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Rev 2, 4/88

SAFETY ANALYSIS REPORT - PACKAGES

LP-50 TRITIUM PACKAGE

(Packaging of Fissile and Other Radioactive Materials)

FINAL REPORT

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DSR 3-17

DON'T SAY IT - WRITE IT

71-6678

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TO GEORGE GARDES LOCATION USNRC MS-4-E-4 DATE 11/20/90

FROM G. CADELLI PHONE NO. 803-725-3763 LOCATION WSRC 730-A.

COPY OF LP-50 SARP, REV. 2, 4/88. PER REQUEST OF STEVE PRIMEAU DOE/HQ EH321.

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Preventive Safety - Prevents Injuries

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NOTE: This Rev. 2, 4/88 SARP applies to LP-50 containers with serial numbers 1065 and below built in the years 1957 to 1968.

The changes in Revision 2 versus Revision 1 are in two areas:

1. Drawings are revised to show the original valve configuration used on the LP-50 and the various valve improvements since original fabrication including the latest Hoke valve used for all present replacements.
2. Maintenance, valve replacement and connection fitting installation procedures have been updated to reflect improvements gained from operating experience and equipment technology.

The original LP-50 was designed to meet the requirements of AECM 0529. (The LP-50 package also meets the 1967 IAEA Safety Standards of Series #6). Quality Assurance for operating and maintenance procedures was added in Revision 1 and updated in this revision (Rev. 2) to meet the requirements in 10CFR71 of January 1, 1979.

New LP-50 containers of the design shown in this SARP cannot be fabricated without the approval of the Nuclear Regulatory Commission (10CFR 71.13a(1) and c).

Pages marked with a Revision 2 in the lower right corner are the only pages changed from the approved Revision 1, 4/78 SARP. The location of the change is shown by a vertical line in the margin.

SAFETY ANALYSIS REPORT - PACKAGES
LP-50 TRITIUM PACKAGE

0.0 GENERAL INFORMATION

0.1 Introduction

Elemental tritium is shipped at low pressure in a stainless steel container (LP-50) surrounded by an aluminum vessel and Celotex^{R1} insulation at least 4 in. thick in a steel drum.

Each package contains a large quantity (greater than a Type A quantity) of nonfissile material, as defined in AECM 0529.* (The package was designed to meet the regulations of AECM 0529 of 6/14/73, see Appendix D). No exemptions are claimed.

0.2 Package Description

0.2.1 Packaging

The total weight of the package is 260 pounds maximum. The various components that constitute the package are shown in figures 1 through 7 and major components, i.e., drum, insulation, secondary container, and product (primary) container, are described in the following paragraphs.

The drum is fabricated from 16 gage carbon steel to the dimensions of 22.5 in. ID by 38.5 in. inside height per Military Standard MS-27683 (or equal). Three 5/16 in. dia holes are drilled, approximately 120° apart, one inch below the top curl of the body and are covered on both sides with lead tape. The holes prevent rupture of the drum during a fire by venting the gases from the insulation. A locking ring with dropped forged lugs, installed with a 3/8 in. high-strength steel bolt, provides closure by securing the cover to the drum.

The insulation that cradles the secondary container, also called aluminum shell, within the drum is Celotex^{R}, laminated military packing board per Military Specification Mil-F-26862-A, except paragraph 3.7 concerning fungus resistance. When the Celotex^{R}, supplied in minimum thickness of 1-1/2 in. is fabricated and coated with Cera-kote^{R2} (120 ft^2, 0.010 in. thick, per gal unthinned high temperature cement), the annular pieces form a 14-1/4 in. ID void within the drum which symmetrically positions the shell. A top outer ring of molded Cera Form^{R3} is cemented with Cera-kote^{R} to the adjacent rings of Celotex^{R} to form a refractory barrier behind the drilled vent holes in the drum. A disk of Cerafelt^{R4} is used as a spacer to restrict the movement of the Celotex^{R} within the drum.

The shell, contained by the insulation, is a two-piece container; the cylindrical body (bottom part) is aluminum alloy, type 356, which houses the primary tritium (product) container (PC). The bottom part of the container is 26-5/16 in. inside depth by 13-1/2 in. ID. The side wall and bottom are nominally 15/64 in. thick. A flange of 16-1/4 in. OD on the bottom section provides attachment to the mating flange on the top section (cover). Two cover designs (figure 1) exist: one flat (cast aluminum alloy #356) and the other domed (formed alum alloy 6061.T6).

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[1] Celotex Corp. trademark.
[2,3,4] Johns Manville Corp. trademarks.

*Changed to DOE 5480.3

Either cover, flat or domed is secured to the bottom part by bolts equally spaced on a 15-1/2 in. dia bolt circle with a buna N gasket compressed between the flanges. Two handles are provided for ease of handling. No credit is taken for the seal on the shell in the safety analysis and no test of its seal tightness is made. The secondary vessel is a mechanical protection barrier.

The type 304L stainless steel PC, of welded construction, is essentially a closed cylinder with a 13 in. ID and 0.078 in. wall thickness, with radiused top and bottom edges. Complete closure of the cylinder is accomplished by welding on a container cover (head top) to which the fill tube and primary seal (vacuum tank valve) are attached.

The PC is held in position by close fit with the shell and by a laminated plywood spacer with neoprene pads that is held between the top of the PC and the shell cover. This method of positioning provides both axial and transverse support and restricts movement of the PC within the shell during transport.

Filling the PC through the valve is accomplished by attaching the supply source to a continuation of the stainless steel tubing which has a Cajon^{R}[1] 4VCR stainless steel connection. The overall length of the container, including the blind Cajon^{R} cap that covers the open end during shipment, is approximately 28-1/4 in.

0.2.2 Operating Features

The operational features of the LP-50 package are described in chapter 6.0, Operating Procedures.

0.2.3 Contents of Packaging

Tritium gas may be pure or may contain varying amounts of protium (hydrogen-1), deuterium, or helium. The following restrictions apply to the use of this container:

Maximum tritium content	75,300 STP cc (193,500 curies)
Radioactive decay heat	22.4 Btu/hr
Maximum initial loading pressure	23.2 psia (1200 torrs) at 25°C
Maximum allowable time for shipment	12 months after loading

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[1] Cajon Co. trademark.

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1.0 STRUCTURAL EVALUATION

1.1 Structural Design

1.1.1 Discussion

The principal structural members of the LP-50 are the stainless steel product container (PC), the aluminum inner container (shell), the plywood spacer between the PC and the shell, the Celotex® insulation, and the carbon steel drum. The PC has a specially fabricated stainless steel valve that is used for loading and the shell has a valve used for leak testing. There are two types of covers for the shell — flat and hemispherical (domed). There are also matching spacers to provide a tight fit between the PC and the shell. The shell fits snugly into the cemented rings of Celotex® insulation. There is a clearance of only 1/8 in. between the Celotex® and the drum. No gasket is used with the locking ring and it is equipped with drop-forged lugs and a special bolt to fasten the cover securely. A drum, made to military specifications (with some modifications), completes the packaging.

1.1.2 Design Criteria

The following tables provide a comparison of the ASME Boiler and Pressure Vessel Code values for maximum allowable stress and the calculated values.

Table 1. Stress Comparison

(0.5 atmos external pressure)

	Maximum Allowable Stress, psi		
Part	ASME	Calc (J.6.3)	Calc/ASME, %
Shell: side	6200	300	5
bottom	6200	5520	89
top	9500	5840	61
Bolt	20,000	14,050	72
Flange hub (Gasket seating)	9300	3450	37
radial	6200	1010	16
tangential	6200	590	10
Flange hub (Operating condition)	9300	2730	29
radial	6200	801	13
tangential	6200	322	5

Table 2. Pressure Comparison

(25 psig external pressure)

	Maximum Allowable Press., psig		
Part	Test	Calc (1.5.2)	Test/Calc, %
Shell (flat cover)	25	123	20
Bottom head	25	33	76
Top head	25	35	71
Shell (dome cover)	25	167	15
	ASME	Calc	Calc/ASME, %
Flange (flat cover) hub	9300	2443	26
(Gasket seating)			
radial	6200	717	12
tangential	6200	289	5

1.2 Weights

Weights of the components of the LP-50 packaging are:

	Wt, lb
Product container	32
Wooden spacer	9
Secondary container	43
Insulation	104
Drum	72
Total	260

1.3 Mechanical Properties of Materials

Information referenced in the American Society of Mechanical Engineers Boiler and Pressure Vessel Code, section VIII, div 1, 1974 edition are abbreviated "ASME, p ."

1. B = 7400; ASME, p 280, figure UNF-28.5.
2. C (bottom head) = 0.3; ASME, p 25, figure UG-34 (b-2).
   C (top head) = 0.2; ASME, p 25, figure UG-34 (d).
3. S (bottom head) = 18,000 psi; ASME, p 149, min yield for SB-26 SG 70A-T71.
   S (top head) = 20,000 psi ASME, p 149, min yield for 356-T6.
4. m = 0.50 for elastomers below 75 Shore Durometer; ASME, p 238, table UA-49.1.
5. y = 0.0 psi for elastomers below 75 Shore Durometer; ASME, p 238, table UA-49.1.
6. $K = \frac{OD}{ID} \quad \frac{16.25}{13.5} = 1.20$; ASME, p 240, figure UA-51.1,
   T = 1.84, U = 11.81, Y = 10.75, and Z = 5.55.
7. f = 1.0; ASME, p 242, figure UA-51.6 (when $g_1/g_o = 1.0$ and $h/h_o = 0.164$).
8. F = 0.909; ASME, p 240, figure UA-51.2 (when $g_1/g_o = 1.0$ and $h/h_o = 0.164$).
9. V = 0.55; ASME, p 241, figure UA-51.3 (when $g_1/g_o = 1.0$ and $h/h_o = 0.164$).
10. Allowable stress for SB-26 SG70A(356)-T71 is 6200 psi; ASME, p 149.
11. B = 5500 psi; ASME, p 278, UNF 28.3.
12. Allowable tensile stress for type 6061-T6 aluminum at 200°F = 9500 psi and at 250°F = 9100 psi; ASME, p 149, table UNF-23.1.
13. Allowable tensile stress for SB-26 SG-70A(356)-T71 up to 200°F = 6200 psi; ASME, p 149, table UNF-23.1.
14. E = 1.0; ASME, p 14, UG-27.
15. Max allowable bolt stress (S) is 20,000 psi; ASME, p 127, table UCS-23.
16. Area of 1/4 in. is 0.0269; Mechanical Engineers Handbook, L. S. Marks, 5th Ed, p 862.

1.4 General Standards for all Packages

1.4.1 Chemical and Galvanic Reactions

There is no reaction between the packaging and contents. However, some tritium can permeate through the wall of the product container (see chapter 3.0, Containment). Also, there will be no significant reaction between any of the parts of the packaging. The following chart shows what dissimilar materials are in contact (X).

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	Aluminum	-		X	X	X			X	X		X		X		
2	Brass		-						X	X		X				
3	Buna N	X		-					X							
4	Celotex®	X			-		X		X		X		X	X		
5	Neoprene	X				-			X				X			
6	Nylon				X		-		X		X		X			
7	Paint							-	X			X		X		
8	Steel (including SS)	X	X	X	X	X	X	X	-	X	X	X	X	X	X	X
9	Viton®	X	X						X	-						
10	Weldwood glue				X		X		X		-		X			
11	Wire seal (lead)	X	X					X	X			-		X		
12	Wood				X	X	X		X		X		-			
13	Zinc or cadmium	X			X			X	X			X		-		
14	Mercury								X						–	
15	Silver								X							–

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1.4.2 Positive Closure

The closure system is made up of two parts; the package cannot be opened inadvertently. The parts of the system are:

- o The shell flange which is secured with bolts (two bolts are also secured with leaded wire seals), and the shell vent valve which is secured with a nipple cap and a leaded wire seal.
- o The drum lid which is fastened to the drum with a bolted locking ring. The lugs on the locking ring are secured with a leaded wire seal.

1.4.3 Lifting Devices

Not applicable. There is no lifting device on the drum.

1.4.4 Tiedown Devices

Not applicable. There is no tiedown device on the drum.

1.5 Standards for Type B and Large Quantity Packaging

1.5.1 Load Resistance

Tests showed that the LP-50 drum could support a uniformly distributed load along its major axis equal to five times its loaded weight.

Bags of lead shot were stacked uniformly from bottom to top against one side of an upright empty LP-50 drum. The lid was installed and the drum was carefully laid over on its side and brought to rest with only the rim at each extreme end in contact with supporting timbers. No deformation or damage resulted.

1.5.2 External Pressure of 25 psig

1.5.2.1 Secondary Container

Shell with Flat Cover

Material of shell and bottom head is type 356 aluminum alloy. However, mechanical specifications for SB-26-SG70A-T71 will be used. Allowable stresses are listed in ASME Code.

Reference for equations is ASME Code, section VIII, div 1, page No. as noted.

$P_a = \frac{B}{D_o/t}$ p 16, UG-28

$t = d\sqrt{CP/S}$ or $P = \frac{S}{C}\left(\frac{t}{d}\right)^2$ p 24, UG-34

where:

L = design length of vessel section, in.

B = factor depending on D_o/t and P_a (dimensionless)

D_o = OD of cylindrical shell, in.

P_a = max allowable working press., psi

t = min required thickness of cylindrical shell on flat head, in.

C = factor depending on method of head attachment (dimensionless) (see 1.3, item 2)

d = dia or short span as in UG-34, in.

P = design press., psi

S = max allowable stress (see 1.3, item 3)

o Shell

$\frac{L}{D_o} = \frac{26.75}{14} = 1.91, \quad \frac{D_o}{t} = \frac{14}{0.234} = 60$

$\therefore B = 7400$ (see 1.3, item 1)

$P_a = \frac{B}{D_o/t} = \frac{7400}{60} = 123$ psig greater than 25 <u>OK</u>

o Bottom Head

$P = \frac{S}{C}\left(\frac{t}{d}\right)^2 = \frac{18,000}{0.3}\ \frac{0.312}{13.25}^{2} = 33.3$ psig

greater than 25 <u>OK</u>

- **Top Head**

$$P = \frac{S}{C}\left(\frac{t}{d}\right)^2 = \frac{20,000}{0.2}\left(\frac{0.25}{13.375}\right)^2 = 35 \text{ psig}$$

greater than 25 <u>OK</u>

1.5.2.2 Secondary Container

Flange and Bolting

$W_{m_2} = \pi b G y$ P 243, UA-49

$A_{m_2} = W_{m_2}/S_a$ p 234, UA-47

$W = 1/2(A_{m_2} + A_b)S_a$ p 243, UA-49

$M_o = Wh_G$ p 243, UA-50

$M_o = H_D\left(h_D - h_G\right) + H_T\left(h_T - h_G\right)$ p 245, UA-55

where:

W_{m_2} = min required bolt load for gasket seating, lb

b = effective gasket seating width (0.25 in.)

G = mean dia of gasket conta[illegible]ce (14.25 in.)

y = gasket unit seating load (0.0 lb) (see 1.3, item 5)

S_a = allowable bolt stress at atmospheric temp, psi

A_{m_2} = total cross-sectional area of bolts at section of least diameter required for seating, in^2

W = flange design bolt load, lb

A_b = cross-sectional area of bolts using root diameter of thread, in^2

M_o = total moment acting upon flange, in.-lb

h = hub length, in.

H_D = hydrostatic end force on area inside of flange

= $0.785\ B^2P$ (B = ID of flange, 13.5 in., and P is 25 psig test pressure)

h_D = radial distance from bolt circle to circle on which H_D acts, in.

H_T = difference between total hydrostatic end force and hydrostatic end force on area inside of flange, lb = $H - H_D$

H = total hydrostatic end force, lb = $0.785\ G^2P$

h_T = radial distance from bolt circle to circle on which H_T acts, in.

h_G = radial distance from gasket load reaction to bolt circle, in.

$W_{m_2} = \pi\ b\ G\ y = \pi\ (0.25)\ (14.25)\ (0.0) = 0.0$ lb

$A_{m_2} = 0.0\ \text{in}^2$

$A_b = 8(0.0269) = 0.215\ \text{in}^2$

$W = 1/2\left(A_{m_2} + A_b\right) S_a = 1/2(0.0 + 0.215)\ (20{,}000) = 2150$ lb

(from page 243, table UA-50)

$h_G = \frac{C - G}{2}$, $h_T = \frac{R + g_1 + h_G}{2}$, and $h_D = R + 0.5\ g_1$.

where:

C = bolt circle dia (15.5 in.)

$R = \frac{C - B}{2} - g_1$,

g_1 = thickness of hub at back of flange (0.234 in.)

$$h_G = \frac{C - G}{2} = \frac{15.50 - 14.25}{2} = \frac{1.25}{2} = 0.625 \text{ in.}$$

$$h_T = \frac{R + g_1 + h_G}{2} = \frac{0.766 + 0.234 + 0.625}{2} = 0.812 \text{ in.}$$

$$R = \frac{C - B}{2} - g_1 = \frac{15.5 - 13.5}{2} - 0.234$$

$$= 1.0 - 0.234 = 0.766 \text{ in.}$$

$$h_D = R + 0.5\ g_1 = 0.766 + 0.5(0.234) = 0.883 \text{ in.}$$

$M_o = Wh_G = 2150\ (0.625) = 1340$ in.-lb (gasket seating)

$H_T = H - H_D = 0.785\ G^2P - 0.785\ B^2P = (0.785\ G^2 - B^2)P$

$MO_o = H_D(h_D - h_G) + H_T(h_T - h_G)$

$\therefore M_o = (0.785)\ B^2P\ (0.883 - 0.625) + (0.785)(G^2 - B^2)(P)(0.812 - 0.625)$

$= (0.785)(13.5)^2(25)(0.258) + (0.785)(14.25^2 - 13.5^2)(25)(0.187)$

$= 923 + 76 = 999$ in.-lb (operating conditions)

Gasket seating moment of 1340 in.-lb is larger and governs.

Bolt stress $= \frac{2150}{0.215} = 10{,}000$ psi <u>OK</u>

Flange stresses (flat top):

$S_H = \frac{fM_o}{L(g_1)^2B}$ p 244, UA-51

$S_R = \frac{(1.33\ t\ e + 1)M_o}{L\ t^2\ B}$ p 244, UA-51

$S_T = \frac{Y\ M_o}{t^2\ B} - Z\ S_R$ p 244, UA-51

where:

S_H = calculated longitudinal stress in hub, psi

S_R = calculated radial stress in flange, psi

S_T = calculated tangential stress in flange, psi

f = hub stress correction factor (a function of g_1/g_o and h/h_o)

g_1 = thickness of hub at back of flange, in.

g_o = thickness of hub at small end, in.

h = hub length, in.

h_o = factor = $\sqrt{B\ g_o}$, in.

B = ID of flange, in.

M_o = total moment acting on flange for gasket seating (or operating conditions), in.-lb

L = factor = $\frac{t\,e + 1}{T} + \frac{t^3}{d}$

t = flange thickness, in.

e = factor for integral flanges = F/h_o

F = factor for integral flanges (a function of g_1/g_o + h/h_o)

T = factor that is a function of K (see 1.3, item 6)

K = ratio of flange OD to flange ID (see 1.3, item 6)

d = factor of integral flanges = $\frac{U}{V} h_o\, g_o^{\,2}$

U = factor that is function of K (see 1.3, item 6)

V = factor for integral flanges (a function of g_1/g_o and h/h_o)

Y = factor that is function of K (see 1.3, item 6)

Z = factor that is function of K (see 1.3, item 6)

Flange factors:

$$f = g_1/g_o = \frac{0.234}{0.234} = 1.0$$

$$h/h_o = \frac{h}{\sqrt{B\,g_o}} = \frac{0.292}{\sqrt{13.5(0.234)}} = \frac{0.292}{1.78} = 0.164$$

$$f = 1.0$$ (see 1.3, item 7)

$$e = F/h_o = \frac{0.909}{1.78} = 0.511$$ (for F, see 1.3, item 8)

$$d = \frac{U}{V}\, h_o\, g_o^{\,2} = \frac{11.81}{0.55}(1.78)(0.234)^2 = 2.$$

(for T,U,Y & Z, see 1.3, item 6)

(for V, see 1.3, item 9)

$$L = \frac{t\ e + 1}{T} + \frac{t^3}{d} = \frac{0.5(0.511) + 1}{1.84} + \frac{(0.5)^3}{2.1}$$

$$= 0.682 + 0.060 = 0.742$$

$$S_H = \frac{f M_o}{L (g_1)^2\ B} = \frac{1.0(1340)}{0.742(0.234)^2(13.5)} = 2443 \text{ psi less than } 1.5\ (6200) \quad \underline{\text{OK}}$$

(see 1.3, item 10)

$$S_R = \frac{(1.33\ t\ e + 1) M_o}{L\ t^2\ B} = \frac{[(1.33)(0.5)(0.511) + 1]\ 1340}{(0.742)(0.5)^2(13.5)}$$

$$= 717 \text{ psi less than } 6200 \quad \underline{\text{OK}}$$

$$S_T = \frac{Y\ M_o}{t^2\ B} - Z\ S_R = \frac{10.75(1340)}{(0.5)^2(13.5)} - 5.55\ (717)$$

$$= 4268 - 3979 = 289 \text{ psi less than } 6200 \quad \underline{\text{OK}}$$

Conclusion: The flat type shell will withstand 25 psig external pressure; therefore, the inner product container should be unaffected.

1.5.2.3 Secondary Container

Shell with Domed Cover

Yield pressure (P) of cover (figure 6,E)

$$P_a = \frac{B}{L_1 / t_h} \qquad \text{P 16}$$

where:

P_a = max allowable working press., psi

L_1 = inside radius of hemispherical head, in.

t = min required thickness of head, in.

B = calculated compressive stress, psi

from $L_1/t_h = \frac{8.25}{0.25} = 33$, and $\frac{L_1}{100\ t_h} = 0.33$

$B = 5500$ psi (see 1.3, item 11)

Since $B = 5500$ and is less than 9100 (see 1.3, item 12)

Allowable external pressure $= P_a = \frac{B}{L_1/t} = \frac{5500}{33} = 167$ psid

Since this is greater than the specified differential pressure of 25 psid, the hemispherical head can withstand the given test pressure (25 psid) with no damage.

1.5.2.4 External Pressure Test of the Product Container

An LP-50 product container (PC) was dimensionally checked (ultrasonically) to confirm that its wall thickness was within design specifications. Fourteen strain gages were cemented to the external surfaces of the PC at points of suspected strain. The PC was then evacuated to 200 microns absolute pressure which is judged to be the most severe case with respect to external pressure. The PC was then placed inside a bell jar. The bell jar pressure was raised in 5 psig increments until 25 psig external pressure was obtained. Strain gage readings were taken during evacuation and external pressurization and are reported in reference 1. The PC did not yield from the test as confirmed by the strain gage readings and later by visual inspection.

1.6 Normal Conditions Of Transport

1.6.1 Heat

1.6.1.1 Summary of Pressures and Temperatures

See 2.1.1.

1.6.1.2 Differential Thermal Expansion

Hypothetical accident condition tests did not cause any damage attributable to differential thermal expansion (see 1.7.3.2). Conditions of normal transport are much less severe, thus no problems will be encountered during "normal transport" or actual transport conditions.

1.6.1.3 Stress Calculations

Repeated shipments (with attendant thermal cycles) have produced no degrading effects on the packaging. Deformation of the product container is checked during unloading operations per Ref. 6.5.1,[5].

1.6.1.4 Comparison with Allowable Stresses

See table in subsection 1.1.2.

1.6.2 Cold

This package contains no liquids or other material harmfully affected by an ambient temperature of -40°F (-40°C). The shell temperature when ambient temperature is 100°F (in shade is 121.1° F (2.5.3). When ambient temperature is -40°F or [100-(-40)] lower, the shell temperature would be 121 - 140 = -19°F. The yield strength of the aluminum shell would be higher at this temperature than at the higher temperatures of normal conditions. Also, the -19°F is within the design range for the gasket materials: buna N, and Viton[R1], the SST PC is unaffected in this temperature range.

---

[1] Du Pont trademark

1.6.3 Pressure (0.5 atmosphere)

1.6.3.1 Secondary Container

It is shown under 2.4.4 that the maximum internal pressure in the secondary container (shell) is 17.5 psia. With 0.5 standard atmospheric pressure on the outside of the shell, the differential across the wall is

$$P = 17.5 - 0.5\ (14.7) = 10.2 \text{ psig and the temperature is } 180°\text{F.}$$

Since allowable stresses for type 356-T51 aluminum are not listed in the ASME Code, the stresses for the similar type SB-26 SG-70A (356)-T71 will be used (see 1.3, item 13).

Allowable stress at 180°F is 6200 psi.

Shell stresses: $P = 10.2$ psig.

This equation is from ASME Code, section VIII, div 1, p 14, UG-27, (c), (1).

$$\text{Shell:}\quad S = \frac{P(R + 0.6\ t)}{E\ t} \text{ or } t = \frac{PR}{SE - 0.6\ P}$$

where:

S = max allowable stress, psi

P = design pressure, psi

R = inside radius, in.

t = min required thickness of shell plates, in.

E = joint efficiency (1.0) (see 1.3, item 14).

$$\text{Shell:}\quad S = \frac{P(R + 0.6\ t)}{E\ t} = \frac{10.2\ [6.75 + 0.6(0.234)]}{1(0.234)} =$$

300 psi less than 6200 OK

These equations are from ASME Code, section VIII, div 1, p 24, UG-34.

Both heads: $S = CP\left(\frac{d}{t}\right)^2$ (see 1.3, item 2) where:

C = factor depending on the method of attachment of head, shell dimensions, etc. (dimensionless)

m = the ratio t_r/t_s (dimensionless)

t_r = required thickness of seamless shell for pressure, in.

t_s = actual thickness of shell, in.

S = maximum allowable stress, psi

P = design pressure, psi

t = min required thickness of cover, in.

d = dia as measured in 1.3, item 2, in.

Bottom head:

$S = CP\left(\frac{d}{t}\right)^2 = (0.3)(10.2)\left(\frac{13.25}{0.312}\right)^2 = 5520$ psi less than 6200 OK

Top head:

$S = CP\left(\frac{d}{t}\right)^2 = (0.2)(10.2)\left(\frac{13.375}{0.25}\right)^2 = 5840$ psi less than 9500

(see 1.3, item 13) OK

(a) Flange and Bolting Operating Conditions

These equations are from ASME Code, section VIII, div 1, page No. as noted, UA-47.

$H_D = 0.785\ B^2P$ p 235

$H_G = 2\ b\ \pi\ G\ m\ P$ p 235

$H_T = 0.785\ (G^2 - B^2)\ P$ p 235

$W_{m1} = H_D + H_G + H_T$ p 236

$M_o = h_D\ H_D + h_G\ H_G + h_T\ H_T$ p 235 where:

H_D = hydrostatic end force on area inside of flange, lb

B = inside dia of flange, in.

P = design pressure, psi

H_G = total joint-contact surface compression load, lb

b = effective gasket seating width, in.

G = dia at location of gasket load reaction, in.

m = gasket factor (see 1.3, item 5)

H_T = difference between total hydrostatic end force and the hydrostatic end force on area inside of flange, lb

W_{m1} = min required bolt load for the operating conditions, lb

M_o = total moment acting upon the flange for operating conditions, in.-lb

$h_{D,G,T}$ = radial distance from bolt circle to corresponding forces $H_{D,G,T}$

$H_D = 0.785\, B^2 P = (0.785)(13.5)^2(10.2) = 1460$ lb; $1460 \times 0.883 =$ 1290 in.-lb

$H_G = 2\, b\, \pi\, G\, m\, P = (2)(0.25)\pi(14.25)(0.5)(10.2) = 114$ lb

$114 \times 0.625 = 71$ in.-lb

$H_T = (0.785)(G^2 - B^2)(P) = (0.785)(14.25^2 - 13.5^2)(10.2) =$ 167 lb; $167 \times 0.812 = 136$ in.-lb

$W_{m1} = 1460 + 114 + 167 = 1741$ lb

$M_o = 1290 + 71 + 136 = 1497$ in.-lb

(b) Gasket Seating

These equations are from ASME Code, section VIII, div 1, p 243, UA-49 and UA-50.

$W_{m2} = \pi b G y$

$A_{m1} = \frac{W_{m1}}{S}$

$W = 1/2 (A_m + A_b) S_a$

$M_o = Wh_G$

where:

W_{m2} = min required bolt load for gasket seating, lb

b = effective gasket seating width, in.

G = dia at location of gasket load reaction, in.

y = gasket seating load, psi (see 1.3, item 5)

A_{m1} = total cross-sectional area of bolts at section of least diameter under stress, required for the operating conditions, in^2.

W_{m1} = min required bolt load for the operating conditions, lb

S = max allowable stress, psi (see 1.3, item 15)

A_b = min cross-sectional area of bolts, in.

W = flange design bolt load for gasket seating, lb

A_m = total required cross-sectional area of bolts, in^2

S_a = allowable bolt stress at atmospheric temperature, psi

M_o = total gasket seating moment acting on flange, in.-lb

h_G = radial distance from gasket load reaction to bolt circle, in.

$W_{m2} = \pi b G y = \pi (0.25)(14.25)(0.0) = 0.0$ less than W_{m1}

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$A_{m1} = \frac{W_{m1}}{S} = \frac{1741}{20,000} = 0.0870 \text{ in}^2$

$A_b = 8(0.0269) = 0.215 \text{ in}^2$ (see 1.3, item 16) OK

$W = 1/2(A_m + A_b)S_a = 1/2\ (0.0870 + 0.215)(20,000) = 3020$ lb

$M_o = Wh_G = (3020)(0.625) = 1890$ in.-lb (gasket seating)

Gasket seating governs

Bolt stress $= \frac{W}{A_b} = \frac{3020}{0.215} = 14,050$ psi less than 20,000 psi OK

For flange constants see 1.3, items 6 through 9.

Gasket seating: Allowable stress is 6200 psi (see 1.3, item 13).

These equations are from ASME Code, section VIII, div 1, p 244, UA-51.

$$S_H = \frac{fM_o}{L(g_1)^2B}$$

$$S_R = \frac{(1.33\ t\ e + 1)\ Mo}{L\ t^2\ B}$$

$$S_T = \frac{YMo}{t^2\ B} - ZS_R$$

where:

S_H = calculated longitudinal stress in hub, psi

f = hub stress correction factor for integral flanges (see 1.3, item 7)

S_R = calculated radial stress in flange, psi

S_T = calculated tangential stress in flange, psi

M_o = total moment acting on flange for gasket seating or operating conditions, in.-lb

L = factor = $\frac{t\,e + 1}{T} + \frac{t^3}{d}$

t = flange thickness, in.

T = factor involving K (ratio of flange OD to flange ID) (see 1.3, item 10)

e = factor for integral flanges = F/h_o

F = factor for integral flanges (see 1.3, item 11) involving $g_1 g_o$ where

g_1 = thickness of hub at back of flange, in.

g_o = thickness of hub at small end, in.

h_o = factor = $\sqrt{B\,g_o}$, in.

d = factor for integral flanges = $\frac{U}{V}\ h_o\ g_o^{\ 2}$

U = factor involving K (see 1.3, item 10)

V = factor for integral type flanges (see 1.3, item 12)

B = inside diameter of flange, in.

Y & Z , see T just listed

$S_H = \frac{f M_o}{L(g_1)^2\ B} = \frac{(1.0)(1890)}{(0.742)(0.234)^2(13.5)}$ = 3450 less than 1.5(6200) <u>OK</u>

$S_R = \frac{(1.33\ t\ e + 1)\ M_o}{L\ t^2\ B} = \frac{[(1.33)(0.5)(0.511) + 1]\ 1890}{(0.742)(0.5)^2(13.5)}$ =

1010 psi less than 6200 <u>OK</u>

$S_T = \frac{Y\ M_o}{t^2\ B} - Z\ S_R = \frac{(10.75)(1890)}{(0.5)^2(13.5)} - (5.55)(1010)$ =

6200 - 5610 = 590 psi less than 6200 <u>OK</u>

Operating condition

$$S_H = \frac{fM_{\Omega}}{L(s_1)^2 B} = \frac{(1.0)(1497)}{(0.742)(0.234)^2(13.5)} = 2730 \text{ psi } 1.5(6200) \qquad \underline{\text{OK}}$$

$$S_R = \frac{(1.33\ t\ e + 1)\ M_{\Omega}}{L\ t^2\ B} = \frac{[(1.33)(0.5)(0.511) + 1]\ 1497}{(0.742)(0.5)^2\ (13.5)} =$$

801 psi less tnan 6200 <u>OK</u>

$$S_T = \frac{YM_{\Omega}}{t^2\ B} - Z\ S_R = \frac{(10.75)(1497)}{(0.5)^2(13.5)} - (5.55)(801) =$$

$$4768 - 4446 = 322 \text{ psi less than } 6200 \qquad \underline{\text{OK}}$$

1.6.3.2 Product Container

Reduction of the external pressure to 7.4 psia would give a maximum differential pressure across the product container wall of 1508 torrs absolute - 380 torrs or 1128 torrs Each product container is annually tested at 1173 torrs (8.11.2) and therefore would not be damaged at a pressure of 1128 torrs.

1.6.4 Vibration

The stainless steel and aluminum containers were shipped for many years without vibration damage. The addition of the insulation and steel drum provides more protection. Therefore, normal vibration will not damage the package.

1.6.5 Water Spray

The closed steel drum, with vent holes sealed with metal tape, is impervious to water spray and is not significantly affected.

1.6.6 Free Drop

Two 4 ft drops of the LP-50 packaging were made. First, the LP-50 was dropped at a 45° angle onto its bottom edge at a point 90° from the plane of the locking ring lugs at the top of the LP-50. The second drop was also made at a 45° angle, but this time the LP-50 was dropped onto the top edge when it was in line with the bottom impact point.

Prior to these drops, the PC was evacuated to 100 microns. After these drops and two subsequent drops from 30 ft, no detectable change in pressure was found. Minimal damage resulted. See figures 19, 20, and 21.

1.6.7 Corner Drop

Since this package is constructed primarily of metal and not wood or fiberboard and also because it weighs more than 110 lb, this test is not applicable.

1.6.8 Penetration

A 13 lb 1-1/4 in. dia rod was dropped four feet onto the side of the drum between two chimes. The maximum deflection of the drum was 1/4 in. with no damage to the Celotex® insulation.

1.6.9 Compression

An empty drum was uniformly loaded to 1700 lb (more than five times its normal package weight). A 2 in. thick plywood load distribution plate was placed on top of an upright drum. Bags of lead shot, weighing 25 lb each, were stacked on the plate to the required total load. After 24 hours, no deformation of the drum had occurred.

1.7 Hypothetical Accident Conditions

1.7.1 Free Drop

Three prototype packages were dropped 30 ft on a flat, unyielding horizontal surface. The surface was a 1 in. thick steel plate weighing about 870 lb supported by a 6 in. thick, 20 × 30 ft concrete slab on firm soil. A crane with a quick release device was used to suspend each package. The first two packages are described in 2.5.1.2 and the third in 0.2.1.

The first package was dropped on its side with impact on the locking ring lugs. The diameter was reduced 3/16 inch (figure 8). The second was dropped on its top corner, resulting in a 3 in. deformation of the corner (figure 13). The third package was first dropped twice from four ft (see 1.6.6) and then dropped on its top corner with the major axis at 15° to the horizontal. A 2-3/4 in. reduction in diameter resulted (figure 21). None of the three drops resulted in exposure of any of the insulation or any other damage that might affect the ability of the package to withstand the subsequent accident conditions.

1.7.2 Puncture

Each of the first two packages mentioned in 1.7.1 was dropped from a distance of 40 in. onto a 6 in. dia steel post. The post was 10 in. high and welded to a 1 in. thick × 1-1/2 ft × 1-1/2 ft steel plate. The side of the drum was indented 1/16 in. in both cases (figure 9).

1.7.3 Thermal

1.7.3.1 Summary Pressure and Temperature

Ambient temp 100.4°F (38°C)

Δt shell to ambient 19.8°F (11°C)

Temp rise of shell 114°F (63°C)

Max product container temp 242°F (117°C)

Max product container pressure 32 psia at age of 12 months

1.7.3.2 Differential Thermal Expansion

The furnace test, see 2.5.1.1, did not cause any damage that could be attributed to differential thermal expansion. The calculated expansion of the shell is 0.026 in. in dia and the product container is only 0.018 in. in dia.

$C_{Al} = 13.7 \times 10^{-6}$ in./in.°F Marks Handbook, 7th Edition

$C_{SS} = 9.9 \times 10^{-6}$ in./in.°F p 6-10

The clearances, the temperature differential involved, and the thermal expansion coefficients of the materials will minimize the effects of thermal expansion.

1.7.3.3 Stress Calculation

None.

1.7.3.4 Comparison with Allowable Stress

This package has shown by testing that it has withstood any stress developed during actual tests of hypothetical accident conditions. See 2.5.4, Maximum Internal Pressure, for discussion of internal pressure and yield strength.

1.7.4 Water Immersion

Not applicable. There is no fissile material in this package.

1.7.5 Summary of Damage

A complete package was dropped on a flat surface and on a piston, then heated in a furnace, in the manner prescribed by AECM 0529*. Three separate tests were performed. The appearance of the package at various stages during the first test is shown in figures 8 through 12, during the second test in figures 13 through 16, and during the third test in figures 19 through 21. The package was not significantly damaged from the drops in any of the tests. Some insulation damage was caused by smoldering near vent holes after the two thermal tests, but the present design (shown in figure 1) prevents this by the use of a noncombustible insulation in the vicinity of the three vent holes which are provided to prevent drum damage by internal gas pressure during a fire. Before the first two tests, the primary container was pressurized to about 29.4 psia. Following the tests, no pressure had been lost and there was no apparent damage to the container valve. During the thermal tests, the surface temperature of the aluminum secondary container was continuously measured. Maximum temperature at various points in the package was determined from the condition of pellets of known melting points. The temperature rise in the furnace test was low enough that tritium permeation and leakage would have been less than the one curie limit.

Prior to the third 30' drop test, the package was subjected to two 4 ft drops as described in 1.6.6. The package still passed the test satisfactorily and the PC also held a vacuum of 100 microns without detectable change.

1.8 Special Form

Not applicable. No special form is claimed.

1.9 Fuel Rods

Not applicable. There are no fuel rods in the shipment.

1.10 Appendix

1.10.1 Reference

1. DPST-79-283, R. G. Derrick to I. B. New, Strain Gauge Measurements on Typical Low-Pressure Product Containers, March 6, 1979. (See Appendix A)

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*Changed to DOE 5480.3

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2.0 THERMAL EVALUATION

2.1 Discussion

The significant thermal design of the LP-50 packaging is the insulated shipping drum or overpack. A sealed product container (PC) inside an aluminum shell is placed in a Celotex® lined carbon steel drum. See 0.2.1 for a complete description and principal dimensions.

The weighted average thickness of Celotex® is 3.8 in. This adequately protects the PC and shell during normal transport and during hypothetical accident conditions. This packaging has been in use for over a decade without adverse effects due to thermal conditions.

The maximum decay heat load is 22.4 Btu/hr. The minimum heat load is zero when the PC is empty. Significant results of the thermal analysis of the package are:

2.1.1 Normal Transport

Drum surface temp sun side	(T_d)	182.9°F	83.8°C
Drum surface temp shade side	(T_d')	132.8°F	56°C
Wall temp of shell	(T_c)	177.2°F	80.7°C
Product container temp	(T_p)	179.9°F	82.1°C
Ambient temp	(T_a)	130°F	54.4°C
Pressure inner vessel	(P)	29.17 psia, assuming 1 year of radioactive decay	
Differential pressure across wall of inner vessel		11.7 psi	
Radioactive heat decay		22.4 Btu/hr	

2.1.2 Hypothetical Accident

Ambient temp	100.4°F	38°C
Temp Δt between shell and ambient	18.9°F	10.5°C
Measured temp rise of shell during furnace test	114°F	63°C
Temp Δt between shell and product container	2.7°F	1.4°C

Temp rise of shell and product container by adiabatic self-heating	4.6°F	3°C
Max product container temp	242°F	117°C
Pressure of product container at max temp	32.0 psia	

2.2 Summary of Thermal Properties of Materials

a. Celotex^R thermal conductivity 0.031 Btu/hr·ft^2(°F/ft), density 13-25 lb/ft^3

b. Cera Form^R thermal conductivity 0.028 Btu/hr·ft^2(°F/ft), density 11-14 lb/ft^3

c. Cerafelt^R thermal conductivity 0.025 Btu/hr·ft^2(°F/ft), density 6 lb/ft^3

d. Cerafelt^R thermal conductivity 0.027 Btu/hr·ft (°F/ft), density 16 lb/ft^3

e. Solar flux 144 Btu/hr/ft^2 [ORNL-NSIC-68, Cask Designers Guide, p 143]

f. Air thermal conductivity 0.0175 Btu/hr·ft^2(°F/ft) @ 177°F [Marks Handbook for Mechanical Engineers, 7th ed, p 4-94, 1967]

g. Absorptivity factor - painted surface = 0.94 [ORNL-NSIC-68, p 133]

2.3 Technical Specifications of Components

2.3.1 **Celotex^R fiberboard made from sugar cane fibers bonded with organic glue** per Mil F-26862A. Shear strength 31-33 psi, stable to 250°F.

2.3.2 Cera Form^R - molded from slurry of alumina-silica refractory fiber and bonded by inorganic binders, stable to 2300°F.

2.3.3 Cerafelt^R - A loosely spun alumina-silica refractory material, stable to 2300°F.

2.3.4 Product Container Valves

Four slightly different valves have been used: a Fulton Sylphon, a modified Fulton Sylphon, a Hoke TY445 and a Hoke 4213x2 (Figure 7A, 7B, 7C and 7D). The valves were tested for tritium leakage at 25° and 110°C with differential pressures of 570-950 torrs. The Hoke valves have a proof test of 3000 psig and a max operating temperature of 600°F. The Fulton Sylphon valves are prooftested at 150 psig.

At 25°C, leakage was well below the 7 x 10^{-8} atm cc/sec limit (see 3.3.2.2) At 110°C leakage was still insignificant when compared with the 0.39 cc (1 curie) loss allowed under accident conditions. [IAEA Safety Series No. 6) "Regulations for the Safe Transport of Radioactive Materials," 1973 Revised edition, section II, p 230, (b).] Current regulations (January 1, 1986 of 10CFR71.51(a)2) allows a leakage of an A$_2$ amount in one week for accident conditions or 1000 ci.

All present replacement valves are the improved Hoke 4213x2 with the Cajon 4VCR fitting shown in Figure 7C (Type IIIA Modified). Future replacement valves are expected to be the Hoke 4213x2 with Cajon fitting and container stub directly welded to the valve body as shown in Figure 7D.

2.4 Thermal Evaluation for Normal Conditions of Transport

2.4.1 Thermal Model

The standard packaging described in 0.2.1, and shown in detail in the reference drawings cited in the Contents (S5-2-5733 et seq) serves as a model for the thermal evaluation.

2.4.1.1 Thermal Evaluation

The thermal evaluation for normal transport was made analytically following the methods and equations of ORNL-NSIC-68 using thermal conductivities from manufacturers technical data sheets. The assumptions used in the calculations follow.

- Assumptions

  1) The package is in thermal equilibrium at 130°F ambient air temperature in sunlight at latitude 42°N during the summer solstice (144 Btu/hr-ft^2, 24-hour average solar heat rate).

  2) Solar heating is applied to the top and one side of the drum over a projected area equal to diagonal height times diameter.

  3) There is no circumferential heat flow in the thin wall of the drum or in the Celotex® insulation.

  4) Heat escape through the bottom of the package is neglected.

  5) The wall temperature of the aluminum shell is uniform (high conductivity, low heat flux).

  6) Heat passage from the sunny surfaces of the drum to the aluminum shell, thence to the shaded surface of the drum, is calculated on the basis of a weighted average insulation thickness.

- Definitions and Constants

  1) Q_s = solar heat input = solar radiation × projected area × absorptivity factor

  Solar radiation = 144 Btu/hr-ft^2 [1]

  Absorptivity factor = 0.94 [2] for a painted drum

Projected area = diagonal height × diameter

$$= \frac{\sqrt{(22.5)^2 + (38.5)^2} \quad x \;\; 22.5}{144} = 6.97 \text{ ft}^2$$

Q_s = 144 × 6.97 × 0.94 = 943.46 Btu/hr

2) Q_R = 0.32 watt/g tritium × 3.4139 Btu/watt/hr × 75,300 cc in 50 liters ÷ 3718 cc/g tritium = 22.4 Btu/hr (vessel @ 1250 torr)

3) A_d = surface area of drum (sun side)

= top surface + 1/2 cylindrical surface

= 12.2 ft^2

4) A'_d = surface area of drum (shade side)

= 1/2 cylindrical surface

= 9.45 ft^2

5) U_o = heat transfer coefficient through insulation (sun side)

$= \frac{K}{L} = \frac{0.038}{0.36} = 0.106$ Btu/hr-ft^2 (°F)

K = thermal conductivity of Celotex® in temp range of 85° to 90°C

= 0.038, estimated from room temp conductivity of 0.030 Btu/hr-ft^2 (°F/ft)

L = weighted average insulation thickness of 3.8 in. + 0.5 in. of Celotex® equivalent of air gap of 0.36 ft

6) U'_o = heat transfer coefficient through insulation (shade side)

$= \frac{K'}{L'}$

K' = 0.036 estimated (158°F/70°C)

L' = 0.36 ft

$= \frac{0.036}{0.36} = 0.10$ Btu/hr-ft^2 (°F)

7) A_m = mean heat transfer area (sun side)

= mean area of drum top + 1/2 mean area of cyl side

= 1.84 ft^2 + 6.14 ft^2 = 7.98 ft^2

8) A'_m = 1/2 mean heat transfer area (shade side)

= mean area of cyl side = 6.14 ft^2

9) T_d = drum surface temperature — sun side, °F

10) T'_d = drum surface temperature — shade side, °F

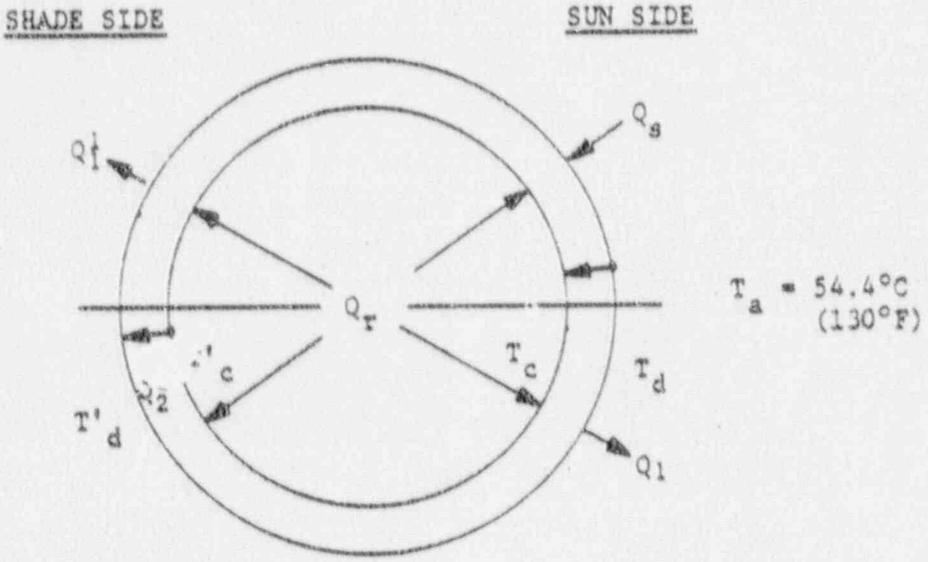
11) T_c = wall temperature of aluminum vessel, °F

12) T_a = ambient temperature = 54°C (130°F)

o Calculations

1) Heat Balances

For determination of temperatures T_d, T'_d, and T_c, heat balances are made on the entire package, the aluminum vessel, and the separate sides of the steel drum.



Entire package

Q in = Q out or $Q_s + Q_r = Q_1 + Q'_1$

$$Q_s + Q_r = Q_1 + Q'_1$$

$$943.36 + 22.4 = (h_c + h_r)\ A_d\ (T_d - T_a) + (h'_c + h'_r) A'_d\ (T'_d - T_a)$$

where:

$h_c = 0.19\ (\Delta T)^{1/3}$ ORNL-NSIC-68 - p 135

$$h_r = 0.173 \times F_a F_e \left[\frac{\left(\frac{T_d + 460}{100}\right)^4 - \left(\frac{T_a + 460}{100}\right)^4}{T_d - T_a} \right]$$

F_a = Angle factor = 1.0 direct sunlight

F_e = Emissivity factor = 0.94

	Q in		Q out
Aluminum	$Q_r + Q_2$	=	Q'_2
Container	$Q_r + U_o A_m (T_d - T_c)$	=	$U'_o\ A'_m\ (T_c - T'_d)$
Steel drum sun side	Q_s	=	$Q_1 + Q_2$
Steel drum shade side	Q'_2	=	Q'_1

By successive substitution of trial values in the above equations, it is found that the following set of temperatures is required for equilibrium.

Drum — sunny side (T_d) = 182.9°F (83.8°C)

Drum — shaded side (T'_d) = 132.8°F (56°C)

Aluminum shell (T_c) = 177.2°F (80.7°C)

2) Temperature Gradient Between PC and Shell

To determine the temperature of the PC (and tritium), it is necessary to estimate the temperature gradient between the PC and the shell.

T_c = Temperature of aluminum shell = 177.2°F (80.7°C)

T_s = Temperature of stainless steel PC, °F, to be determined

A_{co} = Area for heat transfer by conduction

= Cylindrical surface only (large clearances at top and bottom of the PC 22.828 in.) = 6.55 ft^2

L = clearance between cylindrical surfaces = 0.17 in. = 0.014 ft

A_r = area for heat transfer by radiation

= entire surface of PC = 8.0 ft^3

Heat balance: $Q_r = h_{co} A_{co} (T_s - T_c)$

where:

Q_r = radioactive decay heat = 22.4 Btu/hr

h_{co} = heat transfer coefficient by conduction = $\frac{K\ air}{L}$ =

$$= \frac{0.0175\ Btu/(hr)(ft^2)(°F/ft)}{0.014\ ft} = 1.25\ Btu/hr\text{-}ft^2\ (°F)$$

K_{air} @ 177°F = 0.0175 Btu/hr ft^2 [Marks Handbook 7th Edition 4-94 Thermal Conductivity of Air and Steam].

$$T_s - T_c = \frac{Q_r}{h_{co} \cdot A_{co}} = \frac{22.4}{(1.25)(6.55)} = 2.74$$

T_s - 177.2 = 2.7

T_s - 179.9°F (82.1°C)

There will be no significant difference in temperature between the tritium and the inner vessel; therefore, the temperature of the tritium in normal transport will not exceed 180°F (82°C).

2.4.2 Maximum Temperature

The maximum temperatures for normal transport conditions are:

Steel drum	182.9°F	83.8°C
Shell wall	177.2°F	80.7°C
Product container	179.9°F	82.1°C

2.4.3 Minimum Temperature

This is a dry shipment and contains no liquids or other material harmfully affected by a temperature of -40°F (-40°C).

2.4.4 Maximum Internal Pressure

The maximum initial loading pressure is 23.2 psia (1200 torrs) at 25°C. The maximum pressure during normal transport will be at maximum temperature in the PC (see 2.4.2).

$$\text{PC pressure } (23.2)\left(\frac{82 + 273}{25 + 273}\right) \times \text{ helium buildup at 1 year } \left(\frac{1265.55}{1200}\right) = 29.17 \text{ psia}$$

The maximum temperature for the shell is taken to be the average temperature. The initial shell pressure is 1 atmosphere at 25°C.

$$\frac{T_{PC} + T_{shell}}{2} = 81.4°\text{C} \quad P = 14.7\left[\frac{81.4 + 273}{25 + 273}\right] = 17.5 \text{ psia}$$

The ability of the packaging to withstand this pressure is shown in 1.6.3.

2.4.5 Maximum Thermal Stresses

The temperature differentials throughout the package are relatively small and will cause no significant thermal stresses.

2.4.6 Evaluation

The packaging has provided effective protection for many shipments over the past decade.

The package will not be affected by maximum full sunlight temperatures of 130°F (54°C) as the maximum internal temperature will not exceed 180°F (82°C) — well under the 250°F (121°C) plus temperatures that affect the insulating material. Minimum (-40°F or -40°C) temperatures will produce no detrimental effects on the packaging as this is a dry shipment.

The effects of pressure as calculated in section 1.6.3 show that the product container and shell will withstand normal transport conditions.

Vibration and water spray do not affect the packaging (see 1.6.4 and 1.6.5). Free drops and penetration tests had no significant effect on the package (see 1.6.7 and 1.6.8).

The package had no deformation after the compression test (see 1.6.9).

2.5 Hypothetical Thermal Accident Evaluation

2.5.1 Thermal Model

2.5.1.1 Analytical Model

The standard packaging described in 0.2.1 and shown in detail on drawings S5-2-5733 et. seq. serves as a model for the calculations made to extend the thermal test results to packaging components whose temperatures were not directly measured.

2.5.1.2 Test Model

The test model used for both drop and thermal tests is identical to the packaging described in 0.2.1 with three minor exceptions:

a. To eliminate smoldering which developed in the top ring of Celotex® insulation in the vicinity of the drum vent holes during the postfire cooldown period, the affected insulation was replaced in the final design (0.2.1) with a ring of noncombustible Cera Form® (felt) insulation. Subsequent tests on numerous packagings of this generic design indicated no adverse affect of this substitution on either the drop or other test results (none was expected), and no recurrence of smoldering. Two effects are assumed as possible sources of this improvement: (1) replacement of a combustible insulation with a noncombustible type in a zone where postfire smoldering could occur and (2) reduction of air permeation into the drum via the vents as a result of the fine-spun structure of Cera Form® which is known to restrict air flow at small differential pressures.

b. Also, in the final design, a disk of Cerafelt® is specified under the drum cover on top of the Celotex®. Cerafelt® is stable up to 2300°F and may prevent burning or smoldering of the Celotex® even if the closure is breached, assuming no Celotex® is exposed. Equally important, the disk serves as a spacer to ensure that the insulation is tightly constrained to avoid breaching the closure. Several 1/2 in. thicknesses may be used if required.

c. Lastly, a coating of Cera-kote^R is applied to the Celotex^R. Cera-kote^R stabilizes the irritating dust and larger particles of cane fiber gradually released from the Celotex^R surface. Therefore, Cera-kote^R was specified for the final design. For a full account of the development program for this type of package, see reference in section 2.6.

A complete package was dropped on a flat surface and on a piston, then heated in a furnace, in the manner prescribed by AECM 0529*. Two separate tests were performed.

A large annealing furnace was used for thermal tests on full-scale packages. After the furnace was heated to 1475°F, the package was inserted for 30 minutes, then removed for cooling. A thermocouple, inserted through the drum, measured the temperature of the aluminum shell just inside the insulation.

The maximum temperature at various other points was determined from the condition of pellets of known melting points.

The package tested contained no radioactive material.

2.5.2 Package Conditions and Environment

The appearance of the package at various stages during the drop and piston tests is shown in figures 8 through 21. The package was not significantly damaged by the drop tests, and therefore the tests were not detrimental to the cask during the furnace tests.

2.5.3 Package Temperatures

During the thermal tests some insulation damage was caused by smoldering near vent holes, but the present design (shown in figure 1) prevents this by the use of noncombustible insulation in the vicinity of the three vent holes (these holes are provided to prevent drum damage by internal gas pressure during a fire). Before the tests, the primary container was pressurized to about 29.4 psia. Following the test, no pressure had been lost and there was no apparent damage to the container valve. During the thermal tests, the surface temperature of the aluminum shell was continuously measured. The initial temperature of the PC was 24°C. The maximum temperature reached from the fire was 87°C (189°F), a rise of 63°C. The smoldering in the insulation began noticeably showing the temperature decline after about 250 minutes, eventually causing it to level at an abnormally high value. However, extrapolation of the initial part of the decline, shown by the dashed line in figure 18, produces a curve similar to what would be obtained without smoldering and allows an approximation of the time at elevated temperature for tritium permeation calculations. The temperature rise in the furnace test is low enough that tritium permeation and leakage are less than the 1 curie limit

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*Changed to DOE 5480.3

c. Temperature Calculations

The maximum temperature of a loaded primary container in a fire is less than the sum of the following:

1) Calculated temperature of the aluminum shell before the fire.

2) Measured temperature rise of the aluminum shell during the furnace test (114°F or 63°C).

3) Calculated temperature difference between the PC and the aluminum shell (2.7°F or 1.5°C). (see 2.4.1).

4) Calculated temperature rise of the PC and the shell vessels caused by adiabatic self-heating while the temperature is elevated from the fire (see 2.4.1).

The temperature before the fire is calculated on the basis of still ambient air at 38°C without solar radiation. Using values of h_e and h_r as in 2.4.1 and an effective area of 21.6 ft^2 for dissipation of heat from the cylindrical surface and one end of the drum, it is found that the outer surface temperature is about 1°C (1.8°F) above ambient. For a mean heat transfer area of 14.2 ft^2 through the Celotex,® an effective thickness of 0.36 ft and a thermal conductivity of 0.030 Btu/(hr)(ft)(°F) (see 2.4.1), the temperature drop through the Celotex® is -

$$\frac{22.4 \text{ Btu/hr} \times 0.36 \text{ ft}}{14.2 \text{ ft}^2 \times 0.030 \text{ Btu/(hr)(ft)(°F)}} = 18.9\text{°F } (10.5\text{°C})$$

The temperature drop between the aluminum shell and the Celotex® was taken into account in the effective thickness of the Celotex.® Therefore, the calculated temperature of the aluminum shell is

$$100.4 + 1.8 + 18.9 = 121.1\text{°F } (49.5\text{°C}).$$

The temperature difference between the two inner containers is calculated in 2.4.1 to be 2.7°F (1.5°C).

Self-heating following a fire is calculated as follows:

[(Self-heating time from figure 18) × (tritium decay heat rate)] divided by (mass of primary container × specific heat of stainless steel + mass of aluminum shell × specific heat of aluminum) = temperature rise.

$$\frac{(3 \text{ hours})\ (22.4 \text{ Btu/hr})}{(30.5 \text{ lb steel})\,[0.12 \text{ Btu/(lb)(°F)}] + (47 \text{ lb Al})\,[0.23 \text{ Btu/(lb)(°F)}]}$$

$$= 4.6\text{°F } (2.6\text{°C})$$

The sum of the preceding temperatures is the maximum primary container temperature following a fire; 121.1 + 114.0 + 2.7 + 4.6 = 242.4°F (116.7°C).

2.5.4 Maximum Internal Pressure

The initial tritium loading pressure will be 23.2 psia at 25°C which will not cause yielding of the container at the fire temperature of about 242°F (117°C). This was determined as follows:

As the primary container temperature increases, the internal pressure increases, but the container yield pressure decreases (yield pressure is defined as that which produces a 0.2% permanent strain). For a cylinder, yield pressure is directly proportional to yield strength (yield strength of type 304L SS as a function of temperature is listed in the ASME Code, section III, 1965 edition, table N-424). Thus:

$$\frac{P_{117}}{P_{25}} = \frac{S_{117}}{S_{25}}$$

where:

P = yield pressure, gage

S = yield strength

The yield pressure at 25°C was determined experimentally to be 30 psig.

$$\frac{P_{117}}{30} = \frac{20{,}000}{25{,}000} \text{ or } P_{117} = 24.0 \text{ psig or } 38.7 \text{ psia}$$

An initial loading pressure of 23.2 psia at 25°C will be 32.0 psia at 117°C at 1 year of age; therefore, the container pressure would not reach the yield pressure during the thermal accident.

2.5.5 Maximum Thermal Stresses

The package was tested in such a manner that the initial pressure of the product container was 29.4 psia which is equivalent to a pressure of 32 psia at 114°F. There was no pressure loss when the PC was opened at the conclusion of the test.

2.5.6 Evaluation of Package Performance for the Hypothetical Thermal Accident

The package evaluation indicates that it will withstand the accident conditions indicated in 10 CFR 71 Appendix B *. The package was not significantly damaged

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* Changed to 10CFR 71.73

during the free drop and puncture tests.

Furnace tests and calculations show the maximum product container temperature and pressure to be 242°F (117°C) and 32.0 psia. Yield pressure at 117°C is 38.7 psia.

The water immersion test was not done because there is no fissile material in this package.

Limited smoldering that occurred during the initial thermal testing was eliminated by using noncombustible insulation, Cera Form,® near the drum vent holes. The Cera Form® extended into the Celotex® for 1-1/2 inches, the maximum char depth observed on any test.

2.6 Appendix

2.6.1 References

1. Lewallen, E. E., Drum and Board-Type Insulation Overpacks of Shipping Packages for Radioactive Materials, July 1972. USAEC Report DP-1292, E. I. du Pont de Nemours and Co., SRL, Aiken, S. C. 29801.

3.0 CONTAINMENT

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3.0 CONTAINMENT

3.1 Containment Boundary

3.1.1 Containment Vessel

The containment vessel is the product container (PC). It is a 50-liter right circular cylinder made of 0.078 in. thick type 304L stainless steel. See figure 5 for details of specifications for cleanliness and leaktightness.

3.1.2 Containment Penetrations

The only penetration of the PC is a 1/4 in. hole, through the cover, into which a vacuum valve is welded. Originally, all PC's were equipped with the vacuum valve shown in figure 7A. Other similar valves have since been used as replacements (figures 7B & 7C). A future replacement valve assembly will be a SS Hoke valve, model No. 4213X2 (figure 7D). It can operate at 2000 psig and 600°F and has a leakage rate less than 8×10^{-9} atm cc/s.

3.1.3 Seals and Welds

The cover is attached to the PC with an edge weld using a gas tungsten arc weld (GTAW) and no filler material. The vacuum valve is fillet welded in two passes - with a 1/16 in. dia type 308L SS rod on the first pass and with a 3/32 in. type 308L rod on the second pass (using GTAW) - into the 1/2 in. dia countersunk hole at the top of the 1/4 in. dia hole through the cover. A 3/16 in. fillet leg dimension is achieved using the procedure in reference 6.5.1,[14].

3.1.4 Closure

In order to verify a seal, the four types of valves in use are tightened (per procedure reference 6.5.1,[1] to maintain a leak rate of less than 0.1 micron-ft^3/hr (1×10^{-6} atm cc/sec).

3.2 Requirements for Normal Conditions of Transport

3.2.1 Release of Radioactive Material

Gaseous tritium permeates normal materials of construction at rates depending on temperature, pressure, and other factors. The term containment (no release) as used for normal conditions of transport is interpreted to mean no release which would expose any persons to a dose above that received by continuous exposure to the maximum permissible concentration allowed for the public. For transportation in a closed vehicle (the worst case), the maximum allowable release rate per package would be about 7×10^{-8} atm cc/sec of tritium. This value is derived by assuming that air in a closed vehicle is replaced about once a day, that a vehicle contains about 300 ft^3 of air for every package, and that a workman opening and unloading the vehicle would be exposed to the maximum concentration for no more than one minute. The maximum concentration in the vehicle is computed from the maximum permissible concentration for 168 hour/week exposure set by the ERDAM 0524* [1] Concentration Guide by the ratio of exposure time to 168 hours. The actual exposure would be much lower than the calculated because actual tritium release rates will be greatly below the derived upper limit. (It is interesting to note that the IAEA regulations would permit escape of 1.1×10^{-7} atm cc/sec. [2, section II, para 230(a).]

3.2.2 Pressurization of Containment Vessel

At a release rate of 7×10^{-8} atm cc/sec for 365 days of transportation, the mol fraction of hydrogen isotopes in the shell will be:

$$\frac{7 \times 10^{-8} \text{ atm cc/sec} \times 365 \text{ days} \times 24 \text{ hr/day} \times 3600 \text{ sec/hr}}{5200 \text{ (chamber volume)}}$$

$$= 4.2 \times 10^{-4} \text{ or } 0.04\% \text{ tritium}$$

The gas mixture is not ignitable because the beta particles present from tritium decay will catalyze the formation of water from all hydrogen isotopes and oxygen in the annular space. The corresponding pressure increase would also be insignificant; consequently, there is no danger of creating an explosive mixture under conditions of normal transport.

3.2.3 Coolant Contamination

No coolant as such is put into the package. However, the calculations and explanations below describe the permeation phenomena of tritium from the PC into the shell.

Equilibrium hydrogen permeation through type 304L stainless steel

at 82°C is $1.5 \times 10^{-7} \dfrac{\text{STP cc mm}}{(\text{cm}^2)(\text{hr})}$ at 760 torrs [3, p 6].

Corrected for pressure, surface area, and wall thickness, the permeation rate becomes:

$$\frac{1.5 \times 10^{-7} \text{ STP cc mm} \times 8040 \text{ cm}^2}{(3600 \text{ sec/hr})(\text{cm}^2)(\text{hr}) \times 1.98 \text{ mm}} \sqrt{\frac{29}{14.7}} = 2.4 \times 10^{-7} \text{ atm cc/sec}$$

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*Changed to DOE 5480.1A, Chapter XI

A very long time, however, is required to reach equilibrium rate. The time to reach 7×10^{-8} atm cc/sec is obtained from a graphical plot of

$\frac{P_t}{P_\infty}$ vs $\frac{Dt}{L^2}$ [3, p 5] and the equation $D = 0.0265 \times e^{-14,000/RT}$ [4, p 2]

where

P_t = permeation rate at time t or 7×10^{-8} atm cc tritium/sec

P_∞ = permeation rate at equilibrium, atm cc/sec

D = diffusion rate, cm^2/sec

R = gas constant, g-cal/(g-mole)(°K) = 1.987

T = temperature °K = °C + 273 = 82 + 273 = 355°K

L = thickness of PC, cm = 0.198 cm

t = time to reach P_t, sec

$$\text{when } \frac{P_t}{P_\infty} = \frac{7 \times 10^{-8} \text{ atm cc tritium/sec}}{2.4 \times 10^{-7} \text{ atm cc tritium/sec}} = 0.29, \text{ then } \frac{Dt}{L^2} = 0.097$$

$$\text{But } D = 0.0265 \times e^{-14,000/(1.987)(355)} = 6.4 \times 10^{-11} \text{ cm}^2\text{/sec}$$

$$\therefore t = \frac{(0.097)(0.198)^2}{(6.4 \times 10^{-11})(3600)(24)} = 690 \text{ days}$$

Because it is reasonable to expect the transportation to be completed within 365 days, tritium permeation would be significantly less than the 7×10^{-8} atm cc/sec limit.

Other illustrations of these equations and plots are given in references 5,6, and 7.

Tritium may be stored in these containers for up to 1 year before shipment, but the permeation rate is extremely low under normal storage conditions at less than 100°F. Calculations indicate that many years must elapse before the permeation rate reaches only 10^{-8} STP cc/sec, a factor of 10 below the derived maximum allowable limits. Therefore, permeation during normal storage is so small as not to alter the conclusions first drawn.

Before initial use, each container is leak tested (<7 × 10^{-8} atm cc/sec) at 1.5 times its maximum operating pressure to show that it complies with regulations. Loss through the container valve is also negligible (<10^{-8} atm cc/sec) as shown in 3.3.4. Therefore, it is concluded that the LP-50 container does not represent a hazard at the maximum normal operating temperature.

3.3 Containment Requirements for the Hypothetical Accident

3.3.1 Fission Gas Products

Not applicable. There are no fission products in the package.

3.3.2 Release of Contents

3.3.2.1 PC Wall

Equilibrium hydrogen permeation through type 304L SS at 242°F (117°C) is

$1.05 \times 10^{-6} \frac{\text{STP cc mm}}{(\text{cm}^2)(\text{hr})}$ at 760 torrs [3, p 6].

Corrected for pressure, surface area, and wall thickness, the permeation rate becomes:

$$\frac{1.05 \times 10^{-6} \text{ STP cc mm} \times 8040 \text{ cm}^2}{(3600 \text{ sec/hr})\ (\text{cm}^2)\ (\text{hr}) \times 1.98 \text{ mm}} \sqrt{\frac{30}{14.7}} = 1.7 \times 10^{-6} \text{ atm cc/sec}$$

A very long time, however, is required to reach the equilibrium rate. The time to reach 7 × 10^{-8} atm cc/sec is calculated as shown in 3.2.3.

$$\text{for } \frac{P_t}{P_\infty} = \frac{7 \times 10^{-8}}{1.7 \times 10^{-6}} \ \frac{\text{atm cc tritium/sec}}{\text{atm cc tritium/sec}} = 0.041$$

$$\frac{Dt}{L^2} = 0.052 \qquad \text{from [3, p 5]}$$

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where

$$D = 0.0265 \times e^{-14,000/(1.987)(390)} = 3.8 \times 10^{-10}$$

$L = 0.198$ cm

therefore,

$$t = \frac{(0.052)(0.198)^2}{(3.8 \times 10^{-10}\ \text{cm}^2/\text{sec})(3600\ \text{sec/hr})(24\ \text{hr/day})} = 62\ \text{days}$$

Because the time at the elevated temperature is less than 12 hours, the tritium permeation rate would not reach the limit for even normal shipping conditions.

3.3.2.2 PC Valve

Four slightly different valves have been used on the primary containers; the valve shown in figure 7C (Type IIIA Modified) is the present standard (the two types of Hoke valves (figures 7C and 7D) have equivalent specifications). Each type was tested for tightness by cycling between 25° and 110°C with the results shown in the following table:

Tritium Leak Rate,[a] atm cc/sec

Temperatures in Sequence, °C	Valve Fulton 314A	 Modified Fulton	 Hoke
25	1.1	3.8	2.3
110	1.1	2.3	1.5
25	34	1.5	3.4
110	29	1.9	1.9

[a] Multiply by 10^{-9}.

At 25°C, leakage from any valve is well below the 7×10^{-8} atm cc/sec limit. At 110°C, or 82°C, under normal conditions, leakage is still insignificant, especially when compared to the 1 curie (0.39 cc) loss allowed under accident conditions. [2, section II, para 233(b).]

3.4 Appendix

3.4.1 References

1. USERDA Manual Chapter 0524*, Standards for Radiation Protection.

2. International Atomic Energy Agency (Safety Series No.6) "Regulations for the Safe Transport of Radioactive Materials." 1973 Revised Ed.

3. Jennings, A. S., Composite Reservoir Tests, November 1964, USAEC Report DPSTWD-64-168, E. I. du Pont de Nemours and Co., SRL, Aiken, SC, 29801. (Secret)

4. Louthan, M. R. and Dexter, A. H., Tritium Offgassing from Pinch Welds, May 1969. USAEC Report DPSTWD-69-131, E. I. du Pont de Nemours and Co., SRL, Aiken, SC 29801. (Secret)

5. Flint, P. S., The Diffusion of Hydrogen Through Materials of Construction, December 1951, USAEC Report KAPL-659, Knolls Atomic Power Laboratory, Schenectady, New York.

6. Rideout, S. P., et. al., Effects of Hydrogen in Metals, June 1966. USAEC Report DPWD-1057 and DPWD-1057TL, E. I. du Pont de Nemours and Co., SRL, Aiken, SC, 29801. (Secret)

7. Rideout, S. P., et. al., Effects of Hydrogen in Metals - II, December 1967. USAEC Report DPWD-1132 and DPWD-1132TL, E. I. du Pont de Nemours and Co., SRL, Aiken, SC, 29801. (Secret)

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* Changed to DOE 5480.1A Chapter XI

4.0 SHIELDING EVALUATION

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4.2 Source Specification 4-1
4.3 Model Specification 4-1
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4.0 SHIELDING EVALUATION

It is unnecessary to evaluate shielding for this packaging since the radioactive material (tritium) is a beta emitter and gives off no penetrating radiations.

4.1 Discussion and Results

Not applicable.

4.2 Source Specification

Not applicable.

4.3 Model Specification

Not applicable.

4.4 Shielding Evaluation

Not applicable.

4.5 Appendix

Not applicable.

5.0 CRITICALITY EVALUATION

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5.0 CRITICALITY EVALUATION

The radioactive material (tritium) in this package is not fissile and cannot be made to go critical. Therefore, nuclear criticality safety is of no concern in the shipment of this package.

5.1 Discussion and Results

Not applicable.

5.2 Package Fuel Loading

Not applicable.

5.3 Model Specification

Not applicable.

5.4 Criticality Calculations and Experiments

Not applicable.

5.5 Critical Benchmark Experiments

Not applicable

5.6 Appendix

Not applicable.

6.0 OPERATING PROCEDURES

6.1 Procedure for Loading the LP-50 Package 6-1
6.2 Procedure for Unloading the LP-50 Package 6-1
6.3 Preparation of Empty LP-50 Packaging for Transport 6-2
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6.0 OPERATING PROCEDURES

Definition of Terms

The LP-50 tritium packaging is composed of three major parts:

1. A product container (PC) which is a stainless steel vessel into which tritium is loaded.
2. A shell which is an aluminum inner container into which a product container is placed.
3. An insulated shipping drum or overpack which is a carbon steel drum with a lid and locking ring; it contains a PC inside a shell surrounded with insulation.

6.1 Procedure for Loading the LP-50 Package

Loading of the LP-50 product containers (PC) is performed per reference 1 or 2. LP-50 shipping drums are unpacked, inspected, and the LP-50 inside its shell is stored in a ventilation monitored vault per reference 3. Before opening the shell lid, the shell is placed in air flow from a process hood and monitored for tritium leakage from PC to shell volume as the vent valve on top of the secondary container (shell) is opened. If tritium is detected, the vent valve is closed and a special procedure for further handling is prepared. If no tritium is detected in the shell, the valve is closed, the aluminum cover and wooden spacer are removed and the PC is exposed. The PC is inspected for matching serial numbers, visual damage, type of valve, and type of connection fitting per reference 4. Install PC on process connector, leak test the line by rate of pressure rise method, and unload contents per reference 5 or 6. The PC is evacuated until pressure is less than 130 microns for 30 minutes per reference 5 or 6.

The PC is loaded to a maximum of 1200 torrs. The PC valve is determined to be closed by a rate of rise pressure test. (A rise of 7 microns of pressure or less over 40 minutes at 50 microns pressure is acceptable.) The loaded PC is removed from the loading station, put in the shell and a Cajon^R cap with a new gasket is installed after the fill valve. The PC serial number is matched with the shell. The PC is again monitored for tritium which must be less than 8×10^{-5} microcuries/cc. The spacer and cover are installed and the cover of the shell is bolted in place, after the rubber O-ring and groove are verified to be in good condition. Lead seals are installed through two of the bolts, 180° apart. The shell is decontaminated to less than 50 c/m/200 cm^2 beta/gamma. The shell vent valve is closed and sealed using a numbered aluminum tag and a lead seal. The open pipe is capped with a pipe cap. The LP-50 loading and shipping procedure (reference 7) is used, verifying that the PC in the shell is loaded and ready to be placed in an LP-50 overpack shipping drum. Reference 8 is sent with the PC to indicate the valve used (per reference 9).

The shipping drum is opened and inspected for moisture, significant defects, or damage. The sealed PC shell containing the PC is placed in the overpack. The insulation cover is installed. A thin disk of insulation is placed on the cover. The drum lid is secured with a bolted locking ring and a lead seal per reference 9.

The overpack is labeled with two Military shipment labels (Form DD 1387), two Radioactive White I labels (Parag. 172.436), one red Flammable Gas label (Parag. 172.417), and one Cargo Aircraft only label (Parag. 172.448). (The labeling paragraph number is from Hazardous Materials Regulations of the Department of Transportation, Bureau of Explosives, Tariff # BOE-6000-F, effective 4-3-87.) The sealed overpack is decontaminated to less than 150 d/m/100 cm^2 beta/gamma. Procedure (reference 7) is completed by recording the drum serial number, the PC number, and verifying that the shipment has been prepared in compliance with procedures. The date is recorded when the container will be at 2/3 of proof test pressure at 25°C to provide the customer with the time period when the PC would never be subjected to pressures beyond which it has been tested.

The shipment is transferred to the DOE with Courier Receipt, DOE Form AD60 as a record.

These methods provide effective control and have been in use for several hundred shipments during the past decade.

6.2 Procedure for Unloading the LP-50 Package

The overpack is received from DOE using procedure, reference 3. The overpack is monitored for radioactivity. The locking ring bolt seal is broken and the drum lid and top insulation are removed. The PC and shell are removed and inspected for proper seals (180° apart on lid bolts and shell vent valve) and any obvious damage. The PC is placed in a protective ventilated hood and is unloaded per procedure (reference 5 or 6).

6.3 Preparation of Empty LP-50 Packaging for Transport

An empty contaminated LP-50 PC is prepared and transported in a manner identical to that for a loaded PC. Residual radioactive gas is always present from outgassing from the container walls. An "empty" tag is attached to the handle of the LP-50 shell.

6.4 Testing, Cleaning, and Repair

Product containers are pneumatically tested at greater than 1.5 times their maximum normal operating pressure. The tests are certified and the PC's are marked and dated. Certification of tests is valid for one year or until the PC has been used three times, whichever occurs first. This work is done using procedure, reference 10, and certified with procedure, reference 11.
Preparation for repair involves verifying the container to be empty and the PC valve open, heating to 125°C for six hours while continuing to evacuate, cooling to room temperature, and evacuating to less than 200 microns. This is done with procedure, reference 12. Installation of a new Cajon 4VCR connector in place of a compression fitting tube or damaged Cajon connector on a Hoke valve is done with procedure, reference 13. Removing the valve and installing a new Hoke valve with Cajon 4VCR connector is done with procedure, reference 15 and 14 respectively.

6.5 Appendix

6.5.1 References

1. DPSOL 232-H-804, Rev. 17, Loading Product Container LP-50
2. DPSOL 232-H-2050A or 2050B, Rev. 2, Load/Unload Product Containers at CR Hood Station A or B.
3. DPSOL 232-H-208, Rev. 9, Receiving LP-12 and LP-50 Product Containers
4. DPSOL 232-H-821, Rev. 3, Product Container Stations Fittings and Valves.
5. DPSOL 232-H-813, Rev. 17, Unloading Product Container LP-50 on the TS Flange
6. DPSOL 232-H-806, Rev. 4, Unloading Product Container LP-50 on the PL Flange
7. DPSOL 232-H-114, Rev. 9, LP-50 Loading/Shipping Verification
8. DPSOL 232-H-812, Rev. 3, Shipping Product Containers - Identification of Valves
9. DPSOL 232-H-814, Rev. 9, Preparing and Shipping Product Container LP-50
10. DPSOL 232-H-1414, Rev. 10, Pressure and Leak Testing Product Containers LP-12 and LP-50
11. DPSOL 232-H-113, Rev. 8, Certification of Pressure Test - Product Containers
12. DPSOL 232-H-1540, Rev. 6, Preparing Product Containers for Repair
13. DPSOL T-901004, Rev. 0, Welding Cajon Fitting on Product Container Valve
14. DPSOL T-901045, Rev. 0, Replacing Product Container Valve
15. DPSOL T-901046, Rev. 0, LP-50 Product Container Valve Removal

Revision numbers are provided for reference. Procedures are periodically reviewed as needed and revised with management approval.

6.5.2 Labels

		Number used per container
Form DD 1387	Military Shipment Label	2
DOE Form AD60	Courier Receipt	1
	Radioactive White I	2
	Red Flammable Gas, diamond	1
	Cargo Aircraft Only	1

7.0 ACCEPTANCE TESTS AND MAINTENANCE PROGRAM

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7.0 ACCEPTANCE TESTS AND MAINTENANCE PROGRAM

7.1 Acceptance Tests

7.1.1 Visual Inspection of New Containers

Product containers of the design shown in this SARP were last fabricated in 1968 and at that time the PC was inspected for bulges, dents, mars, or other obvious physical defects on receipt at the plant. The inside was flushed with Freon^{R1}TF or Freon^{R1}PCA followed by absolute ethyl alcohol to verify the cleanliness of the container.

Containers used for current shipments are inspected according to 6.1. The shipping packaging is inspected for obvious damage. The insulation is visually checked for voids or cracks. The PC is dimensionally checked by fitting it in a shell.

7.1.2 Structural and Pressure Tests

The maximum normal operating pressure (from 2.4.4) is 29.17 psia - 14.7 = 14.47 psig. Each PC is pneumatically tested with helium gas at a pressure of 1.5 times maximum normal operating pressure (MNOP) or 22.7 psi in accordance with procedure, reference 6.5.1,[10]. The concavity of the bottom is verified to be within specifications and that no permanent deformation is indicated.

7.1.3 Leak Testing

Each PC is leak tested at 1.5 times MNOP with helium. Leak testing is performed per procedure, reference 6.5.1,[10]. A leak rate of 7×10^{-8} atm cc/sec or less is acceptable.

7.1.4 Valves

Valves are checked for operability and are leak tested during the tests noted in section 7.1.3.

7.1.5 Test for Shielding Integrity

Not applicable. No penetrating radiation is present.

7.1.6 Thermal Acceptance Test

The maximum temperature of the product containers is estimated at 177°F when in equilibrium with the shipping drum during the most severe environmental conditions (130°F and full sunlight). This is considerably below the threshold temperature of 285°F, above which significant breakdown of Celotex^{R} insulation occurs. Therefore, no further thermal testing is necessary.
Samples of the Celotex^{R} insulation of the existing shipping drum overpacks indicate that the material is acceptable.

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* Du Pont trademark.

7.2 Maintenance Program

7.2.1 Structural and Pressure Tests

The PC is structurally tested at 12-month intervals or before every fourth usage, whichever occurs first, by a repeat of pressure test specified in 7.1.2.

7.2.2 Leak Tests

The PC is helium leak tested at the same time as in 7.2.1 at 1.5 times MNOP. The leak rate must be less than 7×10^{-8} atm cc/sec helium with a test sensitivity better than 1×10^{-9} atm cc/sec helium.

7.2.3 Valve Replacement

The closure valve for the PC is replaced when it no longer provides an effective seal or is stuck. Before maintenance work, a PC is evacuated to the low micron range and heat decontaminated for 6 hours at 125°C according to procedure, reference 6.5.1,[12]. The defective valve is removed per procedure, reference 6.5.1,[15] and a new valve is installed per procedure, reference 6.5.1,[14] (Appendix B). The PC is then retested per procedure, reference 6.5.1,[10].

The original LP-50 was fabricated with a Fulton Sylphon 1-314 packless needle valve with facility for leak testing the bellows, figure 7A. A simplier design of Fulton Sylphon 314A packless needle valve was used later, figure 7B. Both valves needed frequent replacement due to seat leakage. The Fulton Sylphon valves were replaced with an improved valve with lower leakage rate i.e., the Hoke TY 445 Model #4 Figure 7C (valve Type IIIA). Operating experience and improved valve design technology resulted in the latest Hoke 4213X2 packless valve which is the present day replacement valve Figure 7C (valve Type IIIA Modified). It has a lower leak rate, higher proof pressure, positive opening and closing feature and reduced maintenance (see Section 3.3.2.2). Future valve replacements are planning to use the Hoke 4213x2 valve with a directly welded Cajon 4VCR fitting as shown in Figure 7D (Type IIIB)

Containers with the original Fulton Sylphon valves or containers with newer valves that do not meet the leak test specification have valves replaced according to procedures i.e. Ref. 6.5.1,[15] for valve removal and Ref. 6.5.1,[14] for valve installation. (A copy of the valve installation procedure is included in Appendix B. As operating experience is gained, procedures are reviewed periodically and revised and may differ from the copy in this SARP.). The valve installation maintenance procedure is used to restore the container to original equipment quality and includes the following safety aspects: use of an improved reliability Hoke valve, a welding procedure written to ASME Section IX requirements and a welder certified to ASME requirements for this procedure. The weld must be a fillet weld with 3/16" leg as specified in procedure Ref. 6.5.1,[14] and the socket depth must be not less than 5/32". Weld inspection must be done by a welding inspector certified to inspect and dye penetrant test each weld pass. The welding inspector must read and understand the applicable procedures before starting the job and will observe the job to ensure procedures are followed. The fillet weld must be dye penetrant tested (by a certified welding inspector) and verified to have a 3/16 inch leg using the criteria in DuPont SW60W for class III welds. All documents, and certifications are placed in the QA file under each LP-50 container serial number.

A leak test is performed (Ref. 6.5.1,[10]) before loading the container.

7.2.4 Miscellaneous

The PC shell and shipping drum are visually inspected prior to each use for obvious physical damage. The insulation is inspected for excessive moisture before the PC is installed in its shell.

The gasket in the PC Cajon^R fitting is replaced after each loading.

The O-ring for the shell is inspected prior to each use and replaced as necessary.

At the present time, all valves with compression fittings (Figure 7C, valve Type IIIA) are refurbished to remove the compression fitting and replace with a stainless steel Cajon^R 4VCR fitting (Figure 7C, type IIIA Modified). The Cajon fitting is preferred by customers because of ease of use, better sealing characteristics and standardization. The replacement of the compression fitting with a Cajon fitting is described in Ref. 6.5.1.[13]. (A current revision of the procedure is shown in Appendix B. With improved repair techniques and as operating experience is gained the procedure is reviewed and updated by periodic revision (see 8.6) and may differ slightly from the copy included in Appendix B of this SARP.) In order to ensure original or improved containment, the main safety aspects of this fitting replacement maintenance procedure are: use of a welding procedure written to ASME Section IX requirements and a welder currently certified for the procedure. Weld inspection must be done by a welding inspector certified to inspect and dye penetrant test each welding pass. The weld inspector must read and understand the applicable procedures before starting the job to ensure the procedures are followed. Completed full penetration butt welds must be radiographed (ASME Section V, Article 2) and approved by an American Society for Non-Destructive Testing (ASNT) certified R. T. Level III inspector using the criteria in DuPont SW60W for Class III welds. All documents, radiographs and certifications are placed in the QA file under each LP-50 container serial number.

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[1] During periods of prolonged storage, the pressure and leak tests are not required at these intervals, but they are required prior to shipment.

8.0 QUALITY ASSURANCE REQUIREMENTS

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8.0 QUALITY ASSURANCE REQUIREMENTS

8.1 Organization

Tritium production management is responsible for quality assurance of the shipping packaging. Quality assurance in the Atomic Energy Division of the Petrochemicals Department of E. I. du Pont de Nemours and Co. is an integral part of the operation. This provides a system of checks at all organizational levels that ensures the work produced by any group is scrutinized by other groups over which the producing group has no control.

8.2 Quality Assurance Program

8.2.1 Procedures

Written Quality Assurance (QA) procedures for the design and fabrication of the LP-50 packaging are not available, as this packaging was constructed over two decades ago (8.3 and 8.4). Quality Assurance is incorporated in the operating and maintenance procedures (chapters 6 and 7) and on the design drawings (Fig. 1 to 7D).

8.2.2 Approval

The operating and maintenance procedures are reviewed and approved by Production, Works Engineering, Technical, and Quality supervision through the Plant Staff Level (Department Superintendents).

8.2.3 Safety Related Items

Primary safety related items are the product container, the PC Hoke packless valve, the overpack insulation, and the 18 gage shipping drum. The aluminum shell, the Hoke toggle valve, and Cajon^{R} fitting are secondary safety items.

8.2.4 Training

Personnel are trained by Production supervision using approved operating procedures. An Operator Training Status book is maintained for each operator in the unit. The training status is continually updated. As procedure revisions are issued and reviewed with the operator, the status book is dated and initialed.

8.3 Design Review

This subsection is not applicable for the original LP-50 packaging. The subject packaging was designed, fabricated, and has been in service for over two decades. The drawings in this SARP reflect "as built" and current configuration of the LP-50.

8.4 Procurement Document Control

Procurement of the LP-50 packaging described in the SARP was completed over two decades ago. Available documentation and container verification tests have been placed in the Quality Assurance Record file. Past purchases of LP-50 shipping packages followed the guidelines specified in Du Pont Specification No. 3300. (See 8.19.1.) Purchases of safety related items (8.2.3) are according to procurement levels in the SRP Quality Assurance Manual. Replacement Hoke packless valves are purchased and Cajon^R fittings attached. Material certification and test results are placed in the Quality Assurance Record file (LP-50 730000 459) located in Bldg. 703-A, E16-B.

8.5 Instructions, Procedures, and Drawings

All production and maintenance work of repair, testing, loading, shipping and packaging is performed in strict accordance with written operating procedures or DPSOLs (refer to Chapters 6 and 7).

8.6 Document Control

Operating procedures and drawings are given independent reviews by two levels of Production supervision and two levels of Technical Assistance and Quality personnel. The SRP Quality Assurance Manual requires a review of procedures at least every two years.

Documents to be controlled are plant drawings and procedures. Drawing changes must be approved by Production, Technical Assistance, Works Engineering personnel and the Design Group. The Plant Records Division maintains a file of the latest revisions.

8.7 Control of Purchased Material, Equipment, and Services

Procurement of the LP-50 packaging was completed over two decades ago. Inspections and tests have been performed on a random sample of the existing containers. Items tested were: dimensional verification, densities of insulation (per Military Spec. MIL F26862A except as specified on the drawing), and verification that the drums were fabricated per Military standard MS63054, except as specified on the drawing. The result of these inspections and tests have been included in the Quality Assurance record file located in Building 703-A, E16-B.

8.8 Identification and Control of Materials, Parts, and Components

Procurement of the LP-50 packaging was completed over two decades ago. Verification of material used in the LP-50 packaging is listed in section 8.7. Past packaging purchases were made per Du Pont Specification No. 3300 refer to 8.19.1.

8.9 Control of Special Processes

Fabrication of the LP-50 packaging was completed over two decades ago. The manufacturer of the product container and shell is no longer in business. Fabrication is according to DuPont Specification 3800, refer to 8.19.1. Nondestructive physical testing of the PC ensures that the welding meets the needs of this container. The manufacturer of the steel drums has certified that fabrication was per Military standard MS 63054, except as specified on the drawing.

New welding procedures have been developed to provide a butt weld for the Cajon 4VCR to valve tube and a socket fillet weld for the container to valve tube connection. These welds are made by procedures which are in conformance in form to Section IX, ASME Boiler and Pressure Vessel Code. The procedures have been qualified by destructive and nondestructive tests, the manual welds are made by welders certified with these qualified procedures. Refer to Section 7 of this SARP. Each full penetration butt weld is x-rayed in three views and read by an RT level III trained radiologist who certifies the weld is an ASME Section IX quality weld. Each pass of the socket fillet weld is dye penetrant checked by a qualified weld inspector.

8.10 Inspection

Inspection activities for past purchases of LP-50 shipping packaging have followed the guideline specified in Du Pont Specification No. 3300. This specification indicates mandatory inspection holdpoints, inspection records, welding data, and other pertinent tests required to ensure quality. Welds for valve replacement and Cajon fitting installation are inspected as described in 8.9.

8.11 Test Control

8.11.1 Preoperational Test Program

Preoperational pressure and leak tests of each product container are described by procedure (6.5.1,[10]). The tests are certified by the packaging supervisor on a certification procedure (6.5.1,[11]). The certification sheet is kept in a permanent central file for the life of the container. The pressure and leak test is valid for 1 year or three fillings of the PC unless the PC is damaged or altered. The Building 232H senior line supervisor is responsible for the calibration and testing of new PC's and retesting of the containers prior to loading and shipment.

The procedures used for testing are reviewed and approved by both Production and Technical management to the Plant staff level.

8.11.2 Acceptance Tests and Maintenance Program

When returned from a customer, the PC is physically inspected for damage and pertinent physical dimensions. The valve is verified to be the proper type for shipment and correctly installed. Before every fourth use or annually, the PC is pneumatically pressurized to 8 psig with helium gas. The PC valve is closed and the container placed in a vacuum chamber without a cap on the Cajon^{R}4VCR SS fitting, the chamber is evacuated to 100 microns or less absolute pressure. This results in a pressure differential across the wall of the product container and valve seat seal equal to 22.7 psid, which results in the same unit stress on the PC and valve as a 22.7 psig pressure test with the external of the PC under atmospheric conditions. A helium leak test is then made at this 22.7 psi differential (1.5 times maximum normal operating pressure). The vacuum chamber pressure and leak test is repeated with a cap on the Cajon^{R}4VCR SS fitting and the valve open. This tests the valve bellows and secondary Cajon^{R} seal to the same leak rate specification. The leak test is acceptable if the detectable helium is 7×10^{-8} atm cc/sec or less. The date of the first test is engraved on the PC top disk per (6.5.1,[10]).

Before each use the PC is inspected for obvious physical damage, the serial numbers of the primary and secondary containers are verified to be in agreement, and the valve is determined to be in working order. The PC is vacuum tested for leakage of 1 micron or less in 10 minutes at 250 microns or less per (6.5.1,[1]).

8.12 Control of Measuring and Test Equipment

8.12.1 Calibration

A Heise pressure gage or Precise/Sensotec transducer will be zeroed prior to loading when the system pressure is in the low micron pressure range. These gages are compared annually to a gage recently certified by the Savannah River Plant Standards Laboratory. (The Laboratory maintains standards directly traceable to the National Bureau of Standards). When calibrated a tag displaying the expiration date for the instrument will be affixed to the indicator.

Helium leak detectors are calibrated with a calibrated "standard" leak each time the detector is used.

8.12.2 Primary Standards

New Precise or Sensotec transducers are calibrated by the Savannah River Plant Standards Laboratory annually so they can be used as transfer standards. These instruments are installed in strategic process locations for comparison with process instruments at a variety of pressure readings.

The standard helium leak is calibrated versus a known leak. The known leak is calibrated by PVT determinations with a certified leak supplied by Sandia Laboratory. (Sandia Laboratory supplies certified leaks for DOE.)

8.13 Handling, Storage, and Shipping

The written operating procedures in section 6.4 cover the handling and storage of LP-50 packaging components. The PC in shells are stored inside plant buildings in regulated areas or in locked vaults, which have ventilation systems monitored for tritium beta radioactivity.

Shipment of LP-50 packages is by DOE truck under the supervision of DOE couriers, contract air carrier, or by common carrier for commercial shipments.

8.14 Inspection, Test, and Operating Status

The PC is pneumatically tested at 1.5 times maximum normal operating pressure in accordance with 8.11.2. The two leak tests: 1. valve seat and 2. container closed with secondary seat is acceptable only if detectable helium is 7×10^{-8} atm cc/sec or less for each. This work is done per procedure (6.5.1,[10]). Certification form procedure (6.5.1,[11]) is completed and kept on file as long as the packaging is in use.

The PC, the shell, and the lid are engraved with the date of the first pressure and leak test and the model number which is the drawing number per procedure (6.5.1,[10]) step C-9.

The operating status of a PC and shell is recorded on a tag attached to the handle of the shell as noted in the operating and testing DPSOLs.

8.15 Nonconforming Material, Parts, or Components

8.15.1 Disposition

Damaged or nonconforming containers are tagged as per procedure 6.5.1,[5]. A tag is attached to the shell handle and a supervisor notified. The PC and shell are moved to a segregated storage area.

The supervisor (maintenance coordinator) issues a non conformance report for the nonconforming container. The coordinator is responsible for the repair and/or disposal of nonconforming containers.

8.16 Corrective Action

Operating personnel report the damage or nonconformance of a PC or shell to supervision. Operating supervision notifies the maintenance coordinator who directs the specific action to be taken: a) repair, or b) ensure that the PC is empty before disposal by burial. (If a product container leaks due to valve or Cajon fitting damage, repair is made by replacement of the component, any other PC damage is referred to the maintenance coordinator for specific action).

8.17 Quality Assurance Records

Records are kept in the Plant Records Division (PRD) Quality Assurance File Number LP-50 30000 459 in 703-A E16-B Central File.

8.18 Audits

The Raw Materials and Tritium Quality Department conducts independent surveillances of Tritium Department operations. The surveillance program meets the criteria outlined in NQA-1. Annually, a surveillance is conducted on the LP-50 loading and unloading operations.

8.19 Reference

8.19.1 Specification

1. Du Pont Specification No. 3300, "Vacuum Tank and Shipping Container." (Appendix C)

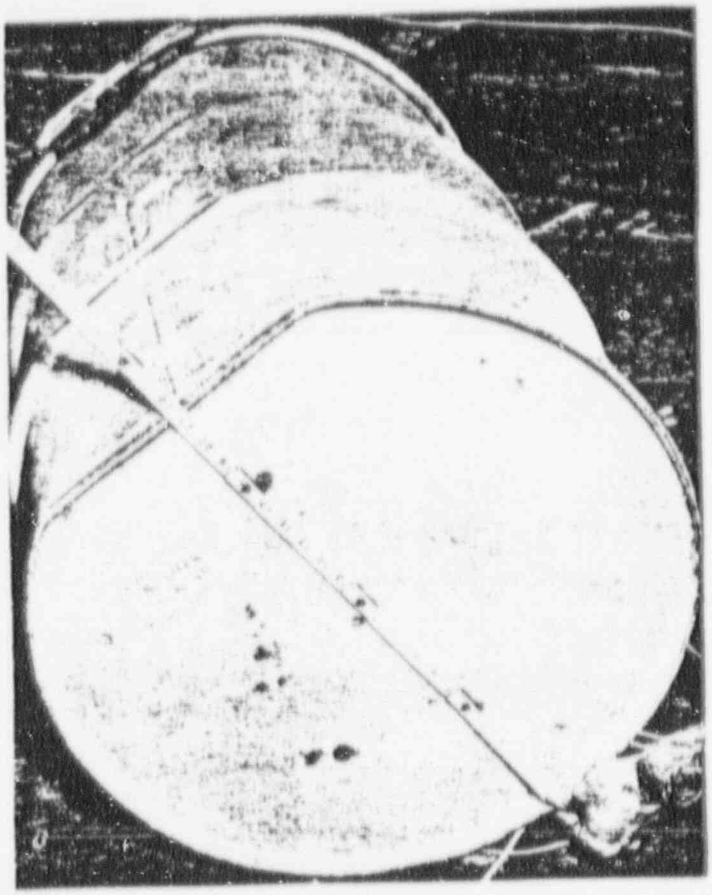

FIGURE 8. FIRST FIRE TEST – EFFECT OF 30-FOOT DROP ON SIDE

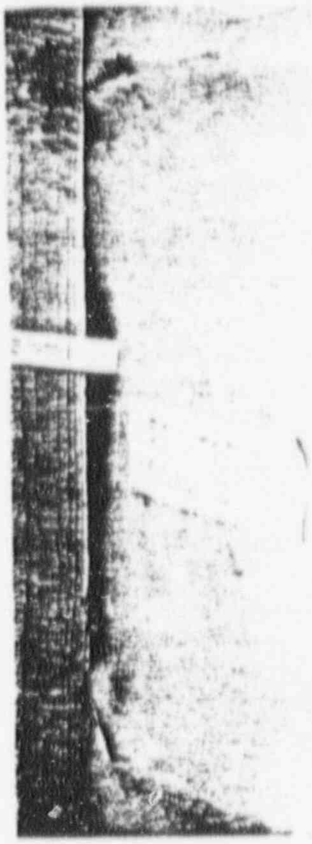

FIGURE 9. FIRST FIRE TEST – EFFECT OF 40-INCH DROP ON 6-INCH PISTON

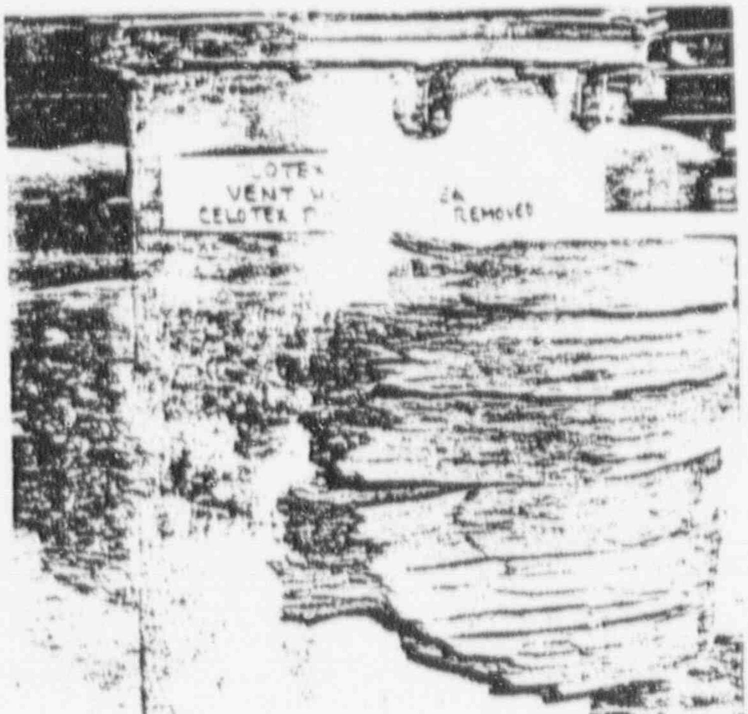

FIGURE 10. FIRST FIRE TEST – EFFECT OF SMOLDERING IN AREA OF VENT HOLES

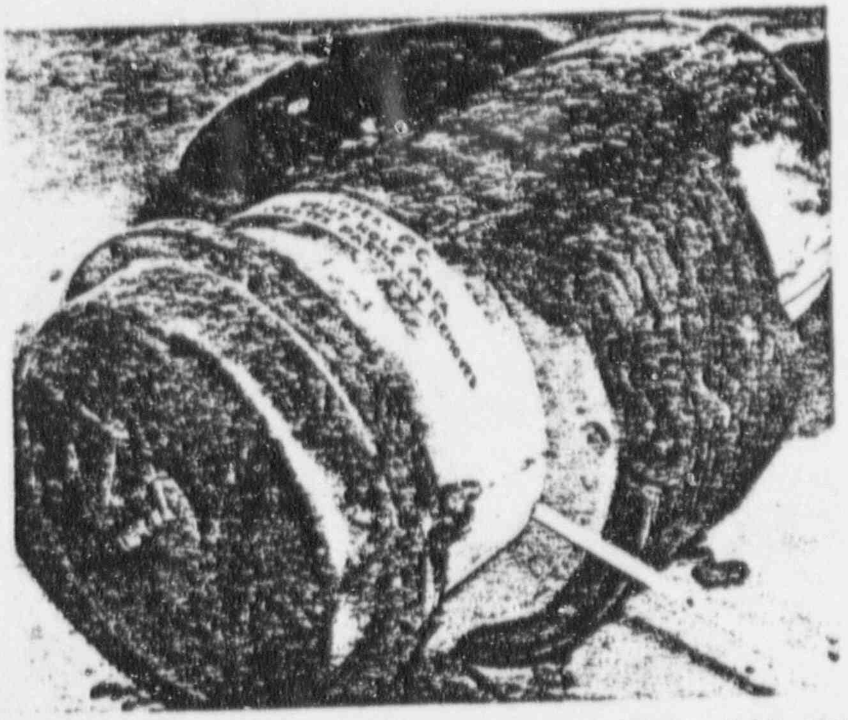

FIGURE 11. FIRST FIRE TEST – UNBURNED "CELOTEX" AWAY FROM VENTS

FIGURE 12. FIRST FIRE TEST – EFFECT OF SMOLDERING ON BOTTOM "CELOTEX" DISK NEAR VENT

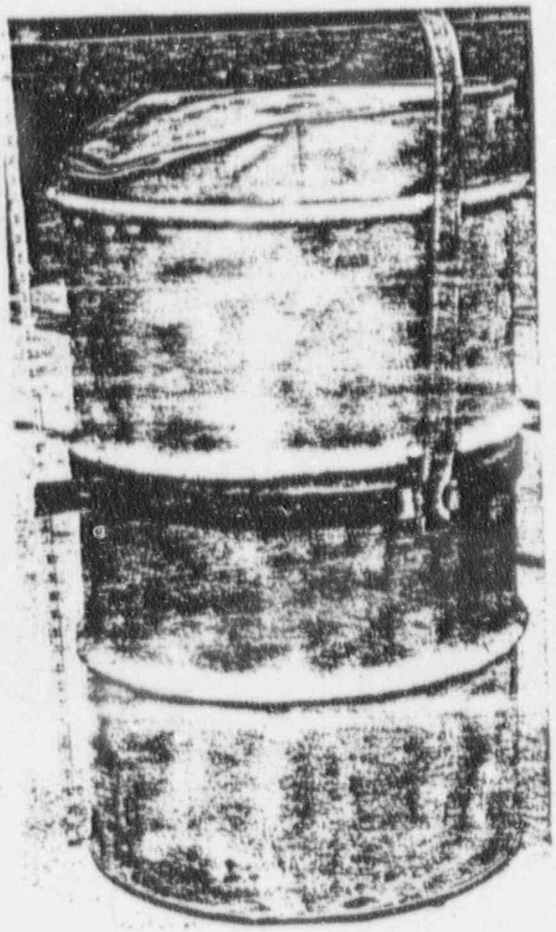

FIGURE 13. SECOND FIRE TEST – EFFECT OF 30-FOOT DROP ON END OF DRUM AND OF PISTON DROP

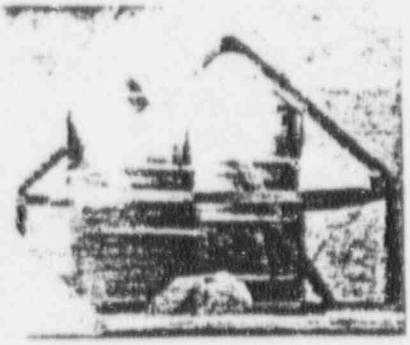

FIGURE 14. SECOND FIRE TEST – VIEW IN FURNACE DURING TEST
(Tritium Container on Left)

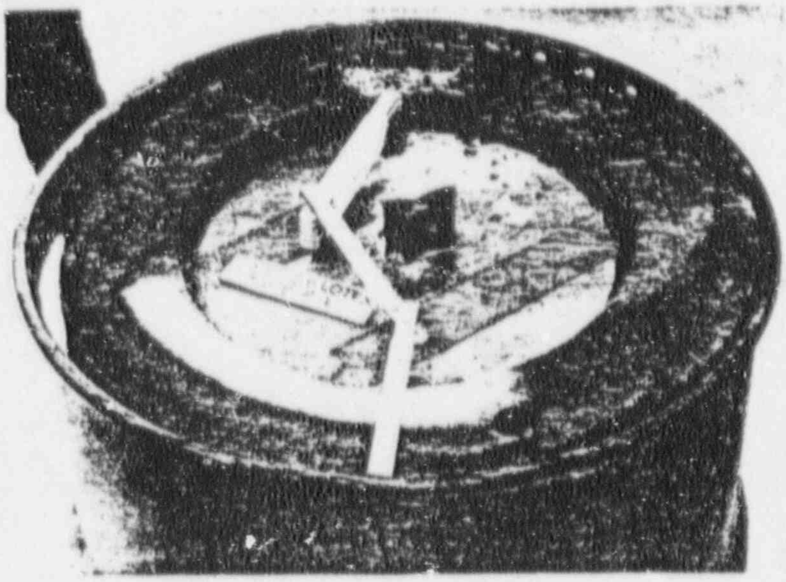

FIGURE 15. SECOND FIRE TEST – EFFECT OF SMOLDERING NEAR VENTS

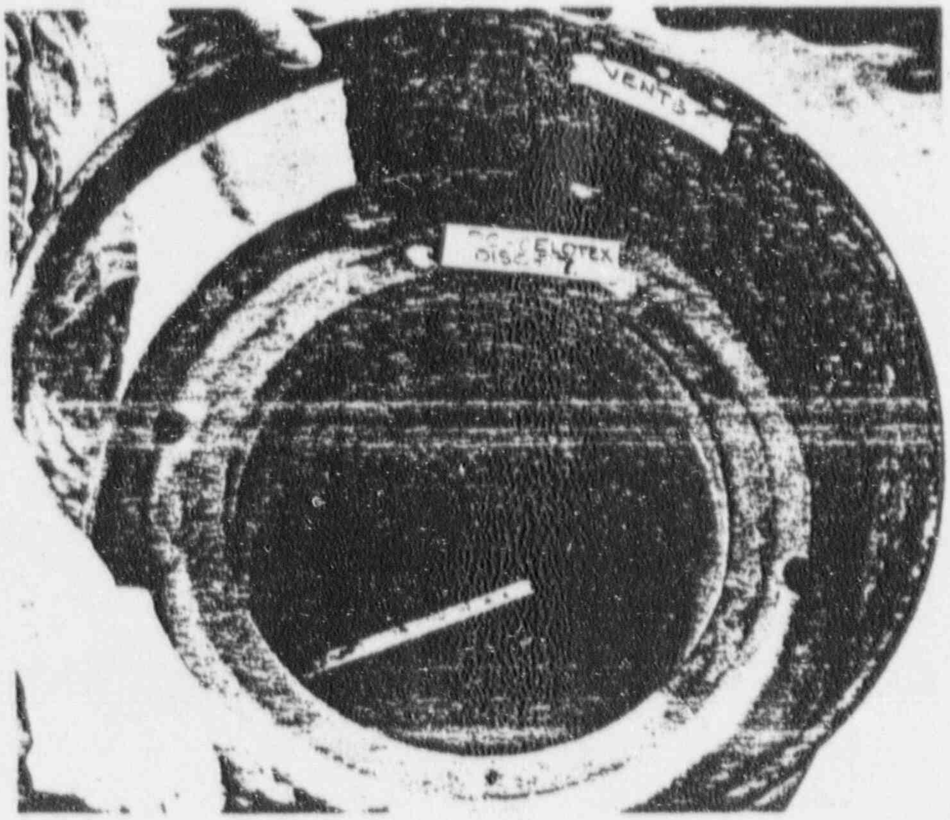

FIGURE 16. SECOND FIRE TEST – SHOWING GOOD CONDITIONS OF "CELOTEX" BELOW VENTS

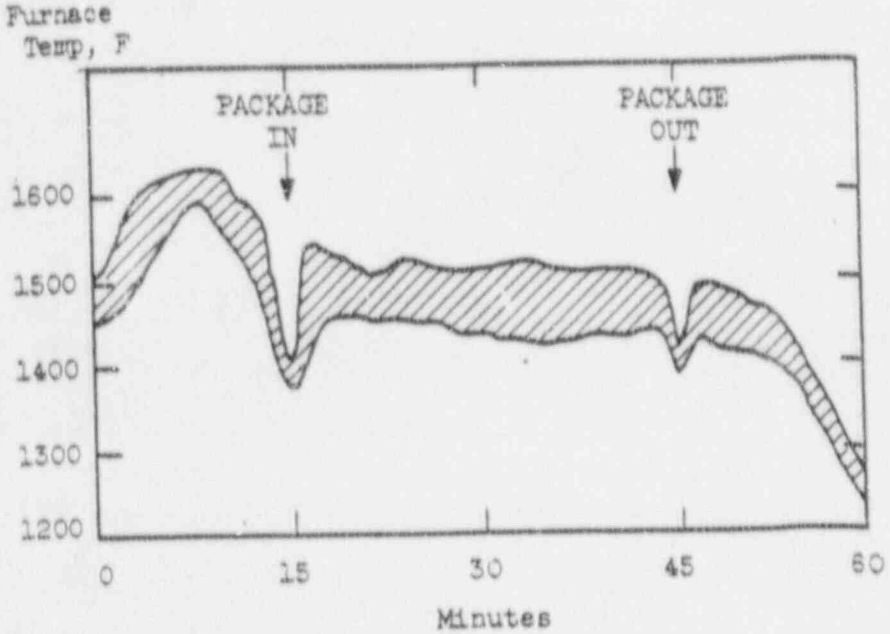

FIGURE 17. FIRE TEST TEMPERATURE

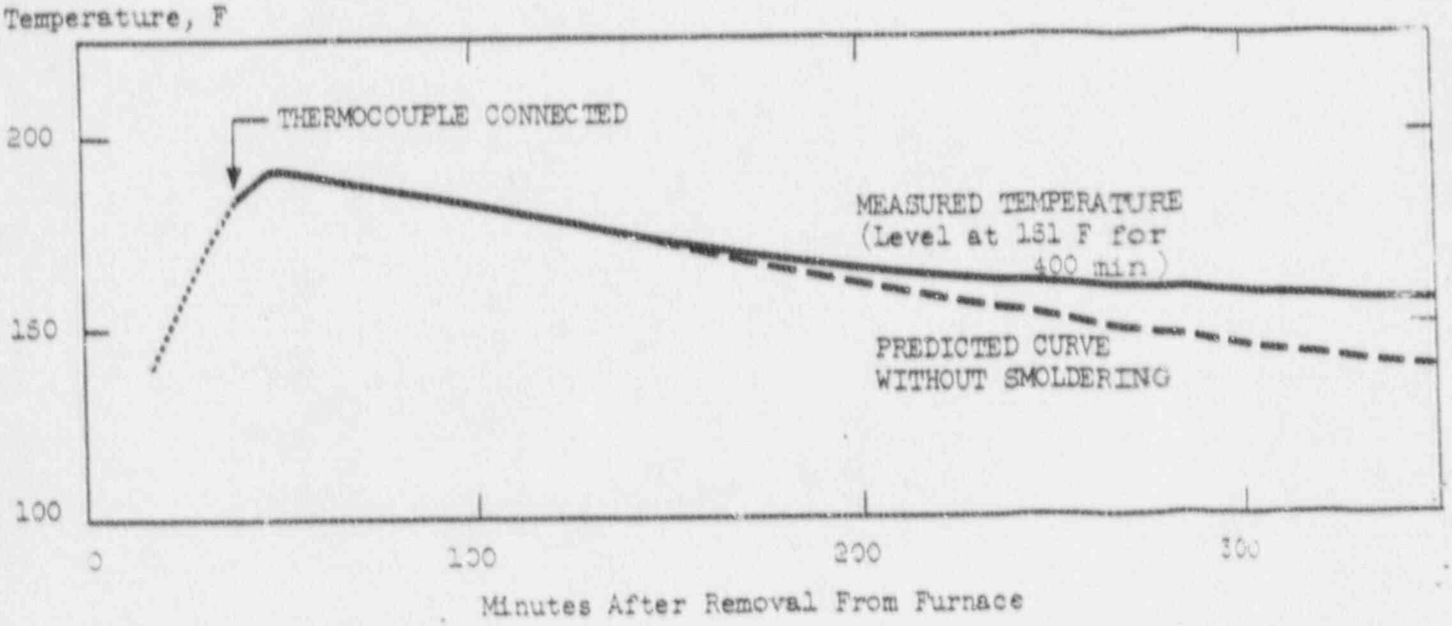

FIGURE 18. ALUMINUM VESSEL TEST TEMPERATURE

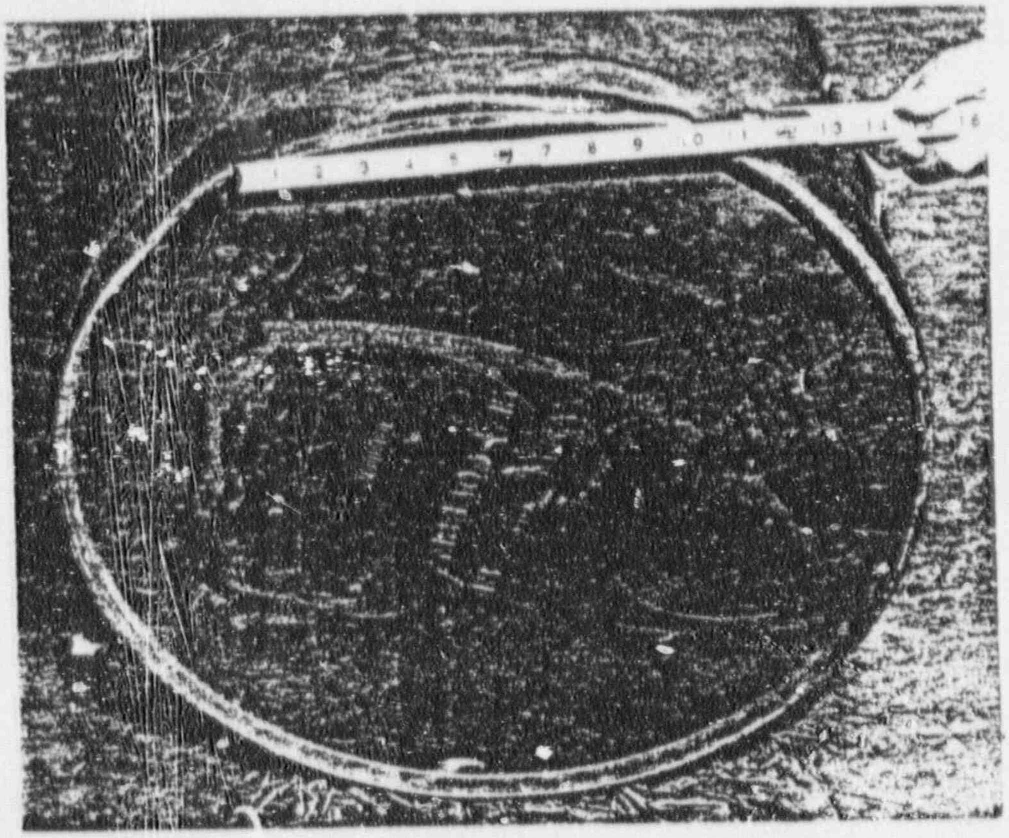

FIGURE 19. FOUR-FOOT DROP ON BOTTOM EDGE

FIGURE 20. FOUR-FOOT DROP ON TOP EDGE

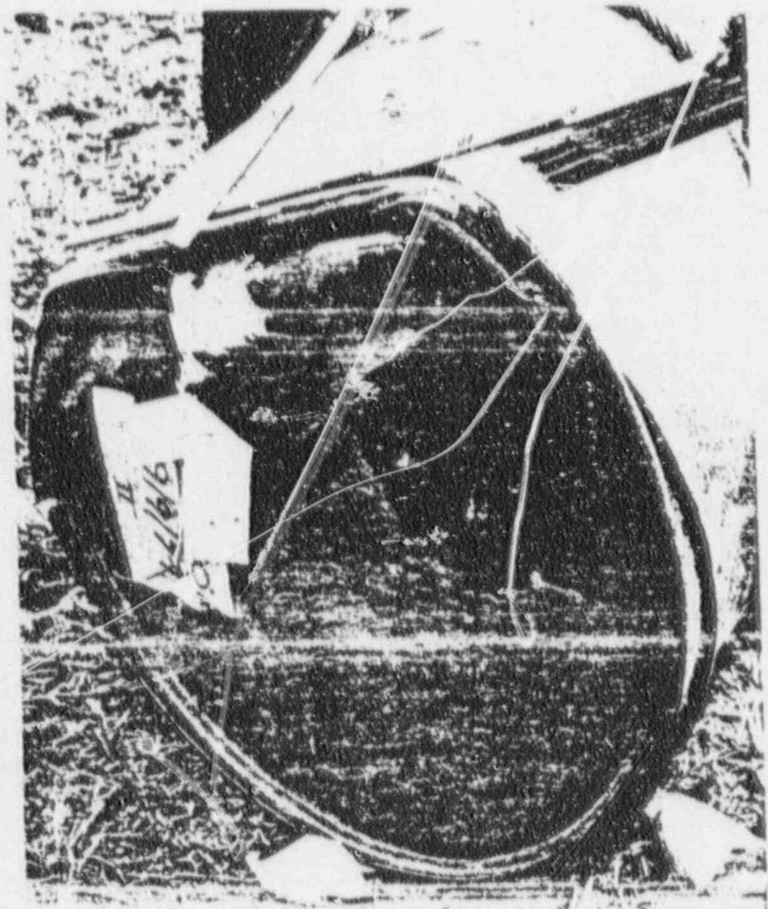

FIGURE 21. THIRTY-FOOT DROP AT 15° TO HORIZONTAL

Appendix A

DPST-79-[illegible]

TECHNICAL DIVISION
SAVANNAH RIVER LABORATORY

DISTRIBUTION:

J. N. Beatty, SRP
P. A. Croll
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M. R. Caverly
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G. G. Chalfan
R. H. Towell
R. L. Folger
T. L. Capeletti
TIS File (2)

March 6, 1979

TO: I. B. NEW

FROM: R. G. DERRICK

STRAIN GAGE MEASUREMENTS ON TYPICAL LOW-PRESSURE PRODUCT CONTAINERS (PC)

To assure that SRP Product Containers comply with NRC off-plant shipping regulations[1], typical containers were selected from the three standard sizes (1, 12, and 50 liter) and tested to determine the amount of strain produced by an external pressure of 40 psig. Only one location, at the bottom edge of the 50 liter PC, exhibited a significant level of strain (0.005 in./in.). These tests were completed in April 1978 and results were reported informally to SRP personnel at that time.

Test Procedures

Prior to pressure testing, SRP Equipment Engineering Division measured wall thickness, using an ultrasonic technique, at selected locations on each of the shipping containers used in the test. Locations and results of the measurements are summarized in Figure 1 and Table I, respectively. No significant variations in wall thickness were detected.

---

(1) Nuclear Regulatory Report 10 CFR, Paragraph 71, Point [illegible] B.

Strain gages were attached at various locations on each type of container tested as indicated in Figure 2 and Table II. The gages were biaxial gages (CEA-09-125UT-120)[2] installed to measure strain in the longitudinal and circumferential directions at each location on the containers.

The containers were then tested using the following procedure:

1. Container was installed in the bell jar in Building 236-H, evacuated, leak checked, and back-filled with one atmosphere helium.
2. Bell jar was secured, evacuated, leak checked, and back-filled with one atmosphere of helium.
3. Strain gages were balanced while maintaining the one atmosphere helium environment inside both the container and the bell jar.
4. Strain measurements were made periodically while
   a) The PC was evacuated and
   b) Pressure in the bell jar was increased to 25 psia.

When steps 4a and 4b were completed, the net differential pressure between the outside and inside of the PC was approximately 40 psia.

Test Results

Only one location, on the 50 liter shipping container, showed any significant amount of strain at 40 psia. Maximum strain for that condition was 0.005 in./in. at the curved surface where the bottom and side walls of the container meet (usually called the knuckle). Results of these tests are summarized in Tables III, IV, and V for the 1, 12, and 50 liter containers, respectively.

RGD:ce

Table I. Summary of Ultrasonic Wall Thickness Measurements on Product Containers Prior to Pressure Testing

		1 Liter Container S/N SRP-0676-04-T1 (inch)	12 Liter Container S/N 82 (inch)	50 Liter Container S/N 858 (inch)
Top	1	.115	.105	.085
	2	.115	.105	.085
	3	.115	.105	.085
Middle	1	.110	.070	.080
	2	.110	.075	.080
	3	.110	.080	.080
Bottom	1	.265	.115	.085
	2	.265	.115	.085
	3	.265	.115	.085
Center		.265	.115	.085

Table II. Strain Gage Locations on the 1, 12, and 50 Liter Product Containers (see Figure 2)

Gage Location	Gage No.	Location on Circumference (degrees)
1	1 and 2	0°
2	3 and 4	180°
7	15 and 16	90° next to weld
8	17 and 18	0° on weld
3	5 and 6	90°
4	7 and 8	270°
9	9 and 10	180° on weld
5	11 and 12	0°
6	13 and 14	center of bottom

Table III. Results of Strain Gage Measurements on 1 Liter Product Container S/N SRP-0676-04-T1

Gage* Location	Gage #	Gage** Direction	Strain Gage Measurements (με)***								
1	1	L	0	+50	+44	+44	+44	+42	+42	+42	+40
1	2	T	0	-13	-22	-26	-38	-50	-58	-71	-82
2	3	L	0	+12	+14	+14	+19	+18	+20	+20	+20
2	4	T	0	- 8	-16	-20	-28	-36	-44	-52	-62
4	7	L	0	+10	+15	+13	+ 6	-20	-42	-57	-38
4	8	T	0	+ 8	+12	+13	+15	+15	+13	+14	+13
5	11	L	0	+100	+113	+121	+134	+142	+145	+153	+160
5	12	T	0	+93	+99	+101	+106	+106	+104	+105	+104
External Pressure (psi)			0	5	9.9	14.7	19.7	24.7	29.7	34.7	39.7

* Gage Location: See Table II and Figure 2.

** Gage Direction: L is longitudinal direction.

T is circumferential direction.

*** One με unit = 1×10^{-6} inch/inch.

Table IV. Results of Strain Gage Measurements on 12 Liter Product Container S/N 82

Gage* Location	Gage #	Gage** Direction	Strain Gage Measurements (με)***								
1	1	L	0	-31	-55	-74	-121	-140	-176	-198	-237
1	2	T	0	- 5	- 6	-14	- 20	- 27	- 29	- 29	- 35
2	3	L	0	-39	-77	-98	-138	-186	-234	-272	-316
2	4	T	0	- 7	-11	-16	- 24	- 28	- 38	- 45	- 53
4	7	L	0	+ 5	-18	-31	- 56	- 47	- 50	- 44	- 52
4	8	T	0	-15	-32	-44	- 62	- 78	-100	-120	-142
5	11	L	0	- 7	+ 2	+ 3	+ 10	+ 26	+ 34	+ 49	+ 81
5	12	T	0	+40	+83	+102	+143	+187	+222	+258	+283
7	15	L	0	-68	-127	-173	-249	-317	-385	-457	-533
7	16	T	0	-26	- 46	- 57	- 85	-103	-138	-162	-189
External Pressure (psi)			0	5	9.9	14.7	19.7	24.7	29.7	34.7	39.7

* Gage Location: See Table II and Figure 2.

** Gage Direction: L is longitudinal direction

T is circumferential direction.

*** Gage με unit = 1 × 10^{-6} inch/inch.

Table V. Results of Strain Gage Measurements . 50 Liter Product Container S/N 858

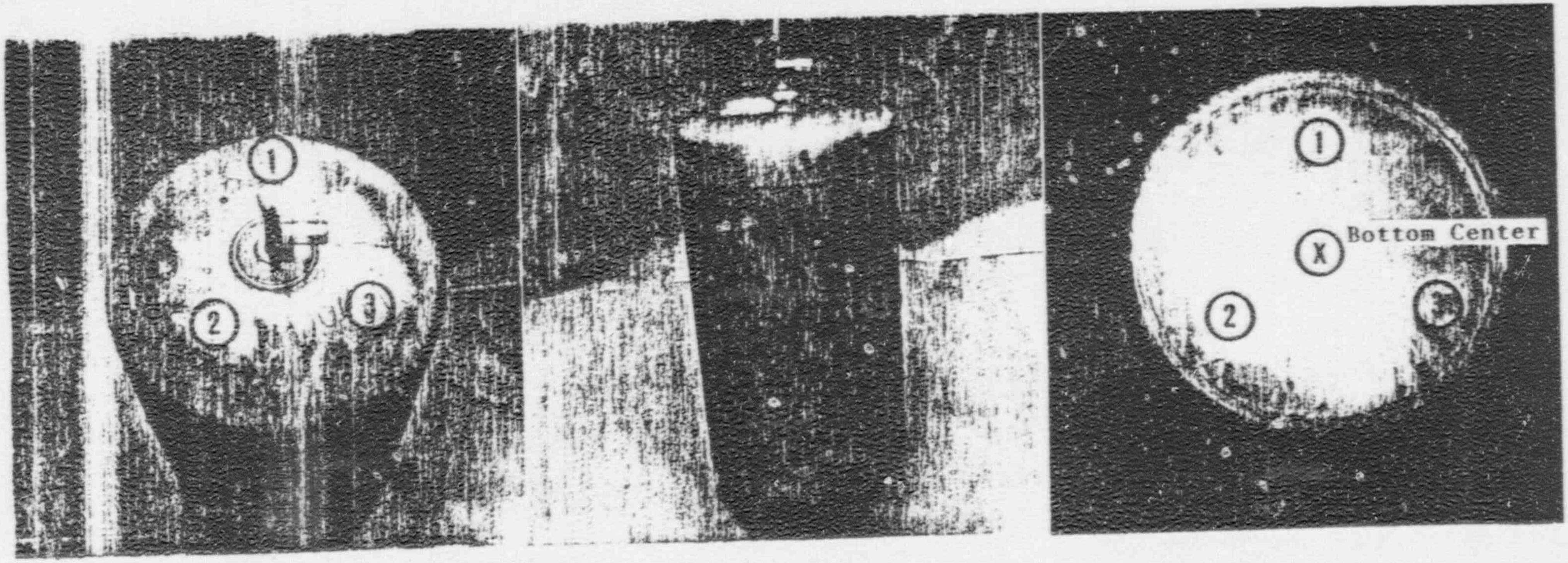
Gage* Location	Gage #	Gage** Direction	Strain Gage Measurements (με)***								
1	1	L	0	-16	-17	-29	-36	-44	-60	-74	-88
1	2	T	0	-16	-17	-25	-33	-42	-57	-72	-88
2	3	L	0	-19	-23	-38	-51	-67	-86	-105	-125
2	4	T	0	-16	-17	-25	-33	-44	-60	- 72	- 87
3	5	L	0	+ 4	+ 7	+19	+24	+25	+25	+ 22	+ 24
3	6	T	0	-15	-17	-20	-36	-51	-70	- 92	-110
4	7	L	0	+ 8	+ 9	+12	0	+18	+40	+ 41	+ 46
4	8	T	0	- 5	- 1	0	0	+ 2	+ 2	+ 2	+ 6
9	9	L	0	-11	-10	-40	-44	-48	-58	- 68	- 75
9	10	T	0	-22	-25	-42	-58	-74	-93	-116	-135
5	11	L	0	+155	+222	+345	+514	+688	+1003	+1978	+5300
5	12	T	0	+32	+49	+70	+97	+130	+141	+168	+168
6	13	L	0	+13	+25	+33	+46	+58	+71	+77	+74
6	14	T	0	+11	+20	+25	+38	+48	+58	+59	+82
7	15	L	0	-41	-52	-87	-128	-164	-201	-242	-278
7	16	T	0	-27	-32	-53	-79	-102	-124	-152	-172
8	17	L	0	- 7	- 6	- 3	- 3	- 5	- 8	-14	-20
8	18	T	0	-18	-19	-31	-38	-46	-52	-63	-70
External Pressure (psi)			0	5	7.9	14.7	19.7	24.7	29.7	34.7	39.7

* Gage Location: See Table II and Figure 2.

** Gage Direction: L is longitudinal direction

T is circumferential direction.

*** One με unit = 1 x 10^{-6} inch/inch.

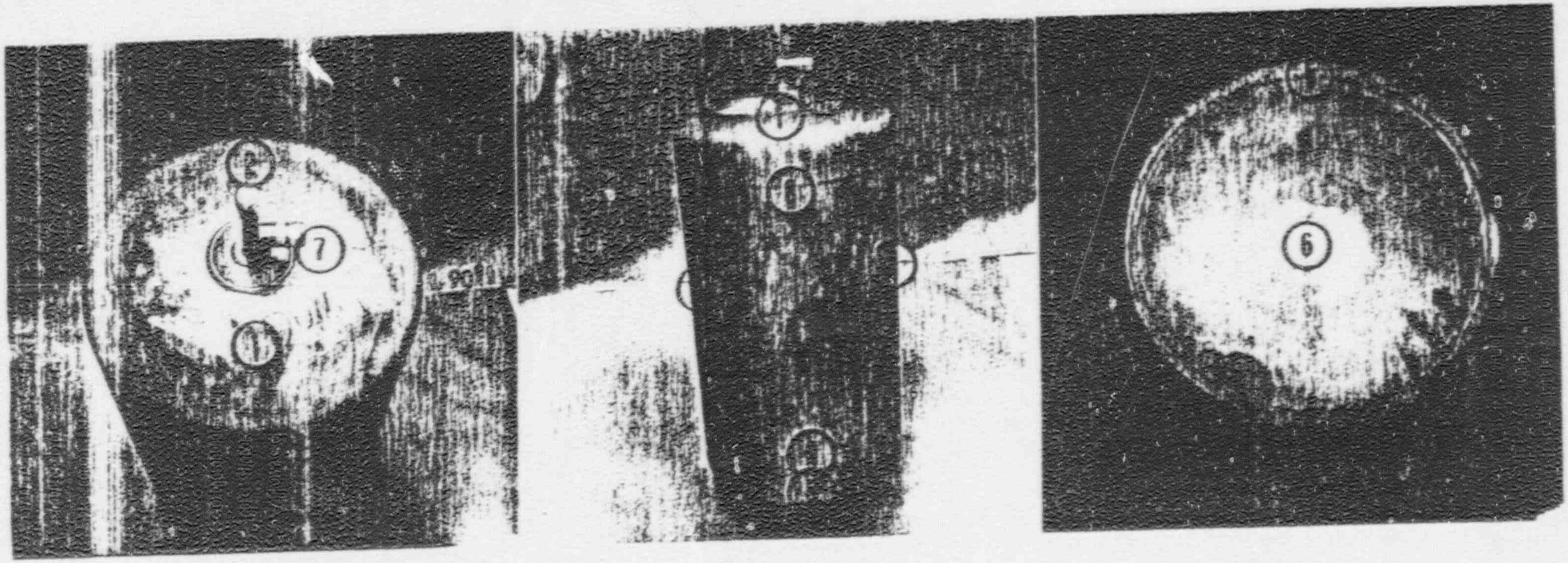


a) Top View

b) Front View

c) Bottom View

Figure 1. Location of Ultrasonic Wall Thickness Measurements on Product Containers Prior To Pressure Testing - Three Equally Spaced Locations on Top, Middle, and Bottom Locations and a Single Measurement in the Bottom Center.



a) Top View

b) Front View

c) Bottom View

Figure 2. Strain Gage Locations on the 1, 12, and 50 Liter Product Containers (See Table II).

Appendix B

DO NOT REMOVE from SRP
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TRITIUM DEPARTMENT - TWE
DPSOP Ref 297-1
TRITIUM FACILITIES

DPSOL T-901004
Revision 0
Approval Date: 3/28/88
Category 3
Page 1 of 7

WELDING CAJON FITTING ON PRODUCT CONTAINER VALVE

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*denotes revisions to this DPSOL

FREQUENCY:
As requested

REFERENCES:
Procedure Qualification Record 2-T -T2 (Attachment 1)
Du Pont Engineering Standard, SW60W (Weld Integrity - Metallic Piping Systems)
DPSOL T-901004A (Summary Sheet for DPSOL T-901004)
DPSOL 232-H-1540 (Preparing Product Containers For Repairs)
DPSOL 232-H-821 (Product Container Stations - Fittings and Valves)
DPSOL 232-H-812 (Shipping PC's - Identification of Valves & Containers)
DPSOL 232-H-1414 (Pressure and Leak Testing Product Containers)
Drawing S5-2-10158 or S5-2-187 (LP-50 Product Container)
Drawing S4-2-633 (Product Container Valve Type III-B)
Drawing S4-2-659 (LP-50 PC Valve Sub-assembly)
Drawing S5-2-2168 (Product Container Valves Type III A&B Modified and Copper Heat Sink)

GENERAL LIMITATIONS:
1) This DPSOL is for information and reference only. DPSOL T-901004A serves to document completion and approval of job.
2) Certified welding inspector must observe job and dye check root pass and final weld before completion of job.
3) The welder must be currently certified under Welding Procedure Specification 2-T, which applies to stainless steel GTAW welding, as well as 2-0T, which was developed specifically for this procedure.
4) The welding inspector must read and understand this procedure, as well as Welding Procedure Specification 2-0T, before beginning work.
5) Completed weld radiographs, the Radiograph Inspection Report, and Data Sheet #1 must be forwarded to the Quality Assurance file in the Tritium Technology Office, 235-H, Room 143.

INFORMATION:
The purpose of this DPSOL is to provide a procedure for welding a CAJON fitting onto a Hoke valve. If the valve is already welded to a product container, a plastic suit is required and the job will be performed in the 232-H regulated maintenance area of 232-H. This procedure also applies to welding CAJON fittings onto new valves which have not yet been placed on a container. This job will be performed in a clean shop.

TOOLS AND EQUIPMENT:

Male and female CAJON 4 VCR fittings, with gasket
Hoke Valve (Type TY445, 4213X2, or 4213Q6Y)
Hacksaw
Tungsten Inert Gas Welding machine with foot pedal control
0.045" diameter ER-308L stainless steel filler rod (with identifying label)
Stainless steel wire brush
Welding shield and gloves
Completely outfitted plastic suits (where required)
Freon TF
De-burring device
Flat file
Custom-made alignment clamp
DC Ammeter
Right-angle Borescope
Foam wad (ear plug)
Copper heat sink assembly (see S5-2-2168)
1/8" argon purge tube
Wood screw
Engraver
Q-Tips
Temperature pencil (175-225°F) (optional)
Argon cylinder, stores or construction supply (sampling required, see Procedure)

AUTHORIZATION:

1) Obtain an authorized Work Request Card
2) Obtain a Work Clearance Permit

SAFETY:

1) Comply with Plant General Safety Rules and DPSOP 326 (E & I Safety Procedures).
2) Observe safe welding practices, including eye and hand protection.
3) The stainless steel container (without the shell, etc.) weighs 32 lbs. and may be lifted by one person.
4) A complete plastic suit is required for the welder and the welding assistant when working on a contaminated LP-50.
5) Comply with requirements of DPSOL 200-FH-2 and DPSOP 40-1.

PROCEDURE:

NOTE: Certain steps in this procedure must be verified in DPSOL T-901004A by initialing and dating. These steps are indicated by a '+' at the beginning.

1) +Assemble a complete CAJON VCR fitting (with male and female nuts and gasket). Prepare the male CAJON fitting by filing away the countersink with a flat file. Remove ID and OD burrs. Clean away metal filings with Freon TF.

2) +Record argon purity on Summary Sheet before beginning welding. If using bottled argon, the purity should be posted on the cylinder. If using argon from Construction's tank, results from a sample taken after the last refilling should be kept in the Maintenance Shop. If results are not posted, request Operations Supervisor to sample. Argon purity, when rounded to one decimal place, must be 99.9% or greater.

3) +Verify that welding machine and torch are set-up within limits described in Welding Procedure Specification 2-OT, which is attached. It will be necessary to adjust the welding machine with a DC ammeter each day that PC welding is performed. In addition, if the welding current must be deviated from the set value, this value and the reset normal value must be measured. (The welding current for each PC is recorded on DPSOL T-901004A.)

4) Operations will supply either a PC with a good Hoke valve, or a new Hoke valve. Operations will also supply a unique identification number for the valve (PCV###).

5) Engrave number on back of Hoke valve.

6) Verify that valve is closed. If valve is on container, lay container on its side. If valve is separate, clamp horizontally in vise.

7) Squeeze and roll foam wad to minimum diameter. Insert into valve tube beyond cut line. (See Figure 1 for cut location)

8) Using a hacksaw, cut off compression fitting on valve. Locate cut just below diameter increase, approximately 13/32" from valve body. (Figure 1) If necessary, file a flat at cut location to aid in starting the cut. Take care to keep cut perpendicular to axis of tube. If cutting a CAJON fitting that was already welded near this location, cut just below center of weld and file away excess weld cap to regain proper wall thickness (maximum OD: 0.386").

9) Using file, flatten and smooth the cut surface. The filed surface should be as perpendicular as possible.

10) De-burr both ID and OD of cut surface.

11) Remove foam wad from valve tube by twisting wood screw into it and pulling.

12) Clean with Freon/TF-wetted Q-Tips. If valve is separate from container, blow air through other end. It is extremely important that no filings remain in valve or tube. This could damage the valve seat and cause a product leak.

13) Install copper heat sink block on valve with mounting screws.

14) If valve is separate, clamp assembly in vise vertically. Otherwise, set PC container in upright position.

15) Using alignment clamp, position complete CAJON fitting assembly on valve. Fitting with male nut is butted to valve. (See Figure 1) Check that tubes are butted together and that alignment is good. ID misalignment will be verified by radiography to be less than 0.02" (per SW60W). (Note: Use of alignment clamp may not be possible with certain valves previously equipped with CAJON fittings.)

[NOTE: Welding Procedure Specification 2-OT applies to Steps 15 through 22.]

16) Place argon purge tube through fitting and below weld position. Check for adequate argon tank capacity. Start argon purge.

17) Tack weld fitting onto valve by placing electrode through opening on alignment tool.

18) Remove alignment clamp. Check for good alignment and centering. Make any necessary adjustments. (If off-center, file off tack and go back to Step 15.)

19) Weld first pass intermittently for full penetration using no filler metal. Maintain argon blanket on weld while hot. Brush weld clean.

20) +After weld cools, examine ID of weld with borescope for full penetration. If lack of full penetration is found, re-weld area and re-examine.

21) +Weld inspector inspect root pass for cracks by using dye penetrant test. If flaws are found, rework.

22) Replace argon purge and weld cover pass intermittently with filler metal. If possible, limit weld cap diameter to that of the larger tube. (This will simplify X-ray evaluation.) Maintain argon blanket on weld while hot. Brush weld clean.

23) +Weld inspector inspect cover pass by using dye penetrant test. If flaws are found, rework.

24) +Have weld radiographed on 3 views (120° apart) by PTL radiographer. Radiograph to conform to Section V, Article 2 of the ASME Code. Use a low voltage X-ray source, using the 1T hole on a #5 ASME pentrameter to indicate sensitivity.

25) Forward the original copy of this procedure to the Procedure Coordinator for file.

NOTE: The radiograph films, Weld Radiographic Inspection Report, and Data Sheet #1 for the repair made are to be sent to EED, RT Level III to be read. He will certify the weld to be according to SW60W Class III, or will indicate deviations. The film and reports item 24 are returned to 232-H, Room 117 and placed in the QA file for the LP-50 containers, which is arranged by container number.

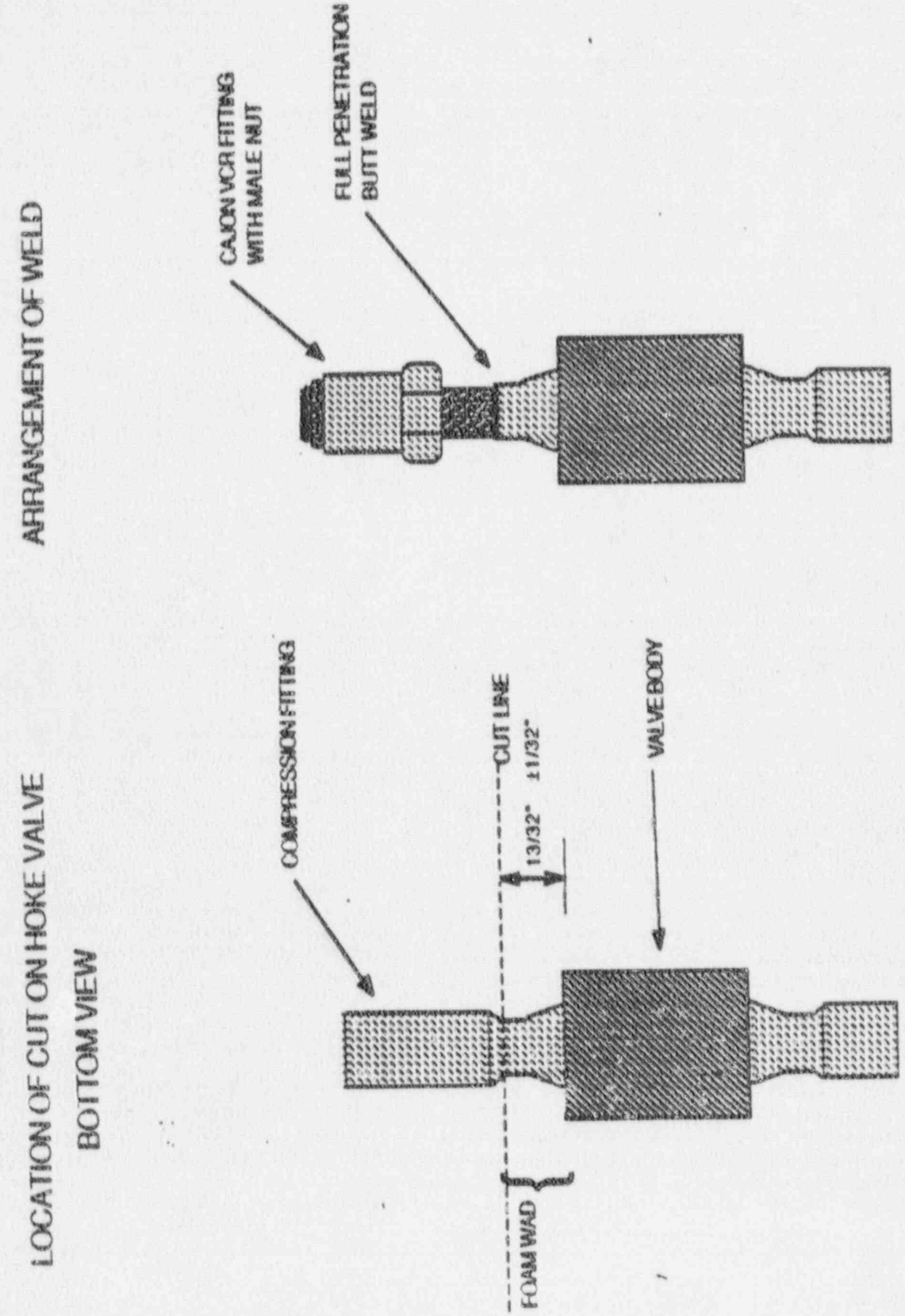
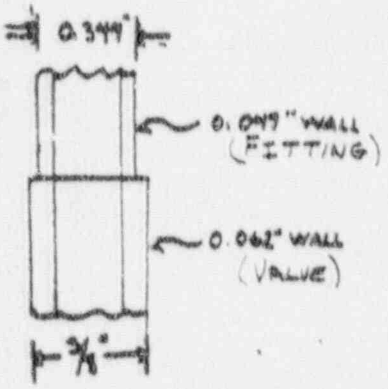

ARRANGEMENT OF WELD
CAJON VCR FITTING WITH MALE NUT
FULL PENETRATION BUTT WELD
LOCATION OF CUT ON HOKE VALVE
BOTTOM VIEW
COMPRESSION FITTING
CUT LINE
13/32" ±1/32"
VALVE BODY
FOAM WAD

FIGURE 1

QW-483 SUGGESTED FORMAT FOR PROCEDURE QUALIFICATION RECORD (PQR)
(See QW-201.2, Section IX, ASME Boiler and Pressure Vessel Code)

Company Name E. I. Du Pont (Savannah River Plant)
Procedure Qualification Record No. 2-T-T2 Date 12/29/87
WPS No. 2-T
Welding Process(es) Gas Tungsten Arc Welding (GTAW)
Types (Manual, Automatic, Semi-Auto.) Manual

JOINTS (QW-402)



Groove Design Used

BASE METALS (QW-403)
Material Spec. SA213
Type or Grade 304-L Tube to 316 Tube
P-No. 8 to P-No. 8
Thickness 0.047" to 0.062"
Diameter 3/8" Tubing
Other

FILLER METALS (QW-404)
Weld Metal Analysis A-No. 8
Size of Electrode 0.045" 2nd Pass Only
Filler Metal F-No. 6
SFA Specification 5.9
AWS Classification ER 308-L
Other 1st Pass: No Filler Metal
2nd Pass: 0.045" ER 308-L

POSITION (QW-405)
Position of Groove Vertical Fixed (2G)
Weld Progression (Uphill, Downhill) N/A
Other

PREHEAT (QW-406)
Preheat Temp. N/A
Interpass Temp. N/A
Other

POSTWELD HEAT TREATMENT (QW-407)
Temperature N/A
Time N/A
Other

GAS (QW-408)
Type of Gas or Gases Argon 20 SCFH
Composition of Gas Mixture 99.9%
Other Backing Gas: 10 SCFH

ELECTRICAL CHARACTERISTICS (QW-409)
Current DC
Polarity Straight
Amps. 20-34 Volts 10-13
Other

TECHNIQUE (QW-410)
Travel Speed N/A
String or Weave Bead String
Oscillation N/A
Multipass or Single Pass (per side) Multiple Passes
Single or Multiple Electrodes Single
Other

QW-483 (Back)

Tensile Test (QW-150)

Specimen No.	Width	Thickness	Area	Ultimate Total Load lb.	Ultimate Unit Stress psi	Character of Failure & Location
1			0.0130	1,802	138,615	Broke in Tube
2			0.0130	1,611	123,923	Broke in Tube

Guided Bend Tests (QW-160)

Type and Figure No.	Result
3 - Face QW 463.2 (g)	Satisfactory
4 - Root QW 463.2 (g)	Satisfactory
5 - Face QW 463.2 (g)	Satisfactory
6 - Root QW 463.2 (g)	Satisfactory

Toughness Tests (QW-170)

Specimen No.	Notch Location	Notch Type	Test Temp.	Impact Values	Lateral Exp.		Drop Weight	
					% Shear	Mils	Break	No Break
	N/A				N/A			

Fillet Weld Test (QW-180)

Result — Satisfactory: Yes N/A No ______ Penetration into Parent Metal: Yes ______ No ______

Macro—Results ______

Other Tests

Type of Test Radiograpny (3 shots taken 120° apart) Accepted per SW60W Class III by Marc Loibl

~~Deposit Analysis~~ ______

Other Leak test, accepted Max. leak rate 2.10^9 by J. M. Googhnour

Welder's Name C. M. Gantt Clock No. 2569 Stamp No. 8T

Tests conducted by: E. I. Du Pont Laboratory Test No. PCV 1,2,3,4,5

We certify that the statements in this record are correct and that the test welds were prepared, welded and tested in accordance with the requirements of Section IX of the ASME Code.

Manufacturer E. I. Du Pont Company

Date December 29, 1987 By ______

(Detail of record of tests are illustrative only and may be modified to conform to the type and number of tests required by the Code.)

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DPSOP Ref 297-1
TRITIUM FACILITIES

DPSOL T-901004A
Revision 0
Approval Date 3/28/88
Category 2
Page 1 of 1

SUMMARY SHEET FOR DPSOL T-901004
WELDING CAJON FITTING ON PRODUCT CONTAINER

This DPSOL is a summary and data sheet for Category 3 DPSOL T-901004, Rev. 0. All necessary instructions and references are found in that document.

Work Request Number __________ Date Work Performed __________

LP-50 Number __________ PC Valve Number PCV__________

Check one:

- New CAJON VCR fitting replacing contaminated compression tube _____
- New CAJON VCR fitting replacing damaged or existing CAJON fitting _____
- New CAJON VCR fitting replacing compression tube on new Hoke valve _____

	Initial/Date
1) Argon purity _____% (99.9% purity required).	____________ (Mechanic)
2) CAJON 4 VCR fitting filed and cleaned.	____________ (Mechanic)
3) Valve tube cut, filed, and cleaned.	____________ (Mechanic)
4) Weld conforms to PQR No. 2-T-T2 ( ) Yes ( ) With Exceptions Welding current: _____Amps. Exceptions: ______________________________	____________ (Weld Insp.)
5) Borescope shows full penetration on root pass.	____________ (Weld Insp.)
6) Root pass passed dye penetrant test.	____________ (Weld Insp.)
7) Final weld acceptable by dye penetrant test	____________ (Weld Insp.)

DPSOL T-901004, Rev. 0 completed with any exceptions noted and initialed on back of this form

______________________________ Certified Welder/Date

______________________________ Certified Welding Insp./Date

Weld radiographed 100% per Section V of ASME code. (3 views at 120°)

______________________________ PTL Radiographer/Date

Radiograph Inspection passed
Yes _____ No _____ (Check)

______________________________ RT Level III, EED/Date

Attach Weld Inspection Report and radiograph film to this sheet and forward to the Product Container Quality Assurance file, 232-H, Room 117.

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DPSOP Ref 297-1
TRITIUM FACILITIES

DPSOL T-901045
Revision 0
Approval Date: 3-28-88
Category 3
Page 1 of 6

REPLACING PRODUCT CONTAINER VALVE

*denotes revisions to this DPSOL

FREQUENCY:

As Requested

REFERENCES:

Welding Procedure Specification 2-T
Procedure Qualification Record 2-T-T1 (page 1 attached)
Du Pont Engineering Standard, SW60W (Weld Integrity - Metallic Piping Systems)
DPSOL T-901045A, (Summary Sheet for Replacing Product Container Valve)
DPSOL T-901004 and T-901004A (Welding CAJON Fitting on Product Container)
DPSOL 232-H-1540 (Preparing Product Containers For Repair)
DPSOL 232-H-821 (Product Container Stations - Fittings and Valves)
DPSOL 232-H-812 (Shipping PC's - Identification of Valves & Containers)
DPSOL 232-H-1414 (Pressure and Leak Testing Product Containers)
Drawing S5-2-10158 or S5-2-187 (LP-50 Product Container)
Drawing S4-2-633 (Product Container Valve Type III-B)
Drawing S4-2-659 (LP-50 PC Valve Sub-assembly)
Drawing S5-2-2168 (Product Container Valves Type III-A and III-B Mod.)

GENERAL LIMITATIONS:

1) This DPSOL is for information and reference only. DPSOL T-901045A serves to document completion and approval of job.
2) Certified welding inspector must observe job and dye check both weld passes before completion of job.
3) The welder must be currently certified under Welding Procedure Specification 2-T, which applies to stainless steel GTAW welding.
4) The welding inspector must read and understand this procedure, as well as Procedure Qualification 2-T-T1, before beginning work.
5) DPSOL T-901045A must be forwarded to the Quality Assurance file in the Tritium Technology office, 232-H, room 117.

INFORMATION:

The purpose of this DPSOL is to provide a procedure for replacing the valve on a product container. This procedure does not include the removal of the old valve and tubing. A 1/2" diameter socket, with a minimum depth of 5/32" and a maximum depth of 1/4", is required on the PC before beginning this procedure. This job requires a plastic suit and will be performed in the 232-H regulated shop.

TOOLS AND EQUIPMENT:

Hoke Valve (type TY445, 4213X2, or 4213Q6Y) fitted with male CAJON fitting
CAJON 4 VCR blind cap and gasket
Tungsten Inert Gas Welding machine
1/16" diameter ER-308L stainless steel filler rod (with identifying label)
Stainless steel wire brush
Welding shield and gloves
Completely outfitted plastic suits (where required)
Freon TF
Rags
Q-Tips
Round file
Engraver
DC Ammeter
Foam wad (ear plug)
Temperature pencil (175 - 225°F) (optional)
Argon cyliner, stores or construction supply (sampling required, see Procedure)
Copper heat sink (1/4" x 2" x 6" bevelled plate with matching holes and set screws)
Two (2) 1/64" thick shim
Vise grip pliers for 1/2" tube
Fillet weld gage (supplied by welding inspector)

AUTHORIZATION:

Obtain an authorized Work Request Card
Obtain a Works Clearance Permit

SAFETY:

1) Comply with plant and Tritium area safety rules.
2) Observe safe welding practices, including eye and hand protection
3) The stainless steel container (without the shell, etc.) weighs 32 lbs. and may be lifted by one person.
4) A complete plastic suit is required for the welder and the welding assistant when working on a contaminated LP-50.
5) Have Health Protection monitor tritium stack losses during job.

PROCEDURE

NOTE: Certain steps in this procedure must be verified in DPSOL T-901045A by initialing and dating. These steps are indicated by a '+' at the beginning.

1) +Verify that argon cylinder to be used has been analyzed. (Analysis from lab should be posted on cylinder.) If not, request operations supervisor to sample. Minimum purity is 99.9% (as rounded to 3 significant digits). Record argon concentration on DPSOL T-901045A.

2) Verify that the PC was back-filled with argon. Container should be taped closed unless valve removal took place immediately before this job.

3) +Verify that welding machine and torch are set-up within limits described in Welding Procedure Specification 2-1T, which is attached. It will be necessary to adjust welding machine with a DC ammeter each day that PC welding is performed. The maximum current delivered with the foot pedal completely depressed should be between 70 and 85 Amps DC. Record the set value on DPSOL T-901045A.

4) +Verify that new valve to be installed has a PCV number marked on it. Record on DPSOL T-901045A. If no number is found, obtain number from operations supervisor and engrave on valve back.

5) Verify that flow arrow on valve points toward CAJON fitting. If not, notify Operations Supervisor.

6) Attach copper heat sink assembly to valve and tighten screws.

7) Open new valve slightly to prevent container from building pressure during welding.

8) Remove tape from socket if present. Check socket for burrs or defects that would prevent insertion of 1/2" valve tube. If filing or de-burring is required, insert foam ear plug into 1/4" orifice to keep metal shavings from entering PC. Leave the cord connected to the plug and on outside of container to remove plug.

9) Clean tape adhesive and metal filings away with Freon -wetted Q-tips, then remove foam plug if used in preceding step.

10) +Measure socket depth with depth gage (thousandths of inch). Inform Operations Supervisor if less than 0.156" (5/32"). Record value on DPSOL T-901045A.

11) Place new valve into socket on Product Container. Make sure that tube is inserted completely to bottom of socket. Clamp vise grip pliers on 1/2" tube with pliers against top of container.

12) Insert 1/64" shim between pliers and top of container to raise tube off of the socket bottom.

13) Verify that torch argon flow is 20 SCFH.

14) Tack weld tube to container top between plier jaws. Remove pliers and shim.

15) Weld first pass for both fusion of joint and fillet accumulation. Use 1/16" ER-308L filler rod with 70-85 amps. Weld specifications are given in PQR 2-T-T1 (Attachment 1).

16) Keep argon purge on weld during initial cool-down. Close valve. Wire brush clean. Freon -wetted rags may be used to cool valve and container, but do not quench weld area directly.

17) +Have welding inspector check first pass visually and with dye penetrant test. If any cracks or defects are found (SW6OW Class III), rework weld area and re-check.

18) Verify that torch argon flow is 20 SCFH.

19) Weld final pass to complete fillet accumulation of 3/16" on horizontal and vertical leg. Use 3/32" ER-308L filler rod with 70-85 amps. Additional passes are allowed if necessary to achieve 3/16" leg dimension. Use 1/16" ER-308-L for additional passes. Weld specifications are given in PQR 2-T-T1 (Attachment 1).

20) Keep argon purge on weld during initial cool-down. Wire brush clean.

21) Place #4 CAJON gasket and blind cap on valve top.

22) +Have welding inspector visually inspect weld for defects and to verify that a 3/16" fillet leg has been achieved. The fillet weld gage should be used to verify weld size.

23) +Have welding inspector perform dye penetrant test on fillet weld.

24) If defects are found or additional fillet thickness is required, perform the following steps:

A) Verify argon purge.
B) Rework fillet weld. Follow PQR 2-T-T1.
C) Keep argon purge on weld during initial cool-down.
D) Wire brush clean finished weld.
E) Have welding inspector perform dye penetrant test. Repeat if defects are found.

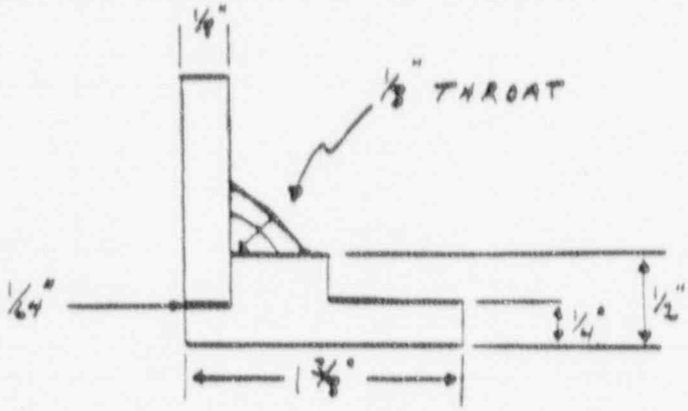
NOTE: DPSOL T-901045A should be completed and forwarded to 235-H, Room 143 and placed in the QA file for the LP-50 containers, which is arranged by container number.

QW-483 SUGGESTED FORMAT FOR PROCEDURE QUALIFICATION RECORD (PQR)

(See QW-201.2, Section IX, ASME Boiler and Pressure Vessel Code)

Company Name E. I. Du Pont Company (Savannah River Plant)
Procedure Qualification Record No. 2-T-T1 Date 3-14-88
WPS No. 2-T
Welding Process(es) Gas Tungsten Arc Welding (GTAW)
Types (Manual, Automatic, Semi-Auto.) Manual

JOINTS (QW-402)



Groove Design Used

BASE METALS (QW-403)
Material Spec. SA213 to SA240
Type or Grade 316 Tube to 304-L Plate
P-No. 8 to P-No. 8
Thickness 1/8" Tubing Wall
Diameter ¼" O.D. Tubing
Other

FILLER METALS (QW-404)
Weld Metal Analysis A-No. 8
Size of Electrode 0.045"
Filler Metal F-No. 6
SFA Specification 5.9
AWS Classification ER 308-L
Other 1st Pass: 1/16" ER 308-L
2nd Pass: 3/32" ER 308-L

POSITION (QW-405)
Position of Groove Vertical Fixed (2G)
Weld Progression (Uphill, Downhill) N/A
Other

PREHEAT (QW-406)
Preheat Temp. N/A
Interpass Temp. N/A
Other

POSTWELD HEAT TREATMENT (QW-407)
Temperature N/A
Time N/A
Other

GAS (QW-408)
Type of Gas or Gases Argon 20 CFH
Composition of Gas Mixture 99.9%
Other

ELECTRICAL CHARACTERISTICS (QW-409)
Current DC
Polarity Straight
Amps. 70-85 Volts 10-14
Other

TECHNIQUE (QW-410)
Travel Speed N/A
String or Weave Bead String
Oscillation N/A
Multipass or Single Pass (per side) Multiple
Single or Multiple Electrodes Single
Other

This form (E00007) may be obtained from the Order Dept., ASME, 345 E. 47th St., New York, N.Y. 10017

QW-483 (Back)

Tensile Test (QW-150)

Specimen No.	Width	Thickness	Area	Ultimate Total Load lb	Ultimate Unit Stress psi	Character of Failure & Location

Guided Bend Tests (QW-160)

Type and Figure No.	Result

Toughness Tests (QW-170)

Specimen No.	Notch Location	Notch Type	Test Temp.	Impact Values	Lateral Exp.		Drop Weight	
					% Shear	Mils	Break	No Break

Fillet Weld Test (QW-180)

Result — Satisfactory: Yes X No ____ Penetration into Parent Metal: Yes [illegible] No ____

Macro—Results No Indications (J. A. Morin)

Other Tests

Type of Test ____

Deposit Analysis ____

Other ____

Welder's Name B. Williams Clock No. 3830 Stamp No. H

Tests conducted by: D. T. Redd Laboratory Test No. ____

We certify that the statements in this record are correct and that the test welds were preprared, welded and tested in accordance w

the requirements of Section IX of the ASME Code.

Manufacturer E. I. Du Pont - SRP

3-14-88 By ____

ord of tests are illustrative only and may be modified to conform to the type and number of tests required by the Code.)

DO NOT REMOVE from SRP
Without Approval
TRITIUM DEPARTMENT - TWE
DPSOP Ref 297-1
TRITIUM FACILITIES

DPSOL T-901045A
Revision 0
Approval Date 3/28/88
Category 2
Page 1 of 1

SUMMARY SHEET FOR DPSOL T-901045
REPLACING PRODUCT CONTAINER VALVE

This DPSOL is a summary and data sheet for category 3 DPSOL T-901045. All necessary instructions and references are found in that document.

Work Request Number ________ Date Work performed. ________

LP-50 Number: ________ PC Valve number: PCV ________

Initial/Date

1) Argon purity (from mass spec. analysis): ______ % (99.9% required)
________ ____
(Mechani..)

2) Socket depth: ________ (thousandths of inch)
Depth MUST be deeper than 0.156 or 5/32 inch. If not deeper, notify supervisor.
____
(Mechanic)

3) Weld conforms to PQR 2-T-T1 Specifications ( ) Yes ( ) With Exceptions
Welding current: ________ Amps.
Exceptions: ________________________________
____
(Weld Insp.)

4) First pass acceptable by visual and dye penetrant test. (SW60W III)
____
(Weld Insp.)

5) Final pass acceptable by visual and dye penetrant test. (SW60WIII)
____
(Weld Insp.)

6) Fillet leg dimension is 3/16" or greater. ( ) Yes ( ) No
____
(Weld Insp.)

DPSOL T-901045 completed with any exceptions noted and initialed on back of this form.

________________ ________________
Certified Welder/Date Certified Welding Inpsector/Date

Forward to the Product Container Quality Assurance file, 232-H Room 117.

Appendix C

Rev. 2

LP-50 Containers 906 to 100

SPECIFICATION 3300, SUPPLEMENT NO. 2

SPECIFICATION FOR VACUUM TANK AND SHIPPING CONTAINERS

SECTION I

Vacuum Tank and Shipping Containers

A. Drawings for Fabrication Work

1. These fabrication specifications apply as indicated to the following Drawings:

   S5-2-187, Transfer Container Details
   S5-2-186, Transfer Container Assembly and Details
   S5-2-1693, Vacuum Tank Valve

   In addition, drawing S3-2-126 illustrates two compression fittings which are recommended for either blanking the stainless steel tubes of the valves or for connecting them to a vacuum system for leak check and evacuation purposes. One of each type of fitting will be furnished the vendor for his shop use. They are recommended for use in leak testing only.

2. Part numbers given in Section I of this Specification for Vacuum Tanks and Shipping Containers refer to drawings S5-2-187 and S5-2-186 unless otherwise indicated.

B. Material

1. Aluminum parts shall be cast from aluminum alloy #356.

2. All aluminum castings shall be smooth and free of visible air holes.

3. Part S5-2-187A shall be fabricated from stainless steel type 304L. Parts S5-2-186E and S5-2-187C shall be fabricated of brass, ASTM B-16, 1/2 hard or equal. Specification QQ-B-611a, composition B is equal. Hardness range of the brass parts shall be between Rockwell B-50 and 70. Part S5-2-187D shall be neoprene, with Durometer (Shore) hardness in the range 35-50.

C. Assembly

1. The finish of the inside of parts S5-2-187B and S5-2-187E shall be as cast with core flash removed by grinding. Machined surface finish shall be as indicated on the drawings. The inside diameter of part S5-2-187B shall accept entry of part S5-2-187A without any binding or forcing. If necessary, the inside cast surface of part S5-2-187B may be machined to indicated diameter and tolerance.

2. Parts S5-2-187B and S5-2-187E shall be impregnated with Mogul Cast Seal Type A or Type B according to specification AN-I-36 to insure freedom from leaks in the casting. Impregnation shall be done after castings are machined. The parts are to be tested by submersion in water with 20 psig inside the container. No visible air bubbles are permitted. The test is to be performed with parts S5-2-187B and S5-2-187E assembled with the "O" ring as indicated on drawing S5-2-186. The assembled container may be pressurized for this test via the Hoke valve. After the container passes this test, the Hoke

valve is to be closed with the container internally pressurized at 20 psig, and the Hoke seat is to be tested by submersion in water. No visible air bubbles are permitted. The Hoke valve shall be installed on part S5-2-187E with the vacuum side of the valve, defined as the side under the seat, closest to part S5-2-187E.

D. Welding

1. Items 1, 2, 3, and 4 of part S5-2-187A are to be joined by heliarc welds in the following sequence:

   a. 3 and 4 by an outside edge weld.
   b. 2 and 3 by an outside butt weld.
   c. 1 and 2 by an outside butt weld.

   All these welds will be made using 1/16" diameter type ER-3081 stainless steel rod with the exception of the edge weld which will be made using no filler metal.

2. Set Item 3 in position with large opening down and insert Item 4 in the small opening to conform to drawing of part S5-2-187A. After blanketing welding area with helium, make an edge weld between Items 3 and 4, breaking the welding arc on the body of Item 4 rather than on the bead weld. Then set Item 2 in place under Item 3, establish a helium blanket around the inner and outer surfaces, and make the butt weld. Set Item 1 in place under Item 2, establish helium blanket around the inner and outer surfaces and make the butt weld.

3. The helium plumbing supplying the helium gas for this welding shall be degreased and then pickled to insure cleanliness of the gas. The gas shall be filtered through a 25 micron cuno filter, or equal, to remove particulate matter. Foreign matter must not become deposited in the vacuum tank assembly as a result of these operations.

4. When joining the valve assembly to part S5-2-187A, Item 4, treat the weld of Item 8, S5-2-186, to Part S5-2-187A, Item 4, similar to Items D-2 and 3 above. Filler rod shall be used for this weld. Blanket the weld inside and outside with helium during the welding operation and maintain the helium blanket until the weld has cooled to room temperature.

   This weld may be blanketed with helium by: a) flushing the vessel through the port in part S5-2-187A, Item 4, as in D-2 and 3 above; b) attaching a helium source to the pressure side of the valve assembly and purging air from the valve assembly; c) blanketing the open end of the port in part S5-2-187A, Item 4, with another helium source; d) removing the flushing tube from the port in part S5-2-187A, Item 4, and inserting the valve tube; e) continuing the helium flow on the pressure side of the valve assembly for a few moments; f) disconnecting the helium source from the valve assembly; g) continuing the external blanketing of the junction of the valve assembly and part S5-2-187A, Item 4, during welding and after welding until the weld bead has cooled. Perform a-b-c together; followed by d-e-f-g in order.

   Before, during and after welding, do not permit any foreign matter to enter parts S5-2-187A, Items 1, 2, 3, and 4, or the valve assembly. Handle carefully to preclude contamination by oil, grease, dirt, fingerprints, etc. The tail of the arrow which is stamped on the valve shall be closest to part S5-2-187A, Item 4, when the valve is attached to part S5-2-187A, Item 4. The arrow shall point away from S5-2-187A, Item 4. In this orientation the vacuum side of the valve, which is defined as being under the seat, is located closest to part S5-2-187A, Item 4.

E. Leak Testing

1. The inleakage of the assembled vacuum tank at 1 micron internal pressure shall not exceed 0.1 micron cu.ft./hr. The final leak shall include, in addition to the walls of the vessel, test of all welds including all valve assembly welds and the main needle valve seat. The valve seat also shall be tested individually for seat leakage. The test shall be made in a suitable helium hood using a mass spectrometer leak detector and an appropriate standard leak in the helium hood. The valve shall be seated hand tight without excessive force which would damage the seat. Valve seat leakage, as such, shall not exceed .05 micron cu.ft./hr. Main valve seat leakage shall be tested as in II, D, 3, b, when the valve is assembled on the tank.

F. Numbering

1. The assembled vacuum tank and shipping containers shall be numbered with serial numbers as designated on the purchase order. The assembly serial number shall be stamped, 1/8" characters, on the assembly components in 4 places: a) top of part S5-2-187E, perpendicular to the handle; b) edge of flange of part S5-2-187E, c) edge of flange of part S5-2-187B (the location in the serial number b and c above shall be adjacent to one another when parts S5-2-187B and S5-2-187E are assembled); d) top of part S5-2-187A, Item 4 (the assembly of tank and shipping container shall be made with serial number a, b, c, d, above all oriented in approximately the same sector of the cylindrical tank).

G. Shipping

1. The tanks shall be shipped in an evacuated condition at an internal pressure not to exceed 10 microns. After the tanks pass final inspection, the valve is to be closed with a tag affixed indicating the pressure within the tank when the valve was last closed.

2. The assembled tank and shipping container shall be packaged adequately for protection during shipment. Sealed corrugated cartons are considered adequate. All nuts, bolts, screws shall be snugged up at final assembly.

3. The Hoke valve, shall be safety wired closed prior to shipment and the open end of the valve shall be capped as indicated on S5-2-186.

SECTION II

Vacuum Tank Valve - Part No. 8

The vacuum tank valve will be a ~~Fulton Sylphon packless valve #314-A~~ or equal as specified by the purchaser.
Due to availability Hoke TY445 Mod 4 packless valve was installed

A. Drawings

1. Assembly of the tubing nipples (parts 2 & 3) to the vacuum tank valve is accomplished by reference to these specifications and the following drawing.

~~S5-2-1593~~, Vacuum Tank Valve
55-2-2168

3. The final dimension (end to end) of the valve must exactly match the dimensions as specified for the complete assembly shown on Print ~~S5-2-1693.~~ S5-2-2168

B. Material

1. The vendor shall procure bar stock or tubing, Type 304L or 347 for the fabrication of items 2 and 3 of S5-2-1693.

2. The parts shall be cleaned prior to assembly according to II. D. 2. below. Items 2 and 3 shall be vapor phase degreased only.

C. Welding

1. All filler welding shall be with 1/16" diameter type ER-308L bare stainless steel rod using heliarc.

2. Welding shall be by heliarc. A continuous flow of helium through the valve body is required during welding and until the weld head has cooled to room temperature.

D. Assembly and Leak Testing

1. Fabricate Items 2 and 3 of S5-2-1693 by drilling bar stock or tubing. Vapor phas degrease after fabrication. After degreasing handle to preclude contamination with oil, dirt, foreign material, fingerprints, etc. Item 3 shall be ground to a 32 finish on the outer cylindrical surface.

2. The vapor phase degrease of the valve shall be conducted in a vertical position with bellows up. The degreasing vessel shall be shielded to preclude entry into the valve of any material other than the vapors of the degreasing agent.

   After cleaning of the valve, items 2 and 3 of S5-2-1693 shall be welded by heliarc to the valve. The 1-inch long 0.500 diameter tube shall be attached to the valve at the port closest to the tail of the arrow which is stamped on the base of part 10. The 1-5/8" 0.500 diameter tube shall be attached at the port closest to the point of the arrow. In this orientation, the shorter tube is located on the vacuum side of the valve which is defined as the side under the seat.

   Every precaution must be taken to preclude entry of any foreign material into the valve; closure of the needle against particulate matter could destroy the seat.

3. Welded joints of the valve assembly are to be tested for leaks on a mass spectrometer leak detector. The valve total inleakage for valve seat leakage shall not exceed .05 micron cu.ft./hr. The valve shall be seated hand tight without excessive force which would damage the seat.

   a. Total Inleakage Test: Cover the vacuum side inlet with a compression blank, attach the other inlet to a leak detector and remove the bonnet. Leak test the valve at 1.0 micron internal pressure while it is in a helium hood and determine the leak rate by using an appropriate size standard leak also in the hood.

b. Seat Test: Without the hood, and with the valve closed, make a leak test across the seat with a vacuum side exposed to helium gas at one atmosphere pressure and the pressure side of the valve at 1.0 micron internal pressure.

c. Reverse Seat Test: Without the hood, and with the valve closed, make a leak test across the seat with the pressure side exposed to helium gas at one atmosphere pressure and the vacuum side of the valve at 1 micron internal pressure.

4. An engraved or stamped arrow will be required on the bottom of the valve body to indicate the direction of flow. This arrow will point from the vacuum side of the valve towards the pressure side. The vacuum side of the valve is defined as the side under the seat. The direction of the arrow is indicated on drawing S5-2-1693.

5. Items 2 and 3 shall be protected against damage during shipment or storage. Each stainless steel tube, Items 2 and 3, shall be adequately capped after final leak check to preclude entry of any foreign matter during shipment or storage.

E. Shipping

1. If shipment of individual valves to a separate plant for final vacuum tank fabrication is required, each valve shall be packaged in an individual cardboard carton to prevent abrasive damage. Several valves, individually packed, may be contained in a larger shipping carton.

SECTION III - CLEANING SPECIFICATIONS

1.0 SCOPE - (For Part Nos. Ref. to S5-2-186 and S5-2-187)

1.1 The inside surface of the container, part S5-2-187A, Items 1, 2, 3 and 4 must be free of grease, oxide, dirt, and all other foreign matter.

1.2 Part S5-2-187A, Items 1, 2, 3, and 4 shall be fired in cracked natural gas at 1800 to 2100°F prior to pickling and welding.

1.3 Part S5-2-187A, Items 1, 2, 3, and 4 shall be pickled after cracked natural gas firing and before welding as follows: Immerse parts in a bath of 10-15% nitric acid and 1-2% Hydrofloric acid, by volume, for 10-15 minutes at a temperature of 120 to 140°F. Thoroughly rinse parts in filtered water and air dry. A soft water containing not more than five parts per million of total solids (dissolved or suspended) shall be used as a final rinse. Parts must be free of grease prior to pickling. If necessary, degrease (vapor phase) prior to pickling.

1.4 Part S5-2-187A, Items 1, 2, 3, and 4 must be free of grease, oxide, dirt or other foreign matter before, during and after welding assembly. To maintain the final required cleanliness, store part S5-2-187A, Items 1, 2, 3, and 4 in closed and/or sealed plastic bags until ready for welding, and after welding until ready for final assembly. The welding and assembly operations shall be performed in a relatively clean area.

1.5 Vapor degreasing - non-halogenated solvents - C.P. methol alcohol (preferred). Benzene (nitration grade) - may be used where halogenated solvent degreasing equipment is not available. Safety precautions governing the use of flammable toxic solvents must be observed.

1.6 Inspection and Test - As a criteria of cleanliness with respect to grease, oil and organic contamination, the following test must be made on the total surface exposed to process of each piece after degreasing.

Measure a quantity of carbon tetrachloride of A.C.S. Reagent Grade, spectroscopically pure in the test range, in the amount of 55 cubic centimeters per square foot to the surface to be tested. Apply this quantity by rocking, shaking or rolling so that the surface is completely wetted for a minimum period of three minutes. Drain the carbon tetrachloride and analyze a sample of it in a spectrophotometer between the wave length of 2.8 and 4.0 microns. If the analysis indicates organic matter in excess of 22 milligrams per 1000 square cm (20.5 mg per sq. ft.), the piece shall be recleaned until this limit is not exceedsd.

The spectrophotometer shall have a sensitivity of 0.01 milligrams grease per cubic centimeter of carbon tetrachloride determined by calibration.

If it is desired to use a large quantity of carbon tetrachloride, such that the dilution of the sample could cause an unreliable analysis by the spectrophotometer an aliquot portion may be concentrated for the spectrophotometer test.

For a discussion of the physiological properties and toxicity of carbon tetrachloride, see Encyclopedia of Chemical Technology, Vol. 3, PP. 197-199.

Appendix D

U.S. ATOMIC ENERGY COMMISSION
AEC MANUAL

Volume: 0000 General Administration
Part : 0500 Health and Safety

AEC 0529-01
OS

Chapter 0529 SAFETY STANDARDS FOR THE PACKAGING OF FISSILE AND OTHER RADIOACTIVE MATERIALS

0529-01 POLICY

Fissile and other radioactive material shall be packaged and prepared for shipment in a manner that provides assurance of protection of the public health and safety during the transportation of such materials.

0529-02 OBJECTIVE

To establish safety standards for the packaging of fissile and other radioactive materials for shipment by AEC or by contractors not subject to 10 CFR 71.

0529-03 RESPONSIBILITIES AND AUTHORITIES

031 **The Director, Division of Operational Safety:**

a. determines the need for, and develops new and revised safety standards to be applied in the preparation of fissile and other radioactive materials for transportation.
b. provides a central point of coordination with the Director of Regulation for developing and revising health and safety codes pertaining to safety in the transportation of fissile and other radioactive materials which are intended for use in the AEC programs or by other federal agencies.
c. conducts periodic appraisals to determine the adequacy of the implementation of this chapter.
d. renders interpretations of this chapter.

032 **The Director, Division of Waste Management and Transportation,** in addition to the responsibilities and authorities assigned in 033, below:

a. administers the program for design review and issuance of AEC Certificates of Compliance as provided in 056, below, AECM 5201, and 49 CFR 172.39-173.396.
b. assists field offices in expediting essential shipments consigned to or by AEC and in securing waivers or exemptions from Federal Transportation Regulations.
c. prepares guidance criteria and procedures for application of package testing and quality assurance standards.
d. coordinates the total input for the General Manager in the development and revision of transportation regulations.

033 **Heads of Divisions and Offices, Headquarters, excluding Regulatory,** provide guidance, instructions, standards, and criteria as described in Chapter 0101, consistent with this chapter, to assure the safe packaging of fissile and other radioactive materials, including:

a. directing cognizant managers of field offices to require modifications of equipment procedures or practices.
b. imposing additional requirements for packaging standards.
c. curtailing or suspending the use of specific packages when necessary.

034 **Managers of Field Offices, and the Director, Division of Naval Reactors,** consistent with guidance, instructions, standards, and criteria issued pursuant to 033, above:

a. grant AEC approval for packages which meet the standards contained in appendix 0529 and 10 CFR 71.31-71.40, and which are to be used for the transportation of fissile or other radioactive materials in greater than Type A quantities.
b. grant AEC approval for shipments made under the National Security Exemption provided to the AEC and DOD under the Transportation of Explosives Act (18 U.S.C. 832c) and in accordance with the requirements of pertinent AEC manual chapters. Packages for such shipments must meet the policy stated in section 01.
c. grant such alternatives to the requirements set forth in appendix 0529 as will provide equivalent protection to life or property and to the common defense and security; and within 30 days after granting an alternative, provide the Director, Division of Operational Safety, a detailed report of the reasons for granting it. The granting of such alternatives is in no way to be construed as the granting of exemptions or exceptions from or to the Department of Transportation or other regulatory agency requirements.
d. conduct annual appraisals of contractor operations to assure compliance with the

requirements of this chapter.

e. require that their contractors carry out, as a minimum, quality assurance programs described in this chapter, and as provided for in appendix 5201.
(*NOTE:* Contractors shall not be permitted to exercise any of the above authorities.)

035 **The Manager, Albuquerque Operations Office**, in addition to the responsibilities and authorities assigned in 032, above, shall establish safety standards for packaging and transportation of nuclear weapons and their components in accordance with 055, below.

0529-04 DEFINITION

041 **AEC Contractor** for the purposes of this chapter, means a prime contractor or subcontractor of the Atomic Energy Commission who is exempt from the requirements of 10 CFR 71.

0529-05 BASIC REQUIREMENTS

051 **Applicability**. The provisions set forth in this chapter and its appendix apply to the Headquarters, field offices, and AEC contractors.

052 **Coverage**. This chapter and its appendix cover policies and procedures for the preparation of fissile and other radioactive materials for shipment outside the boundaries of AEC-controlled sites by for-hire or private carriers, or on public vehicles or aircraft.

053 **Federal Regulations**. When offered to the carrier, each shipment of radioactive materials shall be in compliance with the applicable safety regulations of the Department of Transportation (DOT) or the U.S. Postal Service, depending on the mode of transportation.

054 **Other Regulations**

a. **International Atomic Energy Agency (IAEA) Regulations.** Each shipment of fissile and other radioactive materials consigned to a foreign country must meet the requirements set forth in IAEA Safety Series No. 6, "Regulations for the Safe Transport of Radioactive Materials." Specifically, "Requirements for Packaging and for Delivery of Packages to Transport," must be met to be in compliance with this chapter.

b. International Air Transport Association (IATA) Restricted Article Regulations. Each shipment of fissile and other radioactive materials consigned to a foreign country must meet the requirements set forth in IATA Restricted Articles Regulations when shipped via commercial aircraft.

c. **U.S. Air Force AFM-71-4, Packaging and Handling of Dangerous Materials for Transport by Military Aircraft.** Each shipment of fissile and other radioactive materials must meet the requirements set forth in AFM-71-4 when shipped via USAF aircraft.

055 **Package Standards for Radioactive Materials in Amounts Greater Than Type A Quantities**

a. Packages of radioactive materials shall be prepared for shipment and transported in accordance with the provisions of this chapter. DOT specification containers for Type B and fissile materials are considered to meet the standards of this chapter, and no specific AEC Certificates of Compliance are required for their use.

b. Nuclear weapons and their components shall be packaged and transported in accordance with the standards in this chapter or with other standards which provide a degree of safety at least equivalent to that provided by the AEC and DOT regulations. Standards will be developed and documented under 035, above.

c. Packages shipped under the National Security Exemption of 18 U.S.C. 832.c must be in compliance with the standards in this chapter and must also comply with the provisions of other pertinent AEC manual chapters.

d. All other packages for fissile and other radioactive materials in amounts greater than Type A quantities shall be designed, constructed, and used in accordance with the standards contained in the attached appendix, and in 10 CFR 71.31–71.40. Materials described in 71.6 are exempt from this requirement.

e. A quality assurance program must be established and implemented to assure that packages for radioactive materials are fabricated, maintained, and used in accordance with the regulations and approved design features. The program must meet the requirements in appendix 5201.

056 **AEC Certificates of Compliance for Packages of Radioactive Materials in Excess of Type A**

Quantities. Upon determination that a package design does in fact meet the requirements of this chapter and and its appendix and the AEC Standards in 10 CFR 71.31–71.40, an AEC Certificate of Compliance will be issued by the AEC to the contractor. Procedures for obtaining and issuing these certificates are set forth in AECM 5201. No certificate is necessary for shipments meeting the requirements of 10 CFR 71.6 or 71.7.

057 AEC as Consignor. Where an AEC office serves as the actual consignor, rather than a contractor, appropriate internal procedures shall be established by the responsible field office manager to assure compliance with the standards contained in this chapter.

058 Waivers and Exemptions. Packages which do not meet the standards in the DOT Hazardous Materials Regulations, and which do not qualify for shipment under the National Security Exemption, may be shipped only under the provisions of a waiver or exemption issued by the DOT, or on public vehicles or aircraft if approved under the provisions of AEC 0529-034c. Applications for a DOT Special Permit for waiver or exemption shall be prepared in accordance with 49 CFR 170.13 and shall be forwarded to the DOT for issuance of a special permit.

059 Existing Packagings. Existing packagings for radioactive materials must meet the standards of this chapter. However, Type B packagings designed and constructed prior to February 15, 1969, which could be subject to loss of shielding resulting from subjecting the packaging to the puncture test followed by the thermal test (49 CFR 173.398(c)(2)), are also approved for continued use. The packaging design must be covered by a DOT Special Permit providing for administrative and operational controls as may be necessary to compensate for the deficiencies in package integrity and to provide equivalent safety in transportation.

0529-06 REFERENCES

a. **AEC Regulation.** Title 10, Code of Federal Regulations, Part 71, "Packaging of Radioactive Material for Transport."

b. **DOT Regulations**
   1. Title 49, CFR Parts 170-189, and Title 14, CFR Part 103, "Hazardous Materials Regulations."
   2. Title 46, CFR Part 146, "Transportation or Storage of Explosives or other Dangerous Articles or Substances, and Combustible Liquids on Board Vessels."

c. **U.S. Postal Service Regulation.** Title 39, CFR Parts 124 and 125, "Nonmailable Matter" and "Matter Mailable Under Special Rules."

d. **International Atomic Energy Agency (IAEA) Safety Series No. 6,** "Regulations for the Safe Transport of Radioactive Materials," 1967.

e. **AECM 2401,** "Physical Protection of Classified Matter and Information."

f. **AECM 2405,** "Physical Protection of Unclassified Special Nuclear Material."

g. **AECM 0230,** "Records Disposition."

h. **AECM 0530,** "Nuclear Criticality Safety."

i. **AECM 0560,** "Program to Prevent Accidental or Unauthorized Nuclear Explosive Detonations."

j. **AECM 5201,** "Transportation and Traffic Management" (to be reissued under the title "Transportation of Property").

k. AEC Directory of Radioactive and Fissile Materials Shipping Containers, 1969.

l. International Air Transport Association (IATA) Restricted Article Regulations.

m. **U.S. Air Force AFM-4,** "Packaging and Handling of Dangerous Materials for Transport by Military Aircraft."

n. Transportation of Explosives Act (18 U.S.C. 832.c).

0529-07 NATIONAL EMERGENCY APPLICATION

During a national emergency, as defined in AECM 0601-04, the provisions of this chapter and appendix will continue in effect.

PART I

DEFINITIONS AND EXEMPTIONS

A. DEFINITIONS (as used in this appendix)

1. **Carrier** means any person engaged in the transportation of passengers or property, as common, contract, or private carrier, or freight forwarder, as those terms are used in the Interstate Commerce Act, as amended, or the U.S. Postal Service.

2. **Close Reflection by Water** means immediate contact by water of sufficient thickness to reflect a maximum number of neutrons.

3. **Containment Vessel** means the receptacle on which principal reliance is placed to retain the radioactive material during transport.

4. **Fissile Classification** means classification of a package or shipment of fissile materials according to the controls needed to provide nuclear criticality safety during transportation as follows:

   a. **Fissile Class I.** Packages which may be transported in unlimited numbers and in any arrangement and which require no nuclear criticality safety controls during transportation. For purposes of nuclear criticality safety control, a transport index is not assigned to Fissile Class I packages. However, the external radiation levels may require a transport index number.

   b. **Fissile Class II.** Packages which may be transported together in any arrangement but in numbers which do not exceed a transport index of 50. For purposes of nuclear criticality safety control, individual packages may have a transport index of not less than 0.1 and not more than 10. However, the external radiation levels may require a higher transport index number but not to exceed 10. Such shipments require no nuclear criticality safety control by the shipper during transportation.

   c. **Fissile Class III.** Shipments of packages which do not meet the requirements of Fissile Classes I or II and which are controlled in transportation by special arrangements between the shipper and the carrier to provide nuclear criticality safety.

5. **Fissile Materials** means uranium-233, uranium-235, plutonium-238, plutonium-239, and plutonium-241.

6. **Large Quantity** means a quantity of radioactive material, the aggregate radioactivity of which exceeds that specified in the following table for a transport group as defined in 16., below:

Radionuclide Identification	I	II	III	IV	V	VI-VII	Special Form
Radioactivity	20 Curies	20 Curies	200 Curies	200 Curies	5,000 Curies	50,000 Cureis	5,000 Curies

7. **Low Specific Activity Material** means any of the following:
   a. Uranium or thorium ores and physical or chemical concentrates of those ores.
   b. Unirradiated natural or depleted uranium or unirradiated natural thorium.
   c. Tritium oxide in aqueous solutions, provided the concentration does not exceed 5.0 millicuries per milliliter.
   d. Material in which the activity is essentially uniformly distributed and in which the estimated average concentration per gram of contents does not exceed:
      (1) 0.0001 millicuries of Group I radionuclides; or
      (2) 0.005 millicuries of Group II radionuclides; or
      (3) 0.3 millicuries of Group III or IV radionuclides.

NOTE: This may include, but is not

limited to, materials of low radioactivity concentration, such as building rubble, metal, wood, and fabric scrap, glassware, paper and cardboard, solid or liquid plant waste, sludge, and ashes.

e. Nonradioactive objects externally contaminated with radioactive material, provided that the radioactive material is not readily dispersible and the surface contamination, when averaged over an area of one square meter, does not exceed 0.0001 millicuries (220,000 disintegrations per minute), per square centimeter of Group I radionuclides or 0.001 millicuries (2,200,000 disintegrations per minute) per square centimeter of other radionuclides.

8. **Maximum Normal Operating Pressure** means the maximum gauge pressure which is expected to develop in the containment vessel under the normal conditions of transport specified in annex 1, below, considered individually.

9. **Moderator** means a material used to reduce by scattering collisions, and without appreciable capture, the kinetic energy of neutrons.

10. **Optimum Interspersed Hydrogenous Moderation** means the occurrence of hydrogenous material between containment vessels to such an extent that the maximum nuclear reactivity results

11. **Package** means packaging and its radioactive contents.

12. **Packaging** means one or more receptacles and wrappers and their contents, excluding fissile material and other radioactive material, but including absorbent material, spacing structures, thermal insulation, radiation shielding, devices for cooling and for absorbing mechanical shock, external fittings, neutron moderators, nonfissile neutron absorbers, and other supplementary equipment.

13. **Primary Coolant** means a gas, liquid, or solid, or combination of them, in contact with the radioactive material, or if the material is in special form, in contact with its capsule, and used to remove decay heat.

14. **Sample Package** means a package which is fabricated, packed, and closed to fairly represent the proposed package as it would be presented for transport, simulating the material to be transported, as to weight and physical and chemical form.

15. **Special Form** means any of the following physical forms of radioactive material of any transport group:

a. The material is in solid form having no dimension less than 0.5 millimeter or at least one dimension greater than 5 millimeters; does not melt, sublime, or ignite in air at a temperature of 1000°F; will not shatter or crumble if subjected to the percussion test described in annex 4, below; and will not be dissolved or converted into a dispersible form in amounts greater than 0.005 percent by weight if immersed in water at 68°F or placed in air at 86°F for one week.

b. The material is securely contained in a capsule having no dimension less than 0.5 millimeter or at least one dimension greater than 5 millimeters which (1) will retain its contents if subjected to the tests prescribed in annex 4, (2) is constructed of materials which do not melt, sublime, or ignite in air at 1475°F, and (3) will not be dissolved or converted into a dispersible form in amounts greater than 0.005 percent by weight if immersed for one week in water at 68°F or in air at 86°F.

16. **Transport Group** means any one of the seven groups in which radionuclides in normal form are classified, according to their toxicity and their relative potential hazard in transport (see annex 3).

a. Any radionuclide not specifically listed in one of the groups in annex 3 shall be assigned to one of the groups in accordance with the following table:

	Radioactive Half-Life		
Radionuclide	0 to 1000 days	1000 days to 10^6 years	Over 10^6 Years
Atomic Number 1-81	Group III	Group II	Group III
Atomic number 82 and over	Group I	Group I	Group III

b. For mixtures of radionuclides the following shall apply:
  (1) If the identity and respective activity of each radionuclide are known, the permissible activity of each radionuclide shall be such that the sum of the ratios between the total activity for each group to the permissible activity for each group will not be greater than unity.
  (2) If the groups of the radionuclides are known, but the amount in each group cannot be reasonably determined, the mixture shall be assigned to the most restrictive group present.
  (3) If the identity of all or some of the radionuclides cannot be reasonably determined, each of those unidentified radionuclides shall be considered as belonging to the most restrictive group which cannot be positively excluded.
  (4) Mixtures consisting of a single radioactive decay chain where the radionuclides are in the naturally occurring proportions shall be considered as consisting of a single radionuclide. The group and activity shall be that of the first member present in the chain. Exception: If a radionuclide "x" has a half-life longer than that of the first member and an activity greater than that of any other member, including the first, at any time during transportation, the transport group of the nuclide "x" and the activity of the mixture shall be the maximum activity of that nuclide "x" during transportation.

17. **Transport Index** means the number placed on a package to designate the degree of control to be exercised by the carrier during transportation. The transport index to be assigned to a package of radioactive material shall be determined by either a. or b., below, whichever is larger. The number expressing the transport index shall be rounded up to the next highest tenth; e.g., 1.01 becomes 1.1.
  a. The highest radiation dose rate in millirem per hour at three feet from any accessible external surface of the package.
  b. The transport index for each Fissile Class II package is calculated by dividing the number 50 by the number of such Fissile Class II packages which may be transported together as determined under the limitations of part II.I.1. The calculated number shall be rounded up to the first decimal place.

18. **Type A Quantity and Type B Quantity** mean a quantity of radioactive material, the aggregate radioactivity of which does not exceed that specified in the following table:

Transport Groups (See I.A.16.)	Type A Quantity (in curies)	Type B Quantity (in curies)
I	0.001	20
II	0.05	20
III	3	200
IV	20	200
V	20	5,000
VI and VII	1,000	50,000
Special Forum	20	5,000

B. EXEMPTIONS

A shipper is exempt from all requirements of this appendix to the extent that he delivers to a carrier for transport packages each containing not more than a Type A quantity of radioactive material, as defined in A.18, above, which may include one of the following:
1. Not more than 15 grams of fissile material.
2. Thorium or uranium containing not more than 0.72 percent by weight of fissile material.
3. Uranium compounds, other than metal, (e.g., UF_4, UF_6, or uranium oxide in bulk form, not pelleted or fabricated into shapes) or aqueous solutions of uranium, in which the total amount of uranium-233 and plutonium present does not exceed 1.0 percent by weight of the uranium-235 content, and the total fissile content does not exceed 1.00 percent by weight of the total uranium content.
4. Homogeneous hydrogenous solutions or mixtures containing not more than:
   a. 500 grams of any fissile material, provided the atomic ratio of hydrogen to fissile material is greater than 7600.
   b. 800 grams of uranium-235, provided that the atomic ratio of hydrogen to fissile material greater than 5,200, and the content of other fissile material is

   not more than 1 percent by weight of the total uranium-235 content.
   c. 500 grams of uranium-233 and uranium-235, provided that the atomic ratio of hydrogen to fissile material is greater than 5,200, and the content of plutonium is not more than 1 percent by weight of the total uranium-233 and uranium-235 content.

5. Less than 350 grams of fissile material, provided that there is not more than 5 grams of fissile material in any cubic foot within the package.

PART II

PACKAGE STANDARDS

A. GENERAL STANDARDS FOR ALL PACKAGING

1. Packaging shall be of such materials and construction that there will be no significant chemical, galvanic, or other reaction among the packaging components or between the packaging components and the package contents.
2. Packaging shall be equipped with a positive closure which will prevent inadvertent opening.
3. Lifting devices for packagings.
   a. If there is a system of lifting devices which is a structural part of the packaging, the system shall be capable of supporting three times the weight of the package without generating stress in any material of the packaging in excess of its yield strength.
   b. If there is a system of lifting devices which is a structural part only of the lid, the system shall be capable of supporting three times the weight of the lid and any attachments without generating stress in any material of the lid in excess of its yield strength.
   c. If there is a structural part of the packaging which could be employed to lift the package and which does not comply with a., above, the part shall be securely covered or locked during transport in such a manner as to prevent its use for that purpose.
   d. Each lifting device which is a structural part of the packaging shall be so designed that failure of the device under excessive load would not impair the containment or shielding properties of the packaging.
4. Tiedown devices for packagings
   a. If there is a system of tiedown devices which is a structural part of the packaging, the system shall be capable of withstanding, without generating stress in any material of the packaging in excess of its yield strength the following. (1) a static force applied to the center of gravity of the package having a vertical component of two times the weight of the package, (2) a horizontal component along the direction in which the vehicle travels of 10 times the weight of the package, and (3) a horizontal component in the traverse direction of five times the weight of the package.
   b. If there is a structural part of the packaging which could be employed to tie the package down and which does not comply with a., above, the part shall be securely covered or locked during transport in such a manner as to prevent its use for that purpose.
   c. Each tiedown device which is a structural part of the packaging shall be so designed that failure of the device under excessive load would not impair the ability of the packaging to meet other requirements of this section A.
5. Determination of transport indexes for packagings see part I,A.17. of this appendix.

B. STRUCTURAL STANDARDS FOR TYPE B AND LARGE QUANTITY PACKAGING

Packaging used to ship a Type B or a large quantity of radioactive material, as defined in part I,A.6 and 18, above, shall be designed and constructed in compliance with the structural standards of this section. Standards different from those specified in this section may be approved by the manager or other designated official if the controls proposed to be exercised by the shipper are demonstrated to be adequate to assure the safety of the shipment.

1. **Load Resistance.** Regarded as a simple beam supported at its end along any major axis. packaging shall be capable of withstanding a static load, normal to and uniformly distributed along its length, equal to 5 times its fully loaded weight, without generating stress in any material of the packaging in excess of its yield strength.

2. **External Pressure.** Packaging shall be adequate to assure that the containment vessel will suffer no loss of contents if subjected to an external pressure of 25 pounds per square-inch gauge.

C. CRITICALITY STANDARDS FOR FISSILE MATERIAL PACKAGES

1. A package used for the transport of fissile material shall be so designed and constructed

and its contents so limited that it would be subcritical if it is assumed that water leaks into the containment vessel: and

   a. water moderation of the contents occurs to the most reactive credible extent consistent with the chemical and physical form of its contents: and
   b. the containment vessel is fully reflected on all sides by water.

2. A package used for the transport of fissile material shall be so designed and constructed and its contents so limited that it would be subcritical if it is assumed that any contents of the package which are liquid during normal transport leak out of the containment vessel, and that the fissile material is then:
   a. in the most reactive credible configuration consistent with the chemical and physical form of the material.
   b. moderated by water outside of the containment vessel to the most reactive credible extent.
   c. fully reflected on all sides by water.
3. The manager or other designated official may approve exceptions to the requirements of this section where the containment vessel incorporates special design features which would preclude leakage of liquids in spite of any single packaging error, and appropriate measures are taken before each shipment to verify the leak tightness of each containment vessel.

D. EVALUATION OF A SINGLE PACKAGE

1. The effect of the transport environment on the safety of any single package of radioactive material shall be evaluated as follows:
   a. The ability of a package to withstand conditions likely to occur in normal transport shall be assessed by subjecting a sample package or scale model by test or other assessment to the normal conditions of transport as specified in E., below.
   b. The effect on a package of conditions likely to occur in an accident shall be assessed by subjecting a sample package or scale model, by test or other assessment, to the hypothetical accident conditions, as specified in F., below.
2. Taking into account controls to be exercised by the shipper, the manager or other designated official may permit the shipment to be evaluated together with or without the transporting vehicle for the purpose of one or more tests.
3. Normal conditions of transport and hypothetical accident conditions different from those specified in E. and F., below, may be approved by the manager or other designated official if the controls proposed to be exercised by the shipper are demonstrated to be adequate to assure the safety of the shipment.

E. STANDARDS FOR NORMAL CONDITIONS OF TRANSPORT FOR A SINGLE PACKAGE

1. A package used for the shipment of fissile material or more than Type A quantity of radioactive material as defined in part I, A.6 and 18, above, shall be so designed and constructed, and its contents so limited that under the normal conditions of transport specified in annex 1 below:
   a. there will be no release of radioactive materials from the containment vessel.
   b. the effectiveness of the packaging will not be substantially reduced.
   c. there will be no mixture of gases or vapors in the package which could, through any credible increases of pressure or an explosion, significantly reduce the effectiveness of the package.
   d. radioactive contamination of the liquid or gaseous primary coolant will not exceed 10^{-7} curies of activity of Group I radionuclides per milliliter, 5×10^{-6} curies of activity of Group II radionuclides per milliliter; 3×10^{-4} curies of activity of Group III and Group IV radionuclides per milliliter.
   e. there will be no loss of coolant or loss of operation of any mechanical cooling device.
2. A package used for the shipment of fissile material shall be designed and constructed, and its contents so limited, that under normal conditions of transport specified in annex 1, considered individually:
   a. the package will be subcritical.
   b. the geometric form of the package contents would not be substantially altered.
   c. there will be no leakage of water into the containment vessel. This requirement need not be met if, in the evaluation of undamaged packages

under H.1, I.1.a., or J.1., below, it has been assumed that moderation is present to such an extent as to cause maximum reactivity consistent with the chemical and physical form of the material.

- d. there will be no substantial reduction in the effectiveness of the packaging, including:
  - (1) reduction by more than 5 percent in the total effective volume of the packaging of which nuclear safety is assessed.
  - (2) reduction by more than 5 percent to the effective spacing on which nuclear safety is assessed between the center of the containment vessel and the outer surface of the packaging.
  - (3) occurrence of any aperture in the outer surface of the packaging large enough to permit the entry of a 4-inch cube.

3. A package used for the shipment of more than Type A quantity of radioactive material as defined in part I,A.6. and 18., above, shall be so designed and constructed, and its contents so limited, that under the normal conditions of transport specified in annex 1, considered individually, the containment vessel would not be vented directly to the atmosphere.

F. STANDARDS FOR HYPOTHETICAL ACCIDENT CONDITIONS FOR A SINGLE PACKAGE

1. A package used for the shipment of more than Type A quantity of radioactive material (see part I,A.6. and 18., above) shall be so designed and constructed, and its contents so limited, that if subjected to the sequence of the hypothetical accident conditions specified in annex 2, it will meet the following conditions:
   - a. The reduction of shielding would not be sufficient to increase the external radiation dose rate to more than 1000 millirems per hour at three feet from the external surface of the package.
   - b. No radioactive material would be released from the package except for gases and contaminated coolant containing total radioactivity exceeding neither:
     - (1) 0.1 percent of the total radioactivity of the package contents; nor
     - (2) 0.01 curie of Group I radionuclides, 0.5 curie of Group II radionuclides, 10 curies of Group III radionuclides, 10 curies of Group IV radionuclides, and 1000 curies of inert gases irrespective of transport group.

   A package need not satisfy the requirements of this paragraph if it contains only low specific activity materials, as defined in part I,A.7, above, and is transported on a motor vehicle, railroad car, aircraft, inland watercraft, or hold or deck of a seagoing vessel assigned for the sole use of the shipper.

2. A package, used for the shipment of fissile material shall be so designed and constructed, and its contents so limited, that if subjected to the sequence of the hypothetical accident conditions specified in annex 2, the package would be subcritical. In determining whether this standard is satisfied, it shall be assumed that:
   - a. the fissile material is in the most reactive credible configuration consistent with the damaged condition of the package and the chemical and physical form of the contents.
   - b. water moderation occurs to the most reactive credible extent consistent with the damaged condition of the package and the chemical and physical form of the contents.
   - c. there is reflection by water on all sides and as close as is consistent with the damaged condition of the package.

G. EVALUATION OF AN ARRAY OF PACKAGES OF FISSILE MATERIAL

1. The effect of the transport environment on the nuclear criticality safety of an array of packages of fissile material shall be evaluated by subjecting a sample package or a scale model, by test or other assessment, to the hypothetical accident conditions specified in H., I., or J., below, for the proposed fissile class, and by assuming that each package in the array is damaged to the same extent as the sample package or scale model. In the case of a Fissile Class III shipment, the manager or other designated official may, taking into account controls to be exercised

by the shipper, permit the shipment to be evaluated as a whole rather than as individual packages, and either with or without the transporting vehicle, for the purpose of one or more tests.

2. In determining whether the standards of H.2., I.1.b., and J.2., below, are satisfied, it shall be assumed that:
   a. the fissile material is in the most reactive credible configuration consistent with the damaged condition of the package, the chemical and physical form of the contents, and controls exercised over the number of packages to be transported together.
   b. water moderation occurs to the most reactive credible extent consistent with the damaged condition of the package and the chemical and physical form of the contents.

H. SPECIFIC STANDARDS FOR A FISSILE CLASS I PACKAGE

A Fissile Class I package shall be so designed and constructed and its contents so limited that:

1. any number of such undamaged packages would be subcritical in any arrangement, and with optimum interspersed hydrogenous moderation unless there is a greater amount of interspersed moderation in the packaging, in which case that greater amount may be considered.
2. two hundred and fifty such packages would be subcritical in any arrangement, if each package were subjected to the sequence of the hypothetical accident conditions specified in annex 2, with close reflection by water on all sides of the array and with optimum interspersed moderation unless there is a greater amount of interspersed moderation in packaging, in which case that greater amount may be considered. The condition of the package shall be assumed to be as described in G., above.

I. SPECIFIC STANDARDS FOR A FISSILE CLASS II PACKAGE

1. A Fissile Class II package shall be so designed and constructed and its contents so limited, and the number of such packages which may be transported together so limited, that:
   a. five times that number of such undamaged packages would be subcritical in any arrangement if closely reflected by water.
   b. twice that number of such packages would be subcritical in any arrangement if each package were subjected to the sequence of hypothetical accident conditions specified in annex 2, with close reflection by water on all sides of the array and the optimum interspersed hydrogenous moderation, unless there is a greater amount of interspersed moderation in the packaging in which case the greater amount may be considered. The condition of the package shall be assumed to be as described in G., above.
2. The transport index for each Fissile Class II package is calculated by dividing the number 50 by the number of such Fissile Class II packages which may be transported together as determined under the limitations in I., above. The calculated number shall be rounded up to the first decimal place.

J. SPECIFIC STANDARDS FOR A FISSILE CLASS III SHIPMENT

A package for a Fissile Class III shipment shall be so designed and constructed and its contents and number of packages so limited, that:

1. the undamaged shipment would be subcritical with an identical shipment in contact with it and with the two shipments closely reflected on all sides by water.
2. the shipment would be subcritical if each package were subjected to the hypothetical accident conditions specified in the sequence specified in annex 2, with close reflection by water on all sides of the array and with the packages in most reactive arrangement and with the most reactive degree of interspersed hydrogenous moderation which would be credible considering the controls to be exercised over the shipment. The condition of the package shall be assumed to be as described in G., above. Hypothetical accident conditions different from those specified in this subparagraph may be approved by the manager or other designated official if the controls proposed to be exercised by the shipper are demonstrated to be adequate to assure the safety of the shipment.

PART III

QUALITY ASSURANCE PROCEDURES FOR THE FABRICATION, ASSEMBLY, AND TESTING OF OFFSITE SHIPPING CONTAINERS

A. ESTABLISHMENT AND MAINTENANCE OF PROCEDURES

1. Each field office shall require its contractors to establish and maintain a quality assurance program to:
    a. assure that the requisite standards of quality are met in the fabrication, assembly, and testing of each package.
    b. assure that packages in use continue to meet the requisite standards of quality.

B. ELEMENTS OF A QUALITY ASSURANCE PROGRAM

1. The program shall consist of a formal system of procedural and organizational arrangement which:
    a. require that specific responsibilities be assigned to designated units (including those of the vendor, the fabricator, and the contractor) for assuring specified quality at all stages of construction.
    b. designate codes, standards, and specifications for materials, equipment, methods of fabrication, testing, and performance.
    c. provide for quality control of materials, equipment, and services in instances where these have not already been established by existing standards and specifications.
    d. provide, as required by AECM 0504, for at least an annual audit of the AEC contractors' programs to assess their effectiveness.
    e. provide that quality assurance records are maintained in an auditable file during the service life of the container.
    f. provide for a method of determining that packagings procured for use from other sources, including AEC contractors and subcontractors or from licensees meet the requirements of AECM 0529.
    g. establish acceptance criteria in terms of measurable characteristics and the effects of appropriate tests prescribed in annexes 1, 2, and 4 and as required in part III,C.
    h. provide for a program of routine maintenance inspection and, where necessary, retesting to assure that reusable containers continue to meet the applicable design standards.
    i. provide for required training, testing, and certification of manufacturing and inspection personnel involved in special processes, such as welding and nondestructive examination, and for the required certification of equipment and procedures used in the performance of special processes.

PART IV

OPERATING PROCEDURES

A. ESTABLISHMENT AND MAINTENANCE OF PROCEDURES

1. The shipper shall establish and maintain:
    a. operating procedures adequate to assure that the determinations and controls required by this appendix are accomplished.
    b. regular and periodic inspection procedures adequate to assure that the shipper follows the procedures required by a., above.

B. ASSUMPTIONS AS TO UNKNOWN PROPERTIES

When the isotopic abundance, mass, concentration, degree of irradiation, degree of moderation, or other pertinent property of fissile material in any package is not known, the shipper shall package the fissile material as if the unknown properties have such credible values as will cause the maximum nuclear reactivity.

C. PRELIMINARY DETERMINATIONS

1. Prior to the first use of any packaging for the shipment of more than a Type A quantity of radioactive material or fissile materials, such packaging shall be inspected to ascertain that there are no cracks, pinholes, uncontrolled voids, or other defects which could significantly reduce its effectiveness.
2. Prior to the first use of any packaging for the shipment of more than a Type A quantity of radioactive or fissile materials, where the maximum normal operating pressure will exceed 5 pounds per square-inch gauge, the containment vessel shall be tested to assure that it will not leak at an internal pressure 50 percent higher than the maximum normal operating pressure.
3. Packaging shall be conspicuously and durably marked with its model number. Prior to applying the model number, an inspection shall be made to determine that the packaging has been fabricated in accordance with the approved design.

D. ROUTINE DETERMINATIONS

Prior to each use of a package for shipment of radioactive or fissile material, the shipper shall ascertain that the package with its contents satisfies the applicable requirements of part II including determinations that:

1. the packaging has not been significantly damaged.
2. any moderators and nonfissile neutron absorbers, if required, are as authorized.
3. the closure of the package and any sealing gaskets are present and are free from defects.
4. any valve through which primary coolant can flow is protected against tampering;
5. the internal gauge pressure of the package will not exceed, during the anticipated period of transport, the maximum normal operating pressure.
6. contamination of the primary coolant will not exceed, during the anticipated period of transport, the limits in part II.E.1.d.

E. RECORDS

This shipper shall maintain for a period prescribed in appendix 0230, "Records Disposition," a record of each shipment of fissile material and each shipment of amounts of radioactive material greater than Type A quantities as defined in part I.A.6. and 18., in single packages, showing where applicable:

1. identification of the packaging by model number.
2. details of any significant defects in the packaging, with the means employed to repair the defects and prevent their recurrence.
3. volume and identification of coolant.
4. type and quantity of material in each package, and the total quantity in each shipment.
5. for each item of irradiated fissile material:
    a. identification by model number.
    b. irradiation and decay history to the extent appropriate to demonstrate that its nuclear and thermal characteristics comply with approved conditions.
    c. any abnormal or unusual condition relevant to radiation safety.
6. date of the shipment.
7. for Fissile Class III, any special controls exercised.
8. name and address of the transferee.

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9. address to which the shipment was made.
10. results of the determinations required by C. and D., above.

F. DOCUMENTATION OF TECHNICAL BACKUP SUPPORT FOR SPECIFICATION, CERTIFIED, AND SPECIAL PERMIT PACKAGINGS

Packagings that have been certified by the AEC as meeting DOT regulations and packagings for which specifications have been published by the DOT or a special permit has been issued by the DOT may be used by any shipper having authority to ship radioactive or fissile materials. Therefore, it is essential that technical information and limits pertinent to the construction and use of these packagings be available to all potential users. Accordingly, steps will be taken to implement the following requirements:

1. Field office managers shall require contractors under their jurisdiction to prepare a bound distributable document for each new specification, certified, or special permit, packaging designed, developed, and fabrication by him for offsite shipment of fissile and other radioactive materials. Such a document shall also be required for existing packagings for which the DOT has issued special permits except in those instances of packagings of a highly specialized design and used solely by the originator. Should these specialized packagings be adopted for more general utilization, an appropriate technical document must then be prepared. It shall be the responsibility of the originator or first user to prepare the document for an existing packaging if it is to be used by other AEC field offices and contractors. Obsolete packagings no longer in use and containers used for onsite movement of materials are not subject to these documentation requirements unless they are reactivated, altered, or requested for use in offsite shipments. In such instances the party or parties requiring reactivation and/or alterations shall prepare or have prepared the appropriate document.
2. Each document shall provide, as a minimum, the following information:
   a. a complete physical and tech[illegible] description of the package.
   b. a safety analysis report [illegible] considerations for me[illegible] requirements for pack[illegible] transport safety, nuclear [illegible] safety, and radiological safety. Pe[illegible] documents in existence as of the date of this revision are acceptable.
   c. design and development information including pertinent data, analyt[illegible] methods, and the results of [illegible] prescribed tests.
   d. tables, graphs, drawings, pictures, and technical references as required to give a clear treatment of the subject.
3. Each document shall be prepared and submitted to the Technical Information Center in accordance with appendix 3201, part III.B.2, for reproduction and distribution based upon need.

ANNEX 1

NORMAL CONDITIONS OF TRANSPORT

1. **Heat**—Direct sunlight at an ambient temperature of 130°F in still air.

2. **Cold**—An ambient temperature of -40°F in still air and shade.

3. **Pressure**—Atmospheric pressure of 0.5 times standard atmospheric pressure.

4. **Vibration**—Vibration normally incident to transport.

5. **Water Spray**—A water spray sufficiently heavy to keep the entire exposed surface of the package except the bottom continuously wet during a period of 30 minutes.

6. **Free Drop**—Between 1½ and 2½ hours after the conclusion of the water spray test, a free drop through the distance specified below onto a flat essentially unyielding horizontal surface, striking the surface in a position for which maximum damage is expected.

Free Fall Distance

Package Weight (pounds)	Distance (feet)
Less than 10,000	4
10,000 to 20,000	3
20,000 to 30,000	2
More than 30,000	1

7. **Corner Drop**—A free drop onto each corner of the package in succession or in the case of a cylindrical package, onto each quarter of each rim, from a height of 1 foot onto a flat essentially unyielding horizontal surface. This test applies only to packages which are constructed primarily of wood or fiberboard, and do not exceed 110 pounds gross weight, and to all Fissile Class II packagings.

8. **Penetration**—Impact of the hemispherical end of a vertical steel cylinder 1¼ inches in diameter and weighing 13 pounds, dropped from a height of 40 inches onto the exposed surface of the package which is expected to be most vulnerable to puncture.

9. **Compression**—For packages not exceeding 10,000 pounds in weight, a compressive load equal to either 5 times the weight of the package or 2 pounds per square inch multiplied by the maximum horizontal cross section of the package, whichever is greater. The load shall be applied during a period of 24 hours, uniformly against the top and bottom of the package in the position in which the package would normally be transported.

ANNEX 2

HYPOTHETICAL ACCIDENT CONDITIONS

1. **Free Drop**—A free drop through a distance of 30 feet onto a flat essentially unyielding horizontal surface, striking the surface in a position for which maximum damage is expected.

2. **Puncture**—A free drop through a distance of 40 inches striking, in a position maximum damage is expected, the top end of a vertical cylindrical mild steel bar mounted on an essentially unyielding horizontal surface. The bar shall be 6 inches in diameter, with the top horizontal and its edge rounded to a radius of not more than one-quarter inch, and of such a length as to cause maximum damage to the package, but not less than 8 inches long. The long axis of the bar shall be perpendicular to the unyielding horizontal surface.

3. **Thermal**—Exposure to a thermal test in which the heat input to the package is not less than that which would result from exposure of the whole package to a radiation environment of 1475°F for 30 minutes with an emissivity coefficient of 0.9, assuming the surfaces of the package have an absorption coefficient of 0.8. The package shall not be cooled artificially until 3 hours after the test period unless it can be shown that the temperature on the inside of the package has begun to fall in less than 3 hours.

4. **Water Immersion (fissile material packages only)**—Immersion in water to the extent that all portions of the package to be tested are under at least 3 feet of water for a period of not less than 8 hours.

ANNEX 3

TRANSPORT GROUPING OF RADIONUCLIDES

Element[1]	Radionuclides[2]	Group
Actinium (89)	Ac 227	I
	Ac 228	I
Americium (95)	Am 241	I
	Am 243	I
Antimony (51)	Sb 122	IV
	Sb 124	III
	Sb 125	III
Argon (18)	Ar 37	VI
	Ar 41	II
	Ar 41[3] (uncompressed)	V
Arsenic (33)	As 73	IV
	As 74	IV
	As 76	IV
	As 77	IV
Astatine (85)	At 211	III
Barium (56)	Ba 131	IV
	Ba 133	II
	Ba 140	III
Berkelium (97)	Bk 249	I
Beryllium (4)	Be 7	IV
Bismuth (83)	Bi 206	IV
	Bi 207	III
	Bi 210	II
	Bi 212	III
Bromine (35)	Br 82	IV
Cadmium (48)	Cd 109	IV
	Cd 115 m	III
	Cd 115	IV
Calcium (20)	Ca 45	IV
	Ca 47	IV
Californium (98)	Cf 249	I
	Cf 250	I
	Cf 252	I
Carbon (6)	C 14	IV
Cerium (58)	Ce 141	IV
	Ce 143	IV
	Ce 144	III
Cesium (55)	Cs 131	IV
	Cs 134 m	III
	Cs 134	III
	Cs 135	IV
	Cs 136	IV
	Cs 137	III
Chlorine (17)	Cl 36	III
	Cl 38	IV
Chormium (24)	Cr 51	IV
Cobalt (27)	Co 56	III
	Co 57	IV
	Co 58 m	IV
	Co 58	IV
	Co 60	III
Copper (29)	Cu 64	IV
Curium (96)	Cm 242	I
	Cm 243	I
	Cm 244	I
	Cm 245	I
	Cm 246	I
Dysprosium (66)	Dy 154	III
	Dy 165	IV
	Dy 166	IV
Erbium (68)	Er 169	IV
	Er 171	IV
Europium (63)	Eu 150	III
	Eu 152 m	IV
	Eu 152	III
	Eu 154	II
	Eu 155	IV
Fluorine (9)	F 18	IV
Gadolinium (64)	Gd 153	IV
	Gd 159	IV
Gallium (31)	Ga 67	III
	Ga 72	IV
Germanium (32)	Ge 71	IV
Gold (79)	Au 193	III
	Au 194	III
	Au 195	III
	Au 196	IV
	Au 198	IV
	Au 199	IV
Hafnium (72)	Hf 181	IV
Holmium (67)	Ho 166	IV
Hydrogen (1)	H 3 (see tritium)	
Indium (49)	In 113 m	IV
	In 114 m	III
	In 115 m	IV
	In 115	IV
Iodine (53)	I 124	III
	I 125	III
	I 126	III
	I 129	III
	I 131	III
	I 132	IV
	I 133	III
	I 134	IV
	I 135	IV
Iridium (77)	Ir 190	IV
	Ir 192	III
	Ir 194	IV
Iron (26)	Fe 55	IV
	Fe 59	IV
Krypton (36)	Kr 85 m	III
	Kr 85[3] (uncompressed)	V

Element[1]	Radionuclides[2]	Group
	Kr 85	III
	Kr 85[3] (uncompressed)	VI
	Kr 87	II
	Kr 87[3] (uncompressed)	V
Lanthanum (57)	La 140	IV
Lead (82)	Pb 203	IV
	Pb 210	II
	Pb 212	II
Lutetium (71)	Lu 172	III
	Lu 177	IV
Magnesium (12)	Mg 28	III
Manganese (25)	Mn 52	IV
	Mn 54	IV
	Mn 56	IV
Mercury (80)	Hg 197 m	IV
	Hg 197	IV
	Hg 203	IV
Mixed Fission Products	MFP	II
Molybdenum (42)	Mo 99	IV
Neodymium (60)	Nd 147	IV
	Nd 149	IV
Neptunium (93)	Np 237	I
	Np 239	I
Nickel (28)	Ni 56	III
	Ni 59	IV
	Ni 63	IV
	Ni 65	IV
Niobium (41)	Nb 93 m	IV
	Nb 95	IV
	Nb 97	IV
Osmium (76)	Os 185	IV
	Os 191 m	IV
	Os 191	IV
	Os 193	IV
Palladium (46)	Pd 103	IV
	Pd 109	IV
Phosphorus (15)	P 32	IV
Platinum (78)	Pt 191	IV
	Pt 193	IV
	Pt 193 m	IV
	Pt 197 m	IV
	Pt 197	IV
Plutonium (94)	Pu 238 (F)	I
	Pu 239 (F)	I
	Pu 240	I
	Pu 241 (F)	I
	Pu 242	I
Polonium (84)	Po 210	I
Potassium (19)	K 42	IV
	K 43	III
Praseodymium (59)	Pr 142	IV
	Pr 143	IV
Promethium (61)	Pm 147	IV
	Pm 149	IV
Protactinium (91)	Pa 230	I
	Pa 231	I
	Pa 233	II
Radium (88)	Ra 223	II
	Ra 224	II
	Ra 226	I
	Ra 228	I
Radon (86)	Rn 220	IV
	Rn 222	II
Rhenium (75)	Re 183	IV
	Re 186	IV
	Re 187	IV
	Re 188	IV
	Re Natural	IV
Rhodium (45)	Rh 103 m	IV
	Rh 105	IV
Rubidium (37)	Rb 86	IV
	Rb 87	IV
	Rb Natural	IV
Ruthenium (44)	Ru 97	IV
	Ru 103	IV
	Ru 105	IV
	Ru 106	III
Samarium (62)	Sm 145	III
	Sm 147	III
	Sm 151	IV
	Sm 153	IV
Scandium (21)	Sc 46	III
	Sc 47	IV
	Sc 48	IV
Selenium (34)	Se 75	IV
Silicon (14)	Si 31	IV
Silver (47)	Ag 105	IV
	Ag 110 m	III
	Ag 111	IV
Sodium (11)	Na 22	III
	Na 24	IV
Strontium (38)	Sr 85 m	IV
	Sr 85	IV
	Sr 89	III
	Sr 90	II
	Sr 91	III
	Sr 92	IV
Sulphur (16)	S 35	IV
Tantalum (73)	Ta 182	III
Technetium (43)	Tc 96 m	IV
	Tc 96	IV
	Tc 97 m	IV
	Tc 97	IV
	Tc 99 m	IV
	Tc 99	IV
Tellurium (52)	Te 125 m	IV
	Te 127 m	IV
	Te 127	IV

Element[1]	Radionuclides[2]	Group
	Te 129 m	III
	Te 129	IV
	Te 131 m	III
	Te 132	IV
Terbium (65)	Tb 160	III
Thallium (81)	Tl 200	IV
	Tl 201	IV
	Tl 202	IV
	Tl 204	III
Thorium (90)	Th 227	II
	Th 228	I
	Th 230	I
	Th 231	I
	Th 232	III
	Th 234	II
	Th Natural	III
Thulium (69)	Tm 168	III
	Tm 170	III
	Tm 171	IV
Tin (50)	Sn 113	IV
	Sn 117	III
	Sn 121	III
	Sn 125	IV
Tritium (1)	H 3	IV
	H 3 (as gas, as luminous paint or absorbed on solid material)	VII
Tungsten (74)	W 181	IV
	W 185	IV
	W 187	IV
Uranium (92)	U 230	II
	U 232	I
	U 233 (F)	II
	U 234	II
	U 235 (F)	III
	U 236	II
	U 238	III
	U Natural	III
	U Enriched (F)	III
	U Depleted	III
Vandium (23)	V 48	IV
	V 49	III
Xenon (54)	Xe 125	III
	Xe 131 m	III
	Xe 131[3] m (uncompressed)	V
	Xe 133	III
	Xe 133[3] (uncompressed)	VI
	Xe 135	II
	Xe 135[3] (uncompressed)	V
Ytterbium (70)	Yb 175	IV
Yttrium (39)	Y 88	III
	Y 90	IV
	Y 91 m	III
	Y 91	III
	Y 92	IV
	Y 93	IV
Zinc (30)	Zn 65	IV
	Zn 69 m	IV
	Zn 69	IV
Zirconium (40)	Zr 93	IV
	Zr 95	III
	Zr 97	IV

[1] Atomic Number shown in parentheses.
[2] Atomic weight shown after the radionuclide symbol.
[3] Uncompressed means at a pressure not exceeding one atmosphere.
m Metastable state.
(F) Fissile Material.

ANNEX 4

TESTS FOR SPECIAL FORM MATERIAL

1. **Free Drop**—A free drop through a distance of 30 feet onto a flat essentially unyielding horizontal surface, striking the surface in such a position as to suffer maximum damage.

2. **Percussion**—Impact of the flat circular end of a 1-inch diameter steel rod weighing 3 pounds, dropped through a distance of 40 inches. The capsule or material shall be placed on a sheet of lead, of hardness number 3.5 to 4.5 on the Vickers scale, and not more than 1-inch thick, supported by a smooth essentially unyielding surface.

3. **Heating**—Heating in air to a temperature of 1475°F and remaining at that temperature for a period of 10 minutes.

4. **Immersion**- Immersion for 24 hours in water at room temperature. The water shall be at pH 6–pH 8, with a maximum conductivity of 10 micromhos per centimeter.

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