PDR 71-9023

NL Nuclear

July 6, 1979

Mr. Charles E. MacDonald, Chief
Transportation Branch
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Subject: NLI 10/24 Rail Cask
Certificate of Compliance No. 9023, Rev. 0

Reference: NRC Letter of March 1, 1979

Gentlemen:

In response to the reference letter, NL has revised certain pages and drawings in addition to the information contained in Attachment No. 2.

Enclosed herewith please find eight (8) copies of the revised pages and drawings. Revised pages are those listed on Attachment 1 to this letter.

NL is not requesting any proprietary data withholding regarding the attached data and drawings; therefore, you are hereby authorized to release all of the enclosed data and drawings as deemed necessary by your staff.

Sincerely,

C.E. Williams

C.E. Williams

/ljh

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Enclosure

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Attachment No. 1

Revision List - NLI 10/24 Rail Cask

Safety Analysis Report

Section	Rev. No.	Revised Pages
VIII	2	-3, -4
XI, Part 2	3	2-22h,
	4	2-5, 2-17, 2-22e, 2-22j, 2-22k, 2-22m, 2-22o
	5	2-10, 2-12, 2-18a, 2-21, 2-22
Part 4	4	4-68, 4-71, 4-70
	5	4-73, 4-74
XV	4	-2
	6	-1
XVIII	8	-2
	9	-1

Attachment No. 2, to NL Letter of July 6, 1979

Response to NRC Letter of March 1, 1979

Structural

Inner Closure Lifting Lugs -

Page XI-2-5 has been revised to incorporate a statement specifying the method of lifting that will result in a direct vertical lift on each eye bolt.

Cask Tie-Down System

Section 2.2 Tie-Downs, was revised to reflect information given by the final detail drawings used to construct the casks. The various parts of this section were restructured as explained below to improve the presentation.

2.2 - This part presents the same information; introduction and analysis of applied loads; as the previous edition.

2.2.1 - This part analyses the tie-down at the closure head end of the cask. The difference in presentation here is that the previous edition analyzed both the lugs welded to the car frame and the lug welded to the cask. Since the criteria is different for the two sets of lugs it seemed logical to separate the two conditions. Therefore this revised section deals only with the lug welded to the cask and the tie-down pin.

2.2.2 - This part analyzes the tie-down at the bottom end of the cask. As in Part 2.2.1 the difference in presentation is that the previous edition analyzed both the lugs welded to the car frame and the lugs welded to the cask as well as the support saddles. This revised section deals only with the lugs welded to the cask and the tie-down pin.

2.2.3 - This part analyzes the tie-down lugs and saddles which are welded to the car frame. Also included in this part is the summary of tie-down stresses. The previous edition dealt only with the summary of stresses. The revised edition is subdivided as follows.

2.2.3.1 - Front tie-down, Impact at "B" End.

2.2.3.2 - Front tie-down - Welds.

2.2.3.3 - Rear tie-down - Impact at "A" End and "B" End.

2.2.3.4 - Rear tie-down - Welds Impact at "A" and "B" Ends.

2.2.3.5 - Saddle bearing stresses.

2.2.3.6 - Summary of tie-down stresses.

The following discussion addresses the changes made and their effect.

Dimensional changes to the figure shown on page 2-8 reflect the final detail drawing dimensions used to construct the casks. The specific dimensional changes are as follows:

a) Distance between support points was 205 1/2 inches, now 208 1/2 inches.

b) Distance from front or top end of casks tie-down lug to the center of the rear or bottom end of cask support point was 175.75, now 177 1/4 inches.

c) Distance from rear or bottom end of cask tie-down lug to the center of the top or front end of cask support point was 197.75 inches, now 198 1/4 inches.

d) Distance from the front or top end of cask tie-down lug to the center of the front or top end of the cask support point was 30 3/4 inches, now 31 1/4 inches.

e) Distance from the rear or bottom end of cask tie-down lug to the center of the rear or bottom end of cask support point was 8 3/4 inches, now 10 1/4 inches.

f) Tie-down pin diameter was reduced from 5.5 inches to 5 7/16 inches. This change was necessary to facilitate handling operations.

Dimensional changes (a) thru (e) resulted in a reduction of about 1,000 lbs. in the reaction loads at the support and tie-down points.

Tie-Down Pins:

The reduction in tie-down pin diameter resulted in a decrease in the margin of safety. However, the stresses are still within the design criteria of 0.9 times yield strength.

Comparison of Margins of Safety

	Original Design 5.5 Dia.	Final Design 5 7/16 Dia.
Front Pin: M.S.	.049	.016
Rear Pin:		
M.S. Comb. S	.54	.394
M.S. Bearing	.49	.329

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Front Cask Lug (Closure Head End):

There is a slight change in the lug configuration. The change did not effect the hole size nor the amount of material around the hole. The change provided more material where the lug joins the cask which in turn resulted in additional length of welding. The stress analysis of the lug is the same as the previous edition except the loading is about 2100 lbs. less due to dimensional changes sited in (a) thru (e) above and in the calculation of tension stress the area has been corrected. The results of these changes has been to increase the margins of safety.

Two changes were made in the lug to cask weld analysis. The length of weld "A" increased from 2" to 4 1/2 inches and the assumption that the weld metal in the throat of the weld has a strength at least 90% of that of the base metal (17 - 4 PH) has been deleted in favor of a more conservative approach. It is now assumed that the weld metal is no stronger than the weaker of the two base materials, i.e., 304 stainless steel. The analysis is the same as presented in the previous edition except the margins of safety are less than previously reported due to the change in assumptions which reduced the weld strength values.

Rear Cask Lug (Bottom end):

Only minor corrections were made to the sketch of the lug shown in the SAR. The 7 inch R. is 7 1/8 inches and the 3.5 inch dimension is 3 5/8 inches. The thickness and all other dimensions of the lug remained the same as originally shown. These changes had little effect on the lug analysis. Margins of safety remained essentially the same as originally reported due primarily to the correction of area calculations.

The lug to cask weld analysis is essentially the same as previously presented. As in the case of the front cask lug the assumption on weld metal strength has been revised which has resulted in a reduction in the margins of safety.

There is no change in the length of welds or the weld pattern. The following changes were made in weld size:

Weld	Size
"a"	was 1" fillet, now 1 1/2" fillet
"b"."c","d"	was 1 3/4" fillet + 1/2" penetration now 1 1/2" fillets + 1/2" penetration
"e"	was 1" "J" weld now 1 1/2" fillet

The above resulted in a slight reduction in total weld area (was 175.992 in.^{2}, now 166.86 in.^{2}). The reduction in weld area combined with the reduction in allowable weld strength has resulted in a general reduction in the margins of safety. The design, however, still falls within the allowable stress criteria (.9 times yield).

Front Tie-Down Lug (Rail Car):

The lug analysis presented in this revision has corrected some dimensional errors which existed in the previous edition. Specifically the 1.8 dimension was 2 inches and the 2 3/4" dimension was 3 inches.

Another difference in this analysis is that the allowable design strengths are taken as 100% of the ultimate tensile stress, since the prime concern is the behavior of the rail car lugs during an accident condition.

The only other change in the front tie-down lug design is a reduction in the size of Weld 2 from 3/4 inch fillet to 9/16 inch fillet. The original calculation used the ultimate tensile strength of the lug material (115,000 psi) which resulted in a break away force of 3.25 g's. The revised calculation uses the ultimate tensile strength of the weld metal (95,000 psi) which results in a break away force of 3.55 g's.

Rear Tie-Down Lug (Rail Car):

The following dimensional changes were made to the lug configuration to provide adequate clearance between the tie-down lugs and the cask body and cask tie-down lugs. Clearances are necessary to effect proper rotation of the cask from horizontal to vertical.

Center lug:

6 1/4 inch radius was 6 5/8 inches.
2 1/2 inch dimension was 2 3/4 inches.
3/4 inch X 30° chamfer was 1 inch X 45°.
No change in the thickness of the lug.

Side plates:

Sketch in original calculation was not totally correct.
6 1/4 inch radius now shown was 6 1/4 inch dimension on original sketch.
3 inch dimension was 3 1/4 inches.
3/4 inch X 30° chamfer was 1" X 45°.

These dimensional changes resulted in a slight reduction in cross sectional areas. There is also a slight reduction in loads due to the dimensional changes (a) thru (e) listed previously. The lugs were analyzed in the same manor as the original analysis with adequate margins of safety.

The following changes were made in the attachment welds identified as welds 1, 2 and 3.

Welding: The previous calculations assumed that the strength of the weld joint was equal to that of the base metal, 100,000 psi for T-1 material. The revised calculations used the weld strength of the filler metals as listed on page XI-2-22g. This resulted in a reduction in allowable stress.

Weld #1: The previous weld size was 1 1/2 inch "J" groove with a 1 inch fillet. The revised weld size is 1 1/8 inch "J" groove with a 1 inch fillet. The length of the weld has been reduced from 44 inches to 42 1/2 inches. These dimensional changes still provide a weld which is stronger than sacrifical weld no. 2.

Weld #2: Bottom plate of weldment was 1 1/2 inches thick, now 1 3/4 inches thick. Fillet weld size has been increased from 1 inch to 1 3/8 inches. Length of the weld has been reduced from 95 inches to 88 inches. The net effect however was an increase in square inches of weld from 67.165 to 85.55. These changes did not effect the function of the weld as far as being the plane of separation in a severe accident.

Weld #3: There is a slight reduction in the number of lineal inches of weld but an increased in weld size. The weld was a 1 inch fillet The weld joint now is a 3/4 inch J groove plus a 1 inch fillet. The revised weld joint geometry produces a weld which is stronger than Weld #2 which is the desired condition.

Saddle Supports:

Previous calculations were based on saddle loads resulting from 5 g lateral force. As stated on page XI-2-10 the saddles are designed for 2g lateral which results in a reduction in the saddle load. The only change in the revised calculation is this reduction in saddle load which results in a higher margin of safety.

In reviewing this section some typographical errors were found as well as some dimensional errors on sketches. The effected pages have been corrected and given the next revision level. Each page of the entire section has been marked in the right hand margin indicating the areas of change. With the exception of the above mentioned pages the balance of the section remains at the same revision level as the October 10, 1978 submission.

The drawing package was revised to eliminate duplication of information which reduces the number of drawings in the package. The drawing package was restructured so that all Impact Structure Details are shown on the series of drawings numbered 70666F and all Support Structure and Tie-Down Details are shown on the series of drawings numbered 70667F. On the following page is a flow chart type presentation which explains the new drawing package vs. the old drawing package. Two drawings showing Front & Rear Tie-Down Details required a correction to the Tie-Down Pin diameter. The drawings have been corrected and given the next revision level.

Thermal Stresses

1) The cask end temperatures reported on page XI-3-3A and XI-4-3A were taken from Section VIII, Thermal Analysis, Appendix "D" pages D5, D6, D7 and D8. The data presented in Appendix D and Appendix E was generated specifically for use in the thermal stress analysis calculations. Temperatures reported in Appendix D were used since they presented a more severe condition at the ends of the cask. In all cases the temperatures reported on pages XI-3-3A and XI-4-3A have been rounded off to higher values.

2) The graph on page XI-3-29 is based on a radical cold gap of .105 mils between the aluminum basket and the inner shell. Drawing 70651F, Sheet 2, shows the inside diameter of the cask to be 45 inches. Subtracting the basket dimension of 44.79 from the 45 inch cavity dimension results in a nominal .105 mil radial gap.

NLI 10/24 RAIL CASK

IMPACT STRUCTURE AND TIE-DOWN DRAWINGS

ORIGINAL ISSUE VS LATEST REVISION

655 287

POOR ORIGINAL

PWR Spacer Plug

1) Sketch on page XI-4-73 has been revised to correctly show the 28 1/4 inch dimension.

2) The procedure that will be used to assure that the PWR sapcer length will result in the desired gap is as follows. Depending on whether the particular fuel assembly length is longer or shorter than the reference fuel length (159.8) add or subtract the difference to both the 13.99 and 2.13 dimensions shown on Drawing 70655F to obtain the adjusted fuel spacer heights. Drawing 70655F has been revised to explain the procedure for obtaining adjusted spacer plug dimensions.

   The spacer plug design is such that visual determination of the fuel basket as well as spacer plug orientation can be made as the spacer plug is being lowered into position.

3) The dimension is locating the top edge of the absorber material relative to the fuel support plate in the basket. The absorber material is 151 inches long and is located 3 inches above the support plate as shown on drawing 70652F. The combination of the two dimensions locates the top edge of the absorber material 154 inches from the support plate in the basket. The words "TO TOP OF" have been added to clarify the dimension.

4) The referenced figure on page XI-4-68 should be 3.6.1.2.1(c). The percent of ultimate stress at temperature should be 72%. The exposure time used to obtain 72% at 390°F is 1000 hours. The 1000 hours is more than adequate to cover elapsed transport time. The loading being analyzed is not a constant load but a momentary load resulting from the hypothetical drop accident criteria.

Miscellaneous

There were some typographical errors and omissions in Attachment 1 to our October 6, 1978 letter. We have corrected the listing and resubmit as Revised Attachment No. 1 to October 6, 1978 letter.

Enclosed is a complete page tabulation of Section XI, giving each page number and associate page revision number, as requested.

NLI 10/24 RAIL CASK

SAFETY ANALYSIS REPORT

SECTION XI REVISION STATUS AS OF 6/29/79

SECTION XI	REV.		REV.		REV.
i	3-6/75	-1-29	1-5/ 1/74	-2-22b	2-9/78
ii	3-6/75	-1-30	1-5/ 1/74	-2-22c	2-9/78
iii	3-6/75	-1-31	1-5/ 1/74	-2-22d	3-9/78
iv	2-1/31/75	-1-32	1-5/ 1/74	-2-22e	4-6/79
v	5-5/75	-1-33	2-1/31/75	-2-22f	3-9/78
-1-1	1-5/ 1/74	-1-34	1-5/ 1/74	-2-22g	3-9/78
-1-2	1-5/ 1/74	-1-35	1-5/ 1/74	-2-22h	3-6/79
-1-3	2-1/31/75	-1-36	1-5/ 1/74	-2-22i	3-9/78
-1-4	2-1/31/75	-1-37	3-9/78	-2-22j	4-6/79
-1-5	3-9/75	-1-38	1-5/ 1/74	-2-22k	4-6/79
-1-6	2-1/31/75	-1-39	1-5/ 1/74	-2-22l	3-9/78
-1-7	3-9/75	-1-40	1-5/ 1/74	-2-22m	4-6/79
-1-7a	4-9/75	-1-41	2-1/31/75	-2-22n	3-9/78
-1-7b	4-9/75	-1-42	1-5/ 1/74	-2-22o	4-6/79
-1-7c	4-9/75	-1-43	1-5/ 1/74	-2-22p	3-9/78
-1-7d	4-9/75	-1-44	1-5/ 1/74	-2-22q	--9/78
-1-7e	1-9/75	-1-45	1-5/ 1/74	-2-22r	--9/78
-1-7f	4-9/75	-1-46	1-5/ 1/74	-2-22s	--9/78
-1-7g	4-9/75	-1-47	--1/31/75	-2-23	4-9/75
-1-7h	4-9/75	-1-48	1-9/78	-2-24	3-9/75
-1-7i	4-9/75	-1-49	3-9/78	-2-25	3-9/75
-1-7j	--9/75	-2-1	4-9/75	-2-26	3-9/75
-1-8	1-5/ 1/74	-2-1a	4-9/75	-2-27	3-9/75
-1-9	1-5/ 1/74	-2-1b	5-9/78	-2-28	3-9/75
-1-10	1-5/ 1/74	-2-1c	3-6/75	-2-29	3-9/75
-1-10a	1-2/76	-2-2	1-5/ 1/74	-2-29a	--9/75
-1-10b	--2/76	-2-3	1-5/ 1/74	-2-30	5-9/78
-1-11	1-5/ 1/74	-2-4	1-5/ 1/74	-2-31	5-9/78
-1-12	1-5/ 1/74	-2-5	4-6/79	-2-32	5-9/78
-1-13	1-5/ 1/74	-2-6	3-9/78	-2-33	5-9/78
-1-14	1-5/ 1/74	-2-7	4-9/78	-2-34	4-9/75
-1-15	1-5/ 1/74	-2-8	4-9/78	-2-34a	--6/75
-1-16	1-5/ 1/74	-2-9	4-9/78	-2-34b	--6/75
-1-17	1-5/ 1/74	-2-10	5-6/79	-2-35	1-5/ 1/74
-1-18	1-5/ 1/74	-2-11	4-9/78	-2-36	1-5/ 1/74
-1-19	3-2/76	-2-12	5-6/79	-2-37	1-5/ 1/74
-1-20	2-2/76	-2-13	5-9/78	-2-38	2-1/31/75
-1-20a	--2/76	-2-14	4-9/78	-2-38a	--1/31/75
-1-20b	--2/76	-2-15	3-9/78	-2-38b	--6/75
-1-20c	--2/76	-2-16	3-9/78	-2-38c	--1/31/75
-1-21	2-2/76	-2-17	4-6/79	-2-38d	--1/31/75
-1-22	1-5/ 1/74	-2-18	4-9/78	-2-38e	--1/31/75
-1-23	1-5/ 1/74	-2-18a	5-6/79	-2-38f	--6/75
-1-24	1-5/ 1/74	-2-19	5-9/78	-2-38g	--6/75
-1-25	1-5/ 1/74	-2-20	5-9/78	-2-38h	---------
-1-26	1-5/ 1/74	-2-21	5-6/79	-2-38i	--6/75
-1-27	1-5/ 1/74	-2-22	5-6/79	-2-38j	--6/75
-1-28	1-5/ 1/74	-2-22a	2-9/78	-2-38k	--6/75

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	REV.		REV.		REV.
-2-38L	--6/75	-3-7	2-1/31/75	-3-58	5-2/76
-2-38m	--6/75	-3-8	3-6/75	-3-59	5-2/76
-2-38n	---------	-3-9	5-9/78	-3-59a	3-2/76
-2-38o	--6/75	-3-10	1-5/ 1/74	-3-59b	3-2/76
-2-38p	--6/75	-3-11	1-5/ 1/74	-3-59c	2-2/76
-2-38q	--6/75	-3-12	1-5/ 1/74	-3-59d	2-2/76
-2-38r	--6/75	-3-13	2-1/31/75	-3-59e	2-2/76
-2-39	3-6/75	-3-14	1-5/ 1/74	-3-59f	2-2/76
-2-40	5-2/76	-3-15	3-6/75	-3-59g	2-2/76
-2-41	5-2/76	-3-16	1-5/ 1/74	-3-59h	2-2/76
-2-42	4-9/75	-3-17	1-5/ 1/74	-3-59i	2-2/76
-2-42a	1-2/76	-3-18	1-5/ 1/74	-3-59j	2-2/76
-2-42b	1-2/76	-3-19	1-5/ 1/74	-3-59k	2-2/76
-2-42c	1-2/76	-3-20	1-5/ 1/74	-3-59L	2-2/76
-2-42d	1-2/76	-3-21	1-5/ 1/74	-3-59m	2-2/76
-2-42e	1-2/76	-3-22	1-5/ 1/74	-3-59n	2-2/76
-2-42f	2-2/76	-3-23	1-5/ 1/74	-3-59o	2-2/76
-2-42g	1-2/76	-3-24	1-5/ 1/74	-3-59p	2-2/76
-2-42h	1-2/76	-3-25	1-5/ 1/74	-3-59q	2-2/76
-2-42i	1-2/76	-3-26	1-5/ 1/74	-3-59r	2-2/76
-2-42j	1-2/67	-3-27	1-5/ 1/74	-3-59s	2-2/76
-2-42k	1-2/76	-3-28	1-5/ 1/74	-3-59t	2-2/76
-2-42L	1-2/76	-3-29	1-5/ 1/74	-3-59u	2-2/76
-2-42m	1-2/76	-3-30	1-5/ 1/74	-3-59v	2-2/76
-2-42n	1-2/76	-3-31	1-5/ 1/74	-3-59w	2-2/76
-2-42o	1-2/76	-3-32	1-5/ 1/74	-3-59x	2-2/76
-2-42o-1	1-2/76	-3-33	1-5/ 1/74	-3-59y	2-2/76
-2-42p	--9/75	-3-34	1-5/ 1/74	-3-59z	2-2/76
-2-42q	1-9/78	-3-35	1-5/ 1/74	-3-59aa	2-2/76
-2-42r	1-9/78	-3-36	2-1/31/75	-3-59bb	2-2/76
-2-24s	1-9/78	-3-37	3-9/78	-3-59cc	2-2/76
-2-43	3-6/75	-3-38	3-9/78	-3-59dd	2-2/76
-2-44	1-5/ 1/74	-3-39	2-1/31/75	-3-59ee	2-2/76
-2-45	2-1/31/75	-3-39a	1-6/75	-3-59ff	2-2/76
-2-46	2-1/31/75	-3-39b	1-6/75	-3-59gg	2-2/76
-2-47	2-1/31/75	-3-40	2-9/78	-3-59hh	2-2/76
-2-48	2-1/31/75	-3-41	3-6/75	-3-59ii	2-2/76
-2-49	2-1/31/75	-3-42	3-6/75	-3-59jj	2-2/76
-2-49a	2-1/31/75	-3-43	3-6/75	-3-59kk	2-2/76
-2-49b	--1/31/75	-3-44	3-6/75	-3-59LL	2-2/76
-2-49c	--1/31/75	-3-45	3-6/75	-3-59mm	2-2/76
-2-49d	--1/31/75	-3-46	3-6/75	-3-59nn	2-2/76
-2-49e	--1/31/75	-3-47	3-6/75	-3-59oo	2-2/76
-2-49f	--1/31/75	-3-48	3-6/75	-3-59pp	2-2/76
-2-50	1-5/ 1/74	-3-49	1-6/75	-3-59qq	2-2/76
-2-51	1-5/ 1/74	-3-50	5-2/76	-3-59rr	1-2/76
-3-1	5-2/76	-3-51	5-2/76	-3-59ss	1-2/76
-3-2	5-2/76	-3-52	5-2/76	-3-59tt	1-2/76
-3-3	5-9/78	-3-53	5-7/76	-3-59uu	1-2/76
-3-3a	1-9/78	-3-54	5-2/76	-3-59vv	1-2/76
-3-4	2-9/75	-3-55	5-2/76	-3-59ww	1-2/76
-3-5	1-5/ 1/74	-3-56	5-2/76	-3-59xx	1-2/76
-3-6	2-1/31/75	-3-57	5-2/76	-3-59yy	1-2/76

	REV.		REV.		REV.
-3-59zz	1-2/76	-3-68	4-9/78	-4-16	--6/75
-3-59aaa	1-2/76	-3-69	4-9/78	-4-17	1-9/75
-3-59bbb	1-2/76	-3-70	5-9/78	-4-18	1-9/75
-3-59ccc	1-2/76	-3-71	4-9/78	-4-19	--6/75
-3-59ddd	1-2/76	-3-72	4-9/78	-4-20	--6/75
-3-59eee	1-2/76	-3-72a	4-9/78	-4-21	--6/75
-3-59fff	1-2/76	-3-72b	4-9/78	-4-22	--6/75
-3-59ggg	1-2/76	-3-72c	4-9/78	-4-23	--6/75
-3-59hhh	1-2/76	-3-72d	5-9/78	-4-24	--6/75
-3-59iii	1-2/76	-3-73	2-6/75	-4-25	--6/75
-3-59jjj	1-2/76	-3-74	2-6/75	-4-26	---------
-3-59kkk	1-2/76	-3-75	2-6/75	-4-27	---------
-3-59LLL	1-2/76	-3-76	2-6/75	-4-28	---------
-3-59mmm	1-2/76	-3-77	2-6/75	-4-29	--6/75
-3-59nnn	1-2/76	-3-78	2-6/75	-4-30	--6/75
-3-59ooo	1-2/76	-3-79	2-6/75	-4-31	--6/75
-3-59ppp	1-2/76	-3-80	2-6/75	-4-32	--6/75
-3-59qqq	1-2/76	-3-81	2-6/75	-4-33	--6/75
-3-59rrr	1-2/76	-3-82	2-6/75	-4-34	--6/75
-3-59sss	1-2/76	-3-83	2-6/75	-4-35	--6/75
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-3-59uuu	1-2/76	-3-85	4-9/78	-4-37	1-5/ 1/74
-3-59vvv	1-2/76	-3-86	4-9/78	-4-38	3-9/78
-3-59www	1-2/76	-3-87	4-9/75	-4-39	3-9/78
-3-59www-1	--2/76	-3-88	1-5/ 1/74	-4-40	4-9/78
-3-59www-2	--2/76	-3-89	2-9/75	-4-41	4-9/78
-3-59www-3	--2/76	-3-90	2-9/75	-4-42	4-9/78
-3-59www-4	--2/76	-3-91	1-5/ 1/74	-4-43	3-9/78
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-3-59www-10	---------	-3-97	--6/75	-4-46	4-9/78
-3-59 xx	--9/75	-3-98	--6/75	-4-47	4-9/78
-3-59yyy	--9/75	-4-1	5-2/76	-4-48	4-9/78
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-3-59aaaa	--9/75	-4-3	4-9/75	-4-48b	4-9/78
-3-59bbbb	--9/75	-4-3a	1-9/78	-4-48c	4-9/78
-3-59cccc	--9/75	-4-4	5-9/78	-4-48d	4-9/78
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-4-56	5-2/76	-4-90e	4-9/75	-4-112h	2-9/75
-4-56a	4-9/75	-4-90f	4-9/75	-4-112i	2-9/75
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-4-85	3-6/75	-4-109	4-9/78	-4-121x	--2/76
-4-86	4-9/75	-4-110	4-9/78	-4-121y	--2/76
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-4-88	--6/75	-4-112	1-9/78	-4-121aa	--2/76
-4-89	4-9/75	-4-112a	5-9/78	-4-121bb	--2/76
-4-89a	1-9/75	-4-112b	5-9/78	-4-121cc	--2/76
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-4-90a	3-7/75	-4-112d	3-6/75	-4-121ee	--2/76
-4-90b	4-9/75	-4-112e	3-6/75	-4-121ff	--2/76
-4-90c	4-9/75	-4-112f	1-6/75	-4-121gg	--2/76
-4-90d	3-7/75	-4-112g	--1/31/75	-4-121hh	--2/76

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-4-121nn	--2/76	-4-143	4-9/75	-4-177h	1-2/76
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-4-121pp	--2/76	-4-145	4-9/75	-4-177j	1-2/76
-4-121qq	--2/76	-4-146	4-9/75	-4-177k	1-2/76
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-4-123a	4-5/76	-4-147b	2-9/75	-4-177n	1-2/76
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-4-123b-2	--5/76	-4-149	2-1/31/75	-4-177q	1-2/76
-4-123c	4-5/76	-4-150	3-9/75	-4-177r	1-2/76
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-4-123f	4-5/76	-4-152a	2-1/31/75	-4-177u	1-2/76
-4-123g	4-5/76	-4-152b	2-1/31/75	-4-177v	1-2/76
-4-123h	4-5/76	-4-152c	2-1/31/75	-4-177w	1-2/76
-4-123i	4-5/76	-4-152d	--1/31/75	-4-177x	1-2/76
-4-123j	4-5/76	-4-152e	---------	-4-177y	1-2/76
-4-123k	4-5/76	-4-152f	2-1/31/75	-4-177z	1-2/76
-4-123L	5-9/78	-4-152g	2-1/31/75	-4-177aa	1-2/76
-4-123m	4-9/78	-4-153	2-1/31/75	-4-177bb	1-2/76
-4-123n	4-5/76	-4-154	2-1/31/75	-4-177cc	1-2/76
-4-123o	5-9/78	-4-155	2-1/31/75	-4-177dd	1-2/76
-4-123p	6-5/76	-4-156	2-1/31/75	-4-177ee	1-2/76
-4-123q	4-9/78	-4-157	3-6/75	-4-177ff	1-2/76
-4-123r	2-9/78	-4-158	3-6/75	-4-177gg	1-2/76
-4-123s	--2/76	-4-159	3-6/75	-4-177hh	1-2/76
-4-123t	--2/76	-4-160	3-6/75	-4-177ii	1-2/76
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-4-125	4-9/78	-4-162	3-6/75	-4-179	2-1/31/75
-4-126	4-9/78	-4-163	3-6/75	-4-180	2-1/31/75
-4-127	5-9/78	-4-164	3-6/75	-4-181	2-1/31/75
-4-128	4-9/75	-4-165	3-6/75	-4-181a	2-9/75
-4-129	4-9/75	-4-166	3-6/75	-4-181b	2-9/75
-4-130	4-9/75	-4-167	3-6/75	-4-182	2-1/31/75
-4-131	4-9/75	-4-168	3-6/75	-4-183	2-1/31/75
-4-131a	--9/75	-4-169	2-6/75	-4-184	2-1/31/75
-4-132	4-9/75	-4-170	3-9/75	-4-185	3-9/75
-4-133	4-9/75	-4-171	5-2/76	-4-185a	3-9/75
-4-134	4-9/75	-4-172	5-2/76	-4-186	3-9/78
-4-135	4-9/75	-4-172a	1-2/76	-5-1	1-5/ 1/74
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-4-137	4-9/75	-4-175	5-2/76	-5-4	2-9/78
-4-137a	5-9/78	-4-176	5-2/76	-5-5	1-9/75
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Revised Attachment No. 1 to October 6, 1978 Letter

Revision List - NLI 10/24 Rail Cask
Safety Analysis Report

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	4	-5
	Deleted	-18, -19, -20 (section condensed pages not required)
XVII	4	-2
XVIII	7	-2
	8	-1

Decay heat is removed from the fuel to an aluminum basket by thermal radiation and conduction through helium and by conduction through the neutron absorber liners. After conduction to the periphery of the basket, the decay heat is then transferred to the cask through a helium gap by conduction and thermal radiation and by conduction and convection through the cask body to the atmosphere. The cooling channels are dry.

This mode of heat dissipation is considered as the normal mode of operation for the purposes of determining metal temperatures and pressures for the structural evaluation of the cask.

Forced circulation in the auxiliary cooling system is the actual normal mode of operation even though the normal condition of transport analysis considers the cooling system not to be operating. The cask temperatures will be lower when the cooling system is operating. This will increase the safety of the package above what is required for normal conditions of transport.

The auxiliary cooling system is provided to circulate coolant through cooling channels that are located in the cask at the outer surface of the inner shell.

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The auxiliary cooling system has the capacity to dissipate more than 100% of the decay heat. In operation, not all of the heat is removed by the cooling system. A portion of the decay heat load is removed by a combination of conduction, convection and radiation to the atmosphere.

During cold operation the ambient temperature is $-40^{\circ}F$ in still air without any solar heat load (the cask is in the shade). Detailed analyses of the cask have not been performed under these conditions since a uniform cask temperature of $-40^{\circ}F$ may be conservatively assumed. The neutron shield will be protected from freezing to $-40^{\circ}F$ by using an antifreeze solution.

1.2 Off Normal Conditions

The following off normal conditions have been evaluated:

a). A hypothetical fire accident with conditions applied sequentially as specified in Appendix B of 10 CFR 7.. In some areas additional conservative assumptions were involved.

b). Forced convection and loss of forced convection are evaluated qualitatively.

1.2.1 Hypothetical Accident Conditions

Beginning with an assumed ambient temperature of $100^{\circ}F$, the cask experiences a 30 foot drop onto a flat surface followed by a puncture.

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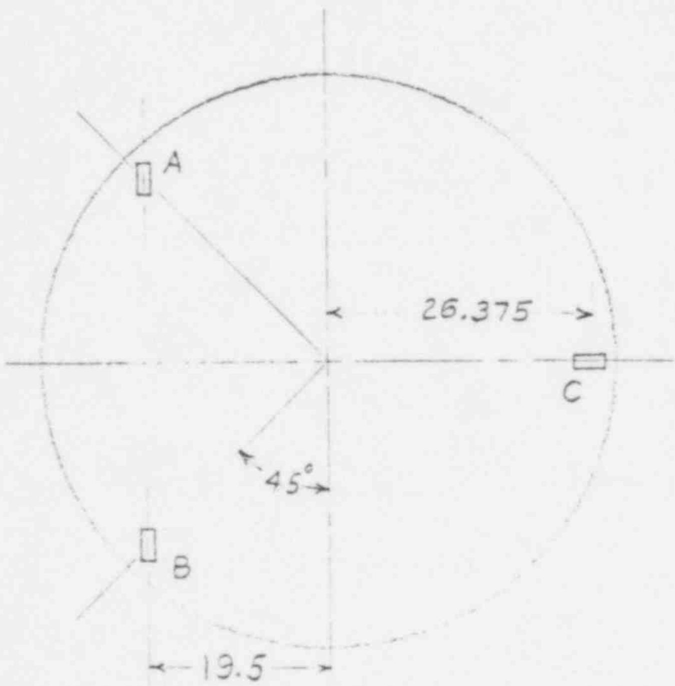
2.1.3 Inner Closure Lifting Lugs

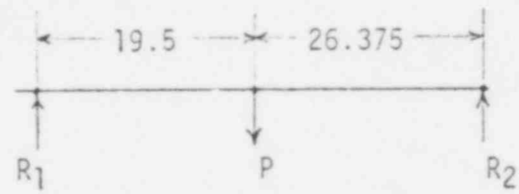
Inner closure design weight is 7400 lb., (sect. VII).

Design load at 3g, P = 3(7400) = 22200 lb.

The inner closure is provided with three threaded eye bolts, which are inserted into tapped holes in the closure for handling. Closure head wil' be handled by a lift rig having lift points located at the same dimensions from its center of lift as the closure head eye bolts are located from the center of the head.



Lifting force model:



Sum forces:

$R_1 + R_2 = P = 22200$

Moments about R_1:

$19.5\ P = 45.875\ R_2$

Solving for eye bolt forces:

$R_2 = 22200\ (19.5/45.875) = 9437$ lb.

$R_1 = 22200 - 9437 = 12763$ lb.

eye bolts A and B, $F_A = F_B = 12763/2 = \underline{6382}$ lb.

Eye bolt C, $F_C = \underline{9437}$ lb

The minimum rated tensile strength of the 1 inch diameter eye bolts is 46850 lb., which is nearly 5 times the design load of 9437 lb. on the most heavily loaded eye bolt.

2.2 Tie-Downs

The tie-down system consists of (1) cask lugs with mating plate anchorages welded to the railcar center sill to take vertical upward and longitudinal loads, and (2) V saddles to take vertical downward and lateral loads.

The rear cask lugs take the entire 10g longitudinal loads in both directions, thus allowing the front cask lug to be free from longitudinal loads so that clearances can be provided longitudinally for cask/railcar relative expansions.

The lugs and pins of the cask at both ends are designed for combined loads of 10g longitudinally, 5g transversely, and 2g vertically, in both directions, without exceeding 90% of the yield point stress. The cask lugs are 17-4 ph material and the plates of the anchorage are T-1 steel, both at a nominal 100,000 psi Y.P. Welds between the bottom of the plate weldment and the mounting blocks on the center sill itself are calibrated to break at a load less than the actual strength of the tie-down unit of lugs and plates, but greater than the minimum specified design loads.

The cask weight rests on and between the 45^0 flat saddle bearing plates (which form a 90^0 V support). Low friction wear bearing linings are provided as part of the saddle construction, thus allowing axial motion between the saddle cover plate and the edge of the impact structure which supports the entire cask weight and vertical reactions.

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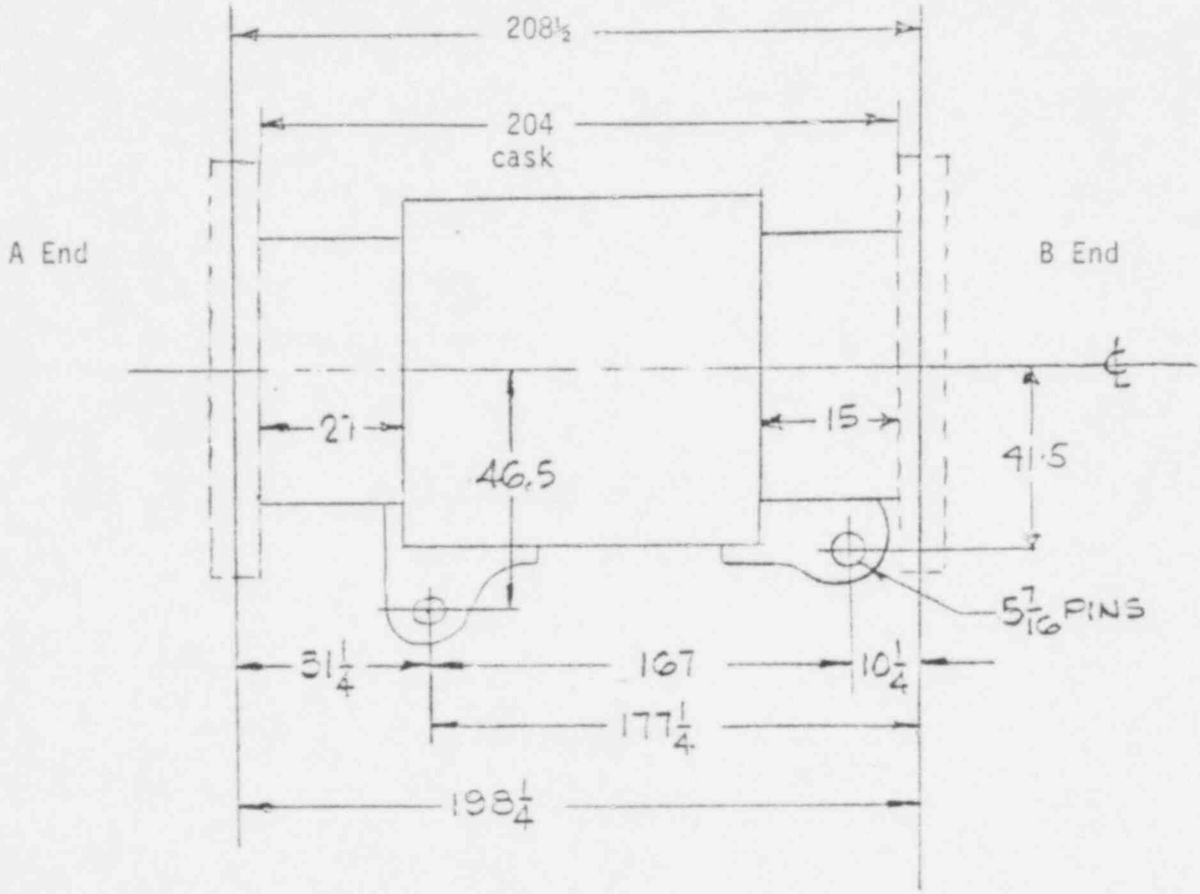
The front tie-down has 1 cask lug and 2 side plates, while the rear tie down, designed for 10g longitudinal, has 2 cask lugs and 3 side plates spaced alternately. Both have 5 7/16 in. dia. pins.



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Analysis of Applied Loads (Specified by 10 CFR - Part 71.31 (d))

10g Longitudinal = 10 x 220,000 = 2,200,000 lbs at rear tie down.

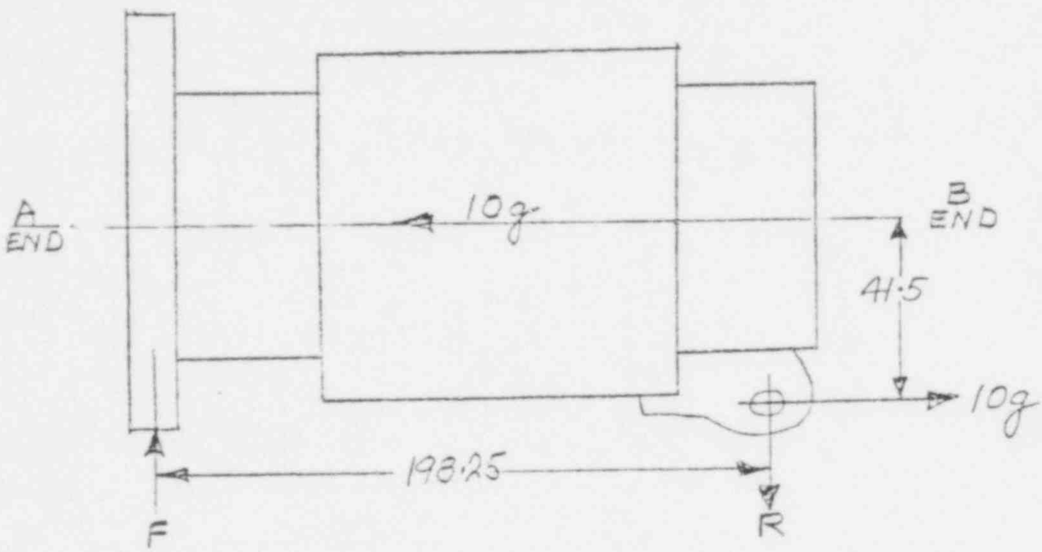
5g Transverse = $\frac{5 \times 220{,}000}{2}$ = 550,000 lbs at front and rear saddles

2g Vertical = $\frac{2 \times 220{,}000}{2}$ = 220,000 lbs at front & rear tie-down or saddle.

Each of the above loads can be applied in either + or - directions.

The particular combinations which produce the maximum loads on a certain structure are developed in the following cases.

(1) A end Impact Car - 10g foreward on cask

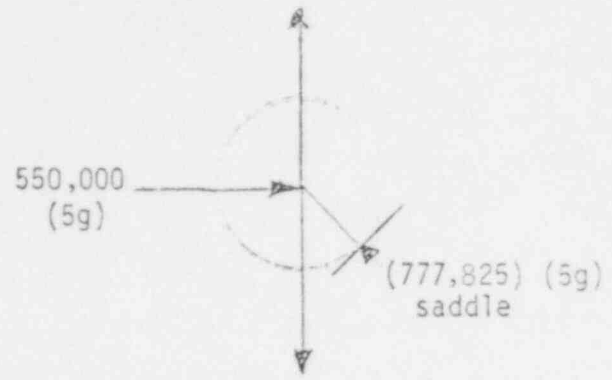


Pitching couple at F and R

$\pm F = \frac{2{,}200{,}000 \times 41.5}{198.25}$ = 460,530 lbs.

Verticals for rear tie down at R	Verticals for front support at F
↑ 460,530 pitching 10g	↓ 460,530 pitching 10g
↑ 220,000 2g V	↓ 220,000 2g V
↓ 110,000 1g static wt.	↓ 110,000 1g static wt.
↑ 570,530 Net tension	↓ 790,530 Net Compression

655 304



Rear Tie-down plane (R)

A End Impact

Rear tie-down cask lug and pin, net loads

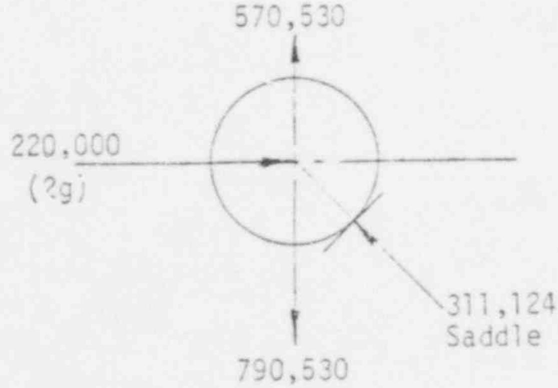
1,120,530 lbs. ↑ vertical, tension

2,200,000 lbs. ← toward A end.

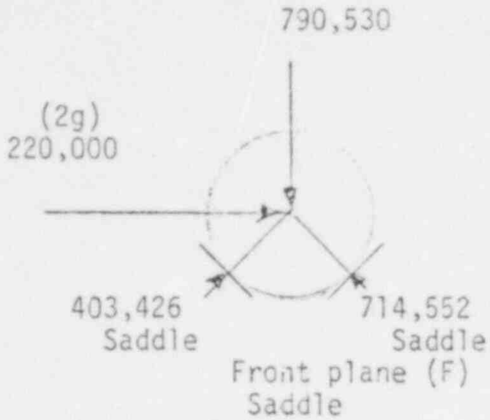
2,468,924 lbs. ↘ resultant

Front tie-down is not loaded with 10gL acting toward A end.

Front and Rear saddles are designed for 2g transverse instead of 5g, since the whole package of car and cask is unstable at about 5g, and 2g design loading provides adequate large margin of safety.



655 305



↓ 460,530 pitching

↓ 220,000 2g V

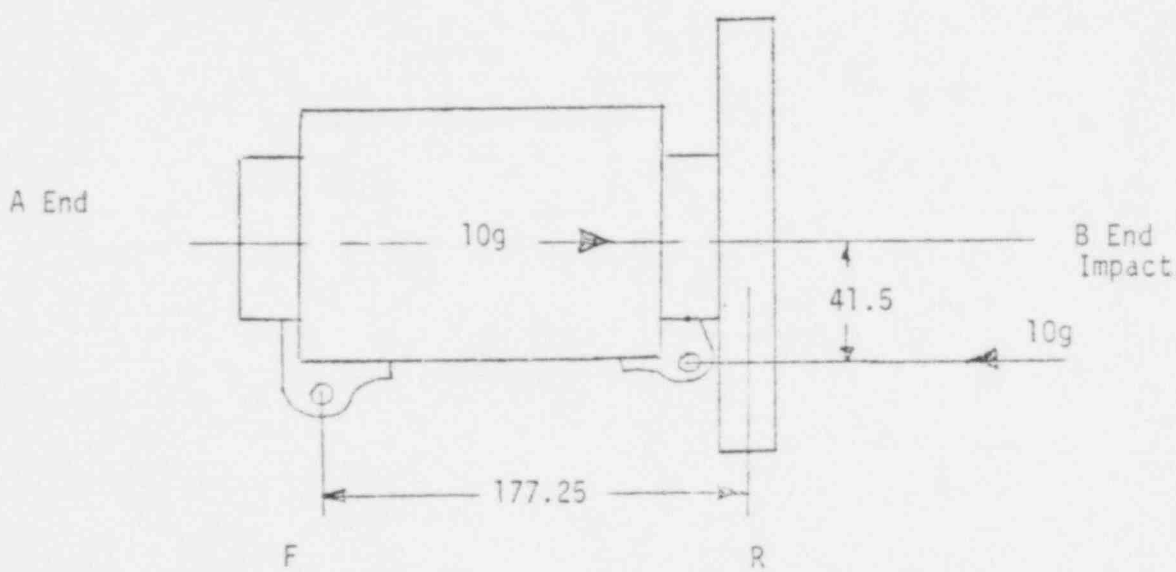
↓ <u>110,000</u> 1g static wt.

↓ 790,530 net compression

<u>A End Impact</u>

(2) <u>For 10g L acting toward B end</u> of car and bottom of cask

<u>B end Impact</u>



Pitching couple at F and R

$$\pm F = \frac{2,200,000 \times 41.5}{177.25} = 515,092 \text{ lbs.}$$

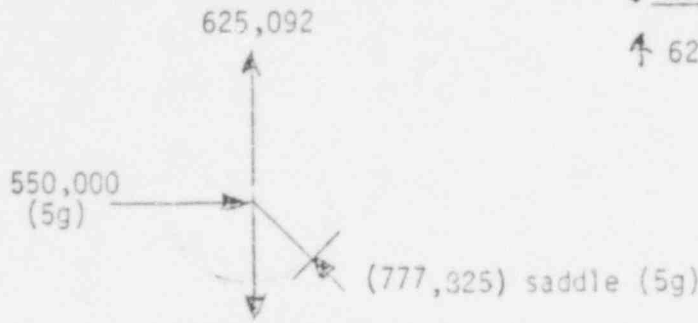
655 306

13505

For front tie-down at F

↑ 515,092 pitching
↑ 220,000 2g V
↓ 110,000 1g Static

↑ 625,092 net tension



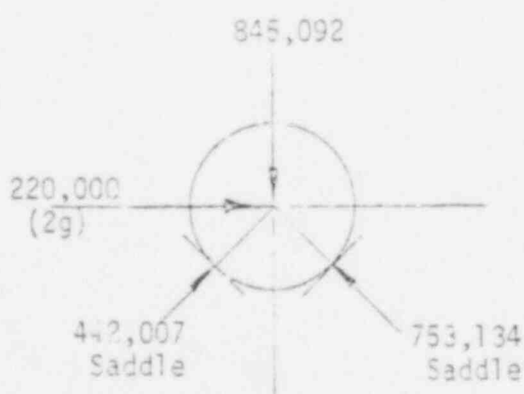
F = 1,175,092 Lug
Front Tie down Plane (F)

B End Impact

For Rear Saddle at R, with 2g transverse

↓ 515,092 pitching
↓ 220,000 2g V
↓ 110,000 1g static wt.

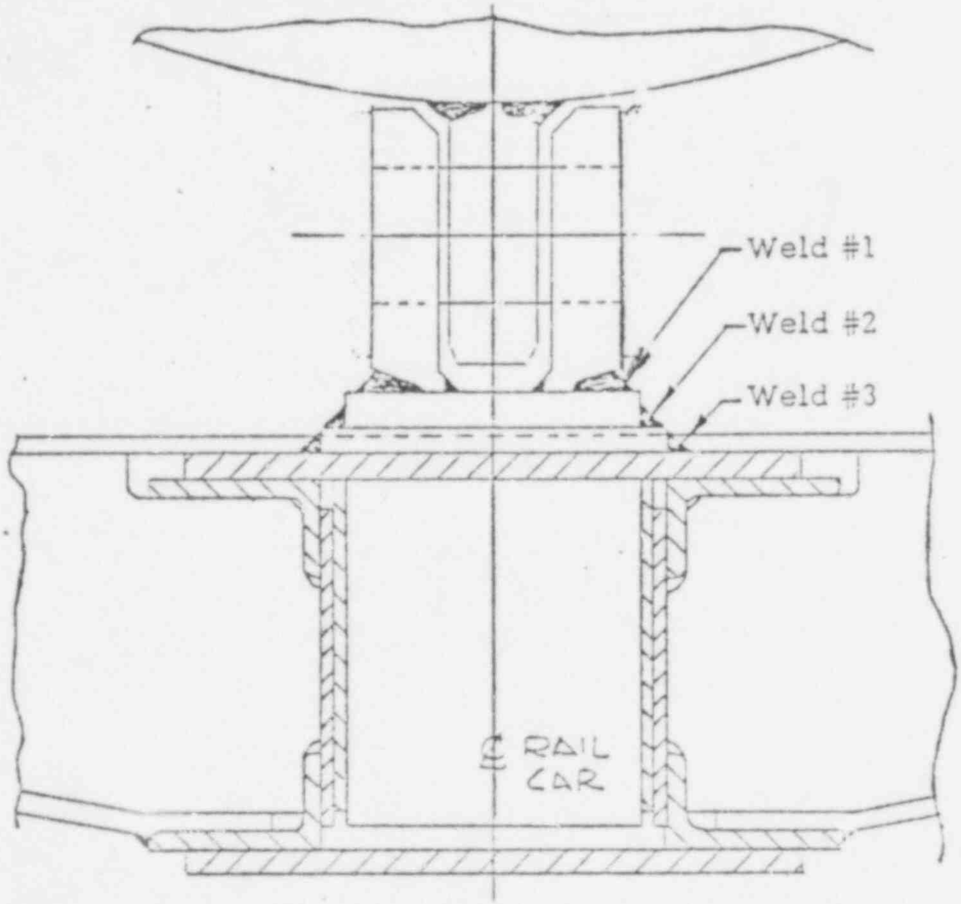
↓ 845,092 net compression



Rear Saddle Plane (R)
B End Impact

655 307

2.2.1 Tie-Down-Cask Closure Head End ("A" End)



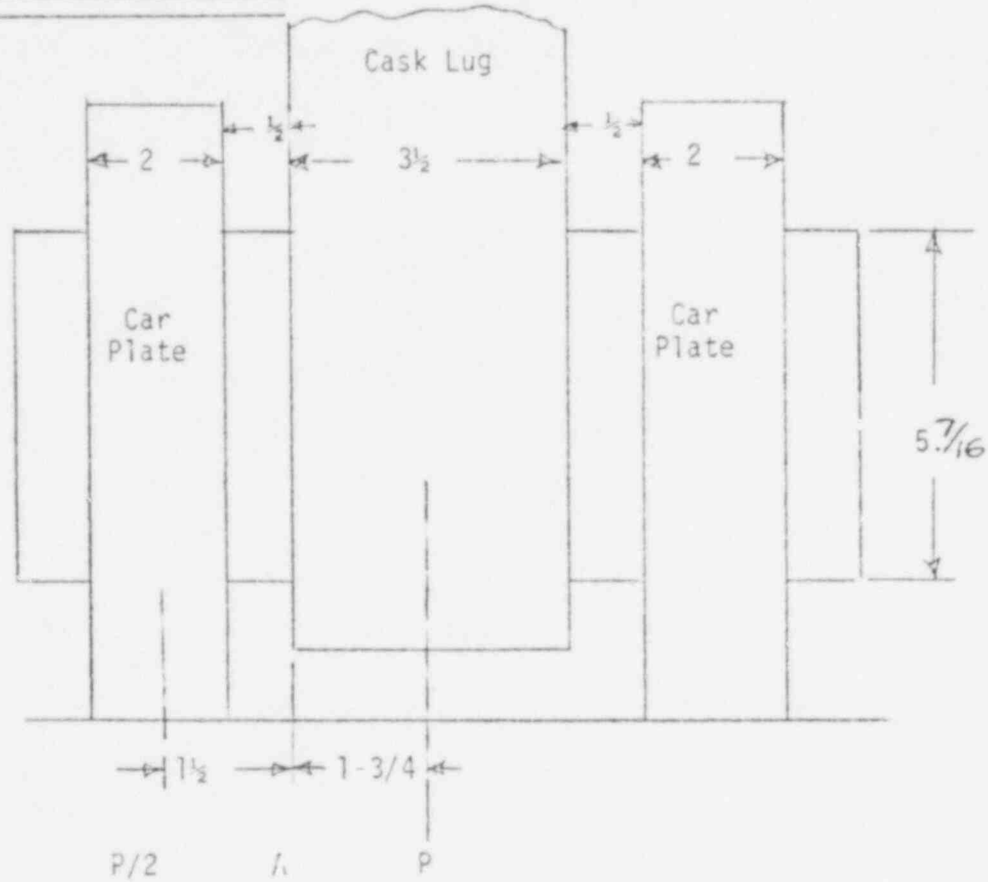
Front Tie Down

"A" End

Also Closure Head End of Cask

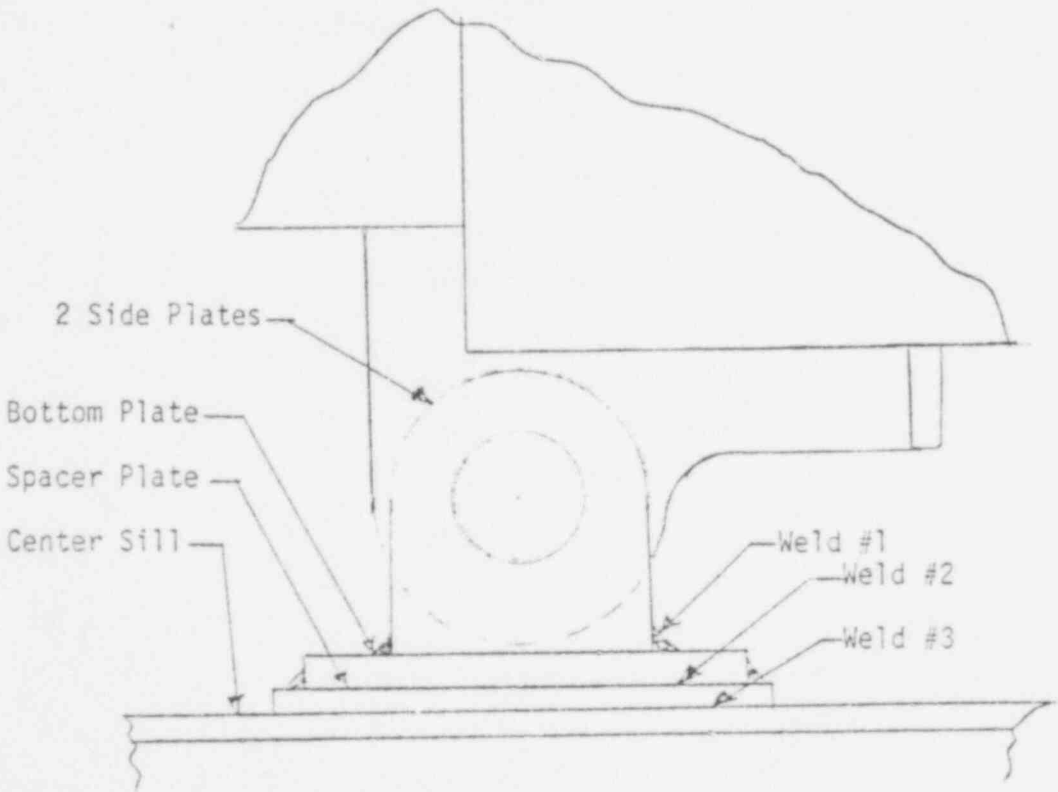
655 308

2.2.1.1 Front Tie-Down Analysis



655 309

13505



Front Tie Down

"A" End

655 310

2.2.1.2 Front Pin analysis

P = 1,175,092 lbs on lug (from B end impact - XI-2-12)

P/2 = 587,546 lbs on each plate

Pin dia = 5-7/16 in.

Material 17-4 ph (100,000 psi Y.P.)

$Z = .098\ (5.4375)^3 = 15.755\ in^3$

$A = \pi/4\ (5.4375)^2 = 23.22\ in^2$

Pin stresses at section A

$M_A = P/2 \times 1.5 = 881,319$ in lbs.

$S_b = \dfrac{881,319}{15.755} = 55,939$ psi

$S_s = \dfrac{587,546}{23.22} = 25,303$ psi

Combined stresses = $\sqrt{55,939^2 + 3x25,303^2} = 71063$ psi

$M.S. = \dfrac{.9 \times 100,000}{71063} - 1 = .266$

Pin stresses at center P

$M_B = P/2 \times 3\frac{1}{4} - P/2 \times 7/8 = P/2 \times 2.375 = 1,395,422$ in lbs.

$S_b = \dfrac{M}{Z_B} = 88,570$ PSI $\quad S_s = 0$

$M.S. = \dfrac{.9 \times 100,000}{88,570} - 1 = \underline{.016}$

655 311

2.2.1.3 Front Cask Lug Analysis

Section through C.L. of pin

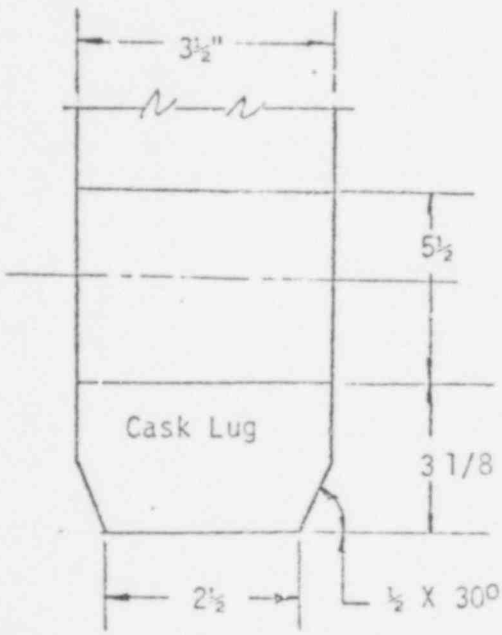
$$\text{Area} = 3\text{-}1/8 \times 3\text{-}1/2 - \frac{.866}{2} = 10.5045 \text{ in}^2$$

Tension Load - 1,175,092 lbs. (from B end impact XI-2-12)

Hoop stress across area - tension

$$S_t = \frac{1,175,092}{2 \times 10.5045} = 55,933 \text{ psi}$$

$$\text{M.S.} = \frac{9 \times 1000,000}{55,933} - 1 = .609$$



Shear tearout at 40° from C.L.

$$\text{Area} = 2\left(3\ 5/8 \times 3\text{-}1/2 - \frac{.75}{2}\right) = 24.625 \text{ in}^2$$

$$S_s = \frac{1.175,092}{24.625} = 47,719 \text{ psi}$$

$$\text{M.S.} = \frac{.6 \times .9 \times 100,000}{47,719} - 1 = \underline{\underline{.131}}$$

Tension area thru diameter

$$\text{Area} = (13-5.5)\ 3.5 = 26.25 \text{ in}^2$$

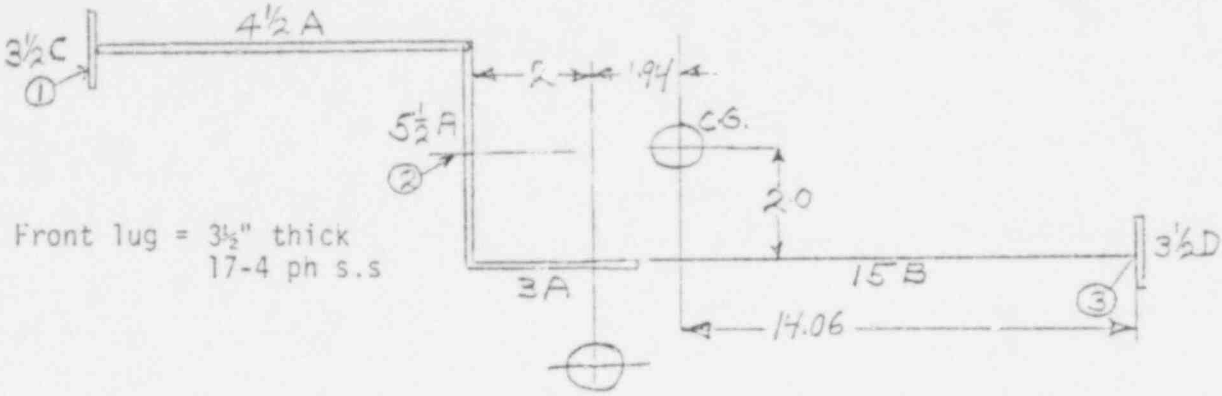
$$S_t = \frac{1,175,092}{26.25} = 44,765 \text{ psi}$$

$$\text{M.S.} = \frac{.9 \times 100,000}{44,765} - 1 = 1.01$$

655 312

13565

2.2.1.4 Front cask lug - Weld strength



Front lug = 3½" thick 17-4 ph s.s

Weld A = 1-1/4" J + 1" fillet on 2 sides of 3½ lug

Weld B = 1 fillet on 2 sides

Weld C = 1" fillet across end of lug on cask

Weld D = 2 x 3/4" fillets at end of lug, normal to cask

Throat areas of welds

A = 2 x 1½" = 3"

B = 2 x .707" = 1.414"

C = .707"

D = 2 x (3/4 x .707) = 1.06"

Weld material has substantially same physical as 304 S.S base material of cask, so values of latter are used.

(75,000 UTS and 30,000 YP)

Therefore, throat area of weld is critical, rather than interface areas of contact with cask or lug.

655 313

C.G. of welds - to find $\overline{X}$ and $\overline{Y}$

Weld	Area (A)	X	AX	Y	AY
3½C	3½ x .707 = 2.47	0	0	5.5	13.585
4½A	4½ x 3 = 13.5	2¼	30.38	5.5	74.25
5.5A	5.5 x 3 = 16.5	4½	74.25	2.75	45.375
3A	3 x 3 = 9.0	6	54.0	0	0
15B	15 x 1.414 = 21.21	15	318.15	0	0
3½D	3½ x 1.06 = 3.71	22½	83.47	0	0
	66.39	x 8.44	=560.25	2.00	133.21

$$
\begin{array}{r} 8.44 \\ -\ 4.50 \\ \hline 3.94 \end{array}
$$

$$I_{yy} = \frac{3.5 \times (.707)^3}{12} + 2.47\,(8.44)^2 + \frac{3 \times (4.5)^3}{12} + 13.5\,(6.19)^2$$

$$+ \frac{2 \times 5.5(1\tfrac{1}{2})^3}{12} + 16.5\,(3.94)^2 + \frac{3 \times 3^3}{12} + 9.0\,(2.44)^2$$

$$+ \frac{1.414\,(15)^3}{12} + 21.21(6.56)^2 + \frac{7 \times (.53)^3}{12} + 3.71\,(14.06)^2 = 3081.8 \text{ in}^4$$

$$I_{xx} = \frac{.707(3.5)^3}{12} + 2.47(3.5)^2 + \frac{2 \times 4.5}{12} \times (1.5)^3 + 13.5\,(3.5)^2$$

$$+ \frac{3 \times (5.5)^3}{12} + 16.5\,(.75)^2 + \frac{3 \times 3^3}{12} + 9.0\,(2.0)^2$$

$$+ \frac{2 \times 15 \times (.707)^3}{12} + 21.21\,(2.0)^2 + 1.06\,\frac{(3.5)^3}{12} + 3.71\,(2.0)^2 = 398.7 \text{ in}^4$$

$$I_p = 3081.8 + 398.7 = 3480.5 \text{ in.}^4$$

655 314

Eccentricity of vertical load = 1.94"

P_1 = 1,175,092 lbs (XI-2-16)

$T = P_1 \times ecc$ = 1,175,092 x 1.94 = 2,279,678 in. lbs.

$$\frac{T}{I_p} = \frac{2,279,678}{3480.5} = 655.$$

$$S_s = \frac{T\rho}{I_p} = \left(\frac{T}{I_p}\right)\rho = 655\rho \text{ for any point}$$

Stress at point (3)

$$\rho = \sqrt{2^2 + 14.06^2} = 14.2 \text{ in.}$$

S_s = 655 x 14.2 = 9301 psi ↑ compression

S_t = Uniform tension stress over all welds

$$= \frac{1,175,092}{66.39} = 17,700 \text{ psi tension} \downarrow$$

Net stress = 17,700 - 9301 = 8399 psi tension

$$M.S = \frac{.9 \times 30,000}{8399} - 1 = 2.21$$

Stress at point (2)

ρ = 3.94

S_s = 655 x 3.94 = 2581 psi ↓

S = 17,700 psi ↓

Net stress = 17,700 psi + 2581 psi = 20,281 psi ↓

$$M.S = \frac{.9 \times 30,000}{20,281} - 1 = .33$$

Stress at point (1)

$$\rho = \sqrt{8.44^2 + 3.5^2} = 9.14"$$

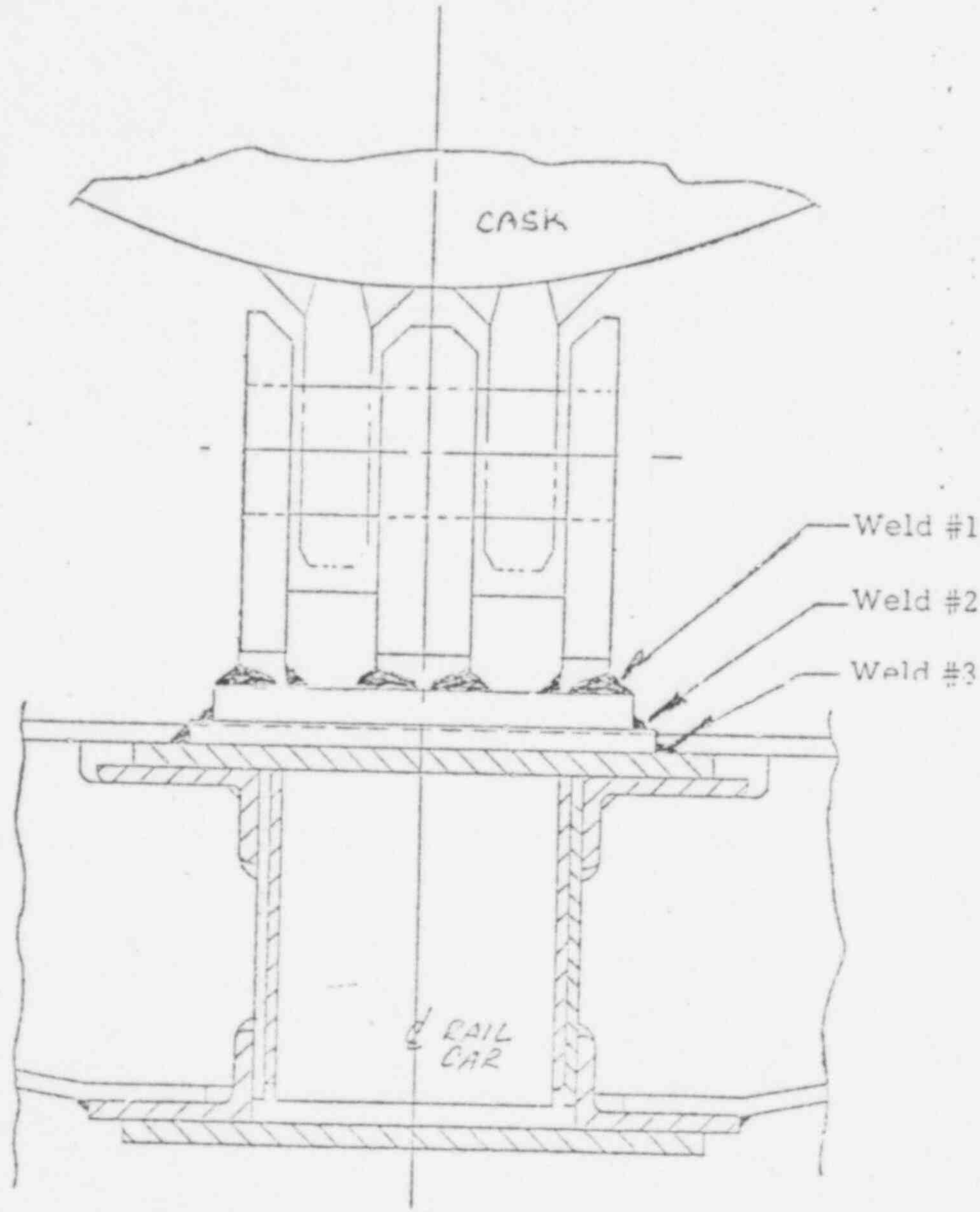
S_s = 655 x 9.14 = 5989 psi ↓

S = 17,700 psi ↓

Net stress = 17,700 + 5985 = 23,682 psi ↓ 655 315

$$M.S. = \frac{.9 \times 30,000}{23,685} - 1 = .14$$

2.2.2 Tie down - bottom end of cask ("B" End)

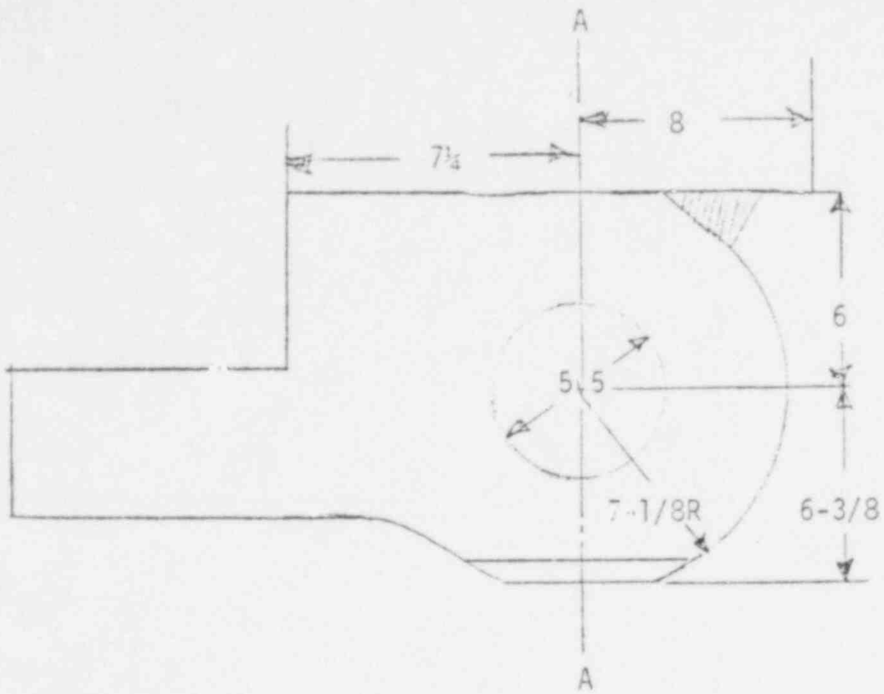


Rear Tie Down

"B" End

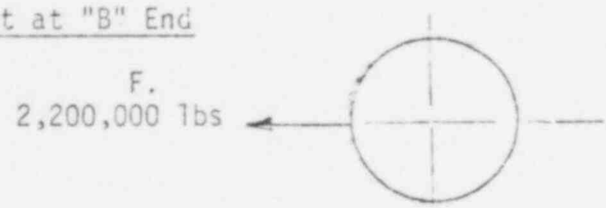
Bottom of Cask

655 316

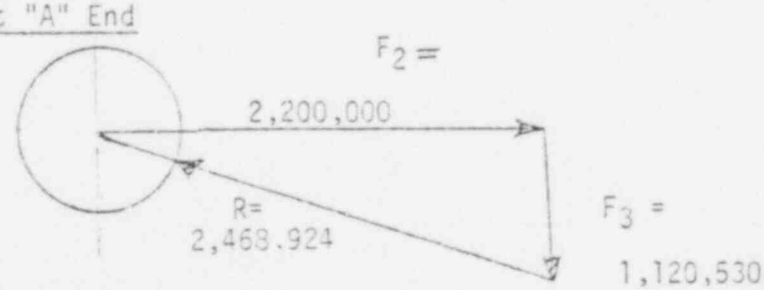


Rear Cask Lug (B End)

For impact at "B" End



For impact at "A" End

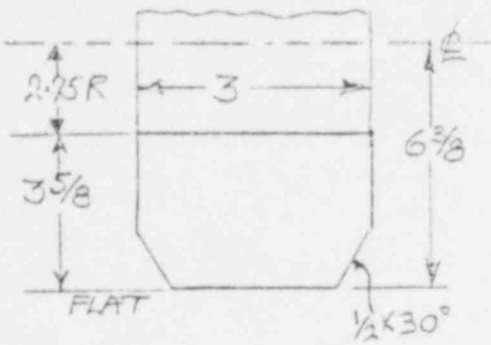


655 317

13505

2.2.2.1 Rear Cask Lugs - B - End

Material - 17 - 4-PH 100,000 psi y.p.



Min. area at vertical section =

(3 x 3-5/8) - ½ x .866 = 10.44 in.^{2}

Max tension load = 2,468,924 lbs

on both lugs (Impact at "A" End)

Hoop stress thru section A = $\frac{2,468,924}{(12.375-5.5)3\times2}$ = 59,852 psi

M.S. = $\frac{.9 \times 100,000}{59,852}$ - 1 = .50

Shear tear - out at 40° to load line

Area = 2 (3 x 4.66) = 27.96"^{2}

S_s = $\frac{2,468,924}{2 \times 27.96}$ = 44,151 psi

M.S. = $\frac{6 \times .9 \times 100,000}{44,151}$ -1 = .223

Bearing stress at P

Bearing area 2 lugs = 2 x 5.5 x 3 = 33in^2

S = $\frac{2,468,924}{33}$ = 74,816 psi

M.S. = $\frac{.9 \times 1.5 \times 100,000}{74,816}$ -1 = .80

655 318

2.2.2.2 Cask pin - B End - 5-7/16 dia.

Material - 17-4 PH 100,000 psi Y.P.

$Z = .098\ (5.4375)^3 = 15.755\ in^3$

$A = \pi/4\ (5.4375)^2 = 23.22 in^2$

Load distribution

Fig. 1

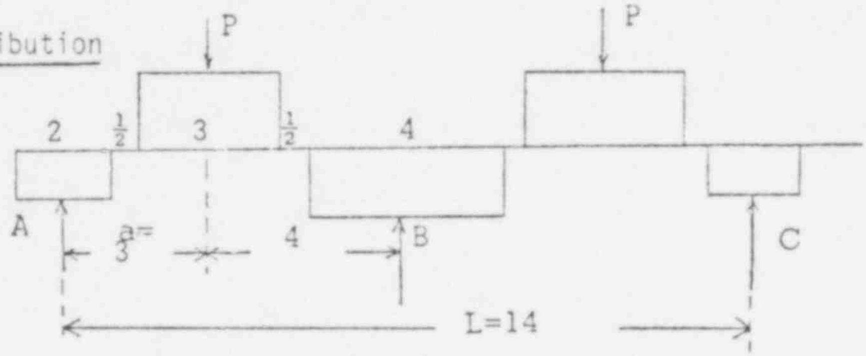


Fig. 2

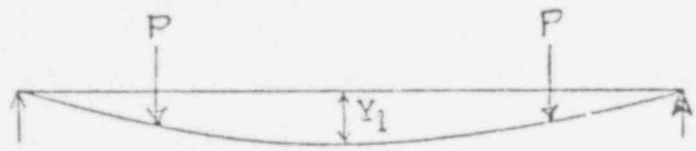


Fig. 3

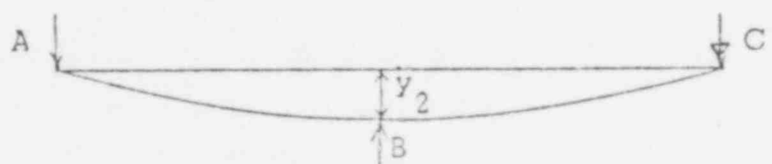


Fig. 2 Shows center deflection y_1, caused by two loads (P) on simply supported beam (support B removed)

Fig. 3 shows support force B required to return center point to save level as ends A and C. $y_2 = y_1$

Max. load = 2P = 2,468,924 from impact at A end .

P = 1,234,462 lbs.

655 319

From Fig. 2 $Y_1 = \frac{Pa}{24EI}(3L^2 - 4a^2)$

$a = 3 \qquad L = 14$

$Y_1 = \frac{P \times 3}{24EI}(3 \times 14^2 - 4 \times 3^2) = \frac{69P}{EI}$

From fig. 3 $Y_2 = Y_1 = \frac{BL^3}{48EI} = \frac{B \times 14^3}{48EI} = \frac{57.1666\,B}{EI}$

Equating $69P = 57.1666\,B$

$B = 1.207\,P$

$A = C = \frac{2 - 1.207}{2}P = .3965P$

But max. $P = 1,234,462$ lbs

$B = 1,489,000$ lbs

$A = C = 489,464$ lbs

Moment at P = $489,464 \times 3 - \frac{1,234,462}{2} \times .75 = 1,005,469$ in lbs

Moment at B = $489,464 \times 7 - 1,234,462 \times 4 + \frac{1,489,000}{2} \times 1 = 767,100$ in lbs

At P, Max $S_b = \frac{1,005,469}{15,755} = 63,819$ psi at P

Shear at P = $489,464 - \frac{1234464}{2} = -127,768$ lbs

$S_s = \frac{-127,768}{23.22} = -5502$ psi

Comb. $S_I = \sqrt{63819^2 + 3(5502)^2} = 64,527$ psi

$M.S = \frac{.9 \times 100,000}{64,527} - 1 = .394$

At B, Bearing $S_{br} = \frac{1,489,000}{4 \times 5.5} = 67,682$ psi

$M.S. = \frac{.9 \times 100,000}{67,682} - 1 = .329$ conservative

655 320

2.2.2.3 Welds of lugs to cask

The two lugs welded to cask are of 17-4ph metal, while the cask itself is 304 S.S. The weld metal is similiar to the base metal and is calculated at 30,000 psi Y. P. The weld is critical thru its throat area.

There are two conditions of applied loads acting through the center of the pin. When the force applied at the cask C.G. acts toward the B end of the railcar, the rear tie-down is loaded only by the 10g L force while the vertical forces are taken in compression on the rear saddle itself. When the force of 10g L is acting in the direction of the top (A) end, then the rear lug pin is loaded with both 10g L and the resultant tension of applied vertical forces (of pitching, etc.)

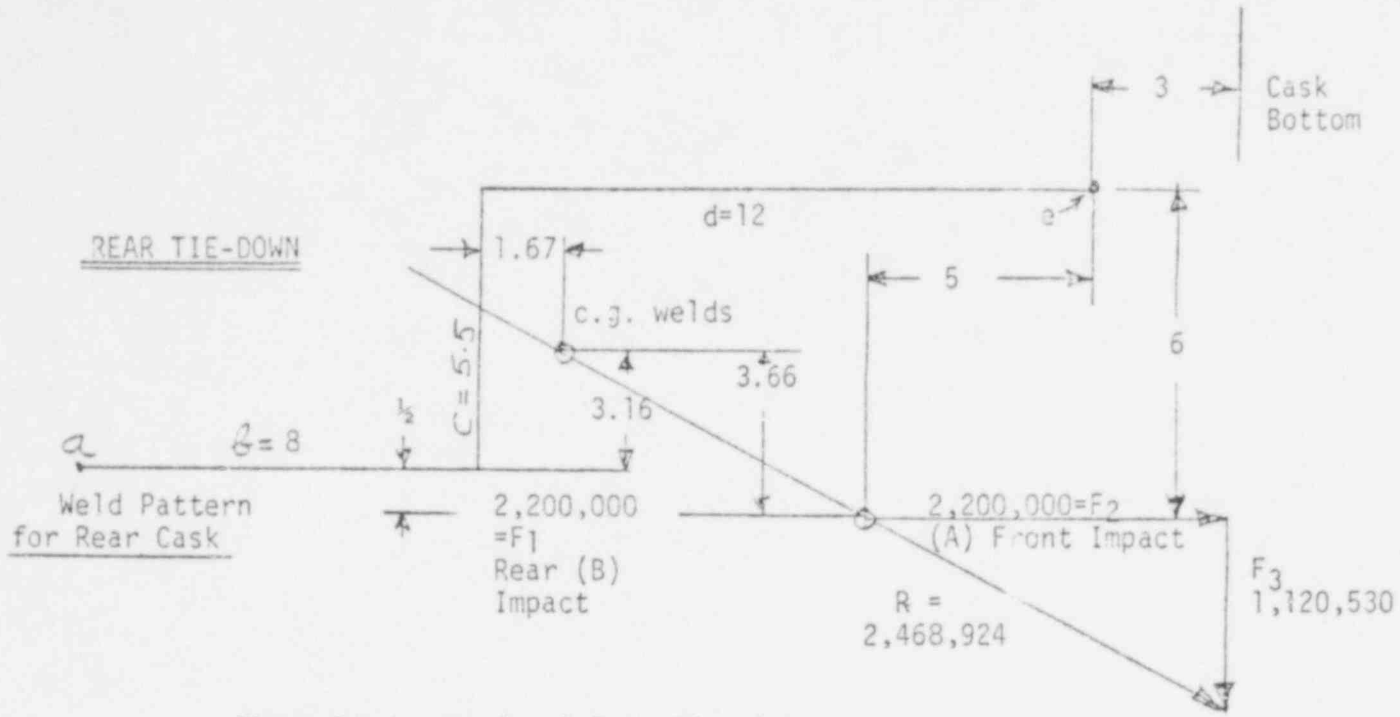
For an impact at (A) end, the total resultant load of 2,468,924 lbs. acts almost through the c.g. of the welds, and so regligible torsional stresses are developed. The main stress is the average uniformly distributed stress of:

$$S = \frac{2,468,924 \text{ lbs.}}{166.86} = 14,800 \text{ psi}$$

Due to the direction of the resultant, this is largely tension across areas a, c and e and largely shear across areas b and d. Even for a point which may be completely oriented to pure shear, this stress is safely low

$$M.S. = \frac{.6 \times .90 \times 30,000}{14,800} - 1 = .095 \text{ shear}$$ (Actually conservative on Y.P.)

655 321



These loads are for 2 lugs 3" thick

655 322

Throat widths - single lug. (w)

a 1½" fillet w = 1.5 x .707 = 1.06 in.

b, c, d each 2 (1½ fillets + 1/2 penetration)

w = 2 x 1.50 = 3.0 in.

e 1½ fillet w = 1.25 in.

To determine C.G. welds

	x w =	A	$\overline{X}$	$A\overline{X}$	y	$A\overline{y}$
a	3 x 1.06	3.18	0	0	0	0
b	8 x 3.0	24.0	4	96	0	0
c	5.5 x 3.0	16.5	8	132	2.75	45.375
d	12 x 3.0	36.0	14	504	5.5	198.
e	3 x 1.75	3.75	20	75	5.5	20.625
		83.43	(9.67)	807	(3.16)	264

Polar moment of inertia I_p for each lug

$$= \sum \left(\frac{wl^3}{12} + wl\,x^2 + \frac{lw^3}{12} + wl\,y^2\right) \quad \text{where } wl = A$$

$$= \sum A \left(\frac{w^2}{12} + \frac{l^2}{12} + x^2 + y^2\right)$$

$$I_p = 3.18 \left(\frac{1.06^2}{12} + \frac{3^2}{12} + 9.67^2 + 3.16^2\right) = 24 \left(\frac{3^2}{12} + \frac{8^2}{12} + 5.67^2 + 3.16^2\right)$$

$$+ 16.5 \left(\frac{3^2}{12} + \frac{5.5^2}{12} + 1.67^2 + .41^2\right) + 36 \left(\frac{3^2}{12} + \frac{12^2}{12} + 4.33^2 + 2.34^2\right)$$

$$+ 3.75 \left(\frac{1.25^2}{12} + \frac{3^2}{12} + 10.33^2 + 2.34^2\right)$$

= 331.769 + 1157.228 + 102.76 + 1331.082 + 423.993

= 3346.858

For both lugs; $2I_p = 6693.7 \text{ in.}^4$

$2A = 166.86 \text{ in.}^2$

655 323

13505

For an impact at the rear (B) end, F_1 = 2,200,000 lbs and the vertical loads are all taken by the impacter rather than by the lug.

$$\text{Average stress } S = \frac{2{,}200{,}000}{166.86} = 13{,}185 \text{ psi for all welds.}$$

Torque due to eccentricity is

$$T = 2{,}200{,}000 \times 3.66 = 8{,}052{,}000 \text{ in. lbs.}$$

$$T/I_p = \frac{8{,}052{,}000}{6693.7} = 1202.9 \text{ psi}$$

Shear stress at any point of the welds to cask.

$$S_s = \rho \; (T/I_p) = 120.219 \rho$$

For point (a) $\rho \sqrt{9.67^2 + 3.16^2} = 10.2$ in.

↑ $S_c = 10.2\ (1202.9) = 12{,}270$ psi (compression against jacket)

← $S_s = 13{,}185$ psi is here a shearing stress

$$S_c = \sqrt{12{,}270^2 + 3 \times 13{,}185^2} = 25{,}925 \text{ psi}$$

$$M.S. = \frac{.9 \times 30{,}000}{25925} - 1 = .04$$ conservative because compressive stress.

For midpoint of (c)

ρ = app. 1.67 ↑ $S_s = 1.67 \times 1202.9 = 2.009$ psi (shear)

$$S_c = \sqrt{13{,}185 + 3 \times 2009^2} = 13{,}636 \text{ psi (compression)}$$

$$M.S. = \frac{.9 \times 30{,}000}{13.636} - 1 = .98$$

For point (e)

$$\rho = \sqrt{10.33^2 + 2.34^2} = 10.59$$

↓ $S_t = 10.59 \times 1202.9 = 12{,}741$ psi tension

← $S = 13{,}185$ psi shear

$$S_t = \sqrt{12{,}741^2 + 3 \times 13{,}185^2} = 26{,}151 \text{ psi}$$

$$M.S. = \frac{.9 \times 30{,}000}{26{,}151} - 1 = .48$$

655 324

2.2.3 Railcar tie-downs and saddles   Accident analysis

This analysis deals with those parts of the tie-down system which are attached to the railcar rather than the cask body itself. The same applied loadings are used as in the previous analyses of the cask members, namely 10g longitudinal, 5g lateral and 2g vertical. The difference in this analysis is that, since it is for an accident condition, the allowable design strengths are 100% of the ultimate tensile stress, contrasted with 90% of the Y P in the previous cask member analyses. To prove that in an accident, the failure would be thru the railcar attachment welds, a final summary of M.S. valves is made, comparing these railcar members with the cask ratings - for the accident condition only.

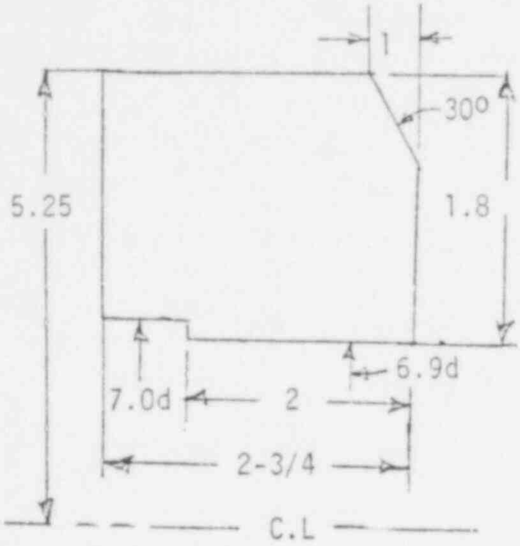
Material properties	- U.T.S. values are taken as
75,000 psi	- 304 stainless steel (also 308 weld rod & wire)
115,000 psi	- 17-4PH Stainless steel
115,000 psi	- T-1 steel
95,000 psi	- 8018 weld rod & wire
75,000 psi	- 7018 weld rod & wire

Refer to sections 2.2.1 and 2.2.2 for pertinent drawings and part dimensions and weld designations.

655 325

2.2.3.1

Front tie-down - Railcar plates - T-1 steel - 2 plates
Impact at B end



Section through C.L.

$$\text{Area} = (1.8 \times 2.75) - (3/4 \times 05) - \left(\frac{1.732}{2}\right) = 4.047''^2$$

$$\text{Load per plate} = \frac{1,175,092}{2} = 587,546 \text{ lbs.}$$

Hoop stress across section

$$S_t = \frac{587,546}{2 \times 4.047} = 72,590 \text{ psi}$$

$$\text{M.S.} = \frac{115,000}{72,590} - 1 = .584$$

Shear tearout at 40° from C.L

$$\text{Area} = 2\left(2.6 \times 2.75 - .05 \times .75 - \frac{1.732}{2}\right) = 12.49\text{in}$$

$$S_s = \frac{587,546}{12.49} = 47,041 \text{ psi}$$

$$\text{M.S.} = \frac{.6 \times 115,000}{47,041} - 1 = .466$$

Tension on diameter

$$\text{Area} = (11 - 6.9)\ 2.75 - 2(.05 \times .75) = 11.20\text{in}^2$$

$$S_t = \frac{587,546}{11.237} = 52,459 \text{ psi}$$

$$\text{M.S.} = \frac{115,000}{52,459} - 1 = \underline{1.192}$$

Bearing $S_{BR} = \frac{587,546}{6.9 \times 2} = 42,576$ psi

$$\text{M.S.} = \frac{115,000}{42,576} - 1 = 1.7$$

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13505

Front tie-down - Railcar welds

Welds 1 and 3 are superior in strength to that of weld 2 which is sacrificed in tension (the only load imposed under transit conditions or when impacted at B end in the accident condition) When impacted at the A end, weld 2 can easily be overturned and separated but only after the rear tie-down has initially released the cask as a free body.

Weld 1 - 2 side plates to bottom plate - (T-1 to T-1) (95,000 UTS welds)

1-1/8" J weld on outer side of each plate

1" fillet welds all around both plates =

$2 \times (11 \times 1\frac{1}{2} \text{ throat} + .707 \times 16\frac{1}{2}) = 56.3 in^2$

P = 1,175,092 lbs. on pin and 2 plates ↑ impact at B end

$$S_t = \frac{1,175,092}{56.3} = 20,872 \text{ psi}$$

$$M.S. = \frac{95,000}{20,872} - 1 = 3.55$$

Weld 3 - spacer plate to center sill (T-1 to 64,000 psi UTS steel) (75,000 UTS welds)

2 welds each 1" fillet x 20" long

$Area = 2 \times 1 \times .707 \times 20 = 28.28 in^2$ - throat of weld

$$S_t = \frac{1,175,092}{28.28} = 41,552 \text{ psi}$$

$$M.S. = \frac{75,000}{41,552} - 1 = .80$$

Interface with center sill is along 1" face of weld.

$Area = 2 \times 1 \times 20 = 40 in.^2$

$$S_t = \frac{1,175,092}{40} = 29,377 \text{ psi}$$

$$M.S. = \frac{64,000}{29,377} - 1 = 1.178$$

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Weld 2 (sacrificial) bottom plate to spacer plate (T1 - T1) - Tension only

9/16 in. fillet welds along 18 in. sides only (95,000 UTS weld)

Area = 2 x 18 x 9/16 x .707 = 14.317in^2

$S_t = \frac{1,175,092}{14.317} = 82,077$ psi

M.S. = $\frac{95,000}{82,077} - 1 = .157$ tension ↑

Therefore, in severe fore and after impact as specified (10g) the welds will all have a generous M.S.

Front tie down weld #2 - accident condition - A end impact

Weld 2 will be separated, not in tension, but by longitudinal bending after the rear tie down has separated.

Bending strength of weld #2 in break away after rear tie down parts

$Z_{xy} = \frac{2\ (9/16 \times .707)\ 18^2}{6} = 42.95$ in^3

Area = 2(9/16 x .707) 18 = 14.317 in.^{2}

Moment arm = 6-1/8 + 1½ = 7-5/8 in. height.

F = hor. force required to cause failure in bending and shear.

M = 7.625F

$S_b = \frac{7.625\ F}{42.95} = .1775F$

$S_s = \frac{F}{14.317}$

Comb. stress = $\sqrt{(.1775F)^2 + 3\left(\frac{F}{14.317}\right)} = .1216F$

F max. = $\frac{95,000}{.1216}$ = 781,250 lbs to break away thru 95,000 UTS welds

$\frac{781,250}{220,000} = 3.55g$

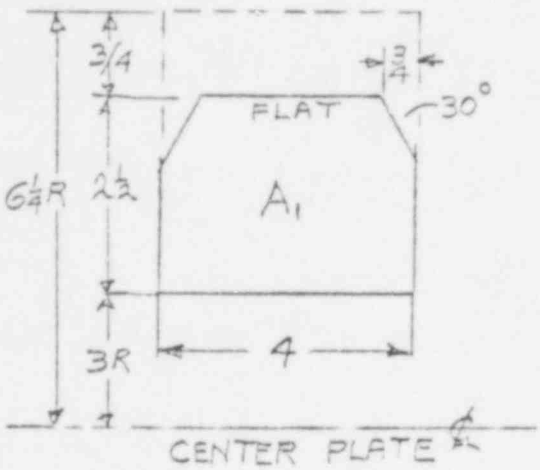
Longitudinal force to break away weld #2

655 328

2.2.3.3 Rear tie-down - Railcar plates

T-1 Steel -- 115,000 psi UTS - 3 plates

Impact at A end



Load on central plate = 1,489,000 lbs.

Hoop stress - - at top - flatted

$A_1 = (4 \times 2\frac{1}{2}) - (.75 \times 1.3) = 9.025 in^2$

$S_t = \frac{1,489,000}{2 \times 9.025} = 82493$ psi

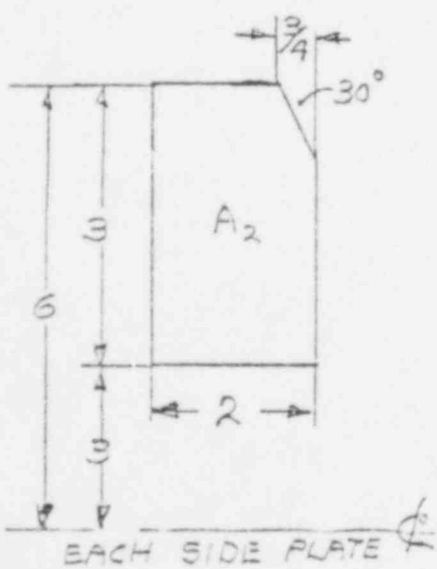
$M.S. = \frac{115,000}{82943} - 1 = .394$

Shear tear out at 40° to 45° load line.

Area = $(4 \times 3\frac{1}{2}) - (3/4 \times 1.3)$
$= 13.025 in^2$

$S_s = \frac{1,489,000}{2 \times 13.025} = 57,160$ psi

$M.S. = \frac{.6 \times 115,000}{57,160} - 1 = .207$



Load on each side plate = 489,464 lbs.

Hoop stress at top - flatted

$A_2 = (3 \times 2) - (.75 \times 1.3) = 5.5125 in^2$

$S_t = \frac{489,464}{2 \times 5.5125} = 44,396$ psi

$M.S. = \frac{115,000}{44,396} - 1 = 1.59$

Shear tear out at 40° to 45° load line

Area = $2 \times 3\frac{1}{2} - \frac{.75 \times 1.3}{2} = 6.51 in^2$

$S_s = \frac{489,464}{2 \times 6.51} = 37,593$ psi

$M.S. = \frac{.6 \times 115,000}{37,593} - 1 = .835$

655 329

Impact at B end

Stresses in all plates are reduced from those calculated above in the rates of $\frac{2,200,000}{2,468,924}$, so they are not critically stressed in this condition.

2.2.3.4 Rear tie-down - welds to railcar

Weld 1 - 3 plates to bottom plate of weldment

(T-1 to T-1) - weld 95,000 psi UTS.

4 x 42½" of 1-1/8"J + 1" fillet = 170" x 1½" throat = 255in^2

(2 x 42½ + 16) of 1" fillet = 101 x .70 throat = 71.4 in^2

Total - weld #1 = 326.4 in^2

Weld 2 - (Sacrificial) Bottom of weldment to center sill spacer plates

(T-1 to T-1) - weld 75,000 psi UTS.

88" of 1-3/8" fillet - 88 x 1-3/8" x .707 = 85.55in^2

Weld 3 Spacer plates to railcar center sill (2)

(T-1 to railcar sill (A441 - 67,000 psi UTS)

Weld 75,000 psi UTS.

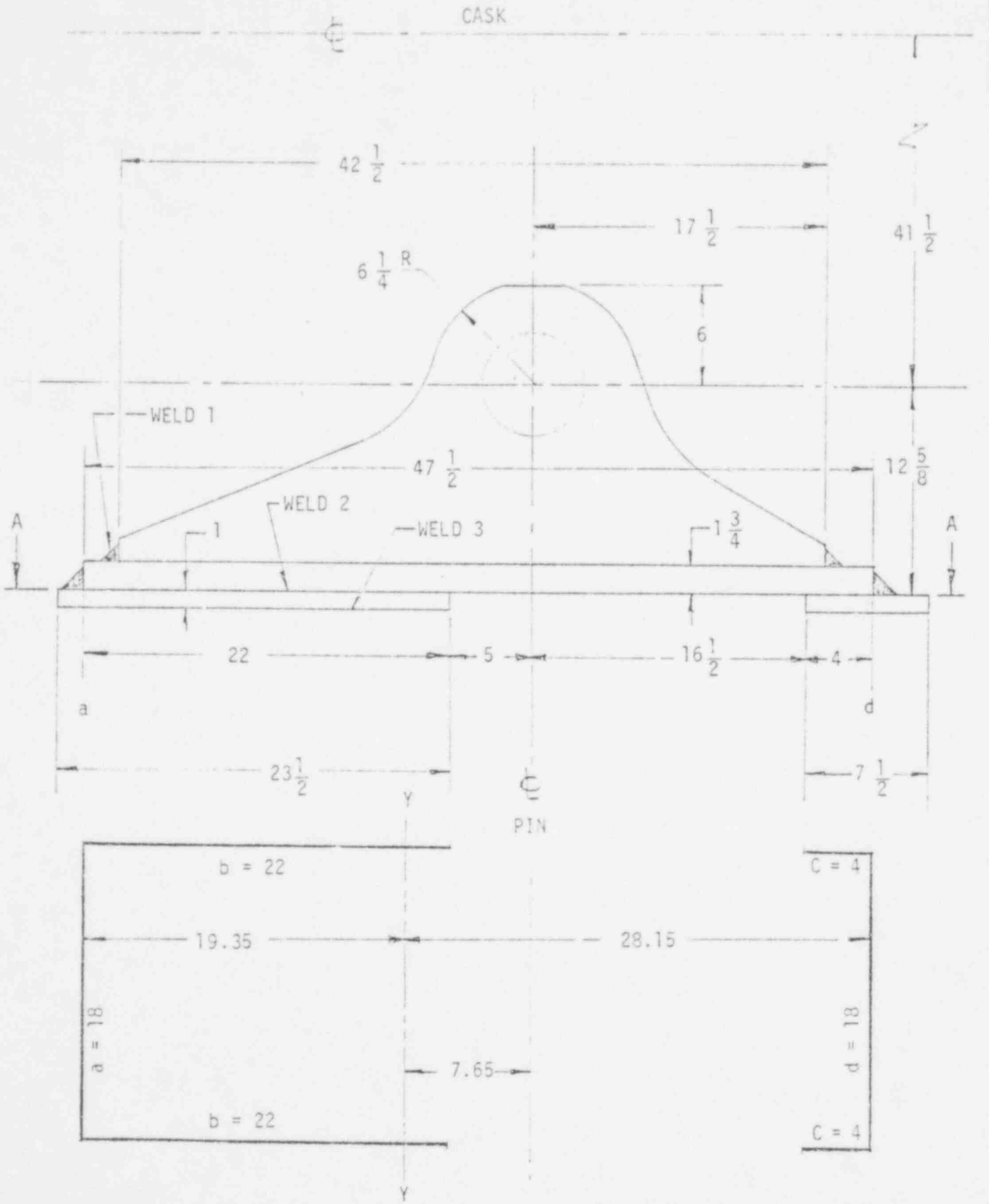
142" of 3/4" penetration + 1" fillet

142" x 1¼" throat = 177.5in^2

Weld 1 and 3 are obviously much stronger than weld 2.

Weld 2 is sacrificial and will be analyzed in detail.

655 330



WELD PATTERN OF PLANE -A- WELD 2

X1-2-22m

To find C.G. of welds - Weld 2

a	18	x	0	=	0
2b	2x22	x	11	=	484.
2c	2x4	x	45.5	=	364
d	18	x	47.5	=	855
	88	x	(19.35)	=	1703 in^2

$I_{yy} = 18 \times 19.35^2 + 2 \times \frac{22^3}{12} + 2 \times 22 \times 8.35^2 + \frac{2 \times 4^3}{12} + 2 \times 4 \times 26.15^2 + 18 \times 28.15^2$

$= 31327.\text{in}^3$ for line welds

Weld throat = 1-3/8" x .707 = .972in

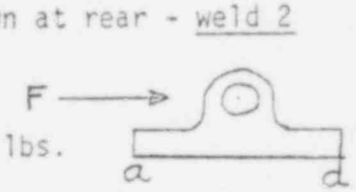
$Z_d = \frac{31327}{28.15} = 1112.86\ \text{in}^2$ for line welds x .972" = 1082 in^3

$Z_a = \frac{31317}{19.35} = 1619\ \text{in}^2$ for line welds x .972" = 1574 in^3

Area = 19.35 in^2

weld length = 88", weld throat area = 85.54 in^2

For impact at rear (B) end - Loads on tie-down at rear - weld 2



$F_1 = 2{,}200{,}000$ lbs.

$M = 2{,}200{,}000 \times 12\ 5/8 = 27{,}775{,}000$ in lbs.

This puts tension at a & compression at d.

There is no vertical load in this case.

Shear stress $S_s = \frac{2{,}200{,}000}{85.54} = 25{,}719$ psi

at a max tension $S_a = \frac{M}{1574} = 17646$ psi

Comb. stress $S = \sqrt{17646^2 + 3 \times 25.719^2}$

$= 47914$ psi

$M.S. = \frac{75{,}000}{47{,}914} - 1 = .565$ at a

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For impact at front end (A) - Loads on tie-down at rear. - weld 2

F_1 = 2,200,000 lbs. ←

V_1 = 1,120,530 lbs. ↑

R = 2,468,924 ↖

M = F_1 x 12-5/8 + V_1 x 7.65 = 36,072,055 in lbs.

This puts tension at D and compression at A

Stress at D (Sac. Weld #2)

$$\frac{M}{Z_d} = \frac{36,072,055}{1,082} = 33,338 \text{ psi}$$

$$\frac{V_1}{A} = \frac{1,120,530}{85.54} = 13,099 \text{ psi}$$

↑ Total tension = 33,338 + 13,099 = 46,437 psi

Shear stress K = 25,719 psi

Comb. stress $S = \sqrt{46,437^2 + 3 \times 25,719^2} = 64,349$ psi

The max stress at the plane A of the sacrificial weld is thus 64,349 psi

The weld is between T-1 plates.

$$\text{Weld M.S.} = \frac{75000}{64,349} - 1 = .165 \text{ at } d$$

This assures adequate strength for 10gL + 5gT + 2gV condition, yet allows controlled break-away above this.

2.2.3.5 Saddle bearing stresses - Impact limiters on support structure

The compression loads on a 45° saddle structure are maximum as following:

753,134 lbs. Rear saddle, impact at B end, 2g lateral

Minimum bearing area of each flat on radial base plate of impact structure is 28 x 1.5 = 42 in²

$$S_{BR} = \frac{753,134}{42} = 17,932 \text{ psi}$$

The material is 6061 - T 6511 with allowable compressive stress at y.p. = 36,000 psi

$$M.S. = \frac{36,000}{17,932} - 1 = 1.00$$

This is for the net area of the edge of the end plate itself, and neglects the load distribution afforded by the actual flange width itself, thus actually giving lower stresses.

2.2.3.6 Summary of Tie-Down Stresses

The various parts which are positioned between the cask proper and the railcar proper, and which constitute the tie-down and support system, are subject to different design requirements.

Summaries of stresses are therefore presented in two groupings, each consistant within itself.

Condition A has loadings of 10g L, 5g T, and 2g V and applies to integral cask tie down lugs and associated pins, with stresses limited to .9 x y.p.

Condition B is the accident condition. The same loadings of 10gL, 5 gT, and 2 gV are applied to the railcar plate weldments which mate with the above pins and are welded to the railcar center sill. Stresses are calculated on the U.T.S of base metal and of weld material for these parts.

To make a consistent comparison of these railcar parts with the above cask related parts, it is necessary to calculate a new set of M.S. values for the latter, based on U.T.S rather than .9 x y.p (as in condition A). This will permit determining how and where separation would occur between cask and railcar in the case of maximum accident.

655 335

Stress Summary - Condition A - Transit - .9 x y.p. Allowable

Impact at	Member	Stress	M.S. (.9 y.p.)
B End	Front Pin	88,570 psi bending	.016
"	Front Lug	47,719 psi shear	.131
"	Front Lug Weld	23,685 psi tension	.14
A End	Rear Pin	64,527 psi comb.	.394
"	Rear Lug	44.151 psi shear	.223
"	Rear Lug weld	14,800 psi shear	.095 +
Bend	" " "	25,925 psi comp.	.04 +

Stress Summary - condition B - Accident - U.T.S allowable

(Note - above cask related members herewith re-evaluated at their U.T.S)

Impact at	Member	Stress	M.S. (U.T.S)
A End	Rear Pin	64,527 psi comb.	.782
"	Rear Lugs	44,151 psi shear	.563
"	Rear lug welds	14,800 psi snear	2.04
"	Rear center rail plate	57,160 psi shear	.207
"	Rear side rail plate	37,593 psi shear	.835
"	Rear Weld #2	64,349 psi comb.	.165 *
B End	Front pin	88,570 psi bending	.298
"	Front Lug	47,719 psi shear	.446
"	Front Lug Weld	23,685 psi Tension	2.166
"	Front rail plates	47,041 psi Shear	.466
"	Front Weld #1	20,872 psi Tension	3.55
"	Front Weld #2	82,077 psi Tension	.157 *
"	Front Weld #3	41,552 psi Tension	.80
"	Rear Lug Weld	25,925 psi Comp.	1.892
"	Rear Weld #2	47,914 psi comb.	.565

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Conclusions - Tie-down Stress Analyses.

Condition A - Transit

The rear, or B end, tie-down takes the entire 10gL in both directions, plus the resultant vertical loads from all three (3) axes of component loadings. The stresses are greater when impact occurs at the front, or A end, putting the cask lug largely in direct tension.

The front, or A end, tie-down takes only vertical loads in tension, which develope only when impact is at the B end.

Satisfactory M.S. valves apply to all cask related members at a conservative .9 x Y.P. stress for 10 gL, 5 gT, and 2g V for the transit condition.

Condition B - Accident

For A end impact all members have M.S. valves greater than the .165 value for the sacrificial weld #2 of the rear (B end) tie-down weldment. This initiates the break-away procedure, followed by rip off of weld #2 of the front (A end) tie down weldment. Break-away of the cask occurs there at a longitudinal force of 11.65 gL.

For B end impact also all members are superior in strength to the #2 welds. The sequence in the break-away, however is reversed. First the front weld #2 breaks in tension as the front end of the cask rises, followed by break-away of the rear weld #2.

Saddle Weldments are integral with the railcar structure and carry only compressive loads. They are not part of the accident failure situation.

In conclusion, the design satisfies the specification requirement that the #2 welds are sacrificial in the accident condition.

655 338

Allowable Stresses for 6061-T6

Temperature of the Spacer is determined by an average of the Inner plate of inner closure and the top end of the basket. (Ref. Sect. VIII - Appendix D)

$$t = \frac{355 + 425}{2} = 390\ ^{o}F$$

From Ref: 27, Figure 3.6.1.2.1 (c)

Table 3.6.1.0 (f)

Percent of Ult at temp. considered = 72%

F_{TU} = 42,000 psi

Allowable tensi.e stress ($S_{aa} = 0.9S_u$) for Al.6061 T6 at 390 ^{o}F from Sect. 1.1 under cask internal structure and Sect. 1.2 equals .72 (42,000) (.9) =

S_{TA} = 27,216 psi

Allowable Shear stress ($.6S_{aa} = 0.54S_u$) for Al. 6061 T6 at 390 ^{o}F from Sect. 1.1 under cask internal structure and Sect. 1.2 equals

S_{sa} = .72 (.54) (42,000) = 16,330 psi

Allowable Bearing Stress = S_{br} = .72 (.90) (67,000) = 43,416 psi

Allowable Weld Stress In a welding operation, dealing with either a strain hardened or heat tempered aluminum alloy, it is impossible to reduce T6 temper to a value less than 0 condition temper. Therefore, the computation of weld allowables may use 0 condition stress allowables as a conservative minimum in the applicalbe equations.

For the 0 Condition

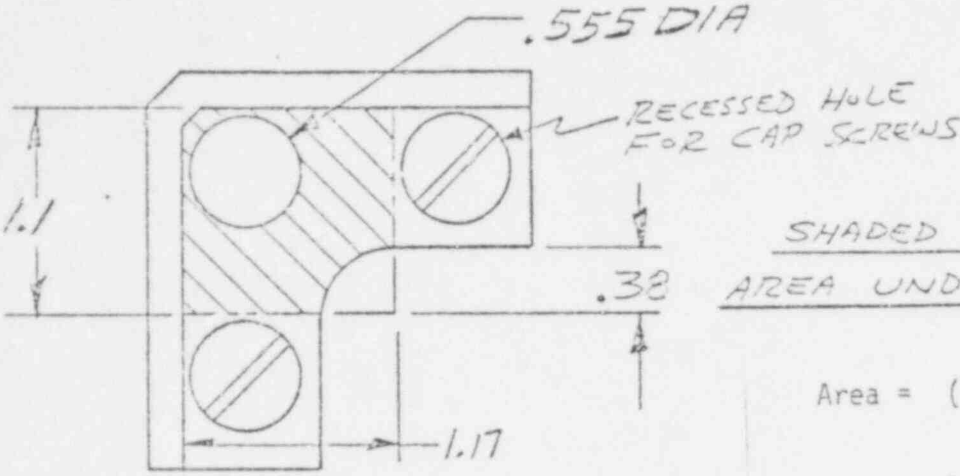
F_{TU} = 18,000 psi (Ref. 14)

Allowable Shear in Weld = 90% (.72) (.6) (18,000) = 6,998 psi

Allowable Tension in Weld = 90% (.72) (18,000) = 11,664 psi

655 339

Adjacent hard points on the Fuel have two holes in each bearing surface, one being .875 in diameter and the other having a diameter of .555.



Top View of Fuel Pick-Up Point

Full Scale

TOP VIEW OF FUEL PICKUP POINT - FULL SCALE

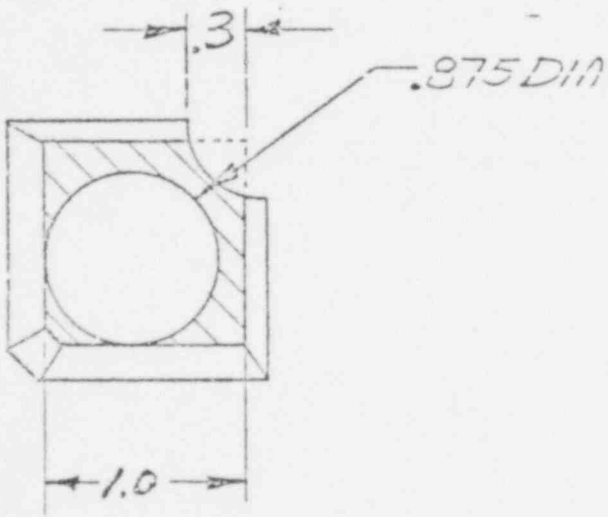
SHADED AREA INDICATES BEARING AREA UNDER COMPRESSION LEG

$$\text{Area} = (1.1)(1.17) - \pi\left(\frac{.555^2}{2}\right) - \frac{\pi}{4}(.38)^2$$

$$\text{Area} = 1.287 - .242 - .113 = .932 \text{ in}^2$$

$$S_{br} = \frac{51{,}000}{4 \times .932} = 13{,}680 \text{ psi}$$

$$\text{M.S} = \frac{43{,}416}{13{,}680} - 1 = 2.17$$



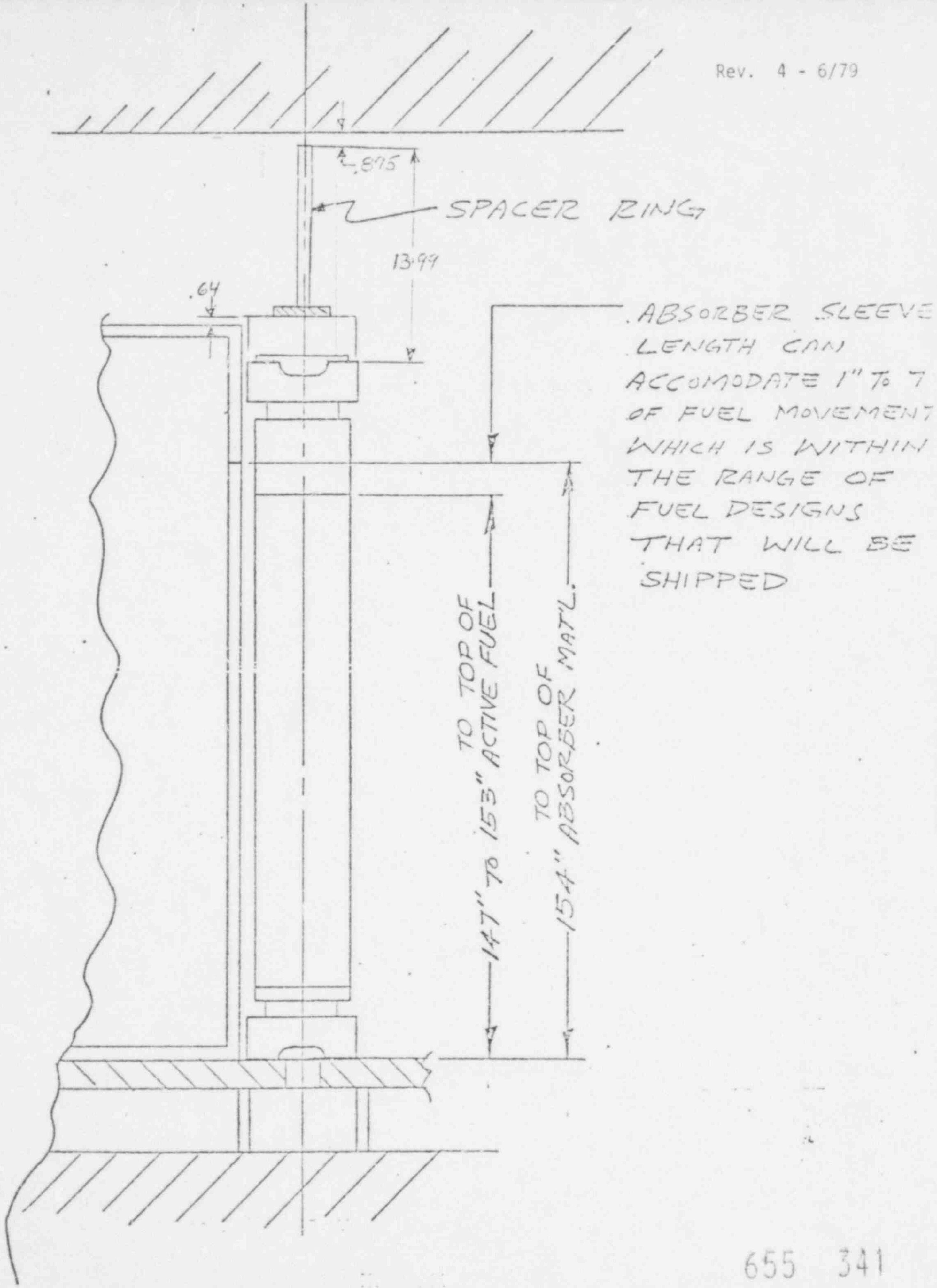
$$\text{Area} = (1.0)^2 - \pi\left(\frac{.875^2}{2}\right) - \frac{\pi}{4}(.3)^2$$

$$\text{Area} = 1.0 - .601 - .0706 = .328 \text{ in}^2$$

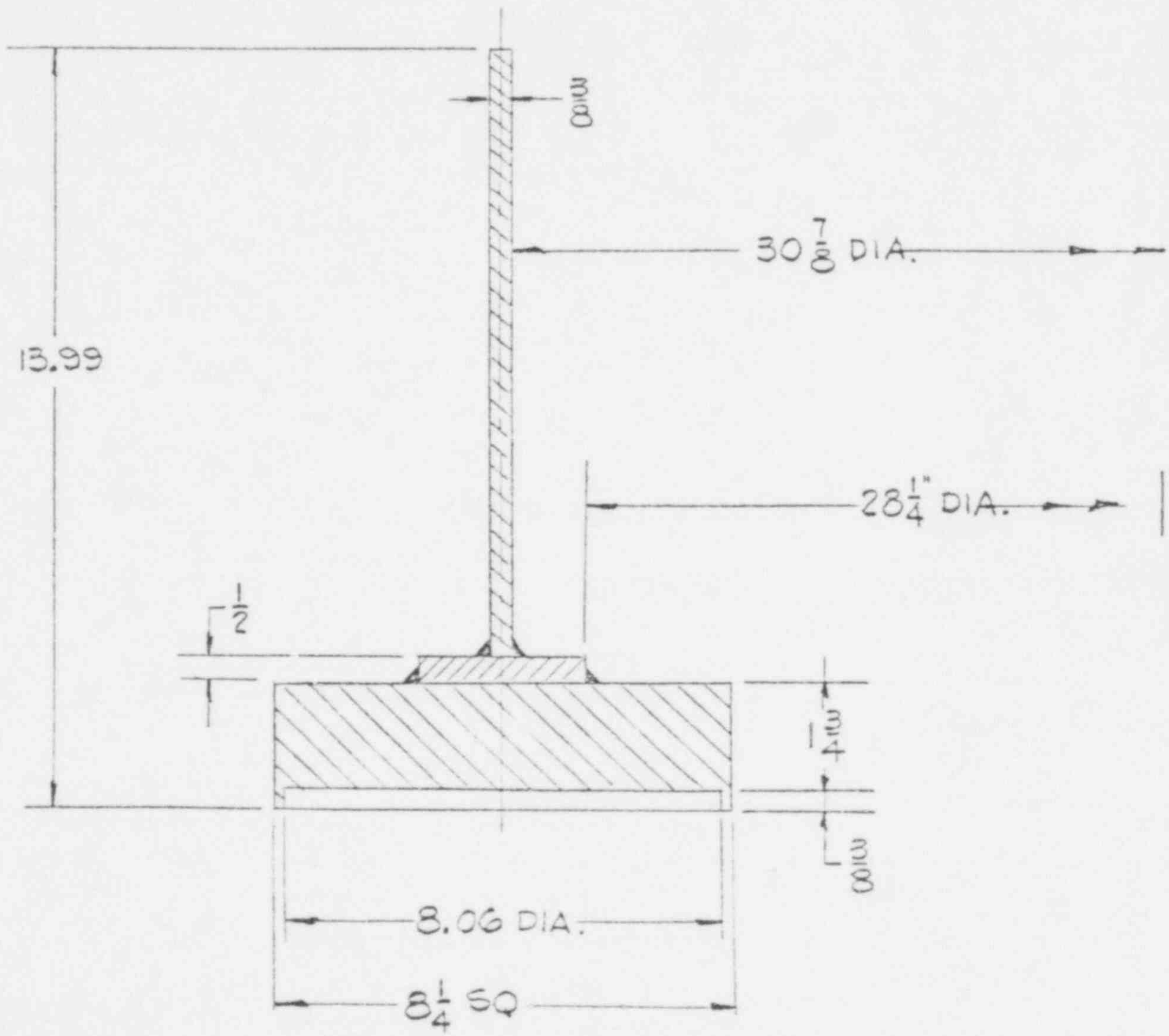
$$S_{br} = \frac{51{,}000}{4 \times .328} = 38{,}871 \text{ psi}$$

$$\text{M.S.} = \frac{43{,}416}{38871} - 1 = .117$$

655 340

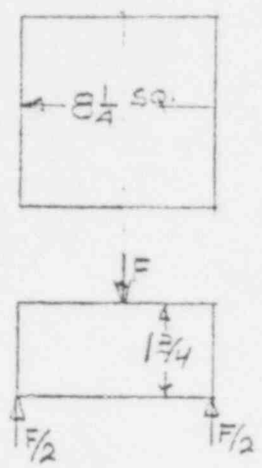

.875
SPACER RING
13.99
.64
ABSORBER SLEEVE LENGTH CAN ACCOMODATE 1" TO 7 OF FUEL MOVEMENT WHICH IS WITHIN THE RANGE OF FUEL DESIGNS THAT WILL BE SHIPPED
147" TO 153" TO TOP OF ACTIVE FUEL
154" TO TOP OF ABSORBER MAT'L.

655 341



655 342

Blocks as simple beams:



$F/2 = \frac{1700 \times 30}{2} = 25,500$ lbs

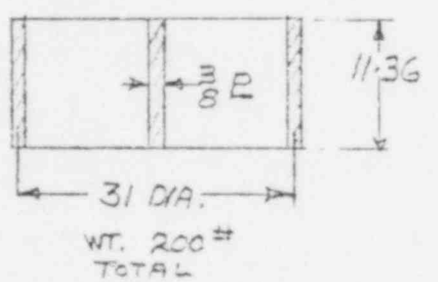
$M = 25,500 \times 4\text{-}1/8 = 105,188$ in lbs.

$Z = \frac{8\frac{1}{4} \times 1.75^2}{6} = 4.21 \text{ in}^3$

$S_b = \frac{105.188}{4.21} = 24,980$ psi

$M.S = \frac{27,216}{24,980} - 1 = .089$ (Conservative)

Plate and Ring in Compression



Total load against closure head = 952,650 + 30 (200) = 958,650 lbs.

area plate and ring = (3/8 x 31) + (3/8 x 30.25) = 47.86 in^2

$S_c = \frac{958,650}{47.86} = 20,030$ psi

$M.S. = \frac{27,216}{20,030} - 1 = .358$

Stability of cylinder

Roark - Table XVI -Case M-ends not constrained (conservative)

$S^1 = .3\ E\ t/r = .3(.9 \times 10,100,000)\ \frac{.375}{15.5} = 65,976$ psi (critical)

Actual S_c = 20,030 psi OK

All welds are in compression, if considered loaded at all, since stack-up of members allows direct contact for transmission of loads.

655 343

655 344

SECTION XV

THERMAL TEST PROCEDURE

Thermal tests will be performed in accordance with detailed thermal test procedure to verify the thermal performance of the shipping cask. The thermal tests will also be used to establish operational parameters relative to preparing a loaded cask for shipment and unloading the cask at the reprocessing plant. Both fuel basket types, i.e., PWR and BWR, will be thermally tested. A cask will only be tested once with the basket type available at time of test. This section describes the thermal test used to verify cask performance and the temperatures used in the thermal stress analysis.

As established in Section VIII, "Thermal Analysis," the thermal response of the cask to PWR and BWR loadings are approximately equal. Therefore, the heat source for the thermal test shall be equivalent to the calculated decay heat source for the ten (10) PWR cask loading of 70kw. The heat source shall be provided by electrical heaters designed and located to simulate the active region of a fuel assembly. The heaters will be positioned such that the 144 inch active length falls within the limits of the neutron shield water jacket. A mockup of the cask closure heads shall be provided which will thermally simulate the top end of the cask. There will be additional penetrations in the closure head mockups to provide for heater leads and thermocouple wire installation.

655 345

The thermal tests are to be performed within an area which will be protected against drafts and large temperature changes. The cask shall be completely assembled on the rail car, i.e., the fuel basket, either PWR or BWR, installed in the cask cavity, closure head mockup with heater and thermocouple leads in place. The assembled cask will be positioned horizontally on the rail car to simulate the shipping attitude. The cooling system will be inoperative and drained for this test.

The assembled shipping cask will be instrumented so that temperatures and pressures of the various elements of the system can be monitored and at established time intervals all data will be recorded. To obtain the necessary temperature data, thermocouples will be installed inside the PWR fuel basket cavities, on the outer surface of the outer shell on the outside surface of the water jacket shell and on the ends of the cask.

The thermocouple locations and heater locations in the basket are shown in Figures 1 and 2. The following thermocouple will also be attached to the cask. (See Figure 3)

1. Seven sets of three thermocouples will be mounted circumferentially on the cask surface and on the outer surface of the outer shell on a plane equidistant from the ends of the heater active zone. As viewed from the end of the cask, one set would be mounted in the 0° and then every 30° to the 180° position.
2. A thermocouple at each end of the cask at the center of the top and bottom head.

SECTION XVIII

ENGINEERING DRAWINGS

70650F	Sheet 1	Rev. 4	General Arrangement 10/24 Rail Cask
70651F	Sheet 1	Rev. 4	10/24 Rail Cask Details
	Sheet 2	Rev. 5	10/24 Rail Cask Details
	Sheet 3	Rev. 5	10/24 Rail Cask Details
	Sheet 4	Rev. 5	10/24 Rail Cask Details
	Sheet 5	Rev. 3	10/24 Rail Cask Details
	Sheet 6		DELETED
	Sheet 7	Rev. 2	10/24 Rail Cask Details
70652F	Sheet 1	Rev. 7	PWR Fuel Basket 10/24 Rail Cask
	Sheet 2	Rev. 5	PWR Fuel Basket 10/24 Rail Cask
70653F	Sheet 1	Rev. 7	BWR Fuel Basket 10/24 Rail Cask
	Sheet 2	Rev. 5	BWR Fuel Basket 10/24 Rail Cask
70654F	Sheet 1	Rev. 5	NLI 10/24 Cask & Rail Car General Arrangement
	Sheet 2	Rev. 2	Piping Plans & Details Rail-road Cask-Cooling System
	Sheet 3		DELETED
70655F	Sheet 1	Rev. 5	PWR Spacer Plug 10/24 Rail Cask
70656F	Sheet 1	Rev. 4	BWR Spacer Plug 10/24 Rail Cask

Engineering Drawings

70640F	Sheet 1		DELETED
70665F	Sheet 1	Rev. 4	Neutron Shield Expansion Tanks 10/24 Rail Cask
70666F	Sheet 1	Rev. 5	10/24 Rail Cask Impact Structure Assembly & Details
	Sheet 2	Rev. 4	10/24 Rail Cask Front Impact Structure Ring Details
	Sheet 3	Rev. 3	10/24 Rail Cask Rear Impact Structure Ring Detail
	Sheet 4		DELETED
70667F	Sheet 1	Rev. 5	10/24 Rail Cask Support Structure Details
	Sheet 2	Rev. 5	10/24 Rail Cask Front Support and Tie Down Details
	Sheet 3	Rev. 5	10/24 Rail Cask Rear Support and Tie Down Details
	Sheet 4		DELETED
70708F	Sheet 1	Rev. 2	10/24 Rail Cask Alternate Construction
70399F	Sheet 1	Rev. 1	Cask, Car Tie-down Arrangement 10/24 Rail Cask
OC-459-1*		Rev. E	General Arrangement - 150 Ton Cask Transfer Car

*Ortner Freight Car Drawing

655 349

655 350