

**Cesium Chloride
Containment Canister
for the Model 1500 Shipping
Package
a Safety Analysis Report Amendment**

Prepared for:

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Under Contract MFJ-XVV-660738

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1.0 GENERAL INFORMATION

1.1 Introduction

The design of a stainless steel containment canister is presented herein for shipment within the Model 1500 package. Up to three radioactive cesium chloride capsules will be directly loaded into the canister, the canister sealed, and the loaded assembly placed within the Model 1500 package (NOTE: The canister can be loaded in the pool or in a dry cell). The individual cesium chloride capsules will have been inspected and tested for integrity prior to loading (see Section 1.2.3). The loaded canister will be dried and leak tested prior to final closure and shipment of the Model 1500 package (see Section 7.1).

1.2 Package Description

1.2.1 Packaging

The cesium chloride capsule canister is a cylindrical can fabricated from 304 stainless steel with a flat bottom which is welded to the side walls of the cylinder. The closure is formed by a flat lid (and associated elastomeric seal) which is attached to a flange on the cylindrical body of the canister via the use of 3 studs and associated bolting blocks and nuts. Elastomeric seals are used to seal the penetrations associated with the studs. Drain and vent port features in the lid are sealed via the use of metal o-rings. The external dimensions of the canister are a 7-1/4 inch O.D. and a 24-3/4 inch height. The internal cavity dimensions are a 6-5/16 inch I.D. and a 20-7/8 inch height. The weight of an empty canister is approximately 70 pounds. Additional details are provided in the following paragraphs and in the drawings provided in Appendix 1.3.1.

The cylindrical cavity of the canister provides space for up to three, cylindrical cesium chloride capsules. The bottom 3/4 inch thick plate is welded directly to the canister cylinder. This end plate incorporates two machined grooves on its lower surface which are used to hold the canister during torquing of the stud nuts. Radial grooves are also provided for drainage on the upper surface of the end plate. The basic canister cylinder is a 6 inch schedule 10 pipe (6.625 inch O.D., 0.134 inch wall). A machined flange is welded to the upper end of the canister cylinder. The following mechanical components complete the canister body assembly:

- o Closure Studs and Bolting Blocks - Three 1/2 - 13 UNC studs are made of A-354 Gr BD material. The studs are threaded into 304 stainless steel machined blocks that are welded to the canister upper flange.
- o Removable Drain Tube Assembly - A 1/4 inch schedule 40 stainless steel tube is utilized to displace pool water from the sealed cavity of the canister. Three stainless steel plates are welded to the lower portion of this tube. These plates center the drain tube inside the canister and act as divider plates between each of the three cesium chloride capsules. The entire assembly is removable to aid in decontamination activities.

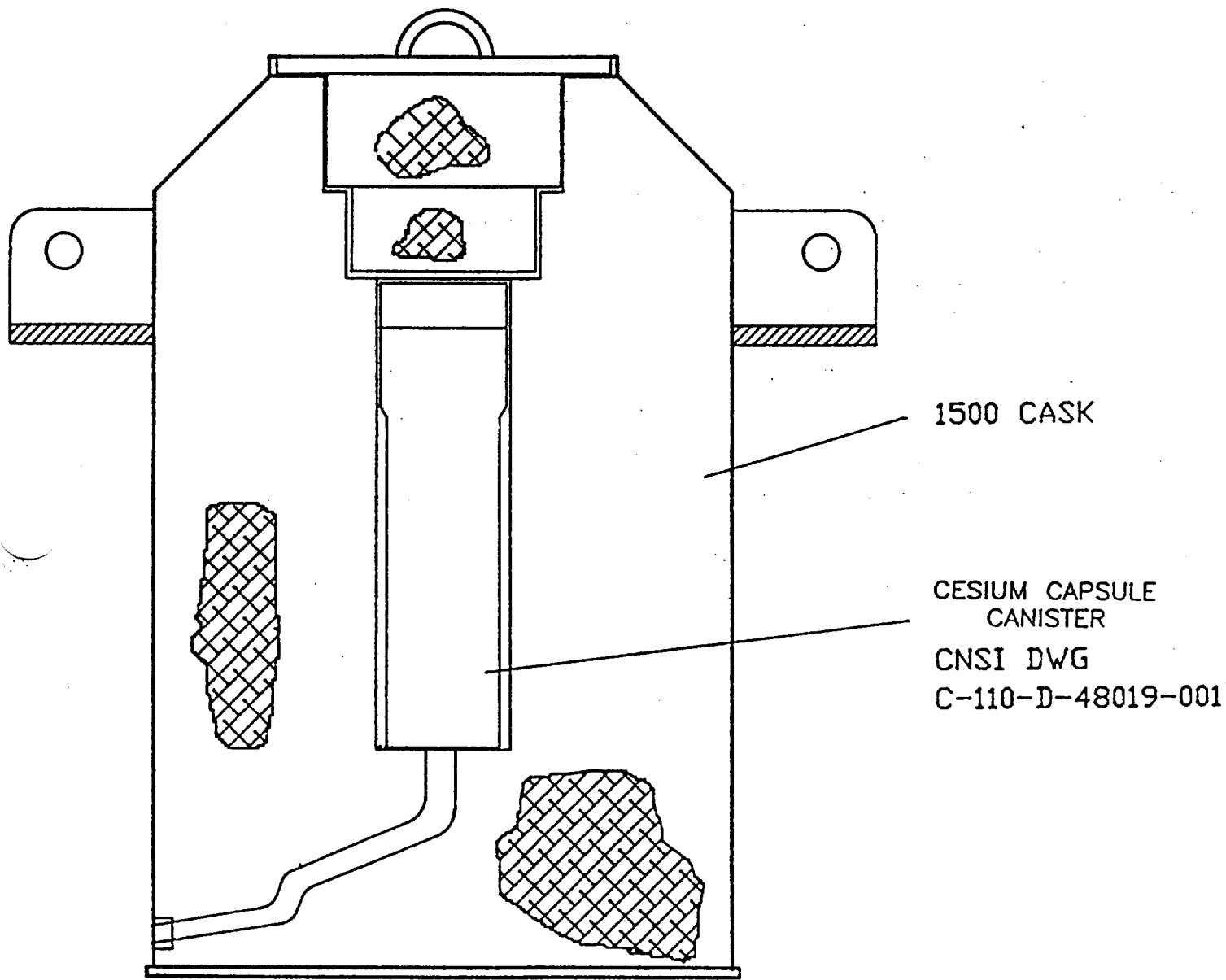
The closure lid is fabricated from 304 stainless steel plate and has dimensions of 7 inch diameter by 2-1/4 inch thickness. The closure lid has provisions for sealing the canister and for draining and drying the loaded canister cavity. The following mechanical components are included with the closure lid:

- o Vent and Drain Service Connections - Valved fittings are recessed within the closure lid. These provide a means of engagement with service lines to provide access to the inner cavity of the closed canister. Metal o-rings are used to obtain a containment boundary seal during transport. During drying operations, an elastomeric seal prevents water in-leakage into the container when the valves are in the open position.
- o Stud Nuts - These A-193 Gr B7 (or better) machined nuts each contains a silicone gasket which seals the stud penetration in the closure lid.
- o Lid Protector - This is a 1/8 inch thick, 304 stainless steel ring which serves to protect the closure lid and appurtenances during top end impact events.

1.2.2 Operational Features

Figure 1.1 shows the canister loaded within the Model 1500 package. All handling operations with the package, other than those pertaining to the loading/unloading the canister, will be performed as noted in the currently approved Model 1500 Safety Analysis Report. Loading/unloading of the canister is a straightforward process as described in Section 7.0 herein. The canister and the Model 1500 package inner cavities will always be dried prior to shipment.

Figure 1.1
Cesium Chloride Capsule Canister
Within the Model 1500 Package



1.2.3 Contents of Packaging

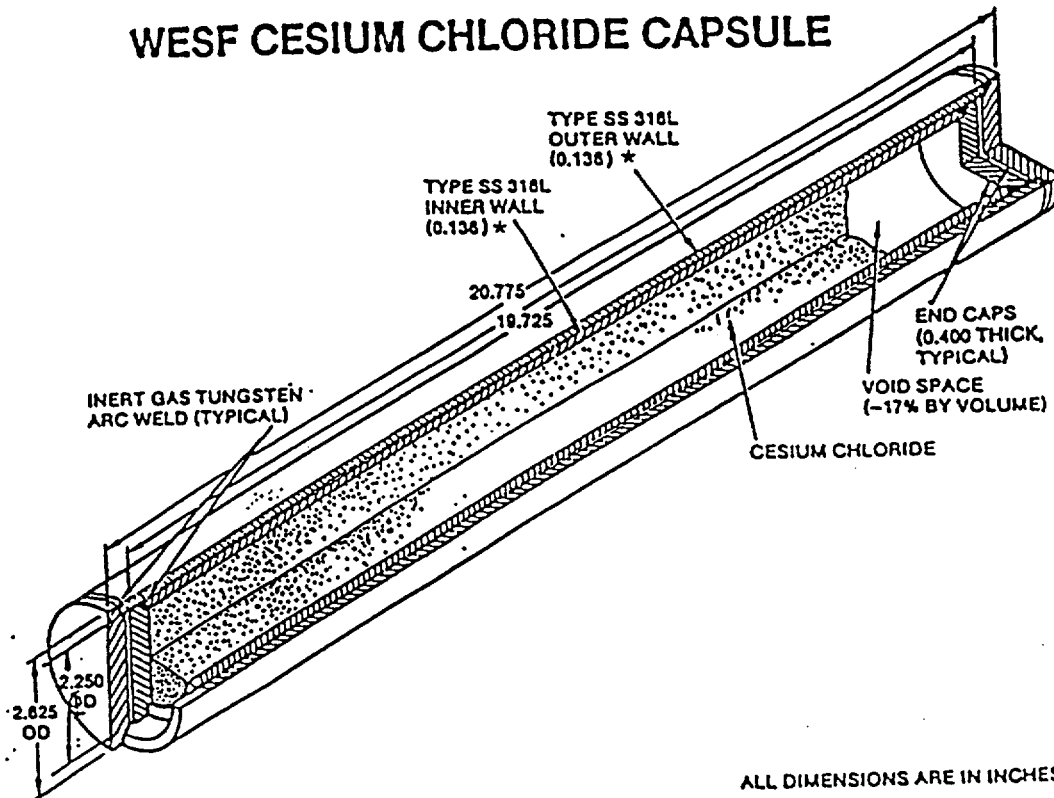
A single canister containing up to three radioactive cesium chloride capsules will be shipped within the Model 1500 package. Each cesium chloride capsule to be shipped will contain a maximum of 53,200 curies and a minimum of 35,000 curies of Cesium-137. Additionally, a worst case shipment of three cesium chloride capsules will contain less than 157,000 curies of Cesium-137. This 157,000 curie value corresponds to the three "hottest" capsules as of March 1988, and will continually decay with time. The maximum weight of a capsule is approximately 20 pounds. The design details for the cesium chloride capsules, which are tested to be special form material (although special form is not claimed herein), are shown in Figure 1.2 and dimensional data are included as Table 1.1. The cylindrical capsules include a double, welded encapsulation of the solid CsCl material. As a prerequisite to loading into the containment canister, each of the capsules will have successfully passed the following three remotely conducted tests:

- o Ring-Gauge Test - The full length of each capsule must pass, without binding, through a 2.750 inch diameter ring.
- o "Clunk Test" - Each capsule will be remotely shaken to ascertain that clearance between the inner and outer capsule shells exists.
- o Visual Test - Each capsule will be remotely examined for defects or other visual indication of leakage during underwater storage.

No cesium chloride capsule will be shipped that indicates, following these tests, a possible failure of the cesium chloride capsule encapsulation.

Figure 1.2

WESF Cesium Chloride Capsule Details



ALL DIMENSIONS ARE IN INCHES

85-M20-0-25

*WALL THICKNESS RANGE FROM 0.095" to 0.136"

Table 1.1

Cesium Chloride Capsule Design Dimensions

a. <u>INNER CAPSULE</u>	APPROXIMATE EQUIVALENT <u>INCHES</u>	<u>IN MM</u>
1. Nominal length	19.725	501.0
2. Nominal diameter	2.250	57.2
3. Tubing		
a. Outside dia (OD)	2.250 ± 0.005	57.2
b. OD at welds	2.246	57.0
c. Wall thickness (WT)	0.103 ± 0.009	2.6
d. WT at top weld	0.080	2.0
e. WT at bottom weld	0.090	2.3
4. End Caps		
a. Thickness	0.400	10.2
b. Thickness at weld	0.300	7.6
c. Outside diameter	2.246	57.0
b. <u>OUTER CAPSULE</u>		
1. Nominal length	20.775	527.7
2. Nominal diameter	2.625	66.7
3. Tubing		
a. Inside diameter	2.407 ± 0.008	61.1
b. OD at welds	2.619	66.5
c. Wall thickness	0.119 ± 0.011	3.0
d. WT at welds	0.100	2.5
4. End Caps		
a. Thickness	0.400	10.2
b. Thickness at weld	0.300	7.6
c. Outside diameter	2.519	66.5
5. Nominal length of cavity	19.975	507.4

1.3 Appendix

1.3.1 Canister Drawings

The following Cesium Canister drawings immediately follow:

- o C-110-D-48019-001, Rev D, Sheets 1 & 2 of 2, *Cesium Capsule Canister*.
- o C-110-A-48019-002, Rev C, Sheets 1 & 2 of 2, *Parts List, Cesium Capsule Canister*.

FIGURE WITHHELD UNDER 10 CFR 2.390

<small>UNLESS OTHERWISE NOTED DIMENSIONS ARE IN INCHES</small> DO NOT SCALE PRINT <small>TOLERANCES (UNLESS OTHERWISE SPECIFIED) DEC. SIZE DEC. SIZE DEC. 24 HOLE DIA. AND LOC. ±.0002 DEC. 2 FRACTIONAL ±.0005 DOES NOT APPLY TO REF. DIMENSIONS</small>	PROJECT NO. 0004/00-1-A	FSON NO. 54643	CHEM-NUCLEAR SYSTEMS, INC.		
	DRAWN: MIKE AMEARN	7/19/88	TITLE CESIUM CAPSULE CANISTER		
	CHECKED: PATRICK PAQUIN	8/3/88			
	ENGINEER: H. SHAMGHANI	8/3/88	SIZE	DRAWING NUMBER	REV.
	QUALITY: CARL ROSS	8/3/88		C-110-D-48019-001	D
APPROVE: R.T. ANDERSON	8/3/88	SCALE	WT	SHEET 1 OF 2	

FIGURE WITHHELD UNDER 10 CFR 2.390

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES DO NOT SCALE PRINT TOLERANCES (UNLESS OTHERWISE SPECIFIED) DEC. DIA. .004 DEC. DIA. .003 DEC. DIA. HOLE DIA. AND LOC. $\pm 1/32$ DEC. DIA. FRACTIONAL $\pm 1/8$ DOES NOT APPLY TO REF. DIMENSIONS	PROJECT NO.	FIG. NO.	CHEM-NUCLEAR SYSTEMS, INC.		
	69-048-04	54643	TITLE CESIUM CAPSULE CANISTER		
	DRAWN:	DATE:			
	MIKE AHEARN	3/18/68	SIZE	DRAWING NUMBER	REV.
	CHECKED:	DATE:	C-110-D-48019-001	D	
PATRICK FAGUNH	8/3/68				
DESIGNED:	DATE:	SCALE	SHEET 2 OF 2		
H. SHAMSIAN	8/3/68				
ROBERT:	DATE:				
CARL ROSS	8/3/68				
APPROVED:	DATE:				
R.T. ANDERSON	8/3/68				

REVISIONS

LTR	DESCRIPTION	DATE	APPROVED
A	REVISED PER ECO #C-110-A-48019-002-001	8/25/89	P. L. PAQUIN
B	REVISED PER ECO #C-110-A-48019-002-002	11/21/89	R. T. ANDERSON
C	REVISED PER ECO #C-110-A-48019-002-003	3/2/90	<i>R.T. Anderson</i>

PROJECT NO. 49019/RSI-2-C		CHEM-NUCLEAR SYSTEMS, INC.	
DRAWN: 7/20/89 M. AHEARN		TITLE PARTS LIST CESIUM CAPSULE CANISTER	
CHECKED: 8/3/89 P. L. PAQUIN			
ENGINEER: 8/3/89 H. SHAMKHANI			
QUALITY: 8/3/89 C. ROSS	SIZE	DRAWING NUMBER C-110-A-49019-002	REV. C
APPROVED: 8/3/89 R. T. ANDERSON	SCALE	WT	SHEET 1 OF 2

PARTS LIST
CESIUM CAPSULE
CANISTER

ITEM	DESCRIPTION	QTY
1)	SHELL 6" SCH10 PIPE 304 SST	1
2)	BASE PLATE 3/4" THK 304 SST	1
3)	DRAIN TUBE 1/4" SCH40 PIPE 304 SST	1
4)	DRAIN TUBE GUSSET 14 GA 304 SST	3
5)	RING FLANGE 6 5/16" I.D. x 15/32" WALL x 5 1/4" LONG 304 SST	1
6)	DRAIN TUBE GASKET 60 DURO 1/4" THK x 1/4" I.D. x 1 1/8" O.D. SILICONE	1
7)	LID BOLTING BLOCK MACHINED FROM 2" SQ x 3" LONG 304 SST	3
8)	LID STUD 1/2-13UNC-2A x 3" LONG SA-354 GR BD	3
9)	LID GASKET 3/16" NOM CROSS SECTION x 6 1/4" I.D. NOM x6 21/32" O.D. NOM SILICONE, TEMP RANGE FROM -65° TO 450/500° F (PARKER COMPOUND S455-70, O-RING # 362 OR EQUIVALENT)	1
10)	STUD CAP GASKET 1/8" NOM. X 1" I.D. NOM. X 1 3/4" O.D. NOM. SILICONE, TEMP RANGE -65° TO 450/500° F (PARKER COMPOUND S455-70 OR EQUIVALENT)	3
11)	LID RING PROTECTOR 1/8" THK 304 SST	1
12)	LID 2 1/4" THK x 7" O.D. 304 SST	1
13)	PLUG 5/8-24UNEF-2A, SA-354 GR BD; OR A563 GR DH; OR 194 GR 2H; OR SA 193 GR B7	2
14)	STUD CAP 1/2-13UNC-2B SA-354 GR BD; OR A563 GR DH; ORD, OR DH3; OR SA 193 GR B7; OR A194 GR 2, OR 2H	3
15)	LIFT LUG 1/8" THK 304 SST	6
16)	DRAIN INSERT 3/4" O.D. x 1/2" , 1/4NPT THRU-304 SST	1
17)	PIN 3/16" NOM DIA 1/2" LONG 304 SST	2
18)	TUBING 1/4" 304 SST (CONNECTIONS FOR DRAIN AND INLET)	2
19)	PLUG GASKET 3/32" NOM CROSS SECTION x .362 I.D. NOM x .568 O.D NOM SILICONE PARKER O'RING # -110 (OR EQUIVALENT)	2
20)	IDENT TAG-SHELL 304 SST	1
21)	IDENT TAG-LID 304 SST	1
22)	SPRING PLUNGER, SST, "VLIER" #SSM-50A (OR EQUIVALENT)	5
23)	SET SCREW, SST W/BRASS TIP ,8-32 1/4" LG, "MCMASTER CARR" #90669A190 (OR EQUIVALENT)	3
24)	GASKET 1/16" TUBE DIA METAL O'RING 1/2" O.D. ,SST, SILVER COATING .001/.002	2

C-110-A-48019-002

2.0 STRUCTURAL EVALUATION

The structural evaluation of the newly designed Cesium Chloride Canister to be used within the existing Model 1500 Packaging is presented herein. The evaluation uses a combination of analysis and the results from full scale testing to establish that the design is structurally acceptable. Thirty foot drop tests of a full scale prototype canister without the protection of the Model 1500 packaging are used to establish the ability of the design to adequately withstand regulatory defined impact events. Quantitative analytic assessments and/or qualitative analytically based arguments are used to determine the response of the canister to applicable pressure loadings, to address differential expansions and to address conditions of interest which were not specifically tested (such as the elevated temperatures which would actually exist at the time of a drop). No modifications to the structure of the Model 1500 Packaging are required in order to transport the newly designed Cesium Chloride Canister.

2.1 Structural Design

2.1.1 Discussion

The specially designed Cesium Chloride Canister provides the containment boundary for up to three cesium chloride capsules. Although containment is expected to be provided by many if not all of the capsules to be shipped, no containment function is claimed for them. Additionally, no containment function is claimed for the Model 1500 Packaging. Rather, the Model 1500 provides confinement for the canister, and the canister itself provides the containment function.

The structural members of the canister which make up the containment boundary consist of a 3/4 inch thick lower end plate, a 6 inch diameter schedule 10 pipe (6.625 OD, 0.134 wall) plus upper end flange, and a 2-1/4 inch thick lid. A 3/16 inch thick elastomeric gasket is used to obtain a containment seal at the lid to upper end flange interface. Three, 1/2 inch diameter high strength studs and associated nuts secure the closure lid to the canister body. Each stud threads into a bolting block which welds directly to the wall of the canister. The bolting blocks also serve as spacers between the 3 cesium chloride capsules. The penetrations used for draining and drying operations are sealed via the use of 1/16 inch cross sectional diameter metallic o-rings. The closure stud penetrations are sealed with 1/8 inch thick silicone gaskets. All containment boundary welds except those associated with the vent and drain port features, are full penetration welds. The vent and drain port welds which are not full penetration are not subjected to significant structural loadings. All containment boundary welds are dye penetrant inspected.

The only noncontainment member which provides a structural function is the 1/8 inch thick upper end skirt which protects the lid and associated appurtenances from impact induced loads on the upper end of the canister. The removable drain tube (with its integral 3 spacer plates) within the canister serves no structural function. Six lift lugs are provided on the upper surface of the lid plate for lifting and handling the loaded canister (130 pounds maximum) or portions thereof.

All containment and noncontainment structural components with the exception of the closure studs and associated nuts are fabricated from 304 stainless steel. The studs and nuts are fabricated from A-354 Gr BD or similar bolting material. Drawings presenting all pertinent design details for the canister are included in Section 1.3.1 herein.

2.1.2 Design Criteria

The design criteria used for all analytic assessments of containment structures are those provided by Regulatory Guide 7.6. Additionally, analytically determined stresses in the closure studs and nuts are limited to the yield strength of the material of construction. Regarding testing, a performance related acceptance criterion is used which requires that following drop testing, the measured leakage rate for the canister is within acceptable limits for the type, amount and form of the payload being transported (i.e., 157,000 curies of solid $^{137}\text{CsCl}$). This leakage rate is established in Section 4.0 to be 5×10^{-4} scc/sec. The acceptance criteria for non-containment components is that their response must not adversely affect the ability of the containment structures to meet their acceptance criteria. Additionally, for both containment and non-containment structures, the buckling criteria of ASME Code Case N-284 is imposed where significant compressive stresses are determined to exist. Regulatory Guide 7.8 is used to establish appropriate worst case load combinations.

2.2 Weights and Centers of Gravity

The weight of a loaded canister to be transported within the Model 1500 Packaging will have a negligible effect on the performance of the packaging. The loaded package will weigh approximately 15,500 pounds whereas the loaded canister alone will weigh a maximum of 130 pounds. The 130 pounds is made up of 60 pounds of cesium chloride capsules (3 at 20 pounds each) and 70 pounds for the canister itself. The 70 pounds for the canister can be subdivided as follows:

Lid assembly	25 lbs
Body assembly	42 lbs
Removable drain assembly	3 lbs

2.3 Mechanical Properties of Materials

The primary materials of construction used for structural portions of the Cesium Chloride Canister are 304 stainless steel and A-354 Gr BD low alloy steel. Mechanical properties available from the ASME Boiler and Pressure Vessel Code as a function of temperature are presented in the following tables (entries are directly available from Tables I-1.2, I-2.2, I-3.2, I-5.0, I-6.0 and I-13.3 of the ASME B&PV Code, Section III).

304 Stainless Steel

Temperature (°F)	Strength (psi) Yield	Strength (psi) Ultimate	Allowable Membrane Stress, S_m (psi)	Young's Modulus (10^6 psi)	Coefficient of Expansion (in/in/°F)
70	30,000	75,000	20,000	28.3	-----
200	25,000	71,000	20,000	27.6	8.79E-6
400	20,700	64,400	18,700	26.5	9.19E-6
500	19,400	63,500	17,500	25.8	9.37E-6
600	18,200	63,500	16,400	25.3	9.53E-6
700	17,700	63,500	16,000	24.8	9.69E-6
800	16,800	62,700	15,200	24.1	9.82E-6

A-354 Gr BD (Low Alloy Steel)

Temperature (°F)	Strength (psi) Yield	Strength (psi) Ultimate	Young's Modulus (10^6 psi)	Coefficient of Expansion (in/in/°F)
70	125,000	150,000	29.35	-----
200	116,900		28.6	6.67E-6
400	109,800		27.5	7.07E-6
500	106,500		27.1	7.25E-6
600	101,800		26.5	7.42E-6
700	95,000		25.3	7.59E-6

NOTE: To minimize the potential for galling, material options are specified for the nuts (A-193 Gr B7; or A-354 Gr BD; or A-194 GR 2 or 2H; or A-563 GR D, DH, or DH3); and for the vent and drain plugs (A-193 Gr B7 or A-354 GR BD). Per ASME Section II Material Specifications Part A, the nut and plug optional materials other than A-193 Gr B7 exhibit greater strengths than does A-354 Gr BD. The mechanical properties for the A-193 Gr B7 material are as follows (again, directly available from the ASME B & PV Code, Section III).

A-193 Gr B7 (1 Cr - 1/5 Mo)

Temperature (°F)	Strength (psi)		Young's Modulus (10 ⁶ psi)	Coefficient of Expansion (in/in/°F)
	Yield	Ultimate		
70	105,000	125,000	29.7	-----
200	98,000		29.0	6.09E-6
400	91,500		27.9	6.74E-6
500	88,500		27.5	7.06E-6
600	85,300		26.9	7.28E-6
700	80,600		26.3	7.51E-6

2.4 General Standards for All Packages2.4.1 Minimum Package Size

The canister is a minimum of 6-5/8 inches in diameter and 24-3/4 inches long, thus even without the presence of the Model 1500 Packaging, the minimum overall dimension exceeds the 4 inch requirement.

2.4.2 Tamper-Indicating Feature

The tamper indicating feature is that provided by the Model 1500 Packaging. The canister itself is not required to, and does not have its own tamper-indicating device.

2.4.3 Positive Closure

Positive Closure is ensured via the presence of the Model 1500 Packaging. Inadvertent opening of the Model 1500 cask and/or the canister cannot occur due to the presence of the outer jacket of the Model 1500 Packaging.

2.4.4 Chemical and Galvanic Reactions

The materials of construction used for the canister (stainless steel and low-alloy carbon steel) are fully compatible with one another, with the payload to be shipped and with the materials used in the Model 1500 Packaging. These materials will not cause significant chemical, galvanic, or other reactions in air, inert gas, or water environments.

2.5 Lifting and Tiedown Standards for All Packages

The transport of the newly designed Cesium Chloride Canister (130 pounds maximum) has no effect on the Model 1500 lifting and tiedown features or the

resultant loads acting on those features. The currently licensed design of the Model 1500 package is therefore fully acceptable without modification. The six lift lugs provided on the canister lid will easily accommodate the 130 pound loaded canister weight without exceeding 1/3 of the yield strength for any canister component.

2.6 Normal Conditions of Transport

2.6.1 Heat

2.6.1.1 Temperatures and Pressures

The maximum canister wall temperature as conservatively determined in Section 3.4.2 for the case of maximum internal heat (752 watts), 100°F ambient temperature, and full solar loading is 447°F. The corresponding maximum canister lid temperature is 364°F. The maximum temperature for the surface of a cesium chloride capsule is also established in Section 3.4.2 to be 700°F. Assuming a dry canister cavity and that the entire gas volume within the cavity of the canister reaches the 700°F capsule temperature results in an internal pressure of 82.2 psig as follows:

$$(P_1/T_1)T_2 = P_2 = 96.9 \text{ psia (82.2 psig)}$$

where,

- P_1 - initial canister pressurization when in pool
- 30 psig = 44.7 psia (see Sections 4.2.3.1 and 7.1.20)
- T_1 - 535°R (75°F) - minimum pool water temperature.*
- T_2 - 1,160°R (700°F)

As discussed in Section 7.1, drying procedures are controlled to virtually eliminate all water from the canister (i.e., if a sufficient level of vacuum cannot be obtained and maintained during the drying process, the canister cannot be shipped). However, to account for the fact that small amounts of free water can be present after drying, the maximum normal operating pressure (MNOP) is rounded up to 90 psig (internal).

* The pool is thermostatically controlled to a nominal temperature of 80°F, with a maximum permissible range of 75°F to 90°F. No cask or canister loadings will be permitted outside this range.

2.6.1.2 Stresses in Canister Members Due to Internal Pressures

The resultant stresses in the canister wall and bottom end plate are as follows:

Canister wall (6 inch schedule 10 pipe, average radius = 3.246 inches, wall thickness = 0.134 inches):

$$\text{Axial stress} = pr/2t = 90(3.246)/2(0.134) = 1,090 \text{ psi}$$

$$\text{Hoop stress} = pr/t = 2,180 \text{ psi}$$

Canister end plate (conservatively assume a simply supported plate with a radius, r , of 3.246 inches, and utilize Table 24, case 10, of Roark, Formulas for Stress and Strain, Fifth edition):

$$\text{Bending stress} = 6M/t^2 = 2,086 \text{ psi}$$

where,

$$M = pr^2(3.3)/16 = 195.6 \text{ in-lb/in}$$

$$t = \text{end plate thickness} = 0.75 \text{ inches}$$

The canister wall and end plate stresses are seen to be negligible under the action of the 90 psig internal pressure. The allowable membrane stress intensity at 447°F is $S_m = 18,136 \text{ psi}$ and the allowable membrane plus bending stress intensity is $1.5S_m = 27,204 \text{ psi}$ for the 304 stainless steel material of construction.

It is noted that a 749 psig pressure would be required for the above specified normal allowable limits to be reached. Under the action of a 749 psig internal pressure, stud stresses would remain well below yield as follows:

The total force on the lid to be shared by 3 studs (using the primary lid/closure seal diameter of 6.281 inches) is:

$$F = pA = 749(3.142/4)(6.281)^2 = 23,208 \text{ lbs}$$

The resultant tensile stress in each stud (using tensile area of a 1/2-13UNC thread of 0.1376 in²) is therefore as follows:

$$\text{tensile stress in stud} = F/[(3)(0.1376)] = 56,220 \text{ psi}$$

It is therefore concluded that very large margins of safety exist for the case of internal pressure within the canister.

2.6.1.3 Stresses Due to Differential Expansions

Differential expansion effects are minimized by using 304 stainless steel as the material of construction for all structural components except the closure studs and nuts. The only differential expansion of significance therefore becomes differential expansion of the studs relative to the lid and that portion of the canister upper flange which is above the bolting blocks. The A354 Gr BD stud material has a lower thermal expansion coefficient than does the adjacent stainless steel, thus on heatup to normal operating temperatures, the load in the studs (and consequently that existing across the lid to upper end flange seal interface) actually tends to increase above that which exists due to initial preloading while in the pool.

With the closure studs, canister lid and upper portion of the canister end flange at 364 °F, and initial preloading occurring in the pool (i.e., 75 °F minimum), the increase in stud strain due to heatup is determined to be 0.000613 in/in as follows.

Consider two reference points, A and B, at points corresponding respectively to where the stud enters the bolting block and to where the stud nut contacts the lid (i.e., at the stud nut seating surface). These points are a distance, L, apart after initial preloading. Considering only the 304 stainless steel members in the path connecting these two points, and assuming no restraint by the stud, on heatup to 364 °F points A and B would separate an amount, D_1 , as follows:

$$D_1 = L\alpha_1(364 - 75) = 0.002635L \text{ inches}$$

where $\alpha_1 = 9.118E-6$ in/in/°F for 304 at 364 °F.

However, considering the A-354 Gr BD stud which also connects points A and B, on heatup to 364 °F these points would only freely separate an amount, D_2 , as follows:

$$D_2 = L\alpha_2(364 - 75) = 0.002022L \text{ inches}$$

where $\alpha_2 = 6.998E-6$ in/in/°F for A-354 Gr BD at 364 °F.

The difference between D_1 and D_2 , or 0.000613L inches, must be accommodated by stretching the studs and/or by compressing the 304 stainless steel members in the path connecting points A and B. Conservatively assuming that the studs are much more flexible than the various 304 stainless steel members in the preload path, and consequently that the studs themselves fully accommodate the 0.000613L inch differential growth, results in a nominal strain in the studs of:

$$\epsilon = (D_1 - D_2)/L = 0.000613L/L = 0.000613 \text{ in/in.}$$

The resultant nominal stress due to differential expansion is 16,971 psi ($E\epsilon$, where $E = 27.70E6$ for A-354 Gr BD at 364°F). Assuming that this nominal stress corresponds to a nominal stud area equal to the average of that provided by the 1/2 inch basic diameter of the stud and the minimum tensile area of the thread (i.e., $1/2(0.1964 + 0.1376) = 0.167 \text{ in}^2$), results in a force of 2,834 pounds. With a maximum initial preload in the studs at 75°F of 9,600 pounds [$F = T/0.2d = 80(12)/\{(0.2)(0.5)\}$], the net tensile force in the stud becomes 12,434 pounds. The corresponding stress in the threads ($A = 0.1376 \text{ in}^2$) is therefore 90,363 psi which is below the yield strength of 111,080 psi at 364°F as desired.

The internal pressure of 90 psig corresponds to a load on the lid of approximately 2,790 pounds which will reduce the load at the lid to upper end flange metal-to-metal interface by 2,790 pounds without significantly affecting loads acting on the more flexible closure studs. Considering the minimum initial preload in the studs of 8,400 pounds (corresponding to a 70 ft-lb torque), the net compressive load at this metal to metal interface for this case becomes 30,912 pounds (11,234 pounds per stud less the 2,790 pound total force due to internal pressure) which is more than sufficient to maintain a seal.

It is also readily shown that the stud is the weakest member in the preload path as desired. The following calculations demonstrate that the studs will yield in tension before stress in any other portion of the structure reaches its corresponding yield strength. Specifically addressed are engagement lengths for the stud nut and for the stud within the bolting block, and shearing of the welds which attach the bolting block to the upper flange of the canister body. At 364°F, the yield strength for the stud is 111,080 psi and the force to yield the minimum tensile area of the stud is therefore 15,285 pounds. As shown below, application of this load will not yield any other portions of the canister structure.

Stud nut engagement length:

The minimum engagement length specified for the stud nut is 5/8 inch. If the stud and nut are made from the same material (A354 Gr BD) or if the nut is stronger than the stud, shear of the stud external threads is more critical than shear of the nut internal threads. This also remains true even if the nut is made of slightly lower strength A-193 Gr B7; i.e., the 43.6% increase in shear area for internal vs external threads easily offsets the reduction in strength. The shear area per unit length for a 1/2-13UNC external thread is 0.7821 in²/in, thus under the action of a force sufficient to yield the stud in tension, the shear stress at the nut interface becomes:

$$\text{Shear stress} \quad - \quad 15,285 / (0.625)(0.7821) = 31,270 \text{ psi}$$

Shear yield for A354 Gr BD at 364°F is 66,648 psi (0.6 times tensile yield) which is over twice the applied shear stress.

Engagement of stud within bolting block:

The minimum engagement length for the stud within the 304 stainless bolting block is 1.25 inches. The shear area per unit length for the 1/2-13UNC internal threads is 1.1231 in²/in, thus under the action of a force sufficient to yield the stud in tension, the shear stress in the 304 stainless threads becomes:

$$\text{Shear stress} \quad - \quad 15,285 / (1.25)(1.1231) = 10,888 \text{ psi}$$

Shear yield for the 304 stainless bolting block (conservatively using the canister side wall temperature of 447°F) is 12,053 psi (0.6 times tensile yield of 20,089) which is 10.7% greater than the applied shear stress.

Stress in the bolting block welds:

Each bolting block is attached to the upper flange of the canister body via a 1/4 inch bevel plus 1/4 inch fillet weld. The minimum effective throat for such a weld is equal to 1.414 times the 1/4 inch leg size, or 0.354 inches. The weld is continuous around the block forming a rectangle with 3 inch long vertical sides and 2-21/32 inch long horizontal sides. The moment arm for the stud force relative to the weld is conservatively estimated to be 0.844 inches (3-5/32 flange inside radius less 2-5/16 stud circle radius). Stress in the weld is determined as follows using formulas available in Section 7-4 of Shigley,

Mechanical Engineering Design, Third edition. These calculations conservatively assume that only the vertical welds resist the direct shear load.

$$\begin{aligned} \text{Direct shear stress} &= P/A \\ &= 15,285/((2)(3)(0.354)) = 7,196 \text{ psi} \end{aligned}$$

$$\text{Shear stress due to applied moment} = Mc/I = 3,323 \text{ psi}$$

where,

$$\begin{aligned} M &= 0.844(15,285) = 12,901 \text{ in-lb} \\ c &= 3/2 = 1.5 \text{ inches} \\ I &= 0.354(d^2/6)(3b + d) = 5.824 \text{ in}^4 \\ d &= 3 \text{ inches} \\ b &= 2.656 \text{ inches} \end{aligned}$$

Combining the direct shear and the shear due to the applied moment via square root sum of squares results in a net weld shear stress of 7,926 psi. As discussed above, shear yield for the 304 stainless base material is 12,053 psi which is 52% greater than the applied shear stress.

The final item to be addressed in this normal heat section is differential expansion of the canister within the Model 1500 cavity and the cesium chloride capsules within the canister cavity. As shown by the following calculations, the 1/8 inch minimum radial and 1/4 inch minimum axial clearance between the canister and the Model 1500 cavity and the 1/8 inch minimum axial clearance between the cesium chloride capsules and the canister cavity are sufficient to preclude introduction of stresses due to differential expansions.

Canister relative to Model 1500 cavity:

Very conservatively assuming that the approximately 25 inch long, 7-1/4 inch diameter canister is at 447°F and that the Model 1500 cavity is at the minimum pool temperature of 75°F, the differential growth of the canister relative to the cavity becomes:

$$\begin{aligned} \text{Axial growth} &= l\alpha(447 - 75) \\ &= 25(9.275E-6)(372) \\ &= \underline{0.086 \text{ inches}} \\ \text{Radial growth} &= r\alpha(447 - 75) \\ &= 3.625(9.275E-6)(372) \\ &= \underline{.013 \text{ inches}} \end{aligned}$$

With a minimum axial clearance of 0.25 inches and a minimum radial clearance of 0.125 inches, no interference will occur.

Capsules relative to canister cavity:

Considering differential axial growth of the cesium chloride capsules relative to the canister cavity results in the following (capsule is at 700°F, canister is at 447°F per Section 3.4.2):

$$\begin{aligned} \text{Relative axial growth} &= L(\alpha_1(700 - 75) - \alpha_2(447 - 75)) \\ &= \underline{0.055 \text{ inches}} \end{aligned}$$

where,

- L - length of capsule and canister cavity - 21 inches
- α_1 - expansion coefficient for 304 at 700°F - 9.69E-6
- α_2 - expansion coefficient for 304 at 447°F - 9.275E-6

With a minimum axial clearance of 0.125 inches, no interference will occur.

2.6.2 Cold

Nearly all components of the Cesium Chloride Canister are made from 304 Austenitic Stainless Steel which does not exhibit a ductile-to-brittle transition over the temperature range of interest. Additionally, the studs and associated nuts will not be subject to brittle fracture concerns since the minimum heat load to be transported will result in a minimum temperature for the studs and nuts of over 70°F (73°F per Section 3.4.3 herein for the case of no solar, -40°F ambient air, minimum internal heat load of 168 watts). Worst case differential expansion effects exist for the case of maximum internal heat which was discussed in Section 2.6.1.

2.6.3 Reduced External Pressure

The effect of a reduced external pressure of 3.5 psia (11.2 psig internal pressure) is of negligible consequence for the Cesium Chloride Canister. Per Section 2.6.1, a normal internal pressure of 90 psig is fully acceptable at maximum normal operating temperatures.

2.6.4 Increased External Pressure

The effect of an increased external pressure of 20 psia (5.3 psig external pressure) is of negligible consequence for the Cesium Chloride Canister. The 5.3 psig external pressure corresponds to a compressive hoop stress of 128 psig

and a compressive axial stress of 64 psig. These stresses are negligible compared to Reg Guide 7.6 and ASME Code Case N-284 (buckling) normal allowable limits.

2.6.5 Vibration

The Cesium Chloride Canister is well isolated from the effects of normal vibration by the surrounding Model 1500 Packaging. The relatively close fit of the canister within the available cavity ensures that no significant interactions of the canister with the Model 1500 Packaging cavity wall will occur as the result of normal vibratory conditions. Maximum vibratory loads can be expected to be no more than a few g's which will be of negligible consequence for the 130 pound loaded canister which is designed to withstand significantly higher impact induced acceleration loadings.

2.6.6 Water Spray

The Cesium Chloride Canister is fully enclosed by the Model 1500 Packaging. With the outer jacket of the Model 1500 being fabricated from carbon steel, the canister itself is negligibly affected by the water spray event.

2.6.7 Free Drop

Normal free drop for the Model 1500 Package which weighs approximately 15,500 pounds is to be from a height of 3 feet. This drop height is only 10% of that required for accident conditions and the test program which demonstrates the ability of the canister to adequately survive the 30 foot drop test demonstrates that the consequences associated with the 3 foot drop are also fully acceptable. Importantly, the allowable leakage rate of 5×10^{-4} scc/sec used for the 30 foot drop testing program enveloped both normal and accident condition leakage rate requirements (see Section 4.2.1). Consequently, it is readily concluded that the containment function provided by the canister will easily be maintained following a worst case 3 foot drop event.

2.6.8 Corner Drop

With a gross package weight in excess of 100 kg (220 pounds), this test does not apply.

2.6.9 Compression

This test does not apply since the package weight is in excess of 5,000 kg (11,000 pounds).

2.6.10 Penetration

The Cesium Chloride Canister is fully enclosed by the Model 1500 Packaging. The Model 1500 Packaging therefore fully protects the canister from the effects of the one meter drop of a 13 pound, steel cylinder.

2.7 Hypothetical Accident Conditions

2.7.1 Free Drop

The hypothetical accident condition free drop event has been addressed via the use of full scale testing of a prototypic production unit canister with a simulated payload of maximum weight (i.e., 3 simulated cesium chloride capsules with a minimum weight of 20 pounds each). The full scale testing was inherently conservative in that the 30 foot drop events were performed without the benefit of the Model 1500 Packaging. For additional conservatism, three sequential drops (top end, bottom end, and side) onto an unyielding surface were performed on a single canister. Corner drops were not specifically performed since the canister is well protected in corner drops by virtue of its close fit within the Model 1500 cavity (i.e., the presence of the Model 1500 cavity does not allow localized crushing of a corner of the canister to occur and consequently, any crushing of the canister will inherently involve a full end and/or full side of the canister).

The most significant result obtained from the testing was that before and after each 30 foot drop, the canister containment boundary was shown to meet the allowable leakage rate of 5×10^{-4} scc/sec established in Section 4.0 herein. This observed result provides sufficient proof that the design will adequately withstand the 30 foot free drop event.

Appendix 2.10.1 provides all pertinent test related details such as the specific canister configuration which was tested and the specific results (including photos) which were obtained. Also included in Appendix 2.10.1 is a discussion of the significance of performing all drops with internal pressure set to 0.0 psig and at the prevailing ambient temperature at the time of the drop.

2.7.2 Puncture

Puncture protection is fully provided by the Model 1500 Packaging, not the canister itself. Per Section 2.2 herein, the loaded canister weight of 130 pounds is such that puncture response of the Model 1500 will not be affected by the newly designed Cesium Chloride Canister. Resultant accelerations acting on the canister will be significantly less for the puncture event than for the free drop events, thus the canister design is not specifically governed by the puncture event.

2.7.3 Thermal

The maximum canister wall temperature resulting from the accident condition thermal event is 554°F per Section 3.5. The corresponding maximum canister lid temperature is 501°F and the maximum temperature for the surface of the cesium chloride capsule is 761°F. Repeating the pressure calculation approach used in Section 2.6.1.1 results in an internal pressure of 87.3 psig as follows (corresponding normal internal pressure was determined to be 82.2 psig).

$$(P_1/T_1)T_2 = P_2 = 102.0 \text{ psia (87.3 psig)}$$

where,

- P_1 - initial canister pressurization when in pool
- 30 psig = 44.7 psia (see Section 4.2.3.1 and 7.1.20)
- T_1 - 535°R (75°F) - minimum pool water temperature
- T_2 - 1,221°R (761°F)

Noting that Section 2.6.1.2 demonstrated very large margins of safety for normal internal pressure conditions, it is readily concluded that the slight increase in internal pressure (5.1 psig) resulting from the accident condition thermal event is also easily acceptable.

Differential expansions are also of no significance for the accident condition thermal event. Utilizing the methodology presented in Section 2.6.1.3, the

resultant nominal strain in the studs at the accident condition temperature of 501°F is 0.000903 in/in as follows:

$$\epsilon = (D_1 - D_2)/L = 0.000903L/L = 0.000903 \text{ in/in}$$

where,

$$D_1 = L\alpha_1(501 - 75) = 0.003992L \text{ inches}$$

$$\alpha_1 = 9.372E-6 \text{ in/in/}^\circ\text{F for 304 at 501}^\circ\text{F}$$

$$D_2 = L\alpha_2(501 - 75) = 0.003089L \text{ inches}$$

$$\alpha_2 = 7.252E-6 \text{ in/in/}^\circ\text{F for A-354 Gr BD at 501}^\circ\text{F}$$

The resultant nominal stress due to differential expansion at 501°F is 24,466 psi ($E\epsilon$, where $E = 27.09E6$ for A-354 Gr BD at 501°F). Assuming that this nominal stress corresponds to a nominal stud area equal to the average of that provided by the 1/2 inch basic diameter of the stud and the minimum tensile area of the thread (0.167 in² per Section 2.6.1.3) results in a force of 4,086 pounds. With a maximum initial preload in the studs at 75°F of 9,600 pounds [$F = T/0.2d = 80(12)/((0.2)(0.5))$], the net tensile force in the stud becomes 13,686 pounds. The corresponding stress in the threads ($A = 0.1376 \text{ in}^2$) is therefore 99,462 psi, which is below the yield strength of 106,450 psi at 501°F, as desired.

The slight increase in internal pressure from the MNOP of 90 psig to 95.1 psig as the result of the accident condition thermal event will not significantly affect stud or seal loads for the same reasons discussed in Section 2.6.1.3. Also as demonstrated in section 2.6.1.3, the strength of the mating threads and the shear block weld strength are all adequate to allow development of the full strength of the stud; i.e., the stud will yield in tension before stress in any other portion of the structure reaches its corresponding yield strength.

2.7.4 Immersion - Fissile Material

This immersion requirement does not apply as the material to be transported is non-fissile in nature.

2.7.5 Immersion - All Packages

The effect of a 21 psig external pressure due to immersion in 50 feet of water is negligible. Assuming that the canister itself must resist this external

pressure (i.e., the Model 1500 Packaging does not provide a pressure boundary), the resultant hoop and axial compressive stresses in the canister wall are readily determined to be 509 psi and 255 psi respectively by ratioing results available from Section 2.6.1. Similarly, the bending stress in the canister end plate becomes 487 psi. These stress levels are less than those associated with normal internal pressure conditions and therefore well within the Reg Guide 7.6 specified accident condition allowable limits. Additionally, by inspection, the compressive shell stresses are well within the Code Case N-284 buckling limits. For the 6 inch schedule 10 pipe used for the body of the canister, these buckling allowables approach yield strength at temperature divided by an applicable factor of safety (factor of safety = 1.34 for accident conditions).

2.7.6 Summary of Damage

As demonstrated by the preceding analyses and drop test results, damage to the cesium chloride containment canister resulting from the sequential application of the hypothetical accident conditions is minimal and fully acceptable. Observed deformations associated with the 30 foot free drop event are limited to areas which do not affect the ability of the container to provide an adequate containment boundary. For example, the most significant damage to the canister is that which occurs in the top end protective skirt. Permanent deformations of the skirt are intended by design to protect the lid from the effects of the free drop event. The only other observed deformation of significance is at the lower end of the canister where a slight bulge occurred as the result of the bottom end drop. This bulge is in a region well removed from the containment seals and is of no consequence regarding the ability of the seals to maintain an adequate seal.

Deformations in and around the primary lid/closure seal were demonstrated by the drop test program to be minimal and the use of an elastomeric seal at that interface easily accommodates the deformations which do occur without compromising the ability of the design to maintain the required leakage rate of 5×10^{-4} scc/sec or less. Permanent deformations which could adversely affect the ability to maintain adequate seals at the various lid penetrations (studs, drain and vent ports) were not observed during the drop test program.

Damage to the container from accident conditions other than the 30 foot free drop have been shown to be negligible.

2.8 Special Form

Although the cesium chloride Capsules to be shipped within the canister may actually qualify as special form, this cannot be guaranteed and special form is not claimed herein.

2.9 Fuel Rods

This section does not apply for the transport of the loaded Cesium Chloride Canister within the Model 1500 Packaging.

2.10 Appendix

2.10.1 Full Scale Drop Testing of Canister and Simulated Payload

2.10.1.1 *Overview*

A cesium capsule canister drop test was conducted on February 28, 1990, at the Chem-Nuclear site in Barnwell, South Carolina. In the actual drop sequence, the canister was loaded with three dummy cesium capsules (each capsule was represented by a 22 pound, sand filled steel cylinder with a 2.75 inch outside diameter and a 20.75 inch length). The canister was then lifted to a height of 30 feet and dropped vertically onto a steel faced, 14'x14'x8' deep concrete pad. The steel facing was 12'x12'x1" thick. All drops were performed without the benefit of the surrounding Model 1500 Packaging. A total of three drops were performed on a single test canister. The drop sequence was top end flat drop first; bottom end flat drop second; and side drop last. Leak tests performed before and after each drop demonstrated that the desired leakage rate of 5×10^{-4} scc/sec was maintained throughout the testing.

2.10.1.2 *Pre-drop Freon Leak Test*

On February 28, 1990, a certified inspector from the Quality Assurance Department at Chem-Nuclear Systems, Inc. (CNSI), performed a freon leak test on all the canister weldments and seals. This leak test was witnessed by a CNSI engineer to verify the integrity of the data.

This test was performed prior to dropping the canister. A General Electric (GE) Model H-25 leak detector was used. Calibration of the leak detector was made in conjunction with a GE Model LS-20 calibrated leak standard. The canister's cavity was pressurized to 30 psig with pure dichlorodifluoromethane (R-12). The detector probe was moved along the exterior surface of the weldments and seals of the canister.

Sensitivity of the test conditions is equivalent to the prescribed procedure sensitivity for leak-tightness of 5×10^{-5} atm-cm³/sec based on dry air at standard conditions as defined in ANSI N14.5.

NOTE: This test was also performed after each drop test of the canister. All leak tests were successful, i.e., the leak rate was always less than 5×10^{-4} scc/sec or less.

2.10.1.3 *Canister Preparation*

Following dimensional measurements of the canister, the canister was loaded with the three dummy cesium capsules (total weight of the dummy capsules was 66 pounds). The lid silicone gasket and the lid were then put on the canister. The closure nuts with their associated silicone gaskets were torqued to the closure studs. A calibrated torque wrench was used to incrementally torque the closure nuts to 70 ft-lbs each (unlubricated) and the vent and drain plugs were torqued to 20 ft-lbs (lubricated). The final package weight was 130 pounds. Photo 1 included at the end of this Appendix 2.10.1 shows the canister after lid closure.

The test article was considered to represent the design with the exception of the following difference. The stud caps (part 14) were fabricated using A36 carbon steel.

The use of A36 for the stud cap nuts rather than the specified A354 Gr BD or A193 Gr B7 material is very conservative. The lowest strength nut (A193 Gr B7) exhibits a yield strength of 105,000 psi and an ultimate strength of 125,000 psi which are well above the A36 strengths (yield strength = 36,000 psi and ultimate strength = 58,000 psi).

2.10.1.4 *Photographic Documentation*

The drop test was also documented photographically. Numerous 35mm colored pictures were obtained before and after each drop to provide more detailed documentation of pre- and post-drop package conditions. A photographic summary (photos 1 through 11) of the entire test program is included at the end of this Appendix 2.10.1.

2.10.1.5 *Drop I: Vertical Top End*

The canister was wrapped with a lifting sling which was attached to a quick release hook on the crane (see photo 2). The canister was then raised to a height of 30 feet above the drop pad. The canister was then released, impacted on the target, rebounded approximately 2 inches then impacted again at a slightly oblique angle and came to rest. Photo 3 illustrates the modest deformation of the lid skirt which acted as an impact limiter to the canister.

A leak test identical to the pre-drop leak test was conducted and the canister did not leak more than 3×10^{-5} scc/sec. In summary, no other damage was observed by visual examination, i.e., the canister did not fail.

2.10.1.6 *Drop II: Vertical Bottom End*

The canister was wrapped with a lifting sling which was attached to a quick release hook on the crane. The canister was lifted to a height of 30 feet. Photo 4 shows the orientation for the bottom end drop.

The canister was dropped and the initial impact was on the bottom base plate. The canister rebounded approximately three inches, tipped to the side, and came to rest. Photo 5 shows the slight bulge caused by this drop. Visual inspection of the canister after this drop showed no other damage.

The canister was leak tested, and the leak test yielded a maximum leak rate of 3×10^{-5} scc/sec. Again, the canister did not fail.

2.10.1.7 *Drop III: Side Drop*

The lifting slings were attached to the lifting lugs that are welded to the canister side as shown in photo 6 (Note: these lift lugs are welded to the production test model only. The production canisters will not have these lugs). The canister was lifted to a height of 30 feet. The canister was released and impacted the pad, hardly rebounded and came to rest. Photo 7 shows the canister after the side drop was performed. Visual inspection showed some scratches and some very minor deformation of the upper flange and bottom end plate.

The canister was leak tested after this drop as shown in photo 8. The canister did not leak more than 5×10^{-5} scc/sec.

2.10.1.8 *Post-test Visual Inspection*

It should be noted that the drop orientations were selected to maximize the damage to the canister. In spite of these "worst cases", the lid skirt experienced only moderate damage and the canister body (lower portion) deformed only slightly during the bottom drop. The lid was visually inspected after it was removed (as shown in photos 8 and 9) and no damage was observed. The flange bolting blocks and closure studs were also examined and no signs of distress were observed (as shown in photos 10 and 11).

2.10.1.9 *Summary*

Inspections and tests of the cesium capsule canister provided confirmation that the canister is structurally adequate to survive accidental drops from 30 feet. The lid and flange areas did not significantly deform. The canister itself did not deform except for the minor deformation shown in photos 5 and 7. Freon leak tests were used to demonstrate that the canister did not lose its sealing capability.

2.10.1.10 *Rationale for Performing Drops With 0.0 psig Internal Pressure and at Ambient Temperatures*

2.10.1.10.1 *Justification for 0.0 psig Internal Pressure:*

Dropping with or without internal pressure within the canister is of little significance. This is due to the fact that pressure induced stresses are very small relative to the accident condition stress limits which apply to the 30 foot drop case. As shown in Section 2.6.1.2 herein, at the Maximum Normal Operating Pressure (MNOP) of 90 psig, the most significant stress in the canister is a tensile hoop stress of 2,180 psi in the 6 inch schedule 10 pipe. This stress intensity magnitude is very small relative to the tensile membrane allowable for the drop accident condition of 43,530 psi ($2.4S_m$ at 447°F). Specific inclusion of internal pressure within the canister is not, therefore, required.

2.10.1.10.2 *Justification for Performing all Drops at Ambient Temperatures:*

The significance of dropping at ambient versus maximum normal operating temperature conditions is addressed in the following paragraphs where general material properties, differential expansion effects, and conservatisms inherent in the "bare" drop test approach are specifically discussed. In summary, the following discussions establish that the "bare" drop conservatisms generally outweigh any adverse effects associated with increased temperatures. For purposes of the discussions herein, a 70°F temperature is used as a lower bound for the canister wall temperature which exists when a drop test actually takes place.

Material properties of interest:

The most significant property of interest is the yield strength at temperature for the structural materials used in the design of the canister. These materials are 304 stainless steel for all components except the closure studs and nuts which are made from A354 Gr BD or similar bolt materials. Of lesser importance are material allowable stresses, ultimate strengths, moduli of elasticity, and expansion coefficients, again as a function of temperature. The following table presents these properties at 70°F, 200°F and the maximum normal operating temperature of 447°F. For each material, a table of absolute magnitudes is first presented followed by a table with properties at 70°F normalized to unity (excluding coefficient of expansion). It is noted that the normalized properties of the optional A193 Gr B7 nut material are nearly identical to the normalized properties of A354 Gr BD.

304

Temp (°F)	Yield (ksi)	Ultimate (ksi)	Allowable S _m (ksi)	Modulus (ksi)	Coefficient of expansion (in/in/°F)
70	30.0	75.0	20.0	28,300	-----
200	25.0	71.0	20.0	27,600	8.790E-6
447	20.09	63.98	18.14	26,171	9.275E-6

304 (normalized properties)

Temp (°F)	Yield (ksi)	Ultimate (ksi)	Allowable S _m (ksi)	Modulus (ksi)
70	1.00	1.00	1.00	1.00
200	0.833	0.947	1.00	0.975
447	0.670	0.853	0.907	0.925

A-354 Gr BD

Temp (°F)	Yield (ksi)	Ultimate (ksi)	Allowable (equal to yield)	Modulus (ksi)	Coefficient of expansion (in/in/°F)
70	125.0	150.0	125.0	29,350	-----
200	116.9	-----	116.9	28,600	6.670E-6
447	108.25	-----	108.25	27,312	7.155E-6

A-354 Gr BD (normalized properties)

Temp (°F)	Yield (ksi)	Ultimate (ksi)	Allowable (equal to yield)	Modulus (ksi)
70	1.00	1.00	1.00	1.00
200	0.935	----	0.935	0.974
447	0.866	----	0.866	0.931

All material data presented above is directly available from the ASME Boiler and Pressure Vessel Code, Section III Appendices. It is noted that ultimate strength of the A354 material as a function of temperature is not specifically included therein, but can be reasonably assumed to be no more significant than the sensitivity of yield strength to temperature.

Significance of the material properties relative to "hot" versus ambient drop testing:

From a study of the above tables, it is apparent that yield strength at temperature for the 304 material is the item of primary interest. An additional item of interest is the differential expansion of the closure studs and nuts relative to the stainless steel canister body and lid. These items are discussed as follows.

With the exception of yield strength for the 304 material, all normalized properties in the above tables equal or exceed a value of 0.853. This 0.853 value indicates a rather modest reduction in material properties as the result of worst case elevated temperatures. Further, this slight reduction is considered to be easily offset by the conservative nature of the proposed ambient drop test program. The reduction in the yield strength of 304 at 447°F to a normalized value of 0.670 is also reasonably offset by the conservatism built into the test program.

More specifically, the impact accelerations which will be experienced by the tested canister will be significantly greater than the accelerations which would result if the canister was dropped within a Model 1500 Packaging with all portions of the package at their maximum normal operating temperatures. This level of conservatism exists for two basic reasons.

First, and most significantly, the fact that the canister is being dropped "bare" (i.e., without the protection of the surrounding Model 1500 Packaging) inherently leads to much greater impact accelerations than would occur if the canister was within a Model 1500 Packaging. In other words, a light-weight package which incorporates no lead shielding and has no built in energy absorbing features (i.e., the all steel, 130 pound loaded Cesium Chloride Canister) will experience significantly greater impact accelerations when dropped from 30 feet than will a relatively heavy package which includes energy absorbing lead shielding and certain other energy absorbing features (i.e., the 15,500 pound loaded Model 1500 Package). The impact acceleration for the first situation will easily be a factor of 1.5 to 2.0 greater than the second situation.

Secondly, impact accelerations are inherently higher at lower temperatures (i.e., material strengths are greater, thus on impact, deformations are smaller and impact accelerations are greater). This effect is not nearly as significant as the "bare" drop effect, but would be expected to result in impact accelerations at 70°F at least 1.1 to 1.2 times those which would occur at 447°F.

Combining the two above discussed effects results in an increase in impact acceleration of 65 to 140% $((1.5)(1.1) = 1.65, (2.0)(1.2) = 2.4)$.

As shown above, yield strength for 304 at 70°F is 1.49 (i.e., 1/0.670) times as great as it would be at 447°F, and all other material properties associated with the canister at 70°F are up to 1.17 (i.e., 1/0.853) times as great (but no greater) as they would be at 447°F. Since impact acceleration associated with a bare drop at 70°F is expected to be at least 1.65 times that which would actually occur for the case of a drop of a canister at 447°F within a Model 1500 Packaging, the proposed ambient temperature testing of a "bare" canister can be considered to generally be conservative.

Differential Expansion of Studs:

At a lid and stud temperature of 364°F, the preload in the closure studs will have increased due to differential expansion effects above the initial preload associated with the 70 to 80 foot pounds of torque applied to the nuts when the canister is initially loaded. The 70 to 80 foot pound torque relates to a preload of 8,400 to 9,600 pounds ($P = T/(0.2d)$) in each of the closure studs. The corresponding stress in the 1/2 - 13UNC threads is 61,047 to 69,767 psi.

The increase in stud stress due to heatup to 364°F is as previously determined in Section 2.6.1.3. From that Section, the maximum stud stress at temperature, assuming an 80 ft-lb initial torque, is 90,363 psi which is 81.3% of yield at 364°F. For ambient temperature drop tests utilizing A354 Gr BD studs and A354 Gr BD or A193 Gr B7 nuts, the initial torque should be adjusted upward so that the stud stress is at 81.3% of the ambient temperature yield strength at the time of the drop, but for conservatism, a 75± 5 ft-lbs torque, as specified in the drawings and significantly lower strength nuts (A36 versus A354 Gr BD or A193 Gr B7) combined with the "bare" drop conservatisms discussed above was used in the verification test.

Photo 1

Initially Assembled Test Unit

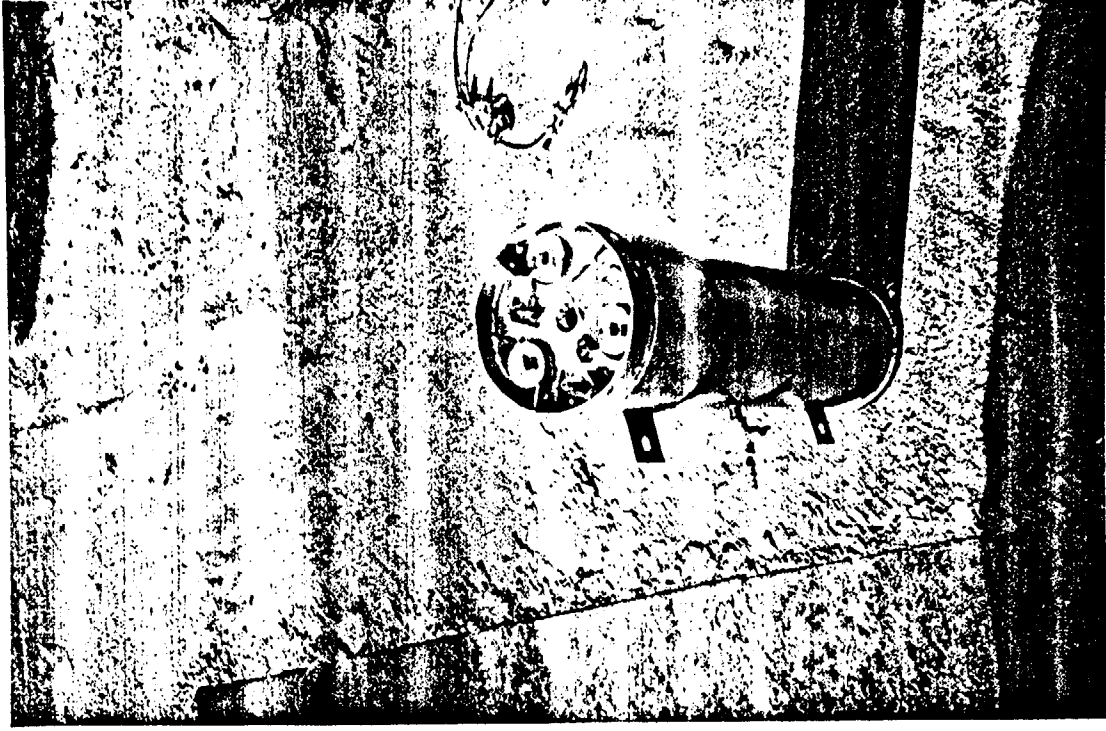


Photo 2

Rigging For Top End Drop



Photo 3

Top End Drop Damage



Photo 4

Rigging For Bottom End Drop

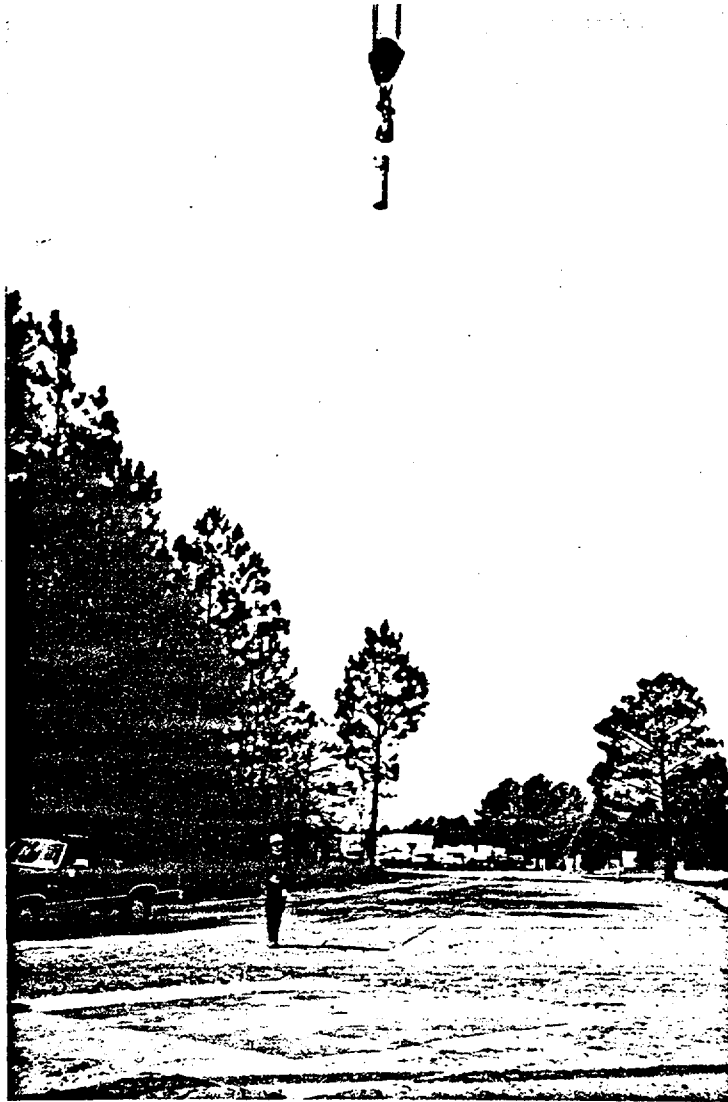


Photo 5

Bottom End Drop Damage

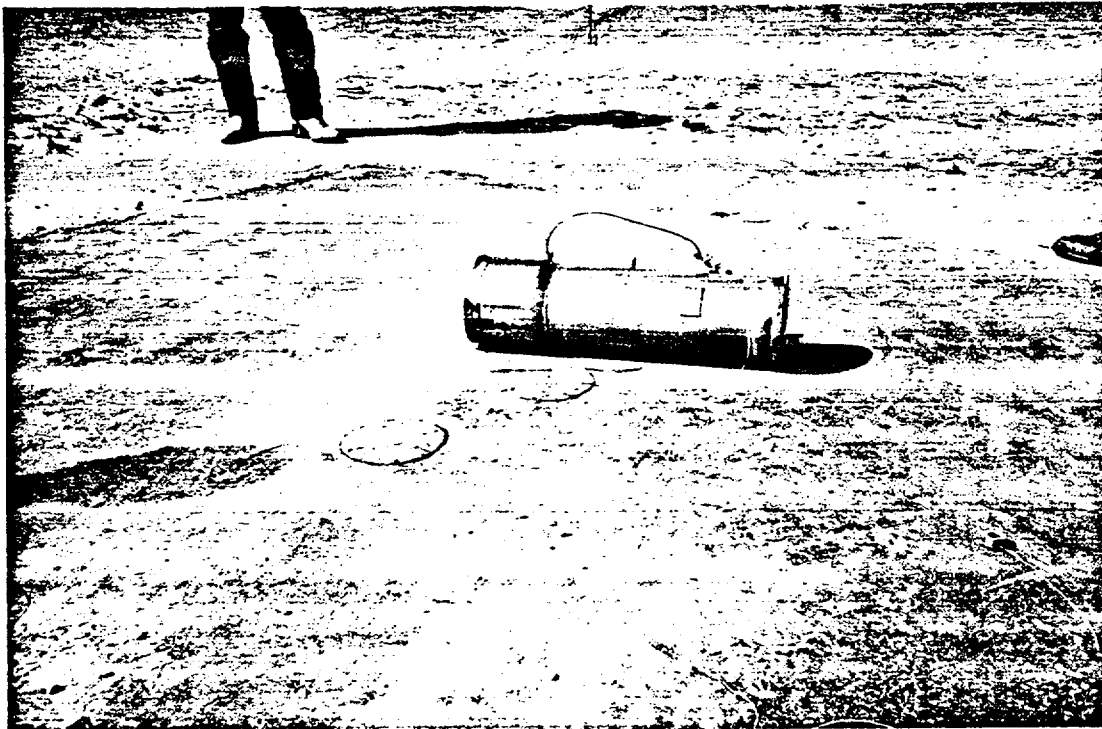


Photo 6

Rigging For Flat Side Drop

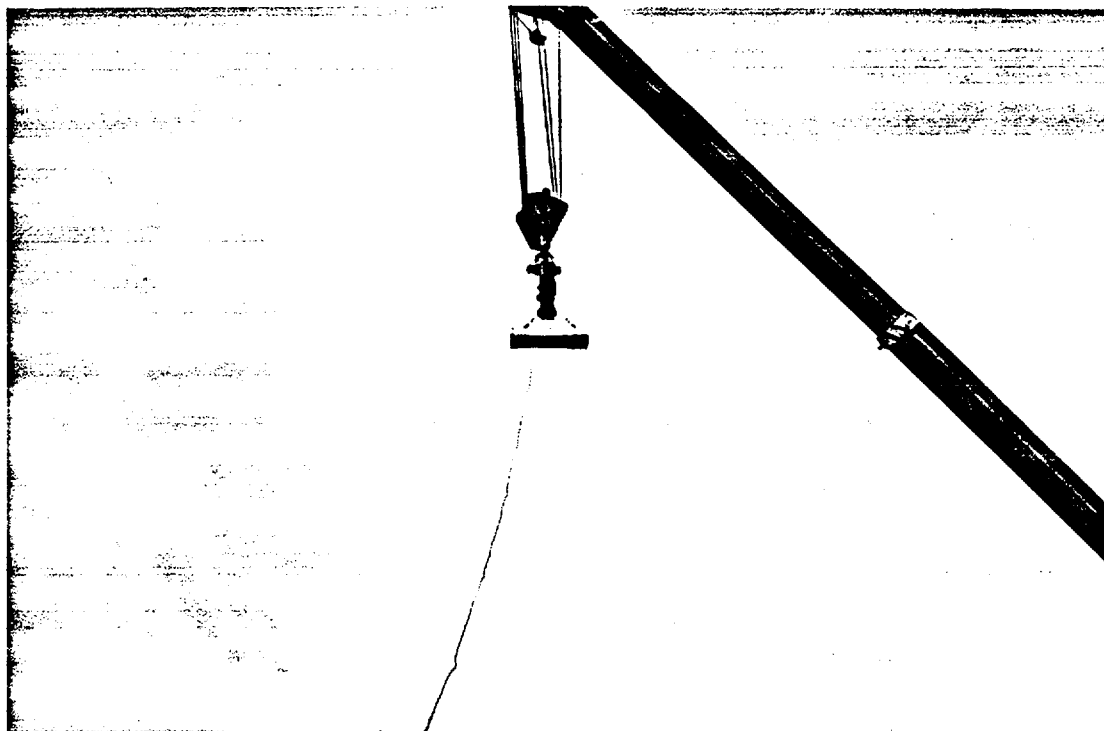


Photo 7

Side Drop Damage

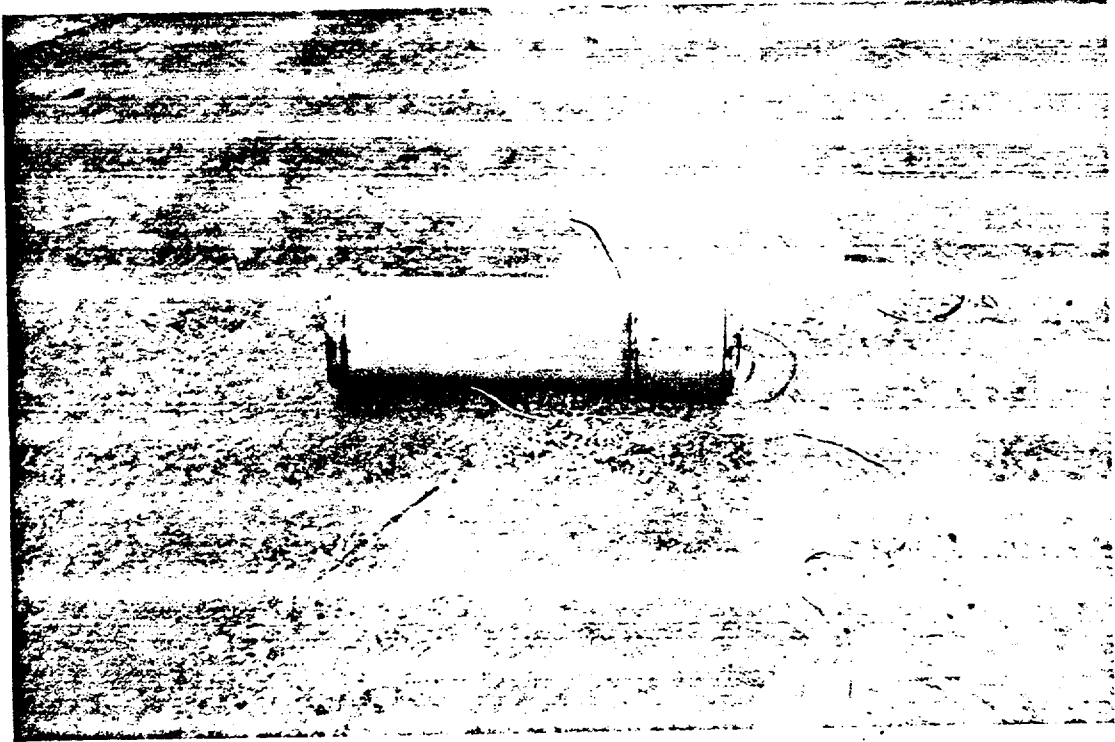


Photo 8

Leak Test Following Each Drop



Photo 9

Lid Removed - Bottom View

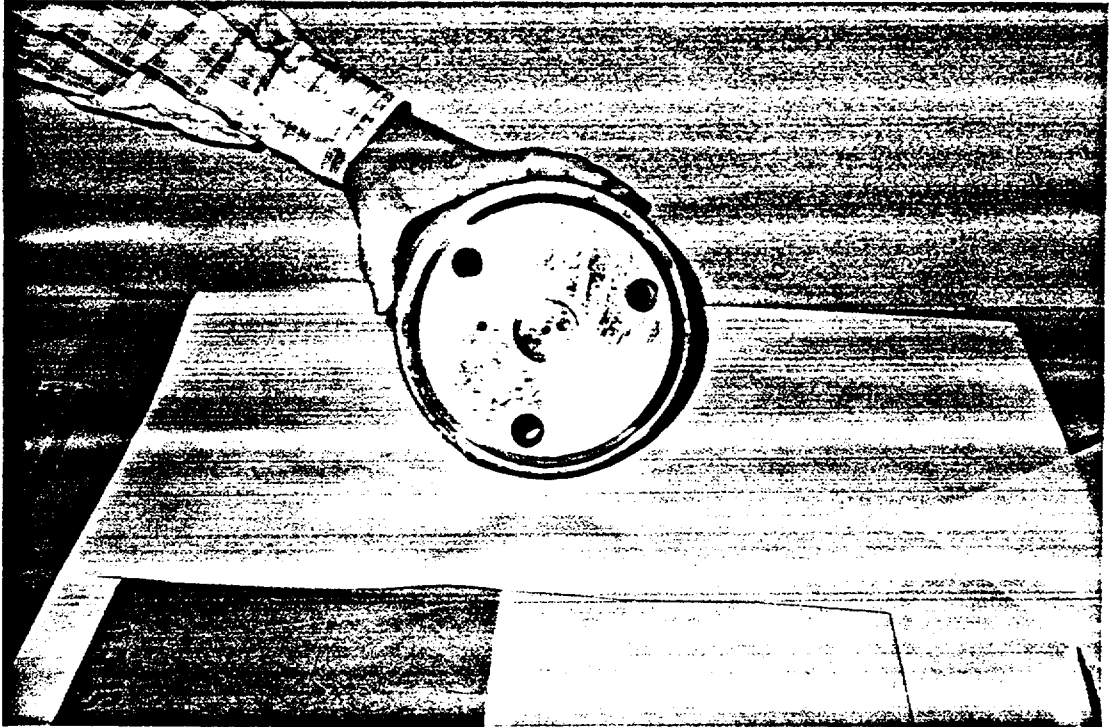


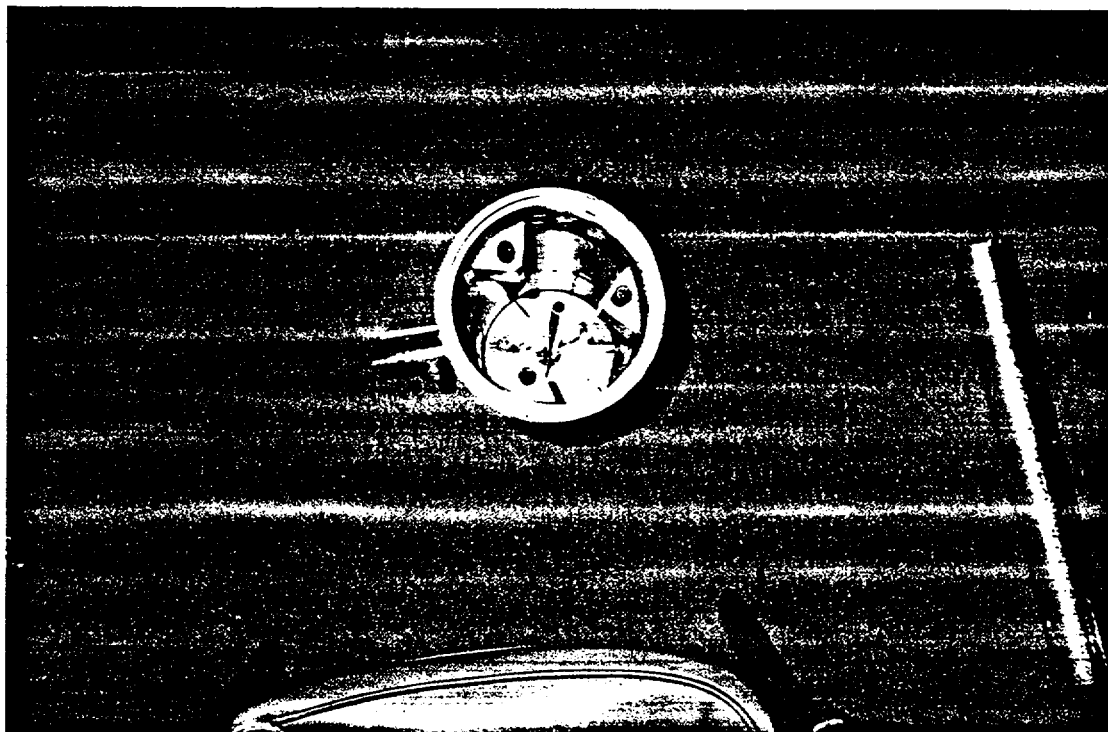
Photo 10

Lid Removed - Side/Top Views



Photo 11

Canister Body - Capsules Removed



3.0 THERMAL EVALUATION

3.1 Discussion

In this section, the thermal behavior of the Model 1500 packaging with one to three WESF cesium chloride capsules in the Cesium Capsule Canister is examined for compliance with 10 CFR 71 normal and hypothetical accident thermal requirements. The maximum internal decay heat associated with a shipment of three capsules is 157,000 Ci of ^{137}Cs :

$$(157,000 \text{ Ci}/209 \text{ Ci/watt}) = 751.2 \text{ watts}$$

The minimum internal decay heat to be shipped in this configuration is one capsule of 35,000 Ci of ^{137}Cs :

$$(35,000 \text{ Ci}/209 \text{ Ci/watt}) = 168 \text{ watts}$$

For purposes of analysis, a maximum heat load of 752 watts and a minimum heat load of 168 watts has been assumed. A two-dimensional model was developed to allow a simple analysis of the package thermal behavior under these decay heat loads. Importantly, the maximum decay load of this amendment is only 24% of the maximum decay heat allowable under the current Certificate of Compliance for the Model 1500 packaging.

The Cesium Capsule Canister is assumed to be filled with air. Heat flows from the capsules to the canister via radiation and gaseous conduction. Internal convection heat transfer is conservatively ignored. The heat is then transferred to the stainless inner shell of the Model 1500 from the stainless Cesium Capsule Canister via the same two heat transfer modes. The model conservatively neglects contact heat transfer through the bottom end of the capsules and canister to the inner shell of the Model 1500.

For analysis, the steel and lead gamma shield are assumed to conduct heat as a monolithic thermal conductor; that is, there is intimate contact between the lead shielding and steel shells. Outside the gamma shielding and the outer stainless steel shell, there are two carbon steel thermal shields surrounded by air gaps. Heat transfer modes include: radiation and air conduction. The outer surfaces of the outer shield (the top and sides) are subjected to solar loads for normal hot conditions per 10 CFR 71.71(c). Solar loads are not imposed for normal cold or hypothetical accident thermal evaluations. Finally, both the internal decay heat and solar loads are dissipated to the environment through radiant and convective heat transfer modes.

Temperatures predicted by the analyses presented in the following sections are summarized below:

Table 3.1-1
Temperature Summary, °F

Location	Normal		Hypothetical Accident
	Minimum	Maximum	Maximum
WESF Cesium Capsule	264	700	761
Cesium Canister Side Shell	108	447	554
Cesium Canister Lid	73	364	501
Inner Surface, Gamma Shield	33	271	429
Outer Surface, Gamma Shield	30	255	449
Inner Thermal Shield	-2	200	1057
Outer Thermal Shield Surface	-27	153	1294
Ambient Environment	-40	100	1475 ($\epsilon=.9$)

3.2 Summary of Thermal Properties of Materials

The thermal properties assumed for the analyses that follow are presented in the table below:

Material	Property	Value	Reference
Carbon Steel	Thermal Conductivity, k (BTU/hr.-ft.-°F)	25.0	(1)1:166
	Sp. Heat Capacity, C (BTU/lb.-°F)	0.125	1:166
	Density, (lb./ft.3)	487	1:166
	Surface emissivity	0.8	3:285
	Thermal Conductivity, k (BTU/hr.-ft.-°F)	11.0	1:166
Stainless Steel	Sp. Heat Capacity, C (BTU/lb.-°F)	0.125	1:166
	Density, (lb./ft.3)	485	1:166
	Surface emissivity	0.63	3:286
	Thermal Conductivity, k (BTU/hr.-ft.-°F)	18.6	1:166
Lead	Sp. Heat Capacity, C (BTU/lb.-°F)	0.0325	1:166
	Density, (lb./ft.3)	687.0	1:166
	Thermal Conductivity, k (BTU/hr.-ft.-°F)	11.0	Assumed
Cesium Chloride Capsule	Sp. Heat Capacity, C	0.2	Assumed
	Density, (lb./ft.3)	305	Assumed
	Surface emissivity	0.63	(Stainless)

1 xx:yy; xx = reference as tabulated in Section 3.6.2; yy = page number of reference.

The conductivity of air was assumed to vary quadratically with temperature according to the following formula:

$$k = 3.762 \times 10^{-6} + 6.471 \times 10^{-9}(T) - 8.52 \times 10^{-13}(T^2)$$

T is in degrees F

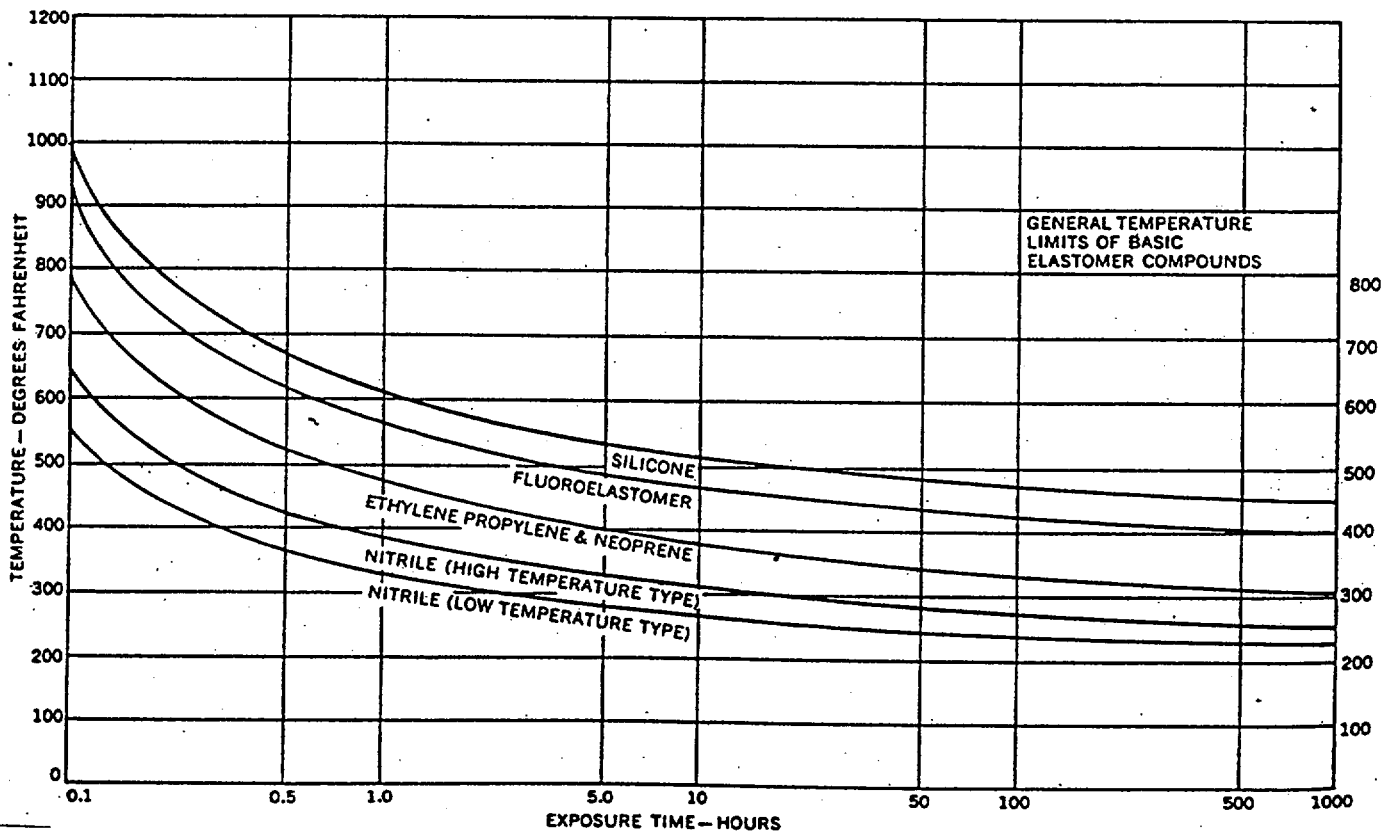
k is in BTU/sec.-ft.-°F

This equation was obtained using least-squares fitting techniques from data in Ref. 3:279. The specific heat capacity of air was assumed to be 0.245 BTU/lb.-°F, from the value for 400°F given in Ref. 2:636.

3.3 Technical Specifications of Components

The only thermally sensitive component of the Cesium Capsule Canister is the silicone closure seal. This silicone seal is specified with a required service range of -65°F to 450/500 °F, see the drawings in Appendix 1.3.1. This is equivalent to Parker compound S455-70 (Ref. 6:A3-38), a specially formulated industrial compound providing the best high temperature compression set characteristics commercially available. Although this particular Parker compound can be expected to be acceptable for normal operation throughout the 450 to 500°F range, a 450°F normal condition temperature limit is imposed herein. Temperature limits associated with short duration transients are as identified by the *silicone* curve in Figure 3.3-1, taken from Figure A3-6, Reference 6:A3-36. Again, this curve corresponds to a 450°F silicone and is therefore somewhat conservative for Parker compound S455-70.

Figure 3.3-1
Elastomeric Seal Life at Temperature



3.4 Thermal Evaluation for Normal Conditions

The thermal evaluation of the Cesium Capsule Canister transported within the Model 1500 packaging has been performed analytically and is presented below. A detailed description of the model is presented in the Appendix, Section 3.6.

3.4.1 Thermal Model

The Cesium Capsule Canister and Model 1500 packaging assembly has been modeled using lumped parameter, electrical analog techniques. The modelling approach was chosen for its conservatism and simplicity, allowing the analyses to be performed quickly, and to be verified by classical hand calculation techniques.

The model shown in Appendix 3.6.1 consists of thirteen (13) solid cells and eight (8) gaseous or air gap cells, including: the environment, the outer thermal shield, the inner thermal shield, the outer surface of the gamma shield, the inner surface of the gamma shield, the Cesium Capsule Canister body and lid, and the cesium capsules. The three capsules are idealized as a single thick-walled cylinder enveloping the locations of the three individual capsules. Heat is assumed to flow radially and axially from the capsules to the canister and then to the Model 1500 inner surface, using both air conduction and radiant heat transfer modes. From the inner surface of the Model 1500 to the outer surface of the cask, both radial and longitudinal (out the top end) flow is modeled. Heat transfer through the lead and stainless steel gamma shield involves both radial and top longitudinal conductive heat flow.

Outside of the gamma shield the two carbon steel thermal shields which make up the Model 1500 jacket are simply modeled, ignoring the thermal effects of the large fin-like covers for the lifting lugs on the side of the gamma shield. Air conduction and radiant heat transfer modes are modeled between the gamma shield and the inner thermal shield as well as between the thermal shields. Convection and radiant transfer is modeled from the outer shield surface to the surrounding environment. Again, both radial and longitudinal flow is modeled through the thermal shields as well as between the outer surface and the environment.

Solar heat loads, when applied, were taken from 10 CFR 71.71(c), and were calculated on the basis of the projected area of the top and sides of a cylinder of the size of the outer thermal shield. Solar loads were applied continuously, as if the total insolation incident on the package over 12 hours per 10 CFR 71.71(c) continued at the same intensity over the entire 24 hour period.

Comparison of temperature predictions from this simplified model with full scale test results for the Model 1500 show that the simplified model conservatively over-predicts temperatures. For example, the thermal differential across the

gamma shield (from inner surface of the protective jacket to the cavity wall) amounts to 168°F by test (Ref. 5:8), and 175°F by means of a benchmark study which used a radial-only version of the thermal model presented herein, adjusted for the heat load of the test program.

3.4.2 Maximum Temperatures

The temperatures predicted for the Model 1500 and Cesium Capsule Canister assembly under maximum solar, internal decay heat, and ambient temperature conditions are presented in Table 3.4.2-1 below. Ambient temperature for this analysis is taken to be 100°F. Insolation on the package is taken to be:

$$(1475 \text{ BTU}/12 \text{ hr}/\text{ft}^2)(36.5 \text{ in. dia.})(53.88 \text{ in. ht.})/(144)(12)$$

- 1679 BTU/hr on side surfaces

$$(2950 \text{ BTU}/12 \text{ hr}/\text{ft}^2)(3.1416)(.25)(36.5 \text{ in.})^2/(144)(12)$$

- 1786 BTU/hr on the top surface

Internal decay heat is taken to be 752 watts, or 2564 BTU/hr.

Table 3.4.2-1
Temperatures Predicted for the Model 1500 and Cesium
Capsule Canister Assembly, °F

Location	Max. Load Case ¹	Min. Load Case ²
WESF Cesium Capsule	700	264
Cesium Canister Side Shell	447	108
Cesium Canister Lid	364	73
Inner Surface, Gamma Shield	271	33
Outer Surface, Gamma Shield	255	30
Inner Thermal Shield	200	-2
Outer Thermal Shield Surface	153	-27
Ambient Environment	100	-40

Notes: (1) Maximum Load Case corresponds to 100°F ambient, full solar loads as defined in the text, and 752 watts internal decay heat.

(2) Minimum Load Case corresponds to -40°F ambient, no solar heat, and 168 watts of internal decay heat.

3.4.3 Minimum Temperatures

Temperatures were calculated assuming that a single, well-aged, or cooled WESF capsule containing only 35,000 Ci of cesium is transported in the Model 1500 and Cesium Capsule Canister assembly. For this calculation, insolation is assumed to be zero, and the ambient temperature is -40°F. Results of this calculation are presented in Table 3.4.2-1 above.

3.4.4 Evaluation

The above analyses demonstrate that the Model 1500 packaging, when loaded with the Cesium Chloride Capsules and Canister, will meet the normal condition thermal requirements of 10 CFR 71. Stresses in the canister as a result of normal thermal conditions are analyzed in Section 2.6 above and shown to be within allowable limits. Temperatures of all seals are within limits to assure effective closure and containment. The silicone seal in particular experiences a maximum temperature of 364°F, or 86°F below its 450°F allowable.

3.5 Hypothetical Accident Thermal Conditions

3.5.1 Thermal Model for Accident Conditions

The accident analysis utilizes the same basic model used for the analysis of the normal conditions, except that the solar heat loads are omitted per 10 CFR 71.73(c). Internal decay heat loads are taken as 752 watts as in the normal condition maximum heat load case, and ambient temperature is taken to be 100°F prior to the start of the hypothetical accident event.

During the first 30 minutes of the event, the package is assumed to be surrounded by a thermal environment at 1475°F with an emissivity of 0.9. The outside surface of the package continues with its emissivity of 0.8 as before. After 30 minutes, the environment reverts back to 100°F.

To model the non-black body emissivity of the environment, an equivalent temperature may be calculated which provides identical heat transfer into the package from the idealized *black body* radiator.

$$\begin{aligned}
 T_{\text{eqv}} &= (E_o(T^4))^{.25} \\
 &= ((.9)(1475 + 459.69)^4)^{.25} - 459.69 \\
 &= 1424.71^\circ\text{F}
 \end{aligned}$$

Temperatures were calculated at 3 minute intervals for the first hour, then at 9 minute intervals for the remainder of the 6 hour thermal transient. All nodes

had reached their maximum temperature and had begun to cool by 4.2 hours after the the start of the event.

3.5.2 Transient Results

Figures 3.5-1 and 3.5-2 present the results of the transient analysis in graphical form. Table 3.5-1 presents the maximum temperature attained by key model nodes throughout the transient.

Table 3.5-1
Maximum Hypothetical Accident Temperatures, °F

Location	Maximum Temperature
WESF Cesium Capsule	761
Cesium Canister Side Shell	554
Cesium Canister Lid	501
Inner Surface, Gamma Shield	429
Outer Surface, Gamma Shield	449
Inner Thermal Shield	1057
Outer Thermal Shield Surface	1294

Figure 3.5-1
MODEL 1500 CASK RESPONSE TO
HYPOTHETICAL FIRE ACCIDENT
752 watts Cesium Chloride Loading

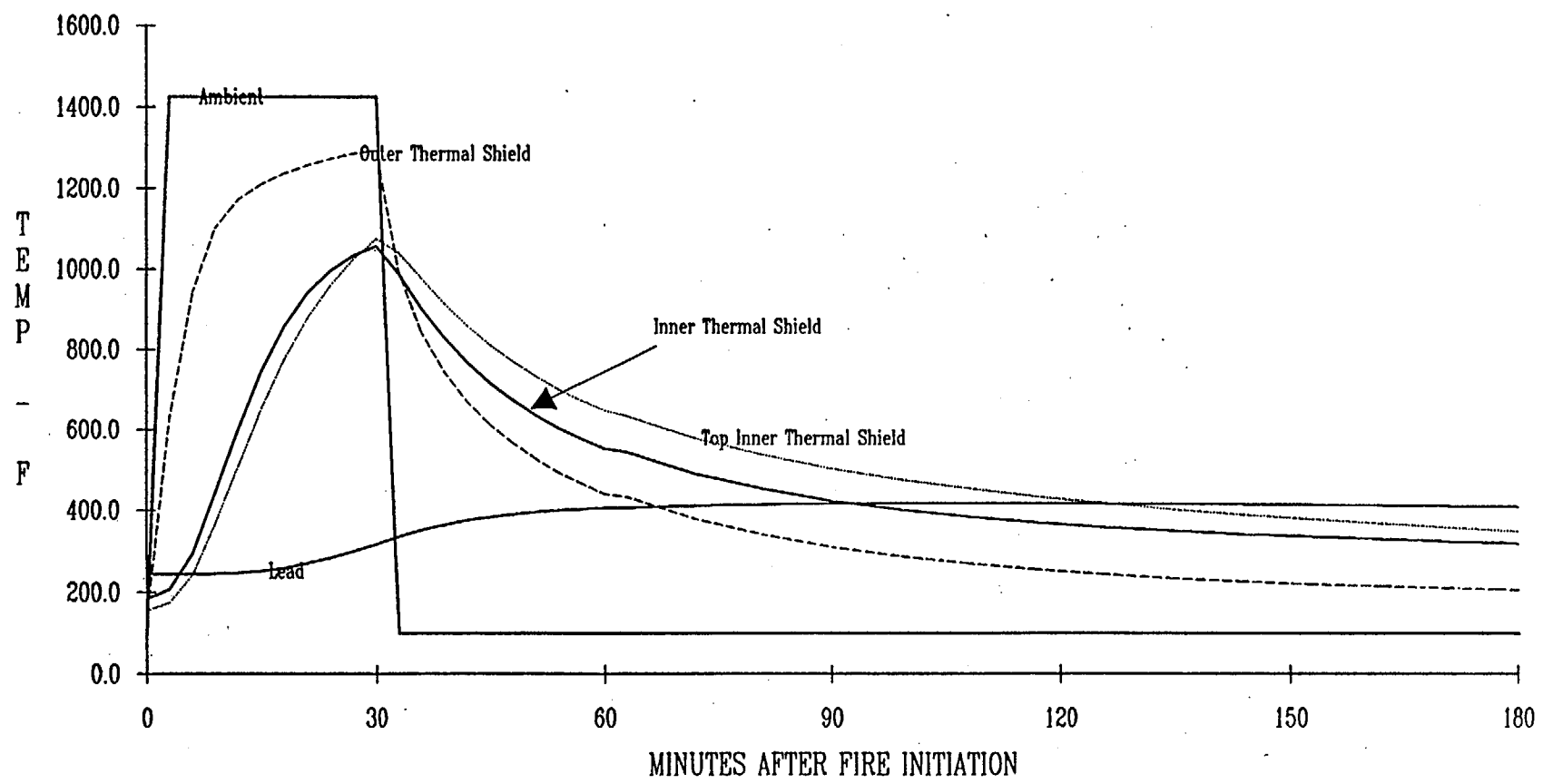
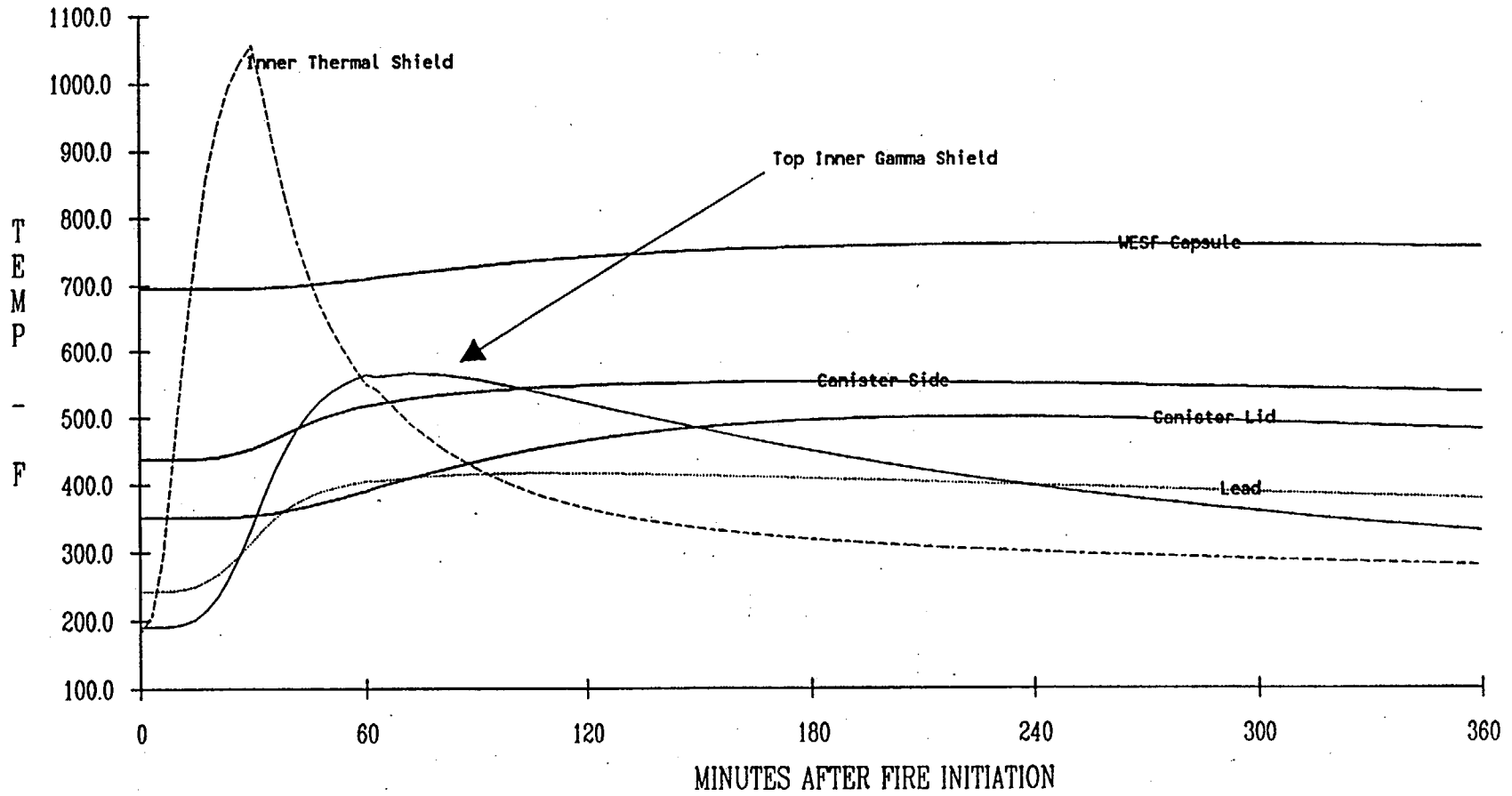


Figure 3.5-2:
MODEL 1500 CASK INTERNALS RESPONSE TO FIRE
752 watts Cesium Chloride Canister Loading



3.5.3 Evaluation

The above analyses demonstrate that the Model 1500 packaging, when loaded with the Cesium Capsules and Canister, will meet the hypothetical accident condition thermal requirements of 10 CFR 71. Response of the canister itself to accident thermal conditions is addressed in Section 2.7 above and shown to be acceptable. Temperatures of all seals are within limits to assure effective closure and containment. The silicone seal in particular experiences a temperature excursion to 500.6°F and remains above 500°F for less than 36 minutes. From Section 3.3, excursions to 515°F for ten (10) hours are fully acceptable.

3.6 Appendix

3.6.1 Thermal Model

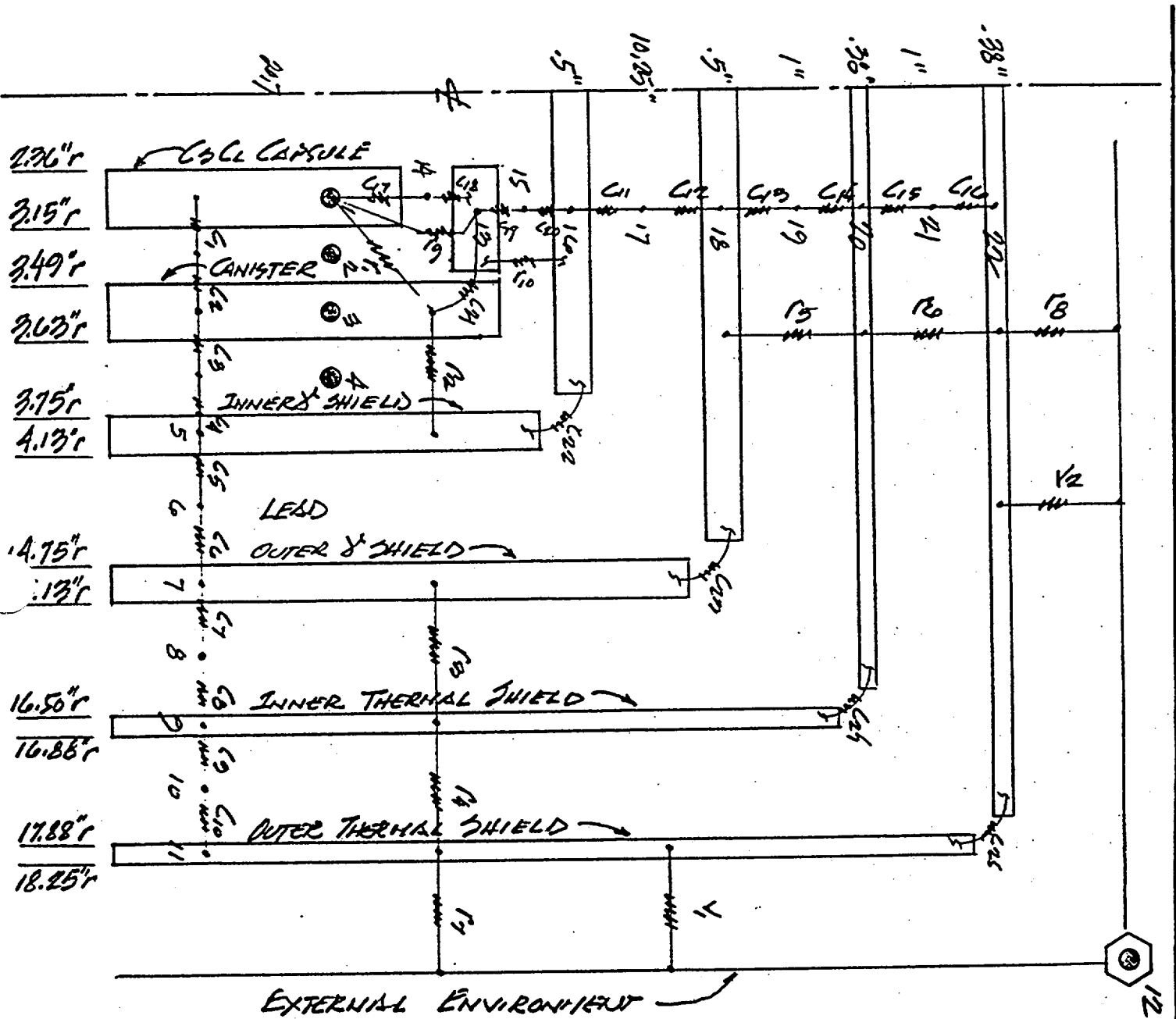
The thermal model used to predict the temperature of the Cesium Capsule Canister is shown schematically in Figure 3.6.1-1. The analysis was performed using a PC heat transfer analysis package called THNET developed by Rowe and Associates. The steady state results were checked by simple and completely independent hand analysis by working inward from the ambient node, solving for the temperatures of each node using an iterative solution technique to solve the non-linear expression for heat flow between the nodes.

The model consists of 22 nodes: At the CsCl capsules, the canister backfill gas (air), the canister shell, the canister lid and bolts, the Model 1500 cavity, the inner stainless wall of the Model 1500, the lead shielding, the outer stainless wall, the gap between the outer wall and the inside surface of the thermal "jacket", that inner thermal jacket surface, the hollow gap inside the jacket, the outer surface of the jacket, and the environment. As described in the text, both radial and axial heat transfer pathways are modeled within the cavity of the Model 1500.

3.6.2 Thermal References:

1. Shappert, "Cask Designer's Guide", ORNL-NSIC-68
2. F. Kreith, *Principles of Heat Transfer*, Third Ed., Intext Press, Inc. 1973
3. J. P. Holman, *Heat Transfer*, McGraw-Hill Book Co., 1963
4. 10 CFR 71, Packaging & Transportation of Radioactive Material.
5. Model 1500 Shipping Container Consolidated SARP, Certificate of Compliance No. 5939, November 18, 1987.
6. Parker O-Ring Handbook, ORD 5700, 1982.

Figure 3.6.1-1
 Cesium Canister & Model 1500
 Thermal Analysis Model Schematic



Note: c_1 = conductive heat transfer
 r_1 = radiation heat transfer
 v_1 = convective heat transfer

4. CONTAINMENT

4.1 Containment Boundary

The containment boundary claimed for the Model 1500 Package, as amended, is described below.

4.1.1 Containment Vessel

The containment vessel consists of a stainless steel canister insert fitted to the 7-1/2" diameter x 25" long payload cavity of the Model 1500 package. This specially designed Cesium Chloride Canister provides the containment boundary for up to three WESF cesium chloride capsules. Although containment is expected to be provided by many and possibly all of the capsules to be shipped, no containment function is claimed for them. Additionally, no containment function is claimed for the Model 1500 Packaging. Rather, the Model 1500 provides confinement for the canister, and the canister itself provides the containment function. Of note, minimum clearances between the canister and the cavity of the Model 1500 are sufficient to preclude introduction of stresses due to differential thermal expansion; 1/8" clearance is provided in the radial dimension, 1/4" clearance is provided in the axial dimension.

The canister itself is a cylindrical stainless steel can with flat ends. The cylindrical portion is composed of a 6 inch diameter Schedule 10 pipe with 0.134 inch thick walls, a 0.75 inch thick lower end plate and an upper end flange surrounding a 2-1/4 inch thick lid. Three 1/2-inch diameter high strength studs and associated nuts secure the closure lid to the canister body. Each stud threads into a bolting block which welds directly to the wall of the canister upper flange. A 3/16 inch thick silicone gasket is used to obtain a containment seal at the lid to upper end flange interface. The containment boundary is designed to maintain an *integral* leak rate for normal and accident conditions not to exceed 5×10^{-4} scc/sec, as defined within ANSI Standard N14.5-1987.

4.1.2 Containment Penetrations

The containment is penetrated by a pair of vent and drain ports and the three high strength closure studs noted above. Vent and drain penetrations are sealed with metallic o-ring face seals; and the closure studs are sealed with silicone gaskets. All penetrations have been deeply recessed within the 2-1/4 inch thick stainless steel closure lid. All penetrations are designed to *individually* maintain a leak rate not to exceed 1×10^{-4} scc/sec, as defined within ANSI Standard N14.5-1987.

4.1.3 Seals and Welds

There are six containment boundary seals: a primary lid to body silicone gasket face seal, two vent/drain port metallic o-ring face seals and three containment stud nut silicone gasket face seals. The gasket and o-rings will be routinely replaced with each use. Sections 7.0 and 8.0 require leak testing of the canister assembly as follows:

Fabrication verification leak tests performed prior to first use of the canister will demonstrate that the integral leak rate does not exceed 5×10^{-4} scc/sec, per Section 6.3.1 of ANSI Standard N14.5-1987. Halogen detection tests, if utilized, will be performed in accordance with Section A3.7 of ANSI Standard N14.5-1987. Periodic verification of this leak rate will be performed after the third use and within twelve months preceeding any subsequent use, per Section 6.4 of ANSI Standard N14.5-1987.

Assembly verification leak tests of the canister, performed with each loading, will demonstrate that the integral leak rate does not exceed 1×10^{-3} scc/sec, per Section 6.5.2 of ANSI Standard N14.5-1987. These tests will be performed using *Gas Bubble* pool immersion testing per Section A3.3 of ANSI Standard N14.5-1987.

All containment boundary structural welds are dye penetrant inspected full penetration welds reflecting conventional ASME Section III practice.

4.1.4 Closure

The containment closure consists of three sets of 1/2 inch diameter high strength studs and nuts fabricated of A-354 Grade BD or similar bolting material. Each nut is torqued to 75 ± 5 ft-lbs.

4.2 Requirements for Normal and Accident Conditions of Transport

Normal and accident conditions are addressed in a consolidated fashion since the physical environment of the Canister is nearly identical for both scenarios. Where differences exist, they are noted. For this application, consolidation allows a more abbreviated, less redundant, treatment than the conventional format of Reg Guide 7.9.

4.2.1 Containment of Radioactive Materials

Conventionally, leak rate requirements are determined by a strict application of the permissible release rates defined within §71.51 of 10 CFR 71. In these assessments, one is concerned with the flow of transport media and radioactive materials from within the package to the external environment. In this application, the cesium chloride material is contained within the non-special

form capsules as a solid, fused-salt. This dry solid possesses a rather low vapor pressure; consequently, conventional containment requirements are modest.

Should water enter the canisters, the containment requirements abruptly become far more demanding. Specifically, cesium chloride is readily soluble in water and, at the elevated temperatures of the canister, the vapor pressure of water provides an aggressive driving mechanism for leakage releases of radioactive materials. Thus, the prevention of water infiltration *into* the canister becomes equally as important as the conventional prevention of material release *from* the canister.

For this reason, leak rate requirements are derived for two bounding conditions within the next Sections. Section 4.2.1.1 develops leak rates for the *outward* transmission of material; Section 4.2.1.2 develops leak rates for the infiltration of water *into* the package containment.

4.2.1.1 Leak Rate to Contain Radioactive Materials.

Each of the three capsules within the canister contains up to 53,200 Ci of ¹³⁷Cesium in a cesium chloride compound. The cesium chloride is cast as a molten salt, which below temperatures of 646°C (1195°F) exists as a monolithic solid. This solid is surrounded by a doubly containing steel cylinder equivalent to that used for special form material. (*Double Containment and Special Form status is not claimed in this application*).

For purposes of this application, it is assumed that the doubly containing cylinder of the capsule is breached. This directly exposes the solid cesium chloride to the containment cavity of the canister. The fused salt solid and the surrounding steel cylinder provide mechanical confinement of the material; never-the-less, cesium chloride vapors mix with the dry air of the containment cavity. This mixture of cesium chloride vapor and dry air constitute the releasible media for this canister package.

4.2.1.1.1 *Basic Release Limits.*

Basic release rates for normal and hypothetical accident conditions are defined in 10 CFR 71, §71.51(1) & (2) as:

<u>Normal Conditions:</u>	R_N	-	$A_2 \times 10^{-6}$ per hour
		-	<u>1×10^{-5} Ci/hr.</u>

This is the partial pressure of the cesium chloride within the containment cavity. At conventional standard conditions (760 mm Hg, 0°C) the volume of cesium chloride within a unit 1ℓ of containment is:

$$\begin{aligned} V_{\text{CsCl}} &= V (P/1 \text{ Atm}) (273^\circ\text{C}/T) \\ &= (1000\text{cm}^3/\ell) (2.58 \times 10^{-8}) [273/(399 + 273)] \\ &= 1.05 \times 10^{-5} \text{ cm}^3/\ell \end{aligned}$$

In moles and grams this becomes:

$$\begin{aligned} V_{\text{CsCl}} &= (1.05 \times 10^{-5} \text{ cm}^3/\ell) / (22400 \text{ cm}^3/\text{mole}) = 4.69 \times 10^{-10} \text{ moles}/\ell \\ &= 8.09 \times 10^{-8} \text{ g}/\ell \text{ CsCl} \quad (\text{molar weight} = 137\text{gCs} + 35.5\text{gCl}) \end{aligned}$$

The quantity of Cesium thus becomes:

$$V_{\text{Cs}} = (8.09 \times 10^{-8}) [137/(137 + 35.5)] = 6.4 \times 10^{-8} \text{ g}/\ell$$

Finally, the specific activity of the releasible media is:

$$\begin{aligned} C_N, C_A - V_{\text{Cs}} \eta &= (6.4 \times 10^{-8}) (98) = 6.30 \times 10^{-6} \text{ Ci}/\ell \\ &= \underline{6.30 \times 10^{-9} \text{ Ci}/\text{cm}^3} \end{aligned}$$

Where: η = 98 Ci/g; the Specific Activity per Table A-1 of 10 CFR 71, August 5, 1983, for the ¹³⁷Cesium radionuclide contents of this package.

4.2.1.1.3 Permissible Leak Rates at Service Conditions.

Permissible leak rates are found from Equations 1 and 3 of ANSI Standard N14.5-1987:

$$\begin{aligned} \text{Normal Conditions: } L_N &= R_N/C_N \times 1/3600 \\ &= (1 \times 10^{-5}) / (6.30 \times 10^{-9}) \times (1/3600) \\ &= \underline{4.41 \times 10^{-1} \text{ cm}^3/\text{s}} \end{aligned}$$

$$\begin{aligned} \text{Accident Conditions: } L_A &= R_A/C_A \times (1.65 \times 10^{-6}) \\ &= (10) / (6.30 \times 10^{-9}) \times (1.65 \times 10^{-6}) \\ &= \underline{2.6 \times 10^{+3} \text{ cm}^3/\text{s}} \end{aligned}$$

4.2.1.1.4 Permissible Leak Rates at Reference Conditions.

This conversion conservatively assumes an upper bound temperature of 750°F (399°C), corresponding to the temperature previously selected for cesium chloride vapor pressure determinations. With this maximum service temperature, the initial 3 Atm (abs) pressurization, at 26.7°C (80°F pool water temperature) becomes:

$$P_u = (3 \text{ Atm}) \times \frac{(399 + 273)}{(26.7 + 273)} = 6.73 \text{ Atm (abs).}$$

The pressure ratios of both Reference Conditions (298°K, 1 Atm) and Service Conditions are as follows:

		ANSI N14.5 Std. Conditions	Service Conditions
P_d	-	0.01 Atm	1.00 Atm
P_u	-	1.00 Atm	6.73 Atm
P_d/P_u	-	0.01	0.15

When these pressure ratios, P_d/P_u , are less than the the critical pressure ratio, r_c , as defined by Equation B6 of ANSI Standard N14.5-1987, the flow is choked.

$$r_c = \left(\frac{2}{k + 1} \right)^{k/(k-1)} = 0.528$$

Where: $k = 1.4$, ratio of specific heats for air

Thus, the flow regimes of both reference and service conditions is choked. For choked flows, conversion to reference leak rates may be achieved by use of Equation B13 of ANSI Standard N14.5-1987:

$$L_R = L_S \sqrt{(298/T_u)} \times (1/P_u)$$

$$= L_S \sqrt{[298/(399+273)]} \times (1/6.73) = 0.0989 L_S$$

Finally, the permissible reference leak rates are:

<u>Normal Conditions:</u>	L_{Rn}	-	$(4.41 \times 10^{-1})(0.0989)$	
		-		$4.36 \times 10^{-2} \text{ cm}^3/\text{s}$
<u>Accident Conditions:</u>	L_{Ra}	-	$(2.6 \times 10^3)(0.0989)$	
		-		$2.57 \times 10^2 \text{ cm}^3/\text{s}$

4.2.1.2 Leak Rate to Preclude Water Infiltration.

The canisters will be loaded in the RSI-Decatur pool on a platform at a waterline depth of 187.5 inches (15.6 feet). The base of the pool is at a water depth of 284.5 inches (23.7 feet). For *normal* leak rate assessment purposes, the hydrostatic head will be conservatively assumed at 25 feet (0.74 Atm). For hypothetical *accident* leak rate assessment purposes, the hydrostatic head is taken at 50 feet (1.47 Atm), per 10 CFR 71, §71.73(b)(5).

The maximum diameter of a leak that can be considered *blocked* by surface tension effects is estimated from Equation B16 of ANSI Standard N14.5-1987:

$$D = \frac{3.95 \times 10^{-6} \sigma}{(P_u - P_d)} = \frac{(3.95 \times 10^{-6})(71.7)}{(0.74 \text{ or } 1.47)}$$

- $3.8 \times 10^{-4} \text{ cm}$ (normal case)
- $1.9 \times 10^{-4} \text{ cm}$ (accident case)

Where:

- P_u - The *upstream* pressure, here the absolute hydrostatic head:
 - $1 + 0.74$ - 1.74 Atm (normal case)
 - $1 + 1.47$ - 2.47 Atm (accident case)
- P_d - The *downstream* pressure, here the absolute pressure within the canister, conservatively assumed as:
 - 1.0 Atm
- σ - 71.7 dynes/cm, the surface tension at 26.7°C (80°F), per CRC data.

The reference leak rate, I_R , corresponding to this hole diameter is found from Equations B2 to B7 of ANSI Standard N14.5-1987. For the flow to be un-choked, the pressure ratio, P_d/P_u , must exceed the critical pressure ratio, r_c , as defined by Equation B6 of ANSI Standard N14.5-1987:

$$r_c = \left(\frac{2}{k+1} \right)^{k/(k-1)} = 0.528$$

Where: $k = 1.4$, ratio of specific heats for air

But, $P_d = 0.01 \text{ Atm}$ | - for ANSI N14.5 Standard Conditions
 $P_u = 1.00 \text{ Atm}$ |

$P_d/P_u = 0.01$, thus, the flow is choked.

The corresponding reference leak rates may now be calculated from the choked flow relation, Equation B7 of ANSI Standard N14.5-1987:

$$I_R = \frac{\pi D^2}{4} \sqrt{\frac{2 k R_o T_u}{M (k+1)}} \times \left(\frac{2}{k+1} \right)^{1/(k-1)}$$

- $2.27 \times 10^{-3} \text{ scm}^3/\text{s}$ (normal case)
- $5.67 \times 10^{-4} \text{ scm}^3/\text{s}$ (accident case).

Where: $R_o = 8.31 \times 10^7$, universal gas constant
 $T_u = 298^\circ\text{K}$, standard condition temperature
 $k = 1.4$, air constant, Table B1, N14.5
 $M = 29 \text{ gmol}$, air gram molecular weight, Table B1, N14.5

Thus, the *accident* case corresponding to a 50 foot immersion, per 10 CFR 71, §71.73(b)(5), defines the water infiltration leak rate criteria.

4.2.1.3 Leak Rate Criteria to Assure Containment of Radioactive Material.

To summarize, the two reference leak rate requirements, derived above, are as follows:

Outward Leakage of Contents: $4.36 \times 10^{-2} \text{ scm}^3/\text{s}$

Inward Leakage of Water: $5.67 \times 10^{-4} \text{ scm}^3/\text{s}$

The more restrictive reference leak rate requirement,

$$L_R = 5.67 \times 10^{-4} \text{ scm}^3/\text{s},$$

precluding water infiltration into the package, defines reference leak rate requirements for this Model 1500 Canister Package.

4.2.2 Pressurization of Containment Vessel.

The canisters are vacuum dried to remove all water vapor prior to backfilling with dry air at 3 atm absolute, see Section 7.1. Once backfilled, pool water intrusion is precluded due to pressure head differentials. Thus, elevated temperature pressure predictions for the canister are based upon the volumetric expansion of dry air only. The canister is initially pressurized to 3 Atm (abs) while immersed within the loading pool, at a temperature of approximately 26.7°C (80°F). At 750°F (399°C), the resultant maximum internal pressure is:

$$P_{750} = (P_{80} - 3 \text{ Atm}) \times \frac{(399 + 273)}{(26.7 + 273)} = 6.73 \text{ Atm (abs)}$$

Since the rupture pressure of the canister is in excess of 50 Atm (rel), see Section 2.6.1.2, which shows that normal allowables can be satisfied with internal pressures as high as 749 psig, the minimum Margin of Safety against burst or loss of containment (due to pressure effects) is:

$$\text{M.S.} = 50/(6.73-1) - 1 = \underline{+ 7.73}$$

4.2.3 Containment Demonstration Criterion

Leak tests appropriate to a reference leak rate, $L_R = 5.67 \times 10^{-4} \text{ scm}^3/\text{s}$, as determined in paragraph 4.2.1.3, will demonstrate compliance of the package and canister to the containment requirements of §71.51 for *normal* (§71.71) and hypothetical *accident* conditions (§71.73). These leak tests will be performed in full accordance with the requirements of ANSI Standard N14.5-1987. Please refer to Chapter 8 of this amendment for specific detail pertinent to fabrication verification, periodic verification and assembly verification.

Of note, assembly verification will employ a gas bubble test, see Section A3.3 of ANSI Standard N14.5-1987, conducted within the water pool used to load the canisters and package. The duration of this test will be not less than 15 minutes, as required in Section A3.3 of ANSI Standard N14.5-1987. This duration is sufficient to demonstrate package canister leak rate characteristics at the pool workstand depth. Supporting analyses demonstrate that pressurization,

bubble size and bubble generation rates are appropriate to assure reliable and accurate leak testing.

4.2.3.1 Required Canister Pressurization:

Gas bubble leak checks will be performed on a workstand at a maximum waterline depth of 16 feet (0.47 Atm). The minimum internal pressure for viable bubble testing is given by Equation B16 of ANSI Standard N14.5-1987:

$$\begin{aligned}
 P_u &= P_d + 3.95 \times 10^{-6} \sigma/D \\
 &= 1.47 + (3.95 \times 10^{-6})(71.7)/(1.9 \times 10^{-4}) \\
 &= 2.96 \text{ Atm} = 43.5 \text{ psia} = 28.8 \text{ psig}
 \end{aligned}$$

$$\text{Say: } P_u = \underline{3 \text{ Atm (abs)} = 29.4 \text{ psig}}$$

4.2.3.2 Bubble Size and Generation Rate:

Bubble size is given by Equation B17 of ANSI Standard N14.5-1987:

$$\begin{aligned}
 D_B &= (6D\sigma g_0 / [g(\rho_1 - \rho_g)])^{0.333} \\
 &= ((6)(1.9 \times 10^{-4})(71.7)/[(981)(1 - 3.87 \times 10^{-3})])^{0.333} \\
 &= \underline{0.044 \text{ cm}} \approx \underline{1/64 \text{ inch.}}
 \end{aligned}$$

Where:

$$\begin{aligned}
 D &= 1.9 \times 10^{-4} \text{ cm, leak diameter from §4.2.1.2} \\
 \sigma &= 71.7 \text{ dynes/cm, from §4.2.1.2} \\
 g_0 &= \text{dimensional constant, } 1 \text{ g cm/(dyne s}^2\text{)} \\
 g &= 981 \text{ cm/s}^2, \text{ gravitational constant} \\
 \rho_1 &= 1, \text{ liquid (water) density, g/cm}^3 \\
 \rho_g &= \text{gas (air) density, g/cm}^3 \\
 &= (29 \text{ g/mole})/22,400 \text{ cm}^3/\text{mole} \\
 &= 1.29 \times 10^{-3} \text{ g/cm}^3 \text{ at 1 Atm (stp)} \\
 &= 3.87 \times 10^{-3} \text{ g/cm}^3 \text{ at 3 Atm}
 \end{aligned}$$

Bubble generation rate is given by Equation B18 of ANSI Standard N14.5-1987:

$$v = \frac{6 L}{\pi D_B^3} = \frac{6(1.7 \times 10^{-3})}{[\pi (.044)^3]}$$

$$= \underline{38 \text{ bubbles/s}}$$

Where: L - the volumetric leak rate, transformed from the reference rate, L_R , to pressures and temperatures of the pool, per Equation B13 of ANSI Standard N14.5-1987:

$$L = L_R (P_w/1) (T/298)^{0.5}$$

$$(5.67 \times 10^{-4})(3)(300/298)^{0.5} = 1.7 \times 10^{-3} \text{ cm}^3/\text{s}$$

Both the bubble size and generation rate are sufficient to assure readily visible demonstrations of leakage in excess of permissible limits, should such exist.

4.3 Containment Requirements for Hypothetical Accident Conditions.

Hypothetical accident conditions have been fully addressed within Section 4.2, above. The capsules contain no fissile gas and the most restrictive of normal and accident criteria applies to Canister containment requirements.

4.4 Special Requirements for Plutonium Shipments.

Not applicable, the package canister is not used for the transport of plutonium materials in any form.

4.5 Appendix

4.5.1 Containment References:

1. Cugin, G. E. and G. E. Kimball, "The Vapor Pressure of Some Alkali Halides", J. Phys. Chem, Vol. 16, No. 11, 1948, p. 1044.
2. Denbigh, Ken, Principles of Chemical Equilibrium, Cambridge University Press, 4th Ed., 1981, pp. 203-206.

5.0 SHIELDING

The model 1500 package is presently authorized to transport up to 458,000 curies of $^{137}\text{Cesium Chloride}$; nearly three times the amount of $^{137}\text{Cesium Chloride}$ to be transported in the shipping configuration defined within this amendment. The Model 1500 package shielding features and capabilities are not altered in any fashion by the configuration of this amendment. Thus, by inspection it may be concluded that external dose rates will not exceed the regulatory requirements defined within 10 CFR 71.47.

With the exception of the elastomeric primary containment seal, no components of the packaging are perceptibly degraded by cumulative radiation effects. The following Sections assess the radiation dose experienced by the seal and the effects of that dose upon the projected useful service life of the seal. The calculation herein is conservatively based on an assumption of 55,000 curies per cesium chloride capsule.

5.1 Introduction

The Cesium Capsule Canister primary containment seal (Part (9) of C-110-D-49019-001) is shielded from radiation by the capsule end plugs and the portion of the canister cover that is between the seal and the capsules. The maximum dose rate to the seal has been calculated for use in determining its service life.

5.2 Calculation Description

Symmetry suggests that the maximum dose rate to the seal will occur at the three points that are adjacent to the capsules. One of these points is shown as P_2 in Figure 5.1. The other points of symmetry (one of which is shown as P_3 in Figure 5.1) are obviously the points of minimum dose.

Symmetry permits the dose rate to be calculated along the axis of a single Cesium Chloride capsule. The point P_{1A} occurs where the axis intersects the plane of the seal. An adjustment is then made to account for the difference between the dose at the center line of each capsule and its contribution to the dose rate at P_2 . Finally, these contributions are summed to give the total dose rate at P_2 .

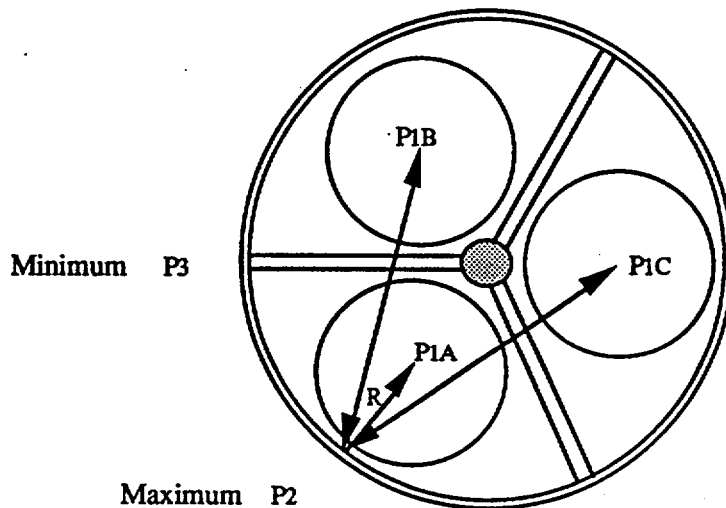


Figure 5.1 Points of Maximum and Minimum Dose Rates

FIGURE WITHHELD UNDER 10 CFR 2.390

Figure 5.2 Input parameters to Calculating Dose Rate at P1 A

5.2.2 Adjustment of Dose Rate from Capsule Closest to P2

Rockwell¹ provides equations for disk sources (p. 348) that can be used to estimate the dose at P₂ that is contributed by capsule A. Dividing Rockwell's equation for the dose at P₂ by P₁ gives:

$$\frac{D_2}{D_1} = K\left(\frac{d}{R_0}, \frac{a}{R_0}, \bar{\mu}R_0\right)$$

where:

$$\bar{\mu} \equiv \frac{\sum_i \mu_i t_i}{\sum_i t_i}$$

where:

μ_i = the macroscopic cross section of the ith shield.

t_i = the thickness of the ith shield.

μ in steel and Cesium Chloride for .68 Mev gammas is obtained by interpolating Rockwell's data (p. 452) for .5 Mev and 1 Mev gammas.

Rockwell provides graphs of the function K. The value of K varies with the distance between the seal plane and the source disk. Figure 5.3 shows the two limiting cases and the data needed to evaluate D₂/D₁. The first case is the disk at the top of the capsule. The second case is the lower effective surface of the Cesium Chloride capsule that is estimated using Rockwell's approximation which ignores the material below 3/μ_{Cesium Chloride} (p. 364). The value of D₂/D₁ ranges from about 0.8 for the first case to about 0.9 for the second case. Self-shielding of the Cesium Chloride limits the contribution of the lower disk to the dose rate at P₂. Conservatively, a D₂/D₁ value of 0.9 will be employed.

¹ Rockwell, Theodore, ed., *Reactor Shielding Design Manual*, McGraw Hill, 1956.

FIGURE WITHHELD UNDER 10 CFR 2.390

Figure 5.3 Estimate of Dose Rate at P2/Dose Rate at PIA from Capsule A

5.2.3 Adjustment of Dose Rate from Capsules Farthest From P2

In a similar manner the dose rate from the other two capsules can be calculated from the data shown in figure 5.4. The value of D_2/D_1 ranges from about 0.08 for the first case to about 0.3 for the second case. Again, self-shielding of the Cesium Chloride limits dose contributions from material below the lower disk. Conservatively, the higher value will be employed.

FIGURE WITHHELD UNDER 10 CFR 2.390

Figure 5.4 Estimate of Dose Rate at P2/Dose Rate at **PIC** from Capsule C

5.2.4 Total Dose Rate at P₂

The total dose at P₂ is the sum of dose contributions from all three capsules:

$$DP_2 = (2.7 \times 10^7) (.9 + .3 + .3) = 4.1 \times 10^7 \text{ mr/hr.}$$

5.2.5 Total Dose

For a 30 day shipment, the accumulated total dose to the containment seal is:

$$(4.1 \times 10^7 \text{ mr/hr})(24 \text{ hr/day})(30 \text{ days})(1 \text{ Rad}/1000 \text{ mr}) = 3.0 \times 10^7 \text{ Rads}$$

5.3 Seal Service Life Evaluation

The containment seal is equivalent to Parker compound S455-70, a specially formulated industrial compound with excellent high temperature properties and good radiation resistance. Parker ranks radiation resistance of S455-70 as third best of seven candidate seal material compounds; slightly above the median.¹

Parker further notes that: "... the majority of elastomers can be expected to maintain a seal after exposure to 10⁷ rads". Thus, S455-70 can be expected to exhibit radiation resistance somewhat in excess of 1 x 10⁷ rads. More definitive silicone seal radiation resistance values are given by Kircher and Bowman². For air exposures, the average radiation stability limit is shown to be approximately 4.8 x 10⁷ rads. For vacuum, the limit *increases* to 2 x 10⁸ rads. In the presence of petroleum materials, the limit is reduced to approximately 1 x 10⁷ rads.

Since the capsule is backfilled with dry air, the air radiation stability limits of 4.8 x 10⁷ rads is applicable. Based on this, the projected minimum service life of the seal is:

$$\begin{aligned} (4.8 \times 10^{10} \text{ mr}) / (4.1 \times 10^7 \text{ mr/hr}) &= 1171 \text{ hours} \\ &= \underline{\underline{49 \text{ days}}} \end{aligned}$$

¹ Parker Standard Compounds, Parker O-Ring Handbook, ORD-5700, Parker Seal Group, Lexington, KY, 1982.

² Kircher, John F., and Richard E. Bowman, *Effects of Radiation on Materials and Components*, Reinhold Publishing Corporation, New York, 1964, Table 3.24, Page 159.

A minimum 49 day service life for the seals provides a generous margin of safety over the 16 day shipping sequence moving capsules from the irradiator facilities to WESF Operations in Richland, WA. The sequence is conservatively estimated as follows:

Loading	2 days
Shipping Preparation	2 days
Shipment	7 days
Receiving	2 days
Unloading	<u>3 days</u>
	16 days

In the event of a tractor breakdown during any shipment, another tractor could be dispatched to retrieve the cask and transport the shipment to WESF Operations in Richland, WA with 7 days. This will increase the total time to 23 days which still provides a wide margin of safety.

6.0 CRITICALITY EVALUATION

Not applicable, fissile materials are not to be transported in the packaging configuration defined within this amendment.

7.0 OPERATING PROCEDURES

This chapter describes the general procedure for loading and unloading of the cesium chloride capsule canister. Loading is done underwater in a pool, whereas unloading is performed in a hot cell environment.

7.1 Procedure for Wet Loading

NOTE: Refer to the Model 1500 cask operating procedure for the pool loading sequence (Reference - Exhibit H of the Model 1500 SARP; Chapter XVIII, Section Q - Model 1500 loading/unloading procedure).

NOTE: Refer to the schedule stated in Sections 8.2.1.2 and 8.2.2.1 of this addendum for gasket and o-ring replacement schedules and periodic leak testing requirements.

7.1.1 Remove the lid if installed.

7.1.2 Perform a visual inspection of the canister (e.g., check the seals for proper positioning; check the lid for any groove defects; check the closure studs for any cracking or deformation).

7.1.3 Use handling tools to lower the open, empty canister into the pool onto the working platform.

CAUTION: The canister and the platform track plate have alignment marks for matching.

Tracks (2) on the platform will mate with the two recessed, slotted channels in the canister base plate.

7.1.4 Disconnect handling tools.

7.1.5 Load the cesium capsule(s) into the canister.

NOTE: Remote handling tools will be used to directly load each of the cesium capsules into the canister cavity. Each cesium capsule will have been previously tested (as per Section 1.2.3 of this Addendum).

7.1.6 Connect the supply and vent lines to the vent and drain connections on the closure lid.

NOTE: The drain connection is located in the center of the lid. The vent connection is offset from the center. The drain and the vent valves in the lid shall be in the open position.

- 7.1.7 Verify that all seals are properly positioned for use.
- 7.1.8 With the vent and drain lines attached, lower the closure lid into the pool and onto the canister body.
- CAUTION:** The lid and canister body have alignment marks to facilitate the proper positioning of the lid onto the body.
- 7.1.9 Using the remote handling tool(s), place a closure nut on each of the three (3) closure studs. Incrementally torque the nuts to 75 ± 5 ft-lbs each. (Unlubricated)
- 7.1.10 Using service air or inert gas, slowly pressurize the canister to a nominal pressure of 15 psig to displace the water from the canister cavity into a condensate trap (CT) for testing.
- NOTE:** Observe the canister lid for bubbles which would indicate that a seal has not been made.
- 7.1.11 Continue the displacement process until the discharge flow is primarily air or inert gas.
- 7.1.12 Continue purging the canister cavity for a minimum of 15 minutes to remove any moisture remaining in the cavity.
- 7.1.13 Secure air or inert gas flow and isolate the vent and drain lines to the canister.
- 7.1.14 Prepare the vacuum system by turning on the pump. Observe the pressure gauge on the vacuum pump inlet to assure that the pump is operating properly.
- 7.1.15 Connect the vacuum pump to the vent and drain lines (above pool).
- 7.1.16 Vacuum dry until a pressure of 10 mm Hg or less is achieved for a minimum of 20 minutes.
- 7.1.17 Turn off the vacuum pump and watch for a pressure rise on the vacuum gauge.
- NOTE:** If pressure rises less than 4 mm Hg in 5 minutes, the canister cavity is considered to be dry. If pressure rise is greater than 4 mm Hg, repeat steps 7.1.15 through 7.1.17.
- 7.1.18 Disconnect the vacuum pump from the vent and drain lines (above pool).

- 7.1.19 Reconnect the air or inert gas supply and vent lines (above pool).
 - 7.1.20 Pressurize the canister with dry air or inert gas to 30 psig.
 - 7.1.21 Close the drain and vent valves by torquing the nuts clockwise. Torque to 25 ± 5 ft-lb each (lubricated).
 - 7.1.22 Continuously observe the canister for any air leakage through the pool water while maintaining pressure for a minimum of 15 minutes. Bubbles will indicate that an adequate seal was not established.
 - 7.1.23 Disconnect the inlet and outlet lines from the lid connection.
 - 7.1.24 Attach the canister lifting bail to the crane hook.
 - 7.1.25 Load the canister into the Model 1500 cask.
 - 7.1.26 Refer to the Model 1500 loading/unloading procedure to prepare the cask for shipment.
 - 7.1.27 Connect the air supply hose to the cask vent connection.
 - 7.1.28 Connect the air purge fitting into the cask drain opening.
 - 7.1.29 Purge the cask for approximately 15 minutes.
 - 7.1.30 Stop the purge and allow the cask to stand approximately 20 minutes.
 - 7.1.31 Disconnect the air supply and drain fitting.
- NOTE:** After the cask has been prepared for shipment and prior to shipment, perform the following steps to ensure that the cask cavity is dry.
- 7.1.32 Connect the vacuum pump to the cask vent connection. Ensure drain plug is installed.

- 7.1.33 Start the vacuum pump drawing a vacuum on the cask cavity. Continue until vacuum reaches 1 Torr.
- 7.1.34 Isolate vacuum pump from cask.
- 7.1.35 Slowly vent cask to allow the cask cavity to reach atmospheric pressure.
- 7.1.36 Remove cask drain plug to verify that the drain tube is dry.
- 7.1.37 Replace vent and drain plugs.

7.2 Procedure for Dry Unloading

- 7.2.1 Refer to the Model 1500 operating procedure for dry unloading.
- 7.2.2 Attach the canister lifting bail to the crane hook.
- 7.2.3 Unload the canister from the Model 1500 and place on an anti-rotation device (in the shielded work area).
- 7.2.4 Use remote handling tools to loosen the vent and drain closure valves to their open positions.
- 7.2.5 Loosen and remove the 3 closure nuts.
- 7.2.6 Remove the closure lid and place in the laydown area.
- 7.2.7 Use remote handling tools to unload each of the cesium capsules from the canister cavity.
- 7.2.8 Move the lid to the decontamination area.
- 7.2.9 Move the canister body to the decontamination area.
- 7.2.10 Decontaminate the canister body and lid.
- 7.2.11 Health Physics shall perform smear and dose rate checks on the canister body and lid prior to release.
- 7.2.12 Document results.

7.3 Procedure for Wet Unloading

- 7.3.1 Refer to the Model 1500 Operating Procedure for wet unloading.

CAUTION: THE CANISTER AND THE PLATFORM TRACK PLATE HAVE ALIGNMENT MARKS FOR MATCHING. TRACKS (2) ON THE PLATFORM WILL MATE WITH TWO RECESSED, SLOTTED CHANNELS IN THE CANISTER BASE PLATE.

7.3.2 With handling tools, remove the canister from the cask and position onto the working platform in the pool.

7.3.3 Disconnect handling tools.

NOTE: THE DRAIN CONNECTION IS LOCATED IN THE CENTER OF THE LID. THE VENT CONNECTION IS OFFSET FROM THE CENTER.

7.3.4 Connect the supply and vent lines to the vent and drain connections on the closure lid.

7.3.5 Verify that the drain and vent valves in the lid shall be in the closed position.

7.3.6 Use remote handling tools to loosen the vent and drain closure valves to their open positions.

7.3.7 Loosen and remove the 3 closure nuts.

7.3.8 With the vent and drain lines attached, raise the closure lid up from the pool to the decontamination area.

7.3.9 Using remote handling tools, unload the Cesium capsule(s) from the canister and position it (them) in an assigned area.

7.3.10 Use handling tools to raise the canister to pool surface.

7.3.11 Remove water from the canister.

7.3.12 Move canister to decontamination area.

7.3.13 Decontaminate the canister body and lid.

7.3.14 Health Physics shall perform smear and dose rate checks on the canister body and lid prior to release.

7.3.15 Document results.

7.4 Procedure For Dry Loading

- 7.4.1 Refer to Model 1500 Operating Procedure for dry loading.
- 7.4.2 Remove the canister lid if installed.
- 7.4.3 Perform visual inspection of the canister (e.g., check the seals for proper positioning; check the lid for any groove defects; check the closure studs for any cracking or deformation).

CAUTION: THE CANISTER AND THE PLATFORM TRACK PLATE HAVE ALIGNMENT MARKS FOR MATCHING. TRACKS (2) ON THE PLATFORM WILL MATE WITH THE TWO RECESSED, SLOTTED CHANNELS IN THE CANISTER BASE PLATE.

- 7.4.4 Position the canister body on an anti-rotation device (in shielded work area).

NOTE: REMOTE HANDLING TOOLS WILL BE USED TO DIRECTLY LOAD THE CESIUM CAPSULE(S) INTO THE CANISTER CAVITY. EACH CESIUM CAPSULE WILL HAVE BEEN TESTED (AS PER SECTION 1.2.3 OF THIS ADDENDUM).

- 7.4.5 Load the Cesium capsule(s) into the canister.

NOTE: THE DRAIN CONNECTION IS LOCATED IN THE CENTER OF THE LID. THE VENT CONNECTION IS OFFSET FROM THE CENTER.

- 7.4.6 Connect the supply and vent lines to the vent and drain connections on the closure lid.

- 7.4.7 Verify that the drain and vent valves in the lid shall be in the open position.

- 7.4.8 Verify that all seals are properly positioned for use.

CAUTION: THE LID AND CANISTER BODY HAVE ALIGNMENT MARKS TO FACILITATE THE PROPER POSITIONING OF THE LID ONTO THE BODY.

- 7.4.9 With the vent and drain lines attached, position the closure lid onto the canister.

CAUTION: THE TORQUING PROCESS SHOULD START WITH 15 FT-LBS. FOR EACH NUT AND THEN INCREASED BY 10 FT-LBS. UNTIL 75 FT-LBS. IS REACHED.

- 7.4.10 Using remote handling tool(s), place a closure nut on each of the three (3) closure studs. Torque the nuts to 75 ± 5 ft-lbs each (unlubricated).
- 7.4.11 With the vent and drain line attached, submerge the loaded canister into a container filled with water.
- 7.4.12 Close the drain valve by turning the nut clockwise. Torque to 25 ± 5 ft-lbs (lubricated).
- 7.4.13 Pressurize the canister with dry air or inert gas to 30 psig.
- 7.4.14 Close the vent valve by turning the nut clockwise. Torque to 25 ± 5 ft-lbs (lubricated).
- 7.4.15 Continuously observe the canister for any air leakage through the water for a minimum of 15 minutes. Bubbles will indicate that an adequate seal was not established.
- 7.4.16 Disconnect the inlet and outlet from the lid connection.
- 7.4.17 Remove the canister from the water container and position on the anti-rotation device.

NOTE: THE CANISTER EXTERIOR SHOULD DRY IN APPROXIMATELY 30 MINUTES.

- 7.4.18 Load the canister in the Model 1500 cask.
- 7.4.19 Refer to the Model 1500 loading/unloading procedure to prepare for shipment.

8.0 ACCEPTANCE TESTS AND MAINTENANCE PROGRAM

8.1 Acceptance Tests

Prior to first use of the cesium capsule canister, the following tests and evaluations shall be performed.

8.1.1 Visual Inspection

All welds will be visually examined and dye penetration tested as noted on the drawings in Appendix 1.3.1.

8.1.2 Pressure and Structural Tests

8.1.2.1 *Pressure Test*

Following fabrication, the sealed canister will be pressurized to 135 psig (1.5 times maximum normal operating pressure).

8.1.2.2 *Structural Test*

Prior to first use of any canister, a one time drop test was performed as presented in Appendix 2.10.1 utilizing a single production unit canister. Three simulated cesium chloride capsules with minimum weights of 20 pounds each were loaded into the canister and the canister lid installed. All drop tests were performed at ambient temperature conditions and with 0.0 psig pressure within the canister. Stud nut torques and other containment penetrations were torqued in accordance with the Section 1.3.1 drawings.

The drop test utilized a steel lined, unyielding impact surface (i.e., drop pad mass shall exceed 10 times the mass of the loaded test article). Three, thirty foot drops were performed on the assembled test unit in the following sequence: top end drop, bottom end drop, flat side drop. The entire containment boundary was leak tested before and after each drop in accordance with the requirements of ANSI Standard N14.5-1987. To be acceptable, the measured leakage rate throughout the testing was 5×10^{-4} scc/sec or less. A test report including photometric coverage of the testing shall be retained in the Quality Assurance files for the life of the Cesium Chloride Canisters.

8.1.3 Leak Test

As noted in Section 4.0, a halogen leak test demonstrating a leakage rate of 5×10^{-4} scc/sec or less shall be performed for each canister. This test shall be performed prior to acceptance and operation of a newly fabricated canister using a General Electric Model H-25 leak detector, or equivalent. Calibration of the leak detector shall be made in conjunction with a General Electric Model LS-20 calibrated leak standard, or equivalent. The cavity will be pressurized to 30 psig with pure dichlorodifluoromethane (R-12). The detector probe shall be moved along the exterior surface of all seals and welds.

8.2 Maintenance Program

The cesium capsule canister shall be subjected to routine and periodic inspections and tests as outlined in this section.

8.2.1 Routine Maintenance

Each of the following safety related items and functional features shall be visually examined for defects or replacement. Corrective action for defects shall be as noted.

8.2.1.1 Fasteners

The three lid studs and nuts shall be visually inspected for defects prior to each loading. Obtain replacement parts as specified in the Appendix 1.3.1 drawings for any components that show cracking or other visual signs of distress.

The plugs for the vent and drain ports shall be visually inspected for defects whenever it is necessary to remove them. Obtain replacement plugs as specified in the Appendix 1.3.1 drawings if any cracking or other visual signs of distress are observed.

8.2.1.2 Gaskets and Seals

8.2.1.2.1 Lid, And Closure Nut Gaskets

New silicone gaskets for the lid and closure nuts shall be installed prior to each use. The gaskets shall be visually inspected for serviceability, ensuring that they are in the proper position and free of cracks, tears, cuts, or discontinuities which may prevent them from sealing properly. The seal seating surfaces shall be visually inspected to ensure that they are free of damage, dirt, gravel, or any foreign matter which might damage the seals. If any defects are detected, the seals shall be replaced and/or the seal seating

surfaces shall be reworked as necessary to ensure that the lid will seal properly.

8.2.1.2.2 Vent and Drain Port Seals

These metallic o-ring seals shall be replaced prior to each use. These seals and seating surfaces shall be inspected as specified in Section 8.2.1.2.1 at any time it is necessary to remove them. Seal replacement and/or seating surface repair shall be as specified in Section 8.2.1.2.1 if any defects are detected.

8.2.1.2.3 Non-containment Seals

Non-containment seals associated with the drain and vent port features shall be replaced as required to support operations.

8.2.2 Periodic Maintenance Program

The following inspections and/or tests shall be performed as specified.

8.2.2.1 Leak Tests

The cesium capsule canister shall be leak tested as described in Section 8.1.3 after the third use and within twelve months preceding any subsequent use.

FIGURE WITHHELD UNDER 10 CFR 2.390

UNLESS OTHERWISE NOTED DIMENSIONS ARE IN INCHES DO NOT SCALE PRINT TOLERANCES (UNLESS OTHERWISE SPECIFIED) DEC. JOG: DEC. JOG: DEC. HOLE DIA. AND LOC. $\pm 1/32$ DEC. \pm FRACTIONAL $\pm 1/32$ DOES NOT APPLY TO REF. DIMENSIONS	PROJECT NO. 48019-001-1-A	FSCM NO. 54643	CHEM-NUCLEAR SYSTEMS, INC.	
	DRAWN: MIKE AHEARN	7/14/00	TITLE CESIUM CAPSULE CANISTER	
	CHECKED: PATRICK PAQUIN	8/3/00		
	ENGINEER: H. SHAMKHANI	8/3/00	SIZE	DRAWING NUMBER
QUALITY: CARL ROSS	8/3/00		C-110-D-48019-001	D
APPROVED: R.T. ANDERSON	8/3/00	SCALE	WT	SHEET 1 OF 2

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FIGURE WITHHELD UNDER 10 CFR 2.390

UNLESS OTHERWISE NOTED DIMENSIONS ARE IN INCHES DO NOT SCALE PRINT	PROJECT NO. 4814/88-61-1	FSCM NO. 54643	CHEM-NUCLEAR SYSTEMS, INC.	
	DRAWN: MIKE AHEARN 7/19/88		TITLE CESIUM CAPSULE CANISTER	
TOLERANCES (UNLESS OTHERWISE SPECIFIED) DEC. .XXX DEC. .XXX± DEC. .X± HOLE DIA. AND LOG. ±1/32 DEC. ± FRACTIONAL ±1/8 DOES NOT APPLY TO REF. DIMENSIONS	CHECKED: PATRICK PAQUIN 8/3/88	ENGINEER: H. SHANKHANI 8/3/88	SIZE	REV. D
	QUALITY: CARL ROSS 8/3/88	APPROVED: R.T. ANDERSON 8/3/88	DRAWING NUMBER C-110-D-48019-001	SHEET 2 OF 2
			SCALE	WT

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