71-9192

ANEFCO

ANEFCO INC.

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August 12, 1985

PDR
Return to
396SS

U.S. Nuclear Regulatory Commission
Transportation Certification Branch
Division of Fuel Cycle and Material Supply
Washington, D.C. 20555

Attention: Charles E. MacDonald, Mail Stop 396 SS

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U.S. NUCLEAR REGULATORY COMMISSION
NMSS
Mail Section

Subject: Model AP-300 Type A Package
Docket No. 71-9192

Dear Mr. MacDonald:

Attached are revisions to the SAR for our AP-300 shipping container which has been submitted to you with our application for a Certificate of Compliance. The revisions have been made to satisfy some questions which were posed by your Mr. Richard Odegarden in my telephone conversation with him about two weeks ago.

The responses are related to the structural aspects of the report and have been marked as revision 6 in the text for easy identification. We have expanded the text further to show in detail that the structure of the shipping container is adequate, with a margin of safety, to satisfy the required simultaneous "g" loadings at the center of gravity of the cask during transport.

We have also provided a toroidal ring at the top of the container and a square tube ring at the base of the container. The calculations show that these will reduce the "g" loading by absorbing the energy of a one foot drop and assure the continued integrity of the container during a presumed one foot drop.

We hope that these revisions clarify the design of the cask and meet with your approval, so that we may be granted a Certificate of Compliance at your earliest convenience.

Very truly yours,

ANEFCO, Inc.

John D. Murphy
President

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REVISION 6 - 8/7/85

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2.4.4 TIE-DOWN DEVICE

In order to satisfy the requirements of 173.412 (d) the cask tie-down blocks were designed to meet Title 10 of the Code of Federal Regulations 71.31 (d) which stipulates that the tie-down structure be capable of sustaining at the center of gravity of the cask a "g" loading component of:

Vertical	=	2 g's
Forward horizontal	=	10 g's
Sideward horizontal	=	5 g's

2.4.4.1 TIE-DOWN FORCES

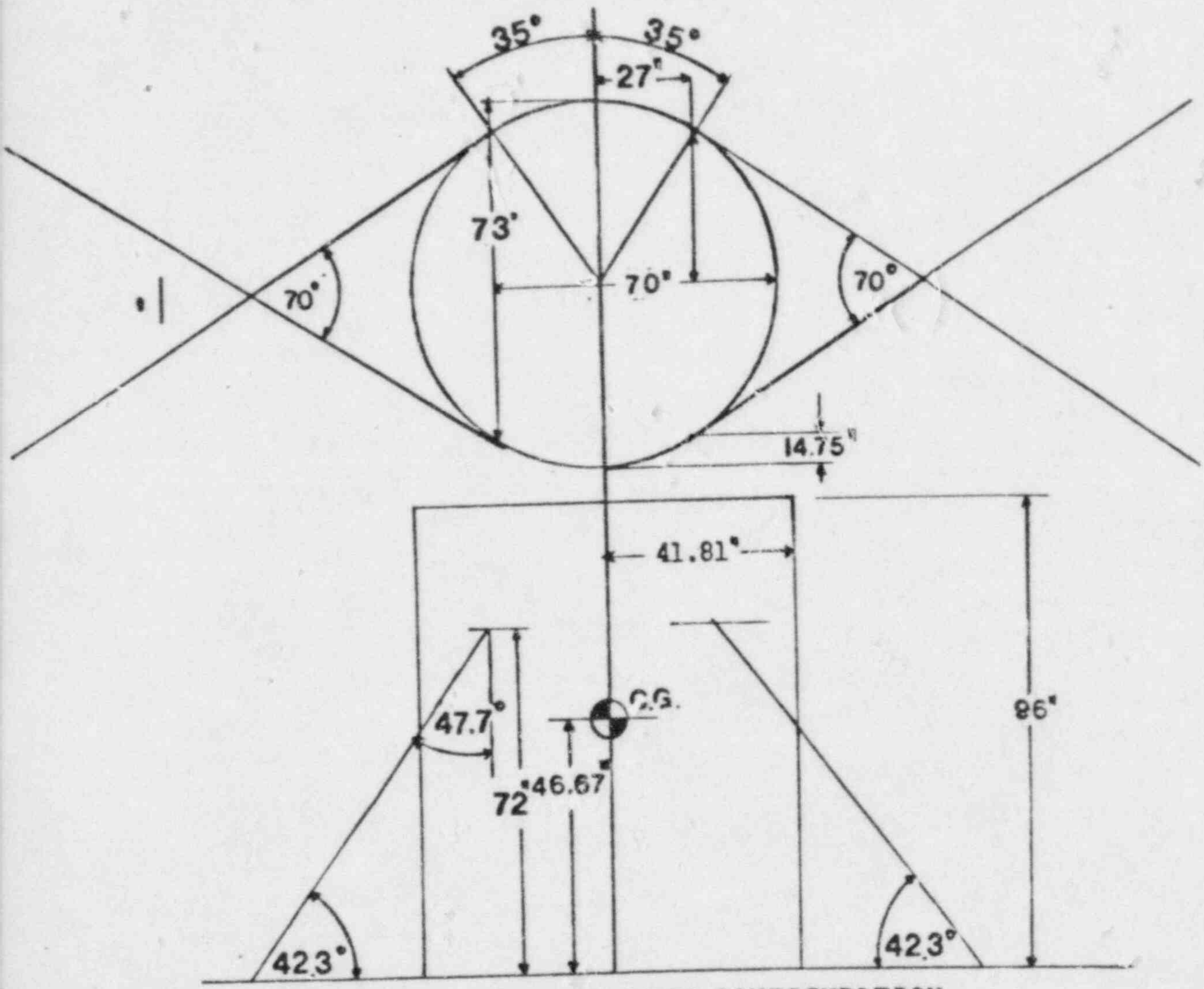


FIGURE 2.4-3 TIE-DOWN CONFIGURATION

4 Cask center of gravity	=	47.66 in. (See Section 2.2)
Cask radius	=	41.8125 in.
Overall Height	=	96 in.
4 Weight	=	66,720 lbs.

For a loaded cask weight of 66,720 lbs, it is considered that the following forces will act simultaneously at the center of the cask in the following directions:

Vertical - V

2g will act in the upward direction and 1g will act in the downward direction for a net 1g force or 66,720 lbs. upward.

Forward Horizontal - H_F

10g will act in the forward horizontal direction or 667,200 lbs.

Sideward Horizontal - H_S

5g will act in the sideward horizontal direction or 333,600 lbs.

6

Load in Tie-Down Rods

Vertical

As shown in Figure 2.4-3, the vertical component of the g force in one rod is = $F_V \cos 47.7°$.

Where F_V = the tension force in a tie-rod due to the vertical g force

Therefore, $4F_V \cos 47.7° = 66,720$ lbs.

Thus, the tension in a tie-rod due to the vertical g force is:

$F_V = 24,784$ lbs.

6

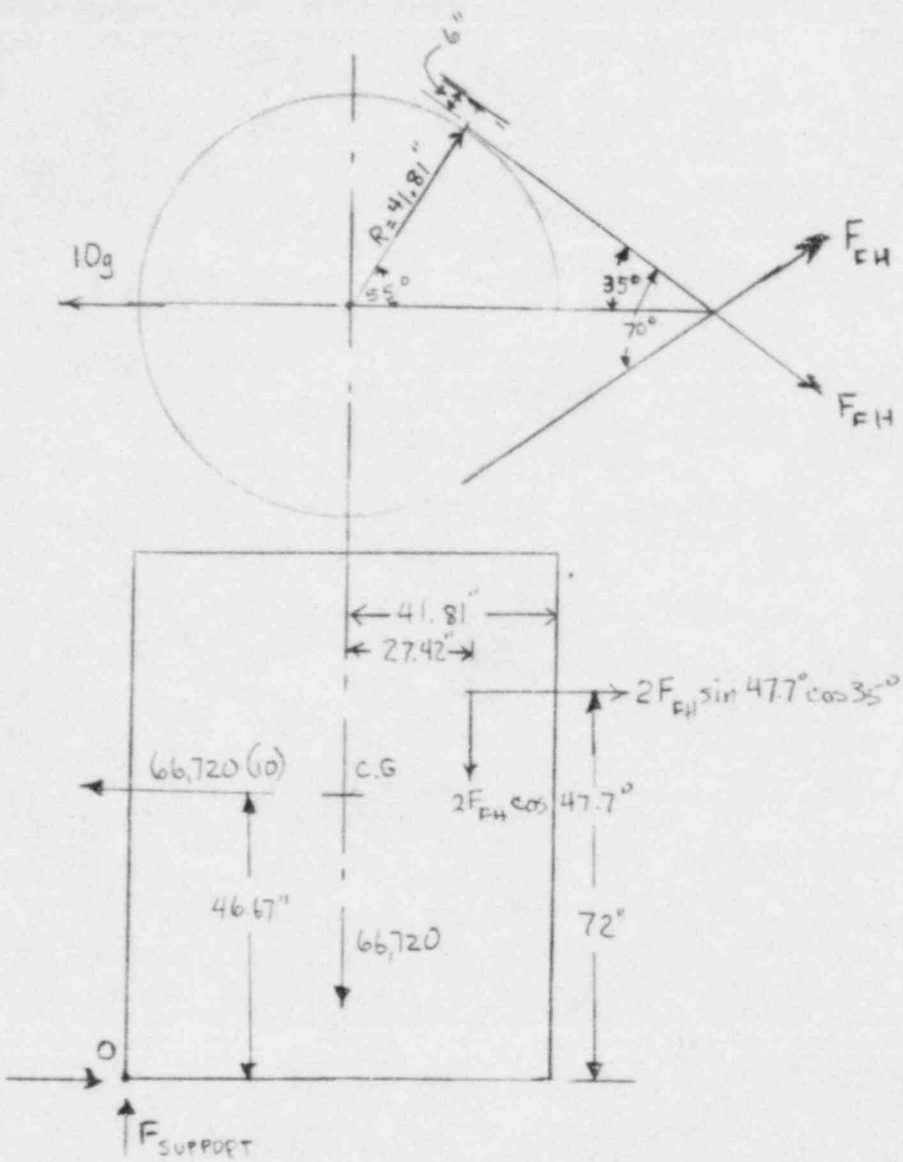


Figure 2.4-3a

Forward Horizontal Tie-Down

Forward Horizontal

Only the two rear rods are effective in resisting the 10g forward horizontal force, as shown in Figure 2.4-3a.

Let F_{FH} = tension force in a tie-rod for forward horizontal g force

Σ Moments at Pt. 0 at bottom
(assume this is pt of rotation)

$$66,720(10)(46.67) = 66,720(41.81) + 2F_{FH}\sin 47.7 \cos 35\ (72) + 2F_{FH} \cos 47.7(41.81+27.42)$$

$$31,138,224 = 2,789,563.2 + 87.245F_H + 93.185\ F_{FH}$$

$$180.43F_{FH} = 28,348,660.8$$

Thus, the tension in a tie rod due to forward horizontal g force is

$$F_{FH} = 157,117 \text{ lbs.}$$

Sideward Horizontal

Only two rods are effective in resisting the 5g sideward force as shown in Figure 2.4-3b.

6

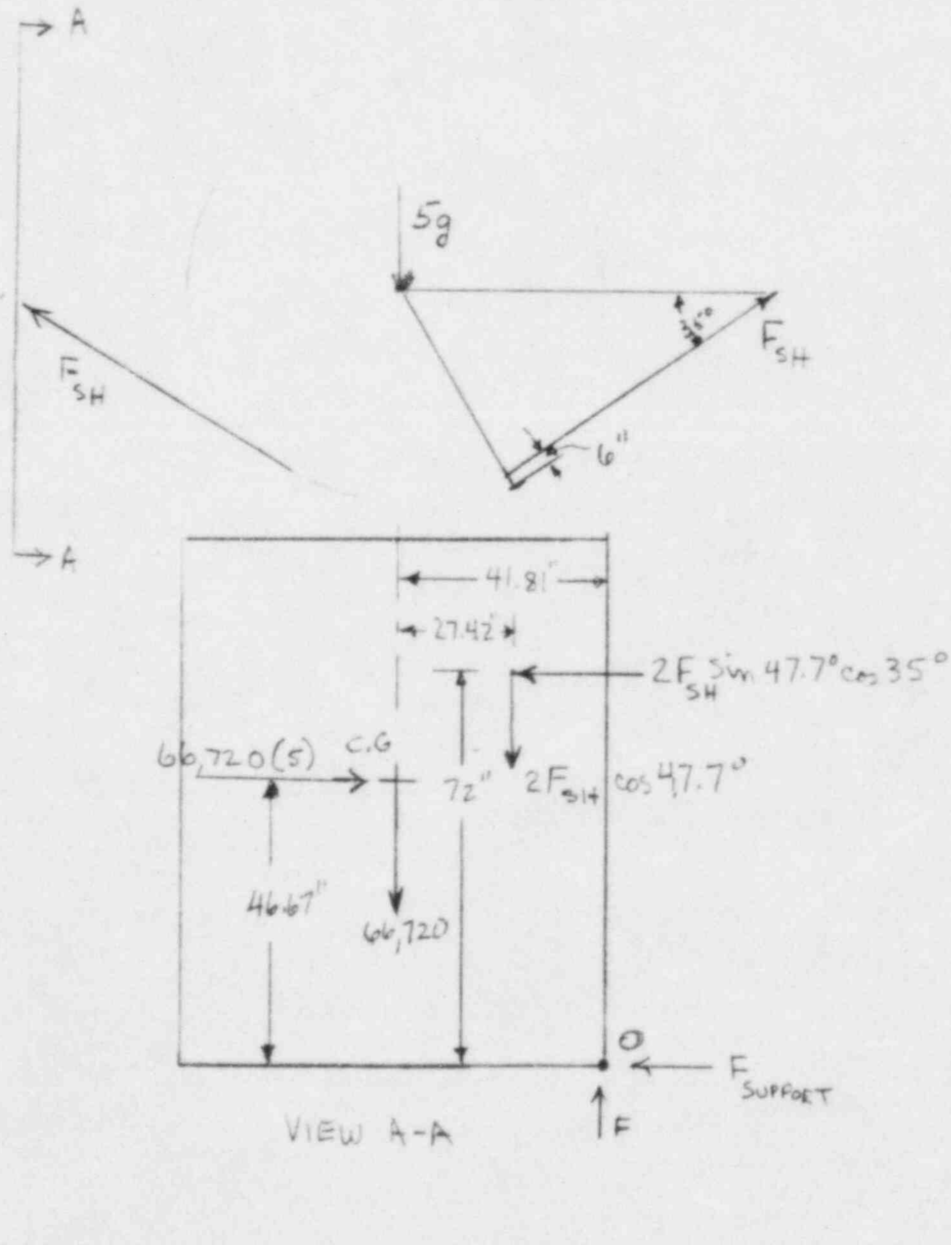


Figure 2.4-3b - Sideward Horizontal Tie-Down

Let F_{SH} = tension in a tie-rod for sideward horizontal g force

Moments at Pt. 0 at bottom

$$66{,}720(5)(46.67) = 66{,}720(41.81)$$
$$+2F_{SH} \sin 47.7 \sin 35.0(72)$$
$$+2F_{SH} \cos 47.7(41.8.1-27.42)$$

$$15{,}569{,}112 = 2{,}789{,}563.2$$
$$+ 61.1\ F_{SH}$$
$$+ 19.4\ F_{SH}$$

$$80.5\ F_{SH} = 12{,}779{,}548.8$$

Thus, the tension in a tie-rod due to sideward horizontal g force is

$$F_{SH} = 158{,}752 \text{ lbs.}$$

Summary of Tie-Rod Forces

The maximum tensile force in a rod from the simultaneous application of the 3 g forces is

$$F_1 = F_V + F_{FH} + F_{SH}$$

$$F_1 = 24{,}784 + 157{,}117 + 158{,}752$$

$$F_1 = 340{,}653 = 340.7 \text{ kip}$$

2.4.4.5 Tie-Down Pads for Cask Assembly

2.4.4.5.1 Loading

The tie-down pads must be capable of sustaining the total force of the maximum force previously calculated, viz. 340.7 kip. The tie-down pads are designed to resist this maximum force. Each pad is designed for 340.7 kip.

2.4.4.5.2 Tie-Down Pad Design

Use steel of Fy - 38^{ksi} min. weld with low hydrogen electrode. Steel to be noted in Group II Table 4.2 of AWS D1.1-80 Structural Welding Code.

Check hole for bearing and shear. (assume 2" min. for Pin)

$$F_p = \frac{340.7}{2 \times 4} = 42.6 \text{ ksi (actual bearing stress)}$$

Allowable AISC (8th Edition specification para. 1.5.1.5 Bearing)
(1.5.1.1 Tension)
(1.5.1.1 Shear)

$F_p = 1.5\ Fy = 1.5 \times 38 = 57$ ksi

Safety Factor to allowable AISC bearing:

$SF = 57/42.6 = 1.34$

Check tear out of hold down device along lines 1-2 and 3-4, Section A-A (page 2.4-13)

$Av = 2 \times 3 \times 4 = 24$ sq. in.

The shear capacity of structural steel is 2/3 of the tensile capacity. Therefore, the tear out capacity is:

$2/3 \times 38 \times 24 = 608$ kip; $SF = \frac{608}{340.7} = 1.78$

At the highest loaded lug the tension force = 340.7 k .
Therefore, horizontal component = 340.7 cos 42.3° = 252.0 k
and the vertical component = 340.7 sin 42.3° = 229.3 k

6

Bending on plane 1-2

$M = 6" \times 340.7 = 2044.2$ kip-in

Assume weld pattern is 22" x 4" pattern.

Area of weld material $= 2(22+4)(.75 \times .707) = 27.6\ in^2$

$$I = 2\left[\frac{1}{12}(.53)(22)^3 + 4(.53)(11)^2\right] = 1453.6\ in^4$$

$C = 11"$

$$S = I/C = \frac{1453.6}{11} = 132.15\ in^3$$

Tension stress on weld $= F_{TW} = \frac{2044.2}{132.15} = 15.47$ ksi

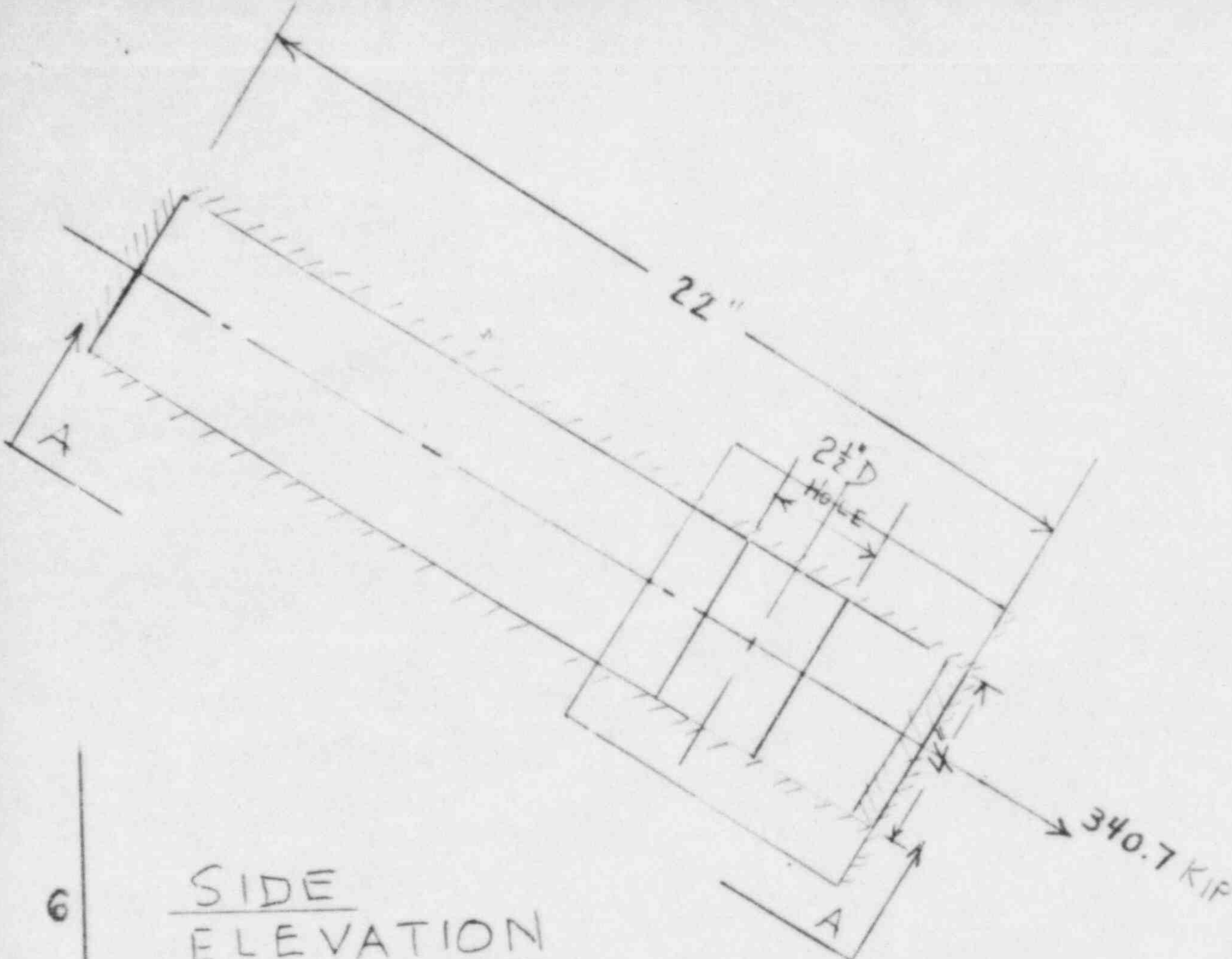
Shear stress on weld $= F_{SW} = \frac{340.7}{27.6} = 12.3$ ksi

Combined stress $= f_{comb}\ \sqrt{(15.47)^2 + (12.3)^2} = 19.76$ ksi

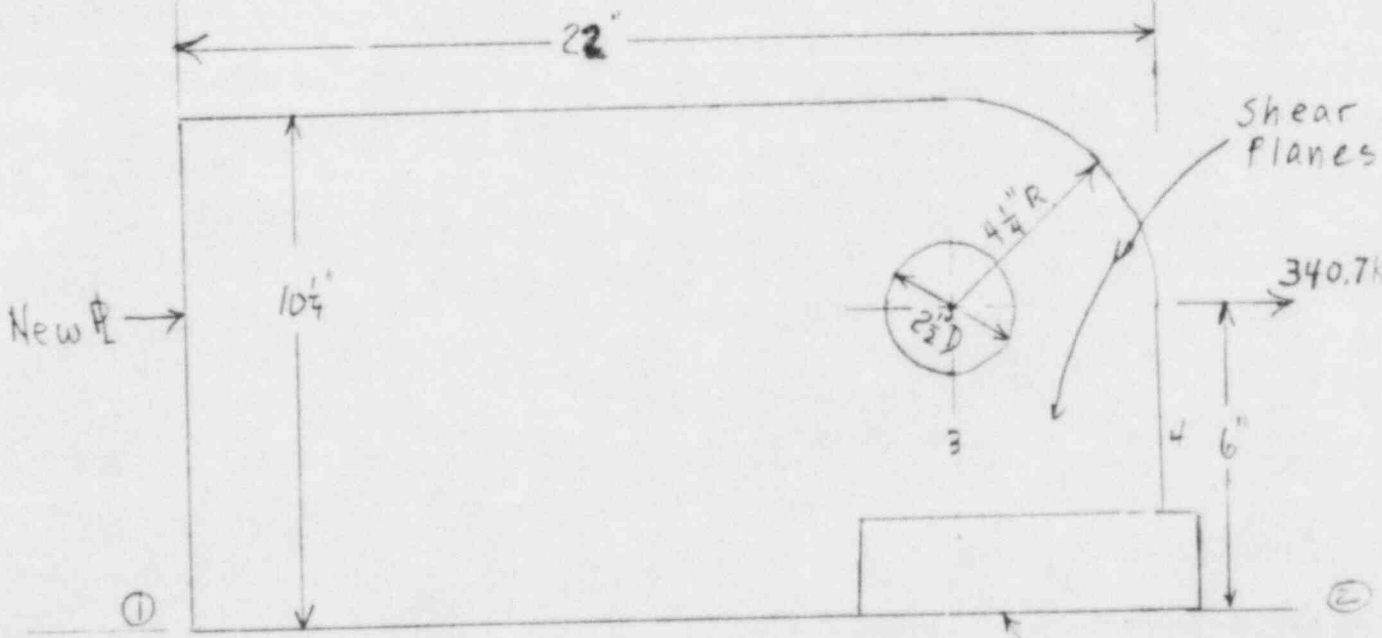
Allowable tensile stress = 21 ksi

S.F. on tension $= \frac{21}{19.76} = 1.063$

6



SIDE ELEVATION



SECTION A-A

LIFTING/TIE-DOWN PAD

Tie-Down Pads

As shown in the drawing, four tie-down pads are provided to attach the shipping cask to the truck bed. A 7" square, 2" high plate is welded to the cask body using a 3/4" fillet weld all around. A plate, 4" thick, 22" long and 10¼" high is welded at right angles to the base plate and the cask body using a 3/4" fillet weld all around. A 2½" diameter hole is provided in the latter plate and used to enable tie-down. Both plates will be fabricated from a steel having a minimum, Fy = 38 ksi and the lug plate will be welded using a E70 ksi low hydrogen electrode. The cask will be installed on the truck bed so that the center line of the 110° angle between adjacent pads is parallel with the direction of travel. The transverse line is parallel to the center line of the 70° angle between adjacent pads.

The lifting/tie down pads and the welds that attach them to the cask shell are therefore adequate with a safety factor in excess of 1.06 to resist the assumed simultaneous maximum g loading during transportation.

2.6.5 Vibration

The approximate natural frequency of the loaded cask is based on the concentric steel shells.

Using Roark * page 576, Case 1b, considering the cask a uniform beam with both ends simply supported, and a uniform load w per unit length including the cask weight.

$$f_n = (9.87/2\pi) \quad (EIg/wl^4)^{0.5}$$

Where:

E= Modulus of Elasticity

I= Area of Moment of Inertia

L= Cask height = 96 in.

l= Distance between supports = 83.5 in.

$$w = \frac{65{,}710.80 \ (lb)}{96 \quad (in)} = 684.49 \ lb/in$$

$$E = 29 \times 10^6 lb/in^2$$

$$R = \text{Outside Radius of Cask Shell} = \frac{83.625"}{2} = 41.8125 \text{ in.}$$

$$R_i = \text{Inside Radius of Cask Shell} = R - 1.25 = 40.5625 \text{ in.}$$

$$EI = E \frac{\pi}{4} (R^4 - R_i^4) = 29 \times 10^6 \times 274 \times 10^3 = 7.946 \times 10^{12}$$

$$fn = (9.87/2\pi) (7.946\times 10^{12} \times 32.2 \times 12/684.49 \times 83.5^4)^{\frac{1}{2}}$$

$$fn = 477 \text{ HZ}$$

This natural frequency is satisfactory for truck transport, since it is well above the low frequency range of truck suspension systems (1-20 HZ)

* R.J. Roark & W.C. Young, "Formulas for Stress & Strain" Fifth edition, McGraw Hill, 1975

2.6.6 WATER SPRAY

A heavy water spray on the package will not harm the package because it is constructed of ASTM A516, Grade 70 steel. In addition, no water will leak into the primary containment because of the bolted closure and seals. Therefore, the only possible effect of the water spray would be to lower the cask temperature.

2.6.7 FREE DROP

In designing a cask for transport of radioactive material, the regulations require that a free drop of the cask through a predetermined distance (in feet) onto a flat, essentially unyielding surface must be investigated. A segmented toroidal ring will be attached to the ANEFCO AP-300 cask to absorb the energy which is generated by a 1 foot drop of the cask, as shown in Figure 2.6-1. As shown in ORNL-NSIC-68 in Section 2.8.2, this ring will protect the cask closure not only in an end drop, but will operate properly regardless of the angle at which the cask impacts on a horizontal surface. The damage evaluated here is that due to deformation at the impact plane and indirect damage due to deceleration.
The toroidal ring will be a 3" O.D. x ¼" thick steel tube made from
6 1020 steel hot rolled and electric resistance welded. Using equation 2.17 on page 67 in ORNL-NSIC-68, the energy absorbing characteristics in a crushing impact are correlated by:

$$E = \frac{S_y t^2 L}{R}\left[\Delta + \frac{0.4\Delta^2}{R}\right]$$

Where:
E = Energy absorbed (in-lb)
Sy = Yield strength of steel (psi)
t = Tube thickness (in)
5 L = Tube length (in)
R = Mean radius (in)
Δ = Deformation of tube (in)

and as shown in Figure 2.6-2.

The energy which must be absorbed by the tube for a 1 foot drop

E = 66,720 lb x 12 in = 800,640 in-lb

For the 3" tube described above

Sy = 38,000 psi   t = 0.25 in
L = 83.625 = 262.7 in
6 $R = \frac{3 + 2.5}{4} = 1.375$

Substituting in the above equation:

$$800{,}640 = \frac{38{,}000(0.25)^2(262.7)}{1.375}\left[\Delta + \frac{0.4}{1.375}\Delta^2\right]$$

$$\Delta = 1.28$$

Since the I.D. of the tube is 2.5 inches, the tube can accommodate the deformation caused by a 1 foot drop of the cask.

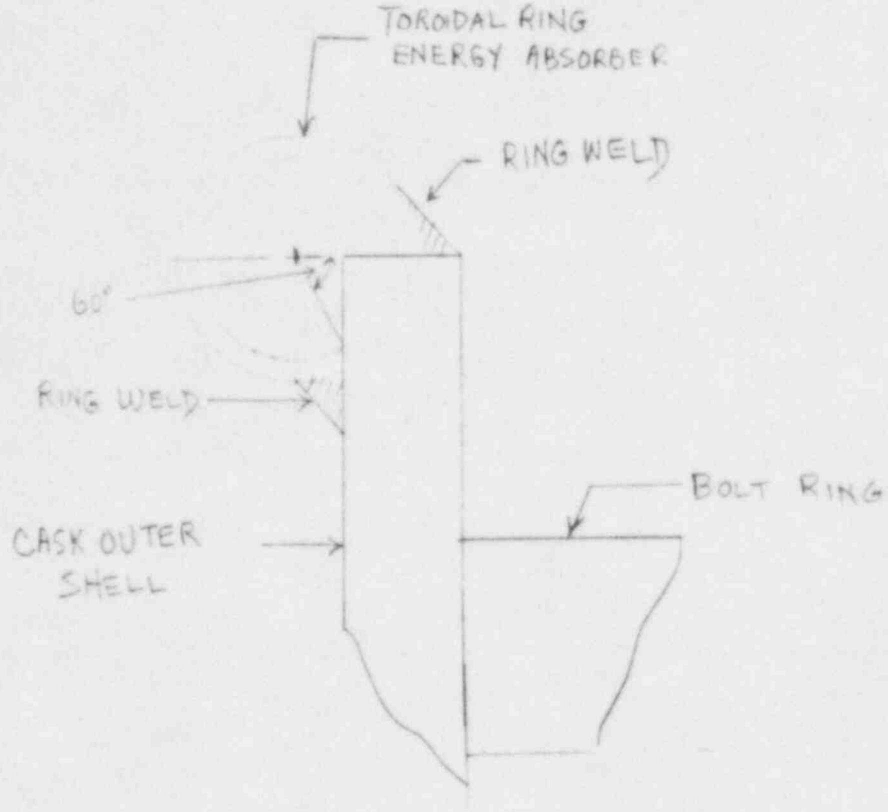


FIGURE 2.6-1 TOROIDAL RING ENERGY ABSORBER

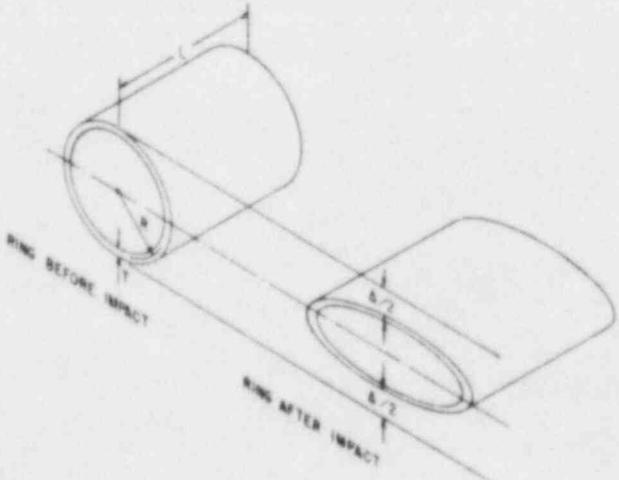


FIGURE 2.6-2 DEFINITIONS OF TERMS USED IN EQ. IN SEC. 2.6.7

The tube will be welded to the cask outside shell with two ½" fillet welds using E70 ksi low hydrogen electrode, which has an allowable tensile stress of 21 ksi, as shown in Figure 2.6-1.

The force due to the deceleration of the cask can be determined using equation 2.4 on page 36 of ORNL-NSIC-68 (Cask Designer's Guide)

$$F = 2Ng(W)$$

Where: W = weight of the leaded cask
Ng = the mean no. of g's the cask subject upon impact

$$Ng = \frac{12}{1.2} = 9.375$$

Ng can be calculated by dividing the drop height by the stopping distance in accordance with the statement in section 2.7 of the Cask Designer's Guide.

Therefore, $$F = 2\left(\frac{12}{1.28}\right)(66{,}720)\text{lbs} = 1.251 \times 10^3 \text{ kip}$$

This force must be resisted by the welds with which the tube is attached to the cask shell. The total area of the 3/4" weld that will resist the force can be calculated as:

$$A = 2\pi(D)(b)$$

Where: D = O.D. of cask
b = effective throat of weld

$$A = 2\pi(83.625)(0.354) = 186 \text{ in}^2$$

The tensile stress on the weld area is:

$$f = \frac{1.262 \times 10^3 \text{ kip}}{186} = 6.73 \text{ ksi}$$

$$\text{Safety Factor} = \frac{21}{6.73} = 3.12$$

Since allowable stress for the weld is 21 ksi, the tube welds will resist the force of the drop impact with a safety factor of 3.12.

A square tube ring, fabricated from ASTM A500-GRB steel, 2 inches on a side and 0.154" thick, will be installed on the bottom of the cask to absorb the energy during a bottom drop of the AP-300 cask through a height of 12". This arrangement is shown in Fig. 2.6-2a.

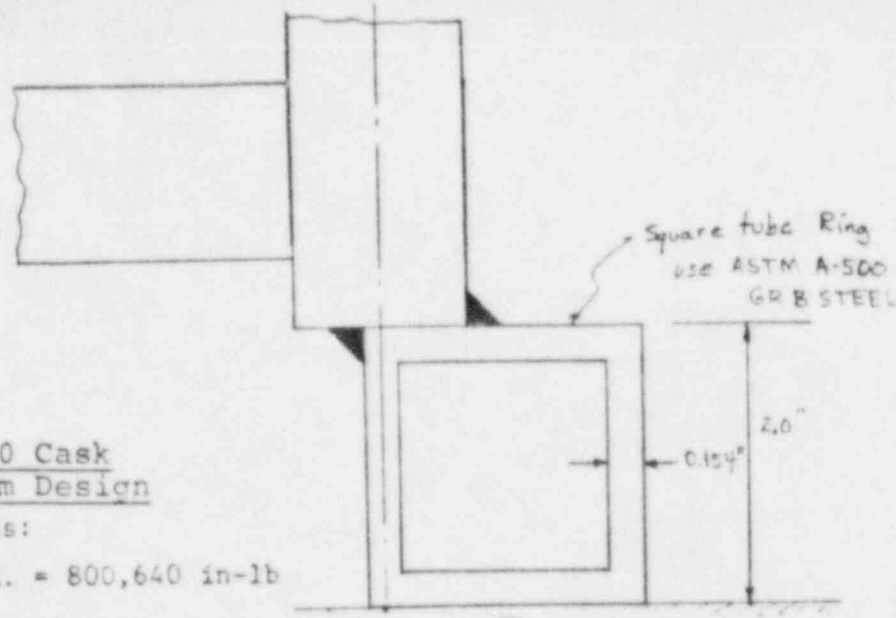


Figure 2.6-2a AP-300 Cask Bottom Design

The energy of the end drop is:

$E = Wh = 66,720 \text{ lbs} \times 12 \text{ in.} = 800,640 \text{ in-lb}$

The volume of ASTM A-500 GrB steel to absorb this energy is:

$$V = \frac{E}{\sigma} = \frac{800,640 \text{ in-lb}}{46,000 \text{ lb/in}^2} = 17.41 \text{ in}^3$$

The surface of the wall of the tube ring which will be impacted by a bottom end drop is:

$$A = \pi Dt = \pi\, 82.375\ (0.154) = 39.9 \text{ in}^2$$

The depth of the ring wall deformed to absorb the drop energy is:

$$d = \frac{V}{A} = \frac{17.41 \text{ in}^3}{39.9 \text{ in}^2} = 0.436 \text{ in}$$

The g loading on the cask lid under the impact conditions can be calculated by dividing the drop height by the stopping distance, as shown in Section 2.7 of the Cask Designer's Guide (ORNL-NSIC-68).

$$g = \frac{12}{.436} = 27.5$$

The g loading on the lid will therefore be

$$Fg = 2Wg = (2)\ 9.46 \text{ kip} \times 27.5 = 520.3 \text{ kip}$$

The force will be distributed on the 2.5" lip (Part No. B-5) where the lid is bolted to the cask, whose area is:

$$A = \frac{\pi}{4}(81.125^2 - 76^2) = 632.5 \text{ in}^2$$

Subtracting the area of the 36 bolts, the net area is:

$$A_B = 36 \times \frac{\pi}{4}(0.7656^2) = 16.6 \text{ in}^2$$

$$632.5 - 16.6 = 615.9 \text{ in}^2$$

The stress on the plate will be:

$$\frac{Fg}{A} = \frac{570.3}{615.9} = 0.84 \text{ ksi}$$

The SA-240 plate, with a yield strength of 30 ksi, will not bend out of shape under a stress of 5.11 ksi with a safety factor of 35.7.

$$SF = \frac{30}{0.84} = 35.7$$

At impact during the bottom drop the force on the impact ring can be expressed as

$$N_f = \frac{2gW}{\pi D} = \frac{(2)66,720g}{82.375} = 515.63g \text{ lb/in}$$

Where g = 27.5 as shown above N_f = 14.18 kip/in

The stress in the wall of the ring will be

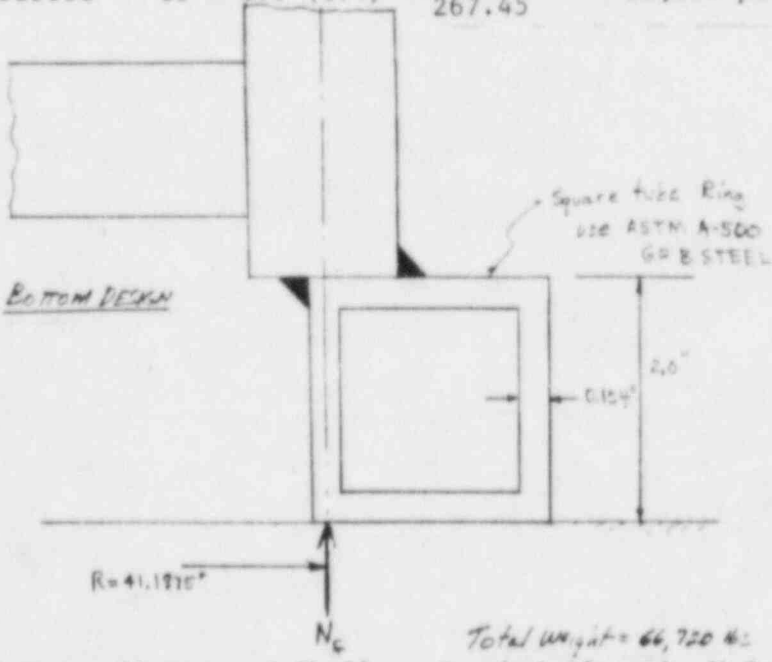
$$f = \frac{N_f}{t} = \frac{14.18 \text{ kip/in}}{.154 \text{ in}} = 92.1 \text{ ksi}$$

The stress at which the wall of the tube will buckle or crush can be calculated *

$$\sigma_{cr} = 0.6\,\gamma\,\frac{Et}{R}$$ where γ = knockdown factor which is a function of R/t

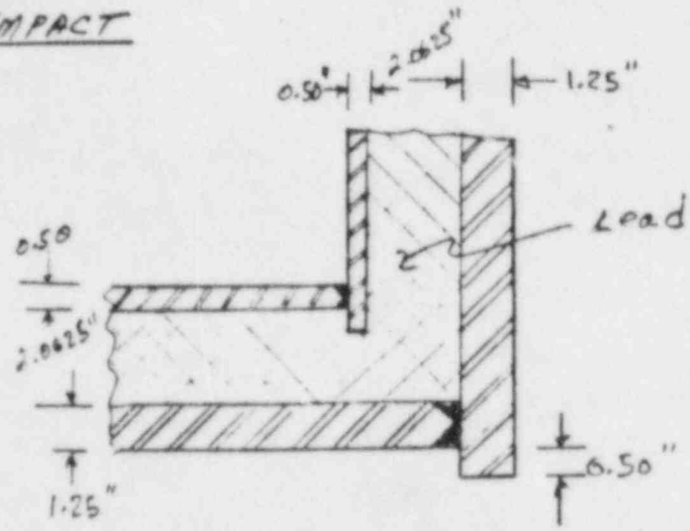
6 for $R/t = \frac{41.1875}{.154} = 267.45$; $\gamma = 0.4$

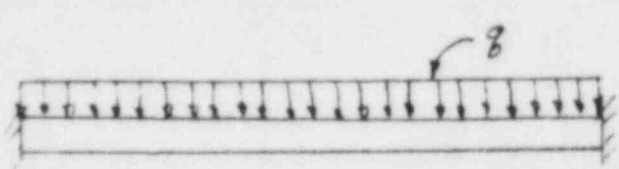
Therefore $\sigma_{cr} = 0.6\,(0.4)\,\frac{(28.5\times10^6)}{267.45} = 25,665$ psi



* Buckling of Bars, Plates and Shells, Brush & Almroth, McGraw Hill, 1975

BOTTOM IMPACT





For bottom, flat impact (g=27.5), the loading on outside bottom plate
6 is due to the weight of the contents, and the weight of the bottom plates
and lead.

$$\text{Weight of lead} = \frac{\pi (81.125)^2 (2.0625)(710)}{4 \quad (12)^3} = 4380 \text{ lbs.}$$

$$\text{Weight of steel} = \frac{\pi (81.125)^2}{4} (1.75)\ (.283) = 2560 \text{ lbs.}$$

$$\text{contents} = \underline{20{,}000 \text{ lbs}}$$
$$26{,}940 \text{ lbs}$$

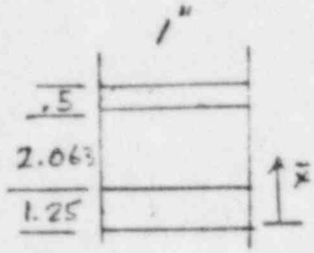
$$q = \frac{26{,}940}{(81.125)^2} (4) = 5.21 \text{ lbs/in}^2$$

$$\text{at impact} \quad q_i = 27.5\ (5.21) = 143.28 \text{ lb/in}^2$$

For uniformily loaded circular plate, with fixed edges reference to Roark & Young, page 363. The edge bending moment is

$$M_{ra} = \frac{qa^2}{8}$$

Therefore $$M_{ra} = \frac{(143.28)\left(\frac{81.125}{2}\right)^2}{8} = 29{,}468 \text{ in lbs/in}$$



Calculate effective bending moment of bottom plate

Assume the inside and outside act together

$$\bar{x} = \frac{0.5(1.0)(3.563) + 1.25(1.0)(.625)}{0.5(1.0) + 1.25(1.0)}$$

$$\bar{x} = \frac{2.563}{1.75} = 1.46"$$

$$I \sim .5(2.099)^2 + 1.25(.835)^2 = 3.074 \text{ in}^4\text{/in}$$

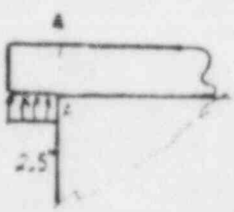
$$\bar{t} = \sqrt[3]{12(I)} = 3.33"$$

$$\text{Stress top fiber} = \frac{Mc}{I} = \frac{29{,}468\ (2.3525)}{(3.074)} = 22{,}551.55 \text{ psi}$$

6 Assume that the weld yield strength for dynamic impact is 25% greater than for static loading

Thus $$FS = \frac{21(1.25)}{22.55} = 1.16$$

and the bottom plate welds are adequate with a factor of safety of 1.16.



The plate bending stress at plane A-A

for 1" strip $M = 840\ \frac{(2.5)^2}{2} = 2{,}625$ in lbs/in

$$f = \frac{6M}{t^2} = \frac{6(2625)}{(2)^2} = 3{,}938 \text{ psi}$$

Edge rotation =

$$\phi = \frac{qa^3}{8D(1+\ )} \qquad q = \frac{520{,}300}{(38)^2} = 114.7 \text{ lb/in}^2$$

$$\phi = \frac{114.7(39)^3}{8(2.09 \times 10^7)(1.3)} = 0.031 \text{ radians } (1.8°)$$

There will be no releases because of compression maintained on the seal.

2.6.8 CORNER DROP

As indicated in Section 2.6.7, the segmented toroidal ring, whose design is evaluated above, will protect the cask closure regardless of the angle at which the cask impacts on a horizontal surface (Cask Designer's Guide, ORNL NSIC-68, page 66).

From a physical standpoint, the maximum direct damage in a corner drop would occur with the cask so oriented that the line passing between the center of gravity and the point of impact coincides with the direction of the fall. The geometrical representation of the corner drop is shown in Figure 2.6-3. The idealization of deformation, the external damage after impact, is indicated as Z.

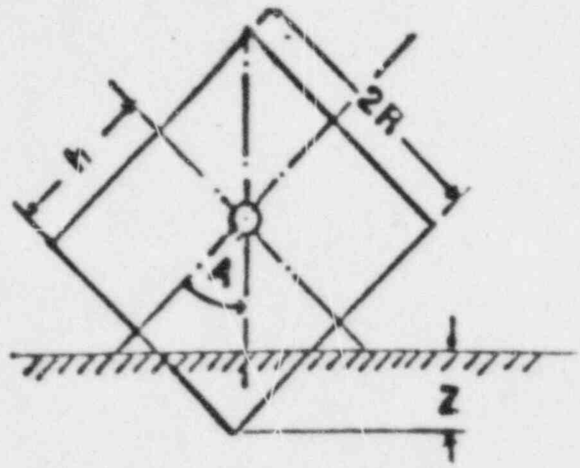


FIGURE 2.6-3 CORNER DROP DEFORMATION GEOMETRY

Using Figure 2.6-3, the angle A (angle of impact) can be seen to be:

$$\text{Tan } A = R/H$$

Where: R = Cask Radius 41.8125"
H = Center of Gravity with relation to the top (lid) end = 49.33"

Therefore, the angle of impact (a) is:

$$\text{Tan } A = 41.8125/49.33" = .8476$$

$$A = 40.28°$$

Impact on the top corner causes an axial force component and a lateral force component. The axial force acts on the cask lid in the same way as analyzed previously. The lateral force component on the contents bears against the sides of the cask before any shear load is transmitted to the bolts connecting the lid to the cask.

6 The behavior response for a corner drop should result in a greater deformation of either the toroidal ring for a top drop or the square ring for the bottom drop. It is speculated that the crushing under the point of impact will be extensive with less deformation occurring away from the point of impact.

This greater deformation would result in "g" factors less than those for a flat drop.

TOP CORNER DROP

Drop angle A = 40.28° from vertical

Bolt Tension

Assume g = 9.375 (same as for flat drop. This is believed to be conservative)

$$F_w = 2Ng(W_1 + W_c) \cos 40.28°$$

$$F_w = 2(9.375)(29,462) \cos 40.28° = 421,432 \text{ lbs.}$$

F_p (from internal pressure) = 52,500

Therefore $$F_b = \frac{421,500 + 52,500}{36} = 13,167 \text{ lbs/bolt}$$

$$F_s = \frac{13,167}{.34} = 38,726 \text{ psi}$$

Bolt Shear

Even though the design is such that bolt shear should not occur, we will
6 assume that the bolts do take the shear induced by the in-plane component of"g" forces on the lid. This is very conservative.

Therefore

$$F_s = 2(9.375)9,462 \sin 40.28 = 114,701 \text{ lbs}$$

$$F_{s_b} = \frac{114,701}{36} = 3186 \text{ lbs/bolt}$$

$$f_s = \frac{3929}{.4418} = 7211 \text{ psi}$$

For bolts in combined tension and shear

Reference: Guide to Design Criteria for Bolted and Riveted Joints, Fisher and Struik, John Wiley and Sons, 1974.

$$\frac{x^2}{(0.62)^2} + y^2 = 1.0$$

Where x = ratio of the shear stress on the shear plane to the tensile strength,

y = ratio of the tensile stress to the tensile strength

Therefore $$x = \frac{7211}{125,000} = 0.058$$

$$y = \frac{38,726}{125,000} = 0.310$$

Therefore $\frac{(.058)^2}{(.62)^2} + (.310)^2 \leq 1.0$

$$0.009 + 0.096 \leq 1.0$$

$0.105 \leq 1.0$ Therefore, Bolt is O.K.

If 50% of the tensile strength is used (62,500 psi)

$$0.034 + 0.384 \leq 1.0$$

$0.418 < 1.0$ Bolt is still O.K.

Therefore, the lid remains in place.

2.6.8.1 Bolting Design

The bolts screwed into the helicoil inserts are designed to withstand the expected decelerating forces resulting from the impact resulting from a one foot drop at the impact velocity.

The helicoil is inserted into the bolt ring which is fabricated of SA-240 Type 304 with a minimum yield of 30 kip/in^2. The root diameter of the 1.5 inch long helicoil is 0.79 inches. Therefore, at yield, the tensile strength of the helicoil in the metal ring is:

$$F = 30{,}000 \text{ lb/in}^2 \times \pi(1.5)(.79) = 112 \text{ kip}$$

The tensile strength of the helicoil assembly based on the manufacturer's data, shown in figure 2.6.4, is 125 kip.

The bolt which will be used is a 3/4 inch SA-320 Grade L7A bolt with a minimum tensile strength of 125 kip/in^2. Therefore, it will be capable of resisting a force

$$F = 125{,}000 \text{ lb/in}^2 \times \frac{\pi}{4}(.75)^2 = 55.2 \text{ kip}$$

Therefore the bolt will yield before either the helicoil, or the ring material when an excessive force is applied to the assembly. This is the basis of selection of the bolt specification.

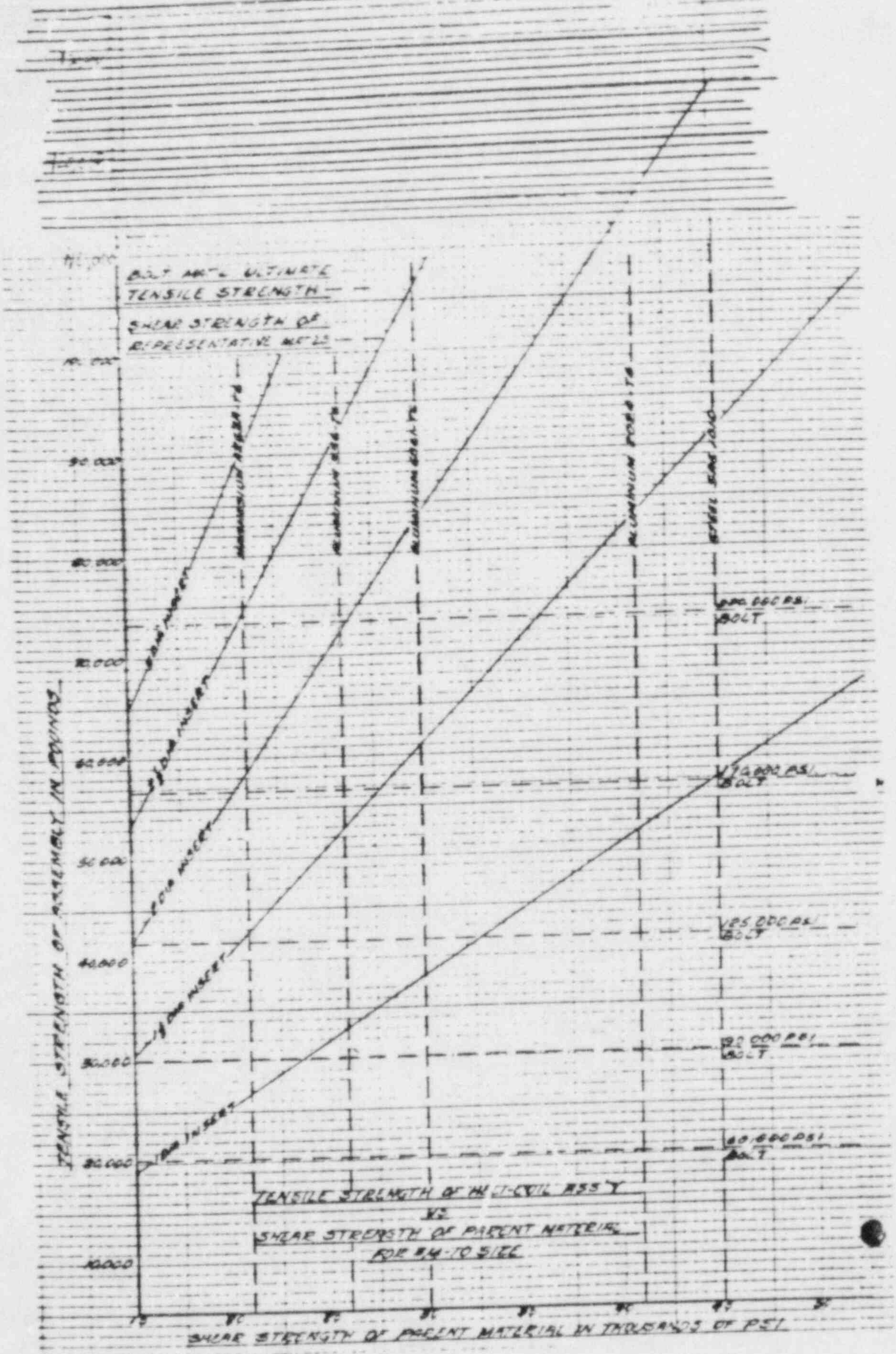


FIGURE 2.6-4, TENSILE STRENGTH OF HELICOIL ASSEMBLY

2.6.8.3.2 BOLTS IN TENSION

Solving for the force in tension on the bolt due to the "g" component using ORNL-NSIC-68 P.37 Formula (2.7) the minimum bolt area for tensile is:

$$A_{min} = \frac{FWV + FG + FP}{Sa}$$

Where:

FW = Tension on the bolts due to the decelerating drop force

FG = Tension on the bolts due to the gasket using Fsg or Foc, whichever is greater

Where:

Fsg = Tension due to gasket seating
Foc = Tension due to maintenance of a tight seal on the gasket
Fp = Tension due to internal pressure at reduced atmospheric pressure
Sa = Ultimate strength of the bolts

Using ORNL-NSIC-68 P.36 Formula (2.4), the tension on the bolts due to the drop (FW) is found to be:

6| FWV = W (2Ng)

Where:

W = cask lid and contents weight = 29,462 lbs.
6| Ng = "g" loading due to the drop = 9.375

6| Therefore: FWV = 29.462 [2(9.375)]
FWV = 552.413 lbs.

Using ORNL-NSIC-68 P.36 Formula (2.5), the tension load due to gasket seating (Fsg) is found to be:

Fsg = bπdy
Where:
d = Mean diameter of the gasket, in = 77.25
y = Minimum yield design seating strength (ASME Section VIII, Table VA-49.1 (1974) for self sealing type gaskets (Neoprene), lb/in^2=0
b = Effective gasket seating width, in = 1.875

Since the y value is "0" the Fsg value is negligible and can be considered "0".

Using ORNL-NSIC-68 P.36 Formula (2.6) to determine the tensile load on the bolts created to maintain a tight seal on a flat gasket (Foc) is found to be:

$$F_{oc} = bdmp$$

Where:

m = gasket factor (ASME Section VIII Table VA-49.1)=0
b = effective seating width in = 1.875
d = mean diameter of the gasket in = 77.25
p = differential pressure, psi = 11.2 (See Section 1.5.2)

Since the m value is "0", the Foc value is negligible and can be considered "0".

Using ORNL-NSIC-68 P.35 (Formula 2.3) the force due to the internal pressure as a result of the case given in Section 1.5.2 yields:

5 $$F_p = \frac{\pi p \, (d)^2}{4}$$

Where:

p = differential pressure across the gasket psi = 11.2
d = mean diameter of the gasket, in = 77.25

5 $$F_p = \frac{\pi (11.2)(77.25)^2}{4}$$

Fp = 52,500 lbs.

Substituting the derived values into the Formula (2.7) for the minimum bolt area it is found to be:

$$AM = \frac{FWV + F_p}{Sa}$$

Where Sa = Ultimate tensile strength of the bolts (A320-L7a from Table 1.3.1) = 125 K psi.

Therefore:

6

$$AM = \frac{(552,500 + 52,500) \text{ lbs}}{125,000 \text{ lb/in}^2}$$

$$AM = 5.76 \text{ sq. in.}$$

Evaluations for the 3/4" bolts yields

$$NB = \frac{AM}{AB}$$

Where:

N_B = number of bolts required

A_{min} = minimum bolt area due to tension

A_B = root Area of the bolts = .34

Therefore:

$$N_B = \frac{5.76}{.34} = 16.9$$

6 N_B = 17 bolts

Since the cask uses 36 - 3/4" bolts, the lid will remain in place during the drop.

Check load/bolt:

$$F_b = \frac{52,500 + 552,500}{36} = 16,806 \text{ lbs}$$

$$\text{Tensile stress} = \frac{16,806}{0.34} = 49,429 \text{ psi}$$

From ORNL-NSIC-68, Stress should not exceed the yield strength <u>or</u> 50% of the ultimate strength

$$F_{TU/2} = 62,000 \text{ psi}$$

6 $$FS = \frac{62,500}{49,429} = 1.26$$

Thus, 36 bolts is adequate with a 1.26 safety factor.

Check local bending of 2" thick flange of lid near a bolt.

$$\text{bending stress in } \mathcal{L} = f = \frac{6M}{t^2} = \frac{6(16,806)}{(2)^2} = 25,209 \text{ psi}$$

$$(\text{F.S.}) \text{ yield} = \frac{30,000}{25,209} = 1.19$$

Check elongation of bolt due to tensile load

$$\Delta = \frac{PL}{AE} = \frac{16,806\ (2.75)}{0.34(28.5 \times 10^6} = 0.005 \text{ in}$$

Rotation at edge of plate (Roark & Young, Table 24, case 10)

$$\theta_a = \frac{qa^3}{8D(1+\ )} \qquad q = \frac{552,500 + 52,500}{(38)^2} = 133.4 \text{ psi}$$

6 $$D = \frac{Et^3}{12(1-\gamma)^2} = \frac{28.5 \times 10^6 (2)^3}{12(1-.3^2)} = 2.09 \times 10^7$$

$$\theta_a = \frac{133.4(39)^3}{8(2.09 \times 10^7)(1.3)}$$

$$\theta_a = \frac{0.0364 \text{ radians}}{(2.1°)}$$

NOTE: This rotation assumes no restraint from bearing of lid flange on the outer shell extension. This effect would reduce the plate edge rotation.

2.8.8.1.3 Bolts in Shear

The plug portion of the lid has a radial clearance less than that of the
5 lid bolts clearance holes, preventing contact of the lid with the closure bolts during the hypothetical drop conditions which would put a shear load on the closure bolts.

2.6.8.1.3 Conclusions

Since all the damage will occur in the toroidal segmented ring and the bolts are sufficient to retain the lid,
5 no release of radioactive contents will occur due to direct or indirect damage in the (1) one foot corner drop.

2.6.9 Compression

The AP-300 cask weighs in excess of 5000 Kg. Therefore, no compression load was considered.

2.6.10 Penetration

The regulations in 49 CFR 173.465 (c) stipulate that the cask must be able to withstand the impact of a 1.25 inch diameter bar with hemispherical end weighing 13.2 lbs. being dropped from a height of 3.3 feet on the most vulnerable region of the cask. The most vulnerable region of the cask is the 1.25 inch thick outer steel shell.

If the ASTM-A516 Grade 70 steel plate is assumed perfectly rigid, the kinetic energy of the falling bar must be absorbed by the shear deformation of the plate. This is conservative because any bending deformation of the plate will also absorb energy and reduce the tendency for shear failure. The energy required to cause shear can be expressed as:

$$E_S = K \pi D\, t^2\, S_S$$

Where: K = ductility factor = .60

S_S = Ultimate strength in shear 27,000 psi

D = Bar diameter = 1.25 in.

t = Plate thickness = 1.25 in.

Thus the energy the outer shell can absorb is:

$$E_s = 99{,}400 \text{ in-lbs.}$$

The kinetic energy of the falling bar is found to be:

$$E_b = Wh$$

$$E_b = 13.2\ (3.3 \times 12)$$

$$E_b = 523 \text{ in-lbs.}$$

Thus, the most vulnerable part of the cask will not be penetrated by the falling bar.

4.2.2 Pressurization of Containment Vessel

The contents of the containment vessel will be only solids, with no possibility of gas release. The only conditions for pressure formation above ambient atomspheric pressure would be exposure of the cask to 100°F temperatures in the shade. Assuming a maximum internal temperature of 180°F the maximum absolute pressure within the containment vessel, assuming that it is loaded at 70°F - 530°R, is:

$$14.7 \text{lb/in}^2 \times \frac{640}{530} = 17.7 \text{ psia}$$

The structural analysis of the cask in Section 2 demonstrates the capacity of the AP-300 cask to withstand an internal pressure of 3 psi gauge.

4.2.3 Coolant Contamination

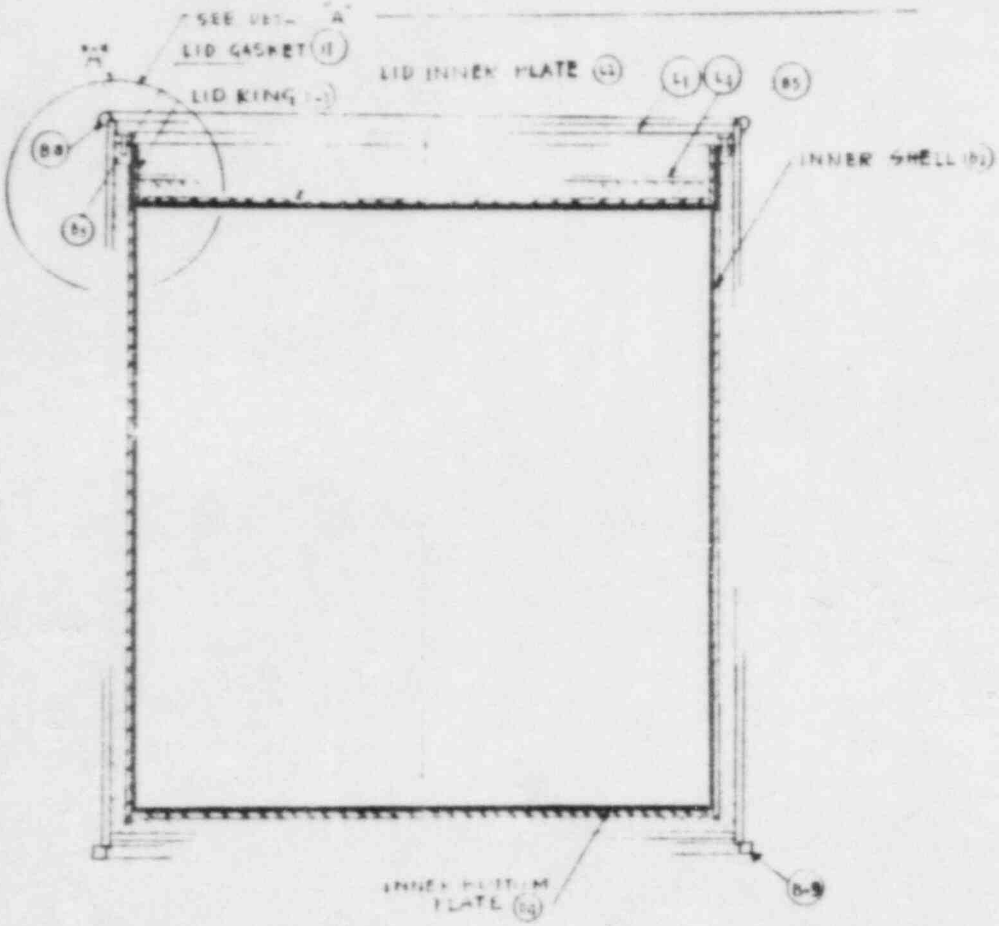
There will be no coolant used in the AP-300 cask.

4.2.4 Coolant Loss

There will be no coolant used in the AP-300 cask.

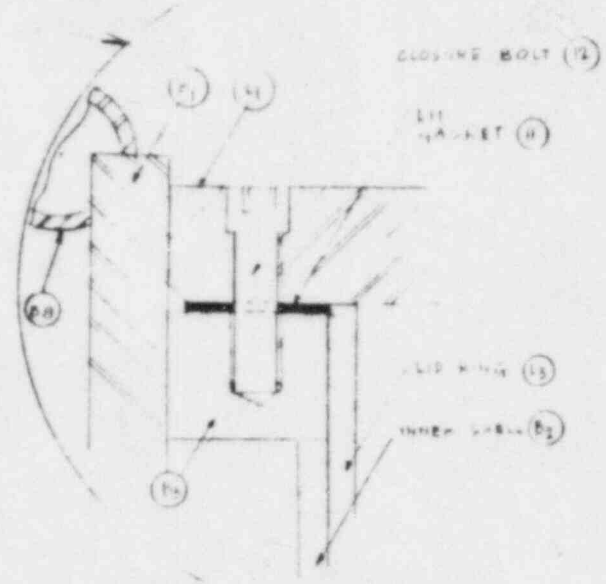
4.3 Containment Requirements for Hypothetical Accident Conditions

The hypothetical accident conditions need not be considered for the AP-300 cask, when it is used to transport greater than A quantity LSA waste packages.



CONTAINMENT BOUNDARY

SCALE : 1/16" = 1"



DETAIL "A"

SCALE : 1/2" = 1"

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SCALE: AS SHOWN		DRAWN BY
DATE: 12/85		

AP-300 CASK

FIG. 4-1

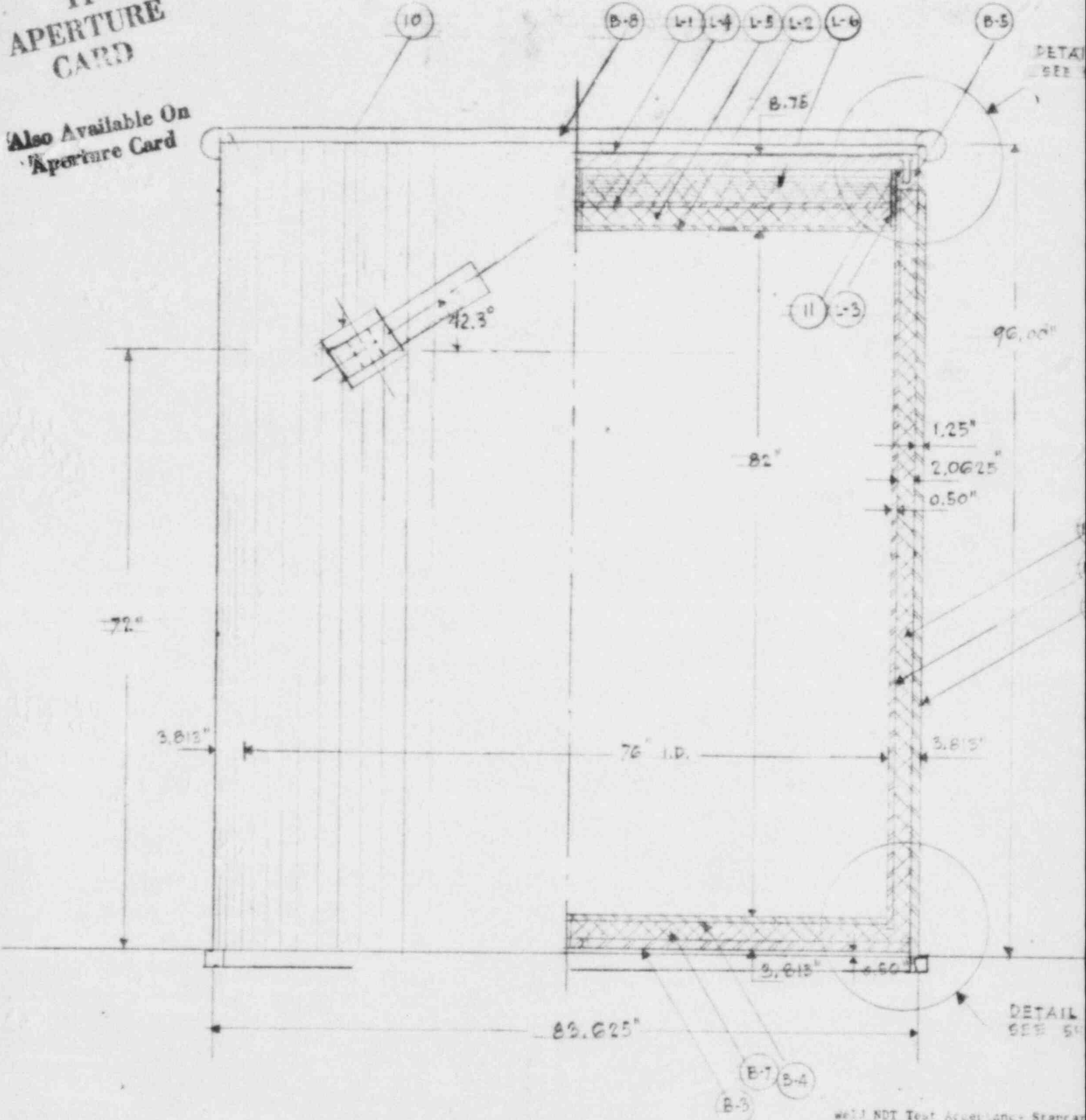

Plate B-1 to be fillet welded using multipass string technique using SMAW & SAW processes. Groove design to be double bevel with 52° bends and 1/8" maximum root gap. Weld to be 100% NDT using x-ray.

Plate B-2 (Inner shell) to be fillet welded using multipass string technique using SMAW & SAW processes. Groove design to be single bevel with 53° with1/8" maximum gap. Weld to be 100% RI.

Weld NDT Test Acceptance Standar

Liquid Penetrant (LP) - ASME Sec

Mag Particle (MP) ASME Section

Radiographic Inspection (RI) ASM

L"B"
SHT NO 134-1

Nº	REVISIONS	APPR.	DATE
1	NOT REQ - ADD REV. BOX	[illegible]	1/5/85
2	LID GASKET SPEC - TIE DOWN PAD &	[illegible]	2/15/85
3	ADD CONCRETE IN LID V^"D	[illegible]	3/20/85
4	No. (B-8) - REVISE - SUBSTITUTE TORDIDAL RING FOR LIFT PAD; DELETE (B-9) - LID LIFTING PAD, CHANGE (10) TO LIFT/TIEDOWN [illegible]	[illegible]	5/2?/85
5	No. (B-8) Rev. ϕ To 3", ADD - SQUARE RING	[illegible]	8/5/85

Nº	DESCRIPTION	MATERIAL	RQ
L-6	CONCRETE - 3.8125 x 75" ϕ	CONCRETE	1
L-1	PLATE 2.00" TH X 81.125" O.D.	A240 TYPE 304	1
L-2	PLATE 0.50" TH X 76.00" O.D. I.03 O.D.	A240 TYPE 304	1
L-3	PLATE RING 0.50" TH. 76.00 O.D. X 6.25" H	A240 TYPE 304	1
L-4	PLATE RING 0.375" TH. 75.00" O.D. H.	A240 TYPE 304	1
B-1	SHELL 1.25" TH. X 96.00" H. X 262.82 ±L. 81.125 $^{+0.25"}_{-0.00}$ I.D.	A516 GRADE 70	1
B-2	INNER SHELL 76.00" I.D. 0.50 TH X 87.40" H 242.00 ±L S.S	A240 TYPE 304	1
B-3	PLATE 1.25" TH. X 81.125" ϕ S.S.	A516 GRADE 70	1
B-4	PLATE 0.50" TH X 76.70 ϕ S.S	A240 TYPE 304	1
B-5	RING 2.25" TH X 76.00 I.D. X 81.125" O.D. H.	A240 TYPE 304	1
B-6	LEAD 2.0625" $^{+0.125}_{-0.00}$ TH X 89.50" H X 254.00 ±L CHEMICAL GRAD LEAD	B-29-55	1
B-7	LEAD 2.0625" $^{+0.125}_{-0.00}$ TH X 77.00" ϕ CHEMICAL GRADE LEAD	B-29-55	1
B-8	SEGMENTED TORDIDAL RING 3" ϕ TUBE x 0.25" TH - BENT TO 84" ϕ	1020 STEEL	1
B-9	SQUARE TUBING RING 2" □ x 0.154" TH - BENT TO 82.4" ϕ	ASTM-A500 GRB	1
10	LIFT/TIE DOWN PAD SEE DWG NO 138 - 20 x 10.25" x 4" TH	A516 GRADE 70	4
11	LID GASKET 76.00" I.D. x 81.125" O.D. x 2 1/2 x 1/8"	ARAMID FIBER w/ SYN. RUB. COMP'D BIND.	1
12	CLOSURE BOLTS 3/4" ϕ X 2 3/4" UNC 3 A BOLT HEX SOCKET	ASTM A320 L7A	36
L-5	LEAD 2.0625 [illegible] x 75.00 ϕ B-29 CHEMICAL GRADE LEAD	B-29-55	1
32	SECURITY LEAD WIRE SEAL 12" LONG		1
33	LID SEAL BLOCK 1/4" TH x 1/2" W x 1/2" W.		1

1. Welders and welding operators shall conform to Section IX of the ASTM Boiler and Pressure Vessel Code.

2. Welding procedures shall conform to Section IX of the ASME Boiler and Pressure Vessel Code.

3. Carbon steel surfaces shall have a protective coating (i.e. Paint) in accordance with ANEFCO spec. A83-GCPO dated 1/12/83, "General Specifcation for Painting & Coating Work, Ship Applied, for ANEFCO Shipping Casks".

"A"
T NO 134-1

ds
tion VIII Div. 1 Appendix 8
VIII Div. 1 Appendix 6 or MIL STD 271E
E Section VIII Div. 1 UW-51

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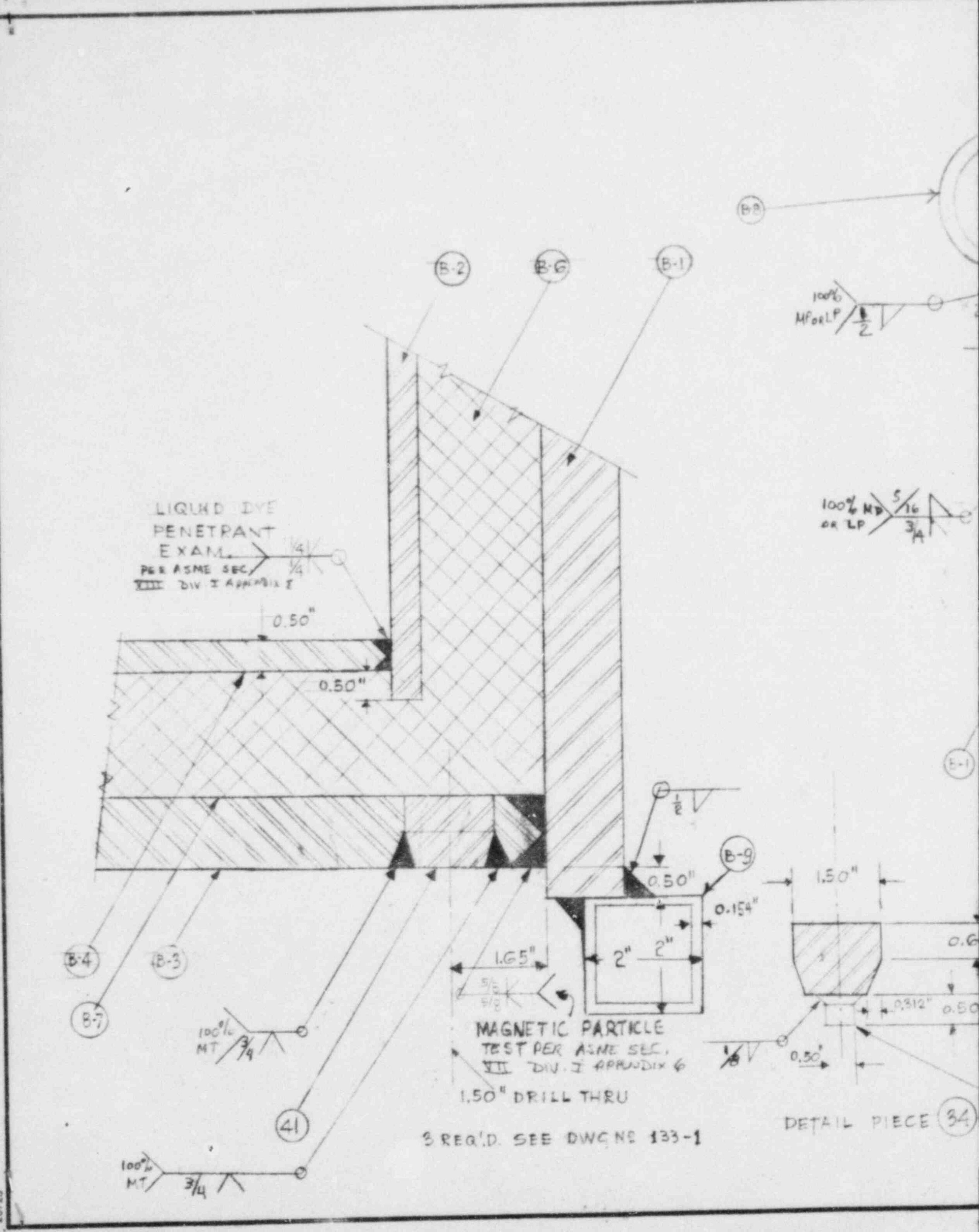
SCALE: 1/16" = 1"	APPROVED BY	DRAWN BY
DATE: 2-15-83		

AP-300 CASK

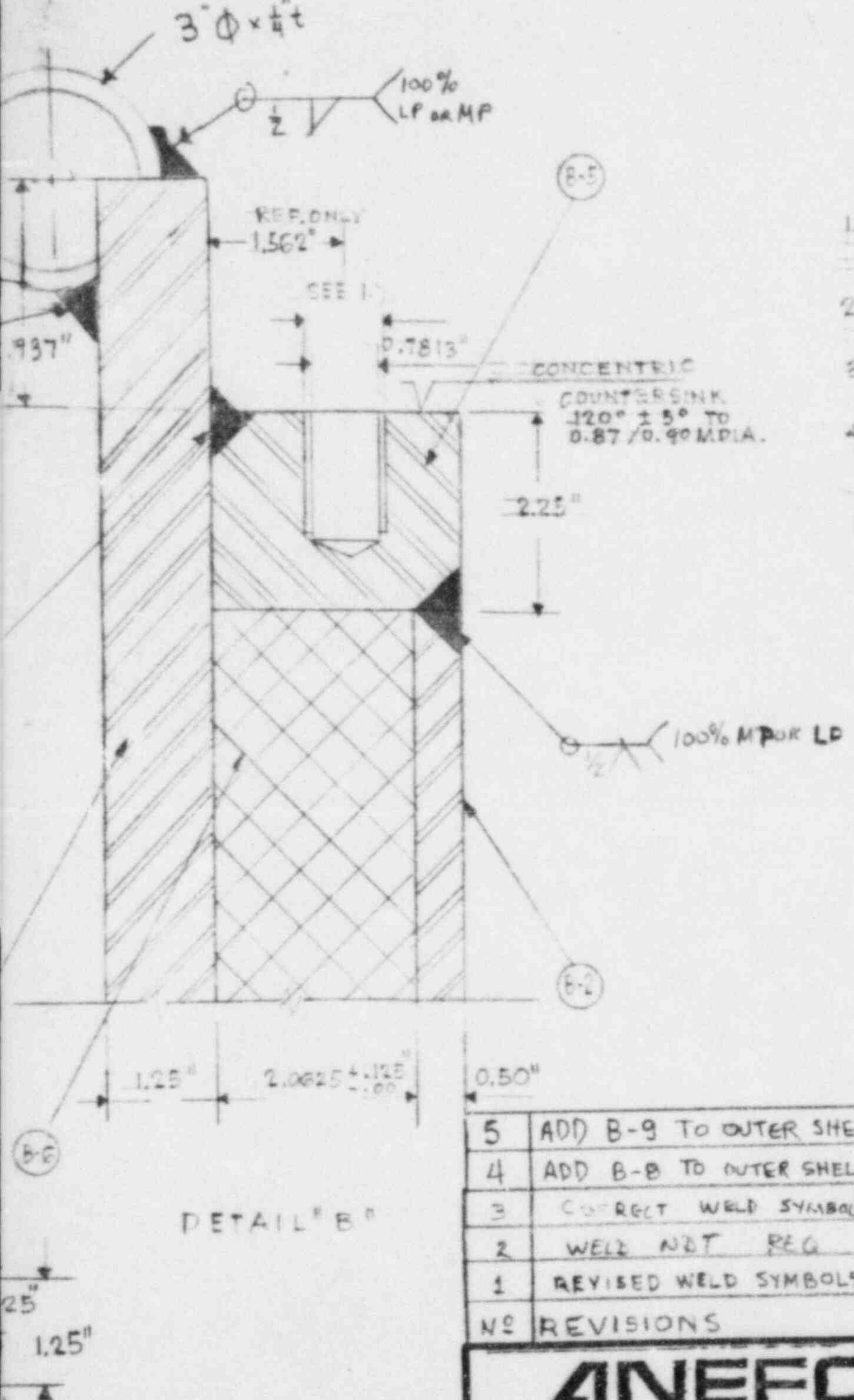
HALF ELEVATION – HALF SECTION

DRAWING NUMBER 133-1 REV. 5

8509260207-01



26723
DIETZGEN MASTER FORM 198MF



1.) TAP W/ HELI COIL
TAP # 20187-12 HS FULL THREAD
DEPTH 1.580"

2.) GAUGE W/ HELI COIL GAUGE
1440-12 RD.

3.) INSTALL HELI COIL INSERT # 1185-12 CN 1500
WITH INSERT TOOL # 3724-12

4.) BREAK OFF TOOL USE LONG NOSE
PLIERS BEND TANG UP AND DOWN TO
SNAP OFF AT NOTCH.

TI
APERTURE
CARD

Also Available On
Aperture Card

REMOVE AFTER
INSTALLATION &
GRIND SMOOTH

Nº	REVISIONS	APPR.	DATE
5	ADD B-9 TO OUTER SHELL		8/5/85
4	ADD B-8 TO OUTER SHELL		5/25/85
3	CORRECT WELD SYMBOLS		2/1/85
2	WELD NDT REQ		11/1/84
1	REVISED WELD SYMBOLS - ADD REV. BLOCK		9/15/84

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Ridgefield, Conn. 06877

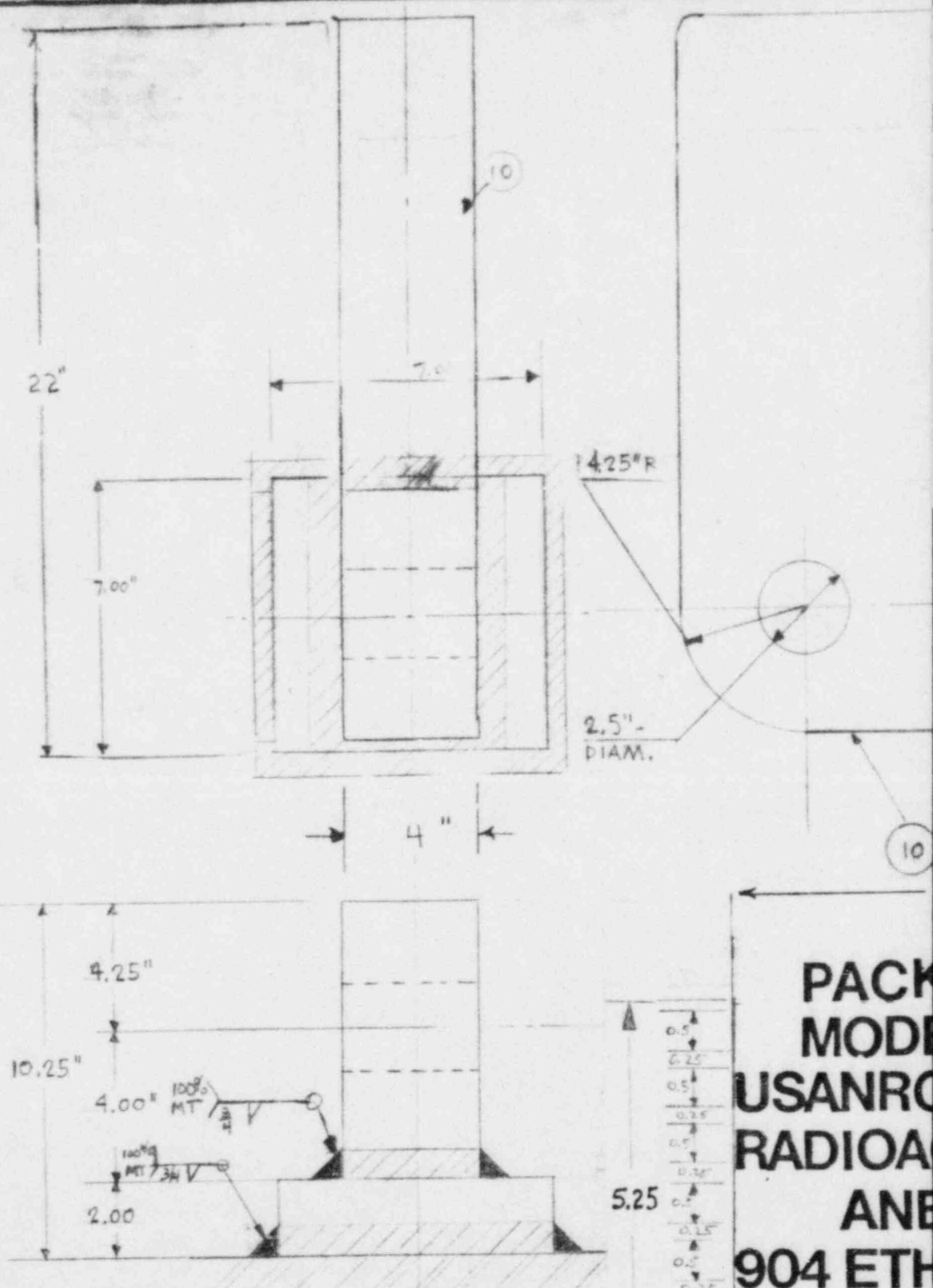
SCALE: 1/2" = 1"	APPROVED BY	DRAWN BY C.C.
DATE: 2-14-83		

AP-300 CASK

DETAILS "A" AND "B"

DRAWING NUMBER 134-1 REV. 5

8509260207-02



PACK
MODE
USANRC
RADIOAC
ANE
904 ETH
RIDGEF
GROSS

CASK LETTE

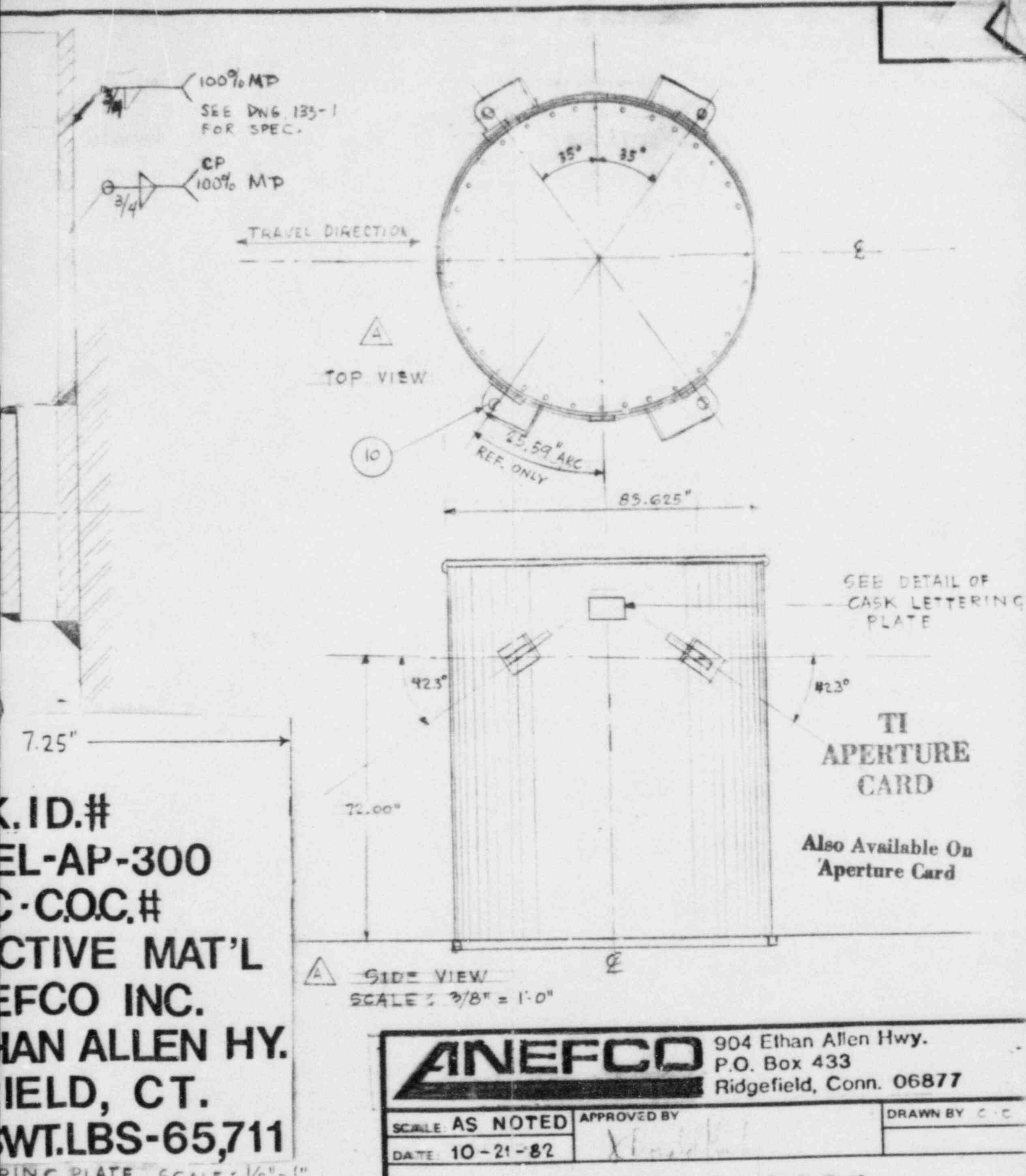
SCALE: 1/4" = 1'-0"

6	CHANGED TIEDOWN DIM.; ADD SQ RING at BASE	ES	8/5/85
5	CHANGED TIEDOWN PAD DIM.; ADD TOROIDAL RING; DELETE LIFT PAD, LID LIFT PAD		6/8/85
4	PACK ID#; WELD FOR TIEDOWN PAD		3/25/85
3	TRAVEL DIRECTION	ES	2/1/85
3	CORR. WELD SYMBOLS - TIE DOWN BOLT 4	ES	2/1/85
2	TIE DOWN ARR., NDT REQ.	ES	11/5/84
2	REV. TIE-DOWN PAD DIM.	ES	11/5/84
2	REV. CASK LETTERING PLATE	ES	11/5/84

1	CORR. WELD SYM
A	ADDED TOP
Nº	REVISIO

28723

DIETZGEN MASTER FORM 198MF



TI APERTURE CARD

Also Available On Aperture Card

		83	5/10/84
SIDE VIEWS - ADD REV. BLOCK		JDM	3/12/83
NS		APPR	DATE

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SCALE: AS NOTED	APPROVED BY	DRAWN BY C.C.
DATE: 10-21-82		

AP-300 CASK

TIE-DOWN PAD (4 PLACES)

DRAWING NUMBER 138-1

8509260207-03