CASK RIGGING ANALYSIS

1600 SERIES CASK WITH REDUNDANT EARS

D. K. Dennison

January 24, 1979

CASK RIGGING ANALYSIS - 1600 SERIES CASK

WITH REDUNDANT EARS

Introduction

Preparations are being made to retrieve fuel rods from several failed bundles at the Vermont Yankee Nuclear Power Plant and ship them to General Electric's Vallecitos Nuclear Center for detailed hot cell examination to determine the cause of gadolinia rod failures. The fuel rods will be punctured and the fission gas released to 1000 mil stainless steel bottles. The rods will then be sheared into sections of appropriate length to fit into a G.E. 1600 series cask for shipment from the site. The purpose of this analysis is to assure that the wire rope rigging which is used to attach the G.E. 1600 series cask to the site overhead crane meets NRC load requirements*.

Description of Cask and Rigging

The G.E. 1600 series lead lined cask is fabricated in the shape of a right circular cylinder with outside dimensions of 38½ inches diameter and 68 inches height. The weight of the cask (assuming approximately a 500 pound payload) is 20,000 lbs. The DOT certificate of competent authority, the NRC certificate of compliance, the cask drawings and other related documentation on the cask have already been received by Vermont Yankee personnel.

The rigging which will be used consists of four independent lifting slings. Each sling will be fabricated from 1-inch diameter improved plow steel (IPS) wire rope with independent wire rope center (IWRC). One end of each sling will have a heavy duty wire rope thimble which during application will be mated with a certified shackle which in turn, will be attached to a cask lifting lug (cask ear). The other end of each sling will have a standard soft eye loop which will be mated to the

*Description of a dynamic load test performed on the 1600 cask itself is outlined in Reference 1.

hook of the site non-redundant hoisting crane. The two wire ropes attached to the primary cask ears will be a matched set with total length of 16 feet. The two wire ropes attached to the redundant ears will be a matched set approximately 16½ feet long and will include a turnbuckle which is needed to adjust these cables so they will be taut. All the hardware including the wire rope, turnbuckle, thimbles and shackles will be certified for the required breaking strength, and will be load tested to 40% of that breaking strength.

Dynamic Load Calculation

To provide assurance that the transport mechanism is adequate to preclude the possibility of cask drop when subjected to a dynamic load situation, a series of calculations covering the maximum potential dynamic loads and the safety factors for two separate cases were performed. Case I involves the conditions where the cask is at rest on a solid surface and is then suddenly lifted at maximum hoist velocity. Case II covers the situation where the cask is completely supported by the crane and the hoist instantaneously either accelerates to or deaccelerates from maximum velocity. This rigging calculation is similar to that submitted to the NRC in May 1978 for a Cf-252 source cask which was used at Vermont Yankee for control blade surveillance activities in June 1978. (see Reference 2).

CASE I:

The calculations for Case I are based onthe following assumptions and conditions.

1) The cask, maximum weight of 20,000 pounds, is completely at rest on a solid surface with slack in the lifting mechanism. The crane attains its maximum hoisting velocity of 17.6 ft/min (3.52 in/sec) prior to supporting any portion of the cask weight and then instantaneously lifts the full weight from the surface while maintaining maximum (zero load) velocity.

2) The effective metallic cross-sectional area of each 1-inch rope is 0.394 in^2, the length of rope available for stretch is at least 192 inches, and the modulus of elasticity of the rope is $11x10^6$ psi. Since the slings are 5.8 degrees from vertical when the upper attachment is at the same point, the actual cumulative force on the ropes under static load conditions is 20,100 pounds.

3) There is no deflection or sag in any component of the hoist mechanisms other than the slings. In the interest of conservatism in determing the safety factors, it will be assumed that the total load is borne by only two wire rope slings and that the other two act to provide a fully redundant system.

The total dynamic load or force for vertical motion is equal to the static load component plus the dynamically generated component. For this case, the standard impact formula for a weight falling on an elastic body can, with appropriate conversion, be applied such that

$$\text{TOTAL DYNAMIC FORCE (P)} = W + W\sqrt{1 + \frac{V^2\ EA}{W\ l\ g}}, \quad \text{where}$$

W = static load (20,100 pounds),

A = effective cross-sectional area of two ropes (0.788 in^2),

V = velocity at impact (3.52 in/sec),

E = modulus of elasticity (11 x 10^6 psi),

l = length of stressed component (192 inches), and

g = gravitational acceleration (386.4 in/sec^2).

$$P = 20{,}100 + 20{,}100\sqrt{1 + \frac{(12.4)\ (11x10^6)(0.788)}{(20{,}100)(192)(386.4)}}$$

$$P = 20{,}100\left(1 + \sqrt{1 + .0720}\right) = 20{,}100\ (1 + 1.035) = 40{,}910 \text{ pounds}$$

CASE II:

The calculations for Case II are based on the following assumptions and conditions.

1) The cask, weight of 20,000 pounds, is fully supported by the crane. The hoist is (a) initially at rest and then raises the cask with the hoist instantaneously achieving maximum velocity or (b) lowering the cask at maximum velocity and then the brakes act instantaneously to stop the downward motion of the hoist.

2-3) These are the same as for Case I.

Again, the total dynamic load is equal to the static load component plus the dynamically generated component. Since for this case the static weight of the cask is already under the control of the lift mechanism, the dynamically generated force component is the same as that for a weight moving horizontally at constant velocity which is suddenly stopped by an elastic body. With appropriate conversion the formula becomes

TOTAL DYNAMIC FORCE (P) = $W + W\sqrt{\frac{V^2}{W}\frac{EA}{l\,g}}$, where the factors are the same as for Case I.

$$P = 20{,}100 + 20{,}100\sqrt{\frac{(12.4)(11\times10^6)(.788)}{(20{,}100)(192)(386.4)}}$$

$$P = 20{,}100\left(1 + \sqrt{0.0720}\right) = 20{,}100\,(1 + .268) = 25{,}500 \text{ pounds}$$

<u>Summary</u>

Each sling will be manufactured from wire rope, shackles, thimbles, etc. which will be certified for a breaking strength of 44.9 tons (89,800 pounds) and they will be individually proof tested to 40% of that strength (36,000 pounds).

CASE I:

Static Load = 20,100 lbs.

Static Load Safety Factor = $\frac{2x89,800}{20,100}$ = 8.93 (per sling)

Dynamic Load = 40,910 lbs.

Dynamic Load Safety Factor = $\frac{2x89,800}{40,910}$ = 4.39 (per sling)

CASE II:

Static Load = 20,100 lbs.

Static Load Safety Factor = $\frac{2x89,800}{20,100}$ = 8.93 (per sling)

Dynamic Load = 25,500 lbs.

Dynamic Load Safety Factor = $\frac{2x89,800}{25,500}$ = 7.04 (per sling)

Conclusions

The results of this very conservative analysis indicate conclusively that the cask rigging is adequate to handle the applied load which, even with the most severe handling conditions is 4.39 times less than the sling breaking strength. Under normal operating conditions using experienced crane operators, the actual dynamic loads will be substantially less than the theoretical worst conditions shown here.

References

1) Letter from R.G. Sears to 1600 Series Cask File, "Experiment Description - Dynamic Load Test, 1600 Redundant Cask Ears", January 8, 1979.

2) Letter from R.F. Thibault (General Electric, I&SE, Massachusetts) to W.F. Conway (Vermont Yankee Nuclear Power Corp.),"Control Blade Surveillance - Cask Analysis", May 24, 1978.

January 8, 1979

cc: J. H. Cherb 139
D. K. Dennison M/C ~~403~~
T. C. Hall
M. E. Sauby M/C 138
J. I. Tenorio
J. D. Tuttle

To: 1600 Series Cask File

Subject: EXPERIMENT DESCRIPTION - DYNAMIC LOAD TEST, 1600 REDUNDANT CASK EARS

This test was done to verify the adequacy of the 1603 cask's redundant ears in an emergency situation.

1. Test Location: The Vallecitos Nuclear Center Hillside Cask Storage and Handling Facility.
2. Test Equipment:
   - 1603 cask
   - Redundant ear
   - Four labeled bolts (premeasured)
   - A fork truck
   - Wrenches, slings, shackles, etc.
3. Test Date: July 27, 1978
4. Test Procedure:
   a. The 1603 was placed under the crane with the fork truck.

   b. The redundant ear was attached to the 1603 using the bolts. Torque was ~ 20 ft pounds.

   c. A shackle was set in the ear and rigged with a sling.

   d. The sling was connected to the crane hook.

   e. The sling was pulled tight (see position 1 attached sketch).

   f. Using the jog button on the crane control, the cask was slowly raised until position 2 was reached.

   g. At position 2 the crane was jogged again pulling the ground support point off the ground. The cask over centered with a jerk (position 3A) and swung to a stop (position 3B).

   h. The fork truck was used in lowering the cask to safety to position 1.

4. i. The bolts and redundant ear were removed and surveyed fo possible contamination.

   j. The ear and bolts were checked for damage and the bolts remeasured.

5. Results:

   a. No deformation or cracking was found on the ear, base metal, or welds.

   b. No visible damage was found in the bolt inspection.

   c. The bolts were remeasured to the nearest 0.001" and no permanent set was observed.

6. Conclusions:

   a. Lifting the 1603 with one ear proves that the ear is capable of handling twice its required emergency service load.

   b. The 1603 experienced a sudden load transfer. As reported in item 4.g above, the cask broke loose from the ground support point and swung into position with a jerk. The actual event was a more severe load than the sudden load transfer criteria specified by Roark*. The dynamic loading of a sudden load doubles the static load involved. Therefore, the redundant ear was successfully tested without damage to four times its required emergency service load.

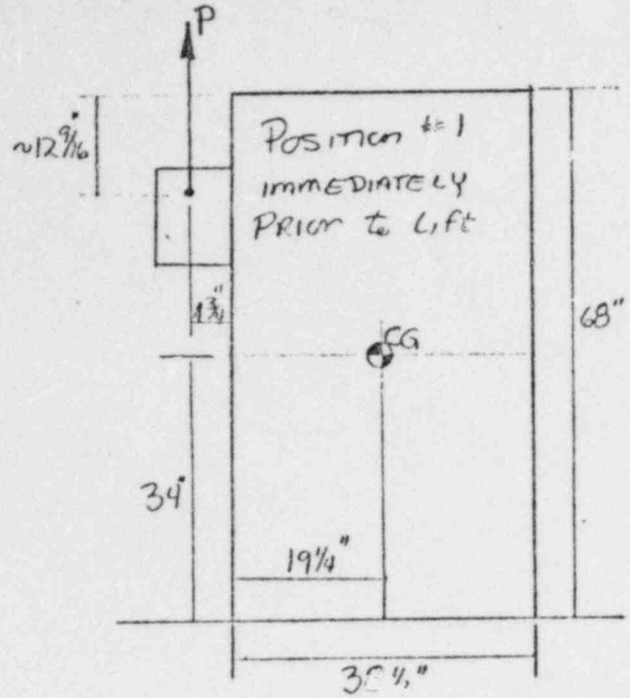
R. G. Sears
Equipment Engineer

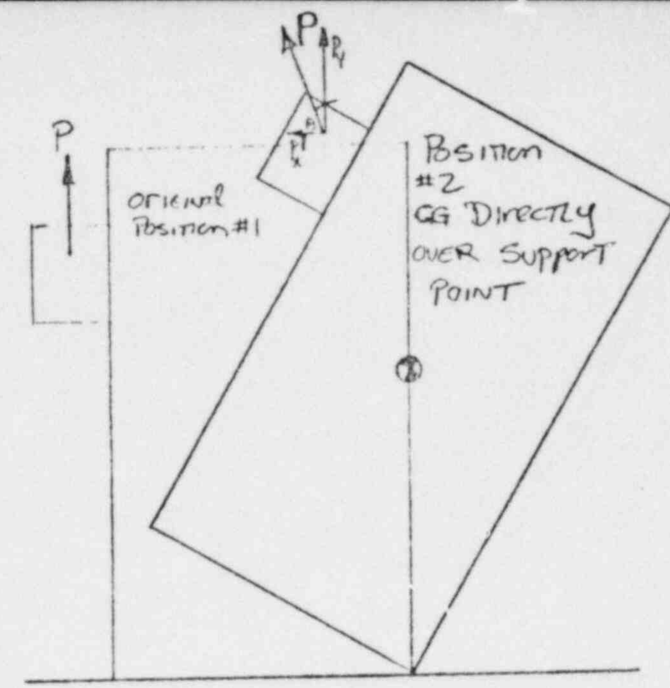
Reviewed and Approved: [signature]
T. C. Hall, Manager
RP&S Equipment Engineering

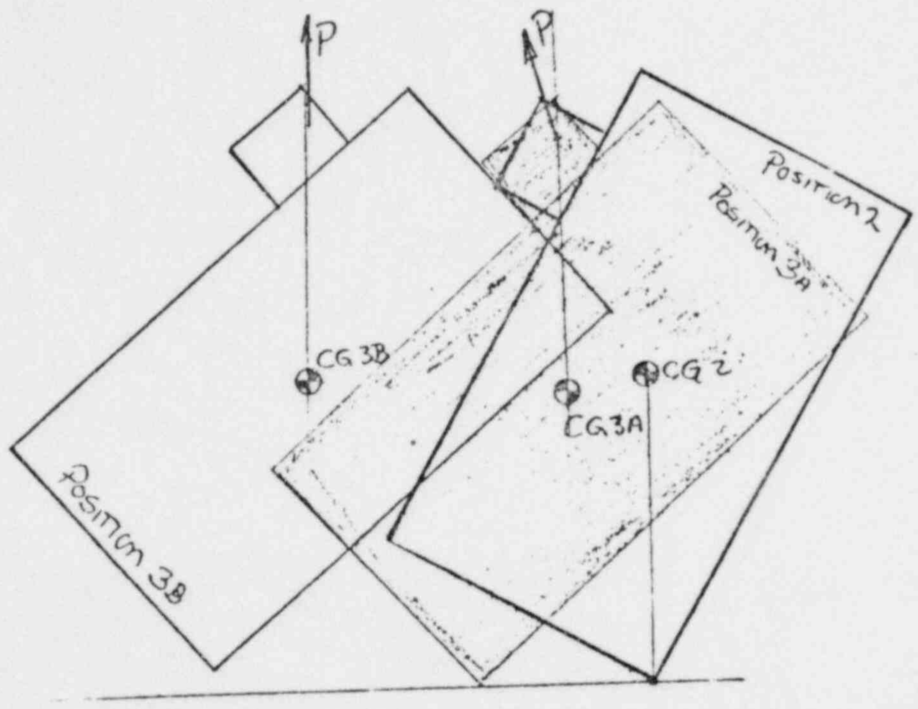
bjs

*Roark, R. J., Formulas for Stress and Strain, 4th Ed., 1965, McGraw-Hill, p 21

1600 CASK HOIST TEST
(RIGGED by ITS Redundant EAR)







Position #1 - AS P IS APPLIED TO The EAR the CASK begins TO RAISE UP UNTIL ...

Position #2 - WHERE the point of support is Directly beneath the CG. The Hoist remains stationary so as the CASK PIVOTS About ITS SUPPORT POINT Px develops with the offset pull angle, θ

Position #3 - With the hoist raising and the cask pivoting the CG shifts unstabily past the point of support. The CG falls directly beneath the hoist point (Position 3A). The cask then swings to position 3B to stablize the system.

[signature] 1-5-79

LOADING SUMMARY

The actual loading will incorporate all four cable slings and all four lifting ears by using turnbuckles in the redundant ear cables. These will be adjusted to establish tension in all four lines. For the analysis, however, it is assumed that the entire weight is taken by two of the rigging cables.

It is planned that the non-redundant look on the crane will be utilized. There is a substantial margin of safety between the 10 ton cask load and the 110 ton rated crane capacity.

Two cases of dynamic load ore shown for comparison in the rigging section and the attached Table I of safety factors; however, only Case II with the load suspended is considered applicable for review against the criteria for static plus dynamic load.

The material used in the redundant ear and bolting is stainless steel. The yield strength is based on the minimum yield strength of 30,000 psi as listed in the ASME Boiler and Pressure Vessel Section III Table I-2.1 (100°F or less).

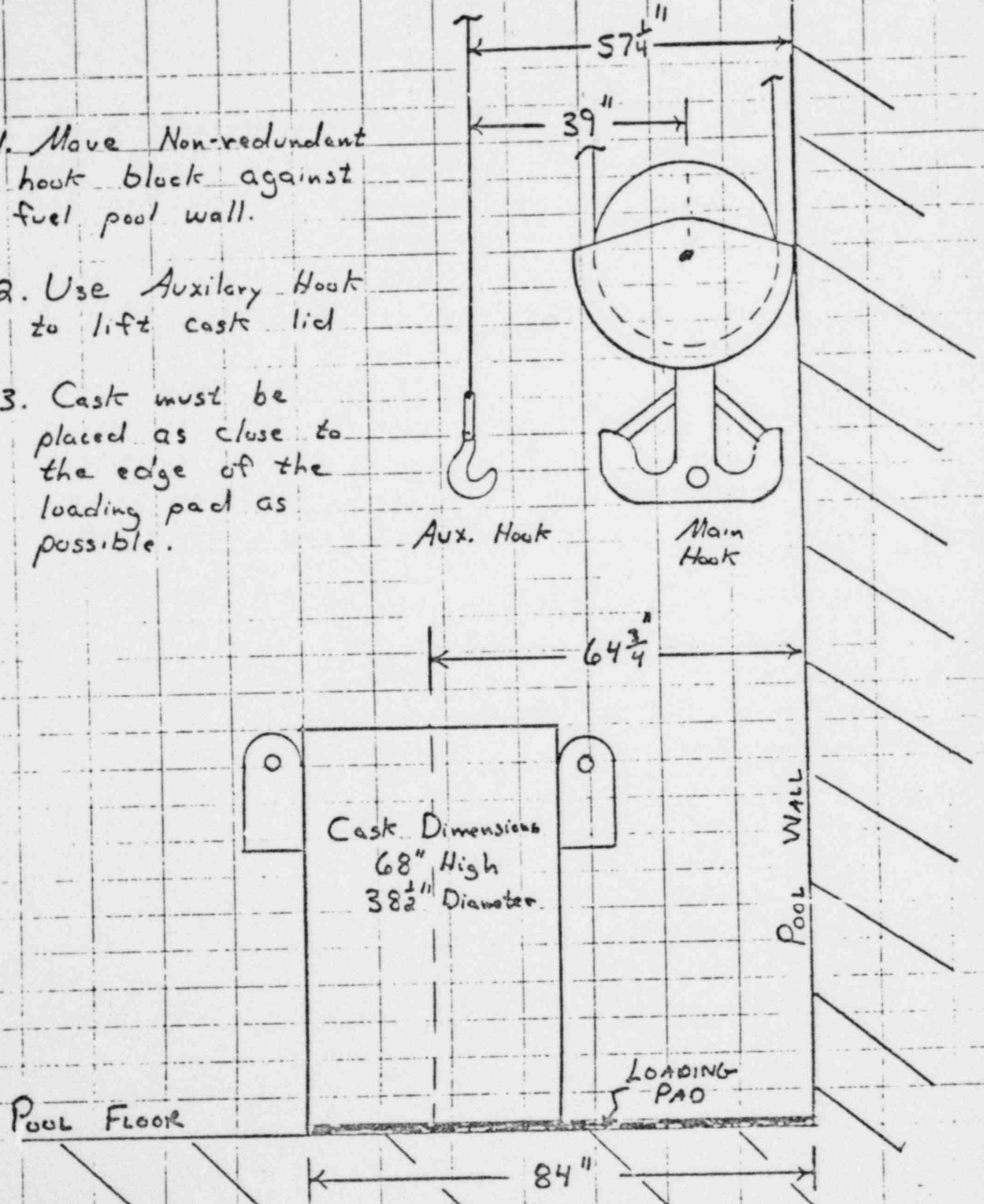
The safety factors in Table I for the redundant ear are based on yield and those for the cable are based on manufacturer's published breaking strength. Shear yield is based .577 times the tensile yield strength per distortion energy theory.

CASK LOADING METHOD

1. Move Non-redundant hook block against fuel pool wall.

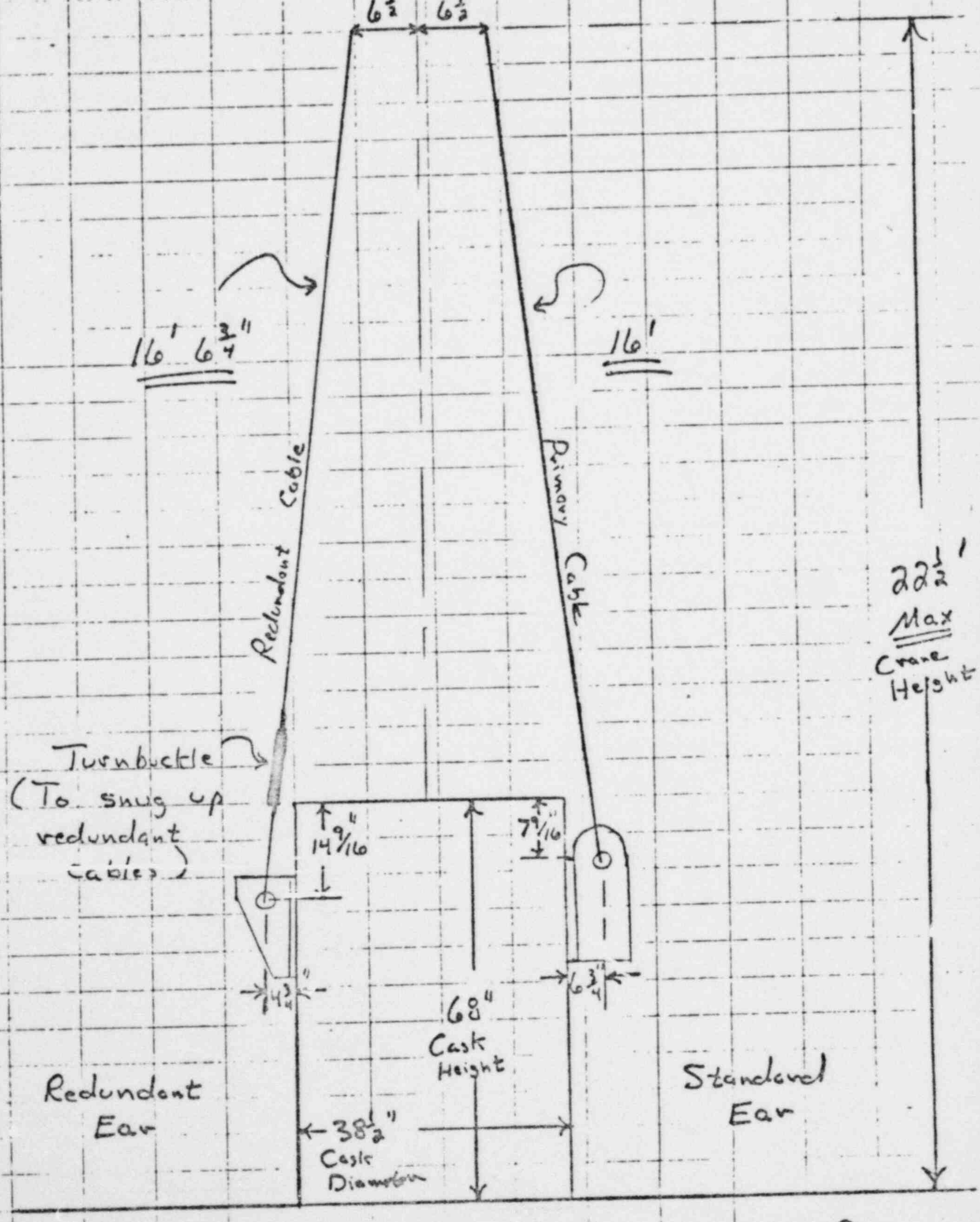
2. Use Auxilary Hook to lift cask lid

3. Cask must be placed as close to the edge of the loading pad as possible.



1/22/79

VERMONT YANKEE CABLE RIGGING
1600 CASK



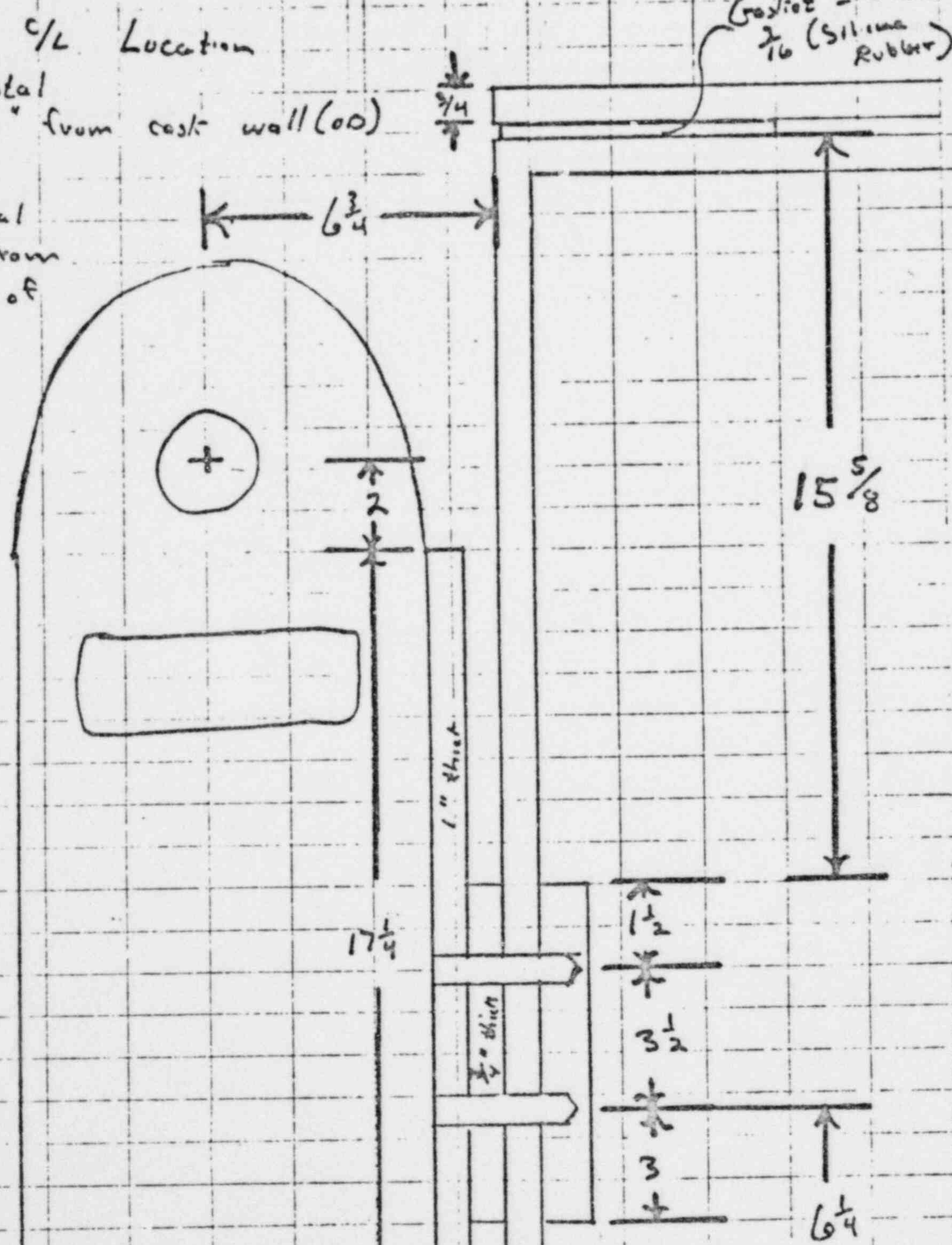
1/18/79

Vermont Yankee Cable Rigging
1600 Cask

S[illegible]ARD EAR DIMENSIONS

Earhole C/L Location

1. Horizontal
   $6\frac{3}{4}$" from cask wall (OD)
2. Vertical
   17" From bottom of cask support ring

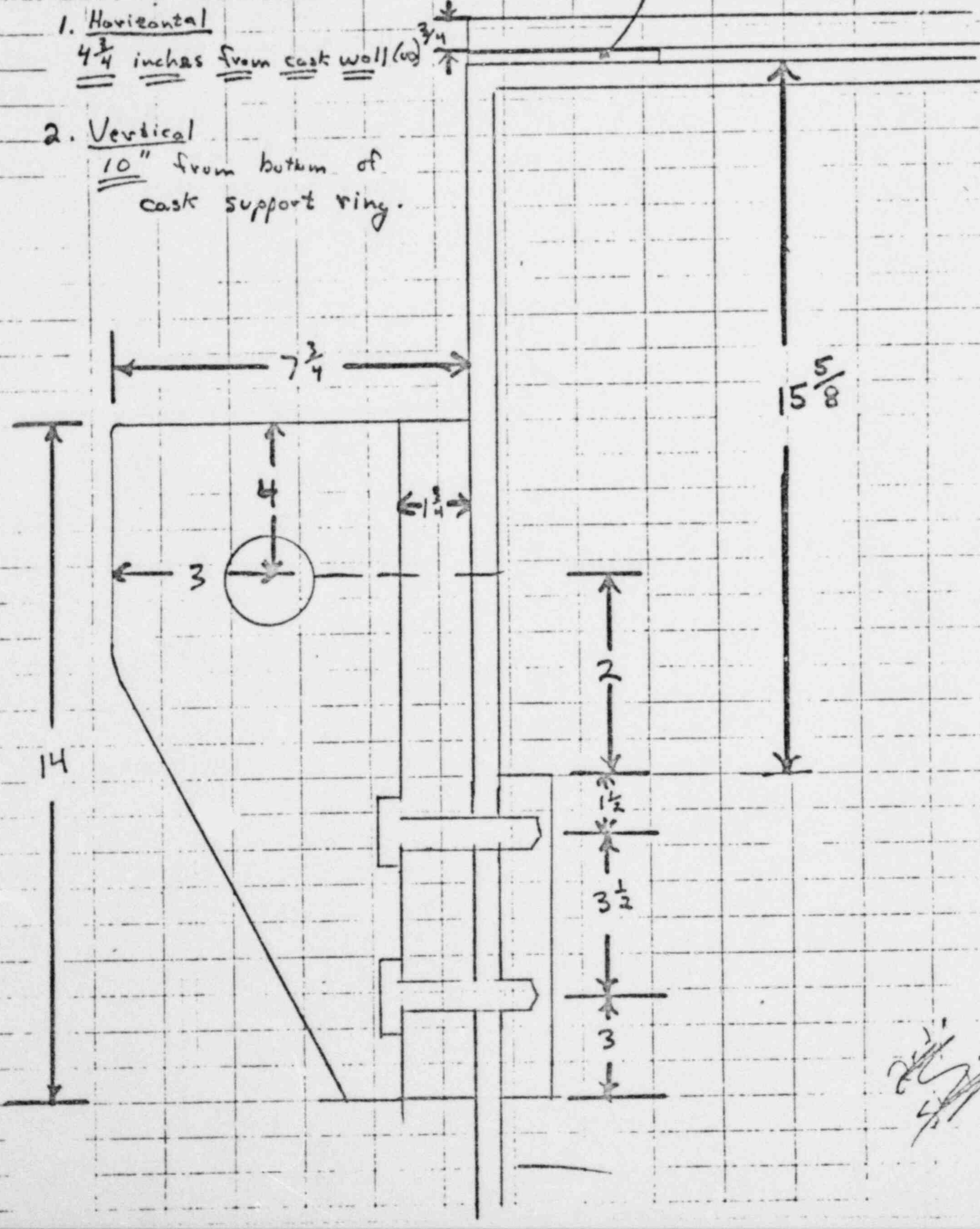


REDUNDANT EAR DIMENSIONS

Earhole C/L location

1. Horizontal
   4 3/4 inches from cask wall (OD)

2. Vertical
   10" from bottom of cask support ring.



1600 SERIES CASK - REDUNDANT EARS

Purpose:

This memo derives the stress applied to the redundant ears of the 1600 cask from the static weight of the cask (19,500 lbs) plus the payload (500 lbs). All of the weight is assumed to be carried by the two redundant ears (10,000 lbs/ear) with no load on the primary ears. The discussion on dynamic load and safety factors is contained in the Loading Summary section of this cask rigging review package.

Only the redundant ears and their load path to the cask are here addressed. These ears are not considered an integral part of the cask since they are removed for shipping and are installed on site prior to the cask lift. In addition, the redundant ears have been added since the issuance of the NRC Certificate of Compliance #9044 Revision 2.

Outline:

Four major load analyses are contained here on the following components:

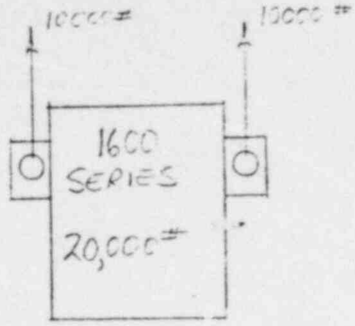
1. Ear Pull-Out -- The effect of the shackle pin on the ear.

2. Ear Tensile Loading -- Adequacy of the ear crossection.

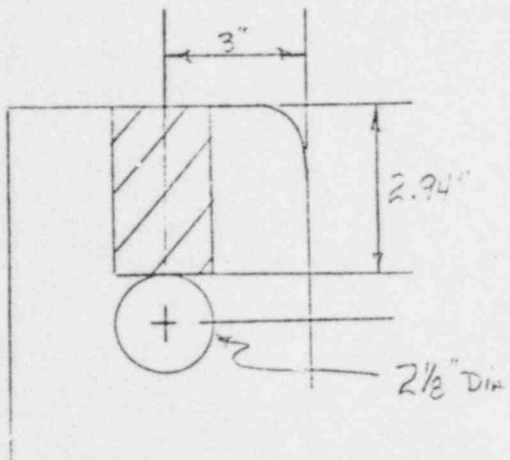
3. Ear Weld Loading -- The effects of shear and moment on the welds joining the two plates forming the lifting ear.

4. Bolt Loading -- The stresses on the four 1" bolts connecting each ear to the cask.

1. Ear Pull-Out



Each ear is subjected to a 10,000# load at the shackle pin.



All shear area is conservatively considered to be above the top of the hole.

A 2-1/8" shackle pin

Shear Area, A

2x2.94"x1" = 5.88 sq in

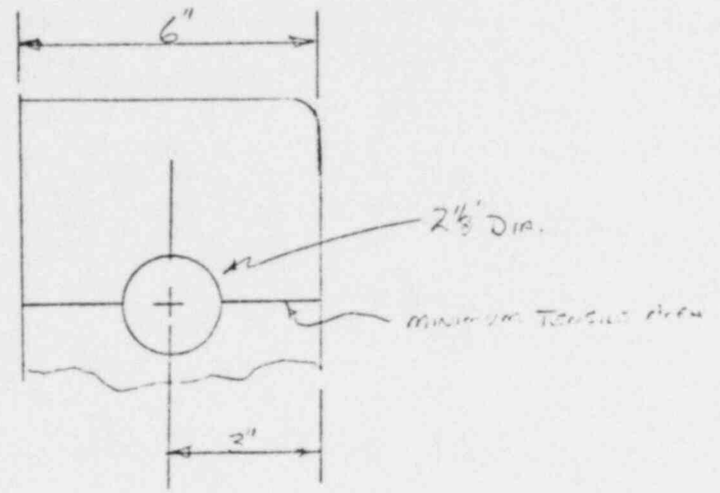
$\tau = F/A$

$F = 10,000\#$

$\tau_1 = \frac{10,000\#}{5.88 \text{ sq in}}$

$\tau_1 = 1700$ psi

2. Ear Tensile Load



The following analysis takes no credit for any load being carried by the welds above the minimum tensile area. This causes the total load to be applied through the minimum tensile area and is, therefore, conservative.

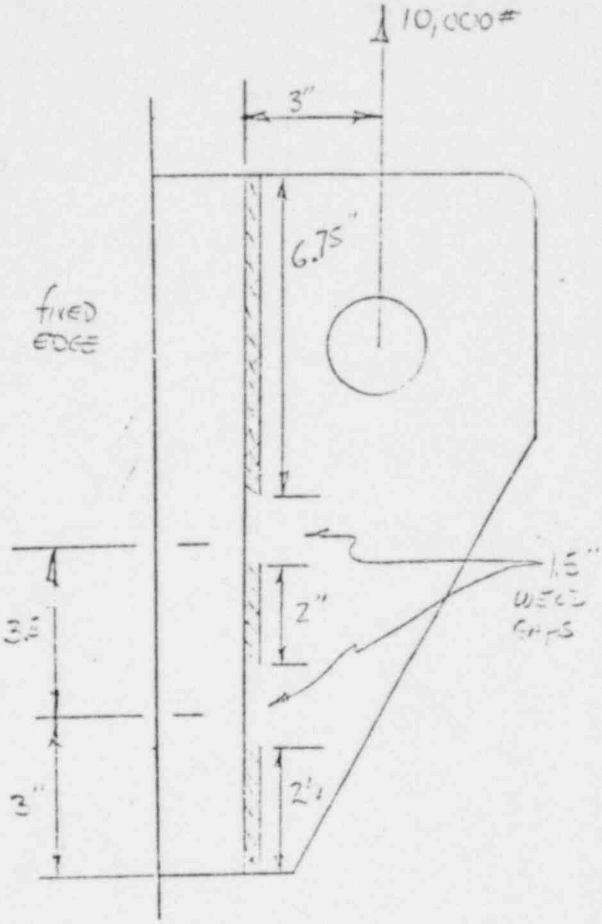
Tensile Area = (6" - 2.12")x1" = 3.88 sq in

σ = F/A   and again F = 10,000#

σ = 10,000#/3.88 sq in = 2580 psi

3. Ear Weld Loading

The model shown in the Figure will be used. No credit will be taken for the 1/8" welds in the vicinity of the bolt holes or the 1/16" seal welds at the top and bottom of the ear. So 11" of weld remain per side.



Weld Shear and Normal Stress

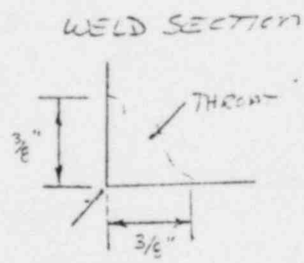
Based on Shigley*
pp 284-286

Shear

$$\tau = \frac{V}{A}$$

$$= \frac{10{,}000\#}{2x.707x.375"x11"}$$

$$= 1710 \text{ psi}$$



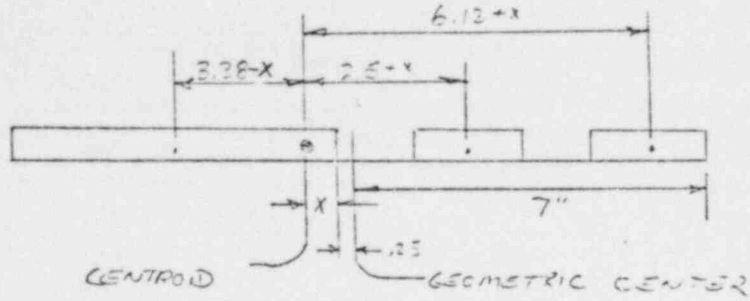
Normal Stress

$$\sigma_X = \frac{MC}{I}$$

M - Acting Moment
C - distance to centroid (max.)
I - moment of inertia

*Shigley, Mechanical Engineering Design, 3rd Ed., McGraw Hill, 1977

Centroid of Weld



Weld Centroid Calculation

$$6.75\ (3.38-X) = 2(2.5+X) + 2.25\ (6.12+X)$$

$$22.8 - 6.75X = 5 + 2X + 13.8 + 2.25X$$

$$11X = 4$$

$$X = .364$$

$\therefore$ The centroid is located 7.61" from the right side of the illustration.

Moment of inertia

Step 1

Using the parallel axis theory

$$I = \Sigma\ (I_{cg} + Ad^2) \qquad I_{cg} = \frac{1}{12}\ bh^3$$

Without the weld skip

$$I = .707x.375x14^3/12 + .707x.375x14x.61^2$$

$$= 60.63 + 1.38 = 62.0\ in^4$$

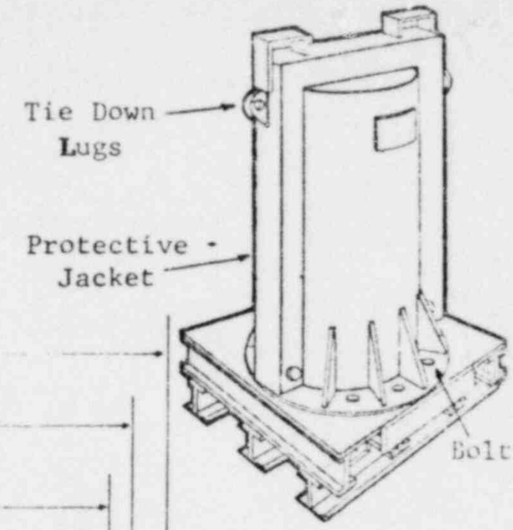
A - Weld Area
d - Parallel axis offset
b - Weld throat
h - Weld length

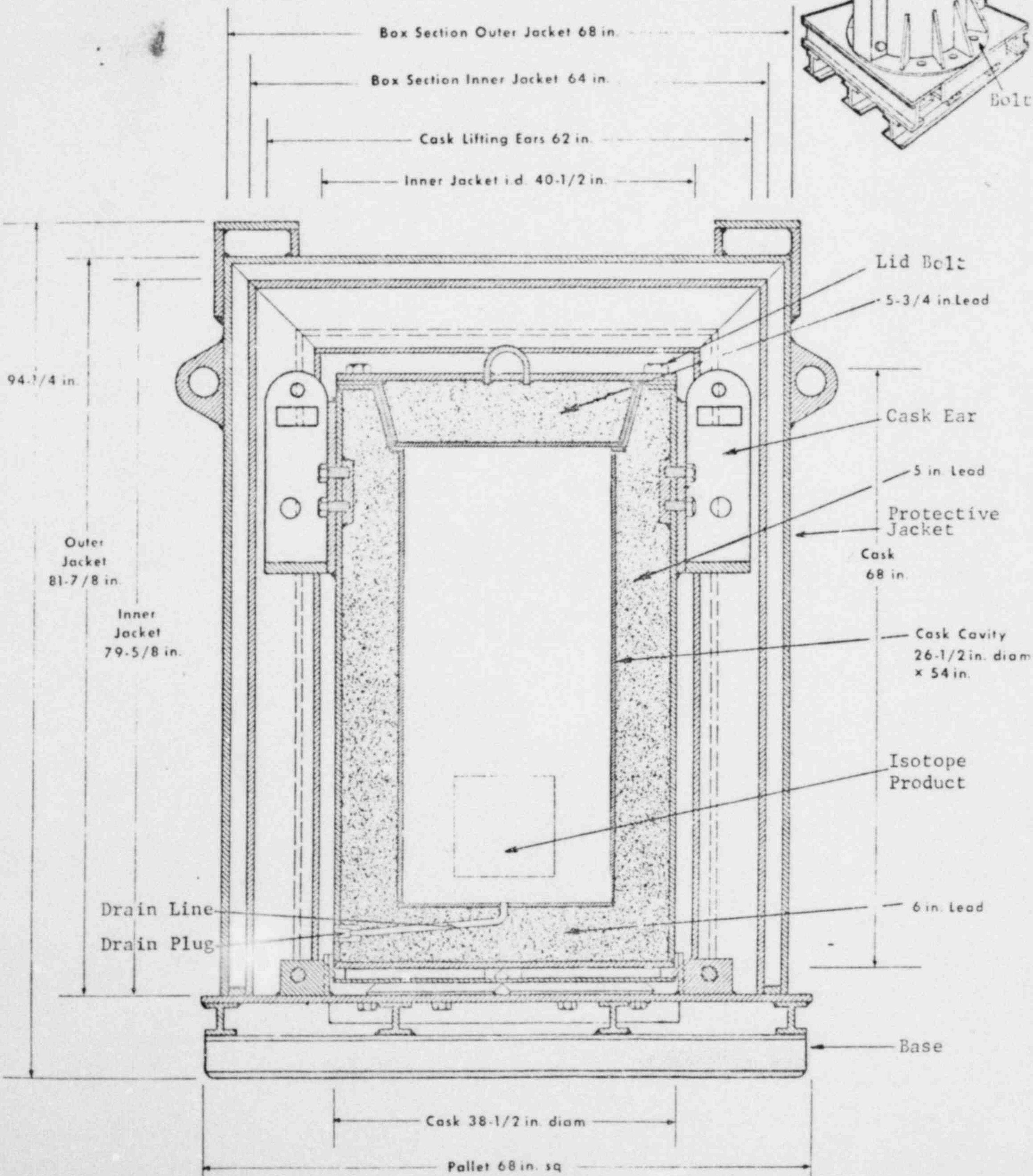
1600 Series D O T SP No 5980
Cask Weight 19,500 Lbs - 8,864 Kgs
Assembly Weight 25,950 Lbs - 11,800 Kgs
Assembly Drawing No 106D3986G1
Modes of Transportation - Motor Vehicle Only
Watt Load at 100°F Ambient 600 Watts
Fissile Load 500/300/300 Grams as Fissile Class III

Liner Cavity
20-1/4 in. diam
× 46 in.

Liner Cavity
7-7/8 in. diam
× 37 in.

Liner Cavity
3-3/8 in. diam
× 36 in.





GENERAL ELECTRIC - MODEL 1600 SHIELDED CONTAINER

9. For packaging of neutron sources, measurements shall be made to determine that the dose rate does not exceed 1000 mrem/hr at 3 feet from the surface of a dry cask with no additional shielding within the cask.

10. The package authorized by this certificate is hereby approved for use under the general license provisions of Paragraph 71.12(b) of 10 CFR Part 71.

11. Expiration date: May 31, 1980.

REFERENCES

General Electric application dated January 8, 1969.

Supplements dated: February 12, 20, and 27, March 10, 24, and April 18, 1969; November 20, 1970; January 29 and March 12, 1971; and July 3 and November 15, 1973.

Nuclear Plant Services supplement dated: July 7, 1975.

FOR THE U.S. NUCLEAR REGULATORY COMMISSION

Charles E. MacDonald

Charles E. MacDonald, Chief
Transportation Branch
Division of Fuel Cycle and
Materials Safety

Date: APR 13 1977

5. (b) Contents (continued)

(1) Type, form, and maximum quantity of material per package (continued)

(iv) Irradiated UC and ThC fuel particles clad in graphite and contained within a standard HTGR hexagonal cross-section graphite block. Decay heat not to exceed 600 watts. Each graphite block shall be contained within a sealed cylindrical inner container constructed in accordance with General Atomic Company Drawing No. 021583, Issue A with three 1/2-inch by 4-1/2-inch radial fins to provide centering within the cavity.

1,400 grams U-235 equivalent mass in each inner container with no more than one inner container per package.

(c) Fissile Class — III

Maximum number of packages per shipment

(i) Contents 5.(b)(1)(i), 5.(b)(1)(ii), or 5.(b)(1)(iii):

Two (2); or

(ii) Contents 5.(b)(1)(iv):

One (1)

6. The U-235 equivalent mass is determined by U-235 mass plus 1.66 times U-233 mass plus 1.66 times Pu mass.

7. For packaging of neutron sources, the cavity drain line shall be closed with a plug with a melting temperature of 200°F and the cask cavity shall be filled with water with a 5-inch air space within the cask cavity. When needed, sufficient antifreeze in the cask shall be used to prevent damage to any component of the package due to freezing.

8. For packaging of other than neutron sources, the cask shall be delivered to a carrier dry and the cavity drain line shall be closed with a plug which will maintain its seal at temperatures up to at least 620°F.

5. (a) Packaging (continued)

(3) Drawings

The packaging is constructed in accordance with the following General Electric Company Drawings Nos.:

212E255, Rev. 3
106D3986, Rev. 1
174F237, Rev. 1
135C5598, Rev. 1
106D3973, Rev. 1

(b) Contents

(1) Type, form and maximum quantity of material per package

(i) Byproduct material and special nuclear material as solid metal or oxides. Decay heat not to exceed 600 watts. All material shall be clad, encapsulated or contained in a metal encasement and tested for leak tightness prior to loading in the package in accordance with the statements and representations contained in the licensee's submittal dated February 12, 1969.

500 gm U-235 equivalent mass; or

(ii) Neutron sources in special form.

500 gm U-235 equivalent mass. Decay heat not to exceed 50 watts; or

(iii) Irradiated PuO_2 and UO_2 fuel rods clad in zircaloy or stainless steel. Decay heat not to exceed 600 watts. All fuel rods shall be contained within a closed 5-inch Schedule 40 pipe with a maximum useable length of 39-5/8 inches.

1,200 gm fissile material with no more than 300 gm fissile material per 5-inch Schedule 40 pipe.

Form NRC-618
(12-73)
10 CFR 71

U.S. NUCLEAR REGULATORY COMMISSION
CERTIFICATE OF COMPLIANCE
For Radioactive Materials Packages

1.(a) Certificate Number	1.(b) Revision No.	1.(c) Package Identification No.	1.(d) Pages No.	1.(e) Total No. P
9044	2	USA/9044/B( )F	1	4

2. PREAMBLE

2.(a) This certificate is issued to satisfy Sections 173.393a, 173.394, 173.395, and 173.396 of the Department of Transportation Hazar Materials Regulations (49 CFR 170-189 and 14 CFR 103) and Sections 146-19-10a and 146-19-100 of the Department of Transportation Dangerous Cargoes Regulations (46 CFR 146-149), as amended.

2.(b) The packaging and contents described in item 5 below, meets the safety standards set forth in Subpart C of Title 10, Code of Federal Regulations, Part 71, "Packaging of Radioactive Materials for Transport and Transportation of Radioactive Material Unde Certain Conditions."

2.(c) This certificate does not relieve the consignor from compliance with any requirement of the regulations of the U.S. Department o Transportation or other applicable regulatory agencies, including the government of any country through or into which the packa will be transported.

3. This certificate is issued on the basis of a safety analysis report of the package design or application—

3.(a) Prepared by (*Name and address*):
General Electric Company
P. O. Drawer B
Pleasanton, California 94566

3.(b) Title and identification of report or application:
General Electric Company application dated January 8, 1969, as supplemented.

3.(c) Docket No. 71-9044

4. CONDITIONS
This certificate is conditional upon the fulfilling of the requirements of Subpart D of 10 CFR 71, as applicable, and the conditions specifi in item 5 below.

5. Description of Packaging and Authorized Contents, Model Number, Fissile Class, Other Conditions, and References:

(a) Packaging

(1) Model No.: GE-1600

(2) Description

Steel encased lead shielded shipping cask. A double-walled steel cylinder protective jacket encloses the cask during transport. It is bolted to a steel pallet. The cask is closed by a lead-filled flanged plug fitted with a silicone rubber gasket and bolted closure. The cavity is equipped with a drain line and the physical description is as follows:

Cask height, in	67.5
Cask diameter, in	38.5
Cavity height, in	54.0
Cavity diameter, in	26.5
Lead shielding, in	5.0
Protective jacket height, in	81.4
Protective jacket width, in	68.0
Packaging weight, lbs	23,050

cc: w/encl
Mr. Alfred W. Grella
Department of Transportation

Chem-Nuclear Systems, Inc.
ATTN: Mr. J. Stewart Corbett
P. O. Box 1866
Bellevue, Washington 98009

Boston Edison Company
ATTN: Mr. J. E. Larson
800 Boylston Street
Boston, Massachusetts 02199

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

APR 13 1977

FCTR:RHO
71-9044

General Electric Company
ATTN: Mr. G. E. Cunningham
P. O. Drawer B
Pleasanton, California 94566

Gentlemen:

Enclosed is Certificate of Compliance No. 9044, Revision No. 2, for the Model No. GE-1600 shipping package. This certificate supersedes, in its entirety, Certificate of Compliance No. 9044, Revision No. 1, dated August 15, 1975.

Changes made to the enclosed certificate are indicated by vertical lines in the margin.

General Electric Company, Boston Edison Company, and Chem-Nuclear Systems, Inc. have been registered as users of this package under the general license provisions of Paragraph 71.12(b) of 10 CFR Part 71 or 49 CFR §173.393a.

This approval constitutes authority to use this package for shipment of radioactive material and for the package to be shipped in accordance with the provisions of 49 CFR §173.393a.

Sincerely,

Charles E. MacDonald

Charles E. MacDonald, Chief
Transportation Branch
Division of Fuel Cycle and
Material Safety

Enclosure:
As stated

cc: See Next Page

$$Y = X\left(\frac{d - d_t}{d - d_r}\right) = \left(\frac{3}{8}\right)\left(\frac{1}{8}\right)\left(\frac{1 - .878}{1 - .838}\right) = .035"$$

$L = 2Y + P/8 = 2\ (.035) + 1/8\ (1/8) = .086$ in/thread

Assuming 1" bolt engagement N = 8

$A_s = nLC_t = 8 \times .086 \times \pi \times .878 = 1.90$ sq in

Shear Stress at the highest loaded bolts.

$\tau = B_{1/A_s} = 1580\#/1.90$ sq in $= 832$ psi

Looking at the worst case

$\sigma = B_1/A$ Tensile stress area for 1" UNC = 0.606 sq in

σ = 1580#/.606 in sq = 2610 psi

Bolt shear load

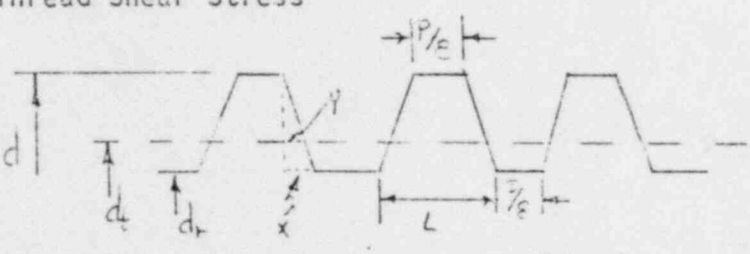
$$R_{1y} = R_{2y} = \frac{10{,}000\#}{4}$$

$$\tau_{1y} = \tau_{2y} = \frac{10{,}000\#}{4 \times .606 \text{ sq in}} = 4120 \text{ psi}$$

Principal Stress*

$$\sigma = \frac{2610}{2} + \sqrt{\left(\frac{2610}{2}\right)^2 + 4120^2} = 5630 \text{ psi}$$

Thread Shear Stress



d = 1"

d_t = .878

d_r = .838

$A_s = nLC_t$

$L = 2y + P/8$

$$\frac{Y}{X} = \frac{d - d_t}{d - d_r}$$

$X = 1/2\ (P - P/4) = 3/8P = 3/8(1/8)$

Where n = # of engaged threads

L = width of thread at d_t

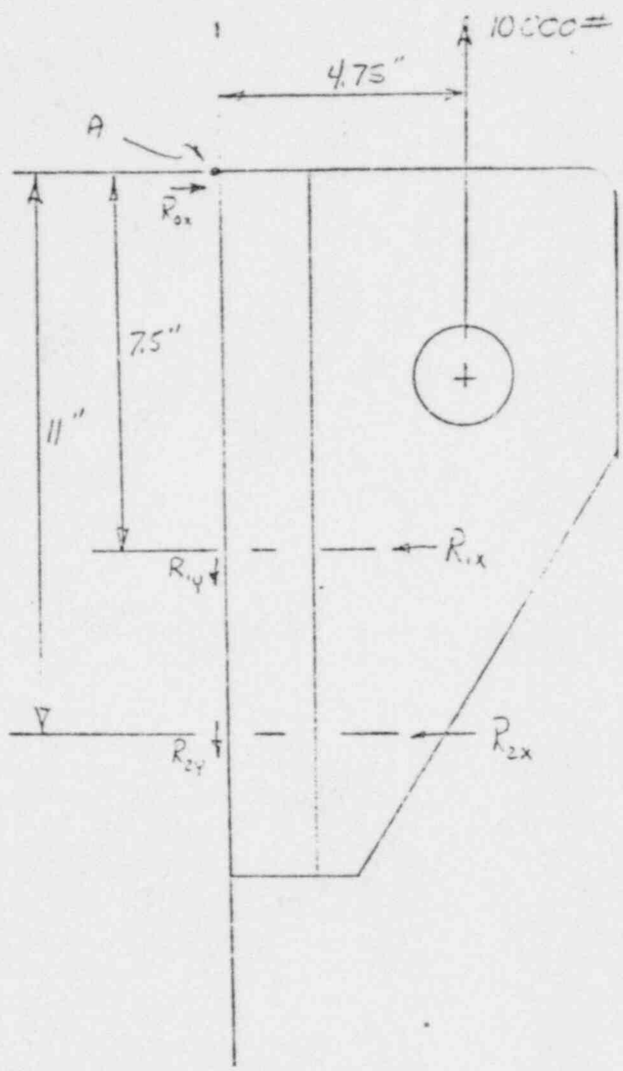
C_t = circumference of thread at $d_t = \pi d_t$

P = 1/8" (1" UNC bolts have 8 threads/inch)

*Shigley, p 29

4. Bolt Loading

The geometry of the ear will level the bolt in both shear and tension. In addition, the thread loading will be investigated.



Summing Moments

$$47{,}500 = 7.5R_{1x} + 11R_{2x}$$

Assuming in the worst case that each bolt takes equal moment.

$$7.5R_{1x} = 11R_{2x}$$

$$\frac{R_{1x}}{R_{2x}} = \frac{11}{7.5} = 1.47$$

$$R_{1x} = 1.47\ R_{2x}$$

$$47{,}500\ \text{in\#} = 22R_{2x}$$

$$R_{2x} = 2160\#$$

$$R_{1x} = 3170\#$$

Since each reaction force is made up of two bolts

$$B_1 - 1580\#$$

$$B_2 = 1080\#$$

Step 2

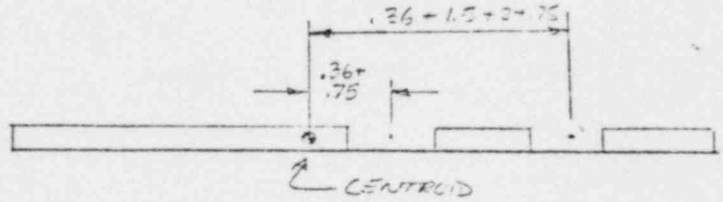
Subtract skips

Centroid

$$I = 62.0 - (1/12 x .707 x .375 x 1.5^3 + 1.5 x .707 x .375 (.75 + .36)^2)$$

$$- (1/12 x .707 x .375 x 1.5^3 + 1.5 x .707 x .375 (4.25 + .36)^2)$$

$$= 62.0 - (.07 + .49) - (.07 + 8.45) = 52.9 \text{ in}^4 \text{ per weld}$$



I = 106 for 2 welds

Moment

$$M = FXL = 10{,}000\# \times 3.00'' = 30{,}000''\#$$

$$\sigma = \frac{MC}{I} = \frac{30{,}000\ (7 + .61)}{106} = 2150 \text{ psi}$$

Principle Stress (Shigley, p 29)

$$\sigma = \frac{2150}{2} + \sqrt{\left(\frac{2150}{2}\right)^2 + 1710^2} = 3100 \text{ psi}$$