SAFETY ANALYSIS REPORT

FOR THE

HN-194S RADWASTE SHIPPING CASK

REVISION 3

Referencing

10CFR71 TYPE "A" Packaging Regulations

STD-R-02-012

Westinghouse Radiological Services Department

1256 North Church Street

Moorestown, New Jersey 08057

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FORM-01(B)

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1.0 GENERAL INFORMATION

1.1 Introduction

The purpose of the following document is to provide the information and engineering analysis that demonstrates the performance capability and structural integrity of the HN-194S Cask and its compliance with the requirements of 10CFR71.

1.2 Package Description

The HN-194S Cask is a top-loading, shielded container designed specifically for the safe transport of radioactive waste materials in Type A quantities and greater than Type A quantities of low specific activity radioactive waste materials between nuclear facilities and waste disposal sites. The radioactive materials can be packaged in a number of different types of disposable containers.

The HN-194S Cask is a primary containment vessel for radioactive materials. It consists of a cask body, a primary cask lid, and a secondary cask lid being basically a top-opening right circular cylinder which is on its vertical axis. Its principal dimensions are 81-5/8 inches outside diameter by 80-1/2 inches high with an internal space of 75-5/8 inches diameter by 74-1/2 inches high.

1.2.1 Packaging

The cask body is a steel annulus in the form of a vertical oriented, right circular cylinder closed on the bottom end. The side walls consist of a 1-1/2 inch thick inner steel shell and a 1-1/2 inch thick outer steel shell. The bottom is three inches thick and is welded integrally to the internal steel body cylinder. The steel shells are further connected by welding at the bottom of the cask and by welding to a concentric top flange designed to receive a Buna-N O-ring seal. Positive cask closure is provided by the gasket seal and the thirty 1-inch holddown studs. Four cask tiedown lugs and three cask lifting lugs are welded to the outer steel shell.

HN-194S casks have two (2) possible drain plug configurations. Both have the drain plug entering horizontal to the cask bottom. These configurations allow the cask to be drained with minimum operational exposure.

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

The secondary cask lid is three inches thick and is fabricated in a design similar to the primary cask lid. It has a Buna-N O-ring seal and uses sixteen holddown studs to provide positive closure. The secondary cask lid also has a lifting lug located at its center to facilitate handling.

The shipping cask has two closure systems:

(1) the primary cask lid is closed with thirty 1 inch studs and a Buna-N O-ring seal,

(2) the secondary cask lid is closed with sixteen 1/2 inch studs and the same seal system used for the primary cask lid but smaller.

The shipping cask tiedown system consists of two sets of crossed tiedown cables (total of 4) and a shear ring (affixed to the vehicle load bed) designed to firmly position and safely hold the cask during transport.

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

Cask Body	22,000 pounds
Primary Cask Lid	3,770 pounds
Secondary Cask Lid	230 pounds
Total Cask (Unloaded) Wgt.	26,000 pounds
Maximum Payload	17,000 pounds
Gross Shipping Weight	43,000 pounds

1.2.2 Operational Features

The HN-194S radioactive waste shipping cask may include a number of required and optional accessories. These include: cavity drain plug, vent/test connection, rain cover tiedowns, signs and mounting brackets, placards and mounting brackets, lid lifting lug covers and security wires.

1.2.3 Contents of Packaging

1.2.3.1 Type and Form of Material

The materials transported in the HN-194S 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 contaminated materials, filter cartridges and solidified liquids. The materials may be dewatered, solidified, 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 of low specific activity materials. Fissile materials in exempt quantities may be transported.

1.2.3.2 Maximum Quantity of Material Per Package

The maximum quantity of material that may be transported in the HN-194S cask will be:

- Greater than Type A quantities of low specific activity radioactive materials in normal or special form.

- Materials and containers with an aggregate weight not exceeding 17,000 pounds.

- Cask, contents and containers with an aggregate weight not exceeding approximately 43,000 pounds.

- Limited to material with activities that do not produce dose rates exceeding 200 mR per hour on the surface of the cask or 10 mR per hour at two meters from the sides of the trailer.

1.3 Appendix

The HN-194S radioactive waste shipping cask is constructed in accordance with Hittman Nuclear Drawing Numbers:

STD-02-078	HN-194S Cask Assembly
STD-02-079	HN-194S Cask Appurtenances

2.0 STRUCTURAL EVALUATION

This section identifies and describes the principal structural engineering design of the packaging, components and systems important to safety in compliance with the performance requirements of 10CFR71.

2.1 Structural Design

2.1.1 Discussion

The principal structural member of the HN-194S cask is the primary containment vessel or transport shield, as described in Section 1.2.1. The above components are identified on the drawing as noted in Appendix 1.3. A detailed discussion of the structural design and performance of these components will be provided below.

2.1.2 Design Criteria

The shield top and bottom are each constructed of a 3 inch thick steel plate. Cylindrical side walls have a thickness of 3 inches and consist of two 1-1/2 inch thick steel plates.

2.2 Weights and Center of Gravity

Weight information is presented in Section 1.2.1. Package center of gravity is assumed to be geometric center of the package.

2.3 Mechanical Properties of Materials

The following materials are used in the construction of the HN-194S cask:

Cask lifting lugs and tiedown lugs - ASTM A515 Gr 70* or ASTM A516 Gr 70*:

S_u = 70,000 psi
S_y = 38,000 psi
S_{su} = 42,000 psi (60% S_u)
S_{sy} = 22,800 psi (60% S_y)
S_{brg} = 55,000 psi

Primary cask lid lifting lugs, secondary cask lid lifting lug, and inner and outer shells - ASTM A515 Grade 55*:

S_u = 55,000 psi
S_y = 30,000 psi
S_{su} = 33,000 psi (60% S_u)
S_{sy} = 18,000 psi (60% S_y)
S_{brg} = 30,000 psi

* Values used are minimum required per ASTM standards.

Lid studs meet requirements of ASTM A 307 Gr A (f_y = 60,000 psi) or ASTM A320 Gr L7 (f_y = 105,000 psi).

Weld shear strength is assumed to be 15,600 psi.

2.4 General Standards for All Packages

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

2.4.1 Chemical and Galvanic Reaction

The shield is constructed from heavy structural steel plates. All exterior surfaces are primed and painted with high quality epoxy base paint. There will be no galvanic, chemical or other reactions among the packaging components.

2.4.2 Positive Closure

The HN-194S cask has a three inch thick steel primary cask lid. The primary cask lid is secured to the cask using thirty 1 inch studs. The studs provide metal to metal contact between the cask and the primary cask lid and compress an O-ring seal to provide a positive closure. The closure is designed to withstand an internal pressure of 1/2 atmosphere (7.35 psi) or a corner impact without elongating the studs an amount that would allow leakage. The secondary cask lid located in the center of the cover is secured with sixteen 1/2 inch studs. An O-ring seal is used to provide positive closure.

2.4.3 Lifting Devices

2.4.3.1 Shipping Cask

Three equally spaced lugs are welded to the upper steel flange and the outer steel shell of the cask body. The cask is lifted using these lugs, slings, and a suitable crane. The lifting lugs are designed to lift three times the weight of the cask with no stresses in excess of their yield stress. See Section 2.10.1 for analysis and details.

2.4.3.2 Primary Cask Lid

The lifting devices for the primary cask lid consist of three equally spaced lugs welded directly to the outside of the primary cask lid. These lifting devices will support three times the weight of the cask lid with no stresses in excess of their yield stress. See Section 2.10.2 for analysis and details.

2.4.3.3 Secondary Cask Lid

The lifting device for the secondary cask lid consists of a single lug welded directly to the upper or outside of the steel plate which is the secondary cask lid. This lifting device will support three times the weight of the secondary cask lid with no stresses in excess of its yield stress. See Section 2.10.3 for analysis and details.

2.4.3.4 Lifting Lug Covers

Since the primary and secondary lid lifting lugs are not capable of supporting the full weight of the package, they will be covered during transit.

2.4.3.5 Lifting Lug Failure

The lifting lugs are more than capable of supporting a load equal to three times the package weight. Should the lugs experience a load great enough to cause a failure, the lugs will shear out locally before any detrimental effects compromise the integrity of the package.

2.4.4 Tiedown Devices

2.4.4.1 Tiedown Forces

The tiedown devices consist of four ratchet binder and cable assemblies attached from the tiedown lugs on the cask to tiedown lugs on the trailer body. Additionally, a shear ring firmly positions and holds the cask on the trailer bed. The tiedown 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 Section 2.10.4 for the analysis and details.

2.4.4.2 Non-Lifting Attachments Covered

The four tiedown lugs located on the cask periphery are covered when not in use with tiedown assemblies to prevent their use as lifting devices.

2.4.4.3 Tiedown Device Failure

The four tiedown lugs on the cask periphery have been designed so that loads transmitted by the tiedown cables under the worst conditions will neither damage the outer steel shell nor cause the tiedown lugs to fail. The tiedown system analysis is shown in Section 2.10.4.4.

2.5 Standards for Type B and Larger Quantity Packaging

This section is not applicable to the HN-194S cask.

2.6 Normal Conditions of Transport

The HN-194S package has been designed and constructed, and the contents are so limited (as described in Section 1.2.3) that the performance requirements specified in 10CFR71.35 will be met when the package is subjected to the normal conditions of transport specified in Subpart F of 10CFR71. The ability of the HN-194S package to satisfactorily withstand the normal conditions of transport has been assessed as described below.

2.6.1 Heat

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

2.6.2 Cold

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

2.6.3 Pressure

The HN-194S cask will withstand an internal pressure of 1/2 atmosphere (7.35 psig). This analysis is contained in Section 4.0, "Containment", specifically Section 4.2.1.

2.6.4 Vibration

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

Specifically, the design closure consisting of the O-ring seal for both the primary and secondary lid closures are capable of withstanding higher temperatures and forces than the cask experiences during normal transport conditions. In a similar manner, the number of bolts and the strength of the bolting design for the closures assure that the bolts will not fail during normal transport.

2.6.5 Water Spray

Since the cask external shell is constructed of steel, this test is not required.

2.6.6 Free Drop

The cask has been analyzed to ensure its structural adequacy to withstand a one-foot drop, striking any cask surface, onto a flat horizontal surface. The analysis is shown in Appendix 2.10.5.

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.

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

This section is not applicable to the HN-194S cask.

2.8 Special Form

This section is not applicable to the HN-194S cask.

2.9 Fuel Rods

This section is not applicable to the HN-194S cask.

2.10 Appendix

2.10.1 Cask Lifting Lugs

2.10.2 Primary Cask Lid Lifting Lugs

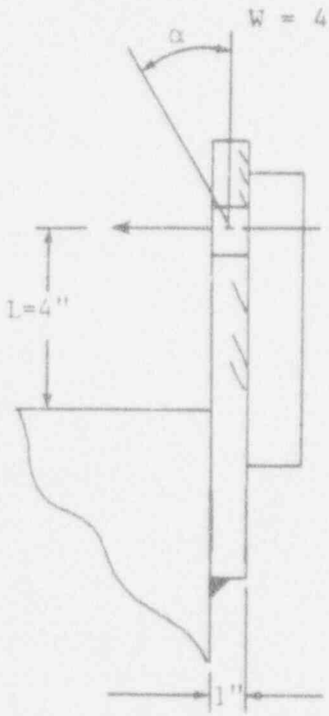
2.10.3 Secondary Cask Lid Lifting Lug

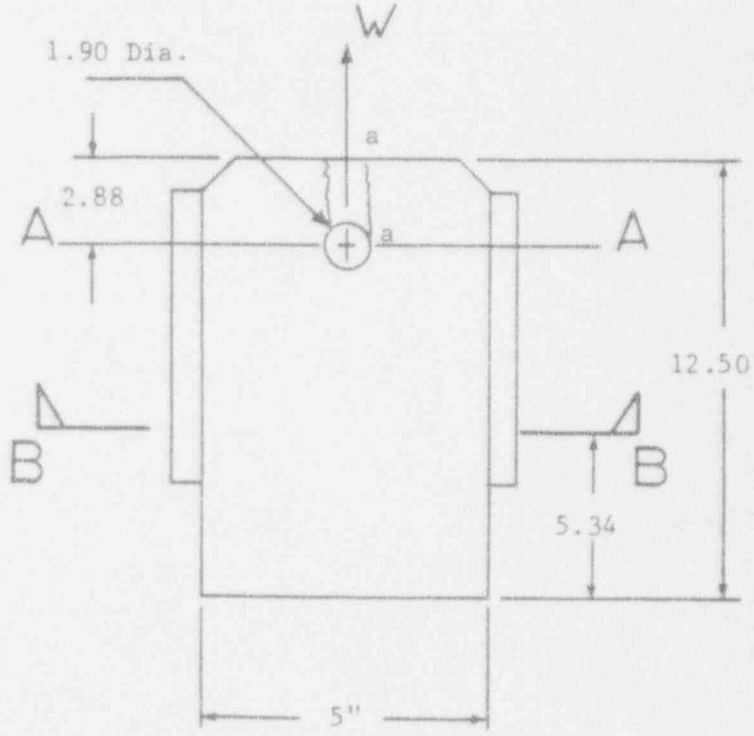
2.10.4 Tiedown Analysis

2.10.5 Free Drop Analysis

2.10.1 Cask Lifting Lugs

Material: ASTM A515 GR 70 (Sy = 38,000 psi)





2.10.1.1 Tension Stress (across Section A-A)

$$W = \frac{(\text{Load})\ (3g)}{3\ \text{lugs}} = \frac{(43{,}000)\ (3)}{3} = 43{,}000\ \text{lb.}$$

$$\sigma_T = \frac{W}{A_1 - A_H + 2A_2} = \frac{43{,}000}{5(1) - 1.9(1) + 2(3)(.5)} = 7050\ \text{psi}$$

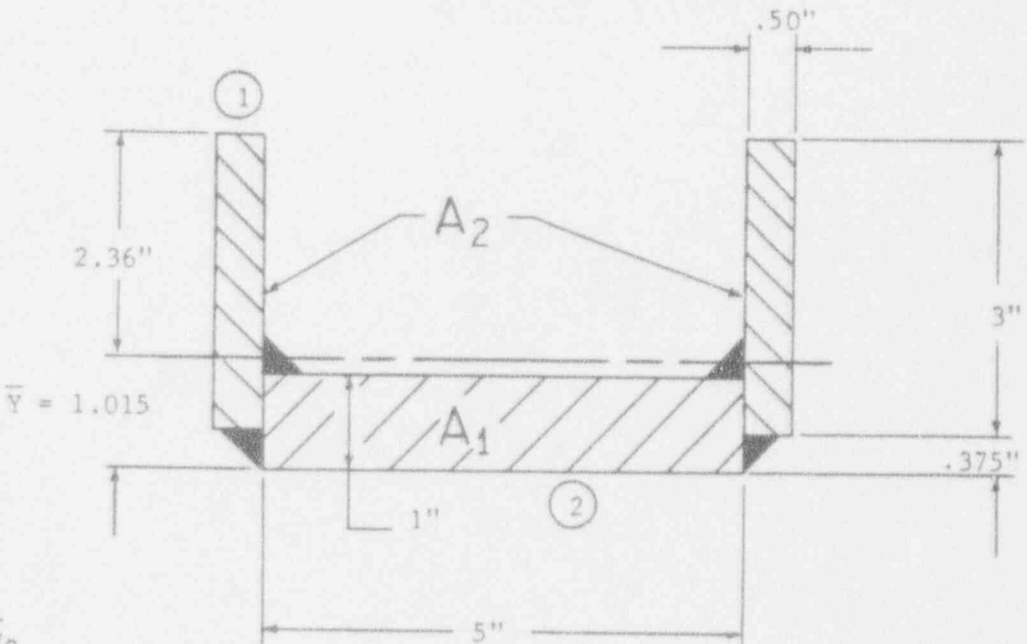
$$\text{Safety Factor} = \frac{S_y}{\sigma_T} = \frac{38{,}000}{7050} = \underline{5.39}$$

2.10.1.2 Combined Stress (Section B-B)

$\sigma_{T1} = \sigma_1 + \sigma_2$ — σ_1 = tensile stress due to vertical load

$\sigma_{T2} = \sigma_1 - \sigma_c$ — σ_2 = tensile stress due to bending

σ_c = compressive stress due to bending



$$A\bar{y} = A_1 y_1 + 2A_2\,\bar{y}_2$$

$$8\bar{y} = 5(.5) + 2\,(3 \times .50\,(1.875))$$

$$\bar{y} = \frac{2.5 + 5.625}{8} = \frac{8.125}{8} = 1.015''$$

$$I_x = \frac{bh^3}{12} + Ad^2$$

$$I_{x1} = \frac{(5)\,(1.0)^3}{12} + 5(1.015 - 0.5)^2 = 1.742 \text{ in}^4$$

$$I_{x2} = \frac{(1)\,(3)^3}{12} + 3(.86)^2 = 4.47 \text{ in}^4$$

$$I_{x2} = \frac{(1)\ (3)^3}{12} + 3(.86)^2 = 4.47 \text{ in}^4$$

$$I_x = I_{x1} + I_{x2} = 6.21 \text{ in}^4$$

$$\sigma_1 = \frac{W}{A_1+2A_2} = \frac{43{,}000}{8} = 5380 \text{ psi}$$

$$\sigma_2 = \frac{MC}{I} \quad M = (W \tan \alpha)\ L = 43{,}000\ (\tan 20°)\ 4$$
$$M = 62{,}600 \text{ lb-in}$$

$$\sigma_2 = \frac{62{,}600 \times 2.36}{6.21} = 23{,}800 \text{ psi}$$

$$\sigma_C = \frac{62{,}60\quad 1.015}{1} = -10{,}230 \text{ psi (compression)}$$

$$\sigma_{T1} = \sigma_1 + \sigma_2 = 5380 + 23{,}800 = 29{,}200 \text{ psi}$$

$$\sigma_{T2} = \sigma_1 + \sigma_2 = 4563 - 10{,}230 = -5670 \text{ psi}$$

$$\text{Sa,ety Factor} = \frac{S_y}{\sigma_{T1}} = \frac{38{,}000}{29{,}200} = \underline{1.30}$$

NOTE: α is procedurally limited to 20° from centerline.

2.10.1.3 Shear Due to Bolt Load (along Planes a-a)

$$\sigma_s = \frac{W}{A_s} = \frac{43{,}000}{2\text{x}1\text{x}2.4} = \frac{43{,}000}{4.8} = 8960 \text{ psi}$$

$$\text{Safety Factor} = \frac{S_{sy}}{\sigma_s} = \frac{22{,}800}{8{,}960} = \underline{2.54}$$

2.10.1.4 Weld Shear Stress

Weld Assumptions

1. Weld Efficiency = .85
2. Allowable Shear Stress = 15,600 psi
3. Weld Fillet Strength (3/4" Fillet) = 7200 lb/in

Actual Weld Length: (ℓ_a) = 16.68 in.

Required Weld Length: $(\ell_R) = \dfrac{43{,}000}{(7200)\ (.85)} = 7.03$ in.

$$\text{Safety Factor} = \frac{16.68}{7.03} = \underline{2.37}$$

2.10.1.5 Pin Bearing Stress

$$\sigma_{BR} = \frac{3W}{Dt} = \frac{43,000}{1.50\ (1.0)} = 28,667 \text{ psi}$$

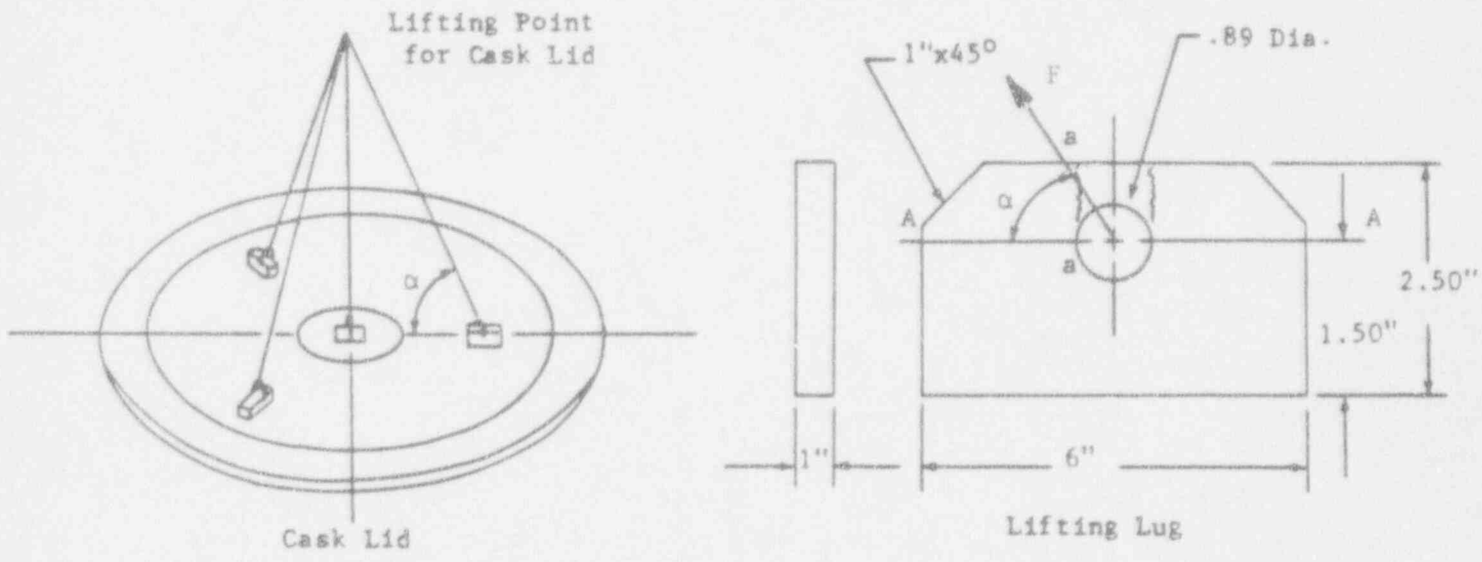
Where D = pin diameter
t = thickness of lug

$$\text{Safety Factor} = \frac{55,000}{28,667} = \underline{1.92}$$

2.10.2 Primary Cask Lid Lifting Lugs

Three lifting points have been provided in the cask lid to accommodate the lift sling attachment. Each of the lifting points is capable of lifting the entire weight of the lid. Lug material is ASTM A515 GR 55 (S_y = 30,000 psi).

Lid Weight = 4000 lb.



2.10.2.1 Shear Due to Bolt Load (along Planes a-a)

Assumptions:
1) $\alpha = 45°$
2) Shear along Planes a-a (the actual area is greater)
3) 3g abrupt lift by 3 lugs will be 4000 lb. per lug.

$F = \sqrt{2}\,W = \sqrt{2}\,(4000) = 5656$ lb.

$A_s = (2)\,(1)\,(0.55) = 1.10\ in^2$

$\sigma_s = \frac{5656\ lb}{1.10\ in^2} = 5142$ psi

$$\text{Safety Factor} = \frac{S_{sy}}{\sigma_s} = \frac{18{,}000}{5{,}142} = \underline{3.50}$$

2.10.2.2 Tension Stress (across Section A-A)

$$\sigma_t = \frac{W}{A} = \frac{4000}{(6-.89)(1)} = 782\ \text{psi}$$

$$\text{Safety Factor} = \frac{S_y}{\sigma_t} = \frac{30{,}000}{782} = \underline{38.4}$$

2.10.2.3 Weld Shear Stress

A 1/2" fillet weld attaches the lug to the lid. The actual weld length (ℓ_a) = 14 in. and 4800 lb/in. is the safe load per linear inch of 1/2" weld.

Lug Safe Load = (4800 lb/in) x (14 inch) = 67,000 lb.

67,000 lb. >> 4000 lb (weight of lid)

The safe working load is much greater than the actual load (cask lid weight), hence the lug weld length is adequate.

2.10.2.4 Pin Bearing Stress

$$\sigma_{BR} = \frac{W}{Dt} = \frac{4000}{.75 \times 1.00} = 5333 \text{ psi}$$

Where D = pin diameter

t = thickness of lug

$$\text{Safety Factor} = \frac{30,000}{5,333} = \underline{5.6}$$

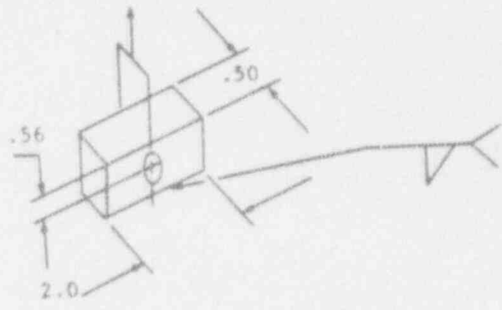
2.10.3 Secondary Cask Lid Lifting Lug

The secondary cask lid lifting lug is a single clevis pin type assembly. Lug material is ASTM A515 GR 55 (Sy = 30,000 psi).

Secondary cask lid = 230 lb

3g x 230 = 690 lb.

The following analysis shows the adequacy of the secondary cask lid lug to support three (3) times the secondary cask lid weight.



2.10.3.1 Shear Due to Bolt Load

σ_S = 690/(2) (.33)(.5) = 2,090 psi

Safety Factor = 18,000/2,090 = 8.6

2.10.3.2 Pin Bearing Stress

$$\sigma_{BR} = \frac{3W}{A} = \frac{3 \times 230 \text{ lb}}{(.5)(0.375)} = 3680 \text{ psi}$$

$$\text{Safety Factor} = \frac{30,000}{3,680} = \underline{8.15}$$

2.10.3.3 Weld Shear Stress

Assuming 2400 lb/in for 1/4" fillet weld

The actual weld length = (2 + 2 + .5 x 2) = 5.0

The weld can support:

2400 lb/in x 5 = 12,000 lb.

12,000 lb > 690 lb.

Hence there is adequate weld length.

2.10.3.4 Tension Stress

$$\sigma_t = \frac{W}{A} = \frac{690}{(2-0.45)(0.50)} = 890 \text{ psi}$$

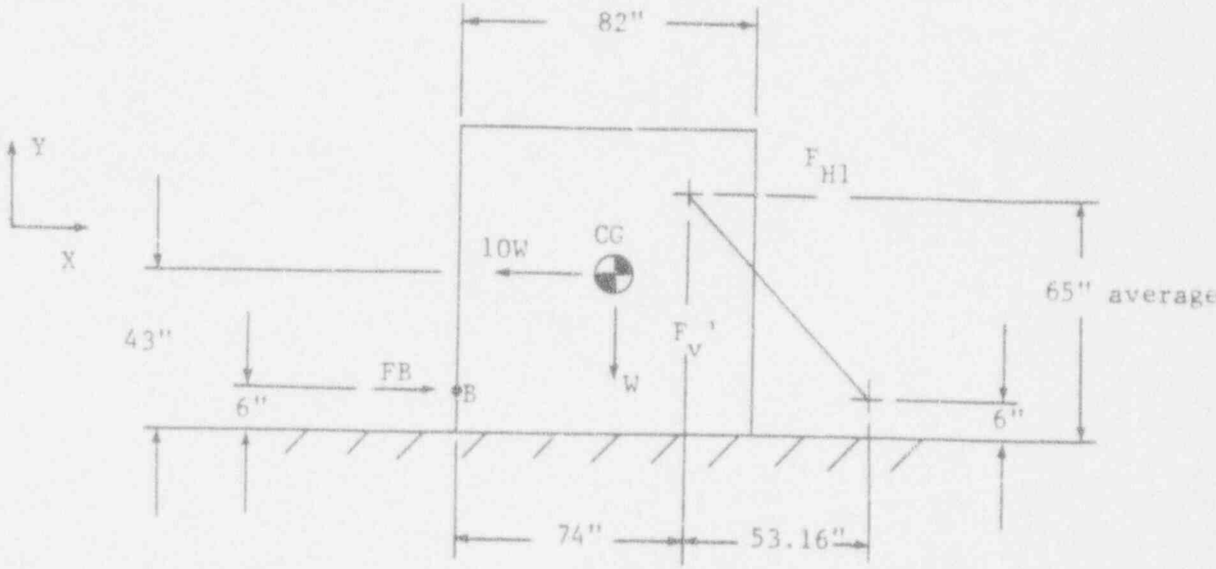
$$\text{Safety Factor} = \frac{S_y}{\sigma_t} = \frac{30,000}{890} = \underline{33.7}$$

2.10.4 Tiedown Analysis

2.10.4.1 Tiedown Loads

The cask tiedowns consist of four (4) cable and turnbuckle assemblies and a shear ring 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.

10g Longitudinal Load



$\sum M_B = 0$

Each rear tiedown must restrain half of the moment.

$$\frac{10W\ (37)}{2} = W\ (41) + F_V'\ (74) + F_{H1}\ (59)$$

$$\frac{F_{V'}}{F_{H1}} = \frac{59}{53.16} = 1.11$$

$$F_V' = 1.11\ F_{H1}$$

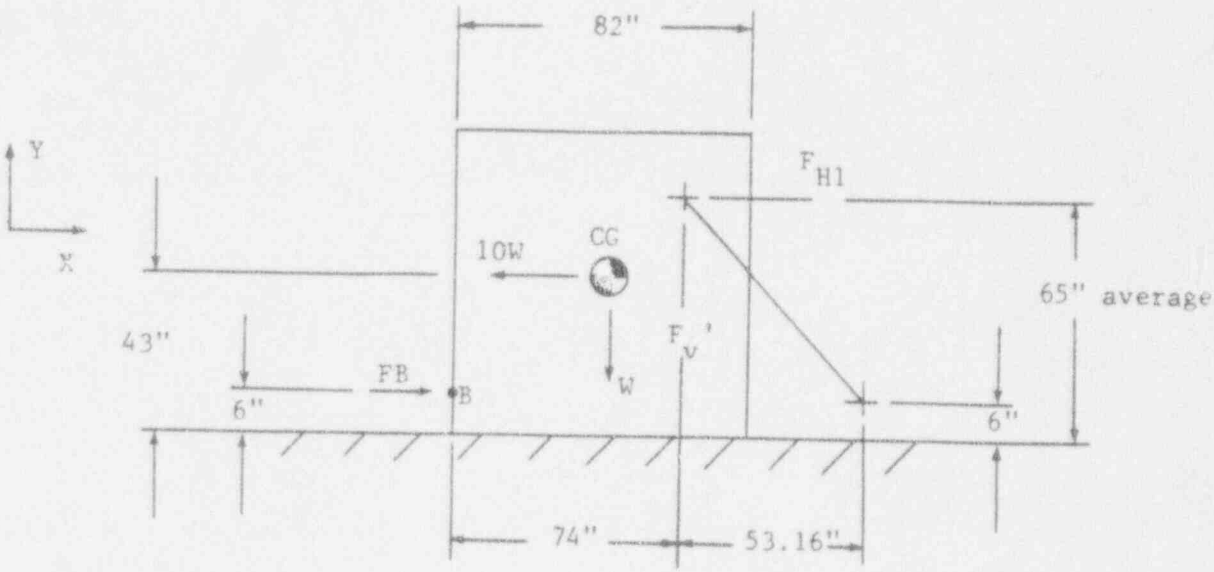
$$10\ (43,000)\ (37)/2 = 43,000\ (41) + 1.11\ F_{H1}\ (74) + F_{H1}\ (59)$$

$$6.192 \times 10^6 = 141.14\ F_{H1}$$

$$F_{H1} = 43,871 \text{ lb.}$$

$$F_V' = 1.11\ F_{H1} = 48,697 \text{ lb.}$$

10g Longitudinal Load



$$\sum M_B = 0$$

Each rear tiedown must restrain half of the moment.

$$\frac{10W\ (37)}{2} = W\ (41) + F_V'\ (74) + F_{H1}\ (59)$$

$$\frac{F_{V'}}{F_{H1}} = \frac{59}{53.16} = 1.11$$

$$F_V' = 1.11\ F_{H1}$$

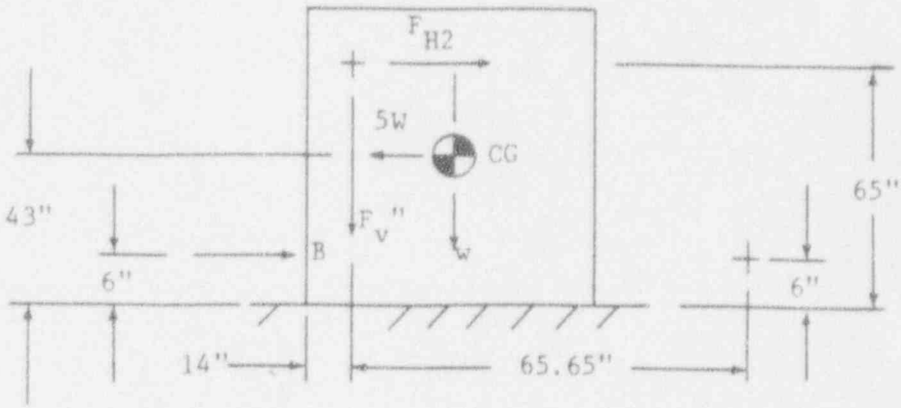
$$10\ (43{,}000)\ (37)/2 = 43{,}000\ (41) + 1.11\ F_{H1}\ (74) + F_{H1}\ (59)$$

$$6.192 \times 10^6 = 141.14\ F_{H1}$$

$$F_{H1} = 43{,}871 \text{ lb.}$$

$$F_V' = 1.11\ F_{H1} = 48{,}697 \text{ lb.}$$

5g Transverse Load



$\sum M_B = 0$

Each side tiedown must restrain half of the moment.

$$\frac{5W\ (37)}{2} = F_V''\ (14) + F_{H2}\ (59) + W\ (41)$$

$$\frac{F_{H2}}{F_V''} = \frac{65.65}{59} = 1.11 \quad \text{therefore} \quad F_{H2} = 1.11\ F_V''$$

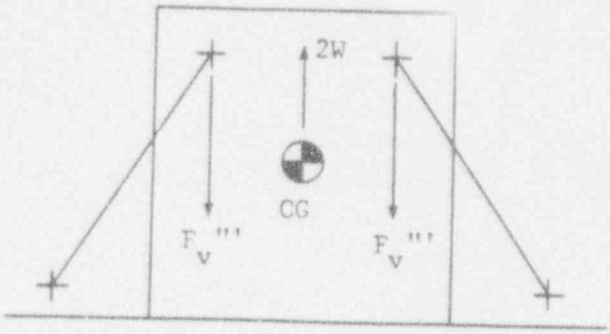
$$5\ (43{,}000)\ (37\ [illegible]) = F_V''\ (14 + 65.49) + 41\ (43{,}000)$$

$$2.[illegible] \times 10^6 = 79.48\ F_V''$$

$F_V'' = 27{,}869$ lb.

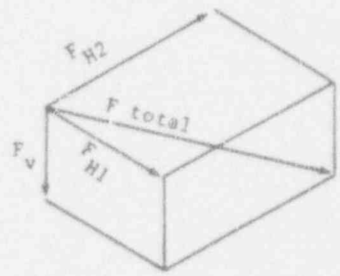
$F_{H2} = 30{,}934$ lb.

2g Vertical Load



$4F_V''' = 2W$ therefore $F_V''' = .5W = .5(43,000) = 21,500$ lb.

Combined Load on Each Lug



$F_V = F_V' + F_V'' + F_V''' = 48,697 + 27,869 + 21,500$

$F_V = 98,066$ lb.

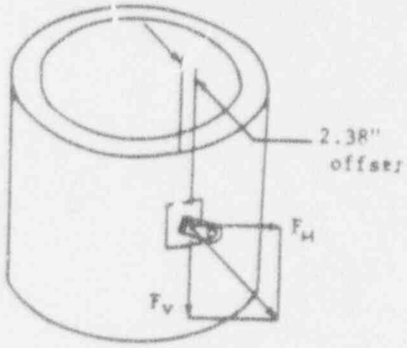
$F_{Total} = \sqrt{(F_{H1})^2 + (F_{H2})^2 + (F_V)^2}$

$F_{Total} = \sqrt{(43,871)^2 + (30,934)^2 + (98,066)^2}$

$F_{Total} = 111,797$ lbs.

2.10.4.2 Analysis of Tiedown Loads on Cask Shell

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



$$F_H = \sqrt{(F_{H1})^2 + (F_{H2})^2} = \sqrt{(43,871)^2 + (30,934)^2} = 53,680 \text{ lb.}$$

F_V = 98,066 lb.

M_e = external longitudinal moment

M_c = external circumferential moment

$M_e = 2.38 \times F_H = 2.38 \times 53,680 = 127,758$ in-lb.

$M_c = 2.38 \times F_V = 2.38 \times 98,066 = 233,397$ in-lb.

The resulting longitudinal and circumferential moments in the cask cylinder outer steel shell are obtained from the external moments using the following formula[1]:

$$M_x = .044 \frac{M_c}{aB} + .051 \frac{M_e}{aB}$$

$$M_\phi = .085 \frac{M_c}{aB} + .032 \frac{M_e}{aB}$$

1 Bijlaard, P.P., "Stresses from Radial Loads and External Moments in Cylindrical Pressure Vessels", ASME, 1960.

where: a = cask outer shell radius = 41"

B = dimensionless ratio $\frac{c}{a} = \frac{6}{41} = .146$

c = mounting plate width = $\frac{12}{2}$ = 6"

$$N_x = 2.6 \frac{M_c}{a^2 B} + 1.37 \frac{M_e}{a^2 B}$$

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

Substituting into these equation yields:

$$M_x = \frac{.044\ (233{,}397) + .051\ (127{,}758)}{41\ (.146)} = 2804 \text{ in-lb}$$

$$M_\phi = \frac{.085\ (233{,}397) + .032\ (127{,}758)}{41\ (.146)} = 3997 \text{ in-lb}$$

$$N_x = \frac{2.6\ (233{,}397) + 1.37\ (127{,}758)}{(41)^2\ (.146)} = 3186 \text{ in-lb}$$

$$N_\phi = \frac{1.32\ (233{,}397) + 3.4\ (127{,}758)}{(41)^2\ (.146)} = 3025 \text{ in-lb}$$

The maximum longitudinal and circumferential stresses in the cask outer shell are:

$$\sigma_x\ (max) = \frac{6M_x}{t^2} + \frac{N_x}{t} = \frac{6\ (2804)}{(1.5)^2} + \frac{3186}{1.5} = 9{,}601 \text{ psi}$$

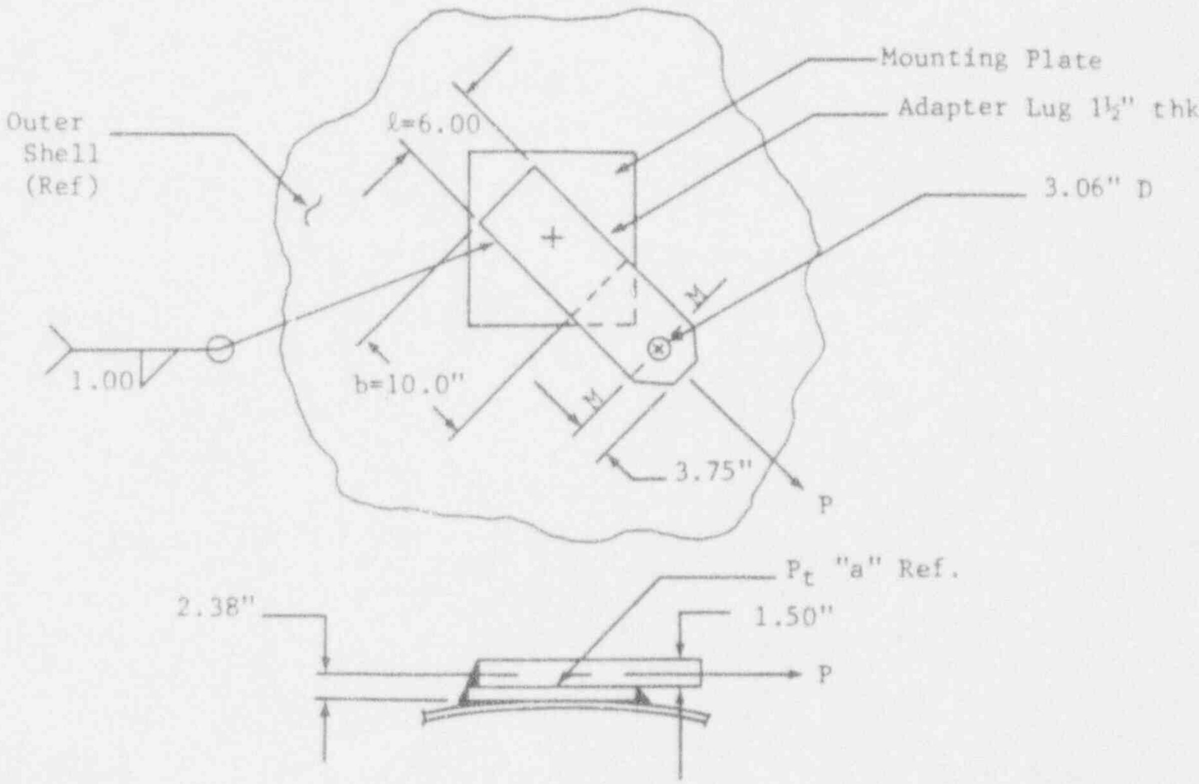
Safety Factor = $\frac{30{,}000}{9{,}601}$ = $\underline{3.13}$

$$\sigma_\phi(max) = \frac{6M_\phi}{t^2} + \frac{N_\phi}{t} = \frac{6(3997)}{(1.5)^2} + \frac{3025}{1.5} = 12{,}675 \text{ psi}$$

Safety Factor = $\frac{30{,}000}{12{,}675}$ = $\underline{2.37}$

2.10.4.3 Analysis of Cask Tiedown Lug

The HN-194S cask tiedown lug is analyzed for the maximum 10g, 5g and 2g combined loading condition.



Let P = 111,797 lb. (See Section 2.10.4.1)
The lug is constructed of ASTM A515 GR70 (S_u = 70,000 psi minimum)

Pin Bearing Stress

$$\sigma_{BR} = \frac{P}{Dt} = \frac{111,797}{1.50x1.5} = 49,680 \text{ psi}$$

$$\text{Safety Factor} = \frac{55,000}{49,688} = \underline{1.11}$$

Tension Stress (across Section M-M)

$$\sigma_T = \frac{111,797}{(6-3.06)1.5} = 25,351 \text{ psi}$$

$$\text{Safety Factor} = \frac{70,000}{25,351} = \underline{2.76}$$

Shear Due To Bolt Load

$$\sigma_s = (111,797)/(2)(1.5)(3.00) = 12,422 \text{ psi}$$

$$\text{Safety Factor} = \frac{33,000}{12,422} = \underline{2.66}$$

Weld Shear Stress

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

The direct shear stress $\sigma_s = \frac{111,797}{1x.707x26}$

σ_s = 6,082 psi

The allowable shear stress is 15,600 psi

$$\text{Safety Factor} = \frac{15,600}{6,082} = \underline{2.56}$$

2.10.4.4 <u>Failure Under Excessive Load</u>

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

$$F = (111{,}797 \text{ lb.}) \left(\frac{55{,}000}{12{,}675}\right) = 485{,}115 \text{ lb.}$$

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

Bearing: (55,000 psi)(1.50 in)(1.5 in) = 123,750 lb.

Tensile: (70,000 psi)(6-3.06in)(1.5in) = 308,700 lb.

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

2.10.5 Free Drop Analysis

2.10.5.1 Corner Drop

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

$$E_k = mgh = (43{,}000 \text{ lb.})(12 \text{ in.}) = 516{,}000 \text{ in-lb}$$

The volume of steel required to abso'b this energy is:

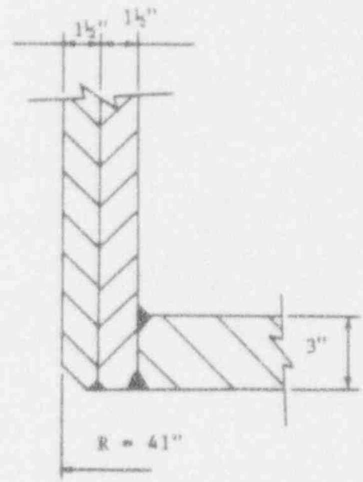
$$V_s = \frac{E_k}{S_y}$$

Material is ASTM A515 GR55 (S_y = 30,000 psi)

$$V_s = \frac{516{,}000}{30{,}000} = 17.2 \text{ in}^3$$

Corner Impact

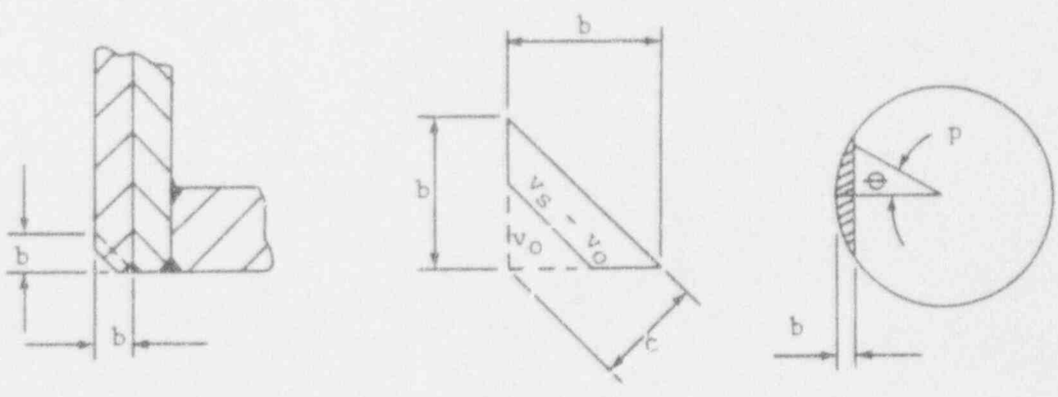
The configuration of the HN-194S cask corner is:



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

$$V_S = R^3 \left(\sin\theta - \frac{\sin^3\theta}{3} - \theta\cos\theta\right)$$

The angle ϕ = 16.4° when the volume of the ungula is 17.3 in.^{3}



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

$$b = 41\,(1 - \cos 16.4°) = 1.66 \text{ in.}$$

$$c = \frac{b}{\sqrt{2}} = 1.18 \text{ in.}$$

The effect on the cask body due to the corner impact event is shown on the above sketch.

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

$$A = \frac{\pi ab}{2} - (xy + ab \sin^{-1} \frac{x}{a}), \text{ where } \theta = 45°$$

R = 41 in.

$a = R/\cos\theta = 41\sqrt{2} = 58$ in.

b = R = 41 in.

h = 1.66 in.

C = R-h = 41 - 1.66 = 39.34 in.

$y = \sqrt{R^2 - C^2} = 11.55$ in.

$x = c/\cos\theta = 39.34\sqrt{2} = 55.63$ in.

$$A = \frac{\pi(58)(41)}{2} - (55.63)(11.55) - (58)(41)\sin^{-1}(\frac{55.63}{58})$$

$A = 39.62 in^2$

Deceleration Force = (39.62 in^2) (30,000 psi)

= 1,188,600 lb.

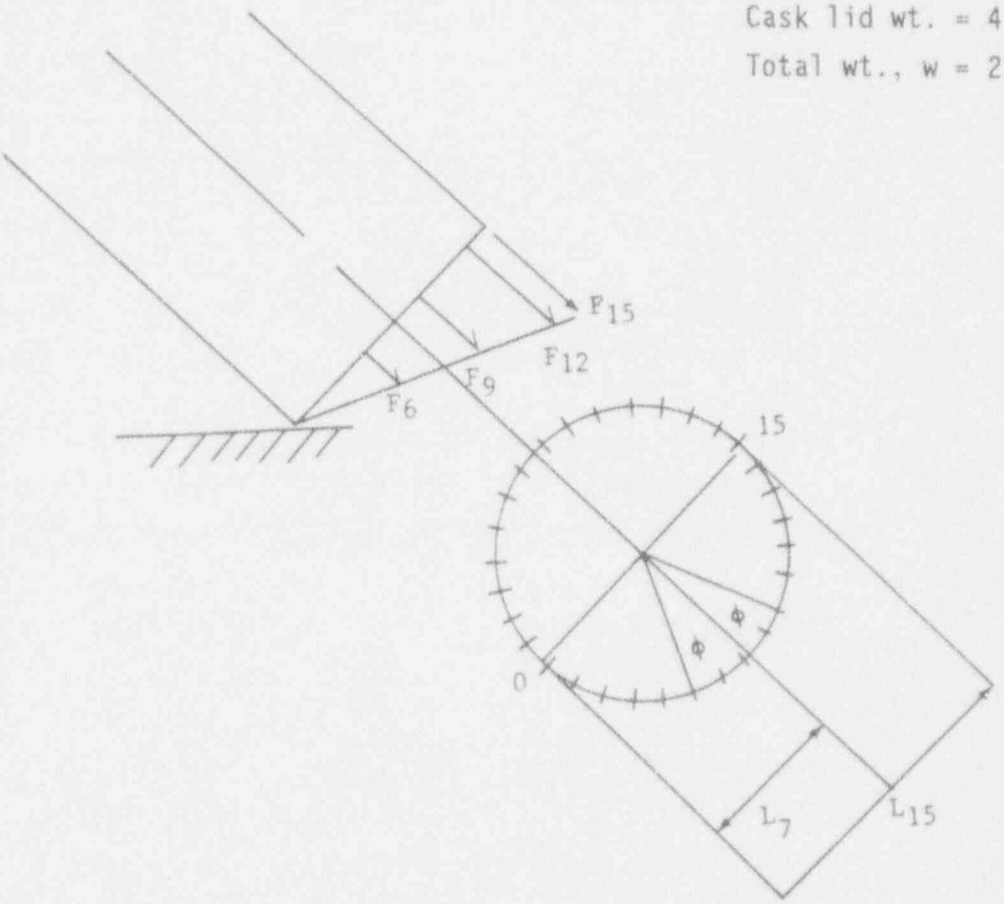
Deceleration = 1,188,600/43,000 = 27.6 g's.

2.10.5.2 Cask Lid Loading-Top Corner Drop

The deceleration 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 the minimum strength of the steel (30,000 psi) the 1.66 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.

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 close fitting or shored to limit actual movement. The loading on the cask lid is realized in the studs. The stud 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. A deceleration force of 28 g's has been used in this analysis.

Contents wt. = 17,000 lbs.
Cask lid wt. = 4,000 lbs.
Total wt., w = 21,000 lbs.



Impact loading on cask lid closure studs.

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

F_{15} = Max. stud force

Taking the summation of moments about point "0".

Sum of stud loads = 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:

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

The moment exerted by each of the studs can be expressed as:

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

The sum of the stud moments will be:

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

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

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

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

$$= (22.37 \times 41) \; P_{15} = 917 \; P_{15}$$

Where:

$L_1 = R \; (1\text{-}\sin 78°) = 0.0218 \; R \qquad L_1^2 = .00047R^2$

$L_2 = R \; (1\text{-}\sin 66°) = 0.0865 \; R \qquad L_2^2 = 0.0075R^2$

$L_3 = R \; (1\text{-}\sin 54°) = 0.1910 \; R \qquad L_3^2 = 0.0365R^2$

$L_4 = R \; (1\text{-}\sin 42°) = 0.3309 \; R \qquad L_4^2 = 0.1095R^2$

$L_5 = R\ (1-\sin 30°) = 0.5000\ R \qquad L_5^2 = 0.2500\ R^2$

$L_6 = R\ (1-\sin 18°) = 0.6910\ R \qquad L_6^2 = 0.4770\ R^2$

$L_7 = R\ (1-\sin 6°) = 0.8960\ R \qquad L_7^2 = 0.8020\ R^2$

$L_8 = R\ (1+\sin 6°) = 1.1050\ R \qquad L_8^2 = 1.0920\ R^2$

$L_9 = R\ (1+\sin 18°) = 1.3090\ R \qquad L_9^2 = 1.7130\ R^2$

$L_{10} = R\ (1+\sin 30°) = 1.5000\ R \qquad L_{10}^2 = 2.2500\ R^2$

$L_{11} = R\ (1+\sin 42°) = 1.6690\ R \qquad L_{11}^2 = 2.7860\ R^2$

$L_{12} = R\ (1+\sin 54°) = 1.8090\ R \qquad L_{12}^2 = 3.2720\ R^2$

$L_{13} = R\ (1+\sin 66°) = 1.9140\ R \qquad L_{13}^2 = 3.6610\ R^2$

$L_{14} = R\ (1+\sin 78°) = 1.9780\ R \qquad L_{14}^2 = 3.9130\ R^2$

$L_{15} = R\ (1+\sin 90°) = 2.0000\ R \qquad L_{15}^2 = 4.0000\ R^2$

$L_{1-14}^2 = 20.37\ R^2$

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

$917\ P_{15} = (28)(21{,}000)(0.707)(41)$

$P_{15} = 18{,}590$ lbs.

The primary lid studs are one inch in diameter and are fabricated from either ASTM A320 Grade L7 or ASTM A307 Grade A. ASTM A307 is the worst case. The studs have a root diameter of 0.878 inches and an area of 0.606 in^2.

The stress in the outer stud will be:

$$f = 18,590 \div 0.606 = 30,676 \text{ psi}$$

The yield strength of A307 steel is 60,000 psi. The safety factor for the studs is:

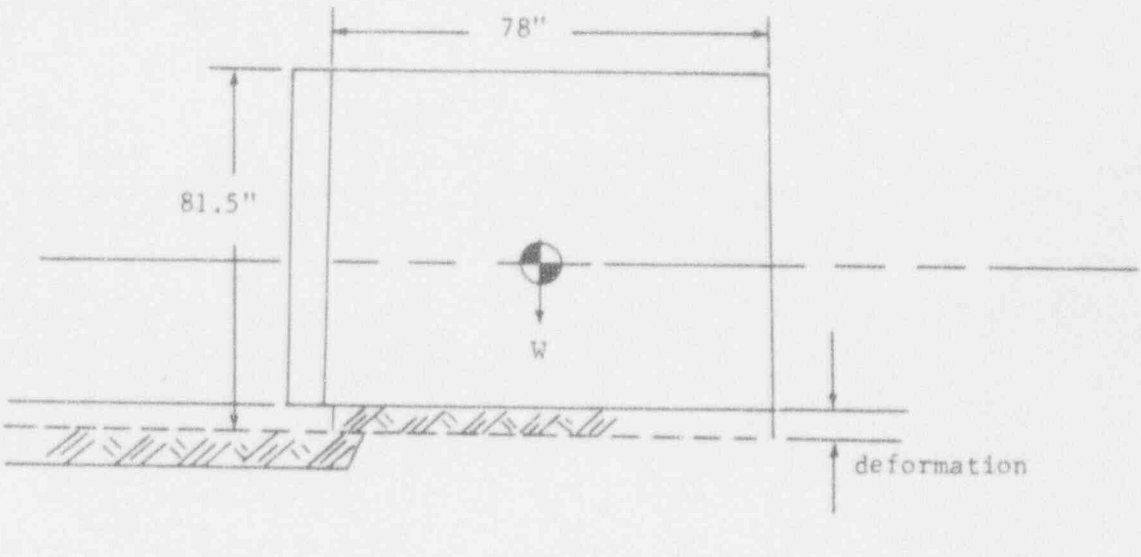
$$\text{Safety Factor (yield)} = \frac{60,000}{30,676} = \underline{1.95}$$

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

$$e = \frac{P\ell}{A\epsilon} = \frac{18,590 \times 4.75}{0.606 \times 29 \times 10^6} = 0.005 \text{ inches}$$

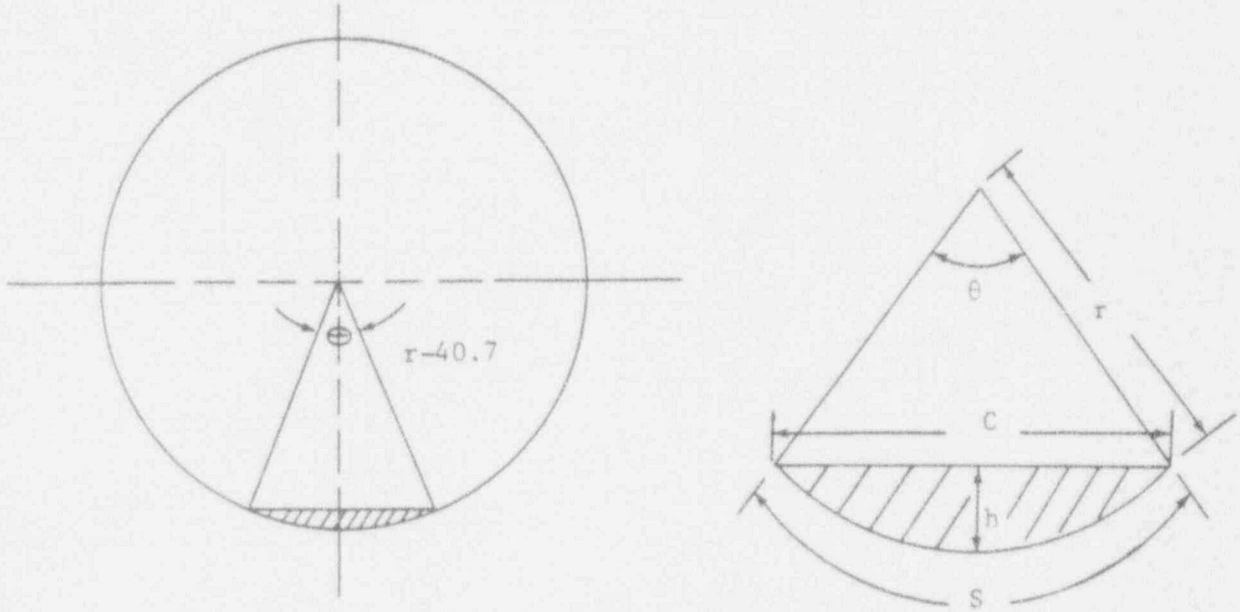
The elongation is a small fraction of the compression of the O-ring seal.

2.10.5.3 <u>Side Drop</u>



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

Kinetic Energy = (43,000 lb)(12) = 516,000 in-lb



Volume = (516,000 in-lb)/30,000 psi = 17.2 in^3

Area of segment = 17.2 in^3/78 in = 0.22 in^2

Area = $1/2\ r^2\ (\theta - \sin\theta)$
$\theta = 0.12\ \text{rad} = 6.87°$

$V = [1/2(40.7)^2(0.12 - \sin 6.87°)]\ (78) = 18.6\ in^3$
(108% of the volume required)

$h = r(1 - \cos\theta/2) = 40.7\ [1 - \cos(6.87/2)] = 0.0732$ in

0.0732 in < 1.5 inch outer plate

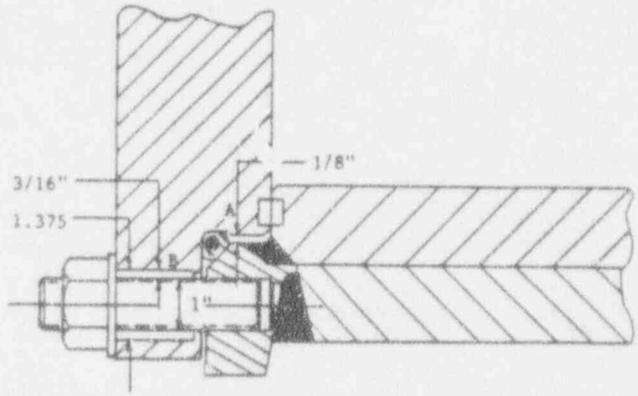
Surface area

$C = 2\sqrt{h(d-h)} = 2\sqrt{(0.0732)(81.5 - 0.0732)} = 4.88$ in

Area = (78)(4.88) = 380 in^2

F = (380 in^2)(30,000) = 11,425,760 lb

11,425,760 lb/43,000 = 265 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 deceleration forces along the surface at "A" as bearing, and as shear along the plane where the gasket corner intersects the lid.

Bearing stress on the surface at "A"

σ_{BR} = (4000 lb)(265)/(81.5)(0.625) = 20,810 psi

Safety Factor = 30,000/20,810 = <u>1.44</u>

Shear of Lid

Shear area of lid = $(77.5)^2(\pi/4)$ = 4,717 in^2

σ_S = (4000)(265)/4,717 = 225 psi

Safety Factor = 18,000/225 = <u>80.0</u>

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

$\sigma = (4000)(265)/(1/2)(\pi/4)(82.75^2 - 77.75^2)$

σ = 3,363 psi

Safety Factor = 18,000/3363 = 5.35

3.0 THERMAL EVALUATION

3.1 Discussion

The HN-194S 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(1) Activity	Total(2) Activity
Cobalt-60	1.33	2.3	10.7
Cesium-137	0.66	12	56

(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-194S cask, the heat generated by the waste will be as follows:

	Heat Generation (watts/curie)	Total Activity (curies)	Total Heat (Watts)	Total Heat (BTU/hr)
Cobalt	0.0154	10.7	0.165	0.561
Cesium	0.0048	56	0.27	0.92

The weight of waste per container will be about 13,000 pounds. Based on a specific heat of 0.156 BTU per degree F., 2028 BTU's or over 90 days with cesium would be required to heat the waste one degree Fahrenheit. Accordingly, the amount of heat generated by the waste is insignificant.

4.0 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. The cask wall consists of two 1-1/2 inch thick steel plates. The heavy steel flange connecting the annular steel shells at the top provides a seat for a Buna-N O-ring seal used to provide a positive atmospheric isolation when the primary cask lid is bolted down by thirty (30) equally spaced 1-inch diameter studs. The secondary cask lid is located in the center of the primary cask lid, has a Buna-N O-ring seal, 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-194S has a drain with plug assembly, the latter consisting of a machined piece of 2" round bar. 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.

The cask may also have an optional vent/test connection in the secondary cask lid. Inner and outer pipe plugs close this connection, a lead plug completes the shielding. The connection is normally to be used for testing an empty cask.

4.1.3 Seals and Welds

Both the primary cask lid and secondary cask lid are sealed by means of a Buna-N O-ring seal.

4.1.4 Closure

The operating procedures for the cask require that the primary cask lid studs 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 primary and secondary cask lid is 4,000 lb.

Total force exerted on the O-ring is:

$(30)(16{,}800) + 4{,}000 = 508{,}000 \text{ lb}$

Area of O-ring = $(78 \text{ in})(\pi)(5/8 \text{ in}) = 153.1 \text{ in}^2$

Total pressure on O-ring material

$508{,}000/153.1 \text{ in}^2 = 3317 \text{ psi}$

The torquing values ensure that there is sufficient pressure on the O-ring to seal the cask.

Similarly, the secondary cask lid torquing requirement is 35 to 40 ft-lb.

$F = (40 \text{ ft-lb})(12 \text{ in/ft})/(0.15)(0.5 \text{ in})$

$F = 6400 \text{ lb/stud.}$

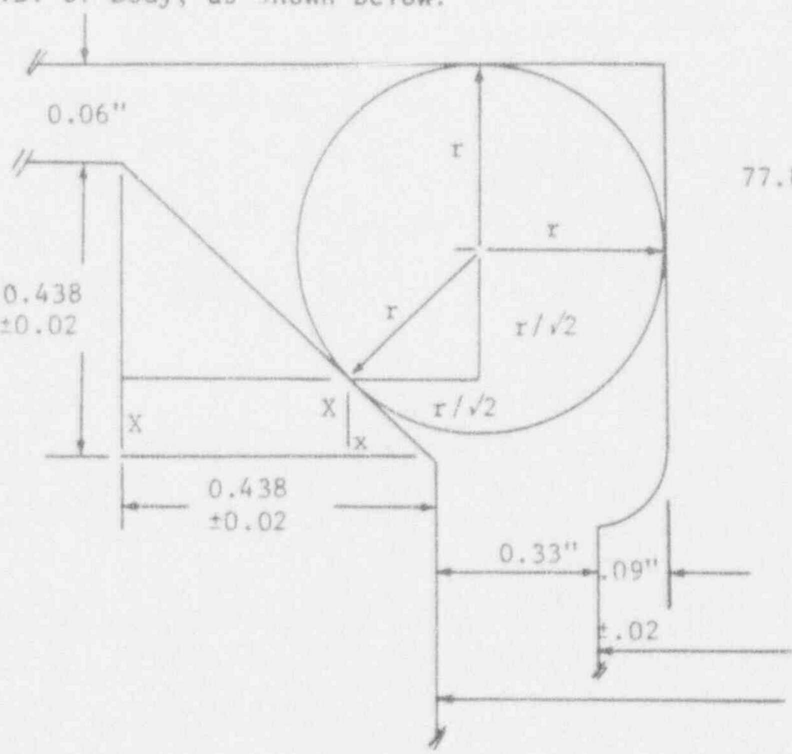
Weight of the secondary cask lid is 230 lb. Total force on secondary cask lid O-ring is (6400 lb)(16 studs) + 230 = 102,630 lb.

$$\text{Area of O-ring} = (18.125)(\pi)(0.5) = 28.47 \text{ in}^2$$

$$\text{Pressure on O-ring} = 102{,}630/28.47 = 3604 \text{ psi}$$

This is sufficient to maintain the O-ring seal.

The previous analysis assumes the lids are properly centered and there is equal pressure over the circumference of the gasket. The minimum affect of the lid which would cause ununiform seating on the gasket would be the lesser of either the tolerance between stud and stud hole in lid or the O.D. of the lid and I.D. of the lid hole. The maximum opening on the primary cask lid is the difference in O.D. of the lid and I.D. of body, as shown below:



77.87 - 77.54 = 0.33 inches

Using geometry, calculate the minimum value r can be and still have contact on the three surfaces.

$$r + r/\sqrt{2} = 0.33 + 0.11 + x$$
$$\underline{r + r/\sqrt{2} = 0.06 + 0.458 - x}$$
$$2r + 2r/\sqrt{2} = 0.958$$

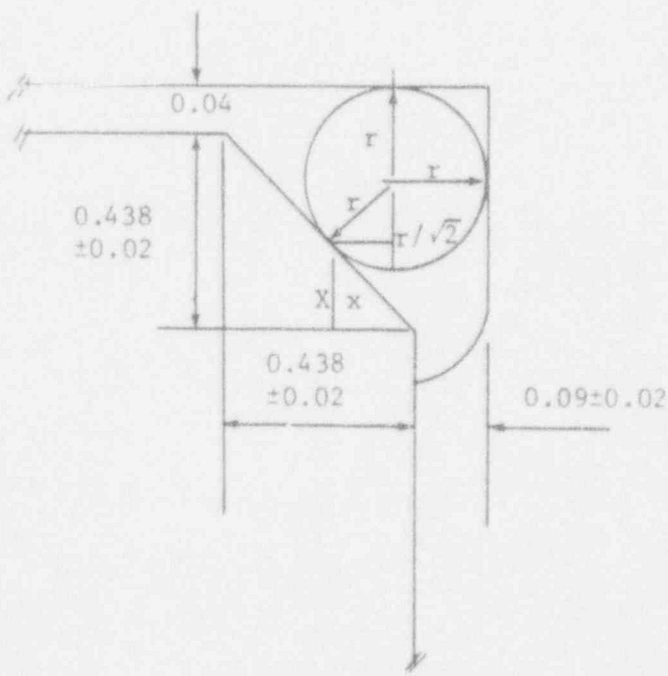
$$r = 0.280 \text{ in}$$

$$\text{diameter} = 0.561 \text{ in}$$

with a 5/8 inch diameter O-ring, percent compression will be:

$$\frac{0.625 - 0.561}{0.625} = 10\%$$

Similarly, maximum compression on the "tight" side occurs when there is metal to metal contact between the I.D. of the cask and the O.D. of the lid.



$$r + r/\sqrt{2} = 0.07 + x$$
$$\underline{r + r/\sqrt{2} = 0.04 + 0.418 - x}$$
$$2r + 2r/\sqrt{2} = 0.528$$

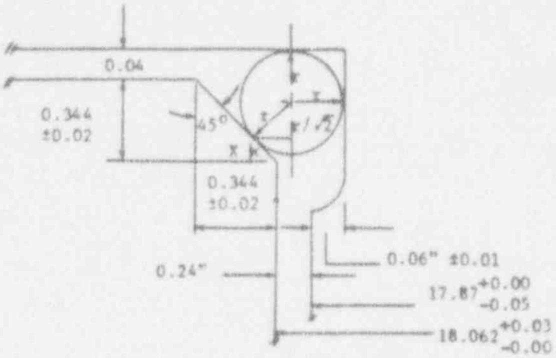
$$r = 0.1546 \text{ inches}$$

$$\text{diameter} = 0.3092 \text{ inches}$$

$$\text{Percent compression} = \frac{0.625 - 0.3092}{0.625} = 50\%$$

<u>Secondary Cask Lid</u> (1/2 inch diameter O-ring)

Similarly, for the secondary cask lid, the maximum potential opening, results from the difference in O.D. of the lid and I.D. of the primary cask lid opening.



18.092 - 17.820 = 0.272

Using geometry -

$$\begin{aligned} r + r/\sqrt{2} &= 0.07 + 0.24 + x \\ r + r/\sqrt{2} &= 0.04 + 0.364 - x \\ \hline 2r + 2r/\sqrt{2} &= 0.714 \end{aligned}$$

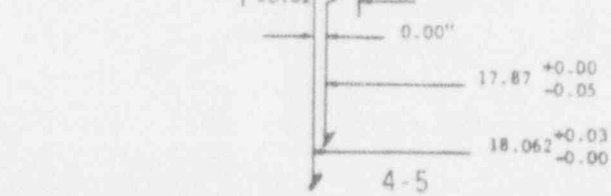
$r = 0.209$ inches

$d = 0.418$ inches

Using 1/2 diameter O-ring minimum compression is:

$$\frac{0.5 - 0.418}{0.5} = 16\%$$

On the tight side, the minimum distance between the stud and the stud hole wall in the secondary cask lid is 0.208 inches. This is greater than the difference in O.D. of the lid and I.D. of the primary cask lid opening of 0.192 inches. Therefore, there will be metal to metal contact -



18.062 - 17.87 = 0.192

Using geometry,

$$r + r/\sqrt{2} = 0.05 + x$$
$$\underline{r + r/\sqrt{2} = 0.02 + 0.324 - x}$$
$$2r + 2r/\sqrt{2} = 0.394$$

$$r = 0.1153 \text{ inches}$$

$$d = 0.230 \text{ inches}$$

$$\text{compression} = \frac{0.5 - 0.230}{0.5} = 54\%$$

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 cask lid from a 1/2 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,

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

$$\delta = \frac{PL}{AE} = \frac{(17{,}920\ \text{lb})(4.75\ \text{in})}{(0.606)\ (29 \times 10^6)} = 0.0048$$

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

Similarly, the secondary cask lid experiences a force of

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

On a per stud basis,

$$1605\ lb/16\ studs = 100.3\ lb/stud$$

Added to the pre-load tension

$$100.3 + 6400 = 6500\ lb/stud$$

$$\delta = PL/AE = (6500)(2.50)/(.4041)^2(\pi/4)(29x10^6)$$
$$= .0044\ in$$

This deflection is too small to break the seal and significantly 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 is not applicable.

5.0 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 used in 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 mesh lines 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 order of quadrature used.

5.4 Shielding Evaluation

The graphs presented in Appendix 5.5 document the shielding capabilities of the HN-194S casks as analyzed by the SPAN 4 computer code. The specific activity is given in μCi/ml; for ease of use the usable waste volume of the container is given below.

Container	Usable Volume (cf)	Maximum Dewatered Resin Prior to Solidification (cf)
HN-194S	136	116.5
Drum	7.3	-----

5.5 Appendix

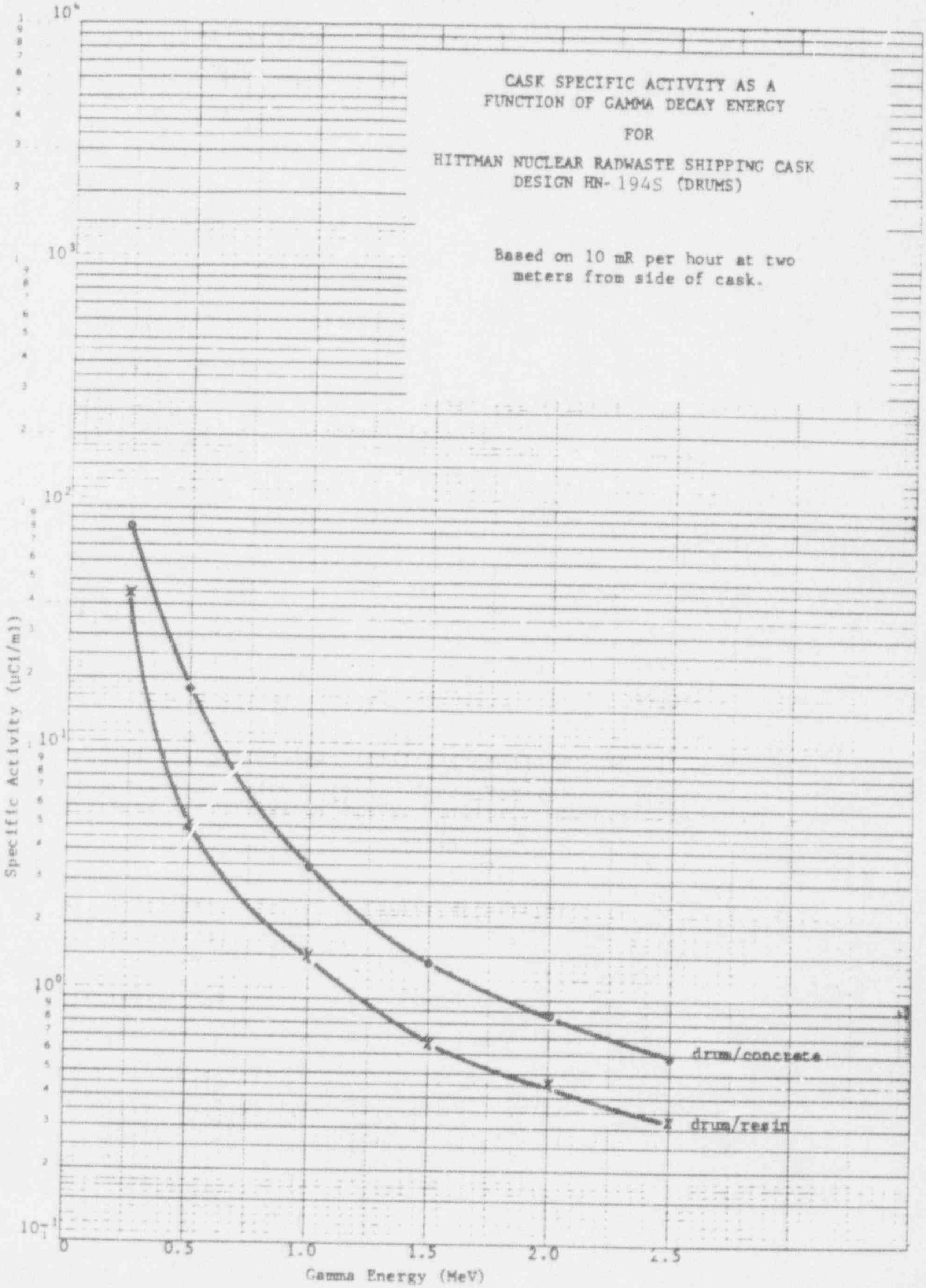
Shielding Capabilities

5.5.1 Cask Specific Activity as a Function of Gamma Decay Energy for Hittman Nuclear Radwaste Shipping Cask, Design HN-194S.

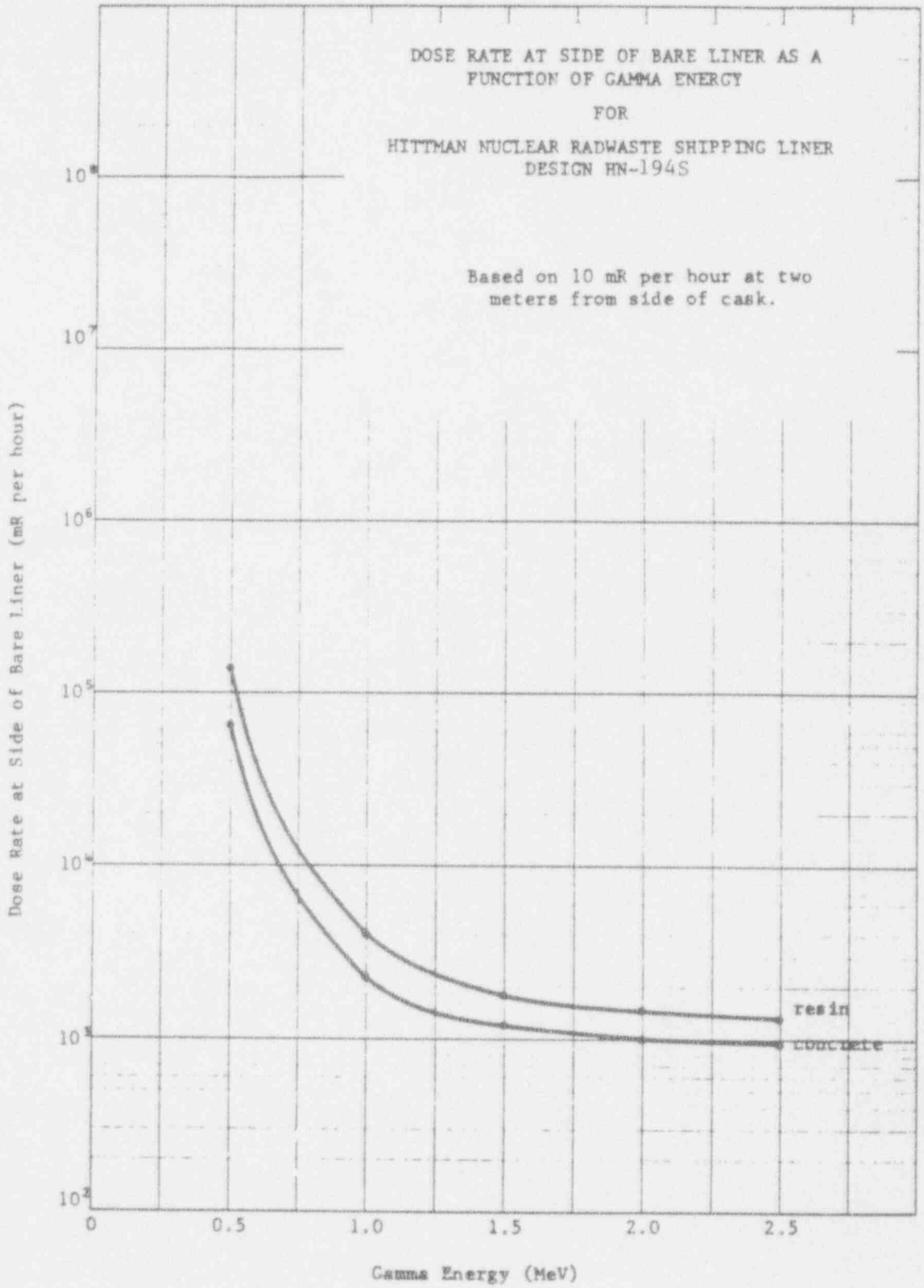
5.5.2 Dose Rate at Side of Bare Liner as a Function of Gamma Energy for Hittman Nuclear Radwaste Shipping Liner, Design HN-194S.

5.5.3 Cask Specific Activity as a Function of Gamma Decay Energy for Hittman Nuclear Radwaste Shipping Cask, Design HN-194S.

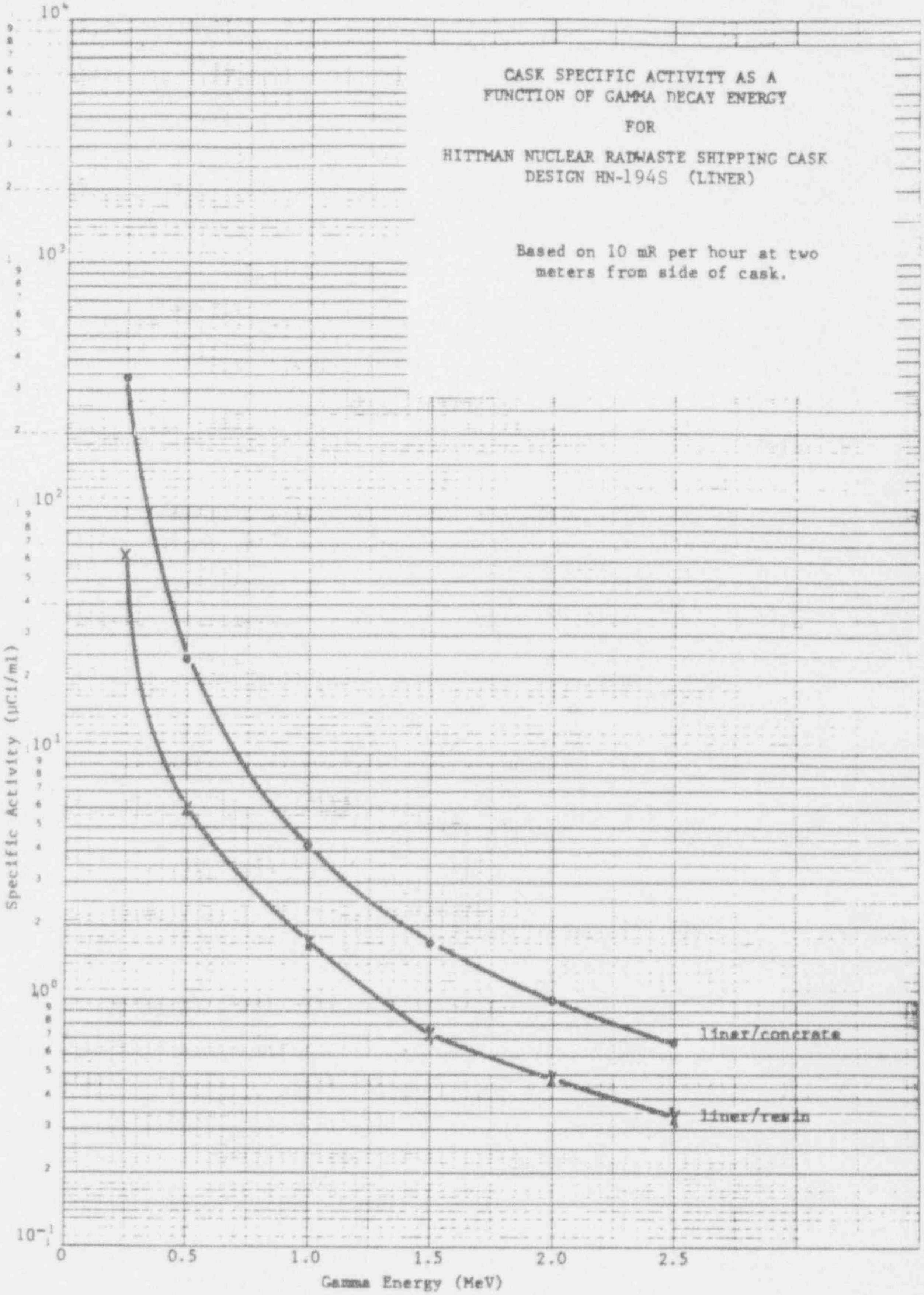
5.5.1


CASK SPECIFIC ACTIVITY AS A FUNCTION OF GAMMA DECAY ENERGY
FOR
HITTMAN NUCLEAR RADWASTE SHIPPING CASK DESIGN HN-194S (DRUMS)
Based on 10 mR per hour at two meters from side of cask.
Specific Activity (µCi/ml)
Gamma Energy (MeV)
drum/concrete
drum/resin
0
0.5
1.0
1.5
2.0
2.5

5.5.2


DOSE RATE AT SIDE OF BARE LINER AS A FUNCTION OF GAMMA ENERGY
FOR
HITTMAN NUCLEAR RADWASTE SHIPPING LINER DESIGN HN-194S
Based on 10 mR per hour at two meters from side of cask.
Dose Rate at Side of Bare Liner (mR per hour)
Gamma Energy (MeV)
resin
concrete
0
0.5
1.0
1.5
2.0
2.5

5.5.3


CASK SPECIFIC ACTIVITY AS A
FUNCTION OF GAMMA DECAY ENERGY
FOR
HITTMAN NUCLEAR RADWASTE SHIPPING CASK
DESIGN HN-194S (LINER)
Based on 10 mR per hour at two
meters from side of cask.
Specific Activity (μCi/ml)
Gamma Energy (MeV)
liner/concrete
liner/resin
10^4
10^3
10^2
10^1
10^0
10^-1
0
0.5
1.0
1.5
2.0
2.5

6.0 CRITICALITY EVALUATION

Not applicable.

7.0 OPERATING PROCEDURES

This section describes the procedures to be followed in using a HN-194S cask. Any maintenance activity, such as inspections, lubrication, gasket replacement/repair, etc. described in this section is described in more detail in Section 8.2, General Maintenance Program.

7.1 Lifting

7.1.1 The cask shall always be lifted using the three (3) provided lifting lugs only. The lifting lugs are the vertically oriented lugs on the sides of the cask spaced at 120° around the cask circumference.

7.1.2 The primary cask lid lifting lugs shall only be used to lift the cask lid (primary cask lid with secondary cask lid installed) or the primary cask lid alone. The secondary cask lid lifting lug shall only be used to lift the secondary cask lid.

7.2 Removal/Installation of Cask Lids

7.2.1 Removal of the Primary Cask Lid

7.2.1.1 Remove the primary cask lid holddown stud nuts.

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

7.2.1.3 Using the three (3) primary cask lid lifting lugs, suitable rigging and exercising caution in the handling of the primary cask lid due to possible contamination of the underside of the lid, remove the primary cask lid.

7.2.2 <u>Removal of Secondary Cask Lid</u>

7.2.2.1 Remove the secondary cask lid holddown stud nuts.

7.2.2.2 Remove the secondary cask lid lifting lug cover.

7.2.2.3 Exercising caution due to the possible contamination of the underside of the secondary cask lid, remove the secondary cask lid.

7.2.3 <u>Installation of Primary Cask Lid</u>

7.2.3.1 Prior to installation, inspect gasket for the following:

a. Gasket not cut, ripped or gouged.

b. Gasket is resilient.

c. Gasket is free of debris, dirt and/or grease.

7.2.3.2 Prior to installation, verify that the date of gasket change reflects compliance with the annual change requirements for the cask.

7.2.3.3 Using the three (3) lifting lugs on the primary cask lid and suitable rigging, lift and place lid on cask using alignment guides to ensure proper positioning. Take care not to damage gasket.

7.2.3.4 Install the primary cask lid stud nuts and torque from 190 ft-lbs to 210 ft-lbs.

7.2.3.5 Install the three (3) primary cask lid lifting covers.

7.2.4 Installation of Secondary Cask Lid

7.2.4.1 Prior to installation, inspect gasket for the following:

a. Gasket not cut, ripped or gouged.

b. Gasket is resilient.

c. Gasket is free of debris, dirt and/or grease.

7.2.4.2 Prior to installation, verify that the date of gasket change reflects compliance with the annual change requirements.

7.2.4.3 Using the one (1) lifting lug on the secondary cask lid and suitable rigging, lift and place lid into the opening on the primary cask lid. Use alignment guides to ensure proper positioning. Take care not to damage gasket.

7.2.4.4 Install the secondary cask lid stud nuts and torque from 35 to 40 ft-lbs.

7.2.4.5 Install the secondary cask lid lifting lug cover.

7.3 Cask Loading

7.3.1 Survey empty cask and the vehicle carrying it to determine the loose and fixed contamination levels. Limitations pertaining to contamination levels shall be defined by regulations imposed on the user by the applicable governing bodies.

7.3.2 Inspect primary and secondary cask lid fasteners to ensure that all are present and undamaged.

7.3.3 Check to ensure that primary and secondary cask lid lifting lug covers are with the cask.

7.3.4 Remove primary cask lid in accordance with Section 7.2.1.

7.3.5 Remove secondary cask lid in accordance with Section 7.2.2, if required.

7.3.6 Inspect interior of cask for standing water.

NOTE: Water must be removed prior to shipment

7.3.7 Inspect interior of cask for obstructions to loading.

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

7.3.9 If loading drums on drum pallets, proceed as follows:

a. Load drums on each pallet.

b. For maximum shielding, position higher dose rate drums in the center of the pallet and toward the front and rear of the trailer.

c. Place slings around or along side drums to prevent pinching or damage to the slings by the lids or top pallet in the cask.

d. Place the loaded pallets in the cask.

e. For the cask lids removed for the loading process, inspect cask lid gaskets, install lids and secure as described in respective sections.

7.3.10 If loading preloaded containers, proceed as follows:

a. Ensure all lids, plugs, caps, etc. are installed on container.

b. Place container into the cask.

c. Install shims/shoring between container and cask as necessary to secure the container in position.

d. For the cask lids removed for the loading process, inspect cask lid gaskets, install lids and secure as described in respective sections.

7.3.11 If loading into container inside cask, proceed as follows:

a. Place empty container in the cask.

b. Install shims/shoring between container and cask as necessary to secure the container in position.

c. Inspect primary cask lid gasket, install and secure primary cask lid as described in respective section.

d. Load the waste into the container through the secondary cask lid opening.

e. Install the liner lid, plugs, caps, etc. onto the container.

f. Inspect secondary cask lid gasket, install and secure secondary cask lid as described in respective section.

7.3.12 Install tamper-proof seals on the cask lids.

7.4 Removal/Installation of Cask from Trailer

7.4.1 Cask Removal Trailer

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

7.4.1.2 Remove pins from shackles.

NOTE: The four (4) cask tiedown lugs shall be covered immediately upon removal of the shackles to prevent their use as lifting devices.

7.4.1.3 Using three (3) cask lifting lugs and suitable rigging, lift cask off trailer.

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

7.4.2 Cask Installation on Trailer

7.4.2.1 Using three (3) cask lifting lugs and suitable rigging, lift cask and place cask in proper position within the shear ring.

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

7.4.2.2 Inspect tiedowns and shackles on the cask and trailer for cracks and wear which would affect their strength.

7.4.2.3 Inspect tiedown cables to ensure they are not damaged (crimped, frayed, etc.)

7.4.2.4 Inspect tiedown ratchets/turnbuckles to ensure they are in proper working condition.

7.4.2.5 Install a shackle through the cask end of each tiedown cable and attach the shackle to the cask tiedown lug.

7.4.2.6 Tighten tiedown ratchets/turnbuckles as necessary to secure cask on trailer.

7.5 Containment Penetration Seals

If the tamper-proof seal on the cask cavity drain port plug or vent/test connection plugs has been removed, the plug(s) must be removed and properly reinstalled. Installation of the plugs used to seal the cavity drain port and vent/test connection shall be done using a pipe joint sealing compound. The plugs shall be torqued to 25 (±2) ft-lbs. Immediately after installation of the plugs a new tamper-proof seal shall be installed.

7.6 Preparation for Shipment

7.6.1 Perform radiation surveys of cask and vehicle, including a determination of surface contamination, to ensure compliance with 10CFR71.47 and 10CFR71.87 and complete the necessary shipping papers, certifications, and checklists.

7.6.2 Placard vehicle and label cask as necessary.

7.7 Receiving a Loaded Cask

The receiver, carrier and shipper are to follow the instructions of 10CFR20.205 when a package is delivered. These instructions include surveying the external surface of the cask for radioactive contamination.

8.0 ACCEPTANCE TESTS AND MAINTENANCE PROGRAM

8.1 Acceptance Tests

Fabrication of the HN-194S cask meets the requirements of Subpart D of 10CFR71. Fabrication is implemented and documented under a Quality Assurance program in accordance with the applicable requirements of 10CFR71, Subpart H.

8.1.1 Visual Inspection

The packaging shall be inspected visually for any adverse condition in materials or fabrication using applicable codes, standards, and drawings. Materials are specified under the ASTM and ASME codes. Weld procedure and welder qualifications are in accordance with ASME Section IX or AWS Codes. Prior to painting, non-destructive testing of welds is accomplished as described in the cask drawings.

8.1.2 Structural and Pressure Tests

After fabrication is complete, the cask assembly is subjected to a pneumatic pressure test of 7.5 psig (-0 psig, + 1.0 psig). The cask is visually inspected after the pressure test. The acceptance criterion is no change has occurred to the cask as a result of the test.

8.1.3 Leak Tests

A leak test of a sensitivity of at least 10^{-3} STD cc/sec shall be performed using a test fixture (with calibrated pressure gauge and pre-set relief valve) mounted into the cask drain port or vent/test connection.

Air is introduced at a maximum rate of 0.5 psig/min until the test pressure of 8 psig (-0 psig, + 1.0 psig) is reached. All joints on the test fixture, primary cask lid and secondary cask lid gaskets, and vent/test connection or cavity drain port (whichever is not utilized to connect the test fixture) are bubble tested. The pressure in the isolated cask is also monitored for at least 30 minutes. The acceptance criteria are:

- No leaks evidenced by the bubble solution.
- No pressure loss over a 30 minute time frame.

The system will be depressurized at a rate not exceeding approximately 2 psig/min, the test fixture removed and the drain port plug or vent/test connection plugs reinstalled. The installation of the plug(s) is to be done in accordance with Section 7.0.

8.1.4 Component Tests

8.1.4.1 Gaskets

Prior to painting, seating surfaces are to have a 125 RMS minimum finish. Leak testing (see Section 8.1.3) of the cask will be final acceptance for gasket design.

8.1.5 Thermal Acceptance Tests

No thermal acceptance testing will be performed on the HN-194S cask.

8.2 General Maintenance Program

8.2.1 General

Maintenance and repair of the HN-194S cask is controlled by the Westinghouse Radiological Services Department Quality Assurance program. The casks and trailers annually undergo three (3) routine technical inspections. These inspections are proceduralized in cask maintenance and repair procedures.

8.2.2 Gaskets

8.2.2.1 Gaskets shall be inspected for resiliency and proper installation.

8.2.2.2 Gaskets which cannot be sealed or are obviously damaged must be replaced in their entirety. Damage may include cuts, nicks, chips, indentations, or any other defect apparent to the naked eye which would affect sealing integrity. Removal of the gasket, preparation of the lid surfaces, and gasket installation shall be performed in accordance with the cask maintenance and repair procedures.

8.2.2.3 All gaskets shall be replaced after 12 months of installation on the cask regardless of apparent condition or cask usage.

8.2.2.4 A leak test, according to Section 8.1.3, shall be performed at least once within the twelve (12) months prior to any use.

8.2.2.5 Any painted surface in contact with the gasket shall be maintained in good condition. Any loose, chipped, or scratched painted surface which would affect seal integrity shall be repaired prior to further cask use.

8.2.3 Welds

8.2.3.1 All welds have been completely checked in accordance with ASME Code requirements using visual, magnetic particle and radiographic methods during fabrication. The cask drawing delineates these inspections. In-use inspections should not be required unless the cask has been involved in an accident or has been lifted improperly or in an overloaded condition. In those cases, inspection shall include the following:

a. Drop or accident: All accessible cask body and lug welds welds shall be magnetic particle inspected in accordance with ASME Code Section III, Division I, Subsection NB, Article NB-5000 and Section V, Article 7. These inspections may be performed with the painted finish in place.

b. Improper or overload lift: All welds on the cask primary or shield plug which were in use at the time of the improper or overload lift shall be magnetic particle inspected per the requirements delineated above.

8.2.3.2 Whenever welding to the cask is required it shall be performed utilizing weld procedures and welders qualified in accordance with ASME Code Section IX requirement.

8.2.4 Studs and Nuts

8.2.4.1 All studs and nuts shall be inspected during each removal of the primary and secondary cask lids and superficially with each cask use. Replacement shall be made if the following conditions are present:

a. Deformed or stripped threads.

b. Cracked or deformed hexs on nuts.

c. Elongated or scored grip length area on studs.

d. Severe rusting or corrosion pitting.

8.2.4.2 In general, all studs and nuts shall be inspected for damage at least once a year under normal usage conditions and replaced when the conditions delineated in Step 8.2.4.1 are present.

8.2.5 Painted Surfaces

8.2.5.1 Painted surfaces shall be cleaned using standard commercial equipment, chemical solutions, and procedures.

8.2.5.2 Chipped or scratched surfaces which could affect seal integrity shall be repainted prior to further cask use. Other chipped or scratched surfaces shall be repainted at the time of the next routine technical inspection referenced in Section 8.2.1.

8.2.5.3 Guide stripes and cask identification markings shall be repainted when they are chipped, peeled off, faded or illegible.