SAFETY ANALYSIS REPORT FOR THE HN-100 SERIES 1 RADWASTE SHIPPING CASK

STD-R-02-006
Revision 0

Referencing

10 CFR 71 Type "A" Packaging Regulations

Hittman Nuclear and Development Corporation
Columbia, Maryland 21045

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Rev.	Rev Date	Prepared by	Supervisor Design/ Drafting	Director Engineering	Transportation	QA Manager	
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HNDC-01(A)

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1. GENERAL INFORMATION

1.1 Introduction

The HNDC HN-100 Series 1 radioactive waste shipping casks were constructed during the period 1971 to 1974. The casks have been in continuous service since construction and are used primarily to transport radioactive waste from nuclear power plants to licensed shallow land burial sites. A number of changes have been made in the casks and several supplements and revisions have been made in the original application and Certificate of Compliance. The consolidated application incorporates all of the previous submittals.

1.2 Package Description

1.2.1 Packaging

The HN-100 Series 1 Shipping Cask is a top-loading, shielded container designed specifically for the safe transport of Type "A" quantities and greater than Type "A" LSA radioactive waste materials between nuclear facilities and waste disposal sites. The radioactive materials can be packaged in a variety of different type disposable containers. Typical configurations for the internals and their model designations are as follows:

Model Number	Cask Internals
HN-100/170	One large disposal container
HN-100/2-80	Two large stackable liners
HN-100/18	Eighteen 30 gallon drums
HN-100/14	Fourteen 55 gallon drums
HN-100/8	Eight 55 gallon drums

The HN-100 Series 1 Shipping Cask is a primary containment vessel for radioactive materials. It consists of a cask body, cask lid, and a shield plug being basically a top-opening right circular cylinder which is on its vertical axis. Its principal dimensions are 81 inches outside diameter by 81.6 inches high with internal cavity of 75.5 inches inside diameter by 74.5 inches high.

1.2.1.1 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 cask is a right circular cylinder 81.5 inches high by 82.75 inches in diameter. The cask cavity is 73.5 inches high by 75.5 inches in diamater. The cask side wall consists of a 3/8-inch thick inner steel shell, a 1-3/4-inch lead shell, and a 7/8-inch thick outer steel shell. The base is a 4-inch thick steel plate which is welded to the inner and outer steel shells of the side wall. A steel flange is welded to the inner and outer steel shells of the side wall to the top. The lid is a 4-inch thick steel plate which is stepped to mate with the steel flange. The cask closure is sealed by a Viton or BUNA-N O-ring gasket located between the lid and steel flange. Positive lid closure is accomplished by thirty, 1-inch studs. The lid contains a centrally located 4-inch thick stepped steel shield plug. The shield plug is sealed by a Viton or BUNA-N O-ring gasket, and sixteen, 1/2-inch studs are used to provide positive closure. Tie-down is accomplished by four tie-down lugs welded to the cask body. There are two or three casks lifting lugs, three lid lugs, and one shield plug lifting lug.

1.2.1.2 Cask Lid

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

1.2.1.3 Shield Plug

The shield plug is four inches thick fabricated to fit the stepped opening in the cask lid. It has a gasket seal and uses sixteen hold-down studs to provide positive cask closure. The shield plug also has a lifting lug located at its center to facilitate handling.

1.2.1.4 Cask Closure

The shipping cask has two closure systems: (1) the cask lid is closed with 30 one-inch diameter studs and a O-ring seal, (2) the shield plug is closed with sixteen 1/2 inch studs and uses an O-ring seal system similar to the seal system used for the cask lid only smaller.

1.2.1.5 Cask Tiedown System

The shipping cask tiedown system consists of two sets of crossed tiedown cables. Four shear blocks or a shear ring affixed to the vehicle load bed firmly position and safely hold the cask during transport.

1.2.1.6 Cask Internals

The HNDC HN-100 shipping cask can use a wide variety of internal containers and configurations. The containers include; custom fabricated steel containers, steel drums, plastic containers and drums, high integrity containers, sealed containers constructed of other metals and materials and racks to secure irradiated and contaminated components. The internal configuration may include; one large disposable container, two large stacked containers, fourteen 55-gallon drums with pallets, eighteen 30-gallon drums with pallets. Shoring will be placed between secondary container's in cases where excessive movement could occur during normal conditions of transport. Shoring is not required for large containers and filled drum pallets designed to fit the cavity with minimal clearances.

1.2.2 Operational Features

The HNDC HN-100 radioactive waste shipping cask may include a number of required and optional accessories. These include: cavity, drain plug, rain cover tiedowns, signs and mounting brackets, placards, mounting brackets, lid lift lug covers and security wires and security wire brackets.

1.2.3 Contents of Packaging

1.2.3.1 Type and Form of Material

The materials transported in the HNDC HN-100 Series 1 cask will consist primarily of process waste and include bead ion exchange resin, powdered ion exchange resins, activated carbon, powdered carbon, diatomaceous earth, granular and fibrous filter media, filter sludge, blasting grit and crud, stabilized incinerator ash, irradiated and contamined materials, filter cartridges and solidified liquids. The materials may be dewatered, solidified, absorbed or solids. The radioactive materials will be primarily by-product materials but may include source and transuranic materials in Type A quantities and greater than Type A quantities as low specific activity materials. Fissile materials in exempt quantites may be transported.

1.2.3.2 Maximum Quantity of Material Per Package

The maximum quantity of material that may be transported in the HNDC HN-100 Series 1 cask will be:

- o Type A quantities
- o Greater than Type A quantities of low specific activity radioactive materials.
- o Materials and containers with weights not exceeding 14,500 pounds.
- o Cask, contents and container with weights not exceeding 50,000 pounds.
- o Activity levels not to exceed 200 mR per hour on the surface of the container or 10 mR per hour at two meters from the sides of the trailer.

1.3 APPENDIX

The HNDC HN-100 Series 1 radioactive waste shipping cask is constructed in accordance with Hittman Nuclear and Development Corporation Drawing Numbers:

STD-02-028, Revision 3	(Figure 1-1)
STD-02-029, Revision 3	(Figure 1-2)
STD-02-030, Revision 2	(Figure 1-3)

2. STRUCTURAL EVALUATION

2.1 Structural Design

2.1.1 Discussion

The HNDC HN-100 Series 1 cask has a number of structural components which are vital to the safe operation of the package. The design and performance requirements of these components are discussed in the following subsections.

2.1.1.1 Cask Closure

The HN-100 Series 1 cask has a four inch thick steel cover. The cover is secured to the cask using 30 one inch studs. The studs provide metal to metal contact between the cask and the cover and compress an O-ring seal to provide a positive closure. The closure is designed to withstand an internal pressure of 8 psig or a corner impact without elongating the studs an amount that would allow leakage. The shield plug located in the center of the cover is secured with 16 one-half inch studs. An O-ring seal is used to provide positive closure.

2.1.1.2 Cask Lifting Devices

Three types of lift lugs are used on the HN-100 Series 1 casks. These are:

Unreinforced lugs for use with lift beams. (Option 1)

Reinforced lugs for use with lift beams or long cable. (Option 2)

Radial lift lugs for use with short cable slings (45°) or lift beams. (Option 3)

Three Option 1 and 2 lift lugs are used on each cask which are equally spaced on the circumference of the cask. Two Option 3 lift lugs are used. The lugs are designed to withstand a 3 g abrupt lift without yielding the lugs or the welds.

2.1.1.3 Cover and Shield Plug Lifting Devices

The three equally spaced lift lugs are welded to the cask cover. These lugs are designed to withstand a 3g abrupt lift using short cable slings (45°) without yielding the material. The lugs will tear out or the welds will fail should these lugs be used to lift the casks. The integrity of the package would not be impaired by the failure of the lugs. A single lift lug is welded to the center of the shield plug. This lug is designed to withstand a 3g abrupt lift without failure.

2.1.1.4 Tiedown Devices

The tiedowns for the HN-100 Series 1 cask consist of steel plates welded to reinforcing plates which are welded to the outer shell of the cask. Four equally spaced tiedowns are on the periphery of the cask. The portion of the tiedowns which are structurally part of the cask (i.e., reinforcing plate and attachment to the cask) are designed to withstand, without generating stress in excess of yield strength, a static force applied to the center of gravity of the package having a vertical component two times the weight of the package with its contents, a horizontal component along the direction of travel of ten times the weight of the package with its contents and a horizontal component in the traverse direction of five times the weight of the package with its contents. In addition, the tiedown lugs are designea to fail under excessive loads before the outer shell of the cask ald be damaged.

2.1.1.5 Free Drop

The HN-100 Series 1 cask is designed to withstand a one foot free drop on any surface without loss of contents or reduction of shielding sufficient to increase the external radiation dose to more than 1,000 millirems per hour at three feet from the external surface of the package. The HN-100 Series 1 cask is designed to absorb the energy from free fall by deformation of the steel structure. In the case of the top corner drop, the cover and the studs which secure the cover to the cask must be capable of withstanding the force generated by the contents times decelleration.

For both the top and bottom corner drops, and side drop, the welds and structural members must be capable of withstanding the decelleration forces.

2.1.1.6 Penetration

The outer shells of the HN-100 cask are constructed of steel having a minimum thickness of 7/8 inch and the impact from a 13 pound rod falling from 40 inches will have no effect on the package.

2.1.1.7 Galvanic, Chemical and Other Reactions

The cask is constructed from heavy structural steel plates. All exterior surfaces are primed and painted with high quality epoxy. There will be no galvanic, chemical, or other reaction among the packaging components. (References 10 CFR 71, Section 71.31).

2.1.2 Design Criteria

The structural analysis is based on the following criteria:

2.1.2.1 Stresses in material due to pure tension are compared to the minimum yield of that material. The safety factor is found by dividing the minimum yield by the calculated stress. A safety factor greater than 1.0 is required for acceptability. See Table 2.3.3 for minimum yield and ultimate stress values used in the analyis.

2.1.2.2 Stresses in material due to shearing is analyzed using the "Maximum Energy - Distortion Theory" which states the shearing elastic limit is $1\sqrt{3}$ = 57.7% of the tensile elastic limit[1]. As with 3.1.3.1, a factor of safety greater than 1.0 is required for acceptability.

2.1.2.3 Weld filler material rod is E70 Grade. Analysis is based on American Welding Society Structural Code D1.1-79. For fillet welds, shear stress on effective throat regardless of direction of loading is 30% of specified minimum tensile strength of weld metal. For complete joint penetration groove welds with tension normal to the effective area the allowable stress is the same as the base metal.

Fillet weld allowable stress = (68,750 psi) (0.3)

= 20,625 psi

In order to be more conservative, a weld efficiency of 85% is also added. Since all weld have been nondestructively examined, weld efficiency is known to be greater than this.

2.2 Weights and Centers of Gravity

2.2.1 Gross Package Weights

The respective gross weights of the cask components and its designated 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-100-LC 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
Calculated Total Gross Weight	50,000 pounds

*The maximum weight of contents for the HN-100, Series 1, Unit 5 is 11,620 pounds.

2.2.2 Center of Gravity

Item	Weight		Arm		Moment
Cask	35,500 lbs	.	40.75"	=	1,446,625 in.-lb
Liner	2,000 lbs	.	39"	=	78,000 in.-lb
Waste	12,500 lbs	.	38"	=	475,000 in.-lb.
	50,000 lbs				1,999,625 in.-lb.

Center of Gravity = 1,999,625/50,000

CG = 40.0 in.

2.3 Mechanical Properties of Materials

The HN-100 Series 1 casks were constructed at various times by several fabricators. Table 2.3.1 lists the materials used in the con-

TABLE 2.3.1 MATERIALS OF CONSTRUCTION
(Certified Minimum Yield/Ultimate Strength, psi)

HNDC HN-100 Series 1
RADWASTE SHIPPING CASKS

Unit Number	Cask Body	Tiedown Lugs	Lift Lugs
HN-100-1	A516, Grade 55 (42,000/64,800)	A203, Grade E (61,100/78,500)	A516, Grade 60 (52,000/71,000)
HN-100-2	A516, Grade 55 (42,000/64,800)	A203, Grade E (61,100/78,500)	A516, Grade 60 (52,000/71,000)
HN-100-3	A516, Grade 55 (50,700/64,000)	A203, Grade E (61,100/78,500)	A203, Grade E 61,200/77,300
HN-100-4	A516, Grade 55 (43,000/64,800)	A203, Grade E (61,100/78,500)	A203, Grade E (58,300/81,900)
HN-100-5	A515, Grade 70 (45,100/75,600)	A515, Grade 70* (50,400/79,300)	A515, Grade 70 (43,900/75,100)

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struction of the cask bodies, lift lugs and tiedown lugs. Table 2.3.2 lists the minimum yield and ultimate strength of materials based on ASTM Standards. Table 2.3.1 also lists the certified yield and ultimate strength of the materials used in the critical components of the cask. These are significantly higher than the minimal values based on ASTM Standards. Table 2.3.3 lists the values for minimum yield and ultimate strength used in analysis of critical components. For non-critical components, the values listed in Table 2.3.2 were used for analysis. The weld filler material used in the casks has a minimum ultimate strength of 68,750 psi.

Table 2.3.2 Minimum Yield and Ultimate Strength Based on ASTM Standards

MATERIAL	YIELD STRENGTH (psi)	ULTIMATE STRENGTH (psi)
A516, Grade 55	30,000	55,000
A203, Grade E	40,000	70,000
A515, Grade 70	38,000	70,000

Table 2.3.3 Minimum Yield and Ultimate Strength Used in the Analysis of Critical Components

	Minimum Yield (psi)	Ultimate Strength (psi)
Cask Body	42,000	64,800
Tie-Down Lugs	61,100*	78,500
Lift Lugs	43,900	71,000

*A minimum yield of 50,400 psi is used for the HN-100 Series 1, Unit No. 5.

2.4 General Standards for All Packages

2.4.1 Chemical and Galvanic Reactions [71.31(a)]

The package contents will consist of process waste materials encapsulated in disposable drums or containers which are placed within the shipping cask. All disposable 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. Further, the exposed internal surfaces of the shipping cask are protected by a suitable primer and an inert epoxy coating.

2.4.2 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 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 disposable containers or the shipping cask.

2.4.3 Lifting Devices

2.4.3.1 Shipping Cask [71.31(c)(1)]

Two types of lift lugs are used on these casks. The options are as follows: (See Appendix 2.10.1, for analysis and details).

Options 1 and 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, with Option 1 lugs are lifted using a lift beam. Cask with

Option 2 lift lugs may be lifted with long cables. 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.

2.4.3.2 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 streses in excess of their yield stress. See Appendix 2.10.1 for analysis and details.

2.4.3.3 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 2.10.1 for analysis and details.

2.4.3.4 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.

2.4.3.5 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.

2.4.4 Tiedown Devices [71.31(d)]

2.4.4.1 Tiedown Forces [71.31(d)(1)]

The tiedown devices consist of four ratchet binder or turnbuckles and cable assemblies attached from the tie-down adapters on the cask to tiedown lugs on the trailer body. Additionally, shear blocks or a shear ring 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 Appendix 2.10.3 for the analysis and details.

2.4.4.2 Non-Tiedown Devices [71.31(d)(2)]

The length of the tiedown cables prevents the use of anything but the tiedown lugs for package tiedown. 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).

2.4.4.3 Tiedown Device Failure [71.31(d)(3)]

The four tiedown adaptors on the cask periphery have been designed so that loads transmitted by the tiedown cables under worse conditions will neither damage the outer steel shell nor cause the tiedown adaptors to fail. The tiedown system analysis is shown in the Appendix 2.10.2.

2.5 Standards for Type B and Large Quantity Packaging

Not applicable.

2.6 Normal Conditions of Transport

2.6.1 Heat

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

2.6.1.1 Summary of Pressures and Temperatures

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, there is no possibility of gas formation which might reduce cask packaging effectiveness.

2.6.2 Cold

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

2.6.3 Pressure

The cask can withstand an external pressure of half an atmosphere. A description of this is contained in Section 4 "Containment," specifically 4.2.1.

2.6.4 Vibration

The cask tiedowns 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.

2.6.5 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 containers constructed of steel, plastic or other materials in the cask cavity.

2.6.6 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 Appendix 2.10.3.

2.6.7 Corner Drop

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

2.6.8 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.

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2.6.9 Compression

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

2.7 Hypothetical Accident Conditions

Not applicable.

2.8 Special Form

Not applicable.

2.9 Fuel Rods

Not applicable.

2.10 Appendix

2.10.1 Lifting Devices.

2.10.2 Tiedown Analysis.

2.10.3 One Foot Free Drop Analysis.

2.10.4 Pentration.

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2.10.1 Lifting Devices

2.10.1.1 Cask Lift Lugs

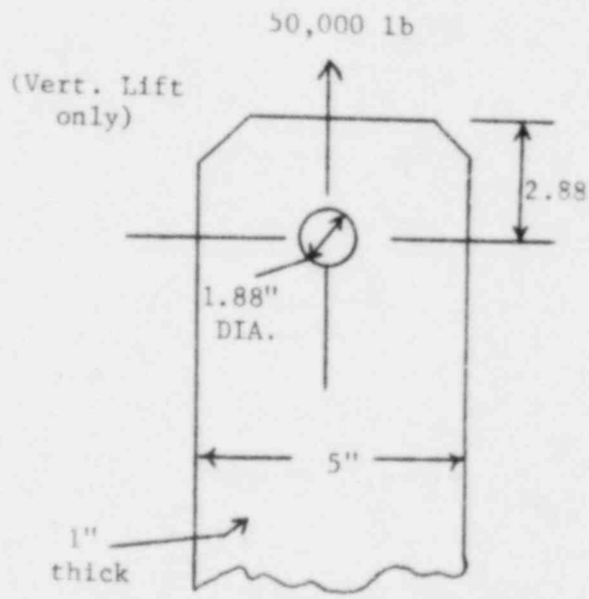
The 3 lift lugs are designed to lift 3 times the weight of the cask. Therefore, each lug will see a vertical force of 3(50,000 lb)/3 lugs = 50,000 lb.

The lift lugs are constructed of either A515, Grade 70; A516, Grade 60; or A203, Grade E.

For analysis purposes, fy = 43,900 psi and fu = 71,000 psi, based on lowest value for the material listed above.

Option 1

Flat plate -



Tearout

σ_s = 50,000 lb/(2)(1)(2.88-0.94)

σ_s = 12,886 psi

S.F. = (.577)(43,900)/(12,886)

= 1.96

Bearing

σ_B = 50,000/(1)(1.875) = 26,666 psi

S.F. = (43,900)(.9)/26,666 = 1.48

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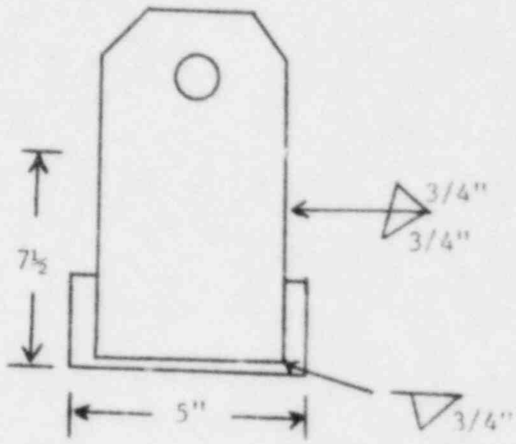
Tension

σ_T = (50,000)/(1)(5-1.88) = 16,025 psi

S.F. = (43,900)/(16,025) = 2.73



Weld

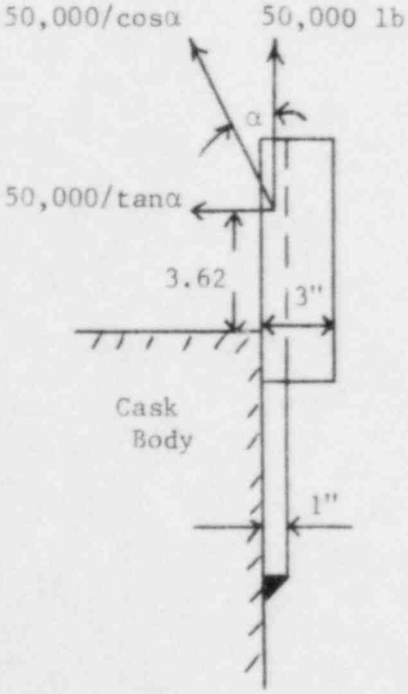
σ_w = 50,000/(7½+5+7½)(.75)(sin 45)(.85)

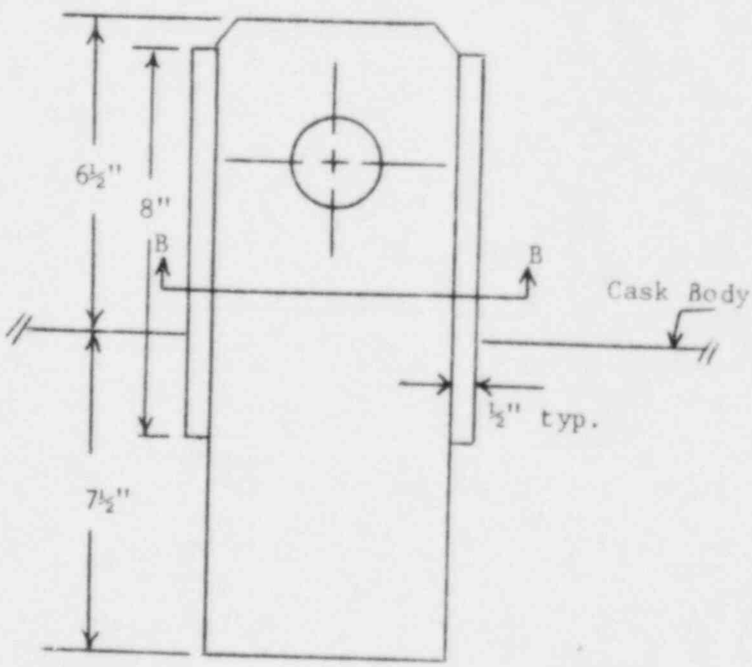
σ_w = 5545 psi

S.F. = 20,625/5545 = 3.72

Option 2

(Reinforcing plates made of either A515 or A516 Gr 70, f_y = 38,000 psi)
(non-vertical lift)





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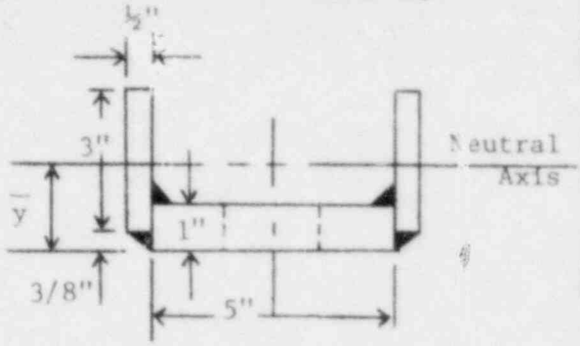


SECTION B-B

Neutral Axis

$$y = \frac{\Sigma_y A}{A} = \frac{(5)(1)(\frac{1}{2})+(2)(\frac{1}{2})(3)(1\frac{1}{2} + 3/8)}{(5)(1) + (2)(3)(\frac{1}{2})}$$

$y = 1.016$

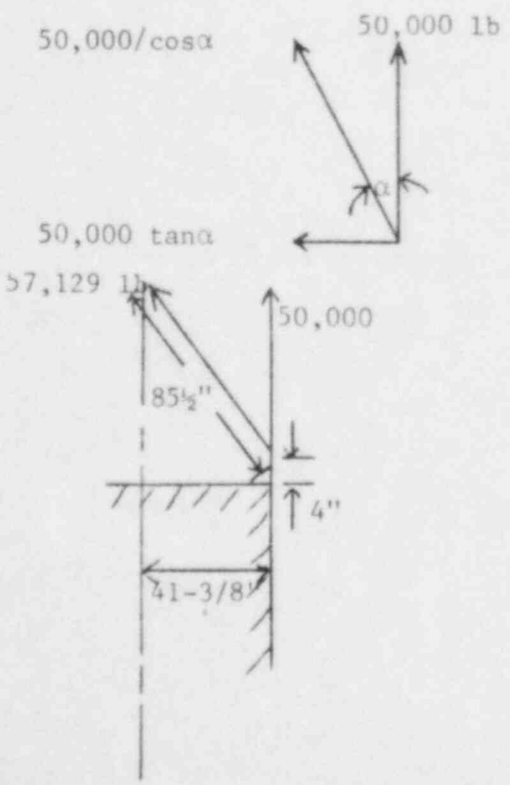
Moment of Inertia = $I_y - y = \Sigma(bh^3/12) = Ad^2$

$$I_1 = \frac{(5)(1)^3}{12} + (5)(1.016 - 0.5)^2 = 1.748 \text{ in}^3$$

$$I_2 = \left[\frac{2(\frac{1}{2})(3)^3}{12} + (3)(\frac{1}{2})(1\frac{1}{2} + 3/8 - 1.016)^2\right] = 4.464 \text{ in}^4$$

$I_T = 6.21 \text{ in}^4$

σ due to bending -



$$\frac{M_e}{I} = \frac{(50,000 \text{ ton } \alpha)(3.62)(3.375-1.016)}{6.21}$$

$\sigma = 38,000 = 68,757 \tan \alpha$

$\tan \alpha = 0.5526$

$\alpha = 28.93°$

Maximum sling length

$$\frac{41\text{-}3/8''}{\sin 28.9} = 85.5'' = 7.13 \text{ ft}$$

The minimum sling length is 7.13 ft.

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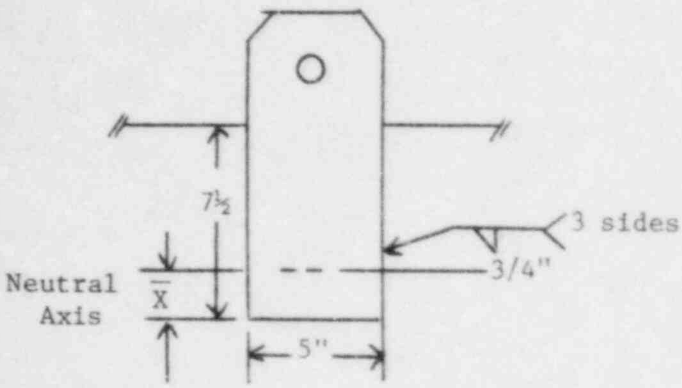
Weld analysis of lift lug (Option 2)
(non-vertical lift)



$$x = \frac{2(7\tfrac{1}{2})(3\text{-}3/4)}{2(7\tfrac{1}{2}) + 5} = 2.8125$$

Shear

σ_s = (50,000/cos 28.9)/[7.5 + 5 + 7.5][.75][sin 45][.85]

= 6,334 psi

Moment

[(50,000 tan 28.9°)(3.62) + (50,000)(.5)]

$= 2\sigma_M = [(2.8125)^2(2)(\tfrac{1}{2})(2/3) + (5)(2.8125)](3/4)(.85)(\sin 45°)$

σ_m = 124,917/17.43 = 7,165 psi

$\sigma_T = \sqrt{\sigma_s^2 + \sigma_m^2} = 9{,}563$ psi

S.F. = 20,625/9,563 = 2.15

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Option 3

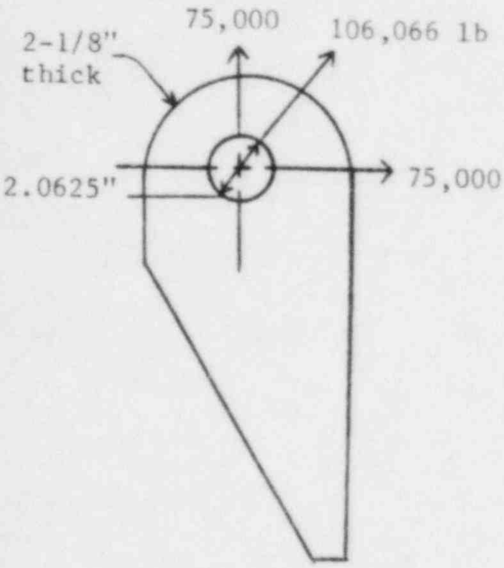
Material for option 3 is specified as A516 Grade 70.

f_y = 38,000 psi

f_u = 70,000 psi

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

45° sling angle



Lug

Tear Out

σ_s = 106,066/(2)(2-1/8)(2.75-1.03125)

= 14,520 psi

S.F. = (.577)(38,000)/14,520 = 1.5

Bearing (1½" Dia. Pin)

σ_B = 106,066/(2-1/8)(1½) = 33,275 psi

S.F. = (.9)(38,000)/33,275 1.03

Tension

σ_T = 106,066/(2-1/8)(5.5 - 2.0625)

= 14,520 psi

S.F. = 38,000/14,520 = 2.61

Weld

Shear

σ_s = 106,066/[14 + 14 + 2-1/8] [1] [.85] [sin 45] = 5,858 psi

Moment

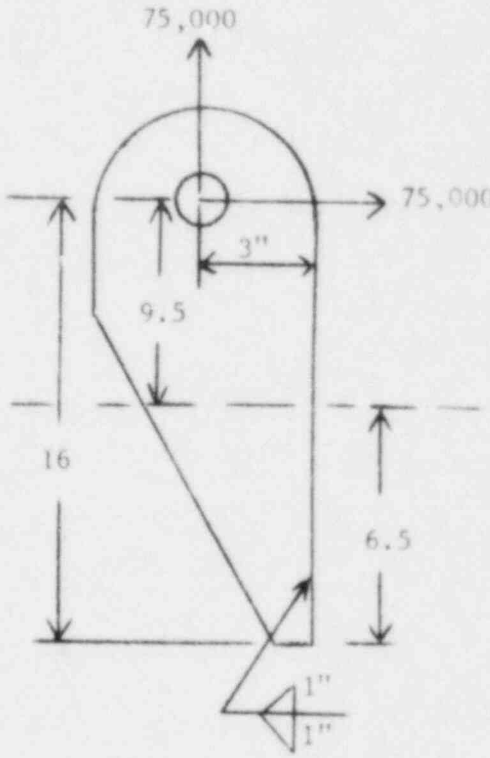
$$X = \frac{2(14)(7)}{2(14) + 2.125} = 6.5 \text{ in}$$

$$(75{,}000)(3 + 9.5) = 2\,\sigma_B\,[6.5)^2(2)(1/2)(2/3) + (2.125)(6.5)]\,(.1)(.85)(\sin 45)$$

σ_B = 18,578 psi

$\sigma_T = \sqrt{\sigma_s^2 + \Sigma_B^2}$ = 19,480 psi

S.F. = 20,625/19,480 = 1.06



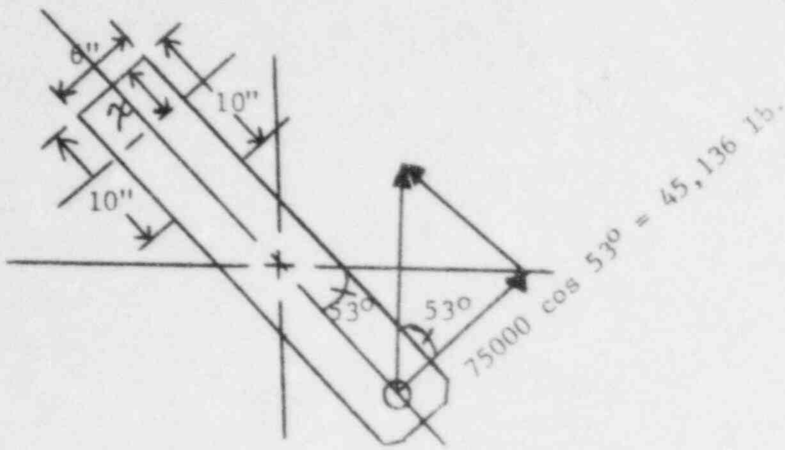
2.10.1.2 Tie Down Lugs for Lifting Cask (Inadvertant Use)

If it is assumed the entire load is carried by two tie-down lugs, the Section Modulus (s) = $bh^2/6$ where b=1.5", thickness of lug; and h=6", the width of the lug. S=9 $in.^3$

Material has a minimum yield of 61,100 psi.

Each lug will see $\frac{(50{,}000)(3 \text{ g lift})}{2 \text{ lugs}}$ = 75,000 lb

PROPRIETARY DATA



$\frac{Mc}{I} = \frac{M}{S} =$

$\frac{(45,136)(10in)}{9} = 50,151$ psi

S.F. = 61,100/50,151 = 1.22

Neutral Axis

$X = \frac{2(10)(5)}{2(10) + 6} = 3.84$ in

Weld

$\sigma_S = (75,000)/(10+6+10)(1)(\sin 45)(.85) = 4,800$ psi

Moment -

$I = \Sigma A[(6^2/12) + r^2]$

$I = 2\{(1)(\sin 45)(10)[(100/12)+(1.16)^2]\} + \{(6)(\sin 45)(1)(36/12)+(3.84)^2\}$

$I = 212\ in^4$

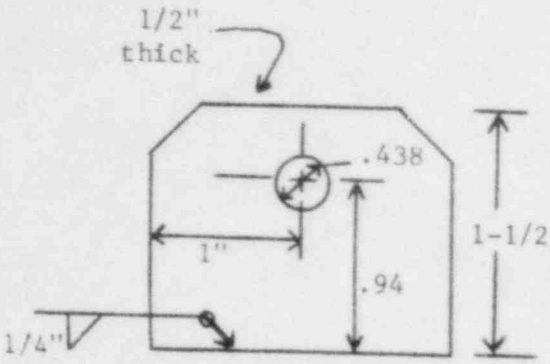
$\sigma_M = \frac{Mc}{I} = \frac{(45,136)(17.16)(3.84)}{212\ in^4} = 14,030$ psi

$\sigma_T = \sqrt{\sigma_s^2 + \sigma_M^2} = 14,828$ psi

S.F. = 20,625/14,828 = 1.4

PROPRIETARY DATA

2.10.1.3 Secondary Shield Lift Lug



Weight of Shield Plug = 500 lb

3g lift for 1 lug = 1,500 lb

Material is 516 Grade 55 (Minimum)

f_y = 30,000 psi

f_{ult} = 55,000 psi

Tear Out

σ_s = 1500/(2)(1/2)(1.5 - .94 - .22) = 4,411 psi

S.F. = (.577)(30,000)/(4411) = 3.9

Bearing

σ_B = 1500 /(1/2")(1/4" dia pin) = 12,000 psi

S.F. = (.9)(30,000)(12,000) = 2.25

Tension

σ_t = 1500/(1/2)(2-.438) = 1,920 psi

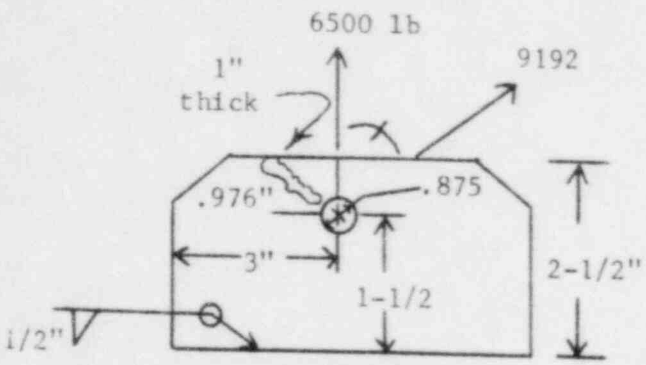
S.F. = 30,000/1,920 = 15.6

Weld

1500/(2 + 0.5 + 2 + .5)(.25)(sin 45)(.85) = 1996

S.F. = 20,625/1996 = 10.3

2.10.1.4 Primary Lid Lift Lugs



Material is A516 Grade 55

f_y = 30,000 psi

f_u = 55,000 psi

Weight of primary and secondary shield plug = 6500 lb

3g lift with 3 lugs = 6500 lb/lug

45° sling angle

Tear Out

σ_s = 9192/(2)(1)(2.5 - 1.5 - .4375) = 8170 psi

S.F. = (30,000)(.577)/8170 = 2.12

Bearing

σ_B = 9192/(1)(1/2" dia pin) = 18,384 psi

S.F. = (.9)(30,000)/18,384 = 1.47

Tension

$\sigma_T = 9{,}192/(1)(.9767) = 9{,}411$ psi

S.F. = 30,000/9,411 = <u>3.18</u>

Weld

Shear $\sigma_s = 9{,}192/(6 + 1 + 6 + 1)(.5)(\sin 45)(.85)$

$\sigma_s = 2{,}185$ psi

Moment

$(6500)(1.5) = 2\ \sigma_M\ [(2)(3)^2(1/2)(2/3) + (1)(3)](.5)(\sin 45)(.85)$

$\sigma_M = 1802$ psi

$\sigma_T = \sqrt{\sigma_s^{\ 2} + \sigma_M^{\ 2}} = 2832$ psi

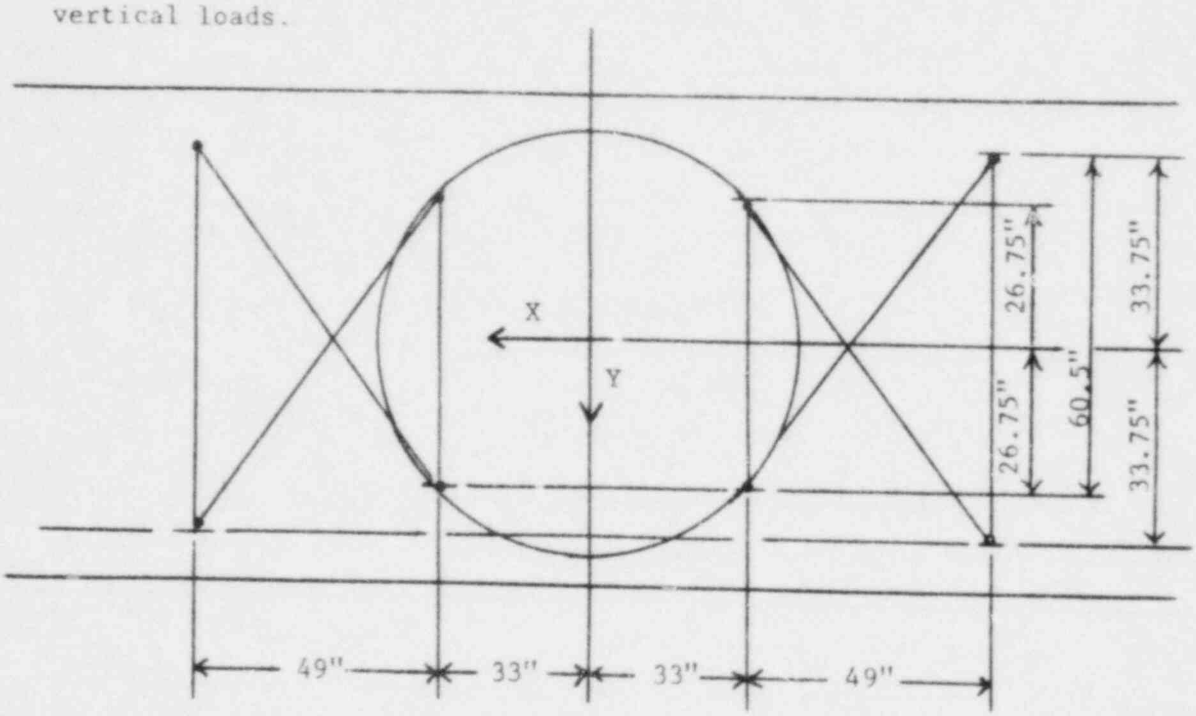
S.F. = 20,625/2832 = <u>7.28</u>

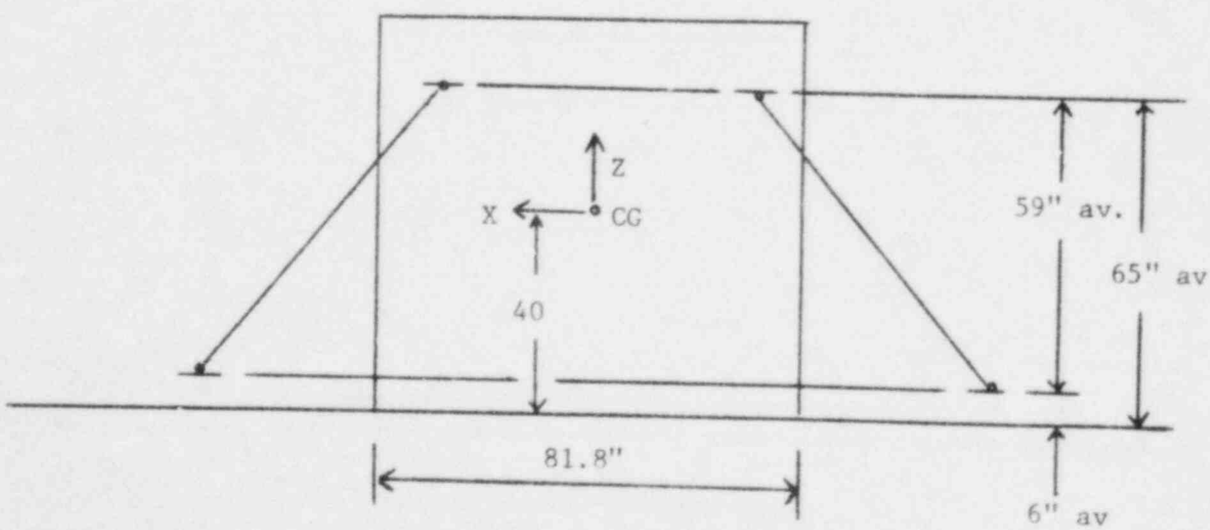
PROPRIETARY DATA

2.10.2 Tiedown Analysis

2.10.2.1 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.





HITTMAN

PROPRIETARY DATA

2.10.2.2 Cask Center of Gravity

Item	Weight		Arm		Moment
Cask	35,500 lbs	.	40.75	=	1,446,625 lb.in
Liner	2,000 lbs	.	39	=	78,000 lb.in
Waste	12,500 lbs	.	38	=	475,000 lb.in
	50,000 lbs				1,999,625 lb.in

Center of Gravity = 1,999,625

CG - 40.0 in.

2.10.2.3 Tie Down Forces

Reference frame with respect to the trailer is shown on the tie down drawing (Page 2.16)

up - down z; front - rear x; side - side y

accelerations: X axis - 10 g's
Y axis - 5 g's
Z axis - 2 g's

2.10.2.4 Tie Down Lengths

Average tie down lengths =

$$\sqrt{(49)^2 + (26.75 + 33.75)^2 + 59^2} =$$

$$\sqrt{49^2 + (60.50)^2 + 59^2} =$$

$$\sqrt{2401 + 3660 + 3481}$$

$$\sqrt{9542} = 97.68"$$

2.10.2.5 Tie Down Tensions

Tie down tensions revolved by vector direction

Along X axis $\frac{49}{97.68} T_L = 0.502$

Along Y axis $\frac{60.5}{97.68} T_L = 0.619$

Along Z axis $\frac{59}{97.68} T_L = 0.604$

2.10.2.6 10G Horizontal Longitudinal Force

Overturning moment due to 10G along X axis

= 10 (50,000 lbs) 40 = 20,000,000 lb-in

Each rear tie down must restrain half of the above moment or

$20{,}000{,}000 \times \frac{1}{2} = 10{,}000{,}000$ in-lbs

Tension in tie downs

$$10{,}000{,}000 = (65) \times (0.502 \times T)$$

$$+ (40.9 + 33) \times (0.064 \times T)$$

$$10{,}000{,}000 = 32.63\ T_{\ell} + 44.64\ T_{\ell}$$

$$77.27\ T_{\ell} = 10{,}000{,}000$$

$$T_{\ell} = 129{,}416 \text{ lbs}$$

PROPRIETARY DATA

2.10.2.7 <u>5G Horizontal Transverse Force</u>

Overturning moment due to 5G along Y axis

= 5 (50,000 lbs) 40.0 = 10,000,000 in-lbs

Each side tie-down unit must restrain half of the moment or:

$$10{,}000{,}000 \times \frac{1}{2} = 5{,}000{,}000 \text{ in-lbs}$$

Tension in side cables:

$$50{,}000{,}000 = (65)(0.619)T_t$$

$$+ (40.9 + 26.75)(0.604)T_t$$

$$5{,}012{,}500 = 40.24\ T_t + 40.86\ T_t$$

$$T_t = 5{,}012{,}500 \div 81.1$$

$$T_t = 61{,}655 \text{ lbs}$$

2.10.2.8 <u>2G Vertical Force</u>

Not vertical force = 2G - W = W

= 50,000 lbs

Each cable must restrain $\frac{1}{4}$ of net vertical force

$$50{,}000 \div 4 = 12{,}500 \text{ lbs}$$

$$0.604\ T_V = 12{,}500 \text{ lbs}$$

$$T_V = 20{,}695 \text{ lbs}$$

2.10.2.9 Total Tension

$$T = T_\ell + T_t + T_v$$

$$= 129,416 + 61,655 + 20,695$$

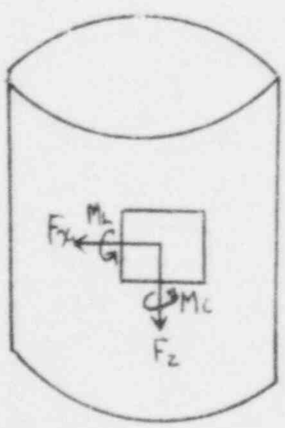
$$= 211,766 \text{ lbs}$$

$$F_v = 211,766 \frac{59}{97.68} = 127,896$$

$$F_H = 211,766 \frac{\sqrt{49^2 + 60.5^2}}{97.68} = 168,766 \text{ lb}$$

2.10.2.10 Analysis of Tiedown on Cask Shell

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



offset distance = 1.75"

$F_v = F_z = 127,896$ lb

$F_h = F_x = 168,766$ lb

M_c = Circumferential moment = (168,766) (1.75) = 295,340 #in.

M_L = Longitudinal moment = (127,896) (1.75) = 223,818 #in.

Reference for method of calculation: Welding Research Council, Bulletin No. 107 (WRC 107), Stress in Cylindrical Pressure Vessels from Structural Attachments.

Υ = r/t = radius to thickness ratio (pg. 2, WRC 107) = 40.3/ .875 = 46.0

C_1 = 1/2 the circumferential width of the loaded plate (pg. 2, WRC 107) = 13/2 = 6.5

C_2 = 1/2 the longitudinal width of the loaded plate (pg. 2, WRC 107) = 13/2 = 6.5

$B_1 = C_1/r$ (pg. 2, WRC 107) = 6.5/40.3 = 0.16

$B_2 = C_2/r$ (pg. 2, WRC 107) = 6.5/40.3 = 0.16

Check that $5 \leq \Upsilon \leq 100$

PROPRIETARY DATA

$$\left(\frac{B_1}{0.3}\right)^2 + \left(\frac{B_2}{1.2}\right)^2 \leq 1$$

General Nomenclature

σ_i = normal stress in the ith direction on the surface of the shell, psi

τ_{ij} = shear stress on the ith face of the jth direction

S = stress intensity = twice maximum shear stress, psi

N_i = membrane force per unit length in the ith direction, lb/in.

M_i = bending moment per unit length in the ith direction, in. lb/in.

K_n = membrane stress concentration factor (pure tension or compression)

K_b = bending stress concentration factor

i = denotes direction. In the case of spherical shells, this will refer to the tangential and radial directions with respect to an axis normal to the shell through the center of the attachment as shown in Fig. 1. In the case of cylindrical shells, this will refer to longitudinal and circumferential directions with respect to the axis of the cylinder as shown in Fig. 2.

$+$ = denotes tensile stress (when associated with σ_i)

$-$ = denotes compressive stress (when associated with σ_i)

E = modulus of elasticity, psi

P = concentrated radial load or total distributed radial load, lb

General Equation

In the analysis of stresses in thin shells, one proceeds by considering the relation between internal membrane forces, internal bending moments and stress concentrations in accordance with the following:

$$\sigma_i = K_n \frac{N_i}{T} \pm K_b \frac{6M_i}{T^2}$$

Nomenclature Applicable to Cylindrical Shells

V_c = concentrated shear load in the circumferential direction, lb

V_L = concentrated shear load in the longitudinal direction, lb

M_c = external overturning moment in the circumferential direction with respect to the shell, in. lb

M_L = external overturning moment in the longitudinal direction with respect to the shell, in. lb

R_m = mean radius of cylindrical shell, in.

l = length of cylindrical shell, in.

c_1 = half length of rectangular loading in circumferential direction, in.

c_2 = half length of rectangular loading in longitudinal direction, in.

T = wall thickness of cylindrical shell, in.

x = coordinate in longitudinal direction of shell

y = coordinate in circumferential direction of shell

ϕ = cylindrical coordinate in circumferential direction of shell

α = l/R_m

β = attachment parameter

β_1 = c_1/R_m

β_2 = c_2/R_m

γ = R_m/T; shell parameter

C_c, C_L = multiplication factors for N_ϕ and N_x for rectangular surfaces given in Tables 7 and 8

K_c, K_L = coefficients given in Tables 7 and 8

M_ϕ, M_x = bending moments in shell wall in the circumferential and longitudinal direction with respect to the shell

N_ϕ, N_x = membrane forces in shell wall in the circumferential and longitudinal direction with respect to the shell

σ_ϕ = normal stress in the circumferential direction with respect to the shell, psi

σ_x = normal stress in the longitudinal direction with respect to the shell, psi

$\tau_{x\phi}$ = shear stress on the x face in the ϕ direction with respect to the shell, psi

$\tau_{\phi x}$ = shear stress on the ϕ face in the x direction with respect to the shell, psi

PROPRIETARY DATA

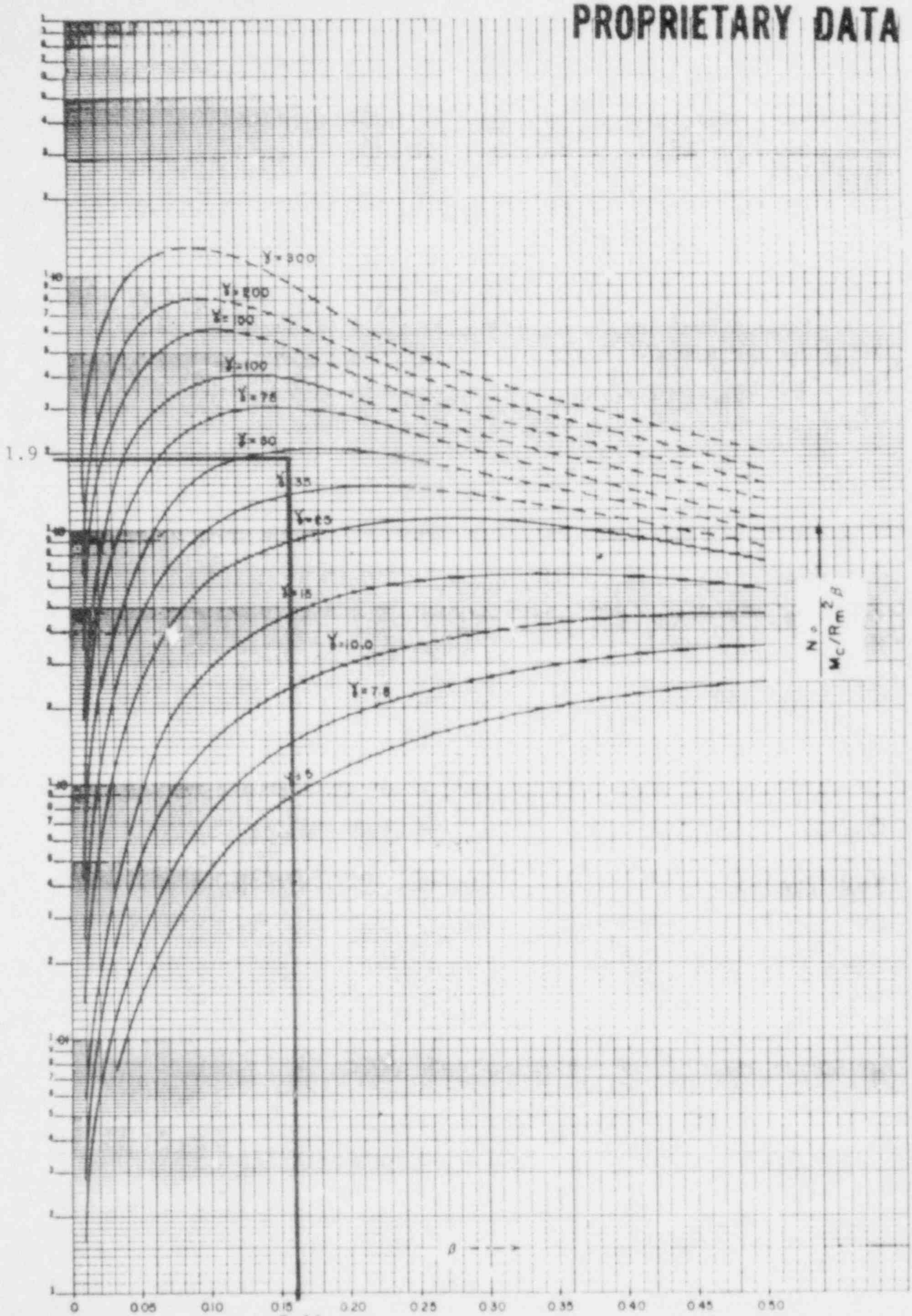


Fig. 3A—Membrane force $N_\phi/(M_c/R_m^2\beta)$ due to an external circumferential moment M_c on a circular cylinder

PROPRIETARY DATA

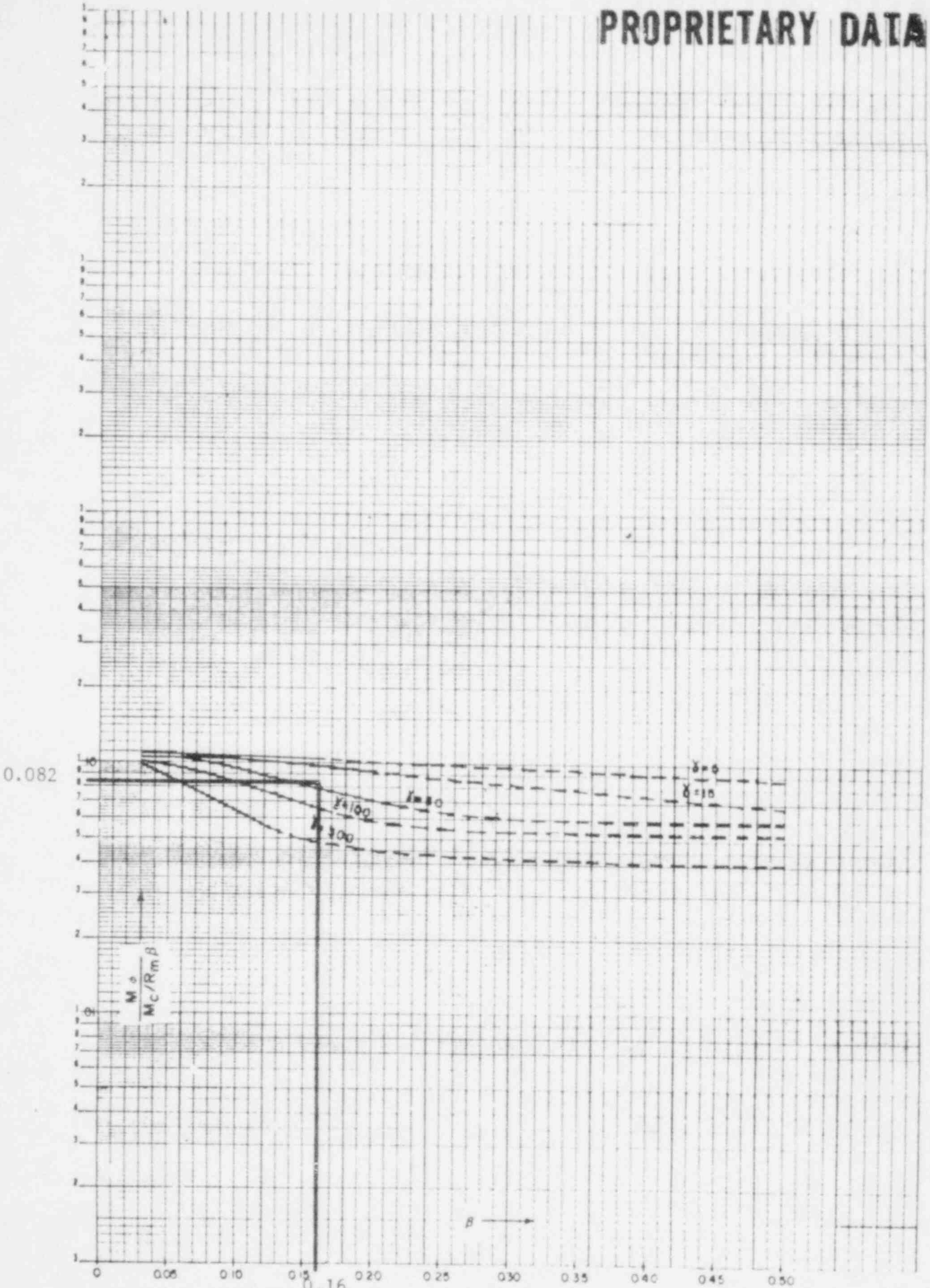


Fig. 1A—Moment $M_\phi/(M_c/R_m\beta)$ due to an external circumferential moment M_c on a circular cylinder

PROPRIETARY DATA

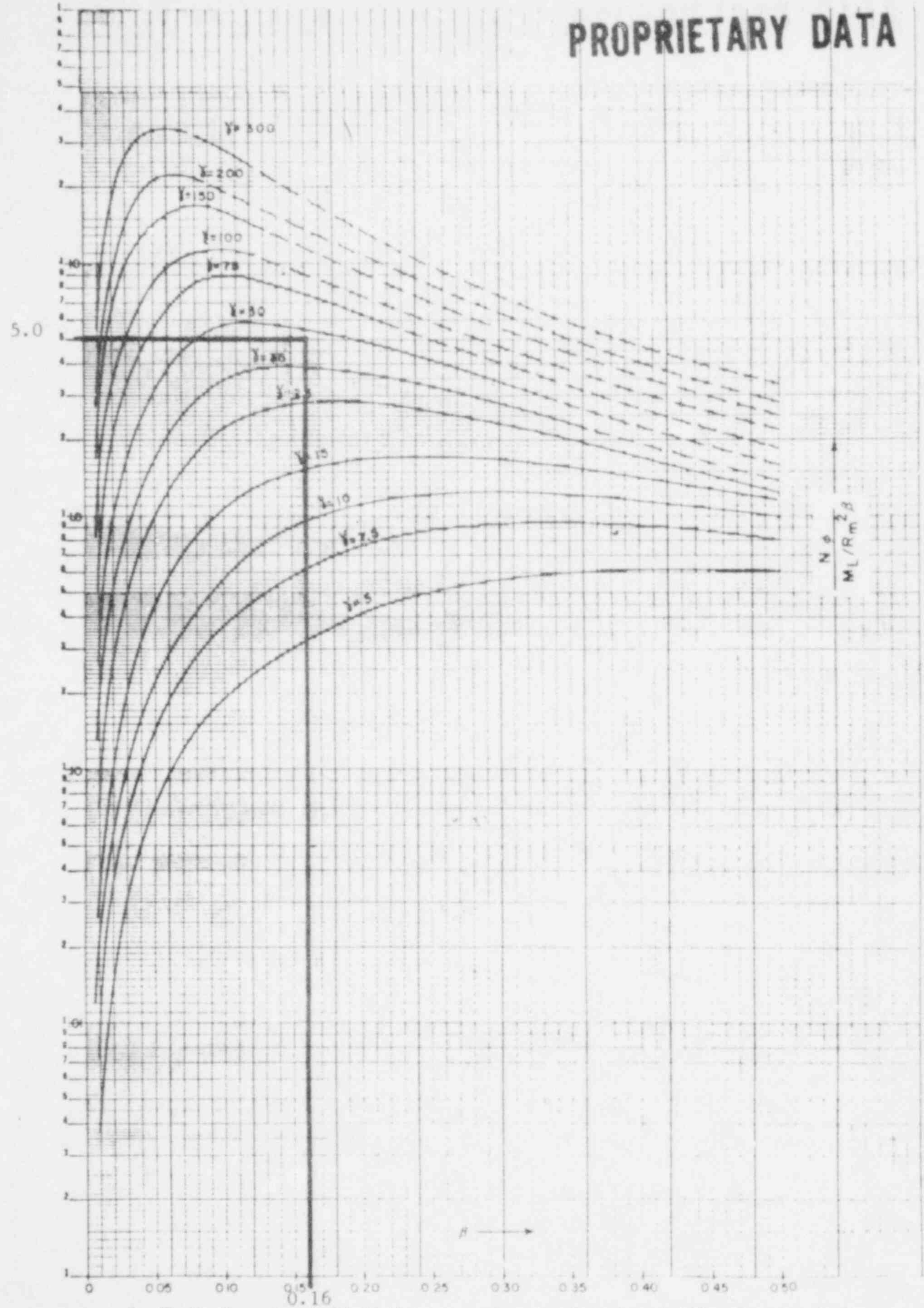


Fig. 3B—Membrane force $N_\phi/(M_L/R_m^2\beta)$ due to an external longitudinal moment M_L on a circular cylinder

PROPRIETARY DATA

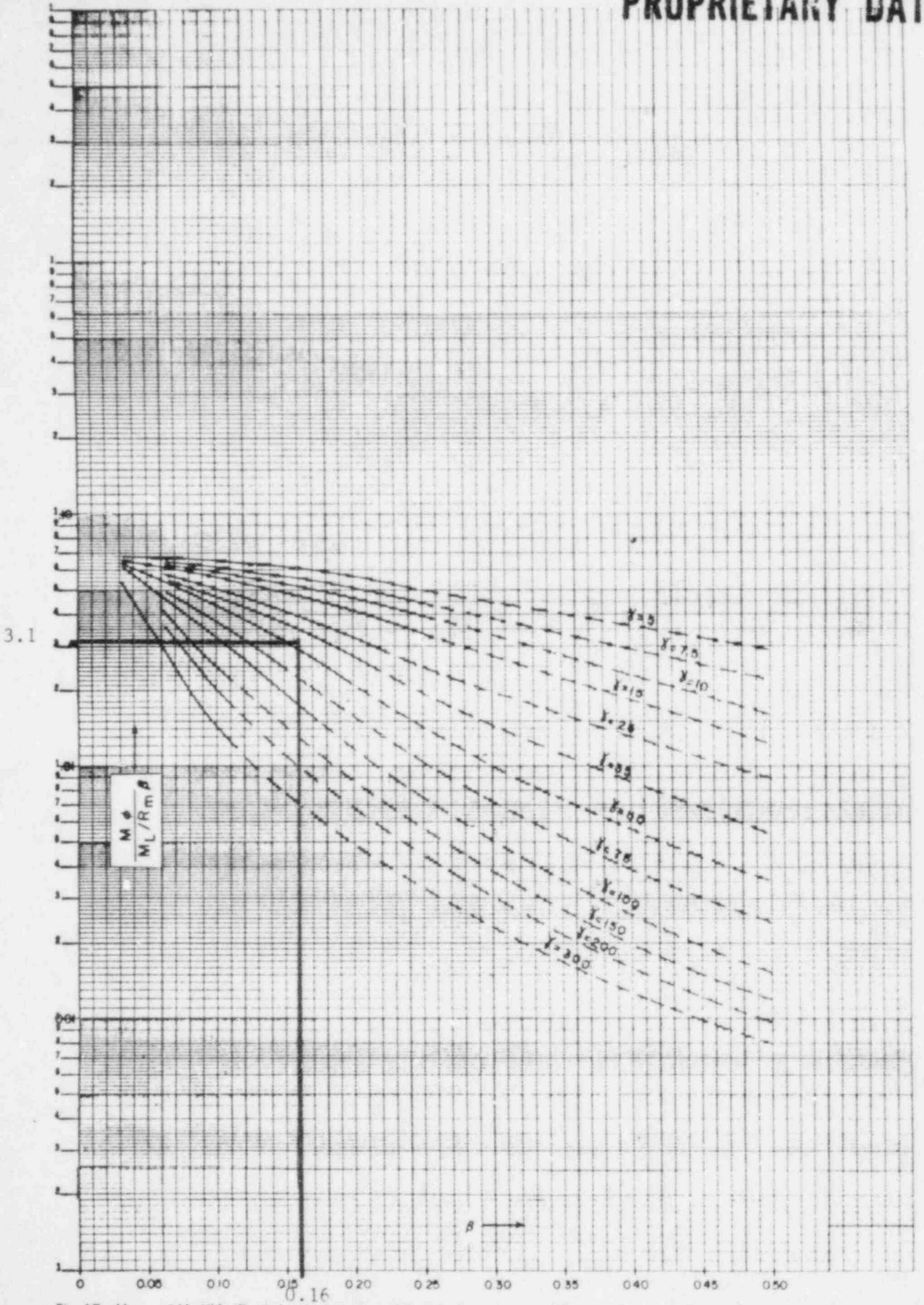


Fig. 1B—Moment $M_\phi/(M_L/R_m\beta)$ due to an external longitudinal moment M_L on a circular cylinder (Stress on the longitudinal plane of symmetry)

PROPRIETARY DATA

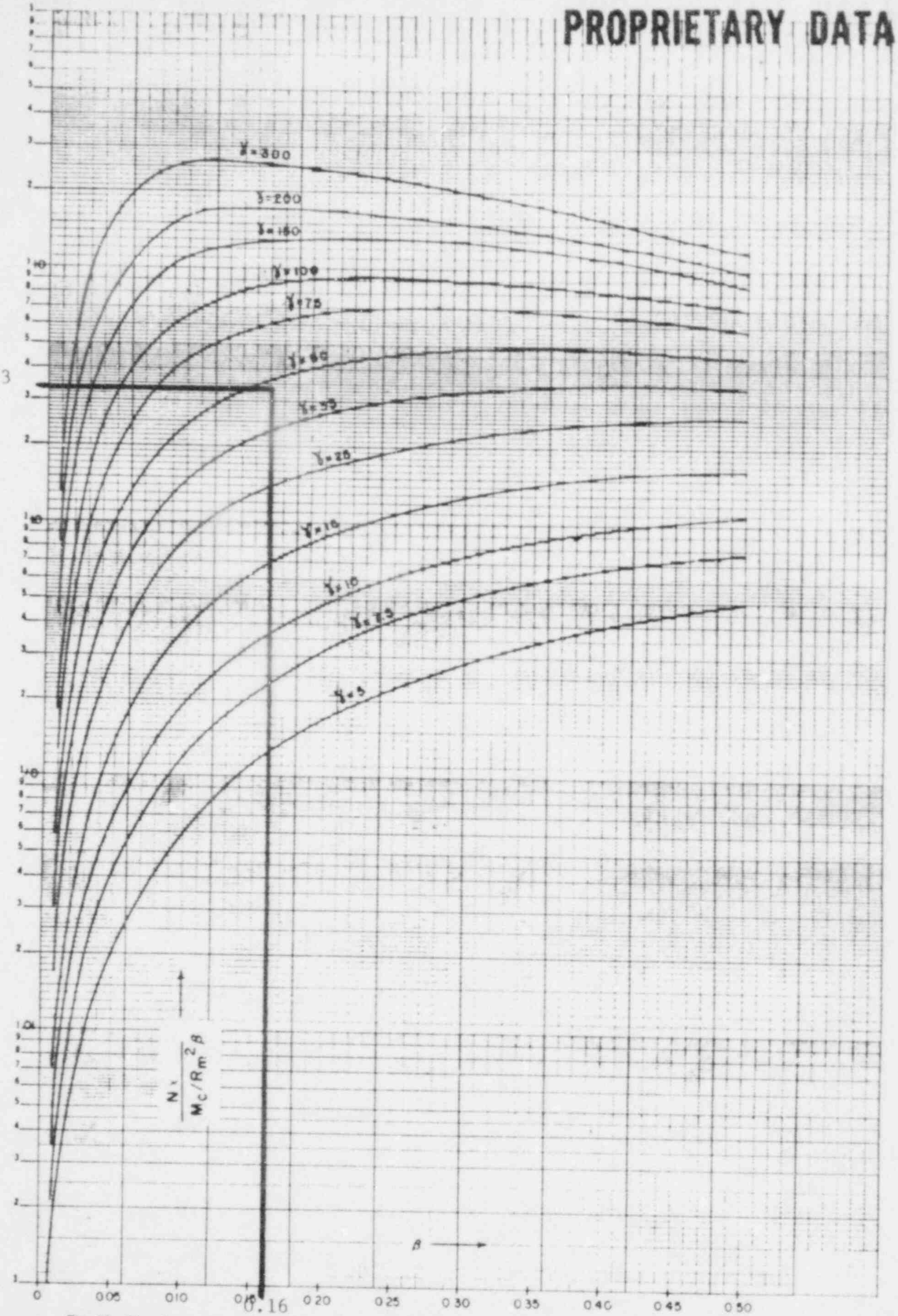


Fig. 4A—Membrane force $N_x/(M_c/R_m^2\beta)$ due to an external circumferential moment M_c on a circular cylinder

PROPRIETARY DATA

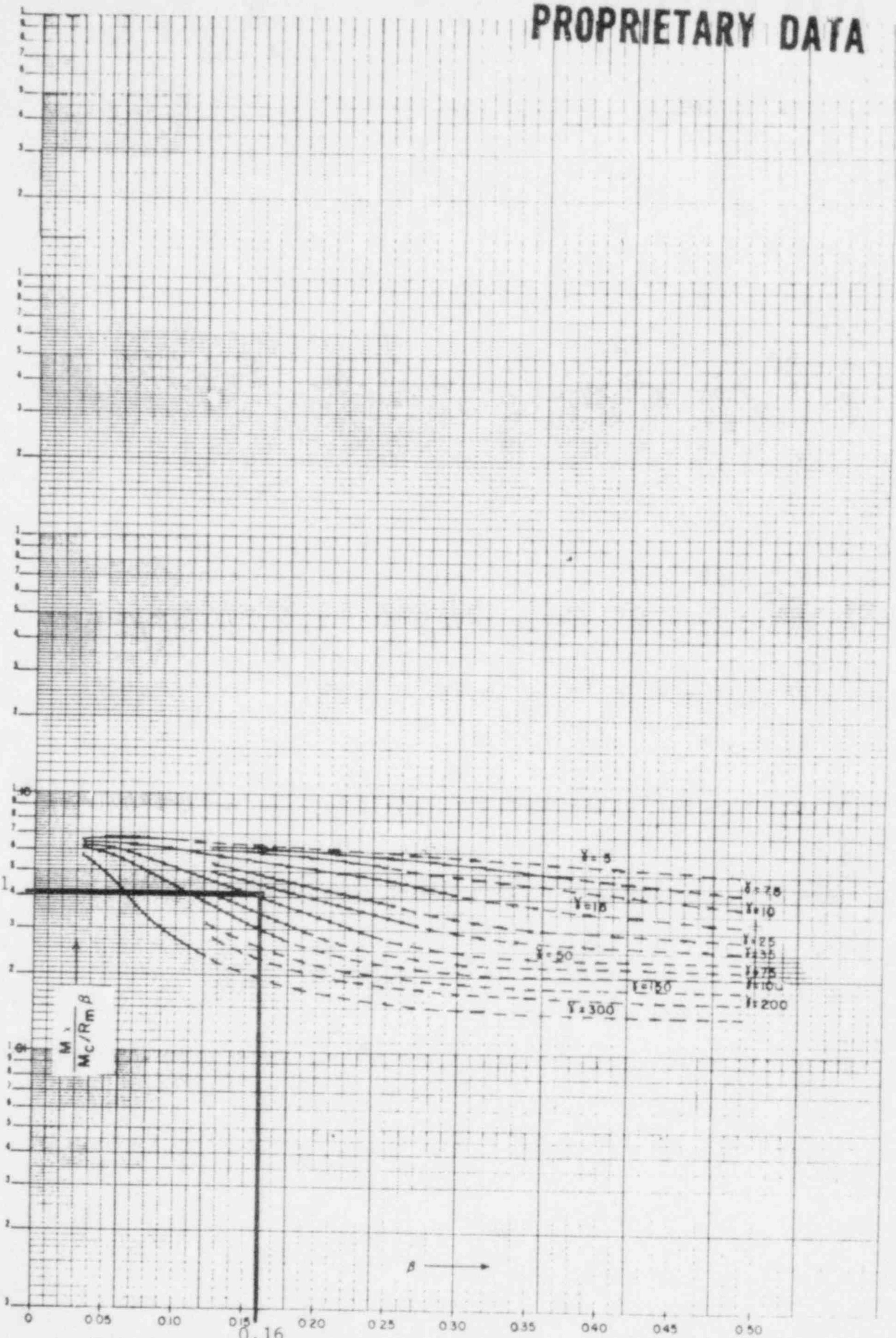


Fig. 2A—Moment $M_x/(M_c/R_m\beta)$ due to an external circumferential moment M_c on a circular cylinder

PROPRIETARY DATA

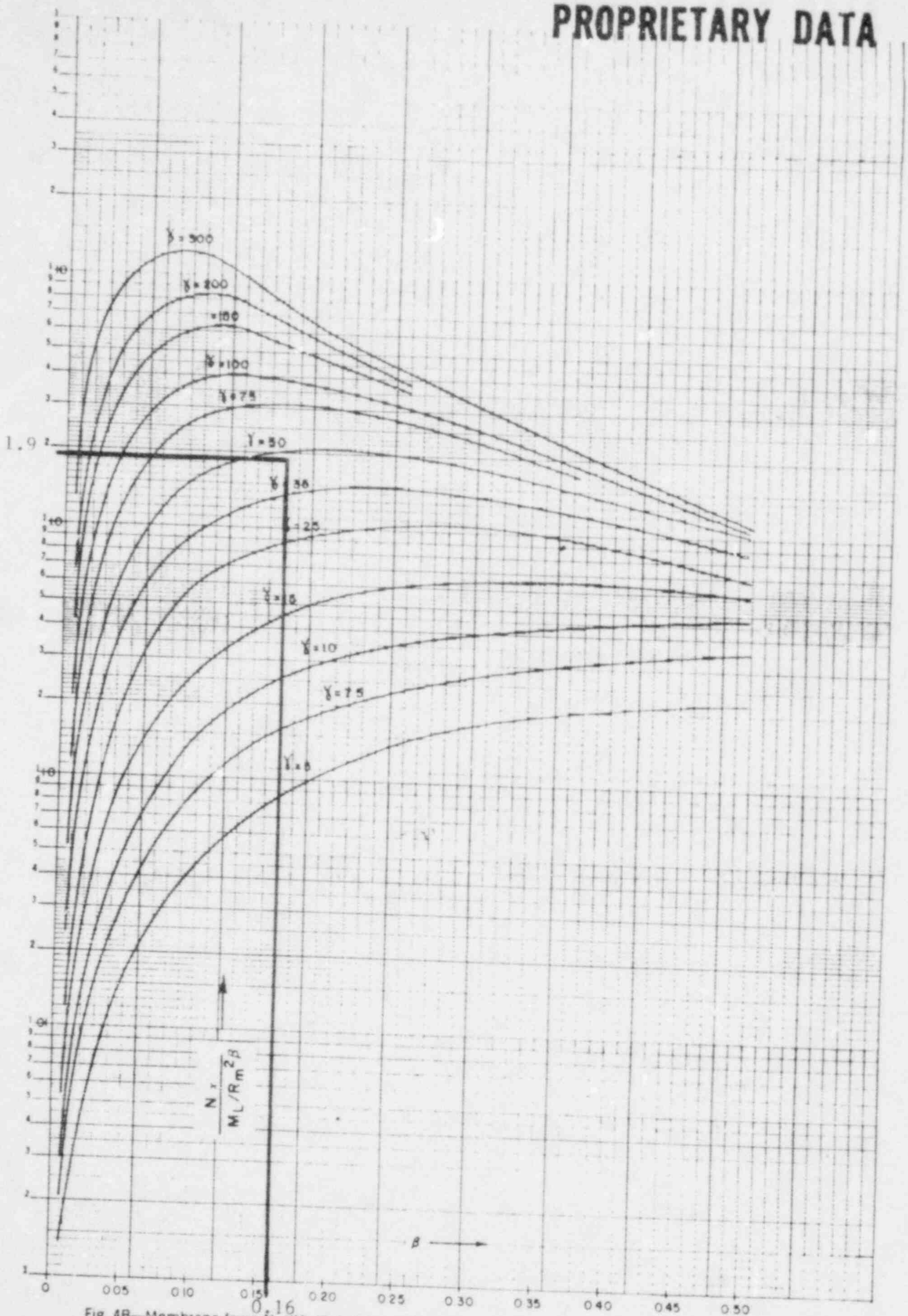


Fig. 4B—Membrane force $N_x/(M_L/R_m^2\beta)$ due to an external longitudinal moment M_L on a circular cylinder

PROPRIETARY DATA

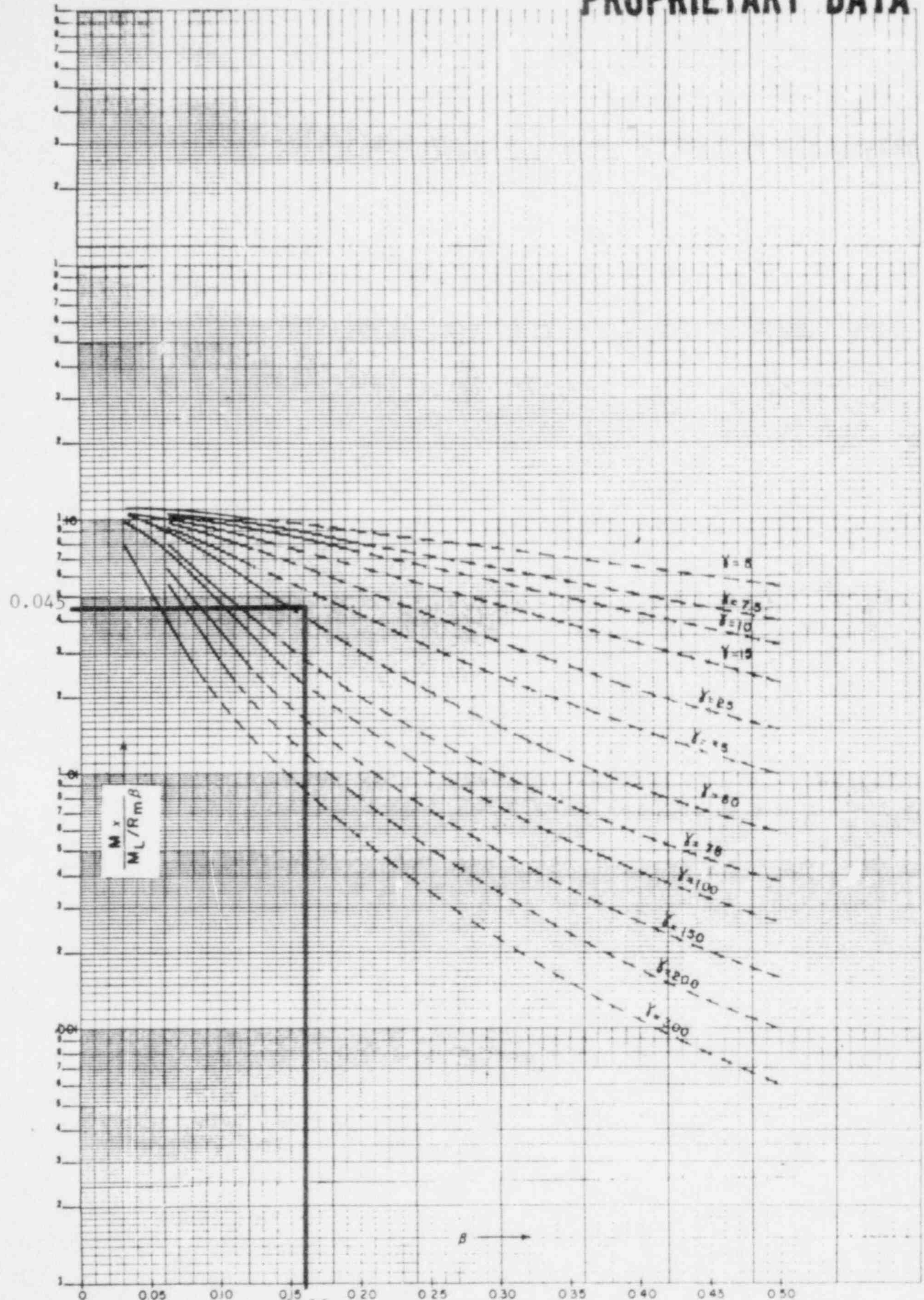


Fig. 2B-Moment $M_x/(M_L/R_m\beta)$ due to an external longitudinal moment M_L on a circular cylinder (Stress on longitudinal plane of symmetry)

Table 5—Computation Sheet for Local Stresses in Cylindrical Shells

1. Applied Loads*

Radial load,	P = —	lb.
Circ. Moment,	Mc = 295340	in. lb.
Long. Moments,	ML = 223818	in. lb.
Torsion Moment,	M_T = —	in. lb.
Shear Load,	Vc = 168766	lb.
Shear Load,	VL = 127896	lb.

2. Geometry

Vessel thickness,	T = 0.875	in.
Attachment radius,	r_o = —	in.
Vessel radius,	Rm = 40.3	in.

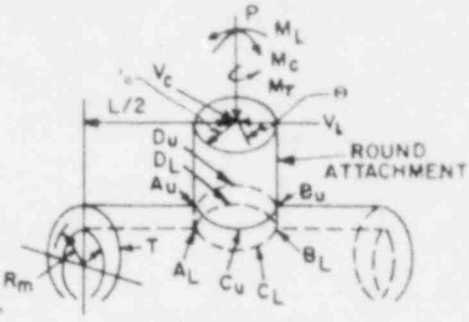
3. Geometric Parameters

   $\gamma = \frac{R_m}{T} = 46$

   $\beta = 0.16$

   Stress Concentration due to:
   a) membrane load, Kn 1
   b) bending load, Kb 1

*NOTE: Enter all force values in accordance with sign convention.



CYLINDRICAL SHELL

From Fig.	Read curves for	Compute absolute values of stress and enter result:	STRESSES – if load is opposite that shown, reverse signs shown: Au	AL	Bu	BL	Cu	CL	Du	DL
3C or 4C	$\frac{N\phi}{P/R_m}$ =	$K_n\left(\frac{N\phi}{P/R_m}\right)\cdot\frac{P}{R_mT}$ =	—	—	—	—	—	—	—	—
1C or 2C-1	$\frac{M\phi}{P}$ =	$K_b\left(\frac{M\phi}{P}\right)\cdot\frac{6P}{T^2}$ =	−	+	−	+	−	+	−	+
3A	$\frac{N\phi}{M_c/R_m^2\beta}$ = 1.9	$K_n\left(\frac{N\phi}{M_c/R_m^2\beta}\right)\cdot\frac{M_c}{R_m^2\beta T}$ =					2468	-2468	+2468	+2468
1A	$\frac{M\phi}{M_c/R_m\beta}$ = 0.082	$K_b\left(\frac{M\phi}{M_c/R_m\beta}\right)\cdot\frac{6M_c}{R_m\beta T^2}$ =					-29433	+29433	+29433	-29433
3B	$\frac{N\phi}{M_L/R_m^2\beta}$ = 5.0	$K_n\left(\frac{N\phi}{M_L/R_m^2\beta}\right)\cdot\frac{M_L}{R_m^2\beta T}$ =	-4922	-4922	+4922	+4922				
1B or 1B-1	$\frac{M\phi}{M_L/R_m\beta}$ = 0.031	$K_b\left(\frac{M\phi}{M_L/R_m\beta}\right)\cdot\frac{6M_L}{R_m\beta T^2}$ =	-8432	+8432	+8432	-8432				
Add algebraically for summation of φ stresses, σ_ϕ			13354	3510	13354	3510	31901	26965	31901	26965
3C or 4C	$\frac{N_x}{P/R_m}$ =	$K_n\left(\frac{N_x}{P/R_m}\right)\cdot\frac{P}{R_mT}$ =	—	—	—	—	—	—	—	—
1C-1 or 2C	$\frac{M_x}{P}$ =	$K_b\left(\frac{M_x}{P}\right)\cdot\frac{6P}{T^2}$ =	−	+	−	+	−	+	−	+
4A	$\frac{N_x}{M_c/R_m^2\beta}$ = 3.3	$K_n\left(\frac{N_x}{M_c/R_m^2\beta}\right)\cdot\frac{M_c}{R_m^2\beta T}$ =					-4286	-4286	+4286	+4286
2A	$\frac{M_x}{M_c/R_m\beta}$ = 0.041	$K_b\left(\frac{M_x}{M_c/R_m\beta}\right)\cdot\frac{6M_c}{R_m\beta T^2}$ =					-14716	+14716	+14716	-14716
4B	$\frac{N_x}{M_L/R_m^2\beta}$ = 1.9	$K_n\left(\frac{N_x}{M_L/R_m^2\beta}\right)\cdot\frac{M_L}{R_m^2\beta T}$ =	-1870	-1870	+1870	+1870				
2B or 2B-1	$\frac{M_x}{M_L/R_m\beta}$ = 0.045	$K_b\left(\frac{M_x}{M_L/R_m\beta}\right)\cdot\frac{6M_L}{R_m\beta T^2}$ =	-12241	+12241	+12241	-12241				
Add algebraically for summation of X stresses, σ_x =			14111	10370	14111	10370	19002	10430	19002	10430
Shear stress due to Torsion, M_T		$\tau_{\phi x} = \tau_{x\phi} = \frac{M_T}{2\pi r_o^2 T}$	+	+	+	+	+	+	+	+
Shear stress due to load, Vc		$\tau_{x\phi} = \frac{V_c}{4C_1T}$	+7418	+7418	-7418	-7418				
Shear stress due to load, VL		$\tau_{x\phi} = \frac{V_L}{4C_2T}$					5622	5622	5622	5622
Add Algebraically for summation of shear stresses, τ =			7418	7418	7418	7418	5622	5622	5622	5622
COMBINED STRESS INTENSITY – S (Units in KSI)		b	14.8	16.3	14.8	16.3	17.1	20.0	17.1	20.0
		a	21.1	15.1	21.1	15.1	34.0	28.7	34.0	28.7

1) When τ ≠ 0, S = largest absolute magnitude of either

$$S = \underbrace{1/2\left[\sigma_x + \sigma_\phi \pm \sqrt{(\sigma_x - \sigma_\phi)^2 + 4\tau^2}\right]}_{a} \text{ or } \underbrace{\sqrt{(\sigma_x - \sigma_\phi)^2 + 4\tau^2}}_{b}.$$

2) When τ = 0, S = largest absolute magnitude of either

$$S = \sigma_x,\ \sigma_\phi \text{ or } (\sigma_x - \sigma_\phi).$$

$N_x/(M_L/R_m^2\beta)$ so determined by (C_L) from Table 8 (see para. 4.3).

4.2.2.5.2: When considering bending moment (M_L): $\beta = K_L\sqrt[3]{\beta_1\beta_2^2}$ where K_L is given in Table 8.

4.3 Calculation of Stresses

4.3.1 STRESSES RESULTING FROM RADIAL LOAD, P.

4.3.1.1 Circumferential Stresses (σ_ϕ):

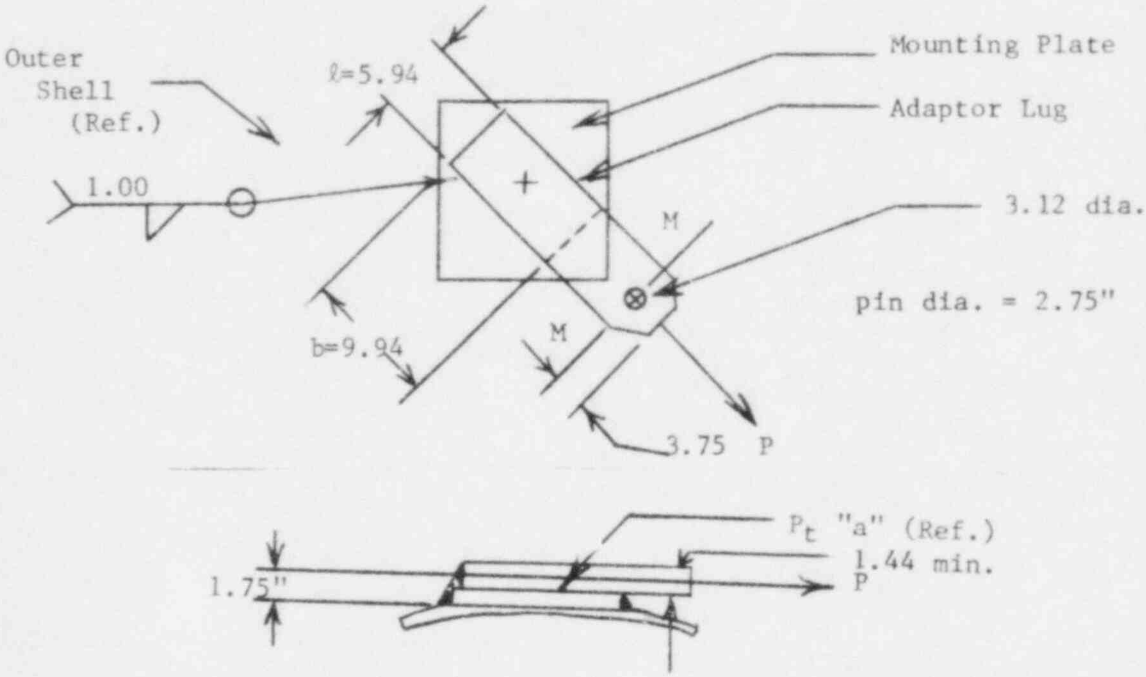
Step 1. Using the applicable values of β and γ

2.10.2.11 Summary

The maximum stress developed in the outer shell at the tie down lug backing plates is 34,000 psi. Based on the actual minimum yield for the material 42,000 psi, the safety factor is 42,000/34,000 = 1.23.

2.10.2.12 Analysis of Cask Tiedown Lugs

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



From Table 2.3.1 and Table 2.3.3, the tie down lugs on the HN-100 Series 1 casks (except for Unit 5) have a minimum yield of 61,100 psi and an ultimate strength of 78,500 psi. The loading on the lugs will be 211,766 psi. The tie-down lugs on Unit 5 have a minimum yield strength of 50,400 psi.

PROPRIETARY DATA

2.10.2.12.1 Bearing Stress in Pin Hole

The allowable stress in bearing based on projected area of pin in reamed, drilled or bored holes is:

$$F_{bp} = 0.90\ F_y$$

$$= 0.90 \times 61.100$$

$$= 54.990 \text{ psi}$$

For the tie down lug the bearing stress is:

$$f_b = \frac{211,766}{2.75 \times 1.44} = 53,476 \text{ psi}$$

$$\text{Safety Factor (yield)} = \frac{54,990}{53,476} = 1.03$$

2.10.2.12.2 Tensile Stress (in Plane M-M)

$$F = \frac{211,766}{(5.94 - 3.12)(1.44)} = 52,149 \text{ psi}$$

$$\text{Safety Factor (yield)} = \frac{61,100}{52,149} = 1.17$$

2.10.2.12.3 Tear Out Due to Shear

Allowable Shear Stress = 0.577 x 61,100 = 35,255 psi

$y_1 = \sqrt{1.56^2 - 1.375^2}$

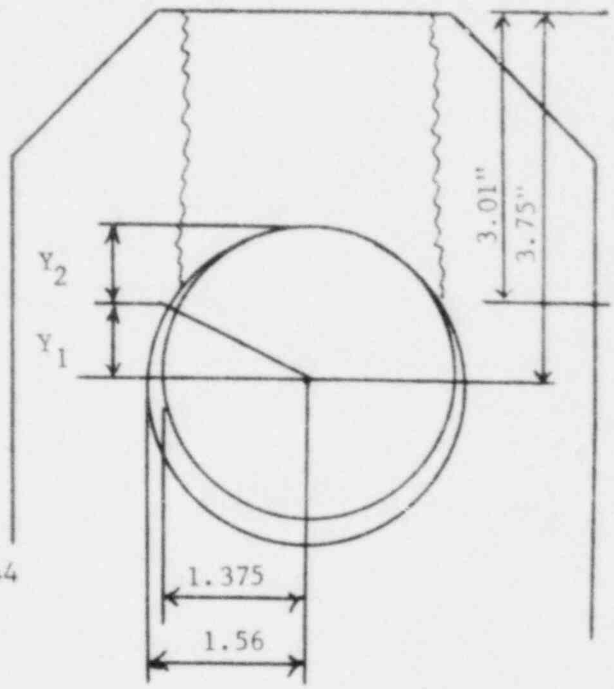
$= 0.74$

$y_2 = 1.56 - 0.74 = 0.82$ in.

$0.82 + (3.75 - 1.56) = 3.01$

$$f = \frac{211,766}{2 \times 3.01 \times 1.44} = 24,428 \text{ psi}$$

$$\text{Safety Margin (Yield)} = \frac{35,255}{24,428} = 1.44$$



2.10.2.12.4 Weld Strength Analysis

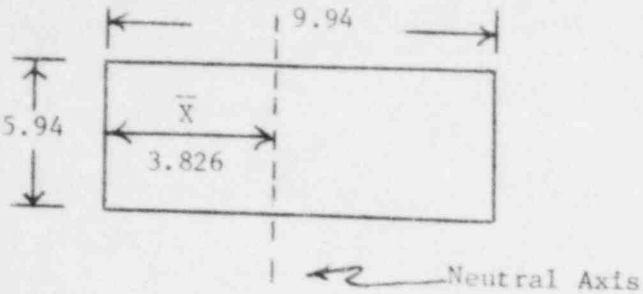
Stress in the weld attaching the tie down lug to the reinforcing plate are a combination of shear stress plus bending.

Direct Shear Stress

$$f_s = \frac{211,766}{1 \times 0.707 \times 24,82 \times .85} = 13,645 \text{ psi}$$

Bending Moment

$$M = 1.44 \times \frac{1}{2} \times 211,766 = 152,472 \text{ in lbs}$$



$$X = \frac{(2)(9.94)(4.97)}{2(9.94) + 5.94} = 3.826$$

M = Compressive Moment + Tension Moment

= 2 (Tension Moment)

$$= 2f\,[(5.94)(3.826) + (3.826)^2\,(2)(1/2)(2/3)]\,(1)(\sin 45)(.85)$$

$$f = \frac{152.472}{34.45} = 3{,}904 \text{ psi}$$

Combined Stress

$$f = \sqrt{(13{,}645)^2 + (3{,}904)^2} = 14{,}192 \text{ psi}$$

Allowable Shear Stress = 0.3 x 68,750

= 20,625 psi

$$\text{Safety Factor} = \frac{20{,}625}{14{,}192} = 1.45$$

2.10.2.13 Restrictions on the Use of Unit 5

Since the HN-100, Series 1, Unit 5 cask have a lower minimum yield strength than the other casks in this series, the gross weight and contents must be restricted. The weight restrictions for Unit 5 are as follows:

Calculated bearing stress in tiedown lugs under conditions specified in 10 CFR 71.31(d)(1): 53,476 psi.

Certified yield strength of tiedown lugs used on HN-100 Series 1, Unit 5: 50,400 psi.

Reduction in load required to reduce stress in lift lugs to yield:

$$\frac{53{,}476 - 50{,}400}{53{,}476} = 5.75\%$$

Required reduction in package gross weight:

50,000 lbs x 57.5% = 2,876 pounds

Allowable weight of contents to avoid stresses in excess of yield:

14,500 lbs - 2,876 lbs = 11,623 lbs

2.10.2.14 Failure Under Excessive Load

The tiedown lugs are designed to fail first under excessive load and preclude damage to the package. Based on the ultimate strength of the shell material, the force required to cause extensive deformation of the shell would be:

$$F = 211{,}766 \times \frac{64{,}800}{34{,}000} = 403{,}600 \text{ lbs.}$$

The lugs would fail due to combination of bearing and tensile stresses. Based on the ultimate strength of the lug, failure would occur with force if:

PROPRIETARY DATA

Bearing

78,500 x 2.75 x 1.44 = 310,860 lbs

Tensile

78,500 x (3.75-1.56) x 1.44 = 247,558 lbs

Accordingly, a tensile failure of the lug will occur before the cask shell is damaged.

2.10.3 Free Drop

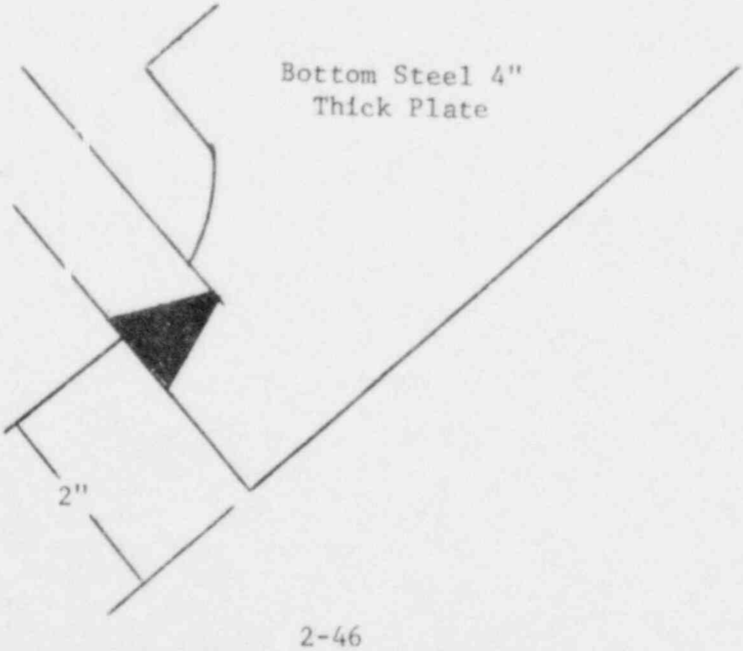
Since the package weighs in excess of 30,000 lbs., it must be able to withstand a one foot drop on any surface, without loss of contents.

2.10.3.1 One Foot Drop on Bottom Corner

Energy to be absorbed = 50,000 lb x 12 in.

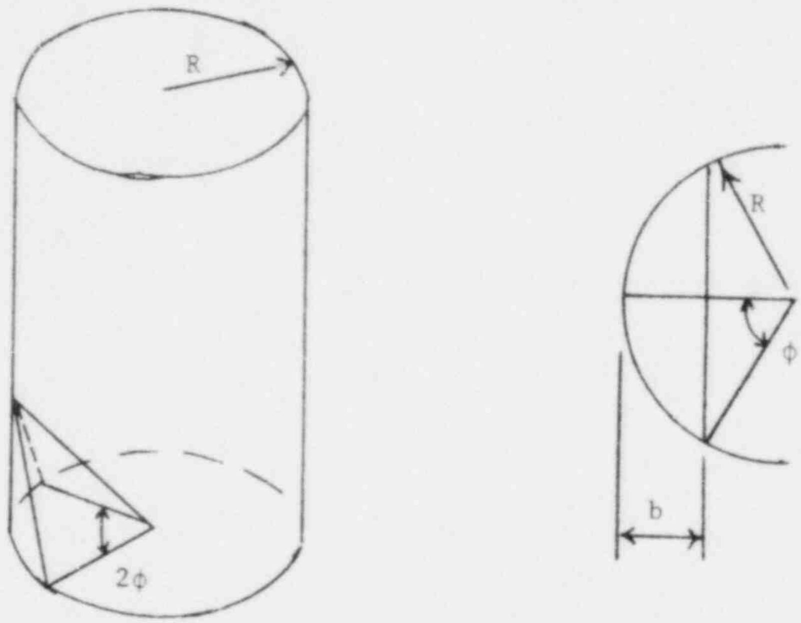
Maximum energy = 6×10^5 in. lb

Energy will be absorbed by crushing of corner.



The volume of the crushed ungula, assuming the worst case of a 45° impact angle is calculated by the following equation:

$$V_S = R^3 \left\{ \text{Sin}\,\phi - \frac{\text{Sin}^3\phi}{3} - \phi\text{Cos}\phi \right\}$$



The volume of steel that must be crushed to absorb the energy from a one foot drop is calculated using the minimum yield strength of A516, Grade 55 steel (30,000 psi). This results in the maximum deformation of the steel.

$$V_S = 600{,}000 \div 30{,}000 = 20 \text{ cubic inches.}$$

The angle ϕ of the crushed ungula is calculated using the equation on the previous page: For $\phi = 17°$

$V_S = 40.7^3\ (0.29237 - 0.00833 - 0.28374)$

$= 67{,}419 \times 0.0002996 = 20.2\ in^3$

Therefore total enegy absorbed for 17° is 606,000 (101%)

The maximum crush distance is calcuated:

$b = R\ (1\text{-}Cos\phi)$

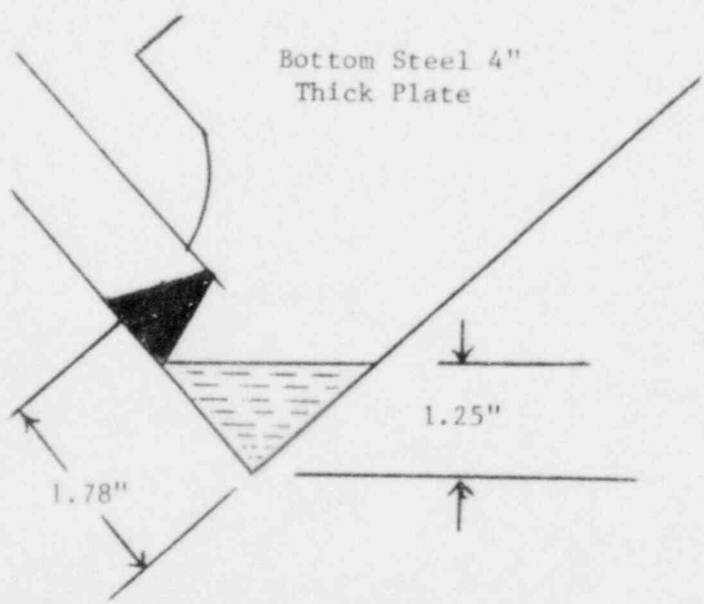
$= 40.7\ (1\text{-}0.95656)$

$= 1.78$ in.

The vertical crush distance will be:

$1.77 \div \sqrt{2} = 1.25''$

As shown on the figure below, the crushed volume will extend into the weld a very short distance on the impacted corner.



PROPRIETARY DATA

The decelleration force exerted on the cask is calculated as the product of the maximum contact surface area and the yield strength of the steel (30,000 psi). The area is calculated:

$$A_U = \frac{\pi ab}{2} - (xy + ab \sin^{1} \frac{x}{a})$$

where for a 45° angle = θ

R = 40.7 in.

a = R/cos 45° = 40.7 ÷ 0.7071 = 57.56

b = R = 40.7 in.

h = 1.78 in.

C = R-h = 40.7 - 1.78 = 38.92

$y = \sqrt{R^2 - C^2} = 11.9$

x = C/cos 45° = 55.04

Sin^1 0.95645 = 73° = 1.274 radians

$$A_U = \pi \frac{(57.56)(40.7)}{2} - [(55.04)(11.9)+(57.56)(40.7) \sin^1 \frac{55.04}{57.56}]$$

= 3679.9 - [655 + 2984.6]

= 40.3 in^2

Decelleration Force = 40.3 x 30,000 = 1,209,000 lb

Decelleration = 1,209,000 ÷ 50,000 = 24.2 g's

The maximum decelleration force will occur with steel having the highest yield strength. The A516, Grade 55 steel used in the HN-100 Series 1 cask may have yield strength as high as 50,000 psi. The decelleration forces based on this value are as follows:

V_S = 600,000 in lbs ÷ 50,000 psi = 12 in^3

ϕ_U = 15° 20'

b = 1.45 inches

A_U = 29.87 in^2

F = 29.87 in^2 x 50,000 psi = 1,493,823 lbs

G = 1,493,823 lbs ÷ 50,000 lbs = 29.87 g

A value of 30 g's is used in the analysis of the effects on the balance of the cask.

PROPRIETARY DATA

2.10.3.2 Effects of Bottom Corner Drop on Balance of Cask

The 30 g decelleration will be transmitted to the outer portions of the cask. This force will be composed of two components, one force will act laterally with respect to the bottom plate. The other component will act axially with respect to the plate.

Summary of cask component weights as used in the following drop analyses

Primary Lid	6,000 lb
Shield Plug	500 lb
Outer Body Shell	6,065 lb
Inner Body Shell	2,010 lb
Bottom Plate	5,900 lb
Lead Shield	13,900 lb
Waste Contents	14,500 lb

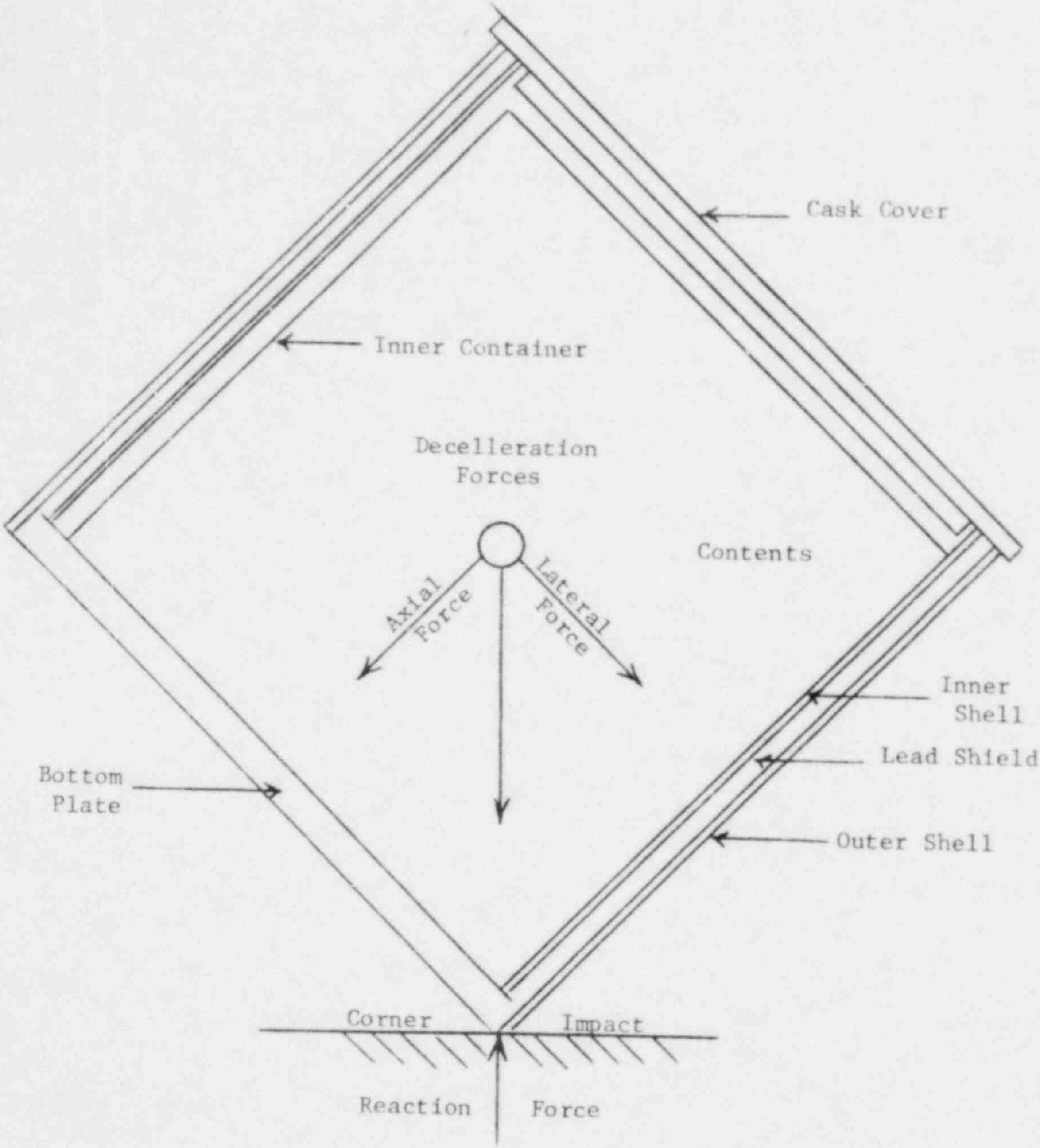
This includes the weight of tiedown lugs, backing plates, etc. The following design criteria and assumptions are the basis for the bottom corner drop analysis. The following load distributions are considered:

1 - Load from primary lid and shield plug will be distributed to the inner and outer shells in accordance with the shell cross sectional areas.

2 - The inner shell will receive loadings at its connection to the upper bottom plate consisting of:

HITTMAN

PROPRIETARY DATA



Bottom Corner Drop

- Load from lid and shield plug

- Load from self weight of inner shell

- Load from waste considered to act on one-half of the shell perimeter nearest corner of impact

- Load from one-half lead shield considered to act on the half of inner shell perimeter not receiving waste loading.

All other loads on the inner shell will be considered to act uniformly around shell perimeter.

3 - The outer shell will receive loadings at its connection to the bottom plate consisting of:

- Load from lid and shield plug

- Load from self weight of outer shell

- Load from one-half of the lead shield considered to act on that half of the shell perimeter nearest the corner of impact

4 - The bottom plate will receive loadings consisting of:

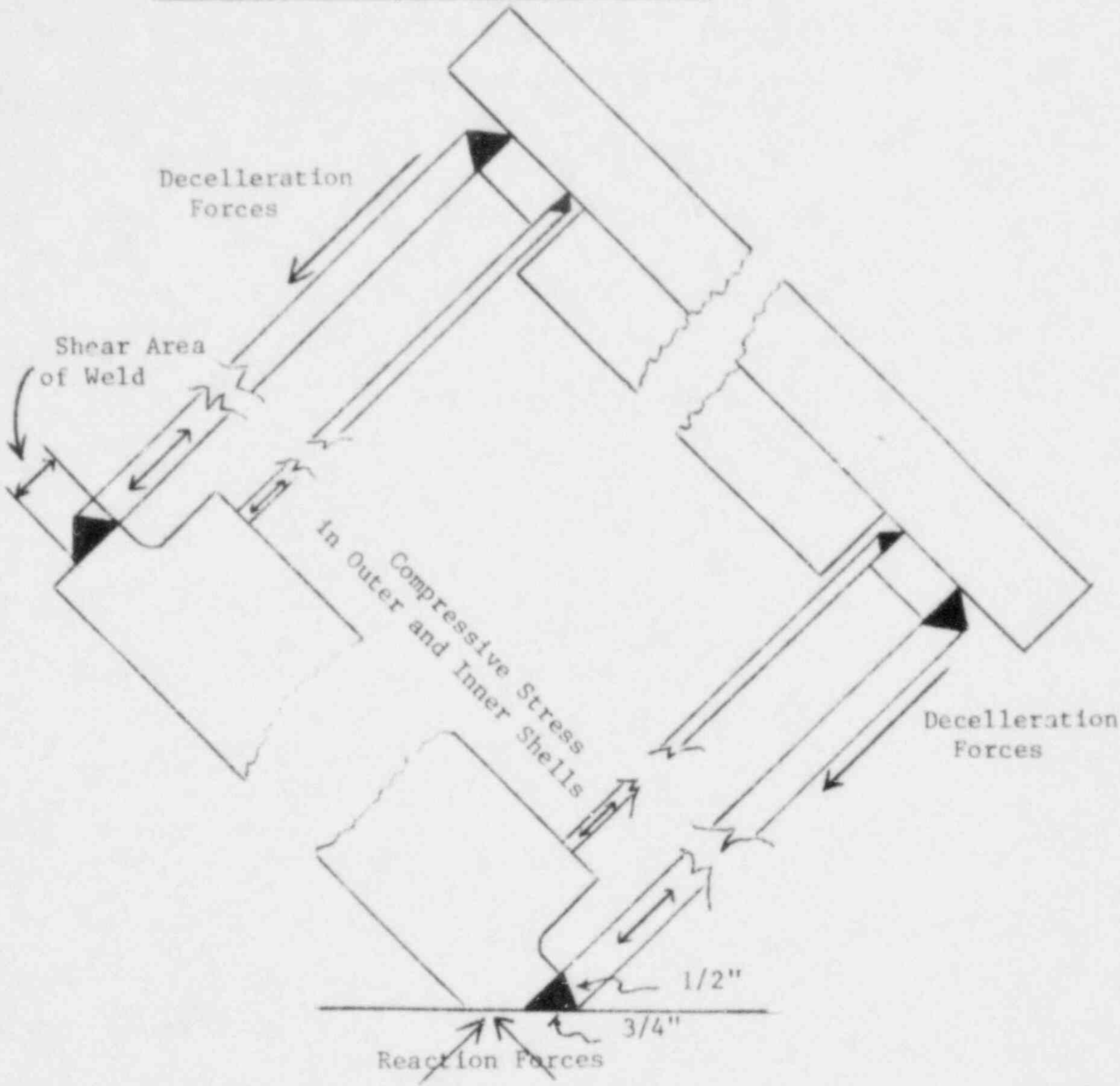
- Loads transferred through the inner shell weld

- Load from self weight of the bottom plate

PROPRIETARY DATA

Cask Analysis

1. Load from Primary Lid and Shield Plug



Loading = (6,000 + 500) 30 = 195,000 lb

Lateral force = 195,000 (sin 45°) = 137,885 lb

Axial force = 195,000 (cos 45°) = 137,885 lb

Inner shell area = $\pi/4(76.25^2 - 75.5^2)$ = 89,388 in^2

Outer shell area = $\pi/4(81.5^2 - 79.75^2)$ = 221.629 in^2

Total Area = 311.017 in^2

Inner area = 89.388/311.017 = 29%

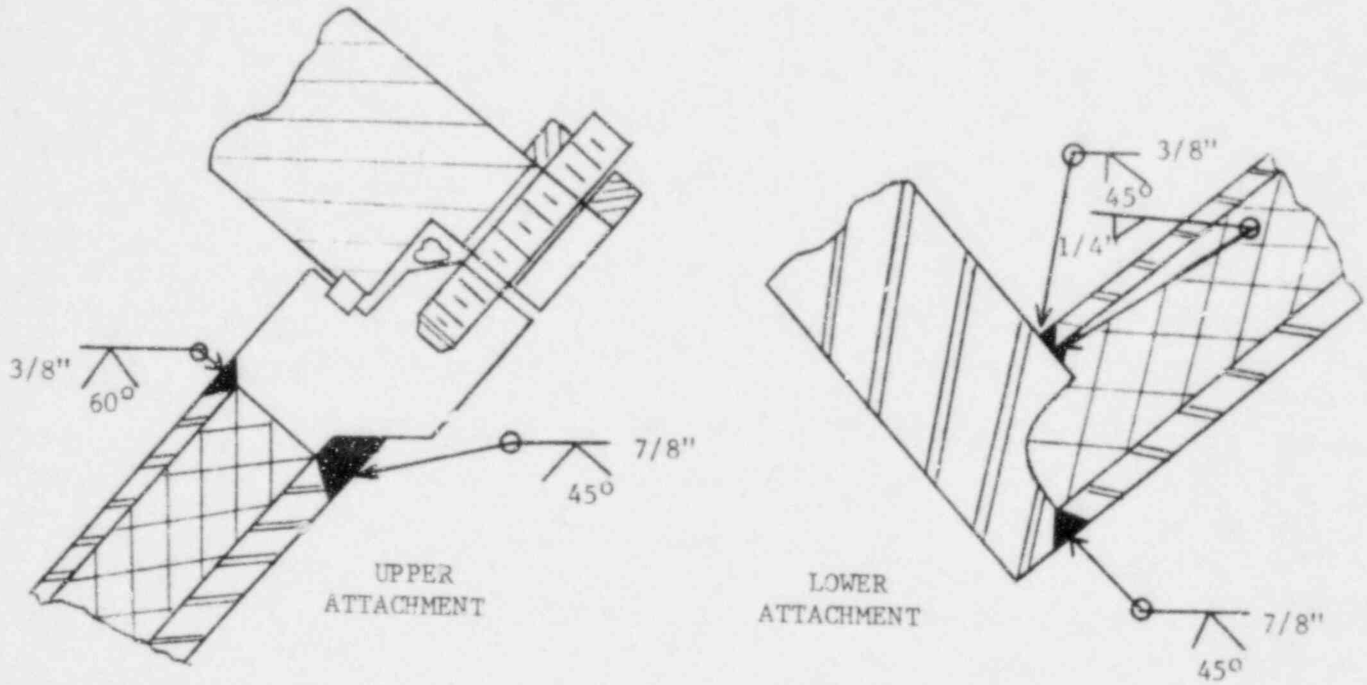
Outer area = 221.629/311.017 = 71%

PROPRIETARY DATA

Force on inner shell = (137,885)(0.29) = 39,986 lb lateral and axial

Force on outer shell = (137,885) (0.71) = 97,898 lb lateral and axial

2. Stresses Developed in Inner Shell and Attachment Welds



Stress in weld around perimeter of inner shell at cask lid

39,986 lb/π(75.5)(3/8)(0.85) = 528 psi

PROPRIETARY DATA

Total Stress = $\sqrt{2}$ (528) = 748 psi

Safety Factor = 20,625/748 = 27.6

Stress in weld connecting inner shell to bottom plate

Total force = ½ self weight of inner shell

+ ½ lid and shield plug (½ of weight acting on ½ of shell)

+ waste

Total force = (2,010/2)(30)(sin 45°)+(39,986/2)+(14,500)(30)(sin 45°)

= 348,903 lb

Lateral Weld Stress = 348,903/π(75.5/2)(2)(3/8)(0.85)

= 4,614 psi (lateral)

Axial weld stress is caused only by lid load and shell self weight

39,986 + 42,638 = 82,624

Axial weld stress = 82,624 lb/π(75.5)(3/8)(0.85)

= 1,093 psi

Total Stress = $\sqrt{4614^2 + 1093^2}$ = 4,741

Axial shell stress = $82{,}624/(76.25^2 - 75.5^2)(\pi/4) = 924$ psi

which is less than weld stress.

Shear shell stress = lateral force/area

$$\frac{[(2{,}010)(30)(\sin 45°) + (39{,}986) + (14{,}500)\ (30)\ (\sin 45°)]}{(76.25^2 - 75.5^2)(\pi/4)(1/2)} = 8{,}730 \text{ psi}$$

Safety Factor = (.577)(42,000)/8,730 = 2.77

3. Stresses Developed in Outer Shell and Attachment Welds

Stress in weld around perimeter of outer shell at cask lid

97,898 lb/π(79.75)(.875)(0.85) = 525 psi both axial and lateral

Total stress $\sqrt{2}$ (525) = 743 psi

Safety Factor = 20,625/743 = 27.75

Stress in weld connecting outer shell to bottom plate

Lateral force = ½ load of outer shell

+ ½ lead shield

+ ½ lid and shield plug (the ½ supported by ½ outer shell)

= (6065/2)(30)(sin 45°) + (97,898/2) + (13,900/2) (30)(sin 45°)

= 260,710

Lateral stress = 260,710/π(79.75/2)(0.875)(0.85) = 2,800 psi

Axial Load = (6065)(30)(sin 45°) + 97,898 = 226,556 lb

Axial Stress = 226,556/π(79.75)(0.875)(0.85) = 1,215 psi

Total Stress in Weld = $\sqrt{(2,800)^2 + (1215)^2}$ = 3,052 psi

Safety Factor = 20,625/3,052 = 6.75

Axial stress in outer shell = 226,556/(81.5^2 - 79.75^2)(π/4)

= 1,022 psi < 42,000 psi yield

Lateral shear stress in outer shell

= 260,710/(81.5^2 - 79.75^2)(π/4)

= 1,176 psi < 24,248 psi yield (shear)

2.10.3.3 Cask Lid Loading-Top Corner Drop

The decelleration forces that will be generated during a top corner drop will be the same as those generated in a bottom corner drop. Since the weight and drop distance are the same, any difference will be due to the yield strength of the steel. Using minimum strength steel (30,000 psi) the 1.78 inch deformation from a corner drop will damage one or two studs at the point of impact but will not affect the integrity of the package. With high strength steel (50,000 psi) to 30 g decelleration force will exert relatively high loads on the closure bolts.

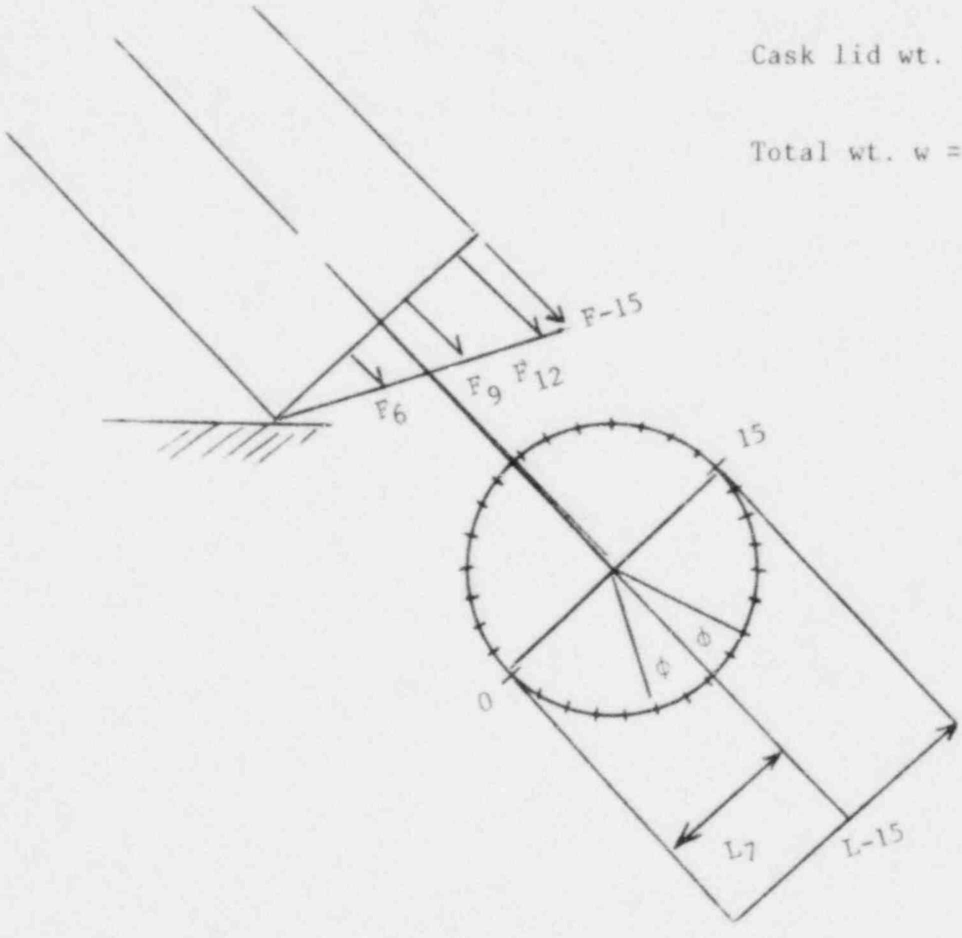
Impact at the upper corner of the cask will result in the cask contents pushing against the cask lid. The contents of the cask, it should be noted are positioned to limit actual movement to one (1) inch or less. The loading on the cask lid is realized in the studs.

The studs stress is therefore equivalent to the inertia load of the contents and the inertia force of the lid itself. The following maximum weights of these constituents have been conservatively estimated. The maximum load will occur with materials having the highest yield strength. A decelleration force of 30 g's has been used in this analysis.

Content wt. = 14,500

Cask lid wt. = 6,500

Total wt. w = 21,000



Impact loading on cask lid closure studs.

PROPRIETARY DATA

The maximum loaded stud is that one furthest from the point of impact. The force acting on this bolt is designated at:

F_{15} = Max. stud force

Taking the summation of moments about point "0."

Sum of stud load = G (Weight Lid + Contents) Cos ϕ x R

The maximum stud load, P_{15}, occurs in the single stud located at L_{15}. The load in the other studs (based on deflection with a rigid lid) will be:

$$L_i = \frac{L_i}{2R} \times P_{15}$$

The moment exerted by the studs can be expressed as:

$$M_i = L_i \times \frac{L_i}{2R} \times P_{15} = \frac{L^2{}_i}{2R} P_{15}$$

The sum of the stud moments will be:

$$2 \left[\frac{L_1{}^2 + L_2{}^2 + L_3{}^2 + L_4{}^2 + \ldots + L_{14}{}^2}{2R} \right] P_{15} + \frac{(2R)^2}{2R} P_{15}$$

$$= [L_1{}^2 + L_2{}^2 + L_3{}^2 + L_4{}^2 + \ldots + L_{14}{}^2 + 2R^2] \frac{P_{15}}{R}$$

$$= [20.37\ R^2 + 2R^2] \frac{P_{15}}{R}$$

$$= 22.37\ R\ P_{15} =$$

$$= (22.37 \times 40.7)\ P_{15} = 910\ P_{15}$$

PROPRIETARY DATA

Where:

$L_1 = R\ (1\text{-}\sin 78°) = 0.0218\ R$	$L_1^2 = .00047\ R^2$
$L_2^2 = R\ (1\text{-}\sin 66°) = 0.0865\ R$	$L_2^2 = 0.0075\ R^2$
$L_3 = R\ (1\text{-}\sin 54°) = 0.191\ R$	$L_3^2 = 0.0365\ R^3$
$L_4 = R\ (1\text{-}\sin 42°) = 0.3309\ R$	$L_4^2 = 0.1095\ R^2$
$L_5 = R\ (1\text{-}\sin 30°) = 0.5\ R$	$L_5^2 = 0.25\ R^2$
$L_6 = R\ (1\text{-}\sin 18°) = 0.691\ R$	$L_6^2 = 0.477\ R^2$
$L_7 = R\ (1 - \sin 6°) = 0.896\ R$	$L_7^2 = 0.802\ R^2$
$L_8 = R\ (1 + \sin 6°) = 1.105\ R$	$L_8^2 = 1.092\ R^2$
$L_9 = R\ (1 + \sin 18°) = 1.309\ R$	$L_9^2 = 1.713\ R^2$
$L_{10} = R\ (1 + \sin 30°) = 1.5\ R$	$L_{10}^2 = 2.25\ R^2$
$L_{11} = R\ (1 + \sin 42°) = 1.669\ R$	$L_{11}^2 = 2.786\ R^2$
$L_{12} = R\ (1 + \sin 54°) = 1.809\ R$	$L_{12}^2 = 3.272\ R^2$
$L_{13} = R\ (1 + \sin 66°) = 1.914\ R$	$L_{13}^2 = 3.661\ R^2$
$L_{14} = R\ (1 + \sin 78°) = 1.978$	$L_{14}^2 = 3.913\ R^2$
$L_{15} = R\ (1 + \sin 90°) = 2R$	$L_{15}^2 = 4\ R^2$
	$L_1^{2}\text{-}_{14} = 20.37\ R^2$

Equating the stud moments to the moment exerted by the contents and cover:

$$910\ P_{15} = (30)(21{,}000)(0.707)(40.7)$$

$$P_{15} = 19{,}921 \text{ lbs}$$

The head studs are one inch in diameter and are fabricated from ASTM A320 Grade L7 or equivalent steel. The studs have a root diameter of 0.8466 inches and an area of 0.563 in^2. The stress in the outer stud will be:

$$f = 19.921 \div 0.563 = 35{,}389 \text{ psi}$$

The yield strength of A320 steel is 105,000 psi and the ultimate strength is 125,000 psi. The safety factor for the studs is:

$$\text{S.F.} = (\text{yield}) = \frac{105{,}000}{35{,}389} = 2.97$$

The maximum elongation will occur at the bolt located in the L_{15} position. The maximum elongation will be:

$$e = \frac{P\ell}{A\varepsilon} = \frac{19{,}921 \times \ell}{0.563 \times 29 \times 10^6}$$

$$e = 0.00122\ell$$

$$\ell = 81.5 - 79.75 = 1.75 \text{ in}$$

$$e = (0.00122)(1.75) = 0.002 \text{ inches}$$

The elongation is a small fraction of the compression of the O ring seal.

2.10.3.4 Stud Spacing

The center-to-center stud spacing is:

$$S = \frac{D \times \pi}{N} = \frac{80.25 \times \pi}{30} = 8.4 \text{ inches}$$

The minimum stud spacing suggested by the cask designers guide is:

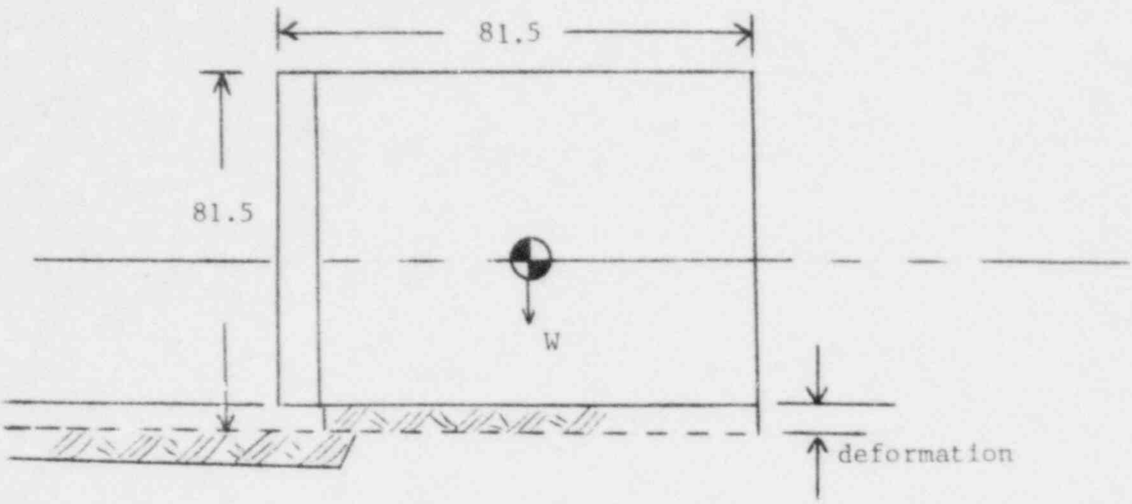
$$S_{min} = \frac{6t}{M + 0.5} + 2a$$

$$= \frac{6 \times 1.75}{1.0 + 0.5} + 2 \times 1 = 7 + 2 = 9 \text{ inch}$$

The spacing of the studs corresponds closely to suggested minimum spacing.

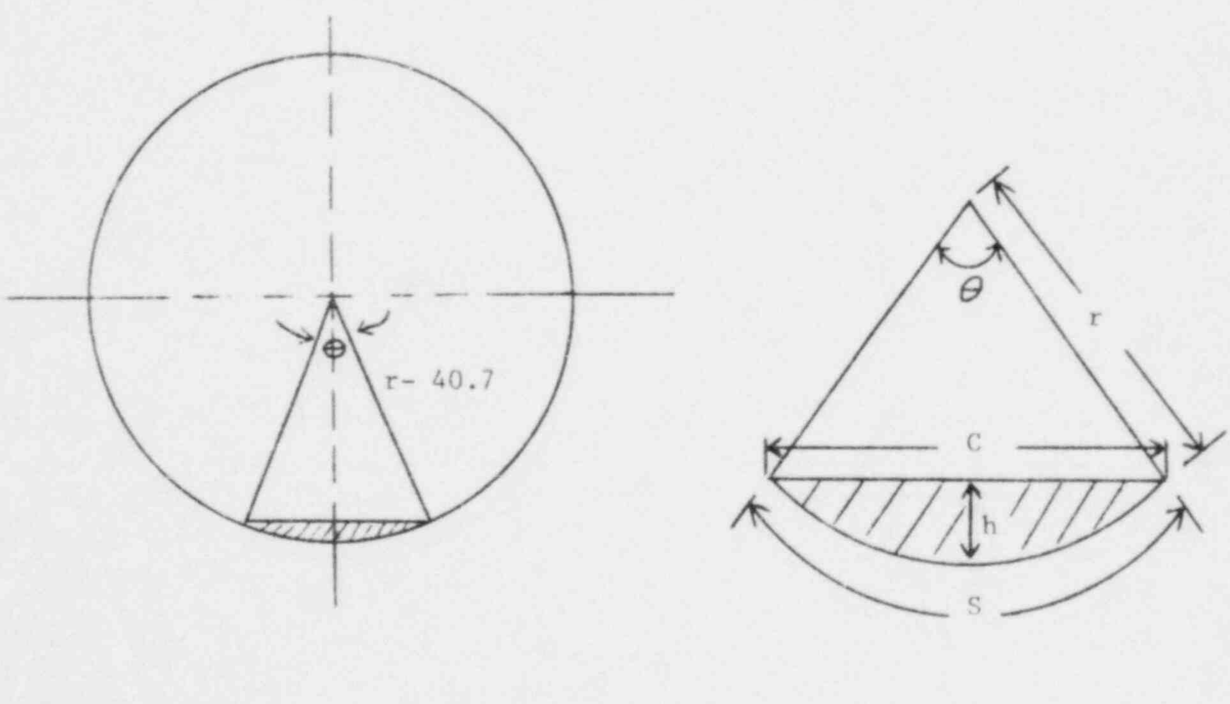
PROPRIETARY DATA

2.10.3.5 Side Drop



(Assumes side drop on entire side, not including flange, to determine maximum decelleration)

Energy (50,000 lb)(12) = 600,000 in-lb



PROPRIETARY DATA

Volume = (600,000 in-lb)/42,000 psi = 14.28 in^3

Area of segment = 14.28 in^3/81.5 in = .1753 in^2

Area = $1/2\ r^2\ (\theta - \sin\theta)$ =>

θ = 0.109 rad = 6.25°

$V = [\frac{1}{2}(40.7)^2(0.109 - \sin 6\frac{1}{4}°)]\ 81.5 = 14.5\ in^3$ (611,555 in-lb)

→102%←

$h = r(1 - \cos \frac{1}{2} A) = 40.7\ [1-\cos(6.25/2)] = 0.060$ in

0.060 in < 0.375 inch outer plate

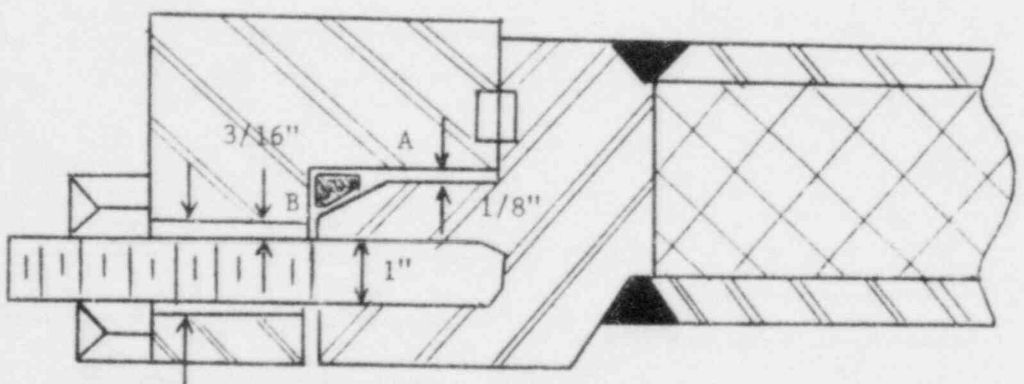
Surface area =>

$C = 2\sqrt{h(d-h)} = 2\sqrt{(0.060)(81.5 - 0.060)} = 4.43$ in

area = (81.5)(4.43) = 361.6 in^2

F = (361.6)(42,000) = 15,187,269 lb

15,187,269/50,000 = 303 g's



The lid will contact at surface "A" before any major shear force is applied to the closure bolts. The lid will take the decelleration forces along the surface at "A" as bearing, and as shear along the plane of where the gasket corner intersects the lid.

The bearing force on the surface at "A."

(6500 lb)(303)/(81.5)(4-1.75) = 57,644
10,740 psi

S.F. = (.9)(42,000)/10,740 = <u>3.5</u>

<u>Shear</u>

Shear area = $(77.5)^2(\pi/4) = 4{,}717 \text{ in}^2$

$\sigma_s = (6{,}500)(303)/4{,}717 = 417.5$ psi

S.F. (.577)(42,000)/417.5 = <u>58</u>

Shear of cask body at surface "A." (Assume only 1/2 of cask body)

$\sigma = (6{,}500)(303)/(1/2)(\pi/4)(82.75^2 - 77.75^2)$

$\sigma = 6{,}250$ psi

S.F. = (.577)(42,000)/6,250 = <u>3.88</u>

2.10.4 Penetration

The minimum outer shell thickness is 7/8 inch and the impact from a 13 pound rod will have no effect on the cask.

2.10.5 Compression

This requirement is not applicable since the package exceeds 10,000 pounds.

PROPRIETARY DATA

3. THERMAL EVALUATION

3.1 Discussion

The HN-100 Series 1 cask will be used to transport waste primarily from nuclear electric generating plants. The principal radionuclides to be transported will be Cobalt-60 and Cesium-137. The shielding on the cask will limit the amount of these materials that can be transported as follows:

Isotope	Gamma Energy mev	Specific Activity (1) µCi/ml	Total Activity (2) Ci
Cobalt-60	1.33	5.0	23.2
Cesium-137	0.66	140.0	650

(1) Based on cement solidified waste at 10 mR at six feet from cask.

(2) Based on 164 cubic feet of solidified material.

3.2 Summary of Thermal Properties of Materials

With the maximum amount of these materials that can be transported in the HN-100 Series 1 cask, the heat generated by the waste will be as follows:

PROPRIETARY DATA

	Heat Generation (watts/curie)	Total Activity (curies)	Total Heat (Watts)	(BTU/hr)
Cobalt	0.0154	23.2	0.35	1.19
Cesium	0.0048	650	3.12	10.7

The weight of waste per container will be about 13,000 pounds. Based on a specific heat of 0.156 BTU per degree F., 2730 BTU's or over 10 days with cesium would be required to heat the waste one degree Fahrenheit. Accordingly, the amount of heat generated by the waste is insignificant.

PROPRIETARY DATA

4. CONTAINMENT

4.1 Containment Boundary

The shipping cask is a vessel which encapsulates the radioactive material and provides primary containment and isolation of the radioactive material from the atmosphere while being transported.

4.1.1 Containment Vessel

The cask is an upright circular cylinder composed of layers of structural steel with lead for radiation shielding, between the steel sheets. The lamina are of 3/8 inch inner shell, 1 3/4 inch of lead shield and a 7/8 inch outer steel shell. The heavy steel flange connecting the annular steel shells at the top provides a seat for a Viton, Buna-N, or equivalent gasket seal used to provide a positive atmospheric isolation when the lid is bolted down by thirty (30) equally spaced 1 inch diameter studs. The shield plug is located in the center of the cask lid, has a Viton, Buna-N or equivalent gasket, and is bolted to the outer portion of the lid with sixteen (16) equally spaced 1/2 inch studs.

4.1.2 Containment Penetrations

The HN-100 series 1 has a drain with plug assembly the latter consisting of a lead filled 1-1/2 inch steel pipe and pipe plug. The drain port is located at the perimeter in the cask wall just above the cask's bottom plate. The penetration hole is angled laterally at 45° to prevent shine, should the plug be removed while waste is in the cask.

4.1.3 Seals and Welds

Both the primary lid and secondary shield plug are sealed by means of a Viton, Buna-N, or equivalent material "O"-ring.

4.1.4 Closure

The forgoing procedures for the primary lid require each stud to be tightened to 190 ft-lb to 210 ft-lb.

The equivalent tension (F) in each stud is

$$F = T/Kd$$

where

T is the torque

d is the stud diameter, and

K is the torque coefficient (= 0.15)

Therefore,

$$F = (210 \text{ ft-lb})(12 \text{ in/ft})/(0.15)(1 \text{ in})$$

$$F = 16{,}800 \text{ lb/stud.}$$

The weight of the lid and shield plug is 6,500 lb.

Total force exerted on the gasket ring is:

(30)(16,800) + 6500 = 510,500 lb

Area of "O" Ring = (78 in) (π)(1/2 in) = 122.5 in^2

Total pressure on gasket material

510,500/122.5 in^2 = 4166 psi

The torquing procedure values ensure that there is sufficient pressure on the gasket to seal the cask.

Similarly, the shield plug torquing requirement is 35 to 40 ft-lb.

F = (40 ft-lb)(12 in/ft)/(0.15)(0.5 in)

F = 6400 lb/stud.

Weight of the shield plug is 500 lb. Total force on shield plug gasket is (6400 lb)(16 studs) + 500 102,900 lb.

Area of gasket = (18.125)(π)(.375) = 21.35 in^2

Pressure on gasket = 102,900/21.35
= 4820 psi

This is sufficient to maintain the gasket seal.

PROPRIETARY DATA

4.2 Requirements for Normal Conditions of Transport

4.2.1 Release of Radioactive Material

An internal pressure of 7.5 psig is the normal condition that may cause a release of radioactive material.

The force exerted on the primary lid from a 1/2 an atmosphere differential pressure is:

$$(7.5\ \text{lb/in}^2)\ (75.5\ \text{in})^2(\pi/4) = 33,577\ \text{lb}$$

on a per stud basis,

$$33,577\ \text{lb}/30\ \text{studs}\ \ 1120\ \text{lb/stud}$$

Add this force to the pre load,

$$1120 + 16,800 = 17,920\ \text{lb}.$$

$$\delta = \frac{PL}{AE} = \frac{(17,920\ \text{lb})(2.25\ \text{in})}{(.844)^2(\pi/4)(29 \times 10^6)} = 0.0025\ \text{in}$$

This is very small and not enough to break the gasket seal and significantly reduce the package effectiveness.

Similarly, the shield plug experiences a force of

$$(7.5\ \text{lb/in}^2)(16.5\ \text{in})^2(\pi/4) = 1605\ \text{lb}$$

On a per stud basis,

$$1605\ \text{lb}/16\ \text{studs} = 100.3\ \text{lb/bolt}$$

PROPRIETARY DATA

Added to the pre-load tension

100.3 + 6400 = 6500 lb/stud

$$\delta = PL/AE = (6500)(1.25)(.4041)^2(\pi/4)(29\times10^6)$$
$$= .0022 \text{ in}$$

This distance is too small to break the seal and signficantly reduce the package effectiveness.

4.2.2 Pressurization of Containment Vessel

Due to the nature of the waste contents, no vapors or gases could form to pressurize the vessel and significantly reduce the package effectiveness.

4.2.3 Coolant Contamination

The vessel contains no primary coolant, therefore this section is not applicable.

4.2.4 Coolant Loss

The vessel contains no primary coolant, therefore this section does not apply.

4.3 Containment Requirements for the Hypothetical Accident Conditions

This section does not apply since the vessel is not a type B package.

5. SHIELDING EVALUATION

5.1 Discussion and Results

The analysis was performed using the SPAN 4 computer code. This code, developed by the U.S. Atomic Energy Commission, is under limited distribution regulations, detailed descriptions of the code calculations are prohibited by the government.

5.2 Source Specification

The primary analytical parameter during the analysis was the Department of Transportation shipping limit of 10 MR/hr at a distance of two meters from the cask surface. Packaging conditions of both solidified waste and dewatered resin were considered. The allowable contents are shown both in terms of the specific activity of the waste form, and the surface radiation levels (for the large containers).

5.3 Model Specification

SPAN 4 calculates gamma-ray flux in rectangular, cylindrical and spherical geometries by integrating appropriate exponential kernals over a source distribution. The shield configuration is flexible -- a first-level shield mesh using any one of the three geometries is specified. Regions of this same geometry or of other geometries having their own (finer) meshes, may then be embedded between the first-level mesh lines defining second-level shield meshes. This process is telescopic -- third-level shield meshes may be embedded between second-level meshlines

PROPRIETARY DATA

in turn. All meshes may have variable spacing. Sources may be located arbitrarily with respect to any shield mesh.

All kernals used assume exponential attenuation. By ray training, the straight-line distances between points in the source and close points are found to be used in calculating the attenuation. Integrals are evaluated by Gouss-Lengendre or Lobatto quadrature. Accuracy is dependent on the accuracy of the library data and on the orders of quadrature used.

5.4 Shielding Evaluation

The graphs presented in Appendix 5.5 document the shielding capabilities of the HN-100 casks as analyzed by the SPAN 4 computer code. The specific activity is given in μCi/ml; for ease of use the usage waste volume of the container is given below.

Container	Usable Volume (cf)	Maximum Dewatered Resin Prior to Soldification (cf)
HN-100-1	136 (125.4)*	103
Drum	7.3	-

*Volume in parenthesis represents a maximum solidified waste volume that is less than usable volume due to weight limitations.

PROPRIETARY DATA

5.5 Appendix

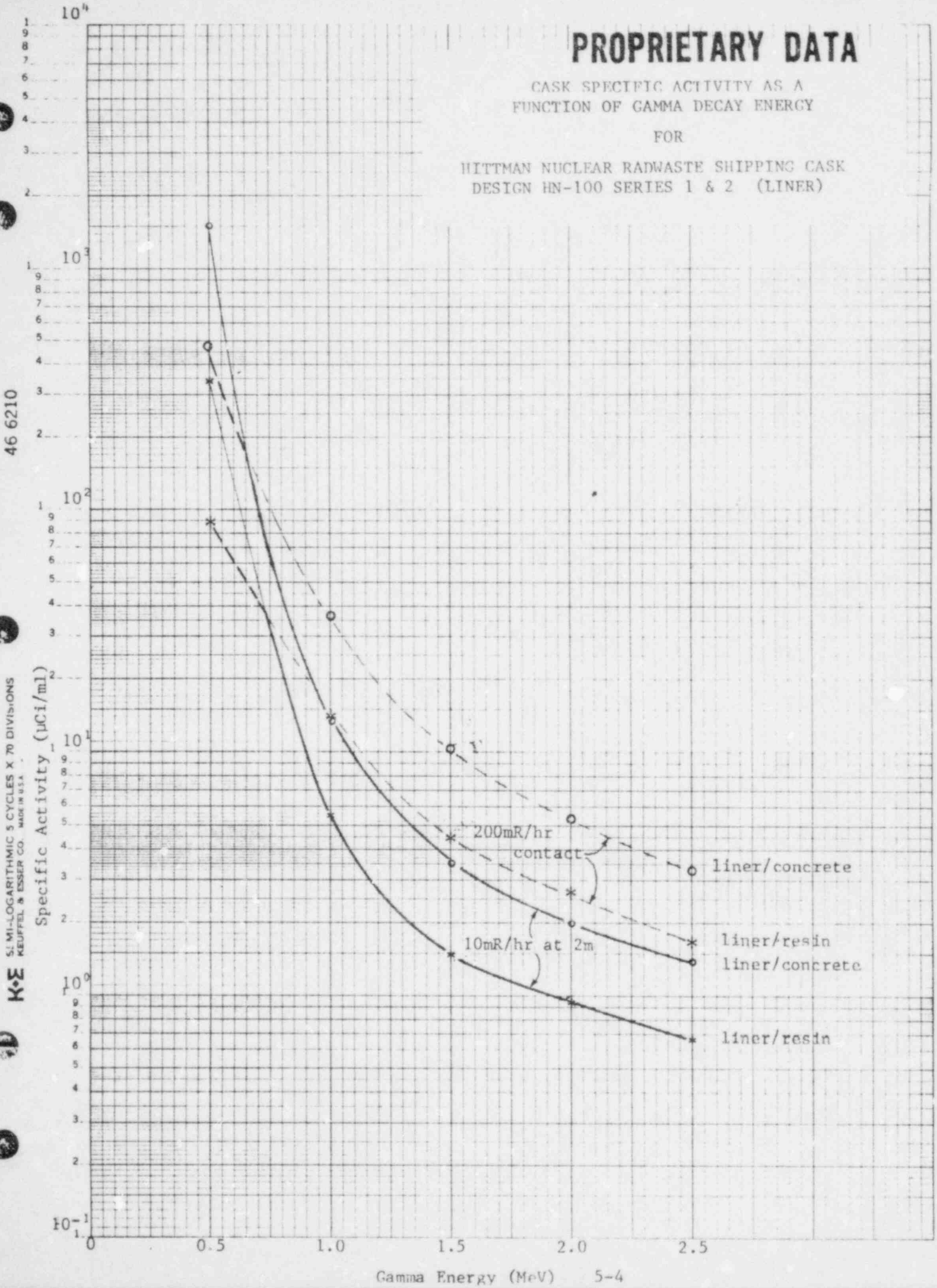
Shielding Capabilities

5.5.1 Cask Specific Activity as a Function of Gamma Decay Energy for Hittman Nuclear Radwaste Shipping Cask, Design HN-100 Series 1 and 2.

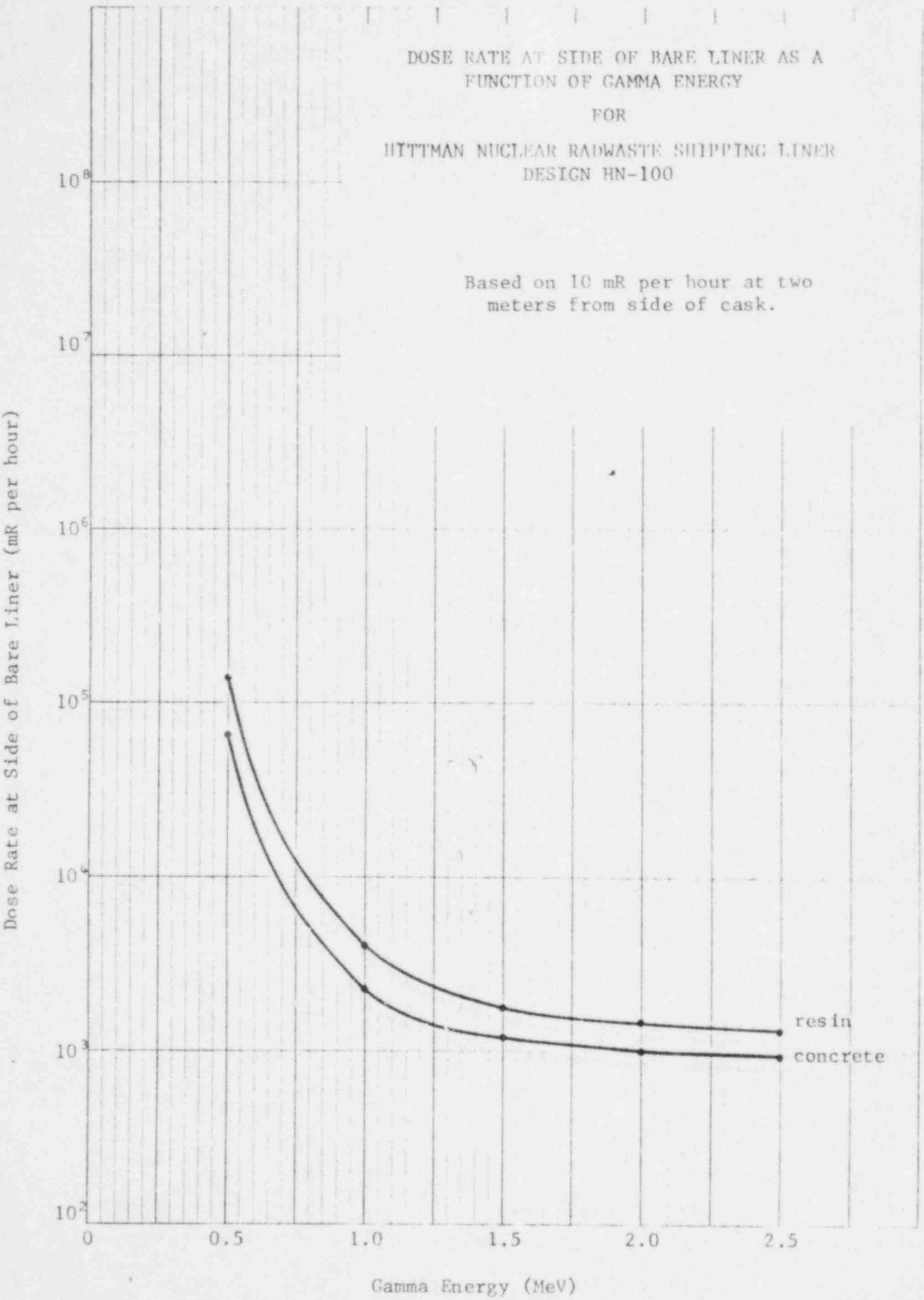
5.5.2 Dose Rate at Side of Bare Liner as a Function of Gamma Energy for Hittman Nuclear Radwaste Shipping Liner, Design HN-100.

5.5.3 Cask Specific Activity as a Function of Gamma Decay Energy for Hittman Nuclear Radwaste Shipping Cask, Design HN-100 Series 1 and 2 (Drums).

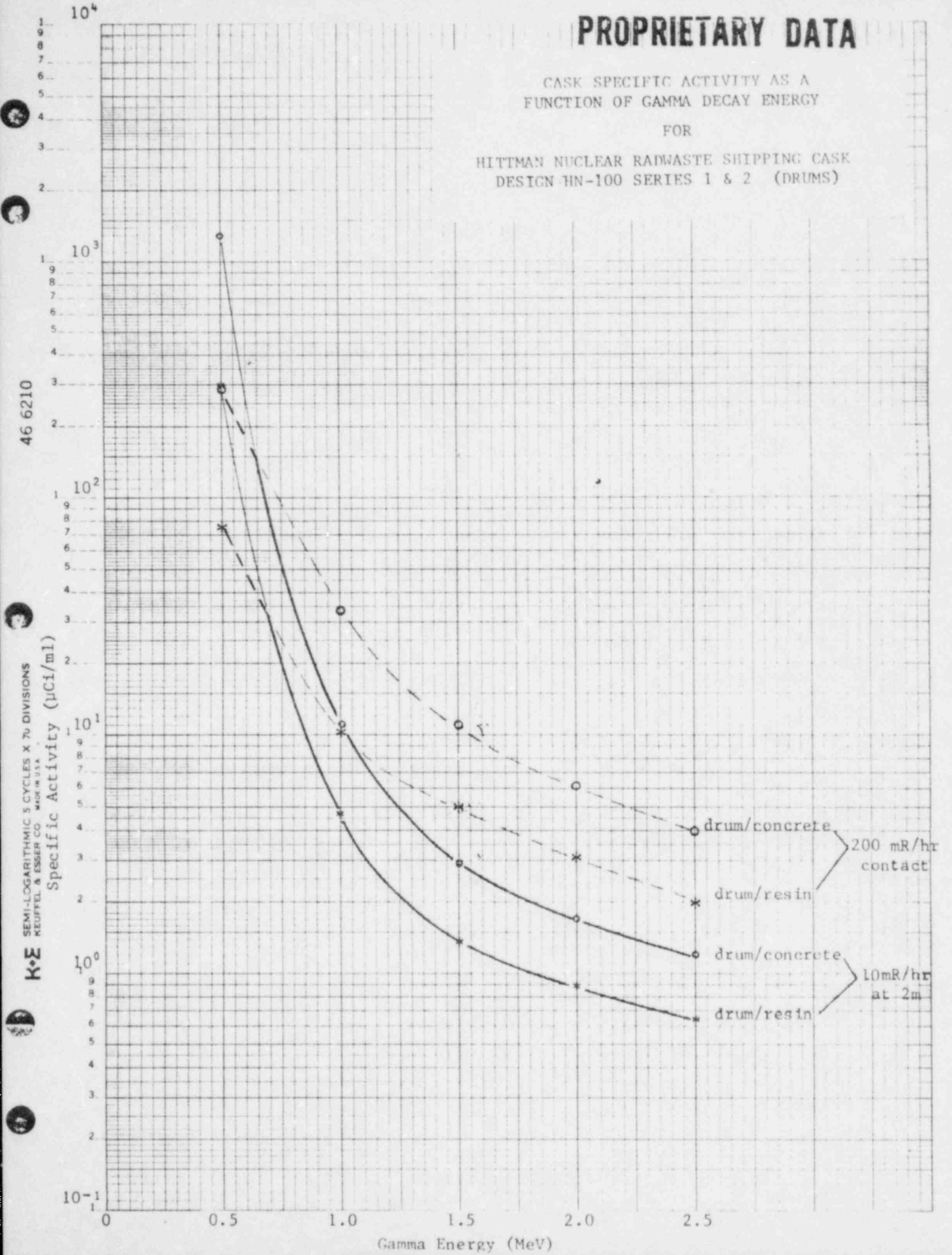
PROPRIETARY DATA



PROPRIETARY DATA



HITTMAN


PROPRIETARY DATA
CASK SPECIFIC ACTIVITY AS A
FUNCTION OF GAMMA DECAY ENERGY
FOR
HITTMAN NUCLEAR RADWASTE SHIPPING CASK
DESIGN HN-100 SERIES 1 & 2 (DRUMS)
drum/concrete
drum/resin
200 mR/hr contact
drum/concrete
drum/resin
10mR/hr at 2m
Specific Activity (μCi/ml)
Gamma Energy (MeV)
0
0.5
1.0
1.5
2.0
2.5
10^4
10^3
10^2
10^1
10^0
10^{-1}
46 6210
K+E SEMI-LOGARITHMIC 5 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.

PROPRIETARY DATA

6. CRITICALITY EVALUATION

Not applicable.

7. OPERATING PROCEDURES

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. Included in this manual are the weight limitations, and type and quantity of licensed material limitations. The operating procedures describe the inspection of the trailer and cask upon arrival at the site, the opening, loading, closing procedures, and the forms that need to be filled out prior to the cask leaving the customer's site. An example is shown in Appendix A. This is all in accordance with Subpart D to 10 CFR 71.

Inspections performed under the operating procedure are done by the customer prior to loading. The cask, by the driver prior to leaving the site, at scheduled stops during transit, and after arriving at the co-signee's site. Inspection includes that cask has not been significantly damaged, closure of the package and any sealing gaskets are present and free of any defects, checking of the maximum loose and fixed contamination levels on the cask, and that the cask has been loaded and closed in accordance with written procedures. This is all in accordance with Section 71.54 of Title 10.

Radioactive Shipment Record describing the shipment and giving the information required by Section 71.62 of the Title 10 are required to be filled out in Triplicate. One copy is telecopied to HITTMAN prior to shipment leaving the site and a copy is mailed to HITTMAN as soon as possible after the shipment leaves the site. The other two copies accompany the shipment to the cosignee. An example is contained in Appendix 7.1.

PROPRIETARY DATA

7.1 Appendix

Cask Handling Procedure

PROJECT COVER SHEET

Document Title

CASK HANDLING PROCEDURE

Project Document Number

HNDC-0-001-1, Rev. 2

for

HN100S and HN100 Series 1

Shielded Transport Cask

Hittman Nuclear & Development Corporation
9190 Red Branch Road
Columbia, Maryland 21045

Ref: Std. Doc. N/A Rev. ____

REVISION LOG

REV.	DATE	ENGINEERING	Q.A.	PROJ. MGR.	ECN #
2	1/17/80	[signature]	[signature]	[signature]	--

I. PURPOSE

The purpose of this procedure is to provide instructions for loading/unloading the HN100 Series 1 and HN100S radioactive waste shipping casks.

II. RESPONSIBILITY

It is the responsibility of the user of a United States Nuclear Regulatory Commission (USNRC) certified package (cask) to assure the following:

1) He has the Certificate of Compliance for the cask and all referenced documents.

2) He is a registered user of the certified cask.

3) Under his Quality Assurance Program, the cask is inspected to verify its compliance with the terms and conditions of the Certificate of Compliance.

4) The cask is loaded and closed in accordance with an appropriate written procedure.

5) The cask is loaded in accordance with the Certificate of Compliance.

6) The shipment meets all the Department of Transportation, U.S. Nuclear Regulatory Commission, Burial Site Disposal Criteria and Burial Site License requirements.

NOTE: If there is a problem meeting any of the above requirements, immediately notify the regional HNDC Operations Office.

III. PROCEDURE

1.0 When ordering the cask, assure the following:

1.1 Waste to be shipped in the cask is either Low Specific Activity [49 CFR 173.389(c)] or Type A quantities of Normal or Special Form [49 CFR 173.389(d), 49 CFR 173.389(g) and 49 CFR 173.389(1)].

1.2 Burial site disposal criteria and/or licenses and current copies of 10 CFR and 49 CFR are in your possession.

1.3 Waste is packaged or will be packaged in an acceptable manner in accordance with the Department of Transportation (49 CFR), U.S. Nuclear Regulatory Commission (10 CFR), and the applicable burial site requirements (burial site Didposal Criteria and/or Licenses).

1.4 Certificate of Compliance USA/9086/A for the HN100 Series 1 or USA/9089/A for the HN100S and all referenced documents are in your possession and your site is a registered user of the cask.

1.5 Your site has an approved U.S. Nuclear Regulatory Commission Quality Assurance Program in accordance with 10 CFR 71.51.

NOTE: If there is a problem assuring any of the above, immediately notify the regional HNDC Operations Office.

2.0 Receipt Inspection

2.1 Survey the empty cask and the vehicle to determine the maximum loose and fixed contamination levels.

Loose contamination levels should be less than 2,200 DPM/ 100 cm^2 Beta-Gamma and less than 220 DPM/100 cm^2 Alpha.

Fixed contamination levels should be less than 0.5 mrem/hr. NOTE: Fixed contamination greater than 0.5 mrem/hr but less than 50 mrem/hr require the cask to have a Yellow II lable. Under such conditions the empty cask must be a Radioactive Shipment and be accompanied by properly completed Radioactive Shipment Records.

NOTE: If cask is received with contamination levels in excess of those above immediately notify the regional HNDC Operations Office.

2.2 Inspect Tiedowns

2.2.1 Inspect tiedown lugs and shackles on cask and trailer for cracks and wear which would affect their strength.

2.2.2 Inspect tiedown cables to assure they are not loose, or damaged (frayed, crimped, etc.).

2.2.3 Inspect tiedown ratchets/turnbuckles to assure they are in proper working condition.

NOTE: If there is a problem with any of the items inspected, immediately notify the regional HNDC Operations Office.

2.3 Inspect Cask

2.3.1 If cask is equipped with raincover, remove raincover and inspect cask lid holddown nuts to assure all 30-1" nuts are present and undamaged.

2.3.2 Check to assure that cask lid (primary lid and shield plug) lifting lug covers are with the cask.

2.3.3 Remove cask lid in accordance with step 4.1.

2.3.4 Inspect primary lid holddown studs for damage.

2.3.5 Inspect primary lid gasket for cracks or tears which would affect proper sealing.

NOTE: Cask must be properly sealed prior to shipment.

2.3.6 Inspect interior of cask for standing water.

NOTE: Water must be removed prior to shipment.

2.3.7 Inspect interior of cask for obstructions to loading.

2.3.8 Inspect interior of cask for defects which might affect the cask integrity or shielding afforded by cask.

2.3.9 Inspect the shield plug holddown nuts to assure they are all present and not damaged.

2.3.10 Unless it can be verified through other means, verify that the shield plug gasket has no cracks or tears which would affect proper sealing as follows:

2.3.10.1 Remove the shield plug from the primary cask lid in accordance with steps 4.2.3.6, 4.2.3.7 and 4.2.3.8.

2.3.10.2 Inspect the shield plug holddown studs for damage.

2.3.10.3 Inspect the shield plug gasket for cracks or tears which would affect proper sealing.

NOTE: Cask must be properly sealed prior to shipment.

2.3.11 If loading drums, install shield plug (if removed) onto primary lid in accordance with steps 4.2.3.11 4.2.3.12 and 4.2.3.13 and proceed to step 4.2.1 or 4.2.2.

2.3.12 If loading preloaded liners, install shield plug (if removed) onto primary lid in accordance with steps 4.2.3.11, 4.2.3.12 and 4.2.3.13 and proceed to step 4.2.4.

2.3.13 If loading waste into liner inside cask, proceed to step 4.2.3 (omitting steps 4.2.3.6, 4.2.3.7 and 4.2.3.8 if shield plug was removed).

NOTE: If there is a problem with any of the items inspected above, immediately notify the regional HNDC Operations Office.

3.0 Removal of Cask from trailer

NOTE: If it is necessary to remove cask from trailer proceed as follows:

3.1 Loosen ratchet binders/turnbuckles as necessary to remove pins from shackles at cask end of tiedown system.

3.2 Remove pins from shackles.

3.3 Loosen cask shear blocks as necessary.

3.4 Using the (3) cask lift lugs and suitable rigging lift cask off trailer and place cask in proper position for loading.

Cask Weight - HN 100 Series 1 - 35,500 lbs.
HN 100 S - 26,000

NOTE: Do not use cask lid lifting lugs to lift the cask.

4.0 Loading Cask

4.1 Remove the primary full diameter cask lid as follows:

4.1.1 If cask is equipped with a raincover, and it has not been removed, remove the raincover from the cask.

4.1.2 Disconnect the cask lid from the cask by removing the 30-1" holddown nuts.

4.1.3 Remove the three (3) cask lid lifting lug covers.

4.1.4 Using the three lifting lugs to accommodate suitable rigging and exercising caution in the handling of the cask lid due to possible contamination of the underside of the lid, remove the cask lid.

Lid Weight HN100 Series 1 - 6,000 lbs
HN100S - 3,770 lbs

4.2 Loading can be accomplished by one of the following methods:

4.2.1 In cask loading of seven (7) drum pallets.

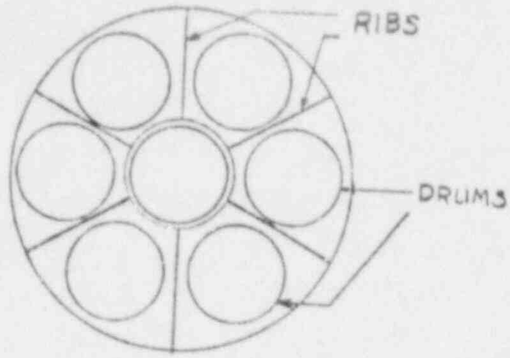
NOTE: Review Pre-release Checklist (Attachment 1) or similar site document and shipping papers to assure that inspections required on checklist or site document are performed during the cask loading process as necessary and that the information required on the shipping papers is determined as necessary.

4.2.1.1 Using the slings provided and exercising caution in the handling of the pallet due to possible contamination, remove the top pallet from the cask.

Pallet Weight - 750 lbs

4.2.1.2 Exercising caution to avoid placing drums on the pallet lift slings, load seven (7) drums on the pallet in the cask.

Maximum Drum Weight - 800 lbs



RIBBED PALLET

SKETCH 1

NOTE: 1. New pallets are ribless, but should be loaded with the same drum pattern.

2. For maximum shielding, load higher dose rate drums in the center position and the positions toward the front and rear of the trailer.

4.2.1.3 Place the top pallet back into the cask.

Pallet Weight - 750 lbs

4.2.1.4 Exercising caution to avoid placing drums on the pallet lift slings, load seven (7) drums on the pallet in the cask (see Sketch 1).

4.2.1.5 Proceed to Step 4.2.5.

4.2.2 Loading the seven (7) drum pallets outside the cask.

NOTE: Review Pre-release Checklist (Attachment 1) or similar site document and the shipping papers to assure that inspections required on the checklist or site document are performed during the cask loading process as necessary and that information required on the shipping papers is determined as necessary.

4.2.2.1 Using slings provided and exercising caution in the handling of the pallet due to possible contamination, remove both the pallets from the cask.

Pallet Weight - 750 lbs

4.2.2.2 Load seven (7) drums onto each pallet (see Sketch 3).

Maximum Drum Weight - 800 lbs

4.2.2.3 Lift one of the loaded pallets and place it inside the cask. For maximum shielding, assure proper orientation of pallet (see Note 2 of Sketch 1).

Maximum Loaded Pallet Weight - 6,400 lbs

4.2.2.4 Lift the other loaded pallet and place it inside the cask on the top of the first pallet. For maximum shielding, assure proper orientation of pallet (see Note 2 of Sketch 1).

Maximum Loaded Pallet Weight - 6,400 lbs

4.2.2.5 Assure easy access to the pallet lifting slings for removal of pallet at burial site.

4.2.2.6 Proceed to Step 4.2.5.

4.2.3 In cask loading of liner

NOTE: Review Pre-release Checklist (Attachment 1) or similar site document and shipping papers to assure that inspections required on checklist or site document are performed during the cask loading process as necessary and that the information required on the shipping papers is determined as necessary.

4.2.3.1 If necessary remove cask from trailer in accordance with steps 3.1 through 3.4.

4.2.3.2 Using the slings provided, place liner in the cask.

Empty Liner Weight - 1,350 lbs

4.2.3.3 Install shims/shoring between liner and cask as necessary to secure in position.

4.2.3.4 Using the three (3) lifting lugs on the cask lid to accommodate suitable rigging lift and place cask lid on cask using alignment pins to assure proper positioning.

Lid Weight - HN100 Series 1 - 6,000 lbs
HN100S - 3,700 lbs

4.2.3.5 Secure the cask lid to the cask as follows:

4.2.3.5.1 Install the 30-1" holddown nuts.

4.2.3.5.2 Tighten the holddown nuts in accordance with Torquing Procedure HNDC-0-1001 or HNDC-0-100S as appropriate.

4.2.3.6 Remove shield plug holddown nuts.

4.2.3.7 Remove the shield plug lifting lug cover.

4.2.3.8 Exercising caution due to possible contamination of the underside of the shield plug, remove the shield plug.

Shield Plug Weight -

HN100 Series 1	- 500 lbs
HN100S	- 230 lbs

4.2.3.9 Load the waste into the liner through the shield plug opening.

4.2.3.10 Install the liner lid, plugs or caps onto the liner.

4.2.3.11 Place the shield plug on the cask using the shield plug guide pins for proper positioning.

NOTE: Care should be taken to avoid damage to the gasket.

Lid Weight - HN100 Series 1 - 500 lbs
HN100S - 230 lbs

4.2.3.12 Secure shield plug as follows:

4.2.3.12.1 Install the 16-1/2" shield plug holddown nuts.

4.2.3.12.2 Tighten the shield plug holddown nuts in accordance with Torquing Procedure HNDC-0-1001 and HNDC-0-100S as appropriate.

4.2.3.13 Install the shield plug lifting lug cover.

4.2.3.14 If cask is equipped with raincover and the cask was not removed from trailer, install raincover.

4.2.3.15 Proceed to Step 5.0 of this procedure if cask was removed from trailer. Otherwise proceed to Step 6.0.

4.2.4 Loading preloaded liner.

NOTE: Review Pre-release Checklist (Attachment 1) or similar site document and the shipping papers to assure that inspections required on the checklist or site document are performed during the cask loading process as necessary and that information required on the shipping papers is determined as necessary.

4.2.4.1 If necessary, remove cask from trailer in accordance with Step 3.1 through 3.4.

4.2.4.2 Assure lid, plugs or caps are is installed on liner.

4.2.4.3 Using the lifting slings provided, place liner into the cask.

Full Liner Weight -
HN100 Series 1 - 14,500 lbs. maximum
HN100S - 17,000 lbs maximum

4.2.4.4 Install shims/shoring between liner and cask as necessary to secure in position.

4.2.5 Install the primary full diameter cask lid as follows:

4.2.5.1 Using the three (3) lifting lugs on the cask lid to accommodate suitable rigging, lift the cask lid and place it on the cask using the alignment pins for proper positioning.

Lid Weight - HN100 Series 1 - 6,000 lbs
HN100S - 3,770 lbs

4.2.5.2 Secure the cask lid in accordance with Step 4.2.3.5.

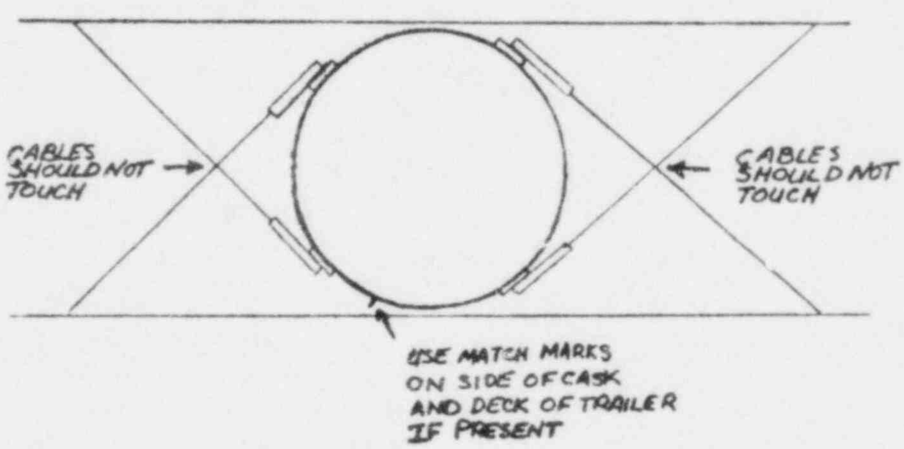
4.2.5.3 Install tamper-proof seals.

4.2.5.4 If cask is equipped with raincover, install raincover.

5.0 If cask was removed from trailer, proceed as follows:

5.1 Using the three (3) cask lift lugs and suitable rigging lift cask and place cask in proper position on trailer. See Sketch 2 for proper orientation.

Loaded Cask Weight -
HN100 Series 1 - 50,000 lbs
HN100S - 43,000 lbs



SKETCH 2

5.2 Install shackles through the end of the tiedown cables and attach to cask tiedown lugs by screwing pin through shackle and hole in lug.

5.3 Tighten the cask shear blocks to secure the cask in position.

5.4 Tighten ratch binders/turnbuckles as necessary to secure cask on trailer.

5.5 If cask is equipped with raincover, install raincover.

6.0 Prepare cask and vehicle for shipment as follows:

6.1 Perform Radiation surveys of cask and vehicle and complete the necessary shipping papers, certifications, and Pre-release Checklist (Attachment 1) or site equivalent.

6.2 Placard vehicle and label cask as necessary.

7.0 Unloading Cask

7.1 Survey the cask and trailer in accordance with applicable site requirements.

7.2 Remove cask lid in accordance with Step 4.1 of this procedure.

7.3 Exercising caution due to possibly high dose rate, connect slings from liner or pallet to a suitable lifting device.

Maximum liner weight - 17,000 lbs
Maximum pallet weight - 6,400 lbs

7.4 Exercising caution due to possible high dose rate, lift liner or pallet clear of the cask and place in disposal area.

NOTE: Care should be taken to avoid damage to lid gasket.

7.5 Repeat Steps 7.3 and 7.4 for second pallet.

7.6 Install cask lid in accordance with Step 4.2.5 of this procedure.

7.7 Survey the cask and trailer for release in accordance with applicable site requirements.

PRE-RELEASE CHECKLIST

Date ______________________________

Shipment No. ______________________

Transport Co. ____

Time of Arrival at Site ______________________________________

Time of Departure from Site __________________________________

		Initial
1.	Inner Container(s) Sealed	______
2.	Inner Container(s) Secured in Place	______
3.	All gaskets and gasket sealing surfaces inspected and free of defects	______
4.	Cask Lid and/or Shield Plug Closure Bolts Torqued/Ratchet Binders Tightened	______
5.	Tamper-proof Seal Inspected	______
6.	Lift Lugs Covers Installed	______
7.	Cask Tiedowns Inspected	______
8.	Cask Properly Labeled	______
9.	Vehicle Properly Placarded	______
10.	Surveys Completed and Recorded	______
11.	Shipping Papers Properly Filled Out and Signed	______

Signature____________________

Title________________________

Date_________________________

ATTACHMENT 1

8. ACCEPTANCE TESTS AND MAINTENANCE PROGRAM

8.1 Acceptance Tests

Materials are specified under the ASTM and ASME codes. Welder qualifications and weld procedures are in accordance with ASME or AWS Codes. Non-destructive testing of specified welds includes visual, liquid penetrant, or magnetic particle as described in the ASTM Code. Upon completion of the lead shielding pour, a gamma scan is done of the cask wall to determine lead thickness, and an existence of any voids or impurities in the poured lead. The gamma scan contains an acceptance criteria for verification that nominal lead thickness is 1-3/4 inches.

The HN-100 Series 1 casks were pressure tested when originally fabricated to verify the adequacy of the seals and cask when subjected to an internal pressure.

8.2 Maintenance Program

Cask maintenance and repair is controlled by the Quality Assurance Program. The casks and trailers undergo a routine technical inspection at least once every four months. These inspections involve checking cask for contamination, damage to interior or exterior, gaskets, studs, signs and placards, shielding and tiedowns. These inspections are covered by Cask Maintenance and Repair procedures. An example is shown in Appendix 8.3.

8.3 Appendix

Cask Maintenance and Repair Procedure

HITTMAN NUCLEAR & DEVELOPMENT CORPORATION	Document Number: HNDC-O-001	Rev: 0	Rev Date: 3/16/81
	Title: Cask Maintenance & Repair		

Rev.	Rev Date	Director Operations	Maintenance Supervisor	Quality Assurance Manager			
0	3/16/81	[signature]	[signature]	[signature]			

No.	Rev.	Date	Title:
HNDC-O-001	0	3/16/81	Cask Maintenance & Repair

1.0 PURPOSE

This procedure describes the administrative controls to be exercised over the periodic maintenance and repair of radwaste shipping packages.

2.0 GENERAL

2.1 The administrative controls described herein shall apply to the following maintenance activities:

a) periodic maintenance and parts replacement required by the package approval and/or necessary to maintain the package in a mechanically safe and sound condition in conformance with the package approval;

b) repair of nonconforming package structures, components, parts or appurtenances as necessary to return those items to a condition in conformance with the package approval.

2.2 The requirements of this procedure do not apply to routine inspections of packages required prior to shipment of radioactive material.

2.3 Primary responsibility for implementing the requirements set forth in this procedure rests with the Maintenance Supervisor.

2.4 The Maintenance Supervisor shall be responsible for the assignment and supervision of individuals, including contractor personnel, performing package maintenance activities required and controlled in accordance with this procedure.

2.5 The Maintenance Supervisor shall insure that the individuals assigned maintenance duties are familiar with operations involved and with the requirements of the package approval.

3.0 PERIODIC MAINTENANCE PROGRAM

3.1 The periodic maintenance program shall include the following main elements:

a) routine inspection of the package at the disposal site after unloading;

b) routine maintenance on a scheduled basis either at HNDC's headquarters or in the field.

3.2 Routine Inspections (Disposal Site)

3.2.1 Routine inspections at the disposal site are not required but should be performed to ensure the early identification of problems.

3.2.2 Responsibility for routine inspections at the disposal site shall rest with HNDC personnel assigned to the site.

3.2.3 The Maintenance Supervisor shall be responsible for communicating to the HNDC personnel assigned to the site the inspections to be performed. This communication may be verbal, written or both as deemed appropriate by the Maintenance Supervisor.

3.2.4 HNDC personnel assigned to the site shall report any conditions which could constitute a nonconformance with the package approval immediately to the Maintenance Supervisor who in turn shall be responsible for initiating a Corrective Action Memo (CAM), if appropriate, in accordance with Section 16 of HNDC-C-200.

3.3 Routine Scheduled Maintenance

3.3.1 Routine scheduled maintenance includes those maintenance activities performed for the purpose of verifying a package's conformance with package approval requirements and to ensure that the package will continue to conform to those requirements during the period of use prior to the next scheduled maintenance.

3.3.2 Routine scheduled maintenance should include as a minimum, the following maintenance activities:

a) visual inspections and measurements of package structure, components, parts and appurtenances for wear, damage and conformance to package approval requirements;

b) adjustments and realignments;

c) replacement of worn or defective parts, including gaskets, o-rings, studs, nuts, binders, signs, canvas covers, tie down cables, cable clamps, lifting lugs, tiedown lugs, shield plug studs, chains, impact skirt, etc.

3.3.3 The Maintenance Supervisor shall be responsible for preparing written instructions and/or checklists for the performance of routine scheduled maintenance.

3.3.4 These instructions and/or checklists may be generic in nature or specific to a particular package or package type. Where measurements or tests are required to determine the conformance of the package or part thereof with the package approval specific acceptance or rejection criteria must be included in the written instructions and/or checklists along with specific requirements for calibration or calibration checks of measuring and test equipment to be used.

3.3.5 The Maintenance Supervisor shall be solely responsible for the preparation, use and control of the written instructions and checklists delineating requirements for routine scheduled maintenance.

3.3.6 Each package shall receive routine scheduled maintenance at least once every four (4) months.

3.3.7 The Maintenance Supervisor shall be responsible for scheduling routine scheduled maintenance for each package.

3.3.8 Routine scheduled maintenance may be performed either at HNDC's headquarters or in the field as determined appropriate by the Maintenance Supervisor.

3.3.9 The Maintenance Supervisor shall maintain a log of all routine scheduled maintenance work done on each package. The log shall include the following information, as a minimum:

a) unique log entry number for work identification purposes

b) package identification

c) date(s) maintenance performed and location

d) names of individuals involved

e) Tag numbers for materials and parts issued from the QA controlled storage area and used for package maintenance.

f) summary description of work performed (reference may be made to instructions or checklists used)

g) summary description of package condition as found during routine scheduled maintenance, including nonconformances identified. If any Corrective Action Memos (CAMs) were issued as a result of conditions found adverse to quality these should also be listed.

3.3.10 The Maintenance Supervisor shall be responsible for keeping the Regional Operations Managers aware of schedule requirements for routine scheduled maintenance.

3.3.11 The Regional Operations Manager shall be responsible for the timely notification of the Maintenance Supervisor of the availability of each package for routine scheduled maintenance.

4.0 REPAIR PROGRAM

4.1 Repairs to packages required as a result of accidents or other incidents causing damage, or as a result of improper maintenance, use or operation of the package shall be reported, documented and controlled in accordance with the requirements of Section 16, "Corrective Action", of HNDC-C-200.

4.2 The Maintenance Supervisor shall in all cases be the "Action Designee" identified on the Corrective Action Memo (CAM) form for repair activities required in order to correct a defect or other nonconforming condition.

4.3 The Maintenance Supervisor shall determine on a case by case basis the need for special maintenance procedures for performing the repairs. Such procedures may be written on the CAM form and/or attached to it. The format and content of such procedures shall be at the discretion of the Maintenance Supervisor except that where measurements or tests are required to determine the conformance of the package or part thereof with the package approval specific acceptance or rejection criteria must be included in the written procedures along with specific requirements for calibration or calibration checks of measuring and test equipment to be used.

4.4 The CAM form and attachments thereto shall serve as the log of package repair activities. The information described in Article 3.3.9, items (b) through (f) shall be included on the CAM.

4.5 Individuals identifying a need for package repair shall report such conditions in accordance with the requirements of Section 16 of HNDC-C-200.

4.6 The Maintenance Supervisor shall be responsible for initiating a CAM when conditions requiring repair are identified during routine scheduled maintenance and/or when such conditions are reported to him verbally by either HNDC or user personnel.