ADDENDUM #1

SAFETY ANALYSIS REPORT

FOR THE

HN-100 SERIES 1 RADWASTE SHIPPING CASK

Revision 1
September 2, 1980

HITTMAN NUCLEAR & DEVELOPMENT CORPORATION
COLUMBIA, MARYLAND 21045

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HN-100 Series 1 Radwaste Shipping Cask

REVISION LOG

REV.	DATE	ENGINEERING	Q.A.	PROJ. MGR.	ECN #
0	9/11/78	[signature]	[signature]	[signature]	—
Rev.	Date	ENGINEERING	Q.A.	TRANSPORTATION	ECN#
1	9-23-80	[signature]	[signature]	[signature]	80-158

INTRODUCTION

This addendum was originally issued to increase the allowable internal load which can be transported in the HNDC HN-100 Series 1 shipping cask. As such, only the areas of the original safety analysis report which are affected by this increase were revised and submitted herein.

Revision 1 to this addendum contains the analysis for modified lifting lugs to be installed on the HNDC HN-100 Series 1 shipping casks to allow the use of shorter lifting cables. Packages in the series are constructed of ASTM A516 Grade 55, ASTM A516 Grade 70, ASTM A515 Grade 70 steel. The safety analysis has been revised based on the use of ASTM A516 Grade 55 steel which has the lower yield and ultimate strength of the steel used in the packages. The tiedown analysis has been revised to combine the longitudinal, transverse and vertical loads in terms of the total tensile force on the cable and calculates the stresses on the shell based on the vertical and total horizontal components on this tensile. The analysis concludes that the package can be operated safely with a maximum weight of contents of 14,500 pounds and a gross package weight of 50,000 pounds.

The description of the package as contained in the original safety analysis report has been revised to reflect the "as built" dimensions and materials of construction of the casks.

1.0 PURPOSE

The purpose of the following document is to provide the information and the engineering analysis that demonstrates the performance capability and structural integrity of the HN-100 Radwaste Shipping Cask and its compliance with the requirements of 19 CFR 71, Section 71.21 and Appendix A.

2.0 DESCRIPTION

The HN-100 Shipping Cask is a top-loading, shielded container designed specifically for the safe transport of radioactive waste materials between nuclear facilities and waste disposal sites. It is basically a top-opening right circular cylinder consisting of a cask body, cask lid and shield plug. Its principal design dimensions are 82.75 inches o.d. by 81.5 inches high with internal space of 75.5 inches I.D. and 73.5 inches high. (Dimensions vary slightly from unit to unit.)

2.1 Cask Body

The cask body is a steel-lead-steel annulus in the form of a vertical-oriented right circular cylinder closed on the bottom end. The side walls consist of a 3/8 inch inner steel shell, a 1-3/4 inch thick concentric lead cylinder, and a 7/8 inch thick outer steel shell. The bottom is a 4 inch thick steel plate welded integrally to both the internal and external steel body cylinders. The steel shells are further connected by welding to a concentric top flange. Positive cask closure is provided by the O-ring seal and the required lid hold-down bolting.

2.2 Cask Lid

The cask lid is a four inch thick steel plate which is stepped to mate with the upper flange of the cask body and its closure seal. Three steel lug lifting devices are welded to the cask lid for handling. The cask lid also contains a "shield plug" at its center.

2.3 Shield Plug

The shield plug is a four inch thick, circular steel plate fabricated in a design similar to the cask lid including the O-ring gasket and the required hold-down bolting to provide positive closure to the cask lid. The shield plug also has a lifting device located at its center to facilitate its handling.

2.4 Cask Closure

The shipping cask has two closure systems: (1) the cask lid is closed with 30 one-inch diameter bolts and an O-ring gasket seal, and (2) the shield plug is closed with 16 half-inch bolts and the same seal system used for the cask lid but smaller.

2.5 Cask Tie Down System

The shipping cask tie down system consists of two sets of two crossed tie down cables (total four cables) and either shear blocks or a retaining ring attached to the trailer. Four to eight shear blocks are used. The shear blocks are either fabricated steel brackets with or without adjustment screws or wooden blocks bolted through the trailer deck adjacent to the steel framing members.

2.6 Cask Internals

The cask internals consist of four separate configurations based on the types of containers to be housed: (1) one large disposable container, (2) eighteen 30 gallon drums (including two 9-drum pallets for material handling), (3) fourteen 55 gallon drums (including two 7-drum pallets), or (4) eight 55 gallon drums (including two 4-drum pallets). All internal containers have integral leak-tight seals or closures, integral lift lugs and vertical symmetrical clearances. Drums are stacked in two tiers or levels, each on removable pallets designed to minimize interaction between drums.

2.7 Gross Package Weights

The respective gross weights of the cask components and its designed radwaste loads are as follows:

Cask Body	29,000 pounds
Closure Lid	6,000 pounds
Shield Plug	500 pounds
Total Cask Unloaded	35,500 pounds
HN-100LC Disposable Container and Waste	14,500 pounds
HN-100-55 (14 drums of Radwaste)	12,500 pounds
HN-100-30 (18 drums of Radwaste)	11,500 pounds

..8 Radwaste Package Contents

The contents of the various internal containers can be process solids in the form of spent ion exchange resins, filter exchange media, evaporator concentrates, and spent filter cartridges. Materials will be either dewatered, solid, or solidified.

3.0 DESIGN CRITERIA AND SUMMARY OF RE' ILTS

The HN-100 Radwaste Shipping Cask was designed and analyzed in accordance with and meets the requirements of 10 CFR 71. The physical data for the construction materials is as follows: lifting lugs, inner and outer steel shells are ASTM A-516, Grade 55 (Units 1, 2, 3 and 4) and ASTM A-515, Grade 70 (Unit 5). The bolting material is ASTM A-320, Grade L7 or ASTM A-307, Grade A for the respective casks. The tiedown lugs are ASTM A-203, Grade E (Units 1, 2, 3 and 4) and ASTM A-515, Grade 70, (Unit 5).

3.1 General Standards for all Packaging (71.31)

3.1.1 Chemical Reactions (71.31(a))

The package contents will consist of process waste materials encapsulated in disposal drums or containers which are placed within the shipping cask. All disposal containers placed within the shipping cask are required to have positive sealing closures. Hence, there are no significant galvanic or chemical reactions between the package contents and the shipping casks.

3.1.2 Positive Closure (71.31(b))

Both types of specification drums (30 gallon and 55 gallon) have positive closures. The large disposable containers will be permanently sealed with a container cap. All disposable containers are placed within the shipping cask which (itself) has positive closure for the cask lid to the body flange surface and also between the shield plug and the cask lid flange surface. Hence, there is no possibility of inadvertent opening of either the disposal containers or the shipping cask.

3.1.3 Lifting Devices (71.31(c))

3.1.3.1 Shipping Cask (71.31(c)(1))

Two types of lift lugs are used on these casks. The options are as follows: (See Appendix for analysis and details).

Option 1 & 2: Three equally spaced lugs are welded to the upper steel flange and the outer steel shell of the cask body. The lugs may be flat plate (Option 1) or reinforced (Option 2). The cask is lifted using a lift beam and the lugs. The lifting lugs are designed to lift three times the weight of the cask with stresses less than yield strength.

Option 3: Two lugs are welded to the upper steel flange and the outer steel shell in diametrically opposite sides of the cask. The two lugs are designed to lift three times the weight of the cask using cable slings with stress less than yield strength. The cask can also be lifted with lift beams or chains.

3.1.3.2 Cask Lid (71.31(c)(2))

The lifting device for the cask lid consists of three equally spaced clevis pin lifting assemblies, attached to stiffener bars which are welded to the cask lid. These lifting devices will support three times the weight of the cask lid with no stresses in excess of their yield stress. See Appendix for analysis and details.

3.1.3.3 Shield Plug (71.31(c)(2))

The lifting device for the shield plug consists of a single clevis pin assembly attached to a lug which is welded directly to the upper or outside of the steel plate which is the shield plug. This lifting device will support three times the weight of the shield plug with no stresses in excess of its yield stress. See appendix for analysis and details.

3.1.3.4 Non-Lifting Attachments Covered or Locked (71.31(c)(3))

Both the cask lid lifting device and the shield plug lifting device will be covered to prevent their being used to lift the shipping cask.

3.1.3.5 Lifting Device Failure (71.31(c)(4))

All lifting devices are designed such that excessive loads will result in failure at the weld joints. These types of failures will not impair the shielding or containment properties of the shipping cask.

3.1.4 Tie Down Devices (71.31(d))

3.1.4.1 Tie Down Forces (71.31(d)(1))

The tie down devices consist of four ratchet binder or turnbuckles and cable assemblies attached from the tie down adapters on the cask to tie down lugs on the trailer body. Additionally, shear blocks firmly position and hold the cask on the trailer bed. The tie down lugs have been designed to allow the cask to withstand a vertical force of two times the weight of the cask, a transverse force of five times the weight of the cask, and a longitudinal force of ten times the weight of the cask with no resulting excessive stresses. See the Appendix for the analysis and details.

3.1.4.2 Non-Tiedown Devices (71.31(d)(2))

The length of the tiedown cables prevents the use of anything but the tiedown lugs for package tie down. There are therefore no structural parts of the cask which could be employed to tie the package down which do not comply with 10 CFR 71.31 (d)(1).

3.1.4.3 Tie Down Device Failure (71.31(d)(3))

The four tie down adaptors on the cask periphery have been designed so that loads transmitted by the tie down cables under worse conditions will neither damage the outer steel shell nor cause the tie down adaptors to fail. The tie down system analysis is shown in the appendix.

3.2 Evaluation of a Single Package (71.34)

Refer to Appendix A - Normal Conditions of Transport. The cask has been designed to withstand conditions likely to occur under normal conditions of transport with design integrity being analytically verified with safety factors in excess of 1.0. Specifically, the HN-100 package meets the following separately applied conditions:

3.2.1 Heat

Since the package is constructed of steel and lead, temperatures of 130°F. will have no effect on the package.

3.2.2 Cold

The steel materials selected for forgings, plate, and bolting each retain structural integrity at temperatures down to -40°F.

3.2.3 Pressure

The cask can withstand an internal vacuum of 7.35 psia. The resulting stress on the inner steel shell is 740 psi, which gives a safety factor of 51.3. This referenced analysis is shown in the appendix.

3.2.4 Vibration

The cask tie downs firmly position the package as to minimize any vibrational effects. In addition, all cask external devices are firmly attached (either by welding or bolting) to the cask.

3.2.5 Water Spray

The cask is sealed by an O-ring gasket seal with suitable holddown bolting to assure it is both water and pressure tight. In addition, the radwaste is contained within sealed steel containers in the cask void volume.

3.2.6 Free Drop

The cask has been analyzed to insure its structural adequacy to withstand a one-foot drop, striking any cask surface, onto a flat horizontal surface. The analysis is in the appendix.

3.2.7 Corner Drop

The specified condition is not applicable since the package weight is greater than 10,000 pounds.

3.2.8 Penetration

The impact of a vertical steel 1-1/4 inch diameter, 13 pound cylinder from a height of four feet will not puncture the cask outer steel shell. In addition, there is no externally mounted equipment on the cask, the damage of which due to this transport condition, would limit the cask structural adequacy or hinder its function.

3.2.9 Compression

This specified condition is not applicable since the package weight is greater than 10,000 pounds.

3.3 Standard for Normal Conditions of Transport for a Single Package (71.35)

3.3.1 Materials Release

The HN-100 cask has been designed to prevent the release of radioactive material during normal conditions of transport as defined in Appendix A of 10 CFR 71. Specifically, the design closure consisting of the O-ring gasket seal for both the cask lid and the shield plug closure are capable of withstanding higher temperatures and forces than the cask experiences during normal transport conditions. In a similar manner, the number of bolts and the strength of the bolting design for the closures assure that the bolts will not fail during normal transport.

3.3.2 Packaging Effectiveness

The packaging effectiveness under "normal conditions" of transport have been analytically verified to protect the contents from excessive heat, vibration, shock, corrosion, or exposure to the effects of weather.

3.3.3 Pressure Increase

The cask contents are either solid, solidified, or dewatered resin. The temperatures and pressures to which these wastes are exposed are not sufficient to generate gas formation. Further, the various individual containers within the cask are sealed precluding any possible interaction between waste types. Hence, these is no possibility of gas formation which might reduce cask packaging effectiveness.

3.3.4 Containment of Primary Coolant (71.35(a)(4))

Not applicable.

3.3.5 Loss of Coolant (71.35(a)(5))

Not applicable. There is insufficient internal heat resulting from isotope decay to require the use of a coolant in this design.

3.3.6 Atmospheric Venting (71.35(c))

Under normal conditions, the HN-100 cask was designed to prevent venting of the casks contents to the atmosphere, plus the individual waste containers in the cask void are sealed.

4.0 Procedural Controls (71.24)

Customers that use the HN-100 casks are supplied a copy of the Rad Services Manual. This manual describes the services that will be supplied and contains a section on operating procedures. This procedure describes the inspection of the cask and trailer upon arrival at the site, the loading procedures and the forms that need to be filled out prior to the cask leaving the customers' site.

Inspections are performed by the customer prior to loading the cask, by the driver prior to leaving the site, and after arriving at the consignee's site.

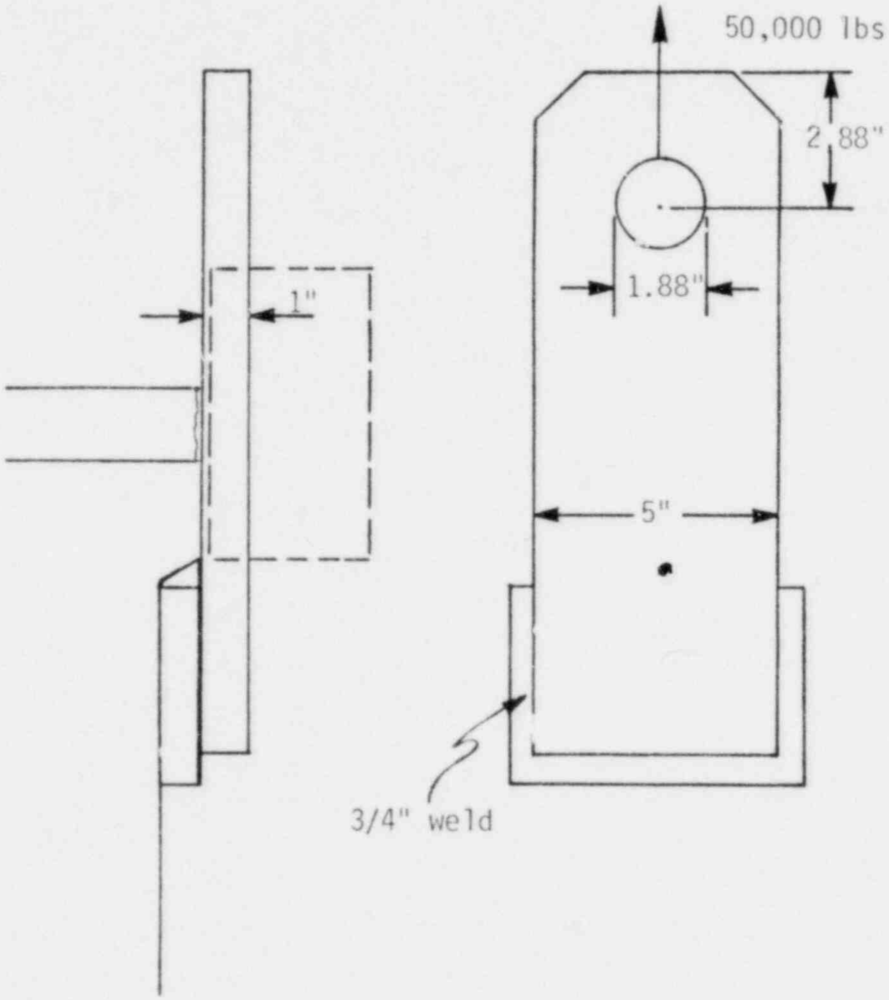
Loading procedures include the opening and closing instructions for the cask and are included as part of the Rad Services Manual.

Radioactive Shipment Records providing the necessary information are required to be filled out. Two copies accompany the shipment to the consignee, one copy is retained by the shipper and one copy is sent to HNDC.

The casks and trailers undergo a routine technical inspection at least once every four months for safety items and semi-annually for all other items. These inspections involve checking cask for contamination, damage to interior or exterior, gaskets, studs, signs and placards, shielding and tie downs.

1. Lifting Devices

A. Cask Lifting Lugs - ..ith and Without Reinforcement (for use only with lifting bars)



1. Tension Stress

$$\text{Load} = \frac{50{,}000 \times 3}{3} = 50{,}000\#$$

$$\text{min. area} = (5 - 1.88) \times 1 = 3.12 \text{ in}^2$$

$$\text{stress} = \frac{50{,}000}{3.12} = 16{,}025 \ \#/\text{in}^2$$

$$\text{safety factor} = \frac{30{,}000}{16{,}025} = 1.87$$

2) Shear Due to Bolt Load

Area = (2.88 - 0.94)2 x 1 = 3.88 in^2

Stress = $\frac{50,000}{3.88}$ = 12,886 lb/in^2

Sy (shear) = 0.6 x 30,000 = 18,000 lb/in^2

Safety Factor = $\frac{18,000}{12,886}$ = 1.40

3) Minimum Weld Length

Weld efficiency = 85%

Weld strength (3/4" fillet) = 7200 lb/in

Required Weld Length = $\frac{50,000}{0.85 \times 7200}$ = 8.17 in

Minimum weld length = 5 + 2 x 3 = 11 in

Safety Factor = $\frac{11}{8.17}$ = 1.346

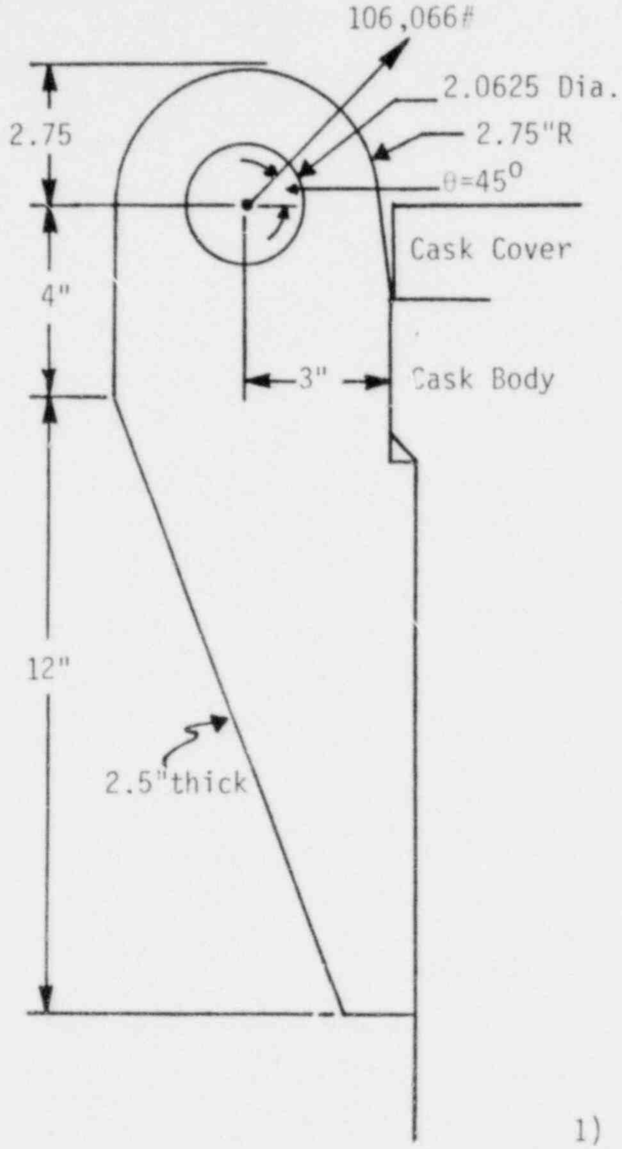
4) Bearing Stress in Hole

Pin dia. (1-1/2" shackle) = 1.675"

Bearing stress = $\frac{50,000}{1.675 \times 1}$ = 29850

Safety Factor = $\frac{30,000}{29,850}$ = 1.005

B. Cask Lift Lugs - Modified Design (for use with lifting bar or slings)



Weight of cask = 50,000 lb

Number of lift lugs = 2

Vertical load per lug =

$$\frac{50,000 \times 3}{2} = 75,000 \text{ lb}$$

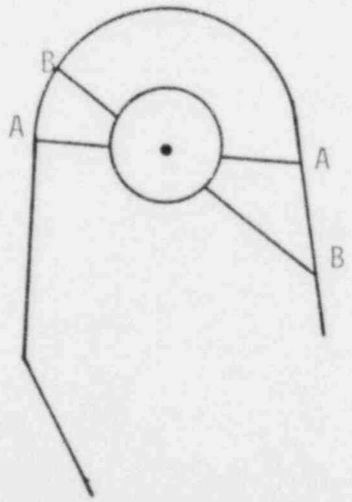
Total load each lug (θ = 45°)

$$= \frac{75,000}{\sin \theta} = 106,066$$

Minimum length of slings =

$$\frac{82.75 + 6}{2} \times \frac{1}{\sin \theta} = 62.77"$$

$$= 5.23'$$



1) Tensile Stress in Lift Lug

Area (A-A) = (2.75 x 2 - 2.0625)2.5

= 8.59 in²

Vertical load = 75,000

$$\text{Stress} = \frac{75,000}{8.59} = 8727 \text{ psi}$$

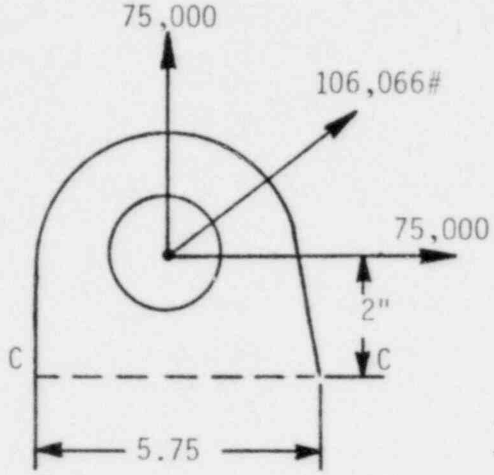
Area (B-B) = $(2.75 + 3 \times \sqrt{2} - 2.0625)2.5$

= 12.33

$$\text{Stress} = \frac{106,066}{12.32} = 8605 \text{ psi}$$

$$\text{Safety Factor} = \frac{30,000}{8727} = 3.43$$

2) Bending Stress in Lift Lug



Bending Stress $I_{c-c} = \frac{1}{12} bh^3$

$= \frac{1}{12} \times 2.5 \times 5.75^3$

$= 39.6 \text{ in}^4$

$M = 75,000 \times 2 + 75,000 \times 0.125$

$= 150,000 + 9375$

$= 159,375$ in-lbs

$f_b = \frac{MC}{I} = \frac{159.375 \times 2.875}{39.6} = 11,571$ psi

Tensile Stress

Area (C-C) = $2.5 \times 5.75 = 14,375 \text{ in}^2$

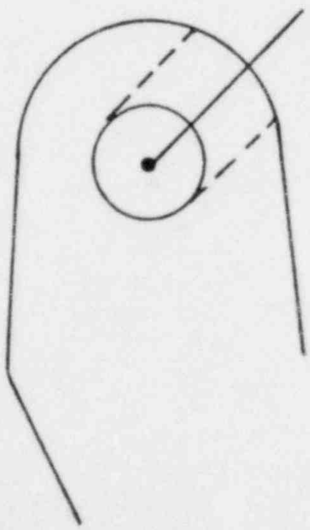
$f_t = \frac{75,000}{14,375} = 5217$ psi

Combined Stress

$f_t = 11,571 + 5217 = 16,788$

Safety Factor = $\frac{30,000}{16,788} = 1.79$

3) Shear Stress in Lift Lug



Area = $2 \times 2.75 \times 2.5 = 13.75 \text{ in}^2$

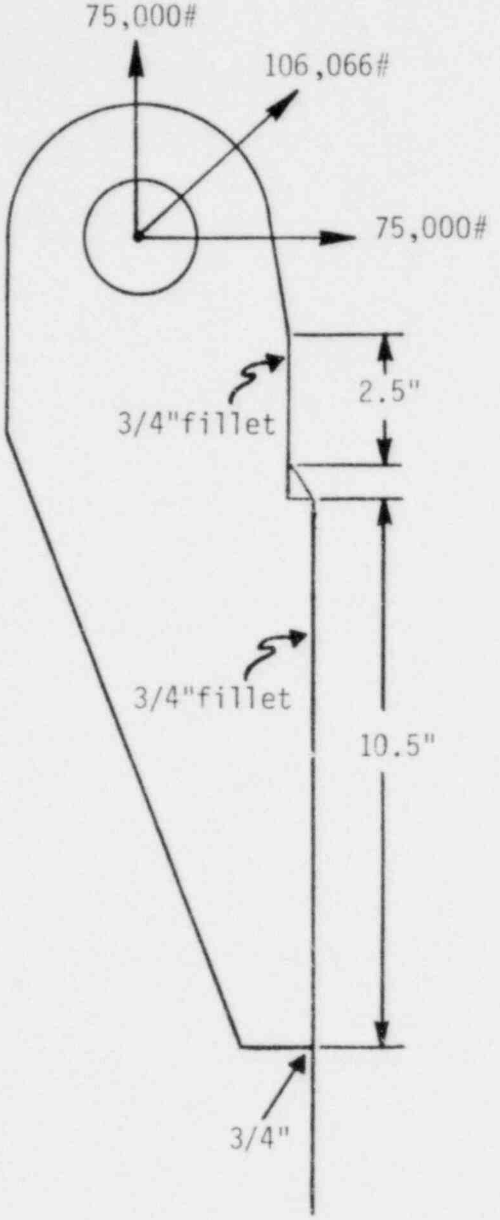
Stress = $\frac{106,066}{13.75} = 7714$ psi

Yield Strength Shear = $0.6 \times 30,000$

= 18,000 psi

Safety Factor = $\frac{18,000}{7714} = 2.33$

4) Weld Strength



Vertical Loading

Length of weld =

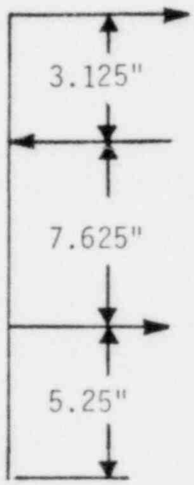
2(2.5 + 10.5) + 2.5 =

26 + 25 = 28.5 inch

$$f = \frac{75,000}{28.5} = 2632 \text{ psi}$$

Bending Load with Slings

(Assume bending around upper flange)



$$75,000\# \times (2 + \frac{2.5}{2})$$

$$= 75,000 \times 3.125$$

$$= 234,375 \text{ in-lbs}$$

$$F = \frac{234,375}{7,625} = 30,738 \text{ lbs}$$

Length of weld

= 10.5 x 2 + 2.5

= 23.5 inch

$$f = \frac{30,738}{23.5} = 1308 \text{ lbs/in}$$

Combined stress $\sqrt{2632^2 + 1308^2} = 2939$ psi

Allowable stress 3/4" weld = 7200 x 0.85 = 6120 lbs/in

Safety Factor = $\frac{6120}{2939} = 2.08$

5) Bearing Stress in Hole

Pin Dia. (1 3/4" in shackle) = 2 in

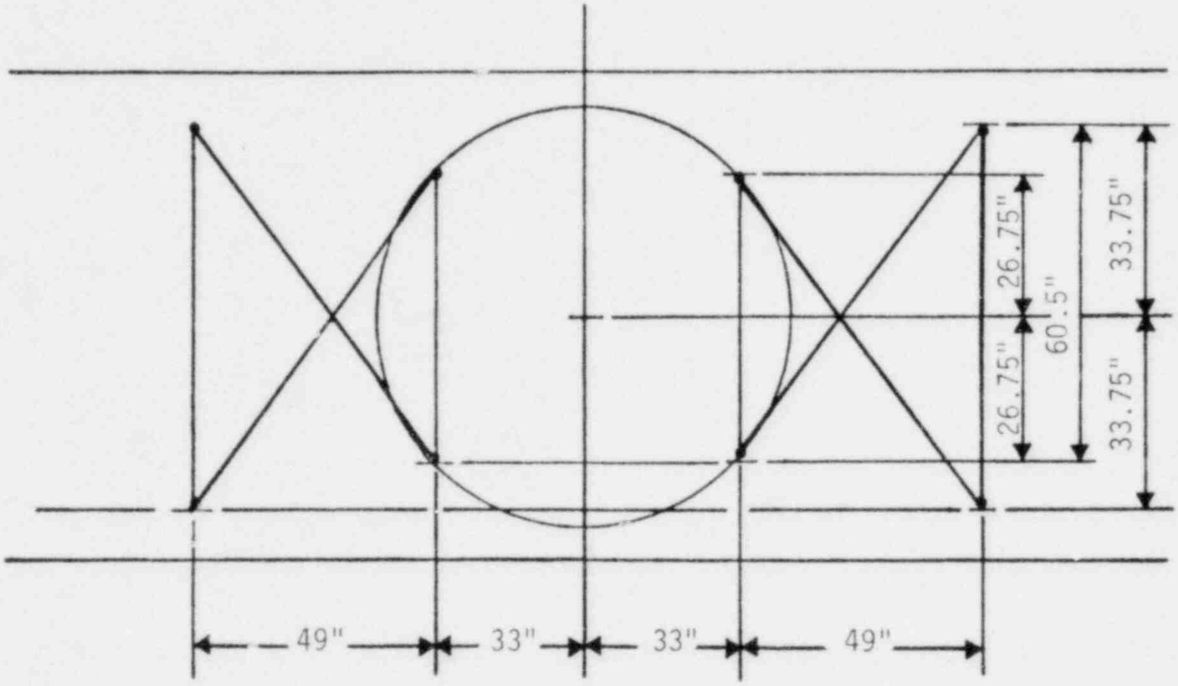
Bearing Stress = $\frac{106,066}{2 \times 2.5}$ = 21,213 psi

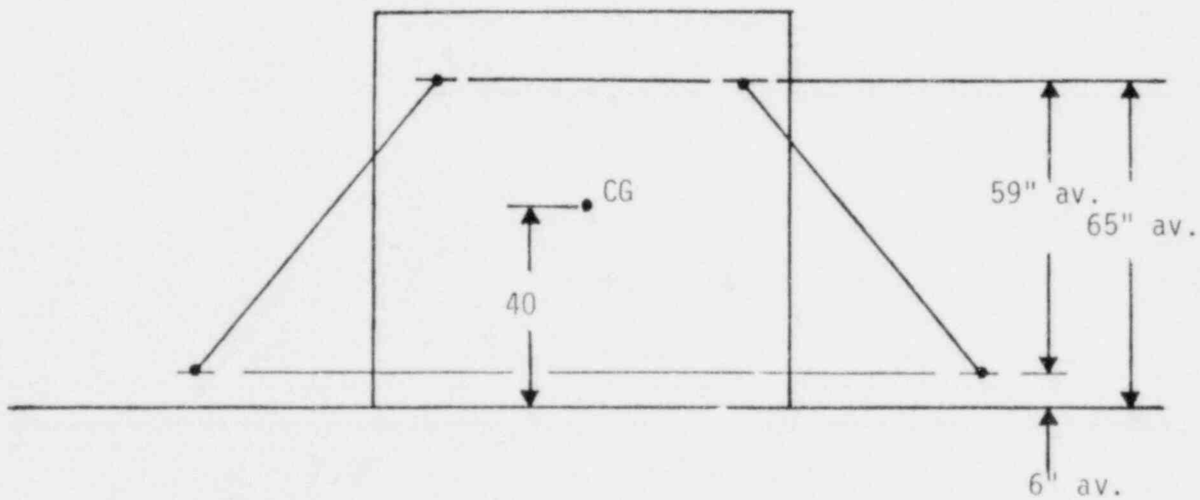
Safety Factor = $\frac{30,000}{21,213}$ = 1.41

2. TIEDOWN ANALYSIS

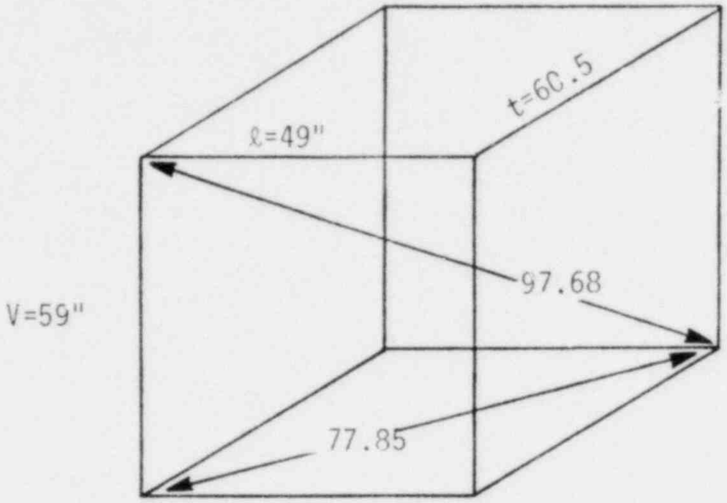
A. Tiedown Loads

The cask tiedowns consist of four cable and turnbuckle or ratchet binders assemblies and shear blocks at the cask base which firmly position and hold the cask to the truck platform. The following analysis shows the ability of the cask tiedown lugs to withstand combined loads due to a 10g longitudinal, 5g transverse and 2g vertical loads.

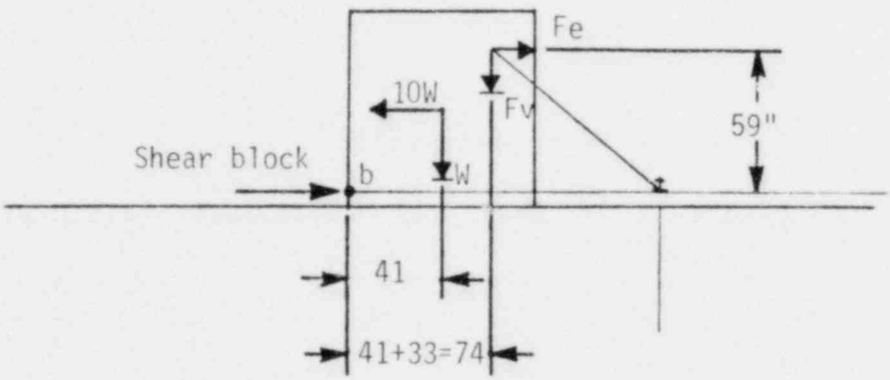




Force Diagram



1) Horizontal Longitudinal Load = 10g



$\Sigma M_b = 0$

$10W\ (40-6) = F_{\ell} \times 59 + F_V \times 74 + W \times 41$

$\frac{F_{\ell}}{F_V} = \frac{49}{59} \qquad F_V = 1.2\ F_{\ell}$

$(340 - 41)W = F_{\ell} \times 59 + 74 \times 1.2\ F_{\ell}$

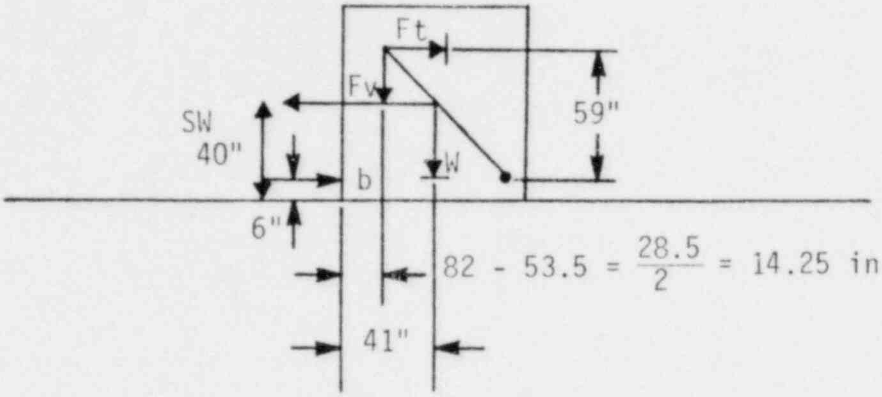
$299W = F_{\ell}(59 + 89.1)$

$F_{\ell} = \frac{299(50{,}000)}{148.1} = 100{,}945\#$

F_{ℓ} = Each tiedown = $\frac{100,945}{2}$ = 50,473#

Total tension @ 10g load = 50,473 x $\frac{97.68}{49}$ = 100,616#

2) <u>Horizontal Transverse Load = 5g</u>



$\Sigma M_b = 0$

$5(W) \times (40-6) = W \times 41 + F_t \times 59 + F_v \times 14.25$

$\frac{F_v}{F_t} = \frac{59}{60.5}$

$F_t = \frac{60.5}{59} \times F_v = 1.025\ F_v$

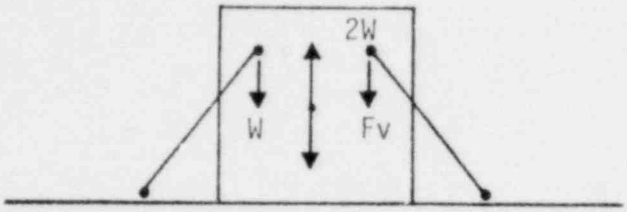
$(170 - 41)(W) = 59 \times 1.025 \times F_v + 14.25\ F_v$

$F_v = \frac{129 \times 50,000}{74.725} = 86,316$

F_v each cable = $\frac{86,312}{2}$ = 43,158

Tension due to 5g transverse load = 43,158 x $\frac{97.68}{59}$ = 71,492#

3) <u>Vertical Force = 2g</u>



F_v total = 2W - W

F_v each cable = $\frac{W}{4} = \frac{50,000}{4}$ = 12,500#

Tension due to vertical load = $\frac{97.68}{59}$ x 12,500 = 20,695#

4) <u>Total Tension and Vertical and Horizontal Components</u>

Total = 100,616 + 71,452 + 20,695

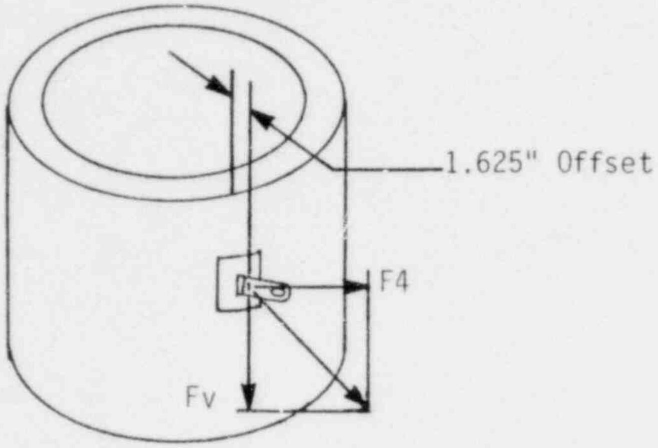
= 192,763#

F_v = 192,763 x $\frac{59}{97.68}$ = 116,431#

F_h = 192,763 x $\frac{77.85}{97.68}$ = 153,630#

B. <u>Analysis of Tiedown Loads on Cask Shell</u>

The tiedown loads are transmitted into the cask as external moments. These moments are the product of the tiedown forces and the offset distance between the cylinder shell and the line of action of the tiedown forces.



$$\text{Offset} = \frac{84.75 - 81.50}{2} = \frac{3.25}{2} = 1.625'$$

M_e = external longitudinal moment

$= F_h \times \text{offset} = 153{,}630 \times 1.625$

= 249,649 in-lbs

M_c = external circumferential moment

$= F_v \times \text{offset} - 116{,}431 \times 1.625$

= 189,200 in-lbs

$$M_x = 0.044 \frac{M_c}{2b} + 0.051 \frac{Mc}{aB}$$

$$M\phi = 0.085 \frac{Mc}{aB} + 0.032 \frac{Mc}{2b}$$

a = outer cask shell radius $= \frac{81.5}{2} = 40.75"$

B = dimension less ratio $= \frac{c}{a} = \frac{6.5}{40.75} = 0.1595$

c = mounting plate width $= \frac{13}{2} = 6.5$

$$Nx = 2.6 \frac{Mc}{a^2B} + 1.37 \frac{Mc}{a^2B}$$

$$N_{\phi} = 1.32 \frac{Mc}{a^2B} + 3.4 \frac{Mc}{a^2B}$$

$$Mx = \frac{0.044 \times 159,200 + 0.051(249,649)}{40.75 \times 0.1595}$$

$$= \frac{8325 + 12,732}{6.50}$$

$$= \frac{21,057}{6.50} = 32.40 \text{ in-lbs}$$

$$M_{\phi} = \frac{0.085 \times 189,200 + 0.032(249,649)}{40.75 \times 0.1595}$$

$$= \frac{16.082 + 7989}{6.5}$$

$$= \frac{24.071}{6.5} = 3703 \text{ in-lbs}$$

$$Nx = \frac{2.6(189,200) + 3.4(249,649)}{(40.75)^2 \times 0.1595}$$

$$= \frac{491,920 + 848,807}{264.9}$$

$$= \frac{1,340,727}{264.9} = 5061 \text{ in-lbs.}$$

$$N_{\phi} = \frac{1.32(189,200) + 3.4(249,649)}{(40.75)^2 + 0.1595}$$

$$= \frac{249,944 + 848,807}{264.9}$$

$$= \frac{1,098,551}{264.9} = 4147 \text{ in-lbs.}$$

The maximum stress and circumferential stress

$$f_x = \frac{6Mx}{t^2} + \frac{Nx}{t} = \frac{6 \times 3248}{(0.875)^2} + \frac{5061}{0.875}$$

$$= 25,454 + 5784 = 31,238 \text{ psi}$$

$$f_\phi = \frac{6M_\phi}{t^2} + \frac{N_\phi}{t} = \frac{6(3703)}{(0.875)^2} + \frac{4147}{0.875}$$

$$= 29{,}019 + 4739 = 33{,}758 \text{ psi}$$

Safety Factors

Type Steel	A-516, Grade 55	A-515, Grade 70
Yield Strength, psi	30,000[1] to 35,500[2]	38,000[1] to 43,500[2]
Design Margin Longitudinal Stress	0.96 to 1.14	1.22 to 1.39
Design Margin Circumferential Stress	0.89 to 1.05	1.13 to 1.29
Ultimate Strength, psi	55,000 to 75,000	70,000 to 90,000
S.F. Longitudinal Stress	1.76 to 2.40	2.24 to 2.88
S.F. Circumferential Stress	1.63 to 2.22	2.07 to 2.67

[1]Minimum value based on 0.002 offset.

[2]Range based on 50% variation of ultimate strength.

The indicated values are considered acceptable based on the following:

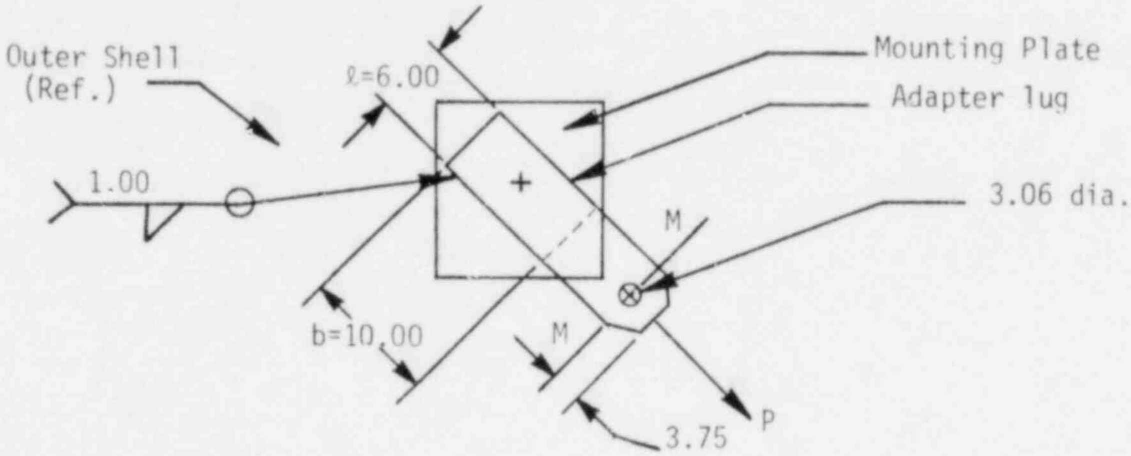
a. The analysis is conservative since energy absorption by the tiedown cable has not been considered.

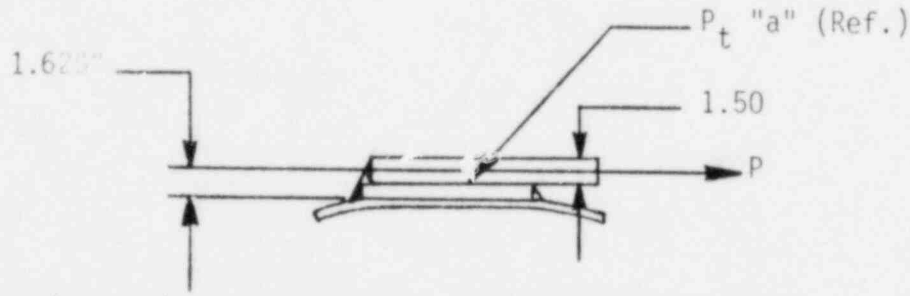
b. The tiedown cables or the truck trailer would fail before these loads could be transmitted to the package.

c. The integrity of the package would not be impaired since adaptor would yield before the attachment to the body of the cask.

C. ANALYSIS OF CASK TIEDOWN ADAPTER

The HN-100 Series 1 cask tiedown adapter is analyzed for 10g, 5g, and 2g combined loading condition.





The adapter is constructed of either ASTM A-203 Grade E alloy steel or ASTM A-515 Grade 70.Since the ASTM A-203 Grade E has a lower yield strength it will be used in the following analysis. The ASTM A-203 Grade E steel has a minimum yield strength of 40,000 psi and a ultimate strength of 70,000 to 90,000 psi. The loading on the adapter will be 186,424 lbs.

1) Bearing stress in pin hole:

$$f = \frac{192,763}{3.06 \times 1.5} = 41,996 \text{ psi}$$

Safety Factors (yield) $\frac{40,000}{40,615} = 0.996$

(ultimate) $\frac{70,000}{40,615} = 1.67$

2) Tearing stress (in Plane M-M)

$$f = \frac{192,763}{(6.00-3.06)(1.5)} = 43,710 \text{ psi}$$

$$\text{Safety Factor (yield)} \quad \frac{40,000}{42,273} = 0.915$$

$$\text{(ultimate)} \quad \frac{70,000}{42,273} = 1.602$$

*Safety factors less than one based on minimum yield strength are considered acceptable since: (1) energy absorption by the cable and trailer has not been included; (2) yielding of the adapter would not impair the safety of the package; (3) loads of this magnitude would not be encountered in actual operations since they would destroy the trailer to which the tiedowns are attached.

3) Weld Strength Analysis

Stresses in the adapter lug to the mounting plate are a result of the direct shear load.

The direct shear stress $\sigma_s = \frac{192,763}{1 \times 0.707 \times 26}$

$$\sigma_s = 10,486 \text{ psi}$$

The allowable shear stress is 15,600 psi

$$\text{Safety Factor} = \frac{15,600}{10,486} = 1.49$$

3. ONE FOOT FREE DROP ANALYSIS

The cask body must absorb the total kinetic energy. The kinetic energy to be absorbed by the cask body is:

$$E_k - mgh = 50{,}000 \times 12 = 600{,}000 \text{ in-lb.}$$

The volume of steel required to absorb this energy is:

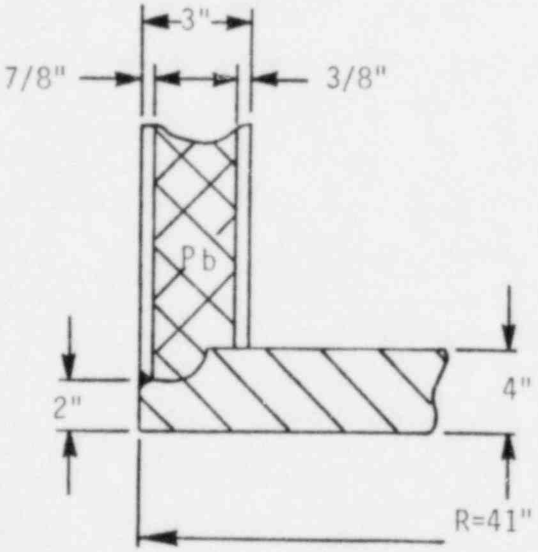
$$V_s = \frac{E_k}{Sy}$$

Material is ASTM A515, Grade 55 (Sy = 30,000 psi)

$$V_s = \frac{600{,}000}{30{,}000} = 20 \text{ in.}^3$$

Corner Impact

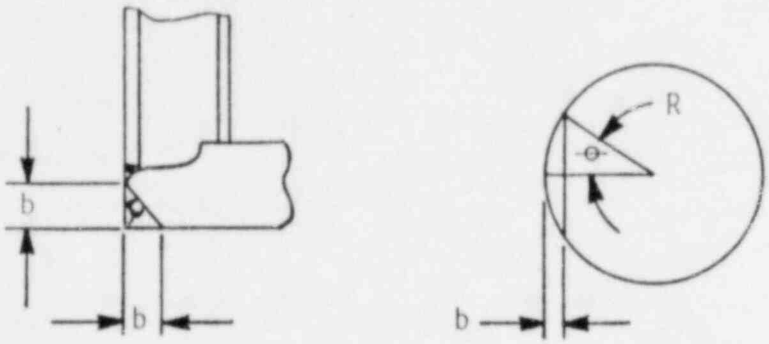
This configuration of the HN-100 cask corner is:



At an impact angle of 45° the steel corner will be deformed in the shape of an ungula and the volume of the deformation is determined by the following equation:

$$V_s = R^3(\sin\theta - \frac{\sin^3\theta}{3} - \theta \cos \theta)$$

$$f(\theta) = \frac{V_s}{R^3} = \frac{20.00}{(41)^3} = 0.000290 \qquad \theta = 0.2967 \text{ radians} = 17^{\circ}$$



$b = R\ (1-\cos\theta)$

$b = 41\ (1-\cos 17^{o}) = 1.79$ in

$c = \frac{b}{\sqrt{2}} = 1.27"$

The effect on the cask body due to the corner impact event is shown on the above sketch. Neither the inner nor outer shells are affected by the corner impact.