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MECHANICAL ANALYSIS
SPENT FUEL STORAGE RACKS
MODIFIED TO 100% STORAGE DENSITY
(IN REGION 2)

R. E. GINNA NUCLEAR STATION

December, 1983
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PREPARED FOR

ROCHESTER GAS AND ELECTRIC CORP.

ROCHESTER, N.Y.

P.O. N-BU-37225

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RECORD OF REVISIONS
FOR REPORT 8369-00-0014

DATE	REV. NO.	RECORD OF REVISION
3-6-84	1	TABLE OF CONTENTS
3-6-84	1	SECTION 1 PAGE 1 OF 3 PAGE 2 OF 3 PAGE 3 OF 3 ADDED
3-6-84	1	SECTION 2 PAGE 2 OF 7 PAGE 5 OF 7
3-6-84	1	SECTION 3 PAGE 2 OF 6
3-6-84	1	SECTION 4 PAGE 2 OF 2
3-6-84	1	SECTION 7 PAGE 3 OF 3
3-6-84	1	SECTION 8 PAGE 1 OF 2 ADDED PAGE 2 OF 2 ADDED
9-20-84	2	SECTIONS 3,5,6 REVISED.

8369-00-0014

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SECTION 1.0

INTRODUCTION

INTRODUCTION:

THE SPENT FUEL STORAGE RACKS ARE CLASSIFIED AS CATEGORY 1 PER NRC REGULATORY GUIDE 1.29. THEIR PRIMARY FUNCTION IS TO MAINTAIN STORED FUEL ASSEMBLIES IN A SUBCRITICAL ARRAY WHILE PROTECTING THEM FROM MECHANICAL DAMAGE DURING ALL CREDIBLE STORAGE CONDITIONS. THIS MECHANICAL ANALYSIS PRESENTS ANALYTICAL PROOF OF STRUCTURAL INTEGRITY.

THE ANALYSIS FOLLOWS NRC GUIDANCE AS DELINEATED IN THE POSITION PAPER "REVIEW AND ACCEPTANCE OF SPENT FUEL STORAGE AND HANDLING APPLICATIONS",DATED APRIL 14,1978 AND MODIFIED JANUARY 18,1979. THE DESIGN CALCULATIONS ARE BASED ON SUBSECTION NF OF ASME BOILER AND PRESSURE VESSEL CODE, SECTION III AND APPENDIX D OF THE STANDARD REVIEW PLAN (SRP)3.8.4. THE PERMISSIBLE WELD STRESSES ARE TAKEN FROM TABLE NF-3324.5(a)-1,1983 EDITION. THIS IS THE SAME AS TABLE NF-3292-1, 1977 EDITION, REFERRED TO IN THE POSITION PAPER AND IN NF-3321. THIS TABLE NO LONGER EXISTS IN THE 1983 EDITION.

THE LOAD COMBINATIONS USED IN THIS ANALYSIS ARE ONLY SUBMERGED DEADWEIGHT PLUS SRSS COMBINATIONS OF OBE AND SSE LOADS. THESE LOAD COMBINATIONS ARE THE RMS VALUES TAKEN DIRECTLY FROM THE SEISMIC ANALYSIS (REF.2). THE RACKS ARE NOT SUBJECTED TO LIVE LOADS NOR TO THERMAL LOADS. THUS THE LOAD COMBINATIONS, D+L+To(OR Ta)+E AND D+L+Ta+E' BECOME D+E AND D+E'.

ANALYSES ARE PERFORMED FOR TWO STORAGE ARRANGEMENTS, ONE REFERRED TO AS "STANDARD" WHEREIN ONE FUEL ASSEMBLY (179 FUEL RODS) IS STORED IN EACH CELL IN REGION 2, THE OTHER REFERRED TO AS "CONSOLIDATED" WHEREIN THE FUEL RODS FROM TWO ASSEMBLIES (358 FUEL RODS) IN A CANISTER ARE STORED IN EACH CELL IN REGION 2.

THE INTERFACE BETWEEN THE RACKS AND BASES IS THE CRUCIFORM BOTTOM PLATE AT THE RACK CORNERS WHICH SPAN THREE BOXES IN EACH DIRECTION. THUS THE PLANE AT THE THIRD ROW LOCATION, AS SHOWN ON FIGURES 2.2 AND 2.3, AND THE THREE-BOX CORNER SQUARE ARE THE WELD PLANES ANALYZED.

FLOOR LOADS FOR REGION 2 ARE TRANSFERRED THROUGH THE BASE TO THE 11" X 11" FLOOR PLATES. BECAUSE OF THE INCREASED STORAGE IN REGION 2 SHIMS ARE INSTALLED BETWEEN THE BASE CORNER AND EACH FLOOR PLATE TO PROVIDE GREATER LOAD TRANSFER AREA THAN THE PRESENT JACKSCREWS. IN REGION 1, HOWEVER, SINCE NO CHANGE IN STORAGE IS BEING MADE THERE IS NO CHANGE IN BASE TO FLOOR PLATES, i.e. THE JACKSCREWS REMAIN. NOR ARE THE REGION 1 RACKS BEING MOVED FROM THEIR PRESENT LOCATIONS WITH THE JACKSCREWS CENTERED ON THE 11" X 11" FLOOR PLATES. THERE IS ENOUGH EDGE DISTANCE TO TAKE CARE OF ANY REGION 2 INDUCED SLIDING.

THERE ARE NO CALCULATIONS FOR WALL LOADS BECAUSE AS FREE-STANDING RACKS AND BASES, DUE TO REMOVAL OF THE WALL SEISMIC RESTRAINTS, THERE ARE RELATIVELY LARGE DIMENSIONS BETWEEN THE RACKS AND WALLS AND CONSEQUENTLY SMALL HYDRODYNAMIC FORCES.

A POSTULATED DROP ACCIDENT OF A FUEL ASSEMBLY STRAIGHT DOWN INTO A STORAGE CELL IS INCLUDED BECAUSE IT WAS NOT ADDRESSED IN THE ORIGINAL REPORT.

SECTION 2.0

EQUIPMENT DESCRIPTION

AND

SUMMARY OF SEISMIC LOADS

2.1 EQUIPMENT DESCRIPTION

SIX OF THE NINE PRESENTLY INSTALLED RACKS ARE MODIFIED FOR 100% STORAGE DENSITY, AND DESIGNATED AS REGION 2 FOR STORAGE OF DEPLETED FUEL AND/OR CONSOLIDATED PIN STORAGE, IN CANISTERS ON A 2:1 RATIO. THE REMAINING THREE RACKS, UNMODIFIED, ARE DESIGNATED REGION 1 FOR STORAGE OF UNIRRADIATED OR FRESHLY DISCHARGED FUEL AT 50% STORAGE DENSITY.

ALL SIX RACKS IN REGION 2 ARE THE SAME SIZE, 140 STORAGE CELLS. MODIFICATION CONSISTS OF REMOVING THE PRESENT BOLT CONNECTIONS BETWEEN RACKS AND BASES AND THE WALL SEISMIC RESTRAINTS,RESULTING IN A FREE-STANDING ARRAY. THE WALL SEISMIC RESTRAINTS ARE ALSO REMOVED FROM REGION 1. ADDITIONALLY A FULL-LENGTH RIGHT ANGLE POISON INSERT IS WELDED IN EACH REGION 2 CELL, AS SHOWN ON THE CROSS-SECTION, FIGURE 2.3 OF THE SEISMIC ANALYSIS (REF.2) AND THE LONGITUDINAL SECTION, FIGURE 2.4 OF THE SEISMIC ANALYSIS (REF. 2).

A SKETCH OF RACK, BASE, SHIMS, AND FLOOR PLATES IS REPRESENTED IN FIGURE 2.1. THE SHIMS ARE ADDED BETWEEN THE BASE AND FLOOR PLATES IN ORDER TO PROVIDE MORE LOAD CARRYING AREA THAN THE PRESENT JACKSCREWS.

2.2 LOADS FROM THE SEISMIC ANALYSIS (REF.2)

TABULATION OF LOADS FROM THE SEISMIC ANALYSIS ARE INCLUDED AS PAGES 3 AND 4. THE LOAD COMBINATIONS OF D+E (OBE) AND D+E' (SSE) ARE THE RMS VALUES LISTED. SET #3, MAXIMUM VERTICAL LOADS ARE THOSE OCCURRING ON 2 OF THE 4 RACK CORNERS AT RETURN IMPACT FOLLOWING LIFT-OFF. SET #4 IS HALF OF SET #3 OR THE LOAD ON A SINGLE CORNER.

SUMMARY OF RESULTS FOR 140 CELL RACK - STANDARD. FILE RGSUM.1A

-------------------SET #1 - MAX. FORCES (KIPS)---------------------

DIR	EVT	AT GAP ELEMENT# 1	2	3	4	5	SUPPORT Fvt	Fhz
NS	OBE	31.4	53.2	53.3	64.4	83.5	271.7	170.0
EW	OBE	0.0	55.6	72.4	73.2	73.2	393.3	156.2
NS	SSE	8.9	62.0	98.3	77.7	97.6	404.7	231.5
EW	SSE	16.6	66.5	115.8	83.9	103.3	381.6	164.2

-----SET #2 - LOADS ON INDIVIDUAL F/A'S (LBS) AND SUPPORTS (KIPS)---

DIR	EVT	1	2	3	4	5	Fvt	Fhz
NS	OBE	224.	380.	381.	460.	596.	135.9	85.0
EW	OBE	0.	397.	517.	523.	523.	196.7	78.1
NS	SSE	64.	443.	702.	555.	697.	202.4	115.8
EW	SSE	119.	475.	827.	599.	738.	190.8	82.1

-SET #3 - MAX. FORCES AT SUPPORT (LBS) -SET #5- MOVEMENT AT BASE (INS)

DIR	EVT	Fvert	Fhoriz	ELASTIC	SLIDING	LIFTOFF
NS	OBE	63,510.	170,000.	0.019	0.080	0.009
EW	OBE	185,110.	156,200.	0.046	0.088	0.048
VT	OBE	53,728.	00,000.			
RMS		411,133.	230,865.			
NS	SSE	196,510.	231,500.	0.026	0.308	0.050
EW	SSE	173,410.	164,300.	0.048	0.513	0.067
VT	SSE	53,728.	00,000.			
RMS		475,723.	283,878.			

-SET #4 - MAX. FORCES ON SUPPORT (LBS)--

DIR	EVT	Fvert	Fhoriz
NS	OBE	31,755.	85,000.
EW	OBE	92,555	78,100
VT	OBE	26,864.	00,000.
RMS		205,567.	115,432.
NS	SSE	98,255.	115,750.
EW	SSE	86,705.	82,150.
VT	SSE	26,864.	00,000.
RMS		237,862.	141,939.

DWT = 233,600. LBS.
BWT = 25,410. LBS.
SWT = 208,190. LBS.

FRICTION FORCES
@ 0.2 FACTOR (LBS)
NSOBE = 41,640.
EWOBE = 82,210.
NSSSE = 59,760.
EWSSE = 101,600.

SUMMARY OF RESULTS FOR 140 CELL RACK - CONSOLIDATED. FILE RGSUM.2A

--------------------SET #1 - MAX. FORCES (KIPS)--------------------

		AT GAP ELEMENT#					SUPPORT	
DIR	EVT	1	2	3	4	5	Fvt	Fhz
NS	OBE	0.0	0.0	100.0	98.4	159.3	312.4	160.2
EW	OBE	0.0	53.6	178.3	176.0	180.1	405.2	153.0
NS	SSE	14.8	214.9	225.6	217.5	250.7	455.7	239.3
EW	SSE	0.0	148.4	249.3	223.2	235.0	512.1	184.7

-----SET #2 - LOADS ON INDIVIDUAL F/A'S (LBS) AND SUPPORTS (KIPS)----

NS	OBE	00.	00.	714.	703.	1138.	156.2	80.1
EW	OBE	00.	383.	1274.	1257.	1286.	202.6	76.5
NS	SSE	106.	1535.	1611.	1554.	1791.	227.9	119.7
EW	SSE	00.	1060.	1781.	1594.	1679.	256.1	92.4

-SET #3 - MAX. FORCES AT SUPPORT (LBS) -SET #5- MOVEMENTS AT BASE (INS)

	Fvert	Fhoriz	ELASTIC	SLIDING	LIFTOFF
NS OBE	* 00.	160,200.	0.018	0.028	0.000
EW OBE	64,140.	153,000.	0.045	0.024	0.015
VT OBE	89,470.	00,000.			
RMS	451,146.	221,524.			
NS SSE	114,640.	239,300.	0.027	0.094	0.017
EW SSE	171,040.	184,700.	0.054	0.128	0.072
VT SSE	89,470.	00,000.			
RMS	565,564.	302,289.			

-SET #4 - MAX. FORCES ON SUPPORT (LBS)--

NS OBE	00.	80,100.
EW OBE	32,070	76,500
VT OBE	44,735.	00,000.
RMS	225,573.	110,762.
NS SSE	57,320.	119,650.
EW SSE	85,520.	92,350.
VT SSE	44,735.	00,000.
RMS	282,782.	151,144.

HWT = 397,400. LBS.
DWT = 389,000. LBS.
BWT = 47,940. LBS.
SWT = 341,060. LBS.

FRICTION FORCES
@ 0.2 FACTOR (LBS)
NSOBE = 49,640.
EWOBE = 51,630.
NSSSE = 68,210.
EWSSE = 68,210.

* BECAUSE OF NO LIFTOFF.

FIG 2.1

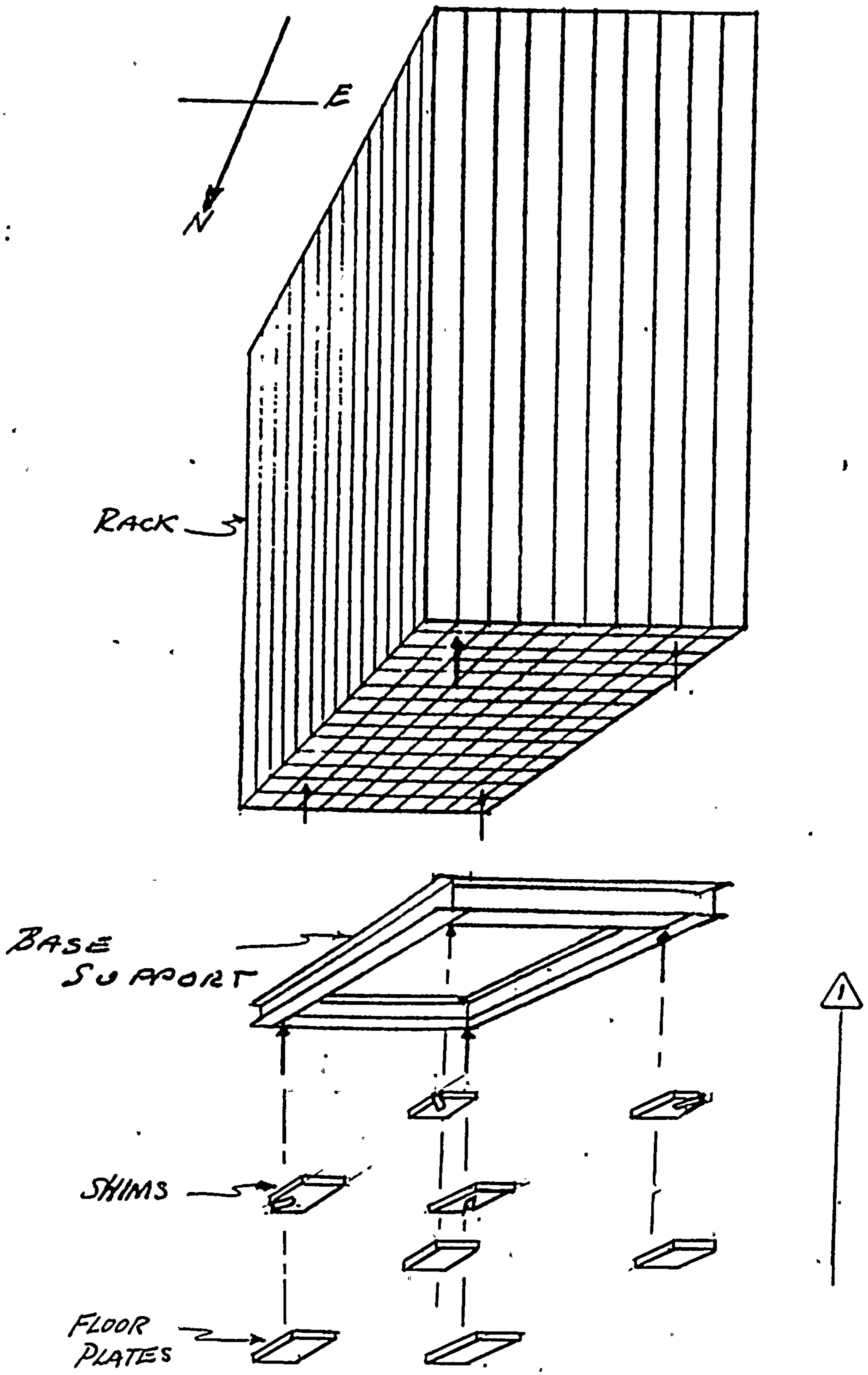
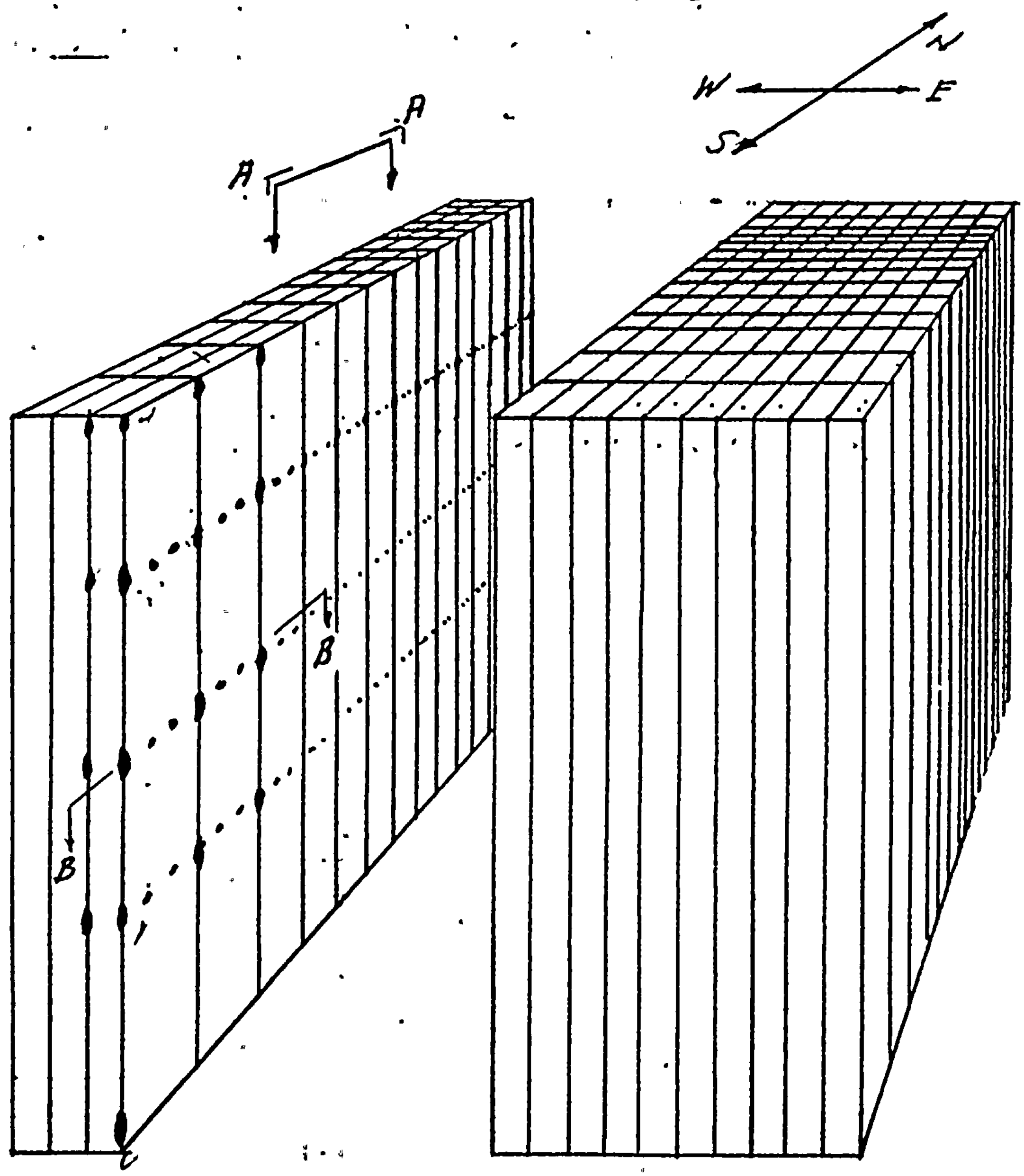
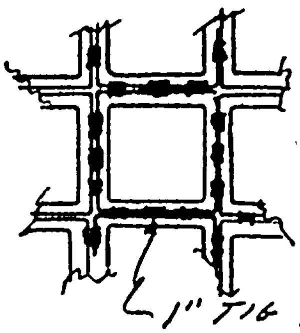


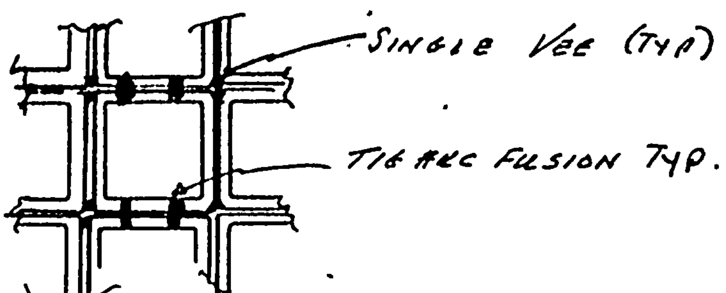
FIG 2.2



SECTION A-A



SECTION B-B



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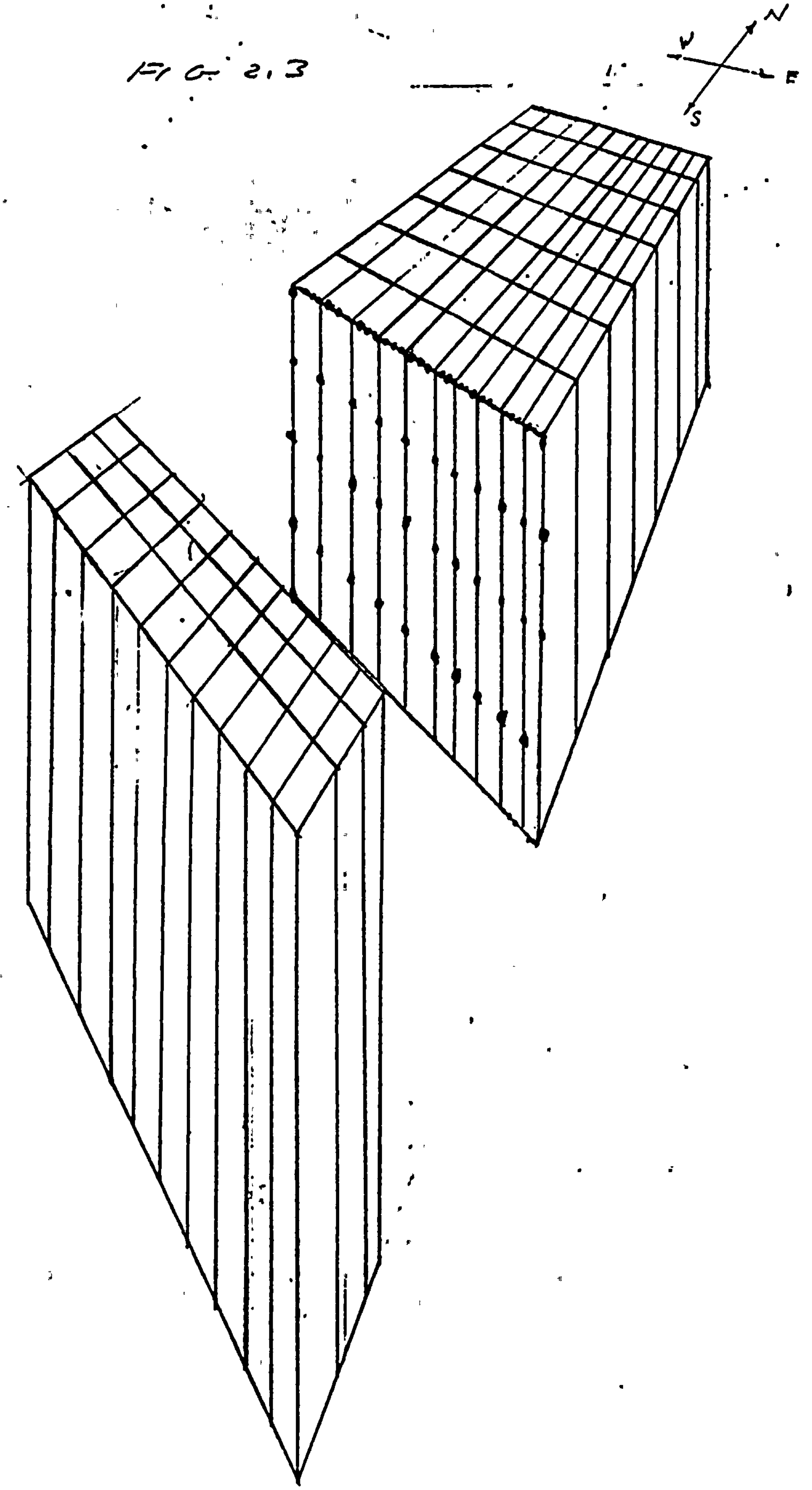
BY [signature] DATE 1/5/84 SUBJECT RACK WELD SECT. 2 SHEET 7 OF 7

CHKD. BY JLD DATE 2/23/84 EAST-WEST PLANE PROJ. NO. 8369

FIG. 2.3



SECTION 3.0

DESIGN CRITERIA AND

SUMMARY OF STRESSES

3.0 DESIGN CRITERIA

3.1 Scope

The Spent Fuel Storage Racks furnished for the R.E. Ginna Nuclear Station have been designed and analyzed as Seismic Category 1 Equipment in accordance with the NRC Reg. Guide 1.29. The basis for design is to ensure that the storage racks protect the fuel assemblies from physical damage and prevent the formation of a critical geometry under all conceivable conditions of storage. The equipment is designed to comply with the guidelines of U.S. Nuclear Regulatory Commission Position Papers and Regulatory Guides referenced in the Specification.

3.2 Methods of Analysis

The analyses in this report use the loads developed in the Seismic Analysis Report (Ref. 2) and applies them to critical portions of the rack and supporting structure. Stresses (axial, shear, bending and torsion) are then evaluated and compared to allowables to determine structural adequacy. All calculations are shown in Sections 5.0 and 6.0.

3.3 Loads and Loading Combinations

Appendix D of SRP Section 3.8.4 defines the load combinations and acceptence limits for each combination. These are listed in Table 3.3. The abbreviations and their significance in the analysis of spent fuel storage racks are as follows:

TABLE 3.3

LOAD COMBINATION	ACCEPTANCE LIMIT
$D + L$	Level A service limits
$D + L + T_o$	
$D + L + T_o + E$	Level B service limits
$D + L + T_a + E$	
$D + L + T_o + P_f$	
$D + L + T_a + E'$	Level D service limits
$D + L + F_d$	The functional capability of the racks should be demonstrated.

Note

The provisions of NF 3231.1 of American Society of Mechanical Engineers, Boiler and Pressure Vessel Code, Section III, Division 1, shall be amended by the requirements of Paragraphs c.2.3 and 4 of Regulatory Guide 1.124 entitled "Design Limits and Load Combinations for Class 1 Linear-Type Component Supports".

a. D -- Dead Load including the rack and supports deadweight and the entrained pool water.

b. L -- Live loads including fuel assemblies and fuel channels.

c. T_o-- Temperature effects and loads during normal operating or shutdown conditions. Experience has shown that the temperature gradient across the rack structure, due to differential heating between a full and an empty cell, is negligible, as is the temperature gradient through the thickness of the cell walls (less than 3°F). The pool temperature after a full core discharge is generally less than 150°F (with both heat exchangers operational). This temperature (150°F) will, therefore, be used for evaluating material properties for the load combinations containing this term.

d. T_a-- Temperature effects at the highest temperature associated with the postulated abnormal design conditions. In the case of a spent fuel storage pool, this would consist of a full core discharge with both heat exchangers inoperable and the likelihood of pool boiling.

Under 40 ft. of water pressure, water will boil at 260°F. Therefore T_a = 260°F.

e. E -- Operating basis earthquake (OBE).

f. E'-- Safe shutdown earthquake (SSE).

g. P_f -- Loads caused by a stuck fuel assembly in any rack location.

h. F_d -- Loads due to postulated fuel handling accident. These include:

1. Straight drop and an inclined drop of a fuel bundle on the top of the rack from a 30 in. height.

2. A straight drop through an individual cell all the way to the bottom of the rack.

3.4 Acceptance Criteria

Appendix D of SRP Section 3.8.4 requires that allowable stress levels be determined using the ASME Code Section III Subsection NF requirements for Class 3 Component Supports.

From ASME Section III NF-3321.1 the following limits apply for Level A, B, and D service loading conditions for linear-type component supports when designed by linear elastic analysis procedures.

a. For Level A Loadings, (Normal), Normal Limits of NF-3322 apply.

b. For Level B Loadings, (Upset), 1.33 times the Normal Limits are allowed.

c. For Level D Loadings (Faulted), Table 3523.(b)-1 allows the Normal Limits of NF-3322 to be increased by a factor of 2 with stresses not to exceed 0.7 S_u. Additionally, paragraph 5 (b) of SRP Section 3.8.4 limits this factor to 1.6, though Appendix D of this Section, which deals specifically with fuel racks, does not require this factor. However, to insure conservatism the lower factor (1.6) is adopted. An additional limit is that the shear stress not exeed 0.42 S_u.

TABLE 3.4

NORMAL STRESS LIMITS

	STRESS CONDITION	ALLOWABLE STRESS *	REFERENCE ASME SECTION III
a.	Tension on net section (except at holes, pin connected plates, or built-up members)	$0.6S_y$	NF-3322.1 (a) (1)
b.	Tension on net section excluded in a.	$0.45S_y$	NF-3322.1 (a) (2)
c.	Shear on gross section	$0.40S_y$	NF-3322.1 (b) (1)
d.	Shear on weld base material	$0.3\ S_u$	NF-3322.1 (b) (2)
e.	Shear on effective throat of fillet welds, or fusion welds	21 KSI	NF-3324.5 (a) -1
f.	Tension normal to partial penetration welds	21 KSI	NF-3324.5 (a) -1
g.	Tension and compression on solid round and square bars and solid rectangular sections bent about their weaker axis	$0.75S_y$	NF-3322.1 (d) (3)
h.	Tension on extreme fibers of hot rolled or built-up members in bending	$0.60S_y$	NF-3322.5 (a)
i.	Compression bearing on milled surfaces and pins	$0.9S_y$	NF-3322.1 (f) (1)
j.	Concrete bearing stress	0.7f'c	NF-3322.1 (f) (4)

* S_y and S_u at Temperature (260°F)

NOTE: In addition to the above limits, NF-3523 (b)-1 requires that the allowable stress in compression to aviod column-type or localized buckling, shall be limited to 2/3 of the critical buckling stress for level A, B, and D service limits.

3.5 Material Properties

The storage racks and their supports are fabricated from stainless steel, ASTM-A240, Type 304 plate. Properties are evaluated at both (150°F) and (260°F). Values are taken from Tables I-2.2 and I-3.2 of ASME, Section III, Division 1, Appendix I.

	150°F	260°F
Yield Stress	27.5 KSI	23.6 KSI
Ultimate Stress	73.0 KSI	68.3 KSI
Modulus of Elasticity	27.9×10^6 PSI	27.3×10^6 PSI
Shear Modulus	10.7×10^6 PSI	10.5×10^6 PSI

Values of 150°F and 260°F are linearly interpolated between the values given for 100°F and 200°F, and 200°F and 300°F respectively.

3.6 Allowable Stresses for Service Load Conditions

The allowable stresses for the loading conditions defined in Appendix D of SRP 3.8.4 are calculated using the limits specified in Table 3.4 of the material properties from Section 3.5. Table 3.6 gives the allowable stresses for 3 categories (1) Level A - Normal, (2) Level B - Upset, and (3) Level D - Faulted. All three conservatively use the material properties at 260°F.

3.7 Stress Summary

Stresses are summarized in Table 3.7 for:

1. Critical rack welds shown in figures 3.1 and 3.2.
2. Shear-out of the corner 9 boxes (shaded area, Figure 3.1).
3. Buckling of box walls.
4. Floor bearing pressure under the base plates.

The margins of safety all prove to be positive.

TABLE 3.6

ALLOWABLE STRESSES IN KSI

(1000 lb/in^2)

Type of Stress	Normal Level A	Upset Level B	Faulter Level D
Tension - membrane	14.1	18.8	22.6
Tension - net section at holes	10.6	14.1	17.0
Shear - gross section	9.4	12.5	15.1
Shear - weld base material	20.5	27.3	28.7 (1)
Shear - Fillet weld throat	21.0	27.9	28.7 (1)
Tension - Partial penetration weld	21.0	27.9	33.6
Bending - tension/compression on solid sections	17.7	23.5	28.3
Bending - tension/compression on rooled or built up sections	14.1	18.8	22.6
Compression - bearing	21.2	28.2	N/A
Bearing - concrete	2.10	2.8	3.4

(1) Limited to 0.42 S_u

TABLE 3.7

SUMMARY OF STRESSES

COMPONENT	REF. SECT.	STRESS TYPE	LOAD	STRESS (KSI)	ALLOWABLE (KSI)	MARGIN SAFETY
Internal Rack Weld	6.3		STD.			
E-W Plane (Fig. 3.1)		Shear	OBE	8.63	27.3	2.16
		Tension		12.71	28.0	1.20
		Shear	SSE	10.13	28.7	1.83
		Tension		14.36	33.6	1.34
			CONS.			
		Shear	OBE	11.39	27.3	1.40
		Tension		15.64	28.0	0.79
		Shear	SSE	12.81	28.7	1.24
		Tension		17.86	33.6	0.88
Internal Rack Weld	6.4		STD.			
N-S Plane (Fig. 3.2)		Shear	OBE	10.60	27.3	1.58
		Tension		13.90	27.3	0.96
		Shear	SSE	11.13	28.7	1.58
		Tension		15.59	28.7	0.84
			CONS.			
		Shear	OBE	12.94	27.3	1.11
		Tension		16.41	27.3	0.66
		Shear	SSE	14.96	28.7	0.92
		Tension		19.80	28.7	0.45
Internal Rack Weld	6.5		STD.			
		Shear	OBE	9.35	27.3	+1.92
		Shear	SSE	10.82	28.7	+1.65
			CONS.			
		Shear	OBE	10.26	27.3	+1.72
		Shear	SSE	12.86	28.7	+1.22
Box Wall Buckling	6.6		STD.			
		Comp.	OBE	9.03	13.5	+0.49
		Comp.	SSE	10.45	13.5	+0.29
			CONS.			
		Comp.	OBE	9.91	13.5	+0.36
		Comp.	SSE	12.42	13.5	+0.09

TABLE 3.7 (Cont'd)

SUMMARY OF STRESSES

COMPONENT	REF. SECT.	STRESS TYPE	LOAD	STRESS (KSI)	ALLOWABLE (KSI)	MARGIN SAFETY
Floor Plate - Concrete	7.2	Bearing	STD.			
			OBE	1.70	2.80	+0.65
			SSE	1.96	3.40	+0.73
			CONS.			
			OBE	1.86	2.80	+0.50
			SSE	2.34	3.40	+0.45

$$* \text{ M.S.} = \frac{\text{ALLOWABLE STRESS}}{\text{COMPUTED STRESS}} - 1.0$$

FIGURE 3.1

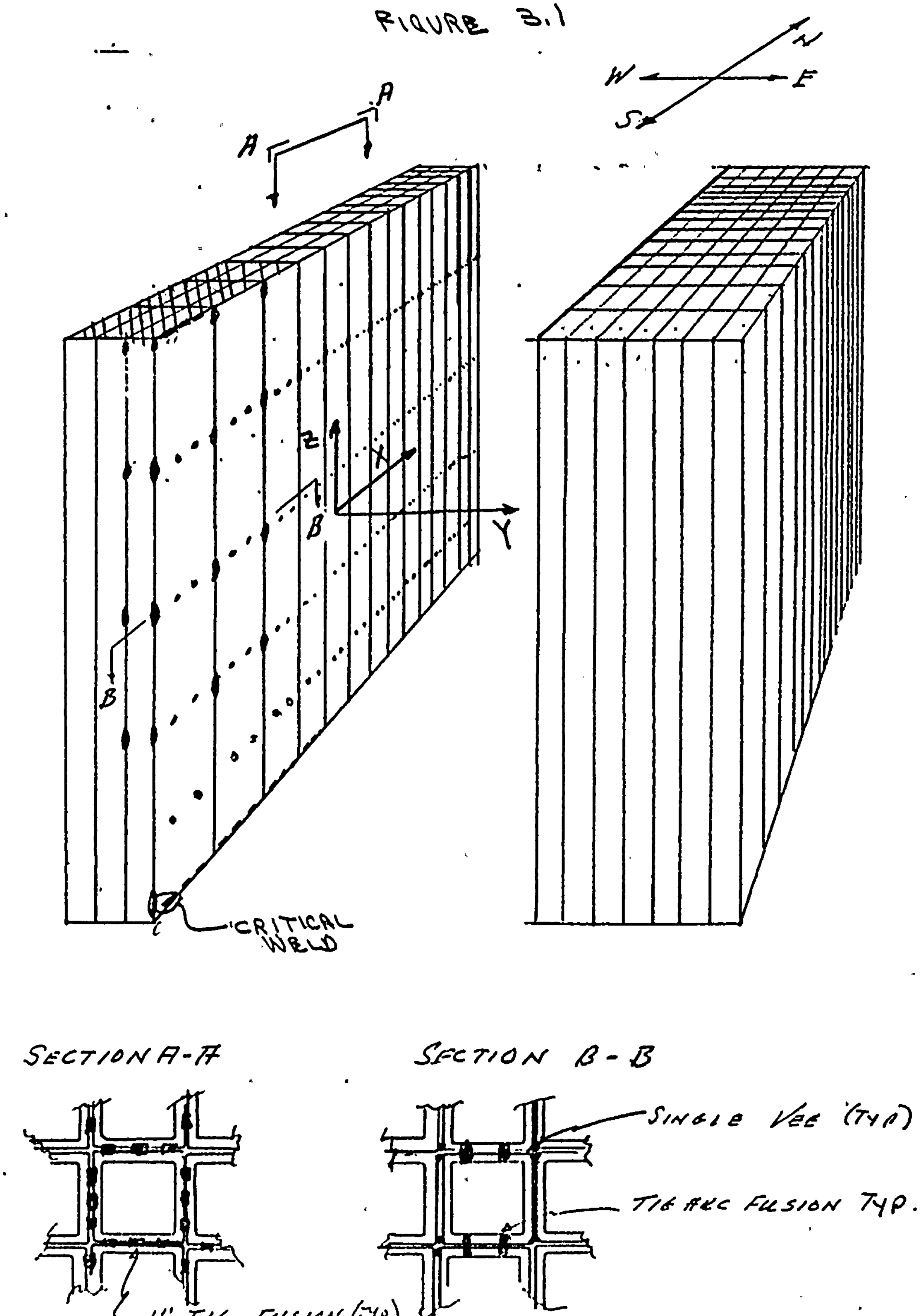
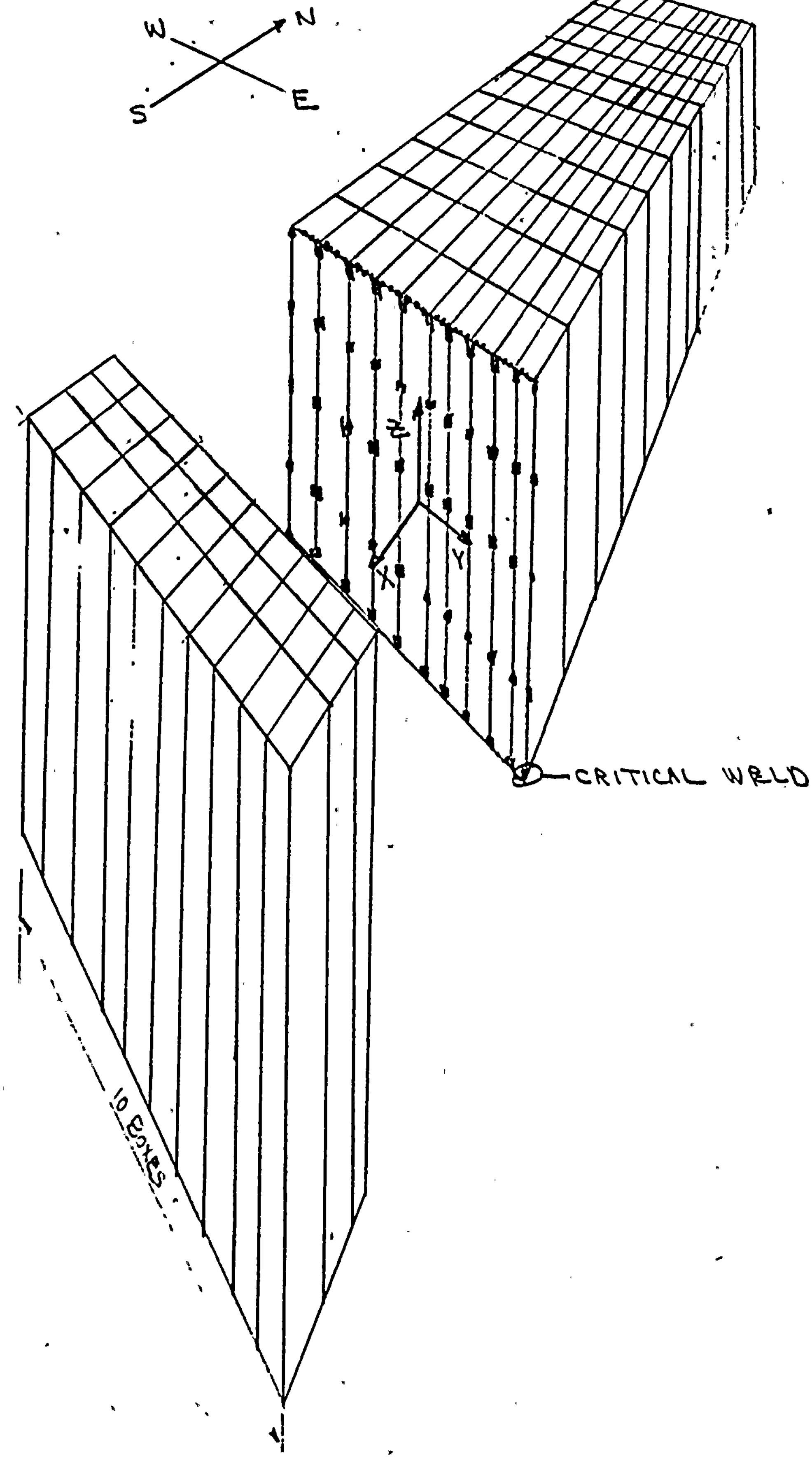

N
W
E
S
A
A
Z
X
Y
B
B
CRITICAL WELD
SECTION A-A
SECTION B-B
SINGLE VEE (TYP).
TIG ARC FUSION TYP.
1" TIG FUSION (TYP)

FIGURE 3.2



SECTION 4.0

REFERENCES

4.0 REFERENCES

NO.	TITLE
1.	ROCHESTER GAS AND ELECTRIC CORP. P.O. N-BU-37225 AND RG&E-USTD AGREEMENT, SECTION 1.1.1 THRU 1.1.6. DATED SEPTEMBER 30, 1983.
2.	U.S. TOOL AND DIE Report 8369-00-0013, SEISMIC ANALYSIS SPENT FUEL STORAGE RACKS MODIFIED TO 100 % STORAGE CAPACITY. Dated December 1983.
3.	ASME Boiler and Pressure Vessel Code, Section III-Div. 1, Subsection NF, 1983 Edition
4.	R.D. Blevins, Ph.D, FORMULAS FOR NATURAL FREQUENCY AND MODE SHAPE, Van Nostrand Reinhold Co., N.Y.,N.Y.,1979.
5.	O.W Blodgett, DESIGN OF WELDED STUCTURES, J.F. Lincoln Arc Welding Foundation, Cleveland, Ohio, 7th. Printing 1975.
6.	American Concrete Institute, MANUAL OF CONCRETE PRACTICE, 329-32, Detroit,Michigan
7.	U.S.Nuclear Regulatory Commission, S.R.P. 3.8.4
8.	Timoshenko, Young, and Weaver, VIBRATION PROBLEMS IN ENGINEERING, 4th Edition, John Wiley & Sons, New York, 1974.

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5.1 DISCUSSION:

THIS SECTION TAKES THE REACTIONS FROM THE SEISMIC ANALYSIS & COMPUTES THE INTERNAL FORCES IN THE RACKS AT THE POINTS OF CRITICAL STRESS - THE WELD PLANES. TREATING THE RACK AS A RIGID BODY, D'ALEMBERT'S PRINCIPLE OF DYNAMIC EQUILIBRIUM IS APPLIED TO DETERMINE INTERNAL FORCES

SECTION 5.2 COMPUTES THE AREAS OF WELD IN SHEAR & TENSION FOR EACH PLANE & DISCUSSES WELD ALLOWABLE STRESSES.

SECTION 5.3 COMPUTES THE RESISTANCE OF THE E-W WELD PLANE TO
1) MOMENT ABOUT GLOBAL Y AXIS (SEE FIGURE 5.1)
2) MOMENT ABOUT Z-AXIS
3) MOMENT ABOUT X-AXIS (TORSION)

SECTION 5.4 DOES THE SAME FOR THE N-S WELD PLANE.

SECTION 5.6 APPLIES D'ALEMBERT'S PRINCIPLE TO THE RACK AS A RIGID BODY SUBJECTED TO THE SEISMIC REACTIONS (FROM SECTION 2.0). THE HORIZONTAL, VERTICAL & ROTATIONAL ACCELERATIONS ARE COMPUTED FOR THE BODY AS A WHOLE. A VERTICAL PLANE IS THEN CUT THROUGH THE RACK & THE INTERNAL FORCES & MOMENTS COMPUTED (ASSUMING THE SAME ROTATIONAL ACCELERATION). THIS IS DONE FOR VARIOUS VERTICAL PLANES & IT IS SHOWN THAT CRITICAL PLANE IS THIRD FROM THE END.
INTERNAL FORCES ARE COMPUTED FOR EACH LOAD CASE: 1) DEADWEIGHT
2) VERTICAL SEISMIC (OBE & SSE)
3) N-S SEISMIC (OBE & SSE)
4) E-W SEISMIC (OBE & SSE)

THE LOADS ARE SUMMARIZED IN SECTIONS 5.7 & 5.8.

UST & D DESIGN SERVICES, INC. U.S. TOOL & DIE, INC.

BY DiPaolo DATE 9/18/84 SUBJECT RACK WELDS SECT 5 SHEET 3 OF 45

CHKD. BY RS DATE 9-25-84 EAST-WEST PLANE PROJ. NO. 8369

FIGURE 5.1.1

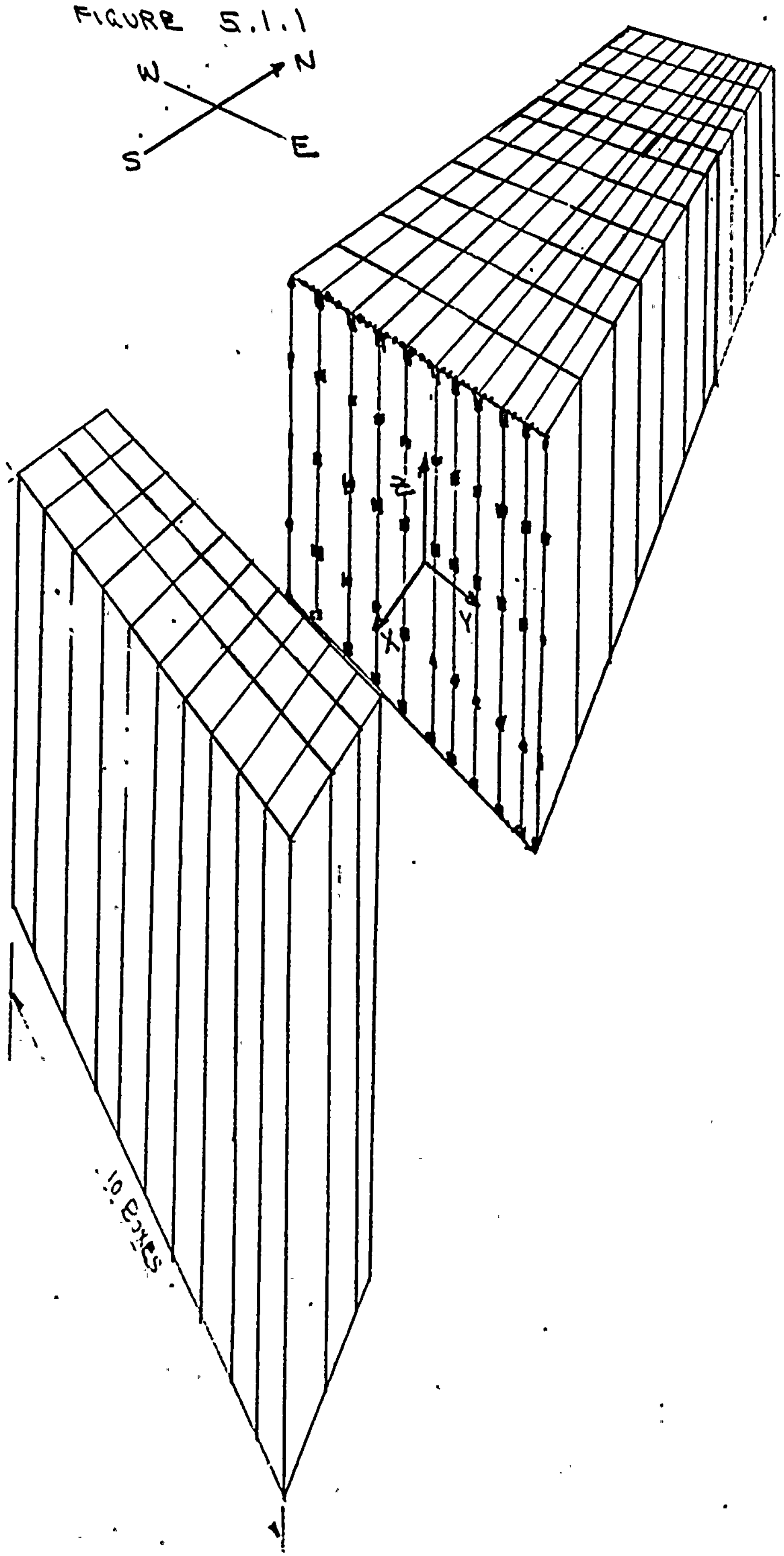
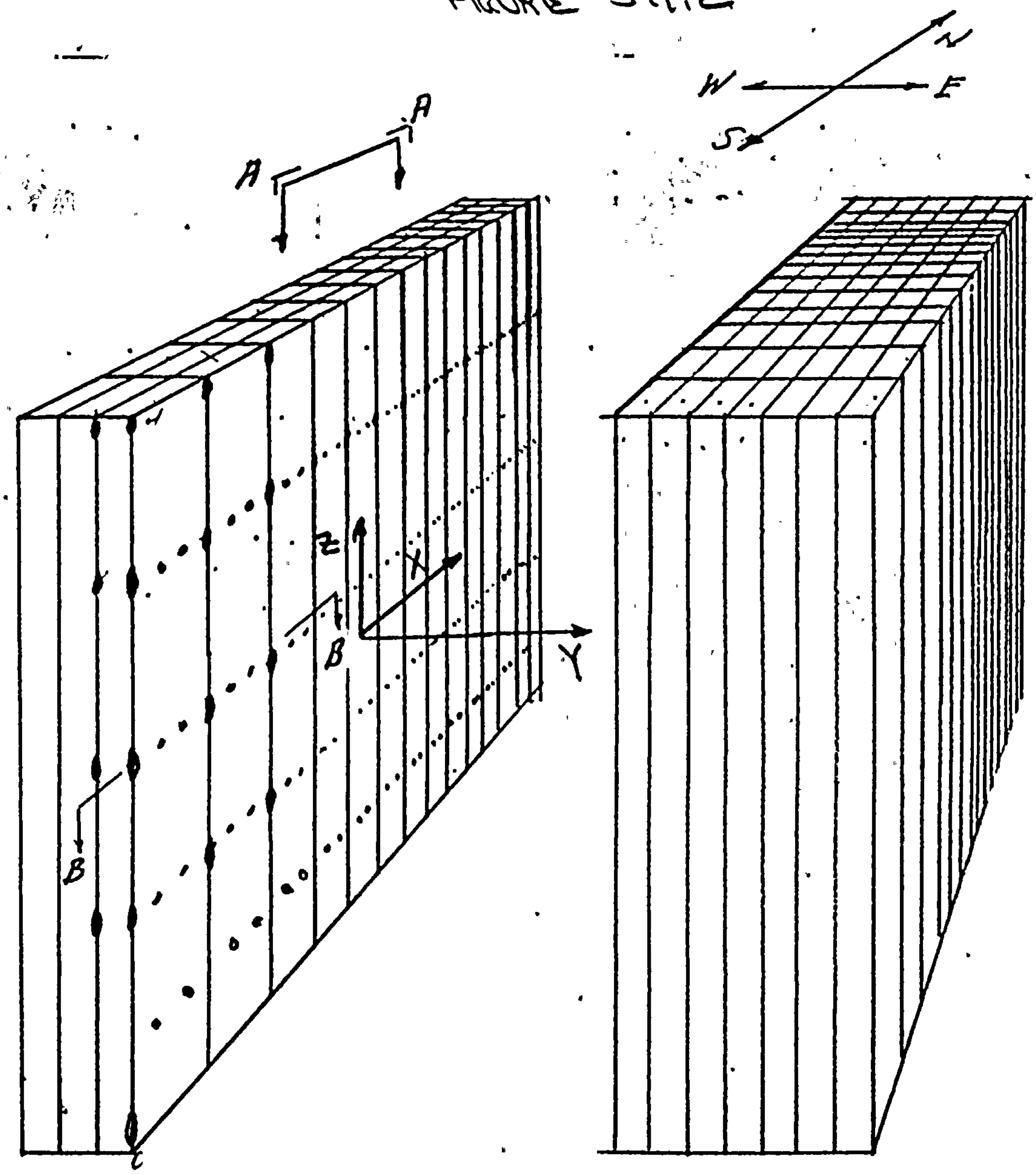


FIGURE 5.1.2


N
W
E
S
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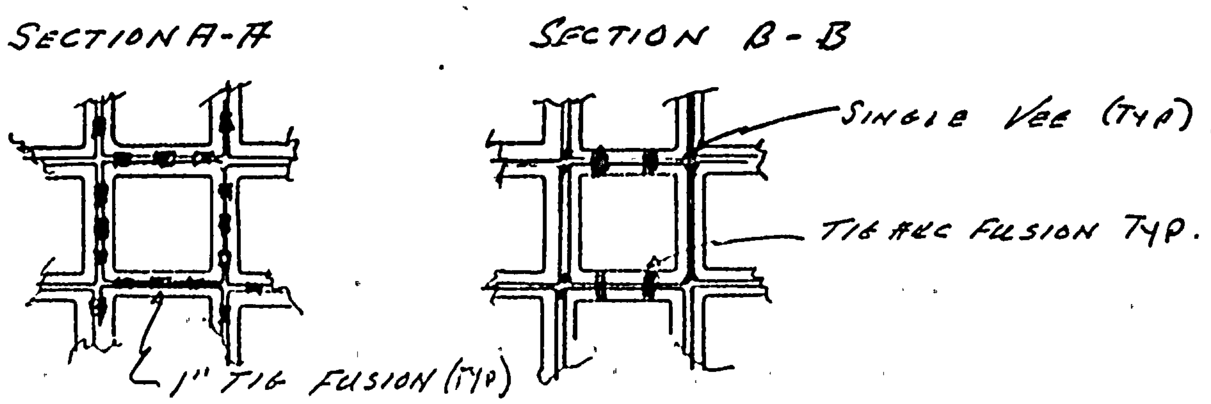

SECTION A-A
SECTION B-B
SINGLE VEE (TYP).
TIG ARC FUSION TYP.
1" TIG FUSION (TYP)

5.2 WELD AREAS:

EAST-WEST PLANE - SEE FIGURES 5.1.1, 5.1.2, 5.2.1 CONSISTS OF:

1) 5 FILLET WELDS ATTACHING BOXES TOGETHER 2" LONG:

$A = 10(2)(5)[(2)(.18)] = 36.0 \text{ IN}^2$ (NO. / AREA)

2) 3 FUSION WELDS TOP & BOTTOM 1" LONG (ASSUMED .18" WIDE)

$A = 2(10)(3)[1.0(.18)] = 10.8 \text{ IN}^2$ (NO. / A)

TOTAL = $36.0 + 10.8 = 46.8 \text{ IN}^2$

NORTH-SOUTH PLANE CONSISTS OF:

1) 8 ½"-Ø FUSION SPOT WELDS / BOX:

$A = 8(4)[\frac{\pi}{4}(.5)^2] = 21.99 \text{ IN}^2$ (NO.)

2) 3 FUSION WELDS - TOP & BOTTOM

$A = 2(4)(3)[0.18] = 15.12$

3) 5 FILLET WELDS ON EACH SIDE OF COMPLETED RACK - THESE ARE ASSUMED TO HAVE FAILED & WILL THEREFORE NOT BE INCLUDED IN THE ANALYSIS

$A = 21.99 + 15.12 = 37.11 \text{ IN}^2$

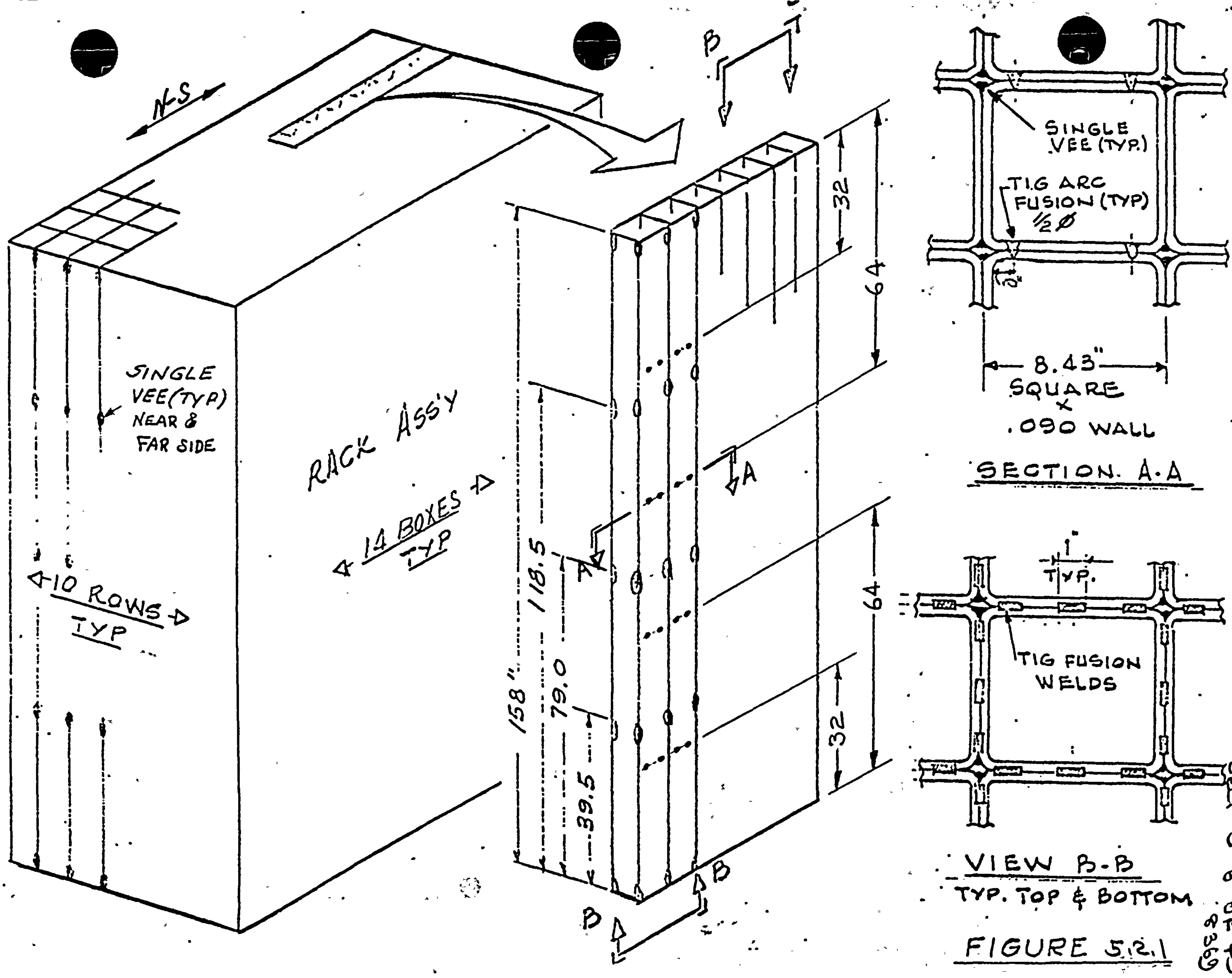

N-S
SINGLE VEE(TYP) NEAR & FAR SIDE
RACK ASS'Y
14 BOXES TYP
10 ROWS TYP
B
A
32
64
64
32
158"
118.5
79.0
39.5
SINGLE VEE (TYP.)
TIG ARC FUSION (TYP) ½ Ø
8.43" SQUARE x .090 WALL
SECTION. A-A
1" TYP.
TIG FUSION WELDS
VIEW B-B
TYP. TOP & BOTTOM

FIGURE 5.2.1

STRESS ALLOWABLES:

THERE ARE 2 DIFFERENT WELDS ON E-W PLANE.

5.2.1 ON THE SIDES OF THE BOXES:

WHETHER THIS IS CALLED A FILLET WELD OR A PARTIAL PENETRATION WELD: THE ALLOWABLES FROM ASME SUBSECTION NF - ARE SIMILAR

FROM TABLE NF-3324.5(a)-1

SHEAR STRESS ON FILLET OR TENSION NORMAL TO AXIS ON EFFECTIVE THROAT OF A PARTIAL PENETRATION WELD = 21 KSI FOR MATERIAL WITH TENSILE STRENGTH = 58-70 KSI

SHEAR ON PARTIAL PENET. WELD - FROM PARAGRAPH NF 3324.5(b)(2)(a) AND NF 3322.1(b)(2) (SHEAR ALLOWABLE ON NET SECTION)

$F_v = 0.30\,S_u = 0.3(68.3) = 20.5$ KSI

FOR SERVICE LIMIT B - THESE VALUES ARE MULTIPLIED BY 4/3 (TABLE NF-3523(b)-1

FOR SERVICE LIMIT D - THESE VALUES ARE MULTIPLIED BY 2.0, WITH A LIMIT OF $0.42\,S_u$

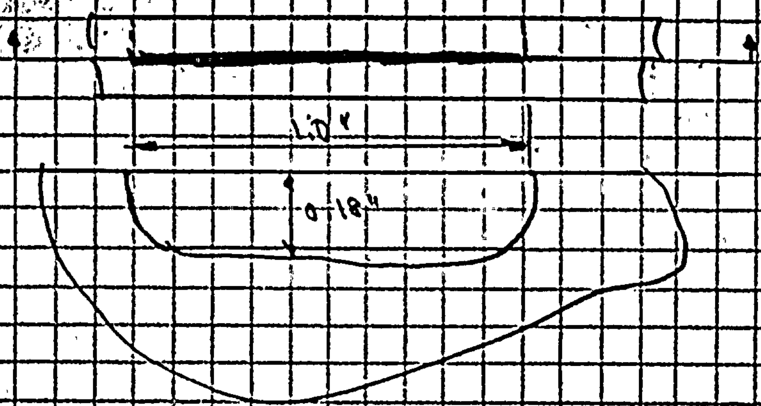
$F_v = 0.42(68.3) = 28.7$ KSI

FOR TENSION: LIMIT B:

$F_t = \frac{4}{3}(21) = 28$ KSI

LIMIT D: $F_t = 21(2) = 39.6$ KSI $< 0.7\,S_u = 47.8$

5.2.2
WELDS AT THE TOP & BOTTOM OF EACH RACK ARE FUSION WELDS ATTACHING THE BOX WALLS TO EACH OTHER & ARE AGAIN CONSIDERED PARTIAL PENETRATION WELDS



SHEAR ALLOWABLE = 0.3 Su = 20.5 KSI (LEV. A)
27.3 KSI (LEV. B)
28.7 KSI (LEV. D)

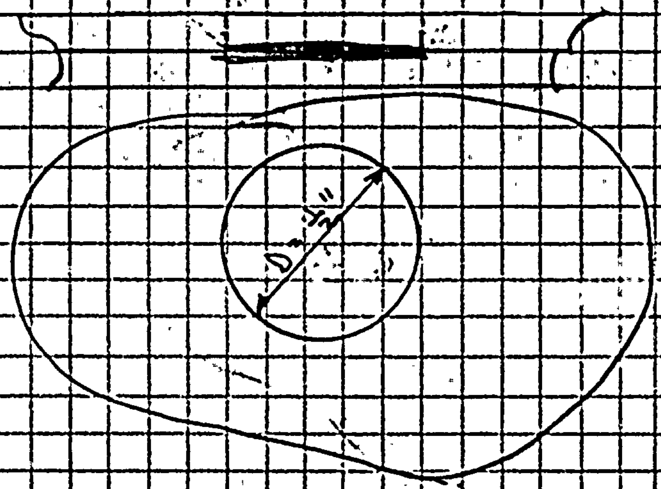
TENSION ON WELD RESULTS IN SHEAR ON PERIMETER OF WELD IN BASE METAL:

AREA ≈ .09(1.0 + .18 + .18) = 0.122 IN²

THOUGH CAPACITY OF WELD IN TENSION IS LARGE, IT IS GOVERNED BY SHEAR IN BASE METAL.

FOR TENSION LOADS ON THIS WELD, USE AREA OF 0.122 IN². (CALCULATION OF I_x SECTION 5.4.1 & I_z SECTION 5.4.2)

5.2.3
FUSION SPOT WELDS ON N-S PLANE ARE OF SAME TYPE



AREA = $\frac{\pi}{4}(.5)^2$

$A = 0.196\ IN^2$

PLANE SHEAR IS THROUGH THE ACTUAL INTERFACE

$\therefore F_v = 0.3\ S_u = 0.3(68.3) = 20.5\ KSI$ (LEVEL A)

$F_v = 4/3(20.5) = 27.3\ KSI$ (LEVEL B)

$F_v = 0.42\ S_u = .42(68.3) = 28.7\ KSI$ (LEVEL D)

TENSION ON THE WELD:

ALLOWABLE = 21 KSI ON AREA OF $0.196\ IN^2$

BUT TENSION ON WELD CAUSES SHEAR AROUND ITS CIRCUMFERENCE (ON THE BASE METAL)
AREA OF PLANE = $\pi(0.5)(.09) = 0.141\ IN^2$

SHEAR ALLOWABLE = $0.3 S_u$ = 20.5 KSI (LEVEL A)
27.3 KSI (LEVEL B)
28.7 KSI (LEVEL D)

5.3 EAST-WEST PLANE

THE 3 FUSION WELDS AT THE TOP & BOTTOM OF EACH BOX ARE MUCH MORE FLEXIBLE THAN THE SIDE FILLETS WHEN THE PLANE IS IN TENSION. THEY ARE THEREFORE NEGLECTED IN THE CALCULATION OF MOMENT RESISTANCE OF THE PLANE. HOWEVER FOR SHEAR LOADS THESE WELDS ARE JUST AS RIGID AS THE SIDE WELDS & WILL BE INCLUDED IN THE CALCULATION OF SHEAR AREA & TORSIONAL PROPERTIES.

THE WELD PROPERTIES IN THE EAST-WEST PLANE ARE CALCULATED FOR RESISTANCE TO:

1) MOMENT ABOUT HORIZONTAL AXIS

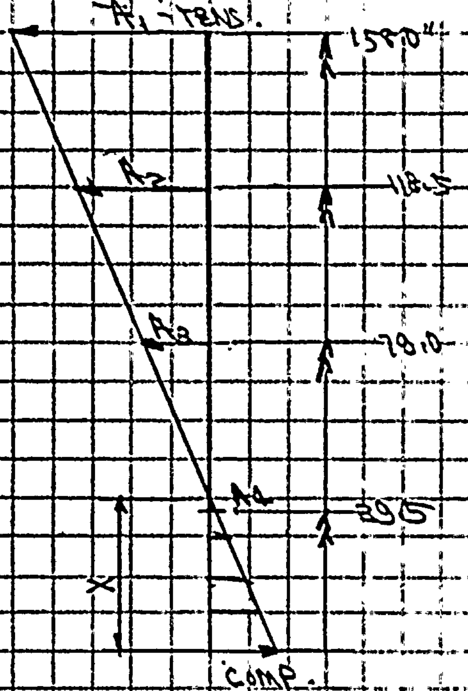
2) MOMENT ABOUT VERTICAL AXIS

3) TORSIONAL MOMENT

GLOBAL AXES - X, Y, & Z ARE DEFINED IN FIGURES 5.1.1 & 5.1.2.

5.3.1 RESISTANCE TO MOMENT ABOUT HORIZ. AXIS (M_Y)

FORCES IN THE WELDS ARE COMPUTED ASSUMING THE PLANE DEFLECTS IN A STRAIGHT LINE I.E. A LINEAR VARIATION IN STRAIN. USING THIS ASSUMPTION THE LOCATION OF THE NEUTRAL AXIS CAN BE COMPUTED BY EQUATING THE MOMENTS OF THE AREAS IN TENSION TO THOSE IN COMPRESSION (SIMILAR TO THE ANALYSIS OF A REINFORCED CONCRETE BEAM)



X IS LENGTH OF AREA IN COMPRESSION.

THE BOX WALLS PERPENDICULAR TO THE PLANE ARE IN COMP.

AREA COMP. = 10(0.18)X = 1.8 X

AREAS OF WELDS IN TENSION:

$A_1 = A_2 = A_3 = A_4 = 20(2)(.18) = 7.2\ IN^2$

A_4 IS ASSUMED TO BE IN COMPRESSION AREA & IS ∴ INEFFECTIVE

EQUATE MOMENTS OF AREAS:

$$1.80X\left(\frac{X}{2}\right) = A_1(158-X) + A_2(118.5-X) + A_3(79-X)$$

$$0.90X^2 = 7.20(355.5-3X)$$

$$0.90X^2 + 21.6X - 2559.6 = 0$$

$$X^2 + 24X - 2844.0 = 0$$

$$X = \frac{-24.0 \pm \sqrt{(24)^2 - 4(-2844)}}{2}$$

$X = 42.66"$

CALCULATE MOMENT OF INERTIA OF CROSS-SECTION:

$$I = \sum_{i=1}^{n} (I_{yi} + A_i d_i^2)$$

FOR WELDS $I_y = 0$.

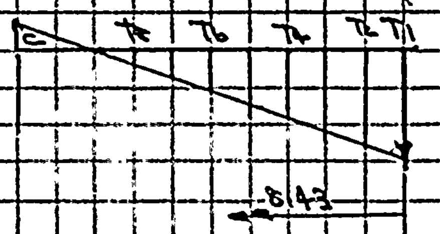
$$I_y = 7.2 \left[115.34^2 + 75.84^2 + 36.34^2 \right] + 1.8 \frac{(42.66)^3}{12} + 1.8(42.66)\left(\frac{42.66}{2}\right)^2$$

$I_y = 193.280$ IN⁴

$$S_{TOP} = \frac{I_y}{Z_{max}} = \frac{193280}{115.34} = 1675.7 \text{ IN}^3$$

5.3.2 - CALCULATION OF I_Z:

MOMENT ABOUT VERTICAL AXIS RESISTED ONLY BY BOTTOM SET OF WELDS IN TENSION & BOTTOM PLATE IN COMPRESSION. (1/2" THICK)



$A_1 = 2(.18) = 0.36\ IN^2$

$A_2 \rightarrow A_{10} = 0.72\ IN^2$

ASSUME ONLY 8 ARE EFFECTIVE IN TENS.:

$$0.5\frac{X^2}{2} = 0.72\left[25.3 + 33.7 + 42.2 + 50.6 + 59.0 + 67.4 + 75.9 - 7X\right] + 0.36(84.3 - X)$$

$$0.25X^2 = 285.3 - 5.4X$$

$$X^2 + 21.6X - 1141.2 = 0$$

$$X = 24.7$$

$$I = \Sigma Ad^2$$

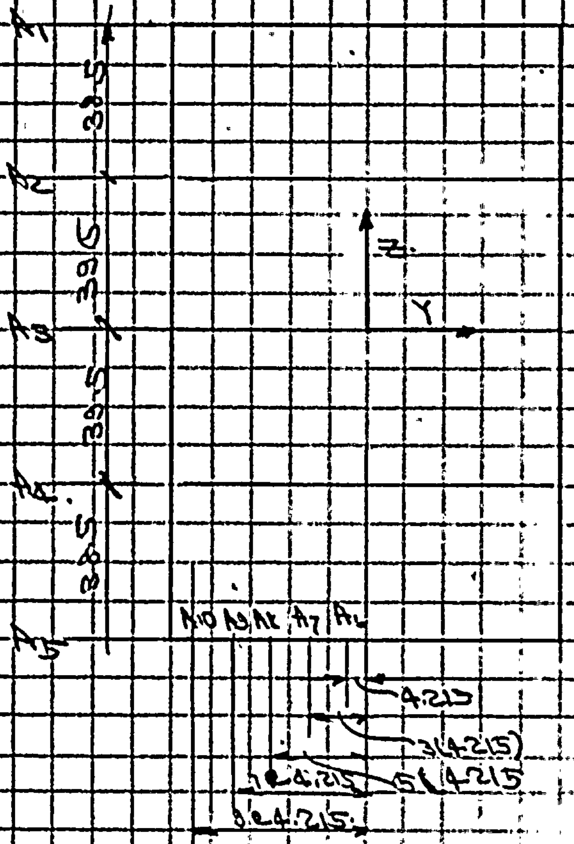
$$= 0.72\left[0.6^2 + 9.0^2 + 17.5^2 + 25.9^2 + 34.3^2 + 42.7^2 + 51.2^2\right] + 0.36(59.6)^2 + \frac{0.5}{3}(24.7^3)$$

$$I_Z = 8600\ IN^4$$

$$S_Z = \frac{8600}{59.6} = 144.3\ IN^3$$

5.3.3 PLANE RESISTANCE TO TORSION:

CALCULATE POLAR MOMENT OF INERTIA OF WELD ($= I_y + I_z$) - INCLUDE TOP & BOTTOM WELDS



$A_1 = A_5 = 20(2)(.18) + 3(10)(.18)$

$A_1 = A_5 = 12.6 \text{ IN}^2$

$A_2 = A_3 = A_4 = 20(2)(.18) = 7.20 \text{ IN}^2$

$I = \Sigma A d^2$

$I_y = 2[7.2(39.5)^2 + 12.6(78)^2]$

$I_y = 175,780 \text{ IN}^4$

$A_6 = A_7 = A_8 = A_9 = A_{10} = 2(3)(.18) + 10(2)(.18) = 4.94$

$I_z = 2(4.94)(4.215)^2(1^2 + 3^2 + 5^2 + 7^2 + 9^2)$

$I_z = 28,963 \text{ IN}^4$

$I_p = I_z + I_y = 28963 + 175780 = 204,700 \text{ IN}^4$

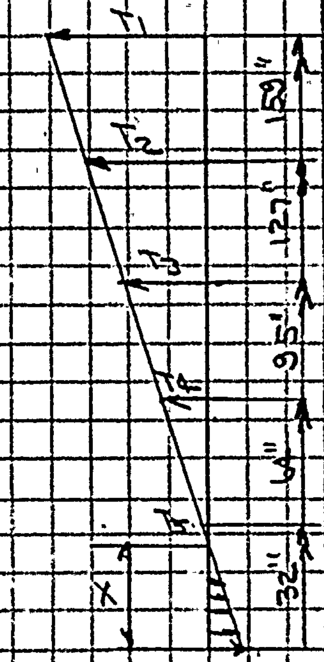
$\tau_y = \dfrac{M_T Z_{max}}{I_p} = \dfrac{M_T (79)}{204700} = \dfrac{M_T}{2591}$

$\tau_z = \dfrac{M_T Y_{max}}{I_p} = \dfrac{M_T (42.15)}{204700} = \dfrac{M_T}{4856}$

5.4 NORTH-SOUTH PLANE:
CONSISTS OF FUSION WELDS AT TOP OF RACK, & 4 ROWS OF FUSION SPOT WELDS & FILLET WELDS ON OUTSIDE OF RACK.

BECAUSE FILLET WELDS ON OUTSIDE OF RACK ARE VERY STIFF IN COMPARISON TO THE OTHERS, ASSUME THEY FAIL FIRST. LOADING THEN MUST BE TAKEN BY OTHER WELDS.

5.4.1 - FORCES IN WELDS DUE TO MOMENT ABOUT GLOBAL X - AXIS



AREA IN COMPRESSION = 14(.18)X = 2.52 IN²/IN

AREA WELDS IN TENSION:

$A_1 = 14(3)(.122) = 5.12\ IN^2$

$A_2 \to A_5 = 2(14)(.141) = 3.95\ IN^2$

EQUATE MOMENTS OF AREAS AROUND N.A.

$2.52\frac{X^2}{2} = A_1(159 - X) + A_2(127 + 95 + 64 + 32 - 4X)$

$1.26X^2 = 814.1 - 5.12X + 1256.1 - 15.8X$

$1.26X^2 + 20.92X - 2070.2 = 0$

$X = 33.07$ ∴ BOTTOM WELD INEFFECT.

$1.26X^2 = 814.1 - 3.95(127 + 95 + 64 - 3X) - 5.12X$

$1.26X^2 + 16.97X - 1943.8$

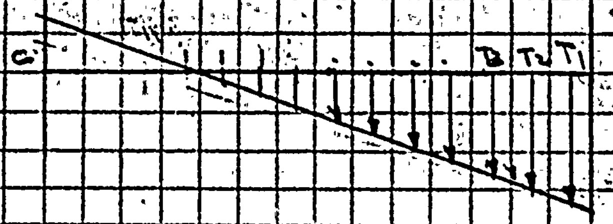
$X = 33.1$

$I_x = \Sigma Ad^2 = 5.12(125.9)^2 + 3.95[93.9^2 + 61.9^2 + 30.9^2]$
$+ 2.52(33.1)^3\left(\frac{1}{12} + \frac{1}{4}\right) = 165352\ IN^4$

$S_X = \frac{I_X}{Z_{MAX}} = \frac{165352}{125.9} = 1313\ IN^3$

5.4.2 CALCULATION OF S_Z

BOTTOM FILLETS IN TENSION. (BOTTOM PL IN COMP.)



A = 3(.122) = .36 IN²

(ASSUME 1/1 IN TENSION)

$$.25X^2 = .36[29.5 + 37.9 + 46.3 + 54.8 + 63.2 + 71.6 + 80.1 + 88.5 + 96.9 + 105.4 + 118.8 - 10X]$$

$$.25X^2 + 3.96X = 285.5$$

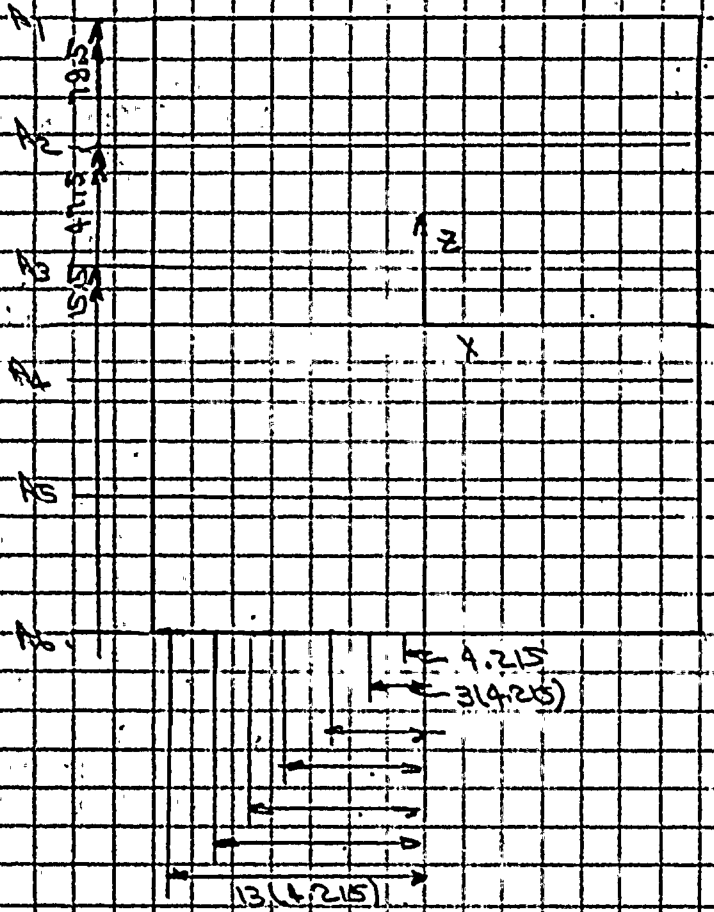
$$X = 26.8$$

$$I_Z = .36[2.7^2 + 11.1^2 + 19.5^2 + 28.0^2 + 36.4^2 + 44.8^2 + 53.3^2 + 61.7^2 + 70.1^2 + 78.6^2 + 92.0^2] + \frac{.5}{3}(26.8)^3$$

$$I_Z = 14307.1 \text{ IN}^4$$

$$S_Z = \frac{14307.1}{92.0} = 155.5 \text{ IN}^3$$

5.4.3 TORSIONAL PROP. (TO RESIST My)



$A_1 = A_6 = 7.56$

$A_2 \rightarrow A_5 = 5.49$

$I_z = 2[(5.49)(15.5^2 + 47.5^2) + 7.56(79.5^2)]$

$I_z = 122{,}970 \text{ IN}^4$

$A = 8(.196) + 6(.18) = 2.648$

$I_x = 2(2.648)(4.215)^2[1^2 + 3^2 + 5^2 + 7^2 + 9^2 + 11^2 + 13^2]$

$I_x = 42{,}810 \text{ IN}^4$

$I_p = 42810 + 122970 = 165780 \text{ IN}^4$

$\tau_x = \frac{T(79.5)}{165780} = \frac{My}{2085}$

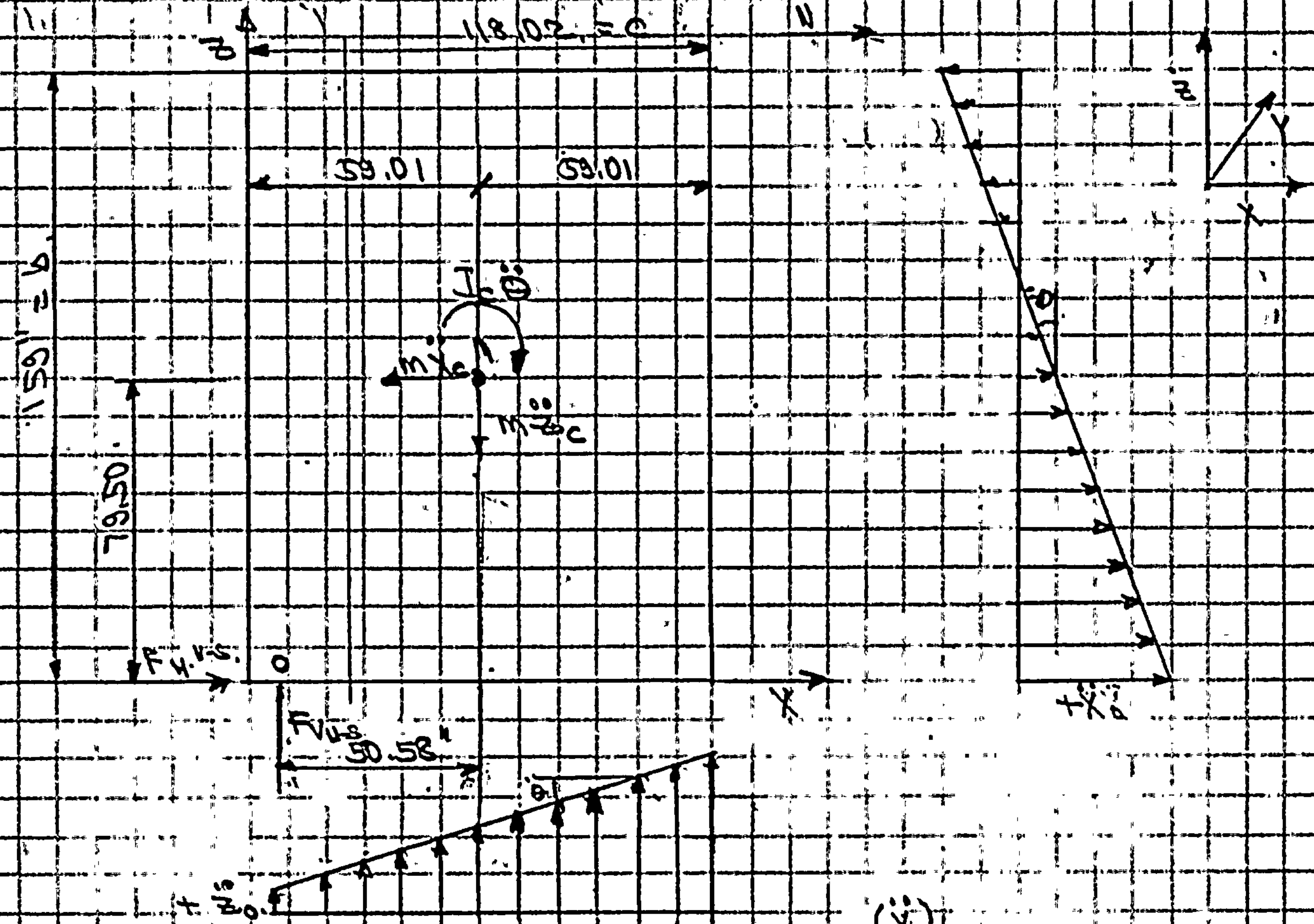
$\tau_z = \frac{T(59.0)}{165780} = \frac{My}{2810}$

SECTION 5.5

INTENTIONALLY BLANK

5.6 RESULTING INERTIA FORCES:
N-S LOADS ON E-W PLANE

D'ALEMBERTS PRINCIPAL OF DYNAMIC EQUILIBRIUM IS APPLIED TO THE RACK AS A RIGID BODY (A SIMILAR SITUATION IS ANALYZED BY TIMOSHENKO - REFERENCE 8). USING THE EQUATIONS OF EQUILIBRIUM THE INTERNAL FORCES & STRESSES CAN BE COMPUTED.



BOTH THE HORIZONTAL ACCELERATION $(\ddot{X})$ & THE VERTICAL $(\ddot{Z})$ VARY WITH THE DISTANCE FROM THE POINT OF ROTATION (POINT O); THE TERMS FOR $m\ddot{X}$ & $m\ddot{Z}$ ARE THEREFORE MORE CORRECTLY STATED AS:

$$m\ddot{z}_c = m(\ddot{z}_o + 50.58\,\ddot{\theta})$$ ($\ddot{\theta}$ IS POSITIVE COUNTERCLOCKWISE)

$$m\ddot{x}_c = m(\ddot{x}_o - 79.50\,\ddot{\theta})$$

NOTE THAT THE INERTIAL FORCES ($m\ddot{z}$, $m\ddot{x}$, $I_c\ddot{\theta}$) ARE OPPOSITE IN DIRECTION TO THE ACCELERATIONS.

APPLYING EQUATIONS OF EQUILIBRIUM TO THE RACK AS A WHOLE:

$\Sigma M_{c.g.} = 0$

$F_{H(N-S)}(79.50) - F_{V\,N-S}(50.58) = I_{N-S}\ddot{\theta}$

$$\ddot{\theta} = \frac{79.50\,F_H - 50.58\,F_V}{I_c}$$

$\Sigma F_H = 0$

$$F_{H\,N-S} = M\ddot{X}_c = M(\ddot{X}_0 - 79.50\,\ddot{\theta})$$

$$\ddot{X}_0 = \frac{F_{H\,N-S} + M\,79.50\,\ddot{\theta}}{M}$$

$\Sigma F_V = 0$

$$F_{V\,N-S} = M\ddot{Z}_c = M(\ddot{Z}_0 + 50.58\,\ddot{\theta})$$

$$\ddot{Z}_0 = \frac{F_{V\,N-S} - 50.58\,M\ddot{\theta}}{M}$$

STANDARD FUEL: $M = 233,600/g$ (LB) (SECT 2.0)

$I_c = \frac{M}{12}(b^2 + c^2)$ (REF #4 P33)

$= \frac{233600}{12(386.4)}(159^2 + 118.02^2)$

$I_c = 1.9754 \times 10^6$ LB-IN-SEC^2

CONSOLIDATED FUEL: $M = 397400/g$ LB (SECT 2.0)

$I_c = 3.360 \times 10^6$ LB-IN-SEC^2

SECT 5.6.1.1

FOR STD FUEL, NS OBE: E-W PLANE

$R_H = 170{,}000$ LB FROM SECT 2.0
$R_V = 63{,}510$ LB

$$\ddot{\theta} = \frac{79.5(170{,}000) - 50.58(68510)}{1.9754 \times 10^6}$$

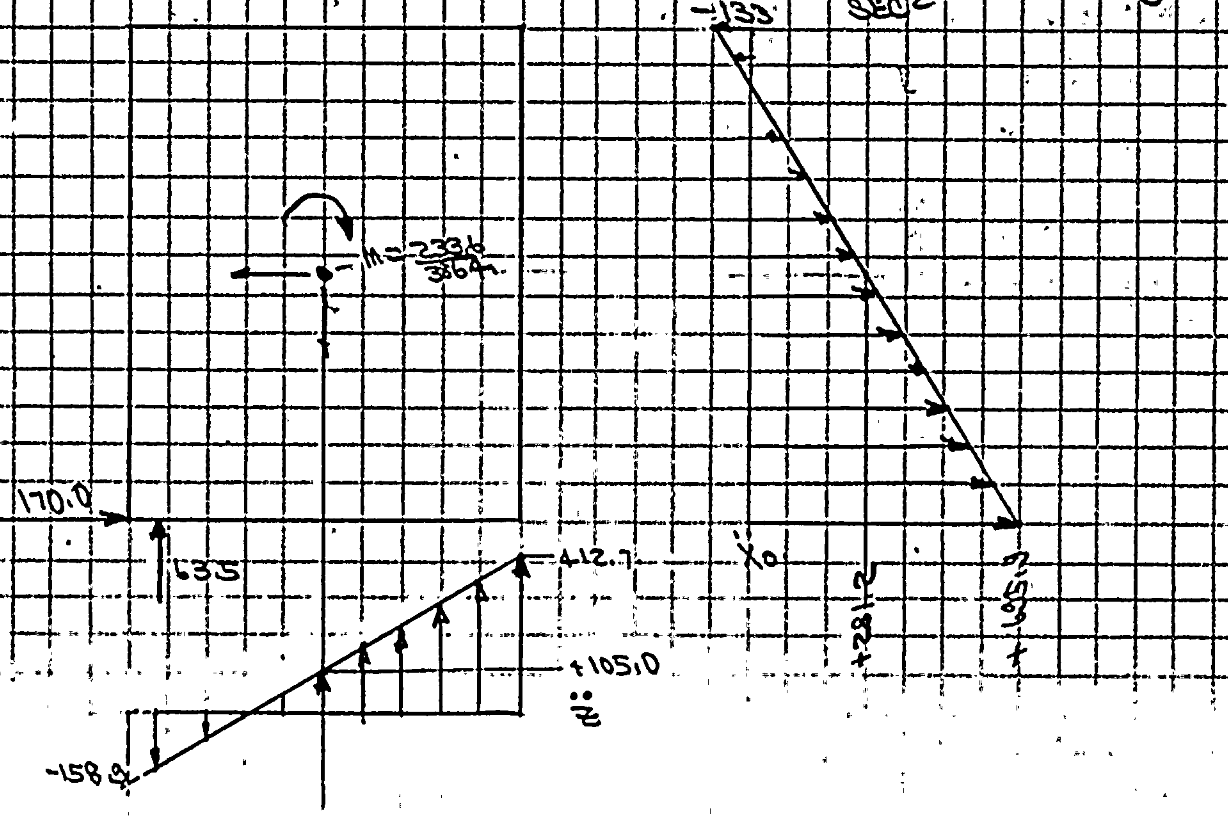
$\ddot{\theta} = 5.216$ RAD / SEC^2

$$\ddot{X}_o = \frac{170{,}000 + 79.5(5.216)\left(\frac{233{,}600}{386.4}\right)}{233{,}600/386.4} = 695.9 \ \frac{IN}{SEC^2}$$

$$\ddot{X}_c = \ddot{X}_o - 79.5\ddot{\theta}$$
$$= 695.9 - 79.5(5.216) = 281.2 \ \frac{IN}{SEC^2} = 0.728\,g$$

$$\ddot{Z}_o = \frac{63.5 - \frac{233.6}{386.4}(50.58)(5.216)}{233.6/386.4} = -158.8 \ IN/SEC^2$$

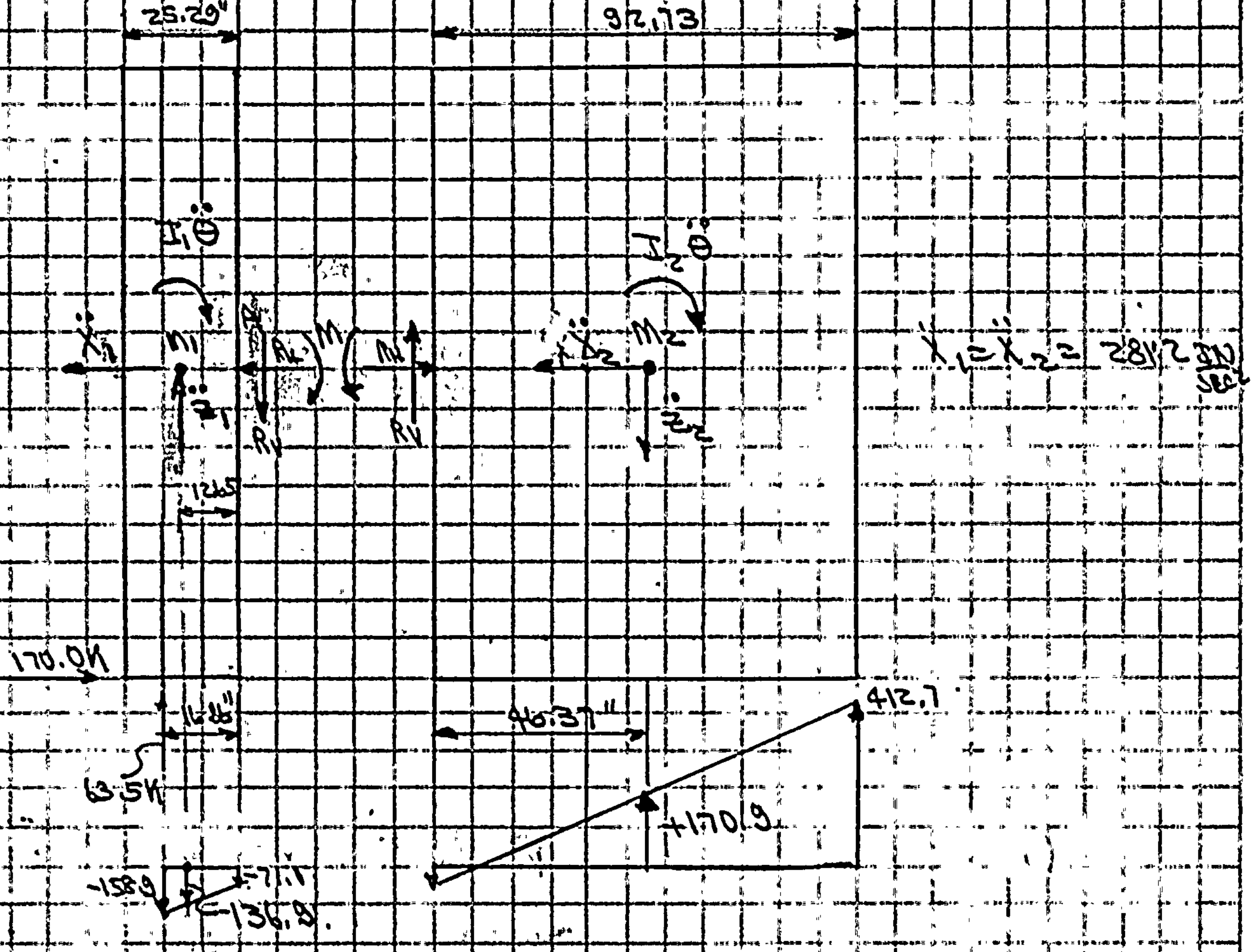
$$\ddot{Z}_c = -158.8 + 50.58(5.216) = 105.0 \ \frac{IN}{SEC^2} = 0.272\,g$$



N-S LOAD STANDARD RACK E-W PLANE

$F_V = 63510$ LB } FROM SECTION 2.0 OF THIS REPORT
$F_H = 170,000$ LB }

ANALYZE THIRD PLANE FROM RACK END



$\ddot z_1 = -158.8 + 5.216(16.86 - 12.65) = -136.9$ IN/SEC² (4.21)

$\ddot z_p = -158.8 + 5.216(16.86) = -71.0$ IN/SEC²

$\ddot z_2 = -158.8 + 5.216(16.86 + 46.37) = +170.9$ IN/SEC² (63.23)

$M_1 = \frac{3}{14}(233.6) = 50.06$ K $\qquad M_2 = \frac{11}{14}(233.6) = 183.54$ K

$I_1 = \frac{M_1}{12}(159^2 + 25.29)^2 \qquad I_2 = \frac{183.54}{12(386.4)}(159^2 + 92.73^2)$

$I_1 = 279.8$ KIP-IN-SEC² $\qquad I_2 = 1341.1$ K-IN-SEC²

E-W PLANE

LEFT FREE BODY:

$\Sigma F_H = 0$:

$M_1 \ddot{X}_1 + R_H = 170.0$

$R_H = 170 - M_1 \ddot{X}$

$= 170 - 50.06 \left(\frac{281.2}{386.4}\right)$

$R_H = 133.6$ K

$\Sigma F_V = 0$:

$R_V = 63.5 + M_1 \ddot{Z}$

$= 63.5 + 50.06 \left(\frac{136.9}{386.4}\right) = 63.5 + 17.7$

$R_V = 81.2$ K

$\Sigma M_A = 0$:

$M = 170(79.5) - 63.5(16.86) - M_1 \ddot{Z}_1 (12.65) - I_1 \ddot{\theta}$

$= 170(79.5) - 63.5(16.86) - 17.7(12.65) - 279.8(5.216)$

$M = 10761.1$ KIP-IN.

RIGHT FREE BODY:

$\Sigma F_H = 0$: $R_H = M_2 \ddot{X} = 183.54 \left(\frac{281.2}{386.4}\right) = 133.6$ K

$\Sigma F_V = 0$ $R_V = M_2 \ddot{Z} = 183.54 \left(\frac{170.9}{386.4}\right) = 81.2$ K

$\Sigma M_2 = 0$ $M = R_V (46.37) + I_2 \ddot{\theta}$

$= 81.2(46.37) + 1341.1(5.216) =$

$M = 10760.4$ K-IN. CHECKS:

TAKING MOMENTS ABOUT WELD N.A. (42.66" FROM BOTTOM) SECT 5.3.1

$M = 10760.4 - 133.6(79.5 - 42.66)$

$M = 5840$ K-IN

THIS LOWER VALUE WILL NOT BE USED TO INSURE CONSERVATISM.

TAKE PLANE 4TH BOX FROM END: : E-W PLANE

$\ddot{Z}_1 = -158.8 + 5.216(25.29 - 16.86) = -114.8$ IN/SEC²

$\ddot{Z}_2 = -158.8 + 5.216(25.29 + 42.15) = +192.9$ IN/SEC²

CHECK ONLY RIGHT FREE BODY:

$M_2 = \frac{10}{14}(233.6) = 166.9K$

$I_2 = \frac{166.9}{(12)(386.4)}(159^2 + 84.3^2) = 1165.5$

$R_H = M_2\ddot{X} = 166.9\left(\frac{281.8}{386.4}\right) = 121.7K$

$R_V = M_2\ddot{Z}_2 = 166.2\left(\frac{192.9}{386.4}\right) = 83.0K$

$M = 83.0(42.15) + 1165.5(5.216) = 9575$ K-IN.

PLANE 5TH BOX FROM END:

$\ddot{Z}_2 = -158.8 + 5.216(71.66) = 215.0$

$M_2 = 150.2K \qquad I_2 = 1005.2$

$R_H = 109.5K$

$R_V = 83.6K$

$M = 83.6(37.9) + 1005(5.216) = 8414$

THE TREND IS OBVIOUSLY CLEAR:

R_H & M DECREASE STEADILY

R_V EVENTUALLY DECREASES (NEXT PLANE)

THE MOST SEVERELY LOADED WELD PLANE IS THE THIRD PLANE FROM THE END. (IT WOULD BE THE FIRST PLANE BUT FOR THE PRESENCE OF THE CRUCIFORMS WHICH REINFORCE THE FIRST & SECOND PLANE.)

5.6.2.2 STANDARD RACK E. N-S SSE E-W PLANE

$R_H = 231.5$ K

$R_V = 196.5$ K

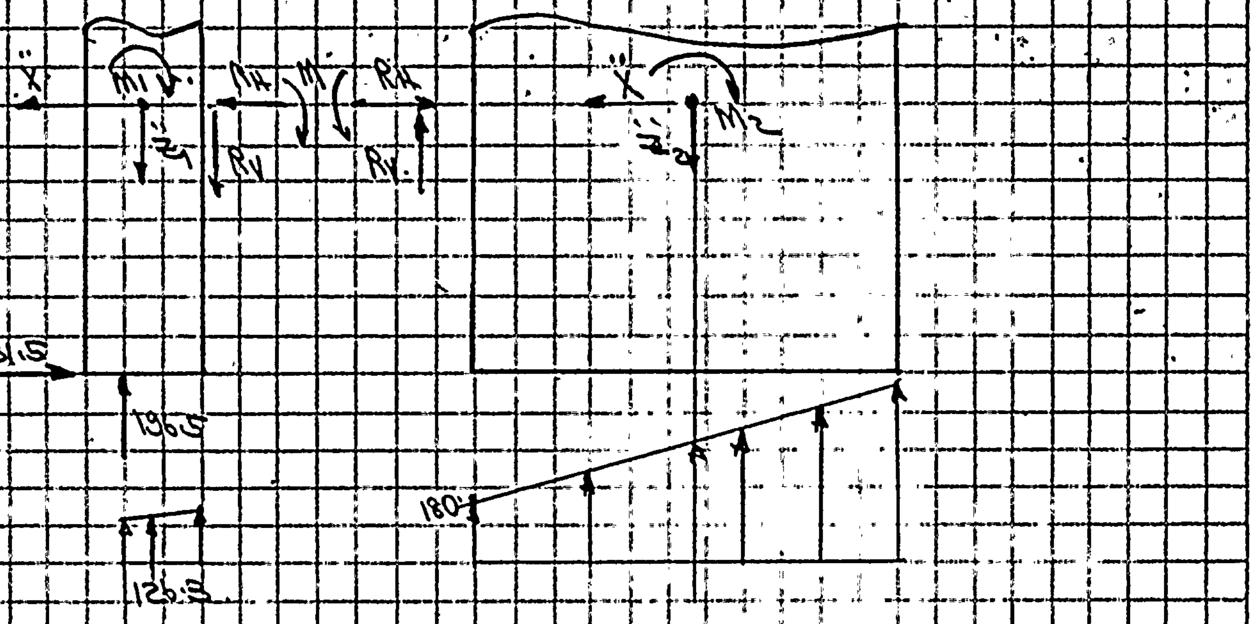
$$\ddot{\theta} = \frac{79.5(231.5) - 50.58(196.5)}{1975.4} = 4.285 \text{ RAD/SEC}^2$$

$$\ddot{X}_0 = \frac{231.5 + 79.5(4.285)\left(\frac{233.6}{386.4}\right)}{233.6/386.4} = 723.6 \text{ IN/SEC}^2$$

$$\ddot{X}_c = \ddot{X}_0 - 79.5\ddot{\theta} = 382.9 \text{ IN/SEC}^2 = 0.991\,g$$

$$\ddot{Z}_0 = \frac{196.5 - \frac{233.6}{386.4}(50.58)(4.285)}{233.6/386.4} = 108.3 \text{ IN/SEC}^2$$

$$\ddot{Z}_c = 108.3 + 50.58(\ddot{\theta}) = 325.0 \text{ IN/SEC}^2 = 0.841\,g$$



$\ddot{Z}_1 = 108.3 + 4.28(4.21) = 126.3$

$\ddot{Z}_2 = 108.3 + 4.285(63.23) = 379.3$

$M_2 = 183.54$

$I_2 = 1341.1$

RIGHT-HAND BODY: E-W PLANE

$\Sigma F_H = 0 \quad R_H = M_2 \ddot{X}_2 = 183.54(0.991) = 181.9K$

$\Sigma F_V = 0 \quad R_V = M_2 \ddot{Z}_2 = 183.54\left(\frac{378.3}{386.4}\right) = 180.2K$

$\Sigma M_c = 0 \quad M = 180.2(46.37) + 134.1(42.83)$

$M = 14{,}103 \text{ K-IN}$

5.6.1.3 CONSOLIDATED RACK – NS OBE E-W PLANE

$M = 397.4K$

$F_H = 160.2K$ $I_c = 3360$

$F_V = 0.0$

$$\ddot{\theta} = \frac{79.5(160.2) - 0.0}{3360} = 3.79 \text{ RAD/SEC}^2$$

$$\ddot{X}_c = \frac{160.2}{397.4} = 0.4038$$

$$\ddot{Z}_0 = 0 - 50.58(3.79) = -191.7 \text{ IN/SEC}^2$$

$$\ddot{Z}_1 = -191.7 + 3.79(4.21) = -176.0 \text{ IN/SEC}^2$$

$$\ddot{Z}_2 = -191.7 + 3.79(63.23) = +47.9 \text{ IN/SEC}^2$$

$$M_2 = \frac{11}{14}(397.4) = 312.24K$$

$$I_2 = 2281.5 \text{ K-IN-SEC}^2$$

R.H. SIDE:

$$R_H = 312.24(.403) = 125.8K$$

$$R_V = 312.24\left(\frac{47.9}{386.4}\right) = 38.7K$$

$$M = 38.7(46.37) + 2281.5(3.79) = 10,441 \text{ K-IN}$$

5806

5.6.1.4 CONS. RACK NS SSE E-W PLANE

$R_H = 239.3$ K

$R_V = 114.64$ K

$$\ddot{\theta} = \frac{79.5(239.3) - 50.58(114.64)}{3360} = 3.936 \text{ RAD/SEC}^2 (+)$$

$$\ddot{X}_c = \frac{239.3}{397.4} = 0.602g$$

$$\ddot{Z}_o = \frac{114.64 - \frac{397.4}{386.4}(50.58)(3.936)}{397.4/386.4} = -87.6 \text{ IN/SEC}^2$$

$$\ddot{Z}_c = -87.6 + 50.58(3.936) = 111.47 \text{ IN/SEC}^2$$

$$\ddot{Z} = -87.6 + 3.936(4.21) = -71.0$$

$$\ddot{Z}_2 = -87.6 + 3.936(63.23) = 161.27$$

$$R_H = 312.24(0.602) = 188.0 \text{ K}$$

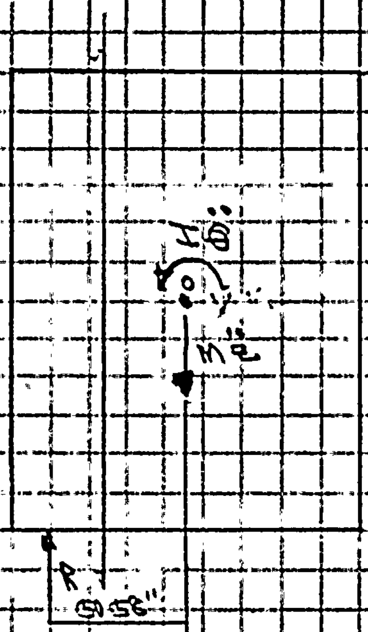
$$R_V = 312.24\left(\frac{161.27}{386.4}\right) = 130.3 \text{ K}$$

$$M = 130.3(46.37) + 2281.5(3.936) = 15,022 \text{ K-IN}$$

8096.

5.6.1.5 DEADWEIGHT E-W PLANE

IT IS CONSERVATIVE TO ASSUME A DEADWEIGHT CONFIGURATION IN WHICH A PEDESTAL HAS LIFTED OFF, SINCE INTERNAL SHEARS & MOMENTS ARE A MAXIMUM



USE SUBMERGED REACTION

STD RACK: R = 208.2 K M = 233.6 K

$$\ddot{z}_c = \frac{R}{M} = \frac{208.2}{233.6} = 0.891\ g$$

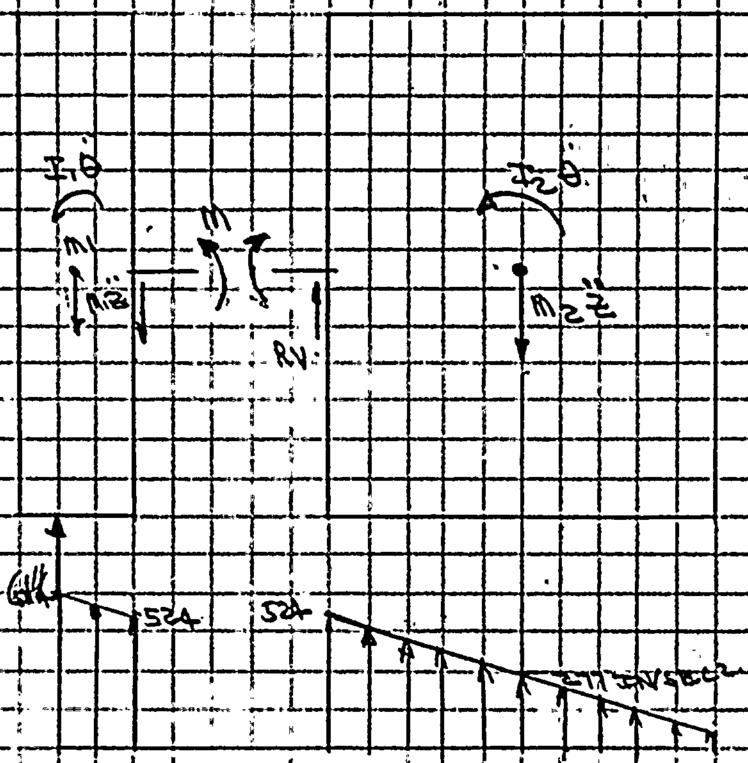
$\Sigma M_o = 0$:

$$R(50.58) = I\ddot{\theta}$$

$$\ddot{\theta} = \frac{208.2(50.58)}{1975.4} = -5.33\ \text{RAD/SEC}^2$$

$$\ddot{z}_o = \frac{208.2 + \frac{233.6}{386.4}(5.33)(50.58)}{233.6/386.4} = 614.0\ \text{IN/SEC}^2$$

$$\ddot{z}_2 = 614 - 5.33(63.23) = 277\ \text{IN/SEC}^2$$



RIGHT SIDE: $RV = m_2\ddot{z}$

$= 183.54\left(\frac{277}{386.4}\right) = 131.6\ K$

$R_H = 0$

$M = m_2\ddot{z}_2(46.37) - I\ddot{\theta}$

$= -131.6(46.37) + 13411(.533)$

$= +1045.8\ K\text{-}IN.$

CONSOLIDATED FUEL: SUBMERGED WT = 341.06 K

$$\ddot{z}_1 = \frac{341.06}{397.4} = 0.859\,g$$

$$\ddot{\theta} = \frac{341.06(50.58)}{3360.5} = 5.13 \text{ RAD/SEC}^2$$

$$\ddot{z}_0 = \frac{341.06 + \frac{397.4}{386.4}(5.13)(50.58)}{397.4/386.4} = 591.3 \text{ IN/SEC}^2$$

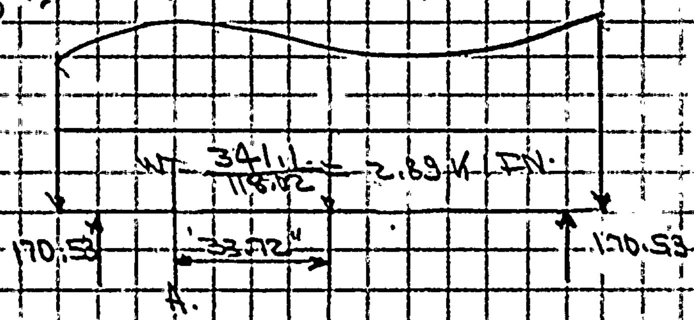
$$\ddot{z}_2 = 591.3 - 5.13(63.23) = 267.0 \text{ IN/SEC}^2$$

$$R_V = M_2\ddot{z}_2 = 312.2\left(\frac{267}{386.4}\right) = 215.5 \text{ K}$$

$$M = -215.5(46.37) + 2281.5(5.13)$$

$$M = 1700.0 \text{ K-IN}$$

IF ONE ASSUMES $\ddot{\theta} = 0$, EACH PEDESTAL WILL CARRY 1/2 LOAD:



$$R_V \text{ AT } A = 2.89(4)(8.43) = 97.4 \text{ K} \quad \text{vs } 215.5$$

$$M_{@A} = 170.53(16.86) - 2.89\left(\frac{25.29^2}{2}\right) = 1951 \text{ K-IN} \quad \text{vs } 1700$$

5.6.1.6 VERTICAL SEISMIC:
ALSO CONSERVATIVELY ASSUMED TO OCCUR WHEN A PEDESTAL HAS LIFTED OFF:

STANDARD FUEL: $F_V = 53.7$ K (BOTH OBE & SSE) (SECTION 2.0).

$$\ddot{\theta} = \frac{53.7(50.58)}{1979.4} = -1.37$$

$$\ddot{z}_0 = \left[\frac{53.7(386.4)}{2336} + 1.37(50.58)\right] = -158.1$$

$$\ddot{z}_2 = 158.1 - 1.37(63.23) = 71.5$$

$$R_V = 183.54\left(\frac{71.5}{386.4}\right) = 34.0\text{ K}$$

$$M = -34(46.37) + 1341.1(1.33)$$

$$M = 260\text{ K-IN}$$

CONSOLIDATED FUEL: $F_V = 89.5$ K

$$\ddot{\theta} = \frac{89.5(50.58)}{3360.5} = -1.35$$

$$\ddot{z}_0 = 155.3$$

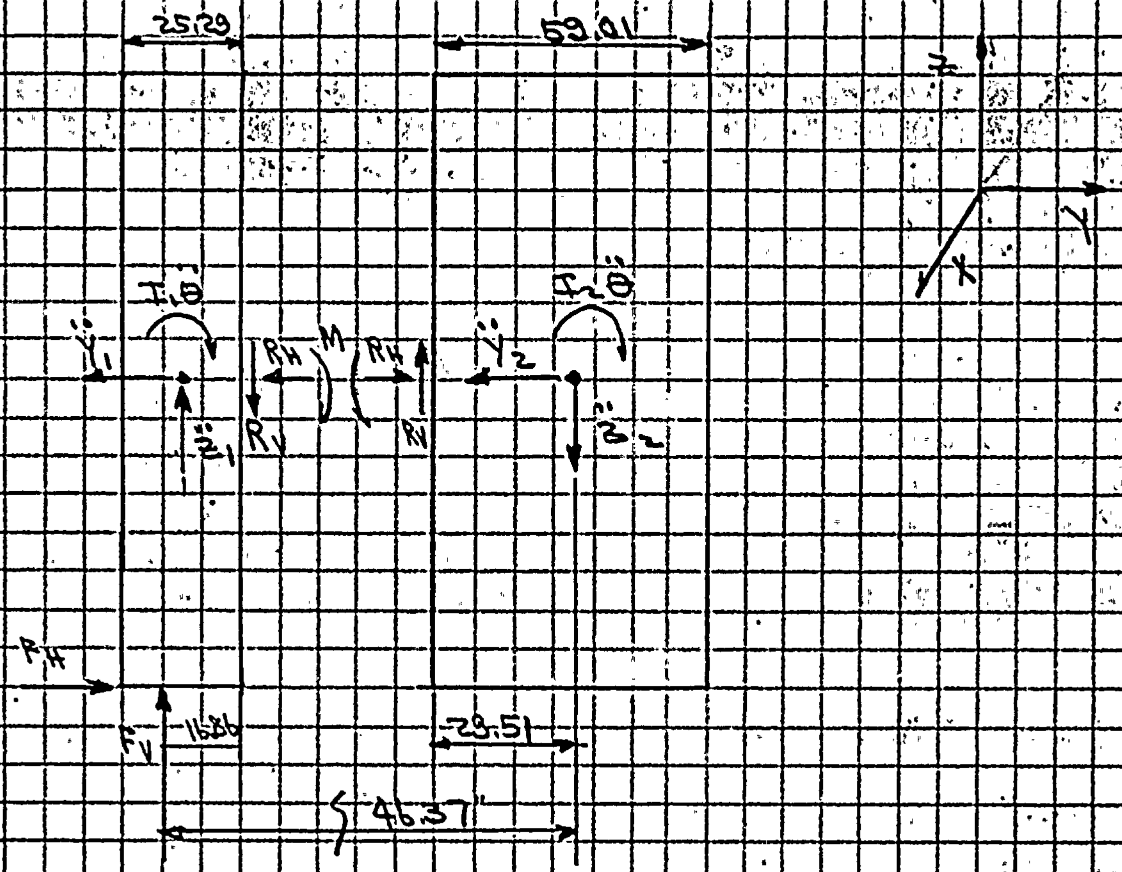
$$\ddot{z}_2 = 70.0$$

$$R_V = 56.5\text{ K}$$

$$M = -56.5(46.37) + 2281.5(1.35)$$

$$M = 460\text{ K-IN.}$$

5.6.2.1 INERTIA FORCES NORTH-SOUTH PLANE



FOR THE WHOLE RACK:

$$M\ddot{Z}_c = M(\ddot{Z}_0 + 33.72\ddot{\theta})$$

$$M\ddot{Y}_c = M(\ddot{Y}_0 + 79.5\ddot{\theta})$$

GENERAL EQUATIONS:

$$\ddot{\theta} = \frac{79.50 F_H - 33.72 F_V}{I_c}$$

$$\ddot{Y}_0 = \frac{F_{H \ddot{x} W} + M(79.50)\ddot{\theta}}{M}$$

$$\ddot{Z}_0 = \frac{F_{V \ddot{x} W} - M(33.72)\ddot{\theta}}{M}$$

STANDARD FUEL: $M = 233.6K$

$$I_c = \frac{233.6}{12(386.4)}(159^2 + 84.3^2) = 1631.6$$

$M_1 = \frac{3}{10}(233.6) = 70.08K$ $M_2 = 163.52K$

$I_1 = \frac{70.08}{386.4(12)}(252.9^2 + 159^2)$ $I_2 = 163.5(59.01^2 + 159^2)$

$I_1 = 391.8$ $I_2 = 1014.4$

CONSOLIDATED FUEL: $M = 397.4K$

$I_c = 2775.8$

$M_1 = 119.2K$ $M_2 = 278.2K$

$I_1 = 666.5$ $I_2 = 1725.6$

5.6.2.1 STD RACK E-W OBE N-S PLANE

$R_H = 156.2\ K$

$R_V = 185.1\ K$

$$\ddot{\theta} = \frac{19.5(156.2) - 33.72(185.1)}{1631.6} = 3.785\ RAD/SEC^2$$

$$\ddot{Y}_c = \frac{156.2}{233.6} = 0.669\ g$$

$$\ddot{Z}_0 = \frac{185.1 - \frac{233.6}{386.4}(33.72)(3.785)}{233.6/386.4} = +178.5\ IN/SEC^2$$

$$\ddot{Z}_2 = +178.5 + 3.785(\overset{46.37}{16.86 + 29.51}) = 354.1\ IN/SEC^2$$

$R_H = 163.52(0.669) = 109.4\ K$

$R_V = 163.5\left(\frac{354.1}{386.4}\right) = 149.8\ K$

$M = 149.8(29.51) + 1014.4(3.785) = 8261\ K\text{-}IN$

5622 STD RACK E-W SSE

N-S PLANE

$F_H = 164.3\,K$

$F_V = 173.4\,K$

$$\ddot{\theta} = \frac{79.5(164.3) - 33.72(173.4)}{1631.6} = +4.42 \text{ RAD/SEC}^2$$

$$\ddot{Y}_C = \frac{164.3}{233.6} = 0.703\,g$$

$$\ddot{Z}_0 = \frac{173.4 - \frac{233.6}{386.4}(33.72)(4.42)}{233.6/386.4} = +137.7 \text{ IN/SEC}^2$$

$$\ddot{Z}_2 = 137.7 + 4.42(46.37) = 342.8 \text{ IN/SEC}^2$$

$R_H = .703(163.5) = 114.9\,K$

$R_V = 163.5\left(\frac{342.8}{386.4}\right) = 145.1\,K$

$M = 145.1(29.51) + 1014.4(4.42) = 8764\,K\text{-IN}$

5.6.2.3 CONS RACK E-W OBE N-S PLANE

$F_H = 153.0K$
$F_V = 64.14K$

$$\ddot{\theta} = \frac{79.5(153.0) - 33.72(64.14)}{2775.8} = 3.603 \text{ RAD/SEC}^2$$

$$\ddot{Y}_0 = \frac{153.0}{397.4} = 0.385 g$$

$$\ddot{Z}_0 = \frac{64.14 - \frac{397.4}{386.4}(33.72)(3.603)}{\frac{397.4}{386.4}} = -59.1 \text{ IN/SEC}^2$$

$$\ddot{Z}_2 = -59.1 + 3.603(46.37) = +107.9$$

$R_H = 278.2(.385) = 107.2K$

$$R_V = 278.2\left(\frac{107.9}{386.4}\right) = 77.7K$$

$M = 77.7(29.51) + 1725.6(3.603) = 8510 \text{ K-IN}$

5.6.2.4 CONS. RACK E-W SSE NS PLANE

$F_H = 184.7\,K$
$F_V = 171.0\,K$

$$\ddot{\theta} = \frac{79.5(184.7) - 33.72(171.0)}{2775.8} = 3.21 \text{ RAD/SEC}^2$$

$$\ddot{Y}_c = \frac{184.7}{397.4} = 0.4658$$

$$\ddot{Z}_0 = \frac{171.0 - \frac{397.4}{386.4}(33.72)(3.21)}{387.4/386.4} = +58.0 \text{ IN/SEC}^2$$

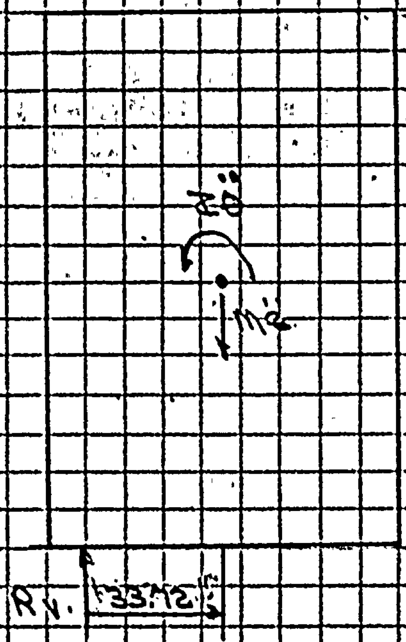
$$\ddot{Z}_2 = 58.0 + 3.21(46.37) = 206.9$$

$R_H = 129.4\,K$

$$R_V = 278.2\left(\frac{206.9}{386.4}\right) = 149.0\,K$$

$$M = 149.6(29.51) + 1725.6(3.21) = 9935\,K\text{-IN}$$

5.6.2.5 DEADWEIGHT : N-S PLANE



$\ddot{z}_c = \frac{208.2}{233.6}(386.4) = 344.2$ IN/SEC²

$\ddot{\theta} = \frac{208.2(33.72)}{1631.6} = 4.30$ RAD/SEC²

$\ddot{z}_0 = 344.2 + 33.72(4.3) = 489.3$

$\ddot{z}_2 = 489.3 - 4.30(46.37) = 290$ IN/SEC²

$R_V = M_2\ddot{z}_2 = 163.52\left(\frac{290}{386}\right) = 122.7$ K.

$M = -122.7(29.51) + 1014.4(4.30)$
$M = 741$ K-IN.

CONSOLIDATED FUEL: $\ddot{\theta} = \frac{341.06(33.72)}{2775.8} = 4.14$

$\ddot{z}_0 = 331.6 + 4.14(33.72) = 471.2$

$\ddot{z}_2 = 471.2 - 4.14(46.37) = 279.2$

$R_V = 278.2\left(\frac{279.2}{386.4}\right) = 201.0$ K.

$M = -201(29.51) + 1725.6(4.14) =$

$M = 1211$ K-IN.

5.6.2.6 VERT SEISMIC:

STD FUEL: $R_V = 53.7$ K (OBE & SSE)

$\ddot{\theta} = \frac{53.7(33.72)}{1631.6} = 1.11$ RAD/SEC²

$\ddot{Z}_C = \frac{53.7}{233.6}(386.4) = 88.8$ IN/SEC²

$\ddot{Z}_0 = 88.8 + 33.72(1.11) = 126.2$

$\ddot{Z}_2 = 126.2 - 1.11(46.37) = 74.8$ IN/SEC²

$R_V = 31.6$ K.

$M = 1912$ K-IN

CONS FUEL: $R_V = 89.5$ K

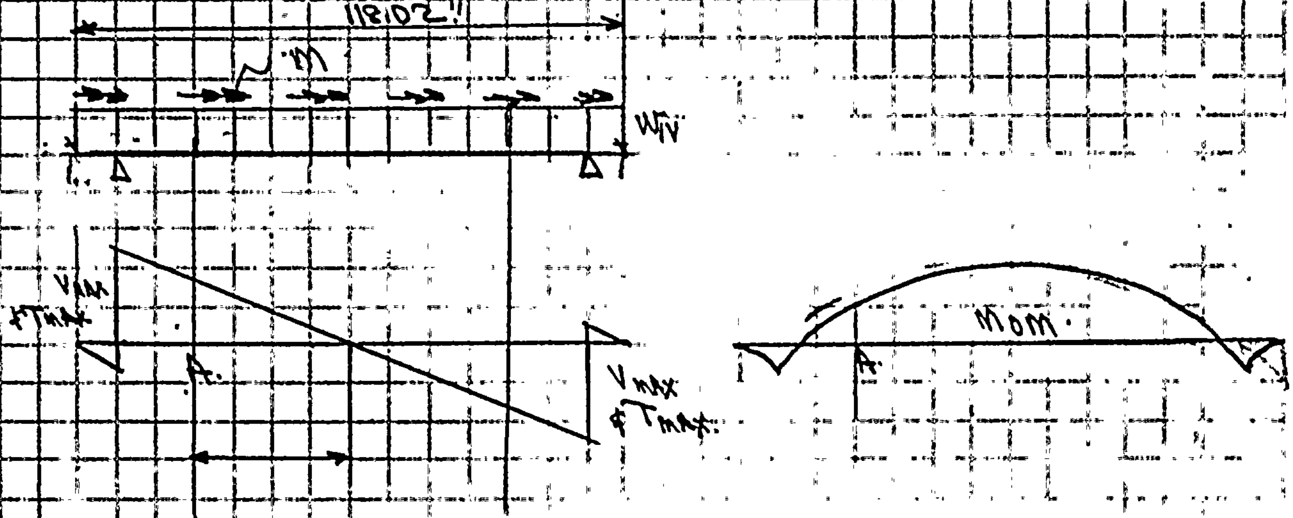
MULTIPLY DWT VALUES BY $\frac{89.5}{341.06} = 0.262$

$R_V = 201.0(.262) = 52.7$ K

$M = 1211(.262) = 317$ K-IN

5.6.3 E-W LOADS ON E-W PLANE.

E-W LOADS ALSO CAUSE STRESS ON N-S PLANE SIMILAR TO A SIMPLY SUPPORTED BEAM SUBJECTED TO SHEAR & TORSION:



CROSS-SECTION IN QUESTION (3D BOX IN)
HAS A V OR $T = \frac{4}{7} w \frac{L}{2} = \frac{4}{14} wL$

WL = TOTAL FORCE

THEREFORE CROSS-SECTION RESISTS 2/7 TOTAL FORCE (SHEAR OR TORSION) ON THE RACK.

STD FUEL E-W OBE: $F_H = 156.2$
$F_V = 185.1$ SEE SECT 5.6.2.1

$M = I_c \ddot{\theta} = 1631.6(3.785)$
$= 6175.6$ K-IN

HORIZONTAL SHEAR $= F_H(\frac{2}{7}) = \frac{2}{7}(156.2) = 44.7$K.

VERT SHEAR $= \frac{2}{7}F_V = \frac{2}{7}(185.1) = 52.9$K

TORSION $= \frac{2}{7}(6175.6) = 1765$ K-IN.

$\text{MOMENT}_A = \frac{F}{2}(16.86) - \frac{F}{118.02}\left(\frac{25.29}{2}\right)^2$
$= 5.72F$ (K-IN).

$M_H = 156.2(5.72) = 893$ K-IN
$M_V = 185.1(5.72) = 1058$ K-IN.

STD FUEL SSE: F_H = 164.3 M_H = 940 K-IN V_H = 46.9 K
(SECT 5.6.2.2) F_V = 173.4 M_V = 992 K-IN V_V = 49.6 K
M = 1631.6(4.42) = 7212 T = 2060 K-IN

CONS. FUEL OBE F_H = 153.0 M_H = 876 K-IN V_H = 43.7 K
(SECT 5.6.2.3) F_V = 64.1 M_V = 367 K-IN V_V = 18.3 K
M = 2775.8(3.60) = 9993 T = 2855 K-IN

CONS. FUEL SSE F_H = 184.7 M_H = 1056 K-IN V_H = 52.8 K
(SECT 5.6.2.4) F_V = 171.0 M_V = 979 K-IN V_V = 48.9 K
M = 2775.8(3.21) = 8910 T = 2546 K-IN

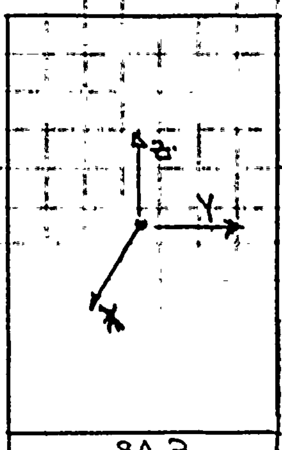
DEADWT (STD)
(SEC 5.6.2.5) F_H = 0 M_H = 0 V_H = 0
F_V = 208.2 M_V = 1191 K-IN V_V = 59.5 K
M = 1631.6(4.3) = 7016 T = 2004 K-IN

DWT (CONS.) F_H = 0 M_H = 0 V_H = 0
F_V = 341.6 M_V = 1953 K-IN V_V = 97.6 K
M = 2775.8(4.14) = 11492 T = 3283 K-IN

VERT SEISMIC STD F_H = 0 M_H = 0 V_H = 0
(SECT 5.6.2.6) F_V = 53.7 K M_V = 308 K-IN V_V = 15.3 K
(BOTH OBE & SSE) T = 517 K-IN

VERT CONS F_H = 0 M_H = 0 V_H = 0
F_V = 89.5 M_V = 513 K-IN V_V = 25.6 K
T = 862 K-IN

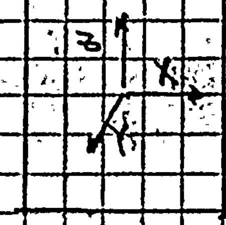
NOTE THAT DEADWEIGHT FORCES & VERTICAL SEISMIC MUST BE ADDED TO THOSE FROM SECT. 5.6.1.5

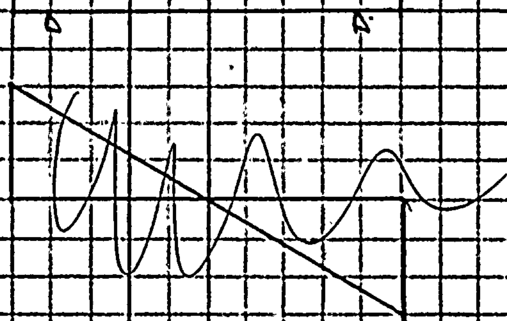


$V_H = F_Y$
$V_V = F_Z$
$T = M_X$
$M_H = M_Z$
$M_V = M_Y$

5.6.4 N-S LOADS ON N-S PLANE

10 BOXES LONG:





AT 3D BOX FROM END:

$V = \frac{2}{5}\frac{WL}{2} = \frac{2}{10}$ TOTAL

$M = \frac{F}{2}(16.86) - \frac{F}{84.3}\frac{(25.29)^2}{2}$

$M = 4.64\,F$

STD. FUEL OBE (SECT 5.6.1.1) F_H 170.0 M_B = 789 F_x = 34.0 K

F_V 63.5 M_x = 295 F_z = 12.7 K

M = 1975.4(5.216) = 10303 M_y = 2060 K-IN

STD FUEL SSE (5.6.1.2) F_H = 231.5 M_z = 1074 F_x = 46.3

F_V = 196.5 M_x = 912 F_z = 39.3

M = 1975.4(4.285) = 8465 M_y = 1693 K-IN

CON FUEL OBE (5.6.1.3) F_H = 160.2 M_z = 743 F_x = 32.0 K

F_V = 0.0 M_x = 0 F_z = 0. K

M = 3360(3.79) = 12734 M_y = 2547 K-IN

CON FUEL SSE (5.6.1.4) F_H = 239.3 M_z = 1110 F_x = 47.9

F_V = 114.6 M_x = 532 F_z = 22.9

M = 3360(3.94) = 13225 M_y = 2645 K-IN

STD. DWT (5.6.1.5) F_H = 0 M_z = 0 F_x = 0 K

F_V = 208.2 M_x = 966 F_z 41.6 K

M = 1975.4(5.33) = 10529 M_y = 2106 K-IN

CON. DWT F_H = 0 M_z = 0 F_x = 0

F_V = 341.6 M_x = 1585 F_z = 68.3 K

M = 3360(5.13) = 17237 M_y = 3447 K-IN

STD VERT (OBE & SSE) F_V = 53.7 M_x = 249 F_z = 10.7 K

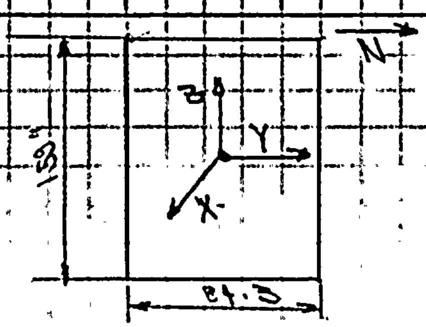
M = 1975.4(1.37) = 2706 M_y = 541 K-IN

CONS VERT. F_V = 89.5 M_x = 415 F_z = 17.9 K

M = 3360(1.35) = 4536 M_y = 907.2 K-IN

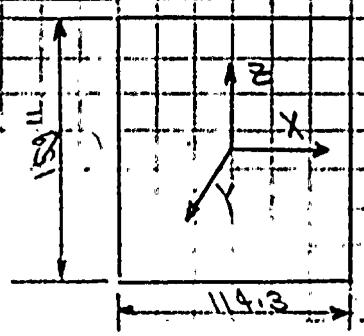
5.7 SUMMARY OF INTERNAL RACK FORCES ON EAST-WEST PLANE: (KIPS & KIP-INCHES)

LOADING CONDITION	REF. SECTION	Fx	Fy	Fz	Mx	My	Mz
DEADWT - STD FUEL	5.6.1.5			131.6		1046	
+	5.6.3			59.5	2004.	1191	
				191.1	2004	2237	
CON FUEL	5.6.1.5			215.5		1700.	
	5.6.3			97.6	3283.	1953.	
				313.1	3283.	3653	
VERTICAL SEISMIC	5.6.1.6			34.0		260.	
STD FUEL	5.6.3			15.3	517	308.	
				49.3	517	568.	
VERT - CONS FUEL	5.6.1.6			56.5		460.	
	5.6.3			25.6	862.	513.	
				82.1	862.	973	
STD. FUEL N-S OBE	5.6.1.1	133.6		81.2		10761.	
N-S SSE	5.6.1.2	181.9		180.2		14103	
CONS. FUEL N-S OBE	5.6.1.3	125.8		38.7		10441	
N-S SSE	5.6.1.4	188.0		130.3		15022	
STD. FUEL E-W OBE	5.6.3		44.7	52.9	1765	1058	893
" E-W SSE	5.6.3		46.9	49.5	2060	992	940
CONS FUEL E-W OBE	5.6.3		43.7	18.3	2855	367	876
E-W SSE	5.6.3		52.8	48.9	2546	979	1056.



5.8 SUMMARY OF INTERNAL RACK FORCES
N-S PLANE (KIPS & KIP-IN.)

LOADING CONDITION	REF. SECTION	Fx	Fy	Fz	Mx	My	Mz
DEADWT - STD FL	5.6.2.5			122.7	741		
+	5.6.4			41.6	966	2106	
				164.3	1707	2106.	
CON. FUEL	5.6.2.5			201.0	1211		
	5.6.4			68.3	1585	3447	
				269.3	2796	3447	
VERT. SEISMIC	5.6.2.6			31.6	191		
STD FUEL	5.6.4			10.7	249	541	
				42.3	440	541	
CON. FUEL	5.6.2.6			52.7	317		
	5.6.4			17.9	415	907	
				70.6	732	907	
STD FUEL E-W OBE	5.6.2.1		109.4	149.8	8261		
E-W SSE	5.6.2.2		114.9	145.1	8764		
CON FUEL E-W OBE	5.6.2.3		107.2	77.7	8510		
E-W SSE	5.6.2.4		129.4	149.0	9935		
STD FUEL NS OBE	5.6.4	34.0		12.7	295	2060	789
NS SSE	5.6.4	46.3		39.3	912	1693	1074
CON FUEL NS OBE	5.6.4	32.0		0.0	0	2547	743.
NS SSE	5.6.4	47.9		22.9	532	2645	1110

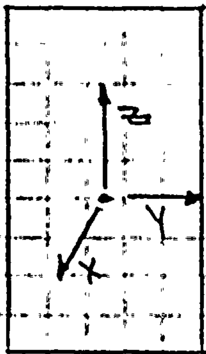


6.0 CALCULATION OF WELD STRESSES.

IN THIS SECTION WELD STRESSES ARE COMPUTED USING THE FORCES & CROSS-SECTIONAL PROPERTIES COMPUTED IN SECTION 5.0

EACH PLANE (N-S) & (E-W) IS TREATED SEPARATELY.

6.0.1 FOR THE EAST-WEST PLANE:



F_x IS ALWAYS COMPRESSIVE. COMPRESSIVE STRESSES WILL BE SMALL (≈ 2-3 KSI) & WILL TEND TO REDUCE THE TENSILE STRESSES. THIS EFFECT WILL THEREFORE CONSERVATIVELY BE NEGLECTED.

FOR EACH LOAD CASE THE FORCES ARE COMBINED AS FOLLOWS:

F_y & F_z ARE SHEARS:

$$\tau_{y1} = \frac{F_y}{A_w} \qquad \tau_{z1} = \frac{F_z}{A_w}$$

A_w IS COMPUTED IN SECTION 5.2

M_x (THE TORSIONAL MOMENT) ALSO CAUSES SHEAR STRESSES IN THE WELDS:

$$\tau_{y2} = \frac{M_x Z_{max}}{I_p} \qquad \tau_{z2} = \frac{M_x Y_{max}}{I_p} \text{ (SECTION 5.3.3)}$$

MAXIMUM AT THE CORNER WELDS.

THESE ARE DIRECTLY ADDITIVE TO EACH OTHER, THE RESULTANT WELD SHEAR STRESS IS:

$$\tau_w = \sqrt{(\tau_{y1}+\tau_{y2})^2 + (\tau_{z1}+\tau_{z2})^2}$$

MY RESULTS IN TENSION IN THE WELD AT THE TOP OR BOTTOM & COMPRESSION ON THE BOX WALLS

$$\sigma_1 = \frac{M_Y}{S_Y} \quad (S_Y \text{ FROM SECT. 5.3.1})$$

MZ ALSO CAUSES TENSION IN THE WELDS, BUT ONLY IN THE BOTTOM ROW

$$\sigma_2 = \frac{M_Z}{S_Z} \quad (S_Z \text{ FROM SECT. 5.3.2})$$

WHICH IS DIRECTLY ADDITIVE TO σ_1 (IF σ_1 IS TENSION ON BOTTOM)

$$\sigma_W = \sigma_1 + \sigma_2$$

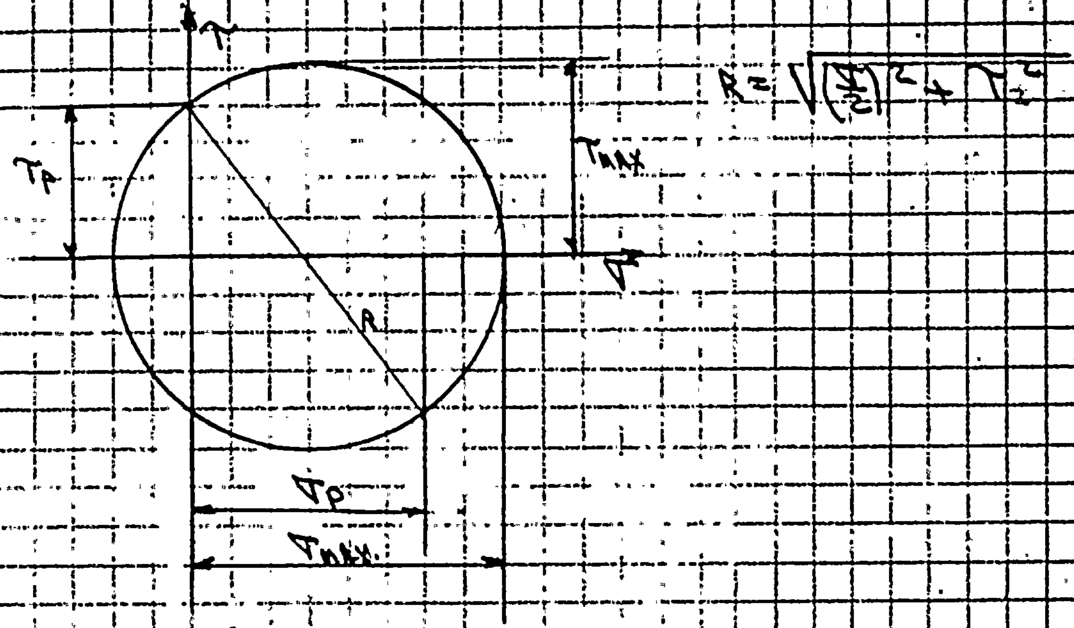
σ & τ WILL BE EVALUATED FOR EACH LOAD CASE (DWT, VERT SEISMIC, N-S SEIS, & E-W SEIS) & COMBINED USING THE SRSS METHOD.

$$\sigma_{TOT} = \sigma_{DWT} + \sqrt{\sigma_{VT}^2 + \sigma_{N-S}^2 + \sigma_{E-W}^2}$$

$$\tau_{TOT} = \tau_{DWT} + \sqrt{\tau_{VT}^2 + \tau_{N-S}^2 + \tau_{E-W}^2}$$

WELDS SUBJECTED TO BOTH SHEAR & TENSION WILL BE EVALUATED BY COMBINING STRESSES:

CONSIDER THE MOHR'S CIRCLE REPRESENTATION OF A BODY SUBJECTED TO SHEAR & TENSION ON ONE FACE



$$\tau_{MAX} = R = \sqrt{\left(\frac{\sigma_p}{2}\right)^2 + \tau_p^2}$$

$$\sigma_{MAX} = \frac{\sigma_p}{2} + R = \frac{\sigma_p}{2} + \tau_{MAX}$$

τ_{MAX} WILL BE COMPARED TO THE SHEAR ALLOWABLE FOR THAT WELD

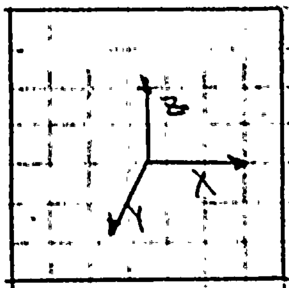
σ_{MAX} TO THE TENSION ALLOWABLE.

AN EQUIVALENT REQUIREMENT IS TO SATISFY THE ELLIPSE EQUATION:

$$\left(\frac{\sigma}{\sigma_{ALL}}\right)^2 + \left(\frac{\tau}{\tau_{ALL}}\right)^2 \leq 1.0$$

THE ABOVE REQUIREMENT ALSO SATISFIES THIS EQUATION.

6.0.2 N-S PLANE STRESS COMBINATIONS.



Fy IS ALWAYS COMPRESSIVE & SMALLER THAN THE TENSILE STRESSES. SINCE STRESSES DUE TO Fy WOULD REDUCE THE TENSILE STRESS, THIS EFFECT WILL CONSERVATIVELY BE NEGLECTED.

SHEARS: Fx & Fz

$\tau_{x1} = \frac{F_x}{A_w}$ $\tau_{z1} = \frac{F_z}{A_w}$ (A_w FROM SECT. 5.2)

My (TORSION) ALSO CAUSES WELD SHEAR STRESS

$\tau_{x2} = \frac{M_y Z_{max}}{I_p}$ $\tau_{z2} = \frac{M_y Y_{max}}{I_p}$ (I_p FROM SECT 5.4.3)

$\tau_{w1} = \sqrt{(\tau_{x1}+\tau_{x2})^2 + (\tau_{z1}+\tau_{z2})^2}$

Mx CAUSES TENSION ON THE TOP OR BOTTOM WELD.

$\sigma_1 = \frac{M_x}{S_x}$ (S_x FROM SEC. 5.4.1)

Mz ALSO CAUSES WELD TENSION, BUT ONLY IN BOTTOM:

$\sigma_2 = \frac{M_z}{S_z}$ (S_z FROM SEC. 5.4.2)

$\sigma_w = \sigma_1 + \sigma_2$.

VALUES ARE COMPUTED FOR EACH LOAD CASE & τ_{TOT} & σ_{TOT} COMPUTED USING SRSS METHOD.

$\tau_{TOT} = \tau_{DWT} + \sqrt{\tau_{VT}^2 + \tau_{NS}^2 + \tau_{EW}^2}$

$\sigma_{TOT} = \sigma_{DWT} + \sqrt{\sigma_{VT}^2 + \sigma_{NS}^2 + \sigma_{EW}^2}$

6.1 EAST-WEST PLANE

FORCES ARE TAKEN FROM TABLE IN SECTION 5.7.

WELD PROPERTIES FROM SECTION 5.2 & 5.3

$A_{WELD} = 46.8 \text{ IN}^2$

$J_p = 204700 \text{ IN}^4$

$S_y = 1675.7 \text{ IN}^3$

$S_z = 744.3 \text{ IN}^3$

MAX TENSION & SHEAR IN WELD DESCRIBED IN SECTION 5.2.1

6.1.1 DEAD WEIGHT: STD FUEL

$$\tau_{z1} = \frac{F_z}{A_w} = \frac{191.1}{46.8} = 4.08 \text{ KSI}$$

$$\tau_{x2} = \frac{M_x(79)}{J_p} = \frac{2004(79)}{204700} = \frac{2004}{2591} = 0.77 \text{ KSI}$$

$$\tau_{z2} = \frac{M_x(42.15)}{J_p} = \frac{2004(42.15)}{204700} = \frac{2004}{4856} = 0.41$$

$$\tau = \sqrt{(4.08+.41)^2 + (0.77)^2} = 4.56 \text{ KSI}$$

$$\sigma_{BOT} = \frac{M_y}{S_y} = \frac{2237}{1676} = 1.33 \text{ KSI}$$

$\sigma_{TOP} = 0.$

CONS. EVAL:

$\tau_z = \frac{3131}{44.8} + \frac{3283}{4856} = 7.37$

$\tau_y = \frac{3283}{2591} = 1.27$

$\tau = \sqrt{(7.37)^2 + (1.27)^2} = 7.47 \text{ KSI}$

$\sigma_{BOT} = \frac{3653}{1676} = 2.18 \text{ KSI} \quad \sigma_{TOP} = 0.0$

STRESS LIMIT A: $\tau_{ALL} = 20.5$ KSI (SEC 5.2.1)
$\sigma_{ALL} = 21.0$ KSI

AT TOP: $\sigma = 0 \quad \tau = 7.47$

$M.S. = \frac{21.0}{7.47} - 1.0 = +1.81$

BOT $\sigma = 2.18 \quad \tau = 7.47$

$\tau_{MAX} = 7.55 \quad M.S. = +1.72$
$\sigma_{MAX} = 8.64 \quad M.S. = +1.43$

7)

UST & D DESIGN SERVICES, INC. U.S. TOOL & DIE, INC.

BY DiPaola DATE 9/18/84 SUBJECT RG&E SECT. 6 SHEET 7 OF 21

CHKD. BY RS DATE 9-20-84 EW R VERT SEISMIC τ PROJ. NO. 8369

6.1.2 VERT SEISMIC (OBE & SSE)

STD FUEL:

$\tau_z = \frac{49.3}{46.8} + \frac{517}{4856} = 1.16$

$\tau_y = \frac{517}{2591} = 0.20$

$\tau_{TOT} = 1.18$

$\sigma_{BOT} = \frac{568}{1676} = 0.34$ $\sigma_{TOP} = 0.0$

CONS. FUEL

$\tau_z = \frac{82.1}{46.8} + \frac{862}{4856} = 1.93$

$\tau_y = \frac{862}{2591} = 0.33$

$\tau_{TOP} = 1.96$ KSI

$\sigma_{BOT} = \frac{973}{1676} = 0.58$ $\sigma_{TOP} = 0.0$

6.1.3 N-S SEISMIC LOADS

STRESSES DUE TO Fx ARE COMPRESSIVE & WILL CONSERVATIVELY BE NEGLECTED.

$$\tau_z = \frac{F_z}{46.8}$$

$$\sigma_{TOP} = \frac{M_y}{1676} \qquad \sigma_{BOT} = 0.0$$

LOADING COND	F_z	M_y	STRESS (KSI) τ	σ_{TOP}	σ_{BOT}
STD FUEL OBE	81.2	10761	1.73	6.42	0.0
SSE	180.2	14103	3.85	8.42	0.0
CONS. FUEL OBE	38.7	10441	0.83	6.23	0.0
SSE	130.3	15022	2.78	8.96	0.0

6.1.4 E-W SEISMIC LOADS

$$\tau_y = \frac{F_y}{46.8} + \frac{M_x}{2591}$$

$$\tau_z = \frac{F_z}{46.8} + \frac{M_x}{4856}$$

$$\tau = \sqrt{\tau_y^2 + \tau_z^2} = \tau_{TOP}$$

$$\sigma_{BOT} = \frac{M_y}{1676} + \frac{M_z}{144.3}$$

		STRESS IN KSI			
		τ_y	τ_z	τ_{TOP}	σ_{BOT}
STD FUEL	OBE	1.64	1.49	2.22	6.87
	SSE	1.80	1.48	2.33	7.16
CONS FUEL	OBE	2.04	0.98	2.26	6.29
	SSE	2.11	1.57	2.63	7.90

$\sigma_{TOP} = 0.01$

6.2 SUMMATION OF STRESSES - N-S PLANE

FORCES FROM SECTION 5.8

WELD PROPERTIES FROM SEC. 5.2 & 5.4

$A_{WELD} = 37.1 \text{ IN}^2$

$S_x = 1313 \text{ IN}^3$ — MAX IN WELD DESCRIBED IN SECT. 5.2.2. SPOT FUSION WELD (5.2.3) IS LESS SEVERELY LOADED IN BOTH SHEAR & TENSION.

$S_z = 155.5 \text{ IN}^3$

$I_p = 165,780 \text{ IN}^4$

$\tau_z = \frac{T(59)}{165780} = \frac{M_y}{2810}$

$\tau_x = \frac{T(79.5)}{165780} = \frac{M_y}{2085}$

6.2.1 DEADWT - STD FUEL -

$\tau_{z1} = \frac{F_z}{A_w} + \frac{M_y}{2810} = \frac{164.3}{37.1} + \frac{2106}{2810} = 5.18 \text{ KSI}$

$\tau_x = \frac{M_y}{2085} = \frac{2106}{2085} = 1.01 \text{ KSI}$

$\tau_{TOT} = \sqrt{(5.18)^2 + (1.01)^2} = 5.28 \text{ KSI}$

$\tau_{BOT} = \frac{M_x}{S_x} = \frac{1707}{1313} = 1.30 \text{ KSI}$

$\tau_{TOP} = 0.0$

CONS FUEL: $\tau_z = \frac{263.3}{37.1} + \frac{3447}{2810} = 8.49 \text{ KSI}$

$\tau_x = 3447/2085 = 1.65$

$\tau_{TOP} = \sqrt{(8.49)^2 + (1.65)^2} = 8.64 \text{ KSI}$

$\tau_{BOT} = \frac{2796}{1313} = 2.13 \text{ KSI}$

$\tau_{MAX} = \sqrt{\left(\frac{2.13}{2}\right)^2 + 8.64^2} = 8.71$ — M.S. = +1.36

$\tau_{MAX} = 9.77$ — M.S. = +1.15

6.2.2 VERTICAL SEISMIC (OBE & SSE)

STD FUEL

$$\tau_z = \frac{42.3}{37.1} + \frac{541}{2810} = 1.33$$

$$\tau_x = \frac{541}{2085} = 0.26$$

$$\tau = 1.36 \text{ KSI}$$

$$\sigma = \frac{440}{1313} = 0.34$$

CONS FUEL

$$\tau_z = \frac{70.6}{37.1} + \frac{907}{2810} = 2.22$$

$$\tau_x = \frac{907}{2085} = 0.44$$

$$\tau = 2.27 \text{ KSI}$$

$$\sigma = \frac{732}{1313} = 0.56$$

6.2.3 E-W. SEISMIC LOADS.

STRESSES DUE TO Fy ARE COMPRESSIVE & WILL CONSERVATIVELY BE NEGLECTED.

$\tau_z = \frac{F_z}{37.1} = \tau_{BOT}$

$\sigma_{TOP} = \frac{M_x}{1313}$

LOADING CONDITION	Fz	Mx	STRESS (KSI) τ	σ	τ BOT
STD. FUEL OBE	149.8	8261	4.04	6.29	0
SSE	145.1	8764	3.91	6.67	0
CON. FUEL OBE	77.7	8510	2.09	6.48	0
SSE	149.0	9935	4.02	7.57	0

6.2.4 N-S SEISMIC LOADS

$$\tau_x = \frac{F_x}{37.1} + \frac{M_y}{2085}$$

$$\tau_z = \frac{F_z}{37.1} + \frac{M_y}{2810}$$

$$\tau_{TOT} = \sqrt{\tau_x^2 + \tau_z^2}$$

$$\sigma_{BOT} = \frac{M_x}{1313} + \frac{M_z}{155.5} \qquad \sigma_{TOP} = 0.0$$

	STRESS (KSI)				
	τ_x	τ_z	τ_{TOT}	σ_{BOT}	σ_{TOP}
STD FUEL OBE	1.90	1.07	2.18	5.29	0
SSE	2.06	1.66	2.65	7.60	0
CONS FUEL OBE	2.08	0.91	2.27	4.78	0
SSE	2.56	1.56	3.00	7.54	0

6.3 FINAL SUMMATION OF STRESSES: E-W PLANE

THE SRSS METHOD IS APPLIED TO STRESSES COMPUTED IN SECTIONS 6.1.1 THRU 6.1.4.

SHEARS ARE A MAXIMUM AT THE WELDS AT THE FOUR CORNERS

TENSION IS A MAX. AT THE TOP OR BOTTOM WELDS:

$$\tau = \tau_{DWT} + \sqrt{\tau_{VT}^2 + \tau_{NS}^2 + \tau_{EW}^2}$$

$$\sigma = \sigma_{DWT} + \sqrt{\sigma_{VT}^2 + \sigma_{NS}^2 + \sigma_{EW}^2}$$

LOADING COND.		τ_{DWT}	τ_{VT}	τ_{N-S}	τ_{E-W}	SRSS
STD RACK	OBE	4.56	1.18	1.73	2.22	7.61
	SSE	4.56	1.18	3.85	2.33	9.21
CONS RACK	OBE	7.47	1.96	0.83	2.26	10.57
	SSE	7.47	1.96	2.78	2.63	11.77

TENSILE STRESS AT TOP OF RACK

LOADING CONDITION		σ_{DWT}	σ_{VT}	σ_{N-S}	σ_{E-W}	SRSS
STD RACK	OBE	0	0	6.42	0	6.42
	SSE	0	0	8.42	0	8.42
CON RACK	OBE	0	0	6.23	0	6.23
	SSE	0	0	8.96	0	8.96

TENSILE STRESS AT RACK BOTTOM

LOADING CONDITION		σ_{DWT}	σ_{VT}	σ_{N-S}	σ_{E-W}	
STD RACK	OBE	1.33	0.34	0	6.82	8.16
	SSE	1.33	0.34	0	7.11	8.45
	OBE	2.18	0.58	0	6.29	8.50
	SSE	2.18	0.58	0	7.90	10.10

E-W PLANE

MAXIMUM STRESSES OCCUR AT WELDS @ RACK BOTTOM

$$\tau_{max} = \sqrt{\left(\frac{\sigma}{2}\right)^2 + \tau^2}$$

$$\sigma_{max} = \frac{\sigma}{2} + \tau_{max}$$

LOADING COND.		τ	σ	τ_{max}	σ_{max}
STD RACK	OBE	7.61	8.16	8.63	12.71
	SSE	9.21	8.45	10.13	14.36
CONS RACK	OBE	10.57	8.50	11.39	15.64
	SSE	11.77	10.10	12.86	17.86

Level B

τ_{max} IS COMPARED TO τ_{ALL} = 27.3 KSI OBE
28.7 KSI SSE

σ_{max} IS COMPARED TO σ_{ALL} = 28.0 KSI OBE
33.6 KSI SSE

MARGIN OF SAFETY = $\frac{\text{ALLOWABLE STRESS}}{\text{CALCULATED STRESS}} - 1.0$

MARGIN OF SAFETY		SHEAR	NORMAL	MINIMUM
STD RACK	OBE	+2.16	+1.20	+1.20
	SSE	+1.83	+1.34	+1.34
CONS. RACK	OBE	+1.40	+0.79	+0.79
	SSE	+1.24	+0.88	+0.88

6.4 FINAL SUMMATION OF STRESSES N-S PLANE

STRESSES FOR EACH LOAD CASE COMPUTED IN SECTIONS 6.2.1 THRU 6.2.4

SHEARS ARE A MAXIMUM AT 4 CORNER WELDS

TENSION MAXIMUM AT TOP OR BOTTOM WELDS

$$\tau = \tau_{DWT} + \sqrt{\tau_{VT}^2 + \tau_{NS}^2 + \tau_{EW}^2}$$

$$\sigma = \sigma_{DWT} + \sqrt{\sigma_{VT}^2 + \sigma_{NS}^2 + \sigma_{EW}^2}$$

LOADING CONDITION	τ_{DWT}	τ_{VT}	τ_{EW}	τ_{NS}	SRSS
STD RACK OBE	5.28	1.36	4.04	2.18	10.07
SSE	5.28	1.36	3.91	2.65	10.20
CONS RACK OBE	8.64	2.27	2.09	2.27	12.47
SSE	8.64	2.27	4.02	3.00	14.15

TENSILE STRESS AT TOP OF RACK

	σ_{DWT}	σ_{VT}	σ_{EW}	σ_{NS}	SRSS
STD RACK OBE	0	0	6.29	0	6.29
SSE	0	0	6.67	0	6.67
CONS RACK OBE	0	0	6.48	0	6.48
SSE	0	0	7.57	0	7.57

TENSILE STRESS AT BOTTOM OF RACK

	σ_{DWT}	σ_{VT}	σ_{EW}	σ_{NS}	SRSS
STD RACK OBE	1.30	0.34	0	5.29	6.60
SSE	1.30	0.34	0	7.60	8.91
OBE	2.13	0.56	0	4.78	6.94
SSE	2.13	0.56	0	7.54	9.69

N-S PLANE

MAXIMUM STRESSES OCCUR AT BOTTOM OF RACK

$$\tau_{max} = \sqrt{\left(\frac{\sigma}{2}\right)^2 + \tau^2}$$

$$\sigma_{max} = \frac{\sigma}{2} + \tau_{max}$$

LOADING CONDITION		σ	τ	τ_{max}	σ_{max}
STD RACK	OBE	10.07	6.60	10.60	13.90
	SSE	10.20	8.97	11.13	15.59
CONS RACK	OBE	12.47	6.94	12.94	16.41
	SSE	14.15	9.69	14.96	19.80

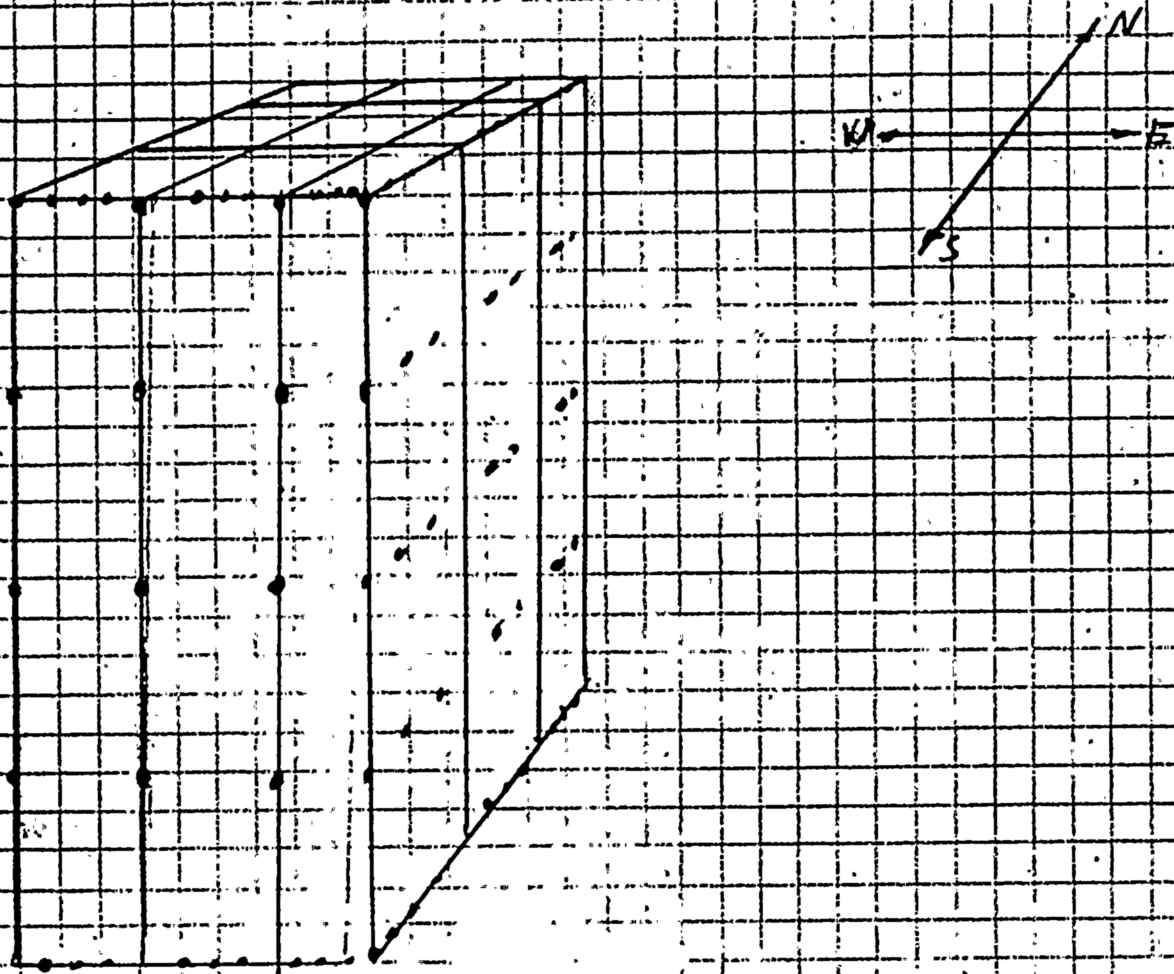
τ_{ALL} = 27.3 KSI OBE
28.7 KSI SSE

SINCE TENSION ALSO CAUSES SHEAR (IN BASE MATERIAL) ALLOWABLE TENSILE = ALLOWABLE SHEAR

$$\text{MINIMUM M.S.} = \frac{\tau_{ALL}}{\tau_{CALC}} - 1.0$$

LOADING CONDITION		M.S.
STD RACK	OBE	+0.96
	SSE	+0.84
CONS RACK	OBE	+0.66
	SSE	+0.45

6.5 SHEAROUT STRESSES AT CORNERS.



THE CRUICFORM SUPPORT CAUSES THREE BOXES TO ACT TOGETHER AT THE CORNERS.

WELD AREA

12 SETS OF 3-1in FILLET WELD - 0.18 tk

$A = (12)(3)(0.18) = 6.48 \ in^2$

6 SETS OF 5-2in FILLET WELD = 0.18 tk

$A = (6)(5)(2)(0.18) = 10.80 \ in^2$

3 SETS OR 8 - FUSION WELDS: $A = 0.196 in^2$

$A = (3)(8)(0.196) = 4.70 \ in^2$

USI & D DESIGN SERVICES, INC. U.S. TOOL & DIE, INC.

BY DiPaolo DATE 9/18/89 SUBJECT STRESSES AT CORNERS SECT. 6 SHEET 19 OF 24

CHKD. BY RS DATE 9-20-89 PROJ. NO. 8369

6.5 - Cont -

TOTAL WELD AREA =

At = 6.48 + 10.80 + 4.70 = 21.98 in²

THE RMS VALUES FROM SET #4 OF THE SUMMARY OF LOADS FROM SECTION 2.0 ARE:

MAXIMUM VERTICAL FORCES

	STANDARD RACK		CONSOLIDATED RACK	
	OBE	SSE	OBE	SSE
RMS LOAD	205 567	237 862	225 573	282 782
σ = F/A	9,350	10,820	11,263	12,860

M.S. - OBE

M.S. = 27,900/11,260 - 1

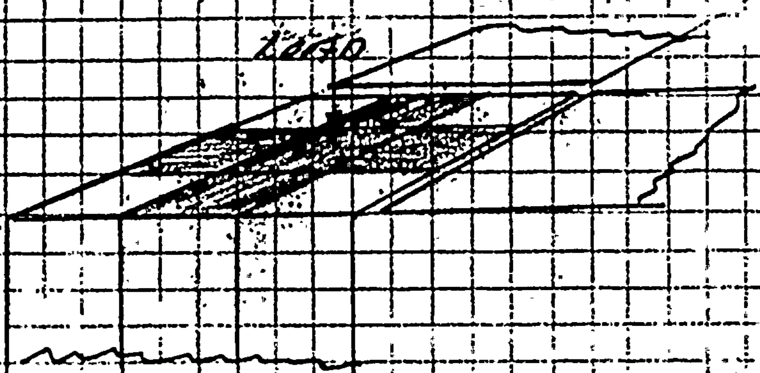
M.S. = 1.72

M.S. SSE

M.S. = 28,700/12,860

M.S. = +1.22

6.4 - BUCKLING STRESS IN BOX SIDES



THE LOAD IS DISTRIBUTED OVER THE CRUCIFORM SUPPORT PLATE AS SHOWN. THE TOTAL NUMBER OF SIDES SEEING THE LOAD IS

INTERNAL - 28 SIDES (2 AT EACH 13 OX)

EXTERNAL - 2 SIDES

TOTAL AREA -

30 SIDES x 8.43 in LONG PER SIDE x 0.09 in TK.

= 22.76 in^2

THE CRITICAL BUCKLING STRESS IS GIVEN

BY: $\sigma_{CR} = \frac{K \pi^2 E}{12(1-\mu^2)} \left(\frac{t}{b}\right)^2$ REF #5 p. 2.12

WHERE: t = PLATE THICKNESS = 0.09

b = PLATE WIDTH = 8.64

E = YOUNGS MODULUS = 28E6

μ = POISSONS RATIO = 0.3

K = CONSTANT - (FIXED-FIXED) = 6.97

$$\sigma_{CR} = (6.97)(\pi)^2 \frac{(28E06)}{10.92} \left(\frac{0.09}{8.40}\right)^2 = 20,250 \text{ PSI}$$

$$\sigma_{ALL} = \tfrac{2}{3}\sigma_{CR} = 13,500 \text{ PSI}$$

6.6 - CONT

	STANDARD RACK		CONSOLIDATED RACK	
	OBE	SSE	OBE	SSE
LOAD = F RMS SET #4	205,562	232,862	225,573	282,782
S = P/A (KSI)	9.03	10.45	9.91	12.42
M.S.	+0.49	+0.29	+0.36	+0.09

$$M.S. = \frac{T_{ALL}}{S} - 1.0$$

SECTION 7.0

FLOOR LOADS DEVELOPED FROM SEISMIC EVENTS

7.0 FLOOR LOADS

7.1 TOTAL FLOOR LOAD

THE MODIFIED RACKS ARE IN REGION #2. THERE ARE SIX (6) RACKS IN THIS REGION. THE TOTAL FLOOR LOAD FOR THE SIX RACKS IS

(6) (SUBMERGED WT.)

THE SWT VALUES ARE GIVEN IN SECT. 2.0

	SWT (LB)	TOTAL FLOOR LOAD (LB)
STANDARD RACK	208,190	1,249,000
CONSOLIDATED RACK	341,060	2,046,360

7.2 BEARING STRESS ON CONCRETE

THE FLOOR PLATES ARE

$11 \text{ in} \times 11 \text{ in} \times 3/4 \text{ in} = 121 \text{ in}^2$ (BEARING)

THE MAXIMUM LOADS ARE THOSE SHOWN IN THE SUMMARY OF RESULTS FROM THE SEISMIC ANALYSIS. THESE VALUES ARE GIVEN IN SECT. 2, SET #4. RMS VALUES ARE USED TO DETERMINE THE BEARING STRESS.

REV 1, 3/6/84 JLD

7.2 - CONT.

	STANDARD RACK		CONSOLIDATED RACK	
	OBE	SSE	OBE	SSE
FLOOR LOAD (LB)	205,567	237,862	225,523	282,782
BEARING STRESS	1700	1965	1864	2337

ALLOWABLE CONCRETE BEARING STRESS (REF. 6)

$S_B = 0.85\ \phi\ f'_c = (0.85)(0.7)(3000\ PSi)$

$S_B = 1785\ PSi$

"AS THE SUPPORTING SURFACE IS WIDER ON ALL SIDES THAN THE LOADED AREA, THE PERMISSIBLE BEARING STRESS ON THE LOADED AREA MAY BE MULTIPLIED BY $\sqrt{A_1/A_2}$ BUT NOT MORE THAN 2

$\therefore S_B = (1785\ PSi)(2) = \underline{3570\ PSi}$

$MIN.\ F.S. = 3570\ PSi / 2337 = 1.53$

SECTION 8.0

EXTERNAL LOADINGS

8.1 STRAIGHT DROP OF A FUEL ASSEMBLY THROUGH AN INDIVIDUAL CELL

THE FUEL BUNDLE DROP CONSIDERED IS A STRAIGHT DROP INTO A FUEL SPACE. THE PROBABILITY OF THIS IS MORE REMOTE THAN ANY OTHER ACCIDENT. IT IS MOST LIKELY THAT THE FUEL BUNDLE WILL STRIKE THE TOP OF THE FUEL BOX AND BE DEFLECTED SO THAT THE ENERGY IS DISSIPATED IN DEFORMATION OF THE BOX OR FUEL BUNDLE ITSELF.

THIS POSTULATED DROP ACCIDENT WOULD CAUSE THE FUEL ASSEMBLY TO IMPACT THE BOTTOM PLATE IN THE CELL. THE CLEARANCE BETWEEN FUEL DIMENSIONS AND BOX DIMENSIONS ARE QUITE CLOSE; THUS THE FUEL ASSEMBLY WOULD BECOME A LEAKY PISTON AND THE FUEL BOX WOULD BECOME A LEAKY CYLINDER. THE HYDRAULIC FORCES GENERATED WHEN THE FUEL ASSEMBLY INITIALLY ENTERS THE FUEL BOX ARE QUITE LARGE AND SERVE TO RETARD THE FUEL ASSEMBLY DURING THE NEXT 13.25 FEET OF ITS DESCENT. THUS IT IS UNKNOWN AS TO THE AMOUNT OF ENERGY IMPARTED TO THE BOTTOM PLATE. THE CAPACITY OF THE 0.090" WELDS WHICH ATTACH THE BOTTOM PLATE TO THE CELL ARE ESTIMATED TO BE PLASTICALLY DEFORMED TO FAILURE IF LOADED HIGH ENOUGH. THIS FAILURE LOAD ESTIMATE IS BASED ON 30,000 psi ULTIMATE SHEAR STRENGTH AND A TYPICAL PLASTIC DEFORMATION OF 20%. THE AREA IN SHEAR IS

0.090" x 4(8.25")=2.97 in.

ENERGY=30,000 psi x (20% x 0.090") x 2.97 in. =1604 in-lbs

COMPARING THIS VALUE TO THE ENERGY AVAILABLE FROM THE STRAIGHT DROP ON THE RACK, WHICH IS 43,500 in-lb WHEN THE FUEL ASSEMBLY IS CONSIDERED AS A RIGID BODY FOR A 30" DROP, THE BOTTOM PLATE WELDS WOULD FAIL.

THIS ACCIDENT WOULD RENDER ONE STORAGE LOCATION UNUSABLE. HOWEVER, THE PHYSICAL CONFIGURATION OF THE SPENT FUEL STORAGE CELLS WILL NOT BE CHANGED;THEREFORE, THE SUB-CRITICAL ARRAY OF THE RACK WILL BE MAINTAINED.