Safety Analysis Report
For The
Model 14-195-H Shipping Cask

Submitted By:

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8005270 525

Table of Contents

for the

14-195H Shipping Cask

1.0 GENERAL INFORMATION
    1.1 Introduction
    1.2 Package Description
        1.2.1 Packaging
            1.2.1.1 Geometry and Materials of Construction
            1.2.1.2 Weights
            1.2.1.3 Containment
        1.2.2 Operational Features & Procedural Controls
        1.2.3 Contents of Packaging

2.0 STRUCTURAL EVALUATION
    2.1 Structural Design Standards
    2.2 Weights
    2.3 Mechanical Properties of Materials
    2.4 General Standards for All Packages
        2.4.1 Lifting Devices
        2.4.2 Tiedown Devices
    2.5 Standards for Type B Packaging
    2.6 Normal Conditions of Transportation
        2.6.1 Heat
        2.6.2 Cold
        2.6.3 Pressure
        2.6.4 Vibration
        2.6.5 Water Spray
        2.6.6 Free Drop
            2.6.6.1 End Drop
            2.6.6.2 Side Drop
            2.6.6.3 Corner Drop

- 2.6.7 Corner Drop
- 2.6.8 Penetration
- 2.6.9 Compression

2.7 Hypothetical Accident Conditions

2.8 Special Form

2.9 Fuel Rods

2.10 Appendix
- 2.10.1 Test Procedure
- 2.10.2 Test Data Sheet
- 2.10.3 Test Report
- 2.10.4 CNSI Dwg. No. 1-189-101, Rev. AF

1

1.0 GENERAL INFORMATION

1.1 Introduction

The CNSI 14-195H shipping cask is a top-loading, shielded container designed for the transport of low specific activity (LSA) radioactive wastes. The cask will accommodate fourteen (14) 55 gallon drums or one 195 cubic foot steel liner.

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 which is used only when the cask contains a 195 cubic foot liner.

The cask is a right circular cylinder 83 1/8-inch diameter by 89 7/8 inch with a 77-inch diameter by 80 1/8-inch cavity. Lead shielding is 2 3/16-inch thick, and is encased in an outer steel shell 3/4-inch thick and inner steel shell 1/8-inch thick. Positive closure of the silicone rubber sealed lid is provided by twelve 1 1/4-inch diameter cap screws. A secondary lid with a neoprene seal uses eighteen 3/4-10UNC bolts for closure. The cask is welded to a 96-inch square base plate, has two lifting trunnions, three lid lift rings and one secondary lid lifting ring. Package gross weight is 56,600 pounds.

1.2 PACKAGE DESCRIPTION

1.2.1 Packaging

1.2.1.1 Geometry and Materials of Construction

CASK BODY

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 2 3/16-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. Two lifting trunnions are welded to the top flange and the outer steel shell.

CASK LID

The cask lid is identical to the cask walls except that the inner shell plate is 1/4-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 6½inch long bolts.

See Chem-Nuclear Systems, Inc. Drawing No. 1-189-101, Revision AF for details on the foregoing.

1.2.1.2 Weights

Gross Cask Weight	38,800 lbs.
Cask Shell Weight	32,500 lbs.
Total Lid Weight	6,300 lbs.
Secondary Lid Weight	850 lbs.
Maximum Payload	17,700 lbs.

1.2.1.3 Containment

All steel components of the cask were constructed with ASTM A-36 steel.

A. All solidified radioactive wastes will be contained with 55 gallon drums or a 195 cubic foot steel liner and there is no potential for galvanic or chemical reactions between the package components and the package contents.

B. 55 gallon drums and 195 cubic foot liners are equipped with positive bolt-on or crimped-on type closures. The cask lid is positively closed as noted in 1.2.1.1. In addition, each cask is equipped with a seal feature which provide positive indication that the cask may have been tampered with.

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

1.2.2 Operational Features and Procedural Controls

As required by Section 71.51 of 10CFR71, Chem-Nuclear Systems, Inc. has established a quality assurance program which satisfies the applicable criteria specified in Appendix E, "Quality Assurance Criteria for Shipping Packages for Radioactive Materials." A description of this program was approved on October 25, 1979 by the Chief, Transportation Certification Branch, Division of Fuel Cycle and Material Safety, NMSS, 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 conditions 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 through the Q.A. personnel located at Barnwell, S.C., is responsible for auditing all critical cask handling, storage and shipping operations conducted by Barnwell Site Operations personnel.

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

Handling and Operating Procedures for the Model 14-195H Transport Cask have been prepared. These procedures are supplied to each user of the package to assist them in adhering to the requirements of Section 71.12 of 10CFR71.

1.2.3 Contents of Packaging

(1) Type and form of material

(i) Process solids, either dewatered, solid or solidified in secondary containers, meeting the requirements for low specific activity radioactive material, or

(ii) Solid reactor components in secondary containers, as required that meet the requirements for low specific activity radioactive material.

(2) Maximum quantity of material per package

Greater than Type A quantities of radioactive material with the weight of the contents, secondary containers and shoring not exceeding 17,700 pounds.

II

2.0 STRUCTURAL EVALUATION

2.1 Structural Design

STANDARDS: TYPE A PACKAGING

Type A packaging must be so designed and constructed that, if subjected to the following environmental and test conditions, no reduction in required package effectiveness would result.

ENVIRONMENTAL

HEAT
Direct sunlight at an ambient temperature of 130°F in still air.

COLD
An ambient temperature of -40°F in still air and shade.

REDUCED PRESSURE
Ambient atmospheric pressure of 0.5 atmospheres(ABSOLUTE, 7.3psia)

VIBRATION
Vibration normally incident to transportation.

TEST CONDITIONS

FREE DROP
A free drop through a distance of 1 foot onto a flat essentially unyielding horizontal surface, striking the surface in a position for which maximum damage is expected.

PENETRATION
Impact of the hemispherical end of a vertical steel cylinder 1¼ inches in diameter and weighing 15 pounds, dropped from a height of 40 inches onto the exposed surface of the package which is expected to be most vulnerable to puncture. The long axis of the cylinder shall be perpendicular to the package surface.

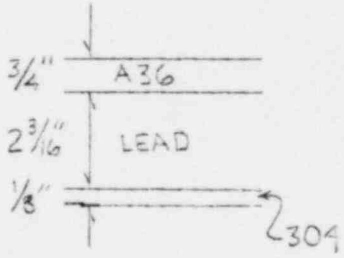
REF: 49CFR§173.398
page 289

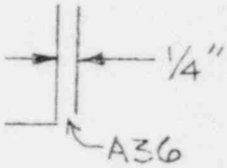
2.2 Weights

1-189-101 DRG.

WEIGHTS

LID





Item 8 : $\frac{\pi(36)^2\ (0.75)}{4}\ \frac{(490)}{1728} = \underline{216.5\ \text{LBS}}.$

Item 4 : $\frac{\pi(30)^2}{4}\ (2.1875)\ \frac{(710)}{1728} = \underline{635.3\ \text{LBS.}}$

Item 9 : $\frac{\pi(50.5)^2\ (0.125)}{4}\ \frac{(490)}{1728} = \underline{25.9\ \text{LBS.}}$

Item 10: $\frac{\pi(29.75)(0.25)(2.1875)(490)}{1728} = \underline{14.5\ \text{LBS.}}$

Item 2: $\left(\frac{\pi}{4}\right)(\overline{79.25}^2 - \overline{26}^2)(0.75)\ \frac{(490)}{1728} = \underline{946.1\ \text{LBS.}}$

Item 4: $\left(\frac{\pi}{4}\right)(\overline{76.875}^2 - \overline{26}^2)(2.1875)\ \frac{(710)}{1728} = \underline{3695\ \text{LBS.}}$

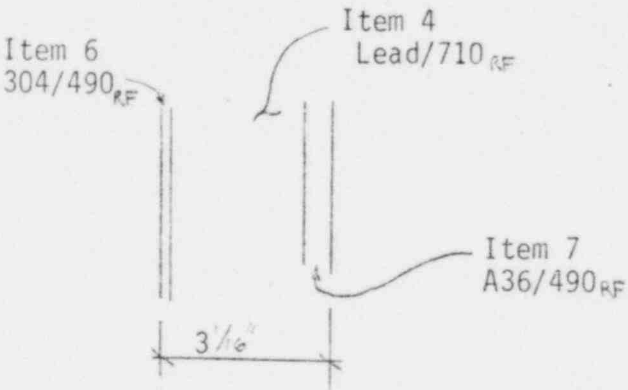
Item 5: $\frac{\pi}{4}(76.75^2 - 26^2)(0.125)\frac{(490)}{1728} = \underline{145.2\text{ LBS}}.$

Item 11: $\frac{\pi(26.125)(0.125)(2.1875)(490)}{1728} = \underline{6.4\text{ LBS}}.$

TOTAL = 5685 LBS

$\boxed{\text{SAY 5700 LBS}}$

WALL



Item 7: $\frac{(82.375)(0.75)(89.125)(490)}{1728} = \underline{4905\text{ LBS}}.$

Item 4: $\frac{(79.44)(2.1875)(85.5)(710)}{1728} = \underline{19178\text{ LBS}}.$

Item 6: $\frac{(77.125)(0.125)(84.8125)(490)}{1728} = \underline{728.4\text{ LBS}}.$

TOTAL = 24811 LBS.

$\boxed{\text{SAY 24,800 LBS.}}$

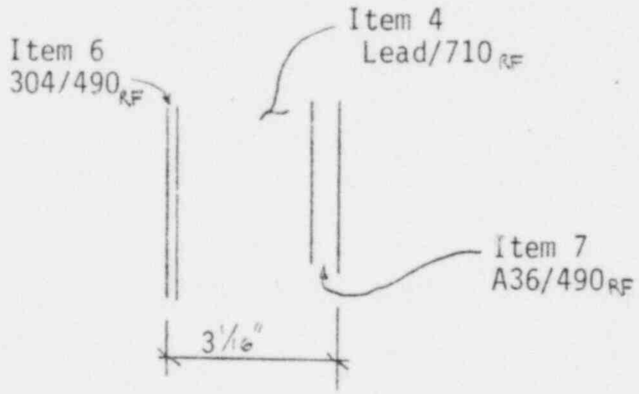
Item 5: $\frac{\pi}{4}(\overline{76.75}^2 - \overline{26}^2)(0.125)\frac{(490)}{1728}$ = 145.2 LBS.

Item 11: $\frac{\pi(26.125)(0.125)(2.1875)(490)}{1728}$ = 6.4 LBS.

TOTAL = 5685 LBS

SAY 5700 LBS

WALL



Item 7: $\frac{(82.375)(0.75)(89.125)(490)}{1728}$ = 4905 LBS.

Item 4: $\frac{(79.44)(2.1875)(85.5)(710)}{1728}$ = 19178 LBS.

Item 6: $\frac{(77.125)(0.125)(84.8125)(490)}{1728}$ = 728.4 LBS.

TOTAL = 24811 LBS.

SAY 24,800 LBS.

BOTTOM

ROUND: Item 13

$$\frac{\pi(85.625)^2}{4}(0.75)\frac{(490)}{1728} = \underline{1225\ \text{LBS}}$$

SQ: $$(96)^2(0.75)\frac{(490)}{1728} = \underline{1960\ \text{LBS}}$$

Item 4: $$\frac{\pi(77)^2}{4}(2.1875)\frac{(710)}{1728} = \underline{4185\ \text{LBS}}.$$

Item 24: $$\frac{\pi(77)^2}{4}(0.125)\frac{(490)}{1728} = \underline{165\ \text{LBS}}.$$

TOTAL = 6380 LBS.

$\boxed{\text{SAY 6500 LBS.}}$

EST. WT.

$$\begin{array}{r} 5700 \\ 24800 \\ 6500 \\ \hline 37000 \end{array} \text{ LBS.}$$

USE 39 kips

CONTENTS

VOL.= $$\frac{\pi(77)^2}{4}(80.125)\frac{(75)}{1728} = \underline{16{,}194\ \text{LBS.}}\ ,\ \underline{\text{SAY 16 k}}$$

2.3 Mechanical Properties of Materials

The mechanical properties of materials of metallic components used for analysis of the CNSI 14-195H Cask, are as follows:

Component	Material	Allowable
External Shell	A-36 Steel	Fty = 36 ksi
Internal Shell	A-304	Fty = 30 ksi
Trunnion	SAE 1018	Fty = 40 ksi
Bolts (1¼" D.)	SAE J 429, Gr.8	Fty = 130 ksi
		Ftu = 150 ksi
Bolts (3/4" D.)	SAE J 429, Gr.2	Ftu = 74 ksi

With Revision AF to Dwg. No. 1-189-101, 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%

STRUCTURAL ANALYSIS - FREE DROP

BOND STRENGTH

Reference: "How to join lead with adhesives", ADHESIVES AGE , September, 1968.

Figure 1 - Effect of different strength adhesives on various adherends; tensile strength of adherend vs. tensile shear strengths of adhesive in lap joints. (Xerox copy page 2-8).

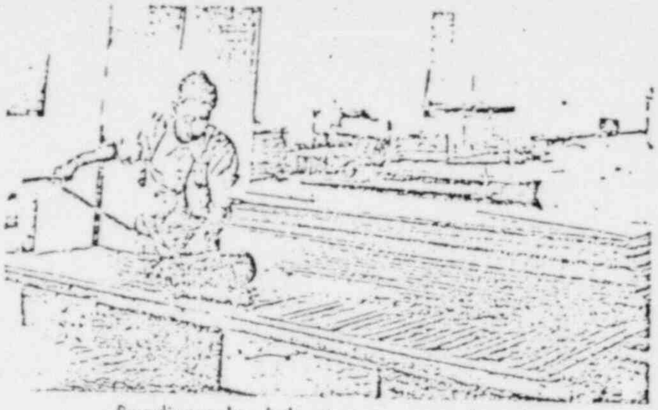
Figure 1 referenced above would definitely seem to indicate that for adhesives capable of developing 4000 psi or better lap shear with aluminum adherends, values of 1000 to 2000 psi are to be expected utilizing lead adherends.

3M data indicates 5000 psi obtained using 2024-T3 aluminum adherend and AF-126(008) structural adhesive.
(Xerox copies, pages 2-10 thru 2-12)

How to Join Lead with Adhesives

by H. E. Howe
American Smelting and Refining Co.
South Plainfield, N. J.

and Dr. S. F. Radtke
International Lead Zinc Research Organization, Inc.
New York, N. Y.



Bonding a lead sheet to a gypsum board

Up to now, the standard methods of joining lead have included mechanical fasteners, soldering, and lead burning (welding). These have passed the test of time and are still recommended for certain applications. Now, however, adhesive bonding provides a method of joining that can open many new application opportunities.

Adhesive bonding, of course, has been used for lead laminations and other applications for many years, but the research data set forth here indicates that much wider use is justified and recommended. Before attempting adhesive joining, however, it is advisable to bear in mind the available forms (i.e., sheets, casting, etc.), basic properties and characteristics of lead. These elements can have vital bearing on adhesive bonding and many references will be made to some of them, especially tensile strength and creep behavior (see Table 1).

The commercial shapes available lend themselves to adhesive bonding because joints are usually made with large area contact and thin cross sections. Beyond this, the case of handling and forming on-site or in the shop make adhesive bonding particularly suitable. Sheet lead, up to ⅛-inch thick, for example, can be bent by hand, and even antimonal or "hard" lead of this thickness is readily formed with simple tools.

Lead is available in many forms — sheet and foil, extrusions, castings, laminations, bonded sheath, powder, and alloys, among others. Sheets, which would probably be the form most commonly involved in adhesive bonding, are produced in standard widths up to 8 feet, with larger sizes available for special requirements.

Sheet lead is made in two ways: (1) by rolling and (2) by continuous castings. Rolling is the traditional method and is still standard by most weights of lead. These sheets start at about 1/32 or 3/64 inch or 2 pounds and 3 pounds per square foot, respectively.

Continuous castings with DM (Direct Manufacture) machine is being used to produce thin lead sheet, typically 1/16 inch or less. The DM continuous casting machine can produce sheets approaching ½ pounds per square foot.

The chart below shows the relation between weight and thickness of lead.

Pounds Per Sq. Ft.	App. Thickness in Inches	
	Decimal	Fraction
½	.0078	1/128
1	.0156	1/64
2	.0312	1/32
3	.0468	3/64
4	.0525	1/16
5	.0731	5/64
6	.0937	3/32
8	.1250	1/8
10	.1563	5/32
12	.1375	3/16

Further technical information on lead is available from many sources, including ILZRO and the lead development associations in various countries throughout the world, such as the Lead Industries Association in the United States, the Lead Development Association in England, and the Australian Lead Development Association.

Why Bond Lead Adhesively

Experience with lead as well as with other materials, combined with data compiled in research, indicate the following advantages in adhesive bonding of lead:

(1) Adhesives permit the joining of lead to itself and to other metals, ceramics, plastics, wood, or other substrates.

(2) Continuous bonds produced by the adhesive distribute loads uniformly, thereby eliminating stress concentrations which are inherent in mechanically fastened assemblies. Uniform load distribution also provides greater strength and rigidity. This factor often allows reduction in size or thickness of material and elimination of stiffening members, with consequent savings in over-all weight and cost. This factor is particularly significant for lead.

Although external loads are seldom if ever applied to lead, it must contend with its own weight. For example, a lead sheet 1/16-inch thick weighs about 4 pounds per square foot. If the sheet is hung vertically to a height of eight feet, a section four feet wide would weigh about 128 pounds. If a fastening method is used which concentrates this load on small cross-sectional area, the stress could result in frac-

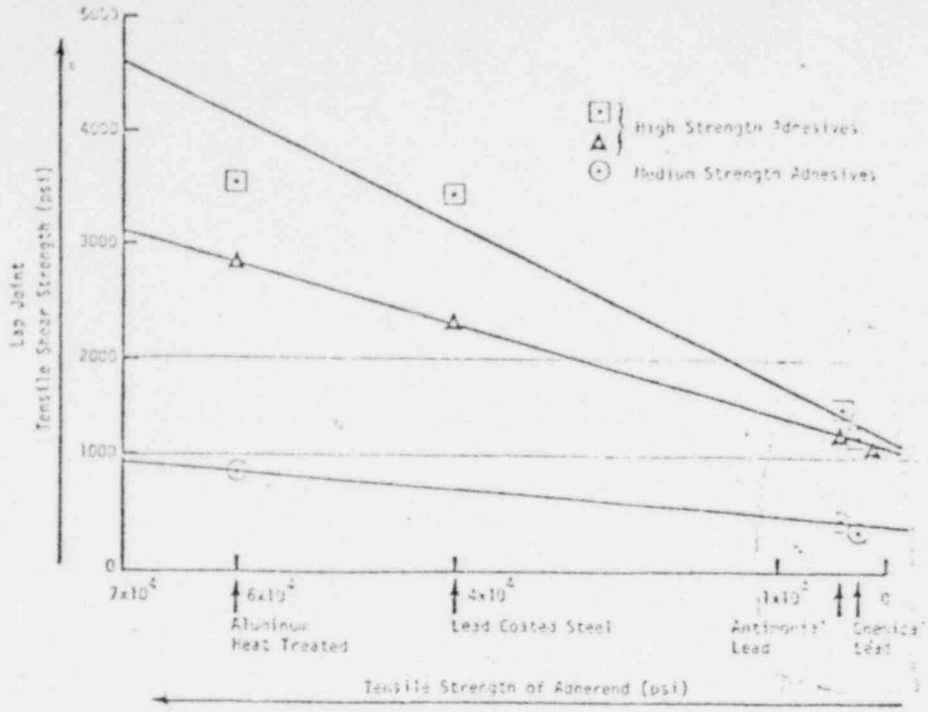


Figure 1 — Effect of different strength adhesives on various adherends; tensile strength of adherend vs. tensile shear strengths of adhesive in lap joints

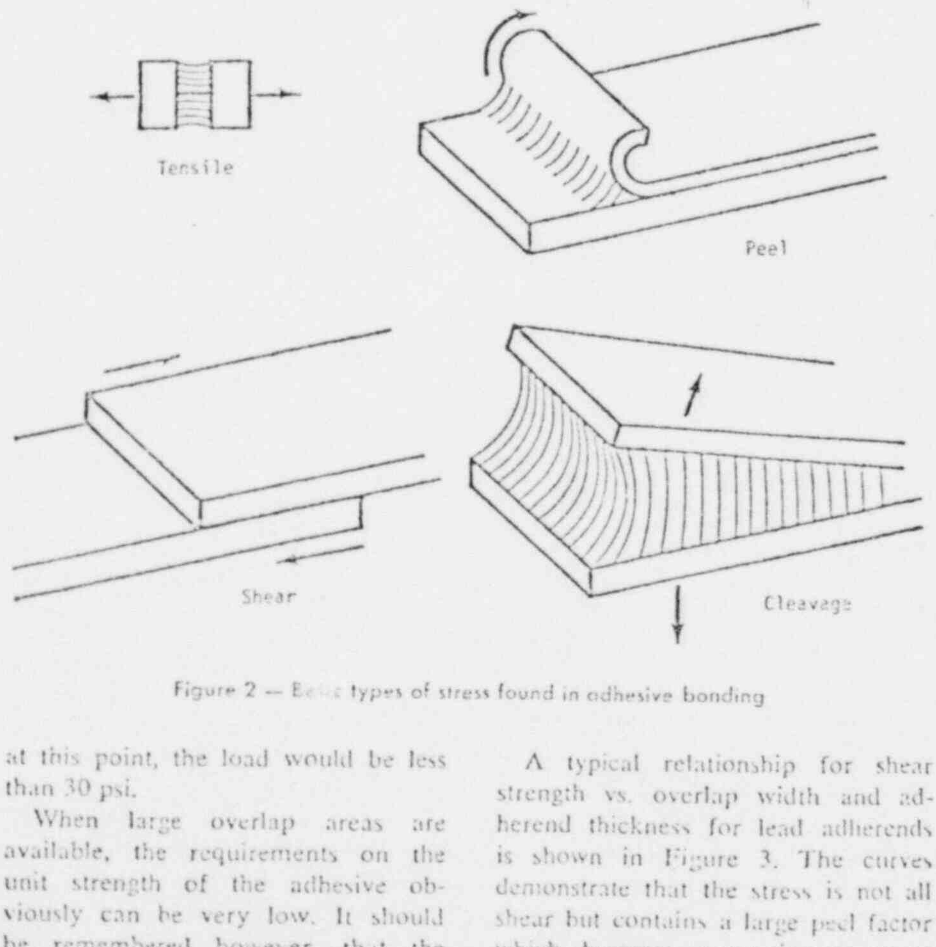


Figure 2 — Basic types of stress found in adhesive bonding

at this point, the load would be less than 30 psi.

When large overlap areas are available, the requirements on the unit strength of the adhesive obviously can be very low. It should be remembered however, that the lap shear strength is not proportional to the increase in lap width because of the uneven distribution of the stress across the lap.

A typical relationship for shear strength vs. overlap width and adherend thickness for lead adherends is shown in Figure 3. The curves demonstrate that the stress is not all shear but contains a large peel factor which becomes more important as overlap width increases.

As the overlap width increases, thickness of the lead adherend (unit load on the cross-section) limits the lap shear strength in two ways: (1) as adherends get thicker, peel stress is a smaller factor; (2) as adherends get thicker, the load on the bond increases before plastic yield occurs in the lead adherend. The strength of the lead adherend limits the load which can be applied before fracture of the adherend occurs.

When bonding bulk lead products where the ratio of allowable bonding area to volume of product is small, a butt joint must be used. The major stresses in butt joints are tensile. Since under these conditions less bonding area is often available, unit loading is greater than in lap joints, and adhesives of at least moderate strength will be required. Tensile strengths for both lap and butt joints are comparable when the same adhesive is used.

As with lap joints, tensile strength is limited by the low yield strength of lead. For example, bulk specimens of lead (0.1 in. by 1 in. by 8 in.) pulled in tensile test showed strengths of 1800 psi. These same lead specimens, cut in half, butted together at the midpoint and bonded together with an adhesive having a rated tensile strength greater than 2500 psi, showed a bond strength of 1600 psi. The lower bond strength was due to the fact that the bond load was approaching the tensile strength of the lead itself.

Available intermediate and high strength adhesive formulations can make adhesive bonds having tensile strength equal to or exceeding the strength of common grades of lead.

Peel and Cleavage

It is apparent that low unit loads will be experienced in many applications of lead. The types of stress experienced by these composites (lead on walls, roof, etc.) include peel and cleavage as well as shear and tensile stresses. Since peeling action localizes stresses on a very narrow area of the adhesive, particularly with soft adherends, this type of stress is the most critical for lead.

Obtaining comparative data on peel strength is difficult since this characteristic is highly sensitive to such influences as: (1) thickness of the adherends (see Figure 4); (2) strength of the adherends. Both may

KI-175 CASK
TYPE 'A'
CN81

ADVANCE
PRODUCT
SPECIFICATION

"Scotch-Weld" BRAND STRUCTURAL ADHESIVE FILM AF-126

INTRODUCTION

"Scotch-Weld" Structural Adhesive AF-126 is a thermosetting, non-volatile, modified epoxy film adhesive designed for structural bonding of metals. This unique product offers the following advantages:

- Cure at temperatures as low as 225°F. Optimum results obtained with a cure of 250°F. for 1 hour.
- Excellent strength in metal-to-metal and honeycomb sandwich applications over a temperature range of -67 to 250°F. Provides exceptionally high metal-to-metal overlap shear and peel values.
- Releases no volatile by-products during cure thereby permitting low pressure bonding.
- Low film weight version (0.03 lbs./sq. ft.) permits use of high (100 psi) pressure bonding without excessive adhesive flow in metal-to-metal applications.
- AF-126 .06 and .08 weights with EC 2320 primer is qualified to the requirements of MIL-A-25463 Type I Class 2 and MMM-A-132 Type I Class 2.
- AF-126 .03 weight with EC 2320 is qualified to the requirements of MMM-A-132 Type I Class 2.
- High degree of tack in the uncured state.

DESCRIPTION

	AF-126 (.03)	AF-126 (.06)	AF-126 (.08)
Form:		Supported film adhesive with protective liners	
Color:	Green	Green	Red
Nominal Weight: (lbs./sq. ft.)	0.030	0.060	0.080
Nominal Caliper: (Approx. inches)	0.005	0.010	0.015
Volatile Content:		Less than 1%	

TEST RESULTS

MMM-A-132 Type I Class 2 Test Data

Test Condition	MMM-A-132 Type I Class 2 & 3 Requirement Min. Avg.	AF-126/ EC 2320 .03 wt. (avg.)	AF-126/ EC 2320 .06 wt. (avg.)	AF-126/ EC 2320 .08 wt. (avg.)
A. TENSILE SHEAR				
1. Normal Temperature (75°F.)	2500 psi	4630 psi	5300 psi	5347 psi
2. 10 min. @ 180°F.	1250 psi	3850 psi	3260 psi	3207 psi
3. 10 min. @ -67°F.	2500 psi	4850 psi	5960 psi	5687 psi
4. Normal Temperature (75°F.) After 30 Days Salt Water Spray	2250 psi	4760 psi	5170 psi	5375 psi
5. Normal Temperature (75°F.) After 30 Days @ 120°F. and 95-100% Relative Humidity	2250 psi	4630 psi	4980 psi	5243 psi
6. Normal Temperature (75°F.) After 30 Days Immersion in Tap Water	2250 psi	5230 psi	5390 psi	5240 psi
7. Normal Temperature (75°F.) After 7 Days Immersion in JP-4 Fuel	2250 psi	4710 psi	5120 psi	5775 psi
8. Normal Temperature (75°F.) After 7 Days Immersion in Anti-icing Fluid	2250 psi	4860 psi	5020 psi	5552 psi
9. Normal Temperature (75°F.) After 7 Days Immersion in Hydraulic Oil	2250 psi	5000 psi	5280 psi	5626 psi
10. Normal Temperature (75°F.) After 7 Days Immersion in Type III Hydrocarbon Fluid	2250 psi	4820 psi	5070 psi	5800 psi
B. CREEP RUPTURE				
11. Normal Tepmerature (75°F.) 192 Hours @ 1600 psi	0.015 inches max. deformation	0.0000 in.	0.0000 in.	0.0000 in
12. 180°F. 192 Hours @ 800 psi	0.015 inches max. deformation	0.0026 in.	0.0023 in.	0.0006 in.
C. FATIGUE				
13. Normal Temperature (75°F.) 750 psi @ 10^6 Cycles	no glue line failure	no glue line failure	no glue line failure	no glue line failure

AF-126 .06 Wt. Unprimed Quick Cure Data

Time In Press Minutes	Platen Temperature	Cold Rolled Steel Solvent Wiped	75°F. Overl ;p Shear On Aluminum (FPL Etched)
60	250°F.	2690 psi	5000 psi
6	300°F.	3180 psi	4700 psi
2	350°F.	3367 psi	800 psi
0.5	400°F.	3120 psi	4000 psi

AF-126 .06 Wt. Overlap Shear Quick Cure Data on Steel

Cure Conditions				Test Temperature (°F.)		
Temp. °F.	Time Minutes	Press psi	Primer	-40	75	180
250	40	25	None	3257	2689	1663
250	40	25	EC 2320**	3257	2820	1890
300	15	25	None	3500	3080	2005
300	12	25	None	3850	3320	2580
300	9	25	None	3472	2953	1880
300	6	25	None	3650	3187	1960
350	8	25	None	4125	3340	1835
350	6	25	None	3840*	3219	1795
350	4	25	None	3550*	3173	2355
350	2	25	None	3750*	3367	2375
400	3	25	None	3800	3120	1590
400	2	25	None	3430	2973	1730
400	0.5	25	None	3430	3123	1600

Adherend: Cold Rolled Steel, 0.035", solvent cleaned
Cure: All cures based on hot press entry and removal

* Metal Failure
** Primer Dry — 24 hours at 75°F.

AF-126 .06 Wt./EC 2320 Overlap Shear on Chromic Acid Anodize After Environmental Aging

	Tested at 75°F.	
	Control	Immersed
Overlap Shear after 30 days in Salt Spray	5750 psi	*5320 psi
Overlap Shear after 30 days 100% Relative Humidity	6150 psi	*5430 psi

Cure Cycle: 1 hour @ 265°F., 50 psi, 4-5°F./minute rise

*Note: Values are an average of 4 immersed specimens. There was no evidence of undercutting or corrosion on any specimen.

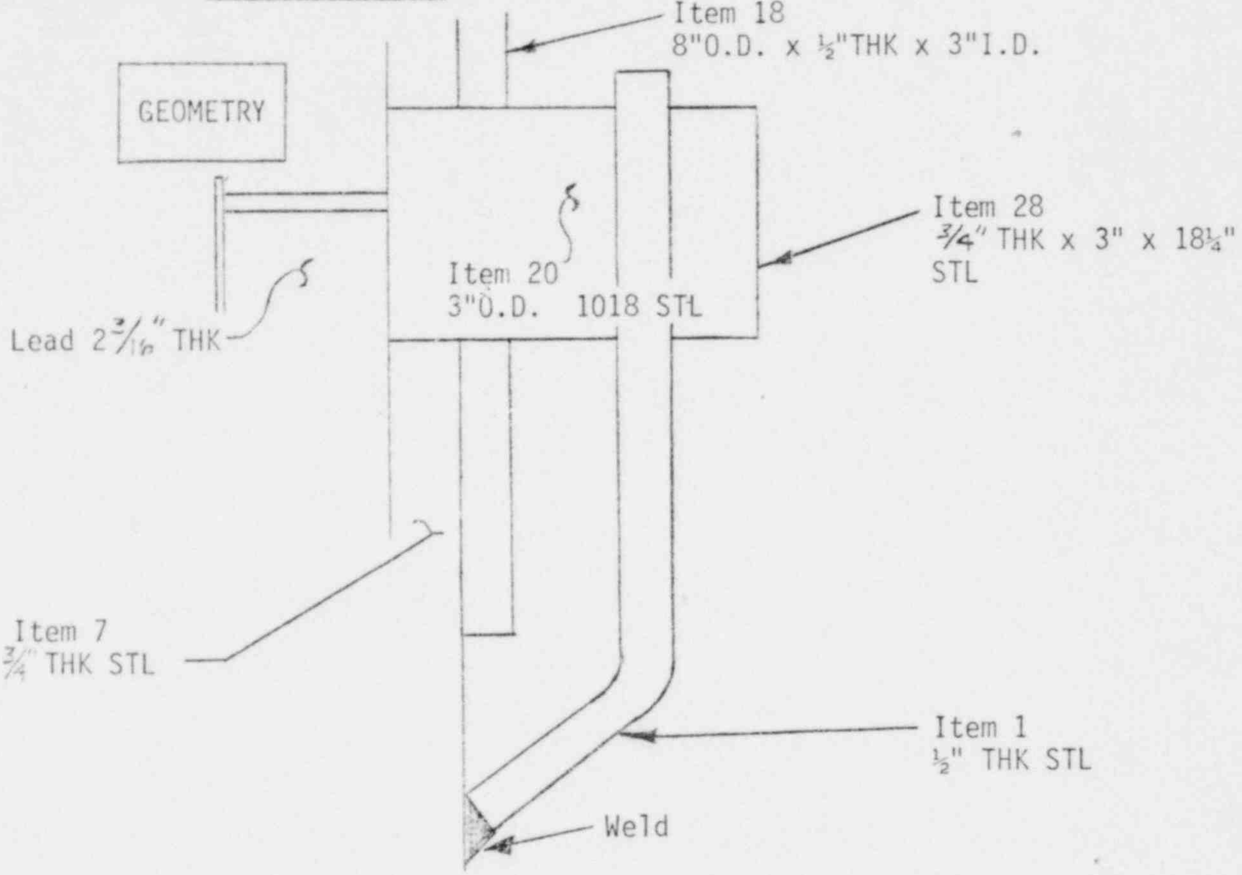
AF-126 Tensile, Modulus of Elasticity and Elongation

	Tested @ 75°F.
Tensile	6052 psi
Modulus of Elasticity	101900 psi
Elongation	23.7%

2.4 General Standards for All Packages

2.4.1 Lifting Devices

GEOMETRY



REFERENCE: DRAWING NUMBER 1-189-101 (Rev. A-F)

LOADS

Crosby & Laughlin 300A eye hooks @ a rated capacity of 22 tons.

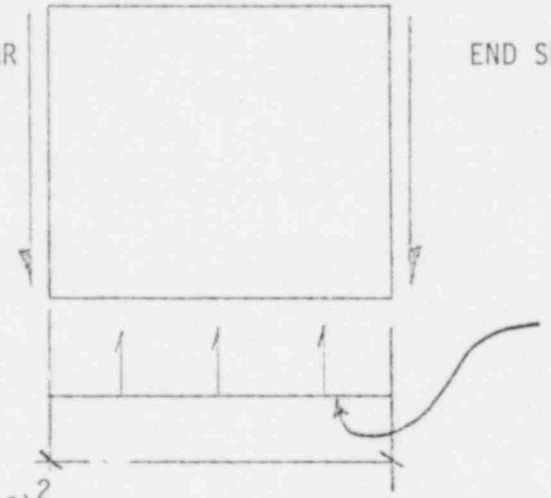
∴ Check design for $\frac{3W}{2}$ ▷ each location.
▷ 10CFR71 requirements for lifting devices.

W=55,000 LBS (WT. + CONTENTS)

LOAD TO EA. $= \frac{3W}{2} = \frac{3(55\text{ k})}{2} = \underline{82.5\text{ k}}$

ANALYSIS

Item 20



$W = \frac{82.5\text{ k}}{3} = \underline{27.5\text{ k/in}}$

Area$= \frac{\pi(3)^2}{4} = \underline{7.07\text{ in.}^2}$

BRG SHEAR $= \frac{5}{8}(27.5)(5) = \underline{51.6\text{ k}}$

F SHEAR $= \frac{51.6}{A} = 7.3\text{ ksi} < 23.1 \quad \therefore$ ok

1018 STL BAR:
Hot rolled properties Ys= 40 ksi (tension)
Shear Yield $= \frac{Ys}{\sqrt{3}} = \underline{23.1\text{ ksi}}$

$$\text{Bend.M} = \frac{WL^2}{8} = \frac{27.5(3)^2}{8} = \underline{31 \text{ in-kips}}$$

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

$$\text{F Bend} = \frac{M}{S} = \frac{51}{2.65} = 11.7 \text{ ksi} < 40 \quad \therefore \text{ ok}$$

Bearing Eye Hook on 3" DIA BAR

ROARK & YOUNG - 5th ED.
Table 33
Case 26

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

$$\text{Stress} = 0.59\sqrt{\frac{27.5(29)(10^3)}{6}} = \underline{215 \text{ ksi}}$$

Slight deformation of hook/bar lowers this value greatly.
→ Not failure mode.

Bearing on cask ⅊'s and weld strength.

<u>Items 7 & 18</u>

(5/8)WL= <u>51.6 kips</u>

$\frac{0.75}{0.75+0.5} = 0.60$ ∴ 60% to Item 7
40% to Item 18

Item 18

Item 7

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

$(F\ BRG)_{18} = \frac{0.4(51.6)}{3(0.5)}$ = same as above

BRG allow A36 = 0.9 Ys = 32.4 ksi > 15.76 ksi ∴ ok

<u>Weld strengths</u>

Item 7 —

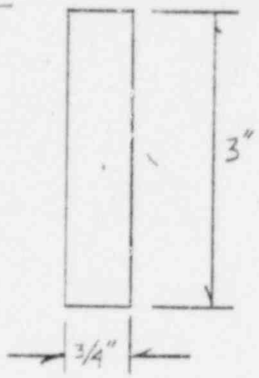
Item 18 — o.923(6)(π)(8) = <u>140 k</u> obviously ok

Item 1

SHEARS $\frac{3}{8}$ WL to Item 28 only

WELD $0.928(8)(\pi)(3) = 70$ k obviously ok

Item 28



$\frac{3}{8}$ WL = $\frac{3}{8}$ (82.5)= 31 k

Complete fixity at ends:

$$M = \frac{PL}{8} = \frac{31(15)}{8}$$

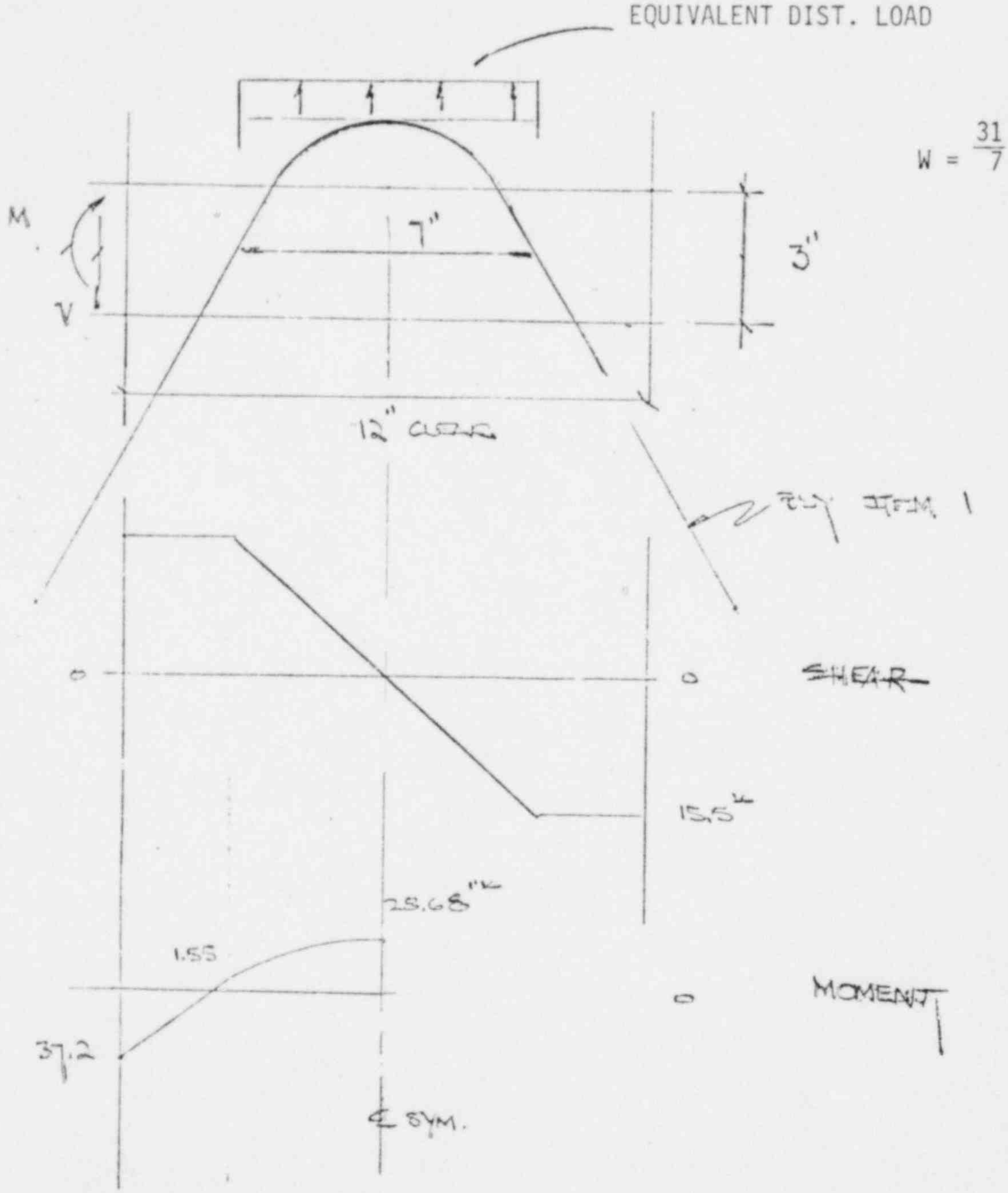
$$= 58 \text{ in-kips}$$

F BEND = $\frac{58(6)}{0.75(3)^2}$ = 52 ksi Too Large !

RECK. Using clear span:

$$\frac{PL}{8} = \frac{31(12)}{8} = 46.5 \text{ in-kips}$$

F BEND = $\frac{46.5(6)}{0.75(3)^2}$ = 41.3 ksi still > Ys.



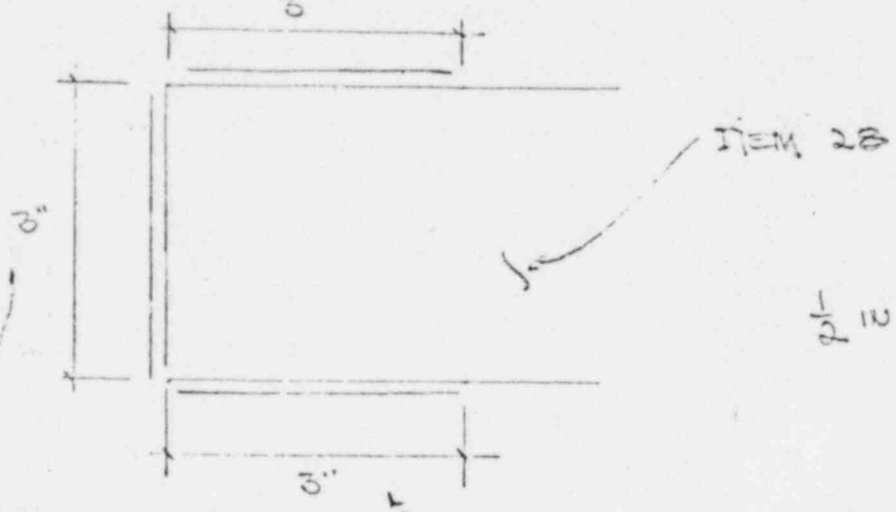
$W = \frac{31}{7} = 4.43\text{k/in.}$

SAY $M = \frac{PL}{10} = \frac{31(12)}{10} = \underline{37.2}$ IN.-KIPS

BENDING $= \frac{37.2(6)}{0.75(3)^2} = 33$ KSI $<$ YS $= 36$ KSI $\therefore$ OK

WELDS AT ENDS $\frac{37.2}{3} = \underline{12.4}^{\text{KIPS}}$

$0.928(8)(3) = 22.3^K$ CAPACITY $> 12.4^K$ ∴ OK



$\frac{1}{2}$ IN. WELD (9 LIN. INCHES)

MOMENT 12.4^K TOP/BOT.

SHEAR $15.5^K < 22.3^K$ ∴ OK

CASK BENDING

ROARK & YOUNG - 5TH ED

TABLE 30
CASE 3

$$\lambda = \left[\frac{3(1-\nu^2)}{R^2 t^2}\right]^{1/4} = \sqrt[4]{\frac{3(1-0.09)}{(41.5)^2(2.1)^2}} = \underline{0.14}$$

t COMPOSITE EQUIV. THK

$\lambda l_1 = 0.14(90) = 12.4$

$$\sigma_2 = \frac{2M_0\lambda^2 R}{t} = \frac{2(M_0)(0.14)^2(41.5)}{2.1}$$

$$= \underline{0.77\ M_0}$$

$M_0 = 31.0\ (0.77) = 24.$ KSI UPPER BND. ∴ OK

RESULTS

Except for local bearing yielding at lifting hook location on Item 20, this system of lifting devices is capable of supporting three times the weight of the loaded package without any generated material stresses in the package greater than the applicable yield value.

2.4.2 Tiedown Devices

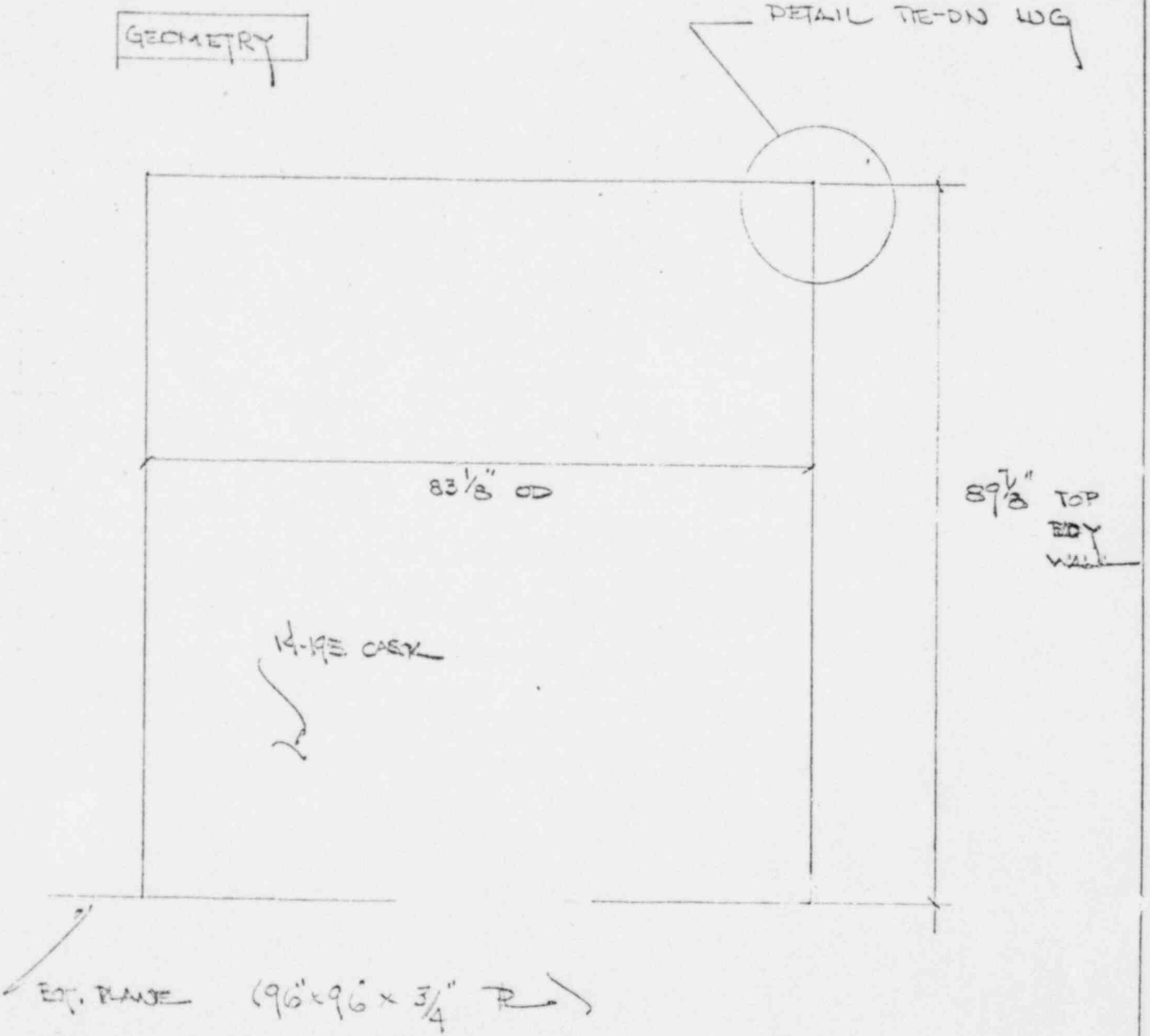
System must be able to withstand a static force applied at the center of gravity of the package with a vertical component equal to two times the weight of package and contents, a horizontal comp. along direction of travel equal to ten times total loaded wt. and a horizontal component transverse to the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

Design

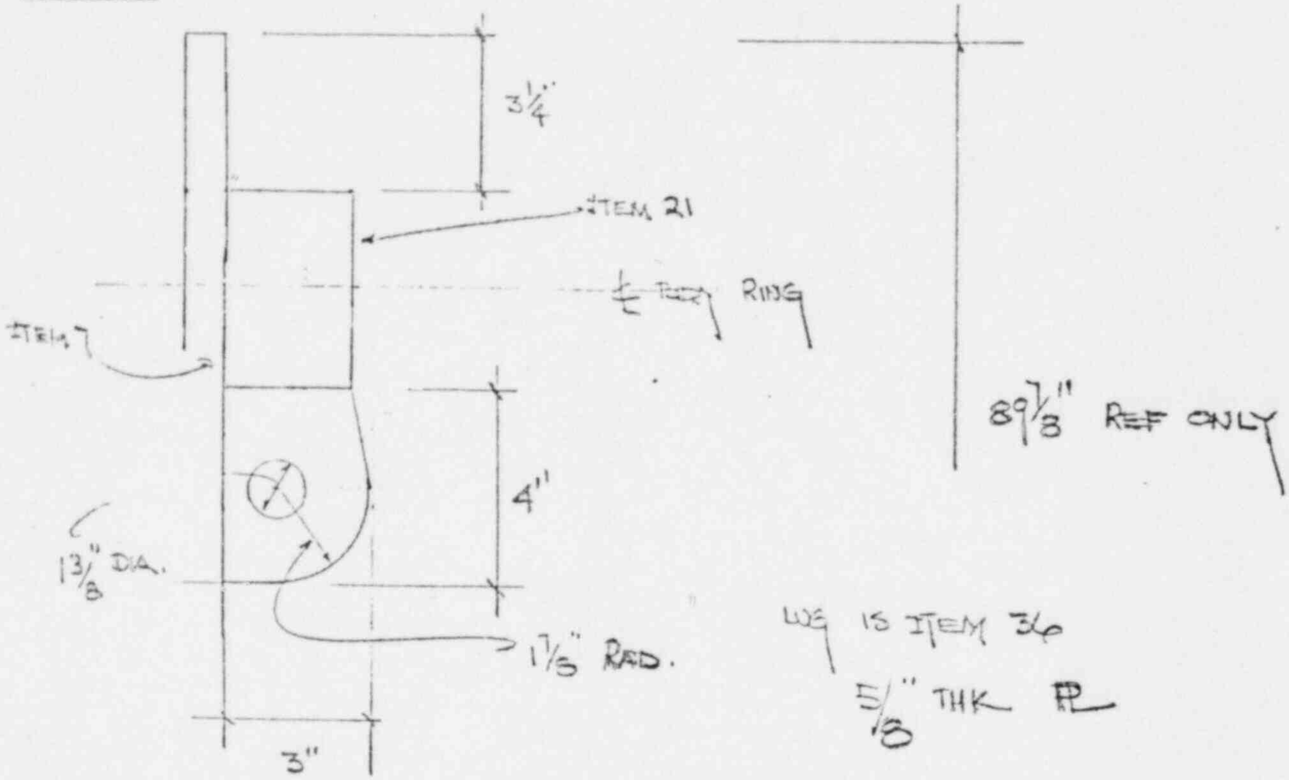
The tie-down system that evolved satisfying the above was a thickened base plate bolted to trailer floor, with a discarding of upper attach cables for anything except normal transport dynamic loads.

TRANSPORT TIE-DOWN

GEOMETRY



DETAIL



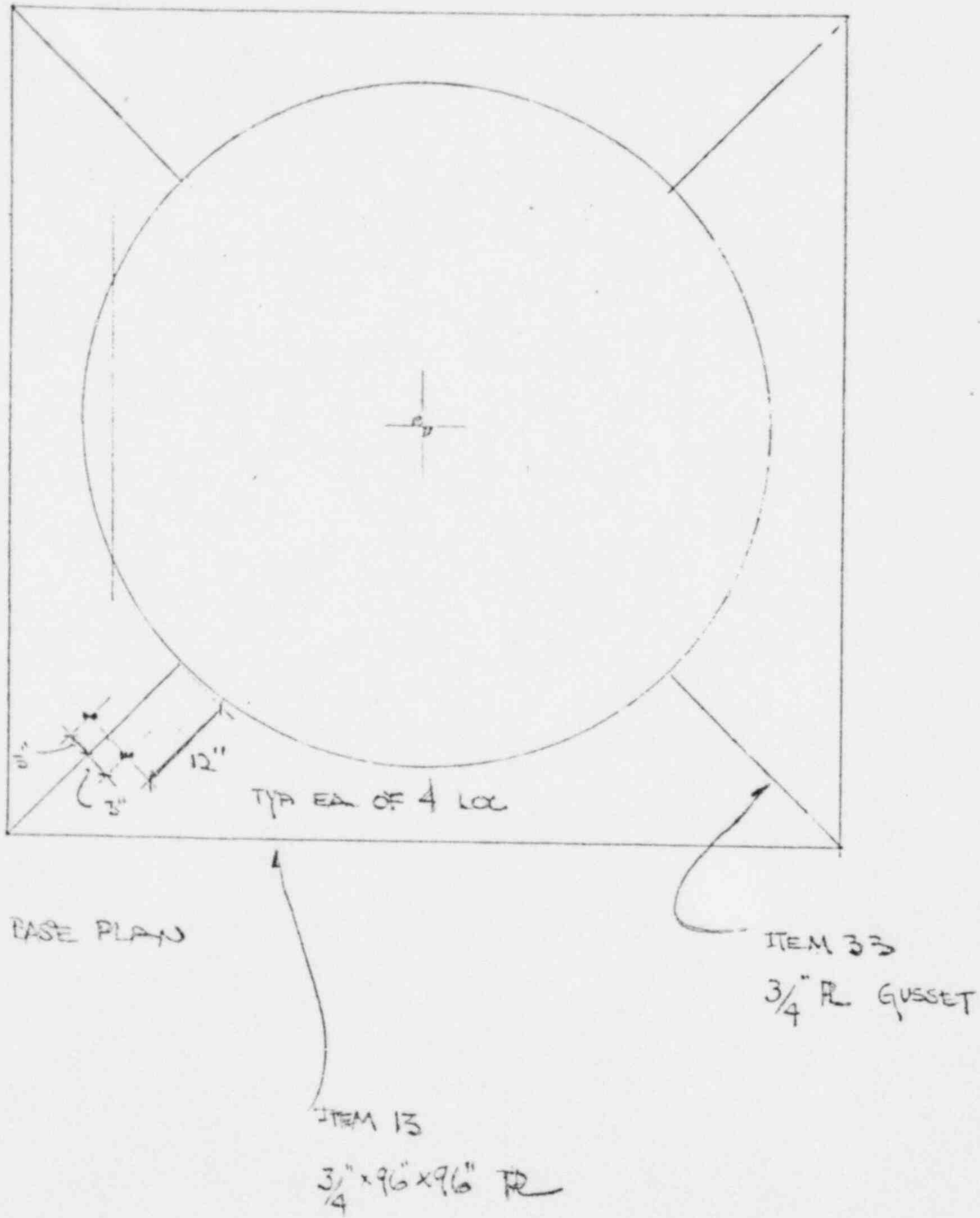
LUG IS ITEM 36
⅝" THK PL

LOADS

10G FORWARD
5G SIDE
2G VERTICAL (UP)

WT. = 55,000 LBS

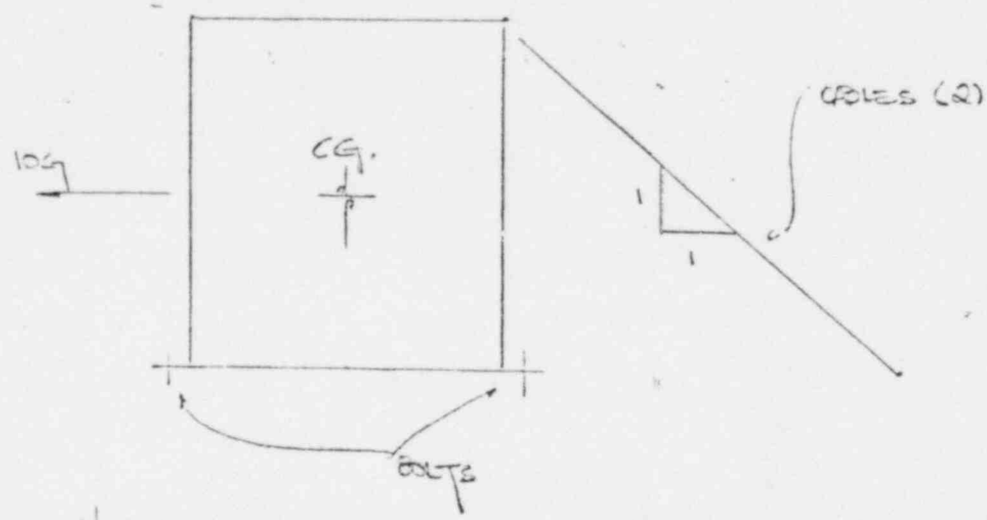
DISTRIBUTION

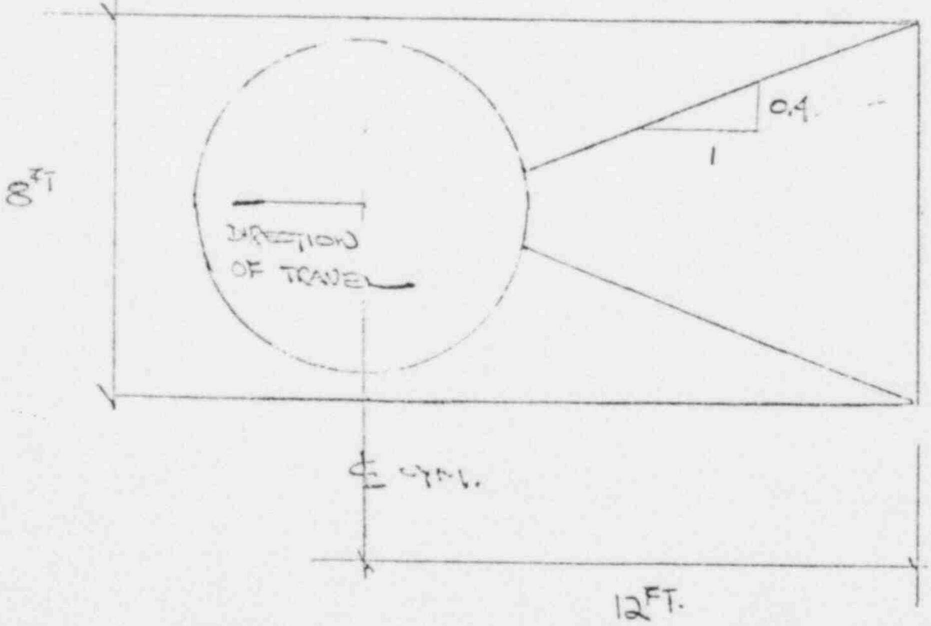


R.ET. $\left[(26)^2(13) - \frac{(23)^2}{2}\left(\frac{23}{3} + 3\right) \right] \frac{1}{(26)^2 - \frac{(23)^2}{2}} = \underline{\underline{14.5\,\text{IN}}}$

ANALYSIS

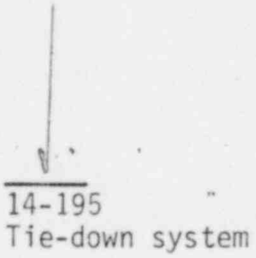
10G FORWARD





CABLE RESULTANT $\propto \sqrt{(1)^2+(1)^2+(0.4)^2} = \underline{1.47}$

Assume base fixity/stiffness compared to cable such that O/T resisted by base bolts half-way between cantilever and propped cantilever beam.



$$(\text{Basemoment})_{\text{cant.}} = \frac{W(10)(86)}{2} = \underline{25{,}650 \text{ in-kips}}$$

$$(\text{Base moment})_{\text{p-cant.}} = \frac{W(10)(86)}{8} = \underline{5912.5 \text{ in-kips}}$$

Say base moment = $\underline{15{,}000}$ in-kips

Req'd. cable tension:

$$\Sigma M_{\substack{\text{¢RT}\\ \text{EDGE}}} = 0 \qquad \circlearrowleft^{+}$$

$$55(10)(45)-55(1)(41.5)+R(41.5)-2V(83)-\left[\frac{2T}{1.47}\right](83+86)=0$$

Cables may be realigned radially if base mts. good for 15,000 in-kips.

$\frac{15,000}{83} = 181$ kips   Total: 4 bolts

Each bolt = $\frac{181}{4} = \underline{45 \text{ kips}}$ Try 1¼" DIA. A325

Base shear= $55(10) - \frac{2(27.7)}{1.47} = \underline{512 \text{ k}}$

Each bolt = $\frac{512}{8} = \underline{64 \text{ k each}}$

Combined Ld.

$F_t = 50 - 1.6 f_v \leq 40.0$

$\searrow 22$

A325 Bolt Values:

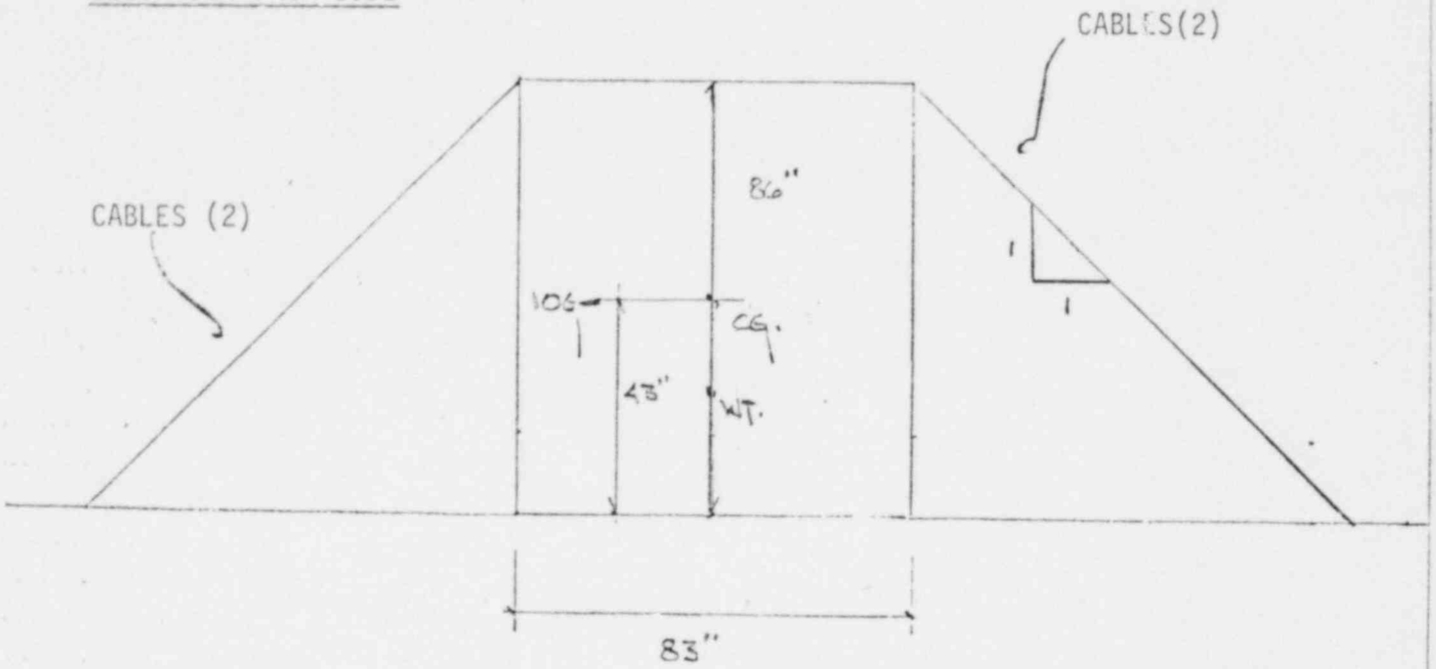
Wt tension = 105 ksi

Ys(tension)= 81 ksi

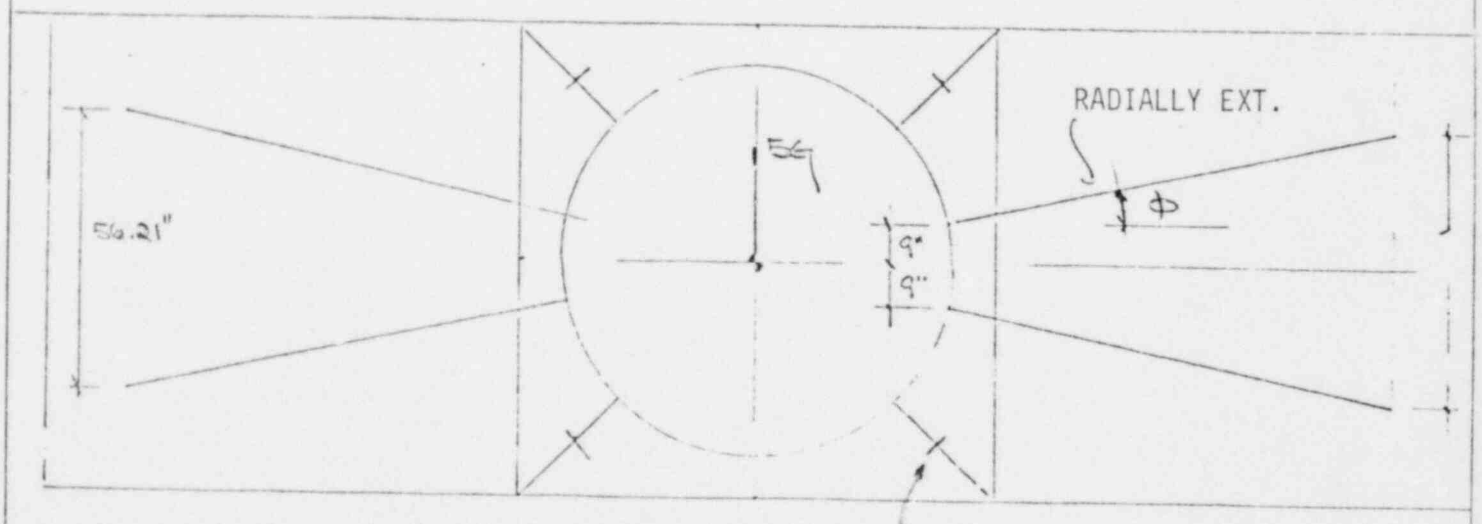
Shear Yield= 47 ksi

BRG = 1.35(81)= 109 ksi   (on bolt)

ELEVATION FROM SIDE



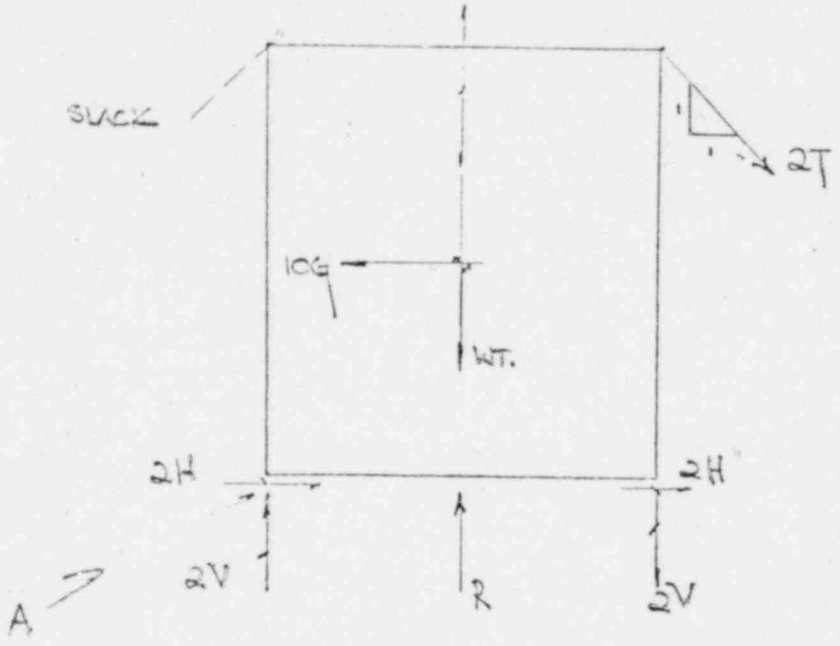
PLAN FROM ABOVE



$$\phi = \sin^{-1}\frac{9}{41.5} = \underline{12.53^\circ}$$

10G FORWARD - REV. 1

FREE-BODY DIAGRAM



$R_{CABLE} \propto \sqrt{(1)^2+(1)^2+(0.22)^2}$

$= \underline{1.43}$

FORCE - KIPS
LENGTH - INCHES

ASSUME :

$$2V(83) = 15{,}000 - \frac{1}{1.43}(2T)(41.5)$$

$$V = \frac{15000 - 55.04T}{166} = \boxed{90.36 - 0.35T} \quad \text{No!}$$

$\Sigma M_A = 0 \quad \circlearrowleft +$

$$10W(43) - \frac{2T}{1.43}(41.5 + 86) - 2V(83) = 0$$

COMBINING :

$$10(55)(43) - 2T(89.16) - 15000 + 55.04T = 0$$

$$8650 = 120.28T \qquad \therefore T_{CABLE\ TENSION} = \underline{71.92^{KIPS}}$$

10G CALC. - REV. 2

$$2V'(83) = 15,000 \text{ IN.-KIPS}$$

$$V'_{\text{BEND O/T EA. LOC}} = \frac{15,000}{166} = \underline{90.36^{K}}$$ EA. LOC. 2 BOLTS

$$\Sigma M_A = 0 \circlearrowleft +$$

$$10W(43) - \frac{2T}{1.43}(86) - 15,000 = 0$$

$$T_{\text{CABLE TENSION}} = \underline{71.92^{KIPS}}$$ USE $\underline{72^{KIPS}}$ CABLE TENSION

→ SAY 1"ϕ WIRE ROPE.

LUG - ITEM 36

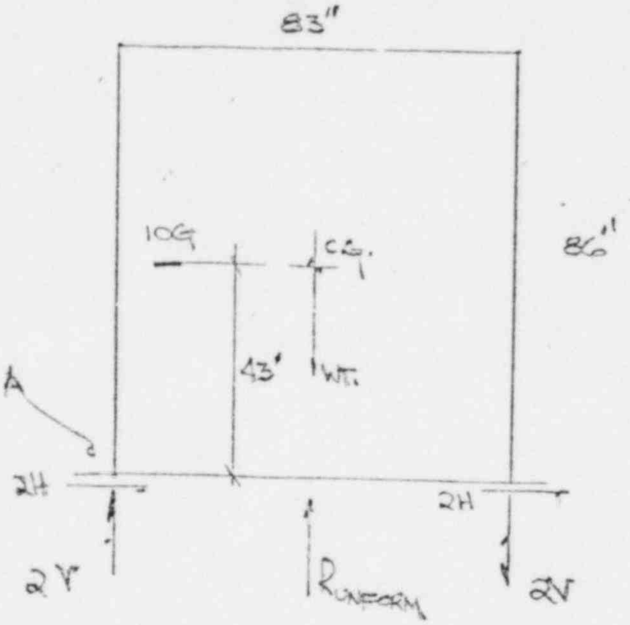
$$f_{\text{BEND}} = \frac{4.3(8P)}{\pi^2 R t} = 36^{K}$$

$$P_{\text{ALLOW}} = \frac{36(\pi^2)(1.875)(0.625)}{4.3(8)} = \underline{12.1^{K}}$$ CABLE TENS

NOTE:

Try for base modification to accept full amt. of O/T moment.

10G COMPUTATIONS - BASE TAKING ALL O/T



$\Sigma M_A = 0 \quad \circlearrowright +$

$$10(55)(43) - 2V(83) = 0$$

$$V = \frac{550(43)}{2(83)} = \underline{142.5^{KIPS}}$$

$\Sigma F_H = 0$

$$4H - 550 = 0 \qquad \therefore \; H = \frac{550}{4} = \underline{137.5^{KIPS}}$$

RESULTS

BOLTS

Axial tension = $\frac{142.5\ k}{n}$

Base shear = $\frac{137.5\ k}{n}$

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

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 = $\frac{142.5}{4}$ = 35.63 k say $\underline{36\ k}$ T

Shear/Bolt = $\frac{137.5}{4}$ = 34.38 k say $\underline{35\ k}$ S

CK Combined Ld:

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

Using Ys values $\longrightarrow$ 47 ksi ALLOW
$F_t = 100 - 1.6 f_v \leq 81$

AXIAL STRESS $= \frac{36}{1.227} = \underline{29.3^{ksi}}$

$f_v = \frac{35}{1.227} = \underline{28.5 \text{ ksi}}$

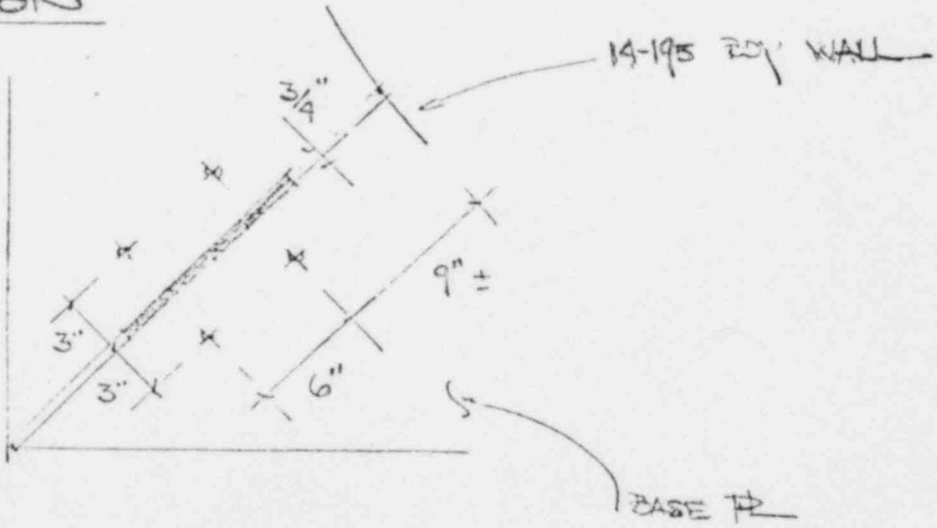
SUBSTITUTING

$F_t = 100 - 1.6(28.5) = 54.4 \text{ ksi} > 29.3^{ksi} \therefore OK$

BRG ON A36 PL

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

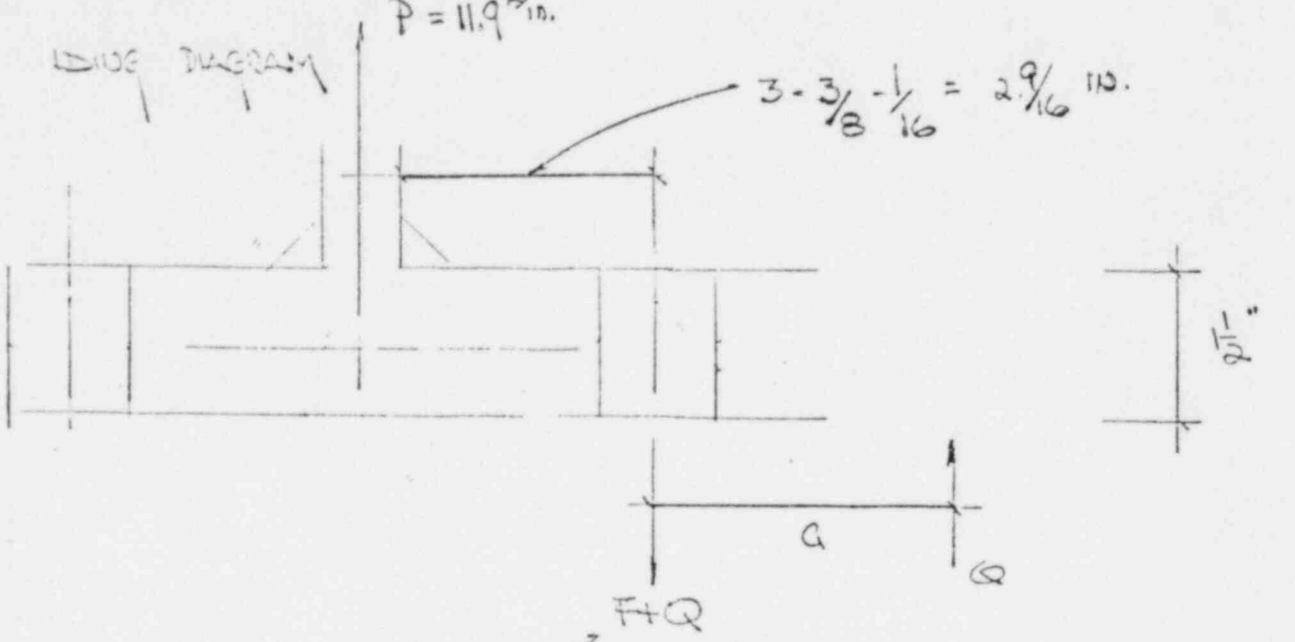
PRYING ACTION



CONSIDER 12 IN. EFFECTIVE GUSSET

$LD/10 = \frac{142.5}{12} = \underline{11.9^{k/in}}$

TRY BASE PL t INCREASED TO 1.5 IN THK.



$$F = \frac{P(6)}{2} = 35.7^{k} \quad \text{SAY } \underline{36^{k}}.$$

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

SAY $a \doteq 3$ in. EFFECTIVE

$$Q = 35.7\left[\frac{400 - 243}{328 + 283.5}\right] = \underline{9.2^{\text{KIPS}}}$$

0.26

$M_2 = 9.2(3) = 27.6$ IN.-KIPS

$M_1 = 45.2(2.56) - 9.2(5.56) = \underline{64.6}$ IN.-KIP (GOVERNS)

$$f_{BEND} = \frac{64.6(6)}{6(1.5)^2} = \underline{28.7} \text{ KSI} < 36 \text{ KSI} \quad \therefore \text{OK}$$

2.5 Standards for Type B Packaging

NOT APPLICABLE

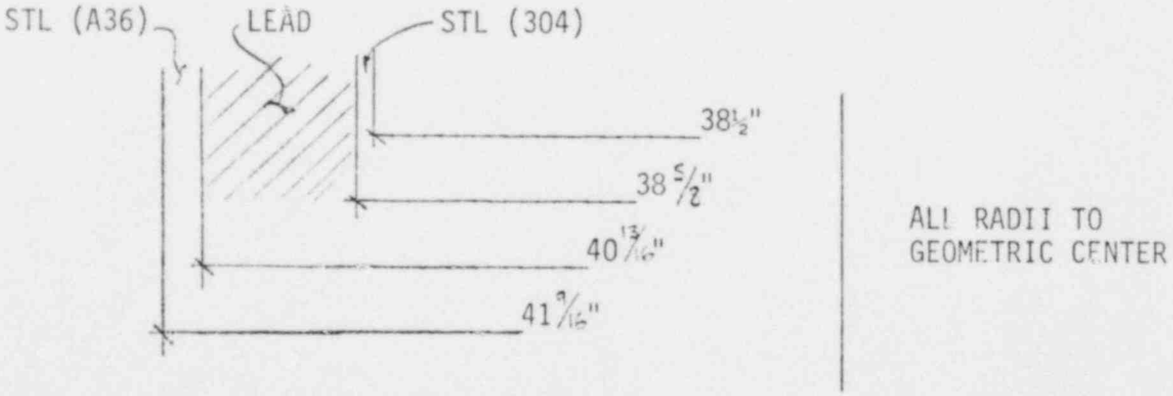
2.6 Normal Conditions of Transport

2.6.1 HEAT

130°F still air (direct sun) in lieu of explicit thermal analysis assume a diff. temp. equal to 160°F which corresponds to a material temp. of 100°F greater than the air.

$$\Delta T = T_f - T_o = (130 + 100) - \underset{\text{Steady state}}{70} = \underline{160^\circ F}$$

GEOMETRY



ANALYSIS

α Values:

STL A36 $11.7(10^{-6})/^{\circ}C$ $E=29(10^{6})psi$

LEAD $29(10^{-6})/^{\circ}C$ $E=2(10^{6})psi$

STL 304 $10.4(10^{-6})/^{\circ}C$ $E=28(10^{6})psi$

Conversion:

$$\boxed{^{\circ}C=5/9\ (^{\circ}F-32)}$$

$$^{\circ}F=9/5\ ^{\circ}C+32$$

Divide values by

$$9/5=\underline{1.8}$$

To obtain /°F values.

$$\alpha\ \text{STL A36}=\frac{11.7(10^{-6})}{1.8}=6.5(10^{-6})/^{\circ}F$$

$$\alpha\ \text{LEAD}=\frac{29(10^{-6})}{1.8}=16.1(10^{-6})/^{\circ}F$$

$$\alpha\ \text{STL 304}=\frac{10.4(10^{-6})}{1.8}=5.78(10^{-6})/^{\circ}F$$

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

Int-face	1	2	3	4	5	6
304					0.0357	0.0356
Lead			0.1051	0.0995		
A36	0.0432	0.0424				

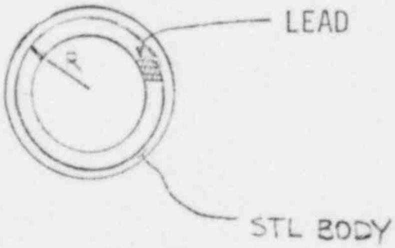
Above values unrestrained.

→ Underlined values significant W.R.T. stresses (Int.)

Lead wants to load STL body wall radially;

STL wants to confine lead expansion.

EQUILIBRIUM



a=outer radius
b=inner radius

INT. PRESSURE FORMULAE:

(LEAD ACTING ON STL)

$$f_{HOOP} = \frac{qb_2^2(a_2^2 + r_2^2)}{r^2(a^2 - b^2)}$$

$$f_{RADIAL} = \frac{-qb_2^2(a_2^2 - r_2^2)}{r^2(a^2 - b^2)}$$

EXT. PRESSURE FORMULAE:

(STL RESTRAINING LEAD)

$$f = \frac{-qa^2(b^2 + r^2)}{r^2(a^2 - b^2)}$$

$$f_{\text{RADIAL}} = \frac{-qa^2(r^2 - b^2)}{r^2(a^2 - b^2)}$$

COMPATIBILITY

$$\Delta \text{LEAD}_{\text{EXT}(3)} = \Delta \text{STL}_{\text{INT}(2)}$$

DEFORMATION RELATIONS

$$(\Delta b)_{\text{STL}} = \frac{qb}{E}\left(\frac{a^2 + b^2}{a^2 - b^2} + \gamma\right) + 0.0424$$

$$(\Delta a)_{\text{LEAD}} = \frac{-qa}{E}\left(\frac{a^2 + b^2}{a^2 - b^2} - \gamma\right) + 0.1051$$

Solution by equating and solving for q
(Bearing measure between STL and lead).

$$\frac{b}{E}\left(\frac{a^2 + b^2}{a^2 - b^2} + \gamma\right) = \frac{40.8}{29(10^6)}\left[\frac{(41.5625)^2 + (40.8125)^2}{a^2 - b^2} + 0.3\right]$$

$$= \frac{40.8125}{29(10^6)}\left[\frac{3393}{61.8} + 0.3\right] = \underline{0.00008}$$

$$\frac{a}{E}\left(\frac{a^2 + b^2}{a^2 - b^2} - \gamma\right) = \frac{40.8125}{2(10^6)}\left[\frac{(40.8125)^2 \pm (38.625)^2}{a^2 - b^2} - 0.45\right]$$

$$= \frac{40.8125}{2(10^6)}\left[\frac{3157}{174} - 0.45\right] = \underline{0.00036}$$

EQ'S.

$0.00008\,q + 0.0424 = -0.00036\,q + 0.1051$

$\longrightarrow q = \underline{143 \text{ psi}}$ (BRG pressure bet. STL and lead)

CK.

$(\triangle b)_{STL} = 0.00008(143) = 0.0112$ in (Load only)

$(\triangle a)_{LEAD} = -0.00036(143) = -0.0515$ in (Load only)

Combine with $\triangle T$ effect:

$$\begin{array}{lll} 0.0424 & 0.1051 & \\ \underline{0.0112} & \underline{-0.0515} & \\ 0.0536 \text{ STL} & 0.0536 \text{ LEAD} & \therefore \text{ok} \end{array}$$

RESULTS

$$(f_{\text{HOOP}})_{\text{STL}} = \frac{q a^2 + b^2}{a^2 - b^2} = \frac{143(3393)}{62} = \underline{7854\text{ psi}} \angle \text{ Yield} \therefore \text{ok}$$

$$(f_{\text{HOOP}})_{\text{LEAD}} = \frac{-q 2a^2}{a^2 - b^2} = \frac{-143(2)(40.8125)^2}{(40.8125)^2 - (38.625)^2} = \underline{2741\text{ psi}}$$

REFERENCE:

ROARK & YOUNG - 5th ED.

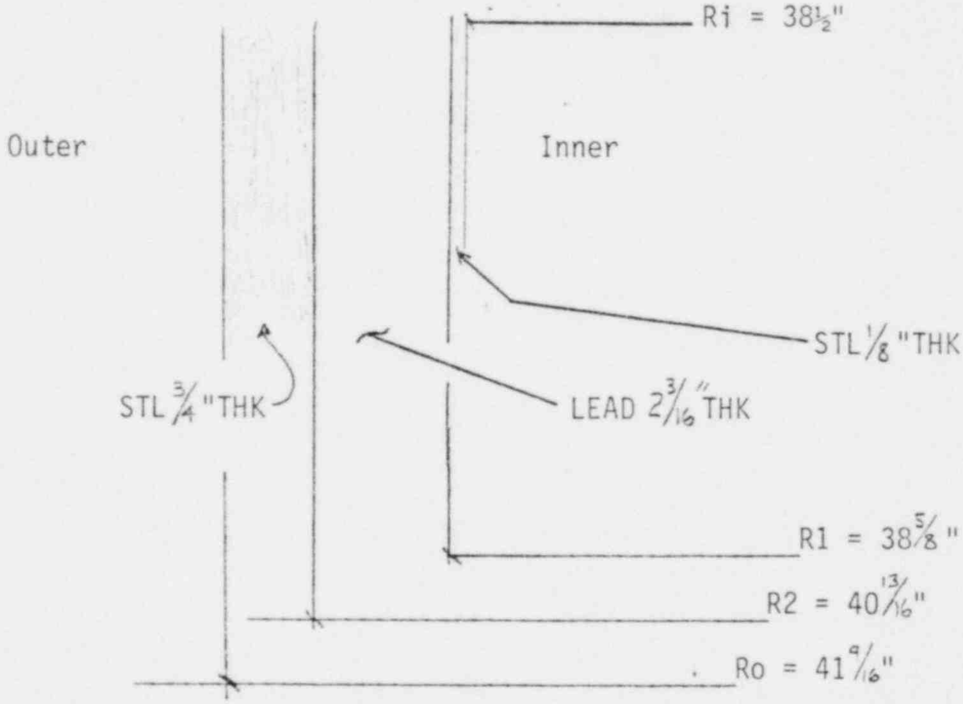
Table 32

Cases 1a & 1c

2.6.2 Cold Temperature

-40°F still air and shade Type 'A' ∴ assume $\Delta T = -100°F$.

GEOMETRY



LOADS

$\alpha\, STL_{3/4''} = 6.5(10^{-6})\ /°F$

$\alpha\, LEAD = 16.1(10^{-6})/°F$

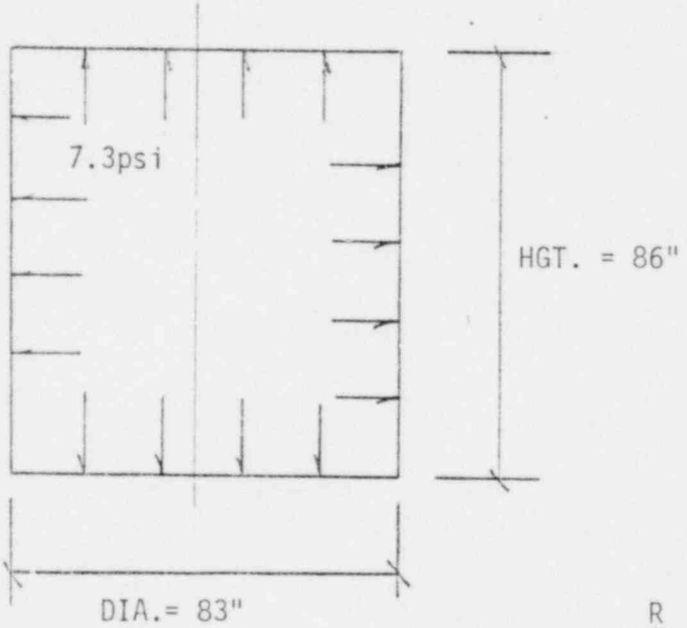
$\alpha\, STL_{1/8''} = 5.78(10^{-6})/°F$

⟶ LEAD WILL COMPRESS STL INNER SHELL.

2.6.3 Pressure

Reduced pressure: ambient at pressure of 0.5 atm.

GEOMETRY



$$\frac{R}{t} = \frac{41.5}{0.75} = \underline{55} > 10$$

ANALYSIS

CYL.

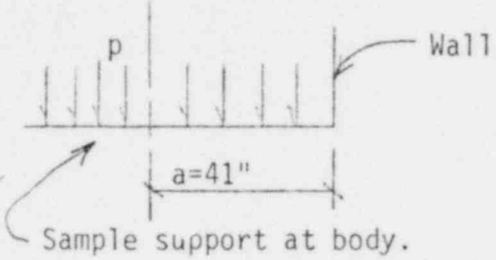
$$\sigma_1 \text{ (axial)} = \frac{pR}{2t} = \frac{7.3(35)}{4(0.75)} = \underline{202 \text{ psi}}$$

$$\Delta R = \frac{pR^2}{Et}\left(1 - \frac{\nu}{2}\right) = \frac{7.3(41.5)^2}{29(10^6)(0.75)}\left(1-0.15\right)$$

$$= \underline{0.0005 \text{ in.}} \quad \text{larger}$$

BOTTOM

Assume unsupported on bottom.



ROARK & YOUNG - 5th ED
Table 24
Case 109

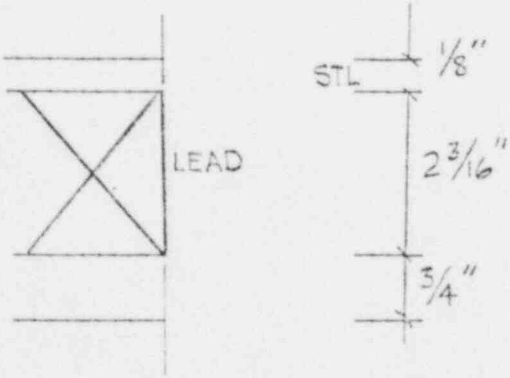
$$Y_c = \frac{-qa^4(5+\nu)}{64D(1+\nu)} \xrightarrow{\quad} \text{Neglect lead for now.}$$

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

$$Y_c = \frac{-7.3(41)^4(5.3)}{64D(1.3)} = 1.17 \text{ IN.}$$

Too large!

Must consider composite action of STL and LEAD.



$t_{\text{eq. STL stiffness}} = \underline{2.10 \text{ in}}$

$$D = \frac{29(10^6)(2.1)^3}{12(1-0.09)} = \underline{24.6(10^6)}\ \text{LB-IN}^2\text{/IN}$$

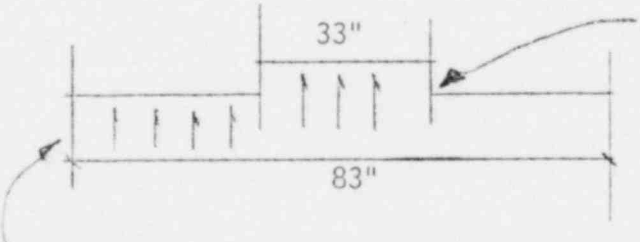
$$Y_c = \frac{-7.3(41)^4(5.3)}{64D(1.3)} = \underline{0.053}\ \text{IN}$$ Valid small diff. theory

$$M_c = \frac{qa^2(3+\nu)}{16} = \frac{7.3(41)^2(3.3)}{16} = \underline{2531}\ \text{IN-LBS/IN}$$ Small!

$$\theta_a = \frac{qa^3}{8D(1+\nu)} = \frac{7.3(41)^3}{8D(1.3)} = 0.002\ \text{Radians}$$

$$= \underline{0.113^\circ}$$

LID BOLTS



18 bolts: $\frac{3}{4}$" DIA. 74ksi Ult.

12 BOLTS: 1" DIA. 150 ksi Ult.

$$\text{LOAD/18 bolts} = \frac{7.3\pi(33)^2}{4} = 6244\ \text{LBS}$$

$$\text{AXIAL STRESS/BOLT} = \frac{6244}{18(0.334)} = \underline{1039\ \text{psi}}$$ ∴ Not critical

$$\text{LOAD}/\text{12 BOLTS} = \frac{7.3\,\pi(83)^2}{4} = \underline{39500} \text{ LBS.}$$

$$\text{AXIAL STRESS}/\text{1}''\phi\text{ BOLT} = \frac{39{,}500}{12(0.606)} = \underline{5432} \text{ PSI}$$

BOLTS ADEQUACY OK.

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 45^0, the effective preload per bolt is:

$$Fa = F \cos 45^0 = 7542 \text{ lbs/bolt.}$$

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

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

$D = 77+5/8 = 77.625$

$p = 14.7/2$ 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:

$$\text{M.S.} = \text{Fa}/\text{Pa} - 1$$

$$= 7542/2899 - 1 = +\ 1.60$$

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:

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

The pressure load per bolt is:

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

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

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:

$$\text{M.S.} = \text{Fa}/\text{Pa} - 1$$

$$= 4444/243 - 1 = +\ 17.3$$

The leak-tightness of these seals has been demonstrated by pressure tests.

2.6.4 VIBRATION

Cask has been transported with no vibration problems during normal travel

2.6.5 Water Spray.

The package is fabricated of material (steel and lead) that are not effected in any fashion by water spray.

2.6.6 Free Drop

Analysis for the one foot free fall indicates that two possible drop orientations, top end and top corner, would result in the most significant loads on the lid attachments. The top end drop was shown to be more severe than the top corner drop provided the outer shell extension would not collapse from a top drop.

A one-foot top end free fall test onto an essentially unyielding surface was performed, see appendicies 2.10.1 to 2.10.3. Post test examination of the cask showed that the outer shell extension did not collapse as a result of the top end drop. This orientation was shown to be the most damaging. It was further observed that there was no significant damage to the containment vessel and no distortion of the closure. No significant damage was observed in the target surface.

The full scale flat drop test was conducted with a payload weight of 11,350 lbs., corresponding to 14 loaded drums, see Appendix 2.10.3, page 1. For a fully loaded 195 cubic foot liner weighing 17,700 lbs., appropriate adjustment to the demonstrated performance of the closure bolts is necessary. The rationale for this adjustment follows.

During the test the closure bolts were required to react the impact loads of the payload (11,350 pounds) and the lid (6,300 pounds), for a total of 17,650 pounds. Combined weight for the liner payload and lid will be 17,700 pounds + 6,300 pounds = 24,000 pounds.

$$K_1 = 24{,}000 \text{ lbs.}/17{,}650 \text{ lbs.}$$

$$K_1 = 1.36$$

This represents an increase of <u>36%</u> in the load carried by the bolts. If we conservatively assumed the bolts were stressed up to their yield point during the test we can conclude that their capacity must be increased by at least 36% to react the higher loads associated with the heavier payload.

By increasing the bolt diameter from the tested (and analyzed) 1 inch diameter to a 1 1/4 inch diameter the basic area of the minor diameter will increase by the following ratio.

$$K_2 = A_1/A_2$$

Where:

$$A_1 = 1.024 \text{ in}^2 \text{ (1½" diameter)}$$

$$A_2 = .6464 \text{ in}^2 \text{ (1" diameter)}$$

$$K_2 = 1.024/.6464 = 1.58$$

or an increase of 58% in capacity.

Margin of Safety

$$M.S. = K_2/K_1 - 1$$

$$= 1.58/1.36 - 1$$

$$= \underline{+.16}$$

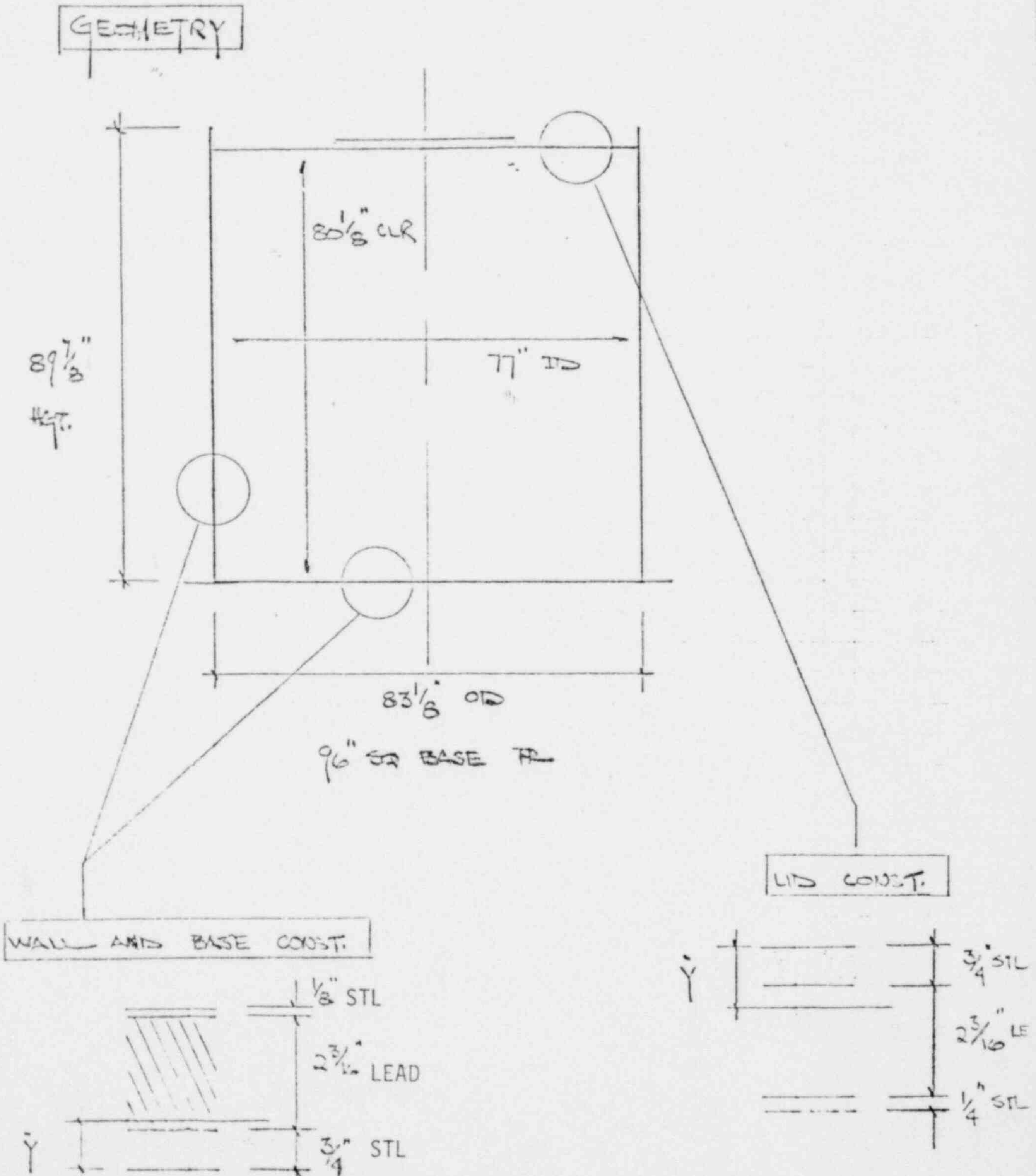
Therefore it can be concluded that the increased bolt size will more than conpensate for the increased payload weight (11,350 lbs. to 17,700 lbs.).

An additional factor of safety is achieved by modifying the lid to react impact loads in direct compression. Through the use of spacers or stand-off blocks, impact loads are reacted through the blocks directly to the lid and payload. This will nearly eliminate all tension loads in the bolts.

The spacer or stand-off blocks are shown as Part 15 on the drawing. It can be seen that these retainer brackets are flush with the top rim of the package. They will react impact loads directly as well as provide protection for the nut.

It should be noted that accelerations experienced during a flat end drop are significantly greater than those of the corner drop. Therefore, if the bolts are able to react the end drop condition a conservative Margin of Safety exists for the corner drop condition. As a result the 14-195H can safely withstand the Normal Conditions of Transport up to a maximum payload weight of 17,700 pounds.

2.6.6.1 End Free Drop - Bottom Down/Max. Loading



LOADS

GROSS WT. CASK	38,800 LBS
PAYLOAD(MAX)	17,700 LBS
TOTAL	56,500 LBS
LID(TOTAL)	6,300
SHELL(CYL)	32,500
SECONDARY LID	850

ASSUMPTIONS:

1. Fully plastic
2. Total energy abs. by body walls.

ENERGY = 56,500(12) = 678,000 IN-LBS

1 Ft. req'd since wt. > 30,000 LBS

$$\text{VOL. STL.} = \frac{678,000}{36,000} = \underline{18.83\ \text{IN}^3}$$

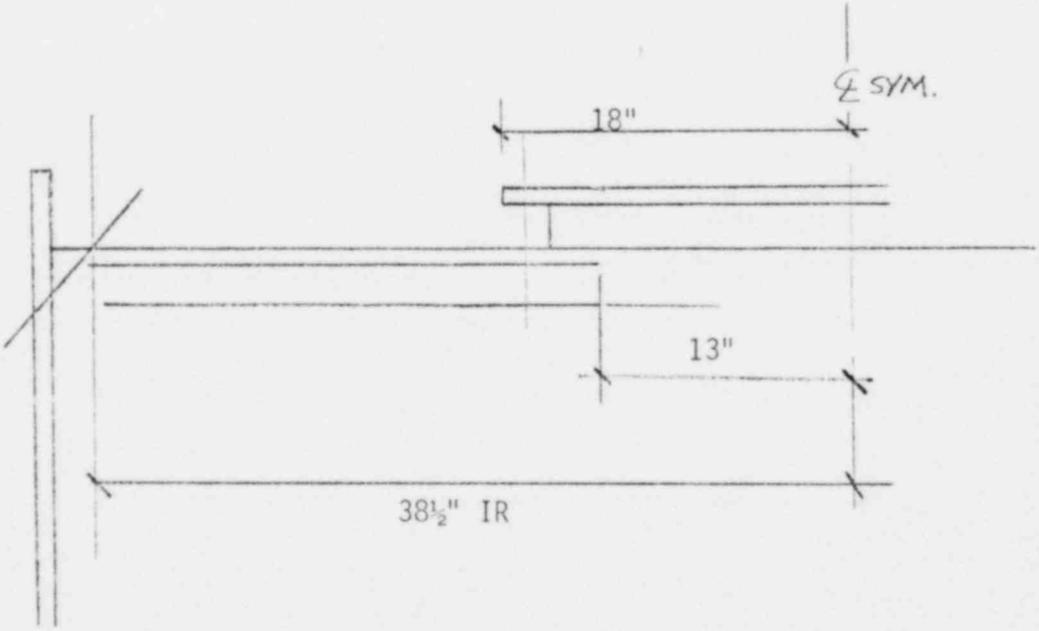
Dyn. flow stress STL. = Yield strength via CASK DESIGNERS GUIDE, page 56.

AREA STL $= \pi(83.125-0.75)(0.75) = \underline{194 \text{ IN}^2}$

$$S_{\text{plastic}} = \frac{18.83}{194.1} = \underline{0.10 \text{ IN}}$$

$$G_{\text{impact}} = \frac{h}{S} = \frac{12}{0.10} = \underline{120}$$

ANALYSIS - LID



$$\text{WT. SECONDARY LID} = \frac{490}{1728}(0.75 + 0.25) + \frac{710}{1728}(2.19)$$

$$= 0.28 + 0.90 = \underline{1.18 \text{ psi}} = q_{DL}$$

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Table 24 Case 10a/10b

Consider half-fixity at inner bolt circle:

$$K_{yc} = \frac{-0.0637 - 0.01563}{2} = \underline{0.040}$$

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

$$y = \frac{K_y\ q\ a^4}{D} \qquad M = K_m q a^2$$

$$M_c = o.144(1.18)(120)\frac{(33.25)^2}{2} = \underline{5626} \text{ IN-LBS/IN}$$

$$D = \frac{Et^3}{12(1-\nu^2)}$$

Secondary lid stiffness (eq. STL)

transformed section properties

$$\left.\right\} \quad \frac{E_{STL}}{E_{LEAD}} = 15$$

$$\sum Ay_{top} = 1(0.75)(0.375) + 1/15(2.1875)(1.844) + 1(0.125)(3.00)$$
$$= 0.281 + 0.269 + 0.375 = \underline{0.925 \text{ IN}^3}$$

$$A/IN = o.75 + 1/15(2.1875) + 0.125 = \underline{1.021 \text{ IN}^2}$$

$$(\bar{Y}top)_{Sec.Lid} = \frac{0.925}{1.021} = \underline{0.906 \text{ IN}}$$

$$I_{\substack{COMPOSITE \\ SECTION}} = \frac{(0.75)^3}{12} + 0.75(0.906-0.375)^2 + \frac{1}{15}\frac{(2.1875)^3}{12} + \frac{2.1875}{15}(0.938)^2$$

$$+ 0.125(3-0.906)^2 = \underline{0.981} \text{ IN.}^4/\text{IN.}$$

$$t_{\substack{EFF \\ STL}} = \sqrt[3]{12(0.981)} = \underline{\underline{2.275 \text{ IN.}}}$$

$$D = \frac{Et^3}{12(1-\nu^2)} = \frac{29(10^6)(2.275)^3}{12(1-0.09)} = \underline{\underline{31.27(10^6)}} \text{ LB-IN.}^2/\text{IN.}$$

$$Y_c = \frac{0.04(1.18)(120)\left(\frac{53.25}{2}\right)^4}{D} = \underline{\underline{0.002 \text{ IN.}}} \ll \text{HALF THK}$$

$$f_{STEEL} = \frac{Mc}{I} = \frac{5626(3.06-0.906)}{0.981} = \underline{\underline{12,353 \text{ PSI}}}$$

$$< \text{YIELD STL}$$

$$f_{LEAD} = \frac{MY}{15\,I} = \frac{5626(3.06-0.906-0.125)}{15(0.981)}$$

$$= \underline{776 \text{ PSI}} < \text{YIELD LEAD}$$

$$Q_{\substack{MAX \\ D}} = \frac{q\,l}{2} = \frac{1.18(120)(53.25)}{4} = 1177 \text{ LB/IN.}$$

$$Q_{STEEL} = 0.75(0.906-0.375) = \underline{0.40} \text{ IN.}^3$$

$$q_{SHEAR} = \frac{VQ}{I} = \frac{1177(0.40)}{0.981} = \underline{480\text{ psi}} < 1000\text{-}2000 \text{ RANGE ACCEPT.}$$

SUMMARY

Secondary Lid:

STL STRESS = 12,350 psi < Yield

LEAD " = 780 psi < Yield

BOND " = 480 psi < Allowable

Main Annular Lid:

Loaded by line load at inner body and uniformly dur to own wt.

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Table 24 Cases 1e and 2e

$$W = \frac{850(120)}{\pi(26)} = \underline{1249} \text{ LBS/IN} \quad \text{AT 120 G}$$

$$\frac{b}{a} = \frac{13(2)}{77} = \underline{0.34}$$

$K_{yb} = -0.03$

$K_m = 0.25$

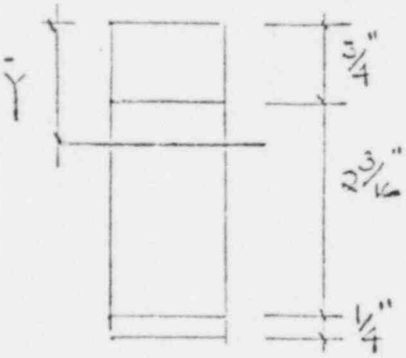
$y = K_y w a^3/D$

$M = K_m w a$

$q = 1.18(120) = \underline{142\ \text{PSF}}$ AT 120 g

$K_{y_b} = -0.01$ | $y = K_y \frac{q a^4}{D}$

$K_{M_{Hb}} = 0.08$ | $M = K_M q a^2$



$$\Sigma A \bar{y}_{TOP} = 0.75(0.375) + \frac{2.1875}{15}(1.844) + 0.25(3.063)$$

$$= \underline{1.32\ \text{IN}^3}$$

$A = \underline{1.15\ \text{IN}^2}$ $\therefore$ $\bar{y}_{TOP} = \underline{1.15\ \text{IN}}$

$$I_{COMPOSITE} = \frac{(0.75)^3}{12} + 0.75(1.15-0.375)^2 + \frac{(2.1875)^3}{15(12)} + \frac{2.1875}{15}(0.694)^2$$

$$+ 0.25(3.063-1.15)^2 = 0.035 + 0.45 + 0.055$$

$$+ 0.070 + 0.915 = \underline{1.53\ \text{IN.}^4/\text{IN.}}$$

$$t_{EFF\ STL} = \sqrt[3]{12(1.53)} = \underline{2.64\ \text{IN}}$$

$$D = \frac{Et^3}{12(1-\nu^2)} = \frac{29(10^6)(2.64)^3}{12(1-.09)} = \underline{48.72(10^6)}\ \text{LB-IN}^2/\text{IN}$$

CONTINUE SOLUTION FOR FINAL RESULTS.

$$Y_c = \frac{-0.03(1249)(33.5)^3}{D} - \frac{0.01(142)(33.5)^4}{D}$$

$$= -0.04 - 0.06 = \underline{0.11 \text{ IN.}} \quad << \text{WALL THK}$$

$$M_{fb} = 0.25(1249)(33.5) + 0.03(142)(33.5)^2$$

$$= \underline{23,860} \text{ IN-LB/IN}$$

REFER TO TEST RESULTS

$$Q_{LD} = \frac{6300(120)}{\pi(77)} = \underline{3125} \text{ LB/IN.}$$

$$q = \frac{VQ}{I} = \frac{3125 \, Q_{STATIC}}{I}$$

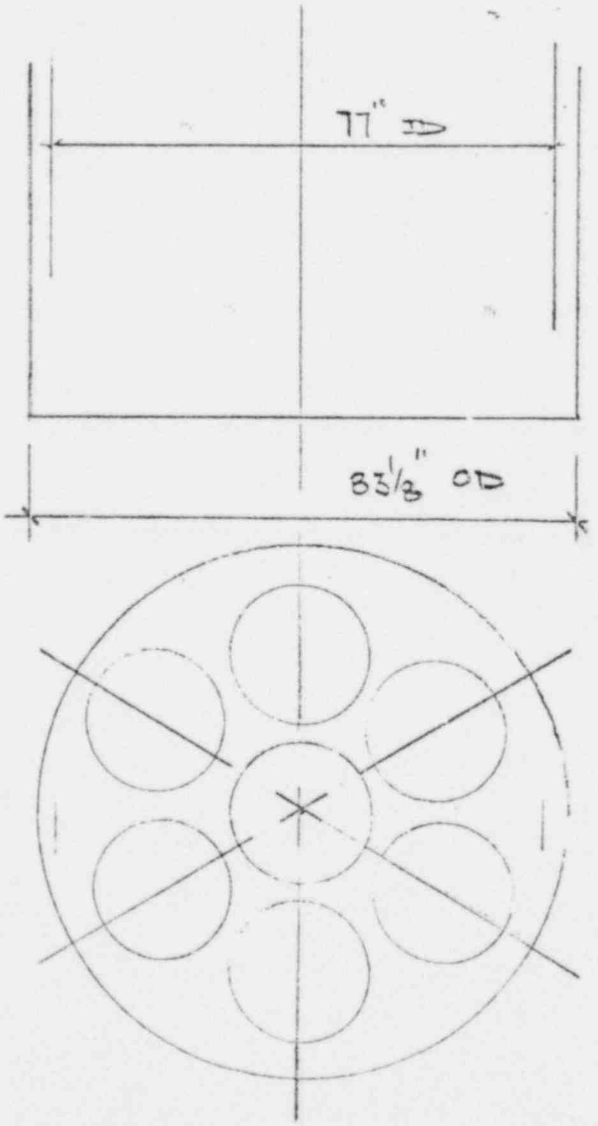
$$Q_{STATIC} = 0.75(1.15 - 0.375) = \underline{0.581} \text{ IN.}^3/\text{IN}$$

$$q = \frac{3125(0.581)}{1.53} = \underline{1187} \text{ PSI} < 1200 \text{ PSI}$$

BUT SEE TEST RESULTS
AS WELL

END FREE DROP - TOP DOWN / DRUM LOADING

GEOMETRY



CRITICAL LOADING UPSIDE DOWN "FLAT" IMPACT IS 14-55 GAL. DRUM PAYLOAD.

LOADS

PAYLOAD

55 GAL. DRUM = 7.35 FT.^{3}

SOLIDIFIED WASTE DENSITY = 75 PCF

WT/55 GAL = 550 LBS. SAY 600 LBS INCL TARE WT.

TOTAL = 14(600) = 8400 LBS + PALLETS = 9000 LBS.

WT. ENERGY = 38,800 + 9000 = 47,800 LBS

IN-LBS = 47,800 (12) = 573,600

$$\text{VOL. STL} = \frac{573,600}{36,000} = 15.93 \text{ IN}^3$$

$$\delta_{\text{PLASTIC}} = \frac{15.93}{194.1} = 0.08 \text{ IN}$$

$$g_{\text{IMPACT}} = \frac{h}{\delta} = \frac{12}{0.08} = 150$$

ANALYSIS

BASE

Subjected to 150 x its dead wt. only.

WT. BOTTOM:

$$\frac{490(0.875)}{1728} + \frac{710(2.1875)}{1728} = 0.25 + 0.90 = \underline{1.15} \text{ psi at 1G}$$

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Table 24 Case 10b

$K_{yc} = -0.01563$ | $y = K_y q a^4 / D$

$K_M = -0.125$ | $M = K_y q a^2$

$D = 31.27(10^6)\text{LB-IN}^2/\text{IN}$ (See page 2-54)

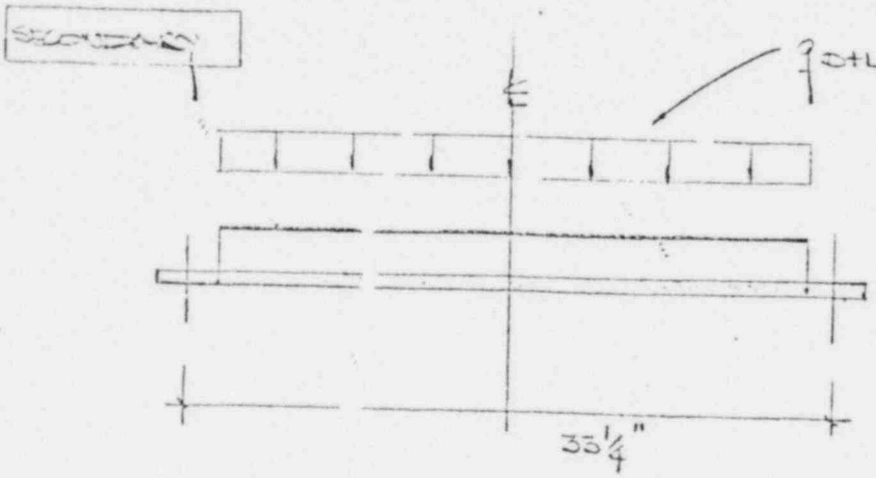
$$_c = \frac{-0.01563(1.15)(150)(38.5)^4}{D} = \underline{0.19 \text{ IN}} < \text{HALF THK}$$

$$M_c = -0.125(1.15)(150)(38.5)^2 = \underline{31,961} \text{ IN-LBS/IN.}$$

$$Q_{\text{force}} = \frac{1.15(150)\pi(77)^2}{\pi(77)4} = \frac{1.15(150)(77)}{4} = \underline{3320 \text{ LBS/IN}}$$

VALIDATED BY TEST!

LID



$$\text{TOTAL WT.} = \frac{1.15\,\pi(29.5)^2}{4} + \frac{2(9000)}{14} = \underline{\underline{2072\text{ LBS}}}\ \text{AT 1G}$$

$$q_{DTL} = \frac{2072\,(150)\,(4)}{\pi(33.25)^2} = \underline{\underline{358\text{ PSI}}}\ \text{AT 150G}$$

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TABLE 24 CASE 10 a

$K_{y_c} = -0.0637$ | $y = K_y\,q\frac{a^4}{D}$

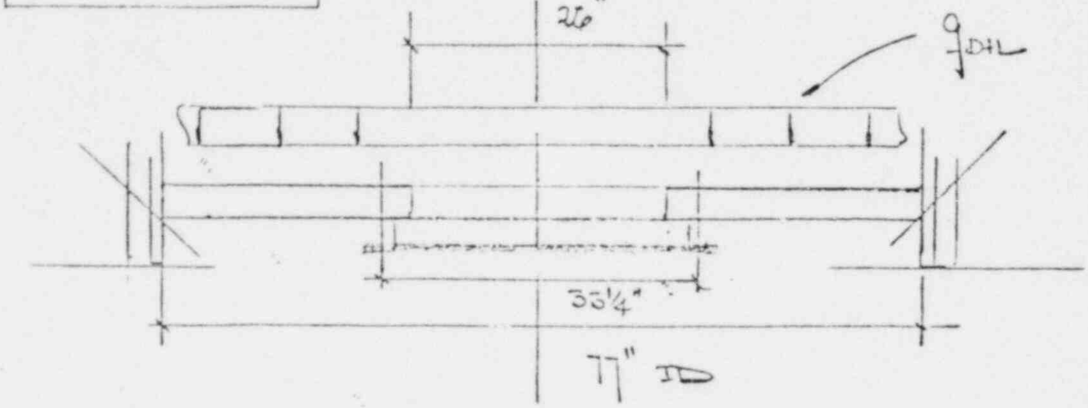
$K_{M_c} = 0.20623$ | $M = K_M\,q a^2$

$$y_c = \frac{-0.0637\,(358)(16.63)^4}{31.27\,(10^6)} = \underline{\underline{0.056\text{ IN}}}\quad \text{OK}$$

$$M_c = 0.20623\,(358)(16.63)^2 = \underline{\underline{20.420\text{ LB-IN/IN}}}\quad \text{MAX.}$$

VALIDATED BY TEST RESULTS.

MAIN NOZZLE



$$\text{TOTAL LOAD AT } 150\,G \bigg| = (6300 - 850)\,150 + \frac{12(9000)(150)}{14}$$

$$'' = (5450 + 7714)\,150 = \underline{1975 \text{ KIPS}}$$

$$q_{DHL}^{EQ.}\ \text{AT } 150\,G \bigg| = \frac{1975^{K}}{\frac{\pi}{4}(77^2 - 26^2)} = 0.48 \text{ KSI} \text{ or } \underline{480 \text{ PSI}}$$

ROARK & YOUNG - 5th ED
TABLE 24 CASE 2c

$$\frac{b}{a} = \frac{33.25}{77} = \underline{0.432}$$

$$K_{y_{MAX}} = \frac{-0.0029 - 0.0005}{2} = \underline{0.002}$$

$$K_{M_{ra}} = \frac{-0.0463 - 0.0101}{2} = \underline{0.028}$$

$$K_{M_{tb}} = \frac{0.0552 + 0.03}{2} = \underline{0.043}$$

$$K_{\theta_b} = \frac{0.6013 + 0.3230}{2} = \underline{0.462}$$

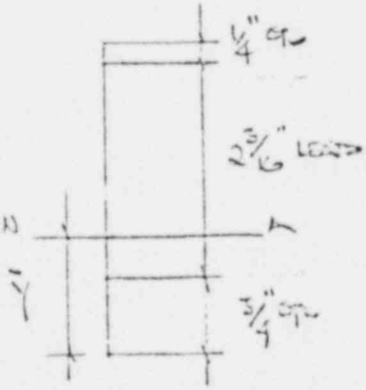
$$Y = K_Y \frac{qa^4}{D} = \frac{0.002(480)(33.5)^4}{48.77(10^6)} = \underline{\underline{0.043 \text{ IN.}}} \quad \text{SMALL!}$$

$$M_{45} = K_{M_{45}}\, qa^2 = 0.028(480)(33.5)^2 = \underline{\underline{17,921}} \text{ LB-IN./IN}$$

$$M_c = K_{M_c}\, qa^2 = 0.043(480)(33.5)^2 = \underline{\underline{30,600}} \text{ LB-IN/IN}$$

$$Q = K_Q\, qa = 0.462(480)(33.5) = \underline{\underline{8540}} \text{ LB/IN}$$

STRESS SUMMARY



$$\left(f_{BEND}\right)_{\substack{STEEL \\ MAX.}} = \frac{Mc}{I} = \frac{30,600(2.04)}{1.53}$$

$$= \underline{\underline{40,750 \text{ PSI}}}$$

$$\left(f_{BEND}\right)_{LEAD} = \frac{30,600(1.79)}{1.53(15)} = \underline{\underline{2387 \text{ PSI}}}$$

$$q_{SHELL} = \frac{VQ}{I} = \frac{8540(0.75)(1.15-0.375)}{1.53} = \underline{\underline{3244 \text{ PSI}}}$$

ABOVE STRESSES MUST BE COMPARED WITH TEST RESULTS FOR FINAL RESOLUTION.

BODY BOLTS

$$\text{BODY REACTION}/\text{in} = \frac{1975^{k} - 824\,(\pi)(33.25)}{\pi(77)} = \underline{\underline{4.48\ {}^{k}/\text{in}}}$$

$$\text{LOAD}/\text{BOLT} = \frac{4.48\ \pi(77)}{12} = \underline{\underline{90}}^{\text{KIPS}} \quad \text{VERT. COMP.}$$

$$\text{TENSION}/\text{BOLT} \doteq \frac{90}{0.707} = \underline{\underline{127}}^{\text{KIPS}}$$

BOLTS ARE SAE J429 GRD 8

MIN. YIELD STRENGTH = 130 KSI

$$A_{1''\phi\ \text{NOM}} = \pi/4 = \underline{\underline{0.79\ \text{in}^2}}$$

$$f_{\text{TEN}} = \frac{127}{0.77} = \underline{\underline{162\ \text{KSI}}} \qquad \text{CLOSE.}$$

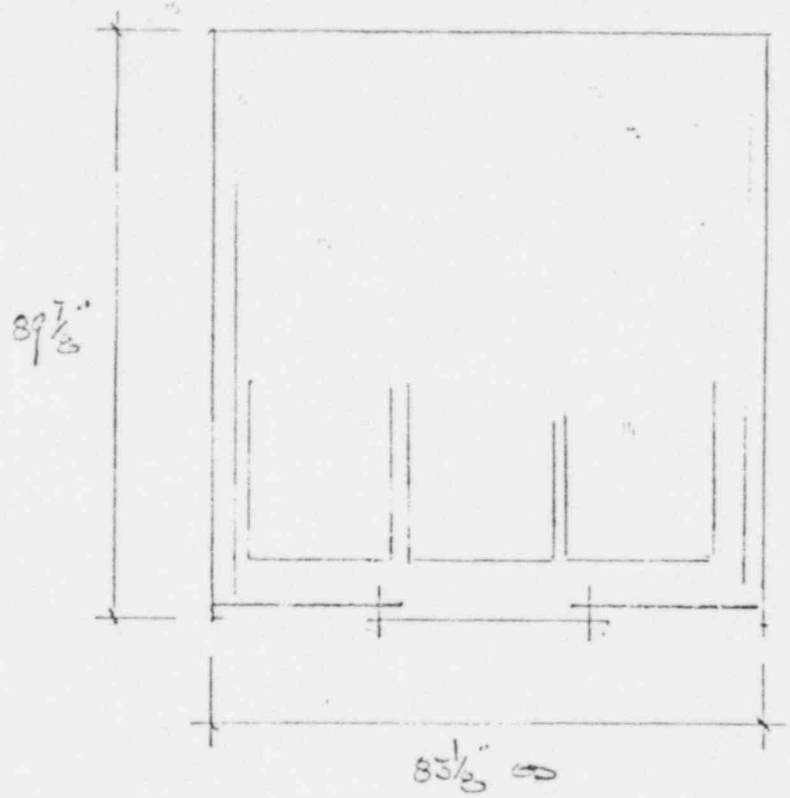
NOTE:

CAPACITY OF BOLTS TO CARRY ACTUAL LOADS MUST BE RESOLVED BY COMPARISON WITH DROP TEST RESULTS.

END DROP TEST - TOP DOWN

DWG 1-189-101

GEOMETRY



CASK LOADED WITH 14 - 55 GALLON DRUMS EACH WEIGHING 750 LBS.

WT. SUMMARY :

14 - 55 GAL DRUMS AT 750# EA	=	10,500 LBS.
2 - PALLETS AT 250# EA	=	500
1 - BRACING GRID	=	350
TOTAL PAYLOAD		11,350 LBS.

LOADS

GROSS WT. = 51,310 LBS ACTUAL TEST WT.

$$\text{ENERGY TBA} = 51.310\,(13) = \underline{667,030}\ \text{IN-LBS}$$

$$\text{VOL STL REQ'D} = \frac{667,030}{36000} = \underline{18.53}\ \text{IN}^3$$

$$\text{BDY AREA IMPACT} = \pi(83.125 - 0.75)(0.75) = \underline{194.1\ \text{IN.}^2}$$

$$\Delta_{\substack{\text{REQ'D}\\\text{TOTAL}}} = \frac{18.53}{194.1} = \underline{0.10}\ \text{IN.}$$

$$G_{\text{PLASTIC}} = \frac{h}{\Delta} = \frac{13}{0.10} = \underline{130}$$

$$F_I = 194.1\,(36,000) = \underline{7000}\ \text{KIPS} \quad \text{AT } 180° \text{ CG DN.}$$

$$G_{\text{LOADS}} = \frac{7000}{51.3} = \underline{136}$$

ANALYSIS

CK BOTTOM

Circular plate 77" DIA.

$$\text{Wt. BOTTOM} = \frac{490(0.75+0.125)}{1728} + \frac{710(2.19)}{1728} = \underline{1.15 \text{ psi}}$$

$$\text{TOTAL}_{ID} = \frac{\pi(77)^2(1.15)}{4} = \underline{5345 \text{ LBS}} \qquad \text{CK}$$

ROARK & YOUNG - 5th ED

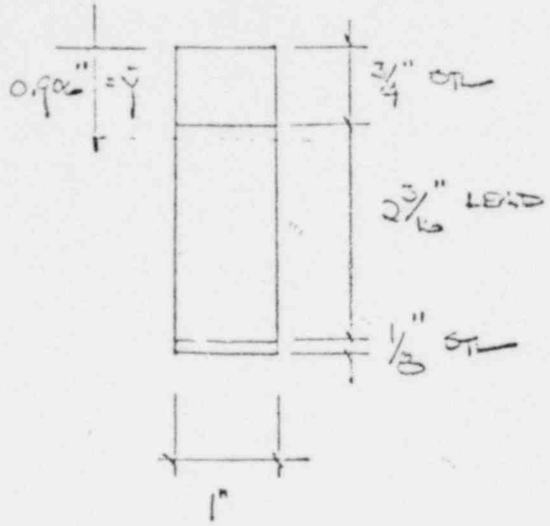
Table 24 Case 10b

$K_m = -0.125 \quad \therefore \quad M_a = -0.125qa^2$

$M_a = -0.125(1.15)(136)(38.5)^2 = \underline{-30,000} \text{ IN-LBS/IN}$

$Yc = K_{yc}qa^4/D$ WHERE $K_{yc} = -0.02$ APPROX.

$$D = \frac{Et^3}{12(1-\nu^2)}$$



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

TRANSFORMED SECTION

$\frac{1}{15} = t_{LEAD} = 0.067$ in

$$A\bar{y}_{TOP/BOT} = \frac{(0.75)^2}{2} + 0.067(2.19)(1.84) + 0.125(3)$$

$$= \underline{0.926 \text{ in}^3}$$

$$A = 0.75 + 0.125 + 0.067(2.19) = \underline{1.02 \text{ in}^2}$$

$$\bar{y}_{TOP/BOT} = \frac{0.926}{1.02} = \underline{0.906 \text{ in.}}$$

$$I_{COMPOSITE} = \frac{(0.75)^3}{12} + 0.75(0.531)^2 + 0.125(2.094)^2$$

$$+ \frac{0.067(0.156)^3}{3} + \frac{0.067(2032)^3}{3}$$

$$= 0.035 + 0.211 + 0.548 + \text{--} + 0.187$$

$$= \underline{0.981 \text{ in.}^4/\text{in}}$$

$$t_{EFF\ STL} = \sqrt[3]{\frac{12(0.981)}{1}} = \underline{2.275 \text{ in}}$$

$$D = \frac{29(10^6)(2.275)^3}{12(0.91)} = \underline{31.26\ (10^6)}\ \text{LB-IN.}^2/\text{IN.}$$

$$Y_c = \frac{-0.02(1.15)(135)(33.5)^4}{D} = \underline{0.22\ \text{IN.}} < 1\ \text{IN.}\ \therefore$$

TEST VALID.

RESULTS

BASE MOMENT CAPACITY DEMONSTRATED BY TEST W/O YIELDING:

$$M_y \geq 0.125(1.15)(136)(33.5)^2 = \underline{29,000}\ \text{IN-LBS}$$

SHEAR VALUE VALIDATED BY TEST W/O BOND FAILURE:

$$Q_{LOAD} \geq \frac{1.15(136)(33.5)}{2} = \underline{3010}\ \text{LBS/IN.}$$

LID MOMENT CAPACITY DEMONSTRATED BY TEST W/O YIELDING

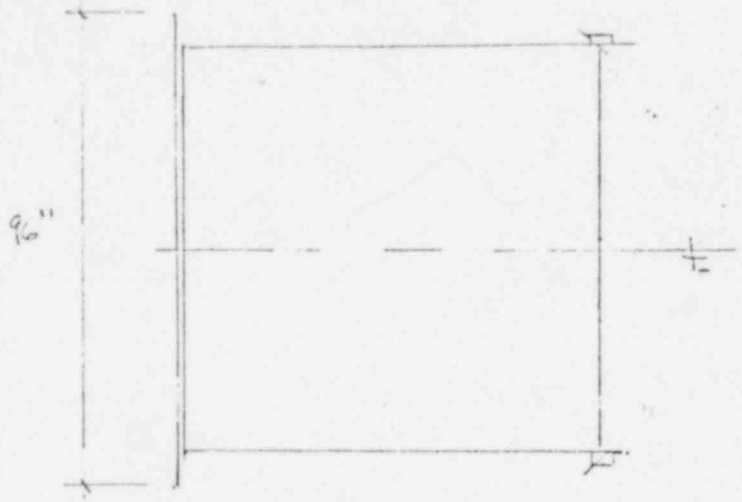
$$M_y \geq \left[5480 + \frac{6(11380)}{7}\right]\frac{136}{1973000}(39,600) = \underline{32,000}\ \text{LB-IN.}$$

CAPACITY OF ALL COMPONENTS OF LID AT LEAST 5% GREATER THAN LOADS SHOWN ON PAGES 2-63 AND 2-64 (NO PERMANENT DEFORMATIONS.)

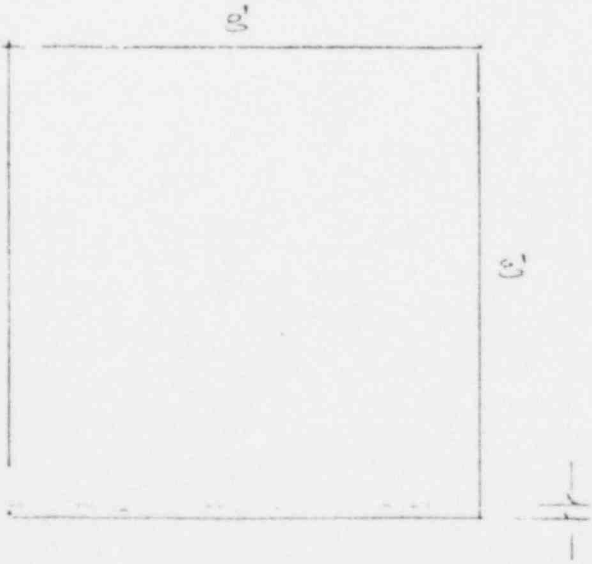
2.6.6.2 Side Free Drop

14-17=#

GEOMETRY



END VIEW OF PLATE



$\delta_T = \delta_{ST}$

ENERGY ABS = 2 × WIDTH (δ) $t_{PL} (f_{yield})_{ST}$

LOADS

ENERGY = Wh = 3 S f_{STL} f_{STL} (TOTAL)

$$\frac{56{,}500\,(12)}{2(96)(0.75)(36{,}000)} = \delta_{STL} = \underline{0.131\ \text{IN}}$$

SAY 50-50 SPLIT
BASE PL AND TOP
RING BAR 2½ × 4.

LOAD = 36,000 (96)(0.75) = 2592 KIPS AT BASE END

$$\text{LOAD FACTOR} = \frac{2592}{56.5/2} = 91.8$$ SAY 92.

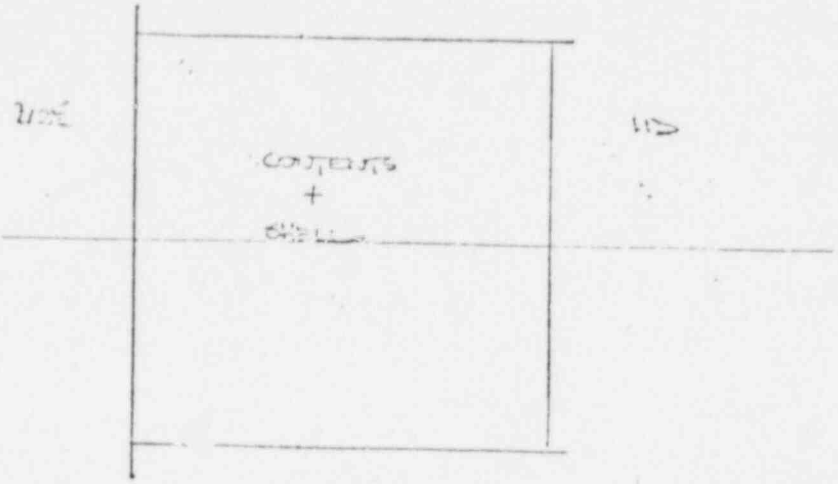
ANALYSIS

CAPACITY BASE PLATE WELDMENT

5/8 IN FILLET BETWEEN SIDE WALL AND BASE.

π(83⅛)(0.625)([illegible]) = 2423 KIPS NORMAL ALLOWABLE AT 21 KSI.

RESULTS



TOTAL WT. = 56,500 LBS

− LID WT. 6300

50,200

− BASE WT 6500

43,700 LBS

1/2 WT EA END

INERTIA LD ACROSS FILLET WELDS = $\frac{43700}{2}(92)$

= 2010 KIPS < 2423 KIPS ∴ OK

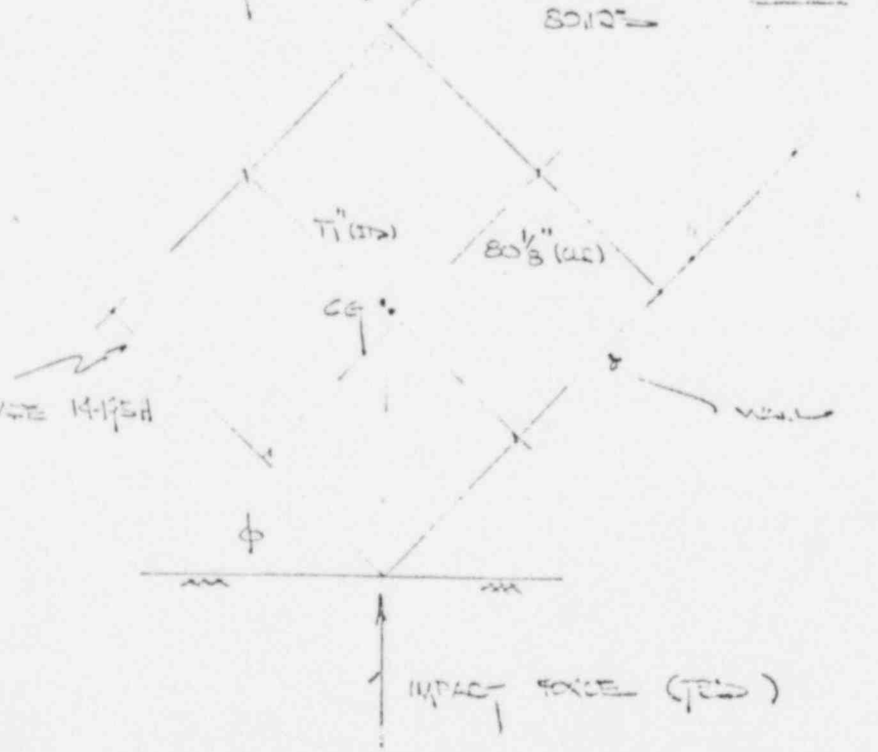
THIS IS INFO RELEVANT TO ITEM 7 IN NRC LETTER DATED 11/17/77.

2.6.6.3 Corner Free Drop - Bottom Down

GEOMETRY

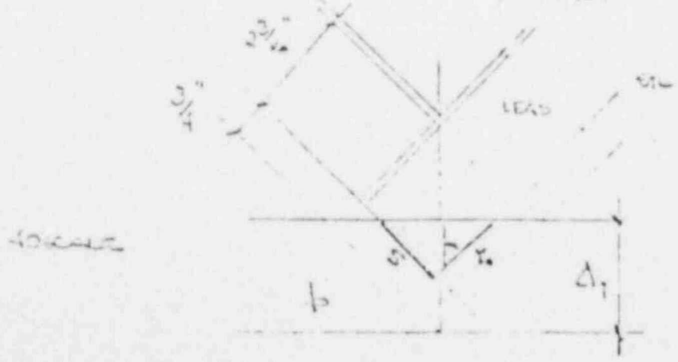
MESH

DROP ANGLE $\phi = \tan^{-1} \frac{77}{80.125} = \underline{43.86°}$ OF VERTICAL



ENERGY TBA = 56,500 (12) = 678,000 IN.-LBS

1 FT. DROP



2 3/16 IN. LEAD

$\frac{2.183}{\cos\phi}$ = HGT. LEAD AT CORNER

= 3.03 IN

LOADS

CK to see if sufficient energy is absorbed for deformation depth equal to Δ_{LEAD} = 3.03 - 0.8(2.183) MAX.

$$\Delta_{LEAD} = 3.03 - 0.8(2.183) = \underline{1.28\ IN}$$

$$TOTAL\ \Delta = 1.28 + \frac{0.75}{\cos\phi} = \underline{2.32\ IN}. \qquad TRY\ \Delta T = 2\tfrac{1}{4}\ IN.$$

VOL. LEAD ONLY = $R^3 \tan\phi(\sin\theta - \theta\cos\theta - \sin^3\theta/3)$

$\cos\phi = \Delta LEAD/YoLEAD = 0.721$ ∴ $(Yo)LEAD = \Delta\ LEAD/0.721$

$$\Delta\ LEAD = 2.25 - \frac{0.75}{\cos\phi} = \underline{1.21\ IN.}$$

This provides more than 80% original shielding.

$\sin\phi = \Delta LEAD/SLEAD$ ∴ $SLEAD = 1.21/\sin\phi = \underline{1.73\ IN}$.

$R - R\cos\theta = S$ ∴ $\cos\theta = 1 - S/R = 1 - (1.75/R)$

$$R = \frac{83.125 - 1.5}{2} = \underline{40.15\ IN}.$$

$$\theta = \cos^{-1}(1 - 1.75/40.81) = \underline{16.84^{\circ}}$$

$$\text{VOL. LEAD} = R^3 \tan\phi \left[\underbrace{0.29 - 0.29(0.96) - \frac{(0.29)^3}{3}}_{2.86(10^{-4})} \right]$$

$$= \underline{18.7 \text{ IN.}^3}$$

ENERGY ABS BY LEAD = 5000 (18.7) = $\underline{93,364 \text{ IN.-LBS.}}$

ENERGY ABSO BY STL WALLS:

$$\tfrac{2}{3} (y_0)_{STL}\, \ell_{STL}\, t_{STL}\, (\sigma_{YIELD})_{STL}$$

$$(y_0)_{STL} = S_{STL} \tan\phi = (1.75 + 0.375) \tan\phi$$
$$= \underline{\underline{2.04 \text{ IN.}}}$$

$$\cos\theta_{STL} = 1 - \frac{S_{STL}}{R_{STL}} = 1 - \frac{2.13}{40.81 + 0.375} = 0.95$$

$$\therefore \theta_{STL} = \underline{\underline{18.5^\circ}}$$

$$^{BDY}\ell_{STL} = \frac{2(18.5)}{360} \pi (40.81 + 0.375)(2) = \underline{\underline{26.6 \text{ IN.}}}$$

$$\text{ENERGY STL WALL} = \frac{2(2.04)}{3} (26.6)(0.75)(36,000)$$

$$= \underline{976,609 \text{ IN.-LBS.}} > 675,000 \text{ IN.-LBS.}$$

NOTE:

AT THIS POINT SHIELDING IS NOT PROBABLY AS LESS THAN 50% ORIGINAL THICKNESS DEFORMED.

ITERATE WITH $\Delta_T = 2.00$ IN

$$\Delta_{LEAD} = \Delta_T - \frac{0.75}{\cos\phi} = 2.0 - 1.04 \doteq \underline{0.96\text{ IN.}}$$

$$\sin\phi = \frac{\Delta_{LEAD}}{S_{LEAD}} \quad \therefore \quad S_{LEAD} = \frac{0.96}{\sin\phi} = \underline{1.39\text{ IN.}}$$

$$S_{STL} = 1.39 + 0.375 = \underline{1.77\text{ IN}}$$

$$y_{STL} = S_{STL}\tan\phi = \underline{1.70\text{ IN}}$$

$$\cos\theta_{STL} = 1 - \frac{S_{STL}}{R_{STL}} = 1 - \frac{1.77}{40.81} = \underline{16.94^\circ}$$

$$2b_{STL} = \frac{2(16.94)}{360}\pi(40.81 + 0.375)(2) = \underline{24.35\text{ IN}}$$

$$\text{VOL STL WALL} = \frac{2}{3}(y_o)_{STL}\, 2b_{STL}\, t_{STL}$$

$$= \frac{2}{3}(1.70)(24.35)(0.75) = \underline{20.70\text{ IN.}^3}$$

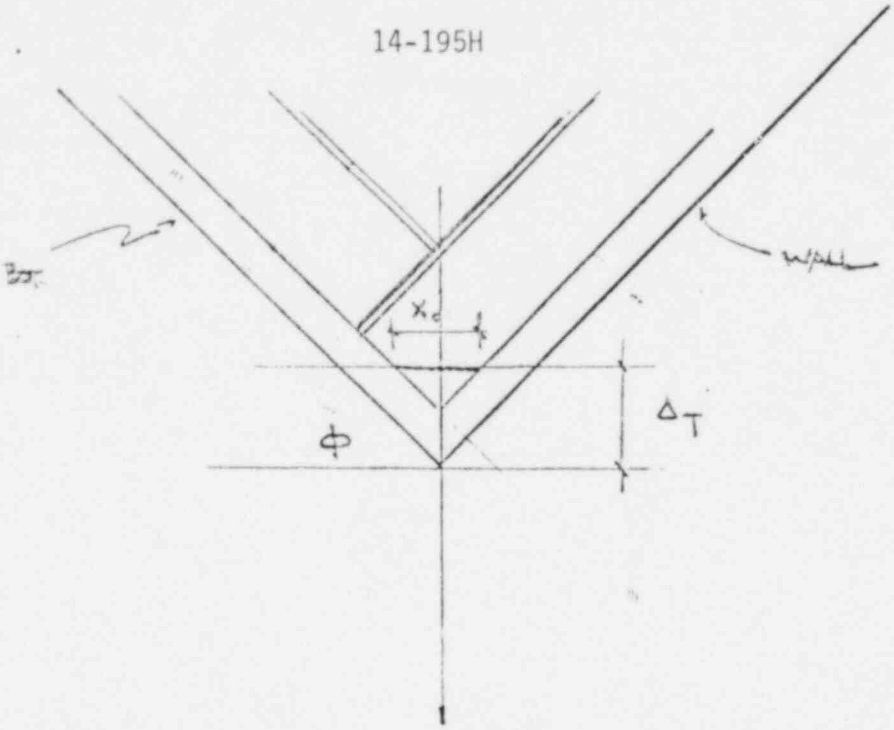
ENERGY ABS BY STL = 36,000 (20.70) = 745,000 IN-LBS

NOTE:

SINCE CONTACT AREA NOT SUPER SENSITIVE TO Δ_T, THIS VALUE WILL BE USED TO DETERMINE INERTIA LOAD FACTOR.

Δ_T = 2.00 INCHES > ACTUAL REQ'D.

14-195H



LEAD IMPACT AREA

$$(A_I)_{LEAD} = ab\left(\frac{\pi}{2} - \sin^{-1}\frac{c}{a}\right) - cd$$

$$a = \frac{\text{MAJOR AXIS}}{2} = \frac{R}{\cos\phi} = \frac{40.81}{0.72} = \underline{56.6 \text{ IN.}}$$

$$b = R = 40.81 \text{ IN.}$$

$$X_o = \frac{\delta_{LEAD}}{\cos\phi} = \frac{1.39}{0.72} = \underline{1.93 \text{ IN.}}$$

$$c = a - X_o = 56.6 - 1.93 = 54.67 \text{ IN.}$$

$$d = \frac{b}{a}\sqrt{a^2 - c^2} = \frac{40.81}{56.6}\sqrt{(56.6)^2 - (54.67)^2} = \underline{10.57} \text{ IN.}$$

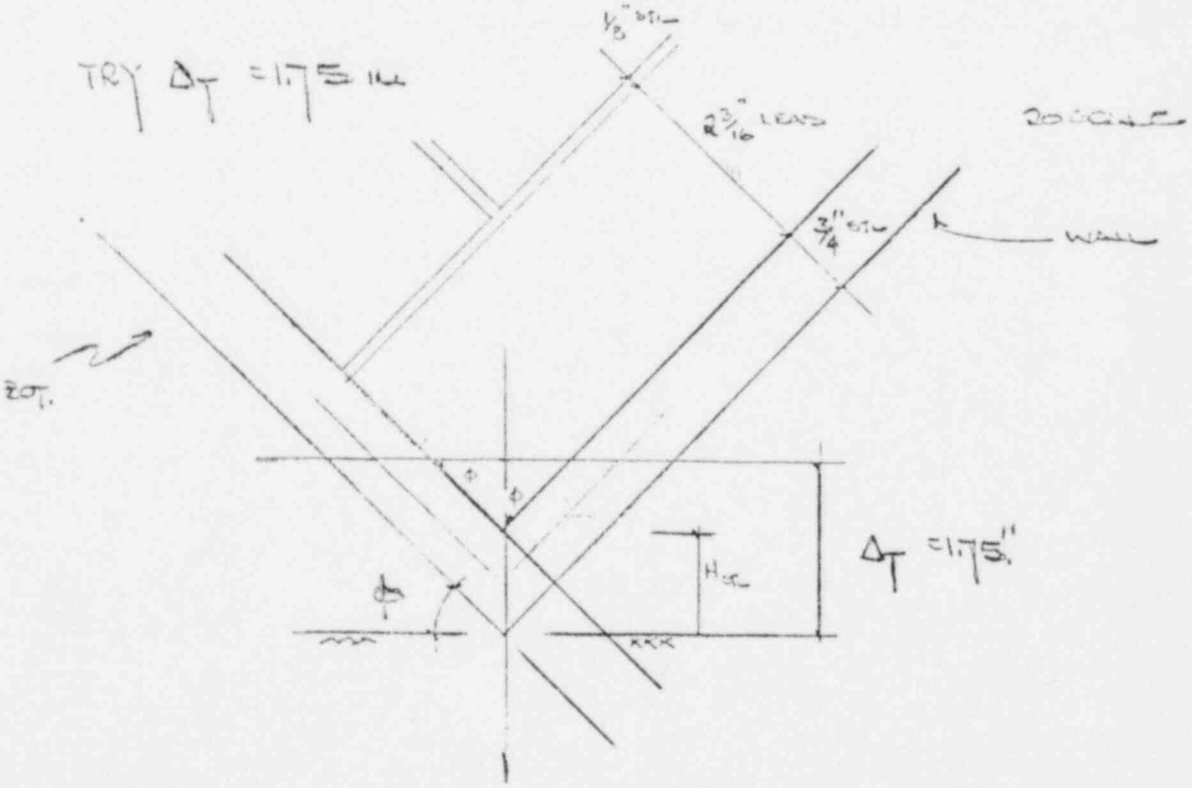
$$(A_2)_{LEAD} = 56.6(40.81)\left(\frac{\pi}{2} - 1.31\right) - 54.67(10.57) = \underline{27.1 \text{ in.}^2}$$

IMPACT FORCE = 10,000(27.1) = $\underline{271,000}$ LBS

STL AREA = 24.35(0.75)

RECALCULATE DEFORMATIONS FOR CLOSER ENERGY BALANCE.

TRY $\Delta_T = 1.75$ in.



ENERGY ABS. BY STL WALL

$$\cos\phi = \frac{\text{THK.}}{H_{STL}} \quad \therefore \quad H_{STL} = \frac{0.75}{0.72} = \underline{1.04 \text{ in.}} \checkmark$$

$$\Delta_{LEAD} = \Delta_T - H_{STL} = 1.75 - 1.04 = \underline{0.71 \text{ in.}} \checkmark$$

$$S_{LEAD} = \frac{\Delta_{LEAD}}{\sin\phi} = \frac{0.71}{0.693} = \underline{1.024 \text{ in.}} \checkmark$$

$S_{STL} = S_{LINER} + 0.375 = \underline{1.4 \text{ IN}}$

$Y_{STL} = S_{STL} \text{ TAN } \phi = \underline{1.345 \text{ IN}}$

$\cos \theta_{STL} = \left(1 - \frac{S}{R}\right)_{STL} = 1 - \frac{1.4}{41.19} = \underline{0.966 \text{ IN}} \quad \therefore \theta_{STL} = \underline{15°}$

$\text{DIAM STL WALL} = \frac{2(15)}{360} \pi (41.19)(2) = \underline{21.54} \text{ IN}$

$\text{VOL STL WALL} = \frac{2}{3} (Y)_{STL} \text{ DIAM}_{STL} \, t_{STL} = \underline{14.5 \text{ IN}^3}$

$(\text{ENERGY})_{STL \text{ WALL}} = 14.5(36{,}000) = \underline{521.480} \text{ IN.-LBS}$

<u>BENDING STL BASE PL</u>

$M_{PLASTIC} = 1.5 M_{YIELD} = 1.5 \frac{(0.75)^2}{6} (36000) = \underline{5062.5} \text{ IN-LBS.}$

$\text{ENERGY} = M \phi = 5062.5 (0.766) = \underline{3875 \text{ IN-LBS}} / \text{IN.}$

NOTE:

THE BULK OF THE ENERGY IS ABS. BY THE STL WALL.

COMPUTE INERTIA LOADS USING IMPACT AREA BASED ON $\Delta T = 1\frac{3}{4}$ IN.

LEAD IMPACT AREA

$(A)\ LEAD = ab(\pi/2 - \sin^{-1}(c/a)\ ) - cd$

a = Major axis/2 = $R/\cos\phi = 40.81/0.72 =$ 56.6 IN.

b = Minor axis/2 = 40.81 IN.

$X_o = S\ LEAD/\ \cos\phi = 1.024/0.721 =$ 1.42 IN.

$c = a - X_o = 56.6 - 1.42 =$ 55.18 IN.

$$d = \frac{b}{a}\sqrt{a^2 - c^2} = \frac{40.81}{56.6}\sqrt{(56.6)^2 - (55.15)^2} = \underline{9.085\ \text{IN}}.$$

$$(\triangle)\ LEAD = 56.6(40.81)\left[\pi/2 - \sin^{-1}(55.18/56.6)\right] - 55.18(9.085)$$

$$= \underline{16.5\ \text{IN}^2}$$

$(\text{Impact Force})_{LEAD} = 10{,}000(16.3) =$ 162,705 LBS

STL WALL IMPACT AREA

$(BDY)_{STL} =$ 21.54 IN.

AREA = $BDY(0.75)/\cos\phi$ = 22.41 IN.^{2}

$(\text{Impact Force})_{STL\ WALL} + 22.41(36000) =$ 306,760 LBS

STL BASE PLATE

$M_{plastic} = 1.5\ M_{yield} = \underline{5062.5}$ IN-LBS/IN.

$2d = 2(9.085) = \underline{18.17\ \text{IN}}$.

TOTAL ENERGY BENDING BASE PLATE = 91,986 ϕ

FORCE = E/ΔLEAD = 91,986 ϕ /0.71 = $\underline{99{,}178\ \text{LBS}}$.

INERTIA FACTOR

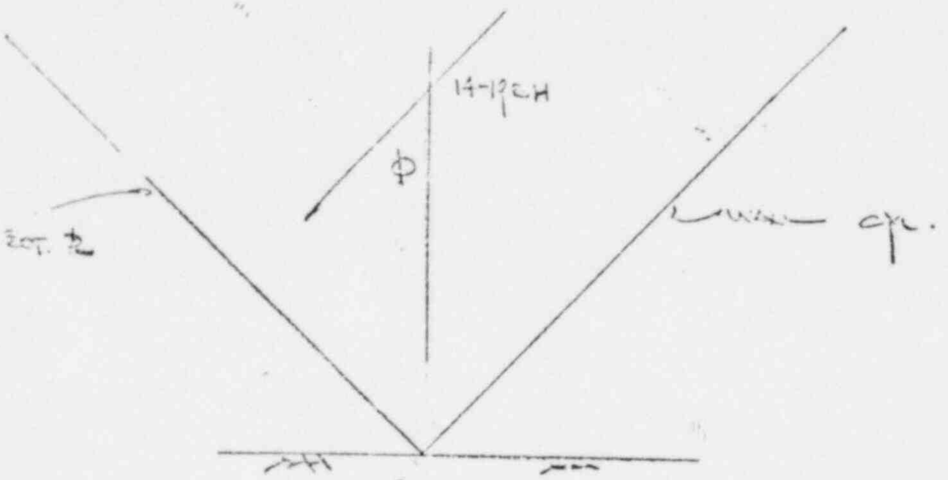
STL WALL	14.3	
LEAD	2.9	
STL BASE ⅊	1.76	
	18.96	USE 19

APPROX. ENERGY %

STL WALL	77
LEAD	13
STL BASE ⅊	10
	100

ANALYSIS

14-195H BOTTOM DOWN CORNER DROP



40 SCALE

IMPACT PLANE ; BENDING OF OVERHANGING BASE PLATE CONSERVATIVELY NEGLECTED.

19G LOAD (CONTENTS + BOTTOM WT.) ACTING ON BASE PL

TOTAL ACTING NORMAL $= (17{,}700 + 6500) \cos\phi$

$= \underline{17{,}449 \text{ LBS}}$

$$(q_{DYN})_{NORMAL} = \frac{17{,}450\ (4)}{\pi \left[\frac{17+85.125}{2}\right]^2} = \underline{3.47 \text{ PSI}} \quad \text{SAY } 3.5$$

REF. PAGE 2-55 OF THIS SUBMITTAL.

q_{DYN} AT 19G = 65.85 PSI $\boxed{\text{SAY } 66. \text{ PSI}}$

$(Y_c)_{\text{CENTER DEFLECTION}} = \dfrac{-0.04(66)(38.2)^4}{31.3(10^6)} = \underline{0.18 \text{ IN.}}$ < HALF EFF. THK < VOID

$M_c = \dfrac{66(38.2)^2(2.3)}{16} = \underline{14{,}063 \text{ IN-LBS/IN}}$

$(f_{\text{BEND}})_{19G} = \dfrac{14{,}063(3.0632-0.906)}{0.984} = \underline{30{,}820 \text{ PSI}}$ < YIELD

$(f_{\text{BEND}})_{\text{LEAD}} = 1456\dfrac{(14063)}{10547} = \underline{1941 \text{ PSI}}$ < YIELD

SHEAR STRESS AT BONDLINE :

$q_{19} = 387\dfrac{(66)}{50} = \underline{511} \ \underline{\text{PSI}}$ LOW !

WELD - BASE PL TO WALL :

1/2 IN. FILLET OR BETTER $7.42^{\text{KIPS}}/\text{IN}$

LENGTH = π 83.125 = 261 IN.

CAPACITY NORMAL = $\underline{1{,}937{,}700}$ LBS

MAX AT 19 G = 17449(19) = $\underline{331{,}531 \text{ LBS}}$ OK

RESULTS

BOTTOM CORNER DROP

Acceleration - 19G for 1 ft. drop height.

Bottom plate - 30,820 psi MAX STL

1,941 psi MAX LEAD

Bondline shear - 511 psi MAX SHEAR STRESS

Weldment - Not Critical

NOTE:

MATERIAL STRESSES ARE ELASTIC.

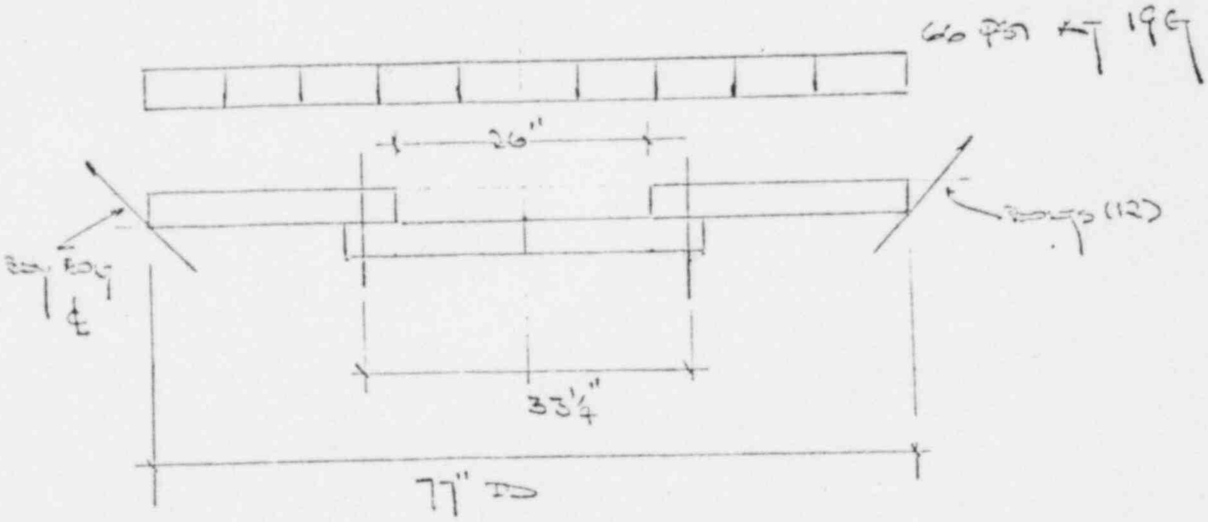
TEST RESULTS WOULD INDICATE ABOVE STRESSES ARE AT LEAST DOUBLE ACTUAL VALUES EXPERIENCED BY CASK.

CORNER DROP - UPSIDE DOWN

ANALYSIS

14-175 H

NO SCALE



DETERMINE EDGE FIXITY AT BOLT (ELASTIC ONLY).

$(M_{yield})_{3/4" \, stl} = S_{3/4} \, f_{yield} = \frac{(0.75)^2}{16} \, 36{,}000 = \underline{3375}$ IN-LBS/IN

FULL FIXITY MOMENT :

ROARK AND YOUNG - 5TH ED.

TABLE 24 / CASE 1 e

$\frac{b}{a} = \frac{13}{38.5} = 0.34$ $\qquad$ $\frac{r_0}{a} = \frac{16.63}{38.5} = 0.43$

IT APPEARS THAT HALF FIXITY IS IN THE CARDS ∴ TRY IT!

<u>CASE 2C</u> | <u>CASE 2G</u>

$K_{MG} = -0.1135$

$K_{M_{tb}} = 0.0778$ | $K_{M_{tb}} = 0.3272$

WHERE $M = K_M q a^2$; THUS, USE THE FOLLOWING :

$K_{M_{ra}} = \frac{-0.1135}{2} = -0.057$

$K_{M_{tb}} = \frac{0.0778 + 0.3272}{2} = 0.203$

UNIFORM LOAD ON ANNULAR PORTION

<u>CASE 1C</u> | <u>CASE 1G</u>

$K_{M_{tb}} = 0.2503$ | $K_{M_{tb}} = 0.621$

$K_{M_{ra}} = -0.1657$

LINE LOAD NEAR INNER EDGE.

WHERE $M = K_M w a$.

CK. CAPACITY :

$0.057\, q a^2 = 0.057(66)(33.5)^2 = 5576$ IN-LBS $> M_{YIELD}$ ∴

NOW TRY 1/4 FIXITY.

$K_{M_{IG}} = -\frac{0.1132}{4} = \underline{-0.028}$ UNIFORM LD COEFF.

$K_{M_{IG}} = \frac{-0.1687}{4} = -\underline{0.042}$ LINE LD COEFF.

$M_{IG} = -0.028(66)(33.5)^2 - 0.042(w)(33.5)$

$W_{LINE} = \frac{66\,\pi(15)^2}{\pi(33.25)} = \underline{333}$ LBS/IN.

$M_{IG} = \underline{3320}$ IN-LBS/IN < 3375 ∴ VALID AT BDY.

$K_{H_{UL}} = 0.3272 - \left(\frac{0.3272 - 0.0778}{4}\right) = \underline{0.265}$ UNIFORM LD FACTOR

$K_{H_{LL}} = 0.621 - \left(\frac{0.621 - 0.2503}{4}\right) = \underline{0.528}$ LINE LD FACTOR

TOTAL LOAD BDY BOLTS = 17,450 (19) = $\underline{331,550}$ LBS.

LOAD/BOLT = $\underline{27,630}$ LBS (REQ'D VERT. COMPONENT)

ANGLE AT 45° YIELDS ACTUAL TENSION = $\underline{39.08}$ KIPS

12 BOLTS SAE J429 TENSION ALLOW = 42.41 KIPS ∴ OK

TENSION STRESS = $\frac{39.^{L}}{0.79}$ = $\underline{49.4}$ KSI < YIELD = 130 KSI

$$M_{AB} = 0.263\,q a^2 + 0.225\,W a = 0.263(66)(28.5)^2 + 0.52(232)(28.5)$$

$$= \underline{32{,}734}\ \text{IN-LBS/IN}$$

$$(f_{BEND})_{\text{WELD STL}} = \frac{32734(3.153-1.13)}{1.333} = \underline{43{,}603\ \text{PSI}} \ \triangleright$$

$$(f_{BOND})_{\text{LEAD}} = \frac{32734(1.79)}{15(1.333)} = \underline{2930}\ \text{PSI} \ \triangleright$$

NOTE :

IF STIFFNESS OF SHELL WAS CONSIDERED, ABOVE VALUES SEEM OK. (TEST RESULTS CONFIRM LOWER BD. VALUE = 32,000.)

SHEAR STRESS AT BOND LINE :

$$q_{\text{SHEAR FLOW}} = \frac{66(28.5)(0.33)}{2\ (1.333)} = \underline{482\ \text{PSI}} \quad \text{LOW VALUE.}$$

RESULTS

IT IS CONCLUDED THAT THE ABOVE CONSERVATIVELY CALCULATED STRESSES DEMONSTRATE ADEQUATE CONTAINMENT.

APPLICABLE TO 14-170 H TRANSPORT CASK.

▷ SEE TEST DEMONSTRATED LOAD VALUES ON PAGE 2-69.

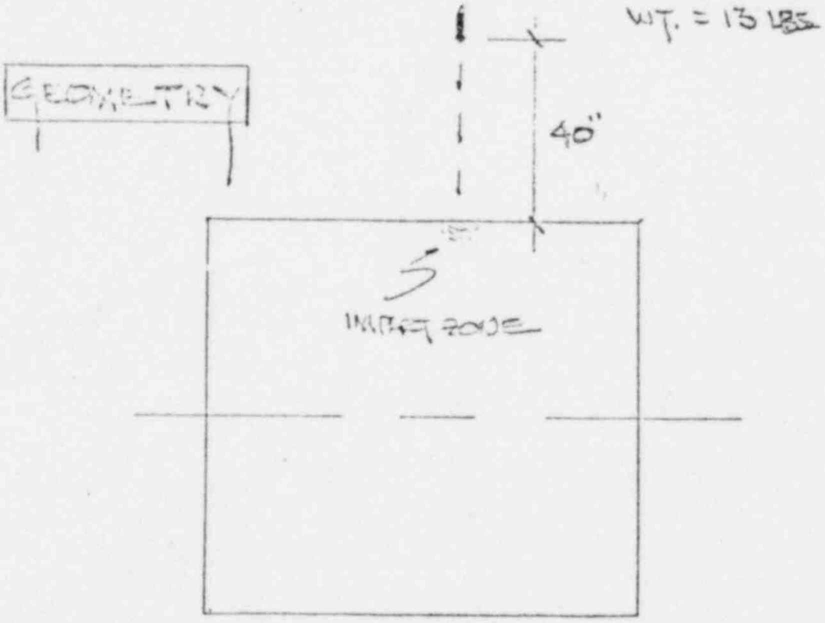
2.6.7 Corner Drop

This provision applies to packages constructed of wood and fibre board and is therefore not applicable to the CNSI 14-195H Cask.

2.6.8 Penetration

IMPACT OF THE HEMISPHERICAL END OF A VERTICAL STEEL CYLINDER $1\frac{1}{4}$ IN. DIA. AND WEIGHING 13 LBS. DROPPED FROM A HGT. OF 40 INCHES ...

THE LONG AXIS OF THE CYL. SHALL BE ⊥ to CASK WALL.



TRY

$$t = \left(\frac{W}{S}\right)^{0.71} = \left(\frac{55000}{75000}\right)^{0.71} = \underline{0.80 \text{ IN.}}$$

NOTE: ABOVE EQ. FOR TYPE 'B' REQM'TS.

NOW GO TO ANALYTICAL APPROACH FOR SPECIFIED TYPE 'A' REQUIREMENTS.

LOADS

$$\text{DYN. MULTIPLIER} = 1+\sqrt{1+\frac{2h}{d}}$$

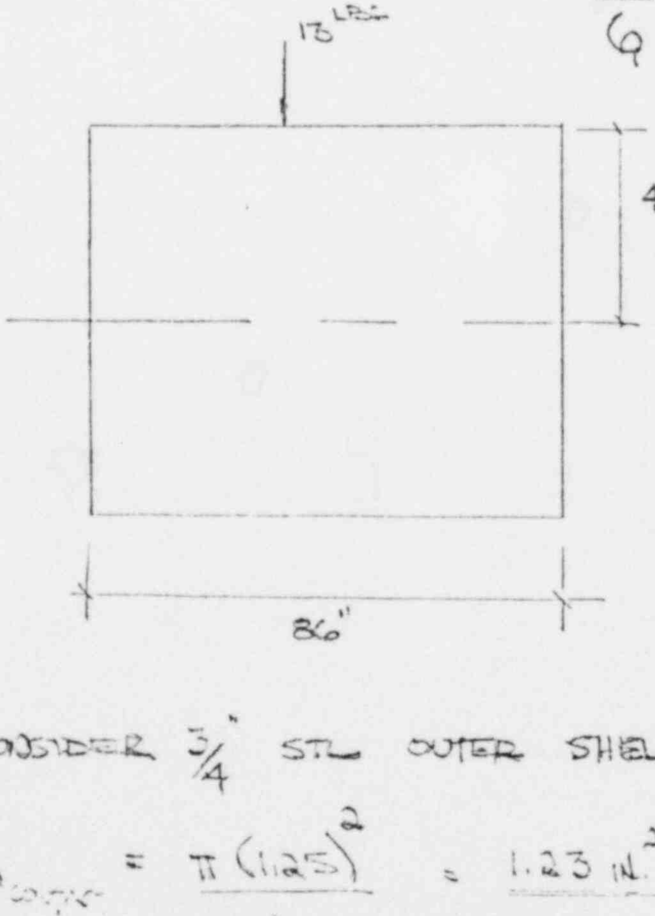
STRESSES AND DEF.

STATIC DEFORMATION

$$K_{\text{ENERGY LOSS}} = \frac{1+\frac{13}{55}\left(\frac{55}{13}\right)}{\left[1+\frac{1}{2}\left(\frac{55}{13}\right)\right]^2} = \frac{2.57}{9.71} = \underline{0.26}$$

$$\frac{2}{6} = \underline{\tfrac{1}{3}} \rightarrow \text{USE } \underline{0.5}$$

CONSERVATIVELY.



CONSIDER $\frac{3}{4}$" STL OUTER SHELL ONLY.

$$A_{\text{[illegible]}} = \frac{\pi(1.25)^2}{4} = \underline{1.23 \text{ IN.}^2}$$

ROARK & YOUNG - 5TH ED.

TABLE 31
CASE 9a

$$\frac{A}{R^2} = \frac{1.23}{(41)^2} = \underline{0.001}$$

$$\frac{R}{t} = \frac{41}{0.75} = \underline{55}$$

SAY $\sigma_2'\left(\frac{t^2}{P}\right) = 1.5$

CONSIDER PT. LOADING:

$$\sigma_2 = 0.4\frac{P}{t^2} = \frac{0.4(13)}{(0.75)^2} = \underline{9.3 \text{ PSI}}$$

$$\sigma_2' = \frac{2.4P}{t^2} = \frac{2.4(13)}{(0.75)^2} = \underline{55.5 \text{ PSI}}$$

$$y = \frac{P}{Et}\left[0.43\left(\frac{L}{R}\right)^{1/2}\left(\frac{R}{t}\right)^{1.22}\right] = \frac{13}{29(10^6)(0.75)}\left[0.43\left(\frac{41}{0.75}\right)^{1.22}\right]$$

= NEGLIGIBLE ! → $4(10^{-5})$ INCHES

$$\sqrt{1+\frac{2h}{d}} = \sqrt{1+\frac{2(40)}{4(10^{-5})}} = \underline{1414} \quad \text{SAY } 1400.$$

$d_{DYN} = \underline{0.06}$ IN

STRESS 52 KSI > YIELD

∴ NOT VALID

CASE 5a

$$Y = 6.5 \frac{P}{Et}\left(\frac{R}{t}\right)^{3/2}\left(\frac{L}{R}\right)^{-3/4} = \frac{6.5(13)}{29(10^6)(0.75)}\left(55\right)^{3/2}\left(2\right)^{-3/4}$$

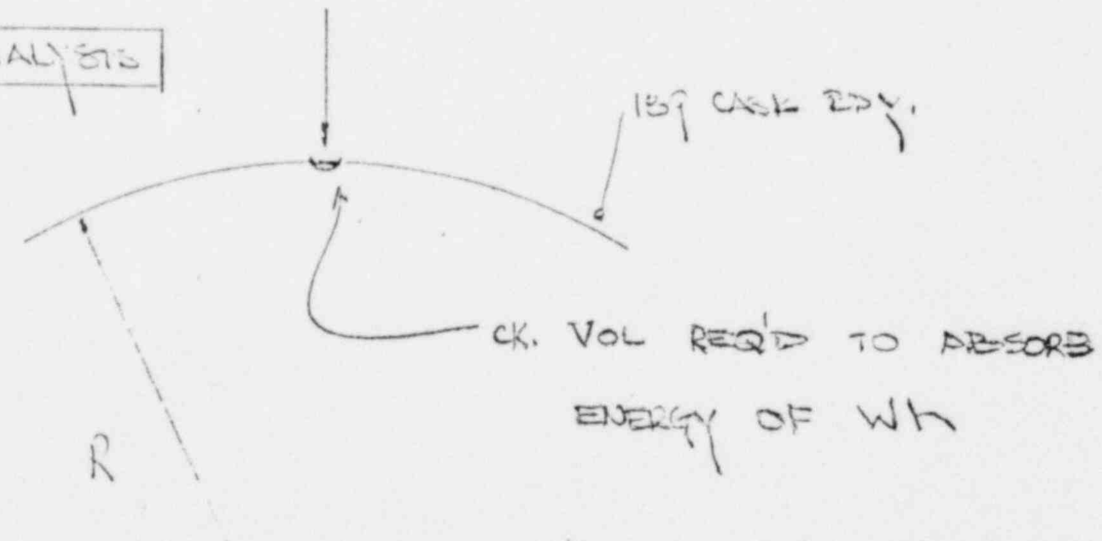
$$= \underline{0.001 \text{ IN.}}$$ NOT VALID SIMULATION

USING K (ENERGY LOSS FACTOR):

$$DYN = 1 + \sqrt{1 + \frac{2hK}{d}} = 1 + \sqrt{1 + \frac{40}{4(10^{-5})}} = \underline{1000}$$

$$STRESS = 1000(60^{+}) = \underline{60{,}000} \text{ PSI} > \text{YIELD}$$

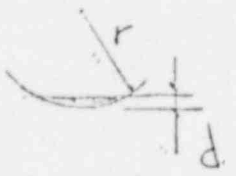
ANALYSIS



$$Wh = 13(40) = \underline{520} \text{ IN-LBS.}$$

$$\text{VOL REQ'D} = \frac{520}{36{,}000} = \underline{0.0144 \text{ IN.}^3}$$

SPHERICAL SEGMENT $= \pi d^2 \left(r - \frac{d}{3} \right)$



$\pi d^2 \left(r - \frac{d}{3} \right) = 0.0144$

SOLVING FOR d.

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

$d^3 - 1.5(1.25)\, d^2 + \frac{3(0.0144)}{\pi} = 0$

$d^3 - 1.88\, d^2 + 0.014 = 0$

-1.88
0
.014

$d_{ROOT} = 1.876$

-0.0844

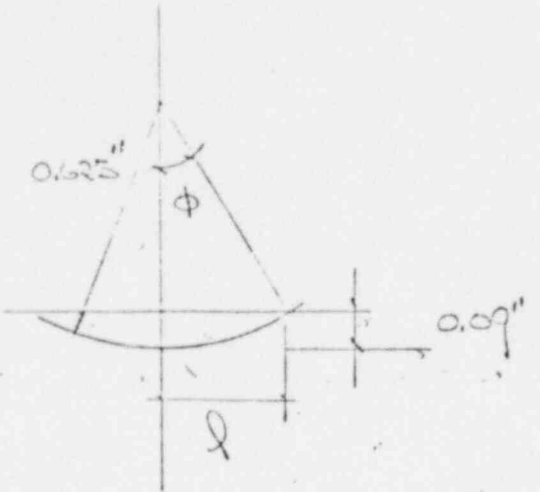
0.0884 → SMALL RATIONAL VALUE.

→ ck.

0.00069
-0.01469
.014

0

EXISTING $r = \frac{1.25}{2} > 0.09$ REQ'D ∴ OK



IS CASK BDY. FLAT BY COMPARISON WITH r.

$$\frac{R}{r} = \frac{41.5}{0.625} = \underline{66.4}$$

$$r(1-\cos\phi) = 0.09$$

$$\frac{r-0.09}{r} = \cos\phi = 0.86 \quad \therefore \quad \phi = \underline{31.1^\circ} \checkmark$$

$$l = r\sin\phi = 0.625(0.52) = \underline{0.32\ \text{IN}}$$

$$A_{\substack{\text{IMPACT}\\ \text{AREA}}} = \pi l^2 = \pi(0.32)^2 = \underline{0.32\ \text{IN}^2}$$

$$F_I = 36{,}000(0.32) = \underline{11.6^{\text{KIPS}}}$$

RESULTS:

$$(S_2)_{DYN} = \frac{0.4(11.6^K)}{t^2} = 8.25\ \text{KSI}$$

$$(S_2')_{DYN} = \frac{2.4P}{t^2} = 49.5\ \text{KSI}$$

COMBINE > YIELD

COMPOSITE ACTION WOULD SHOW IT [illegible]

2.6.9 Compression

NOT APPLICABLE; the CNSI 14-195H weighs wall in excess of the 10,000 lb. limit for this provision.

2.7 Hypothetical Accident Condition

NOT APPLICABLE

2.8 Special Form

NOT APPLICABLE

2.9 Fuel Rods

NOT APPLICABLE

2.10 Appendix

2.10.1 Test Procedure
2.10.2 Test Data Sheet
2.10.3 Test Report (Pittsburgh Testing Laboratory)

2.10.1 Appendix

TEST PROCEDURE
FOR
DROP TEST
OF
14-195H CASK

TO BE PERFORMED
AT
BARNWELL, SC
BY
CHEM-NUCLEAR SYSTEMS, INC.

PREPARED
BY
K. H. KINKADE

December 20, 1977

GENERAL

Chem-Nuclear Systems will perform a one foot drop test onto an unyielding surface, of its 14-195H Cask. The cask will be dropped upside down, onto its lid, which is the most severe case. The drop test will be performed at Chem-Nuclear's Barnwell, S. C. site. Chem-Nuclear personnel will perform this test with a certified testing firm as a witness., Documentation and photos will be implemented prior to and after the test. Refer to schematic for drop test stack-up.

PRELIMINARY PREPARATION

- The cask will be loaded with 14 drums of wet sand and each one weighed and recorded.
- The total cask weight will be recorded 51,310 Lbs.
- Install new bolts in cask
- Install new gaskets in cask
- Paint cask and pad and put numbers on each for photographing purposes.
- Install a 1" thick steel pad on top of a 6" concrete pad.
- Still and movie photography to be available and set-up.
- Certified Testing Representative to be on the site.
- Cask is ready for drop test.

PROCEDURE

Verify that all preliminary preparations have been accomplished.

1/14/78

CNSI Representative Date

Verify the cask is upside down and the cask's lowest point is one foot off an unyielding surface. Measure at different locations around the cask to check the one foot measurement.

1/14/78

Upon the readiness of all parties concerned, start the movie camera____________motion, DROP THE CASK THE MOVIE CAMERA DID NOT WORK DUE TO COLD WEATHER.

Take movies and stills as directed by CNSI representative.

Record all visual observations (blank pages are attached for data)

Raise Cask while taking pictures.

Turn cask to upright position - inspect results and take photos as required.

Log All Information

CASK DROP TEST WITNESSES:

1/4/78 ____________

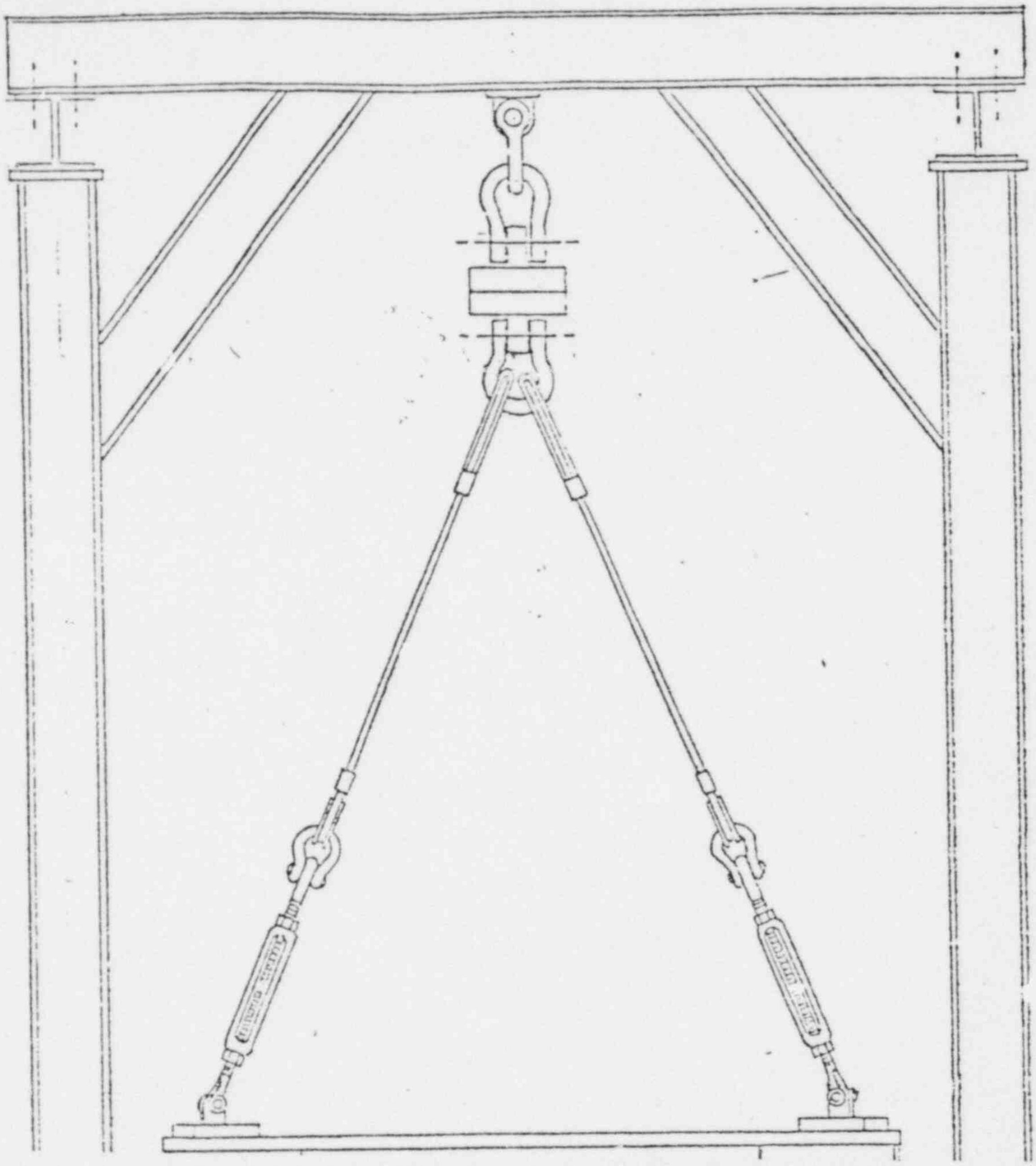
CNSI Representative

R. SCHONMAN - SEE TEST REPORT ____________

Pittsburg Testing Lab.
Representative

NOT ON SITE ____________

CNSI Structural Consultant



2.10.2 Appendix

CNSI DROP TEST DATA SHEET
FOR
CASK 14-195H

LOCATION OF TEST:	CNSI BARNWELL, S. C. SITE
DATE OF TEST:	1-14-78
TYPE OF DROP:	UPSIDE DOWN DROP. THE CASK WAS DROPPED ONTO ITS TOP SURFACE
HEIGHT OF CASK FROM DROP PAD:	12 1/2" to 12 3/4"
CASK WEIGHT:	39,960 lbs.
CONTENTS WEIGHT:	11,350 lbs.
TOTAL WEIGHT:	51,310 lbs.
DROP PAD:	The drop pad was essentially an unyielding surface of a 1" x 8'x 8' steel plate on top of a 6" x 40' x 50' concrete pad reinforced with heavy construction woven wire.
LEVELNESS OF CASK PRIOR TO DROP:	Checked for levelness with 4' carpenter's level
DID CASK DROP LEVEL?	Three explosive bolts were used to drop the cask level and instantaneously. The explosive bolts fire in milliseconds and simultaneously - thus dropping the cask level.
CERTIFIED TEST WITNESS:	R. Scherman Pittsburgh Testing Lab. Columbia, S. C.
PICTURES TAKEN:	Slides and Polaroid
TEST RESULTS:	Pittsburgh Testing Report CNSI observations

Just prior to the drop, witnesses were posted around the cask to observe the drop. A man was spotted up high to observe the bottom of the cask - which was up for this test.

The cask was dropped.

All observers were in full agreement to the following after the cask was dropped and after it was turned over and the contents removed:

SIDE WALLS:	No buckling, bowing or deformation of any kind inside or outside. All welds and laminated surfaces were intact.
BOTTOM:	No bowing or deformation of any kind. All welds intact inside and outside.
TOP:	No turning of any edges, no bending or bowing. All wedges, bolts, lids, etc, intact and unmarked.
BOLTS REMOVED AFTER DROP:	All bolts were removed with no binding, galling, stripping, or bending. The bolts were straight and looked the same as before drop.
STEEL WEDGES ON LID:	All removed - no damage whatsoever.
LARGE LID REMOVED:	Lid removed and replaced with no binding or out-of-roundness whatsoever.
DRUMS INSIDE:	All drums looked perfectly unmarked - all contents of drums still intact.
CASK INSIDE:	No damage - no broken welds - no deformities whatsoever.

The cask integrity concerning shielding and containment did not change in anyway from the original design configuration prior to the one foot drop test on CNSI Cask 14-195H.

The drop test performed on CNSI Cask 14-195H explicitly demonstrated package compliance with the containment and shielding requirements for normal conditions of transport, as defined in Appendix A of 10 CFR Part. 71.

FORM 407 REV.-CO

PITTSBURGH TESTING LABORATORY
ESTABLISHED 1881
802 B SOUTH EDISTO AVE., COLUMBIA, S. C. 29205

LABORATORY No.

CLIENT'S No.

ORDER No. CB - 1132

1st

REPORT

OF

TEST DROP OF NUCLEAR WASTE CONTAINER

PROJECT: Chem-Nuclear Systems

CLIENT: Chem-Nuclear Systems

REPORTED TO: Chem-Nuclear Systems - Box 726 - Barnwell, SC ATTN: Karl Kinkade

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On January 14, 1978, Pittsburgh Testing Laboratory's inspector reported to the above project as requested by the client for the purpose of observing the Test Drop of a Nuclear Waste Container. The purpose of the test was to prove that the container would maintain its form when subjected to an impact to the top surface of the container.

The weight of the container was obtained by the client who first determined the weight of the tractor and trailer as 28,600 lbs. This was subtracted from the weight of the tractor, trailer and container, 68,560 lbs.. The weight of the container was determined to be 39,960 lbs. These weights were obtained on the scale of W. F. Dicks of Barnwell, S.C. who's weight tickets are included in this report.

A Dummy load was placed inside the container to simulate an actual loaded condition. The dummy load consisted of fourteen, 55 gallon drums filled with wet sand and weighing 750 lbs. each. Two pallets weighing 250 lbs. each and a 350 lb. grid were used to brace the drums inside the container. This is an additional 11,350 lbs. and increases the total weight of container to 51,310 lbs. The dummy load was weighed on a Fairbanks-Morse Scale which had no identification plate and had been rented from the Carolina Scales Company of Columbia, SC.

The test required that the container be dropped a distance of one foot, striking the top of the container squarely on a non-yielding surface.

FORM 407 REV.-CO

PITTSBURGH TESTING LABORATORY
ESTABLISHED 1881
802B SOUTH EDISTO AVE., COLUMBIA, S. C. 29205

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LABORATORY No.

CLIENT'S No.

ORDER No. CB - 1132

1st
REPORT
OF
TEST DROP OF NUCLEAR WASTE CONTAINER

PAGE 2

To do this, the container was turned upside-down and suspended from a steel frame. Explosive bolts were used to provide a quicker seperation from the frame support and a straighter drop of the container. The height of suspension was gauged with a steel rod measuring 12 inches in length. The actual test height exceeded 1 foot since the container cleared the rod by approximately one inch, as can be seen in the inclosed photograph. The non yielding surface was provided by a thick steel plate placed on a large concrete slab. Leveling of the container was done with a sand's-craft, SC21AB-48, 4 foot carpenters level manufactured by Sands Levels and Tool Div.; Wichita, Kansas.

After dropping the container, the cylindrical side wall, especially near the impact surface, was visually inspected and no damage of any type could be found. The container was then turned on its side so the impact surface; the top of the container, could be inspected. This surface is covered with small chips and scratches in the paint which have started to rust. The impact was concentrated in the ourter ring, which is the top of the cylindrical side wall. Except for several areas where some paint had been chipped, no damage could be found on this surface. Several of the bolts on the center cover apparently had impacted and scuff marks were visible on them. One such bolt can be seen at center of an enclosed photograph.

INSPECTOR: R. Scherman
Job Time: 8.5 hrs. - Travel Time: 3.0 hrs.

1 - Client
1 - PTL-pgh
1 - PTL-cb

Respectfully submitted,
PITTSBURGH TESTING LABORATORY

Chas H. Nicholson

Chas H. Nicholson
Columbia District Manager

No. 11151

F. H. DICKS

PHONE 259-3486 — BARNWELL, S. C. 29812

Date Jan 12, 1978

~~Bought From~~ Chem NuClear

Address

Commodity

SMK Empty Trailer

Moisture

Foreign Material

Damage

Splits

28600 lbs. Gross

28600 lbs. Tare

28600 lbs. Net

Weighing Paid $3.00

Weigher FHDicks

No. 11155

F. H. DICKS

PHONE 259-3486 — BARNWELL, S. C. 29812

Date Jan 12, 1978

Bought From Chem Nuclear

Address

Commodity

SMK

Moisture

Foreign Material

Damage

Splits

lbs. Gross

68560 lbs. Tare

lbs. Net

Weighing Paid 1.00

Weigher Mc

2.10.4 CNSI Dwg. No. 1-189-101, Rev. AF