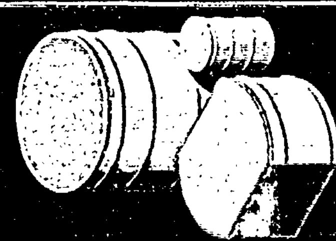
Attachment F2

Revised Pages for Revision 0 (May 2004) of the CH-TRU Payload Appendices

CH-TRU Payload Appendices



Revision 0
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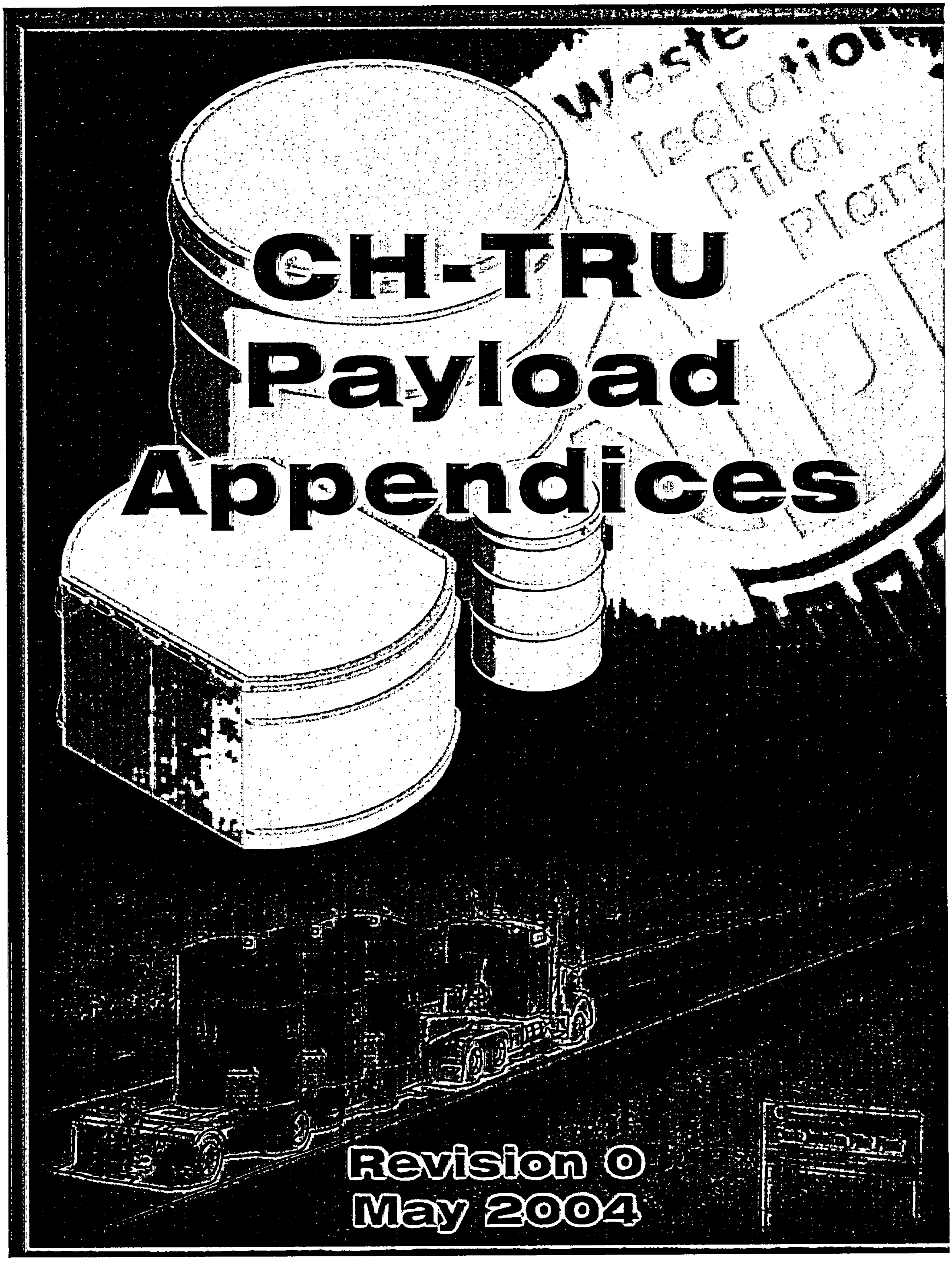
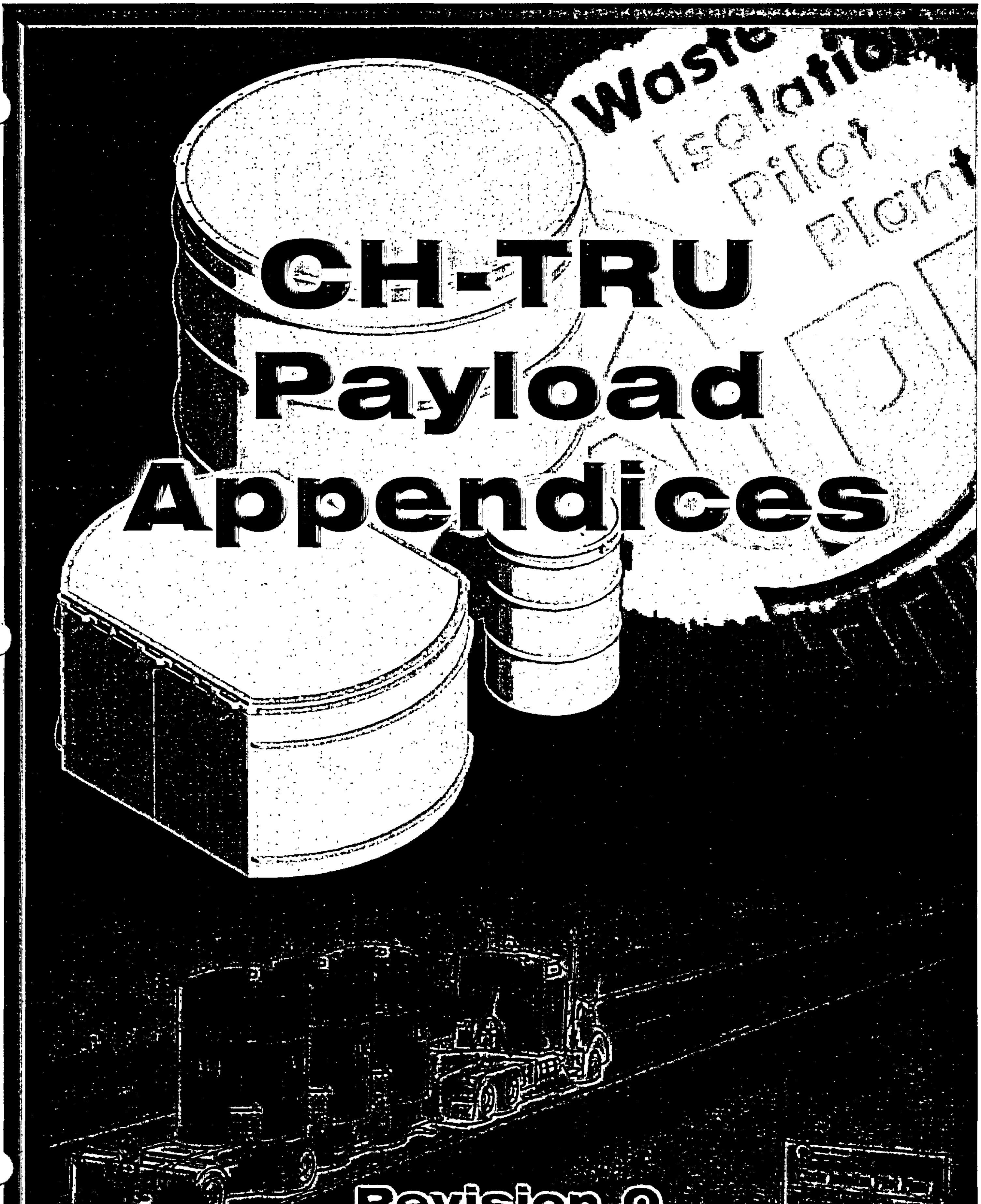

Waste Isolation Pilot Plant
CH-TRU
Payload
Appendices
Revision 0
May 2004

CH-TRU Payload Appendices



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APPENDIX 2.2

PROCEDURE FOR DETERMINING NUMERIC PAYLOAD SHIPPING CATEGORY

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2.2.4 Instructions for Completing Table 2.2-4: Load Type Resistance Worksheet

Shipping Period: Choose the appropriate shipping period for the payload, as follows:

- 60 Days (General Case): All shipments that do not meet the criteria for the other shipping periods.
- 20 Days (Close-Proximity Shipment): For shipments to destinations within a radius of approximately 1,000 miles or less. For example, all shipments from the Los Alamos National Laboratory, the Rocky Flats Environmental Technology Site, and the Nevada Test Site to the Waste Isolation Pilot Plant meet this criterion, and a 20-day shipping period is applicable.
- 10 Days (Controlled Shipment): For all shipments that satisfy the administrative control requirements set forth in Appendix 3.6 of the CH-TRU Payload Appendices and Section 6.2.3 of the CH-TRAMPAC.

Payload Container: Choose the appropriate payload container for the load type. The load type describes how the payload container will be shipped with other payload containers in the TRUPACT-II or HalfPACT inner containment vessel; therefore, select only one load type. For some overpacked configurations, overpacking does not impact the selection of the appropriate Load Type. If a zero was entered in Table 2.2-3 for the overpacking payload container total resistance factor, select the load type for the container that is overpacked. For example, for 55-gallon drums, the total resistance and payload shipping category are not affected by overpacking in an SWB with filters having a total hydrogen diffusivity of 1.48×10^{-5} m/s/mf (equivalent to four filters each with a diffusivity of 3.7×10^{-6} m/s/mf) or greater. A zero should have been entered in Table 2.2-3 for the SWB in this configuration. Therefore, for this overpacked configuration, select the Load Type resistance for a payload of 55-gallon drums (Resistance Factor of 7,147). See Appendix 6.10 of the CH-TRU Payload Appendices regarding the use of equivalent Load Type resistance factors for overpacked configurations.

Resistance Factor: Choose the "Resistance Factor" for the load type.

Total Resistance Factor: Enter the chosen value in the "Total Resistance Factor" column. Enter zero (0) or leave the space blank for load types that are not applicable. Note: Only one value for Total Resistance Factor is entered in Table 2.2-4.

Table 2.2-1 — Numeric Payload Shipping Category Worksheet

Container ID Number:						
Two Digit Waste Type Notation (XX) from Table 2.1-1 of the CH-TRU Payload Appendices						
G Value for Waste Material Type from Table 2.1-2		Four Digit G Value Notation (YYYY) from Table 2.1-2				
	Packaging	Type	Number of Layers	Resistance Factor (Use One Column Only)[a] Column 1	Column 2	Total Resistance Factor[b]
Confinement Layers	Inner Bag Layers	Filtered		From Table 2.2-2		
		Twist and Tape		23,989	17,922	
	Confinement Layers (e.g., Metal Can)	Slip-Top/Unsealed		0	0	
		Filtered		From Table 2.2-2		
	Liner Bag Layers	Filtered Drum Liner Bag		From Table 2.2-2		
		Twist and Tape Drum Liner Bag		2,142	2,142	
		Filtered SWB/Bin/TDOP Liner Bag		From Table 2.2-2		
		Fold and Tape SWB/ Bin/TDOP Liner Bag		1,257	1,257	
	Rigid Drum Liner	Rigid Liner		From Table 2.2-2		
Choose Those That Apply	Payload Container	Pipe Component		From Table 2.2-3		
		55-Gallon Drum or Pipe Overpack		From Table 2.2-3		
		85-Gallon Drum – Direct Load		From Table 2.2-3		
		100-Gallon Drum		From Table 2.2-3		
		Bin		From Table 2.2-3		
		85-Gallon Drum Overpack – One 55-Gallon Drum		From Table 2.2-3		
		SWB – Direct Load or Overpacking Bin		From Table 2.2-3		
		SWB Overpack - Four 55-Gallon Drums		From Table 2.2-3		
		TDOP – Direct Load		From Table 2.2-3		
	Load Type	55-Gallon Drums or Pipe Overpacks		From Table 2.2-4		
		85-Gallon Drums – Direct Load		From Table 2.2-4		
		100-Gallon Drums		From Table 2.2-4		
		SWBs – Direct Load or Overpacking Bin		From Table 2.2-4		
		SWB Overpacks Containing Up To Four 55-Gallon Drums per SWB; or 85-Gallon Drum Overpacks of 55-Gallon Drums		From Table 2.2-4		
		TDOP – Direct Load		From Table 2.2-4		
Total Resistance Factor Sum						
Divide Total Resistance Factor Sum by 100 and Round Up to Whole Number						÷ 100
Total Resistance Notation (ZZZZ) Report as Four Digits. If Waste Material Type II.2 (20 0000), enter 0000.						
Payload Shipping Category (XX YYYY ZZZZ)						

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

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

APPENDIX 3.5

SHIPPING PERIOD — CLOSE-PROXIMITY SHIPMENTS

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3.5 Shipping Period—Close-Proximity Shipments

3.5.1 Introduction

This appendix presents the shipping period determination for close-proximity shipments (i.e., within a radius of approximately 1,000 miles). The three U.S. Department of Energy (DOE) facilities nearest to the Waste Isolation Pilot Plant (WIPP) (i.e., Los Alamos National Laboratory [LANL], Rocky Flats Environmental Technology Site [RFETS], and Nevada Test Site [NTS]) are within a radius of approximately 1,000 miles of WIPP. For close-proximity shipments, the TRUPACT-II or HalfPACT is loaded at the site, transported within a radius of approximately 1,000 miles, and vented within a maximum of 20 days from the closure (or sealing) of the inner containment vessel (ICV). The basis for the 20-day shipping period is defined in this appendix.

3.5.2 Approach

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

- Loading time
- Transport time
- Unloading time.

3.5.2.1 Loading Time

The loading time begins with the sealing of the ICV and ends with the departure of the shipment of the package from the site. All steps in the normal, or expected, loading process for a single package (from attaching the lifting fixture to the crane until the lift fixture lift links are disconnected from the outer closure following loading) can be accomplished in two hours or less. Thus, the time associated with loading the three packages for a single truck shipment is expected to be less than eight hours. However, the maximum expected loading time is conservatively estimated as 24 hours (1 day).

The potential factors that could delay the expected loading time are as follows:

- Initiating loading on a day preceding a holiday weekend
- Difficulty associated with testing the ICV or outer containment vessel (OCV) seals
- Failure associated with payload handling equipment.

Loading could be delayed if initiated on a day preceding a holiday weekend or other scheduled facility closure period. This could result in a maximum loading time of 4 days. Potential delays associated with leak testing or payload handling equipment failures are typically reduced to a matter of hours by the backup or replacement equipment typically available at each shipping facility. However, even with available standby equipment, any equipment failure is likely to result in a lost day due to the time required to identify the problem, attempt corrective measures, and then access the backup or replacement equipment. As a result, a 1-day delay is deemed adequate for either seal testing or payload handling equipment failures. Although unlikely, if loading is assumed to be initiated on a day preceding a holiday weekend and either a seal testing or payload handling equipment failure is assumed to occur simultaneously, 5 days could be required to load three payloads. It should be noted that if excessive loading delays beyond 5 days were to occur due to unanticipated events, the packages could be vented at the shipping facility.

3.5.2.2 Transport Time

The transport time begins with the departure of the shipment from the site and ends with the arrival of the shipment at the receiving site. The transport time is dependent upon the distance between the shipping and receiving sites. For close-proximity shipments, the distance will be within a radius of approximately 1,000 miles. The normal, or expected, travel time for a distance of 1,000 miles is 25 hours based on an average speed of 40 miles per hour (mph). This average speed takes into account stops for vehicle inspections every two hours, fueling, meals, driver relief, and state vehicle inspections.

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

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

Adverse weather could result in transport time delays due to road closures, slower driving speeds, or unforeseen stops. Based on actual delays experienced to date by TRUPACT-II shipments, the average delay time attributed to weather is 23 hours (~1 day). Procedures at sites ensure that shipments are not initiated at times when adverse weather exists or is forecasted. Using operational experience, a 60-hour (2.5-day) delay is deemed adequate for any delay caused by adverse weather conditions.

Vehicle accidents have the potential for the longest transport time delays due to the time required to respond and perform required corrective actions. Based on the training programs provided to local emergency response personnel along the transport routes, accident response time would be minimal (less than one hour). However, additional time may be required for notification and response of other appropriate authorities such as Radiological Assistance Teams (if required). Deployment of other appropriate authorities from either the receiving or shipping facility, whichever is closer, would take no more than 0.5 day to reach an accident scene. The accident mitigation time for close-proximity shipments is considered to be prompt due to the relatively short distance that would be required to provide equipment to perform corrective measures. A backup truck and trailer, as well as special equipment (such as a crane and special lifting fixtures) could be required to return the shipment to the road. Either the shipping or receiving facility, whichever is closer, could provide accident mitigation equipment and personnel. Therefore, up to 3 days is considered appropriate for completing accident corrective action. This time includes deployment of a backup truck and trailer, retrieving and transferring the packages to the backup vehicle, and performing any necessary surveys and/or inspections to confirm the shipment is prepared for transport.

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

The last remaining potential scenario for delaying the transport time is driver illness. The relatively short distances between close-proximity sites would enable prompt replacement of the ill driver(s). No more than 0.5 day would be required to provide a replacement driver if deployed from either the shipping or receiving facility, whichever is closer.

As a result, a 6.5-day transport time accounts for any unexpected impact to the expected transport time.

3.5.3 Unloading Time

The unloading time begins with the arrival of the shipment at the receiving site and ends with the venting of the ICV. The normal, or expected, unloading of a trailer with three packages will be accomplished in less than 0.5 day. However, the maximum expected unloading time is conservatively estimated at 24 hours (1 day).

The potential factors that could delay the expected unloading time are as follows:

- Shipment arrival preceding a holiday weekend
- Failure associated with venting or handling equipment.

Unloading could be delayed if the shipment arrives on a day preceding a holiday weekend or other scheduled facility closure period. This could result in a maximum unloading time of 4 days. Potential delays associated with venting or handling equipment failures are typically reduced to a matter of hours by the backup or replacement equipment typically available at each receiving facility. However, even with available standby equipment, any equipment failure is likely to result in a lost day due to the time required to identify the problem, attempt corrective measures, and deploy the backup or replacement equipment. As a result, a 1-day delay is deemed accurate for either venting or payload handling equipment failures. Although unlikely, if unloading is assumed to be initiated on a day preceding a holiday weekend and either a venting or payload handling equipment failure is assumed to occur simultaneously, 5 days could be required to unload three payloads. It should be noted that the packages could be vented, even if not completely unloaded, at the receiving facility within 5 days.

3.5.4 Summary and Conclusions

Based on an expected loading time of 24 hours, an estimated expected transport time of approximately 25 hours, and an expected unloading time of 24 hours, the maximum expected shipping period is approximately 3 days. The maximum shipment time that has been used in this analysis is based on conservative time estimates for loading (5 days), transport (6.5 days), and unloading (5 days). The additional contingency of a 3.5-day margin of safety results in a maximum shipping period of 20 days. Table 3.5-1 provides a summary of the activities comprising the shipping period.

Table 3.5-1 — Shipping Period Analysis Summary

Activity	Normal Expected Time (days)	Maximum Time Used in Analysis (days)
Loading Time	<1	5
Transport Time	~1	6.5
Unloading Time	<1	5
Margin of Safety	–	3.5
Shipment Time	3	20

This analysis justifies using a 20-day period as the basis for determining potential buildup of flammable concentrations in the package under the specified off-normal conditions with the absence of venting or operational controls during transport.

With twice the expected shipping period being just 6 days, the use of a 20-day shipping period is conservative. Data available for more than 1,800 shipments to the WIPP in more than 5 years show 20 days to be an extremely conservative estimate of shipping period. Sample shipping time data based on 1,467 shipments to WIPP from the three sites within a radius of approximately 1,000 miles are shown in Table 3.5-2. As shown, all shipments were made within a period of two days.

Table 3.5-2 — Sample Shipping Time Data

To WIPP From	Total Number of Shipments as of 04-20-04	Average Shipping Time (hours)*	% of Time Shipments are Completed within Average Time	Shipping Time Delays: Duration of Maximum Delay	Shipping Time Delays: Explanation
LANL	71	9	98%	1 day	Delay occurred at LANL as the result of generator site issues prior to shipment departure
NTS	7	30	100%	N/A	N/A
RFETS	1,389	18	99%	2 days	Weather delay; delay occurred at RFETS prior to shipment departure and en route following departure

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

N/A = Not applicable.

The 20-day shipping period justified herein may be used for any shipment to a destination within a radius of approximately 1,000 miles. For shipments to WIPP from within a radius of approximately 1,000 miles (i.e., from LANL, RFETS, and NTS), the 20-day shipping period is used exclusively.

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APPENDIX 3.6

SHIPPING PERIOD — CONTROLLED SHIPMENTS

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3.6 Shipping Period—Controlled Shipments

3.6.1 Introduction

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

3.6.2 Approach

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

- Loading time
- Transport time
- Unloading time.

3.6.2.1 Loading Time

The loading time begins with the sealing of the ICV and ends with the departure of the shipment of the package from the site. Activities to be completed during the loading time include leak testing and handling of the loaded package(s). As directed by site procedures for controlled shipments, these activities must be completed within 24 hours. If these activities are delayed beyond 24 hours, the package(s) must be vented and the closure process repeated in accordance with the administrative controls described in Section 6.2.3 of the Contact-Handled Transuranic Waste Authorized Methods for Payload Control (CH-TRAMPAC).

3.6.2.2 Transport Time

The transport time begins with the departure of the shipment from the site and ends with the arrival of the shipment at WIPP. The transport time is dependent upon the distance between the site and WIPP and capabilities for efficient response to potential transport time delays. As shown in Table 3.6-1, at an average speed of 40 miles per hour (mph) the longest travel time from a site to WIPP is 46.2 hours. This average speed takes into account stops for vehicle inspections every two hours, fueling, meals, driver relief, and state vehicle inspections.

Table 3.6-1 — Normal Transit Times

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

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

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

Administrative controls in place at the shipping site prohibit the initiation of a controlled shipment at times when adverse weather exists or is forecasted. Any transport time delays associated with adverse weather are expected to be minimal and are, therefore, adequately covered by the margin of safety included in this analysis (see Section 3.6.4).

Prompt emergency response, truck maintenance, and driver or equipment replacement during the transport of controlled shipments is ensured by the application of additional resources. WIPP administrative controls require the designation of a shipment as a "controlled shipment" prior to initiation of the shipment from the site. This designation provides a trigger that requires additional resources to be available in order to provide accelerated response to avoid any significant delay during the transport time. This controlled shipment protocol is in addition to the routine use of the TRANSCOM system at WIPP, which provides continuous tracking of the shipment during transport from the site to WIPP.

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

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

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

As a result of WIPP protocols applied to shipments designated as controlled shipments, a 4-day transport time accounts for any unexpected impact to the expected transport time.

3.6.3 Unloading Time

The unloading time begins with the arrival of the shipment at WIPP and ends with the venting of the ICV. Operational procedures in place at WIPP ensure that processing and unloading procedures for controlled shipments are initiated within 24 hours of shipment arrival regardless of holidays or other schedules facility closure periods. Administrative controls imposed by WIPP procedures ensure that a shipment is not unattended beyond one day of arrival. Section 6.2.3 of the CH-TRAMPAC outlines administrative controls imposed to ensure venting of the ICV within 24 hours of shipment arrival.

3.6.4 Summary and Conclusions

Based on a loading time of 24 hours, an estimated transport time of less than 48 hours, and an unloading time of 24 hours, the normal expected shipping period for controlled shipments is 3 to 4 days. Using a conservatively estimated transport time of 4 days, the maximum expected shipping period for controlled shipments is 6 days. The additional contingency of a 4-day margin of safety results in a maximum shipping period of 10 days. Table 3.6-2 provides a summary of the activities comprising the shipping period.

Table 3.6-2 — Shipping Period Analysis Summary

Activity	Normal Expected Time (days)	Maximum Time Used in Analysis (days)
Loading Time	<1	1
Transport Time	1-2	4
Unloading Time	<1	1
Margin of Safety	–	4
Shipment Time	3-4	10

This analysis justifies using a 10-day period as the basis for determining compliance with gas generation requirements under rigorous operational controls during loading, transport, and unloading as specified in this appendix. With twice the normal expected shipping period being no more than 8 days, the use of a 10-day shipping period is conservative.

Sample shipping time data based on 2,503 shipments to WIPP to date are shown in Table 3.6-3. As shown, all shipments have been made in well under 10 days even without the use of administrative controls specified in this appendix. Therefore, the controlled shipments completed under the conditions specified in this appendix will readily comply with the 10-day shipping period.

Table 3.6-3 — Sample Shipping Time Data

To WIPP From	Total Number of Shipments as of 04-20-04	Average Shipping Time (hours)*	% of Time Shipments are Completed within Average Time	Shipping Time Delays: Duration of Maximum Delay	Shipping Time Delays: Explanation
ANL	11	43	100%	N/A	N/A
Hanford	76	43	98%	2 days	Weather delay; delay occurred at Hanford Site prior to shipment departure
INEEL	603	32	98%	5 days	Weather delay; delay occurred en route; shipment was returned to INEEL and delayed prior to second departure
LANL	71	9	98%	1 day	Delay occurred at LANL as the result of generator site issues prior to shipment departure
NTS	7	30	100%	N/A	N/A
RFETS	1,389	18	99%	2 days	Weather delay; delay occurred at RFETS prior to shipment departure and en route following departure
SRS	346	36	99%	3.7 days	Weather delay; delay occurred at SRS prior to shipment departure

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

N/A = Not applicable.

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

APPENDIX 4.1

DESCRIPTION OF STANDARD PIPE OVERPACK

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4.1 Description of Standard Pipe Overpack

4.1.1 Introduction

The standard pipe overpack, also referred to as pipe overpack payload container, pipe overpack configuration, or pipe overpack assembly, consists of a pipe component, also referred to as pipe container, positioned by dunnage within a 55-gallon drum with a rigid liner. It is designed to be used for the shipment of specific contact-handled transuranic waste forms in the TRUPACT-II and the HalfPACT. Appendix 1.3.1 of the TRUPACT-II Safety Analysis Report (SAR), Appendix 1.3.1 of the HalfPACT SAR, and Section 2.9.2 of the Contact-Handled Transuranic Waste Authorized Methods for Payload Control (CH-TRAMPAC) describe the materials of construction, sizes, and other dimensional specifications for the standard pipe overpack. The purpose of the standard pipe overpack is to provide criticality control, shielding, and containment of fine particulate waste material and to increase the maximum fissile gram equivalent (FGE) loading within the package. This allows for the shipment of up to 7 pipe overpacks in a HalfPACT or up to 14 pipe overpacks in a TRUPACT-II with payload container and packaging FGE limits as presented in Section 4.1.6 of this appendix. This appendix describes the test procedures and analyses that validate the use of the standard pipe overpack, and provides the technical basis for the FGE limits for shipments of pipe overpacks. Appendices 4.2, 4.3, and 4.4 of the CH-TRU Payload Appendices describe the analyses that validate the use of shielded configurations of the pipe overpack and provide the technical basis for the shipment of specific gamma- and neutron-emitting wastes in shielded pipe overpacks in the TRUPACT-II and HalfPACT.

4.1.2 Description

The standard pipe overpack consists of a pipe component surrounded by cane fiberboard and plywood dunnage within a standard 55-gallon drum with a rigid polyethylene liner and lid. A schematic of the pipe overpack is shown in Figure 4.1-1.

The pipe component[1,2] provides three significant control functions with regard to waste materials: (1) criticality control, (2) shielding, and (3) containment of fine particulate waste material. The testing and analyses described in the following sections demonstrate the effectiveness of the pipe overpack design for normal conditions of transport and hypothetical accident conditions.

The pipe component is a stainless steel, cylindrical pipe with a welded or formed bottom cap and a bolted stainless steel lid sealed with a butyl rubber or ethylene propylene O-ring (Figure 4.1-2, Appendix 1.3.1 of the HalfPACT SAR, and Appendix 1.3.1 of the TRUPACT-II SAR). The pipe component is approximately 2 feet long and is available with either a 6-inch (in.) (0.280-in. nominal thickness) or a 12-in. (0.250-in. nominal thickness) diameter. The pipe component must be installed with a filter vent; Section 2.5 of the CH-TRAMPAC provides the specification for the pipe component filter vent. The pipe component is centered in the standard 55-gallon steel drum with dunnage consisting of cane fiberboard packing and plywood (see Figure 4.1-1).

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[1] 6-inch Pipe Component Test Unit Fabrication Drawings:

Rocky Flats Environmental Technology Site, March 1995. Residue Container Fabrication Drawing, P15630, Rocky Flats Environmental Technology Site.

Rocky Flats Environmental Technology Site, September 1996. 6-inch Residue Container Assembly Drawing, SNMP 1001, Rocky Flats Environmental Technology Site.

[2] 12-inch Pipe Component Test Unit Fabrication Drawings:

Rocky Flats Environmental Technology Site, October 1994. Residue Container Fabrication Drawing, P15706, Rocky Flats Environmental Technology Site.

Rocky Flats Environmental Technology Site, September 1996. 12-inch Residue Container Assembly Drawing, SNMP 1019, Rocky Flats Environmental Technology Site.

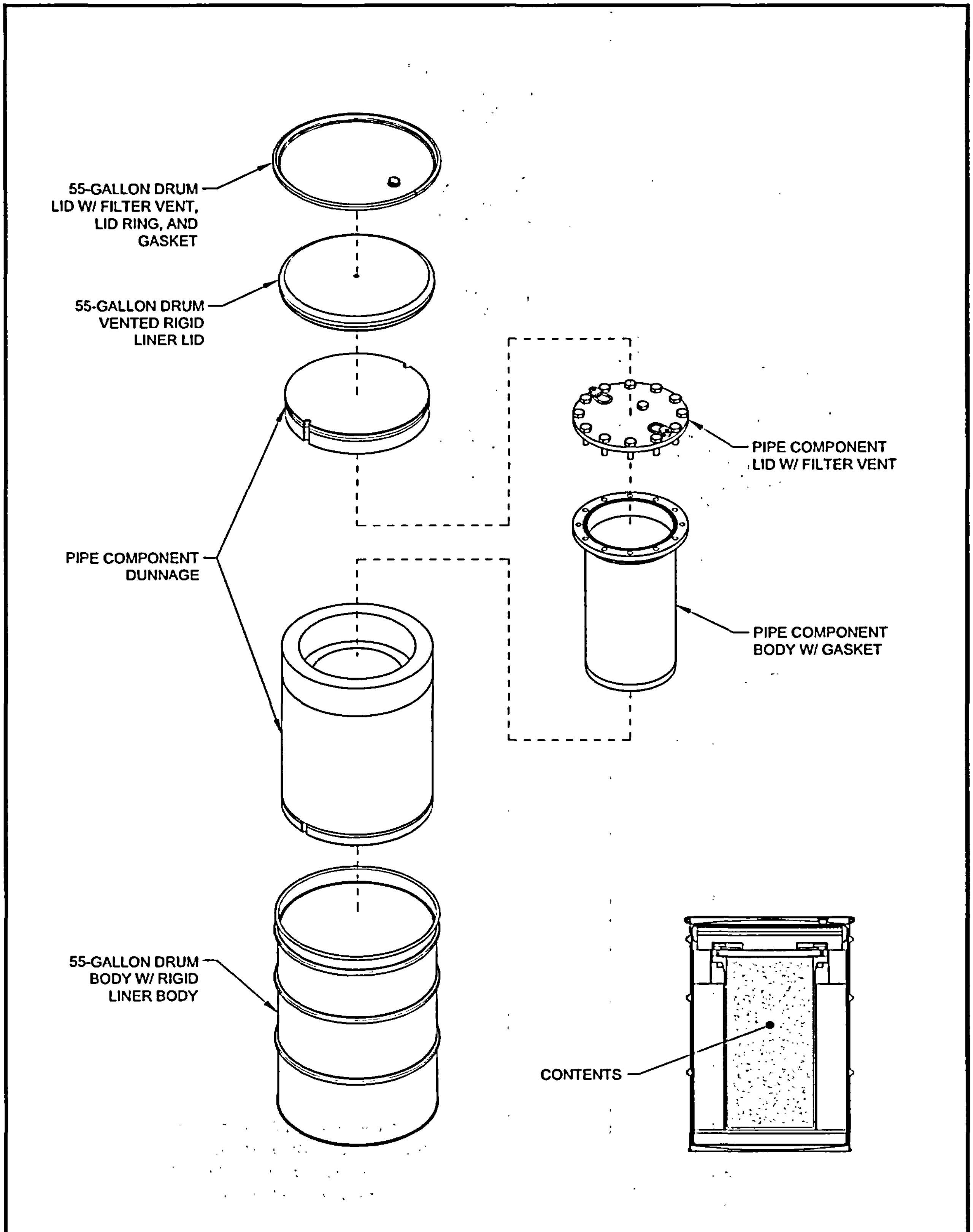
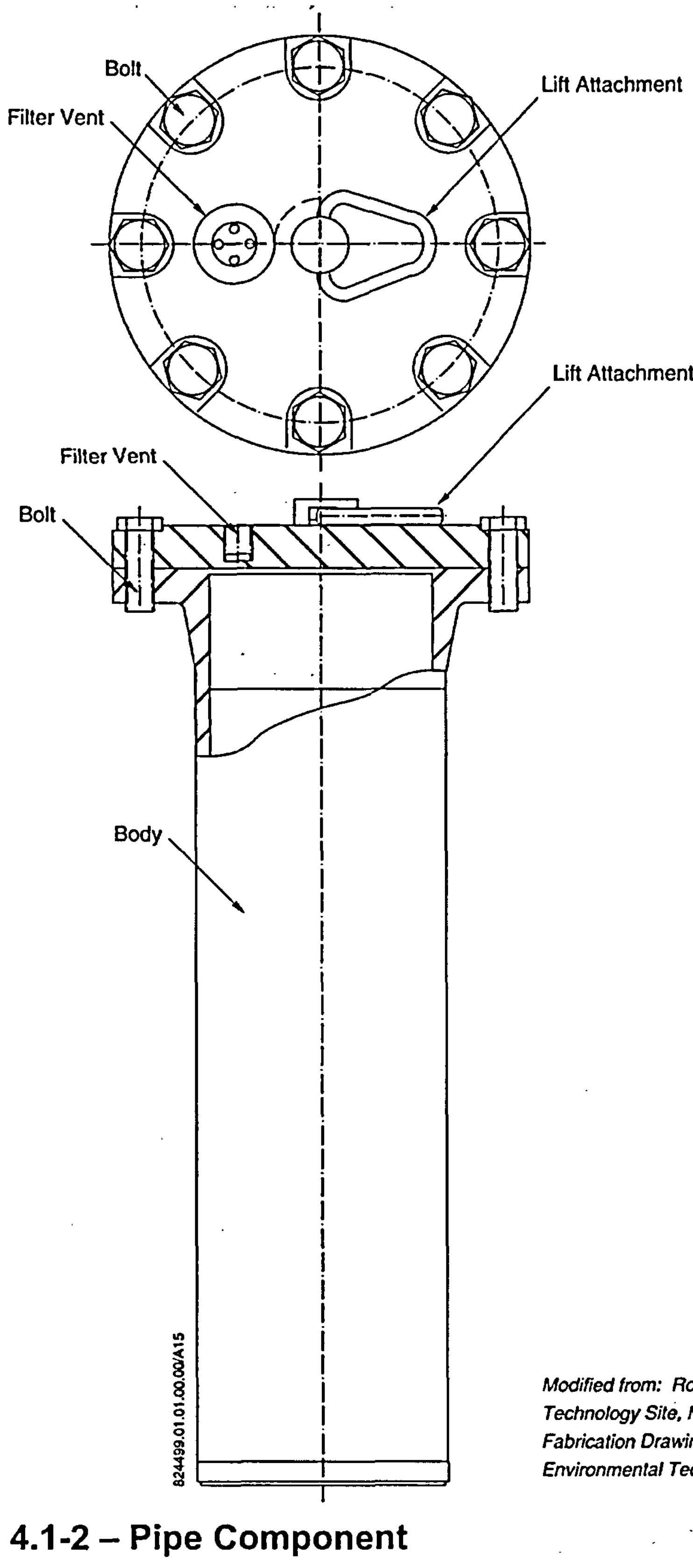


Figure 4.1-1 – Standard Pipe Overpack



Modified from: Rocky Flats Environmental Technology Site, May 1994. Residue Container Fabrication Drawing, P15631, Rocky Flats Environmental Technology Site.

Figure 4.1-2 – Pipe Component

4.1.3 Description of Test Program for the Standard Pipe Overpack

A test program was developed and implemented to demonstrate the structural integrity of the pipe overpack under hypothetical accident conditions. Normal conditions of transport are also bounded by the test program. The test program procedures and results are documented in independent reports[3,4] and are summarized in this section.

Two series of testing, consisting of 30-foot top- and side-impact drops of loaded pipe overpacks, have been performed. The drop tests simulated the interaction effects of other fully loaded pipe overpacks within a TRUPACT-II without subjecting an actual TRUPACT-II packaging to the tests. This resulted in more conservative analyses of the performance of the pipe overpack, since potential damage to the pipe overpacks would be less severe within a TRUPACT-II or HalfPACT.

In the first series of testing, the empty weights of the 6-in. and 12-in. diameter pipe components were approximately 87 pounds and 195 pounds, respectively. Two 6-in. diameter aluminum rods weighing nominally 66 pounds total were placed one on top of the other in each 6-in. nominal diameter pipe component; and six 5.5-in. diameter aluminum rods weighing nominally 167 pounds total were placed in two layers of three in each 12-in. nominal diameter pipe component (Figure 4.1-3a). Nominal loaded weights of the 6-in. and 12-in. diameter pipe components were 153 pounds and 362 pounds, respectively. Six "dummy" pipe components were loaded with steel rods to approximately equal the loaded weights of the test pipe components. The purpose of the "dummy" pipe components was to complete the payload configuration; these components were not tested. The loaded pipe components were overpacked within standard 55-gallon drums. Nominal loaded weights of the pipe overpacks, containing the 6-in. and 12-in. diameter pipe components, were 328 pounds and 504 pounds, respectively.

The second series of testing was similar to the first and was conducted following a revision to the 12-in. diameter pipe component design. The design was revised to remove nonessential weight from the pipe component flange and lid. The revised 12-in. diameter lid design, similar to that of the 6-in. diameter pipe component, is thicker and eliminates the need for a shielding plate to be attached to the lid under the filter opening (see Section 4.1.7). This design increases the available payload weight by 60 pounds over the original design. The modifications to the 6-in. diameter pipe component design are negligible. The design drawings included in the SARs for the TRUPACT-II and HalfPACT encompass both the original and the revised pipe component designs.

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[3] Ammerman, D.J., and J.G. Bobbe, October 1995. "Rocky Flats Pipe Component Testing," TTC-1434, Sandia National Laboratories, Albuquerque, New Mexico.

[4] Ammerman, D.J., J.G. Bobbe, M. Arviso, and D.R. Bronowski, April 1997. "Testing in Support of Transportation of Residues in the Pipe Overpack Container," TTC-1477, Sandia National Laboratories, Albuquerque, New Mexico.

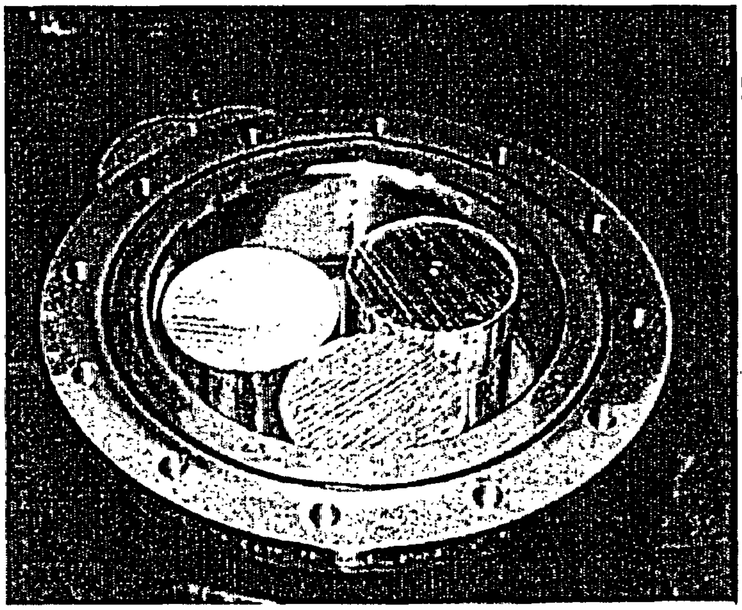

Figure 4.1-3a. Loaded Pipe Component (12-inch diameter)

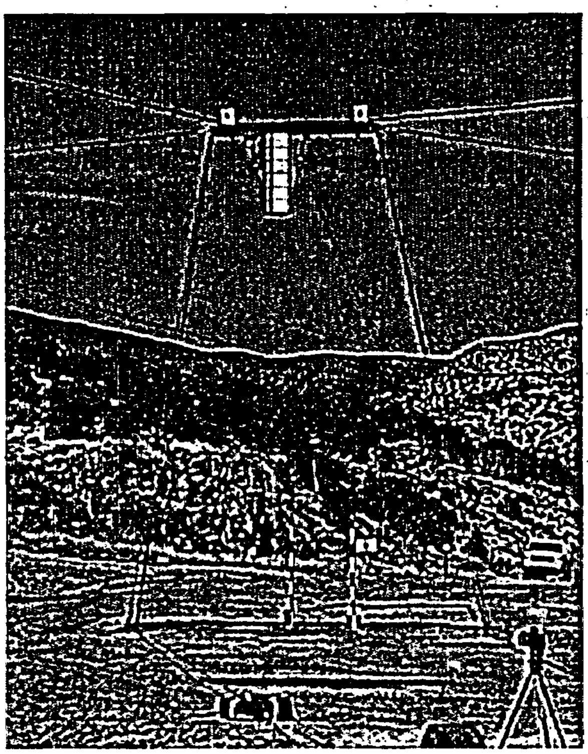

Figure 4.1-3b. Top-Impact Drop Test Set-up

Figure 4.1-3c. Side-Impact Drop Test Set-up

Figure 4.1-3 – Test Program Photographs of the Standard Pipe Overpack (Pre-Test)

For the second series of tests, the nominal loaded weights of the 6-in. diameter pipe component and pipe overpack closely approximated the corresponding weights of the first test series. However, the nominal loaded weight of the revised 12-in. diameter pipe component was 407 pounds, which included contents weighing 225 pounds. The nominal loaded weight of the pipe overpack containing the 12-in. diameter pipe component was 547 pounds. The tests were designed to qualify not only TRUPACT-II payload assemblies of pipe overpacks, containing fourteen 6-in. or fourteen 12-in. diameter pipe components, but also a mixed assembly of pipe overpacks, containing a 7-pack of all 6-in. diameter and a 7-pack of all 12-in. diameter pipe components.

Three top-impact drop tests were performed during both series of tests. In each test, two drums were strapped end-to-end as if positioned for transport within a TRUPACT-II (Figure 4.1-3b). Top-impact drop tests were performed for the following three configurations of pipe overpacks:

- Two 55-gallon drums containing 6-in. diameter pipe components
- Two 55-gallon drums containing 12-in. diameter pipe components
- Two 55-gallon drums; one containing a 12-in. diameter pipe component and one containing a 6-in. diameter pipe component with the 6-in. impacting first.

One side-impact test was performed by dropping an uncertified but functional TRUPACT-II inner containment vessel (ICV) with a payload assembly, including a top layer of seven pipe overpacks containing 6-in. diameter pipe components and a bottom layer of seven pipe overpacks containing 12-in. diameter pipe components (Figure 4.1-3c and Figure 4.1-4). The drop demonstrated a worst case, since potential damage to the pipe overpacks would be less severe within the entire TRUPACT-II packaging, which includes 10 inches of impact-absorbing foam.

A leakage rate test using helium and a mass spectrometer leak detector was performed before and after each drop test to evaluate the containment provided by the pipe component. The pipe components used in the testing were fitted with leak-test ports to allow connection to the leak detector. The leak-test port is not a feature of the pipe component production model. To facilitate the test, the opening in the pipe component filter was sealed with vacuum putty. This allowed the gasket between the filter and the pipe component lid to be leak-tested. After the post-drop leak test, the filters were removed and an evaluation of filter performance was conducted by the filter manufacturer.

4.1.4 Results of Test Program for the Standard Pipe Overpack

The first test series was completed at Sandia National Laboratories/New Mexico in March 1995.[3] Testing of the revised pipe component was completed at the same location in December 1996.[4] There was no loss of containment in any drop test, and all pipe components had a leakage rate of less than 1×10^{-7} cc/sec. The filters showed no damage from the drop tests. Following the leak test, the filters were removed from the pipe components and verified by the filter manufacturer to have maintained undiminished flow and filtering characteristics in accordance with the requirements of Section 2.5 of the CH-TRAMPAC.

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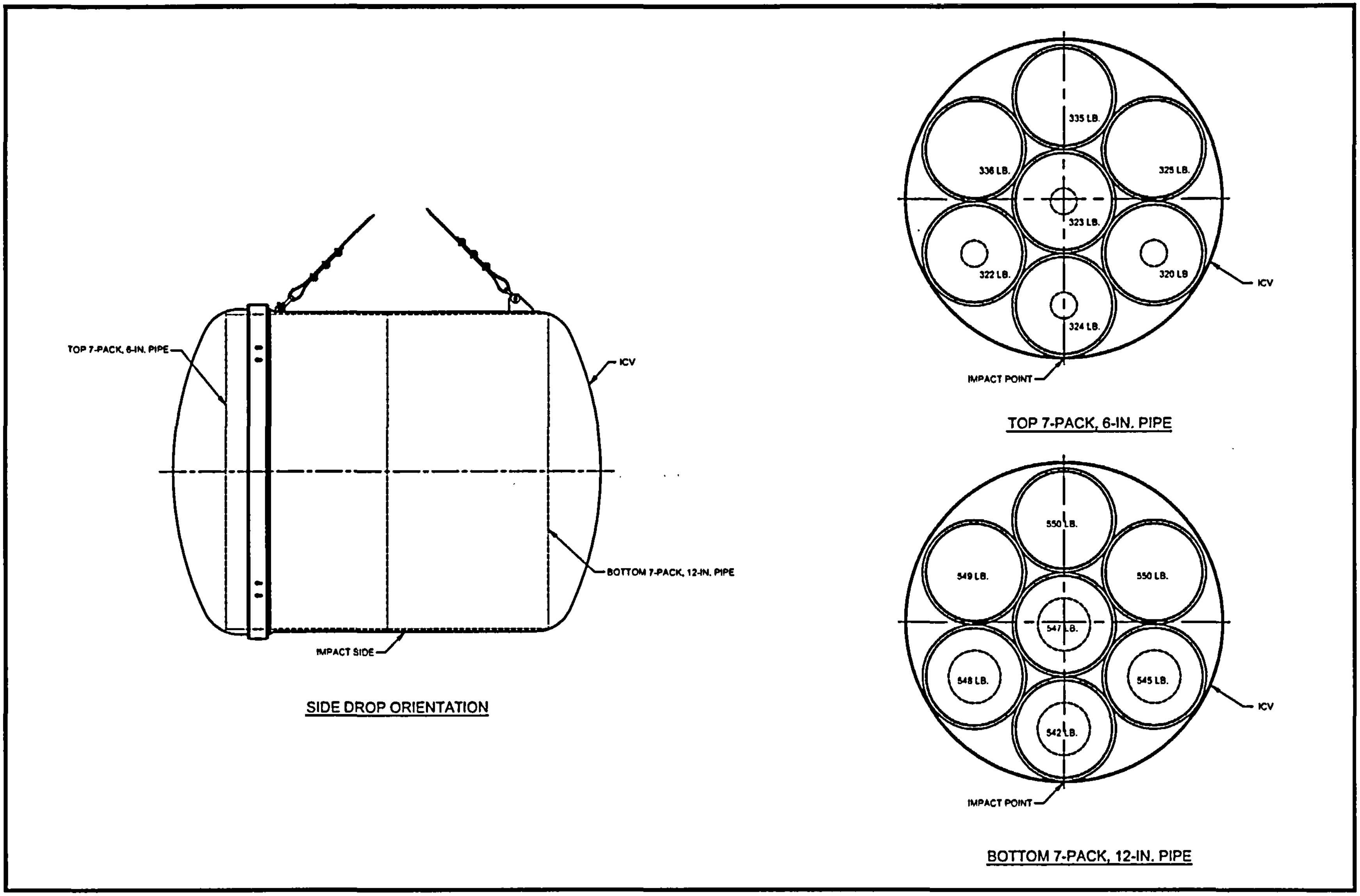

Figure 4.1-4 – Side Drop Configuration and Weights

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In the first test series, some of the bolts in the lids were observed to be loose upon post-test inspection of the two 6-in. diameter pipe components tested in the top-impact drop test. The cause of this anomaly was traced to the specification for bolt fabrication that allowed protruding die marks on the bearing surface of the bolts. During the top-impact drops, the protruding die marks cut into the surface of the pipe component lid causing a reduction of bolt tension. Although this irregularity did not affect the ability of the pipe components to maintain closure and pass the leak tests, the anomaly was corrected by modifying the specification for the screw-fasteners so that the result is a flat bearing-surface and uniform contact pressure.

The only other pipe overpack deformation observed during this test series was to the shielding plate of the 12-in. diameter pipe component lid. During the top-impact drop tests, the force of the pipe component contents pushed the shielding plate, which is located below the filter, closer to the lid surface. The shielding plate (see Section 4.1.7) prevents radiation emission through the filter vent and protects the filter media from potential damage if impacted by the component contents. While these functions were not compromised by the movement of the shielding plate, the abnormality was corrected in the production 12-in. diameter pipe components.

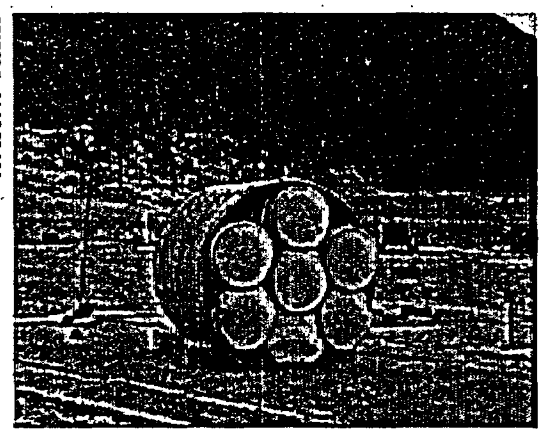
The 6-in. diameter pipe component and the revised 12-in. diameter pipe component do not have shielding plates. The lids of these designs are thicker than that of the original 12-in. diameter pipe component design and encase the bottom portion of the filter vent opening (see Section 4.1.7). Therefore, the lids of the 6-in. diameter pipe component and the revised 12-in. diameter pipe component provide adequate shielding without the addition of shielding plates.

Additionally, the maximum axial drum crush observed during the end drop test was 3.98 in. and 3.63 in. for the 6-in. and 12-in. pipe overpacks, respectively. The maximum diametrical drum crush observed during the side drop test was 4.31 in. and 2.25 in. for the 6-in. and 12-in. pipe overpacks, respectively.

In summary, the results of the test program for the standard pipe overpack demonstrate that under hypothetical accident conditions, the 6-in. and 12-in. diameter pipe components (both original and revised designs) maintain containment of material and do not incur any damage (see Figure 4.1-5).

4.1.5 Structural Analysis of the Standard Pipe Overpack

The pipe component is constructed of grade 304 stainless steel. Protective cane fiberboard and plywood packing material is used to center the pipe component within a standard 55-gallon drum to constitute a pipe overpack. In the original testing, the 20 pipe components involved in the drop tests sustained no visible damage or deformation with the exception of the minor items noted in Section 4.1.4, which have been corrected. The 14 pipe components that were leak tested showed no loss in containment capability. The capability of the pipe components to maintain structural integrity during hypothetical accident testing is due to the design and material construction of the closures.



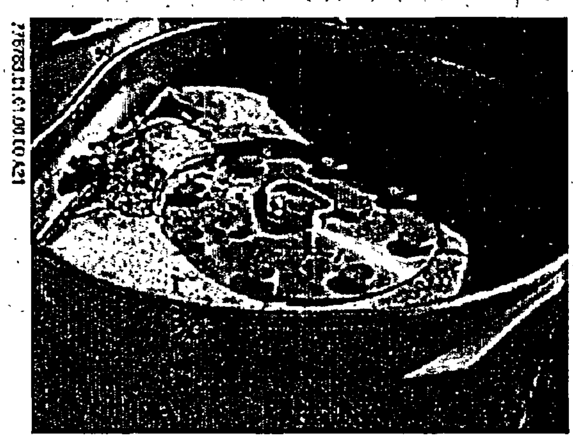


Figure 4.1-5 – Test Program Photographs of the Standard Pipe Overpack (Post-Test)

The observed maximum drum crush values reported in Section 4.1.4 result in idealized minimum right-circular cylinder dimensions for the 6-in. and 12-in. pipe overpacks of 18.19 in. outside diameter by 29.27 in. height and 20.25 in. outside diameter by 29.62 in. height, respectively, utilized in the criticality analysis summarized in Section 4.1.6.

A butyl rubber or ethylene propylene O-ring seals the lid to the pipe component body. Both O-ring materials have a sustained temperature capability of 250 degrees Fahrenheit (°F), which exceeds temperatures realized within the TRUPACT-II ICV during previous testing. Likewise, the neoprene gasket that seals the filter housing to the lid has a 250°F temperature capability. The filter design used in the pipe component functions within specifications at temperatures ranging from well below –40°F to over 280°F. The filters have been shown to survive independent drop tests and impact tests.[5]

4.1.6 Criticality Analysis of the Standard Pipe Overpack

A criticality analysis was performed for two different payload cases, depending on the quantities of special reflector materials in the payload container (see Chapter 6.0 of TRUPACT-II SAR or Chapter 6.0 of HalfPACT SAR for description of special reflector materials), as described below:

- Case E: For Case E, the contents of the pipe overpack payload container contain less than or equal to 1% by weight quantities of special reflector materials. The pipe overpack payload container may contain greater than 1% by weight quantities of special reflector materials provided that one of the following conditions is met:
  - The special reflector materials are chemically or mechanically bound to the fissile material such that no reconfiguration or release of the bond is possible under normal or accident conditions, or
  - The special reflector materials are present in thicknesses and/or packing fractions that render them less effective than a 25% polyethylene/75% water equivalent reflector per the limits in Table 6.2-1 of the TRUPACT-II or HalfPACT SAR.
- Case F: For Case F, the contents of the pipe overpack payload container contain greater than 1% by weight quantities of special reflector materials that do not meet the exceptions listed for Case E.

The criticality analysis demonstrates that a TRUPACT-II shipment of 14 pipe overpacks with contents meeting the requirements of Case E at 200 FGE of ^{239}Pu each (for a total of 2,800 FGE per TRUPACT-II) or a HalfPACT shipment of 7 pipe overpacks with 200 FGE each (for a total of 1,400 FGE per HalfPACT) ensures compliance with the requirements of Title 10, Code of Federal Regulations (CFR), Sections 71.55 and 71.59 (10 CFR 71.55 and 71.59).[6] Additionally, shipments of pipe overpacks with contents meeting the requirements of Case F at 140 FGE for each payload container and 980 and 1960 FGE per HalfPACT and TRUPACT-II, respectively,

[5] Nuclear Filter Technology, Inc., February 1995. "The Effect of Extreme Temperatures, Impacts, and Vibrations on Nuclear Filter Technology, Inc.'s NucFil 013," Nuclear Filter Technology, Inc., Wheat Ridge, Colorado.

[6] Packaging Technology, Inc., May 2004, "Pipe Overpack Criticality Analysis for the TRUPACT-II Package," ED-076, Packaging Technology, Inc., Tacoma, Washington.

ensure compliance with 10 CFR 71.55 and 71.59. Based on an infinite array of undamaged or damaged packages, the criticality transport index is 0.0.

The key parameters in the pipe overpack analysis for Case E are (1) the maximum fissile loading per pipe component is 200 FGE, (2) no more than 1% by weight quantities of special reflector materials are present or greater than 1% by weight quantities of special reflectors are either bound to the fissile material or meet the limits in Table 6.2-1 of the TRUPACT-II or HalfPACT SAR, (3) the spacing between the components (i.e., effective drum diameter) is reduced by the maximum amount reported in Section 4.1.5, and (4) the package arrays are infinite arrays stacked two high.

The key parameters in the pipe overpack analysis for Case F are (1) the maximum fissile loading per pipe component is 140 FGE, (2) the spacing between the components (i.e., effective drum diameter) is reduced by the maximum amount reported in Section 4.1.5, and (3) the package arrays are infinite arrays stacked two high.

The detailed analysis presented in Packaging Technology, 2004[6], presents the results of a series of SCALE 4.4 CSAS25 module[7] (KENO-Va version 4) calculations that establish a maximum system reactivity ($k_s + 2\sigma$) of less than 0.933 and the corresponding Upper Subcriticality Limit (USL) of 0.9377. Therefore, the shipment of 200 FGE or 140 FGE per pipe overpack for Cases E and F, respectively, in the TRUPACT-II and HalfPACT is safely subcritical.

4.1.7 Shielding Analysis of the Standard Pipe Overpack

Adequate shielding is provided in the standard pipe overpack and TRUPACT-II or HalfPACT shipping configuration to ensure that no radioactive payload will exceed the dose rate limits established by 10 CFR 71.47(a) for normal conditions of transport (NCT) or 10 CFR 71.51(a)(2) for hypothetical accident conditions (HAC). Compliance with dose rate limits specified in Section 3.2 of the CH-TRAMPAC for individual pipe overpacks and loaded TRUPACT-IIs or HalfPACTs will be achieved by preshipment radiological surveys. Compliance with NCT and HAC radiation dose rate limits is ensured through the preshipment radiological surveys as demonstrated below. The 6-in. and 12-in. diameter pipe components provide a nominal 0.280 in. and 0.250 in. of steel (pipe wall thickness), respectively, for shielding of gamma radiation. Effective radiation shielding depends on a continuous barrier of dense material (i.e., steel) without "line-of-sight" openings that would allow radiation leakage or "streaming." The pipe components have design features to prevent radiation streaming through the relatively low density filter media of the filter vents.

Incorporated in the original design of the 12-in. diameter pipe component lid is a 3/16-in. thick steel shielding plate attached to the lid under the filter opening to prevent radiation streaming through the filter media material and to provide puncture protection to the filter media from any solid contents within the pipe component (see Figure 4.1-6a). These features are incorporated slightly differently in the 6-in. diameter pipe component and the revised design of the 12-in.

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[7] SCALE4.4., "Modular Code System for Performing Standardized Computer Analyses for Licensing Evaluation for Workstations and Personal Computers," RSICC code package C00545/MNYCP00, Oak Ridge National Laboratory, September 1998.

diameter pipe component. Because their lids are thicker than that of the original 12-in. diameter pipe component, the filter vent does not penetrate the entire thickness of either lid, and shielding is provided by the remaining steel at the bottom of the tapped hole for the filter vent. Continuous venting is provided by four small holes that penetrate the remaining steel lid thickness. The holes are offset from the filter media and thereby avoid a line-of-sight radiation streaming path (see Figure 4.1-6b).

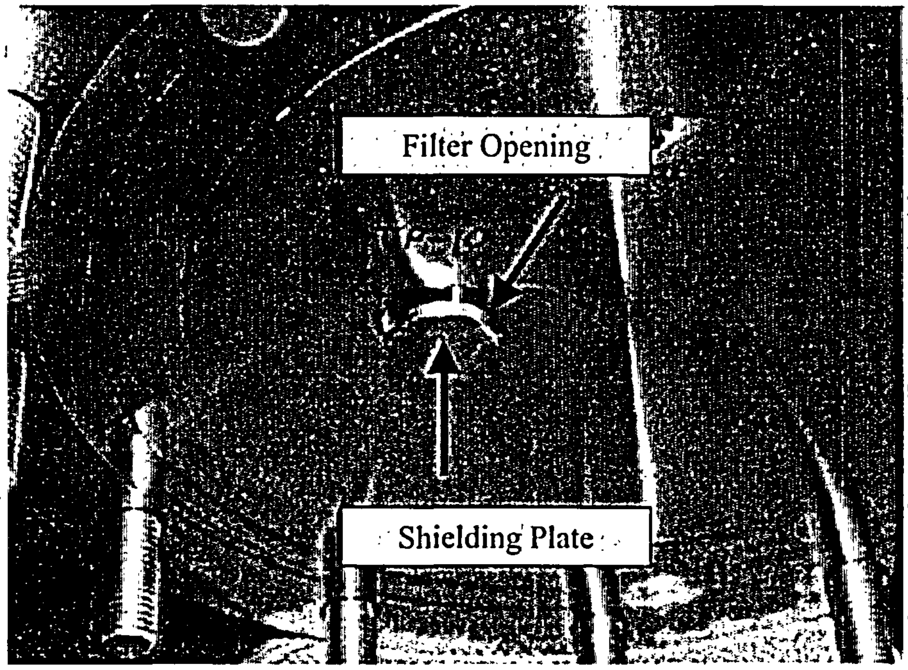
The NCT and HAC radiation dose rate limits are met by ensuring, through preshipment radiological surveys, that the surface dose rate of each pipe overpack is less than 200 millirem per hour (mrem/hr), the surface dose rate of the TRUPACT-II or HalfPACT is less than 200 mrem/hr, and the 2-meter dose rate of the TRUPACT-II or HalfPACT is less than 10 mrem/hr. Ammerman and Bobbe (1995)[3] bounds the radial crush of the pipe overpack during a HAC event at 2.16 in., while the TRUPACT-II and HalfPACT provide approximately 10 in. of additional distance attenuation beyond that of a single pipe overpack in the NCT configuration. The TRUPACT-II and HalfPACT also provide additional material attenuation in the form of the ICV, outer containment vessel, and outer containment assembly inner shells that have a combined thickness of 0.688 in. and 0.438 in. in the NCT and HAC configurations, respectively. The increase in distance and material attenuation provided by the TRUPACT-II and HalfPACT, in addition to the structural integrity of the pipe overpack, ensure that the NCT dose rates will not be significantly increased during a normal condition event and that the HAC dose rate limit will not be exceeded during a hypothetical accident condition.

4.1.8 Authorized Payload Contents for the Standard Pipe Overpack

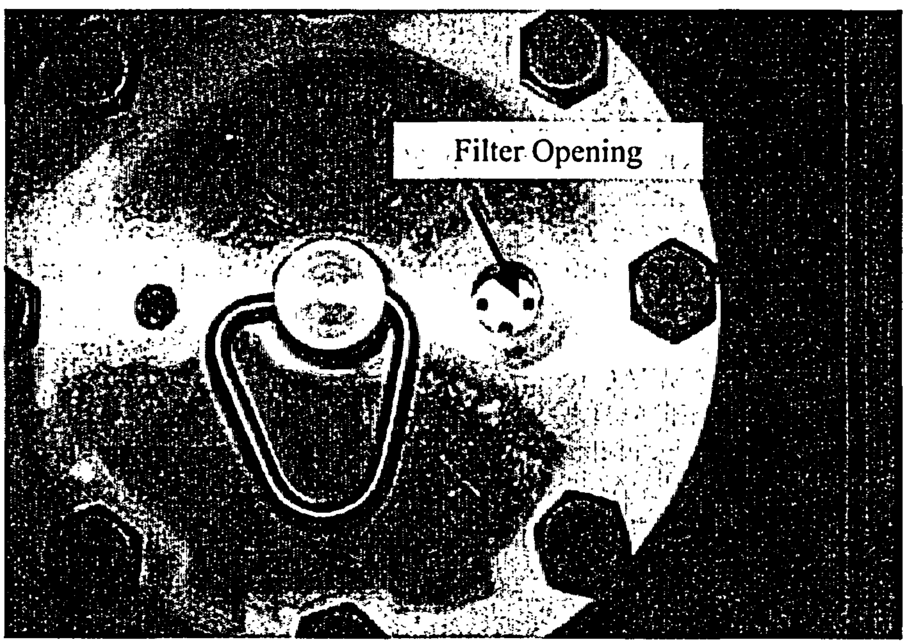
The results of the criticality analyses show the pipe component to be an effective instrument for criticality control. TRUPACT-II or HalfPACT shipments of standard pipe overpacks with contents meeting the requirements of Case E at 200 FGE per standard pipe overpack are subcritical in all cases. Therefore, the pipe component FGE limit for payloads with Case E contents is 200 g, and 2,800 g per TRUPACT-II or 1,400 g per HalfPACT. The FGE limit for payloads with Case F contents is 140, 980, and 1,960 FGE for the pipe overpack, HalfPACT, and TRUPACT-II, respectively.

Section 3.2 of the CH-TRAMPAC requires that each individual standard pipe overpack and loaded TRUPACT-II or HalfPACT be measured prior to shipment to verify compliance with a dose rate limit of 200 mrem/hr at the surface. Additionally, Section 3.2 of the CH-TRAMPAC requires that each loaded TRUPACT-II or HalfPACT be measured prior to shipment to verify compliance with a dose rate limit of 10 mrem/hr at 2 meters. The results of the shielding evaluation show that, when the standard pipe overpack is in compliance with the preshipment survey surface dose rate limit, the dose rate requirements of 10 CFR 71.47(a) and 10 CFR 71.51(a)(2) are met for a TRUPACT-II loaded with 14 standard pipe overpacks or a HalfPACT loaded with 7 standard pipe overpacks.

The results of the pipe overpack test program and the structural analysis demonstrate the effectiveness of the pipe component to maintain containment of waste under normal conditions of transport and hypothetical accident conditions. As illustrated, the containment provided by the pipe component will allow for the effective immobilization of CH-TRU waste materials.



4.1-6a. Lid of 12-inch diameter pipe component showing 3/16-inch thick steel shielding plate attached under filter opening (bottom view).
Lid of 12-inch diameter pipe component showing 3/16-inch thick steel



4.1-6b. Lid of 6-inch diameter pipe component without filter showing four small holes, which penetrate the lid thickness (top view). The holes are offset from the filter media when the filter vent is installed.

Figure 4.1-6 – Photographs of Pipe Component Shielding Features

4.1.9 Conclusion

The standard pipe overpack consists of a pipe component positioned by dunnage within a 55-gallon drum with a rigid liner and lid. The tests and analyses summarized by this appendix demonstrate the ability of the pipe overpack to provide three significant control functions: (1) criticality control, (2) shielding, and (3) containment of fine particulate waste material during normal conditions of transport and hypothetical accident conditions.

The primary purpose of the pipe overpack is to allow the shipment of up to 7 pipe overpacks in a HalfPACT or up to 14 pipe overpacks in a TRUPACT-II, each with a maximum FGE loading of 200 g for payloads with contents meeting the requirements for Case E and 140 g for payloads with contents meeting the requirements for Case F. The results of the criticality analyses show that a payload of pipe overpacks is subcritical in all cases. As determined by the criticality analyses, the FGE limit is 2,800 g per TRUPACT-II and 1,400 g per HalfPACT for Case E shipments of waste packaged in standard pipe overpacks and 1,960 g per TRUPACT-II and 980 g per HalfPACT for Case F shipments of waste packaged in standard pipe overpacks.

The shielding evaluation shows that, when the standard pipe overpack is in compliance with the preshipment survey dose rate limit, the dose rate limits for NCT and HAC are met.

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APPENDIX 4.2

DESCRIPTION OF S100 PIPE OVERPACK

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4.2 Description of S100 Pipe Overpack

4.2.1 Introduction

The S100 pipe overpack is based closely on the standard pipe overpack described in Appendix 4.1 of the CH-TRU Payload Appendices. It differs from the standard pipe overpack in that most of the cane fiberboard dunnage is replaced with neutron shielding material. In addition, neutron shielding material is placed within the pipe component, above, below, and around the payload. It is intended for the shipment of sealed neutron sources in the TRUPACT-II and the HalfPACT. Appendix 1.3.1 of the TRUPACT-II Safety Analysis Report (SAR), Appendix 1.3.1 of the HalfPACT SAR, and Section 2.9.3 of the Contact-Handled Transuranic Waste Authorized Methods for Payload Control (CH-TRAMPAC) describe the materials of construction, size, and other dimensional specifications for the S100 pipe overpack. Up to 14 S100 pipe overpacks may be shipped in the TRUPACT-II, and up to 7 S100 pipe overpacks may be shipped in the HalfPACT. This appendix describes the structural, criticality, and shielding basis of the S100 pipe overpack.

4.2.2 Description

The S100 pipe overpack consists of a 6-inch (in.) pipe component surrounded by neutron shielding material on the sides and by cane fiberboard and plywood dunnage on the top and bottom, within a 55-gallon drum with a rigid polyethylene liner and lid. A schematic of the S100 pipe overpack is shown in Figure 4.2-1. The 6-in. pipe component used in the S100 pipe overpack is identical to the 6-in. pipe component used in the standard pipe overpack described in Appendix 4.1 of the CH-TRU Payload Appendices. Furthermore, the pipe component is placed within the drum, using the same type of cane fiberboard and plywood dunnage below the lower surface of the pipe component and above the upper surface of the pipe component. The space around the sides of the pipe component is filled with a neutron shielding material. The neutron shield may be in the form of a casting (such as a commercial neutron shielding casting compound), a solid monolith (such as a molded or machined unit of solid plastic), or fabricated component (such as a tightly wound roll of plastic film or other built-up fabrication). The minimum properties of the neutron shielding material are given in Section 4.2.6. The neutron shield extends from the lower edge of the pipe component up to the top surface of the lid of the pipe component, and rests on the lower plywood dunnage. The S100 Pipe Overpack is shown in Figure 4.2-1. To provide shielding for the top and bottom of the pipe component, rigid high-density polyethylene plugs approximately 6 in. in diameter and 6.5 in. long are placed below the payload (in the bottom of the pipe component), and above the payload (below the lid of the pipe component) as shown in Figure 4.2-1. A rigid high-density polyethylene shield sleeve is placed between the two end plugs, as shown in Figure 4.2-1.

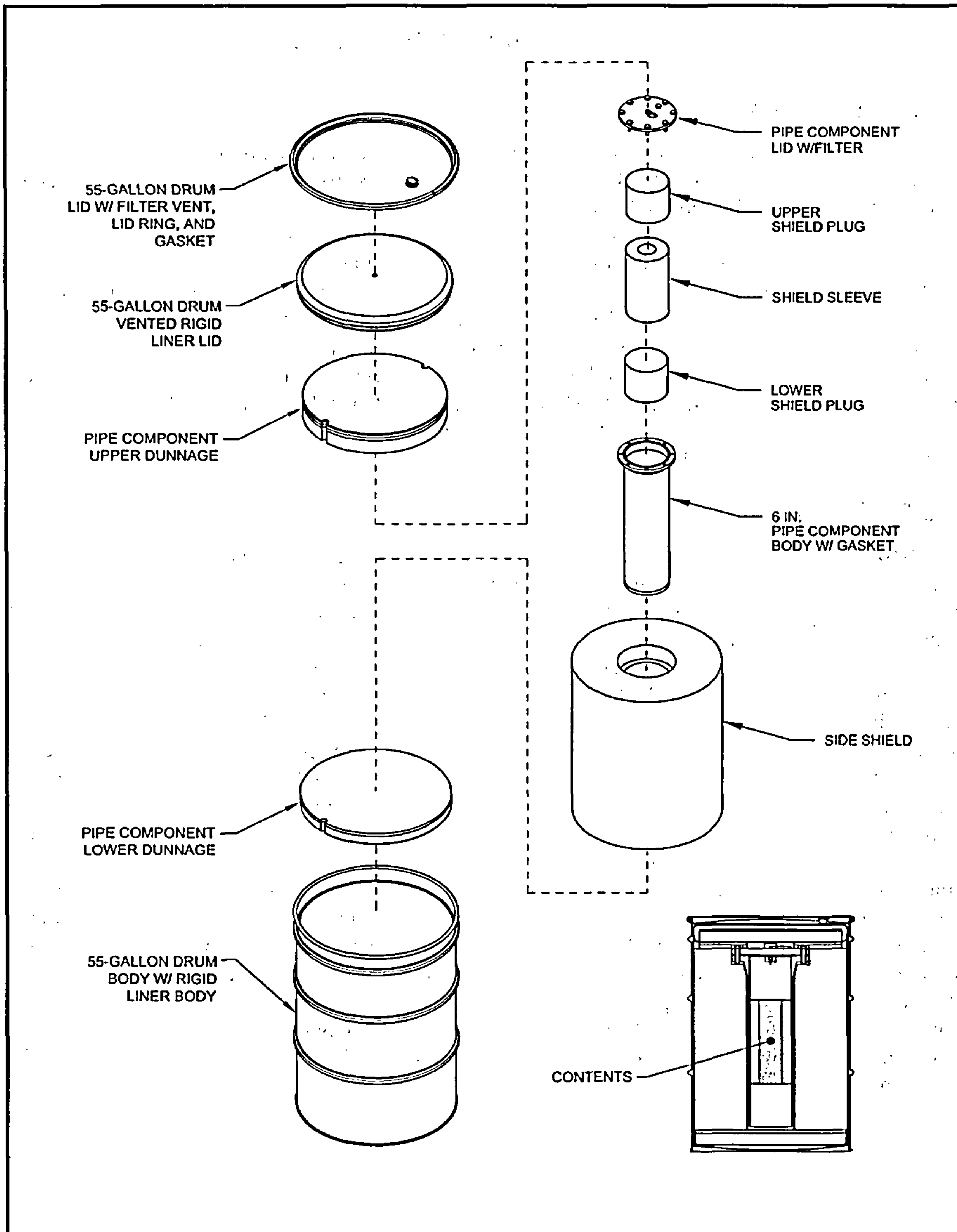

Figure 4.2-1 — S100 Pipe Overpack

The pipe component is a stainless steel, cylindrical pipe of 0.280 in. nominal thickness with a welded or formed bottom cap and a bolted stainless steel lid sealed with a butyl or ethylene-propylene rubber O-ring. The pipe component is approximately 2 feet (ft.) long and has an inner diameter of 6 in. The S100 pipe component is identical to the description of the standard 6-in. pipe component, including the filter vent, found in Appendix 4.1 of the CH-TRU Payload Appendices. The S100 pipe component provides three significant control functions: 1) criticality, 2) shielding, and 3) confinement of the payload. The S100 pipe overpack is designed for the transport of specific sealed neutron source waste forms. The following sections demonstrate the effectiveness of the S100 pipe overpack design for normal conditions of transport (NCT) and hypothetical accident conditions (HAC). All demonstrations are by analysis or by reference to the standard pipe overpack, unless stated otherwise.

4.2.3 Structural Analysis for Normal Conditions of Transport

Under NCT, the S100 pipe overpack remains leaktight and retains the sealed neutron sources within the pipe component. Since the pipe component remains leaktight under HAC as demonstrated in Section 4.2.4, this bounds all NCT, and demonstrations specific to NCT are not necessary.

The maximum damage that could occur to the shielding material in a normal condition free drop is evaluated as follows. As specified in Section 2.9.3 of the CH-TRAMPAC, the maximum weight of the loaded S100 pipe overpack is 550 pounds (lbs). The normal condition free drop height is 3 ft., or 36 in. The maximum damage to the shielding by crush deformation occurs in the side drop orientation. In this orientation, the weight of five of the drums in one layer may be conservatively assumed to be supported by a single drum in the lowest position as shown in Figure 4.2-2. (The two drums on either side of the lowest position each support their own weight.) A determination of crush distance is found by conservatively assuming that 25% of the drop energy of five drums is absorbed by the crush of the neutron absorbing material on one side of the lowest drum, where the percentage of energy absorbed by the neutron absorbing material is derived in Section 4.2.4. The drop energy (E), measured in inch-pounds (in.-lbs), to be absorbed by the neutron shield is:

$$E = 0.25 * (550 \text{ lbs} * 5 * 36 \text{ in.}) = 24{,}750 \text{ in.-lbs}$$

At the maximum payload temperature of 170°F, the minimum crush strength of the neutron shielding material is $\sigma = 300$ pounds per square inch (psi). Therefore, to absorb this energy, the volume (V), measured in cubic inches (in^3), of crushed material is:

$$V = \frac{E \text{ in.-lbs}}{\sigma \text{ psi}} = 82.50 \text{ in}^3$$

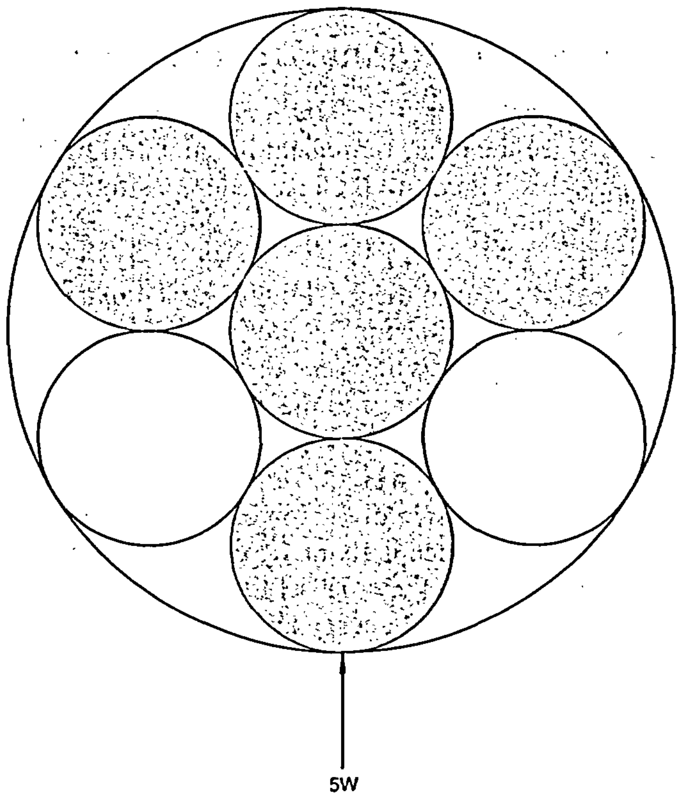

Figure 4.2-2 — NCT Side Drop Drum Loading Diagram

The volume is in the form of a segment of a cylinder having a length equal to the length of the neutron shielding material, or L = 26.7 in. The area (A) of the segment is therefore

$$A = \frac{V\ in^3}{L\ in.} = 3.08\ in^2$$

Based on the area of the circular segment and on the outer diameter of the shield material of 21.5 in., the depth of crush is computed to be 0.63 in. A conservative value of 2 inches is used in the normal condition shielding analysis discussed in Section 4.2.6 of this appendix.

As an alternative to specifying the shielding material crush strength, a test of the full-scale shielding component may be performed. The test shall demonstrate that the shield is capable of absorbing an amount of energy equal to 24,750 in-lbs with 2 in. or less of radial deformation. The energy absorbed may be calculated by integration of the force-deflection curve or other equivalent means. The test must be performed with a material temperature of at least 170°F.

If cast neutron shielding material is used, some moisture may be hydrated by the material upon solidification. At the maximum payload container temperature of 170°F, this moisture could produce a partial pressure of only 6 psi absolute, which would be the case for any moist payload. Therefore, the shielding material does not cause the pressure within the ICV to exceed the bounding maximum value of 61.2 psi absolute given in Section 2.6 of the TRUPACT-II and HalfPACT SARs.

4.2.4 Structural Analysis for Hypothetical Accident Conditions

Under HAC, the S100 pipe overpack remains leaktight and retains the sealed neutron sources within the pipe component. It is shown in Section 4.2.6 that an adequate level of biological shielding for HAC is achieved without any aid from the shielding in the S100 pipe overpack. Since the shielding in the S100 pipe overpack is not required for the HAC shielding analysis, the damage to the shielding material in the accident free drop does not need to be quantified. However, the reduced effective drum diameter, which prescribes the resultant pipe component spacing utilized in the criticality analysis, does need to be quantified.

To demonstrate that the pipe component remains leaktight and retains the sealed neutron sources within the pipe component in a 30 ft. free drop, reference is made to the testing of the Standard Pipe Overpack, as documented in Appendix 4.1 of the CH-TRU Payload Appendices. To account for design differences of the S100 Pipe Overpack, an additional test was performed, as documented below. Normal conditions of transport are bounded by these tests.[1]

The testing of the Standard Pipe Overpack, as documented in Appendix 4.1 of the CH-TRU Payload Appendices, consisted of two types of tests: 1) end drop testing, in which a stacked arrangement of drums was dropped from a height of 30 ft. in an end drop orientation, i.e., along

[1] Packaging Technology, Inc., July 2002, "30' Free Drop Test Report for the S100 Overpack," TR-013, Packaging Technology, Inc., Tacoma, Washington.

the axis of the drums, and 2) side drop testing, in which a bare TRUPACT-II ICV filled with test drums was dropped from 30 ft. in a horizontal orientation. Since, in the S100 design, the energy absorbing configuration at each axial end of the pipe component is identical to the Standard Pipe Overpack design, it was not necessary to repeat the end drop testing. In the side drop testing, however, the load path is through the material that is placed around the sides of the pipe component. In the prior Standard Pipe Overpack testing, this material was Celotex dunnage, and in the S100, it is made of neutron shielding material, which could have a different force-deflection behavior than the dunnage. Therefore, to clearly demonstrate that the S100 remains leaktight under hypothetical accident conditions, an additional drop test was performed.

The test consisted of a drop of a single, bare S100 package from a height of 30 ft. in a horizontal orientation onto an essentially unyielding surface. This test was conservative relative to a hypothetical accident drop inside a TRUPACT-II, since it neglected all of the impact absorption ability of the TRUPACT-II, and consequently, the impact was much higher. In addition, it was not necessary to place any weight on top of the S100 to represent the weight of the 'overburden' of drums ordinarily present within the ICV in a side drop orientation. This is because the effect of 'overburden' drums was conservatively included in the Standard Pipe Overpack drop testing using the 12-in. pipe component as follows:

- The 12-in. pipe version of the Standard Pipe Overpack weighed 547 lbs, which is essentially the same weight as the S100 at 550 lbs, and therefore the 'overburden' loading is equivalent;

- The 12-in. pipe component had a smaller nominal wall thickness and larger diameter than the 6-in. pipe component used in the S100, and thus was more liable to deformation under a given load;

- The 12-in. pipe component was surrounded by approximately 4.2 inches of Celotex dunnage, while the 6-in. pipe component in the S100 was surrounded by approximately 7 inches of neutron shielding, thus affording greater protection from the 'overburden' loads.

The test of the S100 focused, therefore, on the deceleration forces imposed on the 6-in. pipe component due to impact. Since the shielding material is generally stronger than the Celotex dunnage used to surround the 6-in. pipe component in the Standard Pipe Overpack, the impact forces on the pipe component in the S100 could be greater in a hypothetical accident free drop. Since the S100 is dropped bare, without any energy absorption materials present except the shield itself, it is very conservative compared to conditions within a complete TRUPACT-II or HalfPACT.

A helium mass spectrometer leakage rate test was performed before and after the drop test to evaluate the containment provided by the pipe component. There was no loss of leaktight containment as a result of the drop test. The leakage rate of the S100 pipe component after the 30 ft. drop was less than 1×10^{-7} cubic centimeters per second, air. In addition, the function of the filter vent in the lid of the pipe component was unimpaired, as verified by the filter manufacturer after the test.

The maximum radial crush of the S100 pipe overpack and the resulting minimum effective drum diameter from a 30 ft. free drop is determined by comparison of the crush strength and energy absorbing properties of the S100 Pipe Overpack's side neutron shield material and the 6-in. Standard Pipe Overpack's Celotex dunnage. The comparison demonstrates that the side neutron shield material will see less deformation than the Celotex material such that the maximum radial crush and resulting minimum effective drum diameter of 4.31 in. and 18.19 in., respectively observed in the 6-in. Standard Pipe Overpack drop testing and used in the S100 Pipe Overpack criticality analysis is conservative. The following analysis determines the percentage of total drop energy absorbed by the Celotex dunnage in the 6-in. Standard Pipe Overpack 30 ft. side drop.

Following the side drop crush logic provided in Section 4.2.3, the total drop energy from a 30 ft. side drop of an array of 6-in. standard pipe overpacks with a maximum weight of 328 lbs each (as specified in Section 2.9.2 of the CH-TRAMPAC) is given as follows:

$$E_{TOT} = (328 \text{ lbs} * 5 * 360 \text{ in.}) = 590{,}400 \text{ in.-lbs}$$

The actual energy absorbed by the Celotex dunnage in the lower drum can be determined from the measured radial drum crush value of 4.31 in. Based on the depth of crush and the outer diameter of the Celotex material of 21.5 in, the area (A) of the circular segment is computed to be 51.86 in^2. The crushed volume is in the form of a segment of a cylinder having a length equal to the length of the Celotex material, or L = 26.7 in. The crushed volume (V) is therefore

$$V = A \text{ in}^2 * L \text{ in.} = 1{,}384.66 \text{ in}^3$$

Based on the average plateau crush strength of Celotex at 150 °F of 90 psi[2], the actual energy (E) absorbed by the Celotex dunnage is

$$E_{ACT} = V \text{ in}^3 * \sigma \text{ psi} = 124{,}619 \text{ in.-lbs}$$

Therefore, the percentage of total to absorbed energy (f) is given as

$$f = \frac{E_{ACT}}{E_{TOT}} * 100 = 21\%$$

A conservative percentage of 25% is utilized in both the NCT and HAC crush determinations for the neutron shield material in the S100 pipe overpack. Accounting for the increased weight of the loaded S100 pipe overpack over that of the 6-in. standard pipe overpack and taking into account the fraction of total energy absorbed, the energy absorbed by the neutron shield material in a 30 ft. drop is given as follows:

[2] Walker, M.S., January 1991, "Packaging Materials Properties Data", Y/EN-4120, Martin Marietta Energy Systems, Inc., Oak Ridge, Tennessee.

$$E = 0.25 * (550 \text{ lbs} * 5 * 360 \text{ in.}) = 247{,}500 \text{ in.-lbs}$$

Following the calculational methodology employed for the NCT case with the minimum crush strength of the neutron shield material of σ=300 psi at 170°F, the resulting maximum depth of crush of the neutron shield material is 3.01 in. where V=825.00 in^3, A=30.90 in^2, and L=26.7 in. Thus, the crush depth of neutron shielding material in the S100 pipe overpack is less than that observed for the 6-in. standard pipe overpack.

As an alternative to specifying the shielding material crush strength, a test of the full-scale shielding component may be performed. The test shall demonstrate that the shield is capable of absorbing an amount of energy equal to 247,500 in-lbs with 4 in. or less of radial deformation. The energy absorbed may be calculated by integration of the force-deflection curve or other equivalent means. The test must be performed with a material temperature of at least 170°F. This energy absorption requirement is in addition to that specified for the NCT requirements (i.e., 24,750 in-lbs with 2 in. or less of radial deformation).

4.2.5 Criticality Analysis

A criticality analysis was performed for two different payload cases, depending on the quantities of special reflector materials in the payload container (see Chapter 6.0 of TRUPACT-II SAR or Chapter 6.0 of HalfPACT SAR for description of special reflector materials), as described below:

- Case E: For Case E, the contents of the pipe overpack payload container contain less than or equal to 1% by weight quantities of special reflector materials. The pipe overpack payload container may contain greater than 1% by weight quantities of special reflector materials provided that one of the following conditions is met:
  - The special reflector materials are chemically or mechanically bound to the fissile material such that no reconfiguration or release of the bond is possible under normal or accident conditions, or
  - The special reflector materials are present in thicknesses and/or packing fractions that render them less effective than a 25% polyethylene/75% water equivalent reflector per the limits in Table 6.2-1 of the TRUPACT-II or HalfPACT SAR.

- Case F: For Case F, the contents of the pipe overpack payload container contain greater than 1% by weight quantities of special reflector materials that do not meet the exceptions listed for Case E.

The criticality analysis demonstrates that a TRUPACT-II shipment of 14 pipe overpacks with contents meeting the requirements of Case E at 200 FGE of ^{239}Pu each (for a total of 2,800 FGE per TRUPACT-II) or a HalfPACT shipment of 7 pipe overpacks with 200 FGE each (for a total of 1,400 FGE per HalfPACT) ensures compliance with the requirements of Title 10, Code of

Federal Regulations (CFR), Sections 71.55 and 71.59 (10 CFR 71.55 and 71.59).[3] Additionally, shipments of pipe overpacks with contents meeting the requirements of Case F at 140 FGE for each payload container and 980 and 1960 FGE per HalfPACT and TRUPACT-II, respectively, ensure compliance with 10 CFR 71.55 and 71.59. Based on an infinite array of undamaged or damaged packages, the criticality transport index is 0.0.

The key parameters in the pipe overpack analysis for Case E are (1) the maximum fissile loading per pipe component is 200 FGE, (2) no more than 1% by weight quantities of special reflector materials are present or greater than 1% by weight quantities of special reflectors are either bound to the fissile material or meet the limits in Table 6.2-1 of the TRUPACT-II or HalfPACT SAR, (3) the spacing between the components (i.e., effective drum diameter) is reduced by the maximum amount reported in Section 4.2.4, and (4) the package arrays are infinite arrays stacked two high.

The key parameters in the pipe overpack analysis for Case F are (1) the maximum fissile loading per pipe component is 140 FGE, (2) the spacing between the components (i.e., effective drum diameter) is reduced by the maximum amount reported in Section 4.2.4, and (3) the package arrays are infinite arrays stacked two high.

The detailed analysis presented in Packaging Technology, 2004[3], presents the results of a series of SCALE 4.4 CSAS25 module[4] (KENO-Va version 4) calculations that establish a maximum system reactivity ($k_s + 2\sigma$) of less than 0.933 and the corresponding Upper Subcriticality Limit (USL) of 0.9377. Therefore, the shipment of 200 FGE or 140 FGE per pipe overpack for Cases E and F, respectively, in the TRUPACT-II and HalfPACT is safely subcritical.

4.2.6 Shielding Analysis

The payload of the S100 pipe overpack consists of neutron-emitting, actinide-bearing sealed sources, shown in Table 4.2-1. Source terms used in this analysis are for neutron emission and spectra for alpha-n reactions calculated by the SOURCES Version 4A computer code.[5] Of the sources shown in the table, the ^{238}Pu Be was determined to be the governing source for shielding calculations,[6] since it had the highest calculated unshielded dose rate of all the sources that will be transported in the S100.

[3] Packaging Technology, Inc., May 2004, "Pipe Overpack Criticality Analysis for the TRUPACT-II Package," ED-076, Packaging Technology, Inc., Tacoma, Washington.

[4] SCALE4.4., "Modular Code System for Performing Standardized Computer Analyses for Licensing Evaluation for Workstations and Personal Computers," RSICC code package C00545/MNYCP00, Oak Ridge National Laboratory, September 1998.

[5] Wilson, W.B., R.T. Perry, W. Charlton, et al., 1999, "SOURCES 4A: A Code for Calculating (alpha, n) Spontaneous Fission, and Delayed Neutron Sources and Spectra," LA-13639-MS, Los Alamos National Laboratory, Los Alamos, New Mexico.

[6] Gogol, S.L., and J. R. Bland, August 2002, "A Comparison of Dose Rates from (alpha, n) and Spontaneous Fission Neutron Sources," LA-UR-02-5120, Los Alamos National Laboratory, Los Alamos, New Mexico.

Table 4.2-1 S100 Pipe Overpack Payloads

^{241}Am Be	^{238}Pu O	^{239}Pu Li	^{241}Am
^{238}Pu Be	^{239}Pu O	^{238}Pu B	^{238}Pu
^{239}Pu Be	^{244}Cm O	^{239}Pu F	^{239}Pu
^{241}Am O	^{241}Am Li	^{238}Pu ^{13}C	^{244}Cm

The radiation generated by the payload is in the form of neutrons and a relatively small amount of gamma radiation. Some additional gamma radiation is generated by capture of thermal neutrons in the neutron shielding. However, the gamma radiation remains a small fraction of the neutron radiation level.

Neutron shielding is afforded by placement of the pipe component within an annulus of shielding material, having an inner diameter of 7 in. and an outer diameter of 21.5 in. (conservatively neglecting the thickness of the drum poly liner). The side neutron shielding extends along the entire length of the pipe component as shown in Figure 4.2-1. The upper and lower shield plugs (6 in. in diameter and 6.5 in. long) and shield sleeve are made of solid high-density polyethylene and are placed within the pipe component. The side neutron shield may be in the form of a casting (such as a commercial neutron shielding casting compound), a solid monolith (such as a molded or machined unit of solid plastic), or fabricated component (such as a tightly wound roll of plastic film or other built-up fabrication). None of the materials of construction of the S100 pipe overpack, including the neutron shielding material, generate hydrogen gas in excess of 10^{-10} moles hydrogen per second per liter of headspace as a consequence of neutron or gamma irradiation by the payload sources.[7] A combination of the neutron shielding material and the materials of construction of the S100 pipe overpack provide sufficient shielding for both neutron and gamma radiation.

Any material used for the side neutron shield must meet minimum requirements for neutron attenuation and mechanical strength. Neutron attenuation must be at least as good as the reference material, which has an atomic fraction composition of 0.667 hydrogen and 0.333 carbon. A test shall be performed on any alternate materials used for the side shield assembly. The test sample, neutron source, test setup, and acceptance criteria shall be defined in a test specification. The acceptance criteria shall be that the measured neutron attenuation of the equivalent shielding material shall be equal to or greater than the attenuation predicted for the reference material, using the actual test setup and the shielding analysis code.

The side neutron shielding material will have a minimum mechanical strength at a temperature of 170°F. The strength shall be defined as a minimum unit compressive crush strength of 300 psi. Alternatively, it may be defined as a maximum radial deformation of the full-scale shielding component under compressive load. The component must absorb a minimum of 24,750 in-lb. of

[7] Bustos, L.D., W.F. Sandoval, R. Villarreal, and L.R. Field, October 2000, "Hydrogen Generation Rate Potential from Neutron and Gamma Ray Interactions with Shielding/Packaging Materials Contained in the S100 Pipe Component Overpack," Los Alamos National Laboratory, Los Alamos, New Mexico.

energy with a maximum deformation of 2 in. and a minimum of 247,500 in-lb. of energy with a maximum deformation of 4 in., when loaded between the inner dimensions and outer dimensions of the component. Equivalent materials will not generate hydrogen gas in excess of 10^{-10} moles hydrogen per second per liter of headspace gas as a consequence of neutron or gamma irradiation.

Dose rate calculations were performed for a single S100 pipe overpack and for a TRUPACT-II in both the as-loaded and post-NCT free drop configurations.[8] The results were used to determine the maximum loading of the S100 pipe overpack such that the regulatory dose rate limits will be met in each case for NCT and HAC. In the analysis, the bounding payload of ^{238}Pu Be was used, as discussed above. Source gamma radiation was negligible and was not included, but capture gamma dose rate contribution was included in the calculated integrated dose rate. Dose rate calculations were made for a single S100 pipe overpack as presented for loading into a TRUPACT-II, for a TRUPACT-II as presented for transport with a payload of 14 identical S100 pipe overpacks each having the maximum payload, and for a TRUPACT-II including a conservative representation of NCT free drop damage with a payload of 14 identical S100 pipe overpacks each having the maximum payload. (The HAC case is discussed below.) Dose rates were calculated at the surface and at defined distances from the containers as shown in Table 4.2-2. As shown in the table, the limiting dose is for the TRUPACT-II package including NCT free drop damage, and is equal to 10 mrem/hr at a distance of 2 meters from the package surface. The corresponding S100 pipe overpack surface dose limit is 179 mrem/hr. This means that, as long as the surface dose rate of any S100 pipe overpack transported in a TRUPACT-II is at or below 179 mrem/hr, then the dose rate external to the TRUPACT-II will not exceed 10 mrem/hr at 2 meters including NCT free drop damage, nor will any of the other, less governing regulatory limits be exceeded. The TRUPACT-II calculations govern the case of the HalfPACT. Each S100 pipe overpack will be surveyed before loading into a TRUPACT-II or HalfPACT to ensure compliance with the limiting surface dose rate of 179 mrem/hr, as given in Section 3.2 of the CH-TRAMPAC.

The damage to the TRUPACT-II and payload under NCT is assumed to occur in the 3 ft. side drop, and is discussed in Section 4.2.3. The drums are modeled as resting on the inside of the TRUPACT-II ICV, which is resting on its side, and the bottom drum is crushed by a bounding distance of 2 in. The 2 in. of crushed shielding is conservatively assumed to be lost.

[8] Packaging Technology, Inc., August 2002, "Dose Rate Calculations for the S100 Pipe Overpack," ED-071, Packaging Technology, Inc., Tacoma, Washington.

Table 4.2-2 Maximum Dose Rates for S100 Pipe Overpack and TRUPACT-II

	Maximum Dose Rate (mrem/hr)	Limits (mrem/hr)④
S100 Surface	179 ±0.82	200
TRUPACT-II side Surface (undamaged) ①②	58.0 ±0.85	200
TRUPACT-II 2 meters (undamaged)	7.33 ±0.14	10
TRUPACT-II 5 meters (undamaged)③	1.76 ±0.04	2
TRUPACT-II side Surface (damaged)	128 ±1.4	200
TRUPACT-II 2 meters (damaged)	9.85 ±0.15	10

Notes:
1. TRUPACT-II contains 14 identical S100 pipe overpacks, each with a maximum surface dose rate of 179 mrem/hr or less.
2. Side dose rate governs over top or bottom dose rates.
3. The 5 meter distance corresponds to the normally occupied space of the truck cab.
4. Limits established by CH-TRAMPAC (S100 surface) or 10 CFR 71.47(b) (TRUPACT-II).

For HAC, the drums, neutron shielding material, pipe components, and internal dunnage are conservatively removed from consideration in the shielding calculation, and the sum total of all activity in the S100 payload is concentrated as a single point source resting on the inside surface of the TRUPACT-II ICV. In accordance with 10 CFR 71.51(a)(2), the dose point is located 1 meter from the external surface of the package. This is equivalent to a total distance from the source of 1 meter plus the minimum crushed wall thickness of the TRUPACT-II or HalfPACT. For simplicity and conservatism, the calculations assume that there is no material of any kind between the source and the dose point. The crushed wall thickness is found by subtracting the HAC 30-foot free drop side orientation crush damage from the original wall thickness of the package as follows. The outer diameter of the package is 94.38 inches, and the inner diameter of the ICV is 73.63 inches, which gives an undamaged wall thickness of 10.38 inches. The maximum crush damage is found in Table 2.10.3-1 of the TRUPACT-II SAR for Test No. 2, as equal to 3.63 inches. The remaining wall thickness is then equal to 10.38 – 3.63 = 6.75 inches. In the shielding calculations, a value of 6.5 inches is conservatively used. As already discussed, no material is assumed to fill this space. The resulting maximum allowable activity within the TRUPACT-II is a total of 406 Ci, and the resulting conservative dose rate is 999 mrem/hr at 1 meter from the crushed TRUPACT-II surface, which meets the requirements of 10 CFR 71.51(a)(2). As for NCT, the TRUPACT-II HAC calculations govern the case of the HalfPACT.

4.2.7 Authorized Payload Contents

As demonstrated in Section 4.2.6, when loaded with sealed neutron sources of the types specified in Table 4.2-1 (the authorized contents), the S100 pipe overpack meets all regulatory dose rate limits. The bounding payload is defined in three ways: (1) a maximum dose rate on the surface of the S100 pipe overpack of 179 mrem/hr for any S100 pipe overpack placed into the TRUPACT-II or HalfPACT, (2) a maximum activity of 406 Ci within a single TRUPACT-II or HalfPACT, and (3) a maximum payload of 200 FGE per S100 pipe overpack, or a total of 2,800 FGE per TRUPACT-II or 1,400 FGE per HalfPACT when the contents meet the requirements of Case E, or (4) a maximum payload of 140 FGE per S100 pipe overpack, or a total of 1,960 FGE per TRUPACT-II or 980 FGE per HalfPACT when the contents meet the requirements of Case F. Section 4.2.5 demonstrates that 200 FGE per S100 pipe overpack is safely subcritical for Case E shipments and that 140 FGE per S100 pipe overpack is safely subcritical for Case F shipments.

4.2.8 Conclusion

The S100 pipe overpack design is based on the standard pipe overpack. It consists of a 6-in. pipe component within a 55-gallon drum, including a rigid liner and lid. Dunnage is placed above and below the pipe component, and neutron shielding material is placed on the sides of the component. Within the pipe component are placed rigid high-density polyethylene shield plugs and insert. The analyses summarized in this appendix demonstrate the ability of the S100 pipe overpack to provide three significant control functions under NCT and HAC: (1) criticality, (2) shielding, and (3) confinement of the payload.

The primary purpose of the S100 pipe overpack is to allow the shipment of sealed neutron sources of the types listed in Table 4.2-1. The structural analysis shows that the pipe component remains leaktight and the neutron sources remain confined within the pipe component in conservatively bounded normal and accident free drops. For criticality, it is shown that 200 FGE per S100 pipe overpack for Case E payloads is safely subcritical and 140 FGE per S100 pipe overpack is safely subcritical for Case F payloads. The shielding analysis shows that, with the maximum authorized contents, the dose rate limits for NCT and HAC (including appropriate shielding damage assumptions in each case) are met.

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APPENDIX 4.3

DESCRIPTION OF S200 PIPE OVERPACK

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4.3 Description of S200 Pipe Overpack

4.3.1 Introduction

The S200 pipe overpack is based closely on the standard pipe overpack described in Appendix 4.1 of the CH-TRU Payload Appendices. It differs from the standard pipe overpack through the addition of a gamma shield insert located by dunnage inside the pipe component. It is intended for the shipment of transuranic waste forms with high gamma energies in the TRUPACT-II and HalfPACT. Appendix 1.3.1 of the TRUPACT-II Safety Analysis Report (SAR), Appendix 1.3.1 of the HalfPACT SAR, and Section 2.9.4 of the Contact-Handled Transuranic Waste Authorized Methods for Payload Control (CH-TRAMPAC) describe the materials of construction, sizes, and other dimensional specifications for the S200 pipe overpack. Up to 14 S200 pipe overpacks may be shipped in the TRUPACT-II, and up to 7 S200 pipe overpacks may be shipped in the HalfPACT. This appendix describes the structural, criticality, and shielding basis of the S200 pipe overpack.

4.3.2 Description

The S200 pipe overpack consists of a gamma shield insert located by rigid polyurethane foam dunnage inside a standard 12-inch (in.) pipe component which is, in turn, located by cane fiberboard and plywood dunnage within a standard 55-gallon drum with a rigid polyethylene liner and lid. A schematic of the S200 pipe overpack is shown in Figure 4.3-1. The 12-in. pipe component, cane fiberboard and plywood dunnage, and 55-gallon drum with rigid polyethylene liner and lid are identical to the standard pipe overpack described in Appendix 4.1 of the CH-TRU Payload Appendices.

The gamma shield insert is a lead two-component assembly consisting of a cylindrical body with an integral bottom cap and a detachable lid. The shield insert is available in two sizes; the S200-A shield insert has a nominal thickness of 1.000 in. and the S200-B shield insert has a nominal thickness of 0.600 in. The overall dimensions of the S200-A and S200-B shield inserts are nominally 10.125 in. diameter by 10.625 in. long and 9.325 in. diameter by 17.825 in. long, respectively. The rigid polyurethane foam dunnage fills the bottom and annular space between the shield insert and the 12-in. pipe component to position the insert near the lid of the pipe component.

The pipe component provides three significant control functions: (1) criticality control, (2) shielding, and (3) confinement of the waste material. Additionally, the gamma shield insert also provides a shielding control function. The following sections demonstrate the effectiveness of the S200 pipe overpack design for normal conditions of transport (NCT) and hypothetical accident conditions (HAC). All demonstrations are by analysis or by reference to the standard pipe overpack analysis and testing, unless stated otherwise.

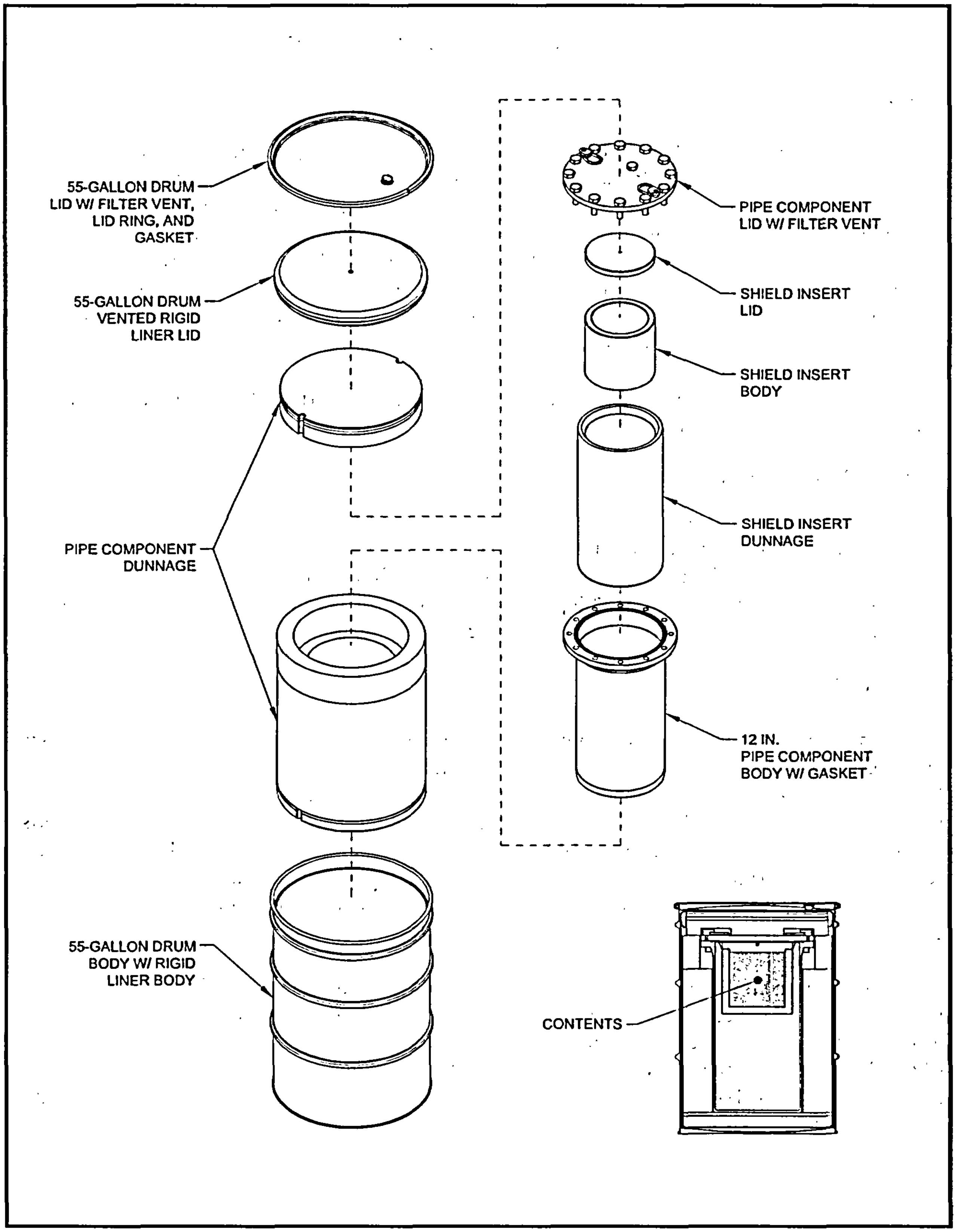

Figure 4.3-1 — S200 Pipe Overpack

4.3.3 Structural Analysis For NCT

The structural effectiveness of the S200 pipe overpack for NCT is demonstrated by showing that the waste contents are confined within the pipe component. The structural effectiveness of the pipe component for NCT is bounded by the structural effectiveness evaluation for HAC given in Section 4.3.4. It is shown in Section 4.3.6 that an adequate level of biological shielding for NCT is afforded by the materials of construction of the TRUPACT-II and HalfPACT, pipe components, and shield inserts themselves, with the 55-gallon drum, fiberboard dunnage, and foam dunnage providing only a distance attenuation contribution. The maximum deflection and resulting radial shift of the pipe overpack array for the NCT side drop, which is limiting for shielding calculations, is bounded by the HAC side drop analysis provided in Section 4.3.4. Additionally, the spacing between pipe components (i.e., effective drum diameter) utilized in the criticality analysis is also bounded by the HAC side drop analysis provided in Section 4.3.4. The following analysis evaluates the maximum damage to the shield insert rigid polyurethane foam dunnage in the end and side drop orientations and thereby shows that the shield lid remains engaged with the shield body and quantifies the maximum shift of the shield insert inside the pipe component.

The shield insert is positioned inside the pipe component by rigid polyurethane foam dunnage with a maximum clearance between the pipe component and shield insert lid of 0.125 in. The shield insert lid has a step feature that has a minimum length of 0.500 in. Therefore, limiting the axial crush of the foam dunnage to less than (0.500 – 0.125) = 0.375 in. in any drop orientation ensures that the shield lid remains engaged with the shield body. The maximum crush deformation of the foam in the end drop orientation may be bounded by assuming all of the drop energy of the shield insert and contents is absorbed by the foam beneath the shield insert body. The drop energy (E) to be absorbed for the S200-A and S200-B shield inserts is the product of the weight of the shield insert and contents in pounds (lbs) and the height of the drop (36 in.):

$$E_{S200\text{-}A} = (202 \text{ lbs})(36 \text{ in.}) = 7{,}272 \text{ in.-lbs}$$
$$E_{S200\text{-}B} = (206 \text{ lbs})(36 \text{ in.}) = 7{,}416 \text{ in.-lbs}$$

Under NCT, the average temperature of the contents of a drum is bounded by a temperature of 170°F for the case where decay heat is uniformly distributed among all drums, as shown in Table 3.4-1 of the HalfPACT SAR. The minimum parallel-to-rise compressive strength of the rigid polyurethane foam material is $\sigma = 400$ pounds per square inch (psi) at 170°F. Therefore, to absorb this energy, the volume (V) of the crush material in cubic inches (in^3) is:

$$V_{S200\text{-}A} = E_{S200\text{-}A} / \sigma = (7272 \text{ in.-lbs}) / (400 \text{ psi}) = 18.180 \text{ in}^3$$
$$V_{S200\text{-}B} = E_{S200\text{-}B} / \sigma = (7416 \text{ in.-lbs}) / (400 \text{ psi}) = 18.540 \text{ in}^3$$

This volume is in the form of a right circular cylinder with a diameter equal to the shield body that generates the following crush area (A) in square inches (in^2):

$$A_{S200\text{-}A} = (\pi/4)(D_{S200\text{-}A})^2 = (\pi/4)(10.125 \text{ in.})^2 = 80.516 \text{ in}^2$$
$$A_{S200\text{-}B} = (\pi/4)(D_{S200\text{-}B})^2 = (\pi/4)(9.325 \text{ in.})^2 = 68.295 \text{ in}^2$$

The bounding axial crush of the foam dunnage and resulting maximum separation of shield body and lid (H) is defined as:

$$H_{S200\text{-}A} = V_{S200\text{-}A} / A_{S200\text{-}A} = (18.180 \text{ in}^3) / (80.516 \text{ in}^2) = 0.226 \text{ in.}$$
$$H_{S200\text{-}B} = V_{S200\text{-}B} / A_{S200\text{-}B} = (18.540 \text{ in}^3) / (68.295 \text{ in}^2) = 0.271 \text{ in.}$$

Therefore, the minimum positive engagement between the shield body and lid in a maximum axial foam crush event is 0.104 in.

The maximum radial shift of the shield insert within the pipe component is also bounded through a volumetric crush analysis. The drop energy is the same as that defined above. The minimum perpendicular-to-rise compressive strength of the rigid polyurethane foam material is $\sigma = 300$ psi at 170°F. Therefore, to absorb this energy, the volume of the crush material is:

$$V_{S200\text{-}A} = E_{S200\text{-}A} / \sigma = (7272 \text{ in.-lbs}) / (300 \text{ psi}) = 24.240 \text{ in}^3$$
$$V_{S200\text{-}B} = E_{S200\text{-}B} / \sigma = (7416 \text{ in.-lbs}) / (300 \text{ psi}) = 24.720 \text{ in}^3$$

The product of the shield body length (L) and the crescent-shaped area generated by the radial shift defines the crush volume. Therefore, the area of crush material is given by:

$$A_{S200\text{-}A} = V_{S200\text{-}A} / L_{S200\text{-}A} = (24.240 \text{ in}^3) / (9.625 \text{ in.}) = 2.518 \text{ in}^2$$
$$A_{S200\text{-}B} = V_{S200\text{-}B} / L_{S200\text{-}B} = (24.720 \text{ in}^3) / (17.225 \text{ in.}) = 1.435 \text{ in}^2$$

The bounding radial crush of the foam dunnage and resulting maximum radial shift of the shield body and lid (R) is defined as:

$$R_{S200\text{-}A} = A_{S200\text{-}A} / D_{S200\text{-}A} = (2.518 \text{ in}^2) / (10.125 \text{ in.}) = 0.249 \text{ in.}$$
$$R_{S200\text{-}B} = A_{S200\text{-}B} / D_{S200\text{-}B} = (1.435 \text{ in}^2) / (9.325 \text{ in.}) = 0.154 \text{ in.}$$

The side drop crush distances are accounted for in the NCT shielding analysis discussed in Section 4.3.6.

4.3.4 Structural Analysis for HAC

The structural effectiveness of the S200 pipe overpack for HAC is demonstrated by showing that the waste contents remain confined within the pipe component. It is shown in Section 4.3.6 that an adequate level of biological shielding for HAC is afforded by the materials of construction of the TRUPACT-II or HalfPACT and pipe components, themselves, without any aid from the shield inserts inside the pipe components. The 55-gallon drum and fiberboard dunnage provides only a distance attenuation contribution. Since the shield insert in the S200 pipe overpack is not required for the HAC shielding analysis, the damage to the shielding material in the accident free drop does not need to be quantified. However, the maximum deflection and resulting radial shift of the pipe overpack array will be quantified for the side drop orientation, which is limiting for shielding calculations. The following comparative analysis shows that the contents remain confined within the pipe component under the HAC free drop. Additionally, the analysis shows the maximum deflection of pipe overpacks and the resulting stacked array configuration resulting from the HAC free side drop.

As shown in Table 2.9-7 of Section 2.9.2 of the CH-TRAMPAC, the weight of the 12-in. standard pipe component contents is bounded by a value of 225 lbs. Additionally, as shown in Table 2.9-16 of Section 2.9.4 of the CH-TRAMPAC, the total weight of the S200 pipe overpack, shield insert, dunnage, and contents is bounded by a value of 225 lbs. Because the design of the standard and S200 pipe overpacks are structurally identical except for items inside the pipe component and since the weight limit for items inside the pipe component are identical, all structural evaluations of the standard pipe overpack apply to the S200 pipe overpack. Ammerman and Bobbe, 1995,[1] demonstrates the leak tightness of the standard pipe overpack when subjected to HAC testing. Therefore, the waste contents will remain confined within the pipe component under the HAC free drop.

Additionally, Ammerman and Bobbe[1] report a 20.250 in. minimum deformed pipe overpack diameter resulting from a free side drop orientation. Therefore, conservatively using a 20.000 in. 55-gallon drum diameter bounds the radial shift of the pipe component with respect to the S200 pipe overpack at (22.500 – 20.000)/2 = 1.250 in. The resulting stacked array of 14 S200 pipe overpacks resting against the TRUPACT-II inner containment vessel is accounted for in the HAC shielding analysis discussed in Section 4.3.6. The maximum drum crush values reported in Ammerman and Bobbe of 20.25 in. outside diameter by 29.62 in. height are directly utilized in the criticality analysis summarized in Section 4.3.5.

4.3.5 Criticality Analysis

A criticality analysis was performed for two different payload cases, depending on the quantities of special reflector materials in the payload container (see Chapter 6.0 of TRUPACT-II SAR or Chapter 6.0 of HalfPACT SAR for description of special reflector materials), as described below:

- Case E: For Case E, the contents of the pipe overpack payload container contain less than or equal to 1% by weight quantities of special reflector materials. The pipe overpack payload container may contain greater than 1% by weight quantities of special reflector materials provided that one of the following conditions is met:
    - The special reflector materials are chemically or mechanically bound to the fissile material such that no reconfiguration or release of the bond is possible under normal or accident conditions, or
    - The special reflector materials are present in thicknesses and/or packing fractions that render them less effective than a 25% polyethylene/75% water equivalent reflector per the limits in Table 6.2-1 of the TRUPACT-II or HalfPACT SAR.

[1] Ammerman, D.J., and J.G. Bobbe, October 1995. "Rocky Flats Pipe Component Testing," TTC-1434, Sandia National Laboratories, Albuquerque, New Mexico.

- Case F: For Case F, the contents of the pipe overpack payload container contain greater than 1% by weight quantities of special reflector materials that do not meet the exceptions listed for Case E.

The criticality analysis demonstrates that a TRUPACT-II shipment of 14 pipe overpacks with contents meeting the requirements of Case E at 200 FGE of ^{239}Pu each (for a total of 2,800 FGE per TRUPACT-II) or a HalfPACT shipment of 7 pipe overpacks with 200 FGE each (for a total of 1,400 FGE per HalfPACT) ensures compliance with the requirements of Title 10, Code of Federal Regulations (CFR), Sections 71.55 and 71.59 (10 CFR 71.55 and 71.59).[2] Additionally, shipments of pipe overpacks with contents meeting the requirements of Case F at 140 FGE for each payload container and 980 and 1960 FGE per HalfPACT and TRUPACT-II, respectively, ensure compliance with 10 CFR 71.55 and 71.59. Based on an infinite array of undamaged or damaged packages, the criticality transport index is 0.0.

The key parameters in the pipe overpack analysis for Case E are (1) the maximum fissile loading per pipe component is 200 FGE, (2) no more than 1% by weight quantities of special reflector materials are present or greater than 1% by weight quantities of special reflectors are either bound to the fissile material or meet the limits in Table 6.2-1 of the TRUPACT-II or HalfPACT SAR, (3) the spacing between the components (i.e., effective drum diameter) is reduced by the maximum amount reported in Section 4.3.4, and (4) the package arrays are infinite arrays stacked two high.

The key parameters in the pipe overpack analysis for Case F are (1) the maximum fissile loading per pipe component is 140 FGE, (2) the spacing between the components (i.e., effective drum diameter) is reduced by the maximum amount reported in Section 4.3.4, and (3) the package arrays are infinite arrays stacked two high.

The detailed analysis presented in Packaging Technology, 2004[2], presents the results of a series of SCALE 4.4 CSAS25 module[3] (KENO-Va version 4) calculations that establish a maximum system reactivity ($k_s + 2\sigma$) of less than 0.933 and the corresponding Upper Subcriticality Limit (USL) of 0.9377. Therefore, the shipment of 200 FGE or 140 FGE per pipe overpack for less than or equal to 1% or greater than 1% by weight quantities of special reflector materials, respectively in the TRUPACT-II and HalfPACT is safely subcritical.

[2] Packaging Technology, Inc., May 2004, "Pipe Overpack Criticality Analysis for the TRUPACT-II Package," ED-076, Packaging Technology, Inc., Tacoma, Washington.

[3] SCALE4.4., "Modular Code System for Performing Standardized Computer Analyses for Licensing Evaluation for Workstations and Personal Computers," RSICC code package C00545/MNYCP00, Oak Ridge National Laboratory, September 1998.

4.3.6 Shielding Analysis

Adequate shielding is provided in the S200 pipe overpack and TRUPACT-II or HalfPACT shipping configuration to ensure that no radioactive payload will exceed the dose rate limits established by 10 CFR 71.47(a) for NCT or 10 CFR 71.51(a)(2) for HAC. Compliance with dose rate limits specified in Section 3.2 of the CH-TRAMPAC for individual S200 pipe overpacks and loaded TRUPACT-IIs or HalfPACTs will be achieved by pre-shipment radiological surveys. Compliance with NCT and HAC radiation dose rate limits will be ensured by limiting radionuclide quantities to satisfy the most-limiting NCT or HAC radiation dose rate limits for worst-case, reconfigured source and post-accident shielding geometries.

A shielding analysis of the S200 pipe overpack and TRUPACT-II shipping configuration was performed to establish the allowable quantities of the radionuclides shown in Table 4.3-1. The analysis utilized a point-source methodology developed by T. Rockwell III for gamma sources and the Nelson methodology for neutron sources.[4, 5, 6]

Table 4.3-1 — Radionuclide Inventory

^{3}H	^{85}Kr	^{103}Ru	^{123}Te	^{144m}Pr	^{209}Tl	^{214}Po	^{227}Ac	^{236}U	^{244}Pu	^{250}Bk
^{14}C	^{86}Rb	^{106}Ru	^{123m}Te	^{146}Pm	^{209}Pb	^{215}Po	^{228}Ac	^{237}U	^{241}Am	^{249}Cf
^{22}Na	^{89}Sr	^{103m}Rh	^{125m}Te	^{147}Pm	^{210}Pb	^{216}Po	^{227}Th	^{238}U	^{242}Am	^{250}Cf
^{32}P	^{90}Sr	^{106}Rh	^{127}Te	^{146}Sm	^{211}Pb	^{218}Po	^{228}Th	^{239}U	^{242m}Am	^{251}Cf
^{51}Cr	^{88}Y	^{107}Pd	^{127m}Te	^{147}Sm	^{212}Pb	^{211}At	^{229}Th	^{240}U	^{243}Am	^{252}Cf
^{54}Mn	^{90}Y	^{109m}Ag	^{125}I	^{151}Sm	^{214}Pb	^{217}At	^{230}Th	^{237}Np	^{245}Am	^{254}Cf
^{55}Fe	^{90m}Y	^{110}Ag	^{129}I	^{150}Eu	^{207}Bi	^{219}Rn	^{231}Th	^{238}Np	^{240}Cm	^{252}Es
^{59}Fe	^{91}Y	^{110m}Ag	^{131}I	^{152}Eu	^{210}Bi	^{220}Rn	^{232}Th	^{239}Np	^{242}Cm	^{253}Es
^{57}Co	^{88}Zr	^{109}Cd	^{134}Cs	^{154}Eu	^{211}Bi	^{222}Rn	^{234}Th	^{240}Np	^{243}Cm	^{254}Es
^{58}Co	^{90}Zr	^{113m}Cd	^{135}Cs	^{155}Eu	^{212}Bi	^{221}Fr	^{231}Pa	^{240m}Np	^{244}Cm	^{255}Es
^{60}Co	^{90m}Zr	^{119m}Sn	^{137}Cs	^{152}Gd	^{213}Bi	^{223}Fr	^{233}Pa	^{236}Pu	^{245}Cm	
^{59}Ni	^{93}Zr	^{121m}Sn	^{133}Ba	^{153}Gd	^{214}Bi	^{223}Ra	^{234}Pa	^{238}Pu	^{246}Cm	
^{63}Ni	^{95}Zr	^{123}Sn	^{137}Ba	^{168}Tm	^{209}Po	^{224}Ra	^{234m}Pa	^{239}Pu	^{247}Cm	
^{64}Cu	^{95}Nb	^{126}Sn	^{137m}Ba	^{182}Ta	^{210}Po	^{225}Ra	^{232}U	^{240}Pu	^{248}Cm	
^{65}Zn	^{95m}Nb	^{125}Sb	^{141}Ce	^{198}Au	^{211}Po	^{226}Ra	^{233}U	^{241}Pu	^{250}Cm	
^{73}As	^{99}Tc	^{126}Sb	^{144}Ce	^{207}Tl	^{212}Po	^{228}Ra	^{234}U	^{242}Pu	^{247}Bk	
^{79}Se	^{99m}Tc	^{126m}Sb	^{144}Pr	^{208}Tl	^{213}Po	^{225}Ac	^{235}U	^{243}Pu	^{249}Bk	

[4] T. Rockwell III, et al., Reactor Shielding Design Manual, TID-7004, First Edition, March 1956, U.S. Atomic Energy Commission, Oak Ridge, Tennessee.

[5] R.D. Wilson, Neutron Dose Rate Estimates for the 72-B Cask Using the Nelson Methodology, ENG-RCAL-021, Rev. 0, March 1999, Waste Management Federal Services, Inc., Northwest Operations, Richland, Washington.

[6] IT Corporation, June 2001, "Shielding Analysis of the S200 Pipe Overpack," IT Corporation, Albuquerque, New Mexico.

The primary shielding for the payload in the NCT configuration is the stainless steel and lead provided by the shield insert, pipe component, and TRUPACT-II. HAC configurations utilize the stainless steel in the pipe component and TRUPACT-II. A detailed description of the shield configurations utilized in the shielding analysis is presented in IT Corporation, 2001.[6]

The shielding analysis presented in IT Corporation, 2001,[6] calculates the maximum allowable radionuclide activity per S200 pipe overpack in the NCT at the surface, NCT at 2 meters, and HAC at 1 meter configurations inside a TRUPACT-II. The minimum of the calculated configuration activities is defined as the limiting activity and presented for both the S200-A and S200-B shield insert configurations in Table 4.3-2. The limiting activity per S200 pipe overpack provided in Table 4.3-2 is also conservative for the HalfPACT configuration because the number of S200 pipe overpacks (and the resulting total activity) is half that of the TRUPACT-II configuration.

Table 4.3-2 — Limiting Activity per S200 Pipe Overpack

Radio-nuclide Name	S200-A Limiting Activity (Ci)	S200-B Limiting Activity (Ci)
^{3}H	unlimited	unlimited
^{14}C	unlimited	unlimited
^{22}Na	3.722E-02	2.343E-02
^{32}P	unlimited	unlimited
^{51}Cr	1.226E+01	1.226E+01
^{54}Mn	8.440E-02	4.331E-02
^{55}Fe	unlimited	unlimited
^{59}Fe	4.192E-02	2.577E-02
^{57}Co	2.641E+01	2.641E+01
^{58}Co	8.829E-02	4.471E-02
^{60}Co	1.906E-02	1.195E-02
^{59}Ni	unlimited	unlimited
^{63}Ni	unlimited	unlimited
^{64}Cu	7.156E+00	4.600E+00
^{65}Zn	9.129E-02	5.486E-02
^{73}As	1.055E+03	1.055E+03
^{79}Se	unlimited	unlimited
^{85}Kr	1.363E+02	3.709E+01
^{86}Rb	5.643E-01	3.353E-01
^{89}Sr	7.224E+02	3.920E+02
^{90}Sr	unlimited	unlimited
^{88}Y	1.709E-02	1.110E-02
^{90}Y	1.328E+06	9.330E+05
^{90m}Y	6.476E-01	2.442E-01
^{91}Y	1.572E+01	9.695E+00
^{88}Zr	9.496E-01	7.384E-01
^{90}Zr	unlimited	unlimited
^{90m}Zr	unlimited	unlimited
^{93}Zr	1.975E+07	1.975E+07
^{95}Zr	1.248E-01	5.705E-02
^{95}Nb	1.100E-01	5.212E-02
^{95m}Nb	8.103E+00	8.103E+00
^{99}Tc	1.693E+07	1.693E+07
^{99m}Tc	1.385E+01	1.385E+01

Radio-nuclide Name	S200-A Limiting Activity (Ci)	S200-B Limiting Activity (Ci)
^{103}Ru	6.524E-01	1.750E-01
^{106}Ru	unlimited	unlimited
^{103m}Rh	1.618E+05	1.618E+05
^{106}Rh	6.710E-01	2.764E-01
^{107}Pd	unlimited	unlimited
^{109m}Ag	2.974E+03	2.974E+03
^{110}Ag	3.900E+00	1.594E+00
^{110m}Ag	2.521E-02	1.351E-02
^{109}Cd	2.974E+03	2.974E+03
^{113m}Cd	7.540E+03	7.540E+03
^{119m}Sn	6.826E+02	6.826E+02
^{121m}Sn	5.948E+03	5.948E+03
^{123}Sn	7.589E+00	4.521E+00
^{126}Sn	1.726E+02	1.726E+02
^{125}Sb	5.782E-01	1.908E-01
^{126}Sb	4.239E-02	1.826E-02
^{126m}Sb	9.044E-02	3.658E-02
^{123}Te	unlimited	unlimited
^{123m}Te	7.703E+00	7.703E+00
^{125m}Te	1.542E+03	1.542E+03
^{127}Te	7.613E+01	4.597E+01
^{127m}Te	1.323E+03	5.207E+02
^{125}I	1.647E+03	1.647E+03
^{129}I	1.465E+03	1.465E+03
^{131}I	9.832E-01	5.754E-01
^{134}Cs	6.216E-02	2.832E-02
^{135}Cs	unlimited	unlimited
^{137}Cs	2.181E-01	8.747E-02
^{133}Ba	1.142E+00	1.142E+00
^{137}Ba	unlimited	unlimited
^{137m}Ba	2.060E-01	8.261E-02
^{141}Ce	2.011E+01	2.011E+01
^{144}Ce	1.539E+02	1.539E+02
^{144}Pr	1.779E+00	1.126E+00

Table 4.3-2 — Limiting Activity per S200 Pipe Overpack (Continued)

Radio-nuclide Name	S200-A Limiting Activity (Ci)	S200-B Limiting Activity (Ci)
^{144m}Pr	5.304E+01	3.512E+01
^{146}Pm	1.958E-01	8.003E-02
^{147}Pm	1.175E+06	1.175E+06
^{146}Sm	unlimited	unlimited
^{147}Sm	unlimited	unlimited
^{151}Sm	3.504E+05	3.504E+05
^{150}Eu	1.001E-01	4.605E-02
^{152}Eu	5.488E-02	3.263E-02
^{154}Eu	4.915E-02	2.843E-02
^{155}Eu	1.743E+02	1.743E+02
^{152}Gd	unlimited	unlimited
^{153}Gd	1.898E+02	1.898E+02
^{168}Tm	8.380E-02	4.045E-02
^{182}Ta	4.298E-02	2.631E-02
^{198}Au	9.004E-01	4.886E-01
^{207}Tl	2.733E+01	1.469E+01
^{208}Tl	1.497E-02	9.959E-03
^{209}Tl	2.596E-02	1.678E-02
^{209}Pb	unlimited	unlimited
^{210}Pb	2.589E+03	2.589E+03
^{211}Pb	1.786E+00	8.441E-01
^{212}Pb	4.342E+00	4.342E+00
^{214}Pb	1.681E+00	1.589E+00
^{207}Bi	4.786E-02	2.598E-02
^{210}Bi	unlimited	unlimited
^{211}Bi	8.296E+00	8.296E+00
^{212}Bi	6.418E-01	3.564E-01
^{213}Bi	2.920E+00	1.052E+00
^{214}Bi	3.569E-02	2.213E-02
^{209}Po	1.519E+01	8.164E+00
^{210}Po	7.613E+03	3.813E+03
^{211}Po	1.055E+01	5.124E+00
^{212}Po	unlimited	unlimited
^{213}Po	2.147E+03	1.038E+03

Radio-nuclide Name	S200-A Limiting Activity (Ci)	S200-B Limiting Activity (Ci)
^{214}Po	unlimited	unlimited
^{215}Po	2.053E+03	9.111E+02
^{216}Po	4.824E+03	2.419E+03
^{218}Po	unlimited	unlimited
^{211}At	6.139E+01	2.565E+01
^{217}At	1.968E+03	8.069E+02
^{219}Rn	7.163E+00	7.163E+00
^{220}Rn	3.632E+02	1.115E+02
^{222}Rn	8.103E+02	2.176E+02
^{221}Fr	2.066E+01	2.066E+01
^{223}Fr	1.078E+01	5.211E+00
^{223}Ra	5.380E+00	5.380E+00
^{224}Ra	5.031E+01	5.031E+01
^{225}Ra	3.668E+02	3.668E+02
^{226}Ra	1.065E+02	1.065E+02
^{228}Ra	5.749E+03	5.749E+03
^{225}Ac	8.245E+01	7.320E+01
^{227}Ac	3.927E+04	3.927E+04
^{228}Ac	7.672E-02	4.385E-02
^{227}Th	4.786E+00	4.786E+00
^{228}Th	7.082E+02	7.082E+02
^{229}Th	2.522E+01	2.522E+01
^{230}Th	1.352E+03	1.336E+03
^{231}Th	2.833E+02	2.833E+02
^{232}Th	2.841E+03	2.809E+03
^{234}Th	9.901E+02	9.901E+02
^{231}Pa	1.330E+01	1.330E+01
^{233}Pa	2.262E+00	2.262E+00
^{234}Pa	5.300E-02	2.859E-02
^{234m}Pa	3.751E+00	2.161E+00
^{232}U	8.615E+02	8.463E+02
^{233}U	1.179E+03	1.130E+03
^{234}U	1.202E+03	1.185E+03
^{235}U	5.003E+00	5.003E+00

Table 4.3-2 — Limiting Activity per S200 Pipe Overpack (Continued)

Radio-nuclide Name	S200-A Limiting Activity (Ci)	S200-B Limiting Activity (Ci)
^{236}U	1.301E+03	1.286E+03
^{237}U	1.002E+01	1.002E+01
^{238}U	1.459E+01	1.443E+01
^{239}U	8.798E+00	4.327E+00
^{240}U	7.356E+02	7.356E+02
^{237}Np	1.416E+02	1.416E+02
^{238}Np	8.656E-02	4.996E-02
^{239}Np	5.101E+00	5.101E+00
^{240}Np	8.373E-02	4.282E-02
^{240m}Np	3.198E-01	1.524E-01
^{236}Pu	5.764E+02	5.597E+02
^{238}Pu	6.171E+02	6.087E+02
^{239}Pu	9.319E+02	8.655E+02
^{240}Pu	1.158E+02	1.145E+02
^{241}Pu	3.874E+06	3.874E+06
^{242}Pu	1.334E+00	1.318E+00
^{243}Pu	9.208E+01	9.208E+01
^{244}Pu	5.548E-03	5.485E-03
^{241}Am	2.788E+02	2.788E+02
^{242}Am	7.973E+05	7.973E+05
^{242m}Am	1.095E+02	1.095E+02
^{243}Am	1.409E+02	1.409E+02
^{245}Am	2.809E+01	2.809E+01
^{240}Cm	1.241E+02	1.227E+02
^{242}Cm	7.823E+01	7.722E+01
^{243}Cm	6.475E+00	6.475E+00
^{244}Cm	4.356E+00	4.306E+00
^{245}Cm	2.649E+01	2.619E+01
^{246}Cm	1.885E-02	1.864E-02
^{247}Cm	1.175E+00	7.922E-01
^{248}Cm	6.126E-05	6.057E-05
^{250}Cm	7.043E-06	6.963E-06
^{247}Bk	5.606E+00	5.606E+00
^{249}Bk	5.710E+03	5.644E+03
^{250}Bk	6.133E-02	3.558E-02
^{249}Cf	1.175E+00	1.175E+00
^{250}Cf	5.989E-03	5.921E-03
^{251}Cf	1.237E+01	1.237E+01
^{252}Cf	1.548E-04	1.530E-04
^{254}Cf	4.781E-06	4.727E-06
^{252}Es	4.418E-01	2.180E-01
^{253}Es	4.677E+01	4.453E+01
^{254}Es	3.681E+01	3.681E+01
^{254m}Es	9.086E-03	8.561E-03

Note: The designation of "unlimited" is made for any radionuclide whose limiting activity is greater than 1×10^8 curies (Ci).

4.3.7 Authorized Payload Contents

As demonstrated in Section 4.3.5, TRUPACT-II shipments of 14 S200 pipe overpacks and HalfPACT shipments of 7 S200 pipe overpacks containing 200 FGE per pipe overpack with contents meeting the requirements of Case E are subcritical in all cases. Therefore, the FGE limit for each S200 pipe overpack with Case E contents is 200 FGE. A maximum TRUPACT-II payload of 14 S200 pipe overpacks and HalfPACT payload of 7 S200 pipe overpacks have allowable FGE limits of 2,800 FGE and 1,400 FGE, respectively for Case E payloads. The FGE limit for Case F payloads is 140, 980, and 1,960 FGE for the S200 pipe overpack, HalfPACT, and TRUPACT-II, respectively.

Section 3.2 of the CH-TRAMPAC requires that each individual S200 pipe overpack and loaded TRUPACT-II or HalfPACT be measured prior to shipment to verify compliance with a dose rate limit of 200 millirem per hour (mrem/hr) at the surface. Additionally, Section 3.2 of the CH-TRAMPAC requires that each loaded TRUPACT-II or HalfPACT be measured prior to shipment to verify compliance with a dose rate limit of 10 mrem/hr at 2 meters. The results of the shielding analyses show that, when the S200 pipe overpack is loaded to the activity limits listed in Table 4.3-2 using a sum of partial fractions for multiple radionuclides, the dose rate limit requirements of 10 CFR 71.47(a) and 10 CFR 71.51(a)(2) are met for a TRUPACT-II loaded with 14 S200 pipe overpacks and a HalfPACT loaded with 7 S200 pipe overpacks.

4.3.8 Conclusion

The S200 pipe overpack design is very closely based on the standard pipe overpack. It consists of a standard 12-in. pipe component within a 55-gallon drum, including a rigid liner and lid. A gamma shield insert is placed inside the pipe component and located by polyurethane foam dunnage. The analyses summarized in this appendix demonstrate the ability of the S200 pipe overpack to provide three significant control functions under NCT and HAC: (1) criticality, (2) shielding, and (3) confinement of the waste contents. The payload of the S200 pipe overpack is transuranic waste with high gamma energies.

The structural analysis shows that the waste contents remain confined within the pipe component in conservatively bounded NCT and HAC free drops. For criticality, it is shown that 200 FGE per S200 pipe overpack is safely subcritical for Case E payloads and 140 FGE per S200 pipe overpack is safely subcritical for Case F payloads. The shielding analysis shows that, with maximum allowable activity specified in Table 4.3-2, the dose limits for NCT and HAC are met.

APPENDIX 4.4

DESCRIPTION OF S300 PIPE OVERPACK

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4.4 Description of S300 Pipe Overpack

4.4.1 Introduction

The S300 pipe overpack is based closely on the standard pipe overpack described in Appendix 4.1 of the CH-TRU Payload Appendices. It differs from the standard pipe overpack through the addition of neutron shielding within the pipe component. It is intended for the shipment of sealed neutron sources in the TRUPACT-II and HalfPACT. Appendix 1.3.1 of the TRUPACT-II Safety Analysis Report (SAR), Appendix 1.3.1 of the HalfPACT SAR, and Section 2.9.5 of the Contact-Handled Transuranic Waste Authorized Methods for Payload Control (CH-TRAMPAC) describe the materials of construction, sizes, and other dimensional specifications for the S300 pipe overpack. Up to 14 S300 pipe overpacks may be shipped in the TRUPACT-II, and up to 7 S300 pipe overpacks may be shipped in the HalfPACT. This appendix describes the structural, criticality, and shielding basis of the S300 pipe overpack.

4.4.2 Description

The S300 pipe overpack consists of a neutron shield insert placed inside a standard 12-inch (in.) pipe component which is, in turn, located by cane fiberboard and plywood dunnage within a standard 55-gallon drum with a rigid polyethylene liner and lid. A schematic of the S300 pipe overpack is shown in Figure 4.4-1. All of the components of the S300 pipe overpack, except the neutron shield insert, are identical to the 12-in. version of the standard pipe overpack described in Appendix 4.1 of the CH-TRU Payload Appendices.

The neutron shield insert is a two-part assembly consisting of a cylindrical body and stepped lid. With the exception of necessary clearances, the insert fits within and fills the 12-in. pipe component. The insert lid is held in place by the lid of the pipe component. The insert is made from solid, high-density polyethylene (HDPE), and has a nominal wall thickness of 4.13 inches.

The pipe component provides three significant control functions: (1) criticality control, (2) shielding, and (3) confinement of the sealed neutron sources. The following sections demonstrate the effectiveness of the S300 pipe overpack design for normal conditions of transport (NCT) and hypothetical accident conditions (HAC). All demonstrations are by analysis or by reference to the standard pipe overpack analysis and testing, unless stated otherwise.

4.4.3 Structural Analysis for NCT

The structural effectiveness of the S300 pipe overpack for NCT is demonstrated by showing that the source material contents are confined within the pipe component. The structural effectiveness of the pipe component for NCT is bounded by the structural effectiveness evaluation for HAC given in Section 4.4.4. It is shown in Section 4.4.6 that an adequate level of biological shielding for NCT is afforded by the shield insert itself, with all other materials providing mainly a distance attenuation function. The maximum deflection and resulting radial shift of the pipe overpack array for the NCT side drop, which is limiting for shielding calculations, is bounded by the HAC side drop analysis provided in Section 4.4.4. Additionally,

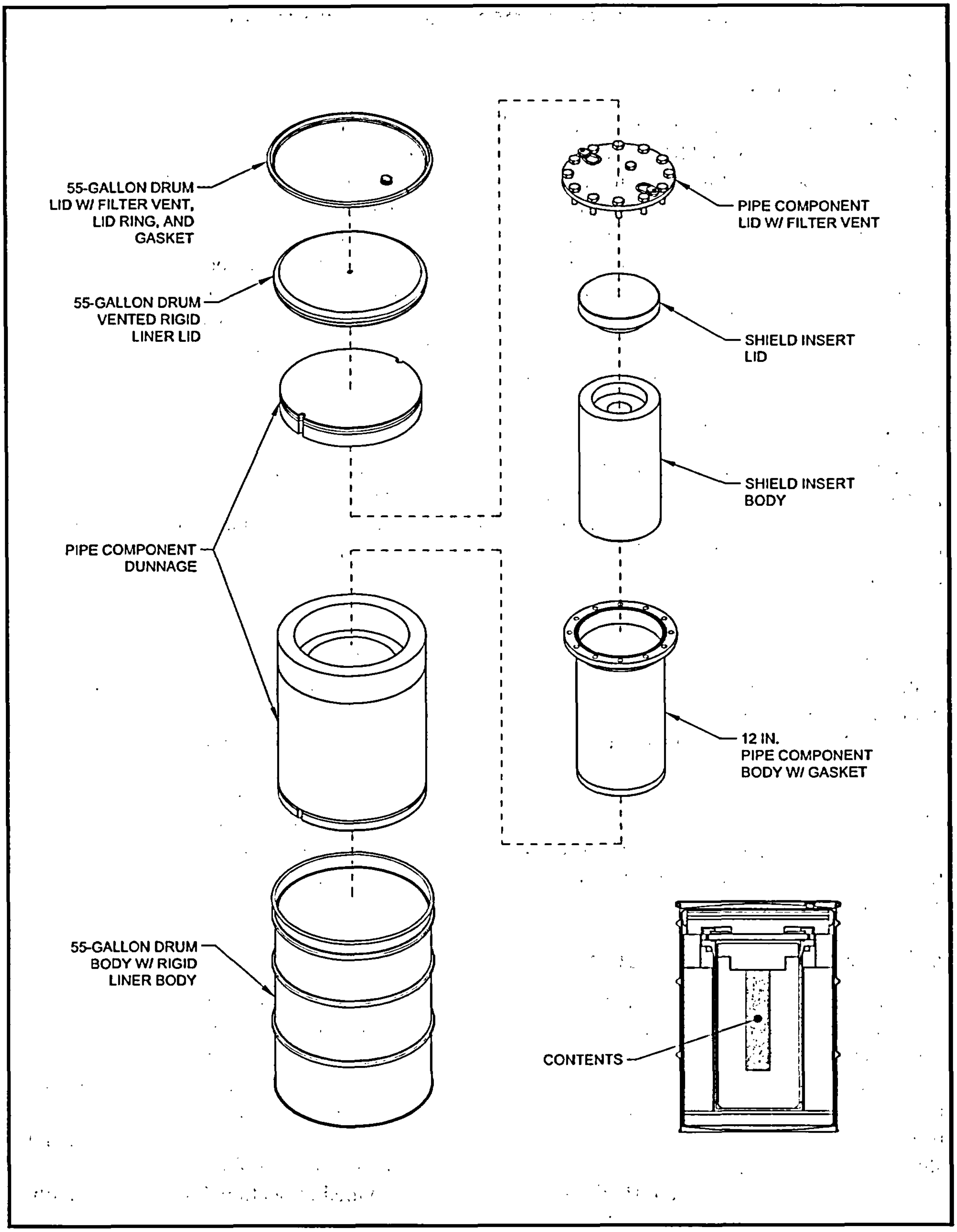

Figure 4.4-1 — S300 Pipe Overpack

the spacing between pipe components (i.e., effective drum diameter) utilized in the criticality analysis is also bounded by the HAC side drop analysis provided in Section 4.4.4.

4.4.4 Structural Analysis for HAC

The structural effectiveness of the S300 pipe overpack for HAC is demonstrated by showing that the source material contents remain confined within the pipe component. It is shown in Section 4.4.6 that an adequate level of biological shielding for HAC is afforded by distance attenuation considering the most conservative post-accident configuration of the TRUPACT-II or HalfPACT and pipe components. Since the shield insert in the S300 pipe overpack is not required for the HAC shielding analysis, the damage to the shielding material in the HAC free drop does not need to be quantified. However, the maximum deflection and resulting radial shift of the pipe overpack array will be quantified for the side drop orientation, which is limiting for shielding calculations. The following comparative analysis shows that the contents remain confined within the pipe component under the HAC free drop. Additionally, the analysis shows the maximum deflection of pipe overpacks and the resulting stacked array configuration resulting from the HAC free drop.

As shown in Table 2.9-7 of Section 2.9.2 of the CH-TRAMPAC, the weight of the 12-in. standard pipe component contents is bounded by a value of 225 lbs. Additionally, as shown in Table 2.9-20 of Section 2.9.5 of the CH-TRAMPAC, the total weight of the S300 pipe overpack shield insert and contents is also bounded by a weight of 225 lbs. Because the design of the standard and S300 pipe overpacks are structurally identical, and because the weight limit for items inside the pipe component are identical, all structural evaluations of the standard pipe overpack apply to the S300 pipe overpack. Ammerman and Bobbe, 1995,[1] demonstrates the leak tightness of the standard pipe overpack when subjected to HAC testing. Therefore, the source materials will remain confined within the pipe component under the HAC free drop.

Additionally, Ammerman and Bobbe[1] report a 20.250 in. minimum deformed pipe overpack diameter resulting from a free side drop orientation. Therefore, conservatively using a 20.000 in. 55-gallon drum diameter bounds the radial shift of the pipe component with respect to the S300 pipe overpack at (22.500 – 20.000)/2 = 1.250 in. The resulting stacked array of 14 S300 pipe overpacks resting against the TRUPACT-II inner containment vessel is accounted for in the HAC shielding analysis discussed in Section 4.4.6. The maximum drum crush values reported in Ammerman and Bobbe of 20.25 in. outside diameter by 29.62 in. height are directly utilized in the criticality analysis summarized in Section 4.4.5.

4.4.5 Criticality Analysis

A criticality analysis was performed for two different payload cases, depending on the quantities of special reflector materials in the payload container (see Chapter 6.0 of TRUPACT-II SAR or Chapter 6.0 of HalfPACT SAR for description of special reflector materials), as described below:

[1] Ammerman, D.J., and J.G. Bobbe, October 1995. "Rocky Flats Pipe Component Testing," TTC-1434, Sandia National Laboratories, Albuquerque, New Mexico.

- Case E: For Case E, the contents of the pipe overpack payload container contain less than or equal to 1% by weight quantities of special reflector materials. The pipe overpack payload container may contain greater than 1% by weight quantities of special reflector materials provided that one of the following conditions is met:
  - o The special reflector materials are chemically or mechanically bound to the fissile material such that no reconfiguration or release of the bond is possible under normal or accident conditions, or
  - o The special reflector materials are present in thicknesses and/or packing fractions that render them less effective than a 25% polyethylene/75% water equivalent reflector per the limits in Table 6.2-1 of the TRUPACT-II or HalfPACT SAR.
- Case F: For Case F, the contents of the pipe overpack payload container contain greater than 1% by weight quantities of special reflector materials that do not meet the exceptions listed for Case E.

The criticality analysis demonstrates that a TRUPACT-II shipment of 14 pipe overpacks with contents meeting the requirements of Case E at 200 FGE of ^{239}Pu each (for a total of 2,800 FGE per TRUPACT-II) or a HalfPACT shipment of 7 pipe overpacks with 200 FGE each (for a total of 1,400 FGE per HalfPACT) ensures compliance with the requirements of Title 10, Code of Federal Regulations (CFR), Sections 71.55 and 71.59 (10 CFR 71.55 and 71.59).[2] Additionally, shipments of pipe overpacks with contents meeting the requirements of Case F at 140 FGE for each payload container and 980 and 1960 FGE per HalfPACT and TRUPACT-II, respectively, ensure compliance with 10 CFR 71.55 and 71.59. Based on an infinite array of undamaged or damaged packages, the criticality transport index is 0.0.

The key parameters in the pipe overpack analysis for Case E are (1) the maximum fissile loading per pipe component is 200 FGE, (2) no more than 1% by weight quantities of special reflector materials are present or greater than 1% by weight quantities of special reflectors are either bound to the fissile material or meet the limits of Table 6.2-1 of the TRUPACT-II or HalfPACT SAR, (3) the spacing between the components (i.e., effective drum diameter) is reduced by the maximum amount reported in Section 4.4.4, and (4) the package arrays are infinite arrays stacked two high.

The key parameters in the pipe overpack analysis for Case F are (1) the maximum fissile loading per pipe component is 140 FGE, (2) the spacing between the components (i.e., effective drum diameter) is reduced by the maximum amount reported in Section 4.4.4, and (3) the package arrays are infinite arrays stacked two high.

The detailed analysis presented in Packaging Technology, 2004[2], presents the results of a series of SCALE 4.4 CSAS25 module[3] (KENO-Va version 4) calculations that establish a maximum

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[2] Packaging Technology, Inc., May 2004, "Pipe Overpack Criticality Analysis for the TRUPACT-II Package," ED-076, Packaging Technology, Inc., Tacoma, Washington.

[3] SCALE4.4., "Modular Code System for Performing Standardized Computer Analyses for Licensing Evaluation for Workstations and Personal Computers," RSICC code package C00545/MNYCP00, Oak Ridge National Laboratory, September 1998.

system reactivity ($k_s + 2\sigma$) of less than 0.933 and the corresponding Upper Subcriticality Limit (USL) of 0.9377. Therefore, the shipment of 200 FGE or 140 FGE per pipe overpack for Cases E and F, respectively, in the TRUPACT-II and HalfPACT is safely subcritical.

4.4.6 Shielding Analysis

The payload of the S300 pipe overpack consists of neutron-emitting, actinide-bearing sealed sources, shown in Table 4.4-1. Source terms used in this analysis are for neutron emission and spectra for alpha-n reactions calculated by the SOURCES Version 4A computer code.[4] Of the sources shown in the table, the ^{238}Pu Be was determined to be the governing source for shielding calculations,[5] since it had the highest calculated unshielded dose rate of all the sources that will be transported in the S300.

Table 4.4-1 S300 Pipe Overpack Payloads

^{241}Am Be	^{238}Pu O	^{239}Pu Li	^{241}Am
^{238}Pu Be	^{239}Pu O	^{238}Pu B	^{238}Pu
^{239}Pu Be	^{244}Cm O	^{239}Pu F	^{239}Pu
^{241}Am O	^{241}Am Li	^{238}Pu ^{13}C	^{244}Cm

The radiation generated by the payload is in the form of neutrons and a relatively small amount of gamma radiation. Some additional gamma radiation is generated by capture of thermal neutrons in the neutron shielding. However, the gamma radiation remains a small fraction of the neutron radiation level.

Neutron shielding is provided by the shielding insert placed within the 12-in. pipe component. It has a minimum wall thickness of 4.06 in., and minimum end thicknesses of 3.58 in. at the bottom and 3.94 in. in the lid. None of the materials of construction of the S300 pipe overpack, including the neutron shielding material, generate hydrogen gas in excess of 10^{-10} moles hydrogen per second per liter of headspace as a consequence of neutron or gamma irradiation by the payload sources.[6] A combination of the neutron shielding material and the materials of construction of the S300 pipe overpack provide sufficient shielding for both neutron and gamma radiation.

[4] Wilson, W.B., R.T. Perry, W. Charlton, et al., 1999, "SOURCES 4A: A Code for Calculating (alpha, n) Spontaneous Fission, and Delayed Neutron Sources and Spectra," LA-13639-MS, Los Alamos National Laboratory, Los Alamos, New Mexico.

[5] Gogol, S.L., and J.R. Bland, August 2002, "A Comparison of Dose Rates from (alpha, n) and Spontaneous Fission Neutron Sources," LA-UR-02-5120, Los Alamos National Laboratory, Los Alamos, New Mexico.

[6] Bustos, L.D., W.F. Sandoval, R. Villarreal, and L.R. Field, October 2000, "Hydrogen Generation Rate Potential from Neutron and Gamma Ray Interactions with Shielding/Packaging Materials Contained in the S100 Pipe Component Overpack," Los Alamos National Laboratory, Los Alamos, New Mexico.

Dose rate calculations were performed for a single S300 pipe overpack and for a TRUPACT-II in both the as-loaded and post-NCT free drop configurations.[7] The results were used to determine the maximum loading of the S300 pipe overpack such that the regulatory dose rate limits will be met in each case for NCT and HAC. In the analysis, the bounding payload of ^{238}Pu Be was used, as discussed above. Source gamma radiation was negligible and was not included, but capture gamma dose rate contribution was included in the calculated integrated dose rate. Dose rate calculations were made for a single S300 pipe overpack as presented for loading into a TRUPACT-II, for a TRUPACT-II as presented for transport with a payload of 14 identical S300 pipe overpacks each having the maximum payload, and for a TRUPACT-II including a conservative representation of NCT free drop damage with a payload of 14 identical S300 pipe overpacks each having the maximum payload. (The HAC case is discussed below.) Dose rates were calculated at the surface and at defined distances from the containers as shown in Table 4.4-2. As shown in the table, the limiting dose is for the TRUPACT-II package at a distance of 5 meters from the package surface (the truck cab, a normally occupied space), and is equal to 2 millirem per hour (mrem/hr). The corresponding S300 pipe overpack surface dose limit is 155 mrem/hr. This means that, as long as the surface dose rate of any S300 pipe overpack transported in a TRUPACT-II is at or below 155 mrem/hr, then the dose rate external to the TRUPACT-II will not exceed 2 mrem/hr at a distance of 5 meters, nor will any of the other, less governing regulatory limits be exceeded. The TRUPACT-II calculations govern the case of the HalfPACT. Each S300 pipe overpack will be surveyed before loading into a TRUPACT-II or HalfPACT to ensure compliance with the limiting surface dose rate of 155 mrem/hr, as given in Section 3.2 of the CH-TRAMPAC.

[7] Packaging Technology, Inc., August 2002, "Dose Rate Calculations for the S300 Pipe Overpack," ED-072, Packaging Technology, Inc., Tacoma, Washington.

Table 4.4-2 Maximum Dose Rates for S300 Pipe Overpack and TRUPACT-II

	Maximum Dose Rate (mrem/hr)	Limits (mrem/hr)④
S300 Surface	155 ±0.36	200
TRUPACT-II side Surface (undamaged) ①②	64.5 ±0.62	200
TRUPACT-II 2 meters (undamaged)	8.06 ±0.10	10
TRUPACT-II 5 meters (undamaged)③	1.97 ±0.03	2
TRUPACT-II side Surface (damaged)	120 ±0.20	200
TRUPACT-II 2 meters (damaged)	9.83 ±0.12	10

Notes:
1. TRUPACT-II contains 14 identical S300 pipe overpacks, each with a maximum surface dose rate of 155 mrem/hr or less.
2. Side dose rate governs over top or bottom dose rates.
3. The 5 meter distance corresponds to the normally occupied space of the truck cab.
4. Limits established by CH-TRAMPAC (S300 surface) or 10 CFR 71.47(b) (TRUPACT-II).

The damage to the TRUPACT-II and payload under NCT is assumed to occur in the 3 ft. side drop, and is discussed in Section 4.4.4. The drums are modeled as resting on the inside of the TRUPACT-II ICV, which is resting on its side. Each drum is conservatively reduced in size to a diameter of 20.0 in., and the array is accordingly compressed and shifted to be in contact with the inside surface of the TRUPACT-II ICV.

For HAC, the drums, neutron shielding material, pipe components, and internal dunnage are conservatively removed from consideration in the shielding calculation, and the sum total of all activity in the S300 payload is concentrated as a single point source resting on the inside surface of the TRUPACT-II ICV. In accordance with 10 CFR 71.51(a)(2), the dose point is located 1 meter from the external surface of the package. This is equivalent to a total distance from the source of 1 meter plus the minimum crushed wall thickness of the TRUPACT-II or HalfPACT. For simplicity and conservatism, the calculations assume that there is no material of any kind between the source and the dose point. The crushed wall thickness is found by subtracting the HAC 30-foot free drop side orientation crush damage from the original wall thickness of the package as follows. The outer diameter of the package is 94.38 inches, and the inner diameter of the ICV is 73.63 inches, which gives an undamaged wall thickness of 10.38 inches. The maximum crush damage is found in Table 2.10.3-1 of the TRUPACT-II SAR for Test No. 2, as equal to 3.63 inches. The remaining wall thickness is then equal to 10.38 – 3.63 = 6.75 inches. In the shielding calculations, a value of 6.5 inches is conservatively used. As already discussed, no material is assumed to fill this space. The resulting maximum allowable activity within the

TRUPACT-II is a total of 406 Ci, and the resulting conservative dose rate is 999 mrem/hr at 1 meter from the crushed TRUPACT-II surface, which meets the requirements of 10 CFR 71.51(a)(2). As for NCT, the TRUPACT-II HAC calculations govern the case of the HalfPACT.

4.4.7 Authorized Payload Contents

As demonstrated in Section 4.4.6, when loaded with sealed neutron sources of the types specified in Table 4.4-1 (the authorized contents), the S300 pipe overpack meets all regulatory dose rate limits. The bounding payload is defined in three ways: (1) a maximum dose rate on the surface of the S300 pipe overpack of 155 mrem/hr for any S300 pipe overpack placed into the TRUPACT-II or HalfPACT, (2) a maximum activity of 406 Ci within a single TRUPACT-II or HalfPACT, and (3) a maximum payload of 200 FGE per S300 pipe overpack, or a total of 2,800 FGE per TRUPACT-II or 1,400 FGE per HalfPACT when the contents meet the requirements for Case E, or (4) a maximum payload of 140 FGE per S300 pipe overpack, or a total of 1,960 FGE per TRUPACT-II or 980 FGE per HalfPACT when the contents meet the reuqirements for Case F. Section 4.2.5 demonstrates that 200 FGE per S300 pipe overpack is safely subcritical for Case E contents and that 140 FGE per S300 pipe overpack is safely subcritical for Case E contents.

4.4.8 Conclusion

The S300 pipe overpack design is very closely based on the standard pipe overpack. It consists of a standard 12-in. pipe component within a 55-gallon drum, including a rigid liner and lid. A neutron shield insert is placed inside the pipe component. The analyses summarized in this appendix demonstrate the ability of the S300 pipe overpack to provide three significant control functions under NCT and HAC: (1) criticality, (2) shielding, and (3) confinement of the payload. The payload of the S300 is sealed neutron sources of the types listed in Table 4.4-1. The structural analysis shows that the source material remains confined within the pipe component in conservatively bounded NCT and HAC free drops. For criticality, it is shown that 200 FGE per S300 pipe overpack for Case E payloads is safely subcritical and 140 FGE per S300 pipe overpack is safely subcritical for Case F payloads. The shielding analysis shows that, with the maximum authorized contents, the dose rate limits for NCT and HAC (including appropriate shielding damage assumptions in each case) are met.

Attachment G

References

The following reference documents are provided in support of the application for Revision 20 of the TRUPACT-II Safety Analysis Report (SAR), Revision 3 of the HalfPACT SAR, Revision 1 of the Contact-Handled Transuranic Waste Authorized Methods for Payload Control (CH-TRAMPAC), and Revision 0 of the CH-TRU Payload Appendices:

Case D Criticality:
- Packaging Technology, Inc., March 2004, "Test Report for Compacted Drums," TR-017, Revision 0, Packaging Technology, Inc., Tacoma, Washington.

General Criticality:
- Neeley, G.W., D.L. Newell, S.L. Larson, and R.J. Green, May 2004, "Reactivity Effects of Moderator and Reflector Materials on a Finite Plutonium System," SAIC-1322-001, Revision 1, Science Applications International Corporation, Oak Ridge, Tennessee.

Standard, S100, S200, and S300 Pipe Overpacks Criticality:
- Packaging Technology, Inc., May 2004, "Pipe Overpack Criticality Analysis for the TRUPACT-II Package," ED-076, Revision 3, Packaging Technology, Inc., Tacoma, Washington.

Flammable Gas Generation:
- Shaw Environmental & Infrastructure, Inc., April 2004, "UFGTP Long-Term Objective Implementation Methodology," Shaw Environmental & Infrastructure, Inc., Albuquerque, New Mexico.