71-9096
Rec'd w/ltr
dtd 04/30/85

SAFETY ANALYSIS REPORT

FOR

CHEM-NUCLEAR SYSTEMS, INC.

MODEL NO. CNS 21-300

CERTIFICATE OF COMPLIANCE NO. 9096

TYPE A RADWASTE SHIPPING CONTAINER

CONSOLIDATED REVISION

APRIL 1985

CHEM NUCLEAR SYSTEMS, INC.

CORPORATE HEADQUARTERS

220 STONERIDGE DRIVE

COLUMBIA, SOUTH CAROLINA 29210

25202

TABLE OF CONTENTS
21-300 SHIPPING CASK

1.0 GENERAL INFORMATION

1.1 INTRODUCTION

The CNS1 21-300 shipping cask is a top-loading, shielded container designed for the transport of Type A and low specific activity (LSA) radioactive wastes. The cask will accommodate twenty one (21) 55 gallon drums, one 300 (nominal) cubic foot liner, or other approved sealed containers.

1.2 PACKAGE DESCRIPTION

1.2.1 Packaging

The cask is the primary containment vessel for the transport of radioactive wastes. It consists of a cask body and main cask lid which incorporates a second smaller diameter lid. The secondary lid is typically used for access when a disposable liner is inserted in the cask. The cask is a right circular cylinder 86-3/4-inch diameter by 117-1/4 inch high, with an 83 inch diameter by 109-1/4 inch high cavity.

The cask body is a steel-lead-steel annulus in the form of a vertically oriented, right circular cylinder closed on the bottom. The side walls consist of a 1/8 inch inner stainless steel shell, a 1-inch thick concentric lead cylinder bonded to the inner and outer shells, and a 3/4-inch thick outer steel shell. The steel shells are welded to a concentric top flange designed to receive a silicone rubber gasket.

The cask primary lid is identical to the cask walls except that the inner shell plate is 1/2-inch steel. Incorporated into the main cask lid is a secondary lid installed concentric to the main lid. The secondary lid covers a 26-inch diameter opening and is fabricated identical to the cask side walls. The secondary lid is fitted with a neoprene gasket and is bolted to the main lid with eighteen 3/4-inch diameter bolts. The main cask lid is bolted to the cask body with twelve 1 1/4-inch diameter by 6 1/2-inch long bolts.

The cask bottom consists of a 1/2 inch steel inner wall, 1 inch thick lead and is welded to a 3/4 inch thick, 96-inch square baseplate. The cask has two lifting trunnions which are welded to the top flange and the outer steel shell, three lid lift rings and one secondary lid lifting ring which is covered during transport.

The lead shielding consists of sheets of lead bonded by an adhesive to the steel walls. CNSI manufacturing procedures 2MP-002 and 2MP-003 control the bonding and curing techniques for fabricating each of the steel-lead-steel composite cask components. This fabrication method has been demonstrated to result in lap shear strengths in excess of 5000 psi. (Reference: "How to join lead with Adhesives", ADHESIVES AGE, September 1968 and 3-M Product Specification Data Sheets for 2024-T3 aluminum adherend and AF-126 (008) structural adhesive). This bonding strength is accounted for in certain portions of the structural analysis.

The model 21-300 shipping cask is also capable of accepting an internal auxiliary shield (Dwg. C-114-E-0004) and a load distribution pallet (Dwg. C-114-D-0006). The packaging configuration can therefore exist in various forms, including the following:

i. single 300 (nominal) cubic foot liner

ii. 21-55 gallon drums with a load distribution pallet.

iii. 21-55 gallon drums with an internal shield and a load distribution pallet.

iv. Single liner (solidified) with an internal shield

The gross cask weight is 57,450 pounds including a maximum payload of 27,250 pounds, including the weight of the liner, internal shield, and/or load distribution pallet if used.

1.2.2 OPERATIONAL FEATURES

There are no complex operational requirements associated with this package.

1.2.3 CONTENTS OF PACKAGING

(1) Type and Form of Material

(i) Processed solids, either dewatered, solid or solidified in secondary containers, meeting the requirements for (LSA) radioactive material, or

(ii) Solid reactor components in secondary containers as required that meet the requirements for (LSA) radioactive material.

(iii) When liquid or resin waste is shipped using the auxiliary shield it shall be solidified with one of the following solidification media:

(a) Dow media;
(b) Cement;
(c) Asphalt;
(d) Delaware custom media; or
(e) Solidification media and process reviewed and approved by the U.S. Nuclear Regulatory Commission, Office of Nuclear Reactor Regulation.

Solidified radiation waste shall have no detectable free standing liquids. For purposes of this condition, the terminology "no detectible free standing liquids" means one-half percent (0.5%) by waste volume of non-corrosive liquids per container.

(2) Maximum quantity of material per package

Greater than Type A quantities of radioactive material with the weight of the contents, secondary containers, auxiliary shield, load distribution pallet and shoring not exceeding 27,250 pounds.

(3) Use of Internal Auxiliary Shields

An internal auxiliary shield with a 1 inch thick steel wall may be utilized to augment cask shielding effectiveness. This shield is depicted in drawing C-114-E-0004 The structural adequacy of the design is demonstrated in Section 2.6.6 of this SAR, and the shielding effectiveness is evaluated in Section 5.0.

1.3 APPENDIX

1.3.1 Figure One -Cask Outline

1.3.2 CNSI Drawing 1-298-101 Rev. J.

1.3.3 CNSI DRAWING NO. C-114-E-0004, Rev. B, Full Height Shield for 21-300 Cask

1.3.4 CNSI DRAWING NO. C-114-D-0006, Rev. B, Load Distribution Pallet

CHEM-NUCLEAR SYSTEMS, INC.

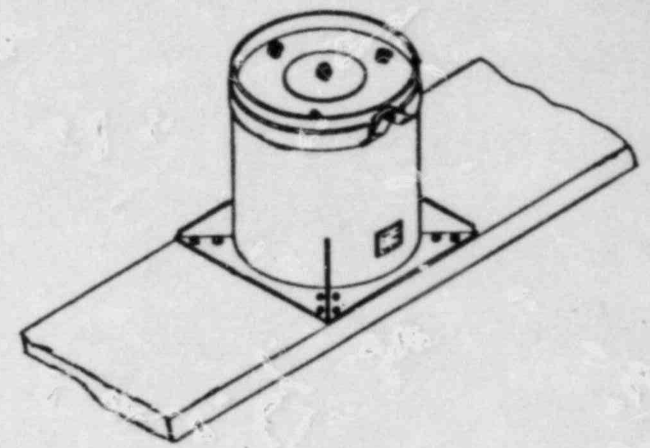
TRANSPORT CASK
CNS. 21-300
SHIELDING : 1.50 IN. LEAD EQUIV.
USA. DOT. SPEC. 7A, TYPE A
U.S.N.R.C. PACKAGE IDENT. NO. USA/9096/A

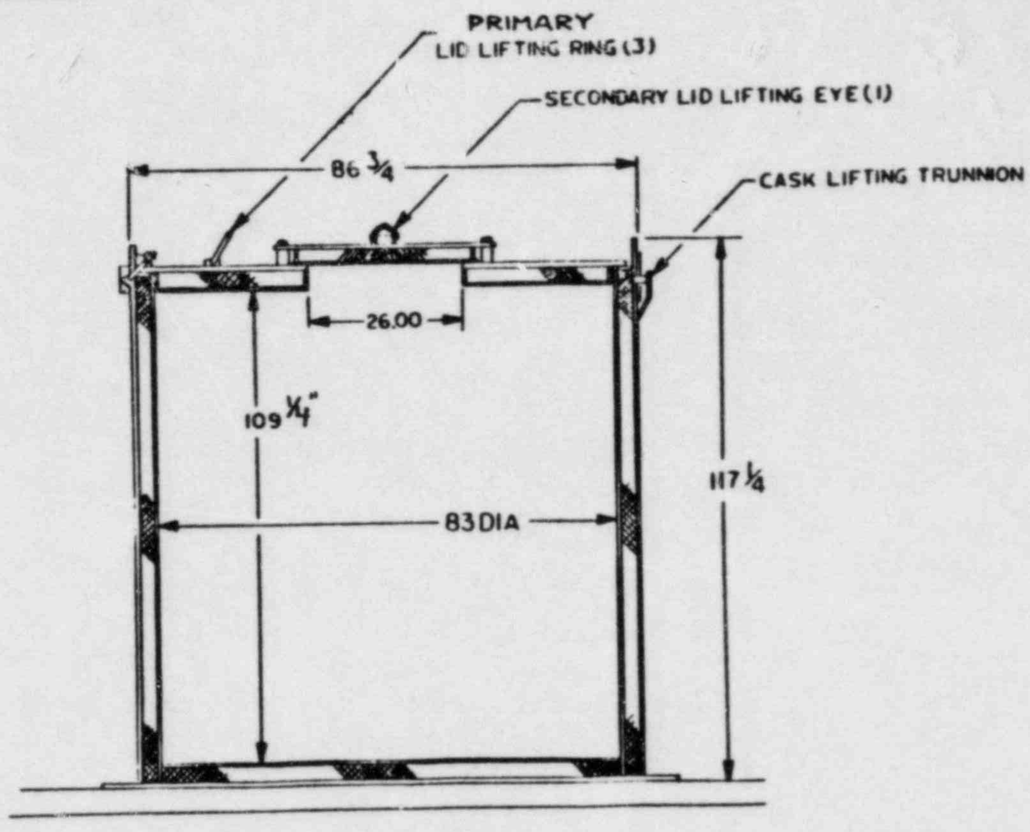
CAPACITY

(21) 55GAL. DRUMS
OR (1) 300 CU. FT. CONTAINER
(NOMINAL)

WEIGHT

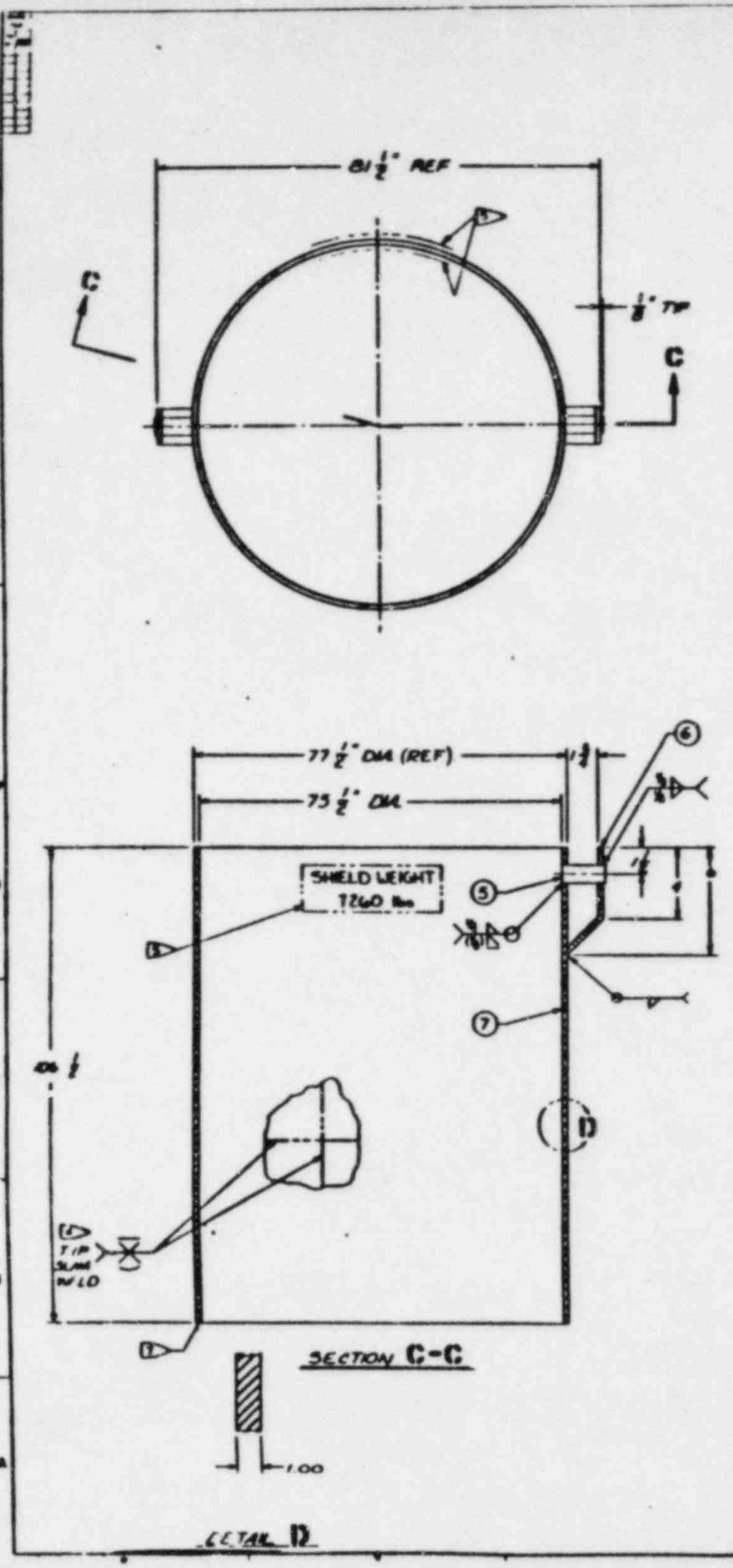
GROSS WT. (EMPTY) 30,200 LBS.
PRIMARY LID 3,450 LBS.
SECONDARY LID 550 LBS.

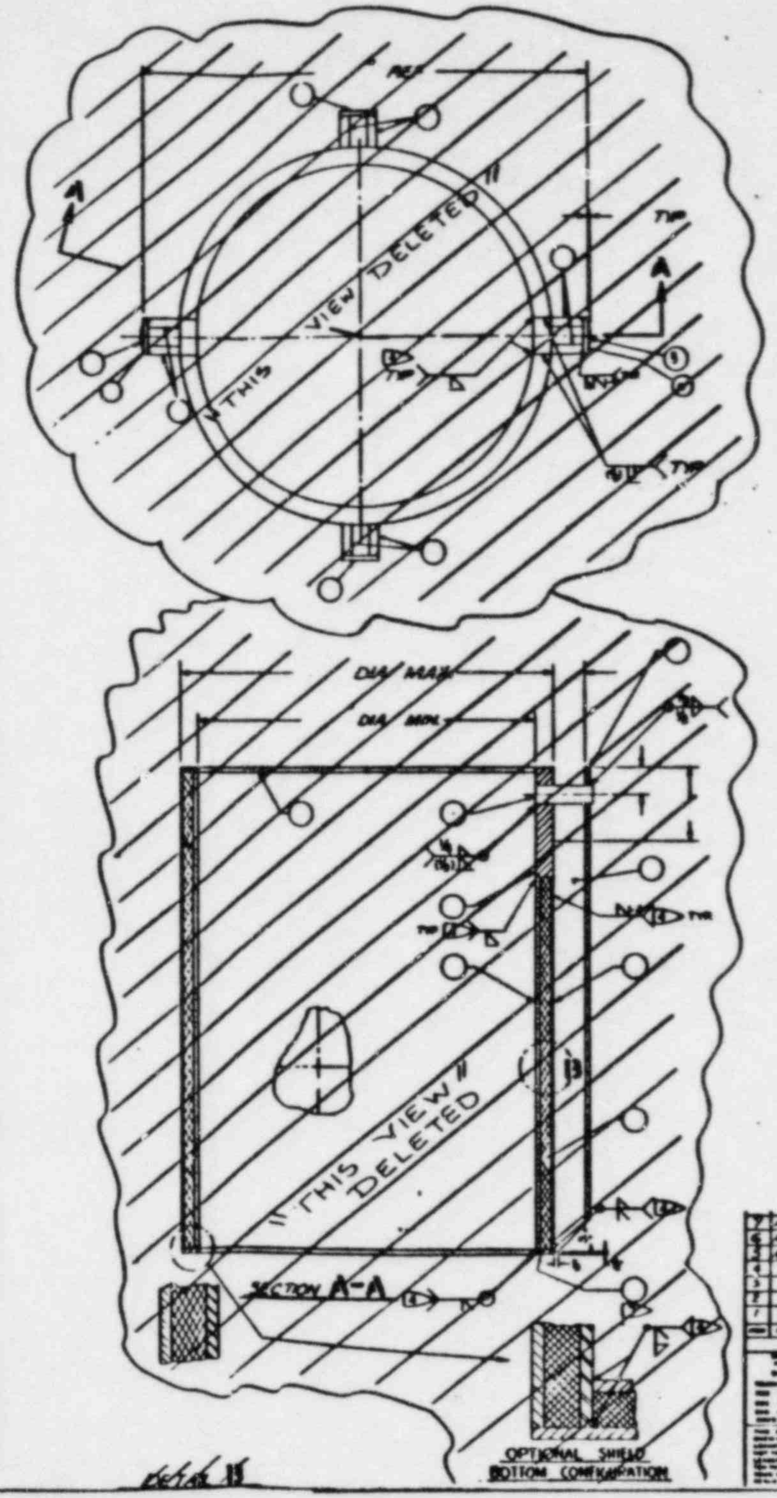




REV. 1

Figure 1





NOTES:

1) WELDING SHALL BE PERFORMED BY WELDERS QUALIFIED PER ASME SECTION IX. WELD PROCEDURES SHALL BE SUBMITTED AND APPROVED PRIOR TO FABRICATION.

2) ALL ITEMS FABRICATED AFTER JUNE 1985 MUST BE ASTM A516 GRADES 55,60...

3) WHEN LIFTING SHIELD, USE OF A SPREADER BAR TYPE ARRANGEMENT IS REQUIRED SO THAT ONLY VERTICAL LOADS ARE EXERTED ON LIFTING EARS.

4) ALL WELDS SHALL BE THE SAME SIZE AS THE MINIMUM MATERIAL THICKNESS. GROOVE WELDS WILL BE FULL PENETRATION.

5) "SHIELD WEIGHT 7260 lbs" TO BE STENCILED IN MIN 2 IN HIGH CHARACTERS (INSIDE & OUTSIDE)

6) CONTENTS MUST BE REMOVED PRIOR TO LIFTING SHIELD.

NOT FOR FABRICATION

7	AR	PLATE, 1" THICK	C-3R	
6	AR	BAR, FLAT 1/2" THK x 2" WIDE	C-3R	
5	4	BAR, ROUND 1" DIA	C-3R	
4		DELETED		
3		DELETED		
2		DELETED		
1		DELETED		

CHEM-NUCLEAR SYSTEMS, INC.

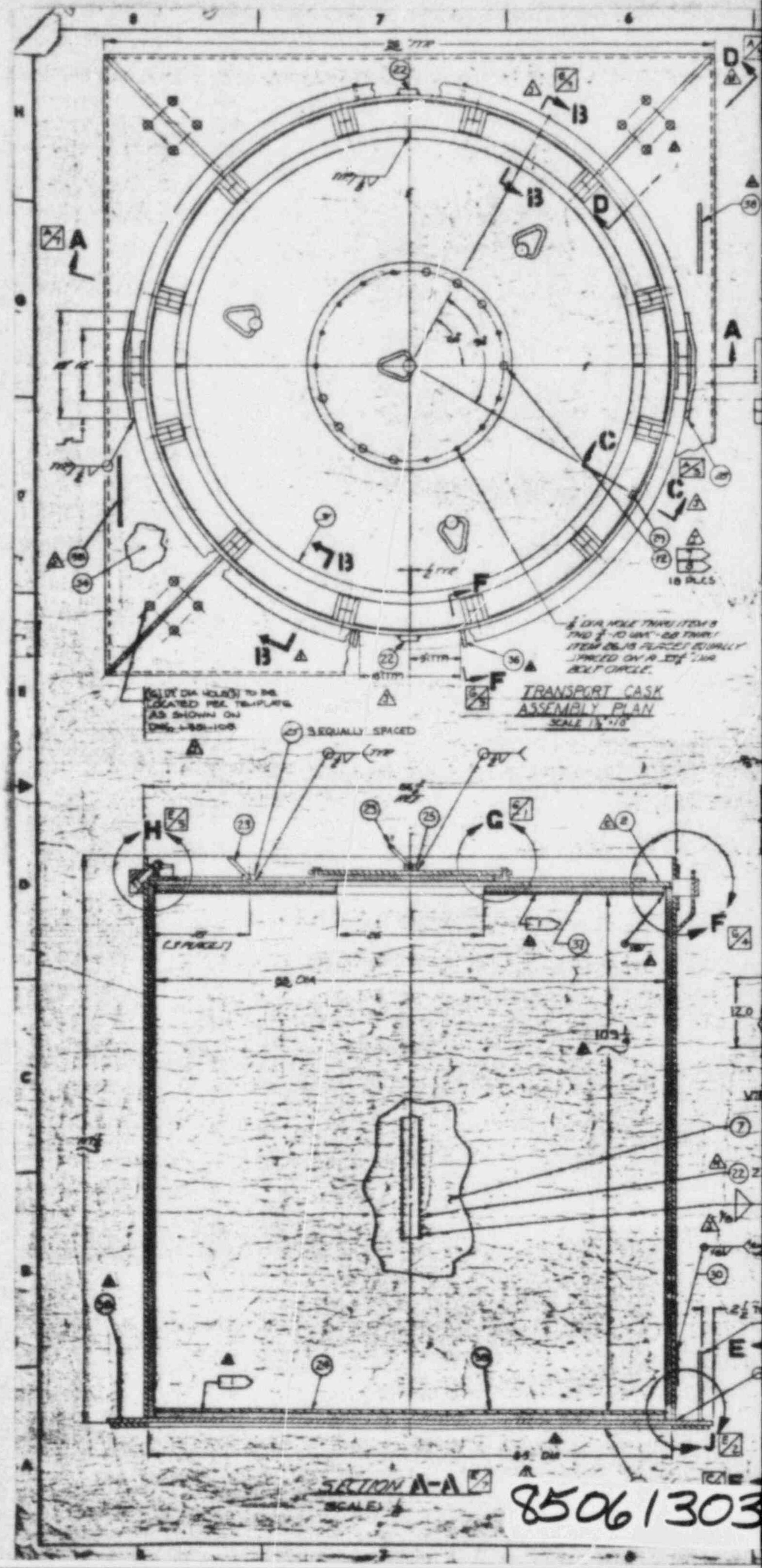
FULL HEIGHT SHIELD FOR 21-300 CASK

T. STANDLEY

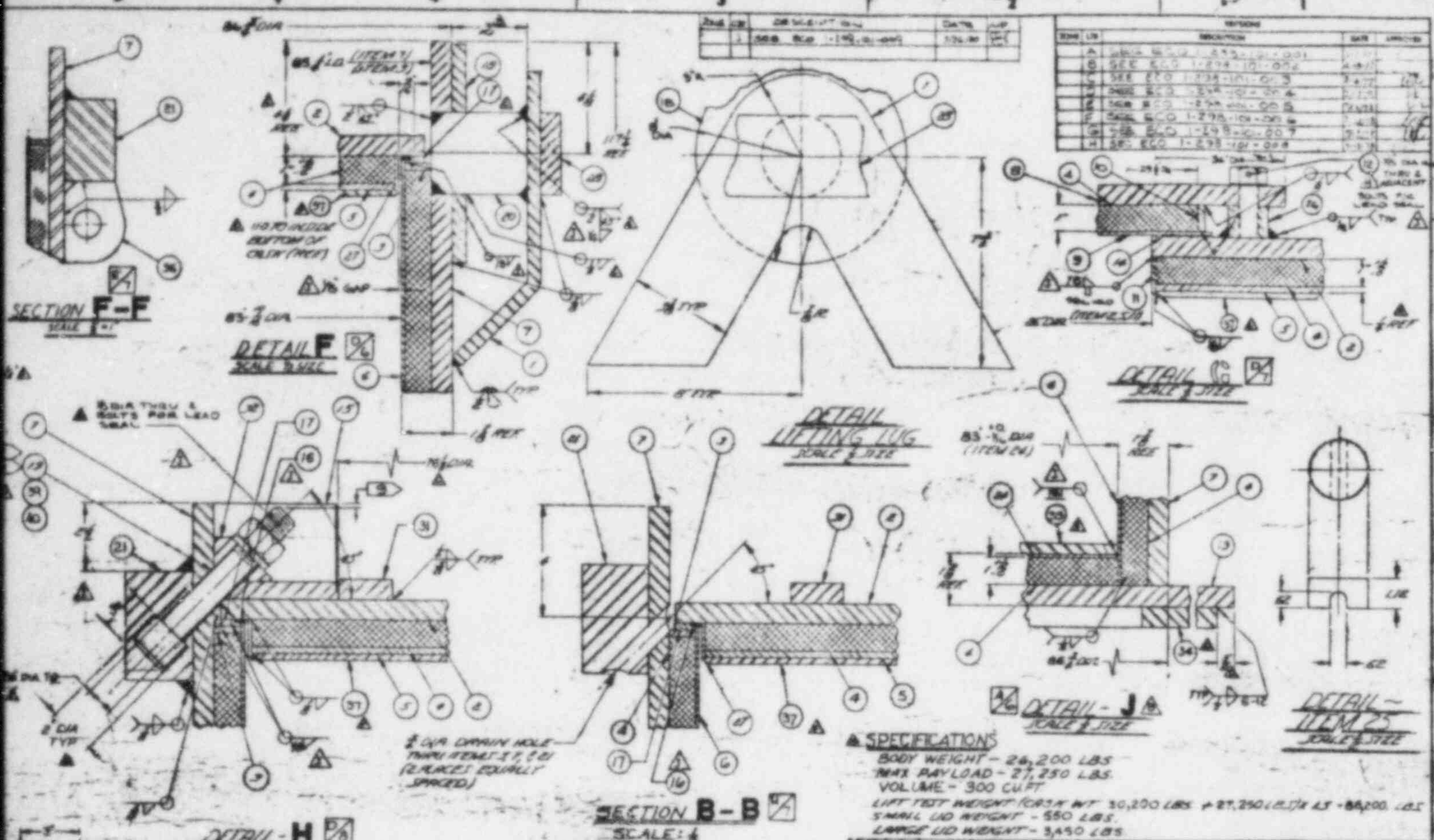
C-114-E-0004 E

Also Available On
Aperture Card

TI
APERTURE
CARD

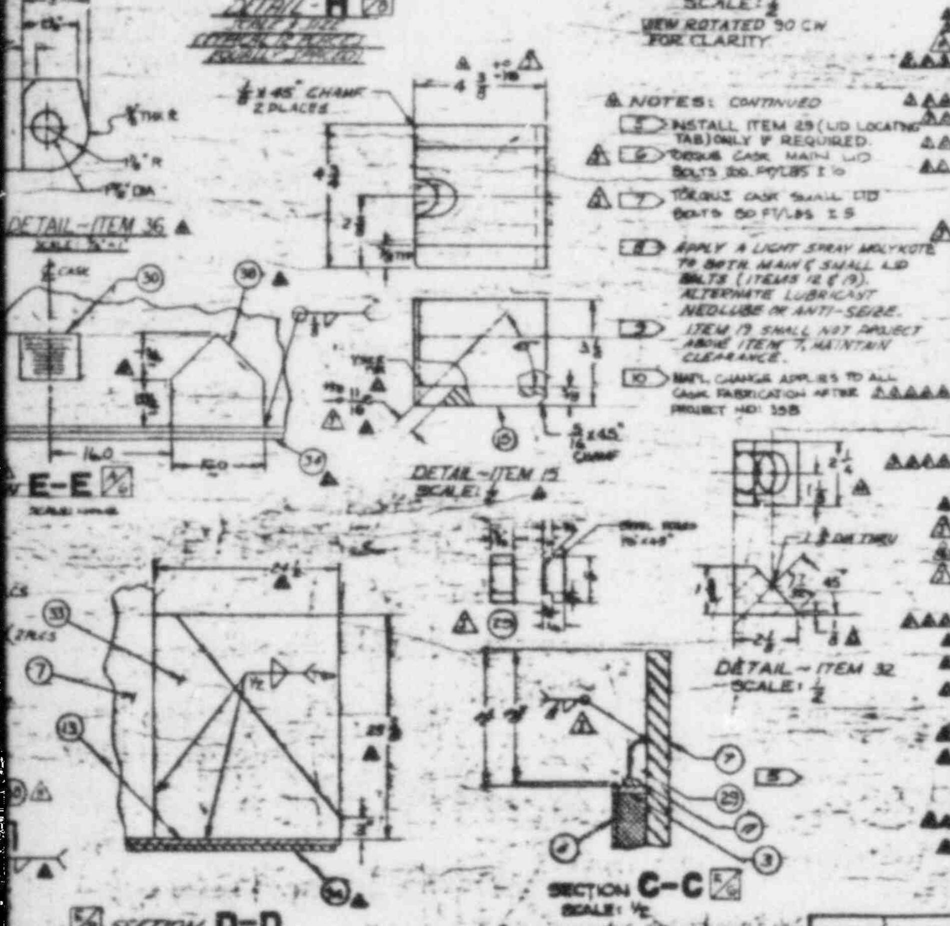


8506130305



SPECIFICATIONS

BODY WEIGHT - 26,200 LBS
MAX PAYLOAD - 27,250 LBS
VOLUME - 300 CU FT
LIFT TEST WEIGHT (CASK WT 30,200 LBS + 27,250 LBS) X 1.5 = 86,200 LBS
SMALL LID WEIGHT - 550 LBS.
LARGE LID WEIGHT - 3,450 LBS



NOTES: CONTINUED

5. INSTALL ITEM 29 (LID LOCATING TAB) ONLY IF REQUIRED.
6. TORQUE CASK MAIN LID BOLTS 300 FT/LBS ± 10
7. TORQUE CASK SMALL LID BOLTS 80 FT/LBS ± 5
8. APPLY A LIGHT SPRAY MOLYKOTE TO BOTH MAIN & SMALL LID BOLTS (ITEMS 12 & 19). ALTERNATE LUBRICANT NEOLUBE OR ANTI-SEIZE.
9. ITEM 13 SHALL NOT PROJECT ABOVE ITEM 7. MAINTAIN CLEARANCE.
10. MATL CHANGE APPLIES TO ALL CASK FABRICATION AFTER PROJECT NO: 358

NOTES:

1. MATL PLACEMENT, BONDING & CURING SHALL BE PER CNSI PROCEDURES 2-MP-002 & 2-MP-005
2. WELDING PROCEDURES & WELDER QUALIFICATION SHALL BE PER ASME SECTION IX OR AWS.
3. MATL CHANGE APPLIES TO ALL CASK FABRICATION AFTER PROJECT [illegible] [illegible] ASTM A20-77 & ASTM A370 EXCEPT ITEM 10

ITEM	QTY	CODE IDENT	NOMENCLATURE OR DESCRIPTION	PART NO.
40	12		WASHER, PLAIN 3/4" I.D. NOMINAL	COML. INC. [illegible]
39	12		[illegible]	[illegible]
38	2		PLATE, 1/4"	A36
37	1		[illegible] DIA x [illegible] THK	CRES 304
36	4		[illegible] x 3 x 4	A36 [illegible]
35	1		[illegible] DIA x [illegible] THK	CRES 304
34	1		[illegible] x 94 1/2 SQ (83 [illegible] DIA)	A36 [illegible]
33	4		GUSSET [illegible] THK x 24 1/2 x 29 [illegible]	A36 [illegible]
32	12		BAR [illegible]	A36 [illegible]
31	4		BAR [illegible] x 2 x 56 [illegible]	A36 [illegible]
30	1		NAMEPLATE	[illegible] 298-102
29	1		BAR [illegible] LG	A36 [illegible]
28	2		[illegible] THK x 3 x 18 [illegible] LG	A36 [illegible]
27	1		[illegible] THK x 1 [illegible] x 280 [illegible] APPROX	CRES 304
26	18		TUBE 1 [illegible] DIA x [illegible] WALL x [illegible] LG	A36 [illegible]
25	4		BAR [illegible] LG	A36 [illegible]
24	1		[illegible] 83 [illegible] DIA x [illegible] THK	CRES 304
23	4		RING [illegible]	[illegible]
22	2		BAR [illegible] x 4 x 12 [illegible] LG	A36 [illegible]
21	2		BAR [illegible] x 4 x 34 LG	A36 [illegible]
20	2		BAR 3 O.D. x 3 [illegible] LG	AISI 1018
19	12		SOC HD SCREW [illegible] UNC x [illegible] LG	[illegible]
18	2		[illegible] O.D. x [illegible] THK x 3 I.D.	A36 [illegible]
17	1		BAR [illegible] x 256	CRES 304
16	1		SEAL [illegible] x 83 [illegible] O.D. x 82 1/2 I.D.	SILICONE RUBBER [illegible]
15	12		BAR 3 [illegible] x 4 [illegible] x 4 [illegible]	A36 [illegible]
14	1		SEAL [illegible] x 29 O.D. x 27 I.D.	[illegible]
13	1		[illegible] x 36 x 36	A36 [illegible]
12	45		HEX HD CAPSCR [illegible] UNC [illegible] LG	[illegible]
11	1		[illegible] 26 I.D. x [illegible] WALL x 1 [illegible] HIGH	CRES 304
10	1		[illegible] I.D. x [illegible] WALL x 1 HIGH	CRES 304
9	1		[illegible] 29 [illegible] O.D. x [illegible] THK	CRES 304
8	1		[illegible] 36 O.D. x [illegible] THK	A36 [illegible]
7	1		[illegible] 85 [illegible] I.D. x [illegible] WALL x 116 [illegible] HIGH	A36, A [illegible] OR A516
6	1		[illegible] 85 [illegible] O.D. x [illegible] WALL x 112 [illegible] HIGH	CRES 304 OR 316
5	1		[illegible] 26 I.D. x 82 [illegible] O.D. x [illegible]	CRES 304
4	AR		LEAD	[illegible] SPEC QQ-L-201 GR [illegible]
3	1		[illegible] 83 [illegible] I.D. x 85 [illegible] O.D. x [illegible] THK	CRES 304
2	1		[illegible] 26 I.D. x [illegible] x 84 [illegible] O.D.	A36 - CUT FR ITEM 34
1	8		[illegible] x 12 x 16	A36 [illegible]

PARTS LIST

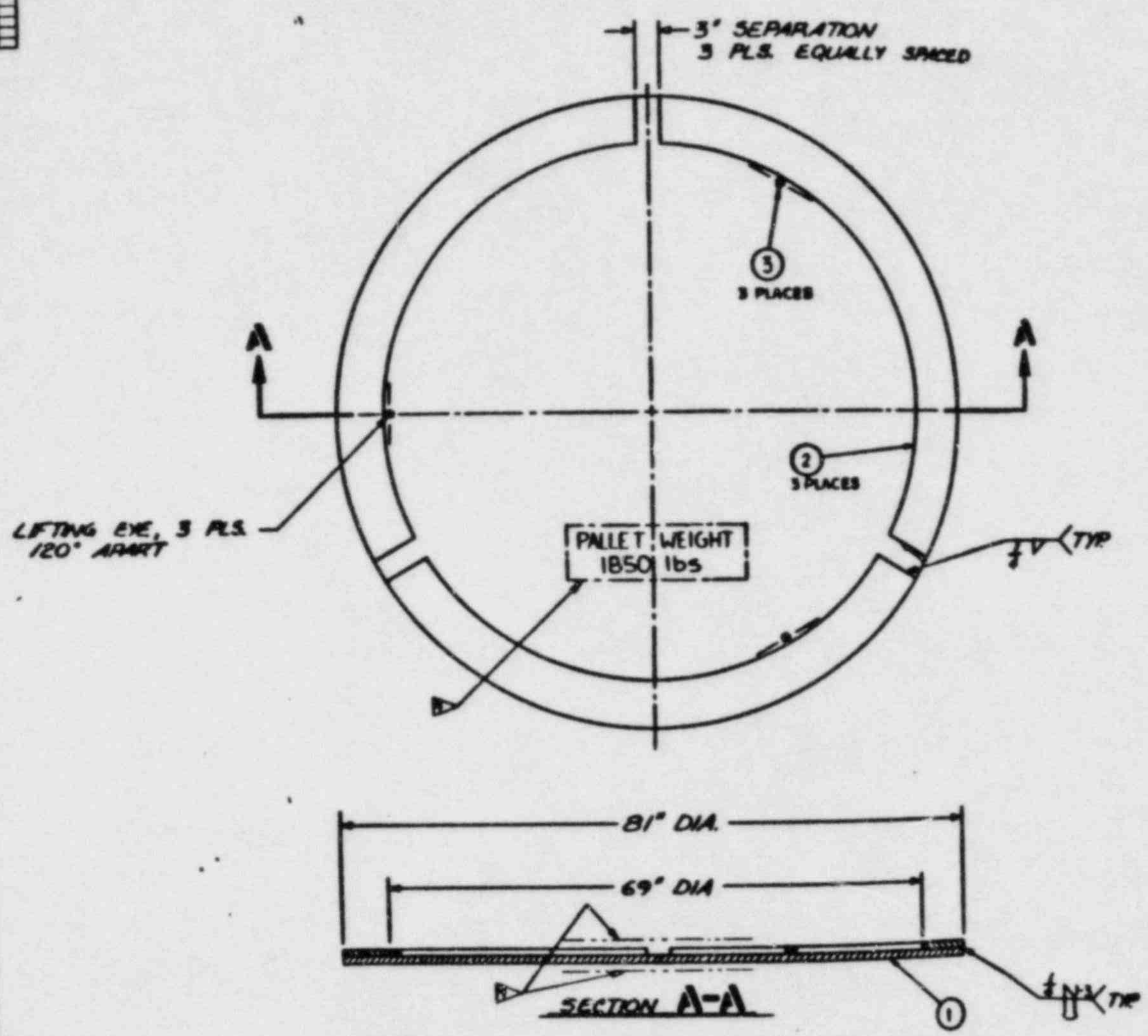
CHEM-NUCLEAR SYSTEMS, INC.

21-300 TRANSPORT CASK

DRAWN: R. STONE

DWG NO. 1-298-101 REV. [illegible]

38-01



NOTES:

1) REMOVE ALL BURRS AND SHARP EDGES.
2) WELDING SHALL BE PERFORMED BY WELDERS QUALIFIED PER ASME SECTION IX. WELD PROCEDURES SHALL BE SUBMITTED AND APPROVED PRIOR TO FABRICATION.
3) PAINT ITEMS 1, 2, & 3.
4) "PALLET WEIGHT 1850 lbs." TO BE STENCILED IN MIN 2" HIGH CHARACTERS (TOP AND BOTTOM).

NOT FOR FABRICATION

3	3	BAR, FLAT, 5/8" x 1" x 1 1/4" LG.	C' STL.
2	3	PLATE, 1" THK.	C' STL.
1	1	PLATE, 3" THK.	C' STL.

A ADDED NOTE 4/PALL. WEIGHT

CHEM-NUCLEAR SYSTEMS, INC.

DO NOT SCALE PRINT

20533

LOAD DISTRIBUTION PALLET 21-300 CASK

D C-114-D-0006 A

2.0 STRUCTURAL EVALUATION

Analyses are presented herein that demonstrate the acceptability of the packaging design features with respect to regulatory criteria in effect at the time that this container was initially approved for use.

2.1 INTRODUCTION

This section identifies and describes the principal structrual engineering design features of the model 21-300 cask, which are important to safety in compliance with the performance requirements of 10 CFR 71 as applicable for a Type A package.

2.2 WEIGHTS AND CENTERS OF GRAVITY

The empty container weighs approximately 30,200 pounds and is capable of carrying a maximum payload of 27,250 pounds. The center of gravity for the assembled package is located at the approximate geometric center. A weight summary of cask components is as follows:

Cask Shell Weight	26,200 pounds
Total Lid Weight	4,000
Maximum Payload	27,250
Gross Cask Weight	57,450
Internal Auxiliary Shield	7,260
Load Distribution Pallet	1,850

The weight of the shield and pallet must be accounted for in the payload so that the allowable gross cask weight is not exceeded.

2.3. MECHANICAL PROPERTIES OF MATERIALS

The mechanical properties of materials of metallic components used for analysis of the CNSI 21-300 Cask are as follows:

Component	Material	Allowable
External Shells	A-36 Steel	Fty = 36 ksi
Internal Shells	A-304	Fty = 30 ksi
Trunnions	SAE 1018	Fty = 40 ksi
Bolts (1-1/4"D.) (Primary lid)	SAE J 429,Gr.8	Fty = 130 ksi Ftu = 150 ksi
Bolts (3/4" D.) (Secondary lid)	SAE J 429, Gr.2	Fty = 57 ksi Ftu = 74 ksi

With Revision J to Dwg. No. 1-298-101, A-36 Steel is replaced with ASTM A-516, Gr.70 Steel. This provides additional safety margins above those shown elsewhere within this report, as follows:

	A-36	A-516, Gr.70	% Increase
Tension Yield, Fty	36 ksi	38 ksi	5.6%
Tension Ultimate, Ftu	58 ksi	70 ksi	20.7%

The 516 material is incorporated in packagings fabricated after April 14, 1980. Analysis performed for this SAR are based upon the A-36 properties for conservatism.

2.4 GENERAL STANDARDS FOR ALL PACKAGES

2.4.1 Chemical and Galvanic Reactions

All solidified radioactive wastes will be contained within 55 gallon drums or approved liners. There is no potential for galvanic or chemical reactions between the package components and the package contents.

2.4.2 Positive Closure

The cask lid is positively closed as noted in Section 1.2.1. In addition, each cask is equipped with a seal feature which provides positive indication that the cask may have been tampered with.

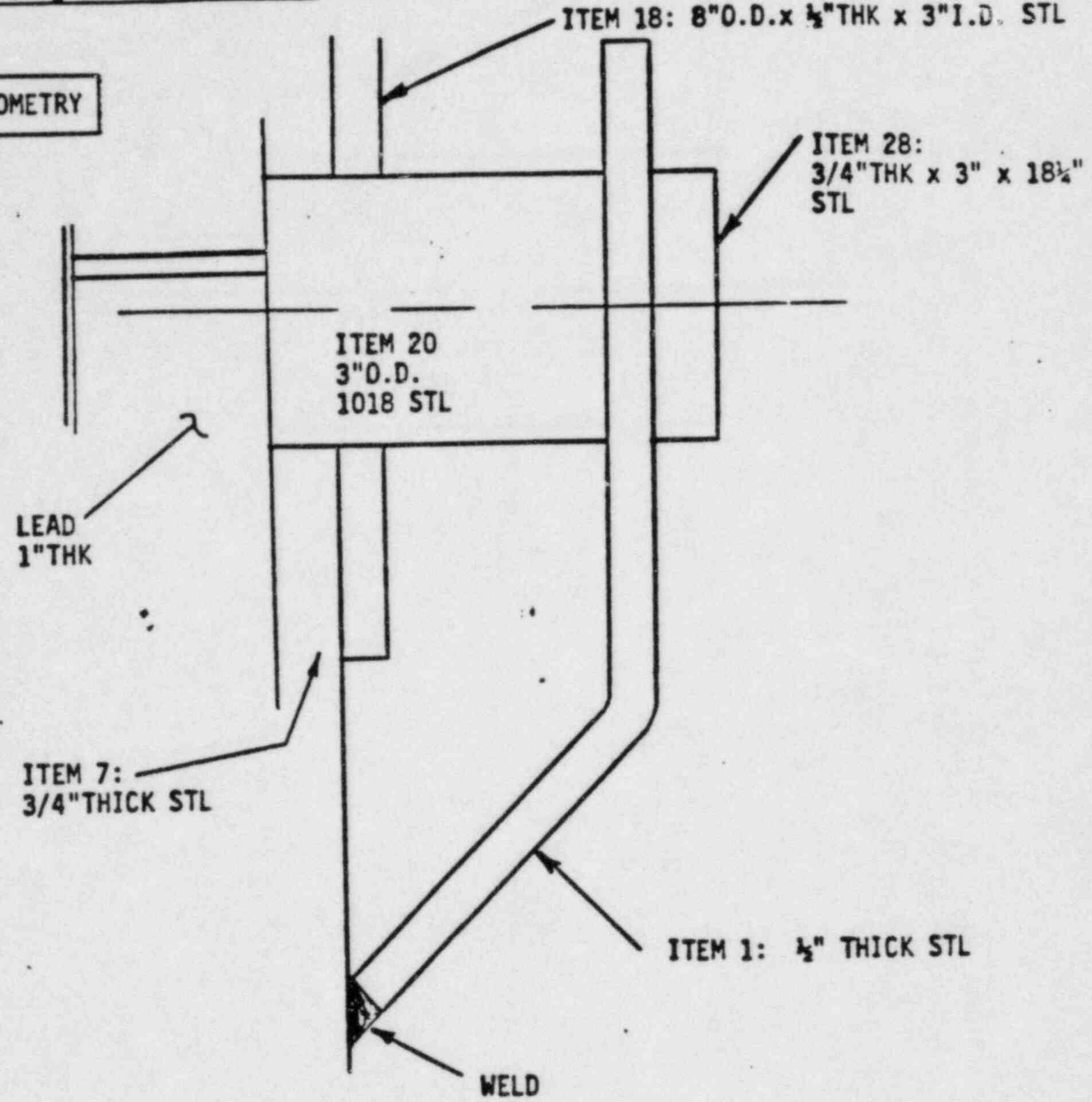
The main cask lid is sealed with a silicone rubber gasket and the secondary lid with a neoprene seal. Both lids are bolted to assure that they are water and pressure tight.

2.4.3 Lifting Devices

10CFR 71.45 (a) requires that any lift point be designed with a minimum safety factor of three against yielding when used to lift the package in the intended manner. The CNS 21-300 package is equipped with two lifting trunnions as shown on CNS drawing 1-298-101 Rev J. The following anaylsis therefore evaluates one trunnion subjected to 3 times one-half of gross package weight, or a total load of 86,175 pounds. This analysis shows that the lifting devices can withstand 3 times the gross package weight without failure.

Lifting Devices Analysis

GEOMETRY



REFERENCE: DRAWING NUMBER 1-298-101 Rev. J
DETAIL F AND DETAIL LIFTING LUG

LOADS

The regulatory criterion of three times gross package weight will be shared by two lifting trunnions.

MAXIMUM GROSS PACKAGE WEIGHT, W=57, 450 POUNDS

LOAD TO EACH TRUNNION = $\frac{3W}{2}$ = $\frac{3(57.45\ k)}{2}$ = <u>86.2 k</u>

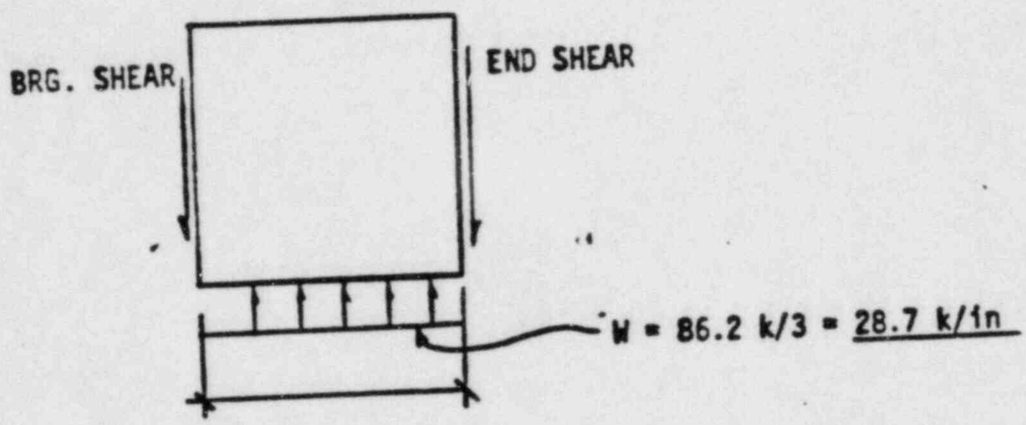
ANALYSIS

<u>ITEM 20</u> (1018 STEEL)

ALLOWABLE STRESSES:

TENSILE YIELD STRENGTH, Y_s = 40 ksi

SHEAR STRENGTH, $S_s = \frac{Y_s}{\sqrt{3}}$ = 23.1 ksi



AREA = $\frac{\pi(3)^2}{4}$ = $\underline{7.07\ IN^2}$

BRG. SHEAR = 5/8 (28.7)(3) = <u>53.9 k</u>

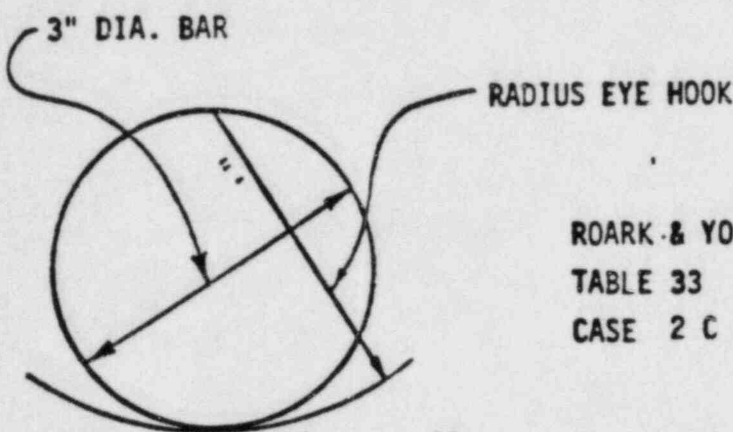
f_{SHEAR} = 53.9/A = 7.6 ksi < 23.1 ∴ OK

$$\text{BENDING MOMENT} = \frac{WL^2}{8} = \frac{28.7(3)^2}{8} = \underline{32.3 \text{ IN-KIPS}}$$

$$S_o = \frac{\pi R^3}{4} = \frac{\pi(1.5)^3}{4} = \underline{2.65 \text{ IN}^3}$$

$$f_{BEND} = \frac{M}{S} = \frac{32.3}{2.65} = 12.2 \text{ ksi} < 40 \therefore \text{OK}$$

BEARING EYE HOOK ON 3" DIA. BAR



ROARK & YOUNG - 5th EDITION
TABLE 33
CASE 2 C

$$K_b = \frac{D1D2}{D1-D2} = \frac{6(3)}{6-3} = \frac{18}{3} = \underline{6}$$

$$\text{STRESS} = 0.591\sqrt{\frac{PE}{K_b}} = 0.591\sqrt{\frac{28.7(29)(10^3)}{6}} = \underline{220 \text{ ksi}}$$

Even though this calculated stress is higher than the corresponding allowable, this is not judged to be significant because this calculation is based on a conservative model. The actual effect in this situation would be a slight deformation of the hook/bar which would greatly reduce the stress value.

BEARING ON CASK PLATES AND WELD STRENGTH

ITEMS 7 & 18

$(5/8)WL = \underline{51.6 \text{ kips}}$

$$\frac{0.75}{0.75 + 0.5} = 0.60 \qquad \therefore \quad \begin{array}{l} 60\% \text{ TO ITEM 7} \\ 40\% \text{ TO ITEM 18} \end{array}$$

(0.75 → ITEM 7; 0.5 → ITEM 18)

$$(f_{BRG})_7 = \frac{0.6(51.6)}{3(0.75)} = \underline{13.76 \text{ ksi}}$$

$$(f_{BRG})_{18} = \frac{0.4(51.6)}{3(0.5)} = \text{Same as above}$$

BRG ALLOW A-36 = 0.9 Ys = 32.4 ksi > 13.76 ksi ∴ OK

WELD STRENGTHS:

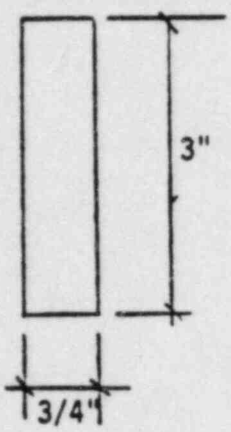
ITEM 7, ITEM 18 } $0.928(6)(\pi)(8) = \underline{140 \text{ k}}$ Obviously OK

ITEM 1

SHEARS 3/8 WL TO ITEM 28 ONLY.

WELD: $0.928(8)(\pi)(3) = \underline{70\ k}$ Obviously OK.

ITEM 28



$3/8\ WL = 3/8\ (86.1) = \underline{32.3\ k}$

COMPLETE FIXITY AT ENDS:

$M = PL/8 = 32.3(15)/8$

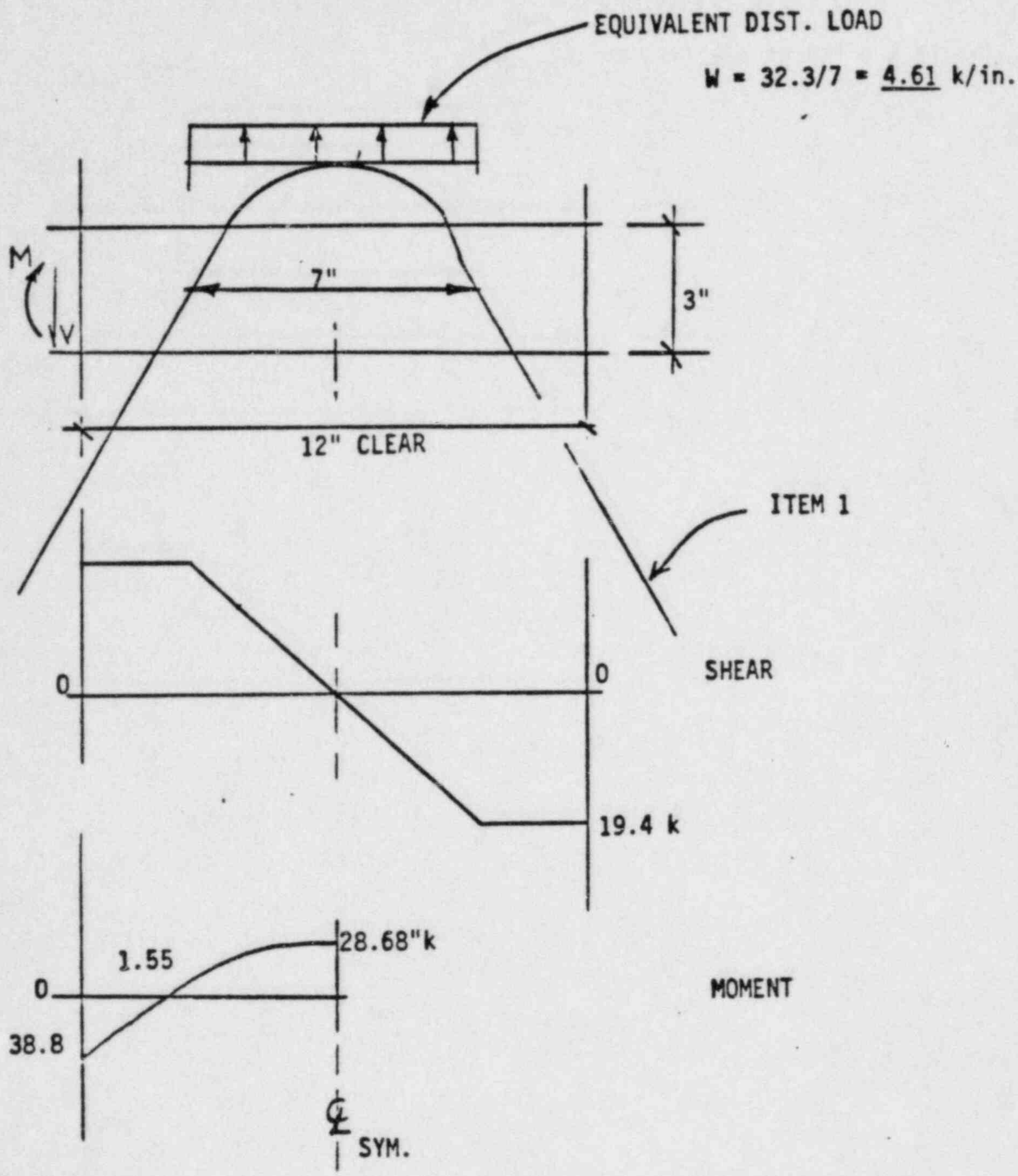
$= \underline{60.5\ \text{IN-KIPS}}$

$f_{BEND} = \frac{60.5(6)}{0.75(3)^2} = \underline{53.8\ ksi}$ TOO LARGE!

RECK. USING CLEAR SPAN

$\frac{PL}{8} = \frac{32.3(12)}{8} = \underline{48.5\ \text{IN-KIPS}}$

$f_{BEND} = \frac{48.5(6)}{0.75(3)^2} = \underline{43.1\ ksi}$ STILL > Ys

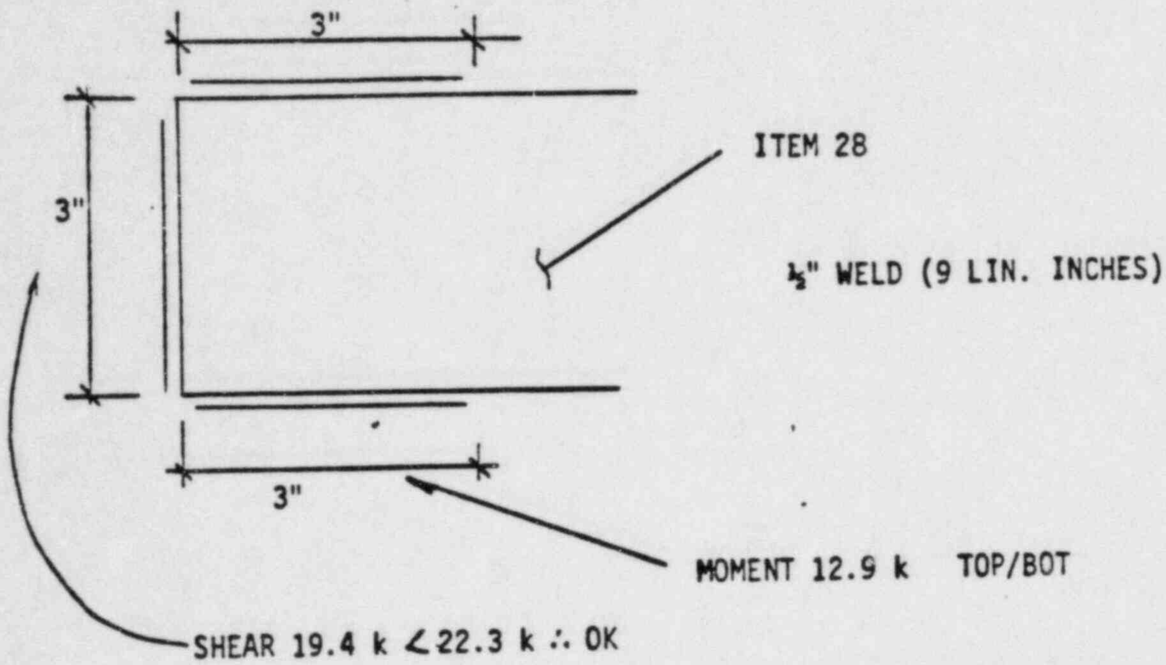


$$\text{SAY } M = \frac{PL}{10} = \frac{32.3(12)}{10} = \underline{38.8 \text{ IN-KIPS}}$$

$$\text{BENDING} = \frac{38.8(6)}{0.75(3)^2} = 34.5 \text{ ksi} < Y_s = 36 \text{ ksi} \therefore \text{OK}$$

WELDS AT ENDS 38.8/3 = 12.9 kips

0.928(8)(3) = 22.5 k CAPACITY > 12.9 k ∴ OK



CASK BENDING

ROARK & YOUNG - 5th ED.

TABLE 30

CASE 3

$$\lambda = \left[\frac{3(1-\nu^2)}{R^2t^2}\right]^{1/4} = \sqrt[4]{\frac{3(1-0.09)}{(41.5)^2(2.1)^2}}$$

$= \underline{0.14}$

COMPOSITE EQUIV. THK

$\lambda\ell = 0.14(90) = 12.4$

$$f = \frac{2M_o\lambda^2R}{t} = \frac{2(M_o)(0.14)^2(41.5)}{2.1} = \underline{0.77\ M_o}$$

$M_o = 31.0(0.77) = \underline{24\ ksi}$ UPPER POD $\therefore$ OK

2.4.4 Tiedown Devices

The package tiedown system must be able to withstand a static force applied at the center of gravity of the package with a vertical component equal to two times the weight of package and contents, a horizontal component along the direction of travel equal to ten times total loaded weight, and a horizontal component transverse to the travel direction equal to five times the total weight. The resulting stresses in the package material shall be less than appropriate yield strengths.

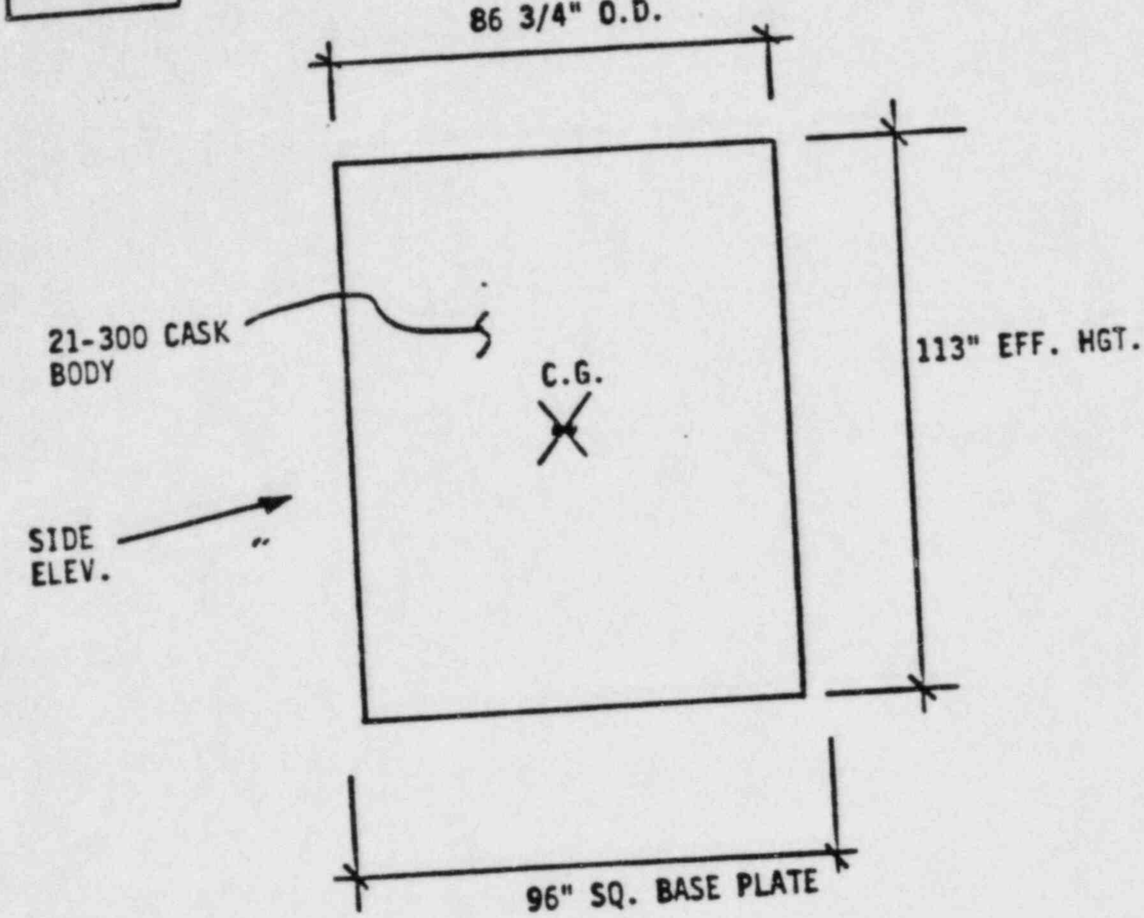
The tie-down system that evolved satisfying the above is a thickened baseplate with gusset stiffeners in each corner of the baseplate welded to the cask body.

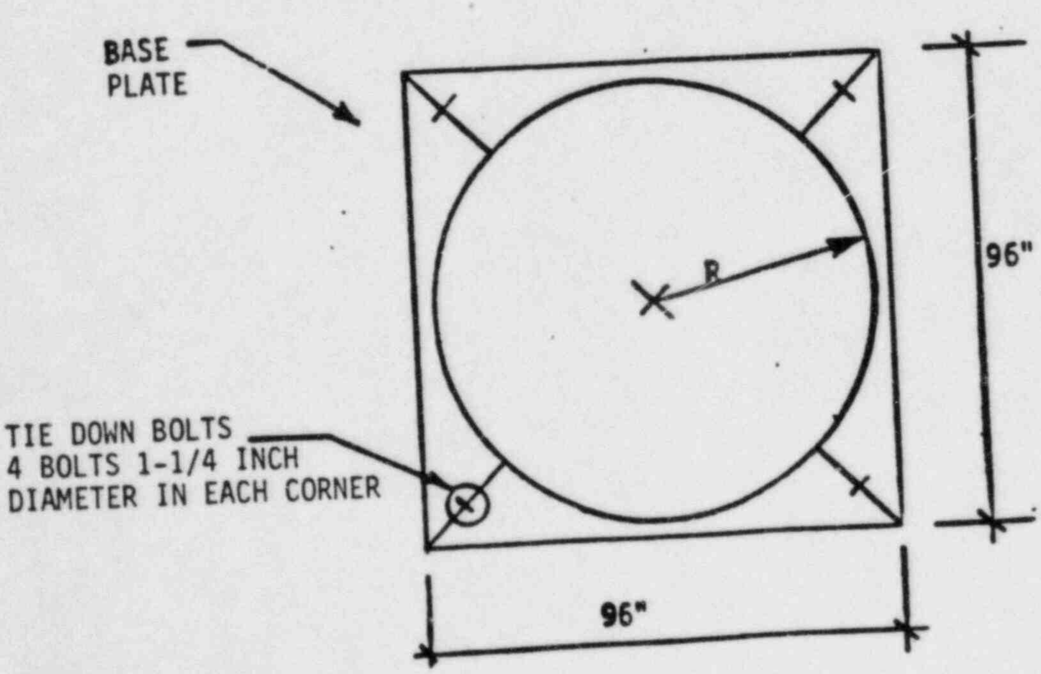
The baseplate consists of two plates welded together to provide a total thickness of 1-1/2 inches. The baseplate is secured to the trailer floor with 16-1 1/4 inch bolts. The following analysis demonstrates the acceptability of this design.

TIE-DOWN ANALYSIS

REFERENCE DRAWING NUMBER 1-298-101 REV. J

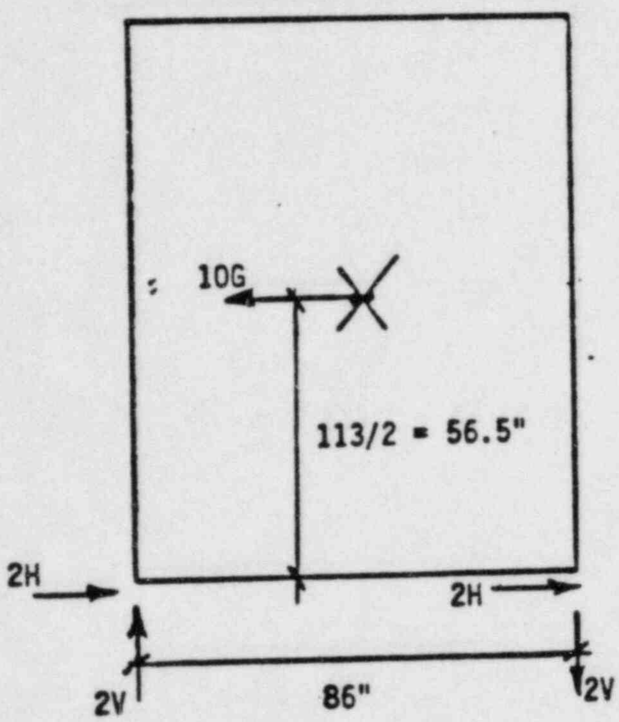
GEOMETRY





LOADS

CRITICAL LOADING BASED ON 10G IN DIRECTION OF TRAVEL.
EVALUATE CAPABILITY OF TIE DOWN SYSTEM TO RESIST TIPPING.



WT. = 55.5 kips at 1G

$$\Sigma M_{forward} = 0 \circlearrowleft^{+}$$

$$= 55.5(10)(56.5) - 2V(86) = 0$$

$$V_{\text{each corner bolt detail}} = \frac{55.5(10)(56.5)}{2(86)} = \underline{182.3 \text{ kips}}$$

$$\Sigma F_{forward} = 0 \overset{+}{\leftarrow}$$

$$= 10(55.5) - 4H = 0$$

$$H_{\text{each corner bolt detail}} = 555/4 = \underline{139 \text{ kips}}.$$

ANALYSIS

BOLT LOADS:

USE (4) - 1¼" DIA. A325 x BOLTS EACH LOC.

AXIAL TENSION = 182.3/4 = **45.6 KIPS** PER BOLT

SHEAR = 139/4 = **35 KIPS** PER BOLT

ALLOWABLE STRESSES FOR A-325

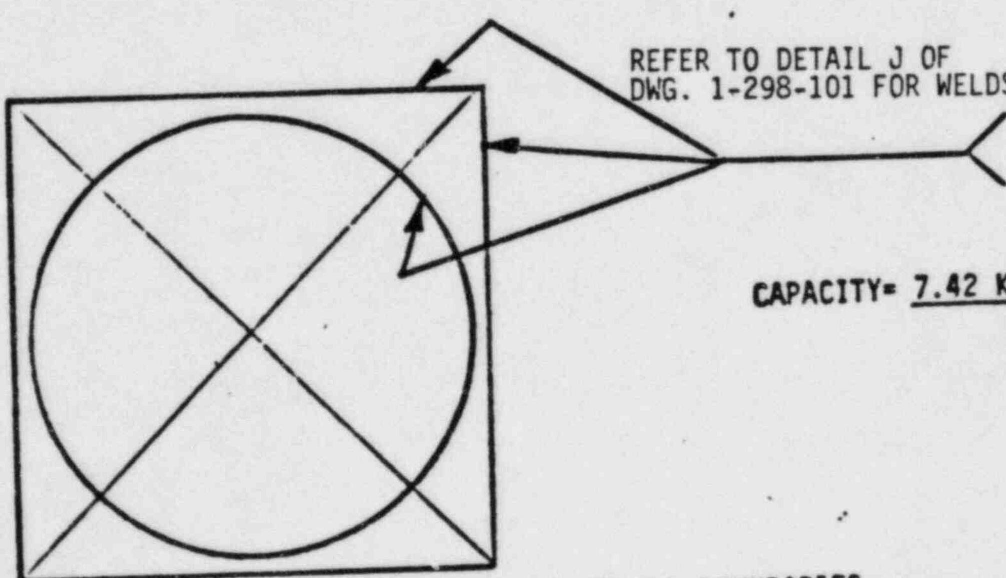
TENSILE ULTIMATE = 105 ksi

TENSILE YIELD = 81 ksi

SHEAR STRENGTH = 47 ksi

RESULTS

3/4" REINF. PLATE WELDED TO 96 IN SQ. BASE PLATE.



CAPACITY= 7.42 KIPS/IN WEL

EFF 7.42/2 = 3.71 K/IN RUNNING INCH AT ALL BOUNDARIES.

RESULTS

BOLTS

AXIAL TENSION = 142.5 K/n

BASE SHEAR = 137.5/n

Where n equals no. of bolts at each of 4 locations.

Try 4 - 1¼" DIA. A325 x Bolts ea. loc. (4 places).

TENSION CAP = 1.227(81)= 99.4 KIPS

SHEAR CAP = 1.227(47) = 57.7 KIPS

TENSION/BOLT = 142.5/4 = 35.63 k — SAY 36 K TENSION

SHEAR/BOLT = 137.5/4 = 34.38 k — SAY 35 K SHEAR

CK COMBINED LOAD:

AISC SPEC. 1.6.3 $F_t = 50 - 1.6f_v \leq 40.0$

USING Ys VALUES $F_t = 100 - 1.6f_v \leq 81$ ← 47 ksi allow.

AXIAL STRESS = 36/1.227 = 29.3 ksi

f_v = 35/1.227 = 28.5 ksi

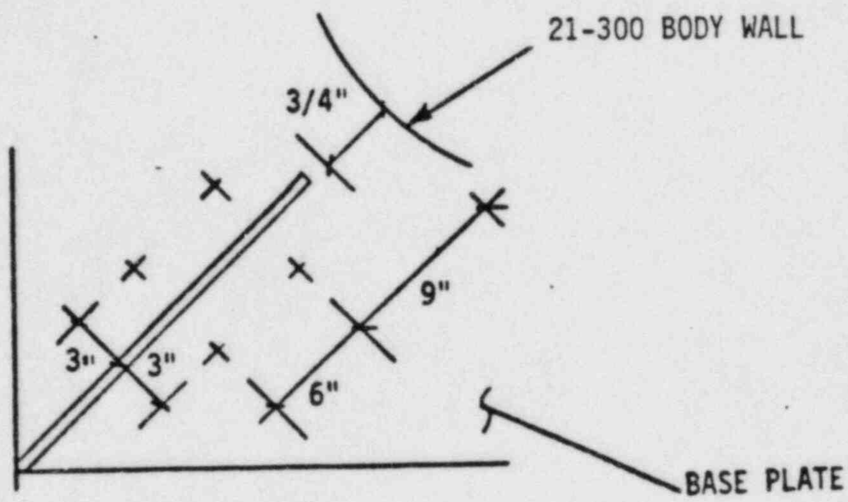
SUBSTITUTING

$F_t = 100 - 1.6(28.5) = 54.4$ ksi > 29.3 ksi ∴ OK

BRG ON A36 PLATE

$\frac{35k}{0.75(1.25)}$ = 37.33 ksi < 48.6 ksi ∴ OK

PRYING ACTION

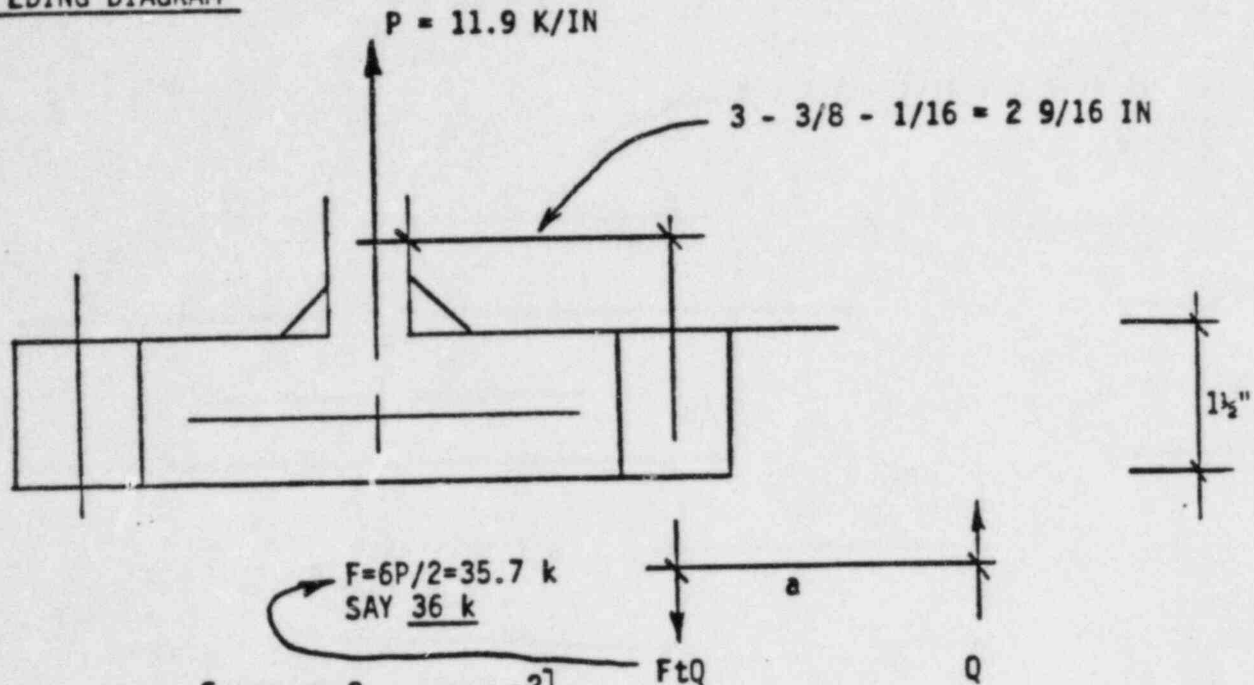


CONSIDER 12 IN EFFECTIVE GUSSET

LD/IN = 142.5/12 = 11.9 K/IN

TRY BASE PLATE 4 INCREASED TO 1.5 IN THK.

LDING DIAGRAM



$$Q = F\left[\frac{100b(db)^2 - 18W(t_f)^2}{70a(db)^2 + 21W(t_f)^2}\right]$$

$$= 35.7\left[\frac{100(2.56)(1.25)^2 - 18(6)(1.5)^2}{70a(1.25)^2 + 21(6)(1.5)^2}\right]$$

a= 3 IN. EFFECTIVE

$$Q = 35.7\ \frac{400 - 243}{328 + 283.5} = \underline{9.2\ \text{KIPS}}$$

0.26

$M_2 = 9.2(3) = \underline{27.6\ \text{IN-KIPS}}$

$M_1 = 45.2(2.56) - 9.2(5.36) = \underline{64.6\ \text{IN-KIPS}}$ (GOVERNS)

$f_{bend} = 64.6(6) / 6(1.5)^2 = 28.7$ ksi $<$ 36 ksi ∴ OK

2.5 Standards for Type B Packaging
N/A for CNSI Model 21-300

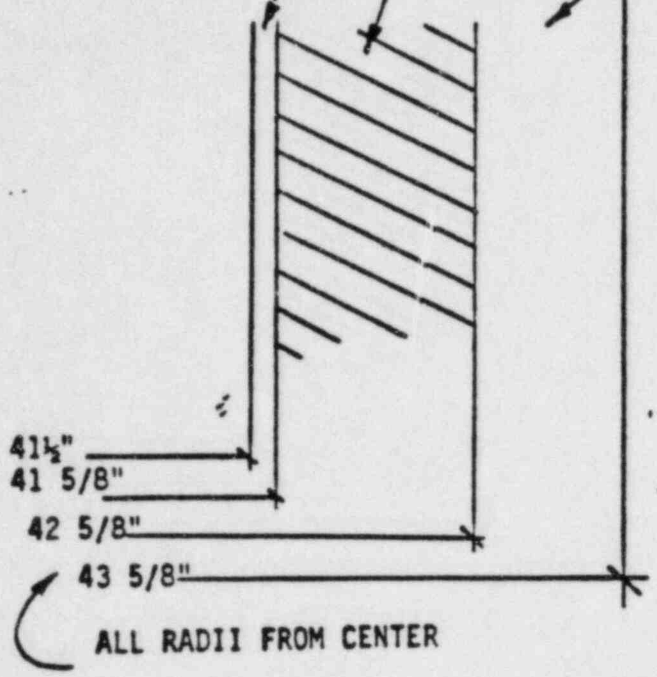
2.6 Normal Conditions of Transport

2.6.1 Heat

An evaluation was performed to consider the affects of increased ambient temperature on cask integrity. For this evaluation, an ambient temperature of 130° is assumed and an additional 100°F conservatively added to the surface temperature to account for solar insolation. Assuming that the cask is in an equilibrium, stress free condition at 70°F, this results in a net temperature change of 160°F to induce stesses in the cask wall as a result of differential thermal expansion between the steel and lead. The following analysis shows that this condition will cause the lead to load the outer shell in tension by 3784 psi which is well below the 36,000 psi yield strength of A-36 steel.

ANALYSIS FOR INCREASED AMBIENT TEMPERATURE

GEOMETRY



ITEM	t_{WALL}	R_{AVG}(IN)
6	0.125	41.56
4	1.0	42.13
7	0.75	43.0

LOADS

$\Delta T = (130 + 100) - 70 = \underline{160^{\circ}F}$

Assume temp. 100° > ambient.

$\alpha \Delta T R = \Delta R$

$\alpha_{LEAD} = 16.1(10^{-6})/^{\circ}F$

$\alpha_{STL} = 6.5(10^{-6})/^{\circ}F$

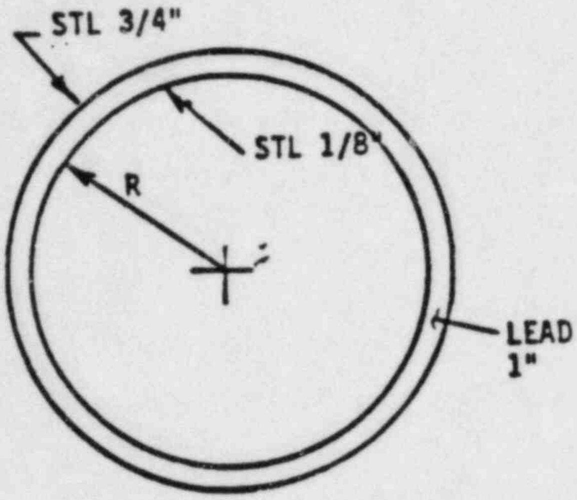
THUS LEAD WILL LOAD OUTER SHELL IN TENSION.

$\Delta R_{LEAD} = 16.1(10^{-6})(160)(42.15) = \underline{0.109\ INCHES}$

$\Delta R_{STL} = 6.5(10^{-6})(160)(43.0) = \underline{0.045\ IN.}$

→ THIN SHELL THEORY SINCE $t/R < 0.10$

ANALYSIS



AT EQUILIBRIUM:

EXTERNAL BEARING PRESSURE (q) ACTING ON LEAD LINER IS EQUAL TO BEARING PRESSURE ACTING ON INNER SURFACE OF OUTER STEEL SHELL.

ROARK & YOUNG -5th ED
TABLE 29
CASE 1b

$f_{HOOP} = qR/t$ + sign for INT.
- sign for EXT.

$f_{STL} = q_{BRG}(43)/0.75 = \underline{57.33\ q_{BRG}}$

$f_{LEAD} = -q_{BRG}(42.13)/1 = \underline{-42.13\ q_{BRG}}$

DEFORMATION

$\Delta R = qR^2/Et$ + INT q (STL)
- EXT q (LEAD)

$$\Delta R_{STL} = \frac{q_{BRG}(43)^2}{29(10^6)(0.75)} = 85(10^{-6})\, q_{BRG}$$

$$\Delta R_{LEAD} = \frac{-q_{BRG}(42.13)^2}{2(10^6)(1)} = -887(10^{-6})\, q_{BRG}$$

COMPATIBILITY

$\Delta R_{STL} = \Delta R_{LEAD}$ AT R= 42 5/8 IN. INTERFACE

SUBSTITUTING:

$$85(10^{-6})q_{BRG} + 0.045 = -887(10^{-6})\, q_{BRG} + 0.109$$

$$q_{BRG} = \frac{0.109 - 0.045}{(887 + 85)10^{-6}} = \underline{65.84 \text{ psi}} \rightarrow \underline{\text{SAY } 66 \text{ psi}}$$

RESULTS

$f_{STL} = 57.33(66) = \underline{3784 \text{ psi}} < \text{YIELD} \therefore \text{OK}$

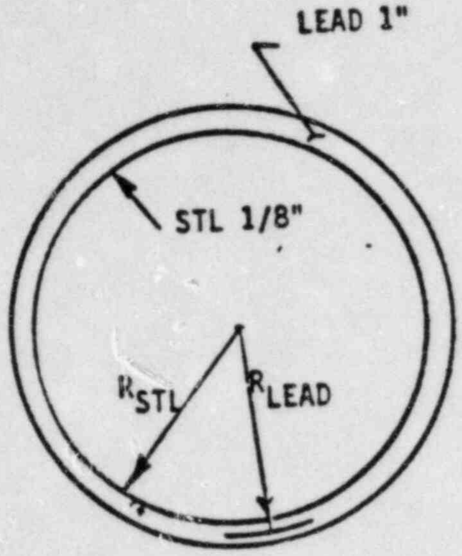
$f_{LEAD} = -42.13(66) = \underline{2780 \text{ psi}}$

2.6.2 Cold

An evaluation was performed to consider the effects of reduced ambient temperature on cask integrity. An environmental temperature of -30°F was considered which results in a temperature difference of 100°F below the 70°F stress-free condition. The 100°F temperature change causes a differential thermal contraction between the lead and inner steel wall. This results in a compressive loading on the inner wall of 10,725 psi which is below the yield strength of 30,000 psi for A-304 steel.

ANALYSIS FOR REDUCED AMBIENT TEMPERATURE

GEOMETRY



R_{STL} = 41 9/16 "(AVG)

R_{LEAD} = 42 1/8" (AVG)

LOADS

$\Delta T = -100^{\circ}F$ ASSUMED

$\Delta R = \alpha \Delta T R$ DUE TO TEMP. CHANGE

$\Delta R_{LEAD} = 16.1(10^{-6})(-100)(42.125) = \underline{-0.068 \text{ IN}}$

$\Delta R_{STL} = 5.78(10^{-6})(-100)(41.5625) = \underline{-0.024 \text{ IN.}}$

→ Thus lead will ext. compress STL inner liner.

Use thin shell theory since $t_{MAX} = 0.0024R_{LEAD} < 0.1R$

ANALYSIS

EQUILIBRIUM

EXT q ON STL 1/8" THK INNER SHELL

INT q ON LEAD

$f_{HOOP} = qR/t$ + IF INT. LOADING (LEAD)
- IF EXT. LOADING (STL)

$$f_{STL} = \frac{-q_{BRG}(41.56)}{0.125} = \underline{-332.5\ q_{BRG}}$$

$$f_{LEAD} = \frac{q_{BRG}\ (42.125)}{1} = \underline{42.125\ q_{BRG}}$$

DEFORMATION

$\Delta R = qR^2/Et$ (NO DIRECT END LOADING EX. TEMP.)

$$\Delta R_{STL} = \frac{-q_{BRG}(41.56)^2}{29(10^6)(0.125)} = \underline{-477\ q_{BRG}\ (10^{-6})}$$

$$\Delta R_{LEAD} = \frac{q_{BRG}(42.125)^2}{2(10^6)(1)} = \underline{887(10^{-6})\ q_{BRG}}$$

COMPATIBILITY

$\Delta R_{STL} = \Delta R_{LEAD}$ AT R= 41 5/8 IN.

SUBSTITUTING

$-477(10^{-6})\, q_{BRG} - 0.024 = 887(10^{-6}) q_{BRG} - 0.068$

$$q_{BRG} = \frac{(0.068 - 0.024)(10^6)}{887 + 477} = \underline{32.26 \text{ psi}}$$

→ SAY 32 psi

RESULTS

$f_{STL} = -332.5(32) = \underline{10{,}725 \text{ psi}}$ < YIELD ∴ OK

$f_{LEAD} = 42.125(32) = \underline{1360 \text{ psi}}$

STABILITY CHECK

STL INNER SHELL 1/8" THK $q_{BRG\ EXT} = 32$ psi

ROARK & YOUNG - 5th ED
TABLE 35
CASE 19b

$$q' = 0.807 \frac{Et^2}{lr} \sqrt[4]{\left[\frac{1}{(1 - \nu^2)}\right]^3 \left[\frac{t^2}{r^2}\right]} = 77.86(0.06) = \underline{4.6 \text{psi}}$$

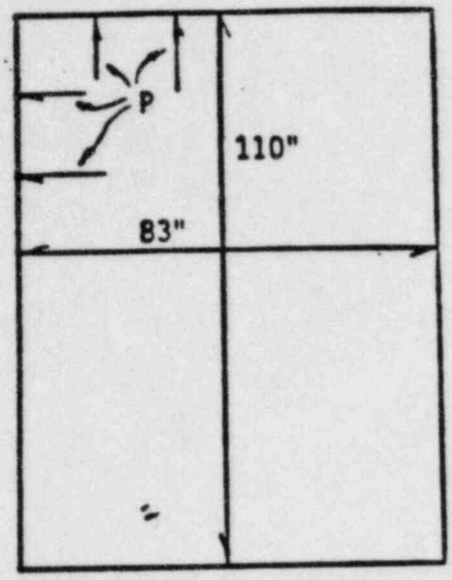
Not valid over bonded construction!

2.6.3 <u>Pressure</u>

An evaluation is presented which considers the effects of a reduced ambient pressure of 0.5 atmosphere on cask integrity. This is equivalent to an internal over pressure of 7.3 psi. The following analysis verifies that stresses in the cask bottom, walls, and lid bolts are acceptable. The analysis also shows that the specified bolt torque at assembly is sufficient to maintain a leak tight seal under this reduced pressure condition.

REDUCED AMBIENT PRESSURE ANALYSIS

GEOMETRY



→ INSIDE DIMENSIONS ARE SHOWN.

P = 7.3 psi EFFECTIVE INTERNAL PRESSURE

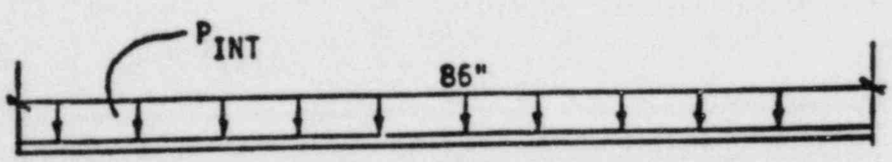
LOADS

AMBIENT ATMOSPHERIC PRESSURE = 0.5 ATM

ANALYSIS

BOTTOM

CHECK ASSUMING UNSUPPORTED EXCEPT AT WALLS.



ROARK & YOUNG - 5th ED
TABLE 24
CASE 10

SAY HALF-FIXITY AT WALLS.

$K_{Yc} = \frac{-0.0637 - 0.01563}{2} = \underline{-0.04}$

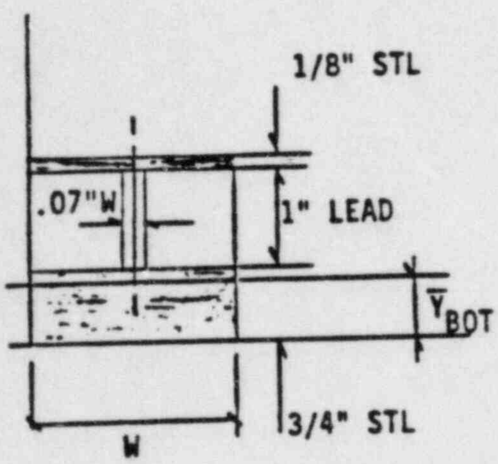
$Y_c = -0.04\ qa^4/D$ $\quad$ q= 7.3 psi, a= 43 in.

$D = \frac{Et^3}{12(1-\nu^2)} = 29(10^6)(0.75)^3/\ 12(1-0.09) = 1.12(10^6)$ LB-IN²/IN

$Yc = \frac{-0.04(7.3)(43)^4}{1.12(10)^6} = \underline{-0.89\ IN}$ $>$ HALF 0.75 IN.

$\therefore$ NOT VALID

<u>CALCULATE COMPOSITE SECTION</u>



$E_{STL} = 29(10^6)$

$E_{LEAD} = 2(10^6)$ psi

$n = 2/29 = \underline{0.07}$

$A\overline{Y}_{BOT} = 1(0.75)^2/2 + 1(0.125)(1.8125) = 0.51\ IN^3$

$\overline{Y}_{BOT} = 0.51/0.875 = \underline{0.58\ IN}$

$A_{LEAD} = 0.07(1) = \underline{0.07\ IN^2}$

$A\overline{Y} = 0.07(1.25) = \underline{0.09\ IN^3}$

$\overline{Y}_{BOT} = \frac{0.54 + 0.07}{0.875 + 0.09} = \underline{0.60\ IN}$

$$\text{INERTIA} = 1(0.125)(1.8125 - 0.6)^2 + (0.75)^3/12 + 0.75(0.375-0.6)^2$$

$$= \underline{0.26}\ \text{IN}^4/\text{IN}$$

$$\text{EQUIVALENT } t = \sqrt[3]{12(0.257)} = \underline{1.456\ \text{IN}}$$

USE FOR STIFFNESS COMPUTATIONS

$$D = \frac{E(1.456)^3}{12(1 - \nu^2)} = \frac{29(10^6)(1.456)^3}{12(1-0.09)} = \underline{8.2(10^6)}\ \text{LB-IN}^2/\text{IN}$$

$$Y_c = \frac{-0.04(7.3)(43)^4}{8.2(10^6)} = \underline{-0.12}\ \text{IN} < 1.456/2 \quad \therefore \text{VALID}$$

SMALL DEFLECTION THEORY FORMULAE

$$K_{Mc} = \frac{0.20625 + 0.08125}{2} = \underline{0.144}$$

$$M_c = 0.144qa^2 = 0.144(7.3)(43)^2 = \underline{1940}\ \text{IN-LBS/IN}$$

$$f_{BEND} = \frac{M\,c}{I} = \frac{1940(1.8125 - 0.6)}{0.26} = \underline{9515\ \text{psi}}$$

LESS THAN ALLOWABLE

∴ OK

WALLS

$f_{AXIAL} = \frac{qR}{2t}$

ROARK & YOUNG - 5th ED
TABLE 29
CASE 1c

$\Delta R = \frac{qR^2}{Et}\left[1 - \frac{\nu}{2}\right]$

CHECK INT. STL ONLY

$\Delta Y = \frac{qRY}{Et}(0.5 - \nu)$

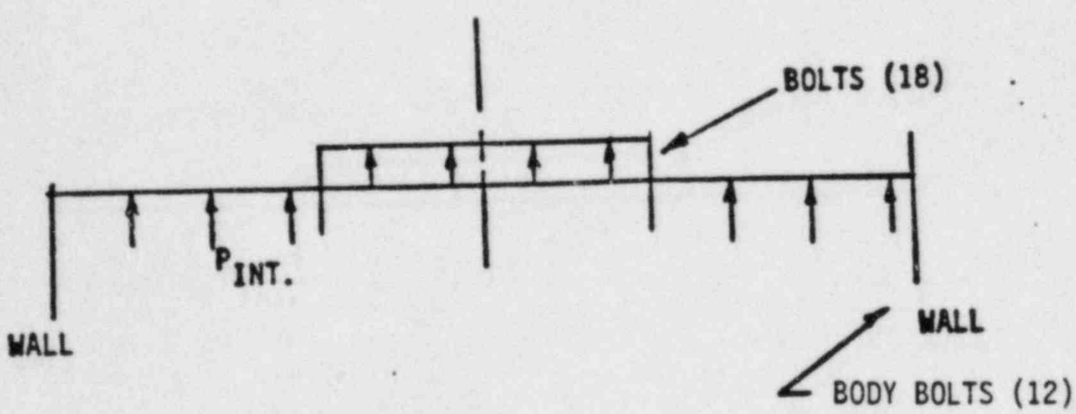
AXIAL STRESS $= \frac{7.3(41.56)}{2(0.125)}$

$=$ 1213 psi Obviously (

$\Delta R = \frac{7.3(41.56)^2(1-0.13)}{29(10^6)(0.125)} = 0.003$ IN   SMALL ∴ OK

$\Delta Y = \frac{7.3(41.56)(110)(0.5-0.3)}{29(10^6)(0.125)} = 0.002$ IN   SMALL ∴ OK

LID BOLTS



SMALL LID :

$Q = qa/2 = 7.3(13)/2 =$ 47.45 LBS/IN

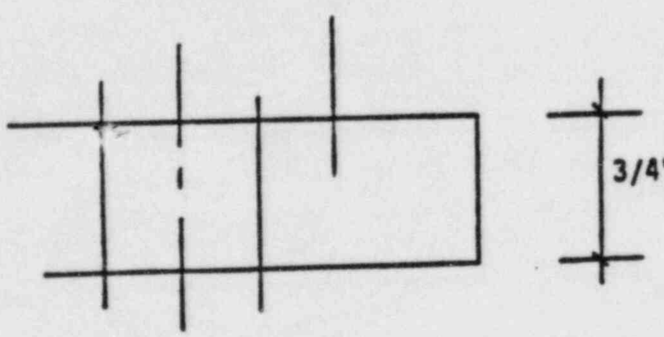
LOAD/BOLT $= \frac{\pi(13)^2(7.3)}{18} =$ 215 LBS $\therefore$ NOT CRITICAL

CHECK CONTINUITY AT BOLT:

$M_a = -qa^2/8 = 7.3(13)^2/8 =$ 154 IN-LBS/IN

$\frac{\pi D}{18} = \frac{\pi(33)}{18} =$ 5.76 IN

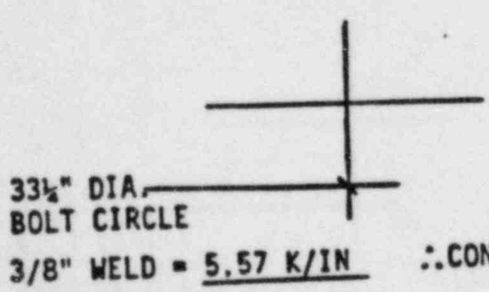
LOAD/BOLT = 5.76 (154) = 887 IN-LBS



BEARING/PRYING ARM = 1 1/8"

FORCE = 887/1.125 = 788 LBS

$\therefore$ NO PROBLEM



3/8" WELD = 5.57 K/IN $\therefore$CONTINUITY MANINTAINED

Primary and secondary seals consist of silicone rubber and flat neoprene gaskets respectively. They are compressed by imposed displacements determined by torqued, or preloaded, lid bolts and mechanical stops reacting the bolt preload. Proper gasket performance is assured provided the bolt and mechanical stop preload is maintained during the reduced pressure event. Primary lid bolts are torqued to 200 ft-lbs. and secondary lid bolts are torqued to 50 ft-lbs. The adequacy of these preloads is demonstrated by the following analysis:

Primary Lid Bolts (12 each, 1¼" - 7UNC)

$T = KDF$; T = torque, in-lb.

K = torque coefficient, 0.18

D = Nominal bolt diameter, in

F = Bolt Preload

$T = 200$ ft-lbs $(12) = 2400$ in-lbs

$$F = \frac{T}{KD} = 2400/(.18)\,(1.25) = 10667 \text{ lbs/bolt}$$

Since the bolts are installed at 45°, the effective preload per bolt is:

$$Fa = F \cos 45^{\circ} = 7542 \text{ lbs/bolt}$$

The internal pressure of ½ atmosphere produces a bolt load of:

$$Pa = \frac{pA}{N} \qquad A = \frac{D^2}{4}$$

$D = 77 + 5/8 = 77.625$

$p = 14.7/2$ psi $= 7.35$ psi

$N = 12$ bolts

$$Pa = \frac{(7.35)\left(\frac{\pi}{4}\right)(77.625)^2}{12} = 2899 \text{ lbs/bolt}$$

Therefore, since the pressure load, Pa, is significantly below the bolt preload, the integrity of the seal is maintained. The sealing margin of safety is:

$$M.S. = Fa/Pa - 1$$
$$= 7542/2899 - 1 = +1.60$$

Secondary Lid Bolts (18 each, 3/4" - 10UNC)

The torque is:

$$T = 50 \text{ ft-lbs } (12) = 600 \text{ in-lbs}$$

The bolt preload is:

$$Fa = \frac{T}{KD} = 600/(.18)(3/4) = 4444 \text{ lbs/bolt}$$

The pressure load per bolt is:

$$Pa = \frac{p \frac{\pi}{4} D^2}{N} \quad ; D = 27.5 \text{ in}$$

$$= \frac{(7.35) \frac{\pi}{4} (27.5)^2}{18} = 243 \text{ lbs/bolt}$$

Once again, the integrity of the seal is maintained because the bolt preload force exceeds the pressure force by a wide margin. The sealing margin of safety is

$$M.S. = Fa/Pa - 1$$
$$= 4444/243 - 1 = + 17.3$$

2.6.4 Vibration

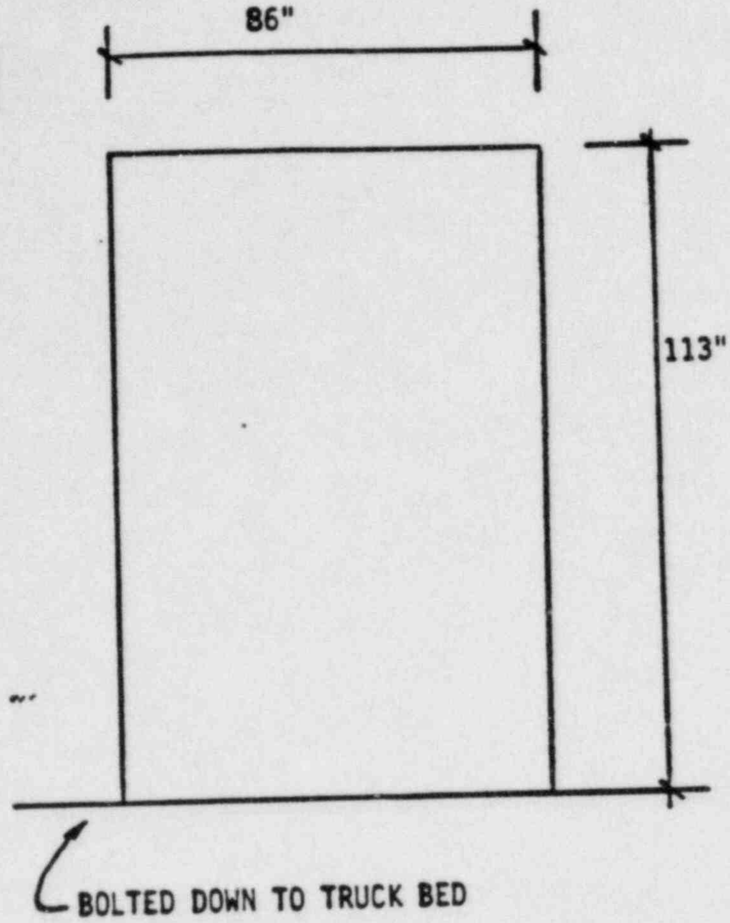
The following analysis determines the resonant frequency of the cask and shows that this value is higher than the vibration frequency normally encountered for truck suspension systems and therefore it can be concluded that vibration normally incident in transportation will not affect the cask.

2.6.5 Water Spray

The model 21-300 is fabricated of materials (steel and lead) which are not affected by water spray.

VIBRATION ANALYSIS

GEOMETRY



LOADS

Consider as cantilever beam.

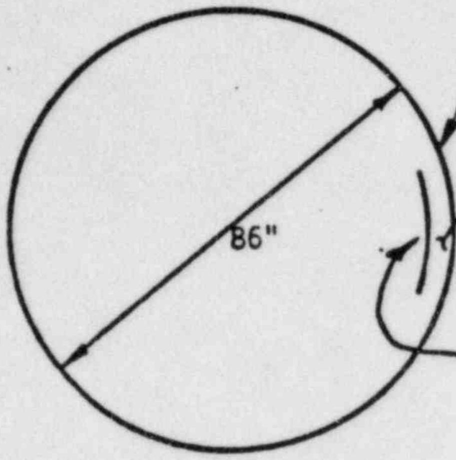
$$f_N = \frac{K_N}{2\pi} \sqrt{\frac{EIg}{Wl^4}}$$

ROARK & YOUNG -5th ED
TABLE 36
CASE 3b

FUNDAMENTAL MODE:

$$K_N = 3.52$$

ANALYSIS



$EI = 29(10^6)\pi R_{AVG}^3 t = \underline{6.34(10^{12})\ LB\text{-}IN^2}$

$g = 32.2(12) = 386.4$ IN/SEC.

$W = 55{,}500$ LBS

RESULTS

$$f_N = \frac{3.52}{2\pi}\sqrt{\frac{6.34(10^{12})(386.4)}{55{,}500(113)^3}} = \underline{98\ Hz}$$

This is well above the 1-20 cps range for truck suspension systems.

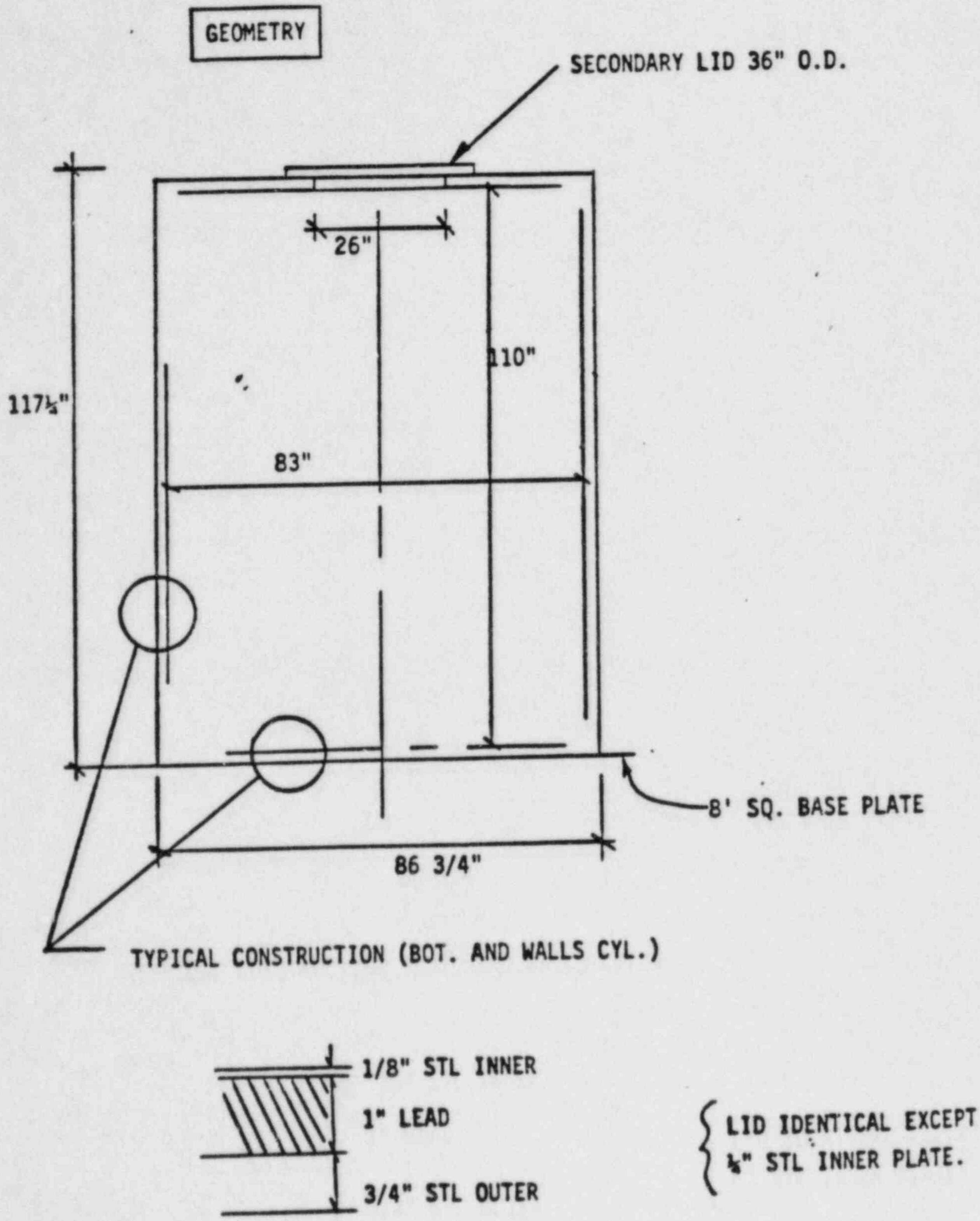
∴ OK Since resonance avoided.

2.6.6 Free Drop

This section presents the analyses performed which verify that cask integrity is maintained when subjected to a free drop from one foot. Analyses are performed with the cask in the following orientations:

2.6.6.1 End Drop (bottom)
2.6.6.2 Side Drop
2.6.6.3 Corner Drop
2.6.6.4 Structural Analysis of Load Distribution Pallet
2.6.6.5 Load Distribution Pallet and Internal Shield

2.6.6.1 ANALYSIS FOR END DROP - BOTTOM DOWN



LOADS

MAX GROSS CASK WEIGHT = 57,450 lbs.

ENERGY IMPACT = 57,450 (12) = 689,400 In-lbs

ASSUMPTIONS:

1) PLASTIC FLOW
2) ALL ENERGY TRANSMITTED THROUGH BODY WALLS, 3/4" THK 86" MEAN DIAMETER.

VOL. STL REQUIRED = 689,400/36,000 = $19.15\ IN^3$

AREA STL CONTACT BODY = $\pi(86)(0.75)$ = $202.63\ IN^2$

$\delta_{BODY} = 19.15 / 202.63 = 0.094\ IN$

$G_{PLASTIC} = h/S = 12/0.094 = 127.6$ $\therefore$ USE 130

ANALYSIS - LID

WT. SECONDARY LID = 550 LBS.
ANNULAR MAIN LID = 3450 LBS.

CHECK WT. $= \frac{490(0.875)}{1728} + \frac{710(1)}{1728} = 0.25 + 0.41 = 0.66$ psi SECONDARY LID

$A_{STL} = \frac{\pi(29.75)^2}{4} = 695\ IN^2$ OK

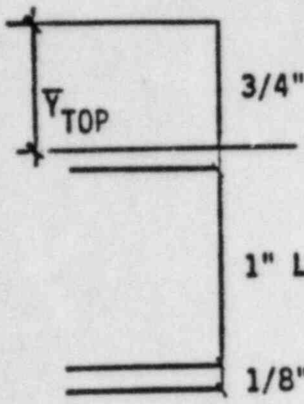
MAIN LID $= \left[\frac{490}{1728} + \frac{710}{1728}\right](1) = 0.69$ psi DEAD WT.

$A_{MAIN\ LID} = \frac{\pi}{4}(83^2 - 26^2) = 4880\ IN^2$ OK

PROPERTIES:

$$\frac{E_{STL}}{E_{LEAD}} = 15$$

SECONDARY LID



$$\sum A\overline{Y}_{TOP} = 0.75(0.375) + 1/15\ (1.25) + 0.125(1.8125)$$

$$= \underline{0.59\ IN^3}$$

$$A = 0.75 + 1/15 + 0.125 = \underline{0.942\ IN^2}$$

$$\overline{Y}_{TOP\ COMPOSITE\ SECTION} = 0.59/0.942 = \underline{0.628\ IN}$$

$$I_{COMPOSITE\ PLATE} = \frac{0.628^3}{3} + \frac{(0.75-0.628)^3}{3} + \frac{1^3}{15(12)} + 1/15\ (1.25-0.625)^2$$

$$+ 0.125(1.8125 - 0.625)^2$$

$$I_{COMPOSITE\ PLATE} = \underline{0.29\ IN^4/IN}$$

ROARK & YOUNG - 5th ED
TABLE 24
CASE 10a

$K_{Yc} = -0.06370$

$K_{Mc} = 0.20625$

$K_{\theta a} = 0.09615$

$$Mc = K_{Mc}qa^2 = 0.20625(0.66)(130)(13)^2 = \underline{2991\ LB\text{-}IN/IN}$$

(0.66) ← WT. AT 1G; (130) ← G FACTOR; (13) ← EFF. RADIUS

$$f_{BEND} = MC/I = 2991(1.378)/0.29 = \underline{14{,}128\ psi} < \text{YIELD STL}$$

$t_{EFF\ STL} = \sqrt[3]{12(0.290)}$ $\underline{1.52\ IN}$ REFERENCE ONLY

$$D = \frac{Et^3}{12(1-\nu^2)} = \frac{29(10^6)(1.52)^3}{12(1-\nu^2)} = \frac{29(10^6)(0.29)}{0.91} = \underline{9.24(10^6)\ LB\text{-}IN^2/IN}$$

$$Y_c = K_{Y_c}\, qa^4/D = \frac{-0.06370(0.66)(130)(13)^4}{9.24(10^6)} = \underline{0.017\ IN}$$ SMALL!

$$\theta a = K_{\theta a} qa^3/D = \frac{0.09615(0.66)(130)(13)^2}{9.24(10^6)} = \underline{1.96(10^{-3})\ RAD}$$

$$= \underline{11^\circ}$$

YIELD MOMENT 3/4" STL PLATE:

$$M_y = 36{,}000(0.75)^2/6 = \underline{3375\ LB\text{-}IN/IN}$$ NO ROTATION

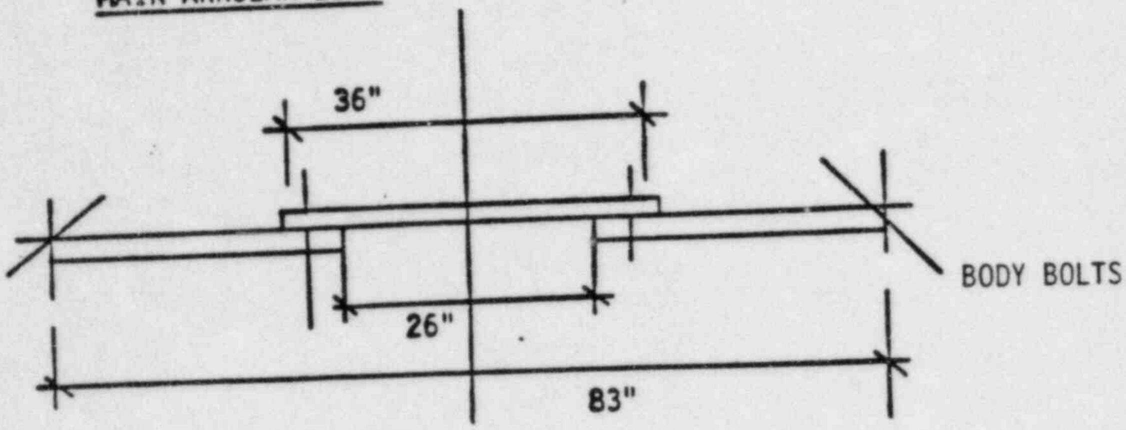
$$(f_{LEAD})_{MAX} = \frac{2991(1.12)}{15(0.29)} = \underline{770\ psi} < \text{YIELD LEAD}$$

$$q = VQ/I = \frac{0.66(130)(13)(0.628)^2}{2(0.29)(2)} = \underline{379\ psi} < 1000\ psi$$

MIN. VALUE DEMONSTRATED

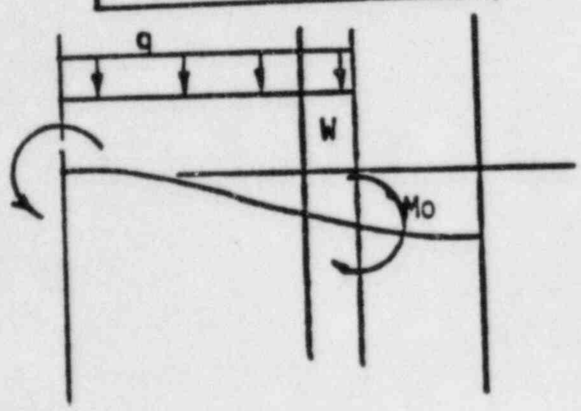
THUS SECONDARY LID OK DUE TO 130 G IMPACT.
(BOTTOM DOWN FLAT IMPACT)

MAIN ANNULAR LID



ROARK & YOUNG - 5th ED
TABLE 24
CASES 5e,2e,1e

LINE MOMENT
UNIFORM LOAD
LINE LOAD



$M_o = qa^2/8$ LB-IN/IN AT SECONDARY LID BOLT LOCATIONS
RADIUS = 33.25/2 IN.

q_{ACTUAL} = 0.69 psi AT 1G

$W = \frac{550}{\pi D_{BOLT}} = \frac{550}{\pi(33.25)}$ = 5.27 LB/IN AT 1G

c VALUES :

$b/a = 26/83 = \underline{0.31}$

L VALUES:

$r_o/a = 33.25/83 = \underline{0.40}$

LINE LOAD W

$$Yb = -Wa^3/D\left[\frac{c_1L_6}{c_4} - L_3\right]$$

$c_1 = 0.76561$

$c_4 = 1.361667$

$L_3 = 0.02229$

$L_6 = 0.099258$

$$\frac{0.7651(0.099258)}{1.361667} - 0.02229 = \underline{0.034}$$

$$M_{rG} = -Wa\left[L_9 - \frac{c_1L_6}{c_4}\right]$$

$L_6 = 0.099258$

$L_9 = 0.297036$

$c_4 = 1.361667$

$c_7 = 1.380167$

$$L_9 - \frac{c_7L_6}{c_4} = 0.297036 - \frac{1.380167(0.099258)}{1.361667}$$

$$= \underline{0.196}$$

UNIFORM LOAD q

$r_o = b$

$b/a = 26/83 = \underline{0.313}$

$Yb = K_{Yb} q a^4 / D$

$K_{Yb} = -0.0132$

$K_{Mra} = -0.1135$

$Mra = K_{Mra} q a^2$

LINE MOMENT, Mo

$$Mo = \frac{-0.66(130)(13)^2}{8} = \underline{-1812 \text{ LB-IN/IN}}$$

SECONDARY LID PLATE BENDING DUE TO BOLTED CONNECTION.

$$Yb = Moa^2/D \left[\frac{c_1 L_5}{c_4} - L_2 \right]$$

$c_1 = 0.76561$

$c_4 = 1.361667$

$L_2 = 0.136697$

$L_5 = 0.42$

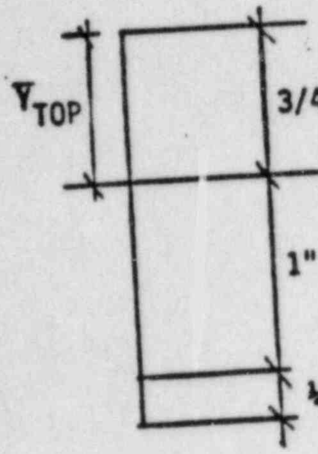
$$\frac{c_1 L_5}{c_4} - L_2 = \frac{0.76561(0.42)}{1.361667} - 0.136697 = \underline{0.099}$$

$$Mra = Mo \left[L_8 - \frac{c_7 L_5}{c_4} \right]$$

$L_8 = 0.706$

$$L_8 - \frac{c_7 L_5}{c_4} = 0.706 - \frac{1.330167(0.42)}{1.361667} = \underline{0.280}$$

MAIN LID STIFFNESS



$$\sum A\bar{Y}_{TOP} = 0.75(0.375) + 1/15\ (1.25) + 0.25(1.875)$$
$$= \underline{0.833\ IN^3/IN} \quad \text{EQUIVALENT STL}$$

$$A_{EQ.} = 0.75 + 1/15 + 0.25 = \underline{1.067\ IN^2}$$

$$\bar{Y}_{TOP} = 0.833/1.067 = \underline{0.781\ IN}$$

$$I_{\text{COMPOSITE SECTION}} = \frac{0.75^3}{3} + \frac{1^3}{45} + \frac{0.25^3}{12} + 0.25(1.125)^2$$

$$= \underline{0.481\ IN^4/IN}$$

$$t_{EQ.\ ST.} = \sqrt[3]{12(0.481)} = \underline{1.794\ IN}$$

$$D = \frac{Et^3}{12(1-\nu^2)} = \frac{29(10^6)(0.481)}{0.91} = \underline{15.33(10^6)\ LB\text{-}IN^2/IN}$$

$$Yb = \frac{-0.034(5.27)(130)(41.5)^3}{D} - \frac{0.0132(0.69)(130)(41.5)^4}{D}$$

$$- \frac{0.099(1812)(41.5)^2}{D} = \underline{\underline{-0.358\ IN}} < \text{HALF THICKNESS OK}$$

$$Mra = 0.196(5.27)(130)(41.5) - 0.1135(0.67)(130)(41.5)^2 - 0.28(1812)$$
$$= \underline{23{,}614 \text{ LB-IN/IN}}$$

$$(f_{BEND})_{3/4"\text{STL PLATE}} = \frac{23{,}614\ (.781)}{0.481} = \underline{38{,}342 \text{ psi}}$$

$$(f_{BEND})_{1/4"\text{STL PLATE}} = \frac{23{,}614(1.22)}{0.481} = \underline{59{,}894 \text{ psi}}$$

$$(f_{LEAD})_{MAX} = \frac{23{,}614(.97)}{15(0.481)} = \underline{3175 \text{ psi}}$$

$q = VQ/I$ AT BOUNDARY

$$V = \frac{0.69(130)(41.5^2 - 13^2)}{2(41.5)} + \frac{5.27(130)(33.25)}{83}$$

$$V = \underline{1953 \text{ LB/IN}}$$

$$q = \frac{1953(0.75)(0.375)}{0.481} = \underline{1143 \text{ psi}}$$

The above calculational method used to determine bending stresses is very conservative. This is demonstrated by the results of a drop test of a CNSI 14-195H Cask (NRC Docket 71-9094) which has a geometry very similar to the 21-300. That test dropped an actual fully loaded cask from a distance of one foot, onto its lid. Using the above calculation method, the bending stresses in the inner wall of the cask bottom were determined to be 65,948 psi. However the test result demonstrated that no permanent deformation of any kind actually occurred under these conditions.

Therefore, if one conservatively assumes that the material was on the verge of yield, then the stress could be estimated to be 36,000 psi. (F_{ty} for A-36).

A conservatism factor can now be defined as:

$$\frac{36{,}000}{65{,}948} = .55$$

Applying this factor to the above results:

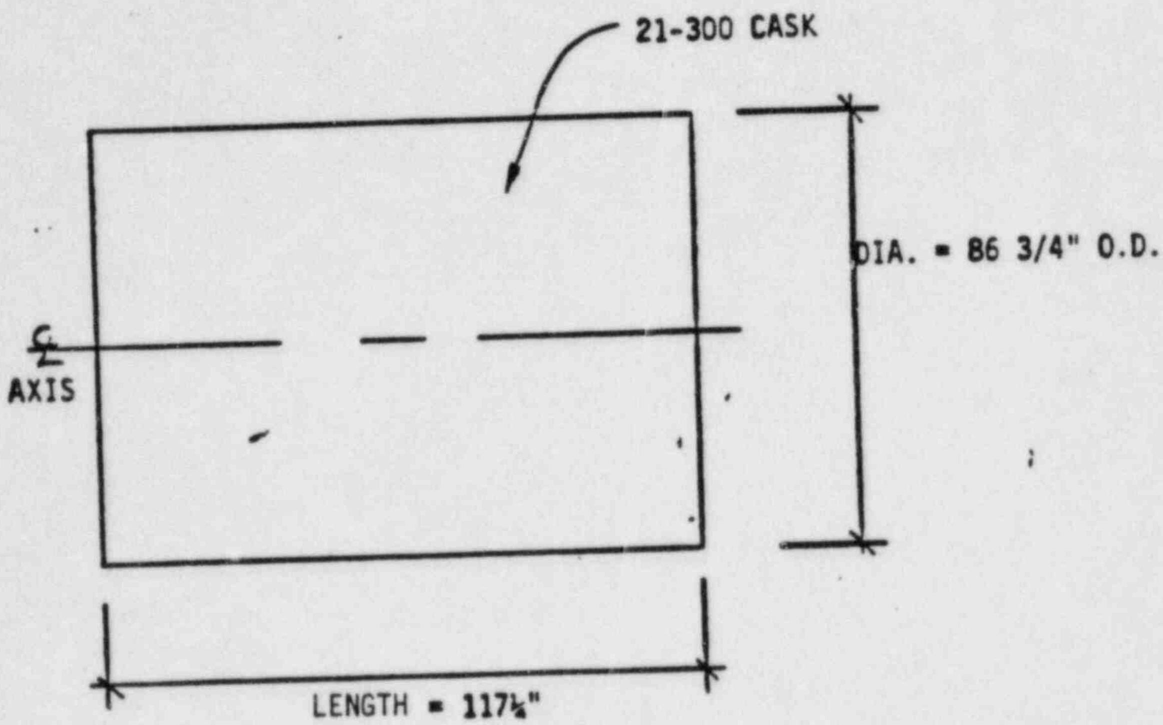
$$(f_{Bend})\ 3/4" \text{ STL Plate} = (38{,}342)(.55) = \underline{21{,}088 \text{ psi}}$$

$$(f_{Bend})\ 1/4" \text{ STL Plate} = (59{,}894)(.55) = \underline{32{,}941 \text{ psi}}$$

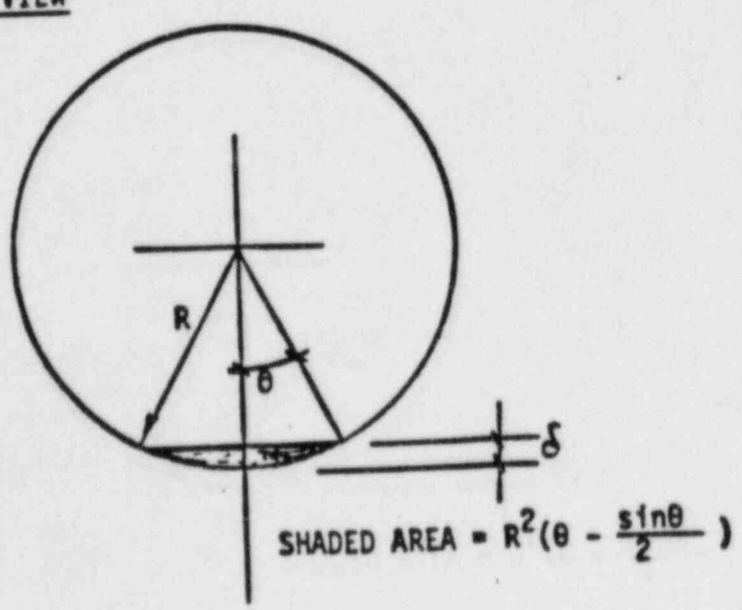
The structural requirements for the primary lid are therefore satisfied.

2.6.6.2 ANALYSIS OF SIDE DROP

GEOMETRY



END VIEW



ENERGY ABSORBED BY THE FOLLOWING:

1) DEFORMATION OF END PLATES (LEAD AND STL)
2) MOVEMENT OF LEAD (CYL. LINING)
3) STL SHELL DEFORMATION (CYL. ONLY)

$$E_{\substack{STL \\ \text{EXT SHELL} \\ \text{ONLY}}} = R t_{STL} L f_{YIELD} \left[\sin\theta(2 - \cos\theta) - \theta \right]$$

REF: CASK DESIGNER'S GUIDE, ORNL-NISC-68
FEB. 1970 by L.B. SHAPPERT (2.12)

LOADS

$$Wh = 55{,}500(48) = 2664 \text{ IN-KIPS}$$

EQUATING ENERGY TO (3) ITEMS ABOVE:

$$Wh = 2R^2_{\substack{END \\ PLATES}} \; t_{STL} f_{YIELD} \left[\theta - \frac{\sin 2\theta}{2} \right] + R^2_{Lead} \; HGT \; f_{LEAD} \left(\theta - \frac{\sin 2\theta}{2} \right)$$

$$+ R_{\substack{STL \\ BDY}} \; t_{STL} \; HGT \; f_{\substack{YIELD \\ STL}} \left[\sin\theta(2 - \cos\theta) - \theta \right]$$

COMBINING TERMS:

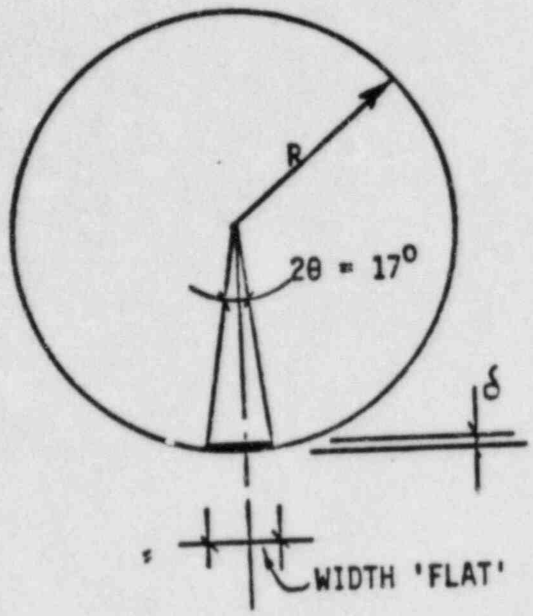
$$\frac{Wh}{t_{STL} R_{AVG} H f_{\substack{STL \\ YIELD}}} = F_1(\theta) \left[\frac{2R_{AVG}}{t_{STL}} + \frac{R_{AVG}}{t_{STL}} \left(\frac{f_{LEAD}}{f_{STL}} \right) \right] + F_2(\theta)$$

$$\frac{Wh}{t_{STL} R_{AVG} f_{STL\ YIELD}} = \frac{55{,}500(45)}{0.75(43)(113)(36{,}000)} = 0.0203$$

Determination of the half angle subjected to crushing is an iterative procedure. Evaluation results in:

$$\theta = 8\text{-}1/2^{0}$$

ANALYSIS



$\delta = R(1-\cos\theta) = 43(1-0.989) = \underline{0.47\text{ IN}}$ SAY ½"

$\text{'FLAT'} = 2R\sin\theta = 2(43)(0.1478) = \underline{12.71\text{ IN}}$ SAY 12 3/4"

SINCE LEAD THICKNESS = 1 IN. ASSUMPTIONS ARE VALID.

IMPACT AREA = $12.75(113) = \underline{1441\text{ IN}^2}$

STL ENDS

AREA = $12.75(0.75)(2) = \underline{19.13\text{ IN}^2}$ (2 = EACH END)

$(\text{FORCE})_{STL} = 36000(19.13) = \underline{688.5\text{ k}}$

→ SAY 690 k

LEAD LINING

$$\text{AREA} = \underline{1220\ \text{IN}^2}$$

$$(\text{FORCE})_{\text{LEAD}} = 10{,}000\ (1220) = 12{,}200\ \text{KIPS}$$

$$\text{NO. G's} = \frac{12{,}200 + 690}{55.5} = 232$$ SEEMS HIGH.

SINCE IMPACT AREA VERY SENSITIVE TO VOLUME REQ'D, RECALCULATE VOLUME USING LEAD DYNAMIC STRESS = 10,000 psi HAVING ALREADY SHOWN DEFORMATION COMPATIBILITY.

$$\frac{2R}{H} + \frac{R}{t_{STL}}\left(\frac{\text{LEAD}}{\text{STL}}\right) = \frac{2(43)}{113} + \frac{43}{0.75}\left(\frac{10}{36}\right) = \underline{16.7}$$

$$\theta = 6.5^{\circ}$$

$$\text{FLAT} = 2R\sin\theta = 2(43)(0.1132) = \underline{9.74\ \text{IN}}$$ SAY 9 3/4 IN.

$$\text{IMPACT AREA} = 113(9.75) = \underline{1102\ \text{IN}^2}$$

$$\delta = R(1-\cos\theta) = 43(1-0.9936) = 0.2764\ \text{IN}$$ SAY ¼ IN

$$\text{VOL.} = \left(\frac{\theta - \sin 2\theta}{2}\right) R^2\ \text{HGT} = 0.001(43)^2(113) = 203\ \text{IN}^3$$

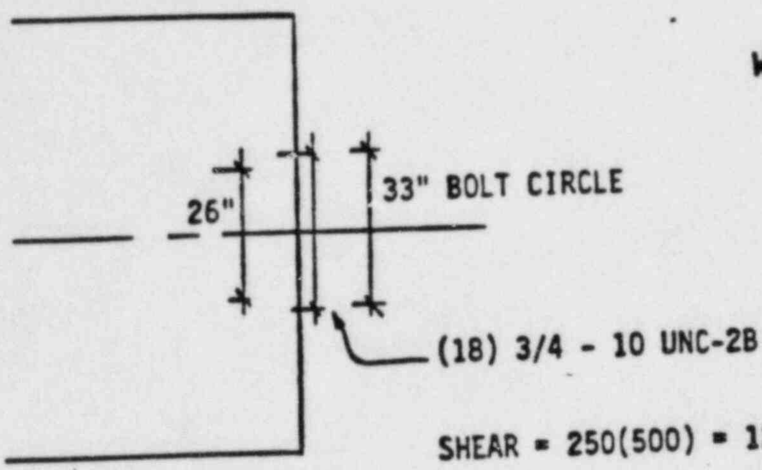
$$(W_o)_{EFF.} = \frac{Wh}{V} = \frac{2664}{203} = \underline{13.12 \text{ ksi}}$$

$$q_{LD} = \frac{13.120(1102)}{55{,}500} = \underline{260}$$

→ USE 250

RESULTS

SMALL LID :



WT. LID = 500 LBS

SHEAR = 250(500) = 125 k

SHEAR LOAD/BOLT = 6945 LBS

AREA = 0.442 IN^2

SHEAR STRESS PER BOLT = 15,700 psi

ALLOWABLE = $(0.3)(F_y) = (0.3)(57{,}000) = 17{,}000$ psi

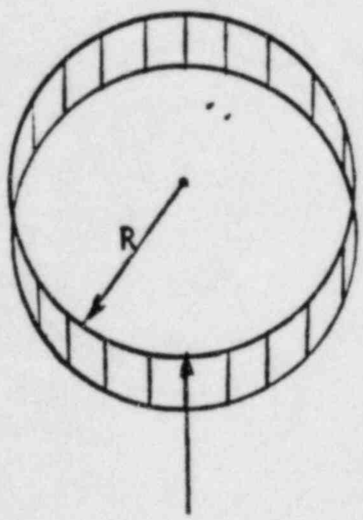
THEREFORE SECONDARY LID BOLT SHEAR STRESSES ARE ACCEPTABLE

BRG. ON 3/4" A-36 PLATE = 27.3 k > 6.95 k

WELD: 3/8" FILLET

ALLOW. $= \pi(0.75)(0.928)(6) = 13.12$ k > 6.95 k ∴ OK

CASK BODY



WT. CASK/IN. = 30,000/113 = 265 LB/IN

ROARK & YOUNG - 5th ED

TABLE 17

CASE 13

$$W = 265/2\pi R = \frac{265}{2\pi(43)} = 0.98 \text{ LB/IN}$$

SAY 1.0 LB/IN

$$M = (3/2)WR^2 = 1.5(1.0)(43)^2 = 2773.5 \text{ LB-IN.}$$

$$f_{BEND} = \frac{2773.5(Y)}{0.26} = 10,700 \text{ psi} < \text{YIELD} \quad \therefore \text{OK}$$

2.6.6.3 ANALYSIS OF CORNER DROP

From the drawing (1-298-1C1 Rev. J) it can be seen that the top lip of the cask consists of an external skin of 3/4 inch steel plate and a heavy solid steel bar (2½" x 4"). A corner drop anywhere along the top edge will result in local deformation and the associated energy absorbtion.

Using the simplified volume displacement concept for energy absorbtion, the acceleration experienced under a corner drop condition can be determined.

The energy can be determined as follows:

$$KE = (\text{Vol})\ (\text{Crush Strength}) = \frac{D^4 Fc}{8L}\left(\sin\theta - \frac{\sin^3\theta}{3} - \theta\cos\theta\right)$$

Where:

D = 92 in

Fc = 36000 psi (A36)

L = 117¼ in

W = 57450 lbs (30200 lbs cask + 27,250 lbs Payload)

h = 12 in

Solving for θ

$\theta = 16.5^{\circ}$ $\quad\quad$ $\theta\alpha = 38.06^{\circ}$

Deflection is given as

$= R\,(1-\cos\theta)\sin\alpha$

$= (46)\,(1-\cos 16.5^{\circ})\sin 38.06^{\circ}$

$= 1.17$ in

Impact area is given as:

$A = r^2\,(\theta - \sin\theta\cos\theta)\,/\,\cos\alpha$

$A = 46^2\,(16.5^{\circ} - \sin 16.5\ \cos 16.5^{\circ})\,/\,\cos 38.06^{\circ}$

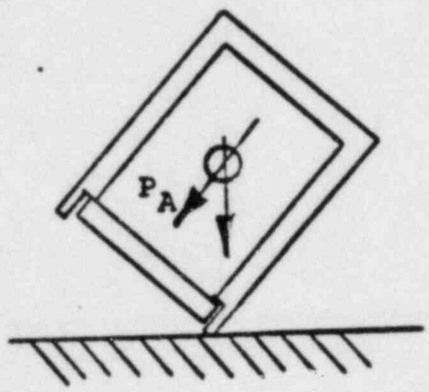
$A = 42.08 \text{ in}^2$

Acceleration is given as:

$$Ag = (42.08 \text{ in}^2)\ (36000 \text{ psi})\ /\ (57450 \text{ lbs})$$

$$Ag = 26 \text{ g's}$$

Therefore, assuming the impact takes place on a corner the acceleration will be 26 g's.



The axial load felt by the closure bolts will be the combination of the payload and lid weight acting in the axial direction.

$$P_A = (27250 \text{ lbs payload} + 6000 \text{ lbs lid})\ A_g \cos 38.06^\circ$$

$$P_A = (33250 \text{ lbs})\ (26 \text{ g's})\ (\cos 38.06^\circ)$$

$$P_A = 680677 \text{ lbs}$$

This load will be reacted by 12-1¼ diameter Grade 8 bolts for a load per bolt of:

$$P_b = (680{,}677 \text{ lbs} / 12 \text{ bolts}) / \cos 45^\circ$$

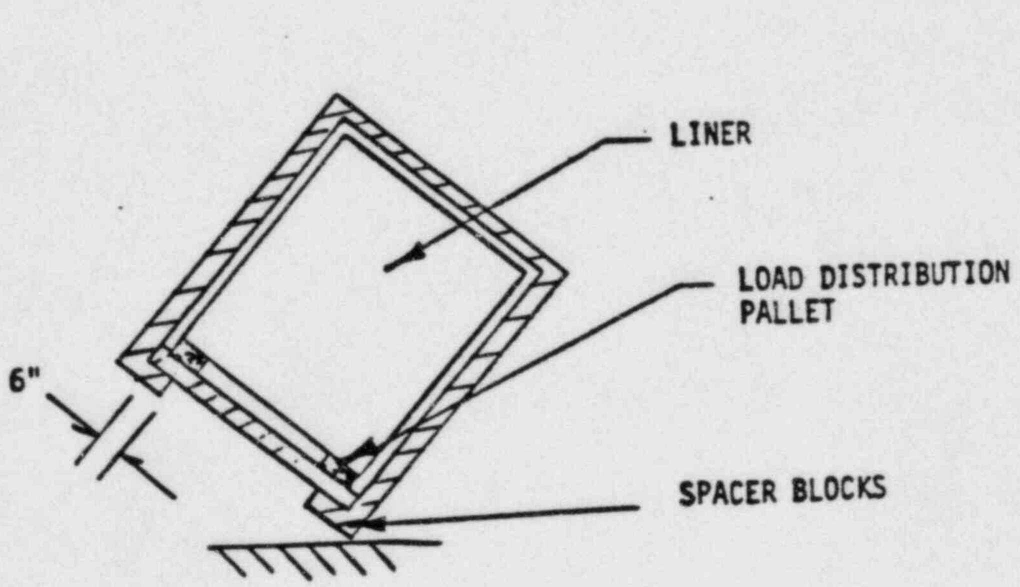
$$P_b = 80218 \text{ lbs / bolt (tension)}$$

$$\text{Tensile Stress per Bolt} = \frac{80{,}218 \text{ lbs}}{1.0237 \text{ in.}^2 \text{ Minor Area}} = 78{,}360 \text{ psi}$$

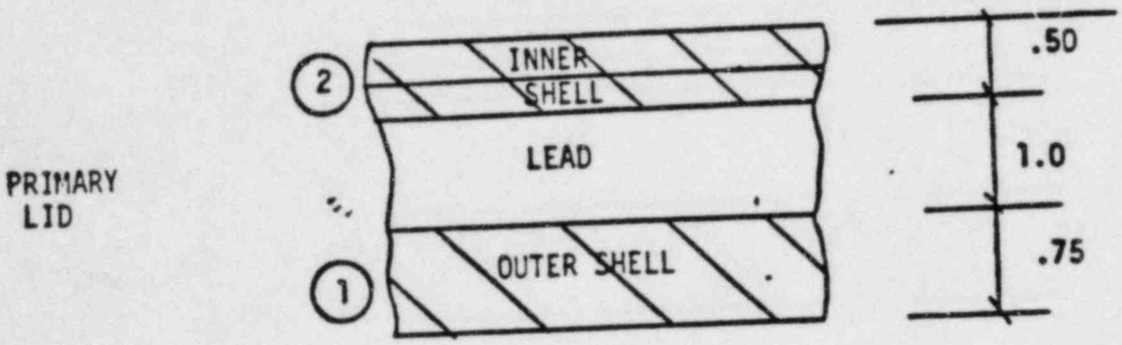
Allowable Stress = 130,000 psi

Therefore Primary Lid Bolt Loading is acceptable.

Also, in evaluating the effects of a corner drop, the bending stresses in the primary lid are considered. This analysis takes credit for the use of a load distribution pallet (CNSI Dwg. C-144-D-0006) which concentrates the resultant loading from the cask contents onto the outer portion of the primary lid.



The lid is composed of a one inch thick lead plate sandwiched between two steel plates. As noted, the assembly is bonded together thus causing it to act as a single composite plate. The equivalent thickness is calculated as follows. Note that the stiffness of the lead has been conservatively eliminated.



	A	Y	AY	Io
1	.750	.375	.28125	.0352
2.	.50	2.00	1.00000	.0104
	1.25		1.28125	.0456

$\bar{y} = \Sigma Ay / \Sigma A = 1.023$

$I_x = I_o + \Sigma A_n d_n^2$

$I_x = .600 \text{ in}^4$

This is equivalent to a steel plate of the following thickness:

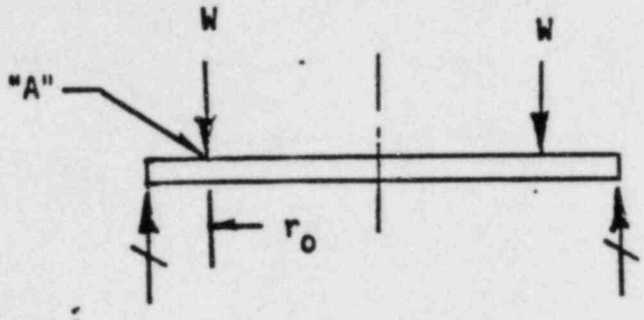
$I_x = bt^3/12 = .600 \text{ in}^4$

$t = \sqrt[3]{(.600)(12)}$

$t = 1.92 \text{ in}$

Conservatively assume that the impact is reacted by the pallet which inturn applies a concentrated point load at "A".

From Roark, Fourth Edition, Case 3, Page 216, stress in a circular plate is given as:



$$f = 3W \left[(m + 1) \ln a/r + (m-1) r_o^2/2r^2 - (m-1) r_o^2/2a^2\right] /2\pi mt^2$$

Where:

$W = P_A = 680677$ lbs

$m = 1/\nu = 3$

$a = 41.5$ in.

$r = 37.5$ in.

$r_o = 37.5$ in.

$t = 1.92$ in.

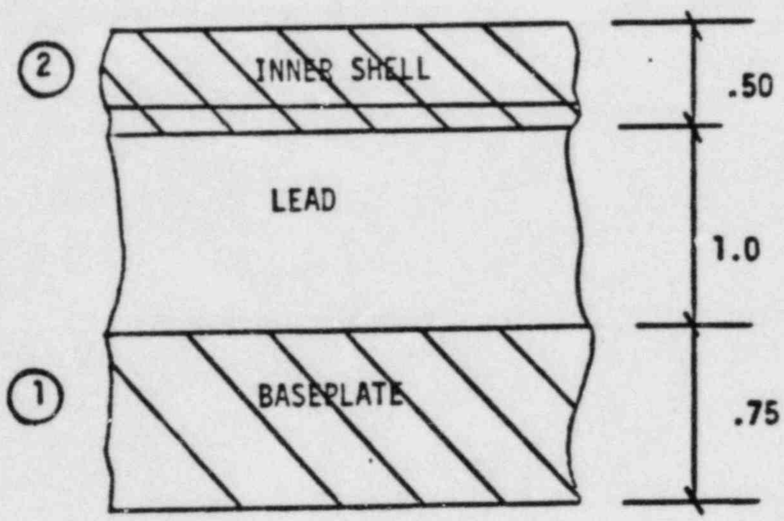
$$f = (3)(680677) \left[4 \ln \frac{41.5}{37.5} + 1 - 2 (37.5)^2/2(41.5)^2\right] /2\pi (3)(1.92)^2$$

<u>$f = 17649$ psi</u>

Therefore, it can be concluded that the lid can react the bending stress imposed by the payload for a corner drop condition.

Evaluation of Cask bottom during corner drop is as follows:

GEOMETRY



REFERENCE: Dwg. 1-298-101 Detail J
(Rev J)

	A	Y	AY	Io
1	.75	.375	.28125	.0352
2.	.50	2.000	1.00000	.0104
	1.25		1.28125	.0456

$\bar{Y} = \Sigma Ay/\Sigma A = 1.28125/1.25 = 1.025$

$I = I_o + \Sigma Ad^2$

$I = .0456 + (.75)(1.025-.375)^2 + (.25)(2.0-1.025)^2$

$I = .6000 \text{ in}^4$

This is equivalent to a steel plate of the following thickness:

$I_x = bt^3/12 = .600$

$t = \sqrt[3]{(12)(.60)} = 1.92 \text{ in}$

From Roark, Fourth Edition, Case 6, Page 217 maximum stress in a circular plate under a uniformly distributed load is given as:

$S_r = 3W/4\pi t^2$

Where:

$W = 680677$ lbs

$t = 1.92$ in

$S_r = (3)(680677)/4\pi(1.92)^2$

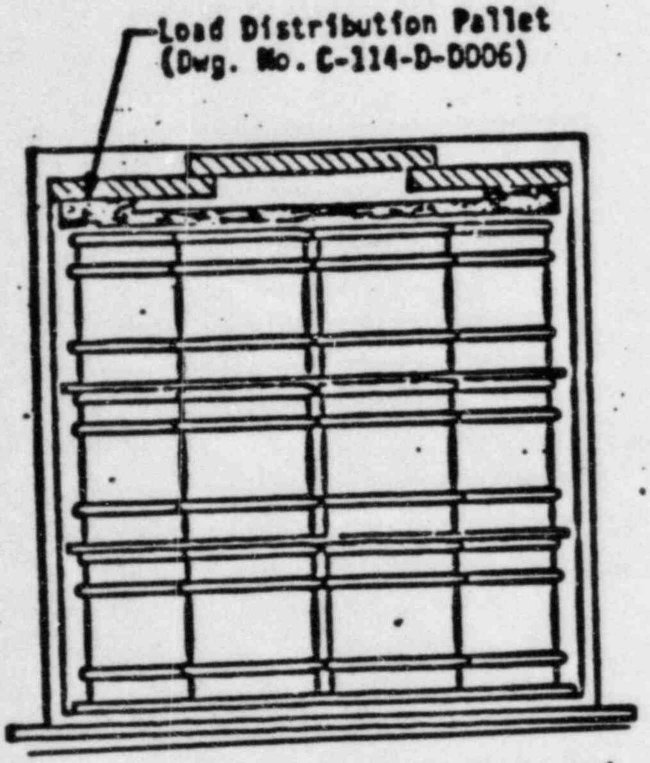
$S_r = 44{,}080$ psi

This stress is well below the 75,000 psi allowable for stainless or the 58,000 psi minimum for the carbon steel plate.

2.6.6.4 Structural Analysis of Load Distribution Pallet

The load distribution pallet is effective in providing a rigid load path around the periphery of the cask lid with the cask loaded in the 21-55 gallon drum configuration. This pallet design also provides the following operational advantages: (1) Provisions for the stowage of cables on top of the pallet, thereby minimizing hook-up time, substantially reducing personnel exposure, and (2) facilitates a standard and consistent procedure for the 21 drum stack-up configuration.

An evaluation of the structural capability of the load distribution pallet is presented below.



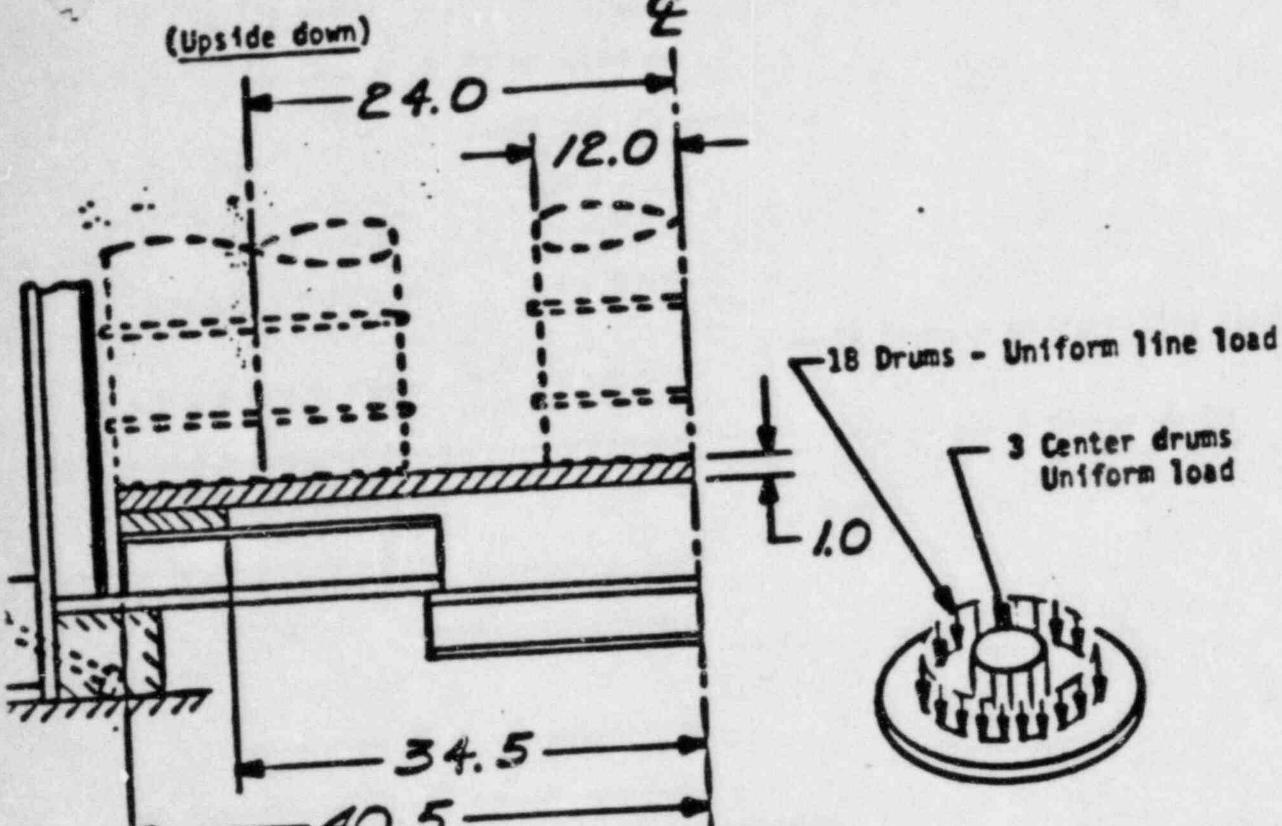
21-300 Cask Loaded with 21 Drums and Load Distribution Pallet

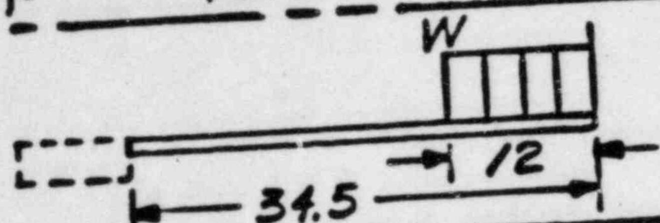
Weights

Load Distribution pallet....... 1,850 lbs.

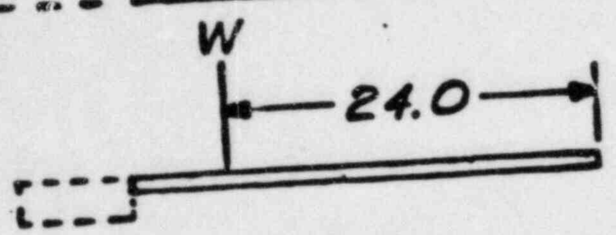
Contents Illustrated ....
21 drums 750 lbs. ea.......... 15,750 lbs.

Total payload 17,600 lbs.





Three center drums - uniformily loading the pallet over a circular area of 12.0 in. radius.



18 drums - uniformally distributed line load @ 24.0 in. radius

The load distribution pallet is modelled as a circular plate with fixed edges and loaded by the center 3 drums as a uniform load over a circular area of 12.0-in. radius from center. The outer 18 drums bear on the plate as a uniform line load around the plate at a radius of 24.0-in. from the center of the plate as indicated above. The solution to obtain the maximum stress in the pallet is obtained by superposing the results of the two indicated load cases.

1.3 - continued

It is evident from the sketch that conditions at the edge of the pallet are neither simply supported or fixed and are at best defined as mixed boundry conditons. For evaluating the bending stress and deflection in the central portion of the pallet, the edges are assumed to be fixed. Since 86% of the load (18 of the 21 drums) is concentrated near the edge, the primary mode of loading the edge of the pallet will be direct bearing (compression) with little or no bending. Consequently, the determination of stress and deflection at the center of the pallet is the primary consideration in the structural evaluation of the pallet.

Uniform load at center (Ref. R.J. Roark, Third Edition, pg. 19E, Case 7)

Deflection:

$$\delta_{max} = \frac{3W(m^2-1)}{16\pi E m^2 t^3}\left[4a^2 - 4r_o^2 \ln\frac{a}{r_o} - 3r_o^2\right]$$

$m = \frac{1}{v} = \frac{1}{.3} = 3.33$

$a = 34.5$ in

$r_o = 12.0$ in

$$\delta_{max} = \frac{W}{t^3}\frac{(3)(10.08)}{16\pi(29X10^6)(3.33)^2}\left[4(34.5)^2 - 4(12)^2(1.05) - 3(12)^2\right]$$

$$= (6.97x10^{-6})\frac{W}{t^3}$$

$W = 750$ lbs/drum X 3 drums

$= 2,250$ lbs.

$t = 1.0$ in.

$$\delta_{max} = \frac{2,250}{(1)^3}(6.97x10^{-6}) = .016 \text{ in.}$$

Stress:

$$\sigma_{max} = \frac{3W}{2\pi m t^2}\left[(m+1)\ln\frac{a}{r_o} + (m+1)\frac{r_o^2}{4a^2}\right]$$

$$= \frac{W}{t^2}\frac{(3)}{2\pi(3.33)}\left[(4.33X1.05) + 4.33\frac{(12)^2}{(4)(34.5)^2}\right]$$

$$= .67\frac{W}{t^2} = \frac{.67(2,250)}{(1)^2}$$

$$= 1,509 \text{ psi}$$

Uniform Line Load @ r_o=24.0 in. (Ref: R. J. Roark, 3rd ED. PG. 196, Case B)

Deflection:

$$\delta_{max} = \frac{3W(m^2-1)}{2\pi E m^2 t^3}\left[\frac{1}{2}(a^2-r_o^2)-r_o^2 \ln\frac{a}{r_o}\right]$$

a = 34.5 in
r_o = 24.0 in
$m = \frac{1}{\nu} = \frac{1}{.3} = 3.33$

$$\delta_{max} = \frac{W}{t^3}\frac{(3)(10.08)}{2\pi(29X10^6)(11.08)}\left[\frac{1}{2}(34.5^2-24^2)-(24)^2 \ln\frac{34.5}{24}\right]$$

$$= (1.469x10^{-6})\frac{W}{t^3}$$

W = 750 lbs/drum X 18 drums
= 13,500 lbs.
t = 1.0 in.

$$\delta_{max} = (1.469x10^{-6})\frac{(13,500)}{(1)^3} = .02 \text{ in.}$$

Stress:

$$\sigma_{max} = \frac{3W}{4\pi m t^2}\left[(m+1)(2\ln\frac{a}{r_o}+\frac{r_o^2}{a^2}-1)\right]$$

$$= \frac{W}{t^2}\frac{(3)}{(4)\pi(3.33)}\left[(4.33)((2)(.362)+.483-1)\right]$$

$$= .064\frac{W}{t^2}$$

W = 13,500 lbs
t = 1.0 in

$$= .064\frac{(13,500)}{(1)^2} = 864 \text{ psi}$$

Superposing the two cases, the maximum center static deflection is then:

$$\delta_{max} = .016 + .02 = .036 \text{ in.}$$

As indicated at the outset, the focus of interest in confined to the central portion of the pallet. Assuming the stiffness and response characteristics of the central portion of the plate are approximated by the single degree of freedom spring-mass model, the dynamic load magnification at the center of the pallet when dropped in the flat end orientation 12.0-in. is then:

DLM = Dynamic Load Multiplier

$$DLM = 1 + \sqrt{1 + \frac{2h}{\delta_{static}}}$$ (Ref. R.J. Roark, 3rd Ed., Pg. 331)

$$DLM = 1 + \sqrt{1 + \frac{2(12)}{.036}} = 26.8$$

Combining the stress due to each load.

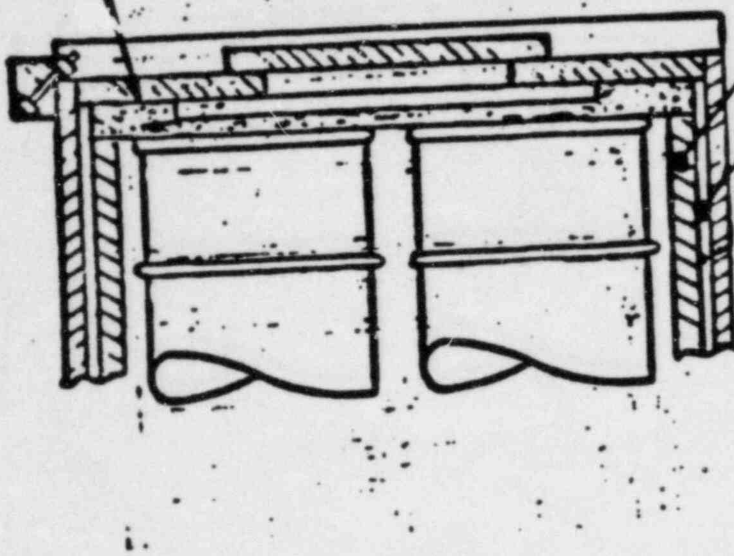
$$\sigma_{static} = 1{,}509 + 867 = 2376 \text{ psi}$$

$$\sigma_{dynamic} = 2{,}376 \times 26.8 = 63{,}677 \text{ psi}$$

The dynamic stress: 63,677

For ASTM 572 Gr. 65
fty = 65,000 psi
ftu = 85,000 psi

2.6.6.5 LOAD DISTRIBUTION PALLET AND INTERNAL SHIELD



Weights

Load distribution pallet...	1,850 lbs.
Shield	7,260 lbs.
21 drums @ 750 lbs. ea.	15,750 lbs.
Total	24,860 lbs.

SHIELD

The internal configuration shown in Figure 1.2 is the same as Figure 1.1 except that in this configuration a full length shield is placed in the 21-300 cask and the contents are placed inside the shield. In the critical flat drop condition, the shield bears directly on the stiff outer portion of the load distribution pallet with no effect on the central portion of the pallet. In this configuration the shield wall geometry and construction and configuration weights shall conform to the following limitations:

1) Wall thickness shall be 1.00 in. thick steel.

2) Weight of drums shall not exceed 15,750 lbs.

3) Combined weight of shield, contents, (including any drum lifting slings or fixtures) and load distribution pallet shall not exceed 27,250 lbs.

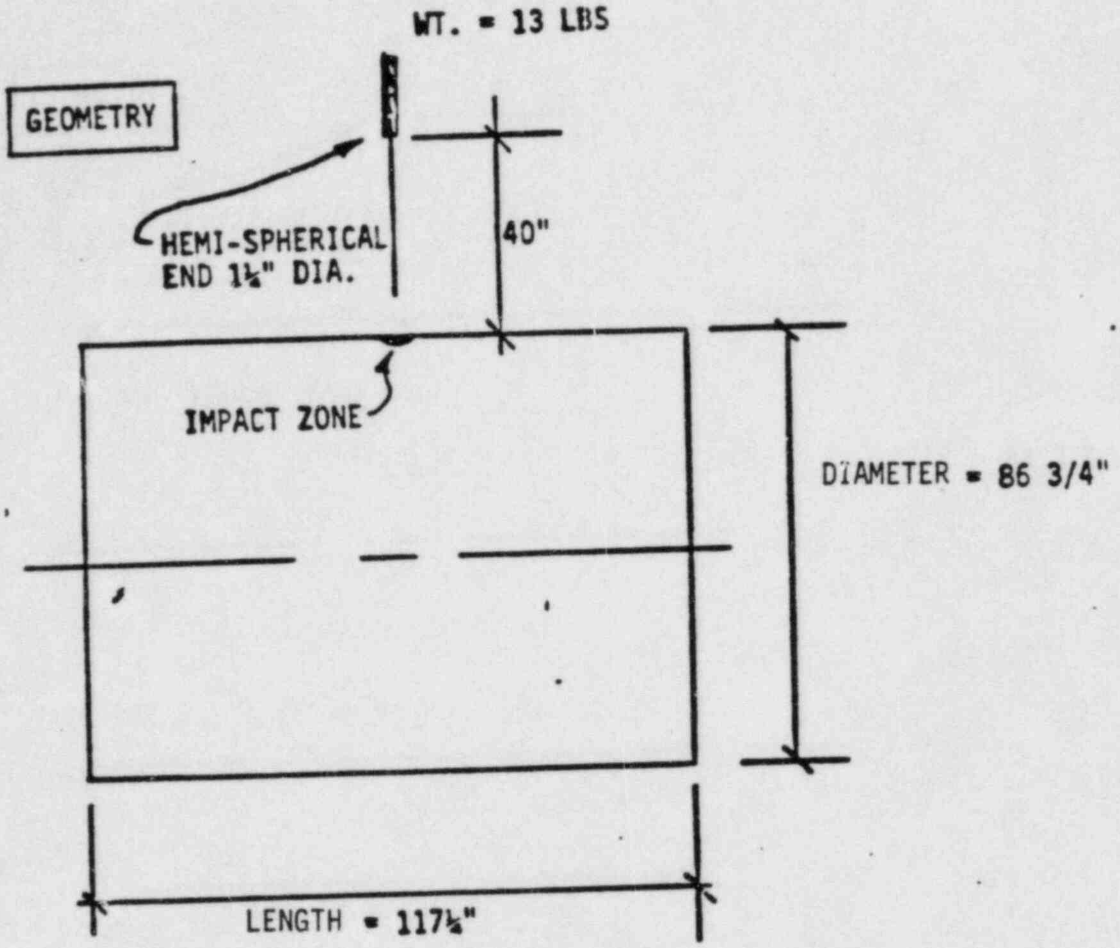
4) Shield shall be shored to prevent movement during transportation.

2.6.7 Penetration

The following analysis evaluates the effect of a 1.25 inch diameter, 13 pound cylinder impacting the cask after a free fall through 40 inches. This analysis conservatively estimates a maximum penetration of 0.06 inches which is much less than the 3/4 inch thick outer wall. Hence the integrity of the package or shielding is not compromised.

PENETRATION ANALYSIS

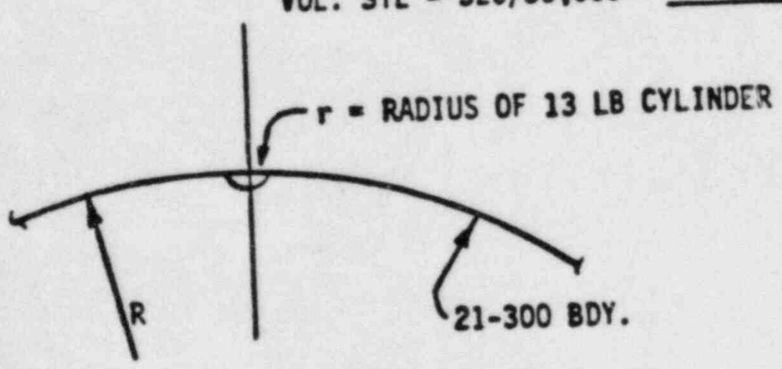
GEOMETRY



LOADS

ENERGY = Wh = 13(40) = 520 IN-LBS

VOL. STL = 520/36,000 = 0.0144 IN^3



$$r/R = \frac{1.25}{2(43)} = 0.0145$$

or R/r = 69

SINCE R/r VERY LARGE CONSIDER VOLUME AS PORTION OF SPHERE CUT BY PLANE SURFACE.

VOL. SPHERICAL SEGMENT $= \pi d^2(r - d/3)$

d = depth of penetration into cask outer surface

d = <u>0.0884 INCHES</u>

CHECK VALUE:

$$\pi(0.884)^2\left(\frac{1.25}{2} - \frac{0.0884}{3}\right) = 0.0144$$

$0.0146 \sim 0.0144$ CLOSE ENOUGH

IMPACT AREA PROJECTED = <u>0.32 IN^2</u>

FORCE = <u>11,600 LBS</u>

ANALYSIS

ROARK & YOUNG - 5th ED
TABLE 31
CASE 9

$$(f_{HOOP})_{MEMBRANE} = 0.4p/t^2$$

$$(f_{HOOP})_{BENDING} = 2.4p/t^2$$

$$Y = \frac{P}{Et}\left[\ 0.48\left(\frac{L}{R}\right)^{\frac{1}{2}}\left(\frac{R}{t}\right)^{1.22}\right]$$

RESULTS

$$(f_{HOOP})_{MEMBRANE} = \frac{0.4(11,600)}{(0.875)^2} = \underline{6060\ psi} \quad \text{CONSERVATIVE}$$

INNER STL = 1/8"
OUTER STL = 3/4"

$$(f_{HOOP})_{BEND} = \frac{2.4(11,600)}{(1.5)^2} = \underline{12,400\ psi}$$

Effective Thickness

COMBINE < YIELD ∴ OK CASK BODY

$$Y = \frac{11,600}{29(10^6)(0.75)}\left[\ 0.48\left(\frac{117}{43}\right)^{\frac{1}{2}}\left(\frac{43}{0.75}\right)^{1.22}\right] = \underline{0.06\ IN}$$

< THICKNESS SMALL
∴ OK

2.6.8 Compression

The model 21-300 weighs in excess of 11,000 pounds and therefore is not subject to this condition in accordance with 10 CFR 71.71 (c) (9).

2.7 Hypothetical Accident Conditions
Not applicable for Model 21-300

2.8 Special Form
Not applicable for Model 21-300

2.9 Fuel Rods
Not applicable for Model 21-300

2.10 Appendix

Table 2-1 Summary of Characteristics of Major Cask Components

TABLE 2-1

Summary of Characteristics of Major Cask Components

Component	Dimensions	Material	Item No. (2)
Cask Walls	Outer Shell 3/4" thick	A516 (1)	7
	Shield Region 1" thick	lead	4
	Inner Shell 1/8" thick	A304	6
Primary Lid	Outer Shell 3/4" thick	A516 (1)	2
	Shield Region 1" thick	lead	4
	Inner Shell 1/2" thick (Consist of 2 layers at 1/4" thick each)	A304	5 and 37
	Lid OD 82-5/8" to 84-3/4"		
	Lid ID 26"		
Primary Bolts	12 at 1-1/4" dia. x 6-1/2" long	SAE J 429 A490 Gr. 8	19
Secondary Lid	Outer Shell 3/4" thick	A516 (1)	8
	Shield Region 1" thick	lead	4
	Inner Shell 1/8" thick	A304	9
	Diameter 36"		
Secondary Bolts	18 at 3/4" dia. x 1-1/2" long	SAE J429, A307, Gr. 2	12
Cask Bottom	Outer Shell (baseplate) 3/4" thick	A516 (1)	13
	Shield Region 1" thick	lead	4
	Inner Shell 1/2" thick (consist of 2 layers, one at 1/8" and one at 3/8")	A304	24 and 35

(1) A516 replaced A36 for all casks fabricated after April 14, 1980.

(2) CNSI Drawing 1-298-101 Rev. J

3.0 Thermal Evaluation

A thermal analysis was performed which considers the effect of a steady state condition including the following parameters:

1) Ambient Temperature = 130^{o}F
2) Solar heat absorbed = 15,507.8 btu/hr
3) Internal heat generation = 30 watts

The analysis provided the following results:

maximum external temperature = 169.5^{o}F
corresponding internal cask pressure = 0.56 atm

These results will have no deleterious effect on the ability of the cask to perform its intended function.

The details of this analysis are presented on the following pages.

Thermal Analysis of CNSI 21-300 Transport Cask General Assumptions and Analysis Method

This analysis will determine cask temperature under worst-case (highest temperature) conditions. This assumption includes the following parameters:

- Direct Sunlight (Summer 42^{o}N latitude)
- Ambient Air Temperature (T_{∞}) = 130^{o}F
- Internal Heat Load = 30 watts
= 102.4 btu/hr
- Laminar External Convection Conditions
- Adiabatic Bottom Conditions

Heat Loads on the Cask Include:

- Solar Radiation
- Waste Decay Heat (30 watts)
(102.4 btu/hr)

Heat is lost from the cask by the following modes:

- Convection
- Radiation to the atmosphere

The analysis used to determine the maximum exterior temperature of the cask assumes steady state conditions where the heat load on the cask equals the heat lost.

In addition, conduction through the cask walls will be considered to determine the temperature difference between the inner and outer surfaces of the cask,

Heat Transfer from the Cask

Convection

$$q = hA\,(T_{EXT} - T_{\infty})$$

From Heat Transfer (4th Ed) by J.P. Holman:

Approximated Convection Coefficients

$$h = 1.42 \left(\frac{\Delta T}{L}\right)^{1/4} \quad W/M^2\ {}^{o}C$$

(For vertical cylinders Laminar Conditions)

$$h = 1.32 \left(\frac{\Delta T}{L}\right)^{1/4} \quad W/M^2\ {}^{o}C$$

(For Horizontal Plates, Heated, Facing Upward, Laminar Conditions)

Converting to English Units:

$$h = 0.25 \left(\frac{\Delta T}{L}\right)^{1/4} \quad BTU/HR\ Ft^2\ {}^{o}F$$

For Vertical Cylinder

and similarly

$$h = 0.23 \left(\frac{\Delta T}{L}\right)^{1/4} \quad BTU/HR\ Ft^2\ {}^{o}F$$

For Horizontal Plates

External Surface Areas:

$$A_{Top} = \frac{\pi}{4} D^2 = \frac{\pi}{4} (86.75)^2 = 5910.6 \text{ in}^2 = 41 \text{ ft}^2$$

$$A_{Sides} = \pi r H = \pi (86.75)(109.25) = 29774.2 \text{ in}^2 = 206.8 \text{ ft}^2$$

The Total Heat Loss is the sum of the sides and top:

$$q_{Conv.} = 0.25 \left(\frac{T_{ext} - 130}{109.25/12}\right)^{1/4} 206.08 \ (T_{ext} - 130) \ +$$

$$0.23 \left(\frac{T_{ext} - 130}{86.75/12}\right)^{1/4} 41 \ (T_{ext} - 130)$$

Radiation

$$q = \sigma \ A_{Total} \ \epsilon \ (T_{ext}^4 - T_\infty^4)$$

Where:

ϵ = 0.8 (assumed for cask)

$\sigma = 0.17 \times 10^{-8}$ BTU/hr ft^2 $^oR^4$

(All Temps in ^oR)

$$q_{RAD} = 0.8 \ (0.17 \times 10^{-8}) \ (247.8) \ (T_{ext}^4 - 590^4)$$

Heat Load on the Cask

Solar Radiation

Total Solar Heat Absorbed:

$$Q = A_N \, q_{si} \, \alpha$$

Where:

A_N = Normal Area (Total)

q_{si} = Solar Intensity

α = Surface Absorbtivity (0.8 assumed for cask)

The total normal area of the cask available for absorption of solar energy is a function of the angle of incidence of the energy, θ.

$$A_N = A_{Top} \cos \theta + A_{Sides} \sin \theta$$

$$A_{Sides(Cross\ Section)} = DH = (86.75)(109.25) = 9477.4 \text{ in}^2$$

$$= 65.8 \text{ ft}^2$$

$$A_{Top} = 41 \text{ ft}^2$$

Data on Solar Intensity is obtained from ORNL-TM-2410: Irradiated Fuel Shipping Cask Design Guide.

From this reference, a peak solar insolation of 19368 BTU/hr is determined. This determination is based on a calculated critical angle (angle between vertical and incident solar rays) which results in maximum solar insolation resulting from a trade-off between sun intensity and cask surface area normal to incident solar rays. Combining this with the assumed absorptivity for this cask (0.8) yields a solar heat load of 15,508.8 BTU/hr.

Steady State Solution

For Steady State: $Q_{in} = Q_{out}$

$$Q_{out} = q_{con} + q_{RAD}$$

$$Q_{in} = q_{solar} + q_{GEN}$$

(Converting all temps to ^oR)

$$0.25 \left(\frac{Text - 590}{109.25/12}\right)^{1/4} 206.08\,(Text - 590) + 0.23 \left(\frac{Text - 590}{86.75/12}\right)^{1/4} (Text - 590)(41)$$

$$+ 0.8\,(0.17 \times 10^{-8})(247.8)(Text^4 - 590^4) = 15508.8 + 102.4 \text{ BTU/hr}$$

Simplifying

Let x = Text

$$51.7 \frac{(x - 590)^{1/4}}{9.1} (x - 590) + 9.43 \frac{(x - 590)^{1/4}}{7.2} (x - 590)$$

$$+ 3.37 \times 10^{-7} (x^4 - 590^4) - 15611.2 = 0$$

Evaluating this expression yields:

Text = 629.5°R

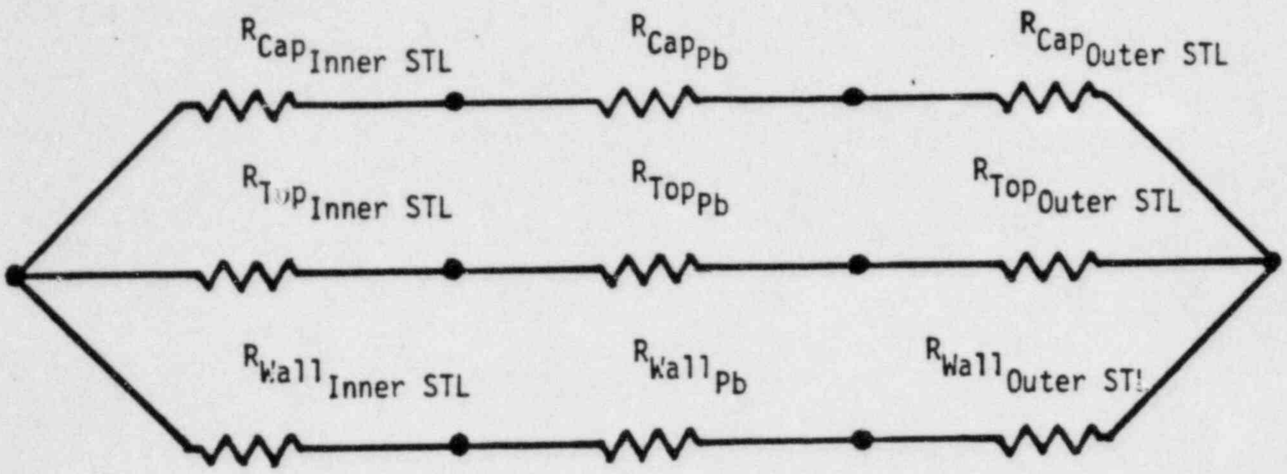
or

Text = 169.5°F

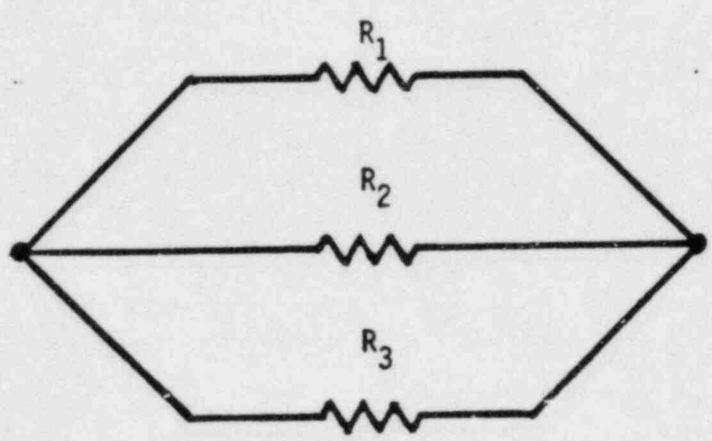
Conductive Heat Transfer Through

Cask Walls

The following equivalent resistance network is used.



Combining:



$$R = \frac{t}{KA}$$

Where thickness, t and area, A are determined from the reference drawing 1-298-101 Rev. J. Thermal conductivities are:

k steel = 25 BTU/hr - ft - °F
k lead = 18.6 BTU/hr - ft - °F

The resulting calculated thermal resistances are tabulated below:

	Steel	Lead	Total
CAP	.0008	.0012	.002 = R_1
TOP	.0001	.0001	.0002 = R_2
WALL	.00001	.00002	.00003 = R_3

$$R_{EFF} = \frac{R1\ R2\ R3}{R_2\ R_3 + R_1\ R_3 + R_1\ R_2} = 2.6 \times 10^{-5}$$

Therefore, temperature gradient through cask wall, Δ t, is:

$$\Delta T = q\ R_{EFF} = (104.4)(2.6 \times 10^{-5})$$

$$= 0.003^{o}F$$

Therefore the interior of the cask will be at virtually the same temperature as the exterior.

Evaluation of Internal Pressure

The pressure increase inside the cask due to heating is based on the assumption that material containing water is loaded at 70°F and the temperature is later increased to a maximum of 170°F.

Partial pressures of water & air @ 70°F are:

P_w = 0.36 psi
P_a = 14.7 - 0.36 = 14.34

Partial pressures @ 170°F are:

P_w = 5.9 psi
P_a = 14.34 (170 + 460)/(70 + 460) = 17.0 psi

The internal pressure increase is:

P = 5.9 + 17.0 - 14.7 = 8.2 psi = 0.56 ATM

This pressure is well within the design limits of the cask.

4.0 Containment

4.1 Containment Vessel

The containment vessel consists of steel-lead-steel composite walls and ends of various thickness as described in Section 1.2 and summarized in Table 2-1. The stainless steel (A304) inner liner which is present on the cask walls, bottom and lid provides an effective barrier between the cask contents and the environment. The containment vessel is fabricated using full penetration welds. Analyses presented in Section 2.0 demonstrate the capability of the overall structure to maintain the integrity of this containment barrier during all hypothesized normal conditions of transport appropriate for a Type A package as specified by 10 CFR 71. Periodic inspection and maintenance performed using approved CNSI procedures ensures that the containment structures continue to perform their intended functions.

4.2 Containment Penetration and Closures

Access to the containment is through one of two lids at the top of the container, depending on the type of contents to be loaded. The small diameter secondary lid provides access through a 26 inch diameter penetration through the primary lid for use with high integrity container type cask liners. The secondary lid seals this penetration using 18 3/4 inch diameter bolts torqued to 50 ± 5 ft-lbs. An elastomer type gasket maintains at positive seal at the interface between the primary and secondary lid.

The primary lid is removable to provide unobstructed access to the entire cask cavity for the loading of 55 gallon drums or similar approved containers, as well as the installation of an auxiliary shield and/or load distribution pallet when appropriate. The primary lid is sealed to the cask body with an elastomer type gasket and 12 - 1-1/4 inch diameter bolts torqued to 200 ± 10 ft-lbs.

There are no other penetrations through the package containment.

5.0 Shielding Evaluation

5.1 Introduction

The CNSI 21-300 packaging consists of steel-lead-steel composite walls, lid and bottom which provide the necessary shielding for the various radioactive materials to be shipped within the package. In addition, an internal auxiliary shield and a load distribution pallet are available for use with this cask which provide increased shielding effectiveness. Analyses described in Sections 2.0 and 3.0 have demonstrated the ability of this container to maintain its shielding integrity. Prior to each shipment, radiation readings are taken to assure compliance with applicable regulations.

Analyses are presented on the following pages which evaluate the shielding capability of this package considering the following assumptions:

1) Maximum allowable dose rate shall be 200 mrem/hour on the cask surface or 10 mrem/hour at six feet from the cask surface, whichever is limiting.

2) The source is modeled as a point source which can exist on any interior cask surface. This is very conservative, as the source is considered to be in contact with all inner cask surfaces at the same time.

3) The auxiliary shields will be modeled in a worst case configuration that assumes the shield is in contact with the package wall with no annular space.

Table 5-1 summarizes the maximum dose rates based on these assumptions.

5.2 Package System Shielding Analysis

The cask side wall consists of the outer 0.75-inch steel shell surrounding a 1.0-inch thickness of lead and an inner wall of 0.125-inch thick steel. Total material shield thickness is 0.875 inches of steel and 1.0 inch of lead. The auxiliary shield will add 1.0 inches of steel to this total.

When the auxiliary shield is used in the 21-300 cask, it is assumed that the contents inside the shield create the maximum dose rate of 10 mrem/hr at six feet from the outer cask surface or 200 mrem/hr on the cask surface, whichever is limiting.

The bottom end of the cask body shielding consists of an outside layer of 0.75-inch thick steel and a 1.0-inch thick lead shield with inner containment layer thicknesses of 0.125 inch and 0.375 inch of steel.

Total material shield thickness of the bottom end of the cask is 1.25 inches of steel and 1.0 inch of lead. There would be no additional shielding provided to the bottom end by the auxiliary shield design.

The outer surface of the top (closure) end of the cask is a 0.75-inch thick steel plate. The internal lead shield thickness is 1.0 inches. The cavity side of the closure assembly is two 0.25-inch thick steel plates. Total material shield thickness is 1.25 inches of steel and 1.0 inch of lead. The load distribution pallet, which forms a top for the auxiliary shield, adds 1.0 inch of steel to this total.

5.2.1 Source Specification

Gamma Source

The cask is to handle non-fuel-bearing reactor components or solid and solidified processed solids. The major gamma radiation source is assumed to be Co-60 from stainless steel components to be handled. Since source geometry will vary considerably for this container, the conservative approach for shield design shall be for the analysis to be based upon a point source (shape and volume factors are not taken into account).

Neutron Source

There are no sources of neutron radiation in the radioactive materials carried in the CNS 21-300 Cask.

5.2.2 Model Specification

Description of the Radial and Axial Shielding Configuration

Dimensions of the radial and axial shielding material modes are shown in Figure 5-1.

Shield Regional Densities

The mass densities for each material are shown in the table below.

SHIELD REGIONAL DENSITIES

MATERIAL	ELEMENT	DENSITY (g/cc)
Carbon Steel	Fe	7.86
Lead	Pb	11.34

5.2.3 Analysis and Results

Radial Model

The gamma radiation sources that correspond to regulatory dose rate limits for the cask in a radial direction were calculated assuming a point source. The dose model used for this calculation is shown in Figure 5-1.

The point source is determined as follows:

$$\phi_\gamma = KB \frac{S_o}{4\pi a^2} e^{-b_1}$$

where, ϕ_γ = Photon Flux, $\frac{\gamma}{cm^2\text{-sec}}$

K = Flux to dose conversion = $2.3 \times 10^{-6} \frac{R/hr}{\phi_\gamma}$ for Co-60

S_o = Equivalent source, $\frac{\gamma}{sec}$

$b_1 = \Sigma_i \mu_i t_i$

B = Buildup factor

a = Distance from source to dose point, cm

Through the side of the cask, the following values are used:

Case 1: No Aux. Shield

Lead: t = 1.0 in. = 2.54 cm, μ/ρ = 0.0600
$\mu = 0.684\ cm^{-1}$

Steel: t = 0.875 in. = 2.22 cm, μ/ρ = 0.0515
$\mu = 0.415\ cm^{-1}$

Case 2: With Aux. Shield

Lead: $t = 1.0$ in. $= 2.54$ cm, $\mu/\rho = 0.0600$
$\mu = 0.684\ cm^{-1}$

Steel: $t = 1.875$ in. $= 4.76$ cm, $\mu/\rho = 0.0515$
$\mu = 0.415\ cm^{-1}$

Giving: $b_1 = 2.66$ (Case 1)
$b_1 = 3.71$ (Case 2)

The buildup factor is taken for steel to represent the laminated shield.

$B = 4.6$ (Case 1)
$B = 6.0$ (Case 2)

Two dose rates will be considered:

$D_1 = 10$ mr/hr, where:

Case 1: $a = 1.875$ in + 72 in. = 73.9 in = 188 cm

which gives, $S_o = 6.0 \times 10^9\ \frac{\gamma}{sec}$

Case 2: $a = 2.875$ in. + 72 in. = 74.9 in. = 190 cm

which gives, $S_o = 1.3 \times 10^{10}\ \frac{\gamma}{sec}$

and, $D_2 = 200$ mr/hr, where:

Case 1: $a = 1.875$ in. = 4.76 cm

which gives, $S_o = 7.7 \times 10^7\ \frac{\gamma}{sec}$

Case 2: $a = 2.875$ in. = 7.30 cm

which gives, $S_o = 4.0 \times 10^8\ \frac{\gamma}{sec}$

The dose rates at the cask surface and at 6 feet from the surface are shown in Figure 5-2 for various source strengths with or without auxilary shields.

Axial Model

The gamma radiation sources that correspond to regulatory dose rate limits for the cask in an axial direction were calculated assuming a point source. The dose model used for this calculation is shown in Figure 5-1.

The point source is determined as follows:

$$\phi_\gamma = KB \frac{S_o}{4\pi a^2} e^{-b_1}$$

where, ϕ_γ = Photon Flux, $\frac{\gamma}{cm^2\text{-sec}}$

K = Flux to dose conversion = $2.3 \times 10^{-6} \frac{R/hr}{\phi_\gamma}$ for Co-60

S_o = Equivalent source, $\frac{\gamma}{sec}$

$b_1 = \Sigma_i \mu_i t_i$

B = Buildup factor

a = Distance from source to dose point, cm

Through the top of the cask, the following values are used:

Case 1: No Aux. Shield

Lead: $t = 1.0$ in. $= 2.54$ cm, $\mu/\rho = 0.0600$
$\mu = 0.684\ cm^{-1}$

Steel: $t = 1.25$ in. $= 3.18$ cm, $\mu/\rho = 0.0515$
$\mu = 0.415\ cm^{-1}$

Case 2: With Aux. Shield

Lead: $t = 1.0$ in. $= 2.54$ cm., $\mu/\rho = 0.0600$
$\mu = 0.684\ cm^{-1}$

Steel: $t = 2.25$ in $= 5.72$ cm., $\mu/\rho = 0.0515$
$\mu = 0.415\ cm^{-1}$

Giving: $b_1 = 3.06$ (Case 1)
$b_1 = 4.11$ (Case 2)

The buildup factor is taken for steel to represent the laminated shield.

$B = 4.8$ (Case 1)

$B = 6.6$ (Case 2)

Two dose rates will be considered:

$D_1 = 10$ mr/hr, where:

Case 1: $a = 2.25$ in. $+ 72$ in. $= 74.25$ in. $= 189$ cm.

which gives, $S_o = 8.7 \times 10^9\ \frac{\gamma}{sec}$

Case 2: $a = 3.25$ in $+ 72$ in. $= 75.25$ in $= 191$ cm

which gives, $S_o\ 1.8 \times 10^{10}\ \frac{\gamma}{sec}$

$D_2 = 200$ mr/hr, where:

Case 1: $a = 2.25$ in $= 5.72$ cm

which gives, $S_o = 1.6 \times 10^8 \frac{\gamma}{sec}$

Case 2: $a = 3.25$ in. $= 8.26$ cm

which gives, $S_o = 6.9 \times 10^8 \frac{\gamma}{sec}$

The dose rates at the cask surface and 6 feet from the surface are shown in Figure 5-3 for various source strengths with or without auxilary shields.

Through the bottom of the cask the following values were used: (Note: There is only one case examined for the bottom as auxilary shielding is not added to this area.)

Lead: $t = 1.0$ in. $= 2.54$ cm., $\mu\ \rho = 0.0600$
$\mu = 0.684\ cm^{-1}$

Steel: $t = 1.25$ in. $= 3.18$ cm, $\mu\ \rho = 0.0515$
$\mu = 0.415\ cm^{-1}$

Giving: $b_1 = 3.06$

The buildup factor is taken for steel to represent the laminated shield.

$B = 4.8$

Two dose rates will be considered:

$D_1 = 10$ mr/hr, where:

$a = 2.25$ in. $+ 72$ in $= 74.25$ in $= 188.6$ cm

which gives, $S_o = 8.7 \times 10^9 \frac{\gamma}{sec}$

D_2 = 200 mr/hr, where:

a = 2.25 in. = 5.72 cm

which gives, $S_o = 1.6 \times 10^8 \frac{\gamma}{sec}$

The dose rates at the cask surface and 6 feet from the surface are shown in Figure 5-3 for various source strengths.

5.3 Appendix

1. Table 5-1 Summary of Maximum Dose Rates
2. Figure 5-1 Shielding Models
3. Figure 5-2 Cask Side Wall
4. Figure 5-3 Cask Top and Bottom

TABLE 5-1

SUMMARY OF MAXIMUM DOSE RATES
(mR/hr)

	Package Surface			6 Feet from Surface of Package		
	Side	Top	Bottom	Side	Top	Bottom
NORMAL CONDITIONS						
Gamma	200	100	100	10	7	7
WITH AUX. SHIELD						
Gamma	80	55	200	6	5	10

Figure 5-1 SHIELDING MODELS

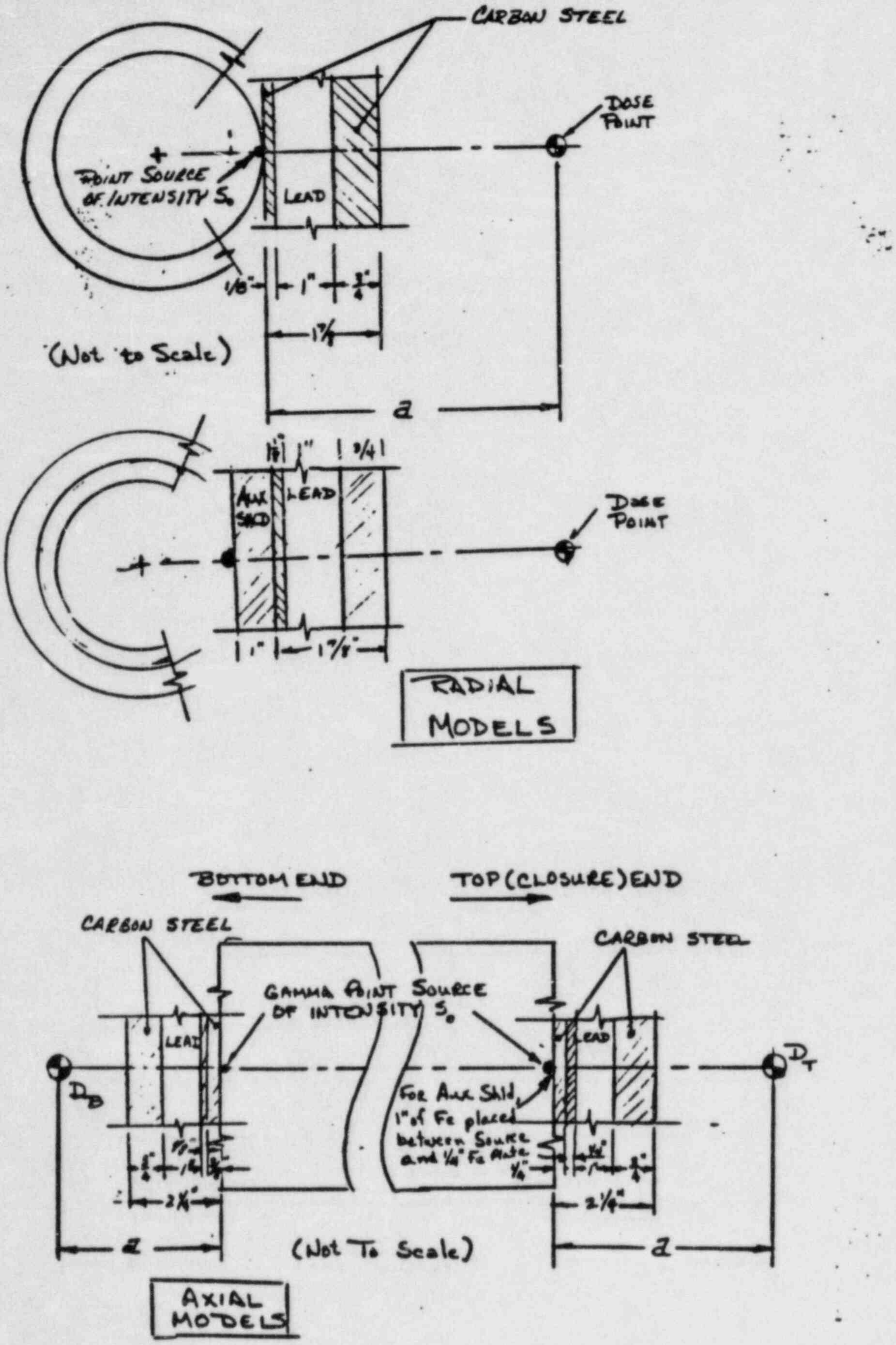


Figure 5-2 CASK SIDE WALL

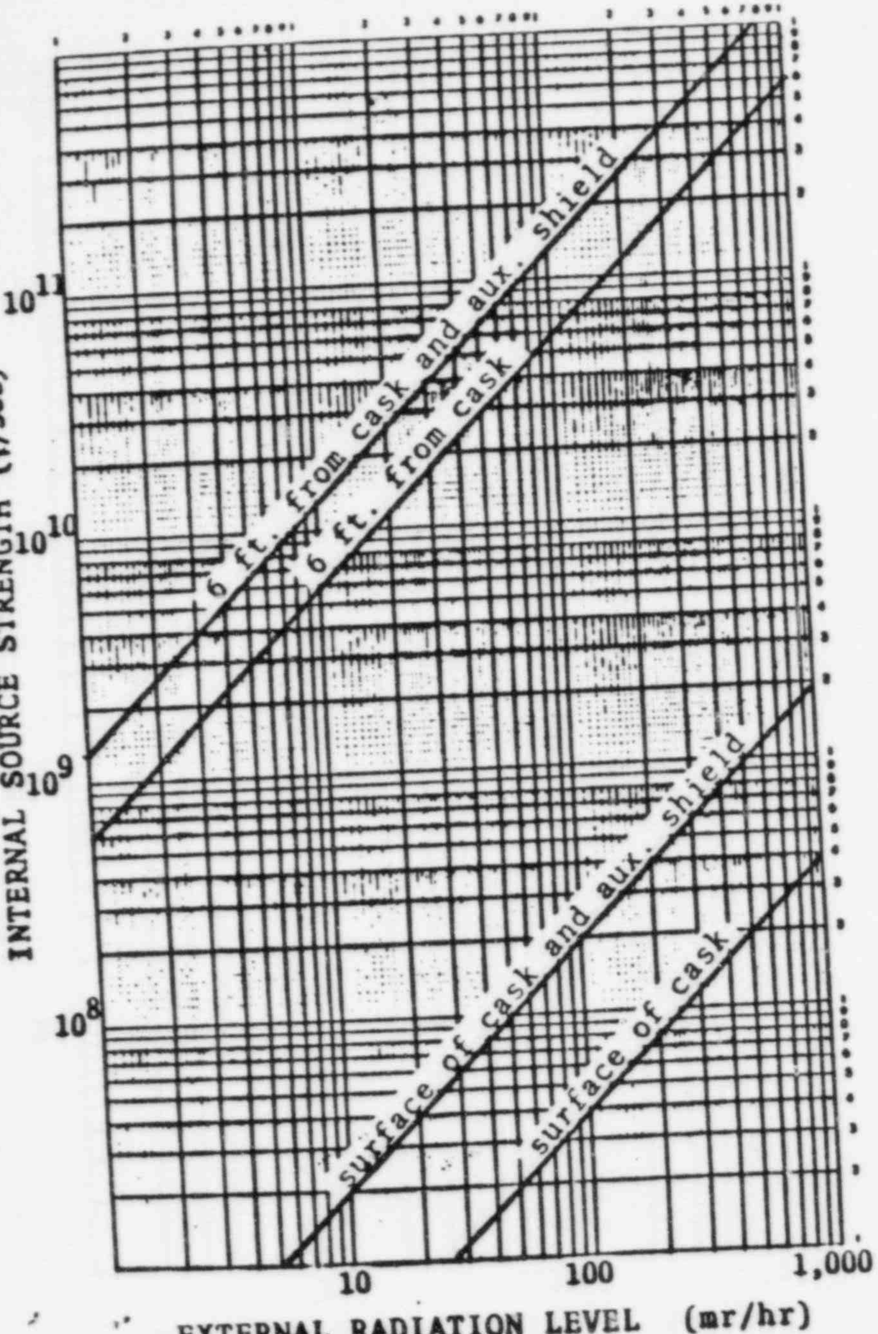
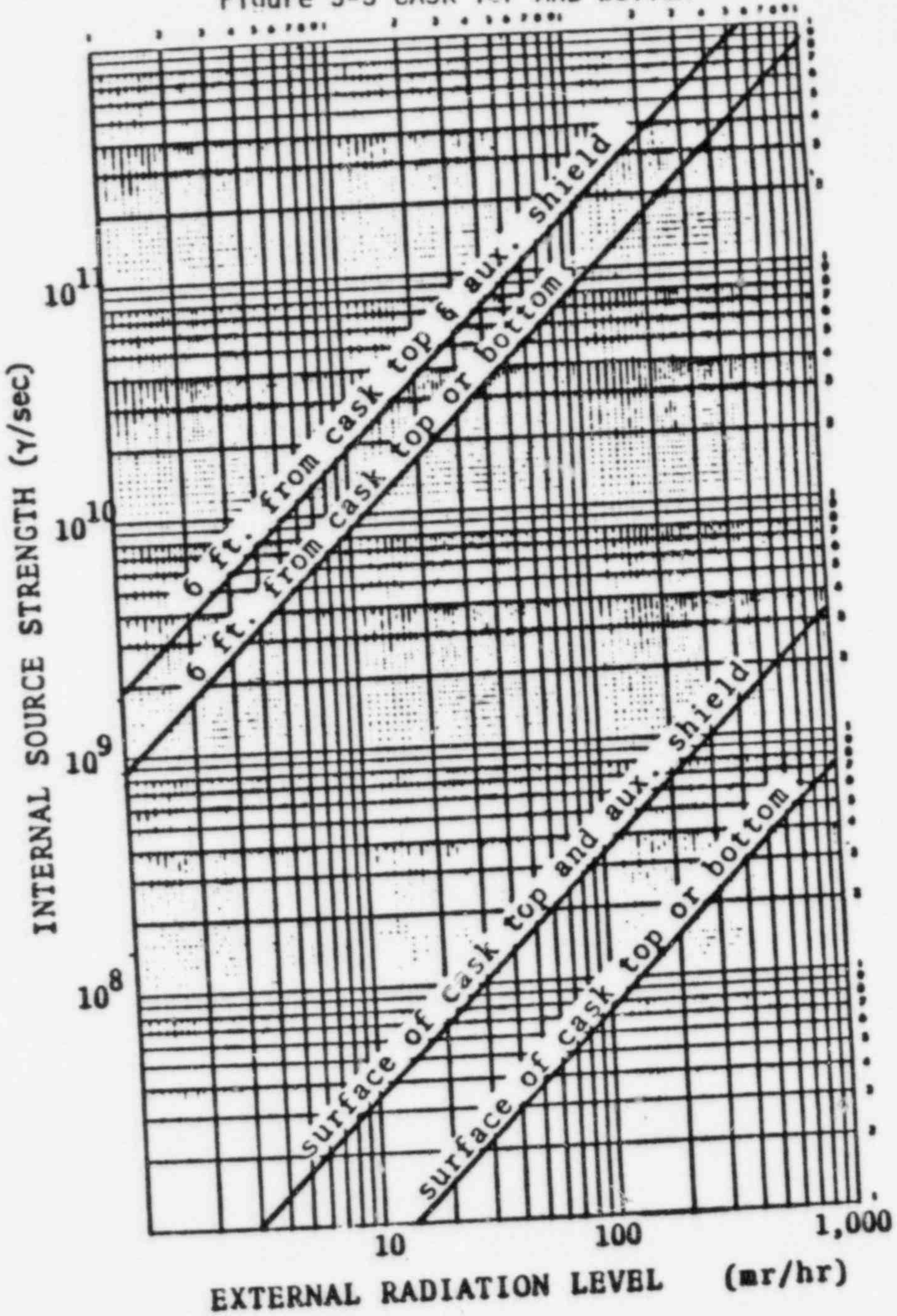


Figure 5-3 CASK TOP AND BOTTOM



6.0 Criticality Evaluation

Not applicable for 21-300 packaging

7.0 Operating Procedure

This section generally describes the procedure for loading and unloading of the CNS 21-300 cask. Detailed procedures developed, reviewed, and approved following requirements of the CNSI Q.A. program are issued to authorized users.

7.1 Loading Procedure for 55 gallon drums
(or for installation of pre-filled liner)

1. Remove and discard the seal wires from the appropriate primary lid bolts.

2. Loosen and remove the (twelve) 12 1-1/4 inch diameter bolts that secure the primary lid to the cask body.

3. Using a lifting sling attached to the three symmetrically located primary lid lifting lugs, lift the primary lid.

4. Inspect and verify integrity of cover gasket.

5. Lay down lid on a suitable protected surface, treating lid underside as potentially contaminated.

6. Using crane and suitable riggings, remove pallet(s) and any shoring material from the cask cavity.

7. Visually inspect cask cavity to verify integrity.

8. Load each pallet with a maximum of (seven) 7 55 gallon drums. Shielding effectiveness may be optimized by placing drums with highest surface dose rate near the center of the pallet.

9. Attach crane to the lifting ring of the pallet and carefully lower into cask cavity, use caution to not damage the gasket seating surfaces or inner walls of cask cavity.

10. Place shoring where appropriate between drums and cask cavity walls to prevent movement during transport.

11. Repeat the loading procedure for the next layer(s) of palletized drums.

Note: For pre-filled liners, use crane to lower liner into cask cavity.

12. Inspect and clean the gasket seating surfaces.

13. Lift the primary lid onto the cask and position properly using key and keyway.

14. Replace the (twelve) 12 1-1/4 inch bolts and torque to 200 ± 10 ft-lbs using a star pattern.

15. Install anti-temper seal wires in appropriate bolts.

16. Perform cask survey and verify all requirements are satisfied.

7.2 <u>Loading Procedure for Liners</u>
(for empty liners pre-installed in cask cavity)

1. Remove and discard the seal wires from the appropriate secondary lid bolts.

2. Loosen and remove the (eighteen) 18 3/4 inch diameter bolts that secure the secondary lid to the primary lid penetration.

3. Attach a lifting sling to the single center-mounted lug on the secondary lid, and lift the secondary lid.

4. Inspect and verify integrity of cover gasket.

5. Lay down lid on a suitable protected surface, treating lid underside as potentially contaminated.

6. Proceed with filling the liner following appropriate personnel precautions and operational procedures.

7. Inspect and clean the gasket seating surfaces.

8. Lift the secondary lid onto the primary lid and position using indicated alignment marks.

9. Replace the (eighteen) 18 3/4 inch bolts and torque to 50 ± 5 ft-lbs using the star pattern.

10. Install anti-tamper seal wires in appropriate bolts.

11. Perform cask survey and verify all requirements are satisfied.

7.3 <u>Unloading Procedure</u>

1. Remove and discard the seal wires from the appropriate primary lid bolts.

2. Loosen and remove the (twelve) 12 1-1/4 inch diameter bolts that secure the primary lid to the cask body.

3. Using a lifting sling attached to the three symmetrically located primary lid lifting lugs, lift the primary lid from the cask.

4. Attach crane and rigging to appropriate lift points on liner or drum pallet.

5. Proceed with removal of all contents from cask cavity.

6. Clean cask interior as required and inspect interior surfaces for integrity.

7. Install new liner or drum pallets in cask.

8. Clean and inspect the gasket sealing surfaces.

9. Lift the primary lid onto the cask and position properly using key and keyway.

10. Replace the (twelve) 12 1-1/4 inch bolts and torque to 200 ± 10 ft-lbs.

11. Install anti-tamper seal wires in appropriate bolts.

12. Prior to departure from site, ensure that exterior radiation levels are acceptable, and proper placarding is in place.

8.0 Tests and Maintenance

CNSI is committed to an ongoing preventative maintenance program for all shipping packages. The CNS model 21-300 package will be subjected to routine and periodic inspections and test as outlined in this section and CNSI approved procedures.

8.1 Structural Tests

Routine visual examinations will be performed to detect and correct damage or defects significant to package condition. Exterior stencils, nameplates, seals and bolts will be verified in place, and in good condition. Painted surfaces will be inspected to insure acceptability. Any refurbishment will be per approved CNSI procedure. Prior to each actual shipment, cask lid alignment marks will be inspected and their placement verified.

8.2 Lid Gasket

The lid gaskets will be inspected every loaded shipment, and replaced as necessary. Regardless of inspection results, the gaskets will be replaced every 12 months, if the cask is in use.

8.3 Shielding

No tests are required for shielding performance other than normal transportation compliance surveys.

8.4 Thermal

No thermal test are required.

9.0 Quality Assurance

As required by Section 71.101 (Subpart H) of 10CFR71, Chem-Nuclear Systems, Inc. has established a quality assurance program which satisfies the specified criteria. A description of this program was approved on January 23, 1985 by the Chief, Transportation Branch, Division of Fuel Cycle and Material Safety, USNRC.

Section 13.2 of the CNSI Quality Assurance Program requires:

1. Transport cask handling and operation shall conform to the written handling and operation procedure for each licensed cask.

2. Prior to the shipment of a transport cask all condition of the NRC's Certificate of Compliance (specifications, tests, inspections) shall be satisfied. All required shipping papers shall be prepared and shall accompany the shipment.

3. Quality Assurance located at Barnwell, S.C., is responsible for inspecting all critical cask handling, storage and shipping operations conducted by Barnwell Site Operations.

4. Established safety restrictions concerning handling, storage and shipping shall be included in the handling and operating procedures for transport casks.

CHEM-NUCLEAR SYSTEMS, INC.
220 Stoneridge Drive • Columbia, South Carolina 29210

~~71-9094~~
71-9096

May 3, 1985
RA-0192-5

Mr. Charles E. MacDonald
Chief, Transportation Certification Branch
Division of Fuel Cycle and Material Safety
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Mr. MacDonald:

REFERENCE: Docket No. 71-9094 and No. 71-9094 (9096)

Enclosed is a check for $300.00 to cover application fees as required by Section 170.31 of 10 CFR 170. The fees are for submittals sent under separate covers dated April 30 May 1, 1985 for certificates of compliance No. 9096 and No. 9094 respectively.

Very truly yours,

CHEM-NUCLEAR SYSTEMS, INC.

L. K. Poppe
Director
Licensing

LKP:as

Enclosure

'85 MAY -9 P2:55
NRC BRANCH

'85 MAY -6 A10:48

~~8505060368~~

25211

Dupe of:
Adv Copy to FCTC 05/08/85

(803) 256-0450 • Telex: 216947