PDR 71-9113

NUCLEAR PACKAGING, INC.

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May 9, 1980

Mr. Charles E. MacDonald, Chief
Transportation Certification Branch
Division of Fuel Cycle and Material
Safety, NMSS
United States Nuclear Regulatory
Commission
Washington, DC 20555

SUBJECT: Certificate of Compliance No. 9113

Dear Mr. MacDonald:

Two Certificates of Compliance have been issued for the same package. Their numbers are USA/9080/A and USA/9113/A. From the drawings it can be seen that the packages are identical. The Certificates of Compliance differ only in the authorized payload and total gross weight. Certificate of Compliance No. 9080 allows 13,000 lbs. payload vs. 7,000 lbs. for No. 9113. Again, these are identical packages.

The purpose of the enclosed revision is to bring No. 9113 in line with No. 9080 and upgrade the material from A-36 to A-516, Grade 70. The original configurations (9080 and 9113) were approved using A-36 carbon steel throughout. Revision 2 proposes changing the A-36 to A-516 material. This steel provides increased strength as well as a significant improvement in nil ductility and cold weather performance. Because of its increased strength (i.e., 70,000 psi vs. 55,000 psi), the resultant package provides a slightly larger positive Margin of Safety than the one previously approved. This represents the only safety related change and the only change to the drawing.

Should you require additional information, please call. Thank you again.

Sincerely yours,

NUCLEAR PACKAGING, INC.

L. J. Hansen

Larry J. Hansen

LJH/dmd

Enclosures

THIS DOCUMENT CONTAINS
POOR QUALITY PAGES

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Summary of the changes are as follows:

Page 0-3	Change payload weight and gross package weight from 7,000 lbs. to 13,000 lbs. and 42,000 lbs. to 48,000 lbs, respectively.
Page 1-2	Changed package weight and material properties for A-516.
Page 1-3	Changed package weight.
Pages 1-4 thru 1-9	Recalculated tiedown lug margin of safety based on new higher material strength. Margin of safety increased.
Page 1-11	Statement on advantages of material damage for cold weather capability.
Pages 1-12 and 1-13	Revised margin of safety for new material.
Page 1-15	Corrected typographical error. Not safety related.
Pages 1-16 thru 1-17b	Revised drawing analysis for higher package weight and corrected typographical error. Small increase in positive margin of safety resulted.
Page 1-19	Revised lid loads due to increased payload weight. M.S. = +.45.
Pages 1-22 and 1-23	Revised lug capacity based on increase in material properties. M.S. = +5.40.
Pages 1-24 thru 1-28	Revised impact analysis for side drop to account for material property and weight increase. M.S. = +.84.
Drawing	Revised weight and material callout. Provided optional use of bolts or studs for secondary lid. Provided optional use of 3 lugs on secondary lid.

INSTRUCTIONS FOR INCORPORATING REVISION 2 AMENDMENTS

Add new pages i through iii	
Insert new page 0-3	Remove old page 0-3
Insert new pages 1-2 through 1-5	Remove old pages 1-2 through 1-5
Insert new pages 1-8 and 1-9	Remove old pages 1-8 and 1-9
Insert new pages 1-11 through 1-13	Remove old pages 1-11 through 1-13
Insert new pages 1-15 through 1-17b	Remove old pages 1-15 through 1-17b
Insert new page 1-19	Remove old page 1-19
Insert new pages 1-22 through 1-28	Remove old pages 1-22 through 1-28
	Remove old pages 8-10 and 8-11

Table of Contents

0.2.1.3 Containment Vessel

The 7-100 cask serves as the containment vessel and its mechanical configuration is described in the foregoing paragraph.

A neoprene gasket is employed in the primary and secondary lid interfaces.

Waste products will be contained in drums or disposable steel liners.

0.2.1.4 Neutron Absorbers

There are no materials used as neutron absorbers or moderators in the Model 7-100 packaging.

0.2.1.5 Package Weight

Gross weight for the package is approximately 48,000 lbs. This includes an estimated payload weight of 13,000 lbs. 2

0.2.1.6 Receptacles

There are no internal or external structures supporting or protecting receptacles.

1.2 Weights and Center of Gravity

The weight of the cask and liner (or payload) will not exceed 48,000 pounds. The cask weight is approximately 35,000 pounds. 2
The center of gravity for the assembled package is located at the approximate geometric center of gravity.

1.3 Mechanical Properties of Materials

The Model 7-100 packaging uses an outer and inner shell fabricated of various thicknesses of low carbon hot rolled steel. Material properties of the steel are as follows:

Per ASME for A-516 Grade 70

F_{tu} = 70,000 psi 2

F_{ty} = 38,000 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"	3/4"
Proof Load :	78,000 psi	85,000 psi
Tensile Strength:	115,000 psi	120,000 psi

1.4 General Standards for all Packages

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

1.4.1 Chemical and Galvanic Reactions

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

1.4.2 Positive Closure

The positive closure system has been previously described in Section 0.2.1. In addition, each package will be sealed with an approved tamper indicating seal and suitable locks to prevent inadvertent and undetected opening.

1.4.3 Lifting Devices

Four lifting lugs and four tiedown lugs are provided.

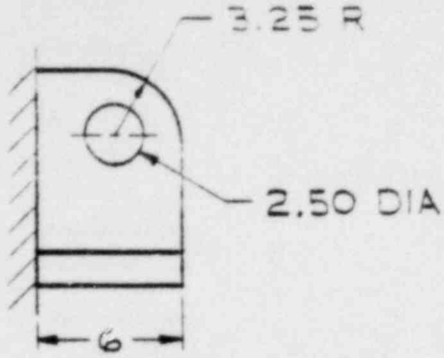
1.4.3.1 Primary Lifting Lugs

Assume that only two of the four lugs are used to lift the package. Therefore, the maximum load per lug will be:

$$P = (48{,}000 \text{ Lbs})(3g\text{'s})/2 \text{ lugs}$$ 2

$$P = 72{,}000 \text{ lbs}$$

From the drawing:



Using Reference No. 1 - Figure 4.4.1-3:

$W/D = 6/2.5 = 2.4$ & $R/D = 3.25/2.5 = 1.3$

$K \approx 1.21$

Ultimate lug capability is given by:

$P_{ult} = K\ D\ t\ F_{Tu}$ Where:

$K = 1.21$
$D = 2.5$ in.
$t = 2.0$
$F_{Tu} = 70{,}000$ psi (A-516)

$P_{ult} = (1.21)(2.5)(2.0)(70{,}000)$
$= 423{,}500$ lbs (ultimate) 2

From Reference No. 1 - Figure 4.4.1-2, the yield correction factor is given to by y = 1.1 or:

$P_{yld} = P_{ult} y\ F_{ty}/F_{Tu}$

$= (423{,}500)(1.1)(38{,}000)/(70{,}000)$ 2

$= 252{,}890$ lbs (yield)

Margin of Safety:

$M.S. = P_{yld}/P - 1$

$= 252{,}890/72{,}000$ 2

$= \underline{\underline{+2.51}}$

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

$P_A = F_{su}A_w$; $A_w = l(t_n)$

$l = 2(6+1) = 14"$ 2

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

$P_A = (35,000)(14)(.707) = 346,430$ lbs. 2

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

M.S. = 346,430/72,000 -1 = <u>+ Large</u> 2

Therefore, it can be safely concluded that the primary lifting lugs will not yield under a load equal to three times the weight of the package.

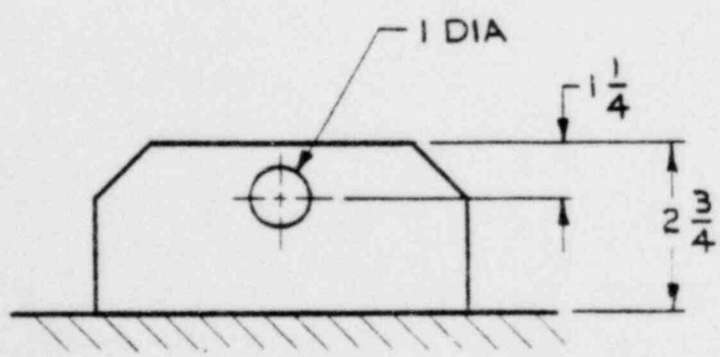
1.4.3.2 Primary Lid Lifting Lugs

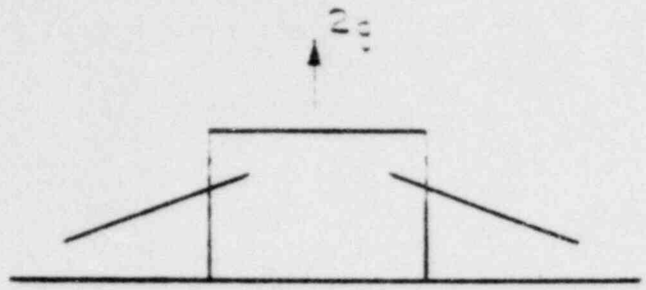
Lid Weight = 8600 lbs

Using three lugs the load per lug is:

P = (8600 lbs) (3 g's)/3 lugs

P = 8600 lbs/lug



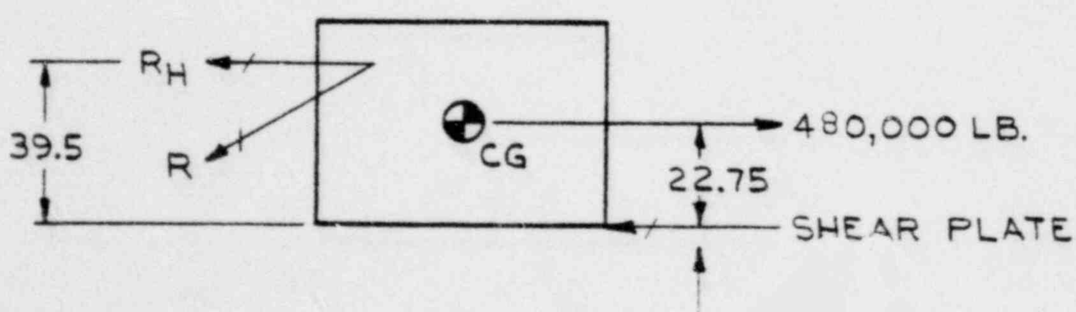


The worst condition is that of the 10 g forward load:

$$P_{10} = (10)(480{,}000\ \text{lbs})$$
$$= 480{,}000\ \text{lbs.}$$ 2

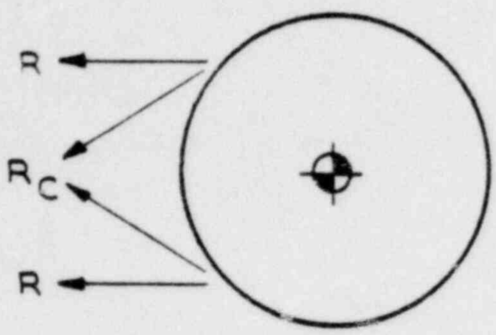
The horizontal component for each lug is:

$$R_H = 480{,}000(22.75)/(2)(39.5)$$
$$R_H = 138{,}200\ \text{lbs.}$$ 2
$$R = R_H/\cos 30^\circ = 159{,}611\ \text{lbs.}$$



2

The cross tie component will give:



$$R_C = R/\cos 30^{\circ} = 184{,}309 \text{ lbs.}$$ 2

Therefore, each lug will experience a load of 184,309 lbs.

From Section 3.1.3.1, the yield strength of the lug was calculated to be:

$$P_{yld} = 252{,}890 \text{ lbs.}$$ 2

Margin of Safety:

$$M.S. = 252{,}840/184{,}309 - 1$$
$$= \underline{\underline{+.37}}$$ 2

Therefore, it can be concluded that the 10 g load will not produce stress in the lug greater than its allowable yield strength. If the load were increased to approximately 19 g's, the lug would fail at the hole. This would not impair the cask's ability to meet the other requirements of Section 71.31.

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. In an effort to improve the cold weather capability, all packages manufactured after July 1, 1980 will be manufactured from A-516, Grade 70 material.

1.6.3 Pressure

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

$$P_s = Ap/N \text{ ; where } A = \frac{D^2}{4}$$

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

$$N = 8$$

For the secondary lid studs, the load is:

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

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

$$P_A = (120,000)(.351) = 42,120 \text{ lbs.}$$

Thus, the margin of safety is:

$$M.S. = 42120/607-1 = +Large.$$

For the primary lid attachments, the load is:

$$P_s = \frac{(75.5)^2}{(\ 4\ )}\frac{(14.7)}{2}\left(\frac{1}{8}\right) = 4113 \text{ lbs/binder.}$$

The tensile strength of each binder is in excess of 85,000 lbs.

Thus the margin of safety is:

$$M.S. = 85000/4113-1 = +Large.$$

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:

$$f_n = PR/t = \left(\frac{14.7}{2}\right)\left(\frac{75.5}{.375}\right) = 740 \text{ psi}$$

$$h_1 = PR/2t = \left(\frac{14.7}{2}\right)\left(\frac{75.5}{.375}\right)\left(\frac{1}{2}\right) = 370 \text{ psi}$$

Assuming these biaxial stresses are additive:

$$F_{max} = 1100 \text{ psi.}$$

The margin of safety is:

$$M.S. = 38000/1100-1 = +Large.$$ 2

Pressure across the end is carried in plate bending by the 2" and 3 1/2" inch thick steel plates top and bottom. Assuming a circular plate only 2" thick, uniformally loaded and with edges simply supported, the stress can be calculated as follows:

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

Where:

$W = (7.35)(\ )(75.5)^2/4 = 32906$ lbs.

$t = 2"$

$M = 1/.33 = 3$

$f_r = (3)(32906)(10)/8\ (3)(8)$

$f_r = 1636$ psi

Margin of safety:

M.S. = 38,000/1636-1 = +Large 2

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

1.6.4 Vibration

Shock and vibration normally incident to transport are considered to have negligible effects on the Model 7-100 packaging.

1.6.5 Water Spray

Since the package exterior is constructed of steel, this test is n t required.

For the 7-100 shielded cask, the variables are:

$H = 12.$ inch

$R = 41.125$ inch

$r = 38.125$ inch

$l = 44.857$ inch

$p = .410\ \text{lbs/in}^3$

$W = \pi(R^2 - r^2)pl = 13{,}654$ lbs. 2

$t_s = 3/4$ inch

$\sigma_s = 45000$ psi

$\sigma_{pb} = 5000$ psi

The predicted lead settlement is thus:

$$H = \frac{(41.125)(13654)\quad(12)}{\pi(41.125^2 - 38.125^2)\left[(3/4)(45000) + (91.125(5000)\right]} = 0.018 \text{ in}$$

This modest settlement "void" in the lead shield cannot transmit radiation because of the stepped design of the package ends. The inner most 3 1/2 inch solid steel end plates completely back (shield) lead settlement regions at both ends of the package. Thus, lead settlement due to flat end drop does not compromise, nor alter, the integrity of radiation shielding in any fashion.

1.6.6.2 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_y = Flow strength of steel per Cask Designer's Guide 2

V_s = Volume of deformed steel (in^3)

The volume of deformed steel is thus:

$$V_s = \frac{(48000)(12)}{50000} = 11.5 \text{ in}^3$$ 2

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

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

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

Where:

δ = impact deformation

R = radius of package = 42"

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

For a volumetric deformation of $Vs = 11.5\ in^3$ the corresponding 2
corner deformation is found to be:

$S = 1.16$ inches 2

Assuming an impact condition along the long edge of the hex-shaped lid the displaced volume would be a triangular wedge.

$Vol = (1/2) b\ h\ l$ 2

Where:

b = base = 2.25 h

h = deformation

l = hex length = 35.36 in. 2

$\alpha = 31.38^\circ$

$V = 11.5\ in^3$ 2

Solving for h:

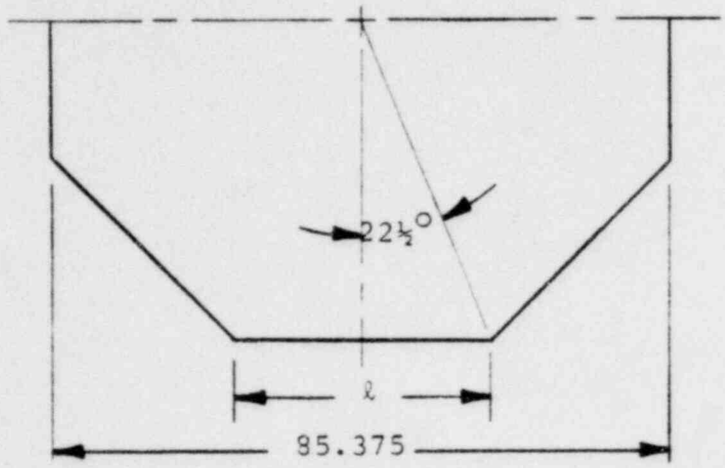
$h = .54$ in deformation 2

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

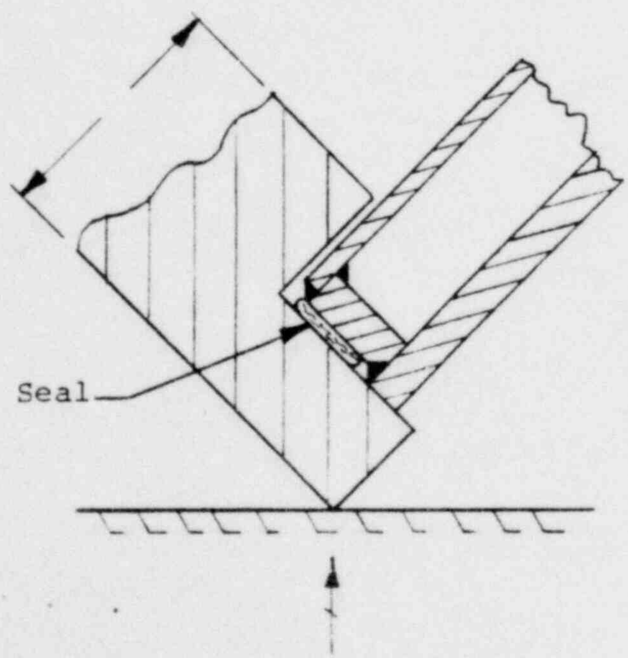
$$A_g = 2(H/S) = \frac{(2)(12)}{.54} = 44.4 \text{ g's}$$ 2

For the maximum acceleration case the impact load occurs along one side of the hex. shaped lid. loads are distributed to the lid over the following length:

$l = 2(\tan 22\ 1/2^{\circ})\ (85.375)/2 = 35.36$ in. 2



Impact loads for the cask body are reacted along the lip of the package. This lip provides protection to seal and prevents it from being crushed on impact. Stress in the lip can be calculated as follows:



Load in lip is:

P = (44.4 g's)(35000 lbs. - 7000 lbs.)(sin 31.38°) 2

P = 647,350 lbs.

Conservatively assume that load is only reacted along the loaded area "1".

f = 647,350 lbs./(35.36 in)(.75 in) 2

f = 24,409 psi

Margin of Safety:

M.S. = 38,000 psi/24,404 -1 2

M.S. = <u>+.56</u>

The protective lip of the cask body will not yield under impact and, therefore, assures that the seal is not damaged. From the drawing it can be seen that a 1/2 inch thick by 2 inch wide seal is compressed a full 1/8 of an inch. This assures good sealing even if the package lid was to momentarily spring open. It should be noted that the lid is manufactured from two solid steel plates totaling 5 1/2 inches thick. Their strength and stiffness assures controlled positive sealing surfaces.

From Detail C of the reference drawing it can be seen that the secondary lid gasket is also protected from over compression by means of steel spacer blocks. These blocks assure a pre-determined 50% compression of the gaskets.

Where:

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

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

$i = T$, total package

$= C$, cask side & bottom

$= P$, payload

$= L$, lid

$W_t = W_c + W_p + W_l$

R = Lid/cask Binder Forces

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

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

$$= (W_L + W_p)\ a_g \cos 58.2^\circ$$

$$= (7000 + 13000)(444) \cos 58.2^\circ = 467{,}940 \text{ lbs.}$$ 2

Since there are eight primary lid closure binders, each binder load is 58,492 lbs. 2

Thus the margin of safety of the primary lid binders is:

$$M.S. = 85000/58492 - 1$$

$$= +.45$$ 2

The lug capability in net area is:

$$P_t = F_{tu}A$$

Where:

$$F_{tu} = 70000 \text{ psi}$$ 2

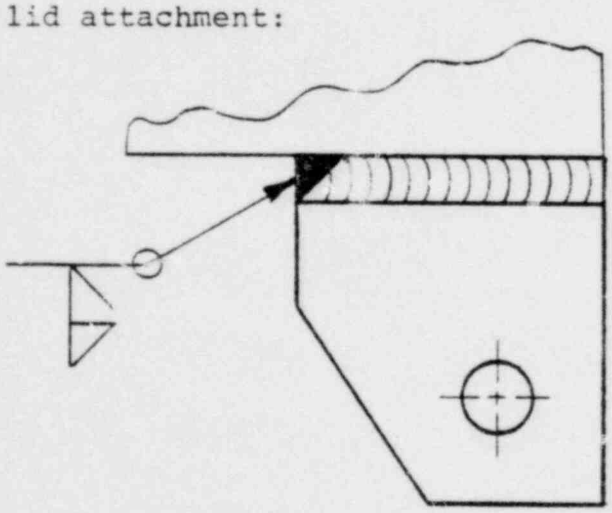
$$A = (3.75 - 1.625)(1.0)$$

$$= 2.13$$

$$P_t = (70000 \text{ psi})\ (2.13 \text{ in}^2)$$

$$P_t = 149{,}100 \text{ lbs. (Net Area)}$$ 2

Lug to lid attachment:



Weld Shearing:

$$P_s = F_sA \text{ weld}$$

Where:

$$F_s = 35000 \text{ psi}$$

$$A = (8 \text{ in})(\sin 45^\circ)(1 \text{ in.})$$

$$= 5.66 \text{ in}^2$$

$$P_s = (35000 \text{ psi})\ 5.66 \text{ in}^2)$$

$$P_s = 198{,}000 \text{ lbs/lug}$$

Binder retaining pin or bolts are 1" GRADE 5 bolts (115,000 psi tensile)

$$F_s = (.6)(115{,}000)$$
$$= 69000 \text{ psi}$$
$$A = .7854 \text{ in}^2$$
$$P = A\ Fs(2)$$
$$= (.7854 \text{ in}^2)(69000 \text{ psi})(2)$$
$$= 108{,}385 \text{ lbs (Double-shear)}$$

Therefore, it can be concluded that the binders and their attachments can safely react the unusual conditions of transport.

The secondary lid closure studs are examined in a comparable
fashion. Conservatively, the total payload mass of 13,000 lbs.
is assumed to be reacted by the secondary lid studs in propor-
tion to its projected area. Thus, the total secondary lid 2
stud load is estimated as:

$$R = (W_L + W_p)\ a_g \cos\alpha\ (29\tfrac{1}{2}/75\tfrac{1}{2})^2$$
$$= (2000+13000)(44.4) \cos 58.2^\circ(.15) = 52{,}642 \text{ lbs.}$$ 2

Since there are eight secondary lid studs (3/4-10UNC, SAE Gr. 5),
each stud load is 6,580 lbs. The tensile strength of the stud is: 2

$$P = \sigma_t A = (120{,}000)(.351) = 42120 \text{ lbs.}$$

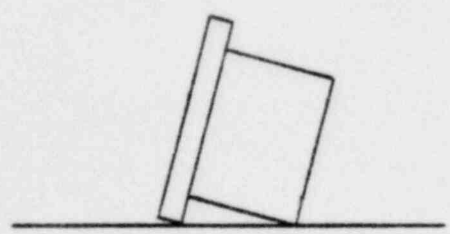
Thus the margin of safety of the secondary lid studs is:

M.S. = 42120/5580 -1 = <u>+5.40</u> 2

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

1.6.6.3 Side Drop

Assume the cask impacts on one corner of the octogenal lid and the opposite end.



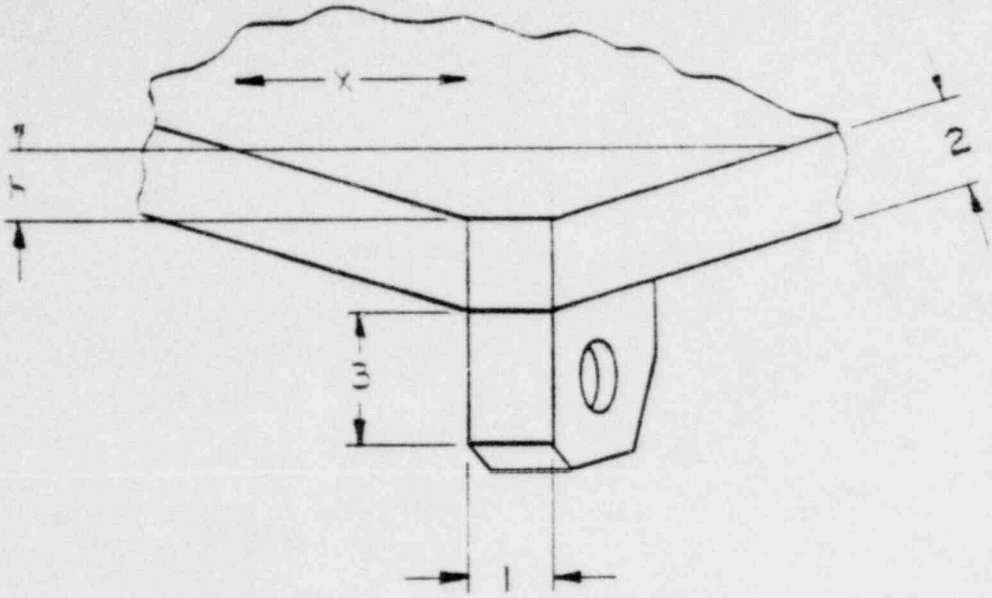
Using the same energy relationship:

$$Vol = WH/\sigma_s$$

$$= 11.5\ in^3$$ 2

Since it is reacted at two locations the volume deformation at the lid is:

$$V_L = 5.75\ in^3$$ 2



$$Vol = (h+hx)t+3h$$

Where:

$$t = 2 \text{ in}$$

$$\tan 22\ 1/2^\circ = h/x$$

$$x = h/\tan 22\ 1/2^\circ$$

$$= 2.41\ h$$

$$Vol = (h+2.41h^2)2+3h$$

$$4.82h^2+5h-5.75 = 0$$

$$h = \frac{-5 \pm \sqrt{25+(4)(4.82)(5.75)}}{(2)(4.82)}$$

$$h = .69 \text{ in}$$

$$x = (2.41)(.69) = 1.66 \text{ in.}$$

$$A = (2)(1.66)(2)+(1)(2)+3.0$$

$$A = 11.66 \text{ in}^2$$ 2

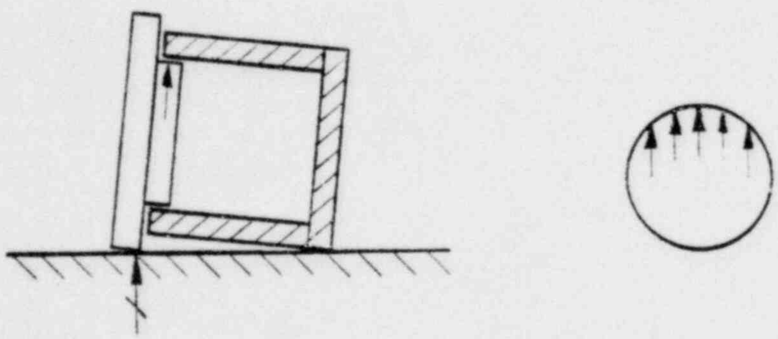
Impact force is then

$$F = \sigma_y A$$

$$= (50{,}000 \text{ psi})(11.66 \text{ in}^2)$$

$$= 583{,}000 \text{ lbs.}$$ 2

This load is transferred through the lid directly to the opposite side of the package and distributed across the projected area.



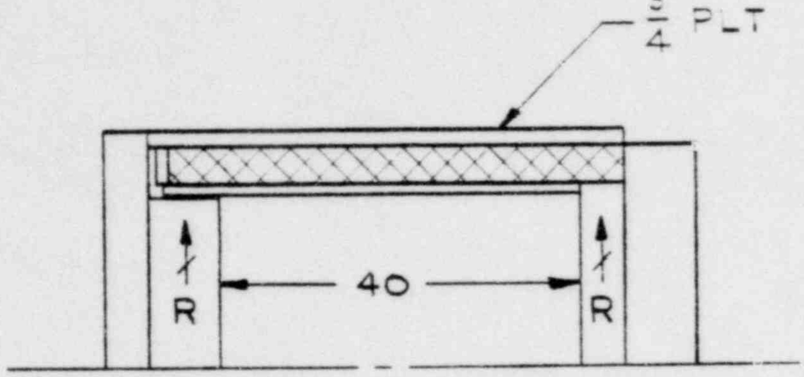
Unit loading on the cask body is given by:

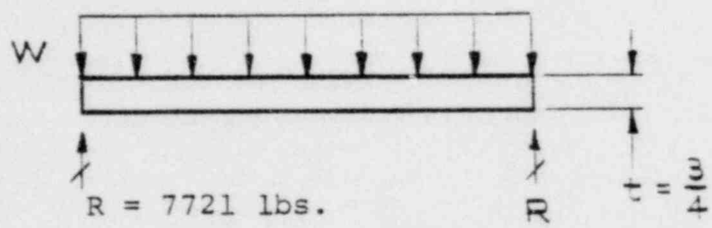
$$p = F/d$$

$$= 583{,}000/75.5$$

$$= 7{,}721 \text{ lbs/in}$$ 2

Conservatively assume that this load is carried by beam bending of the external skin only.





$R = 7721$ lbs

$W = (7721 \text{ lbs})(2)/40$ 2

$W = 386$ lbs/in

$M_{max} = Wl/8$

$= (386)(40)/8$ 2

$= 1930$ in-lbs

$\sigma = 6M/bt^2$

Where:

$M = 1930$ in-lbs 2

$b = 1$ inch (unit width)

$t = .75$ in

$$\sigma = (6)(1930)/(1)(.75)^2$$ 2

$$\sigma = 20591 \text{ psi}$$

Margin of Safety

M.S. = 38000 psi/20591 psi -1 2

<u>M.S. = +.84</u>

Therefore the cask body can react the side impact loads, transferred by way of the lid, without producing deformations detrimental to the sealing area.

From the above it can be seen that the cask is able to safely react the normal condition of transport associated with the drop conditions.