed in its cradle with the slings left attached. The BC tiedowns and tarp are attached and secured with the hydraulic pins. The tiedowns are cinched to proper tension.

3. The transport trailer shield walls, if required, are placed in position. This operation may take place prior to placing the BC on the transport trailer if desired.

4. The proper size skid for the BC to be used is attached to the receiver trailer strongback.

5. All equipment, including the BC lid, ancillary components, receiver trailer, and transport trailer, are prestaged near the tank targeted for retrieval operations. **The BC lid must be sheltered from direct sunlight until just prior to use.**

6. The receiver trailer is raised and leveled with the outrigger screw jacks.

7. The LLCE item is removed from the tank riser with the flexible receiver assembly and bagged.

8. The receiver trailer strongback with the skid attached is raised to the vertical position (approximately 85° from horizontal).

9. The LLCE item is mated to the skid using the hook intercept, and the strongback is lowered to horizontal with the crane rigging attached. When the strongback is nestled in its rest, the crane hook is removed.

10. The receiver trailer is lowered, and the outriggers are stowed. The receiver trailer is now ready to be mated with the transport trailer.

11. The transport trailer outriggers are deployed, and the trailer is readied for mating with the receiver trailer.

12. The receiver trailer is backed up to the transport trailer and positioned in alignment with the trailer mating fixtures.

13. The receiver trailer outriggers are deployed, and the receiver trailer is raised with the screw jacks until the bogey assembly is clear of the ground or roadway. The receiver trailer is then leveled using the level indicators and screw jacks.

14. The transport trailer is raised until the height limit switches are triggered by the receiver trailer stops.

15. The transport trailer is leveled using the level indicators and is aligned with the receiver trailer using the laser alignment device. A secondary visual verification of alignment is provided on the trailers using a telescopic sight on the transport trailer and a target on the receiver trailer.

16. When trailer alignment is verified, the space-frame tug is attached to the BC skid.

17. The space frame tug is used to push the skid into the BC until it reaches its travel limit.

18. The skid is inserted to its final position using the tug screw jack. The tug is then disconnected from the skid, and the hook intercept is removed from the skid.

19. The tug is pulled back to its original position, the receiver trailer is lowered, the outriggers are stowed, and the trailer is removed from the vicinity.

20. The personnel access platform is positioned at the rear of the transport trailer.

21. The BC lid is installed and leak tested per HNF-SD-WM-SPP-002 (PHMC 1997).

22. If required, the BC is void filled per HNF-SD-WM-SPP-002 (PHMC 1997).

23. The BC lid vent-fill and leak ports are plugged and sealed per HNF-SD-WM-SPP-002 (PHMC 1997).

24. The BC lid penetration seals are leak tested per HNF-SD-WM-SPP-002 (PHMC 1997).

25. If the BC has been void filled, an appropriate cure time is given prior to transport.

26. The transport trailer is lowered and the outriggers stowed. The transport trailer is moved to the disposal/storage facility.

6.3 REMOVAL OF PACKAGE FROM THE TRANSPORT TRAILER

1. When the transport trailer is in position at the disposal or storage facility, the hydraulic tiedown retaining pins are retracted, allowing the tiedown straps and tarp to relax.

2. Two cranes are required to lift the lift beam, lift straps, and BC from the transport trailer.

3. The transport trailer is removed from the facility.

4. The BC support chocks are placed in position to receive the BC.

5. The BC is placed on its support chocks.

6. The rigging straps are removed remotely from the lift beam using the rope attached to the lift beam detent pins. Because the rigging straps are disposable, if one or more of the detent pins becomes stuck, the strap can be cut using an appropriate tool; e.g., saw or knife attached to a reach pole.

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7.0 QUALITY ASSURANCE REQUIREMENTS

7.1 INTRODUCTION

This section describes the quality assurance (QA) requirements for the design, procurement, fabrication, and maintenance of the of the LLCE packaging system. The format and requirements for use on the Hanford Site are taken from the *Quality Assurance Manual*, WHC-CM-4-2 and the *Hazardous Materials Packaging and Shipping*, WHC-CM-2-14.

7.2 GENERAL REQUIREMENTS

These requirements apply to activities that could affect the quality of the components of the packaging. The LLCE BC is classified per the WHC-CM-2-14 with a Transportation Hazard Indicator (THI) of 2.

A THI 2 packaging represents the second highest level of hazard for the contents. A packaging assigned must be capable of mitigating a release that could result in a potential dose consequence of between 0.5 rem and 25 rem at the Hanford Site boundary, or greater than 5 rem within the site, if fully released.

Each THI contains a Quality Level (QL) designator consisting of an alpha designator and a numeric designator. The alpha designator assigns the fabrication, testing, use, and quality assurance for each item, component, or activity associated with the packaging. The numeric designator following the alpha designator is the assigned THI number for the packaging. The following are definitions and requirements for each LLCE packaging item, component, or activity.

Quality Level A-2: Critical impact on safety and associated functional requirements: items or components whose failure or malfunction could directly result in an unacceptable condition of containment or confinement, shielding, or nuclear criticality.

This QL refers to the LLCE BC containment boundary, which includes the BC body, end caps, powercore fusion weld, inflatable seal, and penetration plugs and seals. The requirements for fabrication, operations, and maintenance shall comply with the requirements of the codes and standards identified in Part B, Section 7.2. Preventive maintenance and inspection of components shall be performed prior to shipment by personnel qualified to applicable standards specified in the safety documentation.

Materials are to be specified to codes and standards identified in Part B, Section 7.2, with certificates of compliance (CoC) from the sellers.

Any procurement of items shall be from a supplier with an approved QA program in accordance with, or equivalent to, appropriate basic requirements and supplements of American Society of Mechanical Engineers (ASME) NQA-1 (ASME 1989). QA procurement clauses shall be imposed, as applicable, to ensure product quality. Specific requirements are to be developed by the Packaging Quality Assurance engineer and Packaging Engineering cognizant engineer.

The design leak rate shall be as a maximum 10^{-3} cm^3/s, air, and shall be verified by testing, calculation, or similar designs.

Quality Level B-2: Major impact on safety and associated functional requirements. Components or activities whose failure or malfunction could indirectly result in an unacceptable condition of containment or confinement, shielding, or nuclear criticality. An unsafe condition could result only if the failure of this item or subsystem occurred in conjunction with the failure of other items or subsystem in A-2 or this level.

This QL refers to the LLCE BC lift beams and lifting slings. The requirements for fabrication, operation, and maintenance shall comply with the requirements of the applicable codes and standards identified in Part B, Section 7.2. Preventive maintenance and inspection of components shall be performed prior to shipment and/or periodically (not to exceed one year) by personnel qualified to applicable standards specified in the safety documentation.

Materials for fabrication are required to be specified to American Society for Testing and Materials standards with the seller's CoC attesting to the acceptability of the materials.

Any procurement of items shall be from a supplier with an approved QA program in accordance with, or equivalent to, appropriate basic requirements and supplements of ASME NQA-1 (ASME 1989). QA procurement clauses shall be imposed, as applicable, to ensure product quality. Specific requirements are to be developed by the Packaging Quality Assurance engineer and Packaging Engineering cognizant engineer.

Quality Level C-2: Minor impact on safety and associated functional requirements. Items or components whose failure or malfunction would not reduce packaging effectiveness and would not result in an unacceptable condition of containment or confinement, shielding, or nuclear criticality, regardless of other failure in A-2, B-2, or this level.

This QL refers to the LLCE BC tiedowns and tiedown attachments. The requirements for fabrication, operation, and maintenance shall comply with the requirements of the applicable codes and standards identified in Part B, Section 7.2, or Rust Federal Services of Hanford Inc.'s or the seller's prepared requirements media.

Materials for fabrication are required to be specified to recognized industrial, national, or international standards with the seller's CoC attesting to the acceptability of the materials.

Any procurement of items shall be from a supplier with an approved QA program in accordance with, or equivalent to, appropriate basic requirements and supplements of ASME NQA-1 (ASME 1989). QA procurement clauses shall be imposed, as applicable, to ensure product quality. Specific requirements are to be developed by the Packaging Quality Assurance engineer and Packaging Engineering cognizant engineer.

Documentation and review requirements are based upon the QL of each component or activity. Changes or discoveries of noncompliance for all QL A-2 and B-2 components and activities shall be reviewed by the screening process for an unreviewed safety question to ensure the quality and safety of the change or discovery. Changes to the SARP safety bases (contents, shielding, structural, containment, criticality) will require screening for an unreviewed safety question regardless of the QL.

7.3 QUALITY REQUIREMENTS

The LLCE BC is a preengineered transport container designed, procured, and fabricated originally for transport of Type B solid radioactive material in accordance with the Hanford Site requirements. Appropriate QA measures shall be used in the design, procurement, and fabrication of the LLCE BC.

7.3.1 Organization

The organizational structure and the assignment of responsibility shall be such that quality is achieved and maintained by those who have been assigned responsibility for performing the work and that quality achievement is verified by persons or organizations not directly responsible for performing the work.

Packaging Engineering, Loading Facility Operations, Radiological Protection managers, and Receiving Facility managers are responsible for the quality of the work performed by their respective organizations and for performing the following activities:

- Follow current requirements of this SARP
- Provide instructions for implementing QA requirements.

The cognizant Manager, Quality Assurance, is responsible for establishing and administering the Hanford Site Quality Assurance Program, as stated in the WHC-CM-4-2, relative to the LLCE BC.

7.3.2 Design Control

Measures shall be established for the selection and review for suitability of application of materials, parts, equipment, and processes. These measures are essential to the safety-related functions of the materials, parts, and components of the payload encapsulation and dunnage.

7.3.2.1 Design Inputs. Design inputs for the payload encapsulation and dunnage are derived from the radiation limits and operational requirements.

7.3.2.2 Design Process. The responsible design organization for the payload encapsulation shall document the design in a manner to permit verification that the design meets the requirements. Packaging Engineering is the responsible safety analysis organization and shall document the analysis in a manner to permit verification that the design analysis meets the requirements. The payload encapsulation and dunnage-related drawings are developed, stored, updated, and controlled by the design organization in accordance with its respective QA program.

The final design and analysis shall be related to the design input and will be documented for approval.

7.3.2.3 Documentation and Records. Design documentation and records that provide evidence that the design processes were performed in accordance with the requirements of this SARP shall be collected, stored, and maintained by the user facility for no less than five years from the date of shipment.

7.3.3 Procurement and Fabrication Control

7.3.3.1 Procurement Document Control. Procurement documentation for packaging items is initiated by the organization responsible for the packaging design. The purchase requisition shall contain both the technical and quality requirements.

Changes to the purchase requisition or subsequent purchase order (PO) are subject to the same review and approval requirements as the original purchase requisition.

7.3.3.2 Control of Purchased Items and Services. Procurement and fabrication of LLCE BC components shall be documented and controlled based on the requirements of WHC-CM-4-2, as appropriate for each assigned QL

7.3.3.3 Identification and Control of Items. The identification of purchased items shall be verified at initial receipt and maintained through installation and use. The identification of items fabricated or assembled onsite shall be established at the earliest practical time in the fabrication or assembly sequence.

The identification of items shall relate each to an applicable design or other pertinent specifying document, such as POs, procedures, or drawings.

7.3.3.4 Control of Operation/Processes. Processes affecting the quality of packaging items or services shall be controlled by instructions, procedures, drawings, checklists, or other appropriate means. These means shall ensure that process parameters are controlled with defined limits and that specified environmental conditions are maintained.

Special processes performed onsite and by suppliers that control or verify quality, such as those used in welding, shall be performed by qualified personnel who use qualified procedures in accordance with nationally recognized codes and standards.

Records shall be maintained for the currently qualified personnel, processes, and equipment of each special process by the shop or faction performing the process.

7.3.4 Control of Inspection

In-process and final inspections shall be performed to the following guidelines.

7.3.4.1 Inspection Personnel. Inspection for acceptance shall be performed by qualified personnel.

7.3.4.2 In-Process Inspection. In-process inspections will be performed when deemed appropriate for the payload encapsulations and dunnage components. The following activities provide guidelines for the inspections:

- Welding personnel qualifications
- Material certifications
- Proper assembly and disassembly of the packaging
- Welding certification records
- Welding procedures.

7.3.4.3 Final Inspection. Loading/unloading procedures shall be written by the user and will be used to ensure adequate loading, operation, and maintenance of packaging. The loading/unloading procedure identifies actions required by loading personnel to safely and properly load and unload the LLCE BC. The loading/unloading procedure shall also identify when rigging and lifting procedures and maintenance procedures should be referenced.

Final inspections shall include the following items.

- The LLCE BC is properly assembled.
- All shipping papers are properly completed.
- Packagings are conspicuously and durably marked as required by WHC-CM-2-14.
- Measures are established to ensure that an individual trained in onsite shipping requirements, designated by the user of the packagings, signs the shipping papers before authorization for shipping.
- Operational procedures are properly completed.

7.3.5 Control of Nonconforming Items

All items procured or fabricated for the payload encapsulation and dunnage shall be inspected prior to use for compliance with the PO, specification, or fabrication drawing.

7.3.5.1 Identification. Identification of nonconforming items shall be by marking or tagging or by other appropriate methods that shall not adversely affect the end use of the item.

7.3.5.2 Segregation. Nonconforming items are segregated by placing them in a designated and identified holding area until disposition is completed. When segregation is impossible or not practical because of size, weight, or access limitations, other precautionary steps may be used on a case-by-case basis.

7.3.5.3 Evaluation and Disposition. Nonconforming characteristics shall be reviewed, and recommended dispositions of nonconforming items shall be proposed and approved in accordance with applicable documentation. Further processing, delivery, installation, or use of nonconforming items shall be controlled pending an evaluation and approved disposition by the user facility.

Qualified inspectors shall perform the inspections. The user facility shall determine disposition of any packaging items.

The disposition, such as accept, reject, repair, or rework of the nonconforming item, shall be documented.

7.3.5.4 Corrective Action. Nonconformance or conditions adverse to quality are evaluated as described in Part A, Section 7.3.7, and the need for corrective action is determined.

7.3.6 QA Records and Document Control

Records that furnish documentary evidence of quality shall be specified, prepared, and maintained. All documents used to perform and/or verify quality-related activities are controlled. Controlled documents include (but are not limited to) the following: drawings, specifications, POs, plans and procedures to inspect and test, reports, the SARP, and operational and maintenance procedures.

The document control system embodies the following features.

- Document changes are controlled in the same way as the original issue.
- Interfacing documents are properly coordinated and controlled.
- A reference system is in use that provides access to the current issues of project documents.

All records associated with hazardous material packaging and transportation shall be retained for the life of the packaging. All lifetime storage records required for the LLCE BCs shall be stored with either Packaging Engineering or the user facility's engineering files, depending upon the purpose of the document. For records retention periods and location of records for the LLCE BCs (when used per this onsite SARP), see Table A7-1.

Table A7-1. Records Retention and Location.

Document	Retention period	Location
Safety analysis report for packaging	Lifetime	Rust Federal Services Inc., Northwest Operations, Packaging Engineering/Information Resource Management
Radiation surveys	5 years	User facility
Operating procedures	5 years	User facility
Quality assurance audits	Lifetime	User facility
Quality control inspection reports	Lifetime	User facility
Nonconformance reports	Lifetime	User facility
Purchase orders	Lifetime	User facility

7.3.7 Audits

The following are possible activities and files to be audited during the use and maintenance of the LLCE TS and its effective packaging components:

- Design drawings
- Design and safety analysis records
- Operating procedures and acceptance and inspection records.

7.3.8 Handling, Storage, and Shipping

Instructions for the handling, storage, and shipping are found in this SARP and the manufacturer's operating procedures for the trailers and the LLCE BCs. These requirements shall be implemented by the loading and unloading facility within operating procedures, maintenance procedures, acceptance procedures, and test procedures. The transport will be implemented by a radioactive shipment record for onsite transport of Type B material.

Special handling tools or lifting equipment (e.g., lift beams, straps, pins) for the LLCE BCs shall be used and controlled, as necessary, to ensure safe and adequate handling. Special handling tools and equipment shall be inspected and tested in accordance with the *Hanford Site Hoisting and Rigging Manual* (RL 1996) at specified time intervals to verify that the tools and equipment are adequately maintained. Operators of special handling and lifting equipment shall be experienced or trained in the use of the equipment.

Marking, labeling, and transport vehicle placarding for the LLCE BC transport shall be performed per the WHC-CM-2-14. Marking and labeling of the package for storage shall be maintained by storage maintenance procedures.

7.4 QA ACTIVITIES

Each cognizant engineer involved with design, procurement, fabrication, use, or maintenance of the LLCE BCs or related equipment is responsible for ensuring that the assigned tasks are performed in accordance with controlling plans and procedures, which must, in turn, conform to these QA requirements. Quality requirements for tasks are determined and documented in the plans and procedures used by the involved organizations.

The appropriate QL designators for LLCE BC components are given in Table A7-2.

Table A7-2. Long-Length Contaminated Equipment Quality Levels.

LLCE item or component	Quality Level
LLCE BC body	A-2
LLCE BC end caps	A-2
Powercore fusion material	A-2
Inflatable seal	A-2
End cap penetration plugs	A-2
LLCE BC lift beams	B-2
LLCE lift slings	B-2
LLCE BC tiedowns	C-2
LLCE BC tiedown attachments	C-2

BC = burial container.
LLCE = long-length contaminated equipment.

7.5 SARP CONTROL SYSTEM

This SARP is a copy-controlled supporting document to ensure that only up-to-date approved versions of this SARP are used for transport. Any changes made to this SARP will be performed by Packaging Engineering and are incorporated and distributed to users through the Copy Control System.

Any review comment records produced during the initial release or subsequent changes will be on file with Packaging Engineering.

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8.0 MAINTENANCE

8.1 GENERAL REQUIREMENTS

The LLCE BCs are used only once. Maintenance is only required for pre-use conditions. The transport and receiver trailers are maintained separately.

8.2 INSPECTION AND VERIFICATION SCHEDULES

8.2.1 Visual BC Inspections

The following maintenance visual inspections shall be performed on the BC and BC lid prior to use.

1. Visually inspect components for deterioration.
2. Determine surface contamination levels and document.

8.2.2 Visual Lifting/Tiedown Inspections

The tiedown attachments, lift beam, and beam lifting points shall be inspected prior to each use for plastic deformation or cracking. Any indication of cracking or distortion shall be repaired prior to further use of the lifting or tiedown device.

8.3 RECORDS AND DOCUMENTATION

Visual inspection shall be documented, including quality verification, and maintained for the life of the packaging or five years, whichever is longer.

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9.0 REFERENCES

49 CFR 173, 1997, "Shippers--General Requirements for Shipments and Packagings," *Code of Federal Regulations*, as amended.

ANSI, 1987, *American National Standard for Radioactive Materials--Leakage Tests on Packages for Shipment*, ANSI N14.5, American National Standards Institute, New York, New York.

ASME, 1989, *Quality Assurance Program Requirements for Nuclear Facilities*, ASME NQA-1-1989 Edition, American Society of Mechanical Engineers, New York, New York.

ASTM, 1989, "Standard Specification for Polyethylene Plastics Molding and Extrusion Materials," ASTM D1248, *Annual Book of ASTM Standards*, Vol. 8.01, American Society for Testing and Materials, Philadelphia, Pennsylvania.

PHMC, 1997, *Long-Length Contaminated Equipment Burial Containers Fabrication Process Procedures*, HNF-SD-WM-SPP-002, Rev. 0, Rust Federal Services Inc., Northwest Operations, Richland, Washington.

RL, 1996, *Hanford Site Hoisting and Rigging Manual*, DOE/RL-92-36, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

Roach, H. L., 1995a, *Disposal of Tank Farm Long-length Contaminated Equipment: Alternative Options Study and Engineering Support Information*, WHC-SD-WM-ES-265, Rev. 0-A, Westinghouse Hanford Company, Richland, Washington.

Roach, H. L., 1995b, *Disposal of Tank Farm Long-Length Contaminated Equipment: Radiological and Chemical Characterization Plan*, WHC-SD-WM-TCP-007, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

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

WHC-CM-4-2, *Quality Assurance Manual*, Westinghouse Hanford Company, Richland, Washington.

WHC, 1996, *Hanford Site Radiological Control Manual*, HSRCM-1, Rev. 2, Westinghouse Hanford Company, Richland, Washington.

WHC, 1995, *Packaging Design Criteria Transfer and Disposal of Long-length Equipment Hanford Tank Farm Complex*, WHC-SD-TP-PDC-020, Rev. 2, Westinghouse Hanford Company, Richland, Washington.

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10.0 APPENDIX: DRAWINGS

DRAWING NO.	DRAWING TITLE
H-2-827806	LLCE Drawing Index
H-2-827807	LLCE C1 and C2 Field Assemblies
H-2-827808	LLCE C1 and C2 Shop Assemblies
H-2-827809	End Cap C1-C2 Assembly
H-2-827810	LLCE C3 and C4 Field Assemblies
H-2-827811	LLCE C3 and C4 Shop Assemblies
H-2-827812	End Cap C3-C4 Assembly
H-2-827813	LLCE C5 and C9 Field Assemblies
H-2-827814	LLCE C5 and C9 Shop Assemblies
H-2-827815	End Cap C5-C9 Assembly
H-2-827816	LLCE C6 and C7 Field Assemblies
H-2-827817	LLCE C6 and C7 Shop Assemblies
H-2-827818	End Cap C6-C7 Assembly
H-2-827819	Weldring C1-C2 Assembly
H-2-827820	Weldring C3-C4 Assembly
H-2-827821	Weldring C5-C9 Assembly
H-2-827822	Weldring C6-C7 Assembly
H-2-827823	LLCE Small Funnel Assembly
H-2-827824	LLCE Large Funnel Assembly
H-2-827825	LLCE C3-C4 Weld Clamp
H-2-827826	LLCE C5-C9 Weld Clamp
H-2-827827	LLCE C6-C7 Weld Clamp
H-2-827828	LLCE C1-C2 Shipping and Storage Pallet
H-2-827829	LLCE C1-C2 Shipping and Storage Spider
H-2-827830	LLCE C3-C4 Shipping and Storage Pallet
H-2-827831	LLCE C3-C4 Shipping and Storage Spider
H-2-827832	LLCE C5-C9 Shipping and Storage Pallet
H-2-827833	LLCE C5-C9 Shipping and Storage Spider
H-2-827834	LLCE C6-C7 Shipping and Storage Pallet
H-2-827835	LLCE C6-C7 Shipping and Storage Spider
H-2-827836	LLCE C1-C2 Vent & Fill Port Assemblies
H-2-827837	LLCE C3-C4 Vent & Fill Port Assemblies
H-2-827838	LLCE C5-C9 Vent & Fill Port Assemblies
H-2-827839	LLCE C6-C7 Vent & Fill Port Assemblies

DRAWING NO.	DRAWING TITLE
H-2-827840	LLCE Lift Beam components
H-2-827841	LLCE C1-C2 Weld Clamp
H-2-827842	LLCE C1-C2 Shipping and Storage Cradle
H-2-827843	LLCE C3-C4 Shipping and Storage Cradle
H-2-827844	LLCE C5-C9 Shipping and Storage Cradle
H-2-827845	LLCE C6-C7 Shipping and Storage Cradle
H-2-827846	LLCE Long Lift Beam Field Assembly
H-2-827847	LLCE Long Lift Beam
H-2-827848	LLCE Short Lift Beam Field Assembly
H-2-827849	LLCE Short Lift Beam

PART B: PACKAGE EVALUATION

1.0 INTRODUCTION

Tank farms has a large number of long-length contaminated equipment (LLCE) items installed in the risers of flammable, ferrocyanide, and organic watchlist single-shell tanks (SST); non-watchlist tanks; double-shell tanks (DST); vaults; and receivers. Most of the LLCE items will be classified as Type B (possibly fissile) radioactive mixed waste (RMW). Examples of LLCE items include transfer pumps, instrument trees, air lift circulators, and air lances. There are approximately 1,900 LLCE items installed in the SSTs and DSTs at present. Of these 1,900 LLCE items, there are over 585 different types of LLCE, weighing from 181-9,072 kg (400-20,000 lb) and ranging in size from 10-152 cm (4-60 in.) in diameter by 10-19 m (32-62 ft) in length. The nominal radiation level of removed equipment is approximately 5 rem at contact, with a recorded maximum radiation level of 60 rem at contact.

The new debris rule has eliminated the previously acceptable practice of triple rinsing, bagging, and burying of LLCE items removed from the SSTs and DSTs. The current regulatory interpretation of this rule is that the Land Disposal Restriction treatment standard for equipment that has come in contact with tank waste requires that all contacted surfaces, including internal surfaces, be visually inspected. Implementation of this requirement is both difficult, impractical, and costly. Items previously removed from the tanks are currently stored within the Central Waste Complex (CWC) where weekly surveillance inspections are performed. A routine disposal method for LLCE items is not currently implemented onsite.

The past Tank Waste Remediation System's approach for retrieving and disposing of installed LLCE items required a newly engineered system to meet each individual program's requirements for a specific removal operation. This approach proved both costly and time consuming as each removal activity required a new equipment and operations development effort. The LLCE transport system (TS) provides a standardized, comprehensive approach for the disposal of approximately 98% of LLCE scheduled to be removed from the 200 Area waste tanks. This approach provides a generic, cradle-to-grave system for retrieval, transport, and disposal of LLCE items.

1.1 SAFETY EVALUATION METHODOLOGY

The safety evaluation methodology for the LLCE burial containers (BC) uses evaluations for normal transfer conditions as defined by the approved packaging design criteria (PDC), WHC-SD-TP-PDC-020 (WHC 1995), and radiological risk and dose consequence analyses to demonstrate compliance for accident conditions. In addition, shielding and gas generation analyses are performed to identify potential hazards associated with the potential source term possible with removed LLCE items.

Because the removed LLCE items are handled entirely by remote means and the ability to remove contaminants is limited to the wash process using the flexible receiver assembly, a very conservative source term was developed to anticipate the operational controls required during operations.

The controlling document for these evaluations is WHC-CM-2-14, *Hazardous Materials Packaging and Shipping*, which defines the onsite transportation safety program. The evaluations and analyses presented in Part B of this safety analysis report for packaging (SARP) meet WHC-CM-2-14 requirements.

1.2 EVALUATION SUMMARY AND CONCLUSIONS

Based on the analyses in Part B, Sections 4.0 and 7.0, of this SARP, the LLCE BCs are shown to maintain containment of the payload during normal transfer conditions. The effects of lifting, handling, and transportation shock and vibration do not jeopardize the containment boundary of the packaging when used in the appropriate manner.

Based on the analyses in Part B, Section 3.0, of this SARP, the LLCE BC transportation radiological risk and dose consequence analyses show that the onsite transportation safety requirements are met with the following limitations:

- Transport total of 1,545 km (960 mi) per year
- Interarea shipments restricted to north of the Wye Barricade
- Transport route to be closed to unauthorized access during shipment
- Escort vehicles required during transport.

Based on the analyses in Part B, Section 5.0, of this SARP, it is apparent that high-radiation fields may be present during loading, transport, and unloading operations, particularly at the front (tractor) end of the transport trailer. Because the trailer is designed to be operated remotely (e.g., steerable bogey assembly, remote tiedown removal, and remote BC removal), distance can be used by the operators to minimize received dose by observing a safety zone established by the radiological protection personnel. The transport vehicle driver, however, may require additional shielding to keep exposure below 2 mrem/h. Section 5.0 provides data to assist in planning for additional shielding mounted to the cab of the transporter, based on the specific application.

Based on the analysis in Part B, Section 9.0, of this SARP, the worst-case source term may cause the container to pressurize to over 52 kPa gauge (7.5 psig) and develop hydrogen gas concentrations in excess of one-half the lower flammability limit unless the container is properly vented during transport and storage. Specific gas generation analyses must be performed for each LLCE retrieval operation on a case-by-case basis until such time as a database is compiled that accurately predicts the gas generation properties of similarly characterized tanks. If gas generation is expected to be a problem for a particular LLCE item, appropriate high-efficiency particulate air filtration must be installed on the BC for transport and storage.

It is concluded, with the above considerations, that the LLCE TS complies with the requirements of the WHC-CM-2-14.

1.3 REFERENCES

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

WHC, 1995, *Packaging Design Criteria Transfer and Disposal of Long-length Equipment Hanford Tank Farm Complex*, WHC-SD-TP-PDC-020, Rev. 2, Westinghouse Hanford Company, Richland, Washington.

2.0 CONTENTS EVALUATION

2.1 CHARACTERIZATION

The content matrix consists of the BC skid and trimmie tube and the LLCE item with residual RMW contamination and retrieval rigging contained within the flexible receiver bag. When the payload is characterized as nontransuranic, the waste matrix is also comprised of a low-density grout monolith surrounding the remaining constituents of the matrix within the BC.

2.1.1 Radioactive Materials

The derivation of the maximum curie content is documented in Roach (1995a). To summarize the process, numerous drawings were reviewed to determine the tank farm equipment with the largest surface area and/or trapped waste that will fit into each container size. The estimated waste film thickness of 1.6 mm (0.0625 in.) times the exposed surface area plus trapped solids gives the volume (L) of waste that remains on each piece of selected equipment after rinsing. Note that equipment with interior contaminated surfaces can have a total residual waste film thickness of 3.18 mm (0.125 in.) between the interior and exterior surfaces. Waste characterization data were used to determine conservative activity concentrations (Ci/L) for the SST and DST waste. Activity inventories were obtained by multiplying the appropriate activity concentrations (Ci/L) for either SST or DST waste times the waste volumes (L) remaining on the equipment depending on whether the equipment originated in SST or DST tanks. Maximum curie contents were established using this process for seven different container sizes. The container size with the greatest amount of radioactivity was selected for the PDC (WHC 1995) and for all analyses performed in this SARP. The maximum curie content corresponds to 378 A_2s. Therefore, the LLCE TS contains Type B quantities of radioactive material.

The activities for the radionuclides identified as fissile in 49 CFR 173.403 (i.e, ^{238}Pu, ^{239}Pu, ^{241}Pu, ^{233}U, and ^{235}U) are included along with their specific activities from 49 CFR 173.435. The quantity (g) of each fissile radionuclide was calculated by dividing the maximum curie content (Ci) by its specific activity (Ci/g). The total quantity of fissile material is 39 g. Because the total quantity of fissile material is greater than 15 g, a criticality evaluation is required. Part B, Section 6.0, provides the details demonstrating that the criticality safety requirements are met for the LLCE TS.

2.1.2 Nonradioactive Materials

Chemical wastes from various activities, including plutonium extraction from spent nuclear fuel, laboratory analyses, and other national defense support activities, were deposited in SSTs from 1944 to 1980. From 1980 to the present, chemical wastes from similar activities have been deposited in the DSTs. The most recent comprehensive list of potential contaminants is available in WHC-SD-WM-TCP-007, *Disposal of Tank Farm Long-Length Contaminated Equipment: Radiological and Chemical Characterization Plan* (Roach 1995b). A thorough review of the chemical compatibility of high-density polyethylene (HDPE) with these chemicals is provided in Section 2.5. HDPE is found to be acceptable as a material for containing the types and concentrations of chemicals expected to be remaining on the LLCE items removed from the SSTs and DSTs. The majority of chemicals will be removed or diluted from the LLCE item by high-pressure wash during retrieval. However, sampling activities to characterize the waste in each tank will be performed on a case-by-case basis when a new LLCE item removal operation is identified.

2.2 RESTRICTIONS

The contents authorized for transport of LLCE and associated RMW in the BCs is restricted to the bounding maximums described in the following tables. Table B2-1 lists the activity of the design basis contaminated equipment, which was taken from the PDC for the LLCE TS (WHC 1995). Table B2-2 contains the maximum fissile content of the LLCE TS.

Table B2-1. Maximum Curie Content. (2 sheets total)

Nuclide	Ci	A_2	A_2s
^{14}C	6.07 E-02	5.41 E+01	1.12 E-03
^{60}Co	3.32 E+01	1.08 E+01	3.07 E+00
^{63}Ni	9.81 E-01	8.11 E+02	1.21 E-03
^{79}Se	2.44 E-03	5.41 E+01	4.51 E-05
^{90}Sr	2.08 E+02	2.70 E+00	7.70 E+01
^{90}Y*	2.08 E+02	0.00	0.00
^{93m}Nb	6.01 E-03	1.62 E+02	3.71 E-05
^{93}Zr	8.77 E-03	5.41 E+00	1.62 E-03
^{95}Zr	7.57 E+00	2.43 E+01	3.12 E-01
^{99}Tc	1.37 E+00	2.43 E+01	5.64 E-02
^{106}Rh*	8.70 E+00	0.00	0.00
^{106}Ru	8.70 E+00	5.41 E+00	1.61 E+00
^{125}Sb	5.27 E+00	2.43 E+01	2.17 E-01
^{129}I	8.52 E-04	Unlimited	0.00
^{134}Cs	1.39 E+00	1.35 E+01	1.03 E-01
^{137}Cs	9.10 E+02	1.35 E+01	6.74 E+01
^{137m}Ba*	8.61 E+02	0.00	0.00
^{144}Ce	4.24 E+02	5.41 E+00	7.84 E+01
^{144}Pr*	4.24 E+02	0.00	0.00
^{147}Pm	1.58 E-01	2.43 E+01	6.50 E-03
^{151}Sm	1.68 E+00	1.08 E+02	1.56 E-02
^{154}Eu	1.13 E+00	1.35 E+01	8.37 E-02
^{155}Eu	1.13 E+00	5.41 E+01	2.09 E-02
^{233}U	2.58 E-04	2.70 E-02	9.56 E-03
^{234}U	2.32 E-07	2.70 E-02	8.59 E-06
^{235}U	6.98 E-05	Unlimited	0.00
^{237}Np	2.96 E-04	5.41 E-03	5.47 E-02
^{238}Np*	1.91 E-06	0.00	0.00
^{238}Pu	7.72 E-03	5.41 E-03	1.43 E+00
^{238}U	1.69 E-03	Unlimited	0.00
^{239}Pu	4.00 E-01	5.41 E-03	7.39 E+01

Table B2-1. Maximum Curie Content. (2 sheets total)

Nuclide	Ci	A_2	A_2s
^{240}Pu	1.86 E-02	5.41 E-03	3.44 E+00
^{241}Am	3.67 E-01	5.41 E-03	6.78 E+01
^{241}Pu	1.79 E-01	2.70 E-01	6.63 E-01
^{242}Am*	3.81 E-04	0.00	0.00
^{242}Cm	1.15 E-03	2.70 E-01	4.26 E-03
^{242m}Am	3.83 E-04	5.41 E-03	7.08 E-02
^{242}Pu	1.21 E-09	5.41 E-03	2.24 E-07
^{243}Am	1.09 E-02	5.41 E-03	2.01 E+00
^{244}Cm	1.58 E-03	1.08 E-02	1.46 E-01
Totals	3.11 E+03		3.78 E+02

*This radionuclide is a daughter as defined in 49 CFR 173.433; therefore, its activity was set to 0 for the A_2 calculations.

49 CFR 173, 1997, "Shippers--General Requirements for Shipments and Packagings," *Code of Federal Regulations*, as amended.

Table B2-2. Long-Length Contaminated Equipment Transport System Fissile Inventory.

Nuclide	Activity, Ci	Specific activity, Ci/g*	Quantity, g
^{233}U	2.6 E-04	9.7 E-03	2.7 E-02
^{235}U	7.0 E-05	2.2 E-06	3.2 E+01
^{238}Pu	7.7 E-03	1.7 E+01	4.5 E-04
^{239}Pu	4.0 E-01	6.2 E-02	6.5 E+00
^{241}Pu	1.8 E-01	1.0 E+02	1.8 E-03
Totals	7.9 E+00		3.9 E+01

*Specific activities taken from 49 CFR 173.435.

49 CFR 173, 1997, "Shippers--General Requirements for Shipments and Packagings," *Code of Federal Regulations*, as amended.

2.3 SIZE AND WEIGHT

The LLCE BCs were designed specifically around weights inputted from equipment types and a void fill density of 35 lb/ft^3, as required by the approved PDC, WHC-SD-TP-PDC-020 (WHC 1995).

2.3.1 Container Sizes and Weights

The general dimensions and empty and maximum gross weights for each size of LLCE BC are given in Table B2-3.

Table B2-3. Long-Length Contaminated Equipment Burial Container Sizes and Weights.

Container	Length m (ft)	Outside diameter cm (in.)	Wall thickness cm (in.)	Empty weight kg (lb)	Maximum gross weight kg (lb)
C1	17.07 (56)	70.6 (26)	2.24 (0.88)	735 (1,617)	5,127 (11,280)
C2	22.25 (73)	70.6 (26)	2.24 (0.88)	940 (2,066)	6,635 (14,597)
C3	17.34 (56.9)	91.4 (36)	3.10 (1.22)	1,430 (3,147)	9,264 (20,380)
C4	22.32 (73.2)	91.4 (36)	3.10 (1.22)	1,822 (4,008)	12,642 (27,812)
C5	22.37 (73.4)	137.8 (54.25)	4.65 (1.83)	4,214 (9,270)	27,335 (60,137)
C6	17.42 (57.1)	160.8 (63.32)	5.21 (2.05)	4,427 (9,740)	28,792 (63,342)
C7	22.39 (73.5)	160.8 (63.32)	5.21 (2.05)	5,589 (12,295)	43,208 (95,058)
C9	17.39 (57.1)	137.8 (54.25)	4.65 (1.83)	3,315 (7,292)	21,963 (46,118)

Drawings H-2-827807 through H-2-827845 provide fabrication and assembly details for the entire family of LLCE BCs and associated hardware. Drawing H-2-827806 provides the LLCE drawing index for all LLCE BC-related drawings. Part A, Section 10.0, lists all drawings.

2.3.2 Cavity Size

Cavity size varies for each member of the LLCE BC family. Table B2-4 provides the internal volume for each container size.

Table B2-4. Long-Length Contaminated Equipment Burial Container Cavity Volumes.

Burial container	Cavity volume (ft^3)
C1	176
C2	229
C3	338
C4	438
C5	995
C6	1,050
C7	1,362
C9	767

2.4 REFERENCES

49 CFR 173, 1997, "Shippers--General Requirements for Shipments and Packagings," *Code of Federal Regulations*, as amended.

Roach, H. L., 1995a, *Disposal of Tank Farm Long-length Contaminated Equipment: Alternative Options Study and Engineering Support Information*, WHC-SD-WM-ES-265, Rev. 0-A, Westinghouse Hanford Company, Richland, Washington.

Roach, H. L., 1995b, *Disposal of Tank Farm Long-length Contaminated Equipment: Radiological and Chemical Characterization Plan*, WHC-SD-WM-TCP-007, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

WHC, 1995, *Packaging Design Criteria Transfer and Disposal of Long-length Equipment Hanford Tank Farm Complex,* WHC-SD-TP-PDC-020, Rev. 2, Westinghouse Hanford Company, Richland, Washington.

2.5 APPENDIX: CHEMICAL COMPATIBILITY

Westinghouse Hanford Company | **Internal Memo**

From:	300 Area Engineering	86730-96-001
Phone:	376-9988 L6-04	
Date:	July 24, 1996	
Subject:	CHEMICAL COMPATIBILITY	

To: Eric M. Veith H5-68

cc: W. A. McCormick G1-11
LDB File/LB

References:

(1) Ryan Herco Fluid Flow Solution, Burbank, California, 1995 Product Guide.

(2) Cole-Palmer Instrument Company, Chicago, Illinois, 1985-86 Catalog.

(3) Engineering Materials and Their Applications, Second Edition, Richard A. Flinn and Paul K. Trojan, Boston, Massachusetts, 1981.

(4) The Merck Index, Eleventh Edition, Martha Windholz, Rajha, New Jersey, 1989.

(5) WHC-EP-0437, *Polyethylene Liners in Radioactive Mixed Waste Packages: An Engineering Study*, dated May 1992.

(6) WHC-SD-WM-TI-714, *High-Density Polyethylene Liner Chemical Compatibility for Radioactive Mixed Waste Trenches*, dated August 1995.

(7) BHI-00359, *Evaluation of Liner/Leachate Chemical Comparability for the Environmental Restoration Disposal Facility*, dated July 1995.

This letter provides a chemical compatibility review for high-density polyethylene (HDPE) with the attached list of constituents. HDPE has been selected as a waste container material for tank farms equipment contaminated with these constituents. It is my understanding that all pieces of equipment will be drained to the maximum extent possible and pressure washed with water. As a result, the amount of contaminates will be reduced or diluted and the concern for chemical attack is greatly reduced.

The first task was to determine what, in general, is compatible with or attacks HDPE.

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July 24, 1996

Ryan Herco:

HDPE - Resistant to water solutions of acid, alkalis and salts as well as to a large number of organic solvents. Unsuitable for concentrated oxidizing acid.

Cole-Palmer Instrument Company:

HDPE - Excellent against acids (strong and weak), alcohols, and bases. Good against aldehydes, esters, aliphatic hydrocarbons aromatic hydrocarbons. Fair (may experience some softening or swelling) with halogenated hydrocarbons, and strong oxidizing agents.

Engineering Materials and Their Applications:

Polyethylene (high density) - Resistant to weak acid, strong and weak alkalis. Good against organic solvents. Attacked by oxidizing acids.

Merck Index:

Polyethylene - Stable to water, nonoxidizing acids and alkalis, alcohols, ethers, ketones, esters at ordinary temps. Attacked by oxidizing acids, such as nitric acid and perchloric acid, free halogens, benzene, petroleum ether, gasoline and lubricating oils, aromatic and chlorinated hydrocarbons.

The attached list was compared to these basic categories to reduce the number items which may be of concern. All sources agree oxidizers are for HDPE. In many cases, the list provided does not give complete compounds. Instead, several ions are given. Therefore, a more generic review of oxidizing agent was necessary. The term oxidizing material includes several chemicals such as peroxides (O-O), chlorates (ClO_3), perchlorates (ClO_4), nitrates (NO_3), and permaganates (MnO_4). Of these ions, only nitrates appeared.

Halogenated hydrocarbons, chlorinated hydrocarbons and free halogens were listed as a compound that may cause softening or swelling. Ions chlorine, fluorine, and bromine appear on the list as well as some specific reference to 2, 4 dichloropentane and pentachlorophenol.

Aromatic hydrocarbons (specific reference to benzene) were also listed as items that attack polyethylene. The list contained phenol, nitrobenzene, phenanthrene, naphthalene.

The remaining items that attacked HDPE (petroleum ether, gasoline and lubricating oil) were not specifically listed.

With a list of over 100 ions and compounds, only a handful warranted a more detailed review. This reduced list was compared to more specific chemical compatibility information. Several sources have evaluated the chemical compatibility of HDPE for other projects. These reports (References 5, 6, 7) were provided to the author by the requesting organization with the list of constituents. References 5 and 6 included several sources for compatibility information.

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Several nitrate compounds were specifically listed satisfactory up to 140°F. Nitrates do not appear to pose a problem assuming the waste is not to be at an elevated temperature.

Metal chlorides, fluorides and bromides do not pose a threat to HDPE. However, halogenated hydrocarbons (both aliphatic and aromatic) do present a problem. Reference 7 lists recommended maximum concentrations provided by several manufacturers of HDPE liners. The values ranged from 50 to 2000 mg/l for aromatic halogenated hydrocarbons and 100 to 5000 mg/l for aliphatic halogenated hydrocarbons. One manufacturer stated the effect of these compounds to generally degrade the strength of the material. The effects are increased with increases in temperature.

As for the aromatic hydrocarbon, Reference 6 specifically list phenol, nitrobenzene, and naphthalene as resistant up to 73°F. Phenanthrene as well as naphthalene are listed in Reference 7 with a manufacturers maximum concentration recommendation ranging from 200 to 10,000 mg/l.

The only potential concern after completing the detailed review is halogenated hydrocarbons. The provided list does not contain information regarding quantities or concentrations. Several individuals were contacted concerning tank farm waste. All source agree that there are not significant quantities of halogenated hydrocarbons in the tank farms. In general, tank farm waste is aqueous containing many salts.

In conclusion, HDPE is a good choice for chemical compatibility. It should be noted that most chemical compatibility information was temperature dependent. Also, several sources stated HDPE is attacked by sunlight. Extended periods outdoors and in elevated temperatures is undesirable.

If you have any questions, please contact me on 376-4427.

L. D. Bernerski, Senior Engineer
300 Area Engineering

kjr

Attachment

86730-96-016

ATTACHMENT

TCD Chemical Data Sheet for LL/CE Waste Characterization

Consisting of 9 pages,
including cover page

TABLE B1 - TCD CHEMICAL DATA SHEET FOR LLCE WASTE CHARACTERIZATION

CHEMICAL RESISTANCE OF HDPE	CHEMICAL ANALYTES FROM TCD	CAS #	TCD EST MISSING	LISTED	CHARACTERISTIC			STATE ONLY CRITERIA			
				LISTED WASTE	CHAR WASTE	EHW mg/L	DW mg/L	TOXIC	HH	PAH	CARC
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
UNKNOWN	TrimethylSilanol	1066-40-6	-----	-----	----			----	----	----	----
UNKNOWN	HexamethylDisiloxane	107-46-0	-----	----	----			----	----	----	----
UNKNOWN	DBP	107-66-4	-----	----	----			----	----	----	----
UNSATISFACTORY	Phenol	108-95-2	-----	U188, EHW (C)	----			D	----	----	----
UNKNOWN	NaAlO2	11138-49-1	YES	----	----			----	----	----	----
UNKNOWN	Undecane	1120-21-4	-----	----	----			----	----	----	----
UNKNOWN	Dodecane	112-40-3	-----	----	----			----	----	----	----
UNKNOWN	Bis2-ethylhexylphthalate	117-81-7	-----	U028, DW	----			----	----	----	YES
SATISFACTORY	ZrO	12298-97-4	-----	----	----			----	----	----	----
UNKNOWN	Dioctyladipate	123-79-5	-----	----	----			----	----	----	----
UNKNOWN	Decane	124-18-5	-----	----	----			----	----	----	----
SATISFACTORY	SiO3	12627-13-3	-----	----	----			----	----	----	----
UNKNOWN	Citrate	126-44-3	-----	----	----			----	----	----	----
UNKNOWN	TBP	126-73-8	YES	----	----			D	----	----	----
UNKNOWN	Fe2O3	1309-37-1	YES	----	----			----	----	----	----
SATISFACTORY	NaOH	1310-73-2	YES	----	----			----	----	----	----
SATISFACTORY	Al2O3	1344-28-1	YES	----	----			----	----	----	----
UNKNOWN	Tc	Tc	-----	----	----			----	----	----	----
UNKNOWN	PO4---	14265-44-2		----	----			----	----	----	----

TABLE B1 - TCD CHEMICAL DATA SHEET FOR LLCE WASTE CHARACTERIZATION

CHEMICAL RESISTANCE OF HDPE	CHEMICAL ANALYTES FROM TCD	CAS #	TCD EST MISSING	LISTED	CHARACTERISTIC			STATE ONLY CRITERIA			
				LISTED WASTE	CHAR WASTE	EHW mg/L	DW mg/L	TOXIC	HH	PAH	CARC
UNKNOWN	NO3-	14797-55-8	-----	----	----			----	----	----	----
UNKNOWN	NO2-	14797-65-0	-----	----	----			----	----	----	----
UNKNOWN	NH4	14798-03-9	-----	----	----			----	----	----	----
UNKNOWN	SO4--	14808-79-8	-----	----	----			----	----	----	----
UNKNOWN	HEDTA	150-39-0	-----	----	----			----	----	----	----
UNKNOWN	Cl-	16887-00-6	-----	----	----			----	----	----	----
UNKNOWN	F- elemental fluorine?	16984-48-8	-----	----	----			----	----	----	----
UNKNOWN	MethoxytrimethylSilane	1825-61-2	-----	----	----			----	----	----	----
UNKNOWN	HexavalentChromium	18540-29-9	-----	----	----			----	----	----	----
UNKNOWN	CO3--	189	-----	----	----			----	----	----	----
SATISFACTORY	AlO2	20653-98-9	YES	----	----			----	----	----	----
UNKNOWN	Bromide	24959-67-9	-----	----	----			----	----	----	----
UNKNOWN	Oxalate	338-70-5	-----	----	----			----	----	----	----
SATISFACTORY	Na2CO3	497-19-8	YES	----	----			C	----	----	----
UNKNOWN	CN-	57-12-5	-----	----	----			----	----	----	----
UNKNOWN	EDTA 5% wt OK	60-00-4	-----	----	----			----	----	----	----
UNKNOWN	Tridecane	629-50-5	-----	----	----			----	----	----	----
UNKNOWN	Tetradecane	629-59-4	-----	----	----			----	----	----	----
UNKNOWN	Pentadecane	629-62-9	-----	----	----			----	----	----	----
UNKNOWN	Glycolate	666-14-8	-----	----	----			----	----	----	----

TABLE B1 - TCD CHEMICAL DATA SHEET FOR LLCE WASTE CHARACTERIZATION

CHEMICAL RESISTANCE OF HDPE	CHEMICAL ANALYTES FROM TCD	CAS #	TCD EST MISSING	LISTED	CHARACTERISTIC			STATE ONLY CRITERIA			
				LISTED WASTE	CHAR WASTE	EHW mg/L	DW mg/L	TOXIC	IHI	PAH	CARC
UNSATISFACTORY	Acetone OK 4% wT is ok	67-64-1	-----	F003 U002, DW (DI)	----	Tl-71?		D	----	----	----
SATISFACTORY	1-butanol 2-Butanon	71-36-3	----	F003 U031, DW (DI)	----			D	----	----	----
UNKNOWN	Acetate	71-50-1	-----	----	----			----	----	----	----
SATISFACTORY	Al	Al	-----	----	----			----	----	----	----
UNKNOWN	Dy	Dy	-----	----	----			----	----	----	----
SATISFACTORY	Fe	Fe	-----	----	----			----	----	----	----
SATISFACTORY	La	La	-----	----	----			----	----	----	----
SATISFACTORY	Pb	Pb	-----	----	D008	500	5	----	----	----	----
UNKNOWN	Li	Li	-----	----	----			----	----	----	----
SATISFACTORY	Mg	Mg	-----	----	----			----	----	----	----
SATISFACTORY	Mn	Mn	-----	----	----			----	----	----	----
SATISFACTORY	Hg	Hg	-----	----	D009	20	0.2	----	----	----	----
UNKNOWN	Mo	Mo	-----	----	----			----	----	----	----
UNKNOWN	Np	Np	YES	----	----			----	----	----	----
UNKNOWN	Nd	Nd	-----	----	----			----	----	----	----
SATISFACTORY	Ni	Ni	-----	----	----			----	----	----	----
UNKNOWN	Pd	Pd	-----	----	----			----	----	----	----
SATISFACTORY	K	K	-----	----	----			----	----	----	----
UNKNOWN	Pm	Pm	YES	----	----			----	----	----	----
UNKNOWN	Re	Re	-----	----	----			----	----	----	----

TABLE B1 - TCD CHEMICAL DATA SHEET FOR LLCE WASTE CHARACTERIZATION

CHEMICAL RESISTANCE OF HDPE	CHEMICAL ANALYTES FROM TCD	CAS #	TCD EST MISSING	LISTED	CHARACTERISTIC			STATE ONLY CRITERIA			
				LISTED WASTE	CHAR WASTE	EHW mg/L	DW mg/L	TOXIC	HH	PAH	CARC
UNKNOWN	Rh	Rh	-----	----	----			----	----	----	----
UNKNOWN	Ru	Ru	-----	----	----			----	----	----	----
UNKNOWN	Sm	Sm	-----	----	----			----	----	----	----
SATISFACTORY	Si	Si	-----	----	----			----	----	----	----
SATISFACTORY	Ag	Ag	-----	----	D011	500	5	----	----	----	----
SATISFACTORY	Na	Na	-----	----	----			----	----	----	----
UNKNOWN	Sr	Sr	-----	----	----			----	----	----	----
UNKNOWN	Ta	Ta	-----	----	----			----	----	----	----
UNKNOWN	Tl	Tl	-----	----	----			----	----	----	----
UNKNOWN	Th	Th	-----	----	----			----	----	----	----
UNKNOWN	Sn	Sn	-----	----	----			----	----	----	----
SATISFACTORY	Ti	Ti	-----	----	----			----	----	----	----
UNKNOWN	W	W	-----	----	----			----	----	----	----
UNKNOWN	Am	Am	YES	----	----			----	----	----	----
UNKNOWN	Sb	Sb	-----	----	----			----	----	----	----
UNKNOWN	As	As	-----	----	D004	500	5	----	----	----	----
SATISFACTORY	Ba	Ba	-----	----	D005	10000	100	----	----	----	----
SATISFACTORY	Be	Be	-----	----	----			----	----	----	----
SATISFACTORY	B	B	-----	----	----			----	----	----	----
SATISFACTORY	Cd	Cd	-----	----	D006	100	1	----	----	----	----
UNKNOWN	Ce	Ce	-----	----	----			----	----	----	----

TABLE B1 - TCD CHEMICAL DATA SHEET FOR LLCE WASTE CHARACTERIZATION

CHEMICAL RESISTANCE OF HDPE	CHEMICAL ANALYTES FROM TCD	CAS #	TCD EST MISSING	LISTED	CHARACTERISTIC			STATE ONLY CRITERIA			
				LISTED WASTE	CHAR WASTE	EHW mg/L	DW mg/L	TOXIC	HH	PAH	CARC
UNKNOWN	Cs	Cs	YES	----	----			----	----	----	----
SATISFACTORY	Cr	Cr	-----	----	D007	500	5	----	----	----	----
SATISFACTORY	Co	Co	-----	----	----			----	----	----	----
UNKNOWN	Cu	Cu	-----	----	----			----	----	----	----
UNKNOWN	Eu	Eu	YES	----	----			----	----	----	----
UNKNOWN	Gd	Gd	-----	----	----			----	----	----	----
SATISFACTORY	V	V	-----	----	----			----	----	----	----
UNKNOWN	Y	Y	-----	----	----			----	----	----	----
SATISFACTORY	Zn	Zn	-----	----	----			----	----	----	----
SATISFACTORY	Zr	Zr	-----	----	----			----	----	----	----
UNKNOWN	Bi	Bi	-----	----	----			----	----	----	----
SATISFACTORY	Ca	Ca	-----	----	----			----	----	----	----
SATISFACTORY	Na3PO4	7601-54-9	YES	----	----			----	----	----	----
SATISFACTORY	SiO2	7631-86-9	YES	----	----			----	----	----	----
SATISFACTORY	NaNO3	7631-99-4	YES	----	----			D	----	----	----
UNKNOWN	NaNO2	7632-00-0	YES	----	----			X	----	----	----
SATISFACTORY	NH3	7664-41-7	-----	----	----			----	----	----	----
SATISFACTORY	S	S	-----	----	----			----	----	----	----
SATISFACTORY	P	P	-----	----	----			----	----	----	----
SATISFACTORY	H2O	7732-18-5	-----	----	----			----	----	----	----
SATISFACTORY	Na2SO4	7757-82-6	YES	----	----			----	----	----	----

TABLE B1 - TCD CHEMICAL DATA SHEET FOR LLCE WASTE CHARACTERIZATION

CHEMICAL RESISTANCE OF HDPE	CHEMICAL ANALYTES FROM TCD	CAS #	TCD EST MISSING	LISTED	CHARACTERISTIC			STATE ONLY CRITERIA			
				LISTED WASTE	CHAR WASTE	EHW mg/L	DW mg/L	TOXIC	HH	PAH	CARC
UNKNOWN	Se	Se	-----	----	D010	100	1	----	----	----	----
UNKNOWN	Di-n-butylphthalate	84-74-2	-----	U069, DW (D)	----			C	----	----	----
TI 7.14 - OK UNKNOWN	Phenanthrene 4.4.13	85-01-8	-----	----	----	Simulate		----	----	YES	----
TI 7.14 - OK UNKNOWN	Pentachlorophenol 4.4.82	87-86-5	-----	F027, EHW (AH)	D037	(100,000) 10000	100	B	YES	----	YES
TI 7.4 OK UNKNOWN	Naphthalene 4.4.80	91-20-3	-----	U165, EHW (B)	----	(2000)		C	----	YES	----
UNSATISFACTORY	Nitrobenzene Unsat - 7.14, NIC ... 73°C OK	98-95-3	-----	F004 U169, EHW (CI)	D036	200	2	D	----	----	----
UNKNOWN	AlOH4-	ALOH4	YES	----	----			----	----	----	----
UNKNOWN	CrO4	CRO4	YES	----	----			----	----	----	----
UNKNOWN	ETOX	ETOX	YES	----	----			----	----	----	----
UNKNOWN	FeCN6	FERROCYAN ID	-----	----	----			----	----	----	----
UNKNOWN	OH- ?	HYDROXIDE	-----	----	----			----	----	----	----
UNKNOWN	2,4-dichloropentane	K23	YES	----	----			----	----	----	----
SATISFACTORY	TotalCarbon	TC	-----	----	----			----	----	----	----
UNKNOWN	TIC	TIC	-----	----	----			----	----	----	----
UNKNOWN	TOC	TOC	-----	----	----			----	----	----	----
UNKNOWN	ZrOOH2	ZROOH2	-----	----	----			----	----	----	----

Column (4) - Where you find an F code entry in this column, these chemicals are listed in the Dangerous Waste Sources List section WAC-303-9904. Any waste that contains these listed chemicals are assigned the waste code shown in this column.

Additionally if there is a U or P waste code in this column, if this chemical was discarded into the waste tank (must have process knowledge), the waste package that contains these listed chemicsals shall be assigned the U or P waste code shown. Note that U or P waste codes have the designation EHW or DW. The letters in "()" has the following meaning:

X = Toxic category X	A = Toxic category A	B = Toxic category B	C = Toxic category C
D = Toxic category D	? = Toxic category unknown	H = Halogenated hydrocargon	O = Corrosive
P = Persistant, PAH	I = Ignitable	R = Reactive	TC = Toxic characteristic

Column (5) - Where you find an entry in this column, these chemicals are listed in the Toxicity Characteristics list found in WAC-303-090. Any waste that contains these listed chemicals are assigned the waste code based on the content limits listed in column's (6) and (7) in this table.

Column (6) - If the chemical is listed under column (5), if the concentration of the listed chemical exceeds the limits shown in this column the waste is considered EHW (Extremely Hazardous Waste).

Column (7) - If the chemical is listed under column (5), if the concentration of the listed chemical exceeds the limits shown in this column the waste is considered DW (Dangerous Waste).

Column (8) - Chemicals are assigned a Toxic Category X,A,B,C, or D based on comparison of Toxicity limits found in Toxic Category Table found in WAC 173-303-100(5)(b)(i).

Column (9) - An entry in this column indicates the chemical is an HH (Halogenated Hydrocarbon) as specified in WAC 173-303-100(6).
Column (10) - An entry in this column indicates the chemical is an PAH (Polycyclic Aromatic Hydrocarbon) as defined in WAC 173-303-100(6).

Column (11) - An entry in this column indicates the chemical that has been identified by the WDOE as a Carcinogen regulated under WAC-173-303-100(7).

NOTES FOR TABLE B1

Column (1)- The chemicals listed in this column are all of the different chemicals listed in the TCD (Tank Characterization Database) that are found in the 200 Area underground waste storage tanks. Chemical records from TRAC (Track Radioactive Components), HTCE (Historical Tank Content Estimate), and TCR (Tank Characterization Reports) are in the TCD.

Column (2)- CAS (Chemical Abstract Registry) is the unique id number assigned to a chemical.

Column (3)- Many of the chemical records has no entry for content in TRAC, HTCE, or TCR. Current policy for making entries into the TCD is where chemical content is listed as a less than value no entry was made for content in the TCD.

(continued next page)

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3.0 RADIOLOGICAL RISK EVALUATION OF THE LLCE TS

3.1 INTRODUCTION

The LLCE will be transported in packaging consisting of a BC and shielding. The TS will transfer the LLCE from the tank farm complex to the CWC or a disposal site near the CWC. The containers will vary in length from 17.07 m (56 ft) to 22.9 m (73.5 ft). The BC will be loaded and void filled with low-density perlite concrete if no transuranic (TRU) waste is present; the TRU-contaminated LLCE will be bagged, placed in the BC, and transported without the addition of void fill. The loaded TS will weigh up to 109 metric tons (120 tons). Due to the massive proportions of the TS, the roads will be blocked off from other traffic, and the LLCE transport vehicle will be accompanied by escorts. The BC will provide containment for the LLCE during transport.

The LLCE packaging system is designed to withstand normal transfer conditions. For accident environments, the LLCE TS must meet onsite transportation safety requirements as outlined in WHC-CM-2-14 and Mercado (1994). The required safety is determined by a radiological risk evaluation, which assesses the probability of a release and the consequences of a release to determine if the packaging meets the acceptance criteria.

For the radiological risk evaluation, accident scenarios on the Hanford Site are categorized as impact, crush, puncture, and fire. The conditional probability of package failure in each of these four accident categories is determined by assessing the failure thresholds of the package. The conditional probabilities are summed and multiplied by the Hanford Site annual accident rate for trucks to determine an annual release frequency. If the annual frequency is lower than the frequency determined by applying the risk acceptance criteria limits, then onsite transportation safety requirements have been met. In some instances additional administrative controls can be used to ensure safety.

The LLCE shipping campaign will extend over a period of years. The distance covered in the transport will be approximately 16 km (10 mi). The number of trips that may be made in a year will be determined by the risk evaluation. The LLCE will be washed and the residual contaminants will consist of solidified tank waste. The package and transport vehicle will result in a gross vehicle weight from 91-109 metric tons (100-120 tons). The following are assumptions for the radiological risk evaluation:

- Highway mode
- One LLCE per shipment
- 16 km (10 mi) per shipment
- Gross vehicle weight: 91-109 metric tons (100-120 tons)
- Closed or partially blocked roads and escort vehicles.

Risk acceptance criteria are outlined in Section 3.2. Dose consequences are discussed in Section 3.3. Failure thresholds are given in Section 3.4, and the analysis of accident release frequencies are given in Section 3.5. The accident frequencies, when compared to the criteria determined from the dose consequence analysis, provide the necessary input to provide an evaluation of acceptance of the risk related to the transport of the LLCE.

3.1.1 Results

The radiological risk evaluation of the LLCE TS shows that the annual accident release frequency for 96 trips per year is less than the acceptance criteria of 1.0×10^{-6}. Therefore, the TS can ship 96 LLCE containers (void filled or non-void filled) per year and meet onsite transportation safety requirements.

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 (5)	.005 (.5)
Probable	10^{-3} to 1	.002 (.2)	.0001 (.01)

3.3 DOSE CONSEQUENCE ANALYSIS RESULTS

The dose consequence analysis attached in Part B, Section 4.7, conservatively assumes that 100% of the material at risk is released to the environment. The analysis places the worker 3 m from the source term and the offsite receptor at the closest location to any point along the route (11.5 km west of the CWC). The results of the analysis give a total effective dose equivalent to the worker of 0.15 Sv (15 rem); the public receptor dose is less than 0.01 Sv (1 rem). A comparison of the doses with the criteria in Table B3-1 shows that they require an incredible range annual accident release frequency of less than 10^{-6}.

3.4 PACKAGE FAILURE THRESHOLDS AND PROBABILITIES OF OCCURRENCE

No package failure threshold analysis was performed for impact and fire for the LLCE TS because the consequences of a complete release of material meets the acceptance criteria. It is expected that an impact or fire accident would not completely fail the massive packaging system, and any release of material would be lower than the acceptance criteria limits. The conditional probabilities of impact and fire failure given an accident have therefore, for convenience, been set equal to 1.0.

The puncture failure threshold is determined by the equivalent steel thickness of the walls of the package. The polyethylene containers used in the LLCE TS are a minimum of 2 cm (0.8 in.) thick and correspond to an equivalent steel thickness of 6.9 mm (0.27 in.). The conditional release probability is extrapolated from a table for puncture failure probabilities given in a study published by Sandia National Laboratory on the severities of accidents involving large packages (Dennis et al. 1978). The conditional probability of failure given an accident resulting in puncture is found to be 0.00229.

It was determined that the LLCE TS will survive a 142.3-kN (32,000-lb) crush force (see Part B, Section 7.7.1, for verification). The crush force is larger than any static force that could result from the mass of the large tractors that will be used to pull the system. The static weight of the trailer itself is not considered because the trailer system configuration and mass preclude a rollover accident. Therefore, the 142.3-kN (32,000-lb) crush force is larger than any static crush force that could be seen by the package in the Hanford Site transportation environment. The crush conditional probability of failure is accordingly set equal to 0.

The Sandia National Laboratory report (Dennis et al. 1978) also gives the probability of occurrence of an impact, puncture, crush, or fire event given an accident. Assuming an accident has occurred, the probability of the accident resulting in impact or puncture to the package is 0.8. The probability of the accident resulting in a crush force to the package is 0.89. The probability of a fire is 0.0183. Mechanical failure conditional probabilities are not subdivided into those affected by fire because the fire and nonfire cases are effectively being summed for comparison to one risk criteria ($<10^{-6}$).

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. Packages on the Hanford Site do not encounter immersion accident environments. 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.

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 = number of trips/year x miles/trip x accidents/mile

Hanford Site truck accidents have been compiled in a report using Site-specific data (Green et al. 1996). The report calculates the Hanford Site accident rate for trucks to be 2.0×10^{-7} accidents per mile.

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 in Table B3-2.

Table B3-2. Accident Rate Reduction Factors.

Reduction factor	Basis
10	Trained truck drivers
2	Shipments of radioactive materials
2	Shipments north of the Wye barricade
4	Escort vehicles

The LLCE TS will be used to transport radioactive material north of the Wye Barricade and will be driven by trained drivers. The vehicle will require blocked roads and will be escorted during transport. Therefore, a reduction factor of 160 can be applied to the Hanford Site accident rate, reducing the number of truck accidents per year to 1.3×10^{-9}.

3.5.2 Accident Release Frequency Analysis

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. As shown in Table B3-3, the yearly accident frequency is 1.2×10^{-6} for 96 trips per year, which, when multiplied by the total conditional release probability, gives an accident release frequency of 9.8×10^{-7} per year.

3.6 CONCLUSION

The radiological risk evaluation determines the total conditional probability of release for mechanical and thermal accident scenarios for the highway mode. The total conditional release probability is multiplied by the Hanford Site annual accident rate to arrive at an annual accident release frequency. The annual release frequency is compared to 10^{-6}, which is the criterion determined by applying the risk acceptance criteria limits to the dose consequence results. The risk evaluation shows that 96 highway mode shipments of the LLCE TS result in an annual release frequency that is less than the required 10^{-6}. Therefore, 96 shipments can be made from the tank farm complex to the CWC or a nearby storage facility in one year and meet onsite transportation safety requirements.

Table B3-3. Long-Length Contaminated Equipment Accident Release Frequencies.

Accident scenario			Probability of occurrence	Conditional probability of failure	Conditional release probability
Impact: fails any impact			8.00 E-01	1.00 E+00	8.00 E-01
Puncture: t = 0.27-in. steel equivalent			8.00 E-01	2.29 E-03	1.83 E-03
Crush: fails any crush			8.90 E-01	1.00 E+00	0.00 E-00
Fire: fails any fire			1.83 E-02	1.00 E+00	1.83 E-02
Total conditional release probability					0.82 E+00
Truck accidents per mile	*Trips per year*	*Miles per trip*	*Miles per year*	*F*	*Accident release frequency (F x CRP)*
1.3 E-09*	96	10	960	1.2 E-06	9.8 E-07

*Truck accident rate includes a 160 reduction factor.

3.7 REFERENCES

Dennis, A. W., et al., 1978, *Severities of Transportation Accidents Involving Large Packages*, SAND77-0001, Sandia National Laboratories, Albuquerque, New Mexico.

H&R, 1995, *Recommended Onsite Transportation Risk Management Methodology*, H&R522-1, H&R Technical Associates, Inc., Oak Ridge, Tennessee.

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.

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

The LLCE BC is shown to meet the requirements for normal transfer conditions containment as defined in the approved PDC, WHC-SD-TP-PDC-020 (WHC 1995), and the dose consequence acceptance criteria for accident conditions.

The LLCE BC lid seal, butt fusion joints, and end cap penetrations are leak tested to ensure that they do not leak more than 10^{-3} std cm^3/s (air [ANSI 1993]) during fabrication or prior to use.

4.2 CONTAINMENT SOURCE SPECIFICATION

The containment source specification is described in Part B, Section 2.0, of this SARP. Generally, the contents of the LLCE BC will be the LLCE item and retrieval rigging in the flexible receiver bag, the burial container skid, small amounts of tank waste chemicals, and up to the maximum radiological source described in Section 2.0. When the radiological constituents are determined to be nonTRU, the remaining void space in the BC will be filled to a minimum of 90% of the remaining volume with low-density grout (<35 lb/ft^3 density).

4.3 NORMAL TRANSFER CONDITIONS

4.3.1 Conditions To Be Evaluated

For normal transfer conditions, the following requirements must be satisfied per the PDC (WHC 1995).

4.3.1.1 Leak-Testable Seal. The burial container lid must incorporate and demonstrate a leak-testable boundary once permanently sealed. Acceptance criteria for leakage rate testing for all containers is a leak rate equal to or less than 1.0×10^{-3} std cm^3/s (air [ANSI 1987]).

4.3.1.2 Water Spray. The burial container shall be designed such that water sprayed from any direction onto the BC will not remain standing on the package.

4.3.1.3 Lifting and Handling. The structural analysis for lifting and handling the BCs shall consider the void fill to be a maximum of 100% of the available container volume.

4.3.1.4 Increased Internal Pressure. The BCs shall be capable of withstanding an increased internal pressure of 50.7 kPa gauge (7.35 psig).

4.3.1.5 Puncture. The BC shall be capable of withstanding, without failure, the impacting force of a bar 3.2 cm (1.25 in.) in diameter with a hemispherical end weight of 6 kg (13.2 lb), dropped from a height of 1 m (3.3 ft) onto that part of the container where maximum damage is expected to occur.

4.3.1.6 Temperature. The BCs shall be capable of being transported over a temperature range from 0-37.8 °C (32-100 °F).

4.3.1.7 Shock and Vibration. The BCs shall be designed and constructed such that when loaded with the LLCE, void filled, and tied down to the transport trailer, they maintain containment when subjected to normal transport shock and vibration loadings. The minimum shock loading to be evaluated in the design of the BC shall be 0.75*g* applied in the longitudinal direction to simulate hard braking. The minimum vibration loadings shall be derived from ANSI N14.23 (ANSI 1992).

4.3.2 Containment Acceptance Criteria

4.3.2.1 Leak Rate. A bubble check using He/N_2 with a minimum 15-minute soak time and a minimum delta pressure of 21-34.5 kPa gauge (3-5 psig) shall be an acceptable test method.

4.3.2.2 Water Spray. No water shall be standing on the package after water spray.

4.3.2.3 Lifting and Handling. A positive margin of safety must be demonstrated.

4.3.2.4 Increased Internal Pressure. A positive margin of safety must be demonstrated.

4.3.2.5 Puncture. No damage shall be visible to the burial container.

4.3.2.6 Temperature. A positive margin of safety must be demonstrated.

4.3.2.7 Shock and Vibration. A positive margin of safety must be demonstrated.

4.3.3 Containment Model

The containment model for the LLCE BCs is thoroughly discussed in Part B, Section 7.0, of this SARP.

4.4 ACCIDENT CONDITIONS

4.4.1 Conditions To Be Evaluated

Accident conditions are evaluated for the LLCE BCs by radiological risk and dose consequence analyses. The radiological risk evaluation is given in Part B, Section 3.0, of this SARP. The dose consequence and associated transportation hazard index are given in Section 4.7.

4.5 CONTAINMENT EVALUATION AND CONCLUSIONS

4.5.1 Normal Transfer Conditions

The LLCE BC design, based on the transport evaluations required in the approved PDC document (WHC 1995) for normal transfer conditions), has been demonstrated to provide the structural integrity necessary to transport the LLCE payload. The leak rate test and puncture bar test were documented in *Test Report for Long-Length Contaminated Equipment Burial Container* (PHMC 1997).

4.5.1.1 Leak Rate. The BC design prototype was tested using the bubble leak check and passed, demonstrating that the power core fusion process is a viable closure method. The lid penetrations were plugged, sealed, and bubble leak checked. There were no leaks.

4.5.1.2 Water Spray. The BC is a right circular cylinder constructed of HDPE. There are no crevices or gaps where water could be retained. The test was not performed due to the nature of the design. It is impossible for water to stay on the container.

4.5.1.3 Lifting and Handling. Part B, Section 7.7.2, provides the analyses demonstrating that the burial container can be lifted and handled, empty or loaded, with an adequate margin of safety.

4.5.1.4 Increased Internal Pressure. Part B, Section 7.7.2, provides the analyses demonstrating that the BC can withstand an increased internal pressure of 50.7 kPa gauge (7.35 psig) with an adequate margin of safety.

4.5.1.5 Puncture Bar. The required test was performed on the prototype BC. There was no visible damage.

4.5.1.6 Temperature. The material properties of the BC material, listed in Part B, Section 7.7.2, demonstrate that transporting the BC over the specified temperature range is acceptable.

4.5.1.7 Shock and Vibration. Part B, Section 7.7.2, provides the analyses demonstrating that the BC can be subjected to the specified loads and maintain an adequate margin of safety.

4.5.2 Accident Conditions

Based on the radiological risk evaluation in Part B, Section 3.0, of this SARP and the dose consequence evaluation given in Section 4.7 (appendix), the LLCE BCs can be transported a maximum of 1,545 km (960 mi) per annum, while still remaining within the acceptable limits for onsite and offsite receptor doses.

4.6 REFERENCES

ANSI, 1993, *American National Standard for Radioactive Materials--Special Lifting Devices for Shipping Containers Weighing 10,000 Pounds (4500 kg) or More*, ANSI, N14.6, American National Standards Institute, New York, New York.

ANSI, 1992, *Draft American National Standard Design Basis for Resistance to Shock and Vibration of Radioactive Material Packages Greater than One Ton in Truck Transport*, ANSI N14.23, American National Standards Institute, New York, New York.

ANSI, 1987, *American National Standard for Radioactive Materials--Leakage Tests on Packages for Shipment*, ANSI N14.5, American National Standards Institute, New York, New York.

PHMC, 1997, *Test Report for Long-Length Contaminated Equipment Burial Container*, HNF-SD-TP-TRP-004, Rev. 0, Rust Federal Services Inc., Northwest Operations, Richland, Washington.

WHC, 1995, *Packaging Design Criteria Transfer and Disposal of Long-length Equipment Hanford Tank Farm Complex*, WHC-SD-TP-PDC-020, Rev. 2, Westinghouse Hanford Company, Richland, Washington.

4.7 APPENDIX: DOSE CONSEQUENCE ANALYSIS AND TRANSPORTATION HAZARD INDEX

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4.5 Summary of Dose Consequence Results

This engineering analysis documents the dose consequence calculations used to support the Transportation Hazard Index (THI) evaluation for the LLCE transport system. The LLCE transport system will be used to transport long-length contaminated equipment (LLCE) components that are installed in the single- and double-shell tanks at the Hanford site. At some point during operation or decommissioning of the Tank Farms, many of the LLCE components will be removed for interim storage or direct disposal. The analysis assumes the LLCE components will be transported from the Tank Farms in the 200 Area to either a disposal site or the Central Waste Complex (CWC). The LLCE will go to CWC if the equipment is contaminated with transuranic waste (TRU). Otherwise it will be transported to a burial site near the CWC which was designed specifically to receive Tank Farm LLCE.

Table 1 summarizes the dose consequence results from each exposure pathway. The table also includes the total dose to each receptor, which is obtained by summing the dose contributions from each pathway. Because the dose to the onsite worker is greater than 5 rem, the LLCE packaging must fulfill (meet) THI 2 requirements.

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Table 1: Summary of Whole Body Doses (rem) From Each Pathway		
Exposure Pathway	Hanford Site Worker @ 3 m	Public Receptor[a]
External Photon Dose	4.2	NA
External Dose from β-Particles	10	NA
Inhalation & Submersion from the Airborne Transport Pathway	0.54	9.3E-06
Skin Contamination & Ingestion from Handling Package Contents	NA	NA
Submersion Dose from Gaseous Vapor	NA	NA
Total Effective Dose Equivalent (EDE)	15	9.3E-06

Note: 100 rem = 1 Sievert (Sv)

[a] This receptor is located 11,500 m W of the CWC.

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4.5.1 Introduction and Overview

A large number of long-length equipment items are installed in risers of underground single- and double-shell waste storage tanks, vaults, receivers, and other areas within the Hanford Site's Tank Farm complex. Examples include transfer and mixer pumps, instrument trees, airlift circulators, and air lances. They range in size from 12-to-62 ft in length and 1-to-5 ft in diameter. At some point during operation or decommissioning of the Tank Farms, many of the long-length components will be removed for interim storage or direct disposal.

Packaging must be available to contain and transfer the long-length equipment retrieved from the Tank Farm complex to the designated storage (CWC) or disposal site. A transportation system of trailers, a reusable transport container, burial containers, and associated equipment for the transfer, delivery, and burial (or storage) of LLCE removed from Tank Farms is desired. The transport package will be approved for transport by issuance of a Safety Analysis Report for Packaging (SARP).

An estimate of the dose consequences for various exposure pathways is necessary to determine the Transportation Hazard Index (THI) for the LLCE transport system. Section 4.5.2 discusses the general methodology used to perform the dose consequence calculations. Section 4.5.3 addresses the source term, and Sections 4.5.4 through 4.5.9 summarize the results for various exposure pathways. The analysis assumes the LLCE components will be transported from the Tank Farms to the CWC or disposal site, which are both located in the 200 West Area.

4.5.2 Dose Consequence Analysis Methodology

IAEA (1990) defines a standardized approach for evaluating transportation packaging requirements, called the Q-system. The Q-system methods, as outlined in IAEA (1990), have been incorporated into a WHC document - "Report on Equivalent Safety for Transportation and Packaging of Radioactive Materials" (Mercado 1994). This document (Mercado 1994) is used to demonstrate that onsite shipments meet the requirements of WHC-CM-2-14 for transportation safety.

In the Q-system, the following 5 exposure pathways are considered: 1) external exposure to photons; 2) external exposure to β-particles; 3) inhalation; 4) skin contamination and ingestion; and 5) submersion in a cloud of gaseous isotopes. In special cases such as α-particle or neutron emitters, other exposure routes are considered. In some cases a pathway will be judged

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to be small with respect to the others and consideration will be minimal. Modifications to the IAEA scenarios are incorporated to more closely describe the particular conditions of the shipment. Detailed calculations for the postulated accident are performed whenever possible. However, in some cases, the IAEA guide's worst case rules-of-thumb are used.

The Q-system was developed as an all-encompassing generalized methodology using only the isotope as the defining variable. In this report, the specifics of the package are considered. Some of the dose pathways may be considered incredible (frequency $<10^{-6}$/yr), and although these pathways are covered in the IAEA guide, they are disregarded in the analysis.

In this IAEA system, the Q-values that are calculated are the radionuclide activities corresponding to each exposure route which causes the individual to receive the effective dose equivalent limit. The minimum Q-values define the A_2 values for the shipped materials. In the case of non-dispersible materials (limited by the A_1 values) only the first two Q-values (based on exposure to external photon and external beta particles) are used. Note that for all radiation except neutrons, protons, and heavier charged particles (including α-particles), 1 Gray (Gy) = 1 Sievert (Sv), and 1 rad = 1 rem.

There are two receptors of interest in the Q-system. They are: the Hanford Site worker, and the public receptor. The Hanford Site worker is assumed to be located about 3 m from the package. The public receptor is assumed to be located at the site boundary.

4.5.3 Source Terms

Package contents consist of a bagged LLCE, rigging, and radioactive waste not removed by the rinsing system of the flexible receiver assembly. Table 2 lists the activity of the design basis contaminated equipment. The activity (in curies) is based on an estimated 1/16-in. thick film of waste material attached to specific areas of equipment and was taken from Table B2-1.

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Table 2. Maximum Curie Content.

Isotope	Curies
C 14	6.07E-02
CO60	3.32E+01
NI63	9.81E-01
SE79	2.44E-03
SR90	2.08E+02
Y 90	2.08E+02
NB93M	6.01E-03
ZR93	8.77E-03
ZR95	7.57E+00
TC99	1.37E+00
RH106	8.70E+00
RU106	8.70E+00
SB125	5.27E+00
I 129	8.52E-04
CS134	1.39E+00
CS137	9.10E+02
BA137M	8.61E+02
CE144	4.24E+02
PR144	4.24E+02
PM147	1.58E-01
SM151	1.68E+00
EU154	1.13E+00
EU155	1.13E+00
U 233	2.58E-04
U 234	2.32E-07
U 235	6.98E-05
NP237	2.96E-04
NP238	1.91E-06
PU238	7.72E-03
U 238	1.69E-03
PU239	4.00E-01
PU240	1.86E-02
AM241	3.67E-01
PU241	1.79E-01
AM242	3.81E-04
CM242	1.15E-03
AM242M	3.83E-04
PU242	1.21E-09
AM243	1.09E-02
CM244	1.58E-03
TOTAL	3.11E+03

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4.5.4 External Dose Due to Photon (Gamma) Exposure

The IAEA scenario assumes that a person is exposed to a damaged transport package following an accident. The shielding of the package is assumed to be completely lost in the accident. This analysis will be done assuming a person remains 3 meters from the source for a period of 15 minutes.

The computer code ISO-PC (Rittmann 1995) was used to calculate the dose rate 3 meters from the source. The fluence-to-dose conversion factors used were the anterior-to-posterior irradiation pattern as outlined in ANSI standard ANSI/ANS-6.1.1-1991 (ANS 1991).

The burial container will contain an LLCE during storage and burial. As part of the disposal process, the burial container will be void filled. There are burial container designs for five different container diameters and two different container lengths, as shown in Table 3. These burial containers will be fabricated from polyethylene, or other material suitable for burial, with a maximum wall thickness of 2 in. The analysis will be done for the smallest and largest container sizes assuming the maximum curie content from Table 3 is loaded into the containers. The configuration with the highest dose rate will be used. The anticipated void fill material is Perlite concrete with a nominal density of 0.56 g/cc (35 lb/ft^3). The smaller container will hold approximately 1800 lb of removed equipment, and the larger container will hold equipment totalling 11,400 lb.

The smaller container was modeled in ISO-PC as a 30 ft long cylinder with a 2 ft diameter. The larger container was modeled in ISO-PC as a 30 ft long cylinder with a 5-1/2 ft diameter. Although the container lengths are actually longer than 30 ft (see Table 4), the ISO-PC model used 30 ft because the radioactive contamination was assumed to be distributed over a 30 ft length since only 30 ft of the total equipment length is located in the tank waste. The source was assumed to be homogeneously distributed throughout the container volume. The source was modeled as concrete with a density of 0.56 g/cc. The self shielding effect of the LLCE was conservatively ignored in this analysis.

The resulting dose rate from ISO-PC is 16.7 rem/hr (0.167 Sv/hr) at 3 m from the unshielded source for the smaller container, and 7.0 rem/hr (0.07 Sv/hr) for the larger container. Therefore the maximum total external gamma effective dose equivalent (EDE) for the Hanford Site worker is 4.2 rem (0.042 Sv) for a 15 minute exposure period. Note that the 3 m receptor was assumed to be located halfway along the length of the container, which is the location of maximum dose rate. The ISO-PC input decks are included as Attachment 1.

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Table 4. Burial Container Dimensions and Capacity.

#	Container size	Applied load capacities		
		Void fill (lb/ft^3)	Removed equipment (lb)	Skid weight (lb)
1	26-in. od x 52-ft length	35	1,492	1500
2	26-in. od x 70-ft length	35	1,789	1900
3	36-in. od x 52-ft length	35	2,002	2200
4	36-in. od x 70-ft length	35	3,540	2800
5	54-in. od x 70-ft length	35	7,318	4300
6	63-in. od x 52-ft length	35	6,549	4600
7	63-in. od x 70-ft length	35	21,865	5700
8	67-in. od x 70-ft length	35	9,500	6000

od = Outside diameter.

4.5.5 External Dose Due to β-Particle Emitters

Because of the limited range of β-particles relative to that of photons, a shielding factor is used by the IAEA to account for residual shielding from material such as package debris. Except for this factor, no effort is made to account for either self-shielding or shielding from an accurate model of the damaged package. Shielding and dose rate factors are graphed in the IAEA safety guide #7 as a function of the maximum energy of the β-particle. The IAEA beta dose rate calculation methods are based on an individual located 1 m from the unshielded source.

This analysis assumes an individual remains at a distance of 3 m from the source for a 15 minute exposure period. A factor will be applied to the dose rates calculated using the IAEA method to account for the difference between the 1 m distance assumed in developing the shielding factors and the 3 m distance in this analysis. This factor is simply 0.333 [(1 m)/(3 m)], since the dose rate is approximately inversely proportional to the distance for a line source in air, and the LLCE approximates a line source. This conservatively ignores any attenuation of the beta particles over the 3 m distance.

The source term from Table 2 was used in this analysis. Table 4 provides the β-particle dose calculations for those radionuclides in Table 2 that emit a β-particle and contribute more than 0.01% to the total β-particle dose.

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The total β-particle dose rate to the skin for an individual located 3 m from the source is 4.0 x 10^3 rem/hr (4.0 x 10^1 Sv/hr), as shown in Table 4. This results in a β-particle dose of 1.0 x 10^3 rem (10 Sv) to the skin for a 15 minute exposure. Since the tissue weighting factor for the skin is 0.01 (ICRP 1991), the whole body effective dose equivalent (EDE) is then 10 rem (0.1 Sv).

Table 4: β-Particle Dose Rate to the Skin for Beta Emitters Contributing > 0.01% to the Total Dose

Isotope	Activity (Ci)	Activity (Bq)	Branching Ratio	E_{max} (MeV)	Dose Rate Factor[a]	Shielding Factor[b]	Dose Rate (rem/hr)[c]	% Dose
SR 90	2.08E+02	7.70E+12	1	0.54600	1.8E-04	100	1.25E+01	0.31
Y 90	2.08E+02	7.70E+12	0.99989	2.28390	3.6E-04	2	1.25E+03	31.35
RH106	8.70E+00	3.22E+11	0.0192	1.97880	3.6E-04	3	6.69E-01	0.02
			0.098	2.40730	3.6E-04	2	5.13E+00	0.13
			0.082	3.02920	3.6E-04	2	4.29E+00	0.11
			0.787	3.54100	3.6E-04	2	4.11E+01	1.03
CS137	9.10E+02	3.37E+13	0.946	0.51155	1.8E-04	100	5.16E+01	1.30
			0.054	1.17320	3.6E-04	6	9.84E+01	2.47
PR144	4.24E+02	1.57E+13	0.0108	0.81032	1.8E-04	20	1.37E+00	0.03
			0.0117	2.29950	3.6E-04	2	2.98E+01	0.75
			0.9774	2.99600	3.6E-04	2	2.49E+03	62.46
EU154	1.13E+00	4.18E+10	0.114	1.84390	3.6E-04	3	5.16E-01	0.01
TOTALS FOR BETA EMITTERS CONTRIBUTING > 0.01%							3.98E+03	99.97
TOTALS FOR ALL BETA EMITTERS							3.98E+03	100.00

[a] Dose rate factor in units of G/hr or Sv/hr for a 1 mci source from IAEA (1990).

[b] Shielding factor from IAEA (1990).

[c] Note that a factor of 0.333 is applied to the dose rates to account for a source-to-receptor distance of 3 m for this analysis, versus the 1 m distance assumed in the development of the dose rate factors from IAEA (1990).

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4.5.6 Inhalation and Ingestion Dose

Radioactive material may be inhaled following an accident due to resuspension or volatization of radioactive material released from the package. Because of the short emergency response time for a fire (about 15 min) and the fact that the burial container is void-filled with concrete, there is no credible fire scenario which would result in a release of the contamination contained on the LLCE. Therefore, only a non-fire scenario needs to be addressed for this exposure pathway.

4.5.6.1 Accident Scenario for Transfer from Tank Farms to CWC or Disposal

For the non-fire scenario, an accident is postulated that results in a breach of the burial container and a release of the container contents. A portion of the radioactive material contained in the burial container is assumed to be released and transported downwind.

Selection of Airborne Release Fraction

An airborne release fraction times respirable fraction (ARF x RF) of 2 x 10^{-6} is applied to the material at risk to obtain the quantity of radioactive material that is made airborne for the non-fire scenario. This ARF x RF value was obtained using the formula below which was taken from DOE (1994), Free-Fall Spill and Impaction Stress for solids or contaminated brittle material.

$$ARF \times RF = (A)(P)(g)(h)$$

where:

ARF x RF = (Airborne Release Fraction)(Respirable Fraction)
A = empirical correlation, 2×10^{-11} cm^3 per $g\text{-}cm^2/s^2$
P = specimen density, g/cm^3
g = gravitational acceleration, 980 cm/s^2 at sea level
h = fall height, cm.

A fall height of 2 m is assumed for this analysis. This is a typical height used for objects falling off of a trailer. The density of the waste in this case was taken to be 0.74 g/cc, which results in an ARF x RF of 2.9×10^{-6}. Note that in this case ignoring the LLCE contribution to the waste density is non-conservative. Therefore, the weight of the removed equipment was included in the density estimate, which was calculated as follows:

$$\text{Waste Density in Container } (lb/ft^3) = 35\ lb/ft^3 + \frac{1791\ lb}{163.36\ ft^3}$$

$$\text{Waste Density in Container } (lb/ft^3) = 46\ lb/ft^3\ (0.74\ g/cc)$$

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where, the weight of the removed equipment is 1791 lb and the container volume is 163.36 ft^3 for the smaller container. The waste density for the larger container is about 42 lb/ft^3 (0.67 g/cc). Therefore, the 46 lb/ft^3 (0.74 g/cc) value for the waste density is selected for this analysis since it results in a higher ARF x RF.

This ARF x RF is applied to the material at risk, which is conservatively assumed to be the entire container inventory, to obtain the quantity of radioactive material that is made airborne for the postulated accident scenario. The accident release quantities are listed in Table 5.

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Table 5. Accident Release Quantities

Isotope	Curies
C 14	1.8E-07
CO60	9.6E-05
NI63	2.8E-06
SE79	7.1E-09
SR90	6.0E-04
Y 90	6.0E-04
NB93M	1.7E-08
ZR93	2.5E-08
ZR95	2.2E-05
TC99	4.0E-06
RH106	2.5E-05
RU106	2.5E-05
SB125	1.5E-05
I 129	2.5E-09
CS134	4.0E-06
CS137	2.6E-03
BA137M	2.5E-03
CE144	1.2E-03
PR144	1.2E-03
PM147	4.6E-07
SM151	4.9E-06
EU154	3.3E-06
EU155	3.3E-06
U 233	7.5E-10
U 234	6.7E-13
U 235	2.0E-10
NP237	8.6E-10
NP238	5.5E-12
PU238	2.2E-08
U 238	4.9E-09
PU239	1.2E-06
PU240	5.4E-08
AM241	1.1E-06
PU241	5.2E-07
AM242	1.1E-09
CM242	3.3E-09
AM242M	1.1E-09
PU242	3.5E-15
AM243	3.2E-08
CM244	4.6E-09
TOTAL	9.0E-03

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Discussion of Integrated Normalized Air Concentration Value (χ/Q')

After the radioactive material becomes airborne, it is transported downwind and inhaled by onsite workers or the public. The concentration of this material is reduced, or diluted, as it is being transported due to atmospheric mixing and turbulence. χ/Q' (s/m^3) is used to characterize the dilution of the airborne contaminants during atmospheric transport and dispersion. It is equal to the time-integrated normalized air concentration at the receptor. χ/Q' is a function of the atmospheric conditions (i.e., wind speed, stability class) and the distance to the receptor.

Bounding χ/Q' values are generated consistent with the methods described in *Atmospheric Dispersion Models for Potential Accident Consequence Assessments at Nuclear Power Plants*, Regulatory Guide 1.145 (NRC 1982). Since atmospheric conditions fluctuate, a bounding atmospheric condition is determined to be that condition that causes a downwind concentration of airborne contaminants that is exceeded only a small fraction of time because of weather fluctuations. Regulatory Guide 1.145 defines this fraction of exceedance as 0.5% for each sector or 5% for the overall Hanford Site. The Hanford Site is broken up into 16 sectors that represent 16 compass directions (i.e., S, SSW, SW, ..., ESE, SE, SSE). χ/Q' values are generated for weather conditions that result in downwind concentrations exceeded only 0.5% of the time in the maximum sector or 5% of the time for the overall Site. These χ/Q' values are also referred to as 99.5% maximum sector and 95% overall Site χ/Q' values. The greater of these two values is called the bounding χ/Q' value and is used to assess the dose consequences for accident scenarios. The bounding χ/Q' value represents minimum dispersing conditions that result in maximum downwind concentrations (i.e., concentrations exceeded only a very small fraction of the time). This χ/Q' value will therefore result in very conservative estimates of accident consequences.

The χ/Q' values in this report were generated using the GXQ computer program, Version 3.1C (Hey 1993a, 1993b). The meteorological data used by GXQ are in the form of joint frequency tables. The joint frequency data are the most recent data available; they are nine-year averaged data (1983-1991) from the Hanford Site meteorology towers located in the 200 Area. As mentioned above, the χ/Q' values are generated using the methods described in Regulatory Guide 1.145 for a ground release with no credit taken for plume rise, plume meander, plume depletion, or any other models. This is conservative because all of these models reduce the airborne concentration at the downwind receptor locations.

Although we are interested in the dose to a Hanford Site worker at 3 m, the dose to an onsite receptor located 100 m from the release point is calculated using the worst case χ/Q' value at 100 m. This dose is then multiplied by a factor of thirty to obtain the dose to the Hanford Site worker at 1 m in accordance with IAEA (1990). This approach is taken because the Gaussian equation, along with the parameters used to calculate the χ/Q'

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values, are only valid for distances of 100 m or greater. Although this analysis assumes the transport worker remains 3 m from the package, the inhalation portion of the transport worker dose is conservatively taken to be that calculated using the IAEA method for a worker located 1 m from the package.

The worst case χ/Q' value is generated assuming that a member of the public is located at the current Hanford site boundary. The LLCE packaging system will be transported from the Tank Farms located in the 200 East and West Areas to the CWC or a burial ground near CWC. Table 6 lists the site boundary distances for the worst case release point, which in this case is at the CWC or burial grounds. In keeping with current facility methodology, Highway 240, which passes through the Hanford Site, is ignored as a possible public receptor point. Past analysis has shown that the χ/Q' value, and therefore, the public receptor dose, increases by approximately a factor of 4 if Highway 240 is considered as a public receptor point versus the use of the existing Hanford Site boundary.

The maximum onsite receptor χ/Q' value is 3.41E-02 s/m^3, which is associated with a receptor located 100 m east of the 200 Area. The public receptor χ/Q' value is 1.8E-05 s/m^3 which is associated with a receptor located 11.5 km west of the 200 West Area. An example GXQ input file is listed in Attachment 2 and the title of the joint frequency file is listed below.

200 AREA (HMS) - 10 M - Pasquill A-G (1983 - 1991 Average) Created 8/26/92 KR

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Table 6: Public Receptor Distances for CWC	
Transport Direction	Distance m
S	14680
SSW	15010
SW	13800
WSW	11740
W	11500
WNW	11800
NW	14550
NNW	15480
N	17270
NNE	24910
NE	27320
ENE	24550
E	24240
ESE	28930
SE	24600
SSE	19150

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Inhalation & Submersion Dose Calculations

Since the radioactive material consists of surface contamination, the material made airborne during the event is assumed to be in oxide form, i.e., is associated with the "Y" solubility class (dissolution halftimes in simulated interstitial lung fluids of >100 days). The GENII libraries used were as follows:

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
PNL Solubilities, Yearly Dose Increments (23-Jul-93 PDR)

The Effective Dose Equivalent (EDE) for the inhalation and submersion pathways using the airborne release quantities listed in Table 5 is 1.8×10^{-2} rem (1.8×10^{-4} Sv) for the maximum onsite receptor at 100 m. The inhalation dose contribution to the EDE is based on a 50 year dose committment period. In order to compensate for the fact that the onsite dose is calculated at a source-to-receptor distance of 100 m, this dose is multiplied by a factor of thirty to obtain the dose to the transport worker at 1 m in accordance with IAEA (1990). Although this analysis assumes the transport worker remains 3 m from the package, the inhalation portion of the transport worker dose is conservatively taken to be that calculated using the IAEA method for a worker located 1 m from the package. This results in an EDE of 5.4×10^{-1} rem (5.4×10^{-3} Sv) for the Hanford Site worker.

The whole body EDE for the public receptor at site boundary is 9.3×10^{-6} rem (9.3×10^{-8} Sv). Table 7 summarizes the whole body doses for the non-fire scenario. Note that if the nearest public receptor is assumed to be located at Highway 240, the public receptor dose would increase by approximately a factor of 4 to 3.7×10^{-5} rem. However, this has no impact on the THI since the dose is still far below 25 rem which would require the packaging to meet THI 1 requirements.

Table 7: Inhalation and Submersion Dose for Non-Fire Scenario (rem)		
	Hanford Worker (@ 3 m)	Public Receptor[a]
Whole Body EDE	5.4E-01	9.3E-06

Note: 100 rem = 1 Sv

[a] Public receptor is located 11.5 km west of CWC.

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Ingestion & Groundshine Dose

The other potential internal exposure pathway for the public receptor is the ingestion pathway. Exposure through the ingestion pathway occurs when radioactive materials that have been deposited offsite during passage of the plume are ingested either by eating crops grown in, or animals raised on, contaminated soil, or through drinking contaminated water. There are DOE, DOE-RL, state, and federal programs in place to prevent ingestion of contaminated food in the event of an accident (DOE-RL 1994, WSDOH 1993, WS 1994, EPA 1992). The primary determinant of exposure from the ingestion pathway is the effectiveness of public health measures (i.e., interdiction) rather than the severity of the accident itself. The ingestion pathway, if it occurs, is a slow-to-develop pathway and is not considered an immediate threat to an exposed population in the same sense as airborne plume exposures.

The ground shine pathway is an additional potential external exposure pathway for the public receptor. Ground shine refers to the external dose received by a person standing on ground contaminated by radioactive materials deposited during passage of the airborne radioactive plume. Similar to the ingestion pathway, the primary determinant of exposure from the ground shine pathway is the effectiveness of public health measures (i.e., interdiction) rather than the severity of the accident itself. The ground shine pathway is a slow-to-develop pathway and is not considered an immediate threat to an exposed population in the same sense as airborne plume exposures.

Because of the large radioactive inventory contained in the LLCE transport package, it is argued that in the event of an accident scenario that results in the release of a large portion of the inventory, interdictive measures (DOE-RL 1994, WSDOH 1993, WS 1994, EPA 1992) would be taken to prevent ingestion of contaminated food, and exposure through the ground shine pathway. Therefore, the ingestion and ground shine pathway doses were not calculated in this report.

4.5.7 Skin Contamination and Ingestion Dose

In the IAEA guide, it is assumed that 1% of the package contents are spread over an area of 1 m^2 and handling of debris results in contamination of the hands to 10% of this level. It is further assumed that the worker is not wearing gloves but that he recognizes the possibility of contamination and washes his hands within 5 hours. The effective dose equivalent to the skin received by the individual is estimated from a graph provided in the IAEA guide.

The IAEA scenario for the uptake of activity due to ingestion of the material assumes that the person ingests all of the contamination from 10 cm^2 of skin over a 24 hour period. Since the dose per unit uptake via inhalation is generally the same order or larger than that via ingestion, the inhalation

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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.

Both these pathways are ordinarily neglected when calculating the dose consequences from an onsite transportation accident. The transportation workers are trained in the appropriate response to protect themselves from experiencing unnecessary radiation exposure, including preventing skin contamination and ingestion.

4.5.8 Submersion Dose Due to Gaseous Vapor

This exposure pathway is caused by submersion in a cloud of gaseous isotopes that are not taken into the body. A rapid release of 100% of the package contents is assumed. The IAEA guide concentrates entirely on releases within confined structures. No guidance is given for outside releases.

There are no gaseous vapors present in the containers, therefore this exposure pathway is not applicable.

4.5.9 Special Considerations

Alpha particle emitters are not of significance in the material considered in this report. The alpha particle emitters are of a low concentration, and their effect will be through the mechanism of inhalation that has been considered separately. Therefore, they are not addressed in this report. The quantity of radon present in the fuel is insignificant, therefore, radon is not addressed in this report.

Transuranics are included in the source term and several of these emit neutrons through (α,n) and spontaneous fission reactions. However, the neutron source term is low enough that the neutron dose is negligible compared to the dose from the gamma emitters. Therefore, neutrons are not considered separately in this report.

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.

4.5.10 Total Dose

Table 1 in Section 4.5 summarizes the dose from each exposure pathway.

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4.5.11 References

ANS, 1991, *Neutron and Gamma-Ray Fluence-to-Dose Factors*, ANSI/ANS-6.1.1-1991, American Nuclear Society, La Grange Park, Illinois.

DOE, 1988, *Radiation Protection for Occupational Workers*, DOE-5480.11, December 21, 1988, U. S. Department of Energy, Washington, D. C.

DOE, 1992, *Hazard Categorization and Accident Analysis Techniques for Compliance with DOE Order 5480.23, Nuclear Safety Analysis Reports*, DOE-STD-1027-92, U. S. Department of Energy, Washington, D. C.

DOE, 1994, *Airborne Release Fractions/Rates and Respirable Fractions for Nonreactor Nuclear Facilities*, DOE-HDBK-3010-94, U. S. Department of Energy, Washington, D. C.

DOE-RL, 1994, *Emergency Implementation Procedures*, DOE-0223, U.S. Department of Energy, Richland Field Office, Richland, Washington.

EPA, 1992, *Manual of Protective Action Guides and Protective Actions for Nuclear Incidents*, U.S. Environmental Protection Agency, Washington, D.C.

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

Hey, B. E., 1993b, *GXQ Program Verification and Validation*, WHC-SD-GN-SWD-30003, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

IAEA, 1990, *Explanatory Material for the IAEA Regulations for the Safe Transport of Radioactive Material*, Second Edition (As Amended 1990), International Atomic Energy Agency, Vienna, 1990.

ICRP, 1991, *International Commission on Radiological Protection, Annals of the ICRP*, Publication 60, 1991, International Commission on Radiological Protection, New York, New York.

Napier, B. A., et al., December 1988, *GENII - The Hanford Environmental Radiation Dosimetry Software System*, Pacific Northwest Laboratory, Richland, Washington, PNL-6584 Vol. 1, UC-600.

NRC, 1982, *Atmospheric Dispersion Models for Potential Accident Consequence Assessments at Nuclear Power Plants*, Regulatory Guide 1.145, U.S. Nuclear Regulatory Commission, Washington, D.C.

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

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

WHC, 1995, *Packaging Design Criteria, Transfer and Disposal of Long-Length Equipment, Hanford Tank Farm Complex*, WHC-SD-TP-PDC-020, Rev. 2, Westinghouse Hanford Company, Richland, Washington.

WHC-CM-4-46, *Nonreactor Facility Safety Analysis Manual*, Westinghouse Hanford Company, Richland, Washington.

WSDOH, 1993, "Response Procedures for Radiation Emergencies," Appendix A, *Protective Action Guides*, Washington State Department of Health, Olympia, Washington.

WS, 1994, "Fixed Nuclear Facility Emergency Response Procedure," Section 10.6 - Department of Agriculture, Washington State.

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Attachment 1

ISO-PC INPUT FILES

```
0        2   LLCE in Smaller Container
Cylindrical Source Geom - Dose Rate at 3 m
&Input Next= 1 , ISpec= 3 , IGeom= 7 , ICONC=0, SFACT=1, DUNIT=7,
 NTheta= 20, NPsi= 30, NShld= 1 , JBuf= 1, OPTION=0,
 Slth= 1585,
 Y= 792.5 ,
 T(1)= 30.5,
 X= 330.5,
 WEIGHT(451) =   6.07E-02 ,
 WEIGHT(472) =   3.32E+01 ,
 WEIGHT( 27) =   2.44E-03 ,
 WEIGHT( 82) =   2.08E+02 ,
 WEIGHT( 84) =   2.08E+02 ,
 WEIGHT(103) =   6.01E-03 ,
 WEIGHT(102) =   8.77E-03 ,
 WEIGHT(117) =   7.57E+00 ,
 WEIGHT(141) =   1.37E+00 ,
 WEIGHT(172) =   8.70E+00 ,
 WEIGHT(170) =   8.70E+00 ,
 WEIGHT(269) =   5.27E+00 ,
 WEIGHT(290) =   8.52E-04 ,
 WEIGHT(319) =   1.39E+00 ,
 WEIGHT(335) =   9.10E+02 ,
 WEIGHT(336) =   8.61E+02 ,
 WEIGHT(376) =   4.24E+02 ,
 WEIGHT(377) =   4.24E+02 ,
 WEIGHT(388) =   1.58E-01 ,
 WEIGHT(403) =   1.68E+00 ,
 WEIGHT(415) =   1.13E+00 ,
 WEIGHT(418) =   1.13E+00 ,
 WEIGHT(519) =   2.58E-04 ,
 WEIGHT(520) =   2.32E-07 ,
 WEIGHT(476) =   6.98E-05 ,
 WEIGHT(502) =   2.96E-04 ,
 WEIGHT(412) =   1.91E-06 ,
 WEIGHT(492) =   7.72E-03 ,
 WEIGHT(526) =   1.69E-03 ,
 WEIGHT(493) =   4.00E-01 ,
 WEIGHT(494) =   1.86E-02 ,
 WEIGHT(496) =   3.67E-01 ,
 WEIGHT(495) =   1.79E-01 ,
 WEIGHT(499) =   3.81E-04 ,
 WEIGHT(504) =   1.15E-03 ,
 WEIGHT(498) =   3.83E-04 ,
 WEIGHT(497) =   1.21E-09 ,
 WEIGHT(505) =   1.09E-02 ,
 WEIGHT(500) =   1.58E-03 , &
1Conc   16   0.56
End of Input
&Input Next= 6 &
```

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```
0        2   LLCE in Larger Container
Cylindrical Source Geom - Dose Rate at 3 m
&Input Next= 1 , ISpec= 3 , IGeom= 7 , ICONC=0, SFACT=1, DUNIT=7,
 NTheta= 20, NPsi= 30, NShld= 1 , JBuf= 1, OPTION=0,
 Slth= 2133.6,
 Y= 1066.8 ,
 T(1)= 83.8,
 X= 383.8,
 WEIGHT(451) =    6.07E-02 ,
 WEIGHT(472) =    3.32E+01 ,
 WEIGHT( 27) =    2.44E-03 ,
 WEIGHT( 82) =    2.08E+02 ,
 WEIGHT( 84) =    2.08E+02 ,
 WEIGHT(103) =    6.01E-03 ,
 WEIGHT(102) =    8.77E-03 ,
 WEIGHT(117) =    7.57E+00 ,
 WEIGHT(141) =    1.37E+00 ,
 WEIGHT(172) =    8.70E+00 ,
 WEIGHT(170) =    8.70E+00 ,
 WEIGHT(269) =    5.27E+00 ,
 WEIGHT(290) =    8.52E-04 ,
 WEIGHT(319) =    1.39E+00 ,
 WEIGHT(335) =    9.10E+02 ,
 WEIGHT(336) =    8.61E+02 ,
 WEIGHT(376) =    4.24E+02 ,
 WEIGHT(377) =    4.24E+02 ,
 WEIGHT(388) =    1.58E-01 ,
 WEIGHT(403) =    1.68E+00 ,
 WEIGHT(415) =    1.13E+00 ,
 WEIGHT(418) =    1.13E+00 ,
 WEIGHT(519) =    2.58E-04 ,
 WEIGHT(520) =    2.32E-07 ,
 WEIGHT(476) =    6.98E-05 ,
 WEIGHT(502) =    2.96E-04 ,
 WEIGHT(412) =    1.91E-06 ,
 WEIGHT(492) =    7.72E-03 ,
 WEIGHT(526) =    1.69E-03 ,
 WEIGHT(493) =    4.00E-01 ,
 WEIGHT(494) =    1.86E-02 ,
 WEIGHT(496) =    3.67E-01 ,
 WEIGHT(495) =    1.79E-01 ,
 WEIGHT(499) =    3.81E-04 ,
 WEIGHT(504) =    1.15E-03 ,
 WEIGHT(498) =    3.83E-04 ,
 WEIGHT(497) =    1.21E-09 ,
 WEIGHT(505) =    1.09E-02 ,
 WEIGHT(500) =    1.58E-03 , &
1Conc   16   0.56
End of Input
&Input Next= 6 &
```

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Attachment 2

GXQ INPUT FILE

```
Sector 99.5% X/Q Values - On & Offsite Receptor - CWC
c GXQ Version 4.0 Input File
c   mode
    1
c
c MODE CHOICE:
c mode = 1 then X/Q based on Hanford site specific meteorology
c mode = 2 then X/Q based on atmospheric stability class and wind speed
c mode = 3 then X/Q plot file is created
c
c LOGICAL CHOICES:
c   ifox  inorm icdf  ichk  isite ipop
    T     F     F     F     F     F
c ifox  = t then joint frequency used to compute frequency to exceed X/Q
c       = f then joint frequency used to compute annual average X/Q
c inorm = t then joint frequency data is normalized (as in GENII)
c       = f then joint frequency data is un-normalized
c icdf  = t then cumulative distribution file created (CDF.OUT)
c       = f then no cumulative distribution file created
c ichk  = t then X/Q parameter print option turned on
c       = f then no parameter print
c isite = t then X/Q based on joint frequency data for all 16 sectors
c       = f then X/Q based on joint frequency data of individual sectors
c ipop  = t then X/Q is population weighted
c       = f then no population weighting
c
c X/Q AND WIND SPEED ADJUSTMENT MODELS:
c   ipuff idep  isrc  iwind
    0     0     0     0
c DIFFUSION COEFFICIENT ADJUSTMENT MODELS:
c   iwake ipm   iflow ientr
    0     0     0     0
c EFFECTIVE RELEASE HEIGHT ADJUSTMENT MODELS:
c  (irise igrnd)iwash igrav
    0     0     0     0
c ipuff = 1 then X/Q calculated using puff model
c       = 0 then X/Q calculated using default continuous plume model
c idep  = 1 then plume depletion model turned on (Chamberlain model)
c isrc  = 1 then X/Q multiplied by scalar
c       = 2 then X/Q adjusted by wind speed function
c iwind = 1 then wind speed corrected for plume height
c isize = 1 then NRC RG 1.145 building wake model turned on
c       = 2 then MACCS virtual distance building wake model turned on
c ipm   = 1 then NRC RG 1.145 plume meander model turned on
c       = 2 then 5th Power Law plume meander model turned on
c       = 3 then sector average model turned on
c iflow = 1 then sigmas adjusted for volume flow rate
c ientr = 1 then method of Pasquill used to account for entrainment
c irise = 1 then MACCS buoyant plume rise model turned on
c       = 2 then ISC2 momentum/buoyancy plume rise model turned on
c igrnd = 1 then Mills buoyant plume rise modification for ground effects
c iwash = 1 then stack downwash model turned on
c igrav = 1 then gravitational settling model turned on
c       = 0 unless specified otherwise, 0 turns model off
c
c PARAMETER INPUT:
c                   reference                     frequency
c   release         anemometer      mixing        to
c   height          height          height        exceed
c   hs(m)           ha(m)           hm(m)         Cx(%)
c   ___________     ___________     ___________   ___________
    0.00000E+00     1.00000E+01     1.00000E+03   5.00000E-01
c
```

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```
c   initial         initial                                            gravitational
c   plume           plume           release         deposition         settling
c   width           height          duration        velocity           velocity
c   Wb(m)           Hb(m)           trd(hr)         vd(m/s)            vg(m/s)
c   ___________     ___________     ___________     ___________        ___________
    0.00000E+00     0.00000E+00     0.00000E+00     1.00000E-03        1.00000E-03
c
c                   initial         initial                            convective
c   ambient         plume           plume           release            heat release
c   temperature     temperature     flow rate       diameter           rate(1)
c   Tamb(C)         T0(C)           V0(m3/s)        d(m)               qh(w)
c   ___________     ___________     ___________     ___________        ___________
    2.00000E+01     2.20000E+01     1.00000E+00     1.00000E+00        0.00000E+00
c
c (1) If zero then buoyant flux based on plume/ambient temperature difference.
c
c   X/Q             Wind
c   scaling         Speed
c   factor          Exponent
c   c(?)            a(?)
c   ___________     ___________
    1.00000E+00     7.80000E-01
c
c RECEPTOR DEPENDENT DATA (no line limit)
c FOR MODE     make          RECEPTOR DEPENDENT DATA
c 1 (site specific)          sector distance receptor-height
c 2 (by class & wind speed)  class windspeed distance offset receptor-height
c 3 (create plot file)       class windspeed xmax imax ymax jmax xqmin power
c
c RECEPTOR PARAMETER DESCRIPTION
c sector = 0, 1, 2... (all, S, SSW, etc.)
c distance = receptor distance (m)
c receptor height = height of receptor (m)
c class = 1, 2, 3, 4, 5, 6, 7 (P-G stability class A, B, C, D, E, F, G)
c windspeed = anemometer wind speed (m/s)
c offset = offset from plume centerline (m)
c xmax = maximum distance to plot or calculate to (m)
c imax = distance intervals
c ymax = maximum offset to plot (m)
c jmax = offset intervals
c xqmin = minimum scaled X/Q to calculate
c power = exponent in power function step size
0  100  0
 1   14680   0
 2   15010   0
 3   13800   0
 4   11740   0
 5   11500   0
 6   11800   0
 7   14550   0
 8   15480   0
 9   17270   0
10   24910   0
11   27320   0
12   24550   0
13   24240   0
14   28930   0
15   24600   0
16   19150   0
```

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Attachment 3

GENII INPUT FILE

```
######################### Program GENII Input File ############  8 Jul 88 ####
Title: LLCE Onsite - Inhalation & Submersion
     \SAMPL\G-AIR.AC                              Created on 01-22-1990 at 07:30
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 |        Surface Deep    Ground  Surface|
     Radio-  |Air     Water   Waste  |Air     Soil    Soil    Water   Water  |
     nuclide |/yr     /yr     /m3    |/m3     /unit   /m3     /L      /L     |
     --------|------- ------- -------|------- ------- ------- ------- -------|
     C 14     1.8E-07
     CO60     9.6E-05
     NI63     2.8E-06
     SE79     7.1E-09
     SR90     6.0E-04
     Y 90     6.0E-04
     NB93M    1.7E-08
     ZR93     2.5E-08
     ZR95     2.2E-05
     TC99     4.0E-06
     RU106    2.5E-05
     SB125    1.5E-05
     I 129    2.5E-09
     CS134    4.0E-06
     CS137    2.6E-03
     CE144    1.2E-03
     PR144    1.2E-03
     PM147    4.6E-07
     SM151    4.9E-06
     EU154    3.3E-06
     EU155    3.3E-06
     U 233    7.5E-10
     U 234    6.7E-13
     U 235    2.0E-10
     NP237    8.6E-10
     NP238    5.5E-12
     PU238    2.2E-08
     U 238    4.9E-09
     PU239    1.2E-06
```

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```
 PU240    5.4E-08
 AM241    1.1E-06
 PU241    5.2E-07
 AM242    1.1E-09
 CM242    3.3E-09
 AM242M   1.1E-09
 PU242    3.5E-15
 AM243    3.2E-08
 CM244    4.6E-09
 --------|----Derived Concentrations-----|
 Use when|   measured values are known   |
 --------|-------------------------------|
 Release |Terres. Animal  Drink   Aquatic|
 Radio-  |Plant   Product Water   Food   |
 nuclide |/kg     /kg     /L      /kg    |
 --------|------- ------- ------- -------|

TIME ######################################################################

1     Intake ends after (yr)
50    Dose calc. ends after (yr)
1     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              |0        Release type (0-3)
1          Option: 1-Use chi/Q or PM value     |F        Stack release (T/F)
                   2-Select MI dist & dir      |0        Stack height (m)
                   3-Specify MI dist & dir     |0        Stack flow (m3/sec)
3.41e-2    Chi/Q or PM value                   |0        Stack radius (m)
1          MI sector index (1=S)               |0        Effluent temp. (C)
0          MI distance from release point (m)  |0        Building x-section (m2)
T          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 withdrawl location (hr)
           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
```

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```
           ====BIOTIC TRANSPORT OF BURIED SOURCE================SECTION 4=====
T          Consider during inventory decay/buildup period (T/F)?
T          Consider during intake period (T/F)?  | 1-Arid non agricultural
0          Pre-Intake site condition.............| 2-Humid non agricultural
                                                 | 3-Agricultural

EXPOSURE ##################################################################

           ====EXTERNAL EXPOSURE===============================SECTION 5=====
           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)
0          Transit time for release to reach aquatic recreation (hr)
1.0        Average fraction of time submersed 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=====
0          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
             3-Use chi/Q and production grids (PRODUCTION will be overridden)
0          Population ingesting aquatic foods, 0 defaults to total (person)
0          Population ingesting drinking water, 0 defaults to total (person)
F          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
           --- ------  -----  -------   ------   ----- |------------------------
           F   FISH    0.00   0.0E+00    0.00     0.0  | 0      Source (see above)
           F   MOLLUS  0.00   0.0E+00    0.00     0.0  | T      Treatment? T/F
           F   CRUSTA  0.00   0.0E+00    0.00     0.0  | 0      Holdup/transit(da)
           F   PLANTS  0.00   0.0E+00    0.00     0.0  | 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/m2   kg/yr     da       kg/yr
           --- ------  -----  - -----  -----   -----   -------   ------   ------
           F   LEAF V  0.00   0  0.0    0.0     0.0    0.0E+00    0.0      0.0
           F   ROOT V  0.00   0  0.0    0.0     0.0    0.0E+00    0.0      0.0
           F   FRUIT   0.00   0  0.0    0.0     0.0    0.0E+00    0.0      0.0
           F   GRAIN   0.00   0  0.0    0.0     0.0    0.0E+00    0.0      0.0

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

           ---HUMAN---- TOTAL   DRINK    ------------STORED FEED-------------
USE        CONSUMPTION  PROD-   WATER    DIET  GROW  -IRRIGATION--        STOR-
?   FOOD   RATE  HOLDUP UCTION  CONTAM   FRAC- TIME  S RATE  TIME  YIELD  AGE
T/F TYPE   kg/yr  da    kg/yr   FRACT.   TION  da    * in/yr mo/yr kg/m3  da
--- ------ ------ ----- ------  -------  ----  ----  - ----- ----- -----  ----
F   BEEF     0.0   0.0   0.00     0.00   0.00   0.0  0  0.0  0.00  0.00   0.0
```

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F	POULTR	0.0	0.0	0.00	0.00	0.00	0.0	0	0.0	0.00	0.00	0.0
F	MILK	0.0	0.0	0.00	0.00	0.00	0.0	0	0.0	0.00	0.00	0.0
F	EGG	0.0	0.0	0.00	0.00	0.00	0.0	0	0.0	0.00	0.00	0.0
						-------------FRESH FORAGE------------						
	BEEF					0.00	0.0	0	0.0	0.00	0.00	0.0
	MILK					0.00	0.0	0	0.0	0.00	0.00	0.0

###

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CHECKLIST FOR TECHNICAL PEER REVIEW

Document: Engineering Analysis - "Transportation Hazard Index Analysis for the LLCE SARP," January 21, 1997.

Scope: Entire Document

Yes	No	NA	
[X]	[ ]	[ ]	Previous reviews complete and cover analysis, up to scope of this review, with no gaps.
[X]	[ ]	[ ]	Problem completely defined.
[X]	[ ]	[ ]	Accident scenarios developed in a clear and logical manner.
[X]	[ ]	[ ]	Necessary assumptions explicitly stated and supported.
[X]	[ ]	[ ]	Computer codes and data files documented.
[X]	[ ]	[ ]	Data used in calculations explicitly stated in document.
[X]	[ ]	[ ]	Data checked for consistency with original source information as applicable.
[ ]	[ ]	[X]	Mathematical derivations checked including dimensional consistency of results.
[X]	[ ]	[ ]	Models appropriate and used within range of validity or use outside range of established validity justified.
[X]	[ ]	[ ]	Hand calculations checked for errors. Spreadsheet results should be treated exactly the same as hand calculations.
[X]	[ ]	[ ]	Software input correct and consistent with document reviewed.
[X]	[ ]	[ ]	Software output consistent with input and with results reported in document reviewed.
[X]	[ ]	[ ]	Limits/criteria/guidelines applied to analysis results are appropriate and referenced. Limits/criteria/guidelines checked against references.
[X]	[ ]	[ ]	Safety margins consistent with good engineering practices.
[X]	[ ]	[ ]	Conclusions consistent with analytical results and applicable limits.
[X]	[ ]	[ ]	Results and conclusions address all points required in the problem statement.
[ ]	[ ]	[X]	Format consistent with appropriate NRC Regulatory Guide or other standards
[ ]		[X]	Review calculations, comments, and/or notes are attached.
[X]	[ ]	[ ]	**Document approved.**

Paul Rittmann [signature: Paul Rittmann] Jan 28, 1997
Reviewer (Printed Name and Signature) Date

Any notes and/or comments should be attached.

Source has short-lived nuclides which decay significantly in a few years (esp Ce-144).

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HEDOP REVIEW CHECKLIST
for
Radiological and Nonradiological Release Calculations

Document: Engineering Analysis - "Transportation Hazard Index Analysis for the LLCE SARP," January 21, 1997.

Scope of Review: Entire Document

YES	NO*	N/A		
[X]	[ ]	[ ]	1.	A detailed technical review and approval of the environmental transport and dose calculation portion of the analysis has been performed and documented.
[X]	[ ]	[ ]	2.	Detailed technical review(s) and approval(s) of scenario and release determinations have been performed and documented.
[X]	[ ]	[ ]	3.	HEDOP-approved code(s) were used.
[ ]	[ ]	[X]	4.	Receptor locations were selected according to HEDOP recommendations.
[X]	[ ]	[ ]	5.	All applicable environmental pathways and code options were included and are appropriate for the calculations.
[X]	[ ]	[ ]	6.	Hanford site data were used.
[X]	[ ]	[ ]	7.	Model adjustments external to the computer program were justified and performed correctly.
[X]	[ ]	[ ]	8.	The analysis is consistent with HEDOP recommendations.
[ ]		[X]	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.)
[X]	[ ]		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.

Paul Rittmann *Paul Rittmann* Jan 28, 1997
HEDOP-Approved Reviewer (Printed Name and Signature) Date

COMMENTS (add additional signed and dated pages if necessary):

5.0 SHIELDING EVALUATION

5.1 INTRODUCTION

This shielding evaluation supports the shipment of packages containing LLCE from Hanford 200 Area waste tanks. The LLCE packages are to be shipped to a solid waste burial ground also in the 200 Area.

The transportation package consists of a polyethylene container 22.39 m (73.5 ft) in length. Inside this container is a BC skid for the LLCE. A variety of LLCE must be accommodated by the packaging. The length of this equipment ranges from 3.6 m (12 ft) to 18.9 m (62 ft).

External shielding of the package is provided primarily by steel plates mounted on the front, back, and sides of the trailer carrying the LLCE package. There is minimal external shielding above and below the package. Some additional shielding is provided by the BC skid.

The source term used in the shielding analysis of the proposed LLCE shipments was based on a worst-case evaluation. The total activity of this source is 3110 Ci. This source strength combined with the limited external shielding of the package resulted in high dose rates around the transportation trailer. Extra shielding in the form of lead blankets around the tractor cab is required to keep the dose rate to the driver under the limit of 2 mrem/h. The amount of lead shielding required was determined and is reported in Section 5.4.4.2.

Also included (Section 5.8.1) are the results of calculations designed to aide in establishing operational controls during the loading, transportation, and unloading of the LLCE package. These analyses provide information on the 5- and 10-mrem/h boundaries around a loaded transportation trailer and around a polyethylene BC laying on the ground. They also provide data relating dose rates at the front of a loaded trailer to lead shielding requirements for the tractor cab.

5.2 DIRECT RADIATION SOURCE SPECIFICATION

The source term used in the shielding analysis of the proposed LLCE shipments was based on a worst-case evaluation. This source term is described in Part B, Section 2.0, and is listed in Table B5-1.

5.2.1 Gamma Source

The radionuclide inventory listed in Table B5-1 was used as input to the ISOSHLD program (Rittmann 1995) to compute a photon source rate as a function of photon energy. The input file for the ISOSHLD run is listed in Section 5.8.2. The resulting energy distribution is listed in Table B5-2. The total source rate was computed by ISOSHLD to be 4.68×10^{13} photons/s. Bremsstrahlung was included in the ISOSHLD calculation.

5.2.2 Beta Source

The beta source within the loaded LLCE container leads to an insignificant dose rate outside the perimeter of the trailer because of the shielding provided by steel in the LLCE, the steel skid plate, the grout filler (when used), the polyethylene container, the trailer deck, and the external shielding. This shielding is described in Section 5.4.3.

Table B5-1. Maximum Radionuclide Inventory in the Long-Length Contaminated Equipment.

Isotope	Activity*		Isotope	Activity*	
	Bq	Ci		Bq	Ci
^{14}C	2.25 E+09	6.07 E-02	^{151}Sm	6.22 E+10	1.68 E+00
^{60}Co	1.23 E+12	3.32 E+01	$^{154/155}$Eu	4.18 E+10	1.13 E+00
^{63}Ni	3.63 E+10	9.81 E-01	^{233}U	9.55 E+06	2.58 E-04
^{79}Se	9.03 E+07	2.44 E-03	^{234}U	8.58 E+03	2.32 E-07
^{90}Sr	7.70E+12	2.08 E+02	^{235}U	2.58 E+06	6.98 E-05
^{90}Y	7.70 E+12	2.08 E+02	^{237}Np	1.10 E+07	2.96 E-04
^{93m}Nb	2.22 E+08	6.01 E-03	^{238}Np	7.07 E+04	1.91 E-06
^{93}Zr	3.24 E+08	8.77 E-03	^{238}Pu	2.86 E+08	7.72 E-03
^{95}Zr	2.80 E+11	7.57 E+00	^{238}U	6.25 E+07	1.69 E-03
^{99}Tc	5.07 E+10	1.37 E+00	^{239}Pu	1.48 E+10	4.00 E-01
^{106}Rh	3.22 E+11	8.70E+00	^{240}Pu	6.88 E+08	1.86 E-02
^{106}Ru	3.22 E+11	8.70 E+00	^{241}Am	1.36 E+10	3.67 E-01
^{125}Sb	1.95 E+11	5.27 E+00	^{241}Pu	6.62 E+09	1.79 E-01
^{129}I	3.15 E+07	8.52 E-04	^{242}Am	1.41 E+07	3.81 E-04
^{134}Cs	5.14 E+10	1.39 E+00	^{242}Cm	4.26 E+07	1.15 E-03
^{137}Cs	3.37 E+13	9.10 E+02	^{242m}Am	1.42 E+07	3.83 E-04
^{137m}Ba	3.19 E+13	8.61 E+02	^{242}Pu	4.48 E+01	1.21 E-09
^{144}Ce	1.57 E+13	4.24 E+02	^{243}Am	4.03 E+08	1.09 E-02
^{144}Pr	1.57 E+13	4.24 E+02	^{244}Cm	5.85 E+07	1.58 E-03
^{147}Pm	5.85 E+09	1.58 E-01	Total	1.15 E+14	3.11 E+03

*The format of the activities is z.dE±ee, which is interpreted as z.d x $10^{\pm ee}$.

5.2.3 Neutron Source

Actinides listed in Table B5-1 are in very low concentrations. Thus, neutron dose rates were expected to be negligible compared to photon dose rates. This was confirmed using the method described in Nelson (1996) to conservatively estimate neutron doses at several locations around the trailer. Since the neutron dose rates are insignificant, they are not reported.

Table B5-2. Photon Source Rate Energy Distribution.

Average energy (MeV)	Photon source rate* (photons/s)	Average energy (MeV)	Photon source rate* (photons/s)
0.015	2.496 E+12	0.650	2.928 E+13
0.025	1.372 E+12	0.825	2.412 E+11
0.035	4.253 E+12	1.000	3.261 E+10
0.045	8.709 E+11	1.225	2.476 E+12
0.055	4.149 E+11	1.475	5.809 E+10
0.065	3.177 E+11	1.700	2.796 E+09
0.075	2.618 E+11	1.900	1.189 E+09
0.085	4.993 E+11	2.100	1.213 E+11
0.095	2.149 E+11	2.300	1.935 E+08
0.150	3.002 E+12	2.500	5.875 E+07
0.250	3.994 E+11	2.700	1.282 E+07
0.350	2.002 E+11	3.000	2.542 E+06
0.475	2.977 E+11	3.600	1.198 E+05
Total 4.681 E+13			

*The format of the source rate data is z.d E±ee, which is interpreted as z.d x $10^{\pm ee}$.

5.3 SUMMARY OF SHIELDING PROPERTIES OF MATERIALS

The shielding attenuation properties of bulk materials were obtained from the photon cross-section data libraries associated with the MCNP program (Breismeister 1993, Carter 1996) that was used to perform all shielding calculations.

5.4 NORMAL TRANSFER CONDITIONS

5.4.1 Conditions To Be Evaluated

Dose rates will be computed at 0, 1, and 2 m from the front; at the back and side of the trailer; and at the driver's location in the truck cab, which was assumed to be 152 cm (60 in.) in front of the trailer. The amount of lead around the tractor cab required to meet the dose rate limit for normally occupied space (see Section 5.4.2) will be determined. The maximum radionuclide inventory that can be transported without adding shielding to the cab will also be determined.

5.4.2 Acceptance Criteria

For normal transfer conditions, the external dose rate is limited to 2 mrem/h in any normally occupied space of the transport vehicle. A restricted area where the dose rate exceeds 10 mrem/h will be determined after the TS is loaded. Administrative controls will limit access to this area to Hanford radiation workers.

5.4.3 Shielding Model

All dose rate calculations were made using the Hanford version (Carter 1996) of the Monte Carlo N-Particle (MCNP) code (Breismeister 1993). For expediency, some initial scoping calculations were made using the point-kernel option in the code. However, the point-kernel method cannot account for any dose rate contributions from ground shine and sky shine. Because of the minimal amount of shielding on the top and bottom of the transportation package, ground shine and sky shine make a significant contribution to the total dose rate at some locations. Thus, final MCNP calculations were made using the rigorous transport mode to properly account for these effects. Unless noted otherwise, results presented in Sections 5.4.4 and 5.8.1 are from the transport calculations. Dose rates were tallied in MCNP runs using the point detector option.

In all cases, photon cross-section data from the evaluated nuclear data file/B-version V (ENDF/B-V) library were used, and photon fluxes were converted to dose rates using ANSI/ANS-6.1.1-1991 (ANS 1991) fluence-to-dose conversion factors.

Results from MCNP calculations are subject to statistical uncertainties. MCNP provides an estimate of the uncertainty for each computed dose rate. However, there is a statistical uncertainty on this estimate. When using point detectors to tally dose rates, MCNP uncertainties estimated to be less than 5% are generally reliable. Uncertainty estimates in the 5-10% range tend to be reasonably reliable, but should be treated with caution. For uncertainties larger than 10%, there can be a large uncertainty in the given uncertainty. Without additional review, such results should be treated as, at most, order-of-magnitude estimates.

The LLCE container was represented as a long polyethylene pipe lying on a steel flatbed trailer. A plan view of the calculational model is shown in Figure B5-1, and a cross section of the model is shown in Figure B5-2.

The pipe was modeled as having a length of 21.3 m (70.0 ft), an outside diameter (OD) of 170.2 cm (67.0 in.), and a wall thickness of 3.18 cm (1.25 in.). A polyethylene end cap 4.93 cm (1.94 in.) thick was included at each end of the pipe. Inside the polyethylene container is a steel half-shell pipe used as a skid for the LLCE. The skid has an OD of 149.5 cm (58.9 in.) and a thickness of 0.48 cm (0.19 in.). It runs the length of the polyethylene container and includes steel end plates 0.48 cm (0.19 in.) thick.

The LLCE, which sits on the bottom of the skid, was represented as a column of steel pipe having a length of 18.9 m (62.0 ft), an OD of 108.0 cm (42.5 in.), and a wall thickness of 0.64 cm (0.25 in.). The pipe was modeled as being filled with uniformly distributed tank waste (1.6 g/cc density) at one end. The length of pipe containing the waste was 9.1 m (30.0 ft); the remaining 9.8 m (32.0 ft) was empty (air filled). The end with the radioactive source material was located at the front of the trailer. The space around the LLCE inside the polyethylene container will be filled with low density (0.32 g/cc) grout, which is intended to provide stability and shielding unless the contamination is classified as TRU waste. Since the contamination may be classified as TRU, this space was modeled as being empty (containing air) because this is the worst case for shielding.

The steel trailer bed was modeled as being 23.2 m (76.0 ft) long, 287 cm (113.0 in.) wide, and 0.64 cm (0.25 in.) thick. The top of the trailer bed was set at 228.6 cm (90.0 in.) above ground level. The polyethylene container was positioned 33.9 cm (13.3 in.) from the back of the trailer.

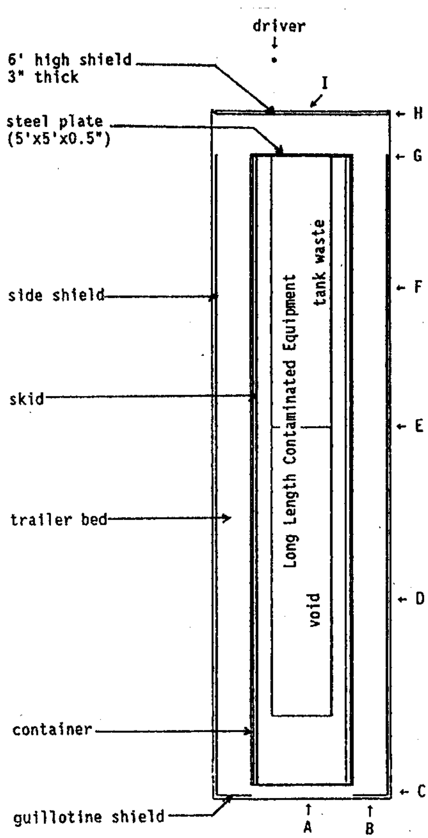
External steel shields on the front, back, and sides of the trailer are incorporated in the design. Along each side of the polyethylene container is a steel plate that runs the length of the trailer bed. Each plate, mounted on top of the trailer bed, is 1.27 cm (0.50 in.) thick and 111.8 cm (44.0 in.) tall.

A guillotine shield 2.54 cm (1.0 in.) thick is located at the rear of the trailer to protect workers while the back cover is placed on the polyethylene pipe and the container void is filled with low-density grout. This shield is 213.4 cm (84.0 in.) tall and runs the width of the trailer. To provide access to the container, there is an opening in the top-center portion of the shield. Because this shield provides only limited protection, to be conservative it was not included in the final reported calculations.

A steel plate directly in front of the polyethylene container was included in the calculational models. This plate, 152 cm (60.0 in.) square and 1.27 cm (0.50 in.) thick, is intended to stabilize the load and provide needed shielding. Additional shielding to the driver is provided by another steel plate located at the very front of the trailer. This shield is 182.9 cm (72.0 in.) tall, extends the width of the trailer, and is 7.62 cm (3.0 in.) thick

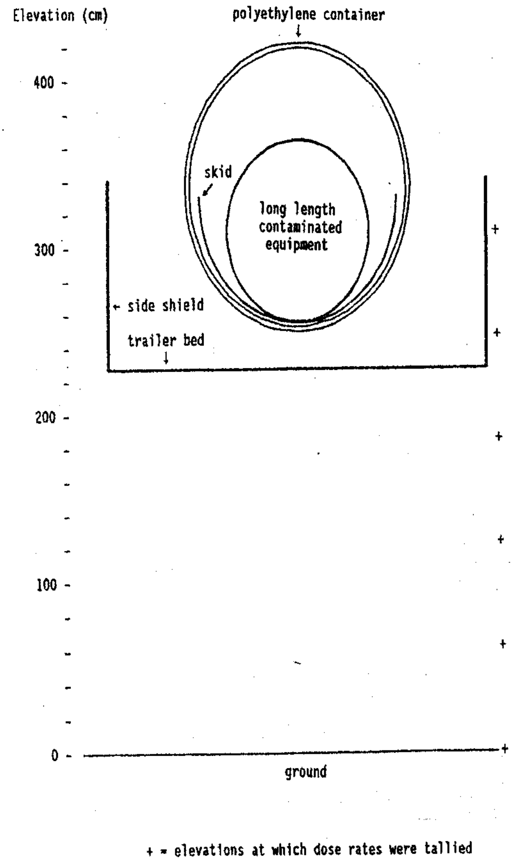
For the purpose of tallying dose rates in the tractor cab, the driver's normal location was assumed to be 152 cm (60 in.) in front of the trailer and offset from the tractor/trailer centerline by 91.5 cm (36.0 in.). Elevations of 100 and 180 cm were assumed to be representative of the driver's position above ground level.

Figure B5-1. Plan View of Monte Carlo N-Particle Calculational Model.



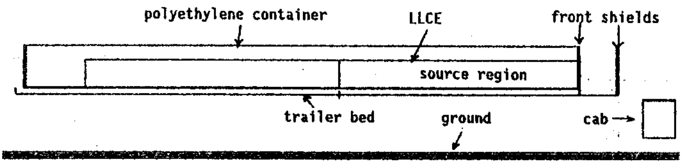
Letters A-I indicate locations where dose rates were computed.
Dose rates were also computed at the driver location.

Figure B5-2. Cross Section of Monte Carlo N-Particle Calculational Model.



Some models simulated lead shielding over the back, top, bottom, and sides of the tractor cab. The back of the cab was assumed to be 91.5 cm (36 in.) in front of the trailer. The floor and roof of the cab were assumed to be 60 cm (23.6 in.) and 210 cm (82.7 in.) above ground level, respectively. The length of the lead shielding above and below the cab was assumed to be 122 cm (48.0 in.). The lead shields on the back, top, and bottom of the cab were modeled as extending from 107 cm (42 in.) left of cab centerline to 122 cm (48 in.) to the right. This asymmetry allowed investigation of the effect that cab width has on dose rates to the driver. The side shielding was modeled as extending from cab floor to roof and extending forward 122 cm from the back of the cab. The thickness of the lead shielding was varied to determine the minimum required to keep the dose rate at the driver's location under 2 mrem/h. A side view of the MCNP model of a loaded transportation trailer and tractor cab is shown in Figure B5-3.

Figure B5-3. Side View of Monte Carlo N-Particle Model of Transportation Trailer and Tractor Cab.



The ground was modeled as a concrete surface. Regions aboveground, but outside the transportation package, were modeled as containing air at standard density. Compositions for all materials used in the calculational model are given in Table B5-3.

A complete MCNP input file for the calculation from which many of the reported dose rates were obtained is listed in Section 5.8.4. This case was a photon transport calculation used to compute dose rates along the back, side, and front of the trailer. The tractor cab and lead shielding were not represented in that model. Other MCNP calculations of the transportation system were variants of the case listed.

5.4.4 Shielding Calculations

5.4.4.1 Dose Rates around the trailer with Worst-Case Source. Dose rates were computed for points at the front, back and side of the trailer, including the approximate driver location. The locations where dose rates were computed are marked in Figure B5-1. Points A and B are behind the trailer. Point A is at the back-center of the trailer, while point B is 31 cm from the corner. Points C through H are along the side of the trailer, and point I is at the front-center of the trailer. For all points A though I, dose rates were computed at 0, 1, and 2 m from the edge of the trailer, and at six different elevations ranging from ground level to 305 cm (120 in.) aboveground.

Results of the dose rate calculations at points A through I are shown in Table B5-4. The MCNP uncertainty estimates associated with most dose rates given in Table B5-4 are less than 10% and appear to be reasonable values. At several locations, though, uncertainty estimates are higher. Dose rates in Table B5-4 with uncertainties larger than 10 percent are flagged, indicating they may be highly uncertain. However, with two noted exceptions, each of the flagged values was assessed and determined to be a reasonable calculation of the dose rate.

5.4.4.2 Dose Rates in the Tractor Cab With the Worst-Case Source. The location of the tractor driver was assumed to be 152 cm (60 in.) in front of the trailer and offset 91 cm (36 in.) from the trailer centerline. Two elevations were chosen as representative of driver's height aboveground while in the cab of the tractor. These elevations were 100 cm (39 in.) and 180 cm (71 in.) above ground level. With the worst-case source term, the computed dose rates at the driver's location in an unshielded cab

Table B5-3. Material Compositions.

Material (density)	Element	Weight fraction
Air (0.00129 g/cc)	N	0.767
	O	0.233
Steel (7.8 g/cc)	Fe	1.000
Polyethylene (0.95 g/cc)	H	0.143
	C	0.857
Lead (11.35 g/cc)	Pb	1.000
Tank waste (1.6 g/cc)	H	0.043
	C	0.020
	N	0.079
	O	0.584
	Na	0.220
	Al	0.030
	P	0.003
	Cl	0.010
	K	0.010
Ground material (concrete at 2.28 g/cc	O	0.441
	Si	0.216
	Ca	0.131
	Fe	0.079
	Al	0.061
	Mg	0.038
	K	0.007
	Na	0.018
	Ti	0.005
	H	0.003
	Mn	0.001
	P	0.001
	S	0.001

were 130 mrem/h (at 100-cm elevation) and 60 mrem/h (at 180-cm elevation). The MCNP estimate of the statistical uncertainty on these values was less than 6%. Any shielding provided by the tractor cab, frame, fuel tank, etc., was not accounted for in the calculational model.

The spatial components of the dose rates in the cab are shown in Table B5-5. The main contribution to the total dose rates is from direct radiation through the back of the tractor cab. The contribution from photons entering through the floor of the cab is primarily due to ground shine. The contributions through the other cab surfaces are due primarily to sky shine.

The dose rates at the 100-cm elevation are significantly higher than at 180 cm because there are direct lines from some portions of the tank waste material under the front shields on the trailer into the tractor cab. The magnitude of this direct shine decreases with elevation and is insignificant above the 228-cm level.

The peak value of 130 mrem/h at the driver's position far exceeds the stated limit of 2 mrem/h. Thus, with the worst-case source term, lead shielding must be added to the tractor cab to meet the limit. The amount of lead required was evaluated. Because of the effect of ground shine and sky shine, lead must not only be placed over the back of the cab but also over the top, bottom, and sides of the cab as indicated in Table B5-5. The surface contributions in Table B5-5 were derived from a sequence of MCNP calculations in which dose rates at the driver's position were tallied. In each calculation, one surface of the cab had no shielding, while the other surfaces had thick (10 cm) lead shielding.

Adding 3.81 cm (1.5 in.) to the back of the cab and 0.25 cm (0.1 in.) to the top, bottom, and sides of the cab reduced the driver's dose rate to a maximum of 2.4 mrem/h. Increasing the lead shielding to 4.09 cm (1.61 in.) on the back of the cab and 0.27 cm (0.11 in.) elsewhere would reduce the dose rate to 2 mrem/h (see Section 5.8.1.3).

5.4.4.3 Maximum Source without Additional Shielding. The worst-case source used in this evaluation has a total radionuclide inventory of 3,110 Ci. This inventory is orders of magnitude higher than normally expected. The installed shielding is probably sufficient to keep the dose rate to the truck driver below 2 mrem/h in most cases.

An MCNP calculation was made to determine the maximum curie inventory of tank waste that can be shipped with the dose rate to the driver less than 2 mrem/h without adding any shielding around the tractor cab. To be conservative in this calculation, the entire LLCE pipe was voided to eliminate any self shielding in the waste material. The source strength and distribution were not changed, however.

Scaling the results from this MCNP calculation to 2 mrem/h at the driver's location, the maximum radionuclide inventory per shipment was inferred to be 18 Ci. With this load, the dose rates given in Table B5-4 would be reduced by about a factor of 170.

Table B5-4. Dose Rates Around the Transport Trailer.

Point[a]	Elevation (cm)	Dose Rate (mrem/h)[b,c] Contact	1 meter	2 meters
A	2	5.9E+00	5.2E+00	5.6E+00[e]
	61	6.4E+00	6.0E+00	6.1E+00[d]
	122	5.9E+00	5.9E+00	5.7E+00
	183	5.3E+00	6.1E+00	5.9E+00
	244	5.0E+00[f]	7.7E+00[d]	1.2E+01
	305	2.6E+01[e]	2.0E+01	1.7E+01
B	2	6.2E+00	6.9E+00	4.9E+00
	61	7.0E+00	6.7E+00	6.2E+00
	122	6.7E+00	6.5E+00	6.1E+00
	183	6.0E+00	6.5E+00	6.2E+00
	244	4.4E+00	7.1E+00	7.2E+00
	305	5.7E+00[d]	6.8E+00[d]	6.4E+00
C	2	6.4E+00	6.9E+00	7.6E+00
	61	7.5E+00	8.3E+00	9.3E+00
	122	7.2E+00	8.2E+00	9.3E+00
	183	7.0E+00	8.1E+00	9.3E+00
	244	5.3E+00	8.5E+00	1.0E+01
	305	5.6E+00	9.1E+00	1.1E+01
D	2	3.4E+01	3.7E+01	3.8E+01
	61	3.4E+01	3.9E+01	3.9E+01
	122	2.8E+01	3.2E+01	3.3E+01
	183	2.2E+01	2.5E+01	3.1E+01
	244	9.9E+00	2.4E+01	3.3E+01
	305	9.9E+00	2.7E+01	3.9E+01
E	2	8.2E+02	5.2E+02	4.4E+02[g]
	61	8.5E+02	6.0E+02	4.1E+02
	122	9.2E+02	6.0E+02	3.8E+02
	183	1.0E+03	5.1E+02	4.0E+02
	244	6.4E+02	5.9E+02	4.4E+02
	305	8.3E+02	7.0E+02	5.0E+02
F	2	1.3E+03	1.0E+03	7.1E+02
	61	1.5E+03	1.1E+03	7.4E+02
	122	1.7E+03	1.1E+03	7.0E+02
	183	1.9E+03	9.9E+02	7.6E+02
	244	1.7E+03[f]	1.1E+03	8.2E+02
	305	1.5E+03	1.3E+03	8.9E+02
G	2	6.9E+02	5.5E+02	4.4E+02
	61	8.1E+02	6.1E+02	4.1E+02
	122	9.1E+02	6.0E+02	3.9E+02
	183	9.7E+02	5.3E+02	4.1E+02
	244	8.8E+02[e]	6.2E+02	4.5E+02
	305	8.2E+02	7.0E+02	5.1E+02
H	2	4.4E+02[f]	3.0E+02	2.7E+02[d]
	61	3.8E+02	3.1E+02	2.4E+02
	122	3.1E+02	2.7E+02	2.1E+02
	183	2.6E+02	2.2E+02	2.2E+02
	244	1.5E+02[d]	2.4E+02	2.3E+02
	305	1.5E+02[d]	2.4E+02	2.5E+02
I	2	3.2E+02	1.9E+02	1.1E+02
	61	3.4E+02	1.9E+02	1.1E+02
	122	3.2E+02	1.8E+02	8.5E+01
	183	3.1E+02	9.8E+01	4.8E+01
	244	1.5E+01	4.8E+01	3.8E+01
	305	7.6E+01[h]	3.8E+01	3.4E+01

MCNP = Monte Carlo N-Particle.

[a]See Figure B5-1 for location of points.

[b]The format of the dose rate data is z.dE±ee, which is interpreted as z.d x $10^{\pm ee}$.

[c]The MCNP estimate of the statistical uncertainty on results shown is less than 10%, unless flagged with a letter (d-h).

[d]Dose rates with MCNP uncertainty estimates up to 15%. 15% appears to be reasonable or conservative estimate of the actual uncertainties.

[e]Dose rates with MCNP uncertainty estimates up to 20%. 20% appears to be reasonable or conservative estimate of the actual uncertainties.

[f]Dose rates with MCNP uncertainty estimates up to 25%. 25% appears to be reasonable or conservative estimate of the actual uncertainties.

[g]The MCNP computed dose rate for this point had a high uncertainty, and the result was judged to be unreliable. The dose rate value shown was estimated from other data points.

[h]The MCNP computed dose rate for this point had a high uncertainty, and the result was judged to be unreliable. The dose rate value shown should be used as an order-of-magnitude indicator only.

Table B5-5. Spatial Components of the Dose Rate in the Tractor Cab With Worst-Case Source Term.

Cab surface	Dose rate contribution (mrem/h)*	
	At 100-cm elevation	At 180-cm elevation
Back	110 (5%)	42 (9%)
Bottom	6.1 (6%)	1.7 (7%)
Top	1.1 (8%)	3.7 (11%)
Sides	5.7 (7%)	5.7 (8%)
Front	0.6 (8%)	0.6 (11%)
Total	130 (4%)	60 (6%)

*Components do not add up to the totals. Some of the differences could be due to statistical variations in the computed results. The Monte Carlo N-Particle estimate of the standard deviation of each component is shown in parentheses. Also, the shield on one surface could affect the photon current at an adjacent surface.

5.5 ACCIDENT CONDITIONS

No specific accident conditions were analyzed as part of this shielding evaluation. However, an unshielded container with the worst-case radionuclide inventory was analyzed, and the results are reported in Section 5.8.1. Accidents that lead to worse consequences than just the loss of all external shielding are discussed in the radiological risk evaluation given in Part B, Section 3.0.

5.6 SHIELDING EVALUATION AND CONCLUSIONS

Shielding of the radiation source in the LLCE package is largely provided by steel plates mounted on the sides and ends of the trailer. This shielding does not form an integral barrier around the source material. It is only partially effective in reducing dose rates around the trailer because of the minimal bottom shielding and the height of the trailer bed aboveground (228 cm or 90 in.). Consequently, the worst-case source term used in this evaluation results in high dose rates (up to 1,900 mrem/h at the perimeter of the trailer). However, the only limit specified in Section 5.4.2 is that the dose rate in any normally occupied space (the tractor driver's position in this case) be less than 2 mrem/h.

The calculated peak dose rate to the driver with the worst-case source and without any shielding around the tractor cab is 130 mrem/h. The majority of this dose rate is due to direct photon streaming under the shields at the front of the trailer into the tractor cab (see Figure B5-3). The driver's dose rate can be reduced to 2 mrem/h by adding lead shielding around the cab. Because of significant contributions from ground shine and sky shine, it is not sufficient to shield just the back of the cab. To meet the 2-mrem/h limit, 4.09 cm (1.61 in.) of lead shielding over the back and 0.27 cm (0.11 in.) on the top, bottom, and sides of the cab are required.

Without any shielding added to the cab, the maximum amount of tank waste material that can be transported is 18 Ci, compared to 3,110 Ci in the worst-case source. However, most shipments are expected to contain under 18 Ci.

The dose rate in the vicinity of the driver's position is sensitive to elevation as can be seen from the data in Tables B5-4 and B5-5. The shields mounted at the front of the trailer become more effective as the elevation is increased.

In general, contact dose rates beside the trailer peak in the range 122 cm (48 in.) to 183 cm (72 in.) aboveground. This is just below the elevation of the trailer bed and the shields mounted on it (see Figure B5-2). Dose rates to personnel working around the trailer could be substantially reduced by installing shields on the ground along the side of the trailer. Doing so could significantly reduce the dose rates at the side of the trailer, but sky shine would probably limit the maximum effectiveness of such shields. No calculations were made to quantify the potential benefit of ground-mounted shields.

5.7 REFERENCES

ANS, 1991, *Neutron and Gamma-Ray Fluence-to-Dose Factors*, ANSI/ANS-6.1.1-1991, American Nuclear Society, La Grange Park, Illinois.

Breismeister, J. F., Editor, 1993, *MCNP - A General Monte Carlo N-Particle Transport Code, Version 4a*, Los Alamos National Laboratory report LA-12625, Los Alamos, New Mexico.

Carter, L. L., *1996, Certification of MCNP Version 4A for WHC Computer Platforms*, WHC-SD-MP-SWD-30001, Rev. 8, Westinghouse Hanford Company, Richland, Washington.

Nelson, J. V., 1996, "Estimation of Neutron Dose Rates from Nuclear Waste Packages" (memorandum 8M730-JVN-96-007 to J. R. Green, March 8), Westinghouse Hanford Company, Richland, Washington.

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

5.8 APPENDICES

5.8.1 Operational Controls

Because of potentially high dose rates around the transportation package, special controls will need to be in place to limit the exposure of personnel involved with the loading, transportation, and unloading of the long-length contaminated equipment (LLCE) package. The purpose of this appendix is to provide information that can be used in planning and carrying out these operations when usually high sources are involved. Included are the 5- and 10-mrem/h boundaries around an LLCE container with the worst-case source. The boundaries are given for the container while on the shielded transportation trailer and while on the ground without any external shielding. Also included are data relating the dose rate at the front of the trailer to the amount of lead shielding required to reduce the dose rate to the tractor driver to the 2-mrem/h limit.

5.8.1.1 Dose Rate Boundaries Around LLCE Container on the Shielded Trailer. Monte Carlo N-Particle (MCNP) calculations were made to compute dose rates as a function of distance from the front, back, and sides of a loaded transportation trailer. The elevation of the dose rate tallies was 100 cm, except at the back of the trailer. There, 310 cm was used because the dose rates peak around that elevation due to the lack of shielding at the back of the trailer. The worst-case source was used in all cases. The results are shown in Table B5.8-1. From the data in this table, Table B5.8-2, which gives the 10- and 5-mrem/h boundaries around the trailer, was constructed using log-log interpolation.

5.8.1.2 Dose Rate Boundaries Around an Unshielded LLCE Container. An unshielded LLCE BC lying on the ground was modeled in MCNP. The worst-case source was again used, and dose rates 100 cm above ground level were tallied at a range of distances from the container. The results are shown in Table B5.8-3. From the data in this table, Table B5.8-4, which gives the 10- and 5-mrem/h boundaries around the container, was constructed as in Section 5.8.1.1.

5.8.1.3 Lead Shielding Requirements As a Function Dose Rate at Front of Trailer. It was calculated that for tank waste inventories above 18 Ci, lead shielding around the tractor cab will be needed to keep the dose rate to the driver from exceeding 2 mrem/h. The amount of lead required will depend on the dose rates at the driver's location without any extra shielding. Calculations were made to determine this relationship, and the results are tabulated in Table B5.8-5. This table can be used to determine the lead shielding requirements for the back, sides, top, and bottom of the cab from dose rates measured 152 cm (60 in.) in front of the trailer bed and 100 cm aboveground. The lead thicknesses shown are not a unique solution. Satisfactory variations exist of the back, top, bottom, and side shielding given. However, the lead thicknesses shown appear to be a reasonable trade-off.

Table B5.8-1. Dose Rate As a Function of Distance From Points on Perimeter of Loaded Transport Trailer.

Distance (m)	Dose rate[a] (mrem/h) at locations identified in Figure B5-1[b]					
	A	C	D	E,G,H[c]	F	I
2.0	17	8.9	38	390	700	95
5.0	13					24
10.0	8.7	17	53	110	140	10
20.0	4.6	16	27	39	44	4.3
30.0		13	17*	19	18	
50.0		5.3	6.0	7.2	7.9*	
80.0		1.6	1.9	2.0	2.0	

[a]Monte Carlo N-Particle uncertainties on all dose rates are less than 10% unless flagged with an asterisk (*).
[b]Point A is at the back of the trailer, points C-H are along the side of the trailer, and point I is at the front of the trailer.
[c]The difference between dose rates at points E, G, and H were statistically insignificant, except at the 2-m distance. There, the dose rate at points E and G was 390 mrem/h, as shown, while the 2-m dose rate at point H was 230 mrem/h.

*Dose rates with uncertainties up to 13%.

Table B5.8-2. 10 and 5 mrem/h Boundaries Around a Loaded Transport Trailer.

Dose rate (mrem/h)	Distance (m) from locations identified in Figure B5-1[a]					
	A	C	D	E, G, H[b]	F	I
10	8	34	38	42	43	10
5	18	51	53	57	58	18

[a]Point A is at the back of the trailer, points C-H are along the side of the trailer, and point I is at the front of the trailer.
[b]The differences between the boundary distances at points E, G, and H were statistically insignificant.

Table B5.8-3. Dose Rate As a Function of Distance From Points on Perimeter of LLCE Container.

Distance (m)	Dose rate[a] (mrem/h) at locations identified in Figure B5-1.[b]					
	A	C	D	E, G[c]	F	I
2.0	28*	13	62	1200	2200	950
10.0	10*	39	95	220	290	55
20.0	4.6	32	50	70	75	15
30.0		21	27	31	32	7.1
50.0		8.8	9.7	10	11	2.3
80.0		3.1	3.2	3.2	3.4	

[a]Monte Carlo N-Particle uncertainties on all dose rates are less than 5% unless flagged with an asterisk (*).
[b]Point A is at the back of the container (i.e., the top end of the long-length contaminated equipment), points C-G are along the side, and point I is at the front of the container.
[c]The differences between dose rates at points E and G were statistically insignificant.

*Dose rates with uncertainties up to 7%.

Table B5.8-4. 10 and 5 mrem/h Boundaries Around an Unshielded Container.

Dose rate (mrem/h)	Distance (m) from locations identified in Figure B5-1[a]					
	A	C	D	E,G[b]	F	I
10	10	46	49	50	52	25
5	19	65	66	67	69	35

[a]Point A is at the back of the container (i.e., the top end of the long-length contaminated equipment), points C-G are along the side, and point I is at the front of the container.
[b]The difference between dose rates at points E and G were statistically insignificant.

For lower photon source rates, the dose rate to the driver can be reduced to 2 mrem/hr by adding lead shielding only to the back of the cab. Table B5.8-6 shows the relationship between the unshielded dose rate at the driver's location and the amount of lead required on the back of the cab. For unshielded rate rates less than 15 mrem/h, Table B5.8-6 can be used as an alternative to Table B5.8-5.

The data in Tables B5.8-5 and B5.8-6 were based on the results of five MCNP calculations in which dose rates at the driver's position in the tractor cab were tallied. Tallies at an elevation of 100 cm were used because the dose rates in the cab were highest there. The five calculations and the dose rates computed for the worst-case source are summarized in Table B5.8-7. Data in Tables B5.8-5 and B5.8-6 were obtained by interpolating on the data in Table B5.8-7, assuming that:

$$D(x + \Delta x) = D(x)e^{-\mu\Delta x}$$

where, D(x) is the dose rate for some shield thickness x (from Table B5.8-7),
Δx is a change in the shield thickness, and
μ is the attenuation coefficient inferred from data in Table B5.8-7.

Then, the equation was solved for Δx to determine the shielding required to reduce the dose rate, $D(x + \Delta x)$, to 2 mrem/h.

The ratio of lead thickness on the top, bottom, and sides of the cab to the thickness on the back of the cab was maintained at 0.25/3.81 (= 0.066) in Table B5.8-5.

Table B5.8-5. Lead Shielding Required on Back, Sides, Top, and Bottom of Cab As Function of Unshielded Dose Rate.

Unshielded dose rate (mrem/h)	Pb shielding required* (cm) Back	Pb shielding required* (cm) Top, bottom, and sides	Unshielded dose rate (mrem/h)	Pb shielding required* (cm) Back	Pb shielding required* (cm) Top, bottom, and sides
2	0.00	0.00	50	2.64	0.17
3	0.25	0.02	60	2.92	0.19
5	0.56	0.04	70	3.15	0.21
7	0.76	0.05	80	3.35	0.22
10	0.98	0.06	90	3.53	0.23
15	1.22	0.08	100	3.69	0.24
20	1.40	0.09	110	3.84	0.25
30	1.86	0.12	120	3.97	0.26
40	2.30	0.15	130	4.09	0.27

*Thickness of lead shielding required on indicated cab surfaces to reduce the driver's dose rate to 2 mrem/h.

Table B5.8-6. Shielding Required As Function of Unshielded Dose Rate If Lead Is Added Only to Back of Cab.

Unshielded dose rate (mrem/h)	Pb shielding required* (cm) on cab back
2	0.00
3	0.67
7	0.91
10	1.66
15	2.78

*Thickness of lead shielding required to reduce dose rate to the driver to 2 mrem/h.

Table B5.8-7. Cases Used in Relating Dose Rates-to-Lead Shielding Requirements.

Lead shielding (cm) on cab		Computed dose rate* (mrem/h)
Back	Top, bottom, and sides	
0.00	0.00	130 (4%)
1.00	0.00	33 (5%)
2.00	0.00	23 (7%)
1.50	0.10	11 (5%)
3.81	0.25	2.4 (6%)

*Computed dose rates are based on the worst-case source. The Monte Carlo N-Particle estimate of the standard deviation of each dose rate is shown in parentheses.

5.8.2 Listing of ISOSHLD Input File

Listed below is the input file for the ISOSHLD run used to compute the photon source rate as a function of energy for the worst-case analysis. This photon energy distribution was used in all MCNP calculations. The ISOSHLD input file (LLEISO2.IN), along with the corresponding output file (LLEISO2.OUT) are stored in the Hanford Common File System under directory /v90720/llce.

```
0       2  Long Length Equipment Container
Package 6 - Dose to Polyethylene with no shield
 &INPUT NEXT=1, IGEOM=7, NTHETA=15, NPSI=9, DELR=1.0,
 NSHLD=2, JBUF=2, IPRNT=0, OPTION=1,
 SLTH=914.4, Y=457.2, X=53.5, DUNIT=6,
 T(1)=53.34,  T(2)=0.001,
 WEIGHT(451)= 6.07E-02, WEIGHT(472)= 3.32E+01,
 WEIGHT(027)= 2.44E-03, WEIGHT(082)= 2.08E+02,
 WEIGHT(084)= 2.08E+02, WEIGHT(103)= 6.01E-03,
 WEIGHT(102)= 8.77E-03, WEIGHT(117)= 7.57E+00,
 WEIGHT(141)= 1.37E+00, WEIGHT(172)= 8.70E+00,
 WEIGHT(170)= 8.70E+00, WEIGHT(269)= 5.27E+00,
 WEIGHT(290)= 8.52E-04, WEIGHT(319)= 1.39E+00,
 WEIGHT(335)= 9.10E+02, WEIGHT(336)= 8.61E+02,
 WEIGHT(376)= 4.24E+02, WEIGHT(377)= 4.24E+02,
 WEIGHT(388)= 1.58E-01, WEIGHT(403)= 1.68E+00,
 WEIGHT(418)= 1.13E+00, WEIGHT(519)= 2.58E-04,
 WEIGHT(520)= 2.32E-07, WEIGHT(476)= 6.98E-05,
 WEIGHT(502)= 2.96E-04, WEIGHT(492)= 7.72E-03,
 WEIGHT(526)= 1.69E-03, WEIGHT(493)= 4.00E-01,
 WEIGHT(494)= 1.86E-02, WEIGHT(496)= 3.67E-01,
 WEIGHT(495)= 1.79E-01, WEIGHT(499)= 3.81E-04,
 WEIGHT(504)= 1.15E-03, WEIGHT(498)= 3.83E-04,
 WEIGHT(497)= 1.21E-09, WEIGHT(505)= 1.09E-02,
 WEIGHT(500)= 1.58E-03, &
 SOURCE  9  1.6
1 GROUT 16          0.32
 End
 &INPUT NEXT=6 &
```

5.8.3 Summary of MCNP Cases

Table B5.8-8 summarizes all the MCNP cases used in this evaluation, and Includes the names of the input and output files. These files are stored in the Hanford Common File System under directory /v90720/llce.

Table B5.8-8. Summary of Monte Carlo N-Particle Cases.

	File names	
Description	Input	Output
Base case for normal conditions. Photon transport calculation of reference LLCE package design. Dose rates computed at front, back, and side of trailer and at the driver's position.	trlr70ab.inp* trlr70ai.inp	trlr70ab.out trlr70ab.out1 trlr70ai.out
Same geometric model as base case. Dose rates were computed out to 5- mrem/h boundary around trailer.	trlr70ac1.inp trlr70ac2.inp trlr70ac3.inp	trlr70ac1.out trlr70ac2.out trlr70ac3.out
Calculation to determine maximum curie inventory with dose rate to driver < 2 mrem/h. Like the base case, except the tank waste material was changed to air and dose rates were tallied only at the driver's location.	trlr70ad.inp	trlr70ad.out
2.5-cm Pb shield on bottom of cab; 10-cm Pb shield on top, back, and sides. Used to determine driver's dose rate component from photons entering cab through front of cab.	trlr70af1.inp	trlr70af1.out
No Pb shielding on back of cab; 10-cm Pb shield on top, bottom, and sides. Used to determine driver's dose rate component from photons entering cab through back of cab.	trlr70ae4.inp	trlr70ae4.out
No Pb shielding on bottom of cab; 10-cm Pb shield on top, back, and sides. Used to determine driver's dose rate component from photons entering cab through floor of cab.	trlr70af3.inp	trlr70af3.out trlr70af3.out5
No Pb shielding on top of cab; 10-cm Pb shield on bottom, back, and sides. Used to determine driver's dose rate component from photons entering cab through top of cab.	trlr70ag3.inp	trlr70ag3.out
No Pb shielding on sides of cab; 10-cm Pb shield on top, back, and bottom. Used to determine driver's dose rate component from photons entering cab through sides of cab.	trlr70ah3.inp	trlr70ah3.out trlr70ah3.out2
3.81-cm Pb shield on back of cab; 0.25-cm Pb shield on top, bottom, and sides. Dose rates were tallied at the driver's position.	trlr70aj2.inp	trlr70aj2.out trlr70aj2.out2
1.5-cm Pb shield on back of cab; 0.1-cm Pb shield on top, bottom, and sides. Dose rates were tallied at the driver's position.	trlr70aj3.inp	trlr70aj3.out
1-cm Pb shield on back of cab; no other Pb shielding on cab. Dose rates were tallied at the driver's position.	trlr70ak1.inp	trlr70ak1.out trlr70ak1.out2
2-cm Pb shield on back of cab; no other Pb shielding on cab. Dose rates were tallied at the driver's position.	trlr70ak2.inp	trlr70ak2.out
Loaded LLCE container, unshielded, on ground. Dose rates were computed out to 5-mrem/h boundary around container.	cntr70a.inp	cntr70a.out

LLCE = Long-length contaminated equipment.

*Input file trlr70ab.inp is listed in Section 5.8.4.

5.8.4 Listing of MCNP Input File for Base Case

```
 LLCE trailer--70 ft container - transport calc.  trlr70ab
c  trlr70ab - 3" th front shield - no guillotine shld
c  calc dose on 3 sides of trailer at 0,1&2m, and at driver loc.
c  Like trlr70j, except air replaces grout inside container, 3" th. frnt shld,
c  side shlds extend to front shld, & E biasing
c
  1  1  -7.80    -1   +2   3   -4    5    -6  $trlr deck
  2  2  -0.95    -7    8  16  -17            $poly container
  3  2  -0.95    -7   10 -16                 $back poly endcap
  4  2  -0.95    -7  -11  17                 $front poly endcap
  5  1  -7.80    -9   14 -15  20 -21          $skid sides
  6  1  -7.80    -9  -15  16 -20             $skid back end
  7  1  -7.80    -9  -15 -17  21             $skid front end
  8  3  -0.00129 -8   16 -17  #5  #6  #7        $rest of container
```

```
                (26:-42:21)
  9   4  -1.6     -21    24  -25                 $source region
 10   1  -7.80    -21    42  25 -26               $LLE pipe
 11   3  -0.00129 -31    5  -27  1   -4   3        $Gilatine shld
              (-28:-29:30)
 12   1  -7.80    -41    31  -32  1   -33  3       $Rt. side plate
 13   1  -7.80    -41    31  -32  1    -4  34      $Left side plate
 14   1  -7.80    -36    11  -37  1   -39  38       $5'x5'x.5" front plate
 15   1  -7.80     -6   41  -40  1   -4   3      $Front shld (6' tall)
 16   3  -0.00129  42   -24  -25                 $Inside empty end of pipe
 30   5  -2.28      50 -51  52 -53 44 -43           $top grnd level
 31   5  -2.28      50 -51  52 -53 45 -44           $2nd grnd level
 32   5  -2.28      50 -51  52 -53 46 -45           $3rd grnd level
 50   3  -0.00129  ( #1 #11 #12 #13 #14 #15 )        $ outside cont., above grnd
               ( 7 : -10 : 11 ) 43 -999
 51   0          -43 (-46:-50:51:-52:53) -999      $ outsode area below grnd lvl
999   0   999                                  $outside universe

  1  pz    228.600              $ top of tlr deck
  2  pz    227.965              $bottom of trlr deck
  3  py      0.0              $right side of trlr
  4  py     287.020              $ left side of trlr
  5  px      0.0              $ rear of trlr deck
  6  px    2316.480              $ front of trlr deck
  7  c/x   143.510   335.4324   85.090   $ cont outer surf
  8  c/x   143.510   335.4324   81.9150  $ cont inner surf
  9  pz    330.0413                 $ top of skid
 10  px     33.8836                 $ outside back end 70' cont
 11  px    2167.4836                  $outside front end 70' cont
 12  px     80.010                  $outside back end 52' cont
 13  px    1664.970                   $outside front end 52' cont
 14  c/x   143.510   330.0413   74.2950  $inside skid surf
 15  c/x   143.510   330.0413   74.7713  $outside skid surf
 16  px     38.8112                 $inside back end 70' cont
 17  px    2162.5560                  $inside front end 70' cont
 18  px     84.9376                 $inside back end 52' cont
 19  px    1660.0424                  $inside front end 52' cont
 20  px     39.2875                 $inside back end 70'skid
 21  px    2162.0798                  $inside front end 70' skid
 22  px     85.4139                 $inside back end 52' skid
 23  px    1659.5662                  $inside front end 52' skid
 24  px    1247.8798                  $back of source region
 25  c/x   143.510   309.73     53.34    $source region
 26  c/x   143.510   309.73     53.98    $LLE pipe
 27  pz    441.96                 $Top of gilatine shld
 28  pz    250.34                 $Top of opening in gil. shld
 29  py     58.40                 $Left side of opening in gil.shld
 30  py    228.62                  $Rt. side of opening in gil.shld
 31  px      2.54                 $Front edge of gil. shld
 32  pz    340.36                 $Top of side shlds
 33  py      1.27                 $Inside edge of rt. side shld
 34  py    285.75                  $Inside edge of left side shld
 36  px    2168.75                  $Front of 5'x5'x.5" front plate
 37  pz    381.00                 $Top of 5'x5'x.5" front plate
 38  py     67.31                 $Rt. side of 5'x5'x.5" front plate
 39  py    219.71                  $Left side of 5'x5'x.5" front plate
 40  pz    411.48                 $Top of 6' front shld
 41  px    2308.86                  $Rear of 6' front shld (3" th)
 42  px    272.32                 $Back end of 62' pipe
 43  pz      0.00                $Ground level
 44  pz     -7.00
 45  pz    -14.00
 46  pz    -21.00
 50  px   -1000.00
 51  px    3400.00
 52  py   -1000.00
 53  py    1000.00
999  s     1158.240   143.510   0.0    4000   $ outside universe marker

mode   p
phys:p  10   1   1
c    idum     2
imp:p     1    1    1    1    1
        1    1    1    1    1
        1    1    1    1    1
        1    1   0.5  0.25    1
        0    0
prdmp   j -480
c    nps    40000
ctme  1500
```

```
sdef     wgt=4.681e13     erg=d1
       pos= 1704.8798    143.510    309.73
       axs=    1          0          0
       rad=d2       ext=d3     cel=9
#      si1          sp1         sb1
       l            d           d
c    Average    Source Total    Source
c    E, MeV     photons/sec     Bias
c    -----------------------------------1
     0.015      2.496E+12      0.25
     0.025      1.372E+12      0.14
     0.035      4.253E+12      0.40
     0.045      8.709E+11      0.10
     0.055      4.149E+11      0.05
     0.065      3.177E+11      0.04
     0.075      2.618E+11      0.03
     0.085      4.993E+11      0.05
     0.095      2.149E+11      0.02
     0.150      3.002E+12      0.25
     0.250      3.994E+11      0.08
     0.350      2.002E+11      0.05
     0.475      2.977E+11      0.10
     0.650      2.928E+13     14.00
     0.825      2.412E+11      0.14
     1.000      3.261E+10      0.02
     1.225      2.476E+12      0.20
     1.475      5.809E+10      0.05
     1.700      2.796E+09      0.01
     1.900      1.189E+09      0.01
     2.100      1.213E+11      0.15
     2.300      1.935E+08      0.004
     2.500      5.875E+07      0.002
     2.700      1.282E+07      0.001
     3.000      2.542E+06      0.0004
     3.600      1.198E+05      0.00004
c    ----------------------------------
c    Total     4.681E+13 photon/sec
c
  si2  0.  53.34
  sp2  -21   1
  si3      456.98
c
c
  m1     26000      1.0   $ Fe
c
  m2      1001.01p  0.666666  $ H    polyethylene  (CH4)n
        6000       0.333334  $ C
c
  m3      8016.01p  0.21  $ O       air
        7014.01p   0.79  $ N
c
  m4   1001.01p  .4372      $H 101 SY Slurry
       6000       .0170      $C
       7014.01p   .0579      $N
       8016.01p   .3725      $O
      11023.01p   .0975      $Na
      13027.01p   .0113      $Al
      15031.01p   .0011      $P
      17000       .0029      $Cl
      19000       .0026      $K
  m5   8016.01p -.4407       $O   grout weight fraction
      14000      -.2157      $Si
      20000      -.1306      $Ca
      26000      -.0788      $Fe
      13027.01p -.0607       $Al
      12000      -.0376      $Mg
      19000      -.0066      $K
      11023.01p -.0182       $Na
      22000.01p -.0049       $Ti
       1001.01p -.0031       $H
      25055.01p -.0013       $Mn
      15031.01p -.0009       $P
      16032.01p -.0009       $S
c
c    ansi/ans-6.1.1-1991
c    fluence-to-dose,photons(mrem/hr/(p/cm**2/s)
de0   log  .01 .015 .02 .03 .04 .05
          .06 .08 .10 .15 .20 .30
          .40 .50 .60 .80 1.0 1.5
           2.0 3.0 4.0 5.0 6.0 8.0
```

```
        10. 12.
 df0    log 2.232e-5 5.652e-5 8.568e-5 1.184e-4 1.314e-4 1.382e-4
         1.440e-4 1.624e-4 1.919e-4 2.797e-4 3.708e-4 5.616e-4
         7.416e-4 9.144e-4 1.076e-3 1.379e-3 1.656e-3 2.246e-3
         2.758e-3 3.672e-3 4.500e-3 5.292e-3 6.012e-3 7.488e-3
         8.892e-3 1.040e-2
c
fc5     cold end dose rate traverse
f5:p    $  X      Y      Z      R0
         -2      31     2      1   $ contact DR
         -2      31     61     1
         -2      31     122    1
         -2      31     183    1
         -2      31     244    1
         -2      31     305    1
        -100     31     2      1   $ 1 meter DR
        -100     31     61     1
        -100     31     122    1
        -100     31     183    1
        -100     31     244    1
        -100     31     305    1
        -200     31     2      1   $ 2 meter DR
        -200     31     61     1
        -200     31     122    1
        -200     31     183    1
        -200     31     244    1
        -200     31     305    1
         -2      144    2      1   $ contact DR
         -2      144    61     1
         -2      144    122    1
         -2      144    183    1
         -2      144    244    1
         -2      144    305    1
        -100     144    2      1   $ 1 meter DR
        -100     144    61     1
        -100     144    122    1
        -100     144    183    1
        -100     144    244    1
        -100     144    305    1
        -200     144    2      1   $ 2 meter DR
        -200     144    61     1
        -200     144    122    1
        -200     144    183    1
        -200     144    244    1
        -200     144    305    1
c
c       trailer side dose rate traverses
c
f15:p   $   X       Y      Z      R0   $ Rear corner of trailer
          0       -2     2      1   $ Contact DR
          0       -2     61     1
          0       -2     122    1
          0       -2     183    1
          0       -2     244    1
          0       -2     305    1
          0      -100    2      1   $ 1 meter DR
          0      -100    61     1
          0      -100    122    1
          0      -100    183    1
          0      -100    244    1
          0      -100    305    1
          0      -200    2      1   $ 2 meter DR
          0      -200    61     1
          0      -200    122    1
          0      -200    183    1
          0      -200    244    1
          0      -200    305    1
f25:p   $   X       Y      Z      R0   $ mid non src, side trlr
         625      -2     2      1   $ Contact DR
         625      -2     61     1
         625      -2     122    1
         625      -2     183    1
         625      -2     244    1
         625      -2     305    1
         625     -100    2      1   $ 1 meter DR
         625     -100    61     1
         625     -100    122    1
         625     -100    183    1
         625     -100    244    1
         625     -100    305    1
```

```
        625   -200   2     1   $ 2 meter DR
        625   -200   61    1
        625   -200   122   1
        625   -200   183   1
        625   -200   244   1
        625   -200   305   1
f35:p   $ X     Y    Z     R0  $ backend of src, side trlr
        1248  -2     2     1   $ Contact DR
        1248  -2     61    1
        1248  -2     122   1
        1248  -2     183   1
        1248  -2     244   1
        1248  -2     305   1
        1248  -100   0     1   $ 1 meter DR
        1248  -100   61    1
        1248  -100   122   1
        1248  -100   183   1
        1248  -100   244   1
        1248  -100   305   1
        1248  -200   0     1   $ 2 meter DR
        1248  -200   61    1
        1248  -200   122   1
        1248  -200   183   1
        1248  -200   244   1
        1248  -200   305   1
f45:p   $ X     Y    Z     R0  $ mid src, side trlr
        1705  -2     2     1   $ Contact DR
        1705  -2     61    1
        1705  -2     122   1
        1705  -2     183   1
        1705  -2     244   1
        1705  -2     305   1
        1705  -100   2     1   $ 1 meter DR
        1705  -100   61    1
        1705  -100   122   1
        1705  -100   183   1
        1705  -100   244   1
        1705  -100   305   1
        1705  -200   2     1   $ 2 meter DR
        1705  -200   61    1
        1705  -200   122   1
        1705  -200   183   1
        1705  -200   244   1
        1705  -200   305   1
f55:p   $ X     Y    Z     R0  $ frontend src, side trlr
        2162  -2     2     1   $ Contact DR
        2162  -2     61    1
        2162  -2     122   1
        2162  -2     183   1
        2162  -2     244   1
        2162  -2     305   1
        2162  -100   2     1   $ 1 meter DR
        2162  -100   61    1
        2162  -100   122   1
        2162  -100   183   1
        2162  -100   244   1
        2162  -100   305   1
        2162  -200   2     1   $ 2 meter DR
        2162  -200   61    1
        2162  -200   122   1
        2162  -200   183   1
        2162  -200   244   1
        2162  -200   305   1
f65:p   $ X     Y    Z     R0  $ front corner of trailer
        2300  -2     2     1   $ Contact DR
        2300  -2     61    1
        2300  -2     122   1
        2300  -2     183   1
        2300  -2     244   1
        2300  -2     305   1
        2300  -100   2     1   $ 1 meter DR
        2300  -100   61    1
        2300  -100   122   1
        2300  -100   183   1
        2300  -100   244   1
        2300  -100   305   1
        2300  -200   2     1   $ 2 meter DR
        2300  -200   61    1
        2300  -200   122   1
        2300  -200   183   1
```

```
        2300    -200    244     1
        2300    -200    305     1
f75:p   $  X      Y      Z     R0   $ end trlr thru truck
        2319     144     2      1   $ Contact DR
        2319    144     61      1
        2319    144     122     1
        2319    144     183     1
        2319    144     244     1
        2319    144     305     1
        2417     144     2      1   $ 1 m DR
        2417    144     61      1
        2417    144     122     1
        2417    144     183     1
        2417    144     244     1
        2417    144     305     1
        2517     144     2      1   $ 2 m DR
        2517    144     61      1
        2517    144     122     1
        2517    144     183     1
        2517    144     244     1
        2517    144     305     1
fc85    Truck Driver dose rate: 3' left of CL, 5' ahead of trlr
f85:p     2469     235     61     1
        2469     235     122     1
        2469     235     183     1
        2469     235     244     1
        2469     235     305     1    $ level with src
```

5.8.5 Checklist for Independent Technical Review

HNF-SD-TP-ANAL-008 Rev. 0

CHECKLIST FOR INDEPENDENT TECHNICAL REVIEW

DOCUMENT REVIEWED
NUMBER: HNF-SD-TP-ANAL-008
TITLE: SARP SHIELDING AND CRITICALITY EVALUATIONS OF LONG LENGTH CONTAMINATED EQUIPMENT TRANSPORTATION PACKAGES
Reviewer(s): H. J. Goldberg

I. Method(s) of Review

- (✓) Input data checked for accuracy
- (NA) Independent calculation performed
  - (NA) Hand calculation
  - (NA) Alternate computer code: ______
- (NA) Comparison to experiment or previous results
- (NA) 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
- (NA) 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
- (NA) Use of resource outside range of established validity is justified
- (✓) Software runstreams correct and consistent with results
- (✓) Software output consistent with input
- (NA) 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
- (NA) Conclusions consistent with analytical results and established limits
- (NA) Uncertainty assessment appropriate and reasonable
- (NA) Other (define) ______

III. Comments: ______

IV. REVIEWER: [signature] DATE: 26 March 1997

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6.0 CRITICALITY EVALUATION

6.1 INTRODUCTION

This criticality evaluation supports the shipment of packages containing LLCE from Hanford 200 Area waste tanks. The LLCE packages are to be shipped to a solid waste burial ground also in the 200 Area. The LLCE after removal from a waste tank could contain up to 39 g of fissile material.

A package containing a significant quantity of fissile material must be controlled during transport to ensure that an array of such packages remains subcritical. To maintain this control, 10 CFR 71 requires that a number N be assigned based on the following conditions being satisfied.

- Five times N undamaged packages with nothing between them must remain subcritical even if reflected on all sides by water.
- Each shipment of two times N packages is to remain subcritical under hypothetical accident conditions with optimum moderation and close reflection by water.

The value assigned to N in this case is 0.5 because each shipment will contain only one package. Thus, the requirements are that three undamaged packages must remain subcritical under normal transfer conditions, and a single package must remain subcritical under accident conditions.

The conclusion of this analysis is all LLCE BCs will remain subcritical under any circumstances.

6.2 CRITICALITY SOURCE SPECIFICATION

The source term used in the criticality analysis of the proposed LLCE shipments was based on a worst-case evaluation. This source term was previously described in Part B, Section 2.0. From the curie inventories given there, the masses of fissile isotopes plus ^{238}U were computed and are listed in Table B6-1. The only fissile isotopes of significance are ^{235}U (32.7 g) and ^{239}Pu (6.4 g). The mass of ^{238}U is 5,030 g, and thus the ^{235}U content of the uranium is 0.65 wt%.

Table B6-1. Maximum Fissile Inventory in a Long-Length Contaminated Equipment Transportation Package.

	Inventory	
Nuclide	Curies	Grams
^{233}U	2.58 E-04	0.03
^{235}U	6.98 E-05	32.7
^{238}U	1.69 E-03	5030
^{239}Pu	4.00 E-01	6.4
^{241}Pu	1.79 E-01	0.002

6.3 SUMMARY OF CRITICALITY PROPERTIES OF MATERIALS

The minimum critical masses of ^{235}U and ^{239}Pu in water are 820 g and 530 g, respectively (Carter et al. 1969). The minimum critical masses of these nuclides is somewhat less in other moderating media with low-capture cross sections, but is still on the order of hundreds of grams. For example, the minimum critical masses for ^{239}Pu in polyethylene is 370 g (Davenport 1977).

Except for highly optimized arrangements of fuel and moderator found only in reactor cores, uranium cannot be made critical with ^{235}U enrichments less than 1%. Uranium of natural enrichment (0.71 wt% ^{235}U) will not go critical with optimal light water moderation.

6.4 NORMAL TRANSFER CONDITIONS

As discussed in Section 6.1, three undamaged packages must remain subcritical under normal transfer conditions. Thus, three packages in close proximity with optimal water reflection on all sides must be evaluated.

With three packages, the total fissile mass is 117 g (^{235}U + ^{239}Pu). This quantity is much less than the minimum critical mass for either ^{235}U or ^{239}Pu given in Section 6.3. Also, the concentration of ^{235}U in uranium is only 0.65 wt%. With ^{235}U enrichment less than 1%, uranium cannot be made critical outside of a reactor facility. Thus, any number of packages could be stacked together without the possibility of a criticality.

6.5 ACCIDENT CONDITIONS

Under accident conditions, a single package must remain subcritical when water- flooded and optimally moderated. One package contains only 39 g of fissile material (^{235}U + ^{239}Pu). As for normal transfer conditions, this quantity is much less than the minimum critical mass for either ^{235}U or ^{239}Pu. Also, water-moderated uranium with a ^{235}U contents of only 0.65 wt% cannot be made critical under any condition.

6.6 CRITICAL BENCHMARK EXPERIMENTS

Because no criticality calculations were necessary, this section is not applicable.

6.7 CRITICALITY EVALUATION AND CONCLUSIONS

This criticality evaluation establishes that there is no possibility of a nuclear criticality accident under any scenario in the loading, transportation, and disposal of LLCE containing the worst-case fissile inventory specified in Part B, Section 2.0. The low total fissile mass and concentration preclude a self-sustaining neutron chain reaction from occurring under both normal and accident conditions.

6.8 REFERENCES

10 CFR 71, 1988, "Packaging and Transportation of Radioactive Material," *Code of Federal Regulations*, as amended.

Carter, R. D., et al., 1969, *Criticality Handbook*, ARH-600, Vol. II, Atlantic Richfield Hanford Company, Richland, Washington.

Davenport, L. C. and J. K. Thompson, 1977, "A Survey of Criticality Parameters for ^{239}Pu in Organic Media," *Trans. Am. Nucl. Soc.*, Vol. 77, p 419.

6.9 APPENDIX: CHECKLIST FOR INDEPENDENT TECHNICAL REVIEW

HNF-SD-TP-ANAL-008 Rev. 0

CHECKLIST FOR INDEPENDENT TECHNICAL REVIEW

DOCUMENT REVIEWED
NUMBER: HNF-SD-TP-ANAL-008
TITLE: SARP SHIELDING AND CRITICALITY EVALUATIONS OF LONG LENGTH CONTAMINATED EQUIPMENT TRANSPORTATION PACKAGES
Reviewer(s): H. J. Goldberg

I. Method(s) of Review

(✓) Input data checked for accuracy
(NA) Independent calculation performed
(NA) Hand calculation
(NA) Alternate computer code: ____
(NA) Comparison to experiment or previous results
(NA) 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
(NA) 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
(NA) Use of resource outside range of established validity is justified
(✓) Software runstreams correct and consistent with results
(✓) Software output consistent with input
(NA) 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
(NA) Conclusions consistent with analytical results and established limits
(NA) Uncertainty assessment appropriate and reasonable
(NA) Other (define) ____

III. Comments: ____

IV. REVIEWER: [signature] DATE: 26 March 1997

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7.0 STRUCTURAL EVALUATION

7.1 INTRODUCTION

The LLCE BC is used for macroencapsulation or packaging of long-length items removed from the risers of SSTs and DSTs in the Hanford tank farms and transported to a disposal or storage facility. Examples of LLCE items include transfer pumps, instrument trees, air lift circulators, and air lances. There are approximately 1,900 LLCE items installed in the SSTs and DSTs at present. Of these 1,900 LLCE items, there are over 585 different types of LLCE, weighing from 181-9,072 kg (400-20,000 lb) and ranging in size from 10-152 cm (4-60 in.) in diameter by 10-19 m (32-62 ft) in length. The BC is a family of containers that come in eight different sizes.

The primary purpose of this section is to demonstrate that the LLCE BC provides structural containment for the retrieved LLCE items during normal transfer conditions, thus meeting the requirements of WHC-CM-2-14.

7.2 STRUCTURAL EVALUATION OF PACKAGE

As part of the initial procurement, the BC design and fabrication contract stipulated that the vendor provide detailed structural analysis based on the requirements of the PDC (WHC 1995). A confirmatory analysis (see Section 7.7.1) was performed to ensure that the vendor calculations were accurate. The vendor analysis is presented in Section 7.7.2. There is some disagreement with the conservative burial overburden calculations provided by the vendor (this is not a transportation issue). Prior to burial of the BC, a structural analysis of the BC, based on the amount of overburden to be applied, should be performed. In general, however, the confirmatory calculations show that the vendor-supplied analysis is correct.

7.2.1 Structural Design and Features

The LLCE BCs are constructed entirely of HDPE. The container body consists of various sizes of commercially available polyethylene pipe joined in sections using a butt-fusion process with powercore wire. The end caps are also manufactured from machined pieces of polyethylene and are fusion welded to the container using the same powercore wire welding process. Foam disks are glued to each end cap to allow for linear thermal expansion and contraction of the container, which prevents the void fill material from providing significant stress to the end caps once the container is sealed. The end caps have leak test, void fill, and vent penetrations, which are sealed with polyethylene plugs when operations are concluded.

The end cap inner radius is machined with a recess containing an inflatable seal, which allows for centering of the end cap when placed on the BC and provides an area to be pressurized for leak testing. The power core wire is also preinstalled in the end caps for fusion welding the cap to the container.

All components of the BC are fabricated per drawings H-2-827806 through H-2-827835. See Part A, Section 10.0, for a complete list of drawings.

The following codes and standards were used in the design and fabrication of the BCs:

- ANSI Y14.5M, "Dimension and Tolerencing" (ANSI 1996)
- ANSI N14.5, *American National Standard for Radioactive Materials--Leakage Tests on Packages for Shipment* (ANSI 1987)

- ANSI N14.6, *American National Standard for Radioactive Materials--Special Lifting Devices for Shipping Containers Weighing 10,000 Pounds (4500 kg) or More* (ANSI 1993)

- ANSI N14.23, *Draft American National Standard Design Basis for Resistance to Shock and Vibration of Radioactive Material Packages Greater than One Ton in Truck Transport* (ANSI 1992)

- ASTM D638, "Test Method for Tensile Properties of Plastics," Vol. 8.01 (ASTM 1996)

- ASTM D746, "Test Method for Brittleness Temperature of Plastics and Elastomers by Impact," Vol. 8.01 (ASTM 1996)

- ASTM D792, "Test Methods for Specific Gravity (Relative Density) and Density of Plastics by Displacement," Vol. 8.01 (ASTM 1996)

- ASTM D883, "Terminology Relating to Plastics," Vol. 8.01 (ASTM 1996)

- ASTM D1238, "Test Methods for Flow Rates of Thermoplastics by Extrusion Plastomer," Vol. 8.01 (ASTM 1996)

- ASTM D1248, "Specification of Polyethylene Plastics Molding and Extrusion Materials," Vol. 8.01 (ASTM 1996)

- ASTM D1505, "Test Method for Density of Plastics by the Density-Gradient Technique," Vol. 8.01 (ASTM 1996)

- ASTM D1693, "Test Method for Environmental Stress-Cracking of Ethylene Plastics," Vol. 8.02 (ASTM 1996)

- ASTM D1898, "Practice for Sampling Plastics," Vol. 8.02 (ASTM 1996)

- ASTM D1928, "Practice for Preparation of Compression-Molded Polyethylene Test Sheets and Test Specimens," Vol. 8.02 (ASTM 1996)

- ASTM D2837, "Test Method for Obtaining Hydrostatic Design Basis for Thermoplastic Pipe Materials," Vol. 8.02 (ASTM 1996)

- ASTM D4991, "Test Method for Leak Testing Empty Containers by Vacuum Method," Vol. 8.03 (ASTM 1996)

- ASTM E1003, "Test Method for Hydrostatic Leak Testing," Vol. 3.03 (ASTM 1996)

- ASTM E1027, "Standard Practice for Exposure of Polymeric Materials to Ionizing Radiation," Vol. 12.02 (ASTM 1996)

- ASTM G21, "Recommended Practice for Determining Resistance of Synthetic Polymeric Material to Fungi," Vol. 8.01 (ASTM 1996)

- ASTM G22, "Recommended Practice for Determining Resistance of Plastics to Bacteria," Vol. 8.01 (ASTM 1996)

- ASTM G53, "Recommended Practice for Operating Light and Water Exposure Apparatus to Nonmetallic Materials," Vol. 8.01 (ASTM 1996)

- ANSI/AWS D1.1-89, *Structural Welding Code–Steel* (AWS 1989)
- *SAE Handbook*, Volume 1, "Materials" (SAE 1996).

In addition, to evaluate transportation shock loads, UMTRI-87-28, *Engineering Analysis of Cargo Restraint on Commercial Highway Trucks* (Gillespie 1987), was utilized.

7.2.2 Mechanical Properties of Materials

The HDPE material used for the BC is Type III, Class C, Category 5, Grade P34 HDPE, meeting ASTM D1248, "Standard Specification for Polyethylene Plastics Molding and Extrusion Materials." This material has a nominal density of 0.941 - 0.959 g/cm^3 and is weather resistant, containing greater than 2% carbon black. The yield strength, modulus of elasticity, and brittle fracture properties of the material are temperature dependent. Viscoelastic creep and the effect of irradiation are time dependent. The fatigue strength of the material is given in Section 7.7.2.

Section 7.7.1 contains confirmatory calculations of the vendor design calculations in Section 7.7.2. Section 7.7.2 contains detailed data on the material properties associated with HDPE as described above. The material is very suitable from a structural standpoint for its intended purpose.

7.2.3 Chemical and Galvanic Reactions

Chemical wastes from various activities, including plutonium extraction from spent nuclear fuel, laboratory analyses, and other national defense support activities, were deposited in SSTs from 1944 to 1980. From 1980 to the present, chemical wastes from similar activities have been deposited in the DSTs. The most recent comprehensive list of potential contaminants is available in WHC-SD-WM-TCP-007, *Disposal of Tank Farm Long-Length Contaminated Equipment, Chemical Characterization Plan* (Roach 1995). A thorough review of the chemical compatibility of HDPE with these chemicals is provided in Part B, Section 2.5. HDPE is found to be acceptable as a material for containing the types and concentrations of chemicals expected to be remaining on the LLCE items removed from the SSTs and DSTs.

7.2.4 Size of Package and Cavity--Weights and Center of Gravity

There are eight different sizes of BCs, as shown in Table B7-1. Cavity size varies for each member of the LLCE BC family. Table B7-2 provides the internal volume for each container size.

The center of gravity for the empty BC will be found in the approximate geometric center. The center of gravity for a loaded container will vary, depending on the type of LLCE item installed and whether or not the BC is void filled. Weight distribution calculations will be required on a case-by-case basis to determine the proper distribution of lifting slings.

7.2.5 Positive Closure

The end caps are fused to the BC by applying a current to the preinstalled powercore material in the end cap. The current causes the powercore to fuse the end cap and BC material together, thus creating a homogenous unit that retains approximately 90% of the HDPE original material properties and provides a leak-testable seal. After fusing the end cap to the container using the powercore, the seal is leak tested by means of an inflatable seal and leak test ports. The annulus around the inner cavity of the BC and end cap is pressurized, and the outer perimeter of the container weld zone is bubble leak checked.

Table B7-1. Long-Length Contaminated Equipment Burial Container Sizes.

Container	Length m (ft)	Outside diameter cm (in.)	Wall thickness cm (in.)	Empty weight kg (lb)	Maximum gross weight kg (lb)
C1	17.07 (56)	70.6 (26)	2.24 (0.88)	735 (1,617)	5,127 (11,280)
C2	22.25 (73)	70.6 (26)	2.24 (0.88)	940 (2,066)	6,635 (14,597)
C3	17.34 (56.9)	91.4 (36)	3.10 (1.22)	1,430 (3,147)	9,264 (20,380)
C4	22.32 (73.2)	91.4 (36)	3.10 (1.22)	1,822 (4,008)	12,642 (27,812)
C5	22.37 (73.4)	137.8 (54.25)	4.65 (1.83)	4,214 (9,270)	27,335 (60,137)
C6	17.42 (57.1)	160.8 (63.32)	5.21(2.05)	4,427 (9,740)	28,792 (63,342)
C7	22.39 (73.5)	160.8 (63.32)	5.21(2.05)	5,589 (12,295)	43,208 (95,058)
C9	17.39 (57.1)	137.8 (54.25)	4.65 (1.83)	3,315 (7,292)	21,963 (46,118)

Table B7-2. Long-Length Contaminated Equipment Burial Container Cavity Volumes.

Burial container	Volume (ft^3)
C1	176
C2	229
C3	338
C4	438
C5	995
C6	1,050
C7	1,362
C9	767

7.2.6 Brittle Fracture

Brittle fracture is not a concern with HDPE. However, crack propagation due to fatigue in potential high-stress areas can be concern during transport operations. High-stress areas associated with the loaded BC are the weld zones. As such, the following guidelines are given for inspection of weld areas for defects. Any defect exceeding these guidelines shall be repaired per HNF-SD-WM-SPP-002 (PHMC 1997a):

- Internal Defect: flat bottom circular hole less than 3.2 mm (0.125 in.) equivalent spaced 1.3 cm (0.5 in.) apart
- External Scratch: less than 50.8 cm (20 in.) long x (0.038 in.) deep spaced 3.8 cm (1.5 in.) apart
- External Gouge: less than 6.4 mm (0.25 in.) long x (0.100 in.) deep spaced 3.8 cm (1.5 in.) apart.

7.3 NORMAL TRANSFER CONDITIONS

7.3.1 Conditions To Be Evaluated

For normal transfer conditions, the following requirements must be satisfied per the packaging design criteria (WHC 1995).

7.3.1.1 Leak-Testable Seal. The BC lid must incorporate and demonstrate a leak-testable boundary once permanently sealed. Acceptance criteria for leakage rate testing for all containers is a leak rate equal to or less than 1.0×10^{-3} standard cm^3/s (air [ANSI N14.5 (ANSI 1987)]).

7.3.1.2 Water Spray. The BC shall be designed such that water sprayed from any direction onto the BC will not remain standing on the package.

7.3.1.3 Lifting and Handling. The structural analysis for lifting and handling the BCs shall consider the void fill to be a maximum of 100% of the available container volume.

7.3.1.4 Increased Internal Pressure. The BCs shall be capable of withstanding an increased internal pressure of 50.7 kPa gauge (7.35 psig).

7.3.1.5 Puncture. The BC shall be capable of withstanding, without failure, the impacting force of a bar 3.2 cm (1.25 in.) in diameter with a hemispherical end weight of 6 kg (13.2 lb), dropped from a height of 1 m (3.3 ft) onto that part of the container where maximum damage is expected to occur.

7.3.1.6 Temperature. The BCs shall be capable of being transported over a temperature range from 0-37.8 °C (32-100 °F).

7.3.1.7 Shock and Vibration. The BCs shall be designed and constructed such that when loaded with the LLCE, void filled, and tied down to the transport trailer, they maintain containment when subjected to normal transport shock and vibration loadings. The minimum shock loading to be evaluated in the design of the BC shall be 0.75*g* applied in the longitudinal direction to simulate hard braking. The minimum vibration loadings shall be derived from ANSI N14.23 (ANSI 1992).

7.3.2 Acceptance Criteria

7.3.2.1 Leak Rate. A bubble check using He/N_2 with a minimum 15-minute soak time and a minimum delta pressure of 21-35 kPa gauge (3-5 psig) shall be an acceptable test method.

7.3.2.2 Water Spray. No water shall be standing on the package after water spray.

7.3.2.3 Lifting and Handling. A positive margin of safety must be demonstrated.

7.3.2.4 Increased Internal Pressure. A positive margin of safety must be demonstrated.

7.3.2.5 Puncture. No damage shall be visible to the BC.

7.3.2.6 Temperature. A positive margin of safety must be demonstrated.

7.3.1.7 Shock and Vibration. A positive margin of safety must be demonstrated.

7.3.3 Structural Model

The structural model is described in Section 7.7.2.

7.3.4 Initial Conditions.

7.3.4.1 Environmental Heat Loading. The initial temperature conditions were given as a range from 0-37.8 °C (32-100 °F) for normal transport. Internal thermal decay heat was not modeled as it is so small as to be insignificant. The maximum internal pressure was given as 50.7 kPa gauge (7.35 psig).

7.3.4.2 Maximum Thermal and Pressure Stresses. Maximum thermal and pressure stresses are given in Section 7.7.2.

7.4 ACCIDENT CONDITIONS

Accident conditions are not specifically modeled in this evaluation. A radiological risk evaluation and a dose consequence evaluation demonstrate that the LLCE BCs can be safely transported on the Hanford Site. For risk evaluation purposes, an evaluation of the effects of a 14,515-kg (32,000-lb) crush load is performed in Section 7.7.2, demonstrating that the BC can withstand a hypothetical load.

7.5 STRUCTURAL EVALUATION AND CONCLUSIONS

The LLCE BC design, based on the transport evaluations required in the approved packaging design criteria document, has been demonstrated to provide the structural integrity necessary to transport the LLCE payload. Leak rate and puncture bar tests are documented in *Test Report for Long-Length Contaminated Equipment Burial Container* (PHMC 1997b).

7.5.1 Leak Rate

The BC design prototype was tested using the bubble leak check and passed, demonstrating that the powercore fusion process is a viable closure method. The lid penetrations were plugged, sealed, and bubble leak checked. There were no leaks.

7.5.2 Water Spray

The BC is a right circular cylinder constructed of HDPE. There are no crevices or gaps where water could be retained. The test was not performed due to the nature of the design. It is impossible for water to stay on the container.

7.5.3 Lifting and Handling

Section 7.7.2 provides the analyses demonstrating that the BC can be lifted and handled, empty or loaded, with an adequate margin of safety.

7.5.4 Increased Internal Pressure

Section 7.7.2 provides the analyses demonstrating that the BC can withstand an increased internal pressure of 50.7 kPa gauge (7.35 psig) with an adequate margin of safety.

7.5.5 Puncture Bar

The required test was performed on the prototype BC. There was no visible damage.

7.5.6 Temperature

The material properties of the BC material, listed in Section 7.7.2, demonstrate that transporting the BC over the specified temperature range is acceptable.

7.5.7 Shock and Vibration

Section 7.7.2 provides the analyses demonstrating that the BC can be subjected to the specified loads and maintain an adequate margin of safety.

7.6 REFERENCES

ANSI, 1996, *Dimension and Tolerencing*, ANSI Y14.5M, American National Standards Institute, New York, New York.

ANSI, 1993, *American National Standard for Radioactive Materials--Special Lifting Devices for Shipping Containers Weighing 10,000 Pounds (4500 kg) or More*, ANSI, N14.6, American National Standards Institute, New York, New York.

ANSI, 1992, *Draft American National Standard Design Basis for Resistance to Shock and Vibration of Radioactive Material Packages Greater than One Ton in Truck Transport*, ANSI N14.23, American National Standards Institute, New York, New York.

ANSI, 1987, *American National Standard for Radioactive Materials--Leakage Tests on Packages for Shipment*, ANSI N14.5, American National Standards Institute, New York, New York.

ASTM, 1996, *1996 Annual Book of ASTM Standards*, American Society for Testing and Materials, Philadelphia, Pennsylvania.

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

Gillespie, T. D., Ph.D., 1987, *Engineering Analysis of Cargo Restraint on Commercial Highway Trucks*, UMTRI-87-28, Final Report, U.S. Department of Transportation Catalog No. 77054, The University of Michigan Transportation Research Institute, Ann Arbor, Michigan.

PHMC, 1997a, *Long-Length Contaminated Equipment Burial Containers Fabrication Process Procedures*, HNF-SD-WM-SPP-002, Rev. 0, Rust Federal Services Inc., Northwest Operations, Richland, Washington.

PHMC, 1997b, *Test Report for Long-Length Contaminated Equipment Burial Container*, HNF-SD-TP-TRP-004, Rev. 0, Rust Federal Services Inc., Northwest Operations, Richland, Washington.

Roach, H. L., 1995, *Disposal of Tank Farm Long-Length Contaminated Equipment: Radiological and Chemical Characterization Plan*, WHC-SD-WM-TCP-007, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

SAE, 1996, "Materials," *SAE Handbook*, Vol. 1, Society of Automotive Engineers, Warrendale, Pennsylvania.

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

WHC, 1995, *Packaging Design Criteria Transfer and Disposal of Long-length Equipment Hanford Tank Farm Complex*, WHC-SD-TP-PDC-020, Rev. 2, Westinghouse Hanford Company, Richland, Washington.

7.7 APPENDICES

7.7.1 Structural Analysis

Review and Confirmation of the LLCE Container Design Calculations

Randall S. Marlow
1/31/97

1.0 Introduction

This document contains a review of the LLCE Container design calculations (Day 1996). (The LLCE containers were designed according to Burgess (1995).) The review includes confirmatory calculations which demonstrate the adequacy of the more important results from the design report. This document also contains ancillary calculations dealing with the crushing of a container and the shifting of a container as the LLCE trailer is backing down an incline.

The design calculation report contains evaluations of the stresses in the various LLCE containers under many different types of loads. The loading scenarios in the design evaluation are:

- container lifting and handling,*
- normal mode vibration,
- shock,
- void filling,
- thermal expansion/contraction,*
- internal pressurization,*
- loading caused by skid transfer,*
- container burial.

The scenarios which produce significant stresses in the containers are marked with an asterisk. The stresses presented in Day (1996) for these conditions have been confirmed with the independent calculations contained in Attachments A through C. The stresses are acceptably small. The design calculations for the scenarios not marked with an asterisk have been reviewed and were found to be more than adequate in every case. Additionally, Attachment D contains a calculation of the effects of a crushing load applied statically along the length of the smallest container and Attachment E contains a calculation of the maximum amount of shift a container might experience as the LLCE trailer is backing down an 8% grade at various speeds.

2.0 Design Calculation Review and Confirmation

2.1 Container Lifting and Handling

Container lifting and handling has the greatest potential for producing very large stresses and deformations of the containers. The containers, which are long grout-filled pipes made of high-density polyethylene (hdpe), are lifted with slings positioned along the length. Because the slings are closely spaced, there will be no significant beam-type bending stresses in the containers. The design calculations show that the bending stresses are indeed very small. The most significant stress that could occur comes from the pinching action of the sling around the circumference of the container. According to the design calculations, the maximum Von Mises stress in the heaviest container is 1356 lbf/in^2. The independent calculation in Attachment A gives the stress as 1760 lbf/in^2. Both calculation show that the stress is acceptable for hdpe (Waterman 1991). The two results are somewhat different because the design calculation is more sophisticated than the confirmatory calculation.

2.2 Normal-Mode Vibration

The design calculations include an evaluation of the effects of a so-called normal-mode vibration as defined by ANSI N14.23 (ANSI 1989). In the design calculations, the vibration is applied as a base excitation of the tie-down strap locations. In actuality, the container is supported by a long trough on the trailer. Therefore, the stresses produced by the design calculations are far larger than the stresses that would be in the actual container. Even so, the design calculations predict stresses which are negligibly small compared with the strength of hdpe (Waterman 1991).

2.3 Shock

The shock calculation in Day (1996) considers the effect of a 0.75*g* deceleration on the container and its contents. The contents, called a monolith, slides forward and comes into contact with the end cap of the container which is assumed to be supported by the bulkhead of the LLCE trailer. Under this scenario, the end cap will be loaded in compression while the body of the container experiences a 0.75*g* inertial load. Consider the heaviest container. Assuming that the entire weight of the container acts on the end cap, the average pressure would be

$$p = \frac{95058 \times 0.75}{\frac{\pi}{4}(63.317 - 2\times 4.4)^2} = 30.5 \text{ lbf/inch}^2$$

and the compressive stress in the wall of the container would be

$$\sigma = \frac{95052 \times 0.75}{\frac{\pi}{4}[63.317^2 - (63.317 - 2\times 4.4)^2]^2} = 87.5 \text{ lbf/inch}^2.$$

The pressure will have no detrimental effect on the end cap and the stress in container wall is negligible. The design calculation attempts to include the effect of the initial impact of monolith against the lid. Once the assumption that the end cap is supported by the bulkhead is made, this calculation becomes moot.

2.4 Void Filling

The internal pressure on the container caused by filling the internal cavity with grout will be negligibly small. The design calculation report adequately demonstrates this fact.

2.5 Thermal Expansion/Contraction

The contraction of a container onto its internal grout monolith could cause significant stress in the wall of the container. The deformation is self-limiting, however, because it is thermally induced. The design calculation adequately demonstrates that under the worst-case scenario, the stress in the container wall is well below the yield of the hdpe. The independent confirmatory calculation in Attachment B also shows that the stress in the container is acceptably small under the worst-case thermal contraction.

2.6 Internal Pressurization

The design calculation report contains an evaluation of the effects of an internal gage pressure of 7.35 lbf/in^2. The design calculation uses the finite-element method to resolve the stress in the container wall. The finite-element model necessarily has a geometric discontinuity at the intersection of the inner lateral container surface and the inner surface of the end cap. The discontinuity causes large stresses to appear in the finite-element solution. In actuality, any discontinuity stress would be redistributed through a very small plastic zone in the highly-ductile hdpe material. Therefore, the stresses reported by the design calculation are a very conservative measure of the strength of the container under an internal pressure. Even so, the design calculation shows that the stress is acceptably small. An independent confirmatory calculation verifies that the stress is acceptable. See Attachment C.

2.7 Skid Transfer Loading

The design calculation report contains an evaluation of the stress in a container caused by the skid transfer operations. These stresses are significantly smaller than the stresses caused by the pinching of the lifting slings described above in Section 2.1. Because the lifting and handling stresses were found to be acceptable in the design calculations and were confirmed with independent calculations, the stresses in the present case are not limiting to the design.

2.8 Container Burial

The stresses reported by the design calculation report for a buried container are assumed to be caused by the localized bending of the container shell about a void space in the grout due to the weight of the overburden. The stress is completely dependent on the assumed size and shape of the void space, which for an actual container is not known. Therefore, the reported stresses may not be representative of the stresses in an actual container. In an actual container, the stress caused by the overburden load will be negligible throughout virtually all of the container because of the void-filling grout. Any localized stresses of the type reported in the design calculation would relax because hdpe is a viscoelastic material.

3.0 Ancillary Calculations

3.1 Crushing Load

Attachment D contains a calculation of the effect of a crushing load on the smallest of the containers. The crushing load is assumed to be a 32,000 lbf load distributed along a line running down the top of the container. The effect of the grout monolith in the container is not included. Even so, the stress in the container is not significant.

3.2 Container Shift

Attachment E contains a calculation of the distance which a container would shift during a sudden deceleration of the LLCE trailer as it is backing down an 8% grade. The calculation assumes that the coefficients of static and dynamic friction between the container and trailer are both 0.3. The largest deceleration which for which no shifting occurs is 0.22*g*. If the trailer could stop instantaneously from 2 mph, a container would shift about 7 inches before coming to rest. The amount of shift decreases with decreasing trailer speed. If the coefficient of friction between the truck tires and the road is assumed to be at most 0.9, then the heaviest package must be restrained with a force of approximately $(0.9\text{-}0.3)\times 100{,}000 = 60{,}000$ lbf to prevent any package movement.

4.0 References

ANSI, 1989, *Design Basis for Resistance to Shock and Vibration of Radioactive Materials Packages Greater Than One Ton in Truck Transport*, ANSI 14.23 (Draft), American National Standards Institute, New York, New York.

Burgess, J.S., 1995, *Packaging Design Criteria, Transfer and Disposal of Long-Length Equipment, Hanford Tank Farm Complex*, WHC-SD-TP-PDC-020, Rev. 2, Westinghouse Hanford Company, Richland, Washington.

Day, Brad, 1996, *LLCE Container and Lift Beam Design Calculation Report*, DCR-96-001, Westinghouse Electric Corp, Government Technical Services Division, Carlsbad, New Mexico.

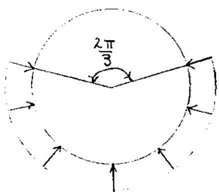
Waterman, Norman A., and Michael F. Ashby, 1991, *CRC-Elsevier Materials Selector*, Vol. 3, CRC Press, Boca Raton, Florida.

Attachment A. Confirmatory Calculation for Lifting and Handling Loads

DESIGN CALCULATION

(1) Drawing ______ (2) Doc. No. ______ (3) Page 1 of 3
(4) Building ______ (5) Rev. ______ (6) Job No. ______
(7) Subject LLCE Sling-Induced Lifting Stress (LLCE SLS)
(8) Originator Randall S. Marlow Date 1/27/97
(9) Checker Bryan Flanagan Date 2/18/97

(10)



L = total sling width
R = outside radius
t = body thickness

Assume uniform pressure along a distance L. Consider longest, heaviest container. Neglect beam-type bending. References:

[1] Roark & Young, Formulas for Stress and Strain, Fifth Edition

[2] LLCE Container and Lift Beam Design Calculation Report

$$W = -LRp_0 \int_{\theta_0}^{\pi} (2)\cos x \, dx$$

$$= -LRp_0 (2)(\sin\pi - \sin\theta_0)$$

$$= 2LRp_0 (\sin\theta_0)$$

$$= \sqrt{3}\, LRp_0$$

$$p_0 = \frac{W}{\sqrt{3}\, LR}$$

$L = (19)(24) = 456 \text{ in}$ $\quad R = \frac{63.317}{2} = 31.659 \text{ in}$

$W = 95{,}100 \text{ lbf}$

BD-6400-060.1 (12/87)

DESIGN CALCULATION

(1) Drawing ______ (2) Doc. No. ______ (3) Page 2 of 3
(4) Building ______ (5) Rev. ______ (6) Job No. ______
(7) Subject LLCE SLS
(8) Originator Randall S Marlow [signature] Date 1/27/97
(9) Checker [signature] Date 2/18/97

(10)

$$P_o = \frac{95{,}100}{\sqrt{3}\,(456)(31.659)} = 3.8 \text{ lbf/in}^2$$

Force/length = $P_o(1)$ around circumference.

The bending moment/length at the bottom is given by [1]:

$$M = -(3.8)(31.659)^2\left[\frac{1}{\pi}\left(\frac{\pi}{3} + 2\sin\frac{\pi}{3} - \frac{\pi}{3}\cos\frac{\pi}{3}\right) - 1 + \cos\frac{\pi}{3}\right]$$
$$+ (31.659)(1-\cos\pi)(3.8)(31.659)\left[\frac{1}{\pi}\left(\sin\frac{\pi}{3} - \frac{\pi}{3}\cos\frac{\pi}{3}\right) + \cos\frac{\pi}{3}\right]$$
$$- (3.8)(31.659)^2\left[1 - \cos\left(\frac{2\pi}{3}\right)\right]$$

$$M \simeq -1{,}900 \text{ in-lbf/in}$$

Neglect the shear and hoop compression. The peak stress is then

$$\sigma \simeq \frac{6M}{t^2}(1 - 0.5^2) = \frac{6(1900)(0.75)}{2.053^2} = 2030 \text{ psi}$$

$$\Rightarrow \text{Mises} = \left[\tfrac{1}{2}(2030 - 1015)^2 + \tfrac{1}{2}(2030)^2 + \tfrac{1}{2}(1015)^2\right]^{\frac{1}{2}}$$
$$= 1{,}760 \text{ psi}$$

BD-6400-060.1 (12/87)

DESIGN CALCULATION

(1) Drawing ______ (2) Doc. No. ______ (3) Page 3 of 3
(4) Building ______ (5) Rev. ______ (6) Job No. ______
(7) Subject LLCE SLS
(8) Originator Randall S. Marlow [signature] Date 1/27/97
(9) Checker [signature] Date 2/18/97

(10)

Reference [2] reports a maximum Von Mises stress for this case to be 1,356 lbf/in²

The %Δ is:

$$\% \Delta = \frac{2|1356 - 1760|}{1356 + 1760} \times 100 \simeq 26\%$$

Therefore, the lifting stresses reported in [2] are confirmed as somewhat conservative.

BD-6400-060.1 (12/87)

Attachment B. Confirmatory Calculation for Thermal Expansion/Contraction

DESIGN CALCULATION

(1) Drawing ____ (2) Doc. No. ____ (3) Page 1 of 2
(4) Building ____ (5) Rev. ____ (6) Job No. ____
(7) Subject Thermal Contraction of LLCE Container (TC LLCE)
(8) Originator Randall S. [signature] Date 1/27/97
(9) Checker [signature] Date 2/18/97

(10)

The limiting pressure on the end caps is 7.35 lbf/in². The effect of this pressure is not considered here.

Assume void fill is rigid & does not contract under a decrease in temperature. Maximum temperature change is $100-(-20) = 120\,°F$.
Take $\alpha = 6.0 \times 10^{-5}\ /°F$ for the coefficient of thermal expansion for the polyethylene.
Consider the container(s) with largest diameter.

$$\alpha \Delta T = 6.0 \times 10^{-5} (120) = 0.0072.$$

The inner radius contracts by an amount

$$\delta = \alpha \Delta T \left(\frac{63.317 - 2(2.053)}{2} \right) = 0.213 \text{ in.}$$

The internal pressure is ([1]):

$$P = \frac{0.213(3 \times 10^5)(29.6055)(31.6585^2 - 29.6055^2)}{(29.6055^2)\left[\frac{1}{2}(29.6055)^2 + \frac{3}{2}(31.6585)^2\right]}$$

$$P = 140 \text{ psi}$$

BD-6400-060.1 (12/87)

DESIGN CALCULATION

(1) Drawing ______ (2) Doc. No. ______ (3) Page 2 of 2
(4) Building ______ (5) Rev. ______ (6) Job No. ______
(7) Subject TC LLCE
(8) Originator Randall S. Marlow [signature] Date 1/27/97
(9) Checker [signature] Date 2/18/97

(10)

The hoop stress at the inner surface is

$$\sigma_h = \frac{29.6055^2(140)}{31.6585^2 - 29.6055^2}\left(1 + \left(\frac{31.6585}{29.6055}\right)^2\right)$$

$$= 2{,}091 \text{ psi.}$$

The stress in the longitudinal direction is negligible as is the radial stress. The calculation shows that the stresses reported in [2] are reasonable.

References:

[1] Higdon, Archie, et al, Mechanics of Materials, John Wiley & Sons, New York.

[2] LLCE Container and Lift Beam Design Calculation Report

BD-6400-060.1 (12/87)

Attachment C. Confirmatory Calculation for Internal Pressurization

DESIGN CALCULATION

(1) Drawing ______ (2) Doc. No. ______ (3) Page 1 of 2
(4) Building ______ (5) Rev. ______ (6) Job No. ______
(7) Subject LLCE Container Internal Pressure (LLCE IP)
(8) Originator Randall S. Marlow Date 1/27/97
(9) Checker [signature] Date 2/18/97

(10)

The container is assumed to contain a pressure of 7.35 psig Consider the largest container only.

The hoop stress on the inner surface is given by

$$\sigma_h = \frac{(29.6055)^2(7.35)}{31.6585^2 - 29.6055^2}\left(1 + \left(\frac{31.6585}{29.6055}\right)^2\right)$$

$$= 110 \text{ psi}$$

The stress in the end cap are calculated by using the formulas for a circular plate clamped at the edge [1] :

$$\sigma_r = \frac{3}{4}\frac{(7.35)(29.6055)^2}{(4.4)^2} = 250 \text{ psi}$$

$$\sigma_t = \nu\,\sigma_r = 125 \text{ psi}$$

DESIGN CALCULATION

(1) Drawing ______ (2) Doc. No. ______ (3) Page 2 of 2
(4) Building ______ (5) Rev. ______ (6) Job No. ______
(7) Subject LLCE IP
(8) Originator Randall S. Marlow Date 1/27/97
(9) Checker B. Fly Date 2/18/97

(10)

The Von Mises stress is

$$\text{Mises} = \left[\frac{1}{2}(250-125)^2 + \frac{1}{2}(250)^2 + \frac{1}{2}(125)^2 \right]^{\frac{1}{2}}$$

$$= 217 \text{ psi}$$

The stresses are far less than those given in [2]. The design calculations include the effect of a singularity.

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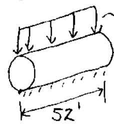
Attachment D. Crushing Load Calculation

DESIGN CALCULATION

(1) Drawing ____ (2) Doc. No. ____ (3) Page 1 of 1
(4) Building ____ (5) Rev. ____ (6) Job No. ____
(7) Subject LLCE Container Crushing Analysis
(8) Originator Randall S. Marlow Date 1/27/97
(9) Checker [signature] Date 2/18/97

(10)

Assume a static load of 32,000 lbf applied along a longitude thusly:



The maximum moment is ([1])

$$M = 0.3183(51.3)(13) = 212 \text{ in-lbf/in}$$

$$\sigma_h \simeq \frac{6(212)}{(0.88)^2}(1-0.5^2) = 1234 \text{psi}$$

$$\sigma_\ell \simeq 0.5(1234) = 617 \text{psi}$$

$$\text{Mises} = \left[\tfrac{1}{2}(1234-617)^2 + \tfrac{1}{2}(1234)^2 + \tfrac{1}{2}(617)^2\right]^{\frac{1}{2}}$$

$$= 1069 \text{ psi}$$

The smallest yield occurs @ +120°F and is 2089 psi

[1] "Formulas for Stress and Strain", Roark & Young, McGraw-Hill.

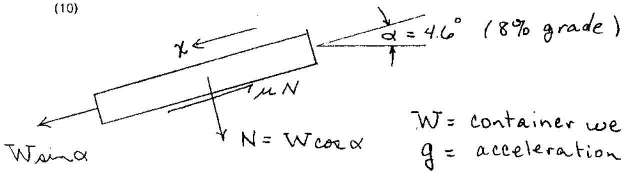
BD-6400-060.1 (12/87)

Attachment E. Container Shift Calculation

DESIGN CALCULATION

(1) Drawing ______ (2) Doc. No. ______ (3) Page 1 of 3
(4) Building ______ (5) Rev. ______ (6) Job No. ______
(7) Subject LLCE Container Shift (LLCE CS)
(8) Originator Randall S. Marlow [signature] Date 1/27/97
(9) Checker [signature] Date 2/18/97

(10)



W = container weight
g = acceleration due to gravity

Container is moving downslope with speed v. The inclination is α. Determine maximum acceleration up the slope such that the container does not shift. Assume coefficient of friction $\mu = 0.3$.

Let $\dot{v}$ be the acceleration; m the mass.

$$m\dot{v} = \mu N - W\sin\alpha$$

$$= \mu W\cos\alpha - W\sin\alpha$$

$$\dot{v} = \mu g\cos\alpha - g\sin\alpha$$

$$= g\cos\alpha\,[\mu - \tan\alpha]$$

$$\dot{v} = g\cos\alpha\,[0.3 - 0.08]$$

$$= g\,\frac{100}{\sqrt{100^2+8^2}}\,[0.22]$$

$$\simeq 0.22\,g \quad (7.1\ \mathrm{ft/s^2})$$

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DESIGN CALCULATION

(1) Drawing ______ (2) Doc. No. ______ (3) Page 2 of 3
(4) Building ______ (5) Rev. ______ (6) Job No. ______
(7) Subject LLCE CS
(8) Originator Randall S. Marlow [signature] Date 1/27/97
(9) Checker [signature] Date 2/18/97

(10)

Under this acceleration, a container moving downslope at 5 mph would come to rest in

$$5\left(\frac{5280}{3600}\right)\left(\frac{1}{7.1}\right) \simeq 1 \text{ sec.}$$

Suppose the container shifts. Determine the max. amount of shift for $v = 5$ mph. ⇒

$$m\ddot{x} = \mu_d\left(\frac{L+x}{L}\right) mg\cos\alpha - mg\sin\alpha$$

where L is the container length. This equation is valid upto such time as $\dot{x} = 0$.

$$\ddot{x} = \mu_d g\cos\alpha - g\sin\alpha - (\mu_d g/L)\cos\alpha \, x$$

$$\ddot{x} - \left(\frac{\mu_d g\cos\alpha}{L}\right)x = \mu g\cos\alpha - g\sin\alpha$$

$$x(t) = -\frac{(\mu_d g\cos\alpha - g\sin\alpha)L}{\mu_d g\cos\alpha} + A\sinh\omega t + B\cosh\omega t \qquad \omega \equiv \sqrt{\frac{\mu_d g\cos\alpha}{L}}$$

BD-6400-060.1 (12/87)

DESIGN CALCULATION

(1) Drawing ______ (2) Doc. No. ______ (3) Page 3 of 3
(4) Building ______ (5) Rev. ______ (6) Job No. ______
(7) Subject LLCE CS
(8) Originator Randall S. Marlow [signature] Date 1/27/97
(9) Checker [signature] Date 2/18/97

(10)

$$x(0) = 0 \Rightarrow B = + \left(\frac{\mu_d g \cos\alpha - g \sin\alpha}{\mu_d g \cos\alpha} \right) L$$

$$\dot{x}(0) = -v \Rightarrow A = -\frac{v}{\omega}$$

$$x(t) = \left(\frac{\mu_d g \cos\alpha - g \sin\alpha}{\mu_d g \cos\alpha} \right) L \ (\cosh\omega t - 1) - \frac{v}{\omega} \sinh\omega t$$

For $L = 882$ in (73.5 ft); $\mu_d = \mu = 0.3$

find that $x = -3.95$ ft when $\dot{x} = 0$.

[For $v = 2$ mph, $x = 7.4$ in when $\dot{x} = 0$.]

[Check:

Assume constant acceleration of 7.1 ft/s².

$$d = \frac{\left(5\left(\frac{5280}{3600}\right)\right)^2}{2(7.1)} = 3.79 \text{ ft}$$]

The container will shift at most 3.95 ft. For $L = 682$ in (56.8 ft), $v = 2$ mph the container shifts 7.4 in.

BD-6400-060.1 (12/87)

7.7.2 LLCE Container and Lift Beam Design Calculation Report

Author: Farok Sharif at ~DOE_HANFORD_1
Date: 2/18/97 6:01 PM
Priority: Normal
TO: Eric M Veith at ~WHC8
Subject: PROPRIETARY STATEMENT ON LLCE PROCEDURES
------------------------------------ Message Contents ------------------------------------

Eric,

Please note that 15 LLCE procedures were transmitted to you December 12, 1996 via CC Mail. The procedures transmitted did not include the standard EPD proprietary statement. The following is a list of the procedures transmitted:

AS/LLCE-001 thru AS/LLCE-005
AS/LLCE-007 thru AS/LLCE-012, and
AS/LLCE-015 thru AS/LLCE-018

As I implied in my memo, the priority statement was inadvertly left on the procedures initially submitted - you are free to use the referenced LLCE procedures at your descresion.

If you have any further questions, comments, or concerns, - give me a holler.

Matt Zeroch III

Project Manager

Tracy, 3/24/97

Here is the CC Mail I sent to Eric on 2/18/97 which was subsequent to a 12/12/96 CC: mail basically providing the same message.

Any questions. Please call

Matt

(505)885-6688
x323

DATE OF ISSUE

NOV - 5 1996

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1075

DCR-96-001

LLCE Container and Lift Beam Design Calculation Report

Westinghouse Electric Corp.
Government Technical Services Division
Engineered Products Department
1502 E. Greene St.
P.O. Box 2138
Carlsbad, New Mexico 88220

Rev.	DCN No.	N/A	Cognizant Engineer	Support Engineer	Engineering Manager	Date
0	Initial Release		Brad Day	Matt Leroch IV	Brad Day	11/4/96

TABLE OF CONTENTS

Section Page

DCR-96-001, LLCE Container and Lift Beam Design Calculation Report

1 OBJECTIVE

The Long Length Contaminated Equipment (LLCE) containers will be used as transportation, short-term storage, and long-term burial of Westinghouse Hanford Tank Farm contaminated equipment. The LLCE Long and Short Lift Beams will be used to handle the LLCE containers. The objective of this report is to provide verification of the container and lift beam designs for the specified handling, transport, void filling, and burial conditions. The design calculations include considerations for all imposed environmental conditions including radiation exposure and long-term creep.

2 ASSUMPTIONS/DESIGN INPUTS

Drawings series LLCE-1100 through LLCE-1400 provide the detailed design of the LLCE containers. Drawings series LLCE-4100 through LLCE-4200 and LLCE-2550 provide the detailed design of the LLCE lift beams. Westinghouse Hanford Company Specification WHC-S-0402 and Statement of Work ETN-94-0054C provides the specific container handling, transport, void filling, and burial requirements. Specific design requirements and assumptions used in the analysis are stated in the design calculation appendix.

3 REFERENCES

[1] Drawing LLCE-1100, Revision 1, "LLCE C1 and C2 Field Assemblies", August 29, 1996.

[2] Drawing LLCE-1110, Revision 1, "LLCE C1 and C2 Shop Assemblies", July 26, 1996.

[3] Drawing LLCE-1120, Revision 2, "End Cap C1-C2 Assembly", August 30, 1996.

[4] Drawing LLCE-1200, Revision 1, "LLCE C3 and C4 Field Assemblies", August 29, 1996.

[5] Drawing LLCE-1210, Revision 0, "LLCE C3 and C4 Shop Assemblies", July 31, 1996.

[6] Drawing LLCE-1220, Revision 1, "End Cap C3-C4 Assembly", August 30, 1996.

[7] Drawing LLCE-1300, Revision 1, "LLCE C5 and C9 Field Assemblies", August 29, 1996.

[8] Drawing LLCE-1310, Revision 0, "LLCE C5 and C9 Shop Assemblies", July 31, 1996.

[9] Drawing LLCE-1320, Revision 1, "End Cap C5-C9 Assembly", August 30, 1996.

[10] Drawing LLCE-1400, Revision 1, "LLCE C6 and C7 Field Assemblies", August 29, 1996.

[11] Drawing LLCE-1410, Revision 0, "LLCE C6 and C7 Shop Assemblies", July 29, 1996.

[12] Drawing LLCE-1420, Revision 1, "End Cap C6-C7 Assembly", August 30, 1996.

[13] Drawing LLCE-2550, Revision 3, "LLCE Lift Beam Components", August 8, 1996.

[14] Drawing LLCE-4100, Revision 1, "LLCE Long Lift Beam Field Assembly", July 25, 1996.

[15] Drawing LLCE-4110, Revision 1, "LLCE Long Lift Beam", July 26, 1996.

[16] Drawing LLCE-4200, Revision 1, "LLCE Short Lift Beam Field Assembly", July 25, 1996.

[17] Drawing LLCE-4210, Revision 1, "LLCE Short Lift Beam", July 26, 1996.

[18] Westinghouse Hanford Company, "Statement of Work for the Long-Length Contaminated Equipment Burial Containers and Associated Hardware", ETN-94-0054C

[19] Westinghouse Hanford Company, "Specification for Contaminated Equipment Burial Container", WHC-S-0402, Rev. 0, July 7, 1995.

[20] Structural Research and Analysis Corporation, "Cosmos/M Engineer Version 1.75 User Manuals", 1996.

[21] Westinghouse Hanford Company, "Facsimile from Eric Veith to Brad Day Regarding Equipment and Skid Weights", January 2, 1996.

[22] Phillips Chemical Co., "Driscopipe Engineering Characteristics", Publication 1092-91 A01, 1991.

[22] Thomson, "Theory of Vibration with Applications", Prentice-Hall 1988.

[23] Shigley and Mitchell, "Mechanical Engineering Design", McGraw Hill, 1983.

[24] Westinghouse Hanford Company, "Burial Container Subsidence Load and Stress Calculations", Document # WHC-SD-WM-CAVR-003, Rev. 1, November 28, 1995.

[25] Phillips Chemical Co., "Driscopipe Engineering Characteristics", Publication 1092-91 A01, 1991.

[26] P. Soo et al., "The Extended Storage of Radioactive Ion-Exchange Resins in Polyethylene High Integrity Containers", Research Report EP 91-05, Brookhaven National Laboratory, 1994.

[27] Phillips Chemical Co., "Engineering Properties of Marlex Resins", Technical Report TSM-243, 1975.
[28] Mark J. Lamborn, Phillips Chemical Co., Inc., "Letter to David Cragun of Phillips Driscopipe regarding fatigue resistance of TR-480 pipe resin", January 22, 1996.
[29] Harvey Svetlik, P.E., Phillips Chemical Co., Inc., "Letter to Jim Greaves of SEG regarding canister pipe specification", March 3, 1992,.
[30] Ray Mello, Phd., Scientific Ecology Group., Inc., "Determination of Allowable Flaw Sizes in the K-25 Container", May 24, 1993.
[31] United States Testing Company, Inc., "Fungus Resistance Test for Marlex HHM 5502 HDPE", Test Report Number 062821, 1990.
[32] Harvey Svetlik, P.E., Phillips Driscopipe, Inc., "Letter to Jim Greaves of SEG regarding chemical compatibility of Driscopipe", March 4, 1992.
[33] Plastics Pipe Institute, "Thermoplastics Pipe for the Transport of Chemicals", TR-19/91, 1991.

4 ANALYSIS METHODS

Conventional "strength-of-materials" formulas and linear/nonlinear finite element analyses using COSMOS/M Engineer [20] were used to evaluate the LLCE containers for handling, transport, void filling, thermal expansion/contraction, internal pressure, skid transfer, and burial loads. The same methods were used to evaluate the LLCE lift beams for lifting and handling loads. Each design calculation appendix states the specific analysis method used in the analysis.

5 ANALYSIS RESULTS AND CONCLUSIONS

The LLCE containers have been evaluated for the handling, transport, void filling, thermal expansion/contraction, internal pressure, skid transfer, and burial loads. Also, the LLCE lift beams have been evaluated for the specified lifting and handling loads. The design calculations are given in Appendix 6.1 of this DCR. Material property information and a review of the environmental condition study is given in Appendix 6.2 of this DCR.

DCR-96-001, LLCE Container and Lift Beam Design Calculation Report

5.1 Summary of Container and Cargo Weight Calculations

The total maximum empty weight of the LLCE containers calculated and used in the analysis is as follows:

$$\text{Container} = \begin{bmatrix} 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \\ 7 \end{bmatrix} \qquad W_{hdpe} = \begin{bmatrix} 1617 \\ 2066 \\ 3147 \\ 4008 \\ 9270 \\ 9740 \\ 12295 \end{bmatrix} \cdot lbf$$

The total maximum gross weight of the LLCE containers and cargo calculated and used in the analysis is as follows:

$$\text{Container} = \begin{bmatrix} 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \\ 7 \end{bmatrix} \qquad W_{total} = \begin{bmatrix} 11280 \\ 14597 \\ 20380 \\ 27812 \\ 60137 \\ 63342 \\ 95058 \end{bmatrix} \cdot lbf$$

5.2 Summary of Container Lifting and Handling Calculations

The maximum VonMises stress imposed on the container during lifting and handling is as follows:

$$\text{Container} = \begin{bmatrix} 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \\ 7 \end{bmatrix} \qquad \sigma_{maxl\_von} = \begin{bmatrix} 1431 \\ 1405 \\ 1161 \\ 1216 \\ 1060 \\ 1225 \\ 1356 \end{bmatrix} \cdot \frac{lbf}{in^2}$$

The corresponding minimum Margin of Safety against failure of the container during lifting and handling is as follows:

Container =	MS_{lift} =
1	0.46
2	0.48
3	0.80
4	0.71
5	0.97
6	0.70
7	0.54

5.3 Summary of Lift Beam Lifting and Handling Calculations

The maximum VonMises stress and associated Margin of Safety against failure of the long lift beam (limiting case) during lift and handling is as follows:

$$\sigma_{von\_weld} = \begin{pmatrix} 7220 \\ 4443 \end{pmatrix} \cdot \frac{lbf}{in^2} \qquad MS_{weld} = \begin{pmatrix} 3.99 \\ 7.10 \end{pmatrix}$$

$$\sigma_{von\_beam} = 5530 \cdot \frac{lbf}{in^2} \qquad MS_{beam} = 5.51$$

$$\sigma_{von\_liftlug} = 18000 \cdot \frac{lbf}{in^2} \qquad MS_{liftlug} = 2.00$$

$$\sigma_{von\_slinglug} = 12600 \cdot \frac{lbf}{in^2} \qquad MS_{slinglug} = 3.29$$

Therefore, the minimum Margin of Safety against failure of the lift beam is as follows:

$MS_{min} = 2.00$

DCR-96-001, LLCE Container and Lift Beam Design Calculation Report

5.4 Summary of Container Transportation Calculations - Normal Mode Vibration

The maximum VonMises stress imposed on the container during normal mode vibration is as follows:

$$\text{Container} = \begin{bmatrix} 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \\ 7 \end{bmatrix} \qquad \sigma_{maxv\_von} = \begin{bmatrix} 38 \\ 36 \\ 44 \\ 27 \\ 23 \\ 20 \\ 32 \end{bmatrix} \cdot \frac{lbf}{in^2}$$

The corresponding minimum Margin of Safety against failure of the container during normal mode vibration is as follows:

$$\text{Container} = \begin{bmatrix} 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \\ 7 \end{bmatrix} \qquad MS_{vibration} = \begin{bmatrix} 37.92 \\ 39.21 \\ 31.87 \\ 54.08 \\ 62.18 \\ 70.54 \\ 44.19 \end{bmatrix}$$

5.5 Summary of Container Transportation Calculations - Shock

The maximum compressive stress imposed on the container end cap and body during maximum deceleration of the transport and resulting shock impact is as follows:

$$\text{Container} = \begin{bmatrix} 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \\ 7 \end{bmatrix} \qquad \sigma_{endcap} = \begin{bmatrix} 421 \\ 440 \\ 357 \\ 433 \\ 371 \\ 357 \\ 540 \end{bmatrix} \cdot \frac{lbf}{in^2} \qquad \sigma_{body} = \begin{bmatrix} 156 \\ 202 \\ 147 \\ 201 \\ 191 \\ 153 \\ 232 \end{bmatrix} \cdot \frac{lbf}{in^2}$$

The corresponding minimum Margin of Safety against failure of the container due to deceleration is as follows:

$$\text{Container} = \begin{bmatrix} 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \\ 7 \end{bmatrix} \qquad MS_{shock} = \begin{bmatrix} 3.95 \\ 3.73 \\ 4.84 \\ 3.82 \\ 4.62 \\ 4.83 \\ 2.86 \end{bmatrix}$$

5.6 Summary of Container Void Filling Calculations

The loads imparted on the container during void fill operations are not limiting due to the relatively low static void fill head and fully supported transport chock. The pressure exerted on the end cap due to void fill is as follows:

$$\text{Container} = \begin{bmatrix} 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \\ 7 \end{bmatrix} \qquad P_{endcap} = \begin{bmatrix} 0.8 \\ 0.8 \\ 0.9 \\ 1.0 \\ 1.4 \\ 1.5 \\ 1.5 \end{bmatrix} \cdot \frac{lbf}{in^2}$$

5.7 Summary of Container Thermal Expansion/Contraction Calculations

The maximum VonMises stress imposed on the container body during radial thermal contraction is as follows:

$$\text{Container} = \begin{bmatrix} 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \\ 7 \end{bmatrix} \qquad \sigma_{vonm\_therm} = \begin{bmatrix} 1560 \\ 1560 \\ 1560 \\ 1560 \\ 1562 \\ 1576 \\ 1576 \end{bmatrix} \cdot \frac{lbf}{in^2}$$

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The corresponding minimum Margin of Safety against failure of the container body due to radial thermal contraction is as follows:

$$\text{Container} = \begin{bmatrix} 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \\ 7 \end{bmatrix} \qquad MS_{therm} = \begin{bmatrix} 2.40 \\ 2.40 \\ 2.40 \\ 2.40 \\ 2.40 \\ 2.37 \\ 2.37 \end{bmatrix}$$

5.8 Summary of Container Internal Pressure Calculations

The maximum VonMises stress imposed on the container body due to internal gas generation is as follows:

$$\text{Container} = \begin{bmatrix} 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \\ 7 \end{bmatrix} \qquad \sigma_{intpres} = \begin{bmatrix} 744 \\ 744 \\ 664 \\ 664 \\ 710 \\ 726 \\ 726 \end{bmatrix} \cdot \frac{lbf}{in^2}$$

The corresponding minimum Margins of Safety against failure of the container due to internal gas generation in long term storage and burial scenarios are as follows:

$$\text{Container} = \begin{bmatrix} 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \\ 7 \end{bmatrix} \qquad MS_{intpres\_storage} = \begin{bmatrix} 0.34 \\ 0.34 \\ 0.51 \\ 0.51 \\ 0.41 \\ 0.38 \\ 0.38 \end{bmatrix} \qquad MS_{intpres\_burial} = \begin{bmatrix} 1.15 \\ 1.15 \\ 1.41 \\ 1.41 \\ 1.25 \\ 1.20 \\ 1.20 \end{bmatrix}$$

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5.9 Summary of Container Skid Transfer Calculations

The maximum compressive stress imposed on the container body due to skid transfer is as follows:

$$\text{Container} = \begin{bmatrix} 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \\ 7 \end{bmatrix} \qquad \sigma_{skidtran} = \begin{bmatrix} 122 \\ 160 \\ 124 \\ 209 \\ 238 \\ 213 \\ 506 \end{bmatrix} \cdot \frac{lbf}{in^2}$$

The corresponding minimum Margin of Safety against failure of the container due to skid transfer is as follows:

$$\text{Container} = \begin{bmatrix} 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \\ 7 \end{bmatrix} \qquad MS_{skidtran} = \begin{bmatrix} 16.13 \\ 12.01 \\ 15.76 \\ 8.96 \\ 7.75 \\ 8.79 \\ 3.12 \end{bmatrix}$$

5.10 Summary of Container Burial Calculations

The maximum VonMises stress imposed on the container body due to long term burial is as follows:

$$\text{Container} = \begin{bmatrix} 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \\ 7 \end{bmatrix} \qquad \sigma_{burial} = \begin{bmatrix} 697 \\ 697 \\ 701 \\ 701 \\ 685 \\ 704 \\ 704 \end{bmatrix} \cdot \frac{lbf}{in^2}$$

The corresponding minimum Margin of Safety against failure of the container due to long term burial is as follows:

Container =	MS_{burial} =
1	1.30
2	1.30
3	1.28
4	1.28
5	1.34
6	1.27
7	1.27

5.11 Conclusions

The analysis confirms that the lifting beams and containers are designed to safely perform all defined operations under the influence of imposed environmental factors.

6 APPENDIX

6.1 Design Calculations

6.2 Material Properties

6.1 Design Calculations

DCR-96-001, LLCE Container and Lift Beam Design Calculation Report

6.1.1 Container and Cargo Weight Calculations

Overview

The total gross weight of each container is calculated by adding the weight of polyethylene, void fill material, transfer skid/bag, and contaminated equipment/waste. The polyethylene and void fill material weights are calculated on a nominal volume/density basis. The polyethylene and void fill material densities are taken as theoretical maximum from References [19] and [22]. The skid/bag and equipment/waste weights are taken as theoretical maximums from Reference [21].

Schematic

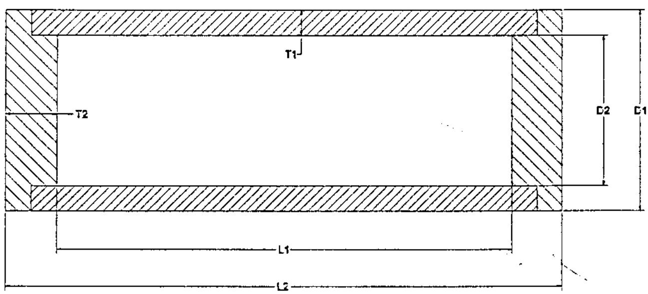

Figure 6.1.1-1 Container Geometry

Design Inputs

Index:

$i := 0..6$

$\text{Container} := (1\ 2\ 3\ 4\ 5\ 6\ 7)^T$

HDPE Density:

$\rho_{hdpe} := 0.03 \cdot \frac{lbf}{in^3}$; $\rho_{hdpe} = 52 \cdot \frac{lbf}{ft^3}$

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Void Fill Density:

$$\rho_{void} := 0.02 \cdot \frac{lbf}{in^3}; \quad \rho_{void} = 35 \cdot \frac{lbf}{ft^3}$$

Body Inside Length:

$$L1 := (678.06\ \ 873.99\ \ 677.74\ \ 873.67\ \ 873.10\ \ 676.86\ \ 872.79)^T \cdot in$$

Body Outside Diameter:

$$D1 := (26.005\ \ 26.005\ \ 36.000\ \ 36.000\ \ 54.245\ \ 63.317\ \ 63.317)^T \cdot in$$

Body Thickness:

$$T1 := (0.880\ \ 0.880\ \ 1.219\ \ 1.219\ \ 1.826\ \ 2.053\ \ 2.053)^T \cdot in$$

End Cap Thickness:

$$T2 := (1.800\ \ 1.800\ \ 2.500\ \ 2.500\ \ 3.750\ \ 4.400\ \ 4.400)^T \cdot in$$

Equipment / Waste Weight:

$$W_{equip} := (957\ \ 1492\ \ 1715\ \ 4309\ \ 8350\ \ 9204\ \ 25287)^T \cdot lbf$$

Skid / Bag Weight:

$$W_{skid} := (1819\ \ 2162\ \ 2327\ \ 2491\ \ 3627\ \ 3395\ \ 4604)^T \cdot lbf$$

Assumptions

The volume of void fill is assumed to be the free space inside the container and neglects the reduction in free space due to the volume of skid/bag and equipment/waste. The assumption is conservative and results in over-predicted void fill weights.

Calculations

Calculations

HDPE Body Volume:

$$V_{body_i} := \frac{\pi}{4} \cdot \left[{D1_i}^2 - \left(D1_i - 2 \cdot T1_i \right)^2 \right] \cdot L1_i$$

$$V_{body}{}^T = (27\ \ 35\ \ 52\ \ 67\ \ 152\ \ 155\ \ 200) \cdot ft^3$$

DCR-96-001, LLCE Container and Lift Beam Design Calculation Report

HDPE End Cap Volume:

$$V_{end_i} = \frac{\pi}{4} \cdot DI_i^{\,2} \cdot T2_i$$

$$V_{end}^T = (\,0.55 \;\; 0.55 \;\; 1.47 \;\; 1.47 \;\; 5.02 \;\; 8.02 \;\; 8.02\,) \cdot ft^3$$

HDPE Body Weight:

$$W_{body_i} = V_{body_i} \cdot \rho_{hdpe} \cdot 1.1$$

$$W_{body}^T = (\,1554 \;\; 2003 \;\; 2979 \;\; 3840 \;\; 8664 \;\; 8826 \;\; 11381\,) \cdot lbf$$

HDPE End Cap Weight:

$$W_{end_i} = V_{end_i} \cdot \rho_{hdpe} \cdot 1.1$$

$$W_{end}^T = (\,32 \;\; 32 \;\; 84 \;\; 84 \;\; 286 \;\; 457 \;\; 457\,) \cdot lbf$$

HDPE Weight:

$$W_{hdpe_i} = W_{body_i} + 2 \cdot W_{end_i}$$

$$W_{hdpe}^T = (\,1617 \;\; 2066 \;\; 3147 \;\; 4008 \;\; 9236 \;\; 9740 \;\; 12295\,) \cdot lbf$$

Void Fill Volume:

$$V_{void_i} = \frac{\pi}{4} \cdot DI_i - 2 \cdot T1_i^{\,2} \cdot L1_i$$

$$V_{void}^T = (\,181 \;\; 234 \;\; 347 \;\; 447 \;\; 1016 \;\; 1079 \;\; 1391\,) \cdot ft^3$$

Void Fill Weight:

$$W_{void_i} = V_{void_i} \cdot \rho_{void} \cdot 1.1$$

$$W_{void}^T = (\,6887 \;\; 8877 \;\; 13191 \;\; 17004 \;\; 38615 \;\; 41003 \;\; 52872\,) \cdot lbf$$

Total Gross Weight:

$$W_{total_i} = W_{hdpe_i} + W_{void_i} + W_{equip_i} + W_{skid_i}$$

$$W_{total}^T = (\,11280 \;\; 14597 \;\; 20380 \;\; 27812 \;\; 59828 \;\; 63342 \;\; 95058\,) \cdot lbf$$

DCR-96-001, LLCE Container and Lift Beam Design Calculation Report

Summary

Container =	W_{hdpe} = (lbf)	W_{total} = (lbf)
1	1617	11280
2	2066	14597
3	3147	20380
4	4008	27812
5	9236	59828
6	9740	63342
7	12295	95058

DCR-96-001, LLCE Container and Lift Beam Design Calculation Report

6.1.2 Container Lifting and Handling Calculations

Overview

The structural response of each container in a lifting and handling scenario is calculated using a combined beam finite element model that simulates a two crane lift. The wire rope bridle slings, lifting beam, wide body basket nylon slings, and container are all modeled simultaneously as discrete components of a lifting system. The lift beam and container are modeled with 2-D linear elastic beam elements. The bridle slings and wide body basket slings are modeled with 2-D nonlinear gap elements to simulate the tension-only load carrying capabilities of these components. The load carrying capacity of the contaminated equipment, skid, and void fill material is not modeled, but the mass of the cargo is incorporated into the system as distributed or point loads applied to the container.

In addition to the combined beam model that is used to determine the bending stresses imposed on each component, a 2-D plane strain nonlinear finite element model of the container is used to determine the localized stresses generated by the pinching affect of the basket slings. As input to the 2-D plane strain model, the magnitude of force acting locally on the container at each basket sling location is determined from the 2-D elastic beam model gap element output. The stresses determined by the two analysis are conservatively added to determine the highest magnitude of stress in the container during lifting and handling.

The polyethylene container material properties are taken from the analysis given in Appendix 6.2. The skid/bag and equipment/waste weights are taken as theoretical maximums from Reference [21]. The void fill and container weights are taken as theoretical maximums from Appendix 6.1.1.

DCR-96-001, LLCE Container and Lift Beam Design Calculation Report

Schematic

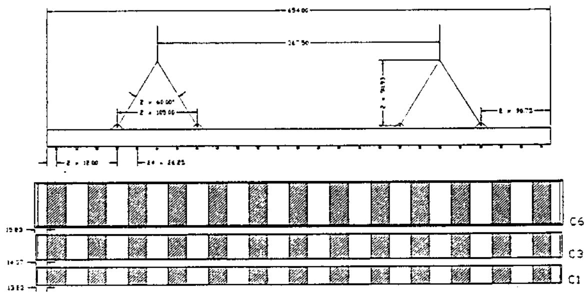

Figure 6.1.2-1 Lifting Beam Model for Containers C1, C3, C6

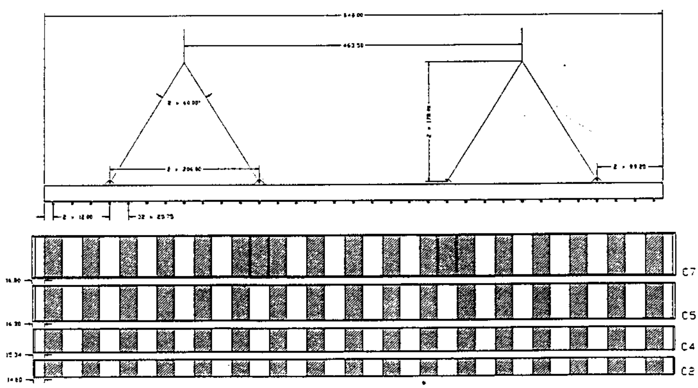

Figure 6.1.2-2 Lifting Beam Model for Containers C2, C4, C5, C7

DCR-96-001, LLCE Container and Lift Beam Design Calculation Report

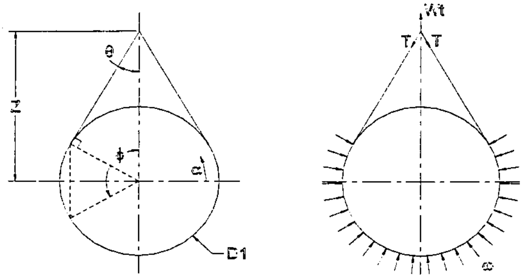

Figure 6.1.2-3 Sling Reaction Force Pressure Conversion

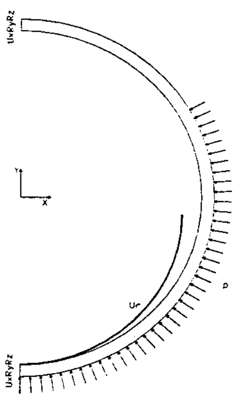

Figure 6.1.2-4 Lifting Plane Strain Model

DCR-96-001, LLCE Container and Lift Beam Design Calculation Report

Design Inputs

Index:

$i := 0..6$

$\text{Container} := (1\ 2\ 3\ 4\ 5\ 6\ 7)^T$

HDPE Yield Strength at 120 deg F:

$\sigma_{hdpe} := 2085 \frac{lbf}{in^2}$

HDPE Modulus of Elasticity at 120 deg F:

$E_{hdpe} := 82500 \frac{lbf}{in^2}$

Sling Angle:

$\theta := 30 \cdot deg$

Sling Width:

$w := (24\ 24\ 24\ 24\ 24\ 24\ 24)^T \cdot in$

Sling Number:

$S := (13\ 17\ 13\ 17\ 17\ 13\ 19)^T$

Assumptions

The worst case load application environment exists at the upper end of the operational temperature requirement of 120 °F. All material properties used in the analysis are based on this temperature. Dynamic loading of the container during lifting and handling operations is neglected. Additionally, the structural stiffness of the void fill material is conservatively neglected. During all phases of the lifting and handling operations, the maximum elevation difference between the two crane pick points is assumed to be 30 in. The load distributions given in Reference [21] and Appendix 6.1.1 are assumed to be worst case. Since the analysis is tailored to the provided and calculated distributions, the integrity of the container is subject to reanalysis and engineering evaluation for all load distributions other than those specified in Reference [21] and Appendix 6.1.1.

DCR-96-001, LLCE Container and Lift Beam Design Calculation Report

Calculations

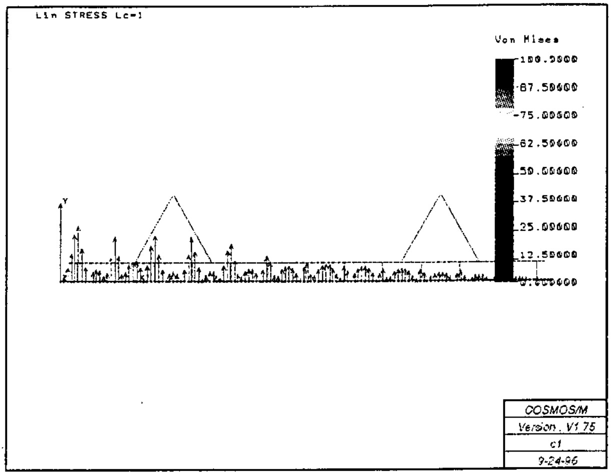

Figure 6.1.2-5 Beam Model VonMises Stress for C1 Lifting

DCR-96-001, LLCE Container and Lift Beam Design Calculation Report

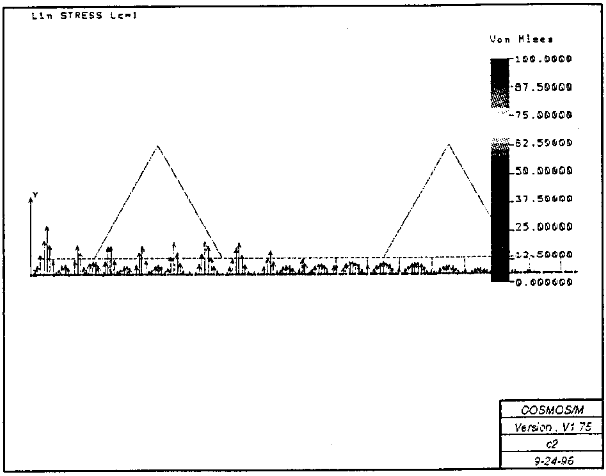

Figure 6.1.2-6 Beam Model VonMises Stress for C2 Lifting

DCR-96-001, LLCE Container and Lift Beam Design Calculation Report

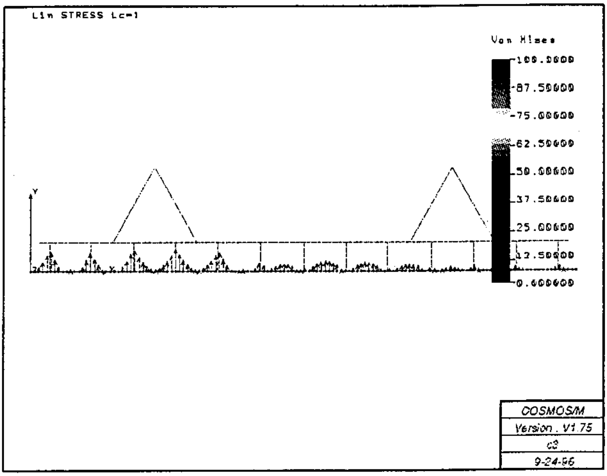

Figure 6.1.2-7 Beam Model VonMises Stress for C3 Lifting

DCR-96-001, LLCE Container and Lift Beam Design Calculation Report

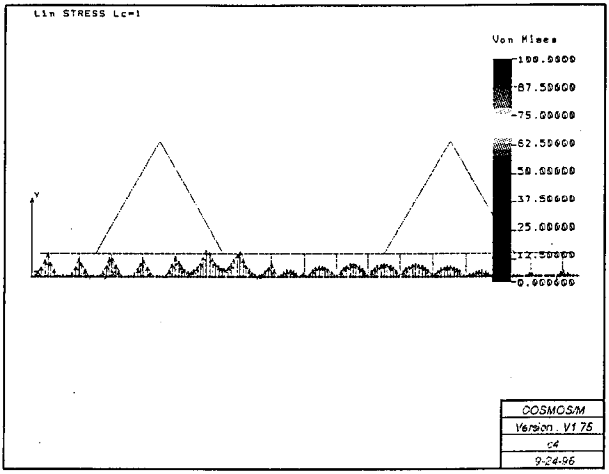

Figure 6.1.2-8 Beam Model VonMises Stress for C4 Lifting

DCR-96-001, LLCE Container and Lift Beam Design Calculation Report

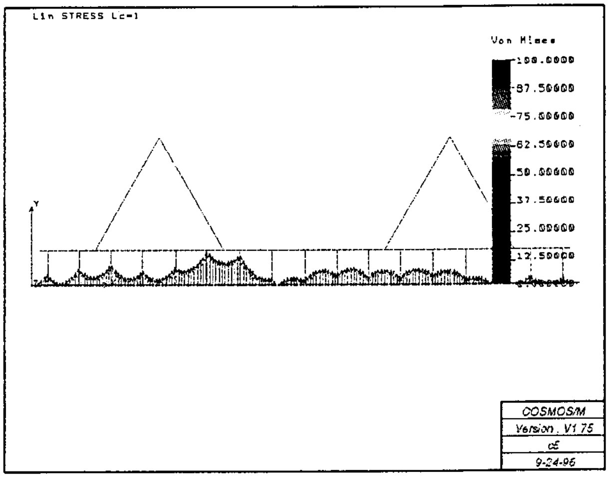

Figure 6.1.2-9 Beam Model VonMises Stress for C5 Lifting

DCR-96-001, LLCE Container and Lift Beam
Design Calculation Report

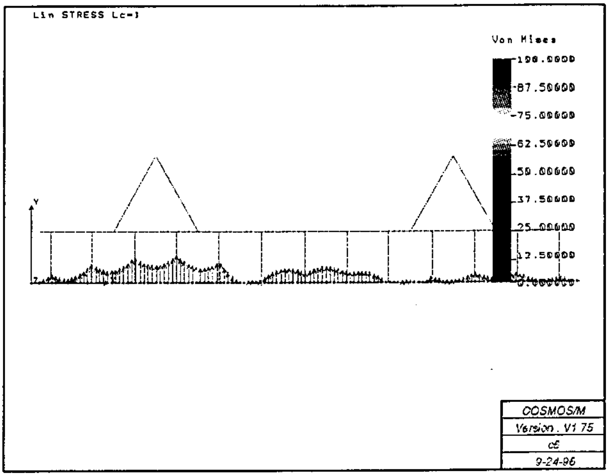

Figure 6.1.2-10 Beam Model VonMises Stress for C6 Lifting

DCR-96-001, LLCE Container and Lift Beam Design Calculation Report

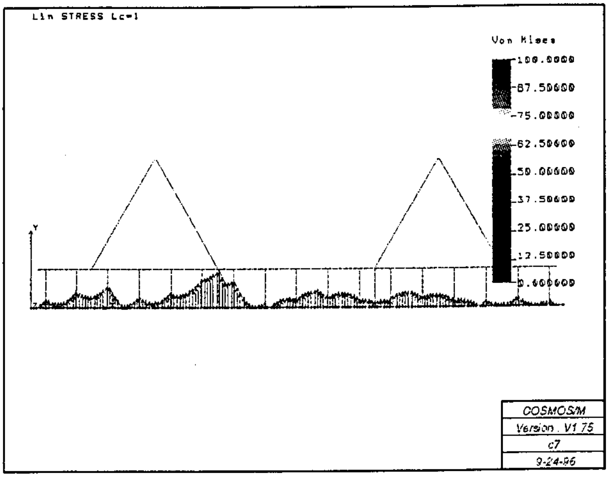

Figure 6.1.2-11 Beam Model VonMises Stress for C7 Lifting

Beam Model VonMises Stress:

$$\sigma_{bl\_von} := (41\ \ 45\ \ 21\ \ 26\ \ 30\ \ 25\ \ 36)^{T} \cdot \frac{lbf}{in^2}$$

Beam Model Lifting Sling Reaction Force:

$$Wt := (2901\ \ 2794\ \ 3550\ \ 3754\ \ 6008\ \ 8797\ \ 9999)^{T} \cdot lbf$$

Lifting Sling Angle Modifier:

$$\phi := 90 \cdot deg + \theta$$

DCR-96-001, LLCE Container and Lift Beam Design Calculation Report

Lifting Sling Force per Unit Length:

$$\omega_i := \frac{Wt_i}{D1_i \cdot \sin(\phi)}$$

$$\omega^T = (\ 128.81\ \ 124.06\ \ 113.87\ \ 120.41\ \ 127.89\ \ 160.43\ \ 182.35\ ) \cdot \frac{lbf}{in}$$

Lifting Sling Pressure:

$$p_i := \frac{\omega_i}{w_i}$$

$$p^T = (\ 5.37\ \ 5.17\ \ 4.74\ \ 5.02\ \ 5.33\ \ 6.68\ \ 7.60\ ) \cdot psi$$

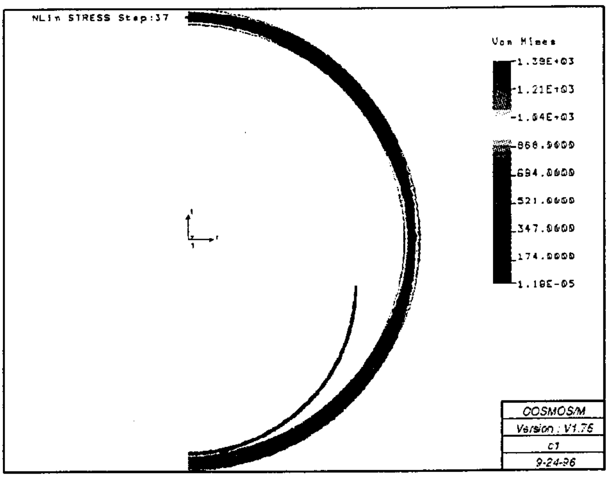

Figure 6.1.2-12 Plane Strain Model VonMises Stress for C1 Lifting

DCR-96-001, LLCE Container and Lift Beam Design Calculation Report

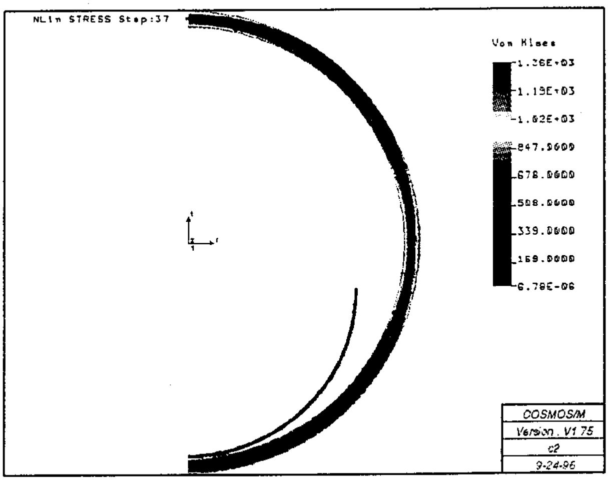

Figure 6.1.2-13 Plane Strain Model VonMises Stress for C2 Lifting

DCR-96-001, LLCE Container and Lift Beam
Design Calculation Report

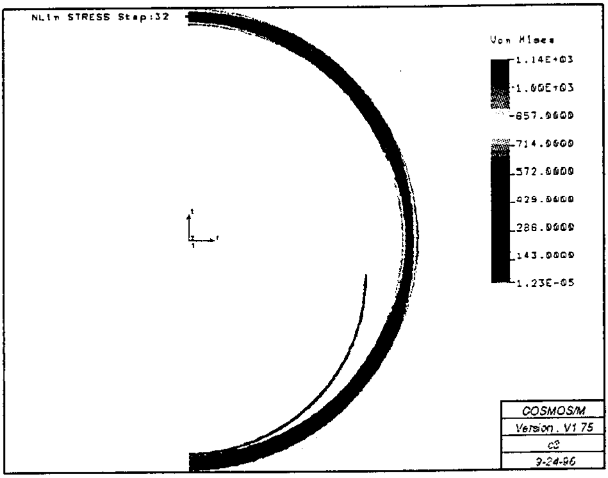

Figure 6.1.2-14 Plane Strain Model VonMises Stress for C3 Lifting

DCR-96-001, LLCE Container and Lift Beam Design Calculation Report

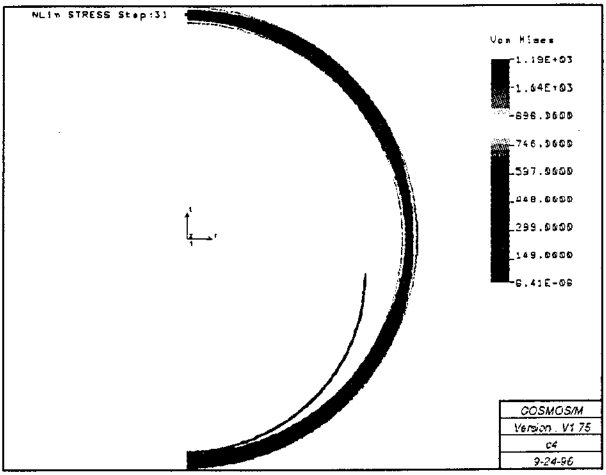

Figure 6.1.2-15 Plane Strain Model VonMises Stress for C4 Lifting

DCR-96-001, LLCE Container and Lift Beam
Design Calculation Report

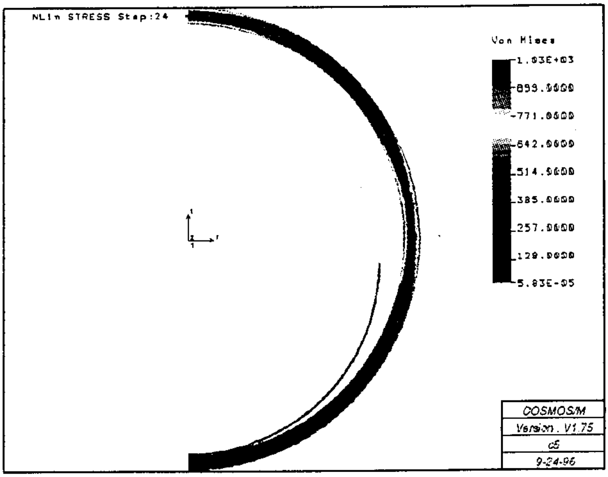

Figure 6.1.2-16 Plane Strain Model VonMises Stress for C5 Lifting

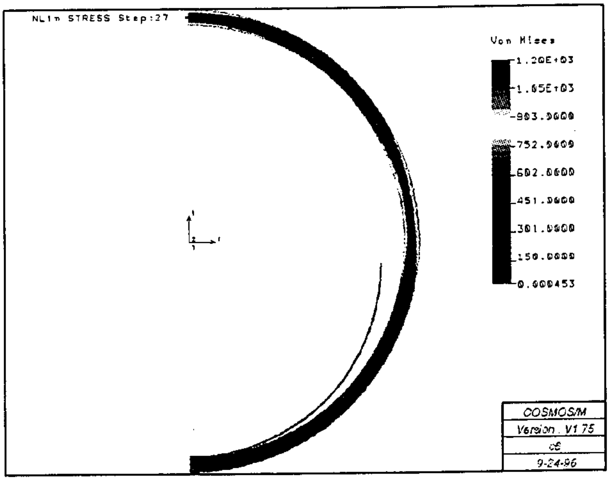

Figure 6.1.2-17 Plane Strain Model VonMises Stress for C6 Lifting

DCR-96-001, LLCE Container and Lift Beam Design Calculation Report

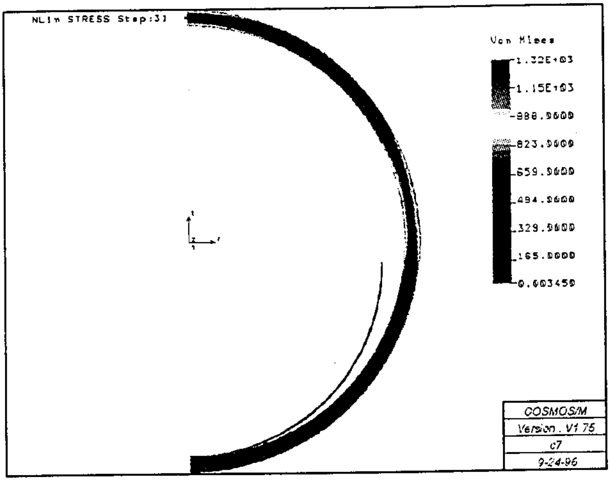

Figure 6.1.2-18 Plane Strain Model VonMises Stress for C7 Lifting

Plane Strain Model VonMises Stress:

$$\sigma_{pl\_von} := (1390\ \ 1360\ \ 1140\ \ 1190\ \ 1030\ \ 1200\ \ 1320)^T \cdot \frac{lbf}{in^2}$$

Maximum VonMises Stress:

$$\sigma_{maxl\_von_i} := \sigma_{bl\_von_i} + \sigma_{pl\_von_i}$$

$$\sigma_{maxl\_von}{}^T = (1431\ \ 1405\ \ 1161\ \ 1216\ \ 1060\ \ 1225\ \ 1356) \cdot \frac{lbf}{in^2}$$

DCR-96-001, LLCE Container and Lift Beam Design Calculation Report

Margin of Safety Against Failure Due to Lifting Container:

$$MS_{lift_i} = \frac{\sigma_{hdpe}}{\sigma_{maxl\_von_i}} - 1$$

$$MS_{lift}^T = (\,0.46 \;\; 0.48 \;\; 0.80 \;\; 0.71 \;\; 0.97 \;\; 0.70 \;\; 0.54\,)$$

Summary

$$\text{Container} = \begin{bmatrix} 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \\ 7 \end{bmatrix} \qquad \sigma_{maxl\_von} = \begin{bmatrix} 1431 \\ 1405 \\ 1161 \\ 1216 \\ 1060 \\ 1225 \\ 1356 \end{bmatrix} \cdot \frac{lbf}{in^2} \qquad MS_{lift} = \begin{bmatrix} 0.46 \\ 0.48 \\ 0.80 \\ 0.71 \\ 0.97 \\ 0.70 \\ 0.54 \end{bmatrix}$$

6.1.3 Lift Beam Lifting and Handling Calculations

Overview

The structural response of the long lift beam in a lifting and handling scenario is calculated using a combined beam finite element model that simulates a two crane lift. The wire rope bridle slings, lifting beam, wide body basket nylon slings, and C7 container are all modeled simultaneously as discrete components of a lifting system. The analysis of the long lift beam lifting the C7 container is determined to be design limiting due to the longer moment arm and higher distributed and point loads. The long lift beam and C7 container are modeled with 2-D linear elastic beam elements. The bridle slings and wide body basket slings are modeled with 2-D nonlinear gap elements to simulate the tension-only load carrying capabilities of these components. The load carrying capacity of the contaminated equipment, skid, and void fill material is not modeled, but the mass of the cargo is incorporated into the system as distributed or point loads applied to the container.

In addition to the combined beam model that is used to determine the bending stresses imposed on each component, 3-D linear finite element models of the lift lug, sling lug, and combined beam/lug are used to determine the localized stresses in these components. As input to the 3-D tetrahedral element models, the magnitude of force acting locally on the lugs and beam are determined from the 2-D elastic beam model output. The stresses determined by the beam model are used to evaluate the long lift beam's resistance to failure in bending. The stresses determined by the tetrahedral models of the lift lug, sling lug, and beam/lug are used to determine the highest stress in the individual components and welds during lifting and handling.

The weld stresses for lift and sling lugs are determined analytically through the use of standard strength-of-materials formulas.

The beam and lug material properties are taken from the ASTM A-36 and AISI 1018 CRS standards. The skid/bag and equipment/waste weights are taken as theoretical maximums from Reference [21]. The void fill and container weights are taken as theoretical maximums from Appendix 6.1.1.

DCR-96-001, LLCE Container and Lift Beam Design Calculation Report

Schematic

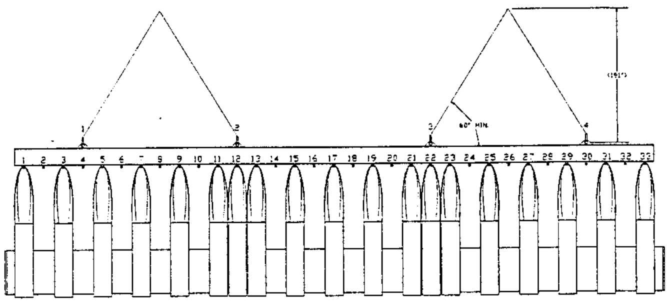

Figure 6.1.3-1 Long Lift Beam Schematic

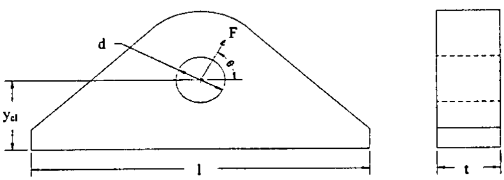

Figure 6.1.3-2 Lift Lug Schematic

DCR-96-001, LLCE Container and Lift Beam Design Calculation Report

Figure 6.1.3-3 Sling Lug Schematic

Design Inputs

Index:

$i := 0..1$

$Lift := 0$

$Sling := 1$

$Lug := (Lift\ \ Sling)^T$

ASTM A-36 Yield Strength:

$$\sigma_{A36} := 36000 \frac{lbf}{in^2}$$

AISI 1018 CRS Yield Strength:

$$\sigma_{1018} := 54000 \frac{lbf}{in^2}$$

Steel Modulus of Elasticity:

$$E_{steel} := 30000000 \frac{lbf}{in^2}$$

Lug Reaction Force Direction:

$$\theta := (60\ \ 75)^T \cdot deg$$

Lug Bearing Hole Diameter:

$$d := (2.333\ \ 0.900)^T \cdot in$$

DCR-96-001, LLCE Container and Lift Beam Design Calculation Report

Lug Thickness:

$$t = (3.000\ \ 7.000)^T \cdot in$$

Lug Length:

$$l = (16.000\ \ 3.000)^T \cdot in$$

Lug Weld Size:

$$h = (0.500\ \ 0.250)^T \cdot in$$

Lug Bearing Hole to Base Weld Distance:

$$y_{cl} = (3.500\ \ 2.500)^T \cdot in$$

Assumptions

Dynamic loading of the lift beam during lifting and handling operations is neglected. During all phases of the lifting and handling operations, the maximum elevation difference between the two crane pick points is assumed to be 30 in. The load distributions given in Reference [21] and Appendix 6.1.1 are assumed to be worst case. Since the analysis is tailored to the provided and calculated distributions, the integrity of the lift beam is subject to reanalysis and engineering evaluation for all load distributions other than those specified in Reference [21] and Appendix 6.1.1.

DCR-96-001, LLCE Container and Lift Beam Design Calculation Report

Calculations

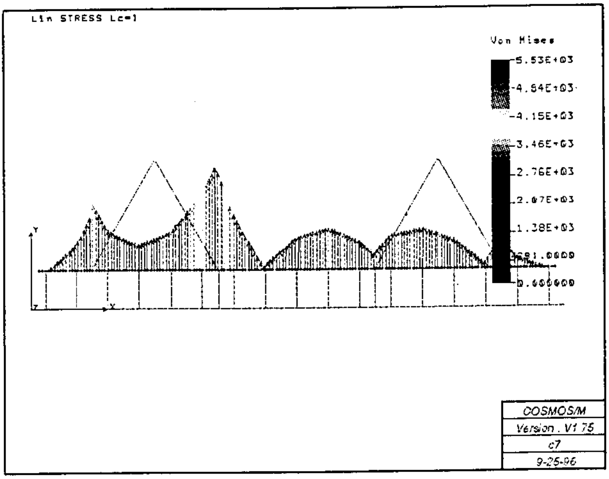

Figure 6.1.3-4 Beam Model VonMises Stress for Lift Beam

Beam Model VonMises Stress of Lift Beam:

$$\sigma_{von\_beam} := 5530 \frac{lbf}{in^2}$$

Margin of Safety Against Failure of Lift Beam:

$$MS_{beam} := \frac{\sigma_{A36}}{\sigma_{von\_beam}} - 1$$

$$MS_{beam} = 5.51$$

DCR-96-001, LLCE Container and Lift Beam Design Calculation Report

Lug Reaction Force Magnitude:

$$F := (60000 \;\; 10000)^T \cdot lbf$$

Lug Moment:

$$M_i := F_i \cdot y_{cl_i} \cdot \cos\left(\theta_i\right)$$

$$M^T = (105000 \;\; 6470) \cdot in \cdot lbf$$

Lug Weld Group Area:

$$A_{weld_i} := 1.414 h_i \cdot \left(l_i - t_i\right)$$

$$A_{weld}^T = (13.433 \;\; 3.535) \cdot in^2$$

Lug Weld Group Moment of Inertia:

$$I_{weld_i} := 0.707 h_i \cdot \frac{l_i^2}{6} \cdot \left(3 \cdot t_i - l_i\right)$$

$$I_{weld}^T = (377.067 \;\; 6.363) \cdot in^4$$

Lug Weld Normal Stress:

$$\sigma_{y\_weld_i} := \frac{F_i \cdot \sin\left(\theta_i\right)}{A_{weld_i}} - \frac{M_i \cdot \frac{l_i}{2}}{I_{weld_i}}$$

$$\sigma_{y\_weld}^T = (6096 \;\; 4258) \cdot \frac{lbf}{in^2}$$

Lug Weld Shear Stress:

$$\tau_{xy\_weld_i} := \frac{F_i \cdot \cos\left(\theta_i\right)}{A_{weld_i}}$$

$$\tau_{xy\_weld}^T = (2233 \;\; 732) \cdot \frac{lbf}{in^2}$$

Lug Weld VonMises Stress:

$$\sigma_{von\_weld_i} := \sqrt{\left(\sigma_{y\_weld_i}\right)^2 - 3 \cdot \left(\tau_{xy\_weld_i}\right)^2}$$

$$\sigma_{von\_weld}^T = (7220 \;\; 4443) \cdot \frac{lbf}{in^2}$$

DCR-96-001, LLCE Container and Lift Beam Design Calculation Report

Margin of Safety Against Failure of Lug Weld:

$$MS_{weld_i} := \frac{\sigma_{A36}}{\sigma_{von\_weld_i}} - 1$$

$$MS_{weld}^{T} = (\ 3.99 \quad 7.10\ )$$

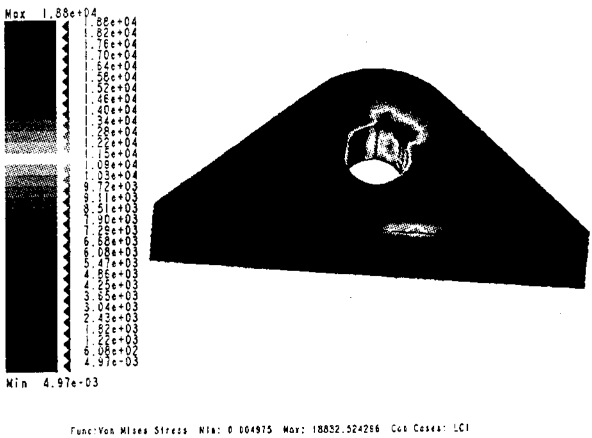

Figure 6.1.3-5 Tetrahedral Model VonMises Stress for Lift Lug

Lift Lug VonMises Stress:

$$\sigma_{von\_liftlug} := 18000 \frac{lbf}{in^2}$$

DCR-96-001, LLCE Container and Lift Beam
Design Calculation Report

Margin of Safety Against Failure of Lift Lug:

$$MS_{liftlug} := \frac{\sigma_{1018}}{\sigma_{von\_liftlug}} - 1$$

$$MS_{liftlug} = 2.00$$

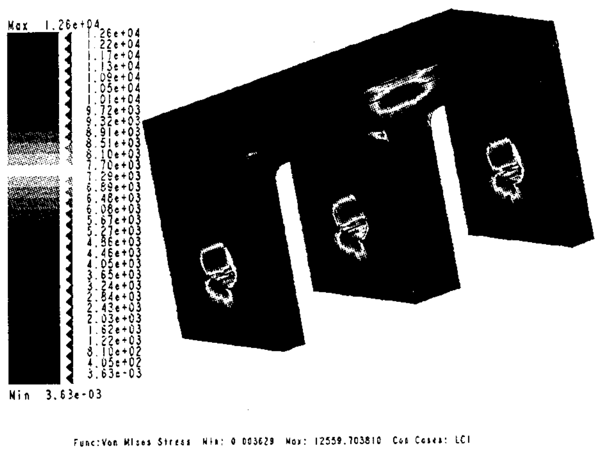

Figure 6.1.3-6 Tetrahedtral Model VonMises Stress for Sling Lug

Sling Lug VonMises Stress:

$$\sigma_{von\_slinglug} := 12600 \frac{lbf}{in^2}$$

DCR-96-001, LLCE Container and Lift Beam Design Calculation Report

Margin of Safety Against Failure of Sling Lug:

$$MS_{slinglug} := \frac{\sigma_{1018}}{\sigma_{von\_slinglug}} - 1$$

$$MS_{slinglug} = 3.29$$

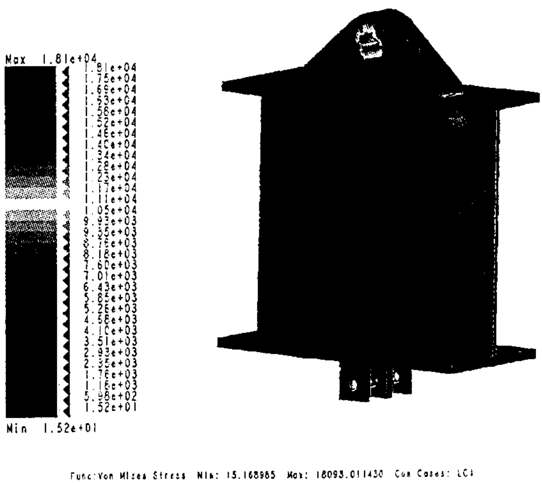

Figure 6.1.3-7 Tetrahedral Model VonMises Stress for Assembled Beam Section

Overall Minimum Margin of Safety:

$$MS := \left(MS_{weld_0}\ MS_{weld_1}\ MS_{beam}\ MS_{liftlug}\ MS_{slinglug}\right)^T$$

$$MS_{min} := \min(MS)$$

$$MS_{min} = 2.00$$

DCR-96-001, LLCE Container and Lift Beam Design Calculation Report

Summary

$Lug = \begin{matrix} 0 \\ 1 \end{matrix}$

$\sigma_{von\_weld} = \begin{matrix} 7220 \\ 4443 \end{matrix} \cdot \frac{lbf}{in^2}$ $\qquad MS_{weld} = \begin{matrix} 3.99 \\ 7.10 \end{matrix}$

$\sigma_{von\_beam} = 5530 \cdot \frac{lbf}{in^2}$ $\qquad MS_{beam} = 5.51$

$\sigma_{von\_liftlug} = 18000 \cdot \frac{lbf}{in^2}$ $\qquad MS_{liftlug} = 2.00$

$\sigma_{von\_slinglug} = 12600 \cdot \frac{lbf}{in^2}$ $\qquad MS_{slinglug} = 3.29$

$MS_{min} = 2.00$

DCR-96-001, LLCE Container and Lift Beam Design Calculation Report

6.1.4 Container Transportation Calculations - Normal Mode Vibration

Overview

The structural response of each container due to normal mode vibration during transport is calculated using a beam finite element model that simulates the normal mode vibration as defined by ANSI N14.23. The container is modeled with 3-D linear beam finite elements subject to a harmonic base-excitation. The base-excitation is applied through the chock sling tie-down strap locations at a specified frequency and displacement magnitude. The load carrying capacity of the contaminated equipment, skid, and void fill material is not modeled, but the mass of the cargo is incorporated into the system by modifying the container material density to impose equivalent inertial loads. The container material density is derived by taking the largest magnitude lifting sling reaction force generated while the container is sitting on the transport trailer, multiplying the reaction force by the total number of slings to obtain an equivalent weight, and dividing by the volume of the container.

In addition to the beam element models that are used to determine the bending stresses imposed on the container, a 2-D plane strain nonlinear finite element model of the container is used to determine the localized stresses generated by the pinching effect of the chock tie-down straps. As input to the 2-D plane strain model, the magnitude of force acting locally on the container at each tie-down strap location is determined from the 3-D harmonic beam model nodal reaction force output. The stresses determined by the two analysis are conservatively added to determine the highest magnitude of stress in the container during normal transport.

The polyethylene material properties are taken from the analysis given in Appendix 6.2. The skid/bag and equipment/waste weights are taken as theoretical maximums from Reference [21]. The void fill and container weights are taken as theoretical maximums from Appendix 6.1.1.

DCR-96-001, LLCE Container and Lift Beam Design Calculation Report

Schematic

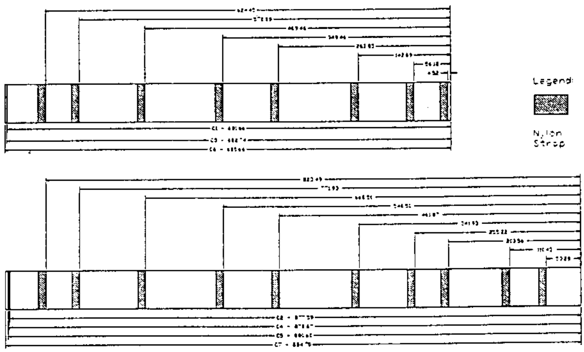

Figure 6.1.4-1 Transportation Tie-Down Strap Locations

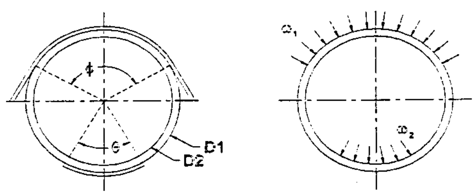

Figure 6.1.4-2 Sling Reaction Force Conversion Diagram

DCR-96-001, LLCE Container and Lift Beam Design Calculation Report

Figure 6.1.4-3 Transportation Plane Strain Model

Design Inputs

Index:

$i := 0..6$

$\text{Container} := (1\ \ 2\ \ 3\ \ 4\ \ 5\ \ 6\ \ 7)^T$

Static Beam Model Lifting Sling Reaction Force:

$Wt_{sling} := (947\ \ 954\ \ 1642\ \ 1802\ \ 4059\ \ 5889\ \ 7382)^T \cdot lbf$

Harmonic Excitation Frequency:

$f := 2 \cdot Hz$

ANSI Tabular Package Weight:

$Wt_{ansi} := (3500\ \ 7000\ \ 14000\ \ 21000\ \ 28000\ \ 35000\ \ 42000\ \ 49000)^T \cdot lbf$

ANSI Tabular RMS Vertical Force:

$RMS_{ansi} := (84\ \ 190\ \ 420\ \ 620\ \ 480\ \ 600\ \ 750\ \ 840)^T \cdot lbf$

Tie-Down Strap Width:

$w_l := (10\ \ 10\ \ 10\ \ 10\ \ 10\ \ 10\ \ 10)^T \cdot in$

DCR-96-001, LLCE Container and Lift Beam Design Calculation Report

Tie-Down Strap Angle of Contact:

$\phi := 30 \cdot deg$

Lifting Sling Angle of Contact:

$\theta := 15 \cdot deg$

Assumptions

The worst case load application environment exists at the upper end of the operational temperature requirement of 120 °F. All material properties used in the analysis are based on this temperature. The ANSI N 14.23 RMS force values are converted to RMS displacements using a single degree of freedom approximation of the momentum equation. Zero damping is assumed in the harmonic analysis. Total number of cycles assumed by taking average transport speed of 7.5 mph over the maximum travel distance of 10 mi. at 2Hz (10,000 cycles).

Calculations

Maximum Equivalent Package Weight:

$Wt_{total_i} := Wt_{sling_i} \cdot S_i$

$Wt_{total}^T = (12311\ \ 16218\ \ 21346\ \ 30634\ \ 69003\ \ 76557\ \ 140258) \cdot lbf$

Maximum Equivalent Package Weight Density:

$\rho g_{equiv_i} := Wt_{total_i} \cdot \left[\left[D1_i^{\ 2} - \left(D1_i - 2.0 \cdot T1_i \right)^2 \right] \cdot \frac{\pi}{4} \cdot L1_i \right]^{-1}$

$\rho g_{equiv}^T = (0.261\ \ 0.267\ \ 0.236\ \ 0.263\ \ 0.263\ \ 0.286\ \ 0.407) \cdot \frac{lbf}{in^3}$

RMS Vertical Force:

$i := 0..3$

$F_{rms_i} := 2.3 \cdot linterp\left(Wt_{ansi}, RMS_{ansi}, Wt_{total_i} \right)$

$i := 4..6$

$F_{rms_i} := 2.3 \cdot Wt_{total_i} \cdot 0.0045$

$F_{rms}^T = (838\ \ 1112\ \ 1410\ \ 1208\ \ 714\ \ 792\ \ 1452) \cdot lbf$

Circular Excitation Frequency:

$i := 0..6$

$\omega := 2 \cdot \pi \cdot f$

$\omega = 12.566 \cdot \frac{rad}{sec}$

DCR-96-001, LLCE Container and Lift Beam
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RMS Vertical Displacement:

$$Y_{rms_i} := \frac{F_{rms_i}}{\left(\frac{Wt_{total_i}}{g}\right)\cdot\omega^2}$$

$$Y_{rms}^{T} = (\ 0.166\ \ 0.168\ \ 0.162\ \ 0.096\ \ 0.025\ \ 0.025\ \ 0.025\ )\cdot in$$

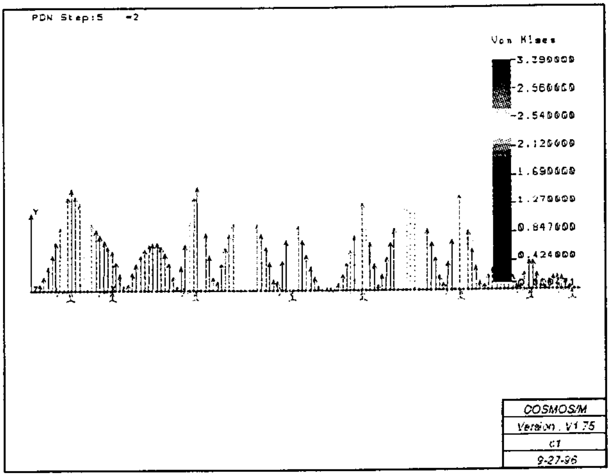

Figure 6.1.4-4 Beam Model VonMises Stress for C1 Transportation

DCR-96-001, LLCE Container and Lift Beam Design Calculation Report

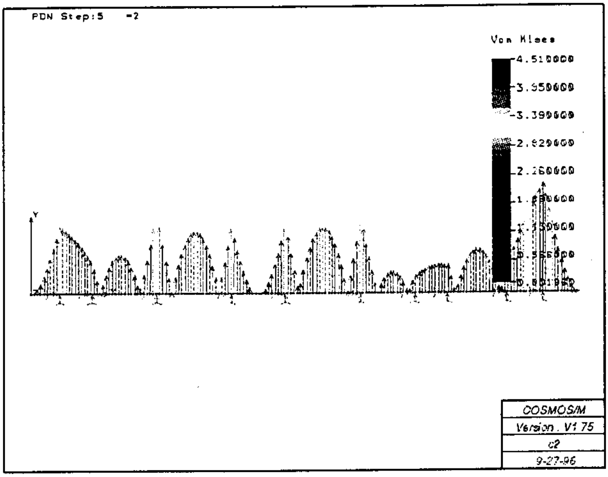

Figure 6.1.4-5 Beam Model VonMises Stress for C2 Transportation

DCR-96-001, LLCE Container and Lift Beam
Design Calculation Report

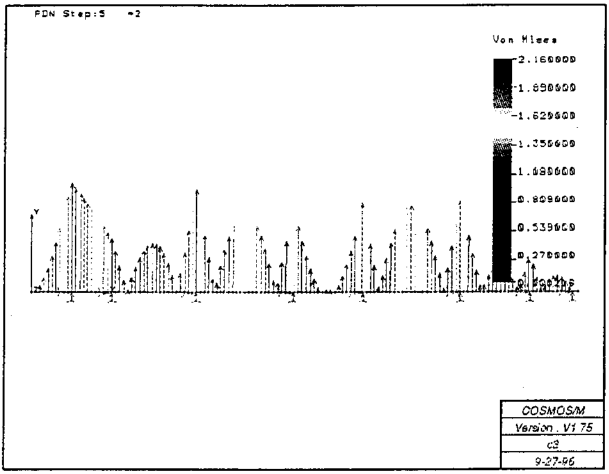

Figure 6.1.4-6 Beam Model VonMises Stress for C3 Transportation

DCR-96-001, LLCE Container and Lift Beam
Design Calculation Report

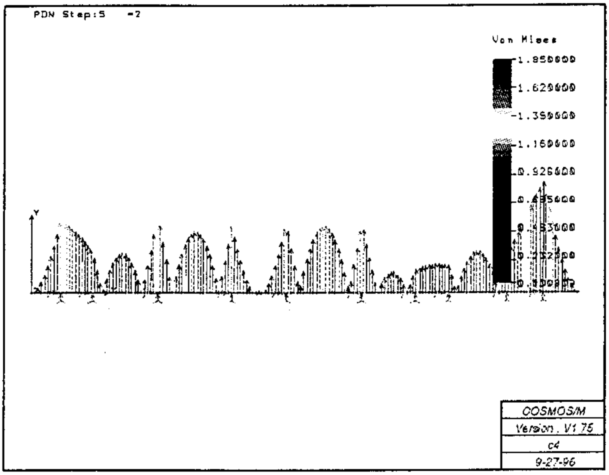

Figure 6.1.4-7 Beam Model VonMises Stress for C4 Transportation

DCR-96-001, LLCE Container and Lift Beam
Design Calculation Report

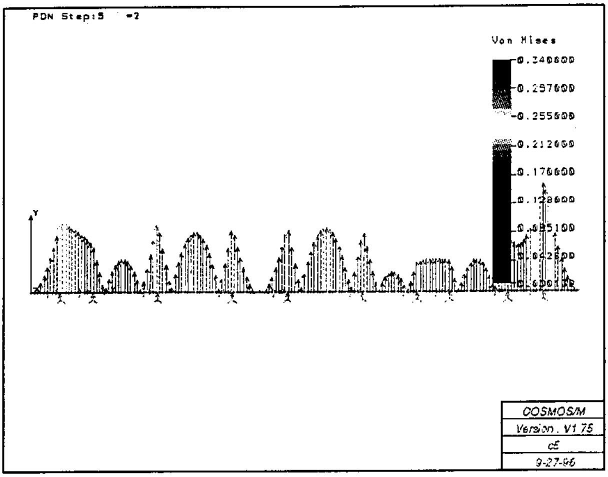

Figure 6.1.4-8 Beam Model VonMises Stress for C5 Transportation

DCR-96-001, LLCE Container and Lift Beam
Design Calculation Report

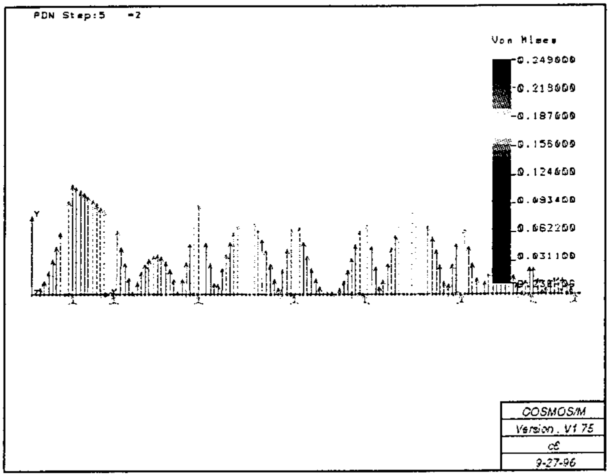

Figure 6.1.4-9 Beam Model VonMises Stress for C6 Transportation

DCR-96-001, LLCE Container and Lift Beam Design Calculation Report

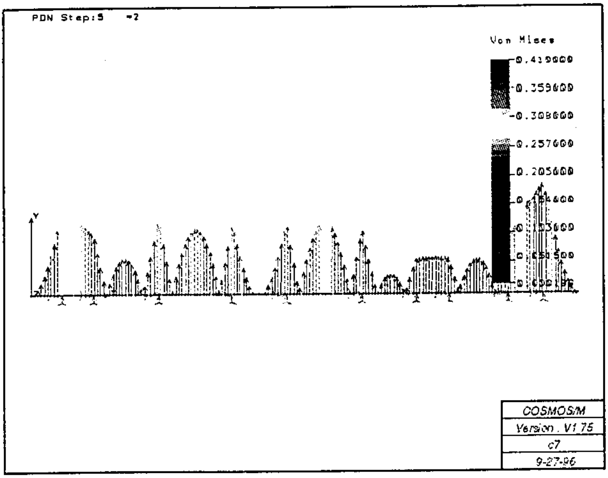

Figure 6.1.4-10 Beam Model VonMises Stress for C7 Transportation

Dynamic Beam ModelVonMises Stress:

$$\sigma_{bv\_von} := (3.4\ \ 4.5\ \ 2.2\ \ 1.9\ \ 0.3\ \ 0.2\ \ 0.4)^T \cdot \frac{lbf}{in^2}$$

Dynamic Beam Model Lowest Natural Frequency:

$$f_N := (4.08\ \ 3.13\ \ 4.29\ \ 3.15\ \ 3.15\ \ 3.90\ \ 2.54)^T \cdot Hz$$

Dynamic Beam Model Tie-down Strap Reaction Force:

$$Wt_1 := (126\ \ 118\ \ 206\ \ 123\ \ 138\ \ 153\ \ 144)^T \cdot lbf$$

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Static Beam Model Lifting Sling Reaction Force:

$$Wt_{2_i} = Wt_{sling_i}$$

$$Wt_2^T = (\ 947\ \ 954\ \ 1642\ \ 1802\ \ 4059\ \ 5889\ \ 7382\ ) \cdot lbf$$

Lifting Sling Width:

$$w_{2_i} = w_i$$

$$w_2^T = (\ 24\ \ 24\ \ 24\ \ 24\ \ 24\ \ 24\ \ 24\ ) \cdot in$$

Tie-down Strap Force per Unit Length:

$$\omega_{1_i} = \frac{Wt_{1_i}}{D1_i \cdot \sin\frac{\phi}{2}}$$

$$\omega_1^T = (\ 19\ \ 18\ \ 22\ \ 13\ \ 10\ \ 9\ \ 9\ ) \cdot \frac{lbf}{in}$$

Lifting Sling Force per Unit Length:

$$\omega_{2_i} = \frac{Wt_{2_i}}{D1_i - 2 \cdot T1_i \cdot \sin\frac{\theta}{2}}$$

$$\omega_2^T = (\ 299\ \ 301\ \ 375\ \ 411\ \ 615\ \ 762\ \ 955\ ) \cdot \frac{lbf}{in}$$

Tie-down Strap Pressure:

$$p_{1_i} = \frac{\omega_{1_i}}{w_{1_i}}$$

$$p_1^T = (\ 1.87\ \ 1.75\ \ 2.21\ \ 1.32\ \ 0.98\ \ 0.93\ \ 0.88\ ) \cdot \frac{lbf}{in^2}$$

Lifting Sling Pressure:

$$p_{2_i} = \frac{\omega_{2_i}}{w_{2_i}}$$

$$p_2^T = (\ 12.47\ \ 12.56\ \ 15.62\ \ 17.14\ \ 25.61\ \ 31.75\ \ 39.80\ ) \cdot \frac{lbf}{in^2}$$

DCR-96-001, LLCE Container and Lift Beam
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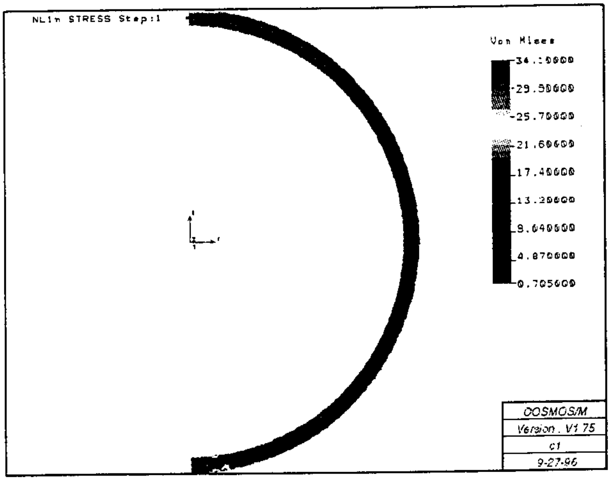

Figure 6.1.4-11 Plane Strain Model VonMises Stress for C1 Transportation

DCR-96-001, LLCE Container and Lift Beam
Design Calculation Report

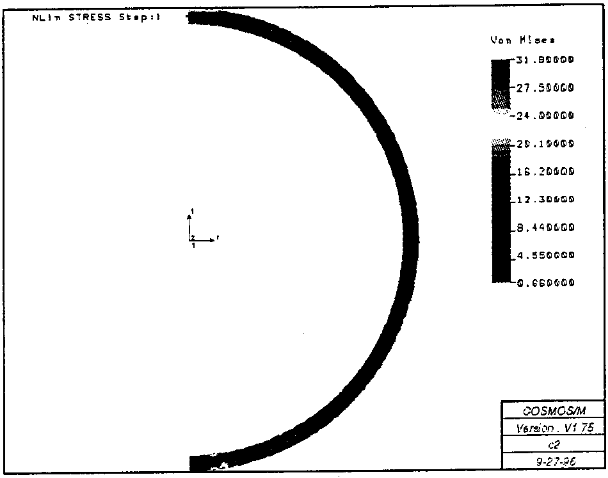

Figure 6.1.4-12 Plane Strain Model VonMises Stress for C2 Transportation

DCR-96-001, LLCE Container and Lift Beam Design Calculation Report

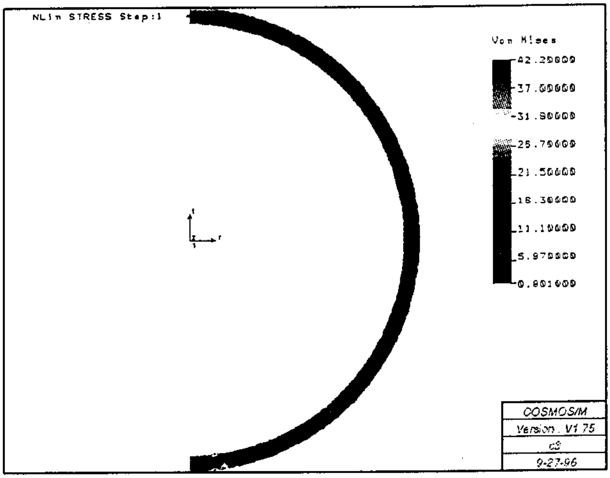

Figure 6.1.4-13 Plane Strain Model VonMises Stress for C3 Transportation

DCR-96-001, LLCE Container and Lift Beam
Design Calculation Report

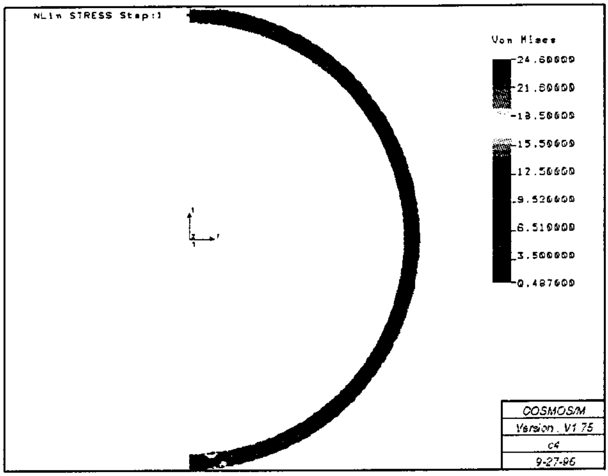

Figure 6.1.4-14 Plane Strain Model VonMises Stress for C4 Transportation

DCR-96-001, LLCE Container and Lift Beam Design Calculation Report

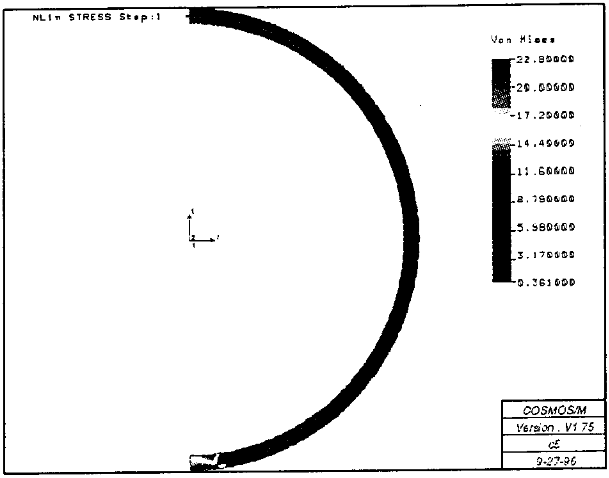

Figure 6.1.4-15 Plane Strain Model VonMises Stress for C5 Transportation

DCR-96-001, LLCE Container and Lift Beam Design Calculation Report

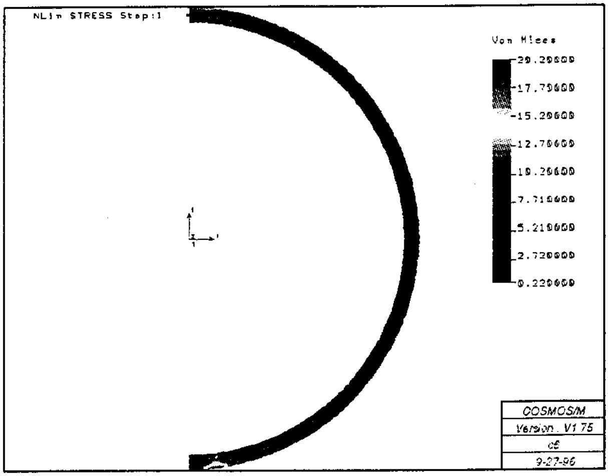

Figure 6.1.4-16 Plane Strain Model VonMises Stress for C6 Transportation

DCR-96-001, LLCE Container and Lift Beam Design Calculation Report

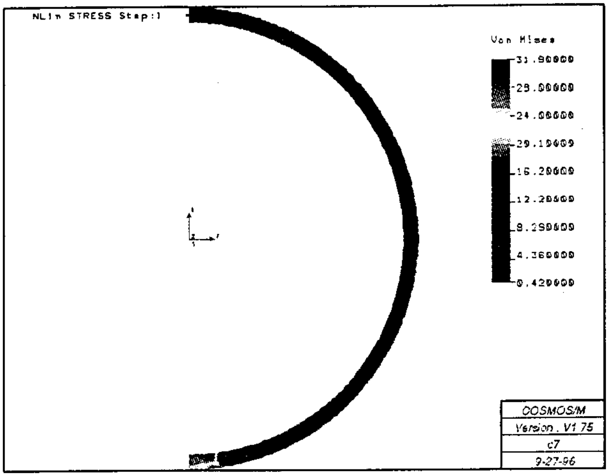

Figure 6.1.4-17 Plane Strain Model VonMises Stress for C7 Transportation

Plane Strain Model VonMises Stress:

$$\sigma_{pv\_von} := (34.1\ \ 31.8\ \ 42.2\ \ 24.6\ \ 22.8\ \ 20.2\ \ 31.9)^{T} \cdot \frac{lbf}{in^2}$$

Maximum VonMises Stress:

$$\sigma_{maxv\_von_i} := \sigma_{bv\_von_i} + \sigma_{pv\_von_i}$$

$$\sigma_{maxv\_von}^{T} = (\ 38\ \ 36\ \ 44\ \ 27\ \ 23\ \ 20\ \ 32\ ) \cdot \frac{lbf}{in^2}$$

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Margin of Safety Against Failure Due to Normal Mode Vibration of Container:

$$MS_{vibration_i} = \frac{\sigma_{hdpe} \cdot 0.70}{\sigma_{maxv\_von_i}} - 1$$

$$MS_{vibration}^T = (\, 37.92 \;\; 39.21 \;\; 31.87 \;\; 54.08 \;\; 62.18 \;\; 70.54 \;\; 44.19 \,)$$

<u>Summary</u>

$$Container = \begin{bmatrix} 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \\ 7 \end{bmatrix} \qquad \sigma_{maxv\_von} = \begin{bmatrix} 38 \\ 36 \\ 44 \\ 27 \\ 23 \\ 20 \\ 32 \end{bmatrix} \cdot \frac{lbf}{in^2} \qquad MS_{vibration} = \begin{bmatrix} 37.92 \\ 39.21 \\ 31.87 \\ 54.08 \\ 62.18 \\ 70.54 \\ 44.19 \end{bmatrix}$$

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6.1.5 Container Transportation Calculations - Shock

Overview

The structural response of each container due to deceleration during transport is calculated using conservation of energy analysis that models the impact of cargo against the "hot" end cap and inertial loads acting on the body. The analysis determines the maximum impact force of the void fill, contaminated equipment, and skid "monolith" against the inner face of the hot end cap. Additionally, the analysis determines the associated compressive stress acting on the end cap, body, and macroencapsulation weld zone during the deceleration.

The polyethylene container material properties are taken from the analysis given in Appendix 6.2.

Schematic

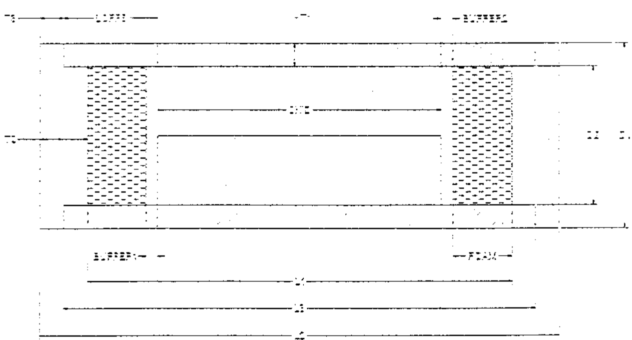

Figure 6.1.5-1 Container Internal Component Layout for Shock

Design Inputs

Index:

$i := 0..6$

$Container := (1\ \ 2\ \ 3\ \ 4\ \ 5\ \ 6\ \ 7)^T$

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Steel Modulus of Elasticity:

$$E_{steel} = 30000000 \frac{lbf}{in^2}$$

Maximum Void Fill Material Modulus of Elasticity:

$$E_{void} = 30000 \frac{lbf}{in^2}$$

Minimum Void Fill Material Crush Strength:

$$\sigma_{void} = 60 \cdot \frac{lbf}{in^2}$$

HDPE Coefficient of Thermal Expansion:

$$\alpha = 1.2 \cdot 10^{-4}$$

Minimum Void Filling Operation Temperature:

$$T_{min} = 32$$

Maximum Transport Operation Temperature:

$$T_{max} = 100$$

Maximum Deceleration Factor:

$$decel = 0.75$$

Foam Thickness:

$$T_{foam} = (9.00\ 9.00\ 9.00\ 9.00\ 9.00\ 9.00\ 9.00)^T \cdot in$$

Assumptions

The worst case load application environment exists at the upper end of the operational temperature requirement of 120 °F. All material properties used in the analysis are based on this temperature. The worst case monolith to hot end cap gap calculation is based on the administratively limited minimum void fill temperature and maximum transportation temperature of 32 and 100 °F, respectively.

The LLCE container is assumed to be carried in the horizontal position on a semi-trailer with the body resting in a full length chock and the forward end cap placed essentially in contact with the bulkhead of the trailer, such that no significant gap exists between the container and the trailer bulkhead in the direction of travel. The monolith is assumed to slide freely through a distance equal to the maximum clearance between the monolith and the forward end cap under the influence

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of a maximum 0.75g deceleration. For purposes of end cap shock analysis, friction between the monolith and body ID is ignored along with the presence of foam material in the gap.

The container is assumed to be firmly strapped down to the semi-trailer, and the end cap of the container is assumed to be fully supported by the trailer bulkhead. When the 0.75g deceleration is imposed, the monolith slides forward without friction until it impacts the inside face of the forward end cap. The end cap is assumed to present a completely rigid surface to the monolith, conservatively ignoring compliance of the end cap, bulkhead, and trailer structures. Since the end cap is supported by the bulkhead of the trailer, the state of stress in the end cap is assumed to be one of simple compression through its thickness.

The impact of an elastic rod having distributed mass against a surface may be modeled as a discrete effective mass connected to a massless spring [22]. The effective mass of a longitudinal spring element may be modeled by placing 1/3 of the mass of the spring discretely at the end of the spring. The monolith is therefore modeled as a longitudinal spring with stiffness as a function of the composite modulus of the void fill, equipment, and skid, the cross-sectional area of the monolith, and the length of the monolith. Conservation of energy is assumed for the system and the impact force is determined by solving for the spring deflection at impact.

In addition to the shock forces present in the end cap due to the monolith impact, inertial and monolith frictional sliding forces are present in the side wall of the container. For body stress calculation purposes, frictional coefficients are assumed to be 1.0. The inertial and frictional sliding forces are assumed to act at a maximum in pure compression on the macroencapsulation weld zone (body/end cap interface).

Calculations

Body Cross-Sectional Area:

$$A_{body_i} = \frac{\pi}{4} \cdot \left[{D1_i}^2 - \left(D1_i - 2 \cdot T1_i \right)^2 \right]$$

$$A_{body}{}^T = (69.46 \;\; 69.46 \;\; 133.20 \;\; 133.20 \;\; 300.70 \;\; 395.13 \;\; 395.13) \cdot in^2$$

Maximum Monolith Slip Distance:

$$h_i = T_{foam_i} - L1_i \cdot \alpha \cdot \left(T_{max} - 70 \right)$$

$$h^T = (11.44 \;\; 12.15 \;\; 11.44 \;\; 12.15 \;\; 12.14 \;\; 11.44 \;\; 12.14) \cdot in$$

Monolith Weight:

$$W_{monolith_i} = W_{void_i} + W_{equip_i} + W_{skid_i}$$

$$W_{monolith}{}^T = (9663 \;\; 12531 \;\; 17233 \;\; 23804 \;\; 50592 \;\; 53602 \;\; 82763) \cdot lbf$$

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Monolith Length:

$$L_{monolith_i} = L1_i - 2 \cdot T_{foam_i}$$

$$L_{monolith}^T = (\ 660.06 \quad 855.99 \quad 659.74 \quad 855.67 \quad 855.10 \quad 658.86 \quad 854.79\ ) \cdot in$$

Monolith Composite Modulus:

$$A_{steel_i} = \frac{W_{equip_i} - W_{skid_i}}{L1_i \cdot 0.29 \frac{lbf}{in^3}}$$

$$A_{steel}^T = (\ 14.12 \quad 14.42 \quad 20.57 \quad 26.84 \quad 47.30 \quad 64.19 \quad 118.10\ ) \cdot in^2$$

$$A_{monolith_i} = \frac{\pi}{4} \cdot \left(D1_i - 2 \cdot T1_i \right)^2$$

$$A_{monolith}^T = (\ 461.67 \quad 461.67 \quad 884.68 \quad 884.68 \quad 2010.35 \quad 2753.56 \quad 2753.56\ ) \cdot in^2$$

$$A_{void_i} = A_{monolith_i} - A_{steel_i}$$

$$A_{void}^T = (\ 447.56 \quad 447.26 \quad 864.11 \quad 857.84 \quad 1963.04 \quad 2689.37 \quad 2635.47\ ) \cdot in^2$$

$$E_{monolith_i} = \frac{A_{void_i} \cdot E_{void} - A_{steel_i} \cdot E_{steel}}{A_{monolith_i}}$$

$$E_{monolith}^T = (\ 946444 \quad 965872 \quad 726685 \quad 939211 \quad 735183 \quad 728604 \quad 1315360\ ) \cdot \frac{lbf}{in^2}$$

Monolith Potential Energy:

$$PE(x) = \frac{1}{3} \cdot W_{monolith_i} \cdot \left(x - decel \cdot h_i \right)$$

Monolith Stiffness:

$$k_i = \frac{A_{monolith_i} \cdot E_{monolith_i}}{L_{monolith_i}}$$

$$k^T = (\ 661981 \quad 520937 \quad 974448 \quad 971052 \quad 1728421 \quad 3045042 \quad 4237209\ ) \cdot \frac{lbf}{in}$$

Monolith Kinetic Energy:

$$KE(x) = \frac{1}{2} \cdot k_i \cdot x^2$$

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Conservation of Energy (Solve KE and PE for Monolith Deflection):

$x := 1\cdot in$ <-- initial guess

$deflection_i := root(KE(x) - PE(x), x)$

$deflection^T = (\,0.294\;\; 0.390\;\; 0.324\;\; 0.394\;\; 0.431\;\; 0.323\;\; 0.351\,)\cdot in$

Monolith Impact Force:

$F_{impact_i} := k_i \cdot deflection_i$

$F_{impact}^T = (\,194539\;\; 203331\;\; 315720\;\; 382677\;\; 745706\;\; 984134\;\; 1486963\,)\cdot lbf$

Monolith Crush Distance:

$$h_{crush_i} := \frac{PE\ deflection_i}{\sigma_{void} \cdot A_{monolith_i}}$$

$h_{crush}^T = (\,1.032\;\; 1.433\;\; 0.964\;\; 1.421\;\; 1.334\;\; 0.963\;\; 1.579\,)\cdot in$

End Cap Compressive Impact Stress:

$$\sigma_{endcap_i} := \frac{F_{impact_i}}{A_{monolith_i}}$$

$$\sigma_{endcap}^T = (\,421\;\; 440\;\; 357\;\; 433\;\; 371\;\; 357\;\; 540\,)\cdot \frac{lbf}{in^2}$$

Margin of Safety Against Failure Due to Monolith Impact on End Cap:

$$MS_{endcap_i} := \frac{\sigma_{hdpe}}{\sigma_{endcap_i}} - 1$$

$MS_{endcap}^T = (\,3.95\;\; 3.73\;\; 4.84\;\; 3.82\;\; 4.62\;\; 4.83\;\; 2.86\,)$

Body Frictional Sliding Resistance Force:

$\mu := 1.0$ <--- assumed maximum

$F_{sliding_i} := W_{monolith_i} \cdot \mu$

$F_{sliding}^T = (\,9663\;\; 12531\;\; 17233\;\; 23804\;\; 50592\;\; 53602\;\; 82763\,)\cdot lbf$

Body Inertial Deceleration Force:

$F_{inertial_i} := \left(W_{body_i} - W_{end_i}\right)\cdot decel$

$F_{inertial}^T = (\,1189\;\; 1526\;\; 2297\;\; 2943\;\; 6712\;\; 6962\;\; 8878\,)\cdot lbf$

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Body Compressive Deceleration Stress:

$$\sigma_{body_i} = \frac{F_{inertial_i} - F_{sliding_i}}{A_{body_i}}$$

$$\sigma_{body}^T = (156 \quad 202 \quad 147 \quad 201 \quad 191 \quad 153 \quad 232) \cdot \frac{lbf}{in^2}$$

Margin of Safety Against Failure Due to Frictional and Inertial Deceleration on Body:

$$MS_{body_i} = \frac{\sigma_{hdpe}}{\sigma_{body_i}} - 1$$

$$MS_{body}^T = (12.35 \quad 9.30 \quad 13.22 \quad 9.38 \quad 9.94 \quad 12.60 \quad 7.99)$$

Overall Minimum Margin of Safety Due to Shock and Deceleration on Container:

$$MS_{shock_i} = \min(MS_{endcap_i}, MS_{body_i})$$

$$MS_{shock}^T = (3.95 \quad 3.73 \quad 4.84 \quad 3.82 \quad 4.62 \quad 4.83 \quad 2.86)$$

<u>Summary</u>

$$Container = \begin{bmatrix} 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \\ 7 \end{bmatrix} \qquad \sigma_{endcap} = \begin{bmatrix} 421 \\ 440 \\ 357 \\ 433 \\ 371 \\ 357 \\ 540 \end{bmatrix} \cdot \frac{lbf}{in^2} \qquad MS_{endcap} = \begin{bmatrix} 3.95 \\ 3.73 \\ 4.84 \\ 3.82 \\ 4.62 \\ 4.83 \\ 2.86 \end{bmatrix}$$

$$Container = \begin{bmatrix} 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \\ 7 \end{bmatrix} \qquad \sigma_{body} = \begin{bmatrix} 156 \\ 202 \\ 147 \\ 201 \\ 191 \\ 153 \\ 232 \end{bmatrix} \cdot \frac{lbf}{in^2} \qquad MS_{body} = \begin{bmatrix} 12.35 \\ 9.30 \\ 13.22 \\ 9.38 \\ 9.94 \\ 12.60 \\ 7.99 \end{bmatrix}$$

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Container		MS_{shock}
	1	3.95
	2	3.73
	3	4.84
Container =	4	MS_{shock} = 3.82
	5	4.62
	6	4.83
	7	2.86

6.1.6 Container Void Filling Calculations

Overview

The magnitude of internal pressures generated during the void filling operation is calculated using a classical static pressure method. The analysis determines the maximum pressure acting on the container end cap due to static head of the void fill material and back-pressure due to air flow restrictions through the vent port HEPA filter.

Schematic

None

Design Inputs

Index:

$i := 0..6$

$\mathrm{Container} := (1\ \ 2\ \ 3\ \ 4\ \ 5\ \ 6\ \ 7)^T$

Maximum Void Fill Density:

$\rho_{void} := 35 \cdot \frac{lbf}{ft^3}$

Maximum Back Pressure of HEPA Filter at 30 cfm:

$P_{hepa} := 0.036 \frac{lbf}{in^2}$

Container Inclination During Void Fill Operation:

$\phi_{fill} := 1 \cdot deg$

Assumptions

The container is assumed to be fully supported by the transportation chock along its length. The transport is assumed to be inclined (fore to aft) 1°. The void fill material is assumed to act as a fluid when exerting pressure on the end cap. Since the void fill equipment is assumed to be immediately stopped upon complete filling of the container, no dynamic pressure will be imparted on the container through the void fill pump. Therefore, only static pressures are calculated. Stress calculations are not performed due to the bounding lifting and handling and internal gas generation analysis presented in Sections 6.1.2, and 6.1.8, respectively.

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Calculations

Maximum Void Fill Static Head:

$$P_{void_i} = \rho_{void} \cdot \left[D1_i - 2 \cdot T1_i - \left(L1_i - 2 \cdot T2_i \right) \cdot \sin \phi_{fill} \right]$$

$$P_{void}^{T} = (\,0.7 \;\; 0.8 \;\; 0.9 \;\; 1.0 \;\; 1.3 \;\; 1.4 \;\; 1.5\,) \cdot \frac{lbf}{in^2}$$

Maximum Void Fill Pressure on End Cap:

$$P_{endcap_i} = P_{void_i} - P_{hepa}$$

$$P_{endcap}^{T} = (\,0.8 \;\; 0.8 \;\; 0.9 \;\; 1.0 \;\; 1.4 \;\; 1.5 \;\; 1.5\,) \cdot \frac{lbf}{in^2}$$

Summary

$$\text{Container} = \begin{bmatrix} 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \\ 7 \end{bmatrix} \qquad P_{endcap} = \begin{bmatrix} 0.8 \\ 0.8 \\ 0.9 \\ 1.0 \\ 1.4 \\ 1.5 \\ 1.5 \end{bmatrix} \cdot \frac{lbf}{in^2}$$

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6.1.7 Container Thermal Expansion/Contraction Calculations

Overview

The state of stress in the container body under maximum thermal contraction after void fill is determined using a classical shrink-fit analysis. The analysis determines the maximum stress in the container body when allowed to thermally contract from the maximum void fill temperature down to the minimum operational temperature. Due to the large longitudinal contraction of the container over the temperature range, the thickness of foam end spacers required to mitigate pressure applied to the end caps is determined. The foam end spacer material and thickness is developed to resist excessive contraction during void fill operations and to limit the maximum pressure exerted on the inner face of each end cap.

The polyethylene container material properties are taken from the analysis given in Appendix 6.2. The void fill material and urethane foam material properties are assumed as stated in this section.

Schematic

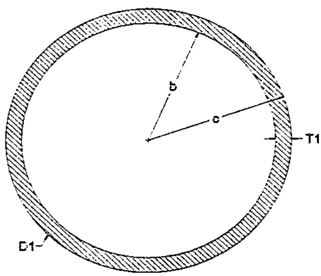

Figure 6.1.7-1 Thermal Contraction Diagram

Design Inputs

Index:

$i := 0..6$

$Container := (1\ 2\ 3\ 4\ 5\ 6\ 7)^T$

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Minimum Operational Temperature:

$T_{min} = -20$

Maximum Void Fill Operation Temperature:

$T_{max} = 100$

HDPE Coefficient of Longitudinal Thermal Expansion:

$\alpha_{long} = 1.2 \cdot 10^{-4}$

HDPE Coefficient of Radial Thermal Expansion:

$\alpha_{rad} = 6.0 \cdot 10^{-5}$

Flexible Urethane Foam Compressive Resistance:

$\delta_{foam} = (0\ \ 10\ \ 20\ \ 30\ \ 40\ \ 50\ \ 60\ \ 70\ \ 80)^T \cdot \%$

$\sigma_{foam} = (0.00\ \ 1.71\ \ 1.80\ \ 1.88\ \ 2.05\ \ 2.32\ \ 2.75\ \ 4.02\ \ 6.54)^T \cdot \frac{lbf}{in^2}$

Maximum Void Fill Pressure:

$p_{void} = \max p_{endcap}$

$p_{void} = 1.5 \cdot \frac{lbf}{in^2}$

Maximum Internal Gas Generation Pressure (Limiting Pressure on End Cap):

$p_{gas} = 7.35 \cdot \frac{lbf}{in^2}$

Void Fill Material Modulus of Elasticity at -20 deg F:

$E_{void\_n20} = 30000 \frac{lbf}{in^2}$

Void Fill Material Poisson's Ratio:

$\nu_{void} = 0.45$

HDPE Yield Strength at -20 deg F:

$\sigma_{hdpe\_n20} = 5310 psi$

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HDPE Modulus of Elasticity at -20 deg F:

$$E_{hdpe\_n20} := 300000 \frac{lbf}{in^2}$$

HDPE Poisson's Ratio:

$$\nu_{hdpe} := 0.45$$

Void Fill Material Inside Radius:

$$a := (0\ 0\ 0\ 0\ 0\ 0\ 0)^T \cdot in$$

Void Fill Material / Container Body Interface Radius:

$$b_i := \frac{D1_i - 2 \cdot T1_i}{2}$$

$$b^T = (\ 12.123\ \ 12.123\ \ 16.781\ \ 16.781\ \ 25.296\ \ 29.605\ \ 29.605\ ) \cdot in$$

Container Body Outside Radius:

$$c_i := \frac{D1_i}{2}$$

$$c^T = (\ 13.003\ \ 13.003\ \ 18.000\ \ 18.000\ \ 27.122\ \ 31.659\ \ 31.659\ ) \cdot in$$

Assumptions

The container is conservatively assumed to freely contract thermally over its entire length both longitudinally and radially. The thermal contraction of the void fill material is conservatively ignored, with deflection due to interface pressure being the only mode of void fill deflection. Therefore, the interaction between the container body and void fill material is modeled by a shrink-fit analysis [23]. The magnitude of maximum pressure applied to the end cap through foam compression is limited at the maximum internal gas generation pressure. Analysis of end cap bending and weld stresses is given in Section 6.1.8.

Calculations

Maximum Body Longitudinal Thermal Contraction:

$$\delta_{body_i} := \alpha_{long} \cdot T_{max} - T_{min} \cdot L1_i$$

$$\delta_{body}^T = (\ 9.76\ \ 12.59\ \ 9.76\ \ 12.58\ \ 12.57\ \ 9.75\ \ 12.57\ ) \cdot in$$

Foam End Spacer Deflection Due to Void Fill Pressure:

$$\delta_{void} := \mathrm{linterp}\ \sigma_{foam}, \delta_{foam}, P_{void}$$

$$\delta_{void} = 8.94 \cdot \%$$

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Foam End Spacer Deflection (Limited by Internal Gas Generation Pressure):

$$\delta_{gas} := \text{linterp}(\sigma_{foam}, \delta_{foam}, p_{gas})$$

$$\delta_{gas} = 83.21 \cdot \%$$

Available Foam End Spacer Deflection:

$$\Delta\delta_{foam} := \delta_{gas} - \delta_{void}$$

$$\Delta\delta_{foam} = 74.28 \cdot \%$$

Minimum Foam End Spacer Required Thickness to Allow Thermal Contraction:

$$t_{foam} := \frac{\delta_{body}}{2 \cdot \Delta\delta_{foam}}$$

$$t_{foam}^{T} = (\,6.57 \;\; 8.47 \;\; 6.57 \;\; 8.47 \;\; 8.46 \;\; 6.56 \;\; 8.46\,) \cdot in$$

Maximum Body Theoretical Radial Thermal Contraction:

$$\delta_{rad_i} := \alpha_{rad} \cdot b_i \cdot (T_{max} - T_{min})$$

$$\delta_{rad}^{T} = (\,0.087 \;\; 0.087 \;\; 0.121 \;\; 0.121 \;\; 0.182 \;\; 0.213 \;\; 0.213\,) \cdot in$$

Void Fill Material / Container Body Interface Pressure:

$$\delta p_i := \left[\frac{b_i \cdot p_i}{E_{hdpe\_n20}} \cdot \left(\frac{c_i^2 - b_i^2}{c_i^2 - b_i^2} - \nu_{hdpe}\right) - \frac{b_i \cdot p_i}{E_{void\_n20}} \cdot \left(\frac{b_i^2 - a_i^2}{b_i^2 - a_i^2} - \nu_{void}\right)\right] - \delta_{rad_i}$$

$p_i := 1.0 \frac{lbf}{in^2}$ <-- initial guess

$$p_{inter_i} := \text{root}(\delta p_i, p_i)$$

$$p_{inter}^{T} = (\,106.70 \;\; 106.70 \;\; 106.75 \;\; 106.75 \;\; 106.29 \;\; 103.41 \;\; 103.41\,) \cdot \frac{lbf}{in^2}$$

Container Body Radial Deflection:

$$\delta_{body\_p_i} := \frac{b_i \cdot p_{inter_i}}{E_{hdpe\_n20}} \cdot \left(\frac{c_i^2 - b_i^2}{c_i^2 - b_i^2} - \nu_{hdpe}\right)$$

$$\delta_{body\_p}^{T} = (\,0.064 \;\; 0.064 \;\; 0.088 \;\; 0.088 \;\; 0.133 \;\; 0.157 \;\; 0.157\,) \cdot in$$

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Void Fill Material Radial Deflection:

$$\delta_{void\_p_i} = \frac{b_i \cdot p_{inter_i}}{E_{void\_n20}} \cdot \left(\frac{b_i^{\,2} - a_i^{\,2}}{b_i^{\,2} - a_i^{\,2}} - \nu_{void} \right)$$

$$\delta_{void\_p}^{\,T} = (\, 0.024 \;\; 0.024 \;\; 0.033 \;\; 0.033 \;\; 0.049 \;\; 0.056 \;\; 0.056 \,) \cdot in$$

Body Tangential Stress:

$$\sigma_{t_i} = p_{inter_i} \cdot \frac{c_i^{\,2} - b_i^{\,2}}{c_i^{\,2} - b_i^{\,2}}$$

$$\sigma_t^{\,T} = (\, 1525 \;\; 1525 \;\; 1525 \;\; 1525 \;\; 1528 \;\; 1545 \;\; 1545 \,) \cdot \frac{lbf}{in^2}$$

Body Radial Stress:

$$\sigma_{r_i} = -p_{inter_i}$$

$$\sigma_r^{\,T} = (\, -107 \;\; -107 \;\; -107 \;\; -107 \;\; -106 \;\; -103 \;\; -103 \,) \cdot \frac{lbf}{in^2}$$

Body Longitudinal Stress:

$$\sigma_{l_i} = p_{gas} \cdot \frac{A_{monolith_i}}{A_{body_i}}$$

$$\sigma_l^{\,T} = (\, 49 \;\; 49 \;\; 49 \;\; 49 \;\; 49 \;\; 51 \;\; 51 \,) \cdot \frac{lbf}{in^2}$$

Body VonMises Stress:

$$\sigma_{vonm\_therm_i} = \sqrt{\frac{\left(\sigma_{t_i} - \sigma_{r_i}\right)^2 - \left(\sigma_{r_i} - \sigma_{l_i}\right)^2 - \left(\sigma_{l_i} - \sigma_{t_i}\right)^2}{2}}$$

$$\sigma_{vonm\_therm}^{\,T} = (\, 1560 \;\; 1560 \;\; 1560 \;\; 1560 \;\; 1562 \;\; 1576 \;\; 1576 \,) \cdot \frac{lbf}{in^2}$$

Margin of Safety Against Failure Due to Thermal Contraction of Body onto Void Fill Material:

$$MS_{therm_i} = \frac{\sigma_{hdpe\_n20}}{\sigma_{vonm\_therm_i}} - 1$$

$$MS_{therm}^{\,T} = (\, 2.40 \;\; 2.40 \;\; 2.40 \;\; 2.40 \;\; 2.40 \;\; 2.37 \;\; 2.37 \,)$$

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Summary

$$\text{Container} = \begin{pmatrix} 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \\ 7 \end{pmatrix} \qquad \sigma_{vonm\_therm} = \begin{pmatrix} 1560 \\ 1560 \\ 1560 \\ 1560 \\ 1562 \\ 1576 \\ 1576 \end{pmatrix} \cdot \frac{lbf}{in^2} \qquad MS_{therm} = \begin{pmatrix} 2.40 \\ 2.40 \\ 2.40 \\ 2.40 \\ 2.40 \\ 2.37 \\ 2.37 \end{pmatrix}$$

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6.1.8 Container Internal Pressure Calculations

Overview

The structural response of each container due to internal gas generation is calculated using a 2-D axisymmetric nonlinear finite element model of the container. The analysis utilizes 8-node quadratic finite elements with the large displacement option.

The polyethylene container material properties are taken from the analysis given in Appendix 6.2. The skid/bag and equipment/waste weights are taken as theoretical maximums from Reference [21].

Schematic

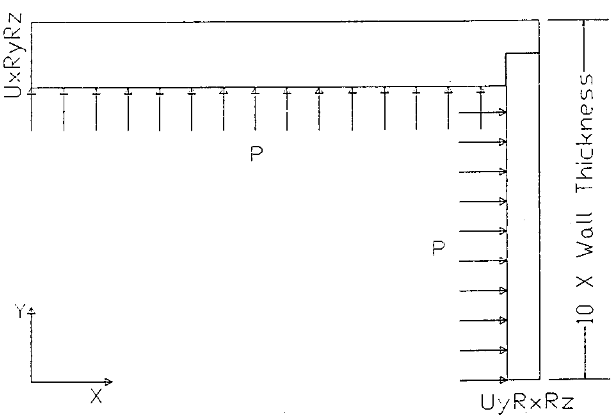

Figure 6.1.8-1 Internal Pressure Axisymmetric Model

DCR-96-001, LLCE Container and Lift Beam Design Calculation Report

Design Inputs

Index:

$i := 0..6$

$Container := (1\ 2\ 3\ 4\ 5\ 6\ 7)^T$

HDPE Creep Yield Strength at 70 deg F:

$$\sigma_{hdpe\_creep70} := 1600 \frac{lbf}{in^2}$$

HDPE Creep Yield Strength of HDPE at 120 deg F:

$$\sigma_{hdpe\_creep120} := 1000 \frac{lbf}{in^2}$$

HDPE Creep Modulus of Elasticity:

$$E_{hdpe\_creep} := 50000 \frac{lbf}{in^2}$$

Assumptions

The worst case load application environment exists at the upper end of the operational temperature requirement of 120 °F for long term storage and at 70 °F for long term burial. All material properties used in the analysis are based on these temperatures in addition to allowance for viscoelastic creep of the material. The container is assumed to be unsupported at each end. The container is assumed to deform freely due to the internal pressure. The void fill material is assumed to have a maximum initial shrinkage equal to 1% of the container inside diameter (with 0 to 1% shrinkage being the actual process requirement).

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Calculations

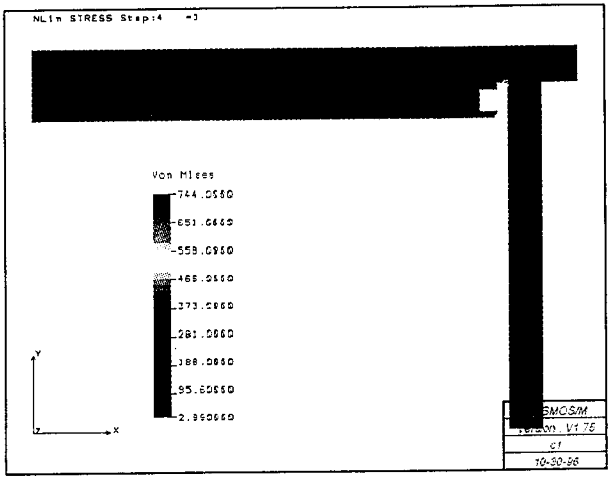

Figure 6.1.8-2 Axisymmetric Model VonMises Stress for C1-C2 Internal Pressure

**DCR-96-001, LLCE Container and Lift Beam
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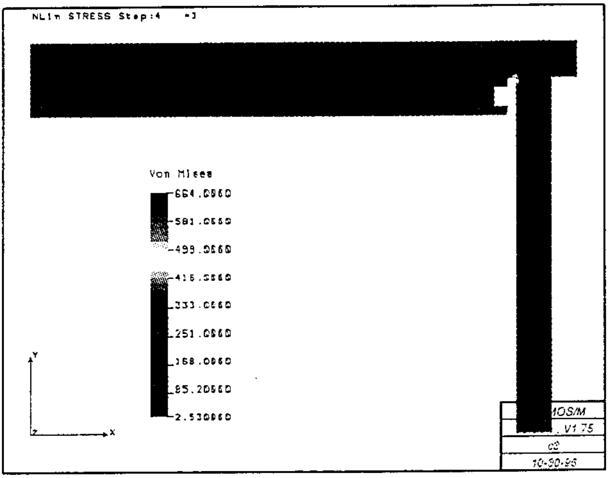

Figure 6.1.8-3 Axisymmetric Model VonMises Stress for C3-C4 Internal Pressure

DCR-96-001, LLCE Container and Lift Beam
Design Calculation Report

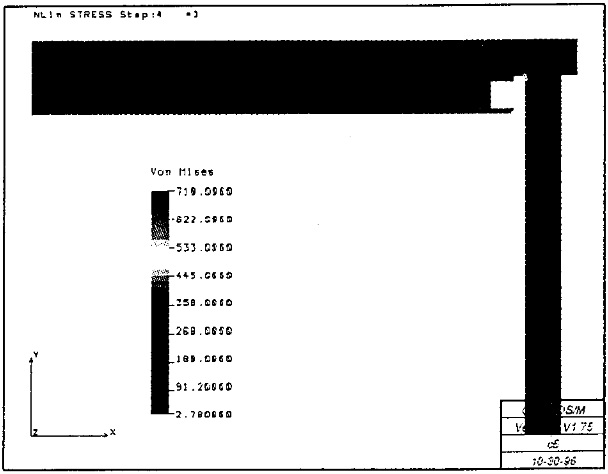

Figure 6.1.8-4 Axisymmetric Model VonMises Stress for C5 Internal Pressure

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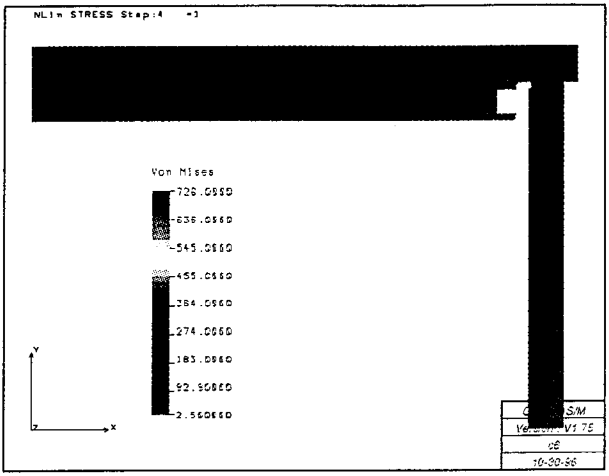

Figure 6.1.8-5 Axisymmetric Model VonMises Stress for C6-C7 Internal Pressure

Axisymmetric Model VonMises Stress Due to Internal Pressure:

$$\sigma_{intpres} := (744\ \ 744\ \ 664\ \ 664\ \ 710\ \ 726\ \ 726)^T \cdot \frac{lbf}{in^2}$$

Margin of Safety Against Failure Due to Internal Pressure in Long Term Storage:

$$MS_{intpres\_storage_i} := \frac{\sigma_{hdpe\_creep120}}{\sigma_{intpres_i}} - 1$$

$$MS_{intpres\_storage}^T = (0.34\ \ 0.34\ \ 0.51\ \ 0.51\ \ 0.41\ \ 0.38\ \ 0.38)$$

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Margin of Safety Against Failure Due to Internal Pressure in Long Term Burial:

$$MS_{intpres\_burial_i} := \frac{\sigma_{hdpe\_creep70}}{\sigma_{intpres_i}} - 1$$

$$MS_{intpres\_burial}{}^{T} = (\,1.15\;\;1.15\;\;1.41\;\;1.41\;\;1.25\;\;1.20\;\;1.20\,)$$

Summary

$$Container = \begin{bmatrix} 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \\ 7 \end{bmatrix} \qquad \sigma_{intpres} = \begin{bmatrix} 744 \\ 744 \\ 664 \\ 664 \\ 710 \\ 726 \\ 726 \end{bmatrix} \cdot \frac{lbf}{in^2}$$

$$Container = \begin{bmatrix} 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \\ 7 \end{bmatrix} \qquad MS_{intpres\_storage} = \begin{bmatrix} 0.34 \\ 0.34 \\ 0.51 \\ 0.51 \\ 0.41 \\ 0.38 \\ 0.38 \end{bmatrix} \qquad MS_{intpres\_burial} = \begin{bmatrix} 1.15 \\ 1.15 \\ 1.41 \\ 1.41 \\ 1.25 \\ 1.2 \\ 1.2 \end{bmatrix}$$

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6.1.9 Container Skid Transfer Calculations

Overview

The magnitude of compressive stress in the container body under maximum weight skid transfer operations is determined using classical methods. The analysis determines the maximum longitudinal compressive stress in the container body due to frictional forces during transfer. Additionally, the analysis determines the maximum bearing compressive stress occurring at one lifting strap support location.

The polyethylene container material properties are taken from the analysis given in Appendix 6.2.

Schematic

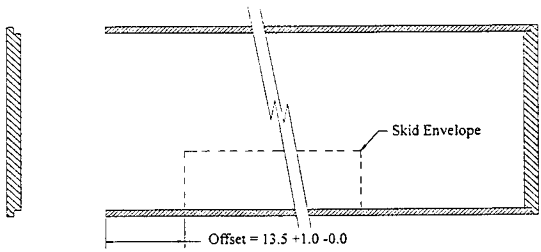

Figure 6.1.9-1 Skid Envelope Offset Diagram

DCR-96-001, LLCE Container and Lift Beam Design Calculation Report

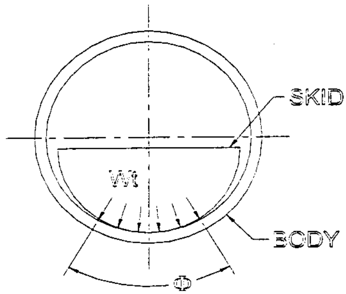

Figure 6.1.9-2 Skid Transfer Diagram

Design Inputs

Index:

$i := 0..6$

$\text{Container} := (1\ \ 2\ \ 3\ \ 4\ \ 5\ \ 6\ \ 7)^T$

HDPE / Steel Static Coefficient of Friction:

$\mu_{hdpe\_steel} := 0.31$

Skid / Body Contact Angle:

$\Phi := 5 \cdot deg$

Assumptions

The worst case load application environment exists at the upper end of the operational temperature range of 120 °F. The container is assumed to be fully supported in the transport chock as the container rests on the default number of lifting slings.

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Calculations

Frictional Force:

$$F_{fric_i} = \mu_{hdpe\_steel} \cdot W_{skid_i} + W_{equip_i}$$

$$F_{fric}^{T} = (\,861 \quad 1133 \quad 1253 \quad 2108 \quad 3713 \quad 3906 \quad 9266\,)\cdot lbf$$

Bearing Force:

$$F_{bear_i} = W_{skid_i} + W_{equip_i}$$

$$F_{bear}^{T} = (\,2776 \quad 3654 \quad 4042 \quad 6800 \quad 11977 \quad 12599 \quad 29891\,)\cdot lbf$$

Compressive Frictional Stress:

$$\sigma_{fric_i} = \frac{F_{fric_i}}{A_{body_i}}$$

$$\sigma_{fric}^{T} = (\,12 \quad 16 \quad 9 \quad 16 \quad 12 \quad 10 \quad 23\,)\cdot\frac{lbf}{in^2}$$

Compressive Bearing Stress:

$$\sigma_{bear_i} = \frac{F_{bear_i}}{\pi \cdot DI_i - 2 \cdot TI_i \cdot \frac{\Phi}{360\,deg} \cdot w_i}$$

$$\sigma_{bear}^{T} = (\,109 \quad 144 \quad 115 \quad 193 \quad 226 \quad 203 \quad 482\,)\cdot\frac{lbf}{in^2}$$

Maximum Compressive Stress:

$$\sigma_{skidtran_i} = \sigma_{fric_i} + \sigma_{bear_i}$$

$$\sigma_{skidtran}^{T} = (\,122 \quad 160 \quad 124 \quad 209 \quad 238 \quad 213 \quad 506\,)\cdot\frac{lbf}{in^2}$$

Margin of Safety Against Failure Due to Skid Transfer:

$$MS_{skidtran_i} = \frac{\sigma_{hdpe}}{\sigma_{skidtran_i}} - 1$$

$$MS_{skidtran}^{T} = (\,16.13 \quad 12.01 \quad 15.76 \quad 8.96 \quad 7.75 \quad 8.79 \quad 3.12\,)$$

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Summary

$$\text{Container} = \begin{pmatrix} 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \\ 7 \end{pmatrix} \qquad \sigma_{skidtran} = \begin{pmatrix} 122 \\ 160 \\ 124 \\ 209 \\ 238 \\ 213 \\ 506 \end{pmatrix} \cdot \frac{lbf}{in^2} \qquad MS_{skidtran} = \begin{pmatrix} 16.13 \\ 12.01 \\ 15.76 \\ 8.96 \\ 7.75 \\ 8.79 \\ 3.12 \end{pmatrix}$$

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6.1.10 Container Burial Calculations

Overview

The long term structural response of the container in a burial scenario is calculated using a plane strain nonlinear finite element model. The nonlinear contact interface between the container body and void fill material is modeled with surface-to-node gap elements. The model uses 8-node quadratic elements with the nonlinear displacement option.

The maximum burial pressure distribution is quarter symmetric and taken from Reference [23]. Due to the long term stable temperature loading condition and the viscoelastic material properties of HDPE, the analysis uses creep based material properties of HDPE at room temperature.

The polyethylene container material properties are taken from the analysis given in Appendix 6.2.

Schematic

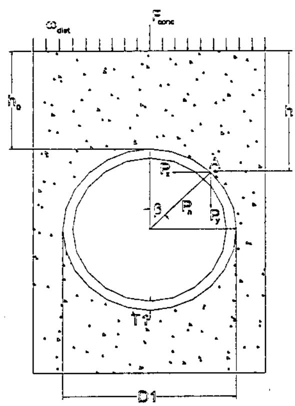

Figure 6.1.10-1 Burial Loading Diagram

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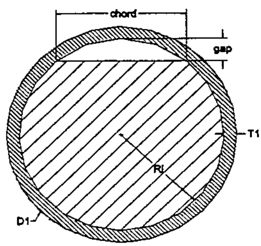

Figure 6.1.10-2 Unsupported Chord Length Diagram

Plane Strain Model

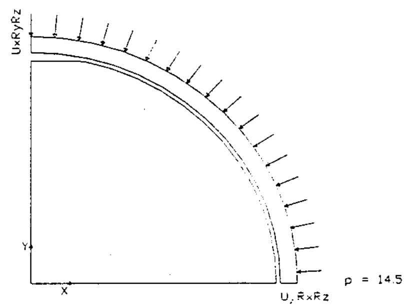

Figure 6.1.10-3 Burial Plane Strain Model

Design Inputs

Index:

$i := 0..6$

$\text{Container} := (1\ \ 2\ \ 3\ \ 4\ \ 5\ \ 6\ \ 7)^T$

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Pressure Angle:

$j := 0..9$

$\beta := (0\ \ 10\ \ 20\ \ 30\ \ 40\ \ 50\ \ 60\ \ 70\ \ 80\ \ 90)^T \cdot deg$

Maximum Unsupported Chord Length:

$chord := (6.9\ \ 6.9\ \ 9.6\ \ 9.6\ \ 14.3\ \ 16.2\ \ 16.2)^T \cdot in$

Assumptions

The worst case load application environment exists at the upper end of the burial temperature range of 70 °F. All material properties used in the analysis are based on this temperature. The bending stresses in the container end cap due to burial pressures are not calculated due to the operational requirement that each container be supplemented with end overpacks which mate with the end cap face and distribute the burial loads to the container body by having center span deflections less than 1/32 inch.

Calculations

Burial Pressure:

$$P_{burial_j} := 34.5\,psi - \frac{34.5\,psi - 14.5\,psi}{90\,deg} \cdot \beta_j$$

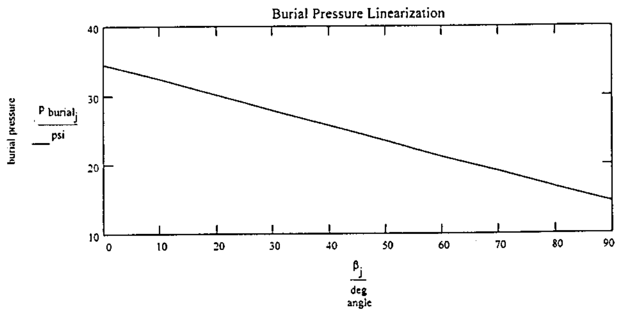

Figure 6.1.10-4 Burial Pressure Linearization

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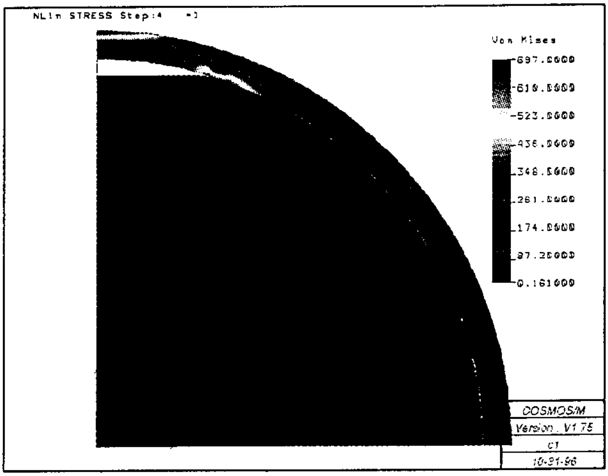

Figure 6.1.10-5 Plane Strain Model VonMises Stress for C1-C2 Burial

DCR-96-001, LLCE Container and Lift Beam
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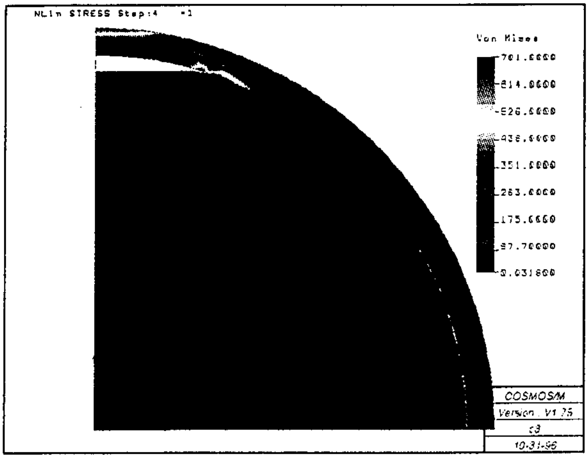

Figure 6.1.10-6 Plane Strain Model VonMises Stress for C3-C4 Burial

DCR-96-001, LLCE Container and Lift Beam Design Calculation Report

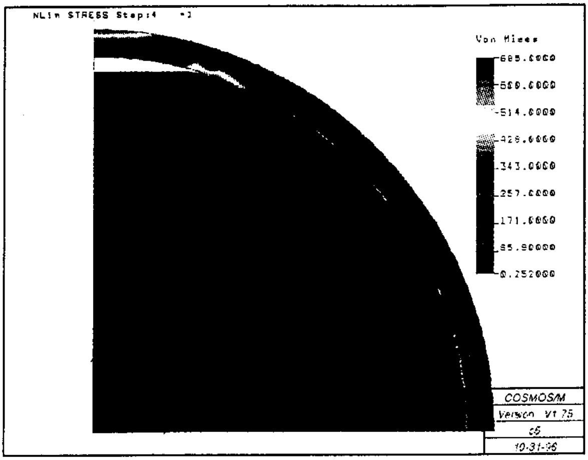

Figure 6.1.10-7 Plane Strain Model VonMises Stress for C5 Burial

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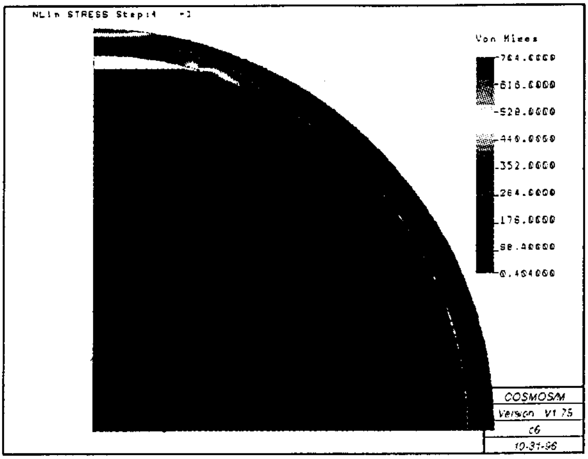

Figure 6.1.10-8 Plane Strain Model VonMises Stress for C6-C7 Burial

Plane Strain Model VonMises Stress:

$$\sigma_{burial} := (697\ \ 697\ \ 701\ \ 701\ \ 685\ \ 704\ \ 704)^T \cdot \frac{lbf}{in^2}$$

Margin of Safety Against Failure Due to Long Term Burial:

$$MS_{burial_i} := \frac{\sigma_{hdpe\_creep70}}{\sigma_{burial_i}} - 1$$

$$MS_{burial}^T = (\ 1.30\ \ 1.30\ \ 1.28\ \ 1.28\ \ 1.34\ \ 1.27\ \ 1.27\ )$$

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Summary

$$\text{Container} = \begin{pmatrix} 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \\ 7 \end{pmatrix} \qquad \sigma_{burial} = \begin{pmatrix} 697 \\ 697 \\ 701 \\ 701 \\ 685 \\ 704 \\ 704 \end{pmatrix} \cdot \frac{lbf}{in^2} \qquad MS_{burial} = \begin{pmatrix} 1.30 \\ 1.30 \\ 1.28 \\ 1.28 \\ 1.34 \\ 1.27 \\ 1.27 \end{pmatrix}$$

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6.2 Material Properties

DCR-96-001, LLCE Container and Lift Beam Design Calculation Report

6.2.1 Pipe Grade High Density Polyethylene Physical Properties

Standard Specification

ASTM D1248 - Standard Specification for Polyethylene Plastics Molding and Extrusion Materials

- Type III - Nominal Density 0.941-0.959 g/cm3
- Class C - Black (weather resistant) with > 2% carbon black
- Category 5 - Nominal Flow Rate 0.4 g/10 minute maximum
- Grade P34 - Pipe Grade Resin with specific physical property requirements

Resin Comparison

Table 6.2.1-1 Selected Resin Comparison with ASTM D1248 Grade P34 Standards

Property	Test Method	ASTM D1248 Grade P34	Petromont DGDB 2480	Phillips Marlex TR-480
Mininum Tensile Strength at Yield (psi)	ASTM D638	3,200	3,200	3,200
Tensile Strength at Break (psi)	ASTM D638	N/A	4,500	5,000
Minimum Elongation at Break (%)	ASTM D638	500	>800	>750
Flexural Modulus (psi)	ASTM D790	N/A	119,000	130,000
Hydrostatic Design Basis for Water at 73 °F (psi)	ASTM D2837	N/A	1600	1600
Maximum Brittleness Temperature (°F)	ASTM D746	-103	<-100	<-180
Minimum Environmental Stress Crack Resistance f_{20} (h)	ASTM D1693 Condition C	192	>2,500 f_0	>5000 f_0

- Resins meet D1248 requirements and are comparable

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Temperature

- Yield Strength decreases with increasing temperature [25]
- Modulus of Elasticity decreases with increasing temperature [25]
- Temperature dependence of material properties must be modeled

Yield Strength:

T_y degF	σ_y psi
-20	5310
0	4850
20	4390
40	3930
60	3469
80	3009
100	2549
120	2089

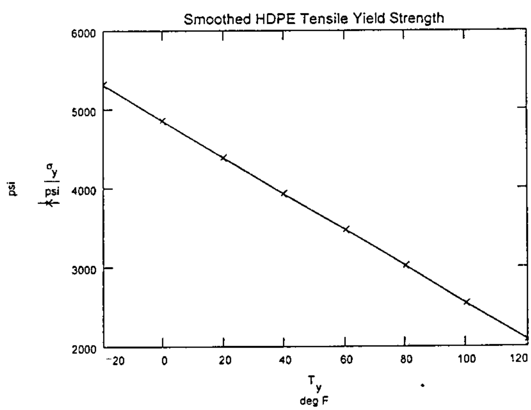

Figure 6.2.1-1 HDPE Tensile Yield Strength vs Temperature [25]

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Modulus of Elasticity:

T_y degF	E_y psi
-20	288399
0	258180
20	227961
40	197742
60	167523
80	137304
100	107085
120	76866

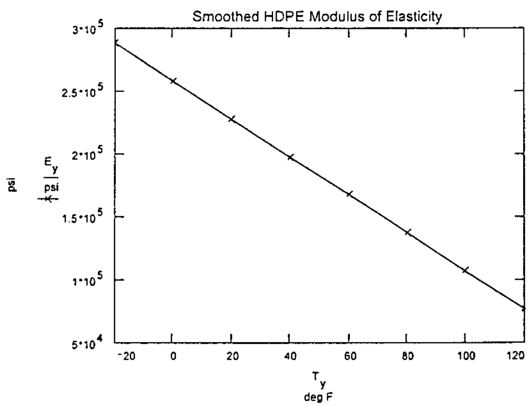

Figure 6.2.1-2 HDPE Modulus of Elasticity vs Temperature [25]

<u>Radiation</u>

- Gamma radiation causes polymer chain scission that can lead to a decrease in strength [26]
- Gamma radiation causes polymer chain cross-linking that can lead to an increase in strength [26]
- Overall result is an increase in yield strength and decrease in ductility [26]

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- Increase in density, tensile strength, hardness [27]
- Radiation effects need not be modeled under prescribed loading

Table 6.2.1-2 Irradiation Effects on Properties of Marlex HDPE [27]

Typical Property	Temperature (°F)	Gamma Irradiation Dosage		
		0 (rad)	1.0×10^7 (rad)	1.0×10^8 (rad)
Tensile Strength at Break (psi)	82	5840	7120	8360
Elongation at Break (%)	82	13	15	1
Hardness (Shore D)	N/A	64	70	70
Density (g/cm³)	N/A	0.952	0.955	0.967

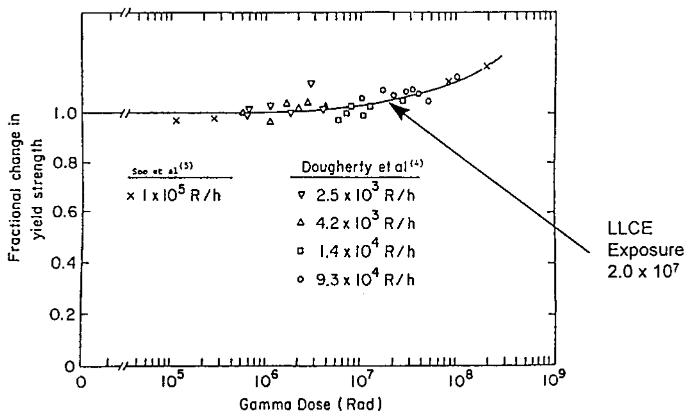

Figure 6.2.1-3 Fractional Change in Yield Strength vs Gamma Dose for Marlex CL-100 HDPE [26]

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Viscoelastic Creep

- Viscoelastic properties require derating the allowable stress with increased load duration [25]
- Viscoelastic properties need not be modeled if stress limit is held below 1600 psi at 73.4 °F or 1000 psi at 120 °F [25]

Table 6.2.1-3 Long Term Strength of HDPE at 73 °F [25]

Time (yr)	Hoop Stress (psi)
11.43	1635
50.00	1604
57.00	1601
114.00	1586

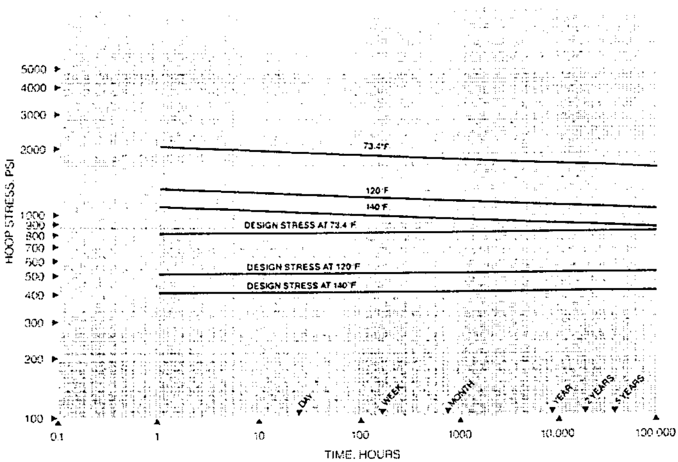

Figure 6.2.1-4 HDPE Creep Stress-Life [25]

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Fatigue

- Fatigue decreases the allowable yield stress under cyclic loading [28]
- Fatigue dependence of material properties must be modeled under cyclic loading

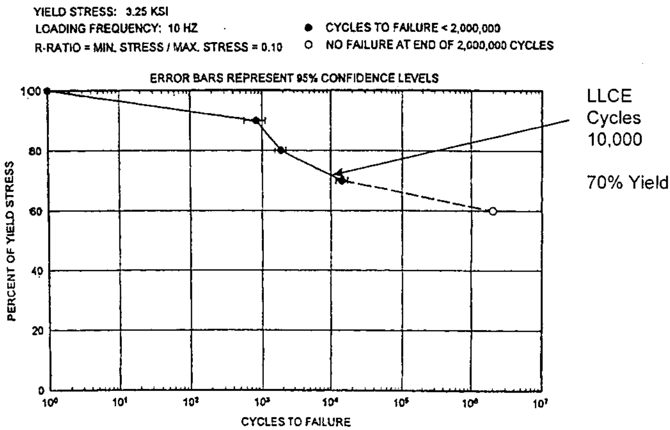

Figure 6.2.1-5 TR-480 HDPE Fatigue Performance [28]

Environmental Stress Crack

- ASTM D3350 cell classification #345434C [29]
- ASTM F1248 environmental stress crack resistance of F50>1000 hrs [29]
- Long Term Crack Propagation Defect Guidelines for High-Stress Areas [30]
  - Internal Defect: less than 1/8" equivalent flat bottom circular hole spaced 0.5" apart
  - External Scratch: less than 20" long x 0.038" deep spaced 1.5" apart
  - External Gouge: less than .25" long x 0.100" deep spaced 1.5" apart
- Stress crack effects need not be modeled under material requirements defined above

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Ultraviolet Radiation

- UV stabilizers utilized in P34 "pipe grade" resins to resist degradation
- Stabilizer is 2 to 3% finely dispersed carbon black
- Samples exposed to the equivalent of > 17 years in Phoenix, Arizona environment (Weather-Ometer tests per ASTM D 1499) experienced no embrittlement or loss of physical properties [25]
- UV effects need not be modeled

Biodegradation

- Resistance to biodegradation is inherent property of plastics
- Fungus resistance test performed in Marlex HHM 5502 High Density Polyethylene per ASTM G21-80 with no fungal growth [31]
- Biodegradation effects need not be modeled

Chemical Compatibility

- Chemical resistance of polyethylene is related to density; HDPE provides highest chemical resistance [31]
- HDPE is not adversely affected by chemicals in soil, perlite, or moisture; defined by < 3% swelling, < 0.5% weight loss, no significant change in elongation at break [32]
- Chemical effects not modeled

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8.0 THERMAL EVALUATION

8.1 INTRODUCTION

Heat dissipation in the LLCE BCs is achieved through passive thermal conduction and radiation. There are no artificial cooling mechanisms employed to dissipate payload decay heat. The heat generation rate for the maximum curie content is 9.88 W, as can be seen in the RADCALC output in Part B, Section 9.0.

8.2 THERMAL SOURCE SPECIFICATION

The thermal source specification consists of the maximum allowable radioisotopic inventory given in Part B, Section 2.0, of this SARP.

8.3 SUMMARY OF THERMAL PROPERTIES OF MATERIALS

The thermal properties of HDPE are given in Part B, Section 7.0, of this SARP.

8.4 THERMAL EVALUATION FOR NORMAL TRANSFER CONDITIONS

The total decay heat for the maximum authorized payload is 9.88 W and is considered of no consequence to the integrity of the packaging. During void fill, a certain amount of exothermic heat transfer takes place; however, the package is vented during this process so pressure buildup is not of concern. In sum, during normal conditions the LLCE BC is not subjected to a significant amount of heat that could jeopardize containment.

Linear expansion and contraction of the container due to heat absorption from direct sunlight can take place. The end cap and burial container lid are fitted with foam disks 25 cm (10 in.) thick to allow for expansion and contraction, thus eliminating the concern of having the container contract to a point where the void fill monolith exerts strain on the end cap or lid.

Prior to installation, the BC lid may warp slightly if left in direct sunlight for a period of time, which will lead to the lid not mating to the parallel surface of the burial container opening face. It is important to shield the burial container lid from direct sunlight until immediately prior to installation on the burial container.

For loading and transport operations, the BC is restricted to initial temperature conditions of 0-37.8 °C (32-100 °F). This is to provide an allowance for linear thermal expansion and contraction of the BC. Brittle fracture is only of concern at temperatures below -73.3 °C (-100 °F [see Part B, Section 7.7.2]).

Relevant thermal calculations are given in Part B, Section 7.0, of this SARP.

8.5 THERMAL EVALUATION FOR ACCIDENT CONDITIONS

Accident conditions are evaluated for the LLCE BCs by radiological risk and dose consequence analyses. The radiological risk evaluation is given in Part B, Section 3.0, of this SARP. The dose consequence and associated transportation hazard index are given in Part B, Section 4.0, of this SARP.

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9.0 PRESSURE AND GAS GENERATION EVALUATION

Radioactive waste transported in the LLCE BC will generate flammable gases from both radiolysis and chemical reactions. Gas generation within the LLCE BC is calculated to determine both pressure rise and the amount of time to reach the lower flammability limit (LFL).

9.1 GAS GENERATION

The gas generation evaluation is presented in Section 9.3. The evaluation describes the process and methodology for determining the radiolytic and chemical hydrogen generation rate as well as the generation rate of other gases. A maximum seal time (shipping window) is determined based on the generation rate and void space in the LLCE BC. The void volume is the amount of free air space that exists in the container. Void spaces ranging from 0.1% to 5.0% were used in the evaluation to show the effect of void space on the shipping window.

Using the worst-case source term combined with the smallest LLCE BC void space (0.1%), the estimated time to reach half of the LFL is six hours from the start of seal time. This is less than the time needed for shipment of the LLCE BC. Due to this short shipping window, a gas generation study shall be performed prior to making a shipment. Determination of venting requirements due to LFL considerations shall be made on a case-by-case basis. Table B9-1 lists the shipping time to LFL as well as the pressure rise to 1.5 atm (7.35 psig) due to gas generation. Gas generation analysis shall be performed only by qualified personnel using a qualified analytical method, such as Radcalc.

Table B9-1. Summary of Results for the Long-Length Contaminated Equipment Container.

	Worst case				
Void volume (as % of total container volume)	0.1	0.5	1.0	2.0	5.0
Half of the time to reach lower flammability limit	6 hours	30 hours	60 hours	5 days	12.5 days
Time to reach 1.5 atm (7.35 psig)	99 hours	20 days	41 days	82 days	200 days

9.2 PACKAGE PRESSURE

Using the worst-case source term and smallest LLCE BC void space, the elapsed time to reach an internal package pressure of 1.5 atm (7.35 psig) is approximately 99 hours (four days) from the start of seal time. Because this time is longer than the six hours allowed for hydrogen generation (Section 9.1), this indicates that hydrogen generation is the bounding condition for transport.

9.3 APPENDIX: HYDROGEN GAS GENERATION IN THE LLCE CONTAINER

ENGINEERING SAFETY EVALUATION

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Checker [signature] Date 01/31/96

I. Objectives:

Equipment contaminated with radioactive waste will be shipped from the Tank Waste Remediation System (TWRS) double shell tanks and single shell tanks in Long-Length Contaminated Equipment containers (LLCEs). The waste is known to generate hydrogen as well as other gases and an evaluation of gas generation is necessary to ensure transportation safety. The purpose of this analysis is to quantify the amount of hydrogen and other gases generated within the containers, and to determine the pressure build-up from the generated gases. A shipping window of half of the estimated time to reach the lower flammability limit (LFL) of the gas mixture will be used to ensure safe transport of the equipment. Decay heat is also calculated.

II. References:

Graves, R. D., 1994, *Topical Report on Flammable Gases in Nonburping Waste Tanks*, WHC-SD-WM-SARR-015, Westinghouse Hanford Company, Richland, Washington.

Green, J. R., K. Hillesland, V. E. Roetman, and J. G. Field, 1995, *Radcalc for Windows*, Version 1.0, Westinghouse Hanford Company, Richland, Washington.

Hopkins, J. D., 1994, *Criteria for Flammable Gas Watch List Tanks*, WHC-EP-0702, Westinghouse Hanford Company, Richland, Washington.

Kummerer, M., 1995, *Pressure and Gas Generation Evaluation for LLCE Containers*, Draft Report, Westinghouse Hanford Company, Richland, Washington.

Meisel, D., C. D. Jonah, S. Kapoor, M. S. Matheson, and M. C. Sauer, Jr., 1993, *Radiolytic and Radiolytically Induced Generation of Gases from Synthetic Wastes*, ANL-93/43, Argonne National Laboratory, Argonne, Illinois.

NRC, 1984, *Clarification of Conditions for Waste Shipments Subject to Hydrogen Gas Generation*, IN 84-72, Nuclear Regulatory Commission, Washington, D.C.

WHC, 1995a, *Packaging Design Criteria, Transfer and Disposal of Long-Length Tank Farm Equipment*, WHC-SD-TP-PDC-020, Rev. 2, Westinghouse Hanford Company, Richland, Washington.

WHC, 1995b, *Safety Analysis Report for Packaging for the LR-56*, WHC-SD-TP-SARP-009, Westinghouse Hanford Company, Richland, Washington.

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III. Results and Conclusions:

The following table summarizes the results calculated using the methods described in Section IV of this report.

Table 1. Summary of Results for the LLCE Container.

	Worst Case				
Void Volume (as % of total container volume)	0.1	0.5	1.0	2.0	5.0
Half of the time to reach LFL	6 hours	30 hours	60 hours	5 days	12.5 days
Time to reach 1.5 atm (7.35 psig)	99 hours	20 days	41 days	82 days	200 days
Decay heat (W)	9.88	9.88	9.88	9.88	9.88

For all cases in this report, the LFL of the mixture is reached when hydrogen gas equals 2.5% by volume. The NRC allows a shipping envelope of half the time it takes to reach 5% hydrogen gas by volume or the LFL of gas mixtures (NRC 1984). Because the LFL of the gas mixture is reached when the hydrogen gas reaches 2.5% by volume (WHC 1995b), the shipping window is determined to be half of the time it takes to reach 2.5% hydrogen gas.

IV. Engineering Evaluation:

Tank waste generates hydrogen, oxygen, nitrous oxide, ammonia, and methane by radiolytic and chemical interactions. Many reports have been issued regarding flammable gas generation in the TWRS tanks. A method for estimating the expected gas generation from tank waste materials was developed in *Topical Report on Flammable Gases in Nonburping Waste Tanks* (Graves 1994). The method focuses on both radiolytical and chemical generation of gases. The method uses empirical data from experiments and sample data from waste.

Radiolytic Generation

The method used in *Topical Report on Flammable Gases in Nonburping Waste Tanks* (Graves 1994) for the radiolytic generation of hydrogen is known as the G value method and is a well accepted calculational technique. The G value method has also been applied in the computer code Radcalc for Windows (Green et al. 1995). The computer code was accordingly used to determine the hydrogen generation from radiolytic interactions for this evaluation. It is also used to calculate decay heat. The worst case source term for this analysis is taken from the PDC, and is shown is Table 3. It should be noted that Np-238 is not contained within the radionuclide library of RadCalc for Windows. However, the activity

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of Np-238 in this source term is small and its contribution can be considered negligable. The source term development is defined in the PDC (WHC 1995a).

A container model for the LLCE is not addressed by RadCalc for Windows. Therefore, the LR-56 container is used as a conservative model due to its high gamma absorption fraction. For more information on this model see Volume II, *Technical Manual*, of the RadCalc for Windows computer code (Green et al. 1995). The smallest LLCE container size is used for this analysis, which, for hydrogen gas generation purposes, conservatively minimizes the container void volume. Several cases were run using different void volumes based on a percentage of the total container volume. The percentages ranged from 0.1% to 5.0%. The LLCE container dimensions are given in Table 2 below.

Table 2. LLCE Container Dimensions

Outside Diameter	26 in.
Inside Diameter	25.25 in.
Length	624 in.
Volume	5120 L

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Table 3: Worst Case Source Term

Nuclide	Activity (Ci)	Nuclide	Activity (Ci)
^{14}C	6.07e-02	^{151}Sm	1.68e+00
^{60}Co	3.32e+01	^{154}Eu	1.13e+00
^{63}Ni	9.81e-01	^{155}Eu	1.13e+00
^{79}Se	2.44e-03	^{233}U	2.51e-04
^{90}Sr	2.08e+02	^{234}U	2.32e-07
^{90}Y	2.08e+02	^{235}U	6.98e-05
^{93}Zr	8.77e-03	^{238}U	1.69e-03
^{95}Zr	7.57e+00	^{237}Np	2.96e-04
^{93m}Nb	6.01e-03	^{238}Np	1.91e-06
^{99}Tc	1.37e+00	^{238}Pu	7.72e-03
^{106}Ru	8.70e+00	^{239}Pu	4.00e-01
^{106}Rh	8.70e+00	^{240}Pu	1.86e-02
^{125}Sb	5.27e+00	^{241}Pu	1.79e-01
^{129}I	8.52e-04	^{242}Pu	1.21e-09
^{134}Cs	1.39e+00	^{241}Am	3.67e-01
^{137}Cs	9.10e+02	^{242}Am	3.81e-04
^{137m}Ba	8.61e+02	^{242m}Am	3.83e-04
^{144}Ce	4.24e+02	^{243}Am	1.09e-02
^{144}Pr	4.24e+02	^{242}Cm	1.15e-03
^{147}Pm	1.58e-01	^{244}Cm	1.58e-03

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Essential to the G value method of calculating the radiolytic production of hydrogen gas is the value chosen for $G(H_2)$. $G(H_2)$ is equal to the number of molecules generated per 100 eV of ionizing radiation. The $G(H_2)$ value used by Kummerer in the LR-56 SARP (WHC 1995b) and in an analysis of the Long Length Contaminated Equipment (Kummerer 1995) is 0.119. She arrives at this value by adding the G value for dissolved organic compound solutions containing nitrates/nitrites to a variable dependent upon the concentration of organics (TOC) within the tanks. This calculation is described in detail in the LR-56 SARP. The $G(H_2)$ value developed in the SARP is adopted for use in this analysis for gamma and beta interactions. For alpha interactions the value was conservatively increased by a factor of four (Green et al. 1995).

The Radcalc input/output file for the LLCE worst case using a 0.1% void volume is listed in the Appendix of this evaluation. Radcalc assumes a waste temperature of 20°C when calculating hydrogen generation. The results of the radiolytic generation of hydrogen gas and heat generated from radioactive decay are given in Table 4.

Table 4. Radiolytic Generation Rates and Decay Heat for the LLCE

	Worst Case
H_2 production rate (cm^3/h)	10.1
Decay heat (W)	9.88

Chemical Generation Rate

The chemical generation rate of hydrogen is dependent on the organic species, temperature, total organic carbon (TOC), and activation energy. Waste and void volume temperature are assumed to be 20° C, corresponding to an average atmospheric temperature. Experiments with tank waste simulant has lead to the following equation which can be used to estimate the chemical generation rate:

$$V_{H_2,C} = V_{H_2,E} V_{LIQ} \frac{TOC_w}{TOC_e} e^{-\frac{E_a}{R}\left(\frac{1}{T_w} - \frac{1}{T_e}\right)}$$

Where:

$V_{H2,C}$	=	Hydrogen chemical generation rate (L/day)
$V_{H2,E}$	=	Hydrogen generation rate in experimental solution at 60 °C, volume adjusted to vapor space temperature (3.3 x 10^{-4} L/day/L solution)
V_{liq}	=	Waste volume (46.2 L)
E_a	=	Activation energy (40900 J/mol) (Meisel 1993)

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R	=	Universal gas constant (8.314 J/mol K)
T_W	=	Waste temperature (293 K)
T_e	=	Temperature of experimental solution (333 K)
TOC_w	=	TOC in the waste, based on SST measurements (52 g/L) (From LR-56 SARP)
TOC_e	=	TOC in the experimental solution (23 g/L)

The generation rate of hydrogen at 293 K is 4.59 x 10^{-3} L/day. The generation rates for the LLCE, converted to cm^3/hr, is 0.191 cm^3/hr.

Lower Flammability Limit Calculation

Hydrogen gas in combination with other gases generated from tank waste reaches the mixture lower flammability limit (LFL) when hydrogen totals 2.5% by volume (WHC 1995b). The time to reach the LFL of the mixture can be derived by the following:

$$t = 0.025 \left(\frac{V_v}{r_{gen}}\right)$$

Where:

t	= time to 2.5% hydrogen
V_v	= void volume (cm^3)
r_{gen}	= generation rate (cm^3/unit time)

Total generation rate and void volume for the LLCE are substituted in the above equation. The results are summarized in Table 6.

Table 6. Total Hydrogen Gas Generation Rates for the LLCE.

	Worst Case				
Void volume (as % of total container volume)	0.1	0.5	1.0	2.0	5.0
Chemical generation (cm^3/h)	0.191	0.191	0.191	0.191	0.191
Radiolytic generation (cm^3/h)	10.1	10.1	10.1	10.1	10.1
Total H_2 generation (cm^3/h)	10.3	10.3	10.3	10.3	10.3
Time to reach LFL of mixture	12 hours	60 hours	120 hours	10 days	25 days
Half the time to reach LFL	6 hours	30 hours	60 hours	5 days	12.5 days

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Total Pressure Rise

In addition to hydrogen gas generation, chemical and radiolytical processes generate other gases that will affect the pressure rise within the container. Radiolytic generation produces other gases in a ratio to hydrogen gas of 1.5:1. Chemical generation produces 43.5% hydrogen gas, the remaining 56.5% consists of other gases (Kummerer 1995). These ratios can be used to calculate the total gas generation rates for each case (See Table 7 below). The rate of pressure rise can then be determined using the following equation:

$$p = \frac{(r_{gen})}{(V_v)}(c_{pres})$$

Where:

p = rate of pressure rise (psi/hr)
V_v = container void volume (5120 cm^3)
r_{gen} = Total generation rate (see Table 7) (25.7 cm^3/h)
c_{pres} = pressure conversion (14.7 psi/atm)

For a void volume of 0.1%, the rate of pressure rise, p, is 0.0738 psi/hr. The total pressure rise to the time needed to reach the LFL can then be found using the times taken to reach 2.5% hydrogen gas by volume from Table 6. The results for the LLCE container are summarized in Table 7.

Table 7. Pressure Rise for the LLCE.

	Worst Case
Radiolytic H_2 generation rate (cm^3/h)	10.1
Radiolytic generation rate of other gases (cm^3/hr)	15.2
Chemical H_2 generation rate (cm^3/h)	0.191
Chemical generation rate of other gases (cm^3/h)	0.248
Total gas generation rate (cm^3/h)	25.7
Pressure rise to half of the LFL (psi)	0.443
Time to reach 1.5 atm (7.35 psig) (0.1% void volume)	99 hours

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V. Appendix:

LLCE Worst Case Scenario

Radcalc for Windows 1.0

Date: 01-10-97 10:08

Performed By: JS Boettger

Checked By: J. Meal 1/31/97

File: LLCEWC.RAD

========== Input Information ==================================

Source from input:

Radionuclide:	Curies:
C-14	6.07e-002
Co-60	3.32e+001
Ni-63	9.81e-001
Se-79	2.44e-003
Sr-90	2.08e+002
Y-90	2.08e+002
Zr-93	8.77e-003
Zr-95	7.57e+000
Nb-93m	6.01e-003
Tc-99	1.37e+000
Ru-106	8.70e+000
Rh-106	8.70e+000
Sb-125	5.27e+000
I-129	8.52e-004
Cs-134	1.39e+000
Cs-137	9.10e+002
Ba-137m	8.61e+002
Ce-144	4.24e+002
Pr-144	4.24e+002
Pm-147	1.58e-001
Sm-151	1.68e+000
Eu-154	1.13e+000
Eu-155	1.13e+000
U-233	2.51e-004
U-234	2.32e-007
U-235	6.98e-005
U-238	1.69e-003
Np-237	2.96e-004
Pu-238	7.72e-003
Pu-239	4.00e-001
Pu-240	1.86e-002
Pu-241	1.79e-001
Pu-242	1.21e-009
Am-241	3.67e-001
Am-242	3.81e-004
Am-242m	3.83e-004
Am-243	1.09e-002
Cm-242	1.15e-003
Cm-244	1.58e-003

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LLCE Worst Case Scenario (cont'd)

Waste Form: Normal
Physical Form: Solid
Container Type: LR-56

Package Void Volume: 5.12e+003 cc
Waste Volume: 4.62e+004 cc
Waste Mass: 7.39e+004 g
Waste True Density: 1.60 g/cc

Date to begin source decay: 14:00 Jan. 10, 1997
Date container sealed: 14:00 Jan. 10, 1997
Days to decay source before seal time: 0.00 days
Calculate number of days sealed until 2.50% hydrogen is reached.

Entered G Values:

G Alpha	G Beta	G Gamma
0.476	0.119	0.119

Comments:
RadCalc calculations using:

Worst Case source term
Smallest LLCE container
0.1% Void Volume

========== Calculated Results ==================================

The sealed container will generate 2.44 % hydrogen in 0.53 days
This corresponds to date: 3:00 Jan. 11, 1997
H2 Volume: 128. cc
H2 Generation Rate: 10.1 cc/hour

Heat Generated: 9.88 Watts
Partial Pressure (H2): 2.54 kPa
Total Pressure (H2 and Air): 104. kPa

10.0 PACKAGE TIEDOWN SYSTEM EVALUATION

10.1 SYSTEM DESIGN

An engineered tiedown system is provided for securing the LLCE to the transport trailer. During staging of the equipment, the BC is placed in a chock secured on the transport trailer, using a lift beam and rigging. The lift beam is then stowed with the rigging still attached on the transport trailer lift beam storage device. Straps are then placed between the lift beam rigging at predetermined intervals (dependent on the size of container used).

On one side of the BC, the tiedown straps are secured with remotely activated hydraulic pins. On the other side of the BC, the straps are tensioned with conventional load binders. The front end (driver end) of the transport trailer provides blocking for the burial container via the shield wall, which is staked and restrained by a system of chains and load binders. The rear end of the trailer is not blocked. Features are available to provide aft restraint; however, it is not expected to be an operational requirement due to the extremely slow speeds and low accelerations anticipated during normal transport.

For unloading purposes, the hydraulic pins are remotely released, and the tiedown straps slide off of the container when it is lifted from the transport trailer chock.

10.2 ATTACHMENTS AND RATINGS

The packaging system is evaluated in Part B, Section 7.7.2, for shock and vibration loads using the tiedown system described. They are determined to be acceptable for use.

DISTRIBUTION SHEET

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Distribution	Packaging Engineering	Date 05/07/97
Project Title/Work Order		EDT No. 621081
Safety Analysis Report for Packaging (Onsite) Long-Length Contaminated Equipment Transport System (HNF-SD-TP-SARP-013)		ECN No. N/A

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