Safety Analysis Report

6-80-2 Shipping Cask

SAFETY ANALYSIS REPORT
FOR

MODEL CNS 6-80-2
TYPE A
RADWASTE SHIPPING CASK

REVISION 4
DECEMBER 2003

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1.0 GENERAL INFORMATION

1.1 Introduction

The Model CNS 6-80-2 packaging is a reusable shipping package developed as a safe means of transporting Type "A" quantities of radioactive materials meeting the definition of "Low Specific Activity." Fissile material is limited to those exempt quantities licensed under 10 CFR 71.7. Authorization is sought for shipment by cargo vessel, motor vehicle and rail.

1.2 Package Description

1.2.1 Packaging

The package consists of a one-inch (1-1/8" for casks fabricated after October 31, 1980) external steel shell and a 3/8-inch internal steel shell. The annulus between sheels is filled with 4-1/4" of lead.

Equivalent lead shielding is 5.00 inches for Cobalt 60.

The top and bottom of the cylindrical cask are constructed from a pair of stacked four-inch thick steel plates. The removable lid is secured to the cask body by eight 1-1/4" studs with nuts (or bolts). A 29-inch diameter secondary cask lid is located in the center of the primary lid. It is secured to the primary lid with eight 1-inch studs with nuts (or bolts). Throughout the rest of the SAR, use of the term studs is meant to include bolts also.

Both lids on Model CNS 6-80-2 (see Drawing No. C-110-D-0028) are sealed using silicone gaskets bonded to the lid plates. The secondary lid has a redundant neoprene seal. Both lids on Model CNS 6-80-2 are sealed using a double O-ring configuration as shown on Drawing No. C-110-D-0020, Revision -. All joints are arc welded. 1

A drain line at the base of the package penetrates the containment vessel. The drain line is sealed with a 1/2-inch NPT pipe plug.

All internal cask surfaces are lined with light gauge stainless steel to facilitate decontamination.

The internal cask cavity dimensions are 59" in diameter and 58" high. The cask is used to ship disposable steel liners and 55-gallon drums.

Tie-downs and lifting devices are structurally part of the package and are shown on the general arrangement drawing included in Appendix 2.10.1.

Materials of construction are given on the drawings in Appendix 2.10.1. Mechanical properties of materials are given in Section 2.3.

1.2.2 Operational Features

Refer to the General Arrangement Drawing in Appendix 2.10.1. There are no complex operational requirements associated with the package.

1.2.3 Contents of Packaging

The contents of this cask will consist of:

(1) Type and form of material

(i) Greater than Type A quantities of radioactive material as process solids, either dewatered, solid, or solidified, in secondary container(s), meeting the requirements for low specific activity radioactive materials as defined in 10 CFR 71.4(g)

(ii) Greater than Type A quantities of radioactive material as activated solid components meeting the requirements for low specific activity radioactive material as described in 10 CFR 71.4(g).

(2) Maximum quantity of material per package

Not to exceed 60 thermal watts of radioactive material. The contents may include fissile materials provided the mass limits of 10 CFR 71.7 are not exceeded.

2.0 STRUCTURAL EVALUATION

This section identifies and describes the principal structural engineering design of the packaging, components, and systems important to safety in compliance with the performance requirements of 10 CFR 71.

2.1 Structural Design

2.1.1 Discussion

The principal structural member of the Model CNS 6-80-2 package is the primary containment vessel or transport shield, as described in Section 1.2.1. The above components are identified on the drawing as noted in Appendix 2.10.1. A detailed discussion of the structural design and performance of these components will be provided below.

2.1.2 Design Criteria

The design loads used for this safety evaluation are those specified by 10 CFR 71 for Type "A" packagings. Acceptance criteria of 10 CFR 71 require that shielding and containment for the package be maintained.

2.2 Weights and Center of Gravity

The weight of the cask and liner (or payload) will not exceed 51,500 pounds. The cask weight is approximately 44,000 pounds. The center of gravity for the assembled package is located at the approximate geometric center.

2.3 Mechanical Properties of Materials

The Model CNS 6-80-2 packaging uses an outer and inner shell fabricated of various thicknesses of low carbon hot-rolled steel conforming to ASTM A-36. For casks fabricated after October 31, 1980, low carbon steel shall conform to ASTM A-516, Grade 70. Both yield and ultimate stresses of A-516, Grade 70, are slightly higher than those of A-36 (5% greater yield; 20% greater ultimate). For conservatism, the lower A-36 values are used for analysis throughout this report. Specific properties are as follows:

Per	MIL-HDBK-V
F_{tu} =	55,000 psi
F_{ty} =	36,000 psi
F_{su} =	35,000 psi
F_{brg} =	90,000 psi

Lead shielding will possess those properties referenced in ORNL-NSIC-68, Table 2.6, Page 84.

Lid studs are all of SAE Grade 5 quality possessing the following properties, per ASTM A325 and A449:

	1"	1-1/4"
Proof Load:	78,000 psi	74,000 psi
Tensile Strength:	115,000 psi	105,000 psi

Tie-down lugs are fabricated of U. S. Steel T-1 material possessing the following properties per ASTM A-514:

	2" Plate
F_{tu} =	115,000 psi
F_{ty} =	110,000 psi
F_{su} =	65,000 psi

2.4 General Standards for all Packages

This section demonstrates that the general standards for all packages are met.

2.4.1 Chemical and Galvanic Reactions

The materials from which the packaging is fabricated (steel and lead) along with the contents of the package will not cause significant chemical, galvanic, or other reaction in air, nitrogen or water atmosphere.

2.4.2 Positive Closure

The positive closure system has been previously described in Section 1.2.1. In addition, each package will be sealed with an approved tamper indicating seal and suitable locks to prevent inadvertent and undetected opening.

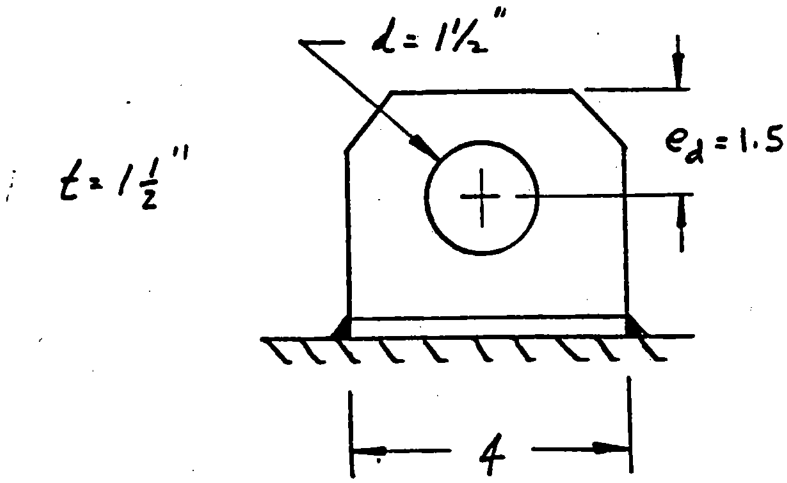
2.4.3 Lifting Devices

Three lifting lugs and four tie-down lugs are provided. The package can be lifted by either the lifting or tie-down lugs. The lifting lugs are primarily designed for lifting the lid only; however, for conservatism, it is assumed the total package is lifted via these three lugs. The lug load is calculated as:

$P_L = Wa_g/N$; Where: W = Package Weight
a_g = Load Factor
N = Number of Lugs

$P_L = (51{,}500)(3)/3 = 51{,}500$ lbs.

The capacity of the lug can be determined from the following:



Using the standard 40° shearout equation:

$$P_a = 2\ F_{su}t \left[e_d - \frac{d}{2} \cos \frac{40^\circ}{2} \right]$$

$$= (2)(35{,}000)(1.5)\ \ 1.5 - .75 \cos 40^\circ$$

$$= 97174 \text{ lbs.}$$

The shearout margin of safety is:

M.S. = (97174/51500)-1 = <u>+0.87</u>

The capacity of the lug-to-lid weld may be estimated as:

$P_a = F_{su}A_w$ $\qquad A_w = l(t_n)$

$l = 2(4 + 1) = 10"$

$t_n = (1/2")\sqrt{2} = 0.707$ ("V" weld)

$P_A = (35{,}000)(10)(.707) = 247487$ lbs.

The lug-to-lid weld margin of safety is:

M.S. = (247487/51500)-1 = <u>+3.81</u>

When lifted by the lid lifting lugs, each primary and secondary lid stud is exposed to a load of:

$P_S = Wa_g/N$; Where: W = Package Weight

a_g = Load Factor

N = Number of Studs

$P_S = (51500)(3)/8 = 19313$ lbs.

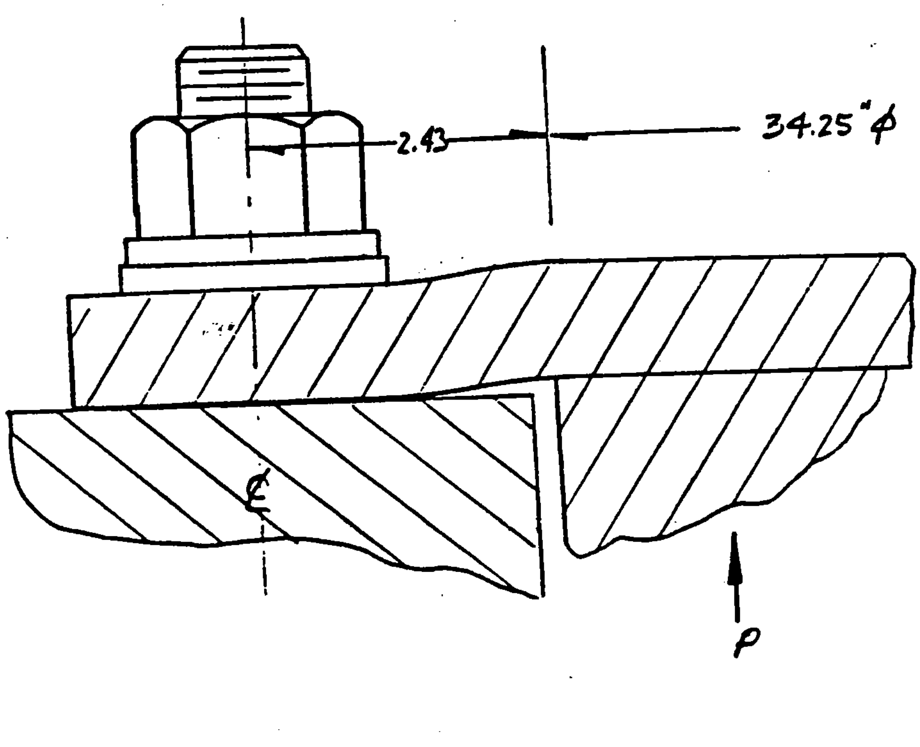
The tensile strength of the smaller secondary lid studs (1-8UNC, SAE Gr. 5) is:

$P_A = F_tA = (115,000)(.563) = 64745$ lbs.

The secondary lid stud margin of safety is:

M.S. = (64745/19313)-1 = $\underline{\underline{+2.35}}$

Loads from the lifting lugs are distributed to the secondary lid where they are reacted by the eight 1-inch diameter Grade 5 studs. The secondary lid must react these loads by plate bending. From the sketch below, it can be seen that the bolts tend to "fix" one end of the plate while the attachment to the two 4-inch plates provides the other fixity.



Bending stress is given as:

$$f_b = 6P(L/2)/\pi Dt^2$$

$$= (6)(51500)(3)(2.43/2)/\pi(34.25)(1)^2$$

$$= 10467 \text{ psi}$$

$$M.S. = (36000/10467)-1$$

$$\underline{M.S. = +2.43}$$

If for conservatism the same analysis was repeated assuming no fixity of the bolts, the stress would be:

$$f_b = 20934 \text{ psi}$$

$$M.S. = (36000/20934)-1$$

$$\underline{M.S. = +.71}$$

Lifting loads from the lugs are distributed into the top plate and the lower four-inch plate by means of plug welds adjacent to each lug as well as a full perimeter weld. Conservatively, assume only the plug welds as being effective. Capacity will be:

$$P = F_tA$$

$$= 36000 \text{ psi } \pi (1)^2/4 \text{ in}^2$$

$$= 28274 \text{ lbs./plug weld}$$

The margin of safety is:

$$M.S. = [(6 \text{ welds})(28274 \text{ lbs./weld})/(3 \text{ g's})(51500 \text{ lbs.})]-1$$

$$\underline{M.S. = +.10}$$

Ultimate capacity of the plug weld is given as:

$$P_u = F_{tu}A$$

$$= (55000 \text{ psi})(\pi)(1)^2/4$$

$$= 43197 \text{ lbs./plug weld}$$

or

$$= 86394 \text{ lbs./lug}$$

This load is (86394/51500 or) 1.67 times greater than the maximum 3g load condition. At loads greater than this, the one-inch thick top plate will locally shear from the lug, out to the adjacent studs. This will leave the primary seal area uneffected and have no detrimental effects on the packages ability to react other requirements of the subpart.

Therefore, it can concluded that the lifting points are more than capable of reacting a load equal to three times the package weight.

2.4.4 Tie-Downs

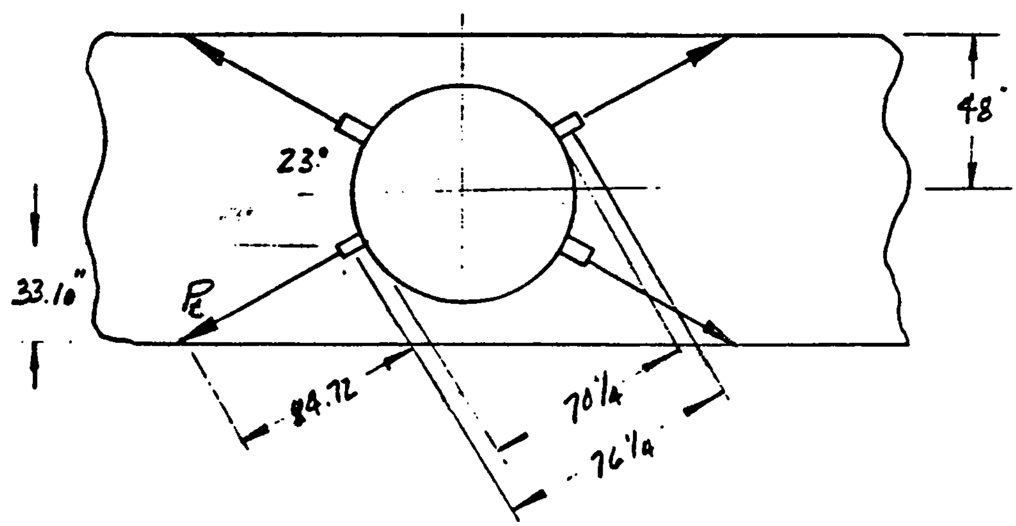
Four tie-down lugs are provided to resist transportation induced loads. The applied load factors are:

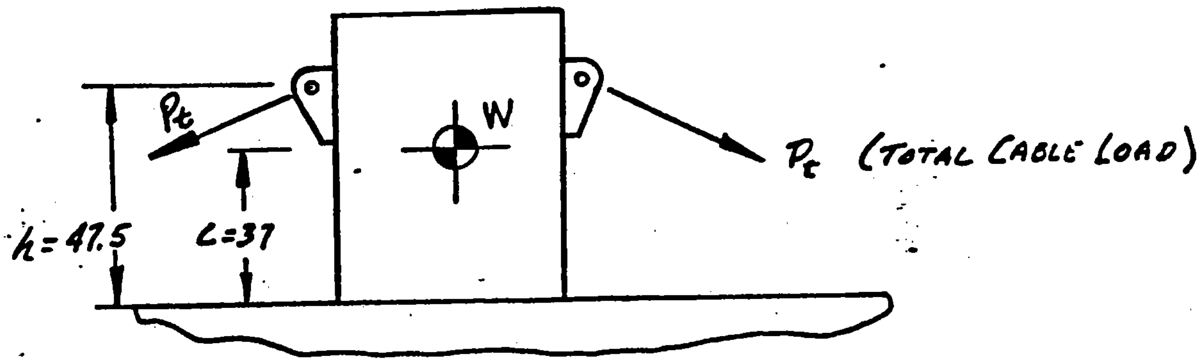
$a_x = 10\,g$ (longitudinal)

$a_y = 5\,g$ (lateral)

$a_z = 2\,g$ (vertical)

Each of the tie-down lugs is located at a 23° angle with respect to the longitudinal axis of the vehicle. Each tie-down cable is presumed to be aligned with the tie-down lug in a plane at a 23° angle witn respect to the longitudinal vehicle axis. The cables are assumed to be tied to the vehicle bed four feet each side of the vehicle center line. The following sketch illustrates the geometry of the tie-down scheme used for loads evaluation.





The tie-down cable geometry may be summarized:

Direction	Length	Direction Cosine
Longitudinal	$l_x = 77.99$	$B_x = .802920$
Lateral	$l_y = 33.10$	$B_y = .340819$
Vertical	$l_z = 47.5$	$B_z = .489041$

A vertical load produces a cable force of:

$P_{Tz} = Wa_z/4B_z$; (4 cables acting)

A longitudinal load factor produces a cable force of:

$P_{Tx} = Wa_x/2B_x\left[(c)/(h)\right]$; (2 cables acting)

Similarly, a lateral load factor produces a cable force of:

$P_{Ty} = Wa_y/2B_y\left[(c)/(h)\right]$; (2 cables acting)

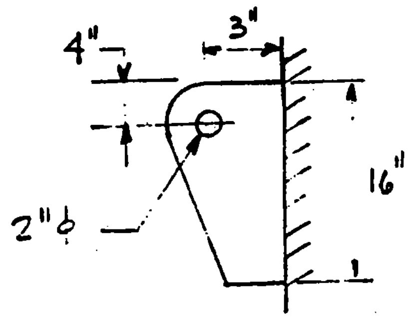
For conservatism, these three loads may be assumed to coincide for the most severely loaded cable:

$$P_T = W\left[\frac{c}{2h}\left(\frac{A_x}{B_x} + \frac{A_y}{B_y}\right) + \frac{A_z}{4B_z}\right]$$

$$= (51500)\left[\frac{37}{(2)(47.5)}\left(\frac{10}{.8029} + \frac{5}{.3408}\right) + \frac{2}{(4)(.4890)}\right]$$

$$= 596726 \text{ lbs.}$$

The capacity of each lug can be determined from the following:



Material:

U. S. Steel T-1

F_{tu} = 115,000 psi

F_{ty} = 110,000 psi

F_{su} = 65,000 psi

Using a 40° shearout, the lug capacity is:

$$P_s = 2F_{su}t\left(e_d - \frac{d}{2}\cos 40^o\right)$$

$$= (2)(65,000)(2)(4 - \frac{2}{2}\cos 40^o) = 840,828 \text{ lbs.}$$

The capacity of the lug-to-cask weld is:

$$P_W = F_{su}A_W; \qquad A_W = 1(t_n)$$

$$1 = 2(16 + 2) = 36''$$

$$t_n = (1'')\sqrt{2}/2 = .707'' \text{ (Fillet)}$$

$$P_W = (35,000)(36)(.707) = 890955 \text{ lbs.}$$

Thus, the minimum margin of safety is associated with shearout and is computed as:

$$M.S. = \left(\frac{840828}{596726}\right) - 1 = +0.41$$

Therefore, it can be concluded that the tie-downs are able to react a load greater than the combined 10, 5 and 2g tie-down loads. Should the tie-downs experience loads greater than 840,828 lbs., the lug will locally shearout. This will not impair the cask's ability to meet other requirements of the subsection.

2.5 Not Applicable

2.6 Normal Conditions of Transport

The Model CNS 6-80-2 packaging has been designed and constructed, and the contents are so limited (as described in Section 1.2.3) that the performance requirements specified in 10 CFR 71.35 will be met when the package is subjected to the normal conditions of transport specified in Appendix A of 10 CFR 71. The ability of the Model CNS 6-80-2 packaging to satisfactorily withstand the normal conditions of transport has been assessed as described below:

2.6.1 Heat

A detailed thermal analysis can be found in Section 3.4 wherein the package was exposed to direct sunlight and 130°F still air. The steady state analysis conservatively assumed a 24-hour day at maximum solar heat load. The maximum steady state temperature was found to be 174°F. These temperatures will have no detrimental effects on the package.

2.6.2 Cold

The materials of construction in this package are identical to those approved and used in numerous existing licensed packages. All of the following utilize the same materials:

1. DOT 6400 Super Tiger
2. DOT 6272 Poly Panther
3. DOT 6679 Half Super Tiger
4. DOT 6553 Paducah Tiger
5. DOT 6744 Poly Tiger
6. NRC 9069 - Model MO-1 Overpack
7. NRC 9073 - Model OH-142 Cask

Therefore, on the basis of years of actual operating experience it is safe to conclude that cold will not substantially reduce the effectiveness of the package.

2.6.3 Pressure

A differential pressure of .5 atmosphere will be reacted by the lid and its associated stud closures. Loads on the lid studs are calculated as:

$$P_S = Ap/N; \quad \text{Where } A = \frac{\pi D^2}{4}$$

$$p = 14.7/2 \text{ psi}$$

$$N = 8$$

For the secondary lid studs, the load is:

$$P_S = \left[\frac{\pi(29)^2}{4}\right]\left(\frac{14.7}{2}\right)\frac{1}{8} = 607 \text{ lbs.}$$

The tensile strength of the 1-8UNC, Gr. 5 studs is:

$$P_A = (115{,}000)(.563) = 64745 \text{ lbs.}$$

Thus, the margin of safety is:

$$\text{M.S.} = (64745/607)-1 = +\text{Large}$$

For the primary lid studs, the load is:

$$P_s = \left[\frac{\pi(59.75)^2}{(4)}\right]\left(\frac{(14.7)}{(2)}\right)\frac{(1)}{(8)} = 2576 \text{ lbs.}$$

The tensile strength of the 1-1/4 - 7UNC, Gr. 5 studs is:

$$P_a = (105{,}000)(.907) = 95248 \text{ lbs.}$$

Thus, the margin of safety is :

$$M.S. = (95248/2576)-1 = +\text{Large}$$

Stresses induced in the cylindrical portion of the cask are conservatively estimated by assuming the pressure differential is totally borne by the 3/8-inch thick inner shell. The hoop and longitudinal stresses are:

$$f_n = PR/t = \left(\frac{14.7}{2}\right)\left(\frac{59/2}{.375}\right) = 578 \text{ psi}$$

$$h_l = PR/2t = \left(\frac{14.7}{2}\right)\left(\frac{59/2}{.375}\right)\left(\frac{1}{2}\right) = 289 \text{ psi}$$

Assuming these biaxial stresses are additive,

$$F_{max} = 867 \text{ psi}$$

The margin of safety is:

$$M.S. = (36000/867)-1 = +\text{Large}$$

Pressure across the end is carried in plate bending by the 2-4 inch thick steel plates top and bottom. Assuming a circular plate, uniformally loaded and with edges simply supported, the stress can be calculated as follows:

$f_r = 3W(3M + 1)/8\pi Mt^2$ (per "Formulas for Stress and Strain" by Roark)

Where: $W = (7.35)(\pi)(70.25)^2/4 = 28489$ lbs.

$t = 4''$

$M = 1/.33 = 3$

$f_r = (3)(28489)(10)/8\pi(3)(16)$

$f_r = 708$ psi

Margin of safety:

M.S. = (36,000/708)-1 = +Large

It can, therefore, be concluded that the packaging can safely react an atmospheric pressure of .5 times standard atmospheric pressure.

2.6.4 Vibration

Shock and vibration normally incident to transport are considered to have negligible effects on the Model CNS 6-80-2 packaging.

2.6.5 Water Spray

Since the package exterior is constructed of steel, this test is not required.

2.6.6 Free Drop

The Model CNS 6-80-2 shielded cask with payload weighs 51,500 lbs. Appendix A.6 of 10 CFR 71 prescribes a drop height of one (1) foot for packages in excess of 30,000 pounds. Three drop orientations are possible: flat end drop, side drop and corner drop. For the flat end drop, the most critical condition will be settlement of the unbonded lead shield at the end opposite the point of impact. For the side drop, no closure or containment components are significantly stressed or deformed. Consequently, the side drop case need not be evaluated. For the corner drop, the most critical condition will be lid closure.

2.6.6.1 Flat End Drop

The evaluation of flat end impact upon settlement of the lead shielding closely follows Shappert's approach for a cylindrical shield, outlined in Section 2.7.3 of his Cask Designer's Guide, ORNL-NSIC-68, February 1970. The lead settlement distance is given by:

$$\Delta H = RWH/\pi(R^2 - r^2)(t_s\sigma_s + R\sigma_{pb})$$

Where:

ΔH = Settlement Depth (in)

H = Drop Height (in)

R = Outer Lead Radius (in)

W = Weight of Lead (lbs)

r = Inner Lead Radius (in)

t_s = Thickness of External Steel Shell (in)

σ_s = Steel Dynamic Flow Stress (psi)

σ_{pb} = Lead Dynamic Flow Stress (psi)

For the CNS 6-80-2 shielded cask, the variables are:

H = 12. inch

R = 59/2 + .375 + 4.25 = 34.125 inch

r = 59/2 + .375 = 29.875 inch

l = 58 + 8-1.25 = 64.75 inch

ρ = .410 lbs/in^3

W = $(R^2 - r^2)\rho l$ = 22685 lbs.

t_s = 1 inch

σ_s = 45000 psi

σ_{pb} = 5000 psi

The predicted lead settlement is thus:

$$\Delta H = \frac{(34.125)(22685) \qquad (12)}{\pi(34.125^2 - 29.875^2)\,[(1)(45000) + (34.125)(5000)]} = 0.050 \text{ inch}$$

This modest settlement "void" in the lead shield cannot transmit radiation because of the stepped design of the package ends. The innermost four-inch solid steel end plates completely back (shield) lead settlement regions at both ends of the package. Thus, lead settlement due to a flat end drop does not compromise, nor alter, the integrity of radiation shielding in any fashion.

2.6.6.2 Corner Drop

The impact energy associated with a corner drop will be absorbed by inelastic deformation of the steel corner. Using the "dynamic flow pressure" concept, total deformation of the corner is estimated and used to compute package deceleration. This deceleration is then used to check the integrity of the lid closure.

The volume of deformed steel is estimated by:

$$K.E. = WH$$

$$K.E. = \sigma_s V_s$$

Thus:

$$V_s = WH/\sigma_s$$

Where:

K.E. = Kinetic energy of drop (in-lb)

W = Package Gross Weight (lb)

H = Drop Height (in)

σ_s = Dynamic Flow Pressure of Steel (psi)

V_s = Volume of Deformed Steel (in^3)

The volume of deformed steel is thus:

$$V_s = \frac{(51500)(12)}{45000} = 13.733 \text{ in}^3$$

Deformation associated with this volume can be estimated from the following geometric expression for a truncated cylinder:

$$V_s = 2 \sin \alpha \left[\frac{t^3}{3} + \frac{r^2 t}{2} \frac{rR^2}{2} \left[\frac{\pi}{2} - \sin^{-1}\left(\frac{r}{R}\right) \right] \right]$$

$$t = (R^2 - r^2)^{\frac{1}{2}}; \; r = \frac{R - S}{\sin \alpha}$$

Where:

S = impact deformation

R = radius of package = 35.125"

α = angle between package bottom and a horizontal plain = 43.5°

For a volumetric deformation of V_s = 13.733 in^3, the corresponding corner deformation is found to be:

S = 1.26 inches

The corresponding deceleration for an impact force which increases with deformation may be computed as:

$$A_g = 2(H/S) = \frac{(2)(12)}{1.26} = 19.1g's$$

Where:

$F_{is} = W_i \, a_g \sin \alpha$

$F_{ic} = W_i \, a_g \cos \alpha$

i = T, total package

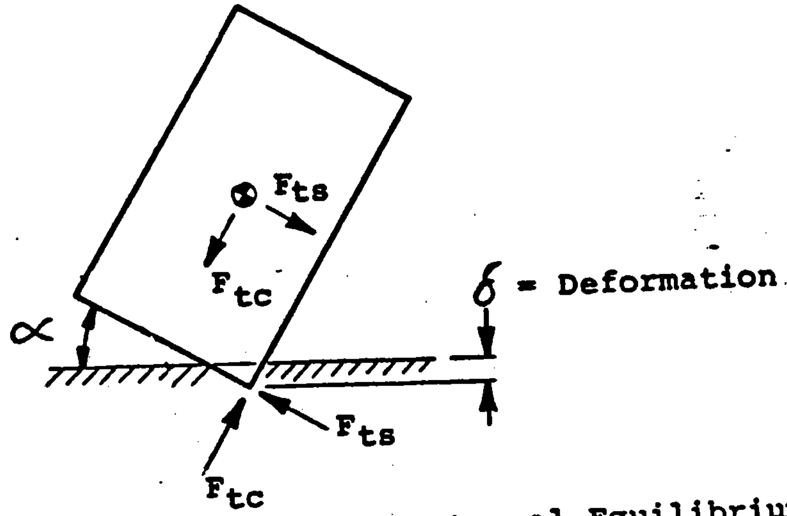
= C, cask side and bottom

= P, payload

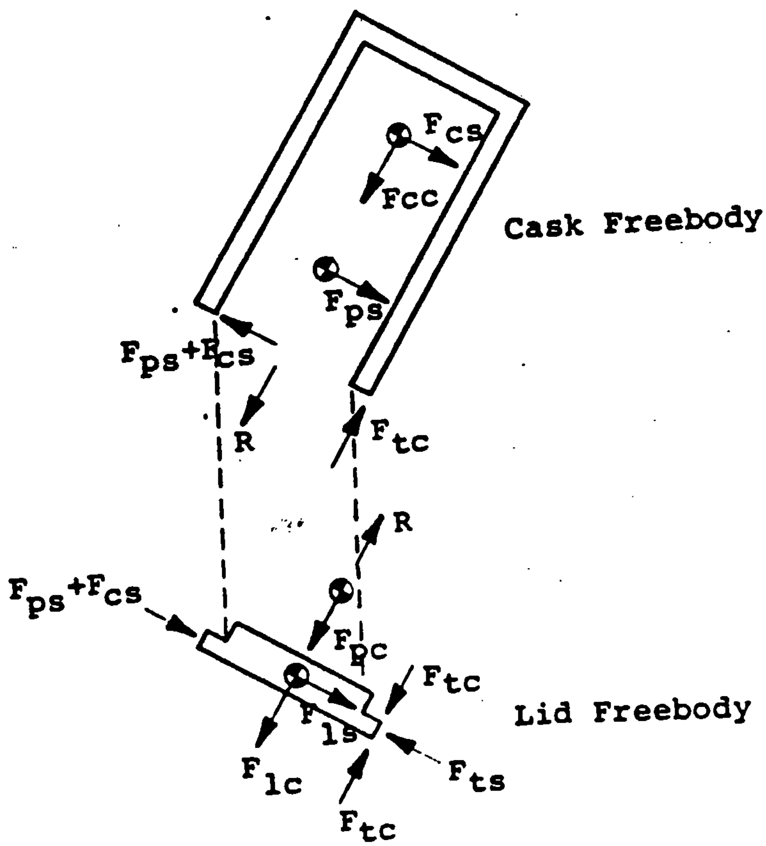
= L, lid

$W_t = W_c + W_p + W_l$

R = Lid/Cask Binder Forces



External Equilibrium
Forces - Corner Impact



Internal Equilibrium
Forces - Corner Impact

This deceleration imposes loads upon the primary lid closure bolts as illustrated in the sketch on the previous page. The total primary lid closure load may be estimated as:

$$R = F_{tc} - F_{cc} = F_{Lc} + F_{pc}$$

$$= (W_L + W_P)\, a_g \cos 43.5^o$$

$$= (7300 + 7500)(19.1) \cos 43.5^o = 205049 \text{ lbs.}$$

Since there are eight primary lid closure studs (1-1/4-7UNC, SAE Gr. 5), each stud load is 25631 lbs. The tensile strength of the stud is:

$$P = \sigma_t A = (10500)(.907) = 95235 \text{ lbs.}$$

Thus, the margin of safety of the primary lid studs is:

$$M.S. = (95235/25631)-1 = \underline{\underline{+2.72}}$$

The secondary lid closure studs are examined in a comparable fashion. Conservatively, the total payload mass of 7500 lbs. is assumed to be reacted by the secondary lid studs. Thus, the total secondary lid stud load is estimated as:

$$R = (W_L + W_P)\, a_g \cos \alpha$$

$$= (2000 + 75000)(19.1) \cos 43.5^o = 131619 \text{ lbs.}$$

Since there are eight secondary lid studs (1-8UNC, SAE Gr. 5), each stud load is 16,452 lbs. The tensile strength of the stud is:

$$P = F_t A = (115{,}000)(.563) = 64745 \text{ lbs.}$$

Thus, the margin of safety of the secondary lid is:

$$M.S. = (64745/16452)-1 = \underline{\underline{+2.94}}$$

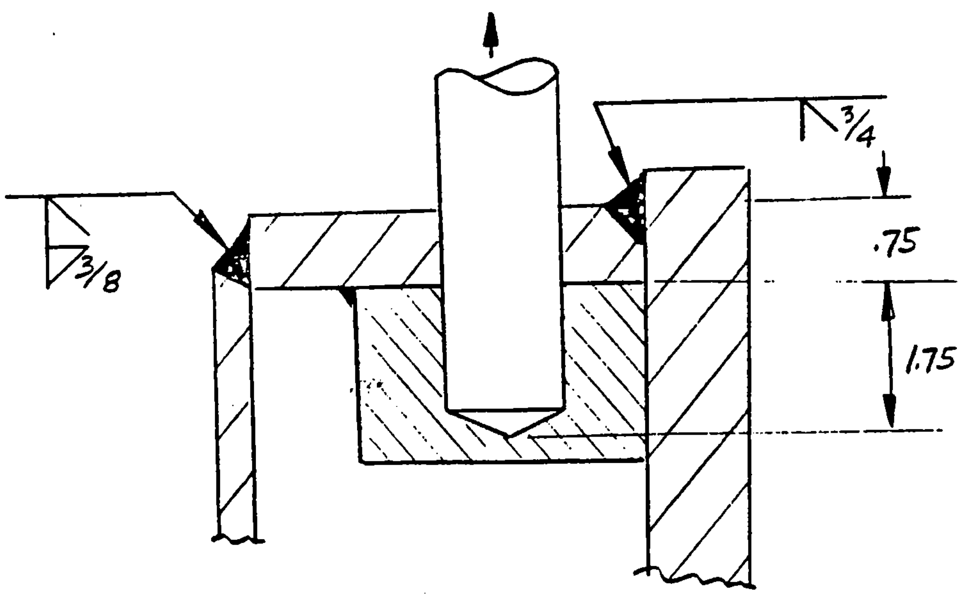
Therefore, it can be safely concluded that the package can survive a normal corner drop.

Detrimental effects resulting from a corner or side drops are limited to the closure areas. Both primary and secondary lids are deeply stepped and manufactured from solid steel plates. From the drawing, it can be seen that the primary lid is designed to be flush with the external edge of the cask. The side impact loads produce lateral shear forces that are reacted in direct compression of the lapped joint. Bolts securing the primary or secondary lids are not required to react this shear force since the radial clearance with their hole is greater than that of their stepped lid, i.e., lid bottoms out before bolts contact. This joint design is identical to the one used in the CH-142 package, Certificate of Compliance Number 9073.

Each stud is threaded into the top closure ring and high strength doubler. Total thread engagement includes .75 inches for the closure ring and 1.75 inches into the doubler. Recommended thread engagement is that equal to the thickness of a heat treated nut of the same tensile strength as the stud. Minimum thickness for a 1-1/4UNC Heavy Hex Nut is 1.250 in. (max.), per Machinery Handbook. Since the doubler is manufactured from a material of greater strength than the stud, the following conservative margin of safety can be calculated.

M.S. = (1.75 in./1.25in.)-1

M.S. = +.40



US T1 STEEL
F_{tu} = 115,000 PSI
2"T x 3"W x 4"L

From the figure on the previous page, tear out or shear strength at the closure ring is calculated as follows. Conservatively assume that the closure ring welds are effective only out 4 inches on either side of the stud center line.

$$P_W = F_{su}A_{weld}$$

Where:

$$F_{su} = 35{,}000 \text{ psi}$$

$$A_{weld} = [(3/4)(.707) + (3/8)]\ 8$$

$$= 7.24 \text{ in}^2$$

$$P_W = (35{,}000 \text{ psi})(7.24 \text{ in}^2)$$

$$P_W = 253{,}470 \text{ lbs.}$$

Margin of safety:

$$M.S. = (253{,}470/25{,}631)-1$$

$$\underline{M.S. = +\text{Large}}$$

Therefore, it can be concluded that both the stud and its attachments are capable of reacting the normal condition loads.

For end drop conditions onto the secondary lid, impact energies will be absorbed primarily by crushing of the top lifting lugs. From the drawing, it can be seen that the lug is chamfered and has a 1-1/2" diameter hole. The effective area can be approximated by the following:

$$A_e = (3 \text{ lugs})(1\text{-}1/2 \text{ in. thick})(4 - 1\text{-}1/2 \text{ in. wide})$$

$$A_e = 11.25 \text{ in.}^2$$

From the standard energy relationships, the crush depth can be calculated as follows:

$$t = (51{,}500 \text{ lbs.})(12 \text{ in.})/(110{,}000 \text{ psi})(11.25 \text{ in}^2)$$

$$t = .50 \text{ in.}$$

Acceleration is given as:

$$A_y = 12\ \text{in.}/.50\ \text{in.}$$

$$A_y = 24\ \text{g's}$$

NOTE: THIS IS A CONSERVATIVE ACCELERATION SINCE IT DOES NOT TAKE INTO CONSIDERATION THE SPRING OR ELASTIC DEFORMATION OF THE LID.

The total load transmitted to the secondary lid is given as:

$$P = (51{,}500\ \text{lbs.})(24\ \text{g's}) = 1.236 \times 10^6\ \text{lbs.}$$

This load must be reacted in directed compression by the seal spacer block. Commpressive stress in the block is:

$$f_b = (1.236 \times 10^6\ \text{lbs.})/(.50)(\pi)(30\ \text{in.})$$

$$f_b = 26{,}200\ \text{psi}$$

Margin of safety:

$$M.S. = (36{,}000/26{,}200)-1$$

$$\underline{M.S. = +.37}$$

Therefore, it can be concluded that the spacer blocks do provide protection to the seal.

2.6.7 Corner Drop

This requirement is not applicable since the Model CNS 6-80-2 packaging is fabricated of steel.

2.6.8 Penetration

From previous container tests, as well as engineering judgement, it can be concluded that the 13-pound rod would have a negligible effect on the heavy gauge steel shell of the cask.

2.7 Hypothetical Accident Conditions

Not applicable for Type "A" packages.

2.8 Special Form

Since no special form is claimed, this section is not applicable.

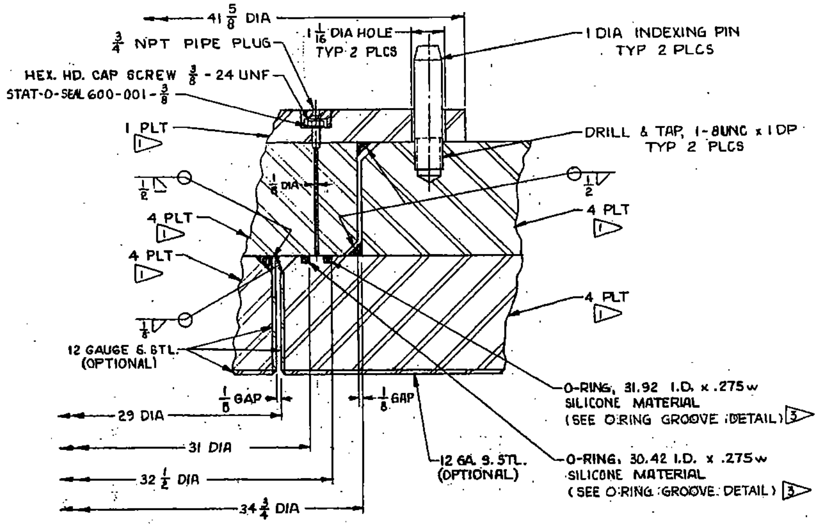
2.9 Fuel Rods

Not applicable.

2.10 Appendix

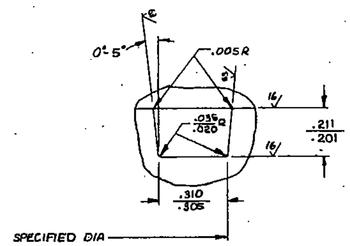
2.10.1 General arrangement drawing of Model CNS 6-80-2 packaging.

ZONE	LTR	DESCRIPTION	DATE	APPROVED
	A	SEE ECO Nº C-110-D-0020-001	12-8-??	[illegible]

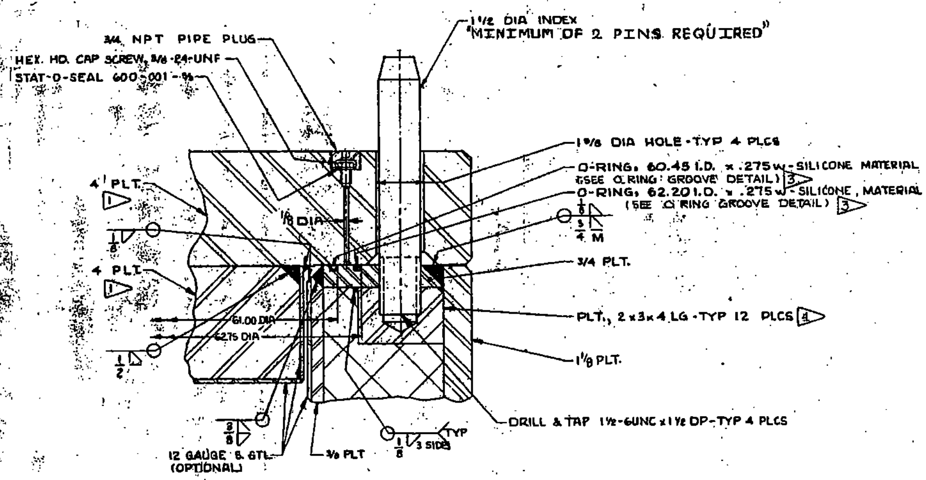


DETAIL C

(REFERENCE ANSI DWG NO. C110-D-0028) 2



O-RING GROOVE DETAIL 3



DETAIL B

(REFERENCE ANSI DWG NO. C110-D-0028) 2

NOTES:

1. MATERIAL: LOW CARBON HOT ROLLED STEEL: STEEL: PLATE AND SHAPES TO CONFORM TO ASTM A-516 GR. 70 SHEETS TO CONFORM TO ASTM A570
2. DETAILS SHOWN ARE OPTIONAL DETAILS TO THE ONES SHOWN ON CHEM-NUCLEAR SYSTEMS DRAWING NO. C-110-D-0028.
3. O-RING GROOVE MAY BE LOCATED ON LID FOR EASE OF MANUFACTURING.
4. MATERIAL: ASTM A 517 GR. F.

ITEM	QTY.	DESCRIPTION	MATERIAL OR PART NO.	MATL. SPEC.	WT.

BILL OF MATERIAL

UNLESS OTHERWISE NOTED DIMENSIONS ARE IN INCHES. DO NOT SCALE PRINT. TOLERANCES (UNLESS OTHERWISE SPECIFIED) DEC. .XX ± DEC. .XXX ± DEC. .X± HOLE DIA. AND LOC. ± 1/32 DEG. ± FRACTIONAL ± 1/8 DOES NOT APPLY TO REF. DIMENSIONS	PROJECT NO. 20549	FSCM NO. 54643
	DRAWN P. SCHULDT	3/1/83
	CHECKED J. STANDLEY	3-2-83
	[signature]	3-3-83
	QUALITY [signature]	5-3-83
	APPROVED [signature]	3/4/83

CHEM-NUCLEAR SYSTEMS, INC.

TITLE: DOCKET NO. 9111/A OPTIONAL LID SEAL CONFIGURATION CNS 8-120 CASK

SIZE D | DRAWING NUMBER C-110-D-0022 | REV 2

SCALE NONE | WT | SHEET OF

ZONE	LTR	DESCRIPTION	DATE	APPROVED
7-C 8-A	A	SECT A-A ADDED 65¾" BOLT CIRCLE SECT A-A ADDED 39⅛" BOLT CIRCLE NOTE 4, REVISED TO "EXTERIOR SURFACES SHALL BE PAINTED TO INHIBIT CORROSION. NOTE 4 WAS "PAINT ALL EXTERIOR SURFACES WITH ONE (1) COAT AND ONE (1) COAT"	9/18/83	[illegible]
	B	SEE ECO Nº C-110-D-0028-002	12-19-85	[illegible]

(NOTES CONT'D)

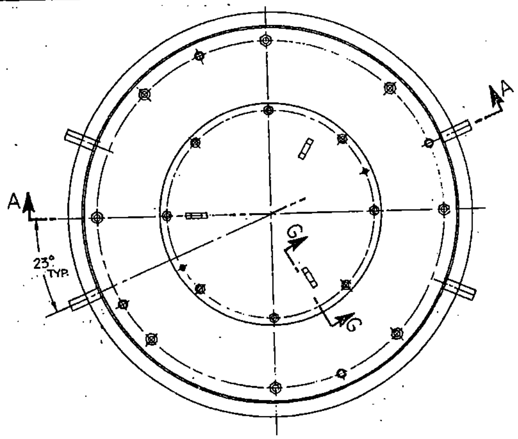
10. NUTS (OR CAP SCREWS) ON EACH LID INSTALLED HAND TIGHT. USING STAR PATTERN, TORQUE BOLTS AS FOLLOWS:
    - (STANDARD) PRIMARY LID - - - 420 ± 42 FT-LB
    - SECONDARY LID 220 ± 22 FT-LB
    - (LUBRICATED) PRIMARY LID 320 ± 32 FT-LB
    - SECONDARY LID - - 160 ± 16 FT-LB

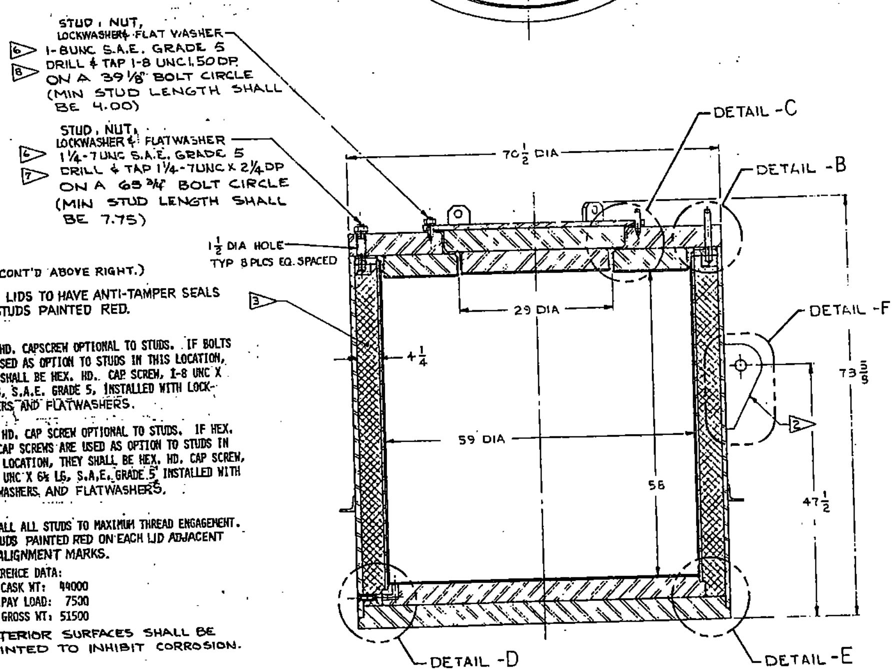
11. WELDING SHALL BE PERFORMED BY WELDERS QUALIFIED PER ASME SECT. IX. INSPECTION PER AWS D1.1-85, STRUCT. WELDING CODE, SECT. 9.25.1

12. PACKAGE IDENTIFICATION:

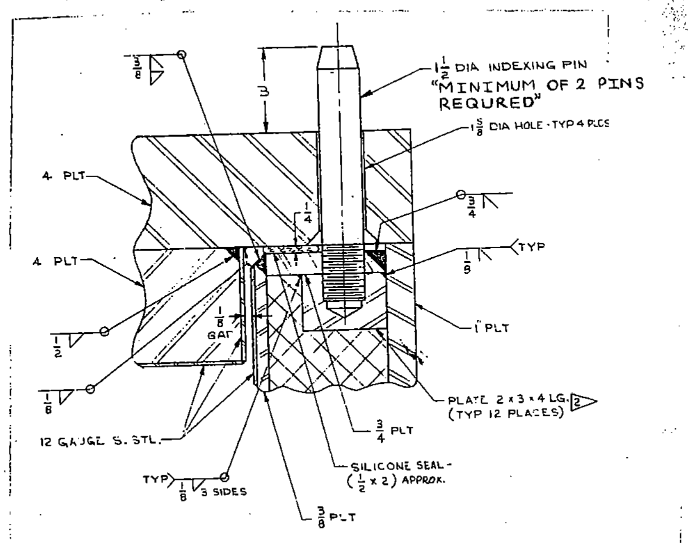
MODEL Nº.: CNS 6-80-2	MODEL Nº.: 6-80-2A
USA/9111/A	USA/9111/A
GROSS WT.: 51,500 LBS.	GROSS WT.: 51,500 LBS.

13. REFERENCE DWG. Nº. C-110-D-0020 FOR OPTIONAL LID CONFIGURATION ON MODEL Nº. 6-80-2A





SECTION A-A



DETAIL - B
SCALE: ½

(NOTES CONT'D ABOVE RIGHT.)

9. BOTH LIDS TO HAVE ANTI-TAMPER SEALS ON STUDS PAINTED RED.

8. HEX. HD. CAPSCREW OPTIONAL TO STUDS. IF BOLTS ARE USED AS OPTION TO STUDS IN THIS LOCATION, THEY SHALL BE HEX. HD. CAP SCREW, 1-8 UNC X 2¾ LG, S.A.E. GRADE 5, INSTALLED WITH LOCKWASHERS AND FLATWASHERS.

7. HEX. HD. CAP SCREW OPTIONAL TO STUDS. IF HEX. HD. CAP SCREWS ARE USED AS OPTION TO STUDS IN THIS LOCATION, THEY SHALL BE HEX. HD. CAP SCREW, 1¼-7 UNC X 6¼ LG, S.A.E. GRADE 5 INSTALLED WITH LOCKWASHERS AND FLATWASHERS.

6. INSTALL ALL STUDS TO MAXIMUM THREAD ENGAGEMENT. 2-STUDS PAINTED RED ON EACH LID ADJACENT TO ALIGNMENT MARKS.

5. REFERENCE DATA:
   - CASK WT: 44000
   - PAY LOAD: 7500
   - GROSS WT: 51500

4. EXTERIOR SURFACES SHALL BE PAINTED TO INHIBIT CORROSION.

3. LEAD: PER FEDERAL SPECIFICATION QQ-L-171e, GRADE A OR C.

2. MATERIAL: U.S. T-1 STEEL

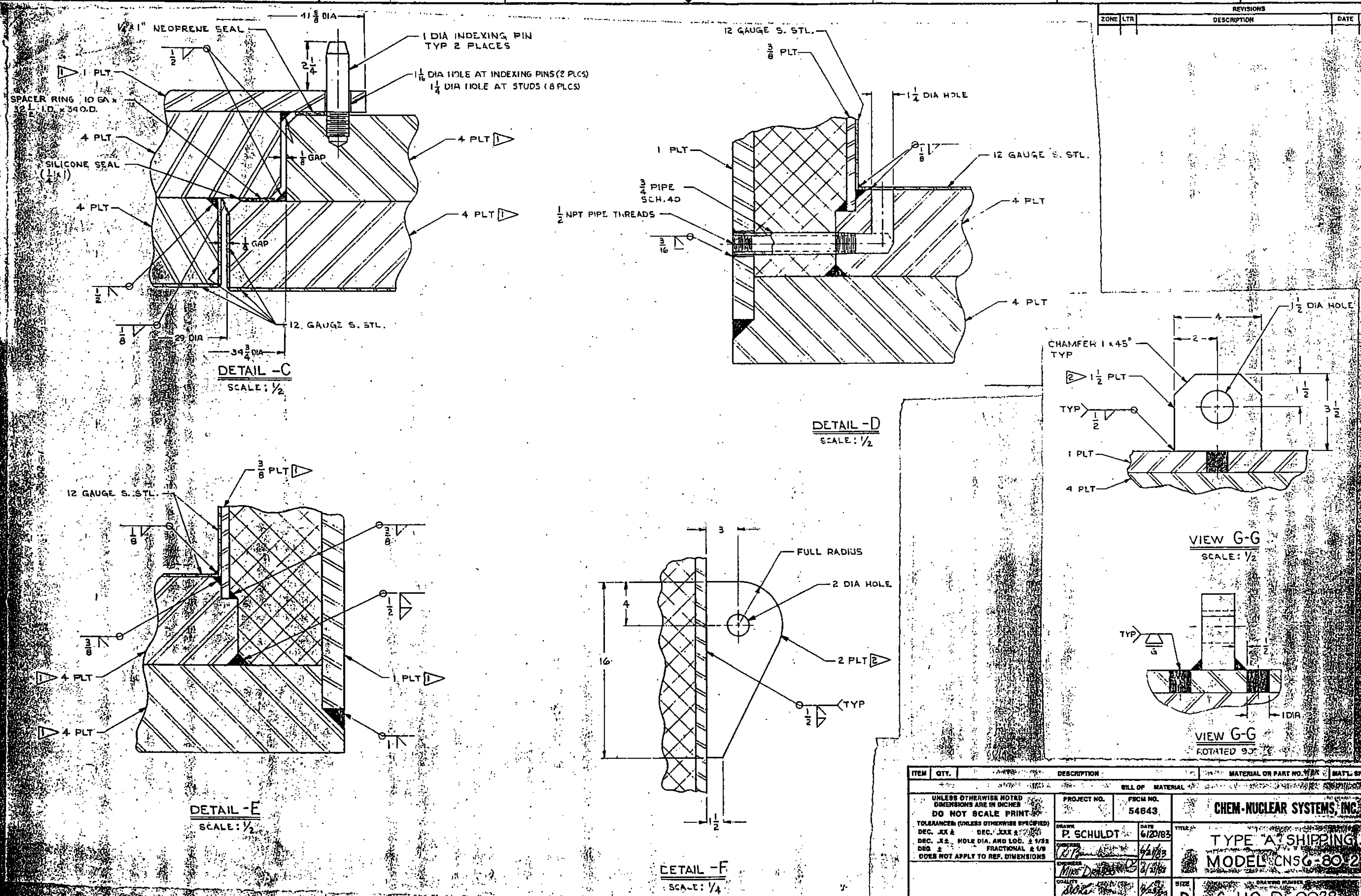
1. MATERIAL: LOW CARBON HOT ROLLED STEEL: PLATE & SHAPES CONFORM TO ASTM-A36. AFTER OCTOBER 31, 1980, ALL PLATE SHALL CONFORM TO ASTM-A516, GRD. 70

ITEM	QTY.	DESCRIPTION	MATERIAL OR PART NO.	MAT'L SPEC.	WT.

BILL OF MATERIAL

UNLESS OTHERWISE NOTED DIMENSIONS ARE IN INCHES
DO NOT SCALE PRINT
TOLERANCES: (UNLESS OTHERWISE SPECIFIED) DEC. .XX ± DEC. .XXX ± DEC. .X ± HOLE DIA. AND LOC. ± 1/32 DEG ± FRACTIONAL ± 1/8 DOES NOT APPLY TO REF. DIMENSIONS

PROJECT NO.	FSCM NO. 54643	CHEM-NUCLEAR SYSTEMS, INC.
DRAWN P. SCHULDT	6/20/83	TITLE TYPE "A" SHIPPING CASK MODEL CNS6-80-2
CHECKED [signature]	6/21/83	
ENGINEER MIKE DRAGO [signature]	6/21/83	
QUALITY [signature]	6/23/83	SIZE D · DRAWING NUMBER C-110-D-0028 · REV. 3
APPROVED [signature]	6/23/83	SCALE 3/32 & NOTED · WT — · SHEET 1 OF 2



REVISIONS			
ZONE / LTR	DESCRIPTION	DATE	APPROVED

ITEM	QTY.	DESCRIPTION	MATERIAL OR PART NO.	MAT'L SPEC.	WT.

BILL OF MATERIAL

UNLESS OTHERWISE NOTED DIMENSIONS ARE IN INCHES
DO NOT SCALE PRINT
TOLERANCES: (UNLESS OTHERWISE SPECIFIED)
DEC. .XX ± DEC. .XXX ±
DEC. .X ± HOLE DIA. AND LOC. ± 1/32
DEG. ± FRACTIONAL ± 1/8
DOES NOT APPLY TO REF. DIMENSIONS

PROJECT NO.	FSCM NO. 54643	CHEM-NUCLEAR SYSTEMS, INC.
DRAWN P. SCHULDT	6/20/83	TITLE TYPE "A" SHIPPING CASK MODEL CNSG-80-2
CHECKED	6/21/83	
ENGINEER Mike DeB...	6/21/83	
QUALITY	6/23/83	SIZE D — DRAWING NUMBER C-110-D-0028 — REV 3
APPROVED R. Williams	6/23/83	SCALE NOTED — WT — SHEET 2 OF 2

3.0 THERMAL EVALUATION

A thermal analysis for the Model CNS 6-80-2 packaging has been conducted for normal transport conditions. The performance of the packaging under normal conditions of transport is described below:

3.1 Discussion

The mechanical features of the packaging have been described in Section 1.2.1. There are no special thermal protection subsystems or features.

The external surface of the cask is predicted to exhibit maximum temperatures ranging from 169° to 174°F, depending upon the quantity of internal decay heat assumed. The lower temperature prediction assumes no internal heat whereas the higher temperature assumes an internal decay heat load of 400 watts. These maximum temperature prediction assume conditions consistent with the Normal Transport "Heat" requirements, specifically:

- Direct sunlight (mid-summer)
- Ambient air at 130°F
- Still air.

For conservatism, the "peak" solar flux has been assumed to exist continuously. This is equivalent to assuming 24-hour sunlight of maximum intensity. Further conservatism is incorporated in the analysis by assuming the cask base is an adiabatic boundary (no heat loss).

The analysis also shows that the internal decay heat (400 watts) raises inside surface temperatures above the external temperatures by only 0.3°F.

3.2 Summary of Thermal Properties of Materials

Only three basic properties of the cask materials were employed in this analysis. They were obtained from conventional handbooks as follows:

Thermal Conductivity

Steel	25 Btu/hr ft-°F
Lead	18.6 Btu/hr ft-°F

Surface Emissivity/Absorptivity

Steel	0.8

3.3 Technical Specification of Components

Not applicable -- no special thermal subsystems.

3.4 Thermal Evaluation for Normal Conditions of Transport

The thermal analysis for Normal Transport "Heat" and "Cold" conditions is presented in Section 3.6, Appendix.

3.4.1 Thermal Model

As outlined in Section 3.6, the unknown external cask temperature was determined by solving for the temperature at which the heat input to the cask system equaled heat output. Input heat consisted of a peak normal solar flux (from Figure 5.3 of ORNL-NSIC-68) plus the internal decay heat. Heat rejection mechanisms consist of the sum of free-convection losses and radiation losses to the prescribed ambient air sink temperature (130°F-"Heat", -40°F-"Cold"). Heat losses were "allowed" only over the vertical cylindrical sides and the top. Convective film coefficients were taken from empirical equations for free convection found in McAdam's "Heat Transmission"..

3.4.2 Maximum Temperatures

Predicted maximum temperatures are:

	External Surfaces	Internal Surfaces
No Internal Heat	169°F	169°F
400 Watts Internal Heat	174°F	174.3°F

3.4.3 Minimum Temperatures

	External Surfaces	Internal Surfaces
No Internal Heat	-40°F	-40°F
400 Watts Internal Heat	-27.3°F	-27.0°F

3.4.4 Maximum Internal Pressures

Assuming the package contains water loaded at 70°F. Under maximum temperature conditions (174.3°F), the pressure would increase as shown below:

The partial pressures of water and air at 70°F are:

$P_{we} = 0.36$ psi

$P_{ac} = 14.7 - .36 = 14.34$ psi

The partial pressures at 175° are:

$P_{wh} = 6.75$ psi

$P_{Ac} = 14.34(175 + 460)/(70 + 460) = 17.18$ psi

The internal pressure differential is thus:

$P = 6.75 + 17.18 - 14.7 = \underline{9.23 \text{ psi}}$

3.4.5 Maximum Thermal Stresses

In Section 2.6.3, the critical elements of the cask were evaluated for a pressure differential of 0.5 atm (7.35 psi). The internal pressure due to maximum temperature, therefore, increases stresses predicted in Section 2.6.3 by the factor: 9.23/7.35 = 1.26. The loads and margins of safety thus become:

Item	Load/ Stress	Allowable Load/Stress	Margin
Secondary Lid Stud	762	64785	Large
Primary Lid Stud	3235	95248	Large
Shell	1089	36000	Large
Lid	889	36000	Large

3.4.6 Evaluation of Package Performance for Normal Conditions of Transport

As the result of the above assessment, it is concluded that under normal conditions of transport:

(1) There will be no release of radioactive material from the containment vessel;

(2) The effectiveness of the packaging will not be substantially reduced;

(3) There will be no mixture of gases or vapors in the package which could, through any credible increase in pressure or an explosion, significantly reduce the effectiveness of the package.

3.5 Hypothetical Thermal Accident Evaluation

Not applicable for Type "A" packages.

3.6 Appendix

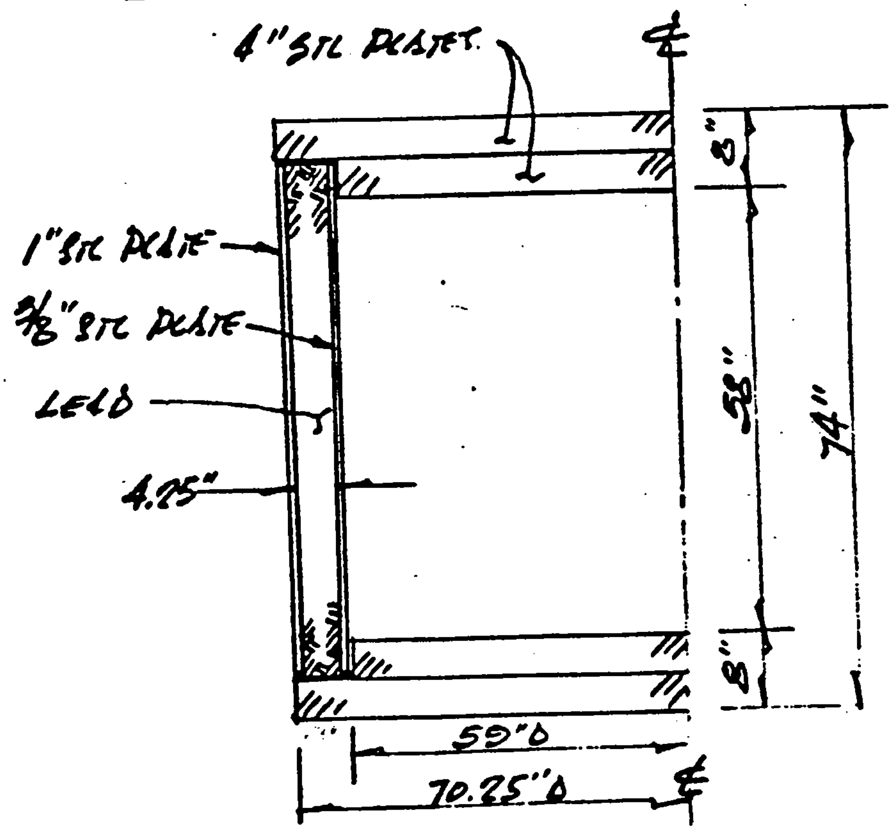
3.6.1 Thermal Analysis - Normal Conditions of Transport - No Overpack (CNS 6-80-2 Cask)

Two cases are specified by Appendix A, 10 CFR 71. Key assumptions for these cases include:

- HEAT - direct sunlight (summer, latitude 42°N)
  ambient air at 130°F
  internal heat load = 0 and 400 watts

- COLD - shade
  ambient air at -40°F
  internal heat load = 0 and 400 watts

3.6.2 Geometry Assumptions (Simplified)



3.6.3 External Connection and Radiant Heat Transfer

Heat leaves the package via combined convection and radiant heat transfer to the ambient air at $T = T_\infty$. Heat is lost only on top and sides; adiabatic assumptions are applied to the base.

3.6.3.1 Convection

$q_C = hA\Delta T$; $\Delta T = T_{ext} - T_\infty$; $T_\infty = 130^oF$ and -40^oF

For free convection, McAdams gives:

$$h = .29\left(\frac{\Delta T}{L}\right)^{\frac{1}{4}}; \text{ vertical cyl. } (L = ft)$$

$$.27\left(\frac{\Delta T}{L}\right)^{\frac{1}{4}}; \text{ horizontal plate (up-heated)}$$

Thus:

$$q_C = (h_S A_S + h_T A_T)\Delta T = \overline{hA}\ \Delta T$$

$$A_S = \pi D l_S = \pi \frac{(70.25)(74)}{144} = 113.41 \text{ ft}^2$$

$$A_T = \frac{\pi D^2}{4} = \frac{\pi(70.25)^2}{4(144)} = 26.92 \text{ ft}^2$$

$$L_S = 74/12 = 6.17 \text{ ft.}; \ A_\Sigma = 140.33 \text{ ft}^2$$

$$L_T = 70.25/12 = 5.85 \text{ ft.}$$

Therefore:

$$\overline{hA} = \Delta T^{\frac{1}{4}} \left[\frac{(.29)(113.41)}{(6.17)^{\frac{1}{4}}} + \frac{(.27)(26.92)}{(5.85)^{\frac{1}{4}}}\right]$$

$$= 25.5435 \times \Delta T^{\frac{1}{4}}, \text{ Btu/hr-}^oF$$

3.6.3.2 Radiation

$$q_R = \sigma A_\Sigma \varepsilon(T_{ext}{}^4 - T_\infty{}^4) = K(T_{ext}{}^4 - T_\infty{}^4)$$

$$\sigma = .1714 \times 10^{-8}$$

$$\varepsilon = .8$$

$$A_\Sigma = 140.33$$

Therefore:

$$K = (.1714 \times 10^{-8})(140.33)(.8) = 192.42 \times 10^{-9}$$

3.6.4 Heat Loads - Solar and Internal

3.6.4.1 Solar Loads

Solar loads are estimated by use of Shappert's normal incident solar energy curve given in Figure 5.3, ORNL-NSIC-68, "Cask Designer's Guide." Assumptions include: clear sky, mid-summer, latitude 42°N. The total solar load absorbed by a body is:

$$Q = A_N \times q_{si} \times \alpha$$

A_N = normal X-set area

q_{si} = solar intensity (norm)

α = surface absorbtivity (.8)

For a right circular cylinder:

$$A_N = A_T \cos \theta + A_S \sin \theta;$$

($\theta = \angle$ wrt vert.)

$$A_T = \frac{\pi D^2}{4(144)} = 26.92 \text{ ft}^2$$

$$A_s = \frac{Dl}{144} = 36.10 \text{ ft}^2$$

Thus:

$$\frac{Q}{A_\Sigma} = \frac{q_{si} \times \alpha}{A_\Sigma}(A_T \cos\theta + A_s \sin\theta) = q_{si} \times \frac{(.8)}{(140.33)} \times [(26.92)\cos\theta + (36.10)\sin\theta]$$

Evaluating using Shappert's variation of q_{si} versus θ:

Btu/hr-ft^2

Solar Time	Elev. Angle θ(°)	Solar Intensity q_{si}	Solar Load (Q/A_Σ)
8 AM	48	250	63.9
8:30	42	260	65.5
9	36	270	$\boxed{66.2}$
9:30	30	275	64.8
10	24	280	62.7
10:30	18	285	59.7

$A_\Sigma = 140.33$ ft^2

Q/A_Σ Max. Solar Load

3.6.4.2 Internal Heat

Internal heat is assumed to be 400 watts.

Thus:

$Q_I = (400)(3.41) = 1364$ Btu/hr

Total heat load is the sum of internal and external (solar) heats:

$q_T \times Q_I + A_\Sigma \times (Q/A_\Sigma)$

	Case	(Q/A_Σ)	Q_I	q_T (Btu/hr)
HOT	1	66.2	1364	10654
	2	66.2	0	9290
COLD	3	0	1364	1364
	4	0	0	0

3.6.5 Steady State Solution

Newton's method is used to solve for cask external temperature $T = T_{ext}$.

$$F(T) = q_{in} - q_{out} \longrightarrow 0$$

$$= q_T - q_R - q_C = q_T - K(T^4 - T_\infty^4) - \bar{h}A(T - T_\infty)$$

$$F(T) = 1 - \frac{K}{q_T}(T^4 - T_\infty^4) - \frac{\bar{h}A}{q_T}(T - T_\infty) \longrightarrow 0$$

$$= \underbrace{\left[1 + \frac{K}{q_T} T_\infty^4 + \frac{\bar{h}A}{q_T} T_\infty\right]}_{r_5} - \underbrace{\frac{K}{q_T}}_{r_6} \times T^{\Delta} - \underbrace{\frac{\bar{h}A}{q_T}}_{r_7} \times T$$

Case	q_T Heat Load (Btu/hr)	$\bar{h}A$ @ $\Delta T = 40°$	$\bar{h}A$ @ $T_{EXT} = T$	T (°R)	T (°F) (Ext. Wall Temp.)
1. Hot-Int. Heat	10654	64.24	65.78	633.7	174.0°F
2. Hot-No Int Heat	9290	✓	63.85	628.7	169.0°
3. Cold-Int. Heat	1364	✓	48.19	432.4	-27.3°
4. Cold-No Int Heat	0	-	-	-	-40°F

$T_\infty = 13$

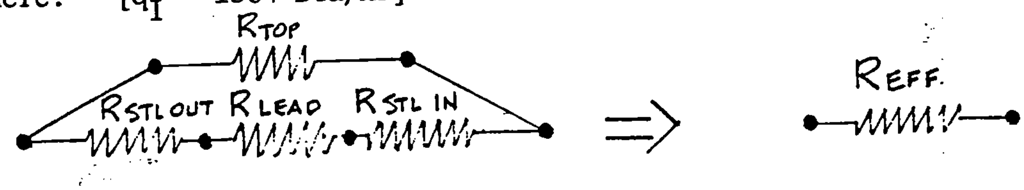
$T_\infty = -4$

3.6.6 Wall Thermal Gradient: $\Delta T_W = (T_{interior} - T_{exterior})$

The conductive properties of the cask wall and the internal heat determine steady state wall temperature gradients:

$$q_I = \frac{\Delta T_w}{R_{EFF}} \quad \Rightarrow \quad \Delta T_w = R_{EFF} \times q_I$$

Where: $[q_I = 1364 \text{ Btu/hr}]$



$$\frac{1}{R_{EFF}} = \frac{1}{R_{TOP}} + \frac{1}{R_{WALL}} \qquad R_{WALL} = R_{STL\ OUT} + R_{LEAD} + R_{STL\ IN}$$

$$R_{TOP} = \frac{t}{K_A}; \qquad K = 25 \text{ Btu/hr-ft-°F (Steel)}$$

$$A = \frac{\pi D^2}{4} \quad \frac{\pi(59)^2}{4(144)}; \; t = 8/12$$

$$R_{TOP} = \frac{(8/12)}{(25)(18.99)} = 1.4046 \times 10^{-3}$$

$$R_{STL\ OUT} = \frac{t}{K_A} = \frac{(1/12)}{(25)[\pi(70.25)(58)/144]} = 37.499 \times 10^{-6}$$

$$R_{STL\ IN} = \frac{t}{K_A} = \frac{(3/8\ \ /12)}{(25)[\pi(59)(58)/144]} = 16.743 \times 10^{-6}$$

$$R_{LEAD} = \frac{\ln(d_o/d_i)}{2\pi\ k\ l} = \frac{\ln(68.25/59.75)}{2\pi(18.6)(58/12)} = 235.47 \times 10^{-6}$$

$$R_{WALL} = 289.71 \times 10^{-6}$$

$$\frac{1}{R_{EFF}} = \frac{1}{1.4046 \times 10^{-3}} + \frac{1}{289.71 \times 10^{-6}} \quad \Rightarrow \quad R_{EFF} = 240.4 \times 10^{-6}$$

THEREFORE:

$$\Delta T_w = (240.4 \times 10^{-6})(1364) = \underline{0.33°F}$$

[@ 400 watts]

4.0 CONTAINMENT

This chapter identifies the package containment for the normal conditions of transport.

4.1 Containment Boundary

4.1.1 Containment Vessel

The containment vessel claimed for the Model CNS 6-80-2 package is the shielded transportation cask as described in Section 1.2 and the general arrangement drawing in Appendix 2.10.1.

4.1.2 Containment Penetration

The drain line is the only penetration of the containment vessel.

4.1.3 Seals and Welds

Both lids on Model CNS 6-80-2 (see Drawing No. C-110-D-0028) are sealed using silicone gaskets bonded to the lid plates. The secondary lid has a redundant neoprene seal. Both lids on Model CNS 6-80-2 are sealed using a double O-ring configuration as shown on Drawing No. C-110-D-0020, Revision -. All joints are arc welded. 1

4.1.4 Closure

The closure devices for the lid consist of eight 1-1/4 inch diameter studs (or bolts) in the primary lid and eight 1-inch diameter studs (or bolts) in the secondary lid as described in Section 1.2.

4.2 Requirements for Normal Conditions of Transport

The following is an assessment of the package containment under normal conditions of transport as a result of the analysis performed in Chapters 2.0 and 3.0. In summary, the containment vessel was not effected by these tests. (Refer to Section 2.6)

4.2.1 Release of Radioactive Material

There was no release of radioactive material from the containment vessel.

4.2.2 Pressurization of Containment Vessel

Normal conditions of transport will have no effect on pressurizing the containment vessel.

4.2.3 Coolant Contamination

This section is not applicable since there are no coolants involved.

4.2.4 Coolant Loss

Not applicable.

4.3 Containment Requirements for the Hypothetical Accident Conditions

Not applicable for Type "A" packages.

5.0 SHIELDING EVALUATION

5.1 Discussion and Results

The Model CNS 6-80-2 packaging consists of a lead and steel containment vessel which provides the necessary shielding for the various radioactive materials to be shipped within the package. (Refer to Section 1.2.3 for packaging contents.) Tests and analysis performed under Chapters 2.0 and 3.0 have demonstrated the ability of the containment vessel to maintain its shielding integrity under normal conditions of transport. Prior to each shipment, radiation readings will be taken based on individual loadings to assure compliance with applicable regulations.

6.0 CRITICALITY EVALUATION

Not applicable for the Model CNS 6-80-2 packaging.

7.0 OPERATING PROCEDURES

This chapter generally describes the procedures to be used for loading and unloading the Model CNS 6-80-2 packaging.

7.1 Procedures for Loading the Package

NOTE: IF IT IS NECESSARY TO REMOVE THE CASK FROM THE TRANSPORT VEHICLE, FIRST DISCONNECT THE TIE-DOWN CABLES FROM THE CASK. VERIFY THAT THE EIGHT (8) 1-INCH SECONDARY LID CLOSURE BOLTS AND THE EIGHT (8) 1 1/4-INCH PRIMARY LID CLOSURE BOLTS ARE IN PLACE AND PROPERLY TORQUED. BOLT TORQUE REQUIREMENTS ARE SPECIFIED LATER IN THIS PROCEDURE. ATTACH SUITABLE LIFTING SLINGS TO THE LID LIFTING LUGS AND LIFT CASK OFF OF THE TRAILER. 1

(1) Loosen and remove the bolts which secure the primary or secondary lid, as necessary. If the primary lid is to be removed, verify that eight (8) 1-inch secondary lid closure bolts are in place and properly torqued.

(2) Remove the lid by attaching suitable hooks to the lid lifting lugs. Care should be taken during the operation so as not to damage the lid to body interface seal while setting the lid down.

(3) Visually inspect the package for damage or defects inside and out. Verify that there are no loose articles inside the cask. Inspection shall include primary and/or secondary lid closure bolts, whichever have been removed, and the drain plug.

Obtain replacement closure bolts or drain plug as specified on CNSI Drawing No. C-110-D-0028 (current revision) for any bolts or plugs that show cracking or other visual signs of defects. 1

(4) Place the disposable steel liner, drums, or other packaging into the cask. Contents should fit snuggly within the cask body using shoring or bracing when required to prevent movement during normal conditions of transport.

(5) Inspect the gaskets (or O-ring seals) according to Section 8.2.1.2 for the primary and/or secondary lid, whichever has been removed. Painted surfaces, identification markings, and match marks used for closure orientation shall be inspected according to Section 8.2.1.3.

(6) Place the primary or secondary lid on the cask using the guide pins for alignment. Use caution in lowering so as not to damage the gasket and guide pins.

(7) Install the primary and/or secondary lid closure bolts and tighten to hand tight. Torque primary lid bolts to 420 ± 42 ft-lbs (320 ± 32 ft-lbs if lubricated) using a star pattern.

Torque secondary lid bolts to 220 ± 22 ft-lbs (160 ± 16 ft-lbs if lubricated) using a star pattern.

(8) If it is necessary to replace the cask onto the transport vehicle, verify that the eight (8) 1-inch secondary lid bolts and the eight (8) 1 1/4-inch primary lid bolts are in place and properly torqued. Attach suitable lifting slings to the lid lifting lugs and lift cask onto the transport vehicle. Cover the lid lifting lugs to prevent them from being inadvertently used to connect the tie-down cables. Attach the tie-down cables to the cask.

(9) Before the cask leaves the facility, the following shall be confirmed: (1

(a) That the licensee who expects to receive a package containing quantities of radioactive material in excess of Type A quantities specified in 10 CFR 20.205(b) meets and follows the requirements of 10 CFR 20.205, as applicable.

(b) That trailer placarding and cask labelling meet DOT Specifications (CFR Title 49, Part 172).

(c) That exterior radiation and surface contamination levels are within the limits of the applicable Federal Regulations.

(d) That lid bolts are sealed with anti-tamper seals.

(e) That the drain plug is properly installed and sealed with a non-hardening pipe thread sealant.

7.2 Procedures for Unloading the Package

In addition to the following sequence of events for unloading a package, packages containing quantities of radioactive material in excess of Type "A" quantities specified in 10 CFR 20.205(b) shall be received, monitored and handled by the licensee receiving the package in accordance with the requirements of 10 CFR 20.205 as applicable.

NOTE: IF IT IS NECESSARY TO REMOVE THE CASK FROM THE TRANSPORT VEHICLE, FIRST DISCONNECT THE TIE-DOWN CABLES FROM THE CASK. VERIFY THAT THE EIGHT (8) 1-INCH SECONDARY LID CLOSURE BOLTS AND THE EIGHT (8) 1 1/4-INCH PRIMARY LID CLOSURE BOLTS ARE IN PLACE AND PROPERLY TORQUED. BOLT TORQUE REQUIREMENTS ARE SPECIFIED LATER IN THIS PROCEDURE. ATTACH SUITABLE LIFTING SLINGS TO THE LID LIFTING LUGS AND LIFT CASK OFF OF THE TRAILER.

(1) Remove the security seal and loosen and remove the bolts which secure the primary lid. Verify that the eight (8) 1-inch secondary lid closure bolts are in place and properly torqued. 1

(2) Remove the lid by attaching suitable hooks to the lid lifting lugs. Care should be taken during the operation so as not to damage the lid to body interface seal while setting the lid down.

(3) Remove the contents using suitable material handling equipment.

8.0 ACCEPTANCE TESTS AND MAINTENANCE PROGRAM

8.1 Acceptance Test

Prior to the first use of a CNS 6-80-2 or CNS 6-80-2A package, the following tests and evaluations will be performed.

8.1.1 Visual Examination

The package will be examined visually for any adverse condition in materials or fabrication.

Welds shall be examined for compliance to the drawings. Weld integrity shall be verified by visual examination according to AWS D1.1, Section 9.25.1.

All Test Reports will be documented and included in the Quality Assurance Records of the cask.

8.1.2 Structural Tests

No structural testing is required.

8.1.3 Leak Tests

Each package shall be leak tested initially. The Test Report shall be documented and included in the Quality Assurance Records of the cask.

8.1.3.1 CNS 6-80-2

The cavity shall be pneumatically pressurized to 14.0 psig and while under pressure, the seals are soap bubble tested for leakage acceptance criteria of no visible bubbles.

8.1.3.2 CNS 6-80-2A

A pressure drop test shall be used. The cavity or volume between the double O-ring seals shall be pressurized to 14.0 psig. Seal acceptance shall be based on no observable leakage over a ten minute period using a pressure gauge with a maximum graduation of two pounds and the pressure supply line disconnected from the cask and text fixture.

8.1.4 Component Tests

8.1.4.1 Gaskets

Gaskets and seals will be procured and examined in accordance with the CNSI Quality Assurance Program. Leak testing of the package will be the final acceptance for gasket's design.

8.1.5 Tests for Shielding Integrity

Shielding integrity of the package will be verified by Gamma Scan or Gamma Probe methods to assure package is free of significant voids in the poured lead shield annulus. The entire surface area backed by lead, less protrusions, shall be marked off in a grid pattern not exceeding the diameter of the radiation detection instrument. Voids resulting in shield loss in excess of 10 percent shall not be acceptable. Results of the Gamma Scan shall be documented and included in the Quality Assurance Records of the cask.

8.2 Maintenance Program

CNSI is committed to an ongoing preventative maintenance program for all shipping packages. The 6-80-2 and 6-80-2A packages will be subjected to routine and periodic inspections and tests as outlined in this section and CNSI approved procedures.

8.2.1 Routine Maintenance

For each shipment, unless noted otherwise, of a loaded package containing radioactive materials in excess of Type A quantities, 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 primary lid bolts and the plug or the drain line shall be visually inspected for defects. The secondary lid bolts shall be visually inspected for defects whenever it is necessary to remove the secondary lid. Obtain replacement bolts or plugs as specified on CNSI Drawing No. C-110-D-0028 (current revision) for any bolts or plugs that show cracking or other visual signs of defects.

8.2.1.2 Gaskets/O-Rings

(a) Primary Lid Gasket/O-Rings

The primary lid gasket (CNS 6-80-2) and O-rings (6-80-2A) 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 seating surface shall be visually inspected to ensure it is free of damage, dirt, gravel or any foreign matter which might damage the gasket/O-rings. If any defects are detected, seals shall be replaced and/or the seating surface shall be reworked as necessary to ensure that the lid closure will seal properly.

The leak test performance date sticker on the cask shall be checked for legibility and expiration date to verify that the seals are current with leak test performance schedule.

(b) Secondary Lid Gasket/O-Rings

The secondary lid gasket (CNS 6-80-2) and O-rings (6-80-2A) and the seal seating surfaces shall be inspected as specified in Section 8.2.1.2 (a) at any time it is necessary to remove the secondary lid. Seal replacement and/or seating surface repair shall be as specified in Section 8.2.1.2 (a) if any defects are detected.

8.2.1.3 Painted Surfaces, Identification Markings, and Match Marks Used for Closure Orientation

The above items shall be visually inspected to ensure that painted surfaces are in good condition, identification markings are legible and that match marks used for closure orientation remain legible and easy to identify.

8.2.2 Periodic Maintenance

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

8.2.2.1 Seals and Test for Seal Integrity (Leak Test)

All seals (gaskets or O-rings) shall be replaced once a year as a minimum regardless of condition.

The seals and seal seating surfaces shall be replaced and/or reworked, respectively, for any condition resulting in a detectable leak.

Tests for seal integrity shall be performed after the annual replacement of all seals as a minimum. A leak test shall be performed in the same manner as delineated in Section 8.1.3.

8.2.2.2 Shielding

Shielding tests will be performed if damage has required repairs affecting shield integrity. Any additional shield testing shall be in accordance with the original criteria specified in Section 8.1.5.

8.2.2.3 Drain Line

Annually the drain line will be verified to be free from obstructions.

9.0 QUALITY ASSURANCE

CNSI's Quality Assurance Program used for the design, fabrication, assembly, testing, use and maintenance of the CNS 6-80-2 cask is designed and administered to meet the 18 criteria of 10 CFR 71, Appendix E. A description of this program has been submitted to the NRC. CNSI has received Quality Assurance Program Approval No. 0231.