Addendum to Application
for Amendment of License SNM-1107
for NFD Shipping Packages,
dated July 13, 1973

14. RCC-4 Packaging

14.1 Packaging Description

Designation-RCC-4 Shipping Container
Gross Weight-8400 pounds
Fabrication - The design and fabrication details for shipping containers in the RCC-4 series are given in Equipment Specification E-953511 and Westinghouse drawings 1460E92 and 1460E94, which are attached as Appendix L to our application dated January , 1979 on Docket 71-5450. Westinghouse drawing 1460E96 is also included in that Appendix L to indicate the location of, and the method of retaining poison plates in the packaging, when they are required.
Coolents - Not applicable

14.2 Contents Description

The descriptions and discussions given in Section 4.2 of reference 1 will be directly applicable in all respects if "and Appendix L" is added after "Appendix A" and drawing 1460E96 is substituted for "drawing 684J580."

14.3 Compliance with Subpart C of 10CFR71

The descriptions and discussions given in Section 4.3 of reference 1 will be directly applicable in all respects if "Equipment Specification E-953511 is substituted for "Equipment Specification E-676200."

14.4 Limits and Controls

The Fissile Class II Limit, Fissile Class III limit and the Procedural Controls presented in Sections 4.4, 4.5, and 4.6 of reference 1 respectively, will apply directly if "Equipment Specification E-953511" is substituted for "Equipment Specification E-676200."

REPORT ON TEST OF FRESH FUEL SHIPPING CONTAINER P/N: 203R001-1 30 FT. DROP TESTS & PIN DROP

FOR

BABCOCK & WILCOX COMPANY
POWER GENERATION DIVISION
NUCLEAR POWER GENERATION DEPT.
LYNCHBURG, VIRGINIA

TESTS PERFORMED BY

CONTAINER RESEARCH CORPORATION
GLEN RIDDLE, PA.

REPORT DATE: 13 January 1970

TEST DATE: 6-7 January 1970

TABLE OF CONTENTS

1.0 PURPOSE:

1.1 The purpose of the tests herein is to verify by prototype testing that the design and construction of the FRESH FUEL SHIPPING CONTAINER will retain the contents in a nuclear safe configuration through a hypothetical accident condition of a 30 Ft. Free Drop. NUCLEAR SAFE CONFIGURATION is defined for this purpose as the two fuel assemblies, the boron-steel poison plates, and the steel strongback plates retained in essentially design relationship; and all retained within the container shell.

2.0 SUMMARY:

2.1 All of the required elements for a nuclear safe configuration were maintained upon complete inspection of the container following the final drop test.

2.2 The final clearances as well as a record of damage to the container are listed in Section 8.0 TEST RESULTS.

3.0 CONCLUSIONS:

3.1 Based on the satisfactory final container configuration, both internal and external, it was unanimously concluded by all attending witnesses as well as the report writer that the container more than adequately performed its desired functions. Much greater damage was anticipated than was actually experienced and no further modification of the container is required to improve its performance under these extremely severe test conditions.

4.0 RECOMMENDATIONS:

4.1 Since the tests herein were performed on a prototype container which had previously been qualification tested and documented (Reference: Container Research Corporation Document No: CRC-69-10 dated 12/10/69), there is every reason to believe that this container design has the structural integrity required to fulfill its mission.

4.2 It is hereby recommended that this container P/N 208R001-1 be granted approval for shipment of production fresh fuel cells

5.0 CONTAINER DESCRIPTION:

5.1 The container description in Section 4.0 of Document No: CRC-69-10 applies with the exception of Para. 4.2 Physical Data which is modified below:

WEIGHTS:

Container & Frame	3940 lbs.	(same)
Fresh Fuell Cells (2)	3360 lbs.	(was 3000)
	7300 lbs.	(was 6940)

6.0 METHOD OF TEST:

6.1 GENERAL:

Two dummy fuel cells (1680 lbs. ea.), were installed in the prototype container and the container cover was secured as ready for shipment.

6.1.1 The container was then subjected to the following test sequence:

a.) Drop #1 Bottom Drop - 30° Rotational

b.) Cover removed for examination of contents

c.) Drop #2 Cover Drop - 30° to horizontal

d.) Drop #3 40 inch Pin Drop (inverted)

e.) Cover removed for examination of contents

6.2 INSTRUMENTATION:

NOT REQUIRED - NOT PROVIDED.

7.0 TESTS:

7.1 DROP #1 BOTTOM DROP-ROTATIONAL:

The loaded container was placed on the ground on its skids. A cable sling was attached to the lifting eyes in the stacking brackets (one hook in each stacking bracket). The sling was then attached to a quick release mechanism on the crane. The container was then lifted off the ground in such a manner that the AFT END raised off the ground first to an angle of 30° to the horizontal (see sketch in appendix A) before the FWD END left the ground. The container was raised to a height of 30 Ft. from the bottom of the skids at the FWD END to the ground. This was determined by a 30 Ft. length of string attached to the FWD END skids with a small weight at the end of the string which just left the ground when the correct height was attained. The quick release was then actuated and the container fell freely to the ground in the same attitude in which it was suspended causing the AFT END to rotate to the ground after the FWD END struck. See appendix B for photographs of results.

7.1.1 The container was then opened and examined for damage. See Section 8 for TEST RESULTS.

7.2 DROP #2 COVER DROP - 30° ANGLE:

The container was placed on its cover with the four skids sticking straight up. The container was then rolled over 30° toward its side until the sealing flange was at a 30° angle from the horizontal (see sketch in appendix A.) A sling was attached to the container and the quick release mechanism on the crane. The container was raised to a height of 30 Ft. from the cover to the ground. The quick release was actuated and the container fell freely to the ground on its cover. The container was not opened after this test for fear of not being able to replace the cover for the pin drop test.

7.3 40 INCH PIN DROP TEST:

A steel pin (size 6 in. dia. x 8 in. lg. with 1/4 in. radius around top circumference) was placed on the ground and the container raised above the pin to a height of 40 inches to the top of the pin. The container was angled in such a manner as to present the undamaged side of the cover to the pin. Upon release, the container cover struck the pin squarely and rolled over on its side to the floor. Photographs were taken of the container and pin immediately thereafter.

7.3.1 The container was then uprighted and the cover removed for examination of the container contents.

7.3.2 See Section 8 for RESULTS OF THE TEST SERIES.

8.0 TEST RESULTS:

8.1 Photographs were taken during the test series and are included in Appendix B.

8.1.1 The following is a list of the photographs and an explanation of what they depict:

PHOTO NO.	DEPICTION
1	Showing container prior to release during drop #1

DOCUMENT NO: CRC-70-1

ISSUE DATE: 1/13/70

PHOTO NO.	DEPICTION
	Bottom Drop - 30° Rotational. NOTE: That the container angled in relation to crane boom.
2.	Immediately after Drop #1. NOTE: The splintered skids (FWD END)
3.	AFT END - this end suffered the rotational impact and bottom end plate distortion of 1 in. out of vertical plane. Also the pork chop was severely distorted.
4.	Showing cover removed - general view looking FWD. The support rod broke loose from its storage position and is leaning against clamp bow. Frame and fuel cells essentially intact.
5.	General view looking AFT.
6.	Showing FWD END - left side shock mount broken loose from suspension frame. Also note container shell directly under frame is formed around skid angle.
7.	Showing AFT END - right side shock mount broken loose and locally distorted channel adjacent to shock mount. Also side & top pressure pads loose as a result of end gate pivot rods slipping out of sleeve brackets when frame bottomed out on skid angle. This caused permanent set in frame rails which in turn loosened top & side pressure pads. The fuel cell on this side slid AFT 5/8".

PHOTO NO.	DEPICTION
8.	Showing FWD END with 5/8" clearance between end gate and fuel cell as a result of cell shifting AFT.
9.	Showing local distortion of vertical poison plate caused by longitudinal bending (1/2" out of plane).
10.	Showing local distortion of frame alongside broken shear mount at AFT END.
11.	Showing FWD END - bottom inside container - NOTE: skin formed over skid angle from frame bottoming out.
12.	Showing AFT END view immediately after Drop #2 COVER DROP - INVERTED.
13.	Showing 3/4 view from AFT END.
14.	Showing container in upright position after Drop #2.
15.	Showing stacking bracket depressed and tear in skin.
16.	Showing container suspended above pin for Drop #3 40 in. PIN DROP TEST.
17.	Same as #16 - opposite side.
18.	Showing Container on its side immediately after 40 in. PIN DROP. A 6 in. long cut through the skin resulted from the sharp edge of the dummy fuel cell inside the container striking the skin directly on the pin.
19.	Showing container opened for examination after 40 in. PIN DROP. NOTE: the frame is still suspended by the shock mounts with the exception of one mount at each end which broke from Drop #1. Close inspection reveals all of the clamp bows on the

PHOTO NO.	DEPICTION
	right side are bent as a result of impact from Drop #2 COVER DROP but still retain the fuel cells in a "NUCLEAR SAFE CONFIGURATION".
20.	Showing view looking AFT (right side) - NOTE: cracks in clamp bows where they contact the pressure pads. Full force of the impact from Drop #2 was taken by these members and although four were loose after the drop, the remaining five on this side were quite adequate to retain the fuel cell in its relative position to the other cell.
21.	Showing view looking AFT - Left Side, NOTE: clamp bows and pressure pads undamaged but pressure pads at 3 stations were loose from frame distortion.
22.	Showing close-up view of AFT END NOTE: broken shock mount attachment to the frame and end gate pivot pins out of their sockets. Also note that clamp bow on near side is cracked and loose but clamp bow next to it is still tight and capable of restraining fuel cell.
23.	Showing AFT END with fuel cell and end gate ass'y removed to expose "T" support casting which came through tests undamaged and maintained a "NUCLEAR SAFE CONFIGURATION" lateral spacing between cells of 2 11/16".

8.2 Measurements of container shell distortion disclosed that that basic configuration of the base had been little affected by the drop tests and the maximum distortion resulted from the COVER DROP (Drop #2).

8.2.1 The ends of the cover received the full force of the impact directly on the two stacking brackets which were depressed to a greater degree than the cover shell itself. Actual measurement disclosed the cover shell had been uniformly depressed 3 inches throughout its length. (See Fig. I)

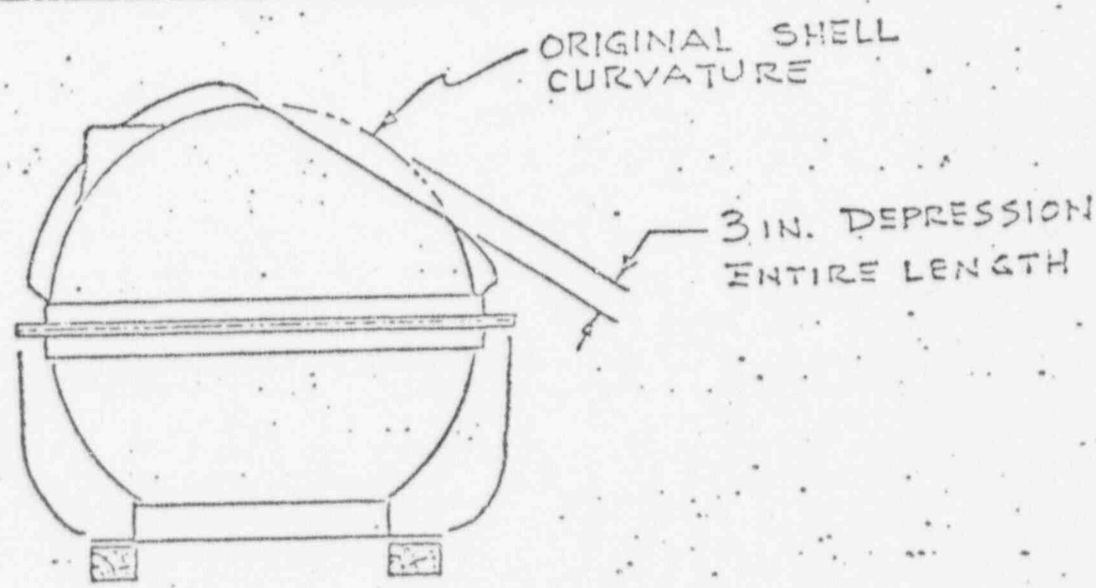


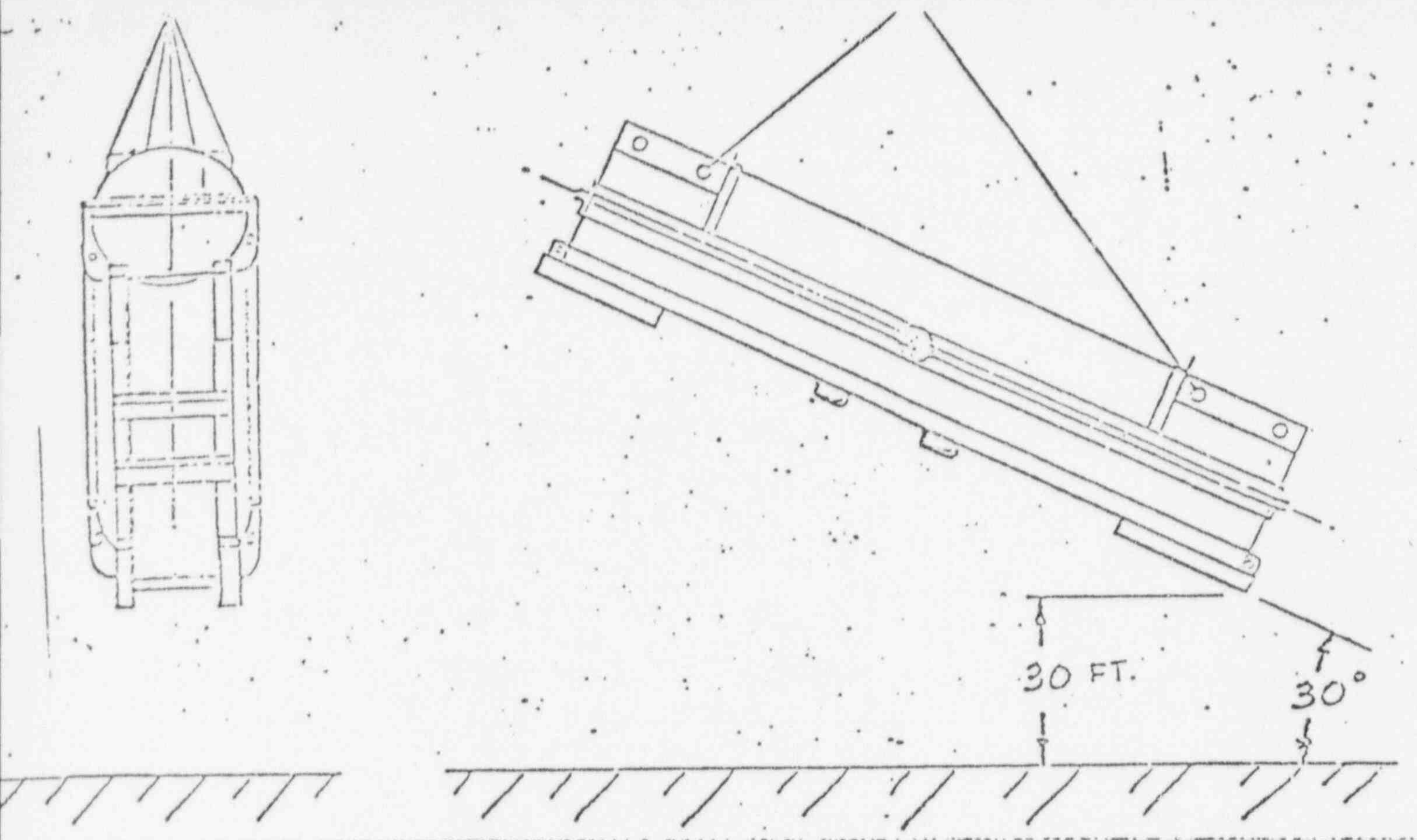
FIG I

8.2.2 At no time during the tests did the sealing flange hardware either break or even loosen. All were checked after each drop.

8.2.3 The photographs in APPENDIX B clearly show external areas of local container distortion which, considering the drop heights, were of minor consideration.

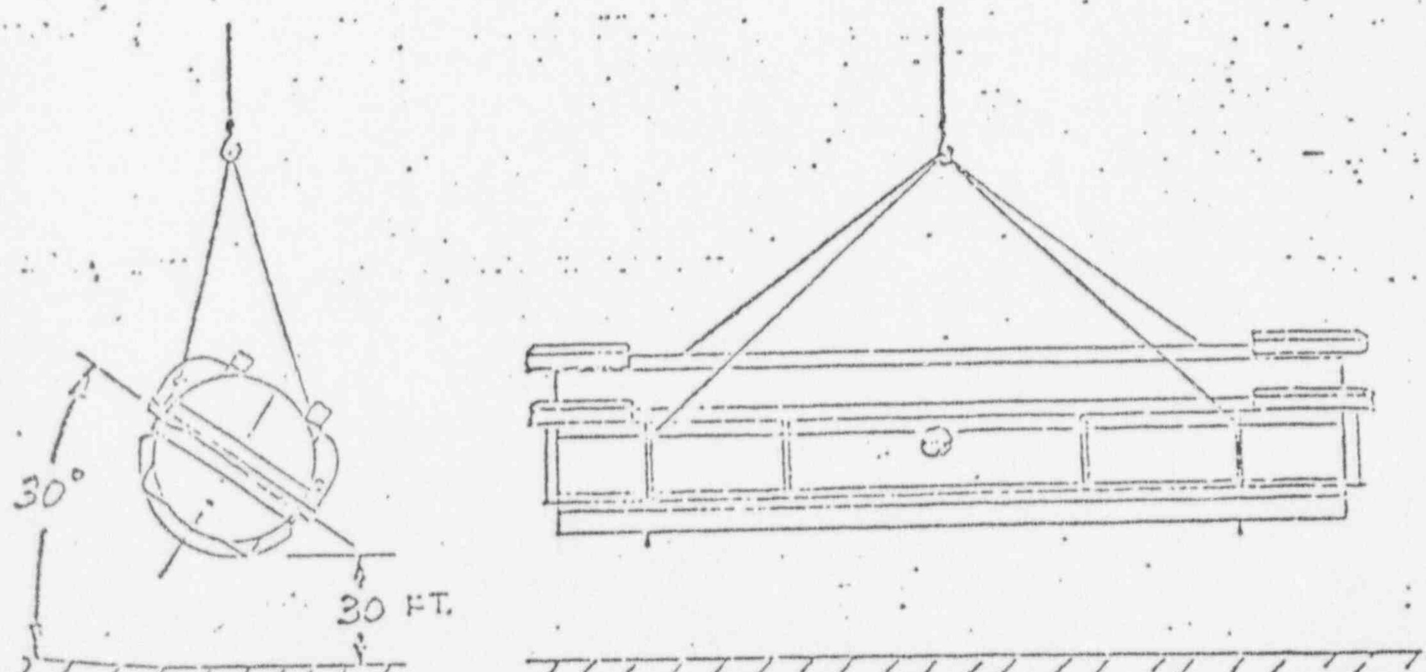
APPENDIX A

TEST DIAGRAMS



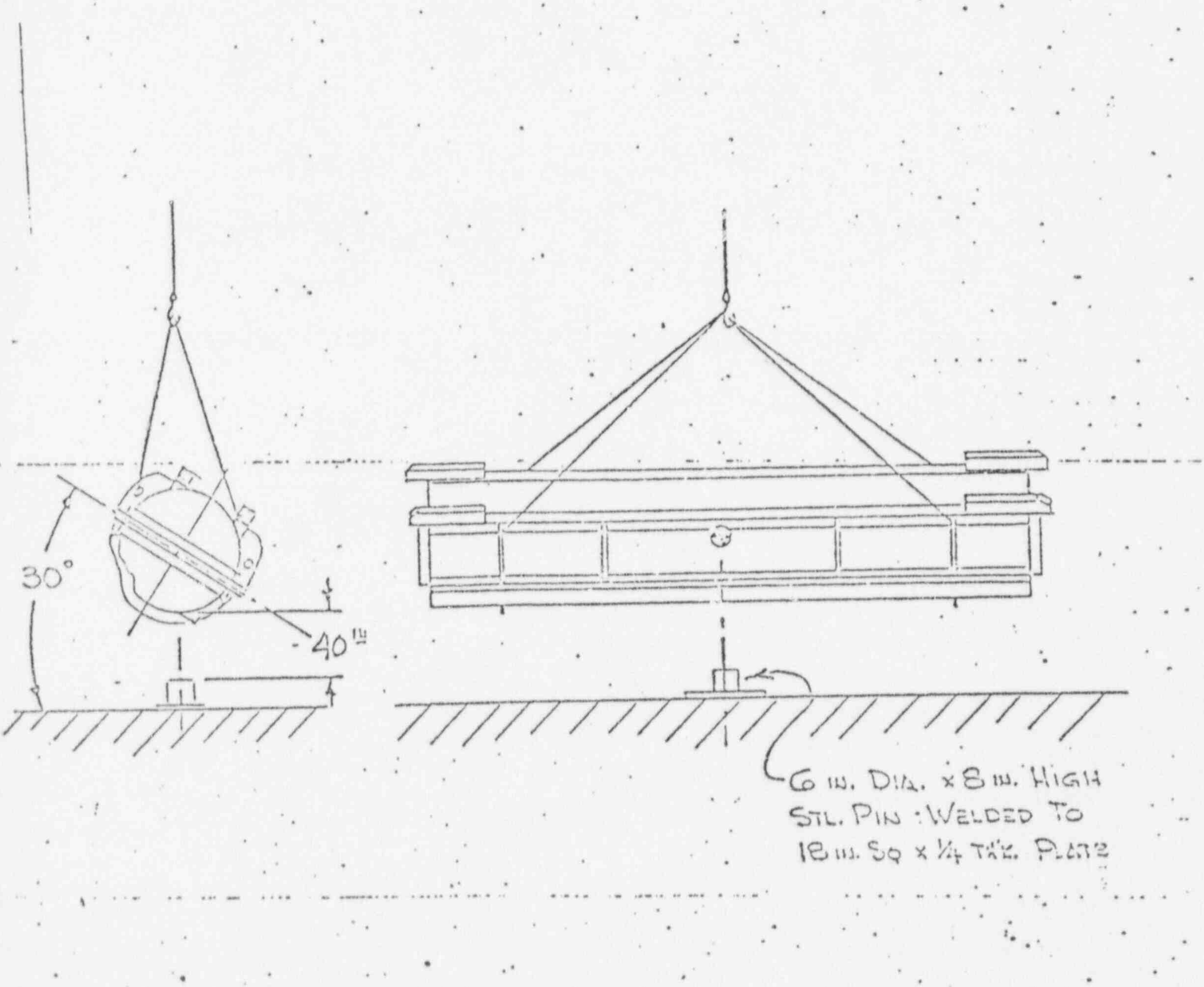
DROP # 1

BOTTOM DROP - 30° ROTATIONAL



DROP # 2

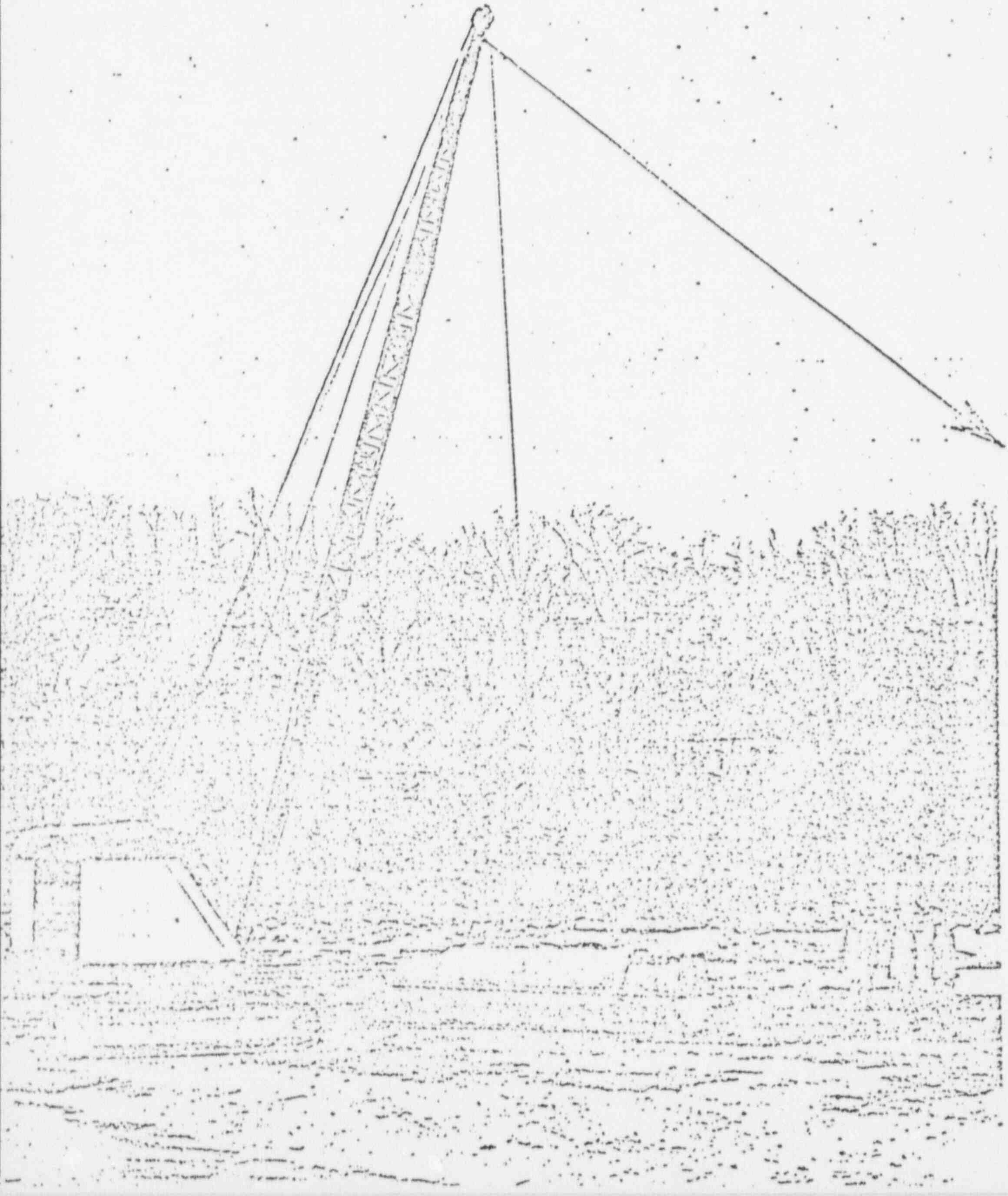
COVER DROP - 30° ANGLE

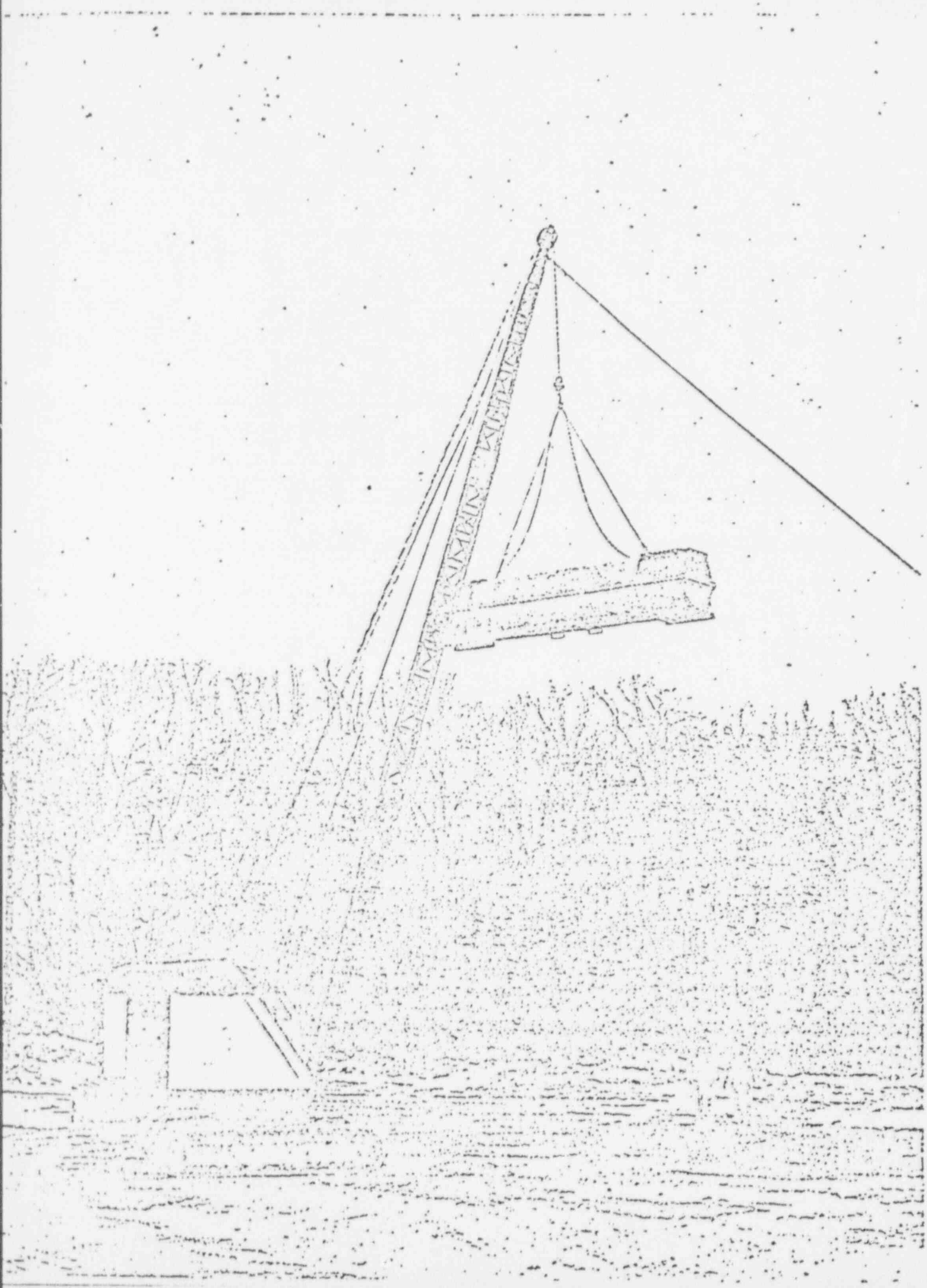


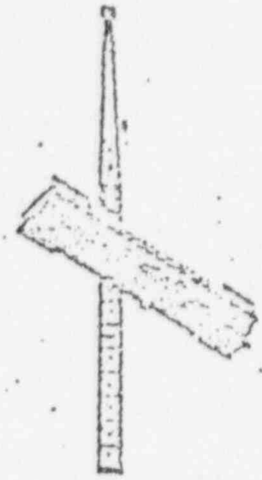
DROP # 3
40 in. Pin Drop (Cover)

APPENDIX B

TEST PHOTOGRAPHS







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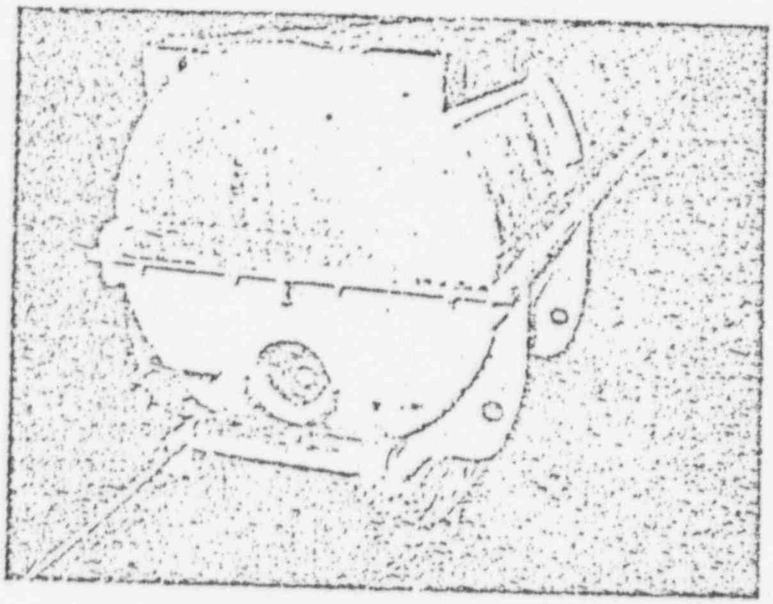

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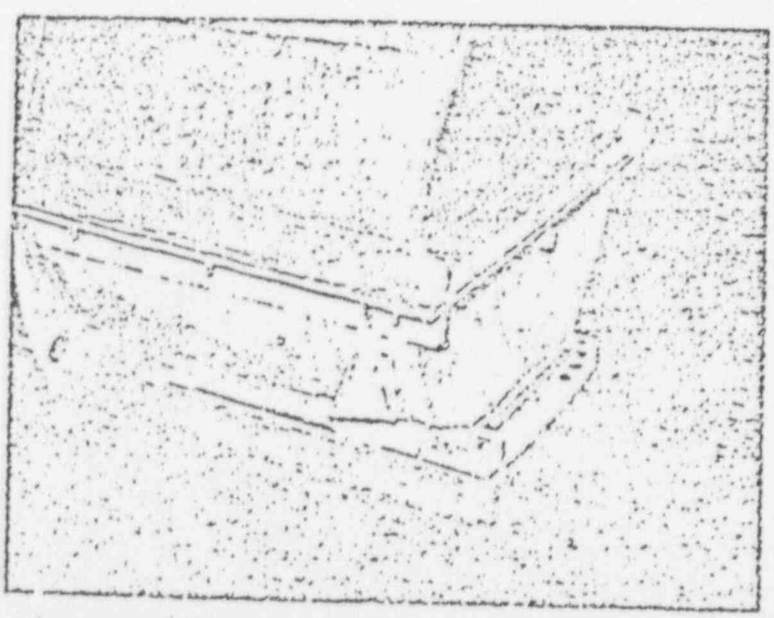

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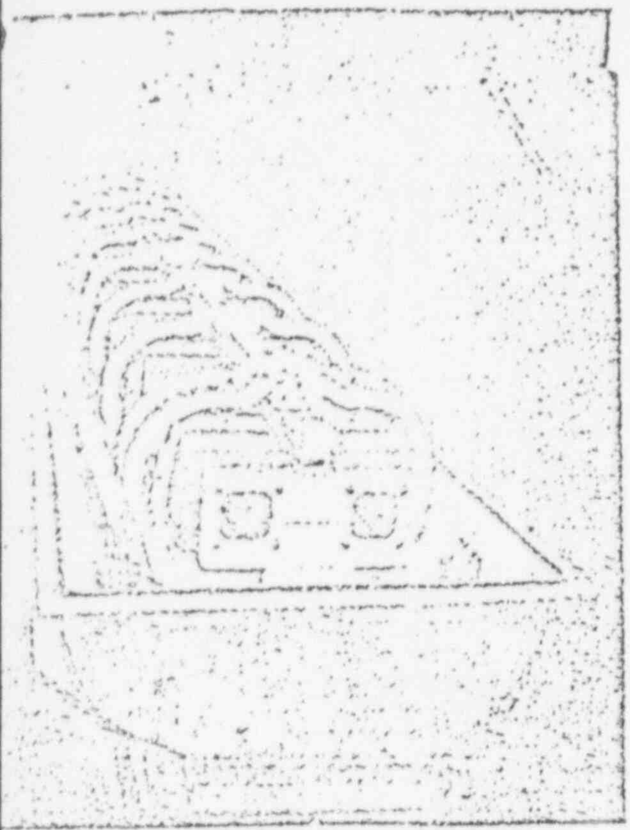
DROP #1 ON SKIDS



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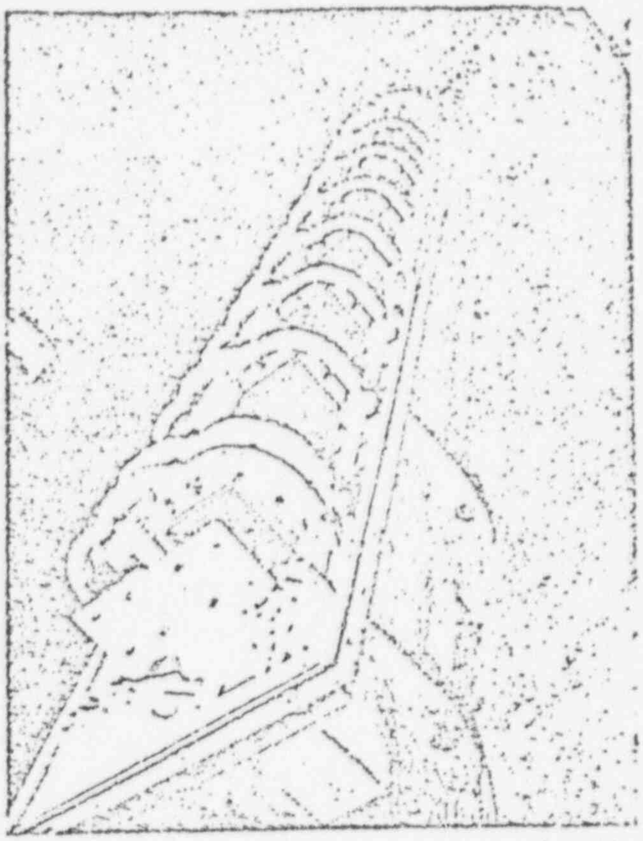

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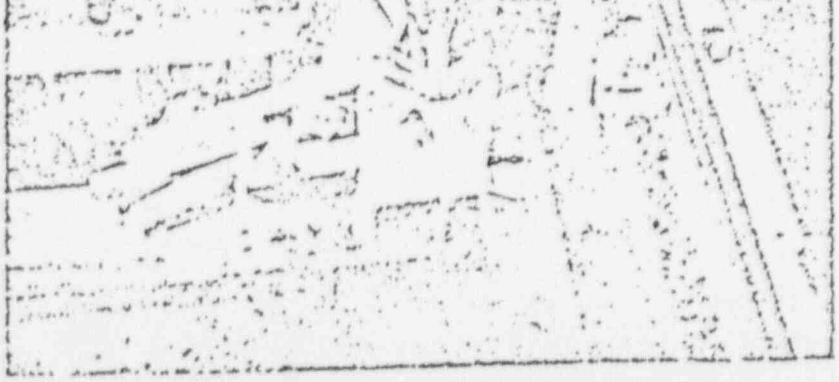

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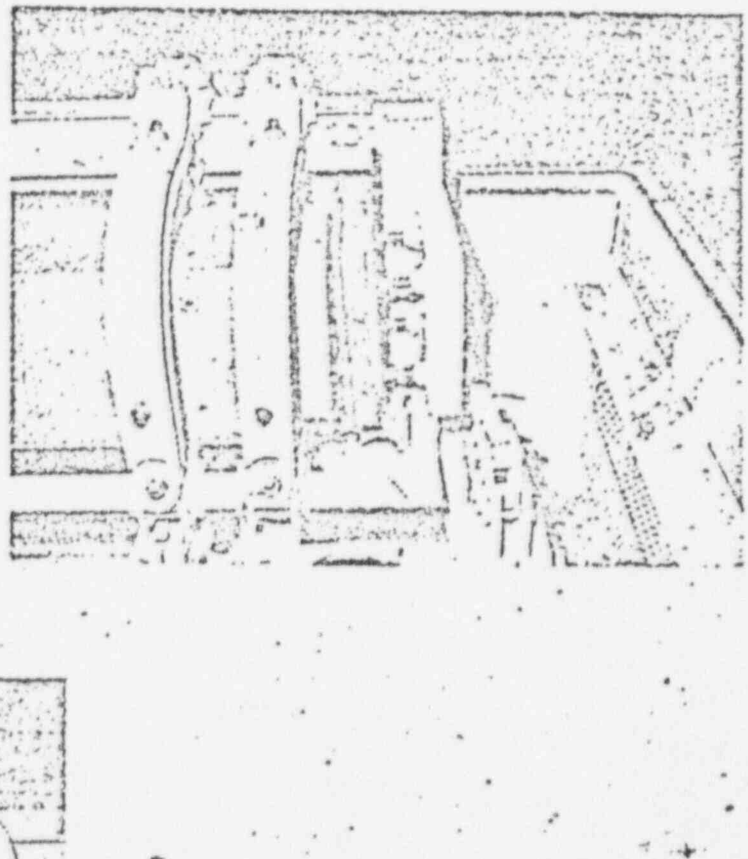

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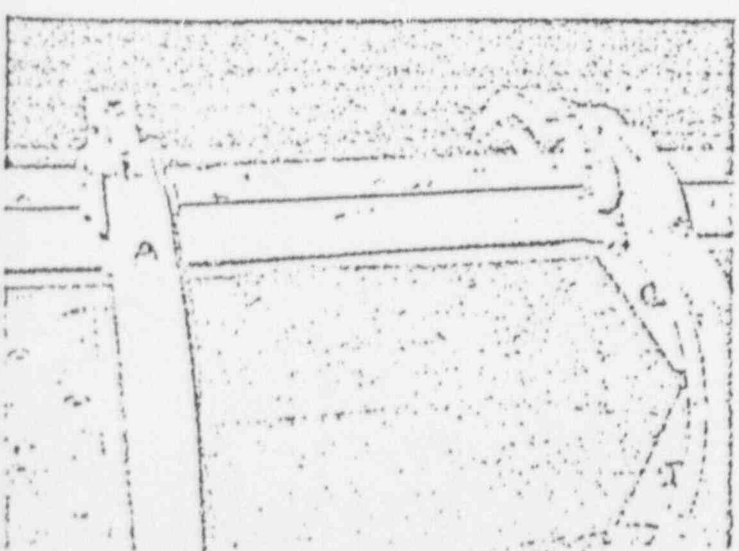

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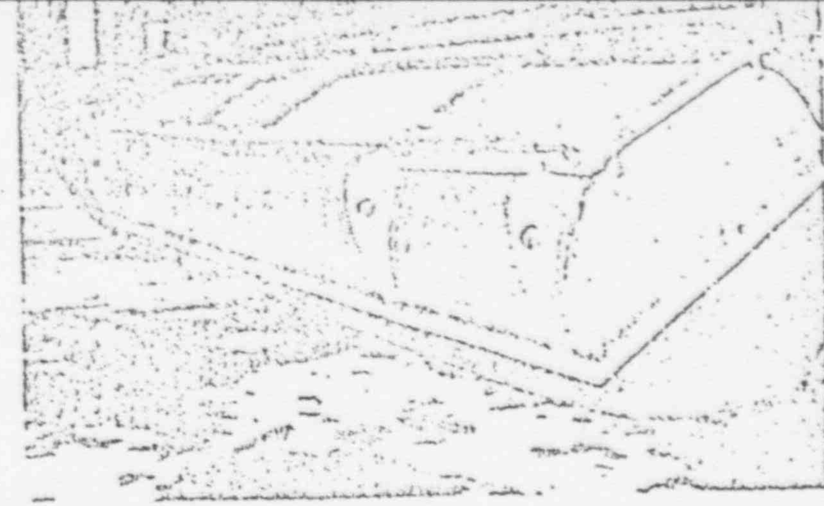

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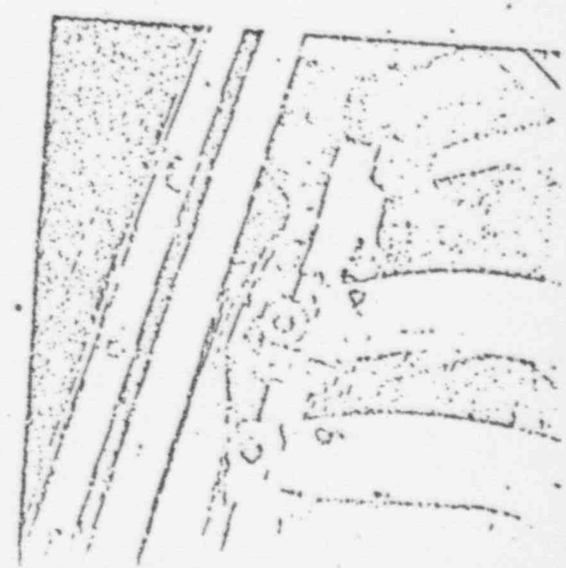

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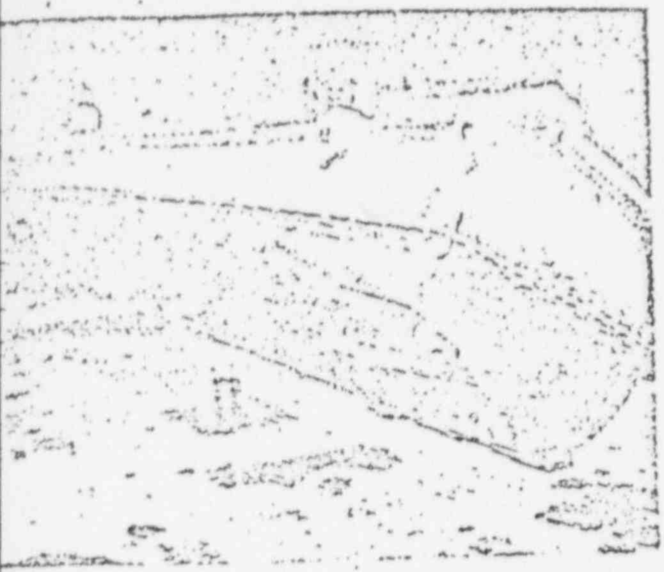

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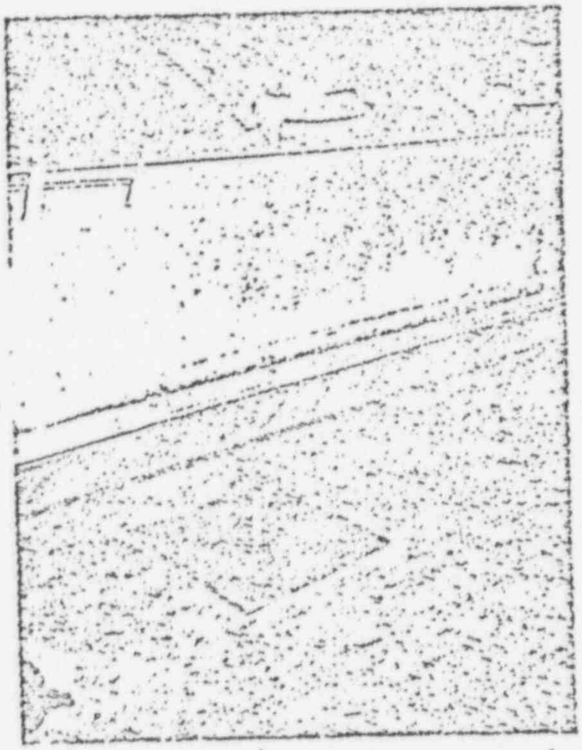

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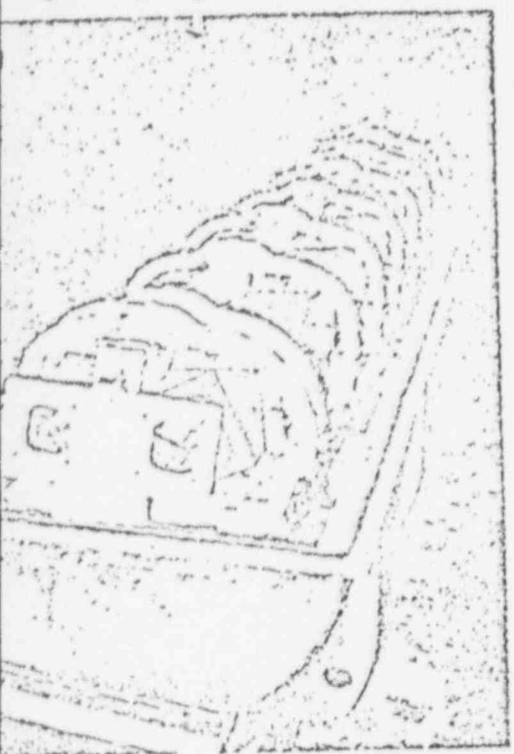
18

DROP #3 (PIN DROP)



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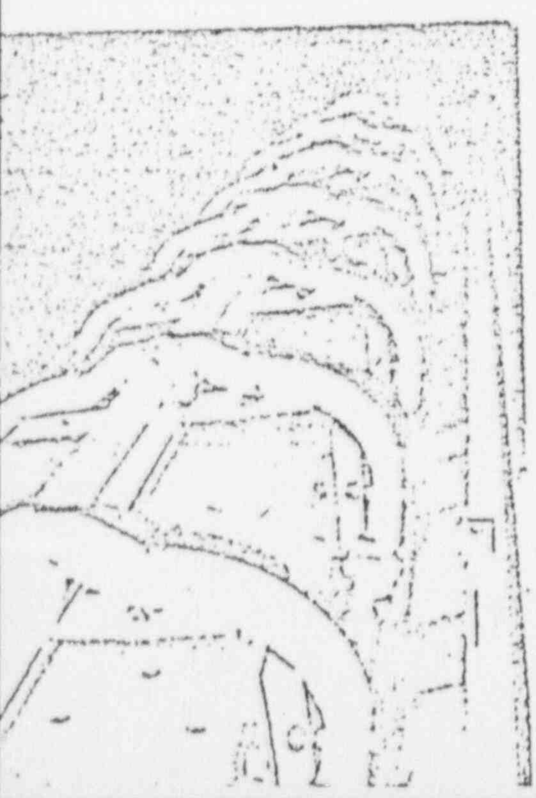

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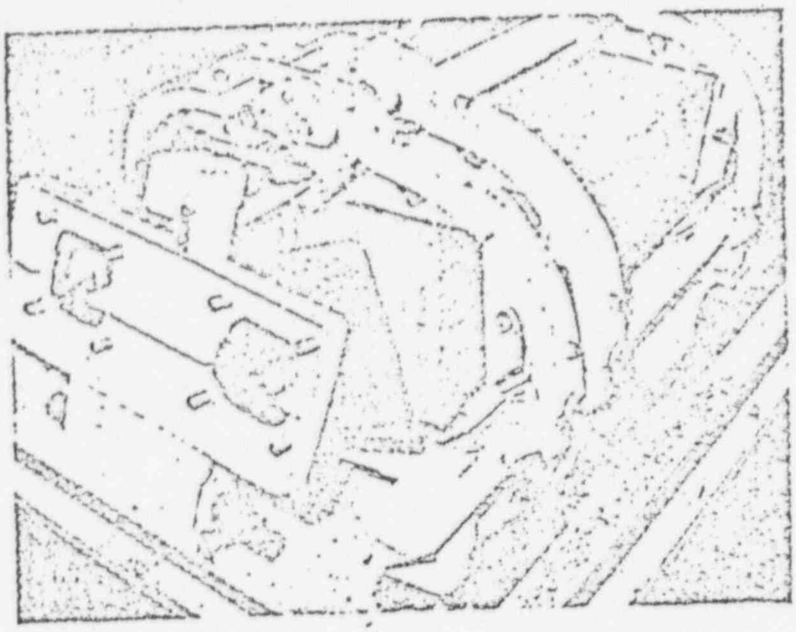

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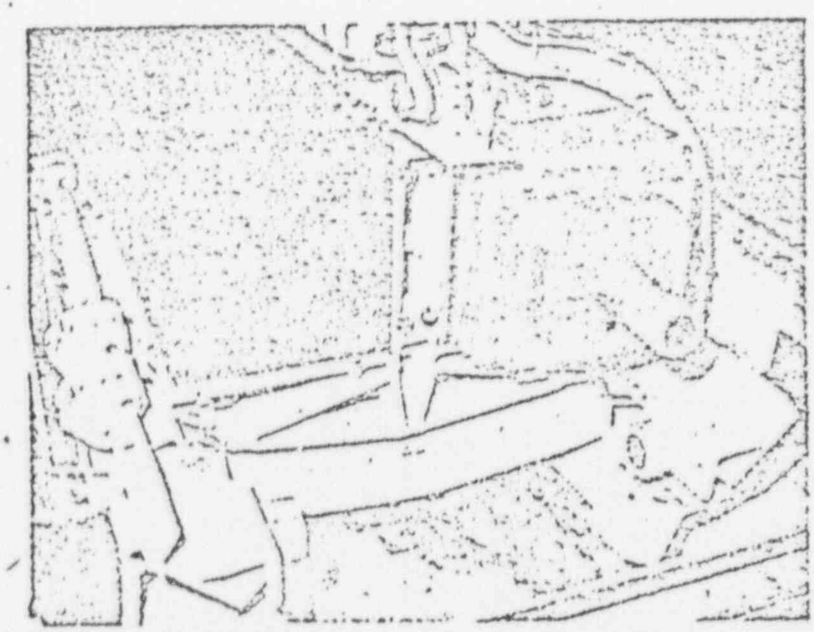

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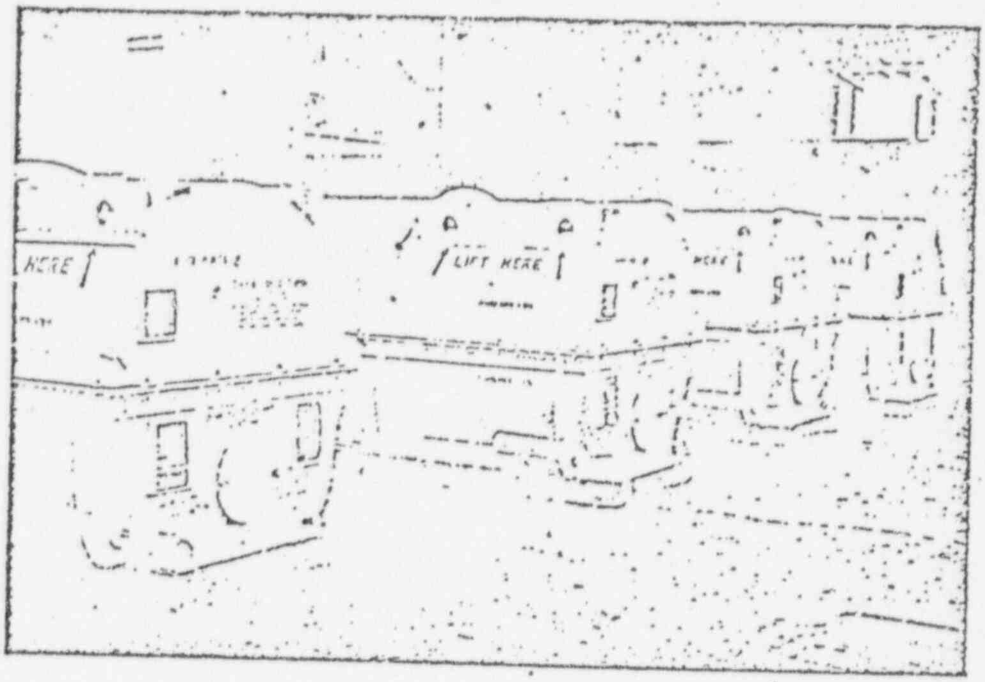
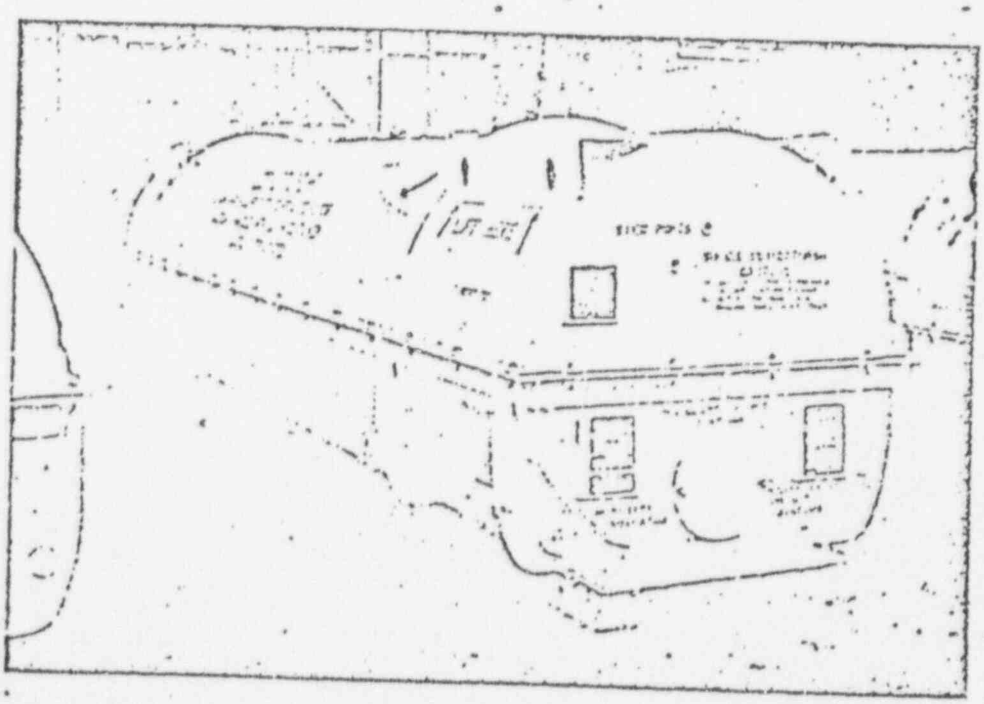




PRODUCTION CONTAINER

ATTACHMENT 2

COMPARISON OF CONTAINER SUBJECTED TO 30-FOOT DROP TEST* AND W RCC4
FUEL ASSEMBLY SHIPPING CONTAINERS

PARAMETER	TESTED	W RCC4
Skin Material	STL 1010-1020	STL 1010-1020
Skin Thickness (in)	.089	.104
Length (in)	197	217
Width (in)	44.5	44.5
Height (in)	47.25	47.54
Shell Radius (in)	20.7	20.7
Loaded Weight (lb)	7300	8825
Weight per unit length of shell (lb/in)	37	41
Percent increase in weight per unit length	-	10
Percent increase in skin thickness	-	17
Cover reinforcement material and thickness (in)	-	STL 1010-1020, .190
Container shell closure hardware-type and number	1/2-13 T-bolts, 42	1/2-13 T-bolts, 50
Container internals suspension system - type and number	Lord shock mount, 18	Lord shock mount, 24

*Test results documented in CRC-70-1 (Attachment 1)

Attachment 3

Determination of minimum distance between pairs of fuel assemblies subsequent to 10CFR71, Appendix B, accident sequence.

1. Purpose

   To determine the minimum separation between pairs of fuel assemblies subsequent to the accident sequence outlined in 10CFR71, Appendix B. If the separation is greater than four inches, then the accident sequence will not produce an arrangement that is more reactive than that analyzed under General Criticality Standards.

2. Method

   Using the test results (Attachment 1) from a similar container which was subjected to the drop tests outlined in 10CFR71, Appendix B, and design comparision data for the tested container and the proposed RCC4 container (Attachment 2), the minimum distance between pairs of fuel assemblies can be quantified.

3. Assumptions

   a. Top to top container configuration will be used as structural material in support frame limits spacing of assemblies in bottom-to-top and top-to-bottom configurations (Figure 3-1).

   b. Each container sustains a 3-inch depression in its lid.

   c. When subjected to fire, the shock mounts of both containers burn away.

   d. A zero gravity condition is assumed to allow the container internals and fuel assemblies to get as close as possible.

4. Results

   Using the information contained in W drawings 1548E55, 1596E22, and 1596E23, together with the information in Attachments 1 and 2, the minimum distance between pairs of fuel assemblies is 15.75 inches.

5. Conclusion

   Since the calculated separation distance between fuel assembly pairs subsequent to the Appendix B accident sequence is far greater than that assumed in the General Criticality Standards, the accident sequence does not produce a more reactive fuel assembly arrangement than that which is analyzed.

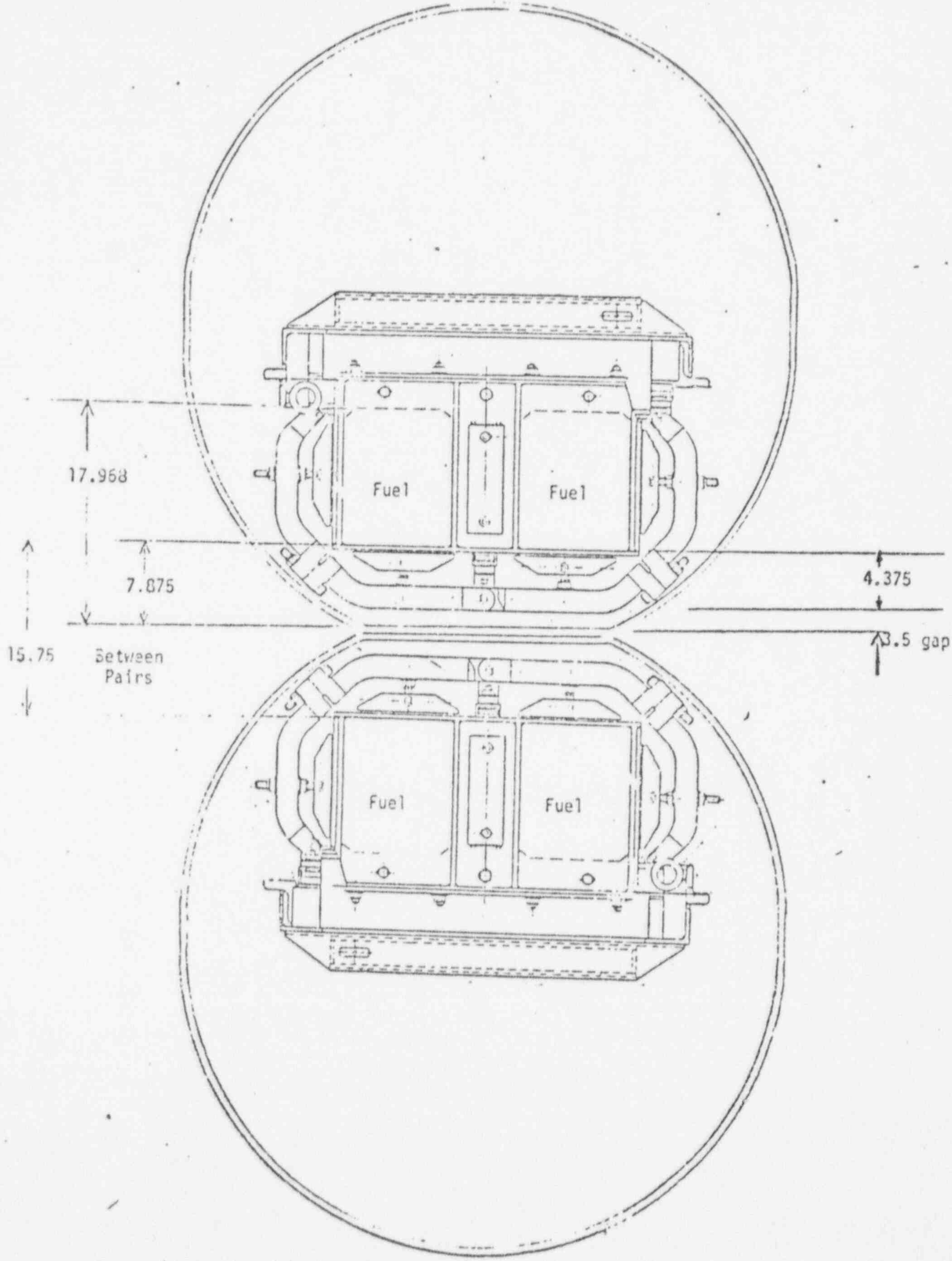


FIGURE 3-1

RELATIVE POSITION OF FUEL ASSEMBLIES SUBSEQUENT TO 10CFR71 APPENDIX B ACCIDENT SEQUENCE

ATTACHMENT 4

COMPARISON OF RCC3 AND RCC4
SHIPPING CONTAINER INTERNALS SUPPORT FRAME DESIGNS

PARAMETER	RCC3	RCC4
Overall Length, in	160.96	189.99
Material	STL 1010-1020	STL 1010-1020
Number of cross members	8	10
Cross member design	REF Drawing	
Number of clamping frames	7	9
Clamping frame design	REF Drawing	
Weight of loaded internals, lbs	4736	5434
Number of shock mounts	18	24
Load per mount, lbs	263	226
Load per unit length of loaded support frame, lb/in	29.4	28.6

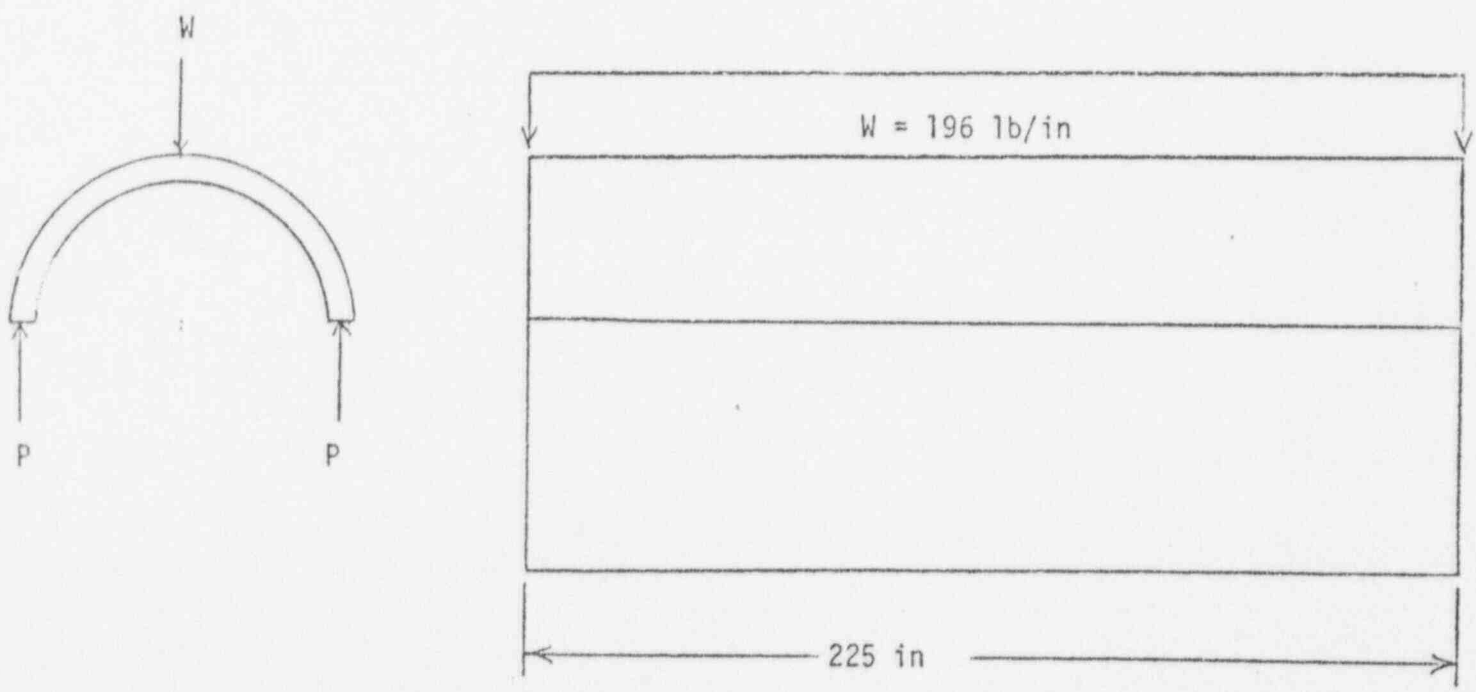
ATTACHMENT 5

Calculation to determine effect of compressive loading on container shell. (10CFR71, Appendix A-9)

Purpose: To ascertain that no deformation of the container shell will occur when loaded per the conditions of 10CFR71, Appendix A-9.

Assumptions:

1. 5 times the loaded container weight will be the applied load
2. Load is uniformly distributed
3. Container is in normal position for transport



Calculations: For a 1 inch section of the shell, the stress is:

$S = P/A = 196/(1)(.104)$

$S = 1885 \text{ lb/in}^2$

$S \text{ allowable} = 30,000 \text{ lb/in}^2$

Conclusion: The container shell will not deform under the compression criteria specified in 10CFR71, Appendix A-9

ATTACHMENT 6

Calculation in support of 10CFR71.32a (Load Resistance)

Purpose: To demonstrate that the container structural materials do not yield when loaded to 5 times the weight of the fully loaded container.

Assumptions: 1. Container treated as simply support beam

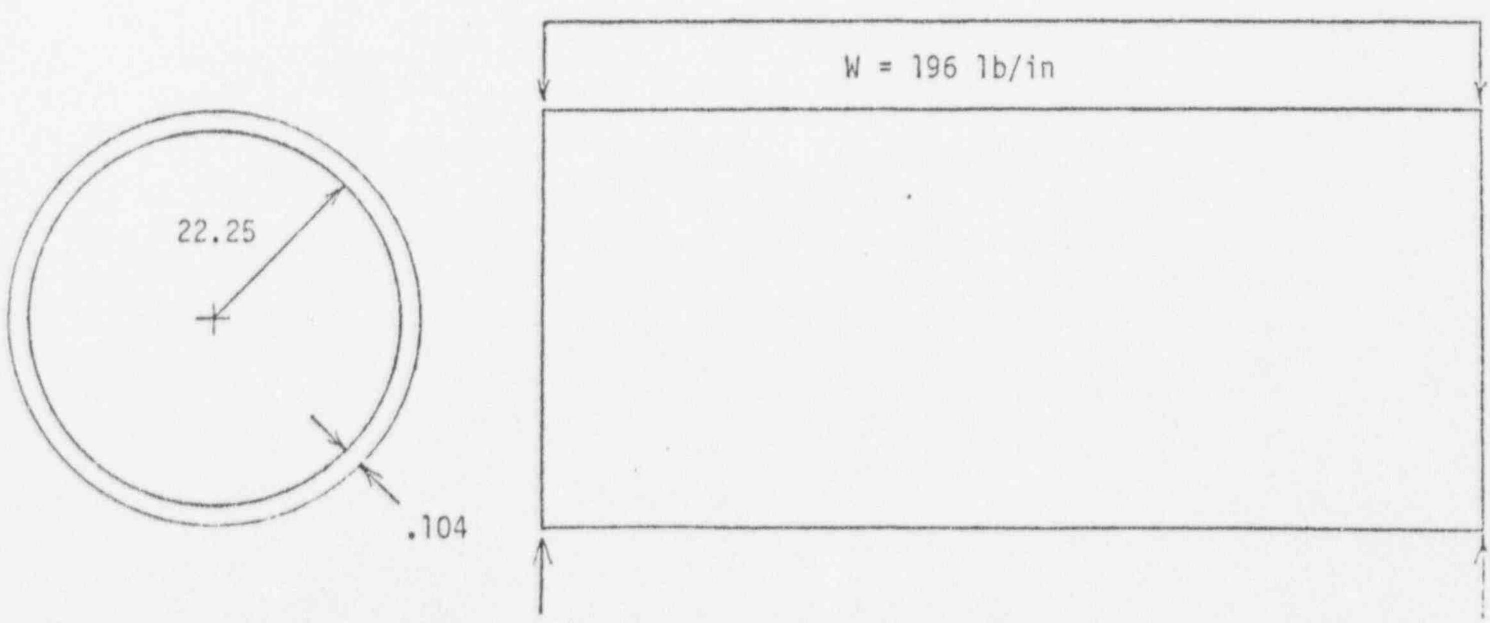
2. Uniformly distributed load equal to 5 times the loaded weight is applied to container

Calculations: 1. Determine loading: $W_{container} = 8825$ lbs

$W_{Total} = 5\ w_c = 44125$ lbs

$L_{container} = 225$ in

Load/in = 44125 lb/225 in = 196 lb/in



2. Moment $M = 1/8\ WL^2$

$$= \frac{196(225)^2}{8} = 1240312 \text{ in lbs}$$

3. I of shell $I = \frac{\pi R^4}{4} - \frac{\pi r^4}{4}$

$$= \frac{3.14\ (22.354)^4}{4} - \frac{3.14\ (22.25)^4}{4}$$

$$I = 3624 \text{ in}^4$$

4. Stress in Shell $S = \frac{Mc}{I}$

$$= \frac{1240312\ (22.354)}{3624}$$

$$S = 7650 \text{ lb/in}^2$$

$$S_{allowable} = 30000 \text{ lb/in}^2$$

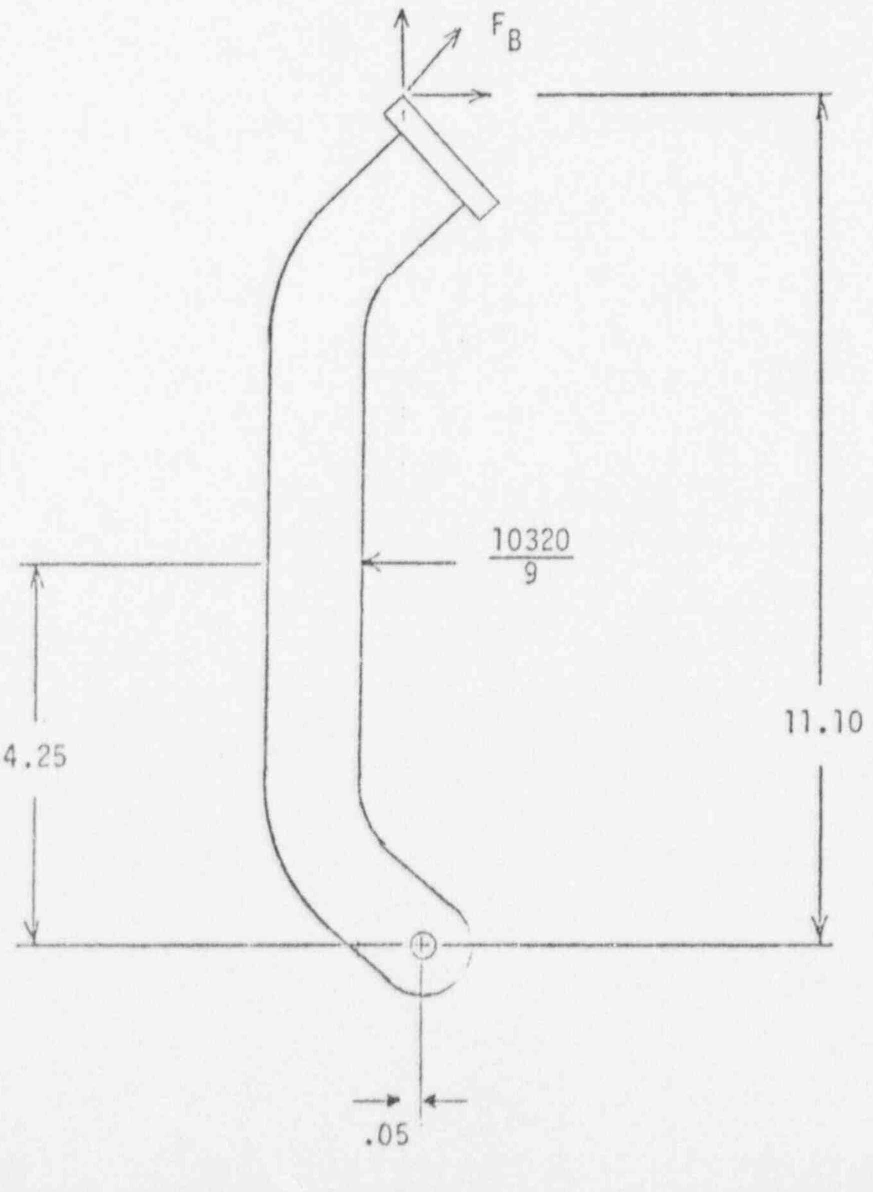
Conclusion: Stress experienced by container under the assumed conditions is far below allowable values.

ATTACHMENT 7

Calculation to verify adequacy of clamping frame bolt at 30-foot drop conditions

Purpose: To verify that clamping frame bolt will not fail under loading sustained in 30-foot drop accident (10CFR71, Appendix B-1)

Assumption: The container shell envelope is designed to accommodate shock mount system deflections experienced by accelerations of 6g's. For accelerations greater than 6g's, the container internals will contact the container shell and, thus, change the mode of loading on the clamping frame and bolt (ie from tension to compression). Therefore, 6g loading will be used as the maximum tensile loading on the bolt.



Calculation: The side clamping frame and bolt are loaded as shown in the sketch. The equation for the moments about the pivot point is:

$$\Sigma M_0 = 0$$

$$\frac{10320}{9}(4.25) = F_B \cos 45\ (0.5) + F_B \cos 45\ (11.10)$$

$$4873 \text{ in/lb} = .3535\ F_B + 7.85\ F_B$$

$$595 \text{ lb} = F_B$$

Area of .5 dia bolt is .1416 in

Tensile stress in clamping frame bolt is

$$\frac{595 \text{ lb}}{.1416 \text{ in}} = 4202 \text{ lb/in}^2$$

Conclusion: Stress in clamping frame bolt during 30-foot drop is well below allowable limits.

ATTACHMENT 8

RCC4 Shipping Container top and bottom support analyses

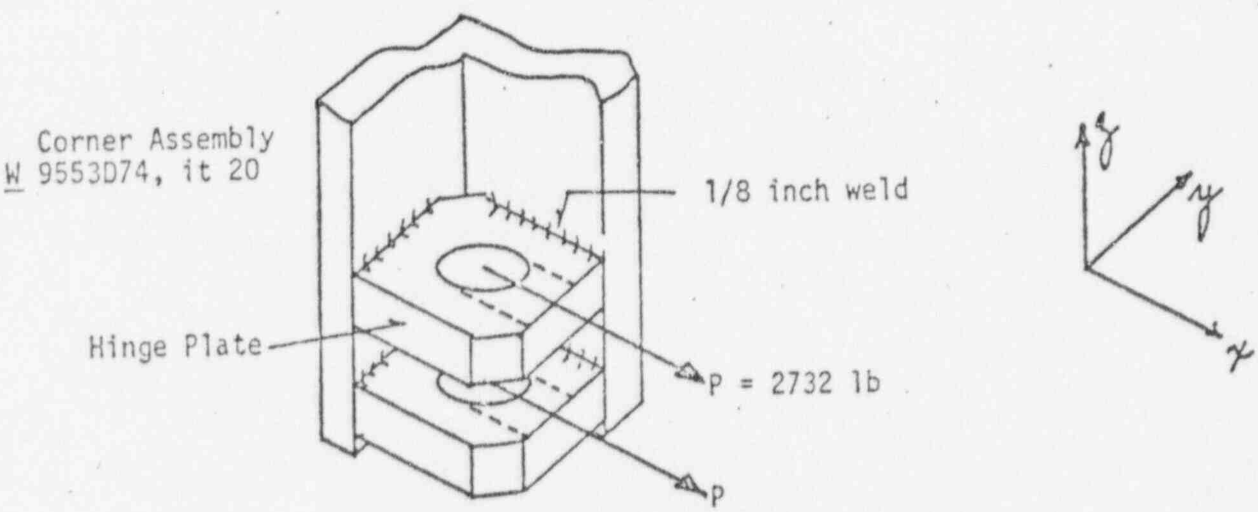
Hinge Plates

Design Criterion

Neither the top closure assembly hinge plates not the welds that secure them shall yield in the 6g minus x-direction acceleration.

Verification

The loading and the shear area on the hinge plates are as shown.



Corner Assembly Loads and Securing Welds

The load P is one eighth of the total 6g inertial load and the shear area in each hinge plate is 0.585 in^2. The shear stress is thus:

$$\tau = \frac{2732 \text{ lb}}{0.585 \text{ in}^2} = 4{,}670 \text{ lb/in}^2$$

Each plate is welded in place with four 1.31 inch lengths of 1/8 inch filet. Weld stress is

$$\tau = \frac{2732 \text{ lb}}{4(1.31)(.125/\sqrt{2})} = 5{,}900 \text{ lb/in}^2$$

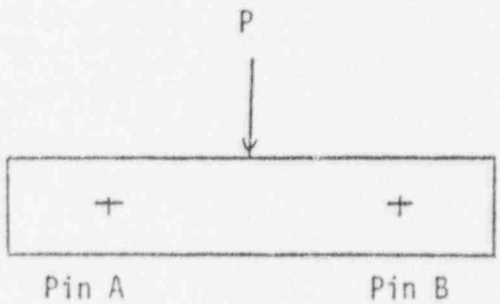
Conclude that neither the top closure assembly hinge plates, nor the welds that secure them, yield in the 6g minus x-direction acceleration.

Top closure hinge pins

Purpose: To determine the shearing stress in top closure pins

Assumptions: 6g loading

6(1720 lb) = 10320 lb



$$\text{Shear A} = \text{Shear B} = \frac{P}{2} \Big/ \text{sheared area of pin}$$

$$= \frac{\frac{10320}{2}}{\frac{d^2}{4}(2)} \qquad = \frac{5160}{\frac{(.5)^2}{4}(2)} \qquad = \frac{5160}{.39}$$

Shear A = Shear B = 13230.77 lb/in^2

Allowable shear for 1010-1020 carbon steel = 14500.00 lb/in^2

Conclusion: Allowable shear > maximum actual shear

Corner Post

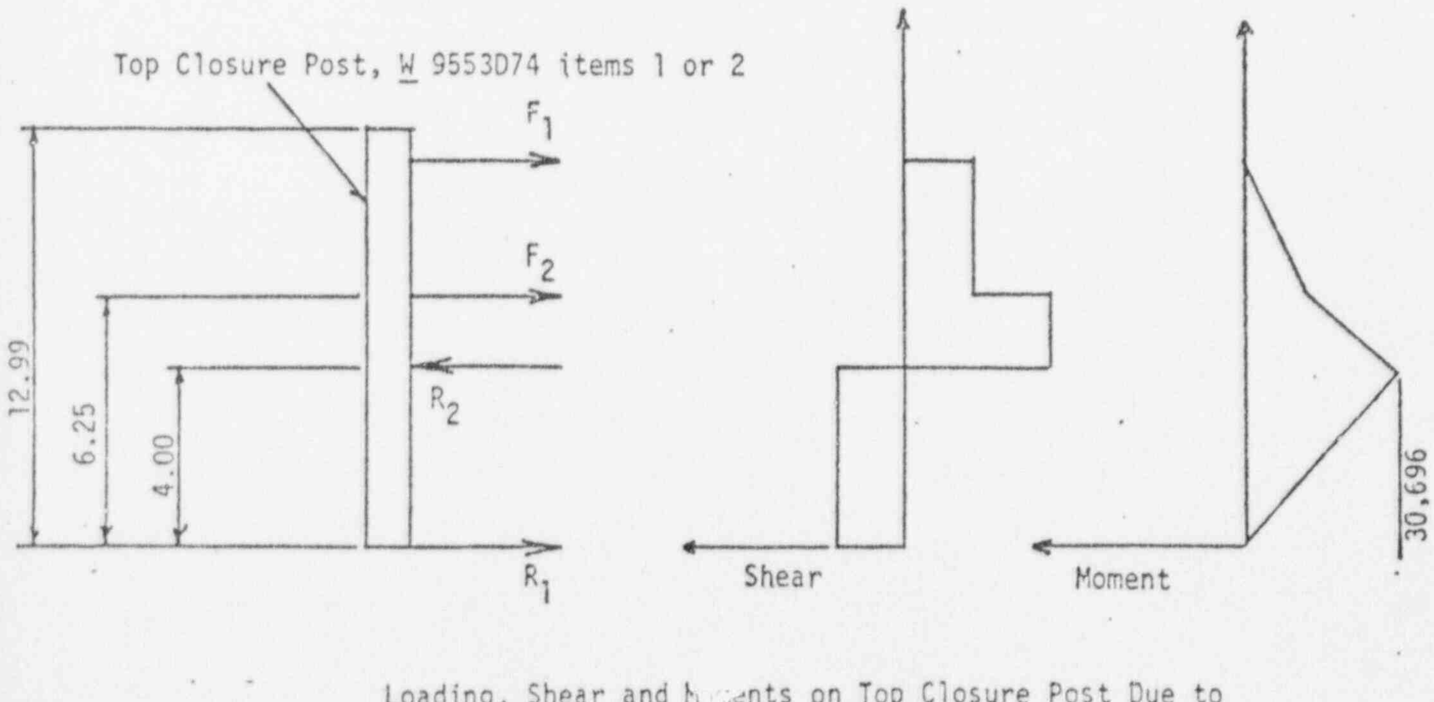
Design Criterion

The bolts securing the top closure post to the top cross frame base tube shall not yield in a 6g minus x-direction acceleration.

Discussion

The top closure post, W 9553D74 or 9553D75 items 1 or 2 carries loads shown in the minus 6g acceleration case. Reaction R_2 is imposed on one of the securing bolts. Loads F_1 and F_2 vary for the XLR and 414 loadings per the tabulation. The maximum bolt load R_2 is imposed in the 414 case and is 13,136 lb. The required yield stress in the bolt material is

$$\sigma_y = \frac{13{,}136 \text{ lb}}{\pi(0.5 \text{ in})^2/4} = 66{,}900 \text{ lb/in}^2$$



Loading, Shear and Moments on Top Closure Post Due to 6g Minus x-Direction Acceleration

	F_1	F_2
XLR Top Closure	0	5463
414 Top Closure	2731	2731

The bolt material is ASTM 354 grade BC which has a minimum tensile yield of 109,000 lb/in^2.

Conclude that the bolts securing the top closure post to the top cross frame base tube do not yield in a 6g minus x-direction acceleration.

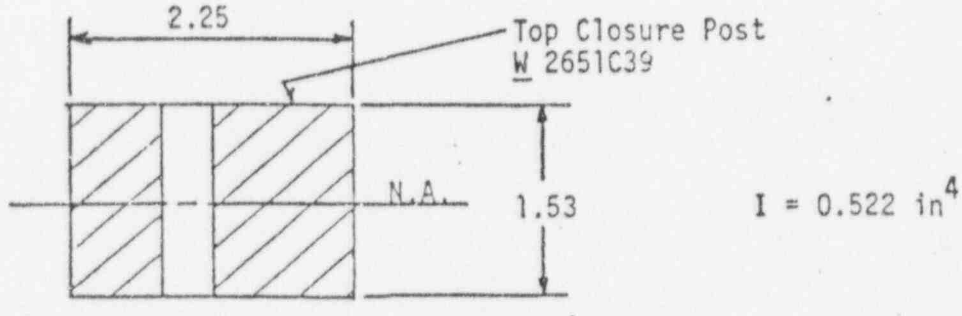
Design Criterion

The top closure post shall not yield due to a 6g minus x-direction acceleration.

Verification

The former diagram shows that the maximum beam moment occurs at the location of the R_2 reaction. The moment is maximum in the case of 414 shipments having value 30,696 in lb. The moment of inertia of the section taking credit for the solid sections only is based on the familiar 1/12 bh^3. The maximum fiber stress is,

$$\sigma = \frac{(30{,}696 \text{ in lb})(0.75 \text{ in})}{0.522 \text{ in}^4} = 44{,}077$$



Top Closure Post Section at Point of Reaction R_2

The upright material is ASTM A572 grade 50 which has yield stress exceeding 50K.

Conclude that the top closure post will not yield due to loadings imposed in the 6g minus x-direction acceleration case.

Jack Screw Buckling Load

Design Criterion

The jack screws that secure the fuel top nozzle shall not buckle in the 6g minus x-direction acceleration.

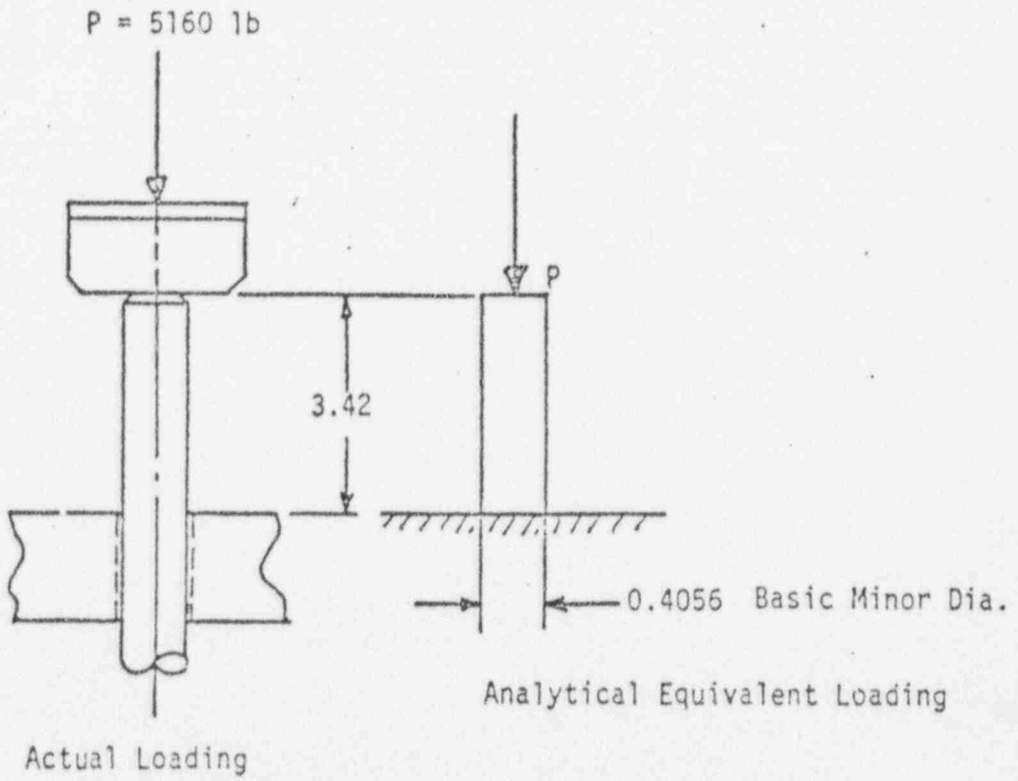
Verification

The maximum inertial loading is on the jack screws that operate with the z-bars and is 5160 pounds on each screw. The actual and analytical equivalent loadings along with relevant dimensions are shown in the sketch. Buckling will occur at the critifal load, P_{CR}, which Shames gives as

$$(P_{CR})_n = \frac{n^2 \pi^2 EI}{4L^2}$$

$$= \frac{(1)^2 \; \pi^2 \; (30\times10^6)}{4(3.42)^2} \frac{(\pi * \; .4056^4)}{64}$$

$$(PCR)_1 = 8{,}408 \text{ pounds}$$



Actual and Analytical Equivalent Loading on Jack Screw in 6g Minus x-dir. Acceleration

Conclude that the jack screws will not buckle in the 6g minus x-direction acceleration case.

Jack Screw Thread Strength

Design Criterion

The jack screw thread shall not yield in a 6g minus x-direction acceleration.

Verification

Two jackscrews share the 6g minus x-direction inertial load from each fuel assembly. Each jaçk screw carries a maximum load of 5160 pounds. R.C. Boucher tabulates shear area for

threads of a 0.500 13UNC 2A bolt in "Strength of Threads", contained in volume 32 of Product Engineering, dated November 27, 1961. The value quoted is 0.7821 in^2 per inch of bolt length. Since one inch of thread engages with the applicable bar the thread stress is

$$\frac{5160 \text{ lb}}{(0.7821 \text{ in}^2)} = 6598 \text{ lb/in}^2$$

The jack screw material is ASTM 354 grade BC which has minimum tensile yield of 109,000 lb/in^2. Minimum shear yield is 54,500 lb/in^2 by deduction.

Conclude that the jack screw threads will not shear in the 6g minus x-direction acceleration.

Stress

Design Criterion

Stress in the Z-bar shall not exceed material yield in a 6g minus x-direction acceleration.

Verification

Although the bar is a Z shape it is treated as straight in this analysis. The loading, shear force distribution and moment distribution are as diagrammed. The center hub is assumed to transmit no portion of the bending moment along the beam. If the two side ligaments transmit the entire load they are stressed to σ, where

$$\sigma = \frac{(19086 \text{ in lb})(0.50 \text{ in})}{1/12 \ (1 \text{ in})(1 \text{ in})^3} = 114{,}516 \text{ lb/in}^2$$

The material yield stress is quoted by note 4 of drawing 9553D72 at 120K to 140K.

Conclude that stress in the Z-bar will not exceed material yield in a 6g minus x-direction acceleration.

f. Z-Bar Thread Strength

Design Criterion

The thread through Z-bar tapped holes shall not yield in a 6g minus x-direction acceleration.

Verification

Two jackscrews share the 6g minus x-direction inertial load from each fuel assembly.

Each Z-bar (W 9553D72) hole is loaded, therefore, to 5160 pounds. R. C. Boucher tabulates shear area for threads of a 0.500 13UNC 2B hole in "Strength of Threads", contained in volume 32 of Product Engineering, dated November 27, 1961. The value quoted is 1.1231 in^2 per inch of threaded hole length. Since the Z-bar threaded hole is one inch long the thread stress is $\frac{5160 \text{ lb}}{(1.1231 \text{ in}^2)} = 4594 \text{ lb/in}^2$

The material shear yield stress is 60,000 lb/in^2.

Conclude that the thread through the Z-bar tapped holes will not yield in a 6g minus x-direction acceleration.

Bottom Support

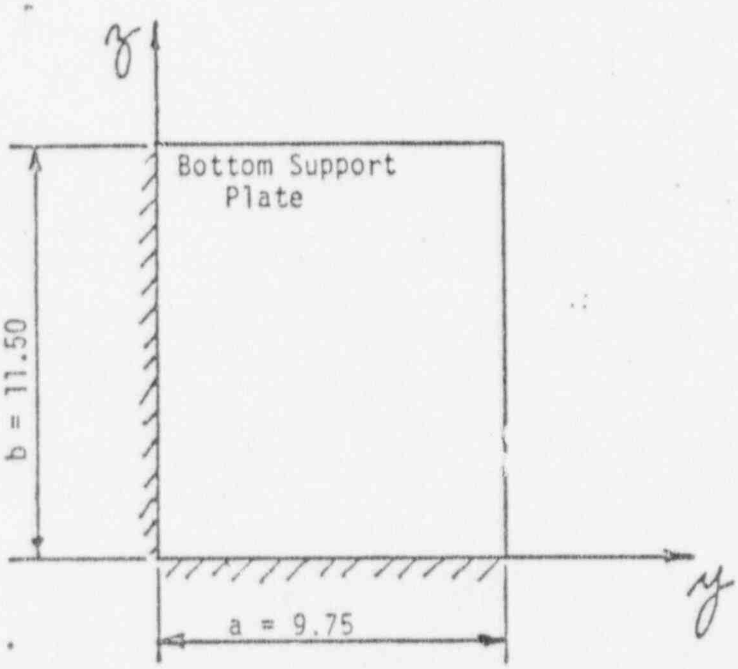
Bottom Support Plate Stress

Design Criterion

Stress in the XL shipping container support frame bottom support shall not exceed yield due to a 6g x-direction acceleration.

Verification

Since it is symmetrical, consider only half of the bottom support plate. The plate edges are considered built in as shown in the sketch and the 6g loading is considered equally distributed over the plate surface, at intensity value q.



$a/b = 0.85$

$q = 97.4\ lb/in^2$

$B_1 = 1.455$

$B_2 = 1.419$

$\gamma_1 = 1.151$

$\gamma_2 = 0.971$

Analytical Model for Bottom Support Plate Stress Calculation

Definitions

t = plate thickness = 0.75 in

σ_a = bending stress in plate parallel to side a

σ_b = bending stress in plate parallel to side b

R = reaction force normal to the plate surface exerted by the boundary support on the plate edge, lb/in

B_1, B_2, γ_1 and γ_2 are functions of a/b given in the reference.

At y = 0 and z = b...

$$\text{Max. } \sigma_a = \frac{-B_2 q b^2}{t^2} = -32{,}000 \text{ lb/in}^2, \text{ and}$$

$$R_2 = \gamma_2 q b = 1088 \text{ lb/in}$$

At y = a and z = o

$$\text{Max. } \sigma_b = -\frac{B_1 q b_1}{t^2} = -33{,}300 \text{ lb/in}^2, \text{ and}$$

$$R_1 = 1289 \text{ lb/in}$$

The maximum stress in the plate is slightly over the commonly accepted yield value. The yield value is actually somewhat higher than 30 as Shames lists the value for annealed 1020 at 48,000 lb/in^2. In addition, the analysis neglects the stiffening effect of the gussets, 9553D93, items 3, and any yielding in the plate would be local and of the self-relieving variety.

Conclude that the bottom support will not yield in the 6g x-direction acceleration.

Bottom Support Welds

Design Criterion

The welds and bolts which secure the bottom support must not yield in a 6g x-direction acceleration.

Verification, Welds

The weld along the y=o edge is a 3/16" fillet which has a strength of 1800 lb/inch of weld. The normal reaction force along this weld has a maximum value of 1088 lb/in which is well below the 1800 lb/in allowable limit.

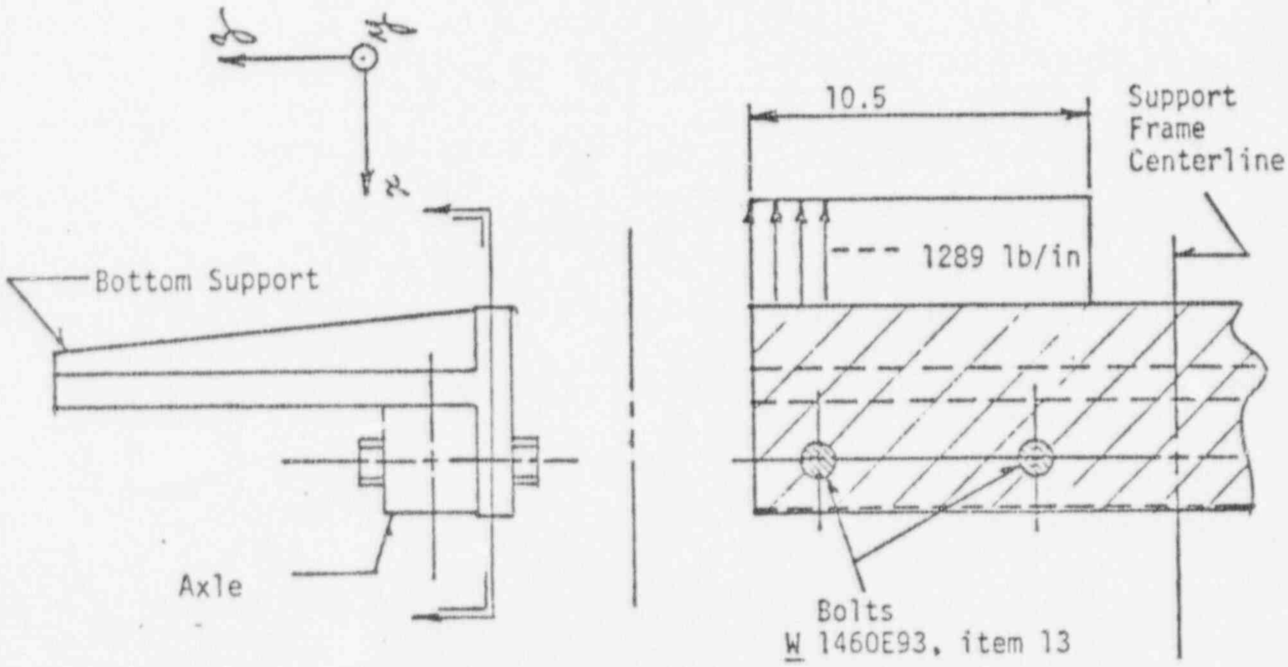
Conclude that the weld along the side where x=o is clearly of sufficient strength.

The weld along the z=o edge (base plate to support plate connection) is a 1/4" fillet weld which has a strength of 2400 lb/in of weld. The normal reaction force along this weld has a maximum value of 1289 lb/in which is well below the 2400 lb/in allowable limit.

Conclude that the weld along the side where z=o is clearly of sufficient strength.

Verification, Bolts

The bolts, oriented on vertical axes (z-axes) running through the bottom support, and axle that restrain the half-plate shown previously are sketched below.



Load and Restraining Bolts on Bottom Support

The bolts support a total load of 15,561 lb. which is assumed equally shared between the bolts, 7780 lb. The shear stress in each is

$$\tau = \frac{7780}{\text{Area}} = 54,943 \text{ lb/in}^2$$

The bolt material is ASTM 354 grade BC which has a minimum tensile yield of 109,000 lb/in^2. By deduction, the minimum shear yield is 65,400 lb/in^2.

Conclude that the bolts which secure the bottom support will not yield in the 6g x-direction acceleration.

Ref. Roark & Young, Formulas for Stress and Strain, 5th Edition. p. 399 case 11a

ATTACHMENT 9

Analysis of RCC4 shipping container tiedown features for verification of conformance to 10CFR71

The following analysis of the RCC4 tiedown system is conservative as it assumes a package loaded weight of 11200 pounds while the estimated loaded weight of the RCC4 package is expected to be approximately 8800 pounds.

CONCLUSION

THE COMPUTATIONS ON THE FOLLOWING PAGES ARE FOLLOWED THROUGH WITH REASONABLE ASSUMPTIONS WHERE REQUIRED, COVER ALL CRITICAL AREAS AND SHOW THAT THE RESULTS OBTAINED ARE WITHIN THE ALLOWABLE LIMITS.

ALLOWABLE STRESSES

A. LIFTING ATTACHMENTS

MATERIAL: ASTM A36 STEEL

(MIN) F_{ty} = 36,000 PSI } Ref. MANUAL OF STEEL
(MIN) F_{tu} = 58,000 PSI } CONST. 6TH ED., P. 5-155

F_t (all.) = 1/5 (F_{tu}) = 1/5 (58,000) = 11,600 PSI < 1/2 (F_{ty}) = 18,000 PSI

ALL. SHEAR STRESS = F_s(all.) = .60 F_t(all.) = .60 (11,600) = 6960 PSI

ALL. BEARING STRESS = F_{br}(all.) = 1.5 F_t(all.) = 1.5 (11,600) = 17,400 PSI

ALL. BENDING STRESS = F_b(all.) = 1.5 F_t (all.) = 1.5 (11,600) = 17,400 PSI

MATERIAL: WELD METAL

ALLOWABLE STRESS = 13,600 PSI (Ref. MANUAL OF STEEL CONST. 6TH ED., P. 5-1[illegible]

F_t (all.) = 1/2 (13,600) = 6800 PSI

ALL. SHEAR STRESS = F_s(all.) = .60 F_t(all.) = .60 (6800) = 4080 PSI

WJT 9-8-70

B. ALL AREAS EXCLUDING LIFTING ATTACHMENTS

MATERIAL: ASTM A36 STEEL

(MIN) F_{ty} = 36,000 PSI } Ref. MANUAL OF STEEL
(MIN) F_{tu} = 58,000 PSI } CONST. 6TH ED., P. 5-155

$F_t(all.) = F_{ty} = 36{,}000$ PSI $< .75(F_{tu}) = 43{,}500$ PSI

ALL. SHEAR STRESS = $F_s(all.) = .6\,F_t(all.) = .6(36{,}000) = 21{,}600$ PSI
ALL. BEARING STRESS = $F_{br}(all.) = 1.5\,F_t(all.) = 1.5(36{,}000) = 54{,}000$ PSI

MATERIAL: WELD METAL

$F_s(all.)$ = 13,600 PSI (Ref. MANUAL OF STEEL CONST. 6TH ED., P 5-1?)

MATERIAL: "AN" BOLTS: F_{ty} = 103,000 PSI
F_{tu} = 125,000 PSI

$F_t(all.) = .75\,F_{tu} = 93{,}750$ PSI $< F_{ty}$

ALL. SHEAR STRESS = $F_s(all.) = .6\,F_t(all.) = .6(93{,}750) = 56{,}250$ PSI

WJT 9-8-70

C. LIFTING ATTACHMENTS

MATERIAL : ASTM A283 GRADE D STEEL

(MIN) Ft_y = 33,000 PSI } REF. MANUAL OF STEEL
(MIN) Ft_u = 60,000 PSI } CONST. 6TH ED., P.5-156

Ft(ALL.) = 1/5(Ft_u) = 1/5(60,000) = 12,000 PSI < 1/2(Ft_y) = 16,500 PSI

ALL. SHEAR STRESS = F_s(ALL.) = .60 Ft(ALL.) = .6(12,000) = 7,200 PSI

ALL. BEARING STRESS = Ftr(ALL.) = 1.5 Ft(ALL.) = 1.5(12,000) = 18,000 PSI

ALL. BENDING STRESS = F_b(ALL.) = 1.5 Ft(ALL.) = 1.5(12,000) = 18000 PSI

MATERIAL : WELD METAL

F_s (ALL.) = 13,600 PSI (REF. MANUAL OF STEEL CONST. 6TH ED., P.5-19)

Ft(ALL.) = 1/2 (13,600) = 6,800 PSI

ALL. SHEAR STRESS = F_s(ALL.) = .6 Ft(ALL.) = .6(6,800) = 4080 PSI

SUPERSEDES SECTION A OF ALLOWABLE STRESSES

d. ALL AREAS EXCLUDING LIFTING ATTACHMENTS

MATERIAL: AISI No. 1010 - 1020 STEEL

AVERAGE PHYSICAL PROPERTIES EXPECTED

(MIN) F_{ty} = 30,000 PSI } AISI No. 1010

(MIN) F_{tu} = 48,000 PSI

F_t (ALL.) = F_{ty} = 30,000 PSI < .75 (F_{tu}) = 36,000 PSI

ALL. SHEAR STRESS = F_s(ALL.) = .6 F_t (ALL.) = .6 (30,000) = 18,000 PSI

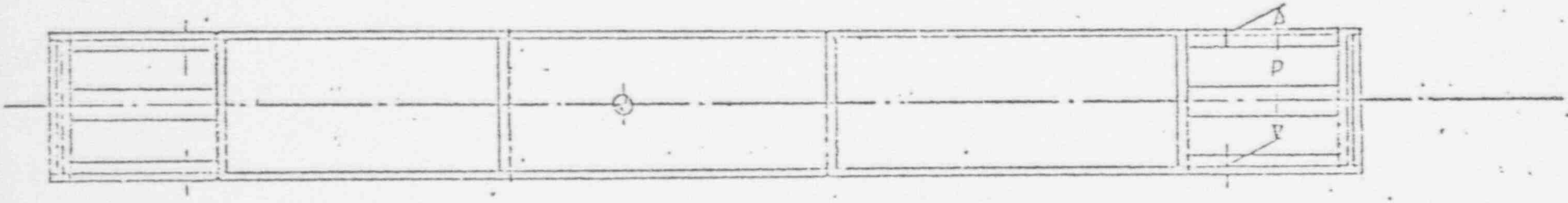
ALL. BEARING STRESS = F_{br}(ALL.) = 1.5 F_t (ALL.) = 1.5(30,000) = 45,000 PSI

MATERIAL: WELD METAL

F_s(ALL.) = 13,600 PSI (REF. MANUAL OF STEEL CONST. 6TH ED., P5-19)

THE ABOVE ALLOWABLE STRESSES EXCEED THE ACTUAL STRESSES IN ALL CONDITIONS.

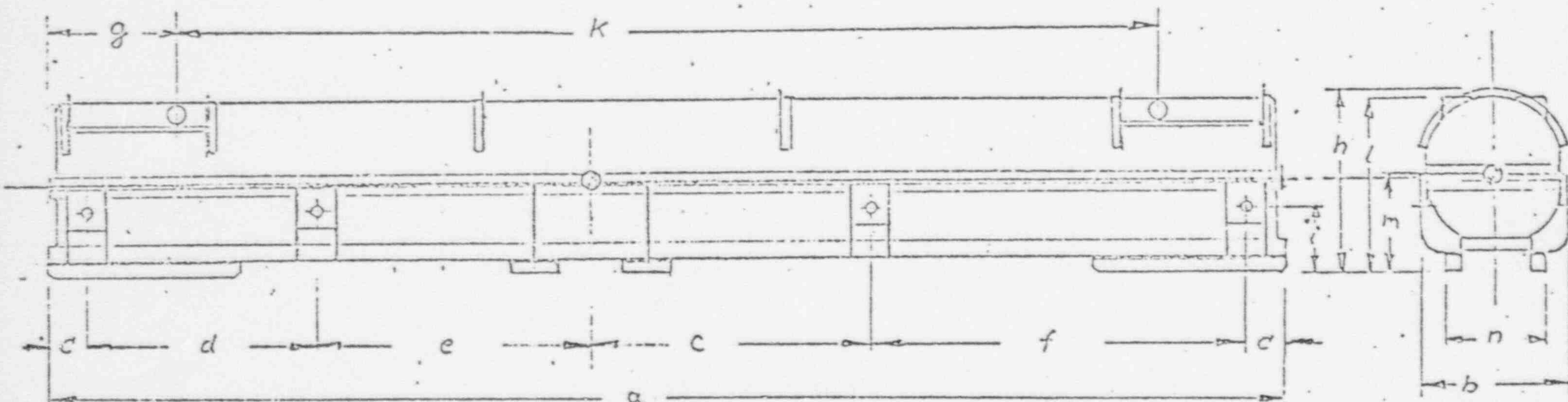
CONTAINER DIMENSIONS

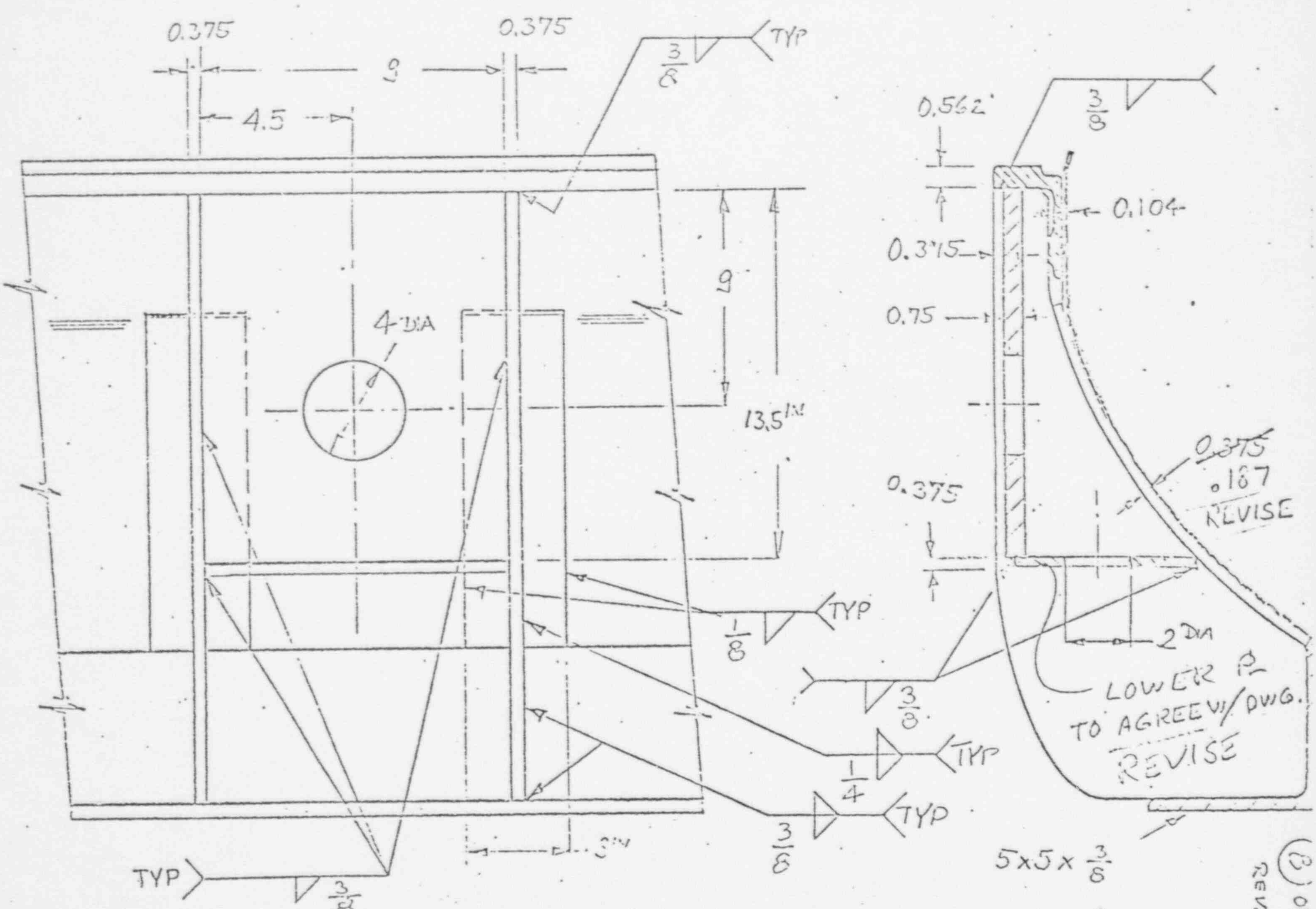


a = 313 d = 67 g = 35.5 K = 242 n = 26

b = 37 e = 70 h = 44.5 l = 42.5 p = 28 1/2

c = 10.5 f = 85 i = 14.0 m = 20




0.375
0.375
9
4.5
TYP
3/8
9
4 DIA
13.5 IN
3 IN
1/8
TYP
1/4
TYP
3/8
TYP
TYP
3/8
0.562
0.104
0.375
0.75
0.375
~~0.375~~ .187 REVISE
2 DIA
LOWER PL TO AGREE W/ DWG.
REVISE
3/8
5x5x3/8

DETERMINATION OF CENTER OF GRAVITY - LOADED CONTAINER

WEIGHTS: CONTAINER LOADED $W = 11200$ LBS

CONTAINER EMPTY : $W_1 = 5900$ LBS

PAYLOAD $W_2 = 5300$ LBS

ESTIM. HEIGHT OF CG - CONTAINER EMPTY $m_1 = 15^{IN}$

HEIGHT OF PAYLOAD CG. $m_2 = 26^{IN}$

COMBINED HEIGHT $m = \frac{m_1 W_1 + m_2 W_2}{W_1 + W_2} =$

$$m = \frac{15 \times 5900 + 5300 \times 26}{5900 + 5300} =$$

$$= \frac{88,500 + 137,800}{11200}$$

$$= \frac{226\,299}{11200} = 20.2 \approx$$

$m = 20.0$

TIE DOWN FORCES

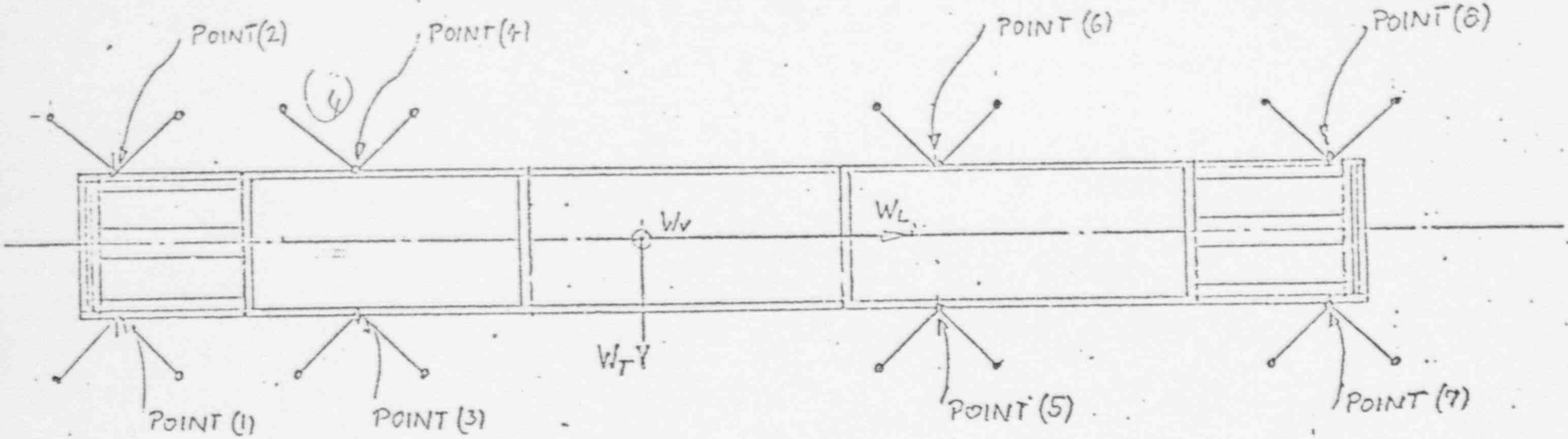
ACCORDING TO THE SPECIFICATION THE CONTAINER TIE DOWN SYSTEM HAS TO WITHSTAND A FORCE APPLIED TO THE CENTER OF GRAVITY THE COMPONENTS OF WHICH ARE TWO TIMES THE WEIGHT OF THE PACKAGE VERTICALLY, 5 TIMES TRANSVERSE AND 10 TIMES LONGITUDINALLY. - TOTAL PACKAGE WEIGHT 10380 LBS

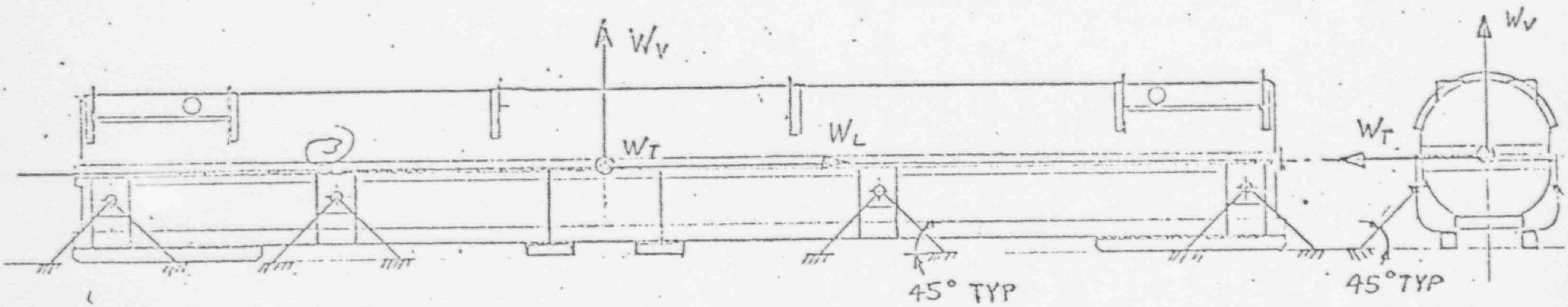
COMPONENTS - VERTICAL W_V = 22,400 LBS
- LATERAL W_T = 56,000 LBS
- LONGITUDINAL W_L = 112,000 LBS

THE REACTIONS OF THESE COMPONENTS ON THE TYING DEVICES ARE ANALIZED SEPARATELY AND LATERON COMBINED PER EACH TIE DOWN POINT.

THE COMPONENT W_L IS DIRECTED TOWARDS THE FORWARD END - SEE FIG. - IN ORDER TO APPLY THE MAXIMUM FORCES PER TIE DOWN POINT.

THE GUY ROPES ARE ASSUMED TO BE ATTACHED TO THE POINTS (1) TO (8) AT AN ANGLE OF 45° - AS SHOWN.



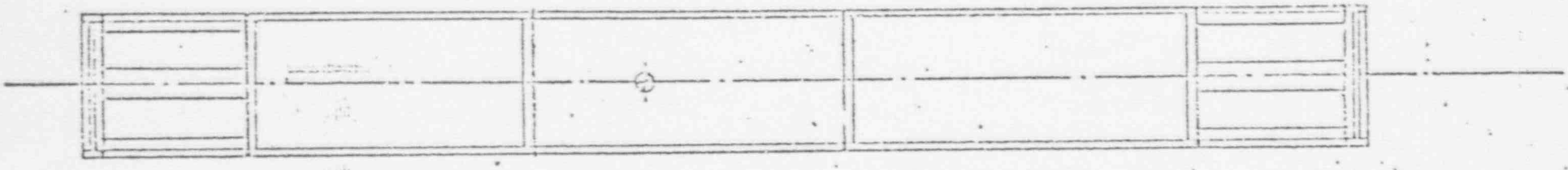


W_V = 22,400 LBS

W_T = 56,000 LBS

W_L = 112,000 LBS

FORCES ACTING ON THE CONTAINER THROUGH COMPONENT W_V



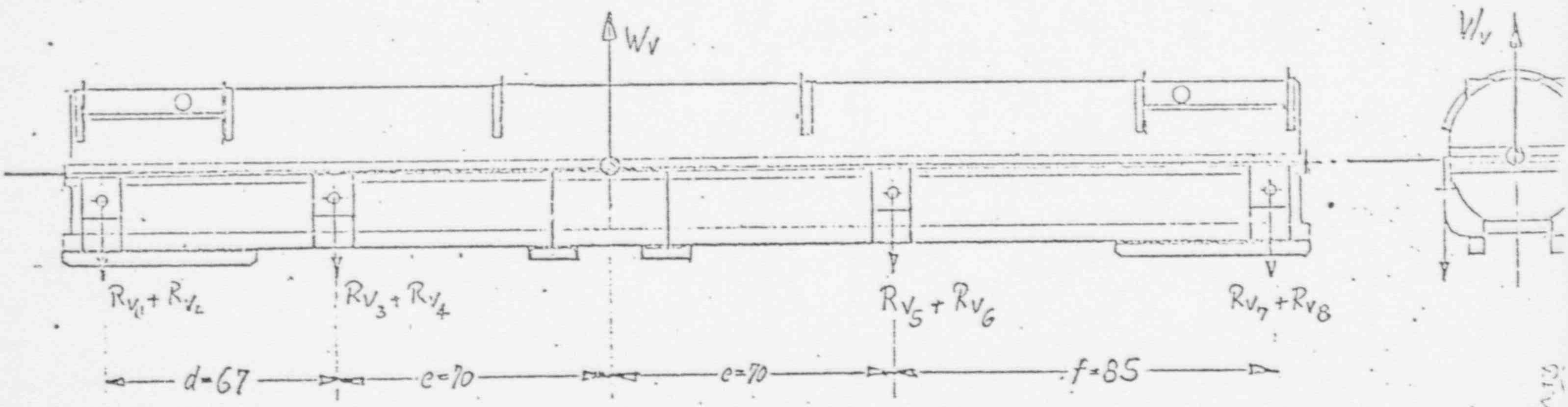
W_V = 22,400 LBS

$R_{V_1} = R_{V_2}$ = 1931.7 LBS

$R_{V_3} = R_{V_4}$ = 3780 LBS

$R_{V_5} = R_{V_6}$ = 3780 LBS

$R_{V_7} = R_{V_8}$ = 1708 LBS



REV. 2

THE CONTAINER IS CONSIDERED RIGID DURING IMPACT IN VERTICAL DIRECTION. THEREFORE IT IS NOT NECESSARY TO CALCULATE IT AS A CONTINUOUS BEAM (FLEXIBLE WITH MULTIPLE SUPPORTS). THE REACTION FORCES ARE SIMPLY DETERMINED ACCORDING TO THEIR DISTANCE FROM THE CENTER OF GRAVITY.

$R_{V1} = R_{V2}$; $R_{V3} = R_{V4}$, $R_{V5} = R_{V6}$, $R_{V7} = R_{V8}$

$R_{V3} = R_{V5}$ AS THEY ARE EQUIDISTANT TO THE CG

MOMENT EQUATION: $\underset{+M}{\Sigma} M_{1,2} = 0$ (POINTS 1 & 2)

① $2 R_{V3} \times d - W_V (c+d) + 2 R_{V5} (2e+d) + 2 R_{V7} (d+2e+f) = 0$

$2 R_{V3} \times 67 - 22{,}400 \times 137 + 2 R_{V3} \times 207 + 2 R_{V7} \times 292 = 0$

$548 R_{V3} + 584 R_{V7} = 3{,}068{,}800$

② $2 R_{V3} + R_{V1} + R_{V7} = \frac{W_V}{2}$

$R_{V7} = 5254.8 - 0.9383 R_{V3}$

$2 R_{V3} - 0.9383 R_{V3} + R_{V1} + 5254.8 = 11{,}200$

$1.0617 R_{V3} + R_{V1} = 5945.2$

(3) $R_{V1} = R_{V3} \frac{e}{e+d}$

$R_{V1} = R_{V3} \frac{70}{137}$;

$1.0617 R_{V3} + 0.51094 R_{V3} = 5945.2$

$R_{V3} = 3780$ LBS ($= R_{V5}$)

$R_{V1} = 3780 \frac{70}{137}$

$R_{V1} = 1931.7$ LBS

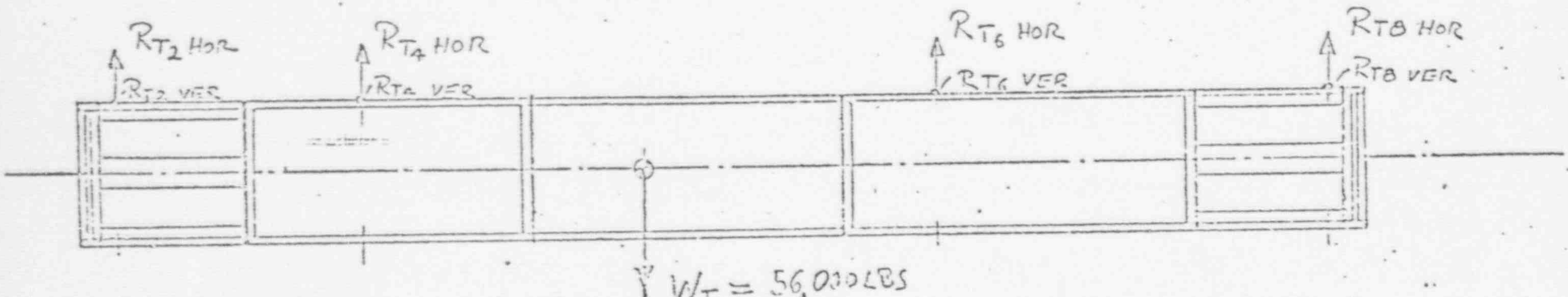
$R_{V7} = 5254.8 - 3546.7$
$R_{V7} = 1708$ LBS

CHECK:

$R_{V1} = 1931.7$
$R_{V3} = 3780$
$R_{V5} = 3780$
$R_{V7} = 1708$

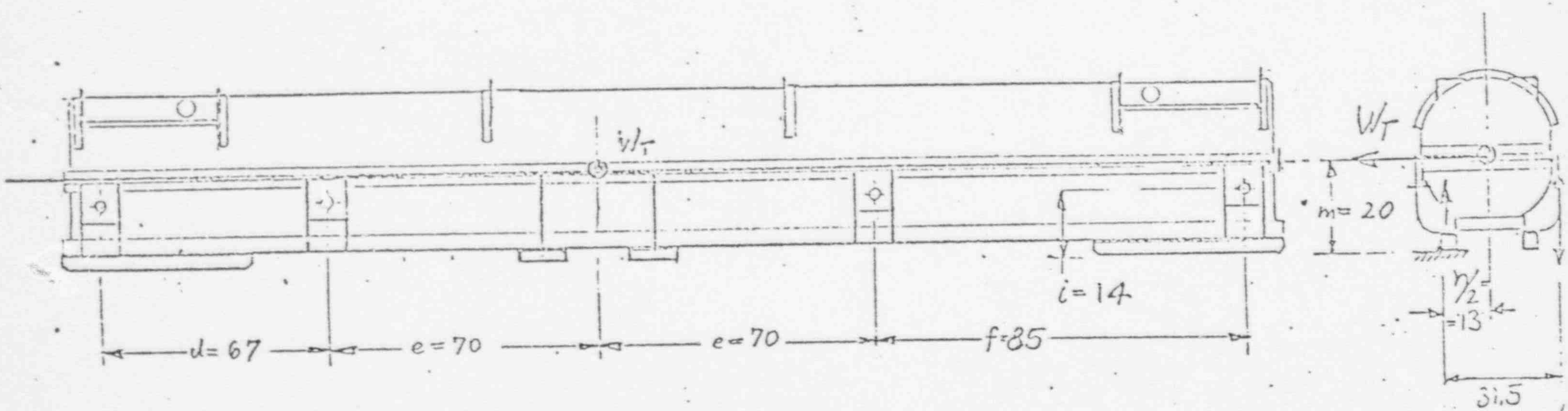
$\Sigma = 11200 \times 2 =$
TOTAL 22400 O.K.

FORCES ACTING ON THE CONTAINER THROUGH COMPONENT V/T



R_{T2} HOR = 9654.4 LBS; R_{T4} HOR = 18900 LBS; R_{T6} HOR = 18900 LBS; R_{T8} HOR = 8540 LBS

R_{T2} VER = 1,963.6 LBS; R_{T4} VER = 3844 LBS; R_{T6} VER = 3844 LBS; R_{T8} VER = 1737 LBS

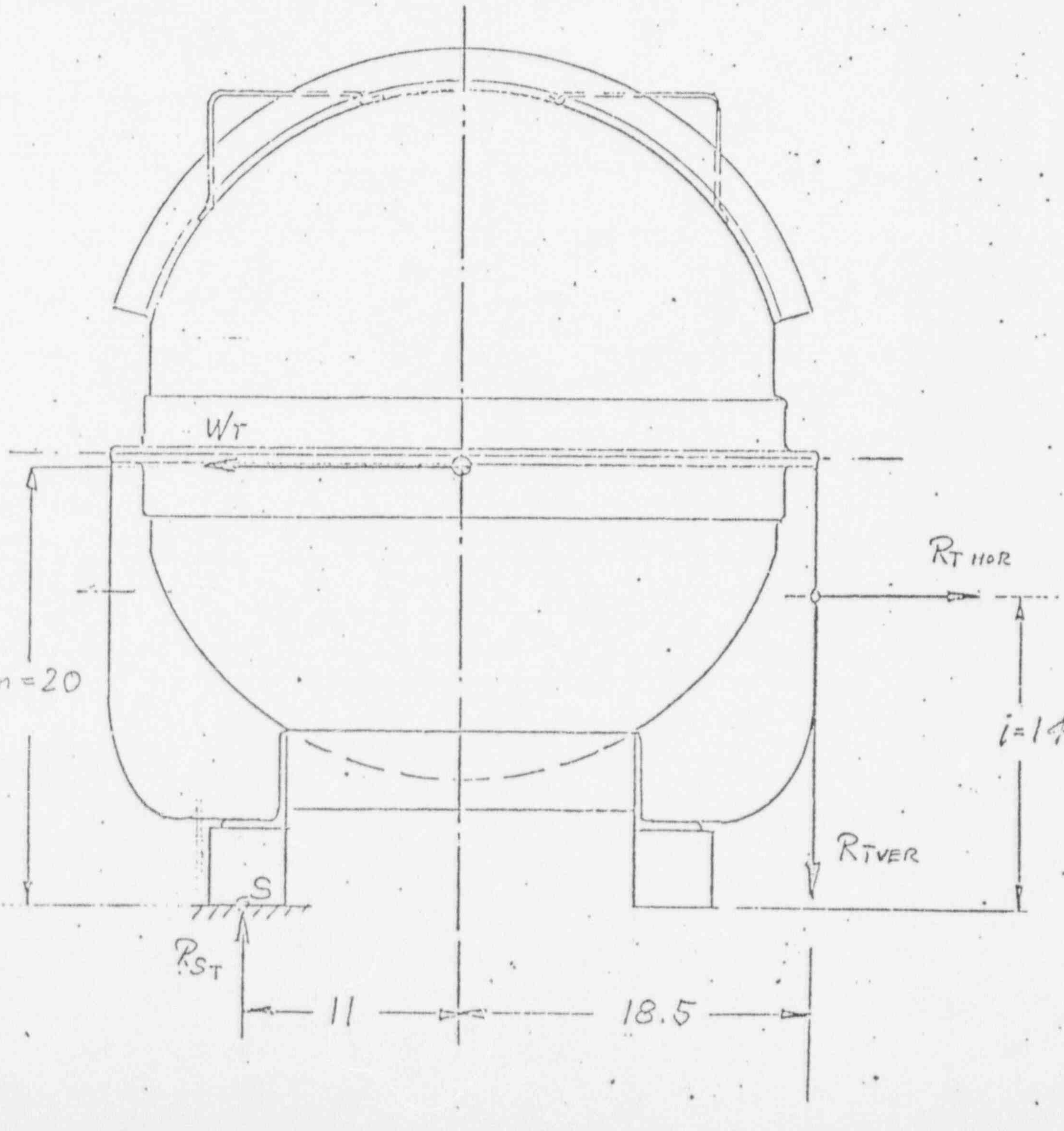


C

$W_T = 56,000$ LBS

$R_{T\,HOR} = 56,000$ LBS

$R_{T\,VER} = R_{S_T} = 11,390$ LBS



THE TRANSVERSE COMPONENT W_T APPLIES REACTIONS ON THE TIE DOWN POINTS 2, 4, 6 AND 8. THE INDIVIDUAL REACTIONS ARE COMBINED IN THE FORCES $R_{T\,HOR}$ AND $R_{T\,VER}$ - ACTING IN THE PLANE VERTICAL TROUGH THE CG. REACTION FORCE IN THE SKIDS IS R_{S_T}.

MOMENT EQUATION: $\Sigma M_S = 0$ (SKID POINT S) $\overrightarrow{+M}$

① $R_{T\,VER} \times 29.5 + R_{T\,HOR} \times 14 - W_T \times 20 = 0$

② $\Sigma_{HOR} = 0; \quad -W_T + R_{T\,HOR} = 0$

③ $\Sigma_{VER} = 0; \quad -R_{ST} + R_{T\,VER} = 0$

$R_{T\,HOR} = W_T = 56,000$ LBS

② IN ① $R_{T\,VER} = \dfrac{W_T(20-14)}{29.5}$;

$R_{T\,VER} = \dfrac{56,000 \times 6}{29.5} =$

$R_{T\,VER} = R_{S_T} = 11,390$ LBS

REACTIONS ON THE SINGLE TIE DOWN POINTS

DISTRIBUTION IS EQUIVALENT TO THE RATIOS OF FORCES $2R_{V_1}$, $2R_{V_3}$ ETC. TO W_V (SAME LOCATIONS).

HORIZONTAL:

$$R_{T2\ HOR} = \frac{2\ R_{V1}}{W_V} \times R_{T\ HOR} =$$

$$= \frac{2 \times 1931.7}{22,400} \times 56,000 = 9,654.4 \text{ LBS}$$

$$R_{T4\ HOR} = \frac{2\ R_{V3}}{W_V} \times R_{T\ HOR} =$$

$$= \frac{2 \times 3780}{22400}\ 56000 = 18,900 \text{ LBS}$$

$$R_{T6\ HOR} = R_{T\ HOR\ (4)} = 18,900 \text{ LBS}$$

$$R_{T8\ HOR} = \frac{2\ R_{V7}}{W_V} \times R_{T\ HOR} =$$

$$= \frac{2 \times 1708}{22400}\ 56000 = 8,540 \text{ LBS}$$

VERTICAL:

$$R_{T2\ VER} = \frac{2\ R_{V1}}{W_V} \times R_{T\ VER} =$$

$$= 0.1724 \times 11390 = 1963.6 \text{ LBS}$$

$$R_{T4\,VER} = \frac{2 R_{V3}}{V/V} \times R_{T\,VER} =$$

$$= 0.3375 \times 11390 = \underline{3{,}844 \quad LBS}$$

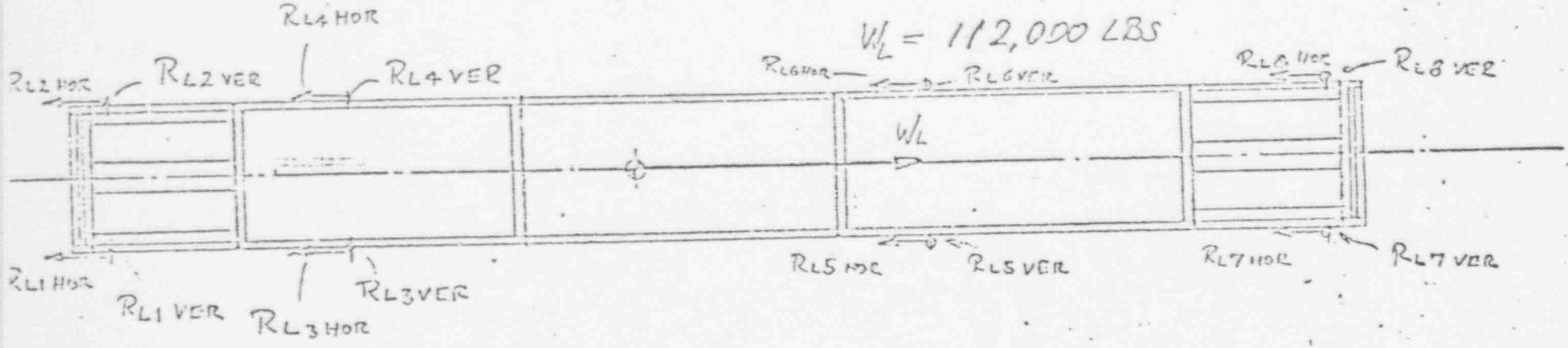
$$\underline{R_{T5\,VER} = R_{T4\,VER} = 3{,}844 \quad LBS}$$

$$R_{T8\,VER} = \frac{2 R_{V7}}{V/V} \times R_{T\,VER} =$$

$$= 0.1525 \times 11390 = \underline{1737 \quad LBS}$$

FORCES ACTING ON THE CONTAINER THROUGH COMPONENT W_L

$W_L = 112{,}000$ LBS



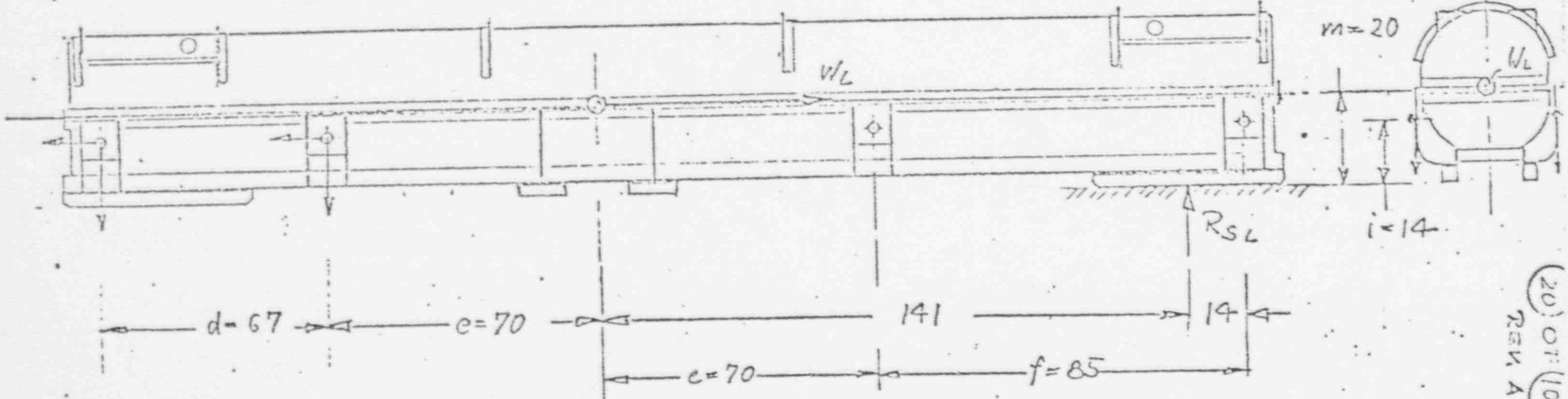
$R_{L1\,HOR} = R_{L2\,HOR} = 14{,}000$ LBS; $R_{L3\,HOR} = R_{L4\,HOR} = 14{,}000$ LBS

$R_{L1\,VER} = R_{L2\,VER} = 424.4$ LBS; $R_{L3\,VER} = R_{L4\,VER} = 830.6$ LBS

$R_{L5\,HOR} = R_{L6\,HOR} = 14000$ LBS; $R_{L7\,HOR} = R_{L8\,HOR} = 14{,}000$ LBS

$R_{L5\,VER} = R_{L6\,VER} = 830.6$ LBS; $R_{L7\,VER} = R_{L8\,VER} = 375.1$ LBS

$R_{SL} = 4921$ LBS



$R_{L1\,HOR} = R_{L2\,HOR}$ $\quad R_{L5\,HOR} = R_{L6\,HOR}$

$R_{L1\,VER} = R_{L2\,VER}$ $\quad R_{L5\,VER} = R_{L6\,VER}$

$R_{L3\,HOR} = R_{L4\,HOR}$ $\quad R_{L7\,HOR} = R_{L8\,HOR}$

$R_{L3\,VER} = R_{L4\,VER}$ $\quad R_{L7\,VER} = R_{L8\,VER}$

R_{SL} = SKID REACTION APPLIED ON BOTH SKID OF FORWARD END.

MOMENT EQUATION :

$\Sigma M_{1,2} = 0$ (POINTS 1 & 2)

① $2 R_{L3\,VER} \times d + W_L \times (m - i) - R_{SL}(e + d + 141) +$
$+ 2R_{L5\,VER}(2e + d) + 2R_{L7\,VER}(d + 2e + f) = 0;$

② $\Sigma\, VERT = 0 \qquad -R_{SL} + 2R_{L3\,VER} + 2R_{L1\,VER} +$
$+ 2R_{L5\,VER} + 2R_{L7\,VER} = 0$

③ $\Sigma\, HOR = 0 \qquad -W_L + 2R_{L3\,HOR} + 2R_{L1\,HOR} +$
$+ 2R_{L5\,HOR} + 2R_{L7\,HOR} = 0$

④ $R_{L1\,VER} = R_{L3\,VER}\dfrac{e}{e+d}$

⑤ $R_{L1\,HOR} = R_{L3\,HOR} = R_{L5\,HOR} = R_{L7\,HOR}$

⑥ $R_{L5\,VER} = R_{L3\,VER}$ (BEING EQUIDISTANT TO CG)

⑦ $R_{L7\,VER} = R_{L5\,VER} \times \dfrac{e}{e+f}$

(5) IN (3) $R_{L1\,HOR} = R_{L3\,HOR} = R_{L5\,HOR} = R_{L7\,HOR} =$

$$= \frac{112\,000}{8} = 14{,}000 \text{ LBS}$$

(4),(6),(7) IN (2):

$$4\,R_{L3\,VER} + 2\,R_{L3\,VER}\,\frac{e}{e+d} + 2R_{L3\,VER}\,\frac{e}{e+f} = R_{SL}$$

$$R_{L3\,VER}\left(4 + 2\times\frac{70}{137} + 2\times\frac{70}{155}\right) = R_{SL}$$

(8) $R_{SL} = 5.925\ R_{L3\,VER}$

(6),(7),(8) IN (1):

$$2\,R_{L3\,VER} \times 67 + 112{,}000 \times 6.0 - 5.925\ R_{L3\,VER} \times 278 = 0$$

$$809.3\ R_{L3\,VER} = 672{,}000$$

$R_{L5\,VER} = R_{L3\,VER} = 830.60$ LBS

$R_{SL} = 4921.3$ LBS

$R_{L1\,VER}$: $830.6 \times \frac{70}{137} = 424.4$ LBS

$R_{L7\,VER} = 830.6\ \frac{70}{155} =$

$= 375.1$ LBS

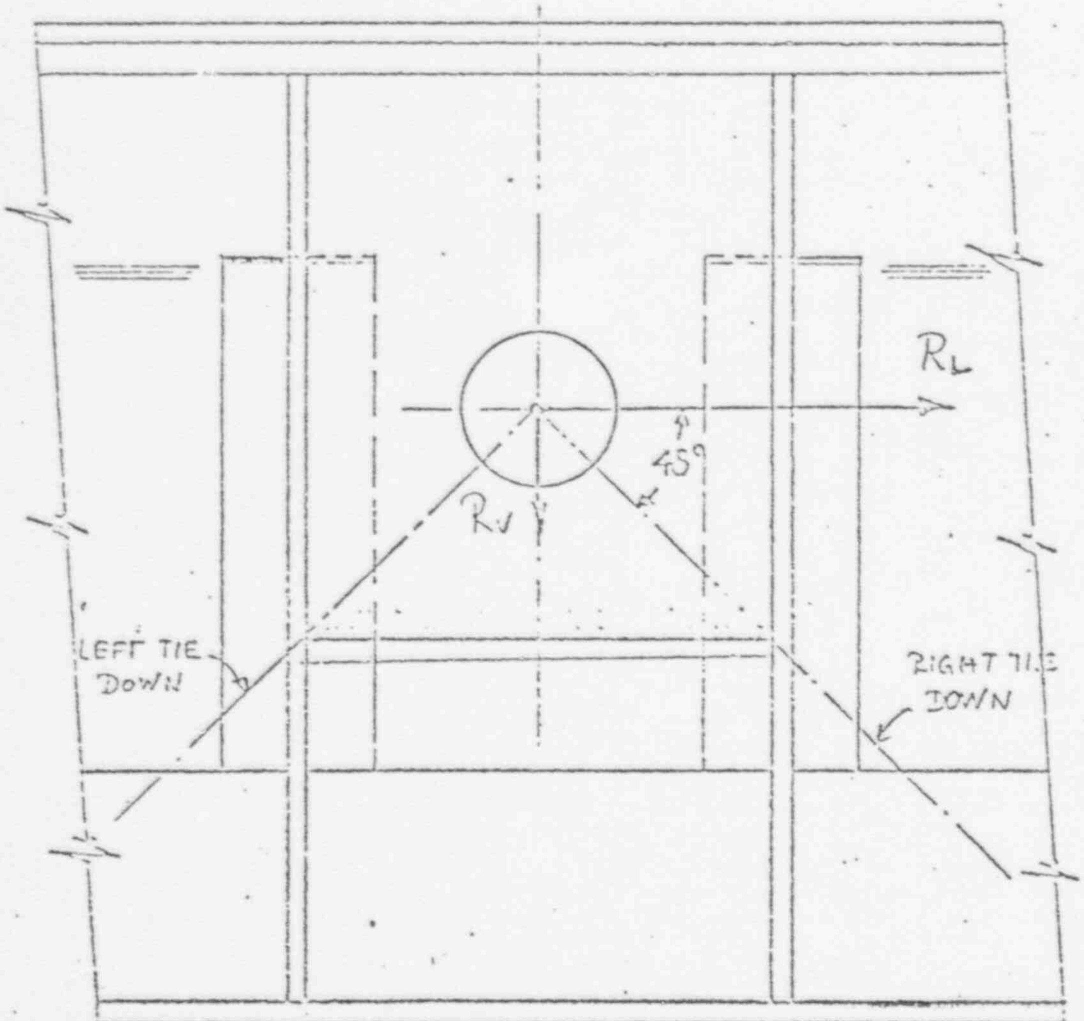
SUMMARY – TIE DOWN FORCES

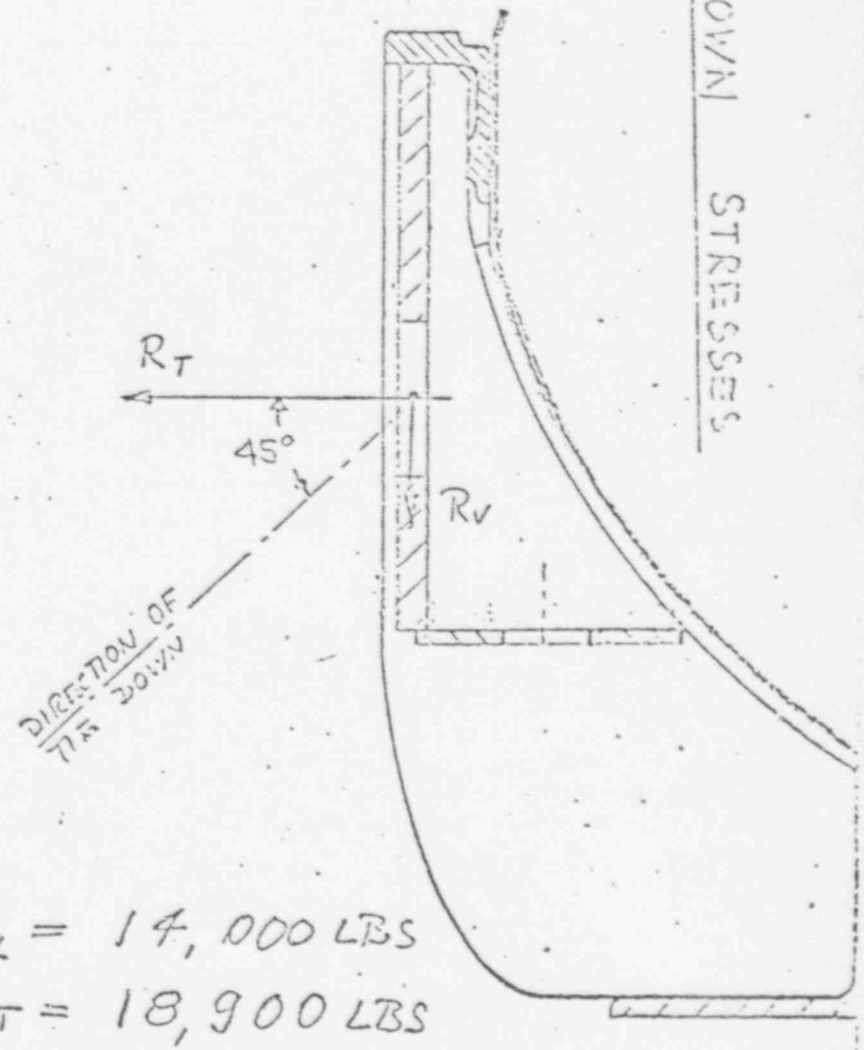
THE POINTS 2 & 4 SUFFER OBVIOUSLY THE MOST STRAIN WHEN THE ACCELERATION COMPONENTS W_L, W_V AND W_T ARE DIRECTED AS SHOWN.

POINT NO.	LOAD COMPONENT APPLIED	REACTION FORCES PER AXIS		
		VERTICAL	LONGITUD.	TRANSVERSE
2	W_L	424.4	14,000	
	W_V	1931.7		
	W_T	1963.6		9654.4
Σ		4319.7	14,000	9,654.4
4	W_L	830.6	14,000	
	W_V	3760.		
	W_T	3844		18,900
Σ		8454.6	14,000	18,900 ← WORST CONDITION

TIE DOWN STRESSES

TYING FORCE	RIGHT	LEFT
LONG. COMPONENT	14000	—
TRANSV. "	9450	9450
VERT. "	4227	4227

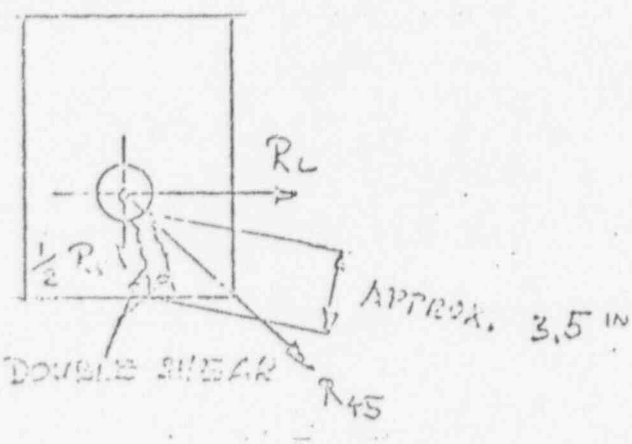




R_L = 14,000 LBS
R_T = 18,900 LBS
R_V = 8,454 LBS

TEAR-OUT OF TIE DOWN HOLE

COMBINED FORCE OF R_L AND $\frac{1}{2}R_V$ APPLIED UNDER 45° (DIRECTION OF TIE DOWN). = $R_{45°}$



$$\cos 45° = \frac{R_L}{R_{L45}} ;$$

$$R_{L45} = \frac{R_L}{0.707} ;$$

$$R_{L45} = \frac{14{,}000}{0.707} \approx$$

$$\approx 19{,}802 \text{ LBS}$$

$$\cos 45° = \frac{\frac{1}{2}R_V}{R_{V45}} ; \quad R_{V45} = \frac{R_V}{\cos 45°} ;$$

$$R_{V45} = \frac{4227}{0.707} \approx 5978 \text{ LBS.}$$

$R_{45} = R_{L45} + R_{V45} =$ <u>25,780 LBS</u>

SHEAR AREA (DOUBLE SHEAR)

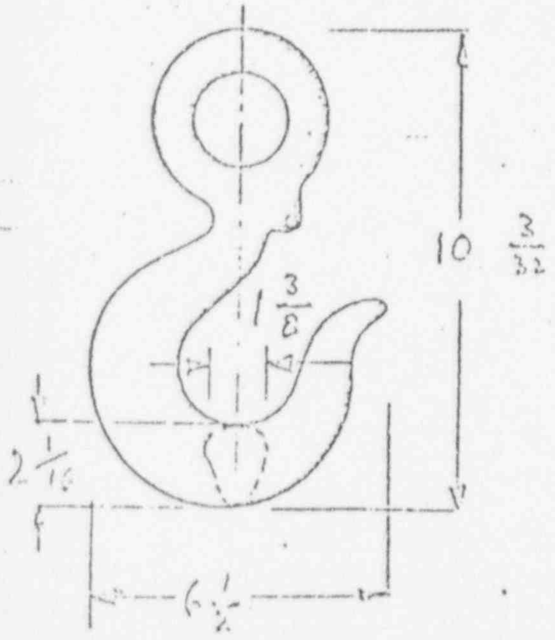
$$A = 2 \times 0.75 \times 3.5 = 5.25 \text{ IN}^2$$

SHEAR STRESS IN PLATE

$$S_S = \frac{R_{45}}{A} = \frac{25780}{5.25} = 4910 \text{ PSI} < S_{ALLOW} = 21600 \text{ PSI}$$

BEARING STRESS IN HOLE

HOOK REQUIRED FOR 28,000 LBS AVERAGE PROOF LOAD ≙ 7 TONS SAFE WORKING LOAD



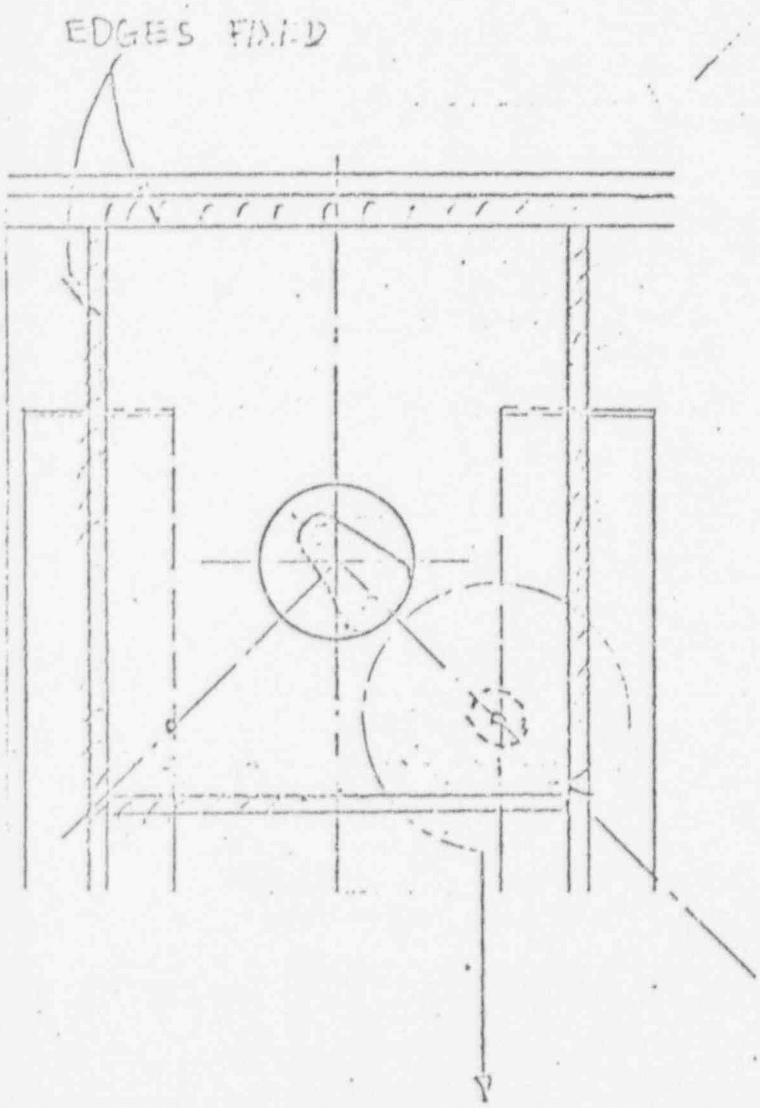
BEARING AREA IN THE HOLE

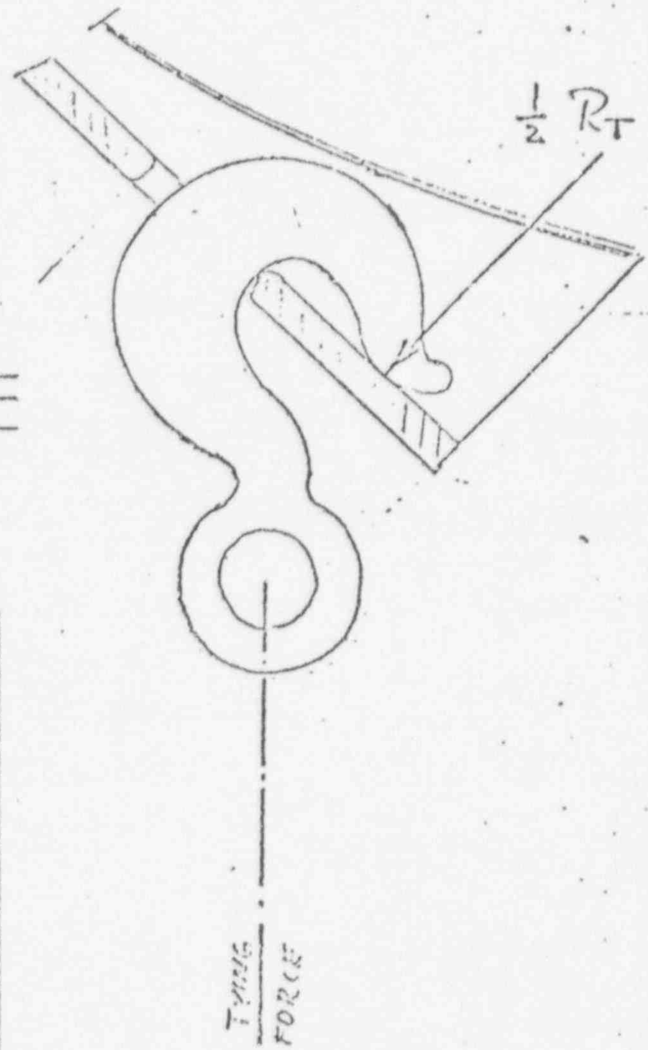
$$A = 1.38 \times 0.75 = 1.035 \text{ IN}^2$$

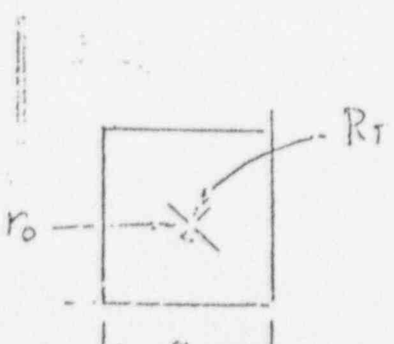
$$P = \frac{R_{45}}{A} = \frac{25,780}{1,035} =$$

$$P = 24,908 \text{ PSI} < P_{ALLOW} = 54.000 \text{ PSI}$$

FLAT PLATE BENDING







$r_0 = 0.5$

$a = 3.5^{IN}$

$\frac{1}{2} R_T = 9450$ LBS

CONDITIONS COMPARABLE WITH CASE NO. 35 IN REF. "ROARK, FORMULAS FOR STRESS AND STRAIN", PAGE 225, 4TH EDITION;

SQUARE PLATE, SOLID
UNIFORM LOAD OVER SMALL CONCENTRIC CIRCULAR AREA OF RADIUS r_0;

STRESS (AT CENTER)

$$S_s = -\frac{3W}{2\pi m t^2}\left[(m+1)\log\frac{a}{2r_0}\right]$$

$W = R_T = 9450$ LBS
m = RECIPROCAL OF POISSON'S RATIO $m = \frac{1}{0.27} = 3.7$
t = THICKNESS OF PLATE $= 0.75$
$a = 3.5^{IN}$
$r_0 = 0.5^{IN}$
$\log$ CONSIDERERED NATURAL LOGARITHM $= \log_e$

$$S_s = -\frac{3 \times 9450}{2\pi\ 3.7\ (0.75)^2}\left[(3.7+1)\log\frac{3.5}{2\times 0.5}\right] =$$

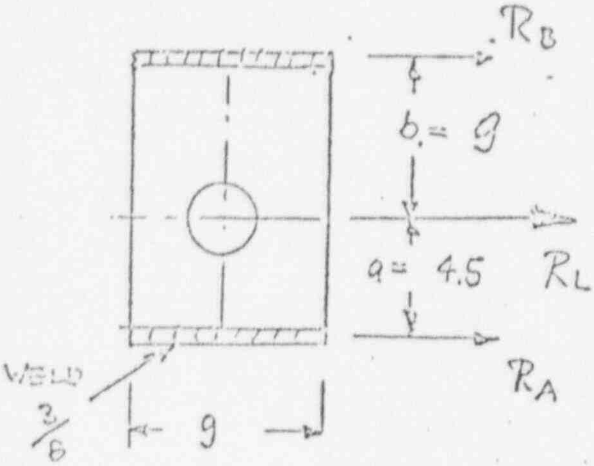
$$= -2167.9\ [4.7 \times 1.252] =$$

$S_s = -12,757$ PSI $< S_{ALLOW} = 36,000$ PSI

WELD STRESSES DUE TO TIE DOWN FORCES

LONGITUDINAL RESULTANT R_L

FOR SIMPLIFIED CALCULATION WE ANALYZED DIFFERENT WELD AREAS FOR EACH FORCE COMPONENT.



REACTION:

$$R_A = R_L \frac{b}{a+b} = 14{,}000 \frac{9}{9+4.5} =$$

$$R_A = 9{,}333 \text{ LBS} \quad \text{(MAX. FORCE)}$$

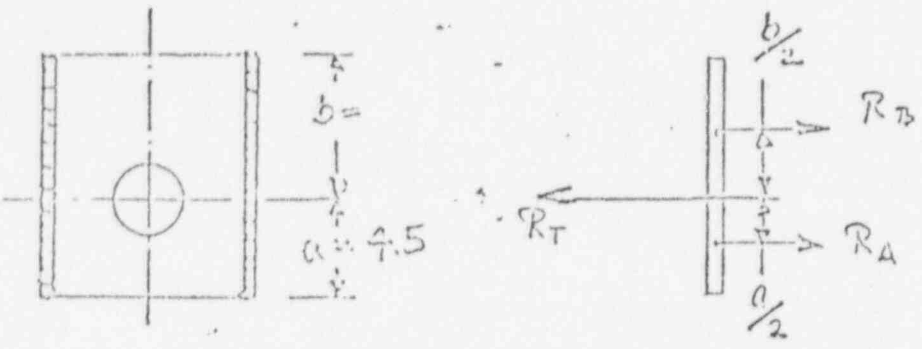
WELD AREA: $A = \frac{3}{8} \times 9 = 3.375 \text{ IN}^2$

SHEAR STRESS $S_s = \frac{R_A}{A} = \frac{9{,}333}{3.375} =$

$\underline{S_s = 2765 \text{ PSI}} < S_{ALLOW} = 13600 \text{ PSI}$

20.3%

TRANSVERSE RESULTANT R_T



R_T = 18,900 LBS

REACTION

$$R_A = R_T \frac{b}{a+b} = 18900 \frac{6.5}{4.5+6.5} =$$

R_A = 12,600 LBS (MAX)

AREA $A = 2 \times a \times .375 = 2 \times 4.5 \times 0.375 =$
$A = 3.375 \; IN^2$

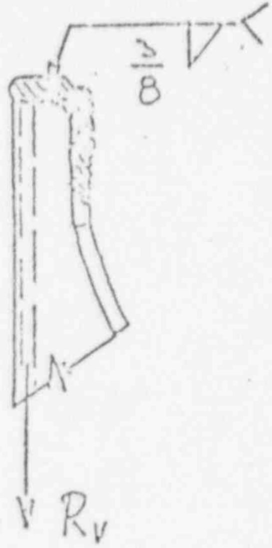
SHEAR STRESS:

$$S = \frac{R_A}{A} = \frac{12\,600}{3.375} =$$

$S = 3733$ PSI $< S_{ALLOW} = 13600$ PSI

VERTICAL RESULTANT R_V

$R_V = 8454$ LBS.



WELD AREA

$A = 2 \times 0.375 \times 1.5 =$

$A = 1.125 \text{ IN}^2$

SHEAR STRESS

$$S_s = \frac{R_V}{A} = \frac{8454}{1.125} = 7515 \text{ PSI} <$$

$< S_{ALLOW} = 13600$ PSI 55.3%