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U. S. TOOL & DIE, INC.
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# MECHANICAL ANALYSIS
# SPENT FUEL STORAGE RACKS
# MODIFIED TO 100% STORAGE DENSITY
# (IN REGION 2 )

R. E. GINNA NUCLEAR STATION

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8369-00-0014
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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

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|---|---|---|
| | | RECORD OF REVISION |
| 3-6-84 | 1 | TABLE OF CONTENTS |
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| 3-6-84 | 1 | SECTION 8 PAGE 1 OF 2 ADDED<br>PAGE 2 OF 2 ADDED |

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# SECTION 1.0

# INTRODUCTION

INTRODUCTION

THE SPENT FUEL STORAGE RACKS ARE CLASSIFIED AS CATEGORY I 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 are not BEING MOVED FROM THEIR PRESENT LOCATIONS WITH THE JACKSCREWS CENTERED ON THE 11" X 11" FLOOR PLATES. THERE IS ENOUGH ~~EDGE~~ DISTANCE to the edge 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 at 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)---

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 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)

| | 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)--

| | | |
|---|---|---|
| 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, 00. | ------------- | 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

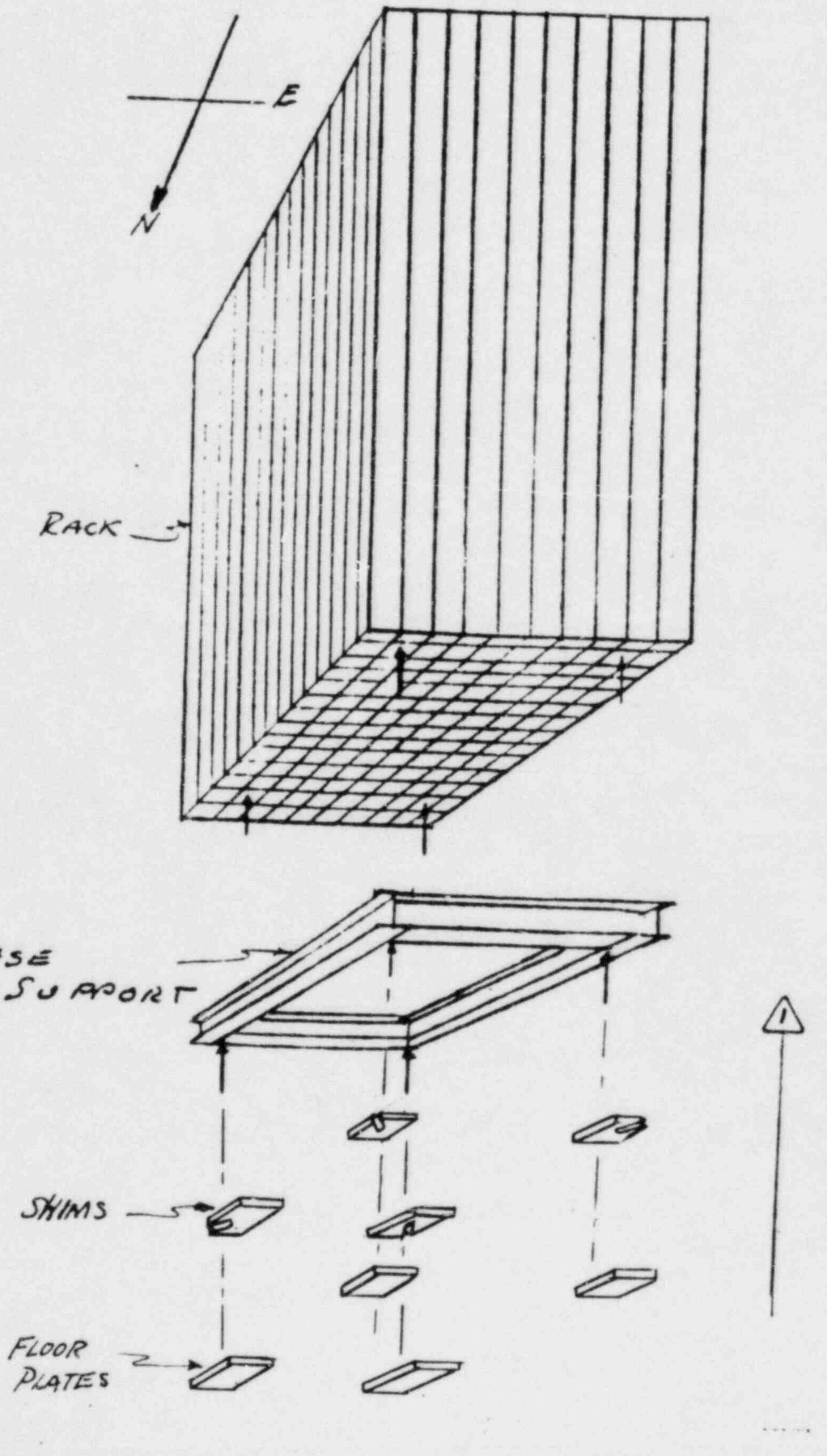
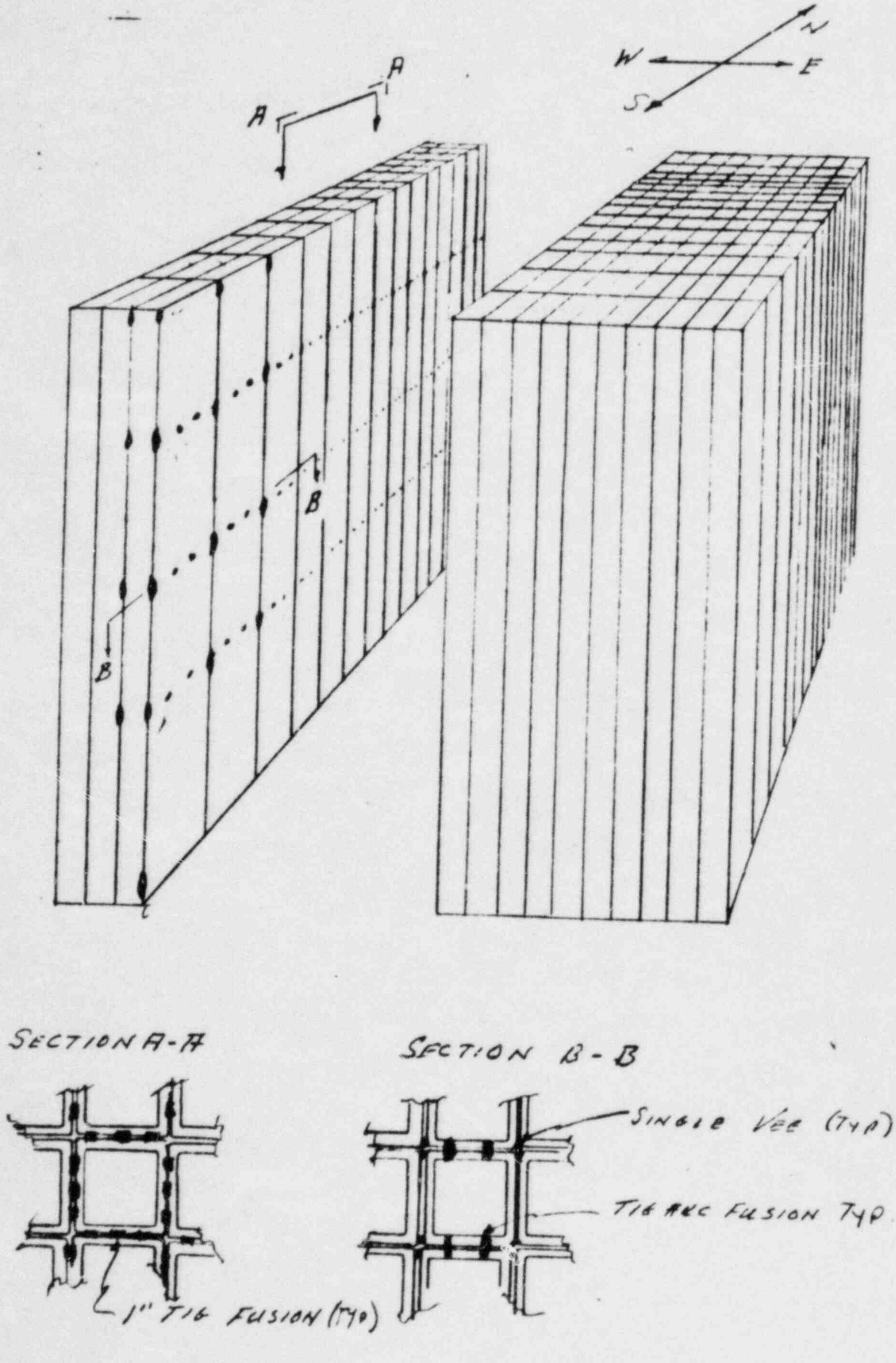


FIG 2.2


N
W
E
S
A
A
B
B
SECTION A-A
SECTION B-B
SINGLE VEE (TYP)
TIG ARC FUSION TYP
1" TIG FUSION (TYP)

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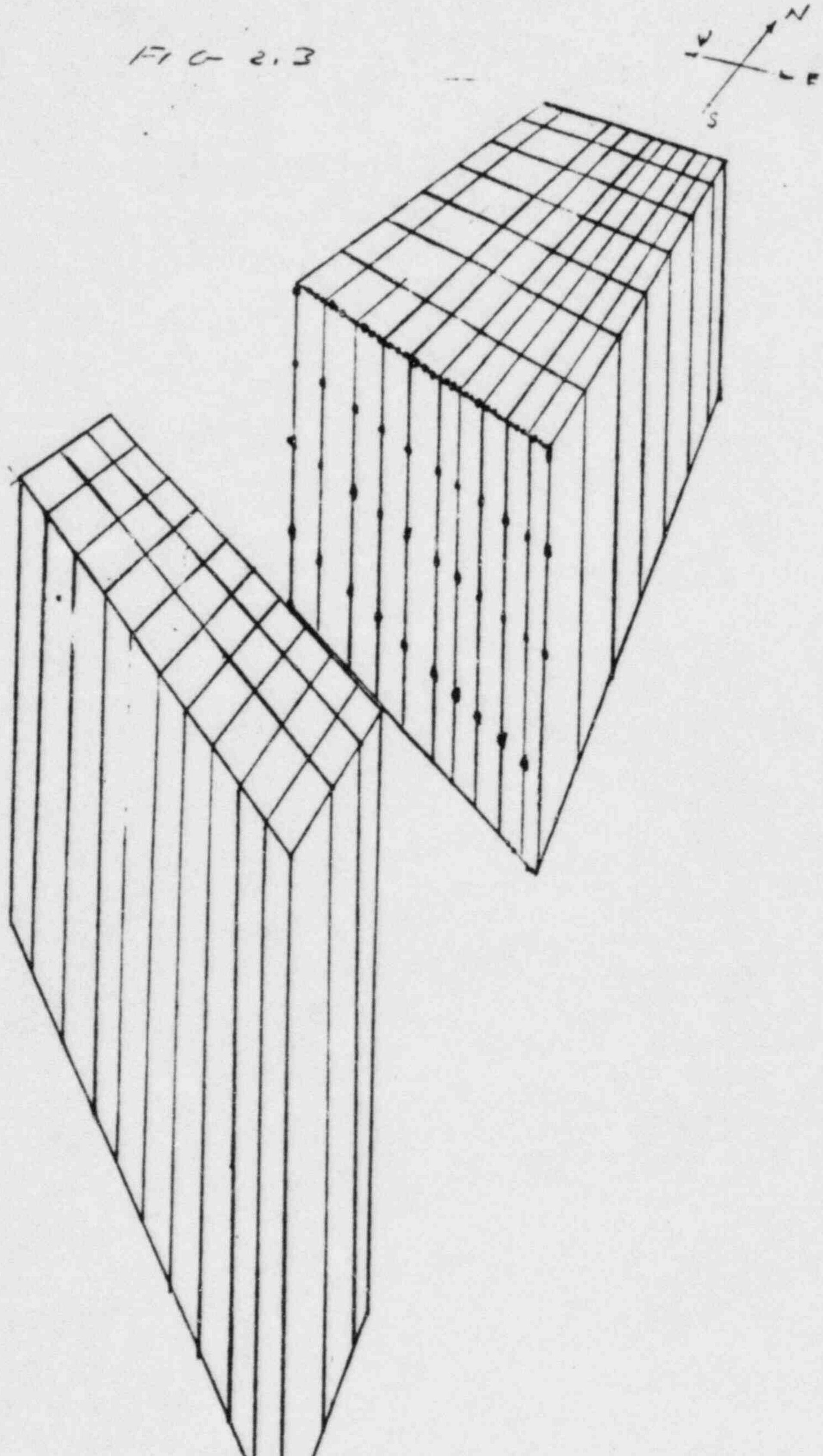
... TOOL & DIE, INC

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

# SUMMARY OF STRESSES

THE STRESSES ARE SUMMARIZED IN TABLE 3.1 FOR

a. SHEAR IN WELDS NO. 1, 2 & 3 SHOWN OF FIGURES 3.1 AND 3.2.

b. SHEAR OUT OF THE CORNER 9 BOXES (SHADED AREA, FIG. 3.1)

c. BUCKLING OF THE BOX WALLS

d. FLOOR LOADS UNDER THE 11 in. X 11 in. BASE PLATE

THE STRESSES IN WELDS NO. 1, 2 & 3 ARE DETERMINED BY CALCULATING THE RMS VALUES OF THE SHEAR LOAD, VERTICAL AND HORIZONTAL TO GET THE NS, EW, VT AND SWT LOADS. THE FORCE IN THE WELD IS CALCULATED BY,

$$F = SWT \pm \sqrt{\overline{Fns}^2 + \overline{Few}^2 + \overline{Fvt}^2}$$

THE SHEAR OUT OF THE CORNER, THE BUCKLING LOAD ON THE PLATE AND THE FLOOR LOAD ARE DETERMINED BY USING THE RMS VALUES FOR THE INDIVIDUAL SUPPORTS GIVEN IN SECTION # 2.

THE MAXIMUM STRESSES IN WELDS 1, 2, & 3 ARE;

| | | | | | |
|---|---|---|---|---|---|
| STD. | RACK, | E-W PLANE, | OBE, | 19,970 psi, | WELD #2 |
| " | " | N-S PLANE, | SSE, | 21,700 psi, | WELD #2 |
| CON. | RACK, | E-W PLANE, | OBE, | 16,940 psi, | WELD #2 |
| " | " | E-W PLANE, | SSE, | 23,340 psi, | WELD #1 |

THE MAXIMUM SHEAROUT STRESSES IN THE CORNERS ARE

| | | |
|---|---|---|
| STD RACK, | OBE, | 11,940 psi |
| " " | SSE, | 13,800 psi |
| CON RACK, | OBE, | 13,110 psi |
| " " | SSE, | 16,430 psi |

THE MAXIMUM FLOOR LOADS IN THE 11 in. X 11 in. BASE PLATE ARE

| | | |
|---|---|---|
| STD. | OBE, | 1700 psi |
| " | SSE, | 1965 psi |
| CON. | OBE, | 1860 psi |
| " | SSE, | 2340 psi |

THE ALLOWABLE WELD OBE SHEAR STRESS IS 24,000 psi (REF. 3, SECT. NF 3000, TABLE NF-3292.1-1) 1

THE ALLOWABLE WELD SSE SHEAR STRESS IS 38,400 psi (1.6 OBE (REF. 7, SRP 3.8.4.5(b)))

THE CRITICAL BUCKLING STRESS IS 19,140 psi (SECT. 6.19)

FLOOR LOADS

THE SIX MODIFIED RACKS ARE IN REGION #2. USING THE SUBMERGED WEIGHT FOR THE RACK THE TOTAL FLOOR LOADS ARE

| | |
|---|---|
| STANDARD RACK | 1,249,000 LBS |
| CONSOLIDATED RACK | 2,046,360 LBS |

THE BEARING STRESS ON THE CONCRETE UNDER THE 11 IN. X 11 IN. X 3/4 IN. SUPPORT PLATES ARE

| LOADS IN POUNDS | STANDARD RACK OBE | STANDARD RACK SSE | CONSOLIDATE RACK OBE | CONSOLIDATE RACK SSE |
|---|---|---|---|---|
| FLOOR LOAD | 205,567 | 237,862 | 225,573 | 282,782 |
| BEARING STRESS | 1700 | 1965 | 1864 | 2337 |

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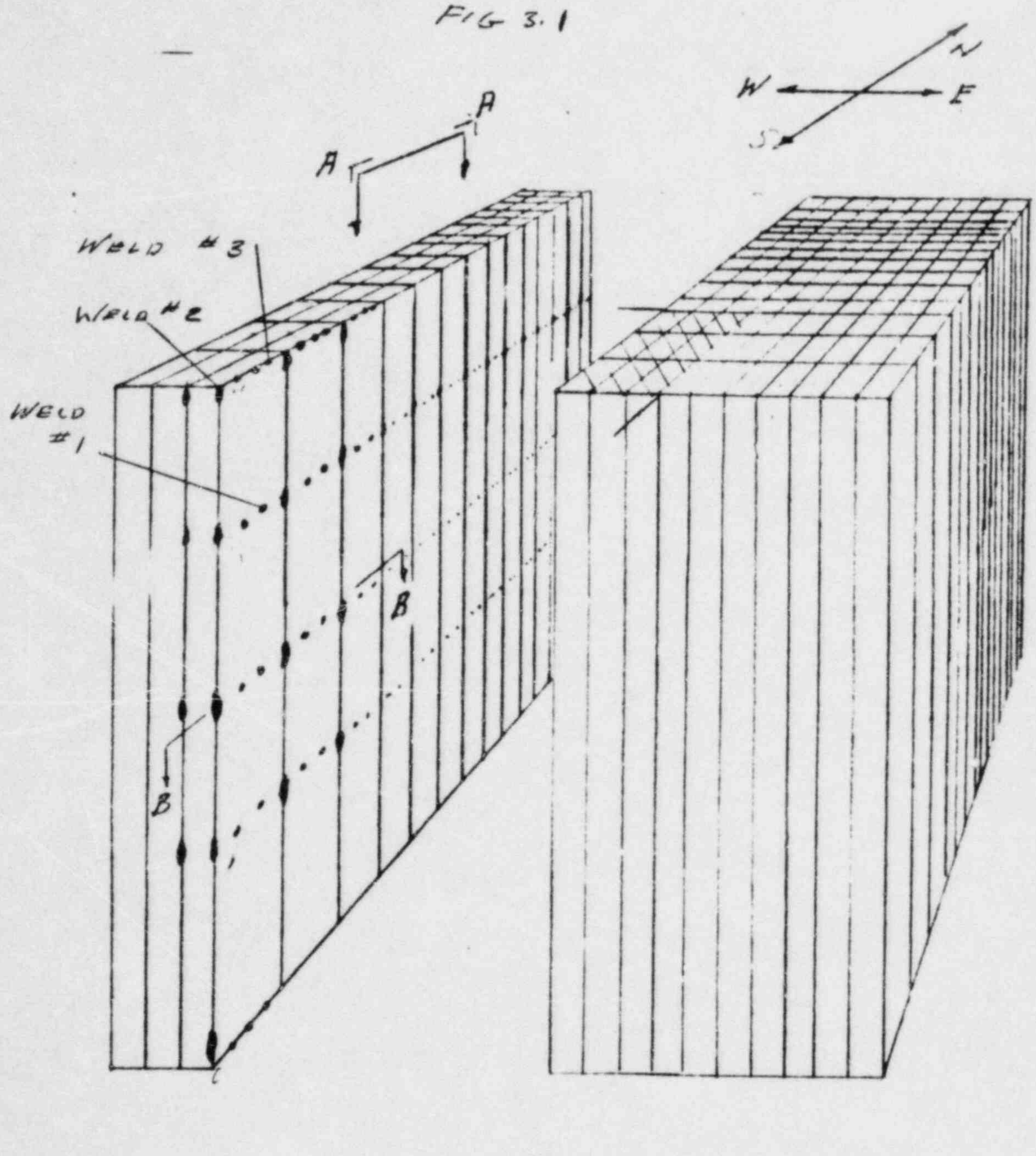
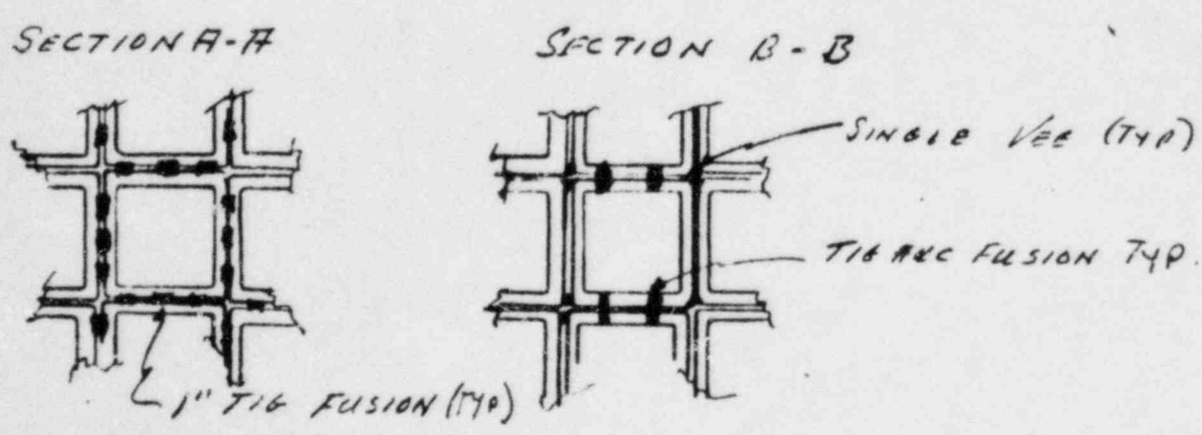
BY Hnw DATE 12/12/83 SUBJECT RACK WELDS SECT. 3 SHEET 4 OF 6

CHKD. BY VLD DATE 2/23/84 NORTH - SOUTH PLANE PROJ. NO. 8369

FIG 3.1



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BY [signature] DATE 1/5/84 SUBJECT RACK WELD SECT. 3 SHEET 5 OF 6

CHKD. BY JLD DATE 2/23/85 EAST-WEST PLANE PROJ. NO. 8369

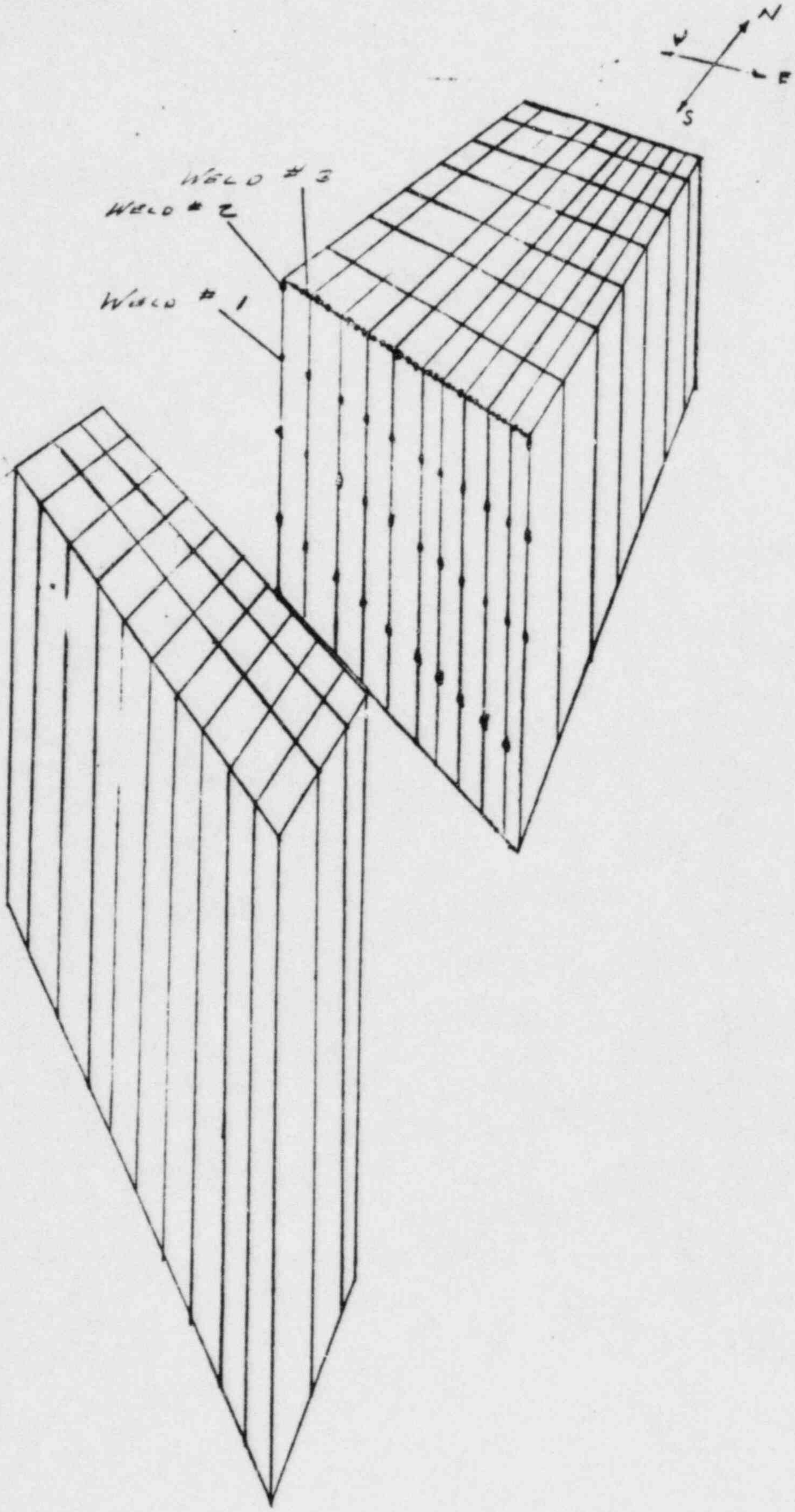

TABLE 3.1

SUMMARY OF STRESSES

| | NORTH-SOUTH PLANE | | | | EAST WEST PLANE | | | |
|---|---|---|---|---|---|---|---|---|
| | STANDARD | | CONSOLIDATED | | STANDARD | | CONSOLIDATED | |
| | OBE | SSE | OBE | SSE | OBE | SSE | OBE | SSE |
| WELD #1 | 11680 | 16200 | 7980 | 17330 | 18480 | 18660 | 14260 | 21260 |
| WELD #2 | 14800 | 21700 | 11280 | 22100 | 19970 | 20270 | 16940 | 23340 |
| WELD #3 | 11350 | 17700 | 12170 | 17200 | 18880 | 19320 | 16720 | 22430 |
| CORNER SHEAROUT * | 11,950 | 13,800 | 13,110 | 16,430 | 11,950 | 13,820 | 13,100 | 16,430 |
| BOX BUCKLING STRESS * | 8800 | 10,200 | 9670 | 12,120 | 8800 | 10,200 | 9670 | 12,120 |
| MAX FLOOR LOADS * | 1700 | 1965 | 1860 | 2340 | 1700 | 2000 | 1860 | 2340 |

* THESE VALUES ARE COMMON TO BOTH PLANES, WELD STRESSES 1, 2, & 3 ARE FROM SECTIONS 6.10 THRU 6.17
CORNER SHEAROUT FROM SECTION 6.18
FLOOR LOADS FROM SECTION 7.0

# 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 Vessels, NUCLEAR VESSELS, Section III, 1980 ed. |
| 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 |

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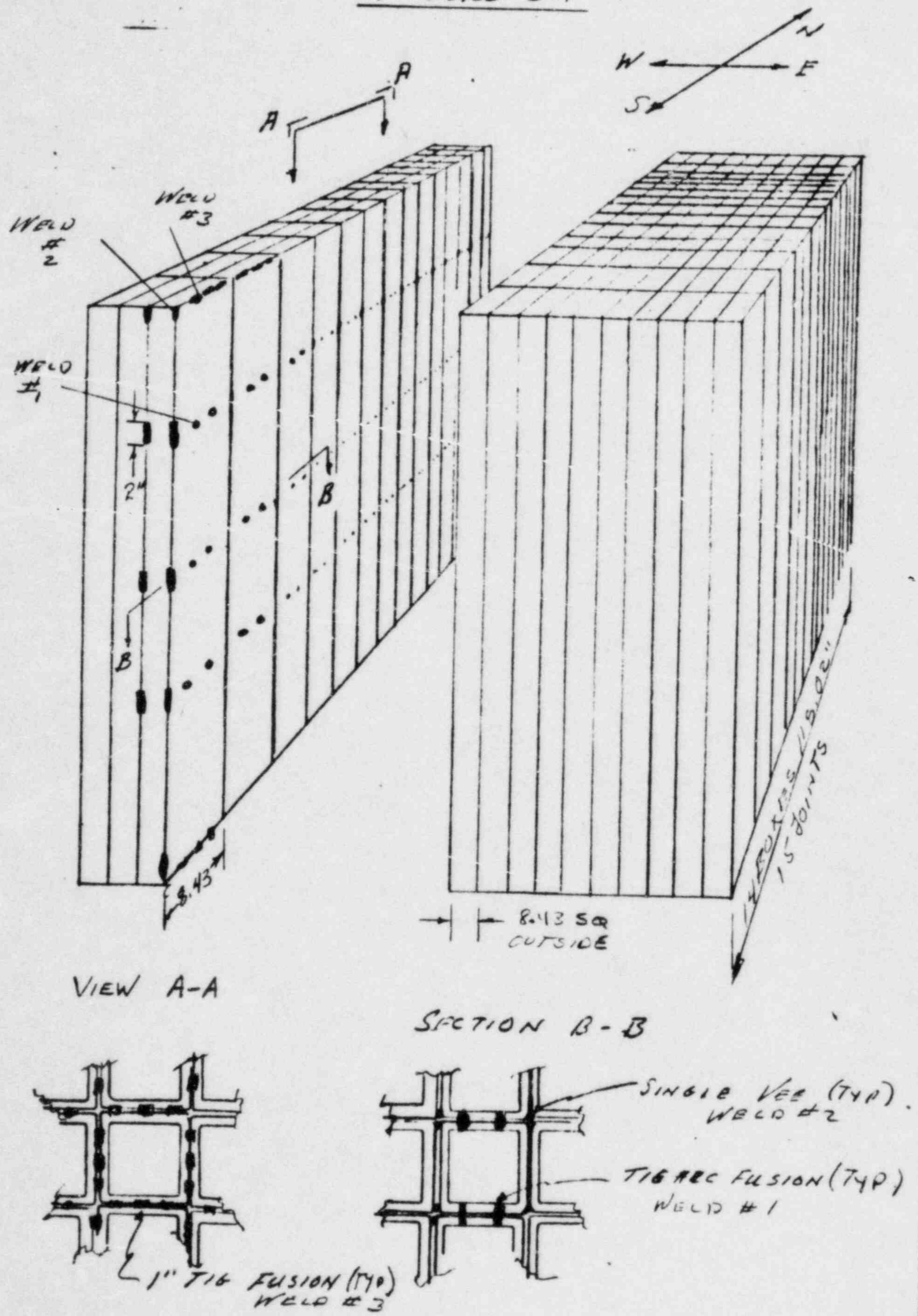
S.1 DISCUSSION.

IN THIS SECTION THE FORCES THAT OCCUR IN THE WELD DUE TO SEISMIC LOADINGS ARE DEVELOPED. THE FORCES DEVELOPED IN SECTION 5 ARE FOR SETS OF WELD. THE FORCES ON THE INDIVIDUAL WELDS ARE GIVEN IN SECTION 6.0.

THE FORCES IN THE WELDS ARE DEVELOPED FOR THE NORTH-SOUTH PLANE AS SHOWN ON FIG 5.1 AND THE EAST WEST PLANE AS SHOWN ON FIGURE 5.2.

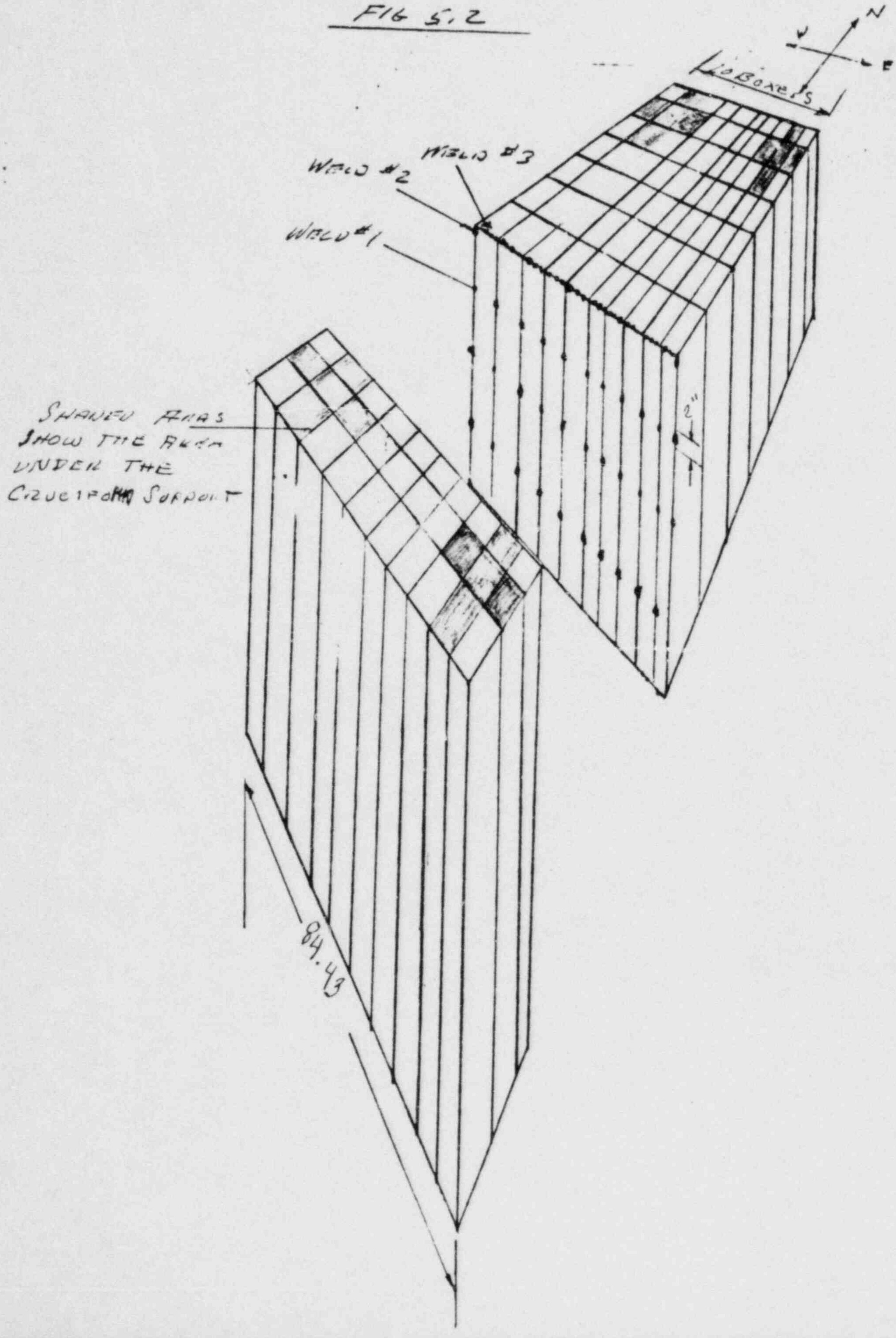
THE CRUCIFORM SUPPORT PLATE ENCOMPASSES 3 ROWS OF BOXES IN BOTH THE NORTH-SOUTH AND EAST-WEST DIRECTION. THE FORCES ARE DEVELOPED ON THE THREE BOX PLANES AS SHOWN IN FIGURES # 5.1 AND 5.2.

FIGURE 5.1


N
W
E
S
A
A
WELD #2
WELD #3
WELD #1
2"
B
B
8.43
8.43 SQ OUTSIDE
12 BOXES 11 SLOTS
15 JOINTS
VIEW A-A
SECTION B-B
SINGLE VEE (TYP) WELD #2
TIG ARC FUSION (TYP) WELD #1
1" TIG FUSION (TYP) WELD #3

EAST-WEST PLANE

FIG 5.2



## 5.2 RACK WELD AREA

### 5.2.1 NORTH SOUTH PLANE

THE NORTH SOUTH PLANE CONSIST OF:

WELD #

6 FUSIONS WELDS PER BOX 0.5 in DIAM.

1 $A = \frac{\pi}{4}(0.5)^2(6)(14\ \text{BOXES}) = 16.5\ in^2$

3 3 FILLET WELDS 1 in lg - TOP & BOTTOM.

THE WELD THICKNESS IS APPROXIMATELY 0.18 in ACROSS THE THROAT.

$A = (3)(2)\ \text{EA BOX}\ (1\ in)(0.18\ in)(14)\ \text{BOXES} = 15.12\ in^2$

2 5 FILLET WELDS AT EA. BOX INTERSECTION END, 2" lg.

$A/\text{SEAM} = 5\ ea\ (2''\ lg)(0.18\ th) = 1.80\ in^2$

$A = 1.80(2) = 3.60\ in^2$

$A_{T\,NS}\ 16.5 + 15.12 + 3.60 = 35.22\ in^2$

### 5.2.2 EAST - WEST PLANE

THE EAST WEST PLANE CONSIST OF:

1 5 FILLET WELDS 2 in lg. x 11 SEAMS.

2 $A = (5)(2)(0.18)(11) = 19.8\ in^2$

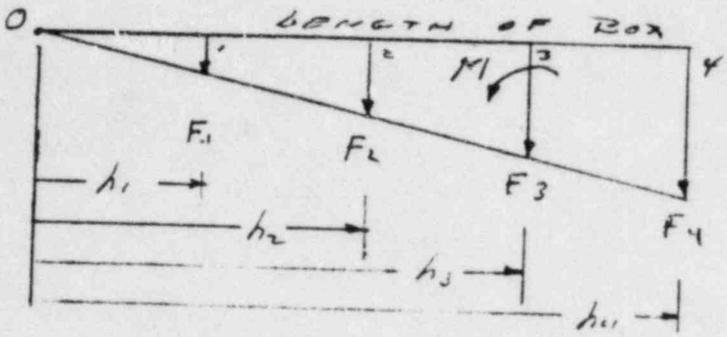
3 FILLET WELD TOP AND BOTTOM 1 in lg

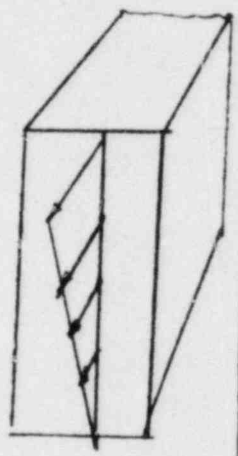
3 $A = (3)(1)(2)(0.18)(10\ \text{BOXES}) = 10.8\ in^2$

$A_{T\cdot EW} = 19.8 + 10.8 = 30.6\ in^2$

## 5.3 FORCES ON WELDS DUE TO MOMENT

ASSUME ROTATION WILL TAKE PLACE AROUND TOP OR BOTTOM OF BOX



$$\frac{\Delta_4}{h_4} = \frac{\Delta_3}{h_3} = \frac{\Delta_2}{h_2} = \frac{\Delta_1}{h_1}$$

$$\Delta = \frac{F l}{A E}$$

ASSUME $\frac{l_1}{E_1} = \frac{l_2}{E_2} = \frac{l_3}{E_3} = \frac{l_4}{E_4}$

$$\frac{F_4}{A_4 h_4} = \frac{F_3}{A_3 h_3} = \frac{F_2}{A_2 h_2} = \frac{F_1}{A_1 h_1}$$

$\Sigma M_0 = 0$

$$M_0 = F_1 h_1 + F_2 h_2 + F_3 h_3 + F_4 h_4$$

$$= \frac{F_4 A_1 h_1^2}{A_4 h_4} + \frac{F_4 A_2 h_2^2}{A_4 h_4} + \frac{F_4 A_3 h_3^2}{A_4 h_4} + \frac{F_4 A_4 h_4^2}{A_4 h_4}$$

$$F_4 = \frac{M A_4 h_4}{A_1 h_1^2 + A_2 h_2^2 + A_3 h_3^2 + A_4 h_4^2}$$

$$F_3 = \frac{M A_3 h_3}{\Sigma A_i h_i^2} \qquad F_1 = \frac{M A_1 h_1}{\Sigma A_i h_i^2}$$

## 5.3.1 WELD AREAS ASSOCIATED WITH $F_i$'s

### 5.3.1.1 - NORTH - SOUTH LOADING - EAST WEST PLANE

$A_4$ (TOP OR BOTTOM ROW)

10 BOXES WIDE X 3EA/BOX X 1in X 0.18

11EA 2in Lg X 0.18.

$A_4 = (10)(3)(1'')(0.18'') + (11)(2'')(0.18'')$

$= 5.40 + 3.96 = 9.36 \text{ in}^2$

$A_3 = A_2 = A_1$

11EA 2in Lg X 0.18 FILLET WELDS

$A_3 = A_2 = A_1 = (11)(2)(0.18) = 3.96 \text{ in}^2$

### 5.3.1.2 - EAST - WEST LOADING - NORTH - SOUTH PLANE

$A_4$ (TOP OR BOTTOM ROW)

14 BOXES WIDE - 3EA 1in X 0.18

2 EA 2in Lg X 0.18

$A_4 = (14)(3)(1)(0.18) + (2)(2)(0.18)$

$= 7.56 + 0.72 = 8.28 \text{ in}^2$

$A_3 = A_2 = A_1$

14 BOXES - 2 FUSION WELDS/BOX 0.5 in DIAM

2 EA 2in X 0.18

$A_3 = A_2 = A_1 = (14)(2)\left(\frac{\pi}{4}\right)(0.5)^2 + (2)(2)(0.18) = 6.22 \text{ in}^2$

$h_1 = 39.5''$ $h_2 = 79.0''$ $h_3 = 118.5''$ $h_4 = 158.0''$

5.3.2 FORCES $F_4$ & $F_3$

5.3.2.1 NORTH - SOUTH LOADING. - E-W PLANE

$$F_4 = \frac{M(9.36)(158.0)}{3.96(39.5^2 + 79^2 + 118.5^2) + 9.36(158)^2}$$

$$= 4.619\ E-03\ M$$

$$F_3 = \frac{M(3.96)(118.5)}{\Sigma A_i h_i^2} = 1.466\ E-03\ M$$

$$F_1 = \frac{M(3.96)(39.5)}{\Sigma A_i h_i^2} = 0.488\ E-03\ M$$

5.3.2.2 EAST - WEST LOADING. - N-S PLANE

$$F_4 = \frac{M(8.28)(158.0)}{6.22(39.5^2 + 79^2 + 118.5^2) + 8.28(158)^2}$$

$$= 3.81?\ E-03\ M$$

$$F_3 = \frac{M(6.22)(118.5)}{\Sigma A_i h_i^2}$$

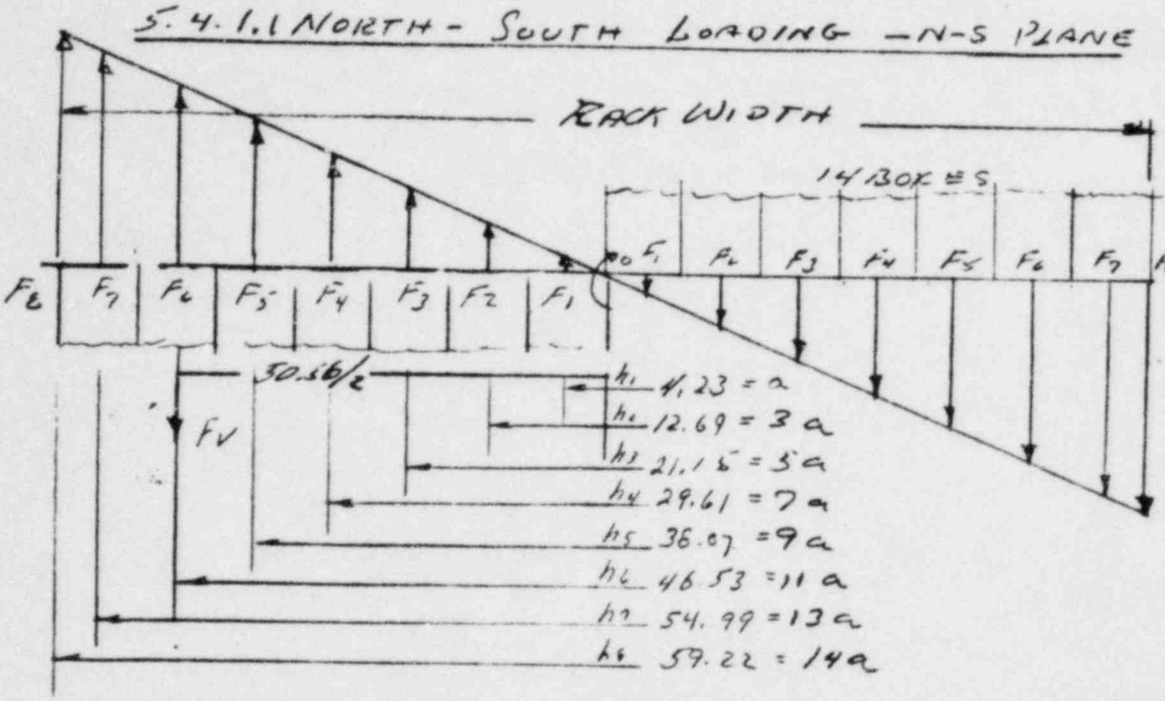
$$= 2.152\ E-03\ M$$

$$F_1 = \frac{M(6.22)(39.5)}{\Sigma A_i h_i^2} = 0.717\ E-03\ M$$

## 5.4 FORCES ON WELDS DUE TO TORSION-

### 5.4.1 FORCES DUE TO VERTICAL FORCE Fv

### 5.4.1.1 NORTH - SOUTH LOADING - N-S PLANE




$$\frac{\Delta_1}{h_1} = \frac{\Delta_2}{h_2} = \frac{\Delta_3}{h_3} = \frac{\Delta_4}{h_4} = \frac{\Delta_5}{h_5} = \frac{\Delta_6}{h_6} = \frac{\Delta_7}{h_7} = \frac{\Delta_8}{h_8}$$

$$\Delta_i = \frac{F_i\, l_i}{A_i E}$$ ASSUME: ALL $\frac{l_i}{E}$ ARE EQUAL

$$\Delta_i = \frac{F_i}{A_i}$$ $T = F_v\,(50.56)$ ← FROM p5.26 OF REF #2

$$\frac{F_i}{h_i A_i} = \frac{F_8}{h_8 A_8} \qquad F_i = F_8\,\frac{h_i A_i}{h_8 A_8}$$

$\Sigma M_o = 0$

$$50.56 F_v = 2\left[F_1 a + F_2(3a) + F_3(5a) + F_4(7a) + F_5(9a) + F_6(11a) + F_7(13a) + F_8(14a)\right]$$

$$25.28 F_v = a\,(F_1 + 3F_2 + 5F_3 + 7F_4 + 9F_5 + 11F_6 + 13F_7 + 14F_8)$$

5.4.1.1 CONT.

$$F = \frac{F_8 \, h_i \, A_i}{h_8 \, A_8}$$

$$25.28 \quad F_V = \frac{a^2 F_8}{h_8 A_8} \left\{ A_0 \left(1^2 + 3^2 + 5^2 + 7^2 + 9^2 + 11^2 + 13^2\right) + 14^2 A_8 \right\}$$

WHEN $h_8 = 14a$

$$F_8 = \frac{(25.28)\, 14\, A_8 F_V}{a(455 A_0 + 196 A_8}$$

$$= \frac{F_V A_8}{a\,[1.285 A_0 + 0.554 A_8]}$$

$A_8 = 1.80\ in^2$ . $A_0 = A_7$ = 6 FUSION WELDS + 6 FILLET WELD 1" LONG = 6(0.196 + 0.18) = 2.256 IN2

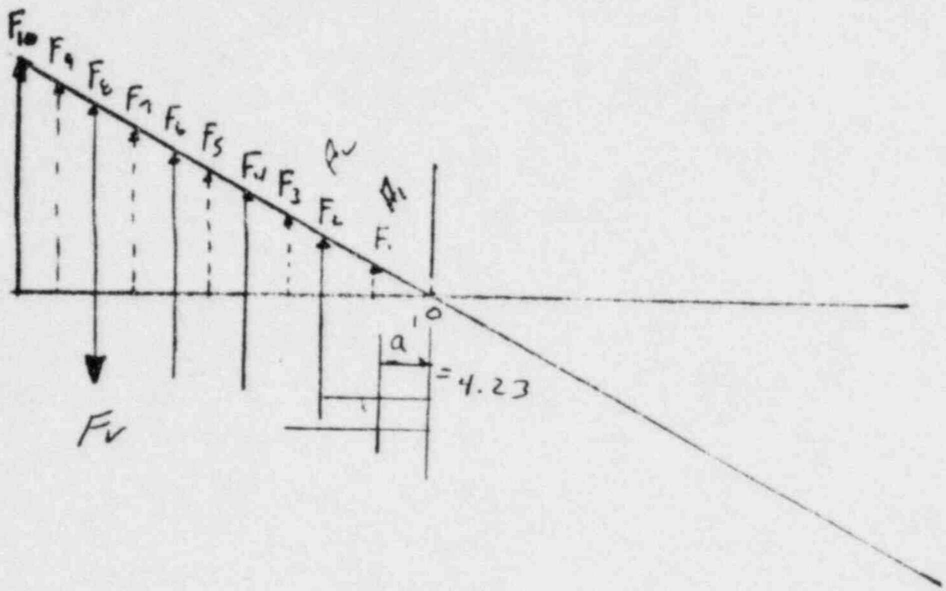
$$F_8 = 109.22\,E{-}02\,F_V$$

$$F_7 = \frac{25.28\,(13)\, A_7 F_V}{a(455 A_0 + 196 A_8}$$

$$= \frac{F_V A_7}{a(1.38 A_0 + 0.596 A_8)}$$

$$F_7 = 127.4\,E{-}07\,F_V$$

5.4.1.2 EAST WEST LOADING - E-W PLANE




$\Sigma M_o = 0$

$$8aF_v = 2a(F_1 + 2F_2 + 3F_3 + 4F_4 + 5F_5 + + + \ldots 10F_{10})$$

$$\frac{\Delta_i}{h_i} = \frac{\Delta_{12}}{h_{12}} = \frac{\Delta_{11}}{h_{11}} \qquad A_2 = A_{12} = A_{10} = \ldots A_2$$

$$\Delta_i = F_i / A_i \qquad A_1 = A_{11} = A_9 = A_1$$

$$\frac{F_i}{h_i A_i} = \frac{F_{10}}{h_{10} A_{10}} = \frac{F_9}{h_9 A_9}$$

$$F_i = \frac{F_{10} h_i A_i}{h_{10} A_i} = \frac{F_9 h_i A_i}{h_9 A}$$

$$8F_v = \frac{2F_{10} a}{10 a A_{10}} \left[ A_1 (1 + 3^2 + 5^2 + 7^2 + 9) \; A_2 (2^2 + 4^2 + 6^2 + 8^2 + 10^2) \right.$$

$$= \frac{2F_{10}}{10 A_{10}} \left[ A_1 (165) + 220 A_2 \right]$$

$$8F_v = \frac{2F_9}{9A_9} \left[ A_1 (165) + 220 A_2 \right]$$

5. 4.1.2 - CONT -

$$A_1 = (3)(2)(1)(0.18) = 1.08 \text{ in}^2$$

$$A_2 = (5)(2)(0.18) = 1.80 \text{ in}^2$$

$$a = 4.23$$

$$8F_v = \frac{2F_{10}}{10(1.80)}\left(1.08(165) + 220(1.80)\right)$$

$$F_v = 7.975\, F_{12}$$

$$F_{10} = 125.4\text{E}-03\, F_v$$

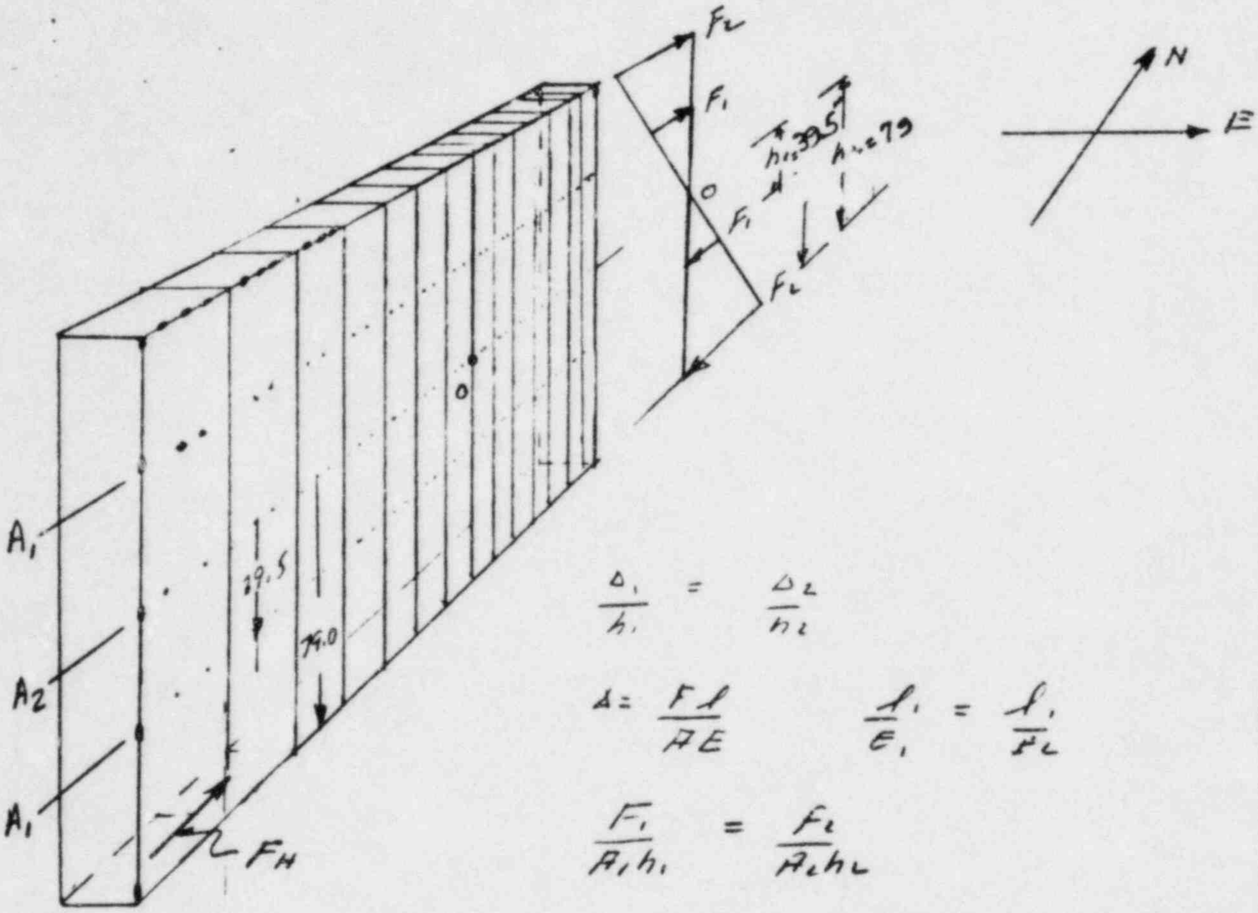
$$8F_v = \frac{2\, F_9}{(9)(1.08)}\left(1.08(165) + 220(1.85)\right)$$

$$F_v = 14.76\, F_{11}$$

$$F_9 = 67.70\text{E}-03\, F_v$$

5.4.2 FORCES DUE TO HORIZONTAL FORCE $F_H$

5.4.2.1 NORTH-SOUTH LOADING - N-S PLANE




$$\frac{\Delta_1}{h_1} = \frac{\Delta_2}{h_2}$$

$$\Delta = \frac{Fl}{AE} \qquad \frac{l_1}{E_1} = \frac{l_1}{E_2}$$

$$\frac{F_1}{A_1 h_1} = \frac{F_2}{A_2 h_2}$$

$$F_1 = \frac{F_2 A_1 h_1}{A_2 h_2} \qquad F_2 = \frac{F_1 h_2 A_2}{A_1 h_1}$$

$$\Sigma M_o = 0 = -F_H h_2 + 2F_2 h_2 + 2F_1 h_1$$

$$F_H h_2 = \frac{2F_2 A_2 h_2^2}{A_2 h_2} + \frac{2F_2 A_1 h_1^2}{A_2 h_2}$$

$$= \frac{2F_2}{A_2 h_2}\left(A_2 h_2^2 + A_1 h_1^2\right)$$

$$F_H h_2 = \frac{2F_1 h_2^2 A_2 + 2F_1 h_1^2 A_1}{A_1 h_1}$$

$$F_2 = \frac{F_H A_2 h_2^2}{(2)(A_2 h_2^2 + A_1 h_1^2)}$$

$$F_1 = \frac{h_2 (A_1 h_1) F_H}{2(A_2 h_2^2 + A_1 h_1^2}$$

5.4.2.1 - CONT -

$$F_2 = \frac{F_H A_2 h_2^2}{2(A_2 h_2^2 + A_1 h_1^2)}$$

$$F_1 = \frac{F_H h_1 h_2 A_1}{2(A_2 h_2^2 + A_1 h_1^2)}$$

LET $A_1$ OCCUR @ $h_1 = 39.5''$

WELDAREA $A_1$ = (2 WELDS)(2" LONG)(0.18 IN²) = 0.72

28 FUSION WELDS @ 0.5" DIA = (0.196)(28) = 5.49

$\therefore A_1 = 6.21 IN^2$

LET $A_2$ OCCUR @ $h_2 = 79.0''$

WELDAREA $A_2$ = (2 WELDS)(2" LONG)(0.18 IN²) = 0.72

(3 FILLET WELDS)(1" LONG)(0.18")(14 BOXES) = 7.56

$\therefore A_2 = 8.28 IN^2$

$$F_2 = \frac{F_H (8.28)(79)^2}{2[8.28(79)^2 + 6.22(39.5)^2]}$$

$F_2 = 420.945E-03 F_H$

$$F_1 = \frac{F_H (6.22)(39.5)(79)}{2[(8.28)(79)^2 + 6.22(39.5)^2]}$$

$F_1 = 158.11E-03 F_H$

5.4.2.2 EAST WEST LOADING - E-W PLANE ($F_H$)

THE LOAD DISTRIBUTION IS THE SAME AS 5.4.2.1

$$F_2 = \frac{F_H \; A_2 h_2^2}{2(A_2 h_2^2 + A_1 h_1^2)}$$

$$F_1 = \frac{F_H \; h_1 h_2 A_1}{2(A_2 h_2^2 + A_1 h_1^2)}$$

$A_1$ = 11 WELDS, 2in lg, 0.18 in.

$A_1 = (11)(2)(0.18) = 3.96\ in^2$

$A_2 = A_1 + (10\ BOX)(2\ welds)(1in\ lg)(0.18in) = 9.36\ IN^2$

$h_1 = 39.5\ in \qquad h_2 = 79.0\ in$

$$F_2 = \frac{F_H\,(9.36)(79)^2}{2[9.36(79)^2 + 3.96(39.5)^2]}$$

$F_2 = 452.17\ E-03\ F_H$

$$F_1 = \frac{F_H\,(39.5)(79)(3.96)}{2[9.36(79)^2 + 3.96(39.5)^2]}$$

$F_1 = 95.62\ E-03\ F_H$

5.5 —

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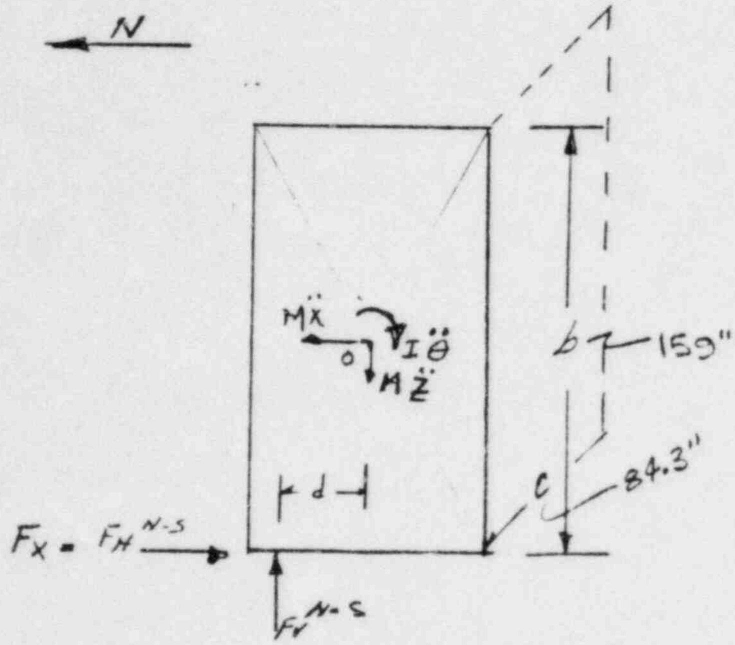
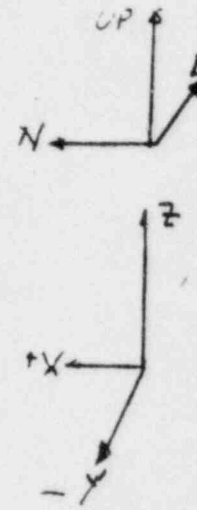
5.6 INERTIA FORCES N-S FORCE ACTING ON E-W PLANE




5.6.1 MASS MOMENT OF INERTIA $I_{zO}$

$$I_{zO} = \frac{M}{12}(b^2 + c^2)$$ REF #4 p 33

b = 159 in  c = 84.3"

M = SWT / 386.4

STANDARD RACK DWT = 233,600 lb. (SECT. 2.0)

$I_{zO}$ = 1631.6 KIP-IN/SEC²

CONSOLIDATED HWT₂ = 397,400 lb. (SECT 2.0)

$I_{zO}$ = 2775.75 KIP-IN/SEC²

5.6 INERTIA FORCES - CONT - N-S (E-W PLANE)

5.6.1 NORTH - SOUTH "g" FORCES.

$F_H^{N-S} = -M\ddot{x}$   $F_V = -M\ddot{z}$

$\Sigma M_o = -I\ddot{\theta} + F_H^{N-S}(b/2) - F_V^{N-S}(d) = 0$

$I\ddot{\theta}^{N-S} = -F_V^{N-S}(d) + F_H^{N-S}(b/2)$

$d = l = 50.58$ in

$I\ddot{\theta}^{N-S} = -50.58\, F_V^{N-S} + 79.5\,(F_H^{N-S})$

5.6.1.1 NORTH-SOUTH STANDARD RACK

$M = 233,600$ lb

$\ddot{Y}^{STD}_{N-S} = -\frac{F_H^{N-S}(g)}{233,600}$

$\ddot{z}^{STD}_{N-S} = +\frac{F_V^{N-S}(g)}{233,600}$

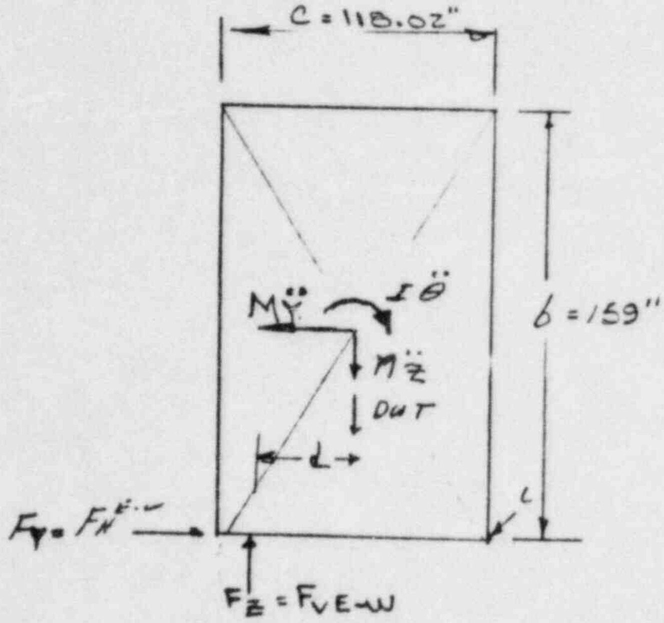
5.6.1.2 NORTH-SOUTH-CONSOLIDATED RACK

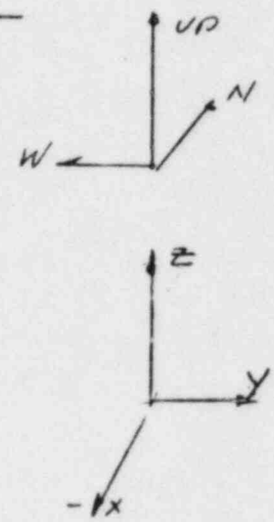
$M = 397,400$ lb.

$\ddot{Y}^{CON}_{N-S} = \frac{-F_H^{N-S}\, g}{397,400}$

$\ddot{z}^{CON}_{N-S} = \frac{+F_V^{N-S}\, g}{397\,400}$

5.6.2 INERTIA FORCES - EAST WEST.
ACTING ON N-S PLANE




MASS MOMENT OF INERTIA.

$I_{XO}^{E-W} = \frac{M}{12}(c^2 + b^2)$ REF 4 P33

C = 118.02" b = 159.0"

M = DWT /386.4

STANDARD RACK DWT = 233,600 LBS.

$I_{XO}^{E-W}$ = 1975.4 KIP-SEC²

CONSOLIDATED DWT = 397,400 LBS.

$I_{XO}^{E-W}$ = 3360.5 KIP-SEC²

5.62 INERTIA FORCES - CONT -

5.6.2.1. EAST WEST "g" FORCES

$$F_H^{E-W} = -M\ddot{z}$$

$$\ddot{y}_{E-W} = \frac{-F_H^{E-W}}{M}$$

$$\Sigma M_o = -I\ddot{\theta} + F_H^{E-W}(b/2) - F_V^{E-W}(d) = 0$$

$$d = 33.72'' \text{ in}$$

$$I\ddot{\theta}_{E-W} = -F_V^{E-W}(33.72'') + 79.5''(F_H^{E-W})$$

5.6.2.1.1 EAST WEST - STANDARD RACK

M = 233,600 lb Sect 2.0

$$\ddot{y} = \frac{-F_H^{E-W}\, g}{233{,}600}$$

$$\ddot{z} = \frac{F_V^{E-W}\, g}{233{,}600}$$

5.6.2.1.2 EAST-WEST - STANDARD RACK

M = 397,400 lb.

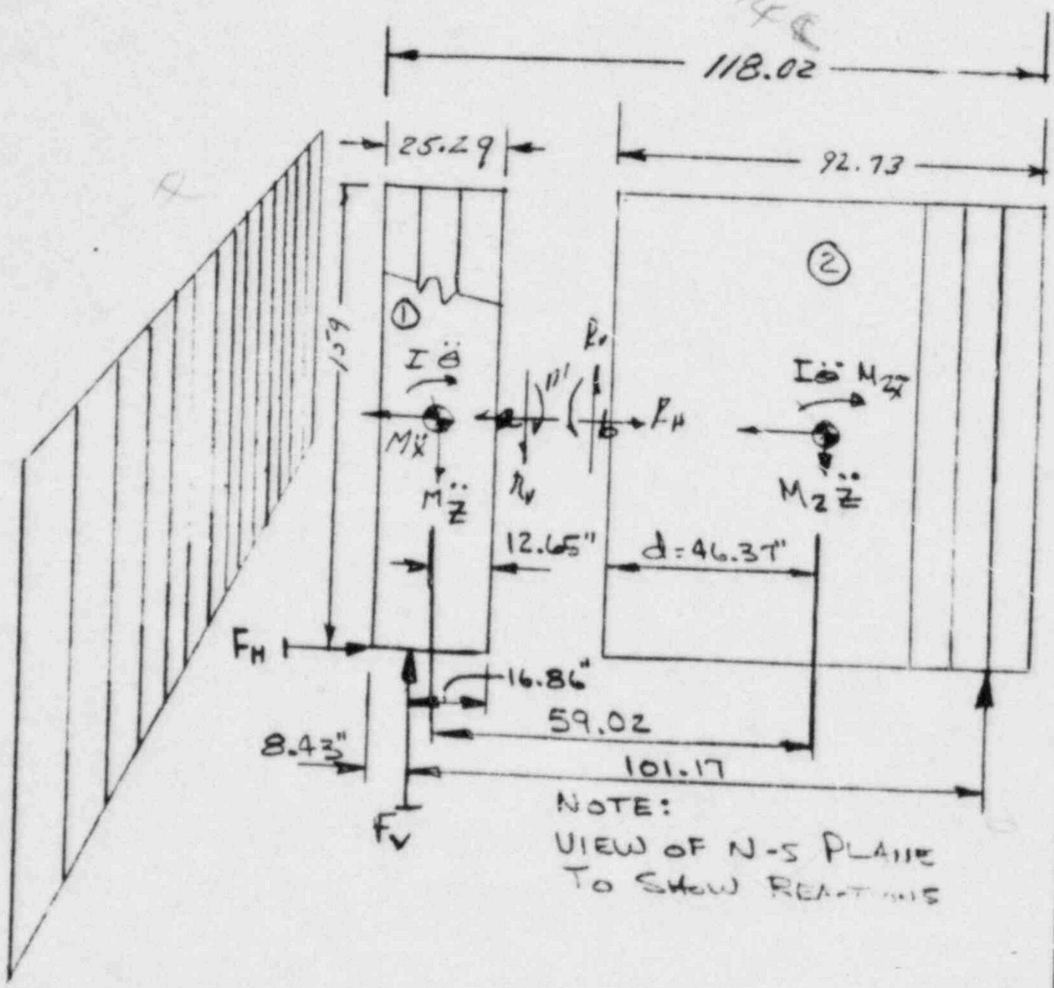
$$\ddot{y} = \frac{-F_H\, g}{397{,}400}$$

$$\ddot{z} = \frac{F_V\, g}{397{,}400}$$

## 5.7 SUMMARY OF ACCELERATIONS

| NORTH - SOUTH | | | EAST WEST | | |
|---|---|---|---|---|---|
| | STD | CONS | | STD | CONS. |
| $\ddot{X}$ | $\frac{F_H g}{233600}$ | $\frac{F_H g}{397400}$ | $\ddot{Y}$ | $\frac{F_H g}{233600}$ | $\frac{F_H g}{397400}$ |
| $\ddot{Z}$ | $\frac{F_V g}{233600}$ | $\frac{F_V g}{397400}$ | $\ddot{Z}$ | $\frac{F_V g}{233600}$ | $\frac{F_V g}{397400}$ |
| $I\ddot{\theta}$ | $-50.58 F_V + 79.5 F_H$ | | $I\ddot{\theta}$ | $-33.72 F_V +$ 7[illegible].5 $F_H$ | |

5.8 Resulting Inertia Forces - N-S Load (As it applies to E-W Plane)




5.8.1 Standard Rack

① 3 Boxes

$$SWT_{①} = \frac{3}{14}(208,190) = 44,612 \text{ lb.}$$

$$DWT_{①} = \frac{3}{14}(233,600) = 50,057 \text{ lb.}$$

② 11 Boxes

$$SWT_{②} = \frac{11}{14}(208,190) = 163,578 \text{ lb.}$$

$$DWT_{②} = \frac{11}{14}(233,600) = 183,543 \text{ lb.}$$

5.8.1.1 STD RACK - N-S OBE - EW PLANE

FROM SECTION 2.0

$F_V = 63,510$ lb (w/out SWT, SET # 3)

$F_H = 170,000$ lb

$$\ddot{X} = \frac{-F_H^{N-S}\, g}{233\,600} = \frac{170,000}{233\,600} = 0.728\,g$$

$$\ddot{z} = \frac{F_V^{N-S}\, g}{233\,600} = \frac{63,510}{233\,600} = 0.272\,g$$

$\Sigma M_a = 0$

$$M_a = -I\ddot{\theta}_1 + M_1\ddot{z}(12.645) - F_V(16.86) + F_H(79.5)$$

$$I\ddot{\theta} = -50.58F_V + 79.5F_H$$

$$= -50.58(63,510) + 79.5(170,000)$$

$$I\ddot{\theta} = 10,302,664$$

$$I\ddot{\theta}_1 (3\text{ BOXES}) = (3/14)(I\ddot{\theta}) = 2,207,713$$

$$I\ddot{\theta}_2 (11\text{ BOXES}) = (11/14)(I\ddot{\theta}) = 8,094,950$$

$$\therefore M_a = -2,207,713 + 50,057(0.272)(12.645) - 63,510(16.86) + 170,000(79.5)$$

$M_a = 10,408,676$ IN-LBS

CK:

$$M_b = M_a = I\ddot{\theta}_2 + M_2\ddot{z}$$

$$= 8,094,950 + 153,543(0.272)(46.365)$$

$M_b = M_a = 10,409,662$ IN-lbs. OK

5.8.1.1 - CONT - STD RACK - N-S LOAD - OBE

$R_H = -M_1 \ddot{x} + F_H$

$= -50,057(0.728) + 170,000$

$= 133,558$ lb.

CHK:

$R_H = M_2 \ddot{x} = 183,543(0.728)$

$= 133,619$ lb.

$R_V = -M_1 \ddot{z} + F_V$

$= -50,057(0.272) + 63,510$

$= +49894$ LB.

CK:

$R_V = M_2 \ddot{z} = 183,543(0.272)$

$R_V = 49,923$ LB.

ok

5.8.1.2 STD RACK - N-S LOAD - SSE (E-W FLANGE)

FROM SECTION 2.0

$F_V = 196,510$ lb w/out SWC (SET #3)

$F_H = 231,500$ lb.

$\ddot{X} = \frac{-F_H^{N-S} g}{233,600} = \frac{231500}{233600} = 0.991 g$

$\ddot{Z} = \frac{F_V^{N-S} g}{233,600} = \frac{196510}{233600} = 0.841 g$

$\Sigma M_a = 0$

$M_a = -I\ddot{\theta} + M_1 \ddot{z}(12.645) - F_V(16.86) + F_H(79.5)$

$I\ddot{\theta} = -50.58 F_V + 79.5 F_H$

$= -50.58(196510) + 79.5(231,500)$

$I\ddot{\theta} = 8,464,774$

$I\ddot{\theta}_1$ (3 BOXES) $= (3/14)(I\ddot{\theta}) = 1,813,880$

$I\ddot{\theta}_2$ (11 BOXES) $= (11/14)(I\ddot{\theta}) = 6,650,834$

$M_a = -1,813,880 + 50,057(0.841)(12.645)$

$- 196,510(16.86) + 231,500(79.5)$

$M_a = 13,809,540$ IN-lbs

CK.

$M_b = M_a = I\ddot{\theta}_2 + M_2 \ddot{z}(46.365)$

$= 6,650,894 + 183,543(0.841)(46.365)$

$M_a = M_b = 13,807,780$ IN-lbs.

5.8.1.2 -CONT- STD RACK - N-S LOAD SSE

$R_H = -M_1 \ddot{x} + F_H$

$= -50,057(0.991) + 231,500$

$= 181,894$ lb.

CHK:

$R_H = -M_2 \ddot{x} = 183,543(0.991)$

$= 181,891$ lb.

$R_V = -M_1 \ddot{z} + F_V$

$= -50,057(0.841) + 196,510$

$= 154,412$ lb

CK:

$R_V = M_2 \ddot{z}$

$= 183,543(0.841)$

$= 154,360$ lb.

## 5.8.2 CONSOLIDATED RACK - N-S LOAD

FROM SECT. 2.0

SWT = 341,060 lb, HWT = 397,400 lb.

3 BOXES WIDE.

$$SWT = \frac{3}{14}(341,060) = 73,084 \text{ lb.}$$

$$HWT = \frac{3}{14}(397,400) = 85,157 \text{ lb}$$

11 BOXES WIDE

$$SWT = \frac{11}{14}(341,060) = 267,976 \text{ lb.}$$

$$HWT = \frac{11}{14}(397,400) = 312,243 \text{ lb.}$$

### 5.8.2.1 CONS. RACK - N-S LOAD OBE

FROM SECT. 2.0 $F_H = 160,200$ lb, $F_V = 0.00$ lb.

$$\ddot{X} = \frac{-F_H g}{397,400} = \frac{160.2}{397.4} = 0.403 g$$

$$\ddot{Z} = \frac{F_V g}{397400} = \frac{0.00}{397.4} = 0.00 g$$

$$I\ddot{\theta} = -50.58 F_V + 79.5 F_H$$

$$= -50.58(0.00) + 79.5(160,200)$$

$$= +12,735,900$$

$$I\ddot{\theta}_{1}(3 BOX) = \frac{3}{14} I\ddot{\theta} = 2,729,121.$$

$$I\ddot{\theta}_{2}(11 BOX) = \frac{11}{14} I\ddot{\theta} = 10,006,779$$

5.8.2.1 - CONT N-S-LOAD E-W PLANE

$\Sigma M_a = 0$

$M_a = -I\ddot{\theta}_D + M_1\ddot{z}(12.645) - F_V(16.92) + F_H(79.5)$

$= -2,729,121 + 85,157(0.0)(12.645)$

$- 0.00(16.92) + 160,200(79.5)$

$= 10,006,779$ in-lb

CK: $M_D = M_a = I\ddot{\theta} + M_2\ddot{y}(46.37")$

$= 10,006,779 + 312,243(0.00)(46.37)$

$= 10,006,779$ in-lb

$R_H = -M_1\ddot{x} + F_H$

$= -85,157(0.403) + 160,200$

$= 125,862$ lb

CK:

$R_H = M_2\ddot{x}$

$= 312,243(0.403)$

$= 125,834$ lb

$R_V = 0.0$

5.8.2.2 CONSOLIDATED RACK – N-S LOAD SSE

FROM SECT 2.0

$F_V = 114,640$ lb.

$F_H = 239,300$ lb

$\ddot{x} = \frac{-F_H g}{397,400} = \frac{239.3}{397.4} = 0.602\ g$

$\ddot{z} = \frac{F_V g}{397,400} = \frac{114.64}{397.4} = 0.288\ g$

$I\ddot{\theta} = -50.58 F_V + 79.5 F_H$

$= -50.58(114,640) + 79.5(239,300)$

$= 13,225,858$

$I\ddot{\theta}_{1}$ (3 BOX) $= \frac{3}{14}(I\ddot{\theta}) = 2,834,112$

$I\ddot{\theta}_{2}$ (11 BOX) $= \frac{11}{14}(I\ddot{\theta}) = 10,391,745$

5.8.2.2 - CONT - CONSOLIDATED RACK N-S LOAD SSE

$\Sigma M_a = 0$

$M_a = -I\ddot{\theta}_D + M_1\ddot{z}(12.645) - F_V(16.86) + F_H(79.5)$

$= -2,834,112 + 85,157(0.288)(12.645)$

$- 114,640(16.86) + 239,300(79.5)$

$M_a = 14,567,528$

CK:

$M_b = M_a = I_2\ddot{\theta} + M_2\ddot{z}(46.365)$

$= 10,391,745 + 312,243(0.286)(46.37)$

$M_b = 14,561,612$

$R_H = -M_1\ddot{x} + F_H$

$= -85,157(0.602) + 239,300$

$= 188,035$ lb.

CK:

$R_H = M_2\ddot{x}$

$= 312,243(0.602) = 187,970$ lb.

$R_V = -M_1\ddot{z} + F_V$

$= -85,157(0.288) + 114,640$

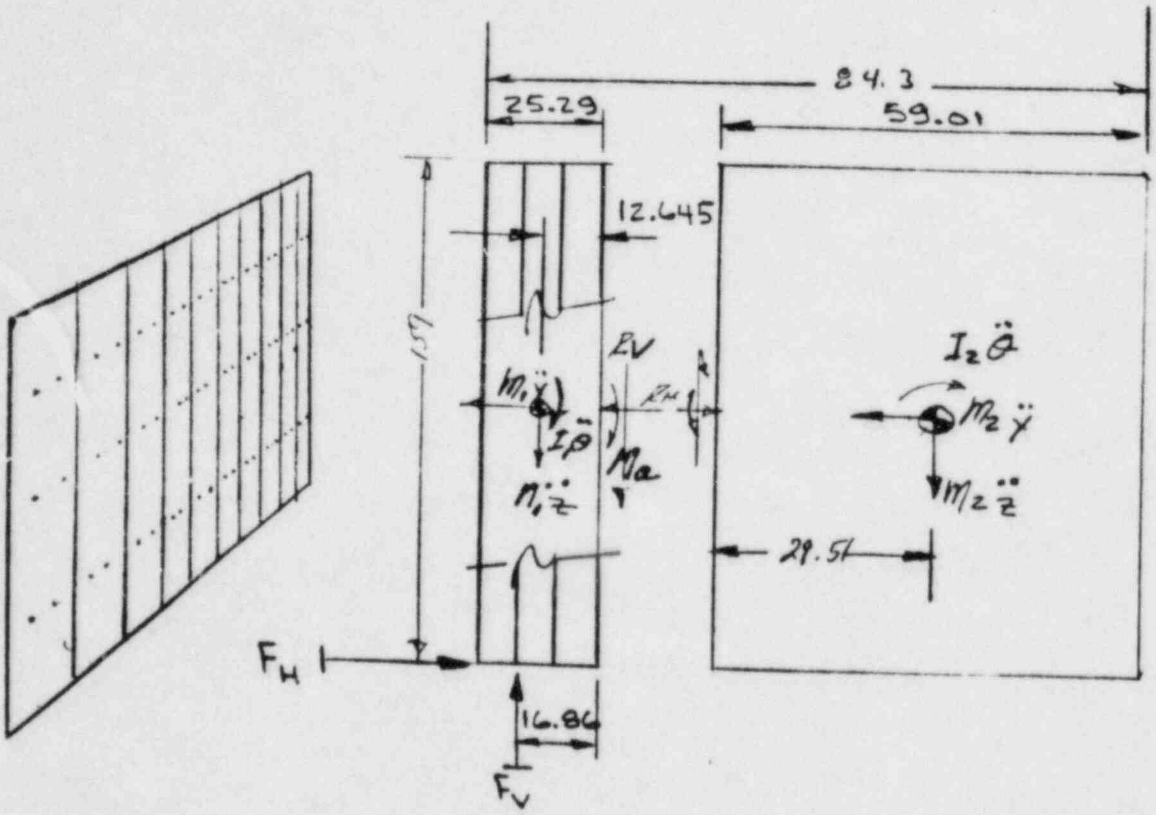
$= 90,114$ lb

CK

$R_V = M_2\ddot{z} = 312,243(0.288)$

$= 89,926$ lbs

5.9. INERTIA FORCES - E-W LOAD, N-S PLANE




5.9.1 STANDARD RACK

3 BOXES SWT = $\frac{3}{10}$ (208,190) = 62,457 lb.

DWT = $\frac{3}{10}$ (233,600) = 70,080 lb.

7 BOXES SWT = $\frac{7}{10}$ (208,190) = 145,733 lb.

DWT = $\frac{7}{10}$ (233,600) = 163,520 lb.

## 5.91.1 STD RACK E-W LOAD OBE

FROM SECT 2.0

$F_V = 185,110$ lb (SET #3)

$F_H = 156,200$ lb.

$$\ddot{Y} = \frac{-F_{H_{EW}} g}{233,600} = \frac{156,200}{233600} = 0.669\ g$$

$$\ddot{Z} = \frac{F_{V_{EW}} g}{233600} = \frac{185,110}{233600} = 0.792\ g$$

(5.7) $I\ddot{\theta} = 79.5(F_H) - 33.72(F_V)$

$= 79.5(156,200) - 33.72(185,110)$

$I\ddot{\theta} = 6,175,990$

$I\ddot{\theta}_{1}(3\ BOX) = (3/10)(I\ddot{\theta}) = 1,852,797$

$I\ddot{\theta}_{2}(7\ BOX) = (7/10)(I\ddot{\theta}) = 4,323,194$

$\Sigma M_a = 0$

$M_a = -I\ddot{\theta}_1 + M_1\ddot{Z}(12.645) - F_V(16.86) + F_H(79.5)$

$= -1,852,797 + 70,080(0.792)(12.645)$

$- 185,110(16.86) + 156,200(79.5)$

$= 8,145,988$ IN-lbs.

CHK:

$M_B = M_a = I\ddot{\theta}_2 + M_2\ddot{Z}(29.61)$

$= 4,323,194 + 163,520(0.792)(29.51)$

$= 8,144,970$ IN-lbs
OK

5.9.1.1 - CONT - Std Rack - E-load - N-S Plane

$R_H = -M_1 \ddot{Y} + F_H = -70,080 (0.669) + 156,200$

$= 109,316$ lb

Ck:

$R_H = M_2 \ddot{Y}$

$= 163,520 (0.669)$

$= 109,395$ lb.

$R_V = -M_1 \ddot{z} + F_V$

$= -70,080 (0.792) + 185,110$

$= 129,607$ lb.

Ck:

$R_V = M_2 \ddot{z}$

$= 163,520 (0.792) = 129,509$ lb.

5.9.1.2 STD RACK - E-W LOAD SSE N-S Pl.

FROM SECT 2.0

$F_V = 173,410$ lb.

$F_H = 164,300$ lb.

$\ddot{y} = \frac{-F_H g}{233,600} = \frac{164.3}{233.6} = 0.703g$

$\ddot{z} = \frac{F_V g}{233600} = \frac{173.41}{233.6} = 0.742g$

$I\ddot{\theta} = 79.5(F_H) - 33.72(F_V)$ (5.7)

$= 79.5(164,300) - 33.72(173,410)$

$I\ddot{\theta} = 7,214,464$

$I\ddot{\theta}_{①}(3\ BOX) = (3/10)(I\ddot{\theta}) = 2,164,339$

$I\ddot{\theta}_{②}(7\ BOX) = (7/10)(I\ddot{\theta}) = 5,050,125$

$\Sigma M_a = 0$

$M_a = -I\ddot{\theta} + M_1\ddot{z}(12.645) - F_V(16.86) + F_H(79.5)$

$= -2,164,340 + 70,080(0.742)(12.645)$

$- 173,410(16.86) + 164,300(79.5)$

$M_a = 8,631,350$ IN-lbs.

CK:

$M_b = M_a = I\ddot{\theta} + M_2\ddot{y}(29.61)$

$= 5,050,125 + 163,520(0.742)(29.51)$

$= 8,630,628$ in-lbs

5.9.1.2 - CONT

$$R_H = -M_1 \ddot{X} + F_H = 70,080(0.703) + 164,300$$

$$= 115,034 \text{ lb.}$$

CK:

$$R_H = M_2 \ddot{Y}$$

$$= 163,520(0.703)$$

$$= 114,955 \text{ lb.}$$

$$R_V = -M_1 \ddot{Z} + F_V$$

$$= -70,080(0.742) + 173,410$$

$$= 121,411$$

CK:

$$R_V = M_2 \ddot{Z}$$

$$= 163,520(0.742)$$

$$= 121,332 \text{ lb.}$$

5.9.2.1 CONSOLIDATED RACK OBE - E-W

3 BOXES $SWT = \frac{3}{10}(341,060) = 102,318$ lb
$HWT = \frac{3}{10}(^*397,400) = 119,220$ lb
} $= M_1$

7 BOXES $SWT = \frac{7}{10}(341,060) = 238,742$ lb.
$= \frac{7}{10}(397,400) = 278,180$ lb.
} $= M_2$

FROM SECTION 2.0

$F_V$ (W/OUT SWT) = 64,140 lb.

$F_H$ = 153,000 lb.

$$\ddot{y} = \frac{-F_H^{N-S}\, g}{397400} = \frac{153,000}{397,400} = 0.385g$$

$$\ddot{z} = \frac{F_V^{NS}\, g}{397,400} \quad \frac{64,140}{397,400} = 0.1614g.$$

$$\Sigma M_a = 0,\ M_a = -I_1\ddot{\theta} + M_1\ddot{z}(12.645) - F_V(16.86) + F_H(79.5)$$

$$I\ddot{\theta} = 79.5(F_H^{N-S}) - 33.72(F_V^{N-S})$$
$$= 79.5(153,000) - 33.72(64,140)$$
$$= 10,000,700$$

$$I\ddot{\theta}_{①}(3\text{ BOXES}) = (3/10)(I\ddot{\theta}) = 3,000,210$$

$$I\ddot{\theta}_{②}(7\text{ BOXES}) = (7/10)(I\ddot{\theta}) = 7,000,490$$

* MASS ASSOCIATED WITH HORIZONTAL MOTION

5.9.2.1 CONSOLIDATED RACK – CONT – OBE –

$M_a = -3,000,210 + 119,220 (0.1614)(12.645)$
$- 64,140 (16.86) + 153,000 (79.5)$
$= 8,325,206$ in - lb.

CHECK: $M_a = M_b$: $I\ddot{\theta}_z + M_z \ddot{z} (29.51)$

$M_a = +7,000,490 + 278,160 (0.1614)(29.51)$
$= 8,325,437$ IN-lb.

$R_H = -M_1 \ddot{y} + F_H = -119,220 (0.385) + 153000$
$= 107,100$ lb

CHK: $R_H = M_2 \ddot{y} = 278,180 (0.385) = 107,100$ lb.

$R_V = -M_1 \ddot{z} + F_V = -119,220 (0.1614) + 64,140$
$= -44,900$ lb.

CHK: $R_V = M_2 \ddot{z} = -278,180 (0.1614)$
$= -44,900$ lb.

## 5.9.2.2 CONSOLIDATED RACK - E-W LOAD - SSE

FROM SECT 2.0

$F_V = 171{,}040$ lb. (SET # 3)

$F_H = 184{,}700$ lb

$\ddot{y} = \frac{-F_{H_{EW}} g}{397{,}400} = \frac{184.7}{397.4} = 0.465\ g$

$\ddot{z} = \frac{F_{V_{EW}} g}{397{,}400} = \frac{171.04}{397.4} = 0.430\ g$

$I\ddot{\theta} = 79.5(F_H) - 33.72(F_V)$

$= 79.5(184{,}700) - 33.72(171{,}040)$

$= 8{,}916{,}181$

$I\ddot{\theta}_{①}(3\ BOX) = (3/10)(I\ddot{\theta}) = 2{,}674{,}854$

$I\ddot{\theta}_{②}(7\ BOX) = (7/10)(I\ddot{\theta}) = 6{,}241{,}327$

$\Sigma M_a = 0$

$M_a = -I\ddot{\theta}_1 + M_1\ddot{y}(12.69) - F_V(16.86)\ F_H(79.5)$

$= -2{,}674{,}854 + 119{,}220(0.430)(12.645)$

$- 171{,}040(16.86) + 184{,}700(79.5)$

$= 9{,}773{,}302$ IN-LBS.

CK:

$M_b = M_c + I\ddot{\theta}_{②} + M_2\ddot{y}$

$= 6{,}241{,}327 + 278{,}180(0.430)(29.51)$

$= 9{,}771{,}236$ IN. lbs

OK

5.9.2.2 CONSOLIDATED RACK – CONT – SSE

$R_H = -M_1\ddot{z} + F_H$

$= -119,220\ (0.465) + 184,700$

$= -129,263$ lb.

CK: $R_H = M_2\ddot{y}$

$= 276,150\ (0.465)$

$= 129,354$ lb.

$R_V = -M\ddot{z} + F_V$

$= -119,220\ (0.430) + 171,040$

$= 119,775$ lb

CK: $R_V = M_2\ddot{z}$

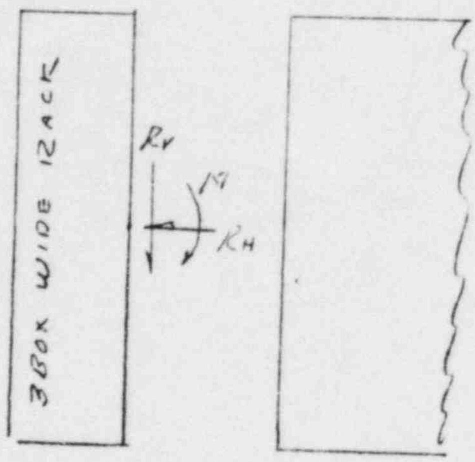
$= 276,180\ (0.430)$

$= 119,617$ lb.

## 5.9.3 SUMMARY OF INERTIA FORCES

| | NORTH - SOUTH LOAD EAST WEST PLANE | | | | EAST - WEST LOAD NORTH - SOUTH PLANE | | | |
|---|---|---|---|---|---|---|---|---|
| | STANDARD RACK | | CONSOLIDATED RACK | | STANDARD RACK | | CONSOLIDATED RACK | |
| | OBE | SSE | OBE | SSE | OBE | SSE | OBE | SSE |
| $R_V$ | 49.9 | 154.4 | 0.0 | 90.0 | 129.6 | 121.4 | 44.9 | 119.8 |
| $R_H$ | 133.6 | 181.9 | 125.9 | [illegible] | [illegible] | [illegible] | [illegible] | 129.4 |
| M | 10,407 | 13,810 | 10,000 | 11,568 | 8146 | 8631 | 8325 | 9774 |

DIMENSIONS - $R_i$ = KIPS , M = IN - KIPS



5.9.3.1 F.' FROM M - CONT.

FROM SECTION 5.3.2.1

NORTH - SOUTH LOADING - E-W PLANE

$F_2 = 4.619E-03\,M$

$F_{1T} = 0.488E-03\,M$

$F_{1B} = 1.466E-03\,M$

EAST WEST LOADING - N-S PLANE

$F_2 = 3.819E-03\,M$

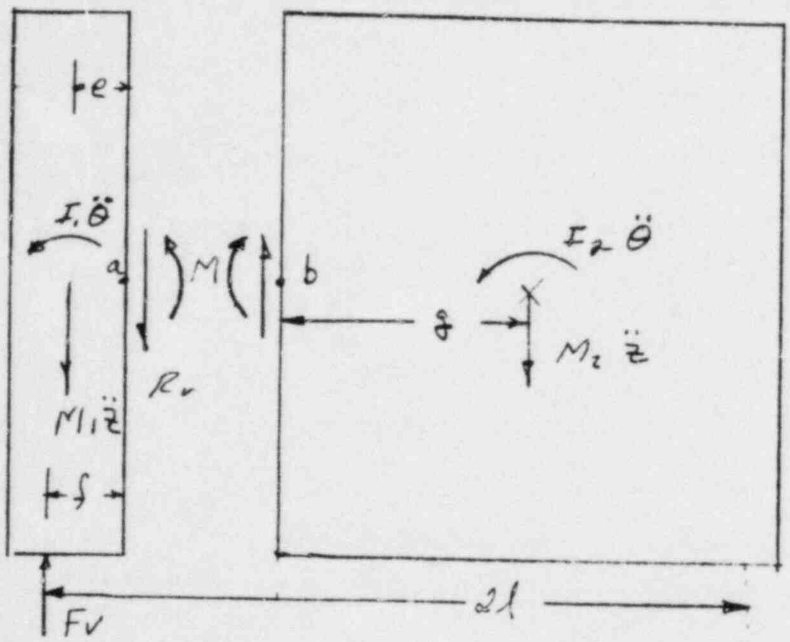
$F_{1T} = 2.152E-03\,M$

$F_{1B} = 0.717E-03\,M$

| | NORTH - SOUTH LOADING EAST - WEST PLANE | | | | EAST WEST LOADING NORTH - SOUTH PLANE | | | |
|---|---|---|---|---|---|---|---|---|
| | STANDARD RACK | | CONSOLIDATED RACK | | STANDARD RACK | | CONSOLIDATED RACK | |
| | OBE | SSE | OBE | SSE | OBE | SSE | OBE | SSE |
| M | 10,407 | 13,810 | 10,000 | 14,568 | 8146 | 8631 | 8325 | 9374 |
| $F_2$ | 48.1 | 63.8 | 46.2 | 67.3 | 31.1 | 33.0 | 31.8 | 35.8 |
| $F_{1T}$ | 15.3 | 20.2 | 14.7 | 21.4 | 17.5 | 18.6 | 17.9 | 20.2 |
| $F_{1B}$ | 5.1 | 6.7 | 4.9 | 7.1 | 5.8 | 6.2 | 6.0 | 6.7 |

## 5.10 INERTIA FORCES - VERTICAL SEISMIC

ASSUME THE VERTICAL SEISMIC OCCURS AT TIME OF LIFT OFF.




WHEN:

$e = 12.645''$

g:

$$I\ddot{\theta} = F_v\, l$$

$$F_v = \frac{DWT\ \ddot{z}}{g} \qquad I\theta = \frac{DWT\ \ddot{z}\ (l)}{g}$$

$$\Sigma M_a = -I_1\ddot{\theta} - (m_1\ddot{z})(e) + F_v\,(f)$$

$$M_a = -F_v\,(f) + I_1\ddot{\theta} + M_1\ddot{z}\,(e)$$

$$M_a = -\frac{DWT\ \ddot{z}\ (f)}{g} + \frac{DWT\ \ddot{z}\ (l)(K_1)}{g} + \frac{DWT\ddot{z}\,eK_1}{g}$$

$$M_a = \frac{DWT\ \ddot{z}}{g}\left[f - K_1\,(l + e)\right]$$

STD. RACK N-S PLANE

$$M_a = \frac{(233{,}600)(0.272g)}{g}\left[16.86 - 0.21\,(50.58 + 12.65)\right]$$

$M_a = 227{,}044$

5.10 - CONT

$$\Sigma M_b = -I_2 \ddot{\theta} + M_2 \ddot{z} (g) - M$$

$$M = +I_2 \ddot{\theta} - M_2 \ddot{z} (g)$$

$$= \frac{DWT \ddot{z} \, l \, K_2}{g} - \frac{DWT \ddot{z} (g) K_2}{g}$$

$$= \frac{DWT \ddot{z} K_2}{g} (-l + g)$$

$$\Sigma F_v\text{'s} = 0 = F_v - m_1 \ddot{z} - R_v$$

$$R_v = F_v - m_1 \ddot{z}$$

$$= \frac{DWT \ddot{z}}{g} - K_1 \frac{DWT \ddot{z}}{g}$$

$$= \frac{DWT \ddot{z}}{g} (1 - K_1)$$

CK. $\Sigma F_v\text{'s} = 0 = R_v - M_2 \ddot{z}$

$$R_v = M_2 \ddot{z}$$

$$= \frac{DWT \ddot{z} K_2}{g}$$

FOR 10WIDE RACK $K_1 = 0.3$, $K_2 = 0.7$

$$R_{v_1} = R_{v_2}$$

5.10 - CONT.

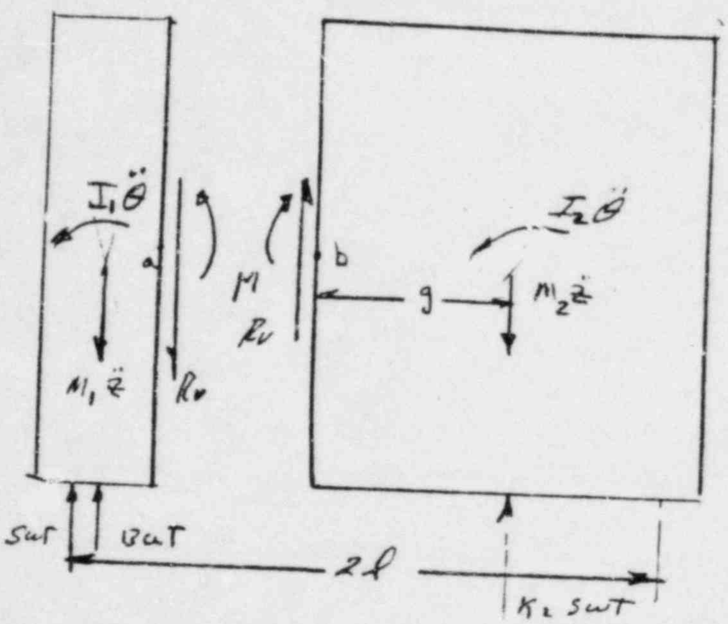
5.10.1 SUMMARY - INERTIA FORCES - VERTICAL

| | STANDARD RACK | | | | CONSOLIDATED RACK | | | |
|---|---|---|---|---|---|---|---|---|
| | NORTH-SOUTH PLANE | | EAST-WEST PLANE | | NORTH SOUTH PLANE | | EAST WEST PLANE | |
| | OBE | SSE | OBE | SSE | OBE | SSE | OBE | SSE |
| Dwt | 233,600 | | | | 389 000 | | | |
| $\ddot{z}$ | .272g | | | | | | | |
| e | 12.645" | | | | | | | |
| f | 16.86" | | | | | | | |
| g | 46.36 | | 29.51 | | 46.36 | | 29.51 | |
| l | 50.56 | | 33.69 | | 50.56 | | 33.69 | |
| $K_1$ | $\frac{3}{14}$ | | $\frac{3}{10}$ | | $\frac{3}{14}$ | | $\frac{3}{10}$ | |
| $K_2$ | $\frac{11}{14}$ | | $\frac{7}{10}$ | | $\frac{11}{14}$ | | $\frac{7}{10}$ | |
| $R_v$ | 50,196 | | 44477 | | 83588 | | 74,066 | |
| M | 227,044 | | 187,472 | | 379,083 | | 312,186 | |
| $F_2$ * | 867 | | 865.9 | | 1447.7 | | 1442 | |
| $F_{1B}$ * | 162.8 | | 274.8 | | 271.8 | | 457.7 | |
| $F_{1T}$ * | 489 | | 91.5 | | 816 | | 152 | |

* SEE SECT 5.9.3.1 FOR REF. FORMULA

5.11 INERTIA FORCES SUBMERGED WEIGHT

ASSUME RACK HAS LIFTED OFF




$$I\ddot{\theta} = SWT \cdot l$$

$$M\ddot{z} = SWT + BWT = DWT$$

$$\ddot{z} = 1g \qquad M_1\ddot{z} = K_1 DWT$$

$$\Sigma M_a = 0$$

$$M = -I_1\ddot{\theta} - M_1\ddot{z}e + SWT\,f + BWT(e)$$

$$= -K_1 SWT\,l - K_1 DWT\,e + SWT\,f + BWT\,e$$

$$DWT - BWT = SWT$$

$$= SWT(-K_1(l+e) + f)$$

$$= SWT(f - K_1(l+e))$$

$$\Sigma M_b = 0$$

$$M = K_2\,SWT\,(l - g)$$

5.11 - CONT

$$\Sigma F_V = 0 = -M_1 \ddot{z} - R_V + SWT + BWT(K_1)$$

$$R_V = SWT - K_1 \frac{DWT}{g} \ddot{z} + K_1 SWT$$

$$\ddot{z} = 1g \qquad SWT = DWT - BWT$$

$$R_V = SWT(1 - K_1)$$

or. $\Sigma F_V = 0$

$$R_V = M_2 \ddot{z}$$

$$= K_2 SWT$$

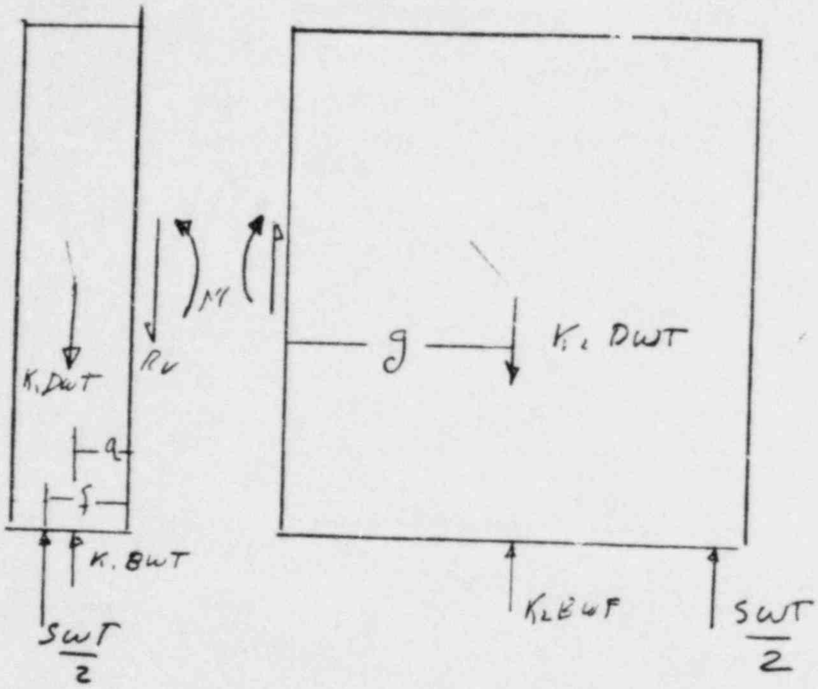
APPLYING THE VALUES FROM TABLE 5.10.1, TO THE ABOVE FORMULAE, THE FOLLOWING SUMMARY IS DEVELOPED

5.11.1 - SUMMARY

| | STANDARD RACK | | CONSOLIDATED RACK | |
|---|---|---|---|---|
| PLANE → | NORTH-SOUTH OBE & SSE | EAST-WEST OBE & SSE | NORTH-SOUTH OBE & SSE | EAST-WEST OBE & SSE |
| SWT | 208,190 | 208190 | 341,060 | 341,060 |
| $R_V$ | 164,470 | 145,730 | 269,440 | 238,740 |
| M | 745,890 | 614,260 | 1,221,932 | 1,006,300 |
| $F_2$* | 2849 | 3445 | 4667 | 5644 |
| $F_{1T}$* | 1605 | 364 | 2630 | 596 |
| $F_{1B}$* | 535 | 1093 | 876 | 1791 |

* SEE SECT 5.9.3.1.

5.11.2 FORCES FOR SWT WHEN RACK DOES NOT LIFT OFF




$$\Sigma F_V = 0 = -R_V - K_1 DWT + K_1 BWT + \frac{SWT}{2}$$

$$R_V = \frac{SWT}{2} - 2K \frac{\overbrace{(DWT - BWT)}^{SWT}}{2}$$

$$= \frac{SWT}{2}(1 - 2K_1)$$

$$CK: \Sigma F_V = 0 = R_V - K_2(DWT - BWT) + \frac{SWT}{2}$$

$$R_V = 2K_2 \frac{SWT}{2} - \frac{SWT}{2}$$

$$= \frac{SWT}{2}(2K_2 - 1)$$

CONSOLIDATED RACK-N.S- SWT = 341,060

$$R_V = \frac{341,060}{2}\left(2\left(\frac{11}{14}\right) - 1\right)$$

$$= 97,429 \text{ LBS}$$

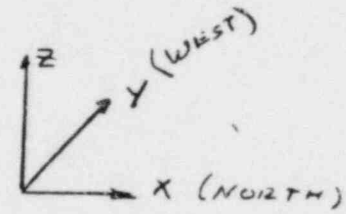
# SECTION 6.0

## TABLE OF CONTENTS

## 6.1 Discussion -

In this section the forces developed on weld sets in Section 5 are broken down into forces on the individual welds shown on the figures in Sect 6.2 & 6.3.

These forces are combined as follows:




In the North - South Plane

The shear force for each direction is given by $\sqrt{F_x^2 + F_z^2}$

In the East - West Plane

The shear force for each direction is given by $\sqrt{F_y^2 + F_z^2}$

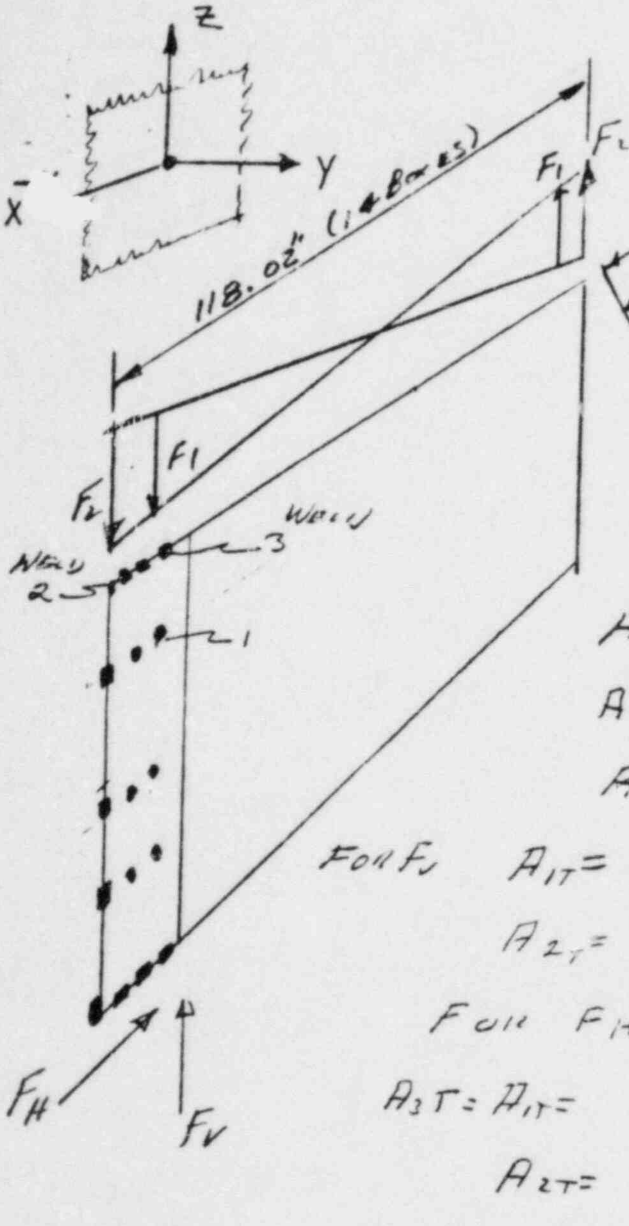
The resulting shear forces are then calculated by:

$$F_T = SWT \pm \sqrt{F_{N-S}^2 + F_{E-W}^2 + F_{UT}^2}$$

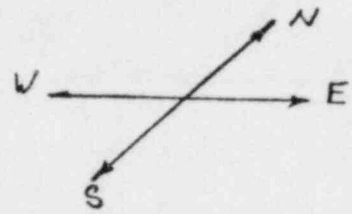
The tensile force in the weld is calculated by

$$F_6 = SWT \pm \sqrt{F_{Z(N\text{-}S)}^2 + F_{Z(E\text{-}W)}^2 + F_{Z(UT)}^2}$$

## 6.2 - NORTH - SOUTH LOADING - N-S PLANE








WELD AREA:

$A_1$ (FUSSION) = 0.196 in²

$A_2$ (2 in FILLET) = 0.36 in²

$A_3$ (1 in FILLET) = 0.18 in²

FOR $F_V$ $A_{1T}$ = 2.98 in² (5.4.1)

$A_{2T}$ = 1.80 in²

FOR $F_H$ FROM 5.

$A_3T = A_{1T}$ = 6.22 in² (5.4.2.1)

$A_{2T}$ = 8.28 in²

FROM 5.4.11 ($F_V$)

$F_1 = F_7 = 127.4E\text{-}\phi3\ F_V$ (5.4.11)

$F_2 = F_8 = 109.22E\text{-}\phi3\ F_V$

FROM 5.4.2.1 ($F_H$)

$F_1 = 158.11E\text{-}\phi3\ F_H$

$F_2 = 420.95E\text{-}\phi3\ F_H$

6.2- CONT-

6.2.1 - FORCES ON INDIVIDUAL WELDS (REF 5A.1.1)

FOR FV ($F_Z$)

$F_1 = 0.196(127.4E\text{-}03 F_V)/2.88 = 8.67E\text{-}03\ F_V$

$F_2 = 0.36(109.72E\text{-}03 F_V)/1.80 = 21.84E\text{-}03\ F_V$

$F_3 = 0.18(127.4E\text{-}03 F_V)/2.236 = 10.256E\text{-}03\ F_V$

FOR FH ($F_X$)

$F_1 = 0.196(158.11E\text{-}03)/6.22 = 4.98E\text{-}03\ F_H$

$F_2 = 0.36(420.95E\text{-}03)/8.28 = 18.30E\text{-}03\ F_H$

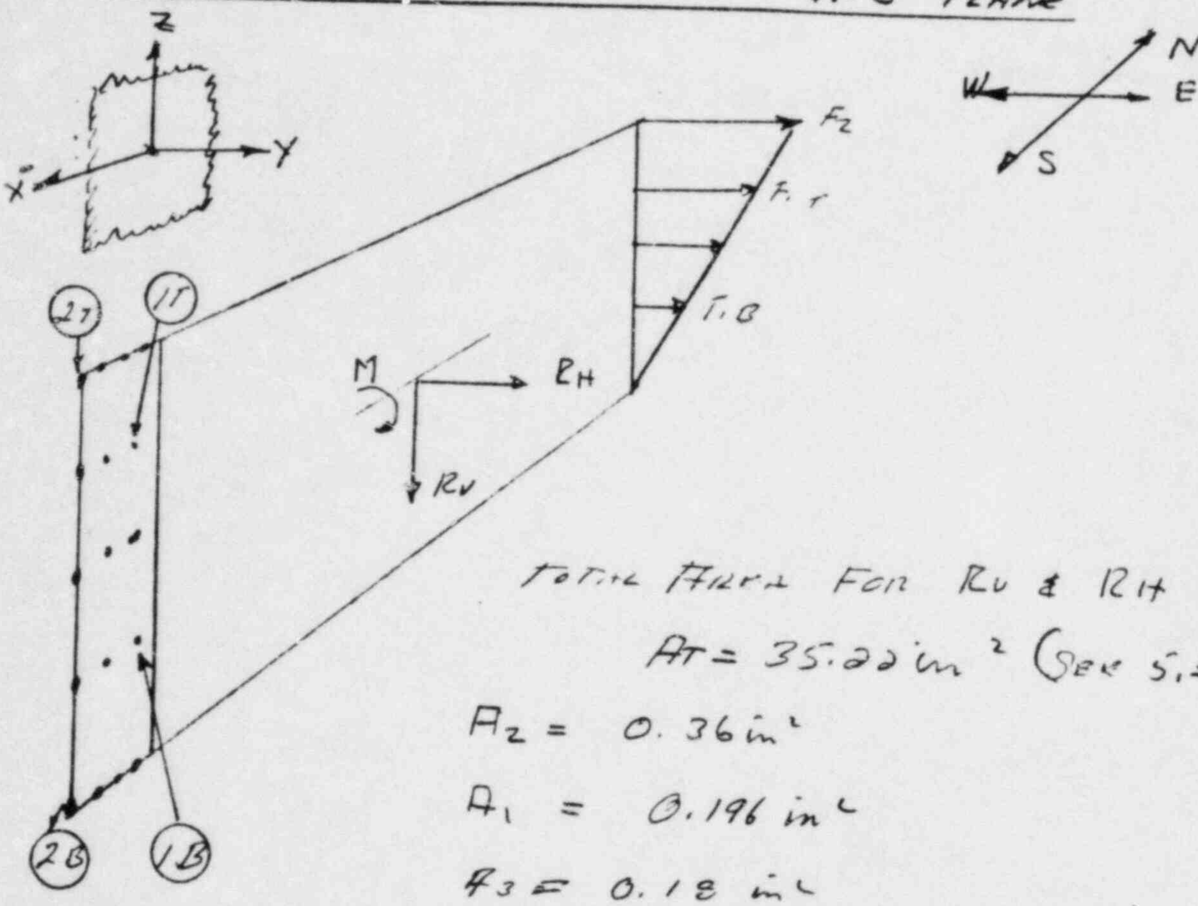
$F_3 = 0.18(158.11E\text{-}03)/6.22 = 4.576E\text{-}03\ F_H$

| | | STANDARD RACK FORCES IN LBS | | CONSOLIDATED RACK FORCES IN LBS | |
|---|---|---|---|---|---|
| | | OBE | SSE | OBE | SSE |
| | $F_V$ ($F_Z$) | 63,510 | 196,510 | 0 | 114,640 |
| | $F_H$ ($F_X$) | 170,000 | 231,500 | 160,200 | 239,300 |
| WELD #1 | $F_X = 4.98E\text{-}03 F_H$ | 847 | 1153 | 797 | 1192 |
| | $F_Y = 0$ | 0 | 0 | 0 | 0 |
| | $F_Z = 8.67E\text{-}03 F_V$ | 550 | 1700 | 0 | 994 |

| | | | | | |
|---|---|---|---|---|---|
| WELD #2 | $F_X = 18.30E\text{-}03 F_H$ | 3111 | 4236 | 2932 | 4379 |
| | $F_Y = 0$ | 0 | 0 | 0 | |
| | $F_Z = 21.84E\text{-}03 F_V$ | 1387 | 4292 | 0 | 2504 |

| | | | | | |
|---|---|---|---|---|---|
| WELD #3 | $F_X = 4.576E\text{-}03 F_H$ | 778 | 1059 | 733 | 1095 |
| | $F_Y = 0$ | 0 | 0 | 0 | 0 |
| | $F_Z = 10.256E\text{-}03 F_V$ | 650 | 2015 | 0 | 1175 |

6.3 EAST WEST LOADING - N-S PLANE




TOTAL AREA FOR RV & RH

$A_T = 35.22 \text{ in}^2$ (SEE 5.3.1)

$A_2 = 0.36 \text{ in}^2$

$A_1 = 0.196 \text{ in}^2$

$A_3 = 0.18 \text{ in}^2$

FOR WELD #1 (RV & RH)

$F_X = 0$

$F_Y = \frac{0.196}{35.22} R_H = 0.006 R_H$

$F_Z = \frac{0.196}{35.22} R_V = 0.006 R_V$

AREAS FOR M

$A_{3T}$ $A_{2T} = 8.28 \text{ in}^2$ (6.2)

$A_{1T} = (2)(2)(0.18) + (0.196)(2)(14) = 6.218 \text{ in}^2$

6.3 - CONT

CONT - FOR WELD #1 & FOR M

$F_x = 0$

$F_y = \frac{0.196}{6.218} F_1 = 0.032 F_1$

$F_z = 0$

FOR WELD #2 FOR $R_V$ & $R_H$

$F_x = 0$

$F_y = \frac{0.36}{36.22} R_H = 0.010 R_H$

$F_z \frac{0.36}{35.22} = 0.010 R_V$

WELD #2 FOR M

$F_x = 0$

$F_y = \frac{0.36 F_2}{8.28} = 0.043 F_2$

$F_z = 0$

FOR WELD #3 FOR $R_V$ & $R_H$

$F_x = 0$

$F_y = \frac{0.18}{35.22} = 0.005 R_H$

$F_z = \frac{0.18}{35.22} = 0.005 R_V$

FOR M $F_x = F_z = 0$

$F_y = 0.18 F_2 / 8.28 = 0.022 F_2$

## 6.3 – Cont- E-W Load – N-S Plane

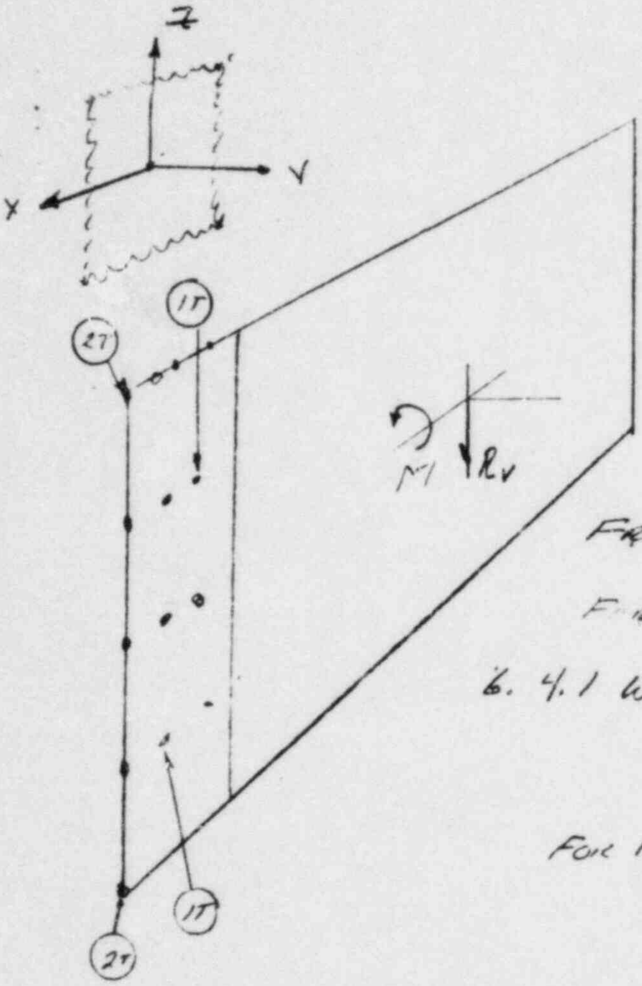
### 6.3.2 Summary

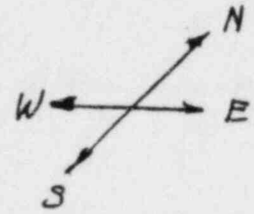
| | | Standard Rack | | Consolidated Rack | |
|---|---|---|---|---|---|
| | | OBE lb | SSE lb | OBE lb | SSE lb |
| Weld #1 | $R_V$ | 129,600 | 121,400 | 44,900 | 119,800 |
| | $R_H$ | 109,400 | 115,000 | 107,100 | 129,400 |
| A= 0.196 in² | Fx | 0 | 0 | 0 | 0 |
| | Fy 0.006 $R_H$ | 656 | 690 | 643 | 776 |
| | Fz 0.006 $R_V$ | 778 | 728 | 269 | 719 |
| | $F_{1(T)}$ M | 17,500 | 18,600 | 17900 | 20,200 |
| | Fx | 0 | 0 | 0 | 0 |
| | Fy 0.032$F_1$ | 560 | 595 | 573 | 646 |
| | Fz | 0 | 0 | 0 | 0 |
| | | | | | |
| Weld #2 | Rv & $R_H$ Fx | 0 | 0 | 0 | 0 |
| | Fy 0.010 $R_H$ | 1094 | 1150 | 1070 | 1294 |
| A = 0.36 in² | Fz 0.010 $R_V$ | 1296 | 1214 | 449 | 1198 |
| | $F_2$ (M) | 31,100 | 33,000 | 31,800 | 35,800 |
| | Fx | 0 | 0 | 0 | 0 |
| | Fy 0.043 $F_2$ | 1337 | 1419 | 1367 | 1539 |
| | Fz | 0 | 0 | 0 | 0 |

6.3.2- Summary -Cont

| | | STN | | Cons. | |
|---|---|---|---|---|---|
| | | OBE | SSE | OBE | SSE |
| Weld #3 | Fx | 0 | 0 | 0 | 0 |
| $A_3$ = | Fy = 0.005 RH | 547 | 575 | 536 | 647 |
| $0.18 IN^2$ | Fz = 0.005 RV | 648 | 607 | 225 | 599 |
| | Fz (#) | 31,100 | 33,000 | 31,800 | 35,800 |
| | $F_x$ | 0 | 0 | 0 | 0 |
| | Fy 0.022 $F_z$ | 684 | 726 | 700 | 788 |
| | Fz | 0 | 0 | 0 | 0 |

## 6.4 VERTICAL LOADING - NORTH SOUTH PLANE




SEE SECTION 5.10 (VERT. SEISMIC)

FROM SECTION 6.3

FOR Rv

6.4.1 WELD #1

$Fx = 0$

$Fy = 0$

$Fz = 0.006\ Rv$

FOR M

$Fx = 0$

$Fy = 0.032\ F_1$

$Fz = 0$

WELD #2
FOR Rv

$Fx = 0$

$Fy = 0$

$Fz = 0.010 Rv$

FOR M

$Fx = 0$

$Fy = 0.043\ F_2$

$Fz = 0$

6.4.2 SUMMARY – VERTICAL – N-S PLANE.

| | | STANDARD RACK | | CONSOLIDATED RACK | |
|---|---|---|---|---|---|
| | | OBE | SSE | OBE | SSE |
| WELD #1 | $R_V$ | 50,196 | | 83,588 | |
| | Fx | 0 | 0 | 0 | 0 |
| | Fy | 0 | 0 | 0 | 0 |
| | Fz (0.006)($R_V$) | 301 | | 501 | |
| | $F_1$ M B<br>T | 163<br>489 | | 272<br>816 | |
| | Fx | 0 | 0 | 0 | 0 |
| | Fy $0.032 F_{1B}$<br>$0.032 F_{1T}$ | 5.2<br>15.6 | 8.8<br>2.9 | 8.7<br>26.1 | 14.6<br>4.9 |
| | Fz | 0 | 0 | 0 | 0 |
| WELD #2 | | | | | |
| | $R_V$ Fx | 0 | 0 | 0 | 0 |
| | Fy | 0 | 0 | 0 | 0 |
| | Fz (0.010)($R_V$) | 502 | | 836 | |
| | $F_2$(M) | 867 | | 1448 | |
| | Fx | 0 | 0 | 0 | 0 |
| | FY $0.043 F_2$ | 37.3 | 37.3 | 62.3 | 62.3 |
| | Fz | 0 | 0 | 0 | 0 |

6.4 – Cont

6.4.2 – Vertical Summary – Cont

| | | STD | | QONS | |
|---|---|---|---|---|---|
| | | OBE | SSE | OBE | SSE |
| Weld # 3 | $F_x$ | 0 | 0 | 0 | 0 |
| | $F_Y$ = 0.005 $R_H$ | 0 | 0 | 0 | 0 |
| | $F_z$ – 0.005 $R_H$ | 212 | 212 | 353 | 353 |
| | $F_z$ (m) B | 866 | 866 | 1442 | 1442 |
| | T | 0 | 0 | 0 | 0 |
| | $F_x$ | 0 | 0 | 0 | 0 |
| | $F_Y$ = 0.022 $F_z$ | 19.1 | 19.1 | 31.7 | 31.7 |
| | $F_z$ | 0 | 0 | 0 | 0 |

## 6.5 SWT LOADING - NORTH-SOUTH PLANE

THE Fx, Fy & Fz 'S ARE SAME AS FOR 6.4

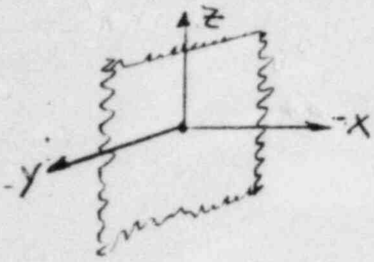
| | | STANDARD RACK | | CONSOLIDATED RACK | |
|---|---|---|---|---|---|
| | | OBE | SSE | OBE | SSE |
| WELD #1 | Rv | 164,470 | | 97,429* | 269,440 |
| | Fx | 0 | 0 | 0 | 0 |
| | Fy | 0 | 0 | 0 | 0 |
| | Fz 0.006 Rv | 987 | | 584 | 1617 |
| | F1(m) T B | 1605 535 | | 2630 876 | |
| | Fx | 0 | 0 | 0 | 0 |
| | Fy T B 0.032(F1) | 51 17 | | 84 28 | |
| | Fz | 0 | 0 | 0 | 0 |
| | | | | | |
| WELD #2 | R1 Fx | 0 | 0 | 0 | 0 |
| | Fy | 0 | 0 | 0 | 0 |
| | Fz 0.010 Rv | 1645 | | 974 | 2695 |
| | Fz (m) | 2849 | | 4667 | |
| | Fx | 0 | 0 | 0 | 0 |
| | Fy 0.043 Fz | 123 | | 201 | |
| | Fz | 0 | 0 | 0 | 0 |

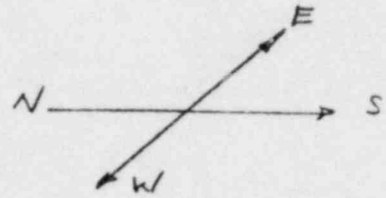
* NO LIFT OFF

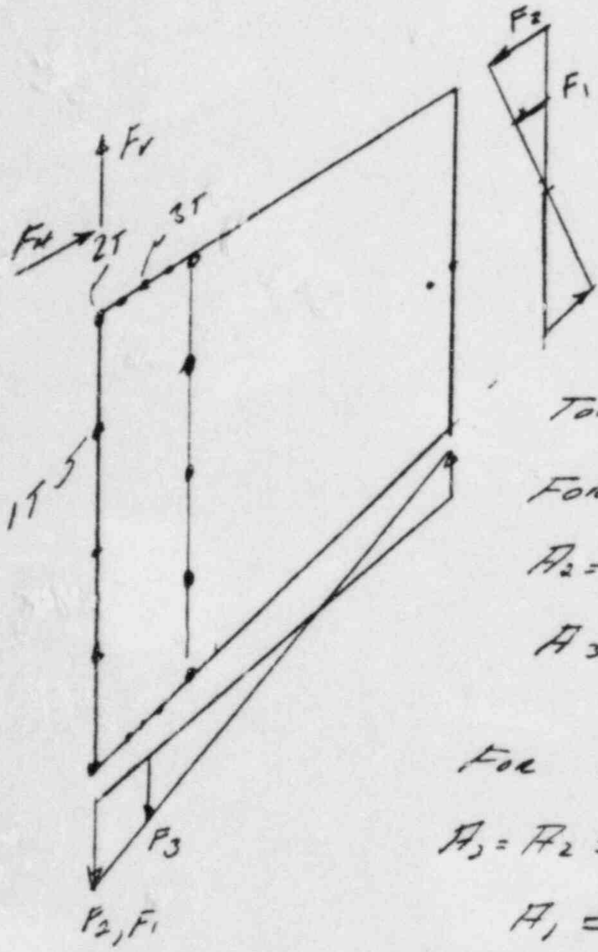
6.5 - CONT.

| | | STD | | CONS | |
|---|---|---|---|---|---|
| | | OBE | SSE | OBE | SSE |
| WELD # 3 | Fx | 0 | 0 | 0 | 0 |
| | Fy | 0 | 0 | 0 | 0 |
| | Fz 0.005 RN | 822 | | 487 | 1347 |
| | Fz (in) B T | 1835 | | 3056 | |
| | Fx | 0 | 0 | 0 | 0 |
| | FY 0.022Fz | 40 | 40 | 67 | 67 |
| | FZ | 0 | 0 | 0 | 0 |

## 6.6 EAST WEST LOAD — E-W PLANE




SINGLE WELD AREA RESISTING FORCE

$A_3 = 0.18\ in^2$

$A_2 = A_1 = 0.36\ in^2$

TOTAL AREAS

FOR $F_V$

$A_2 = A_1 = (5)(0.36) = 1.80\ in^2$

$A_3 = (6)(0.18) = 1.08\ in^2$

FOR $F_H$

$A_3 = A_2 = (11)(0.36) + 10(3)(0.18) = 9.36\ in^2$

$A_1 = (11)(0.36) = 3.96\ in^2$

FROM 5.4.1.2 $F_2 = F_1 = F_{12} = 125.4E{-}03\ F_V$

$F_3 = F_{11} = 67.70E03\ F_V$

FROM 5.4.2.2 $F_2 = 452.17E{-}03\ F_H$

$F_1 = 95.65E{-}03\ F_H$

6.6 - Cont E-W LOAD, E-W PLANE

6.6.1 - Forces on Individual Welds.

For $F_V$ -

$$F_3 = \frac{0.18}{1.08}(67.70E\text{-}03\ F_V) = 11.28E\text{-}03\ F_V$$

$$F_2 = F_1 = \frac{0.36}{1.80}(125.4E\text{-}03\ F_V) = 25.08E\text{-}03\ F_V$$

For $F_H$

$$F_3 = \frac{0.18}{9.36}(452.17E\text{-}03\ F_H) = 8.695E\text{-}03 F_H$$

$$F_2 = \frac{0.36}{9.36}(452.17E\text{-}03\ F_H) = 17.391E\text{-}03 F_H$$

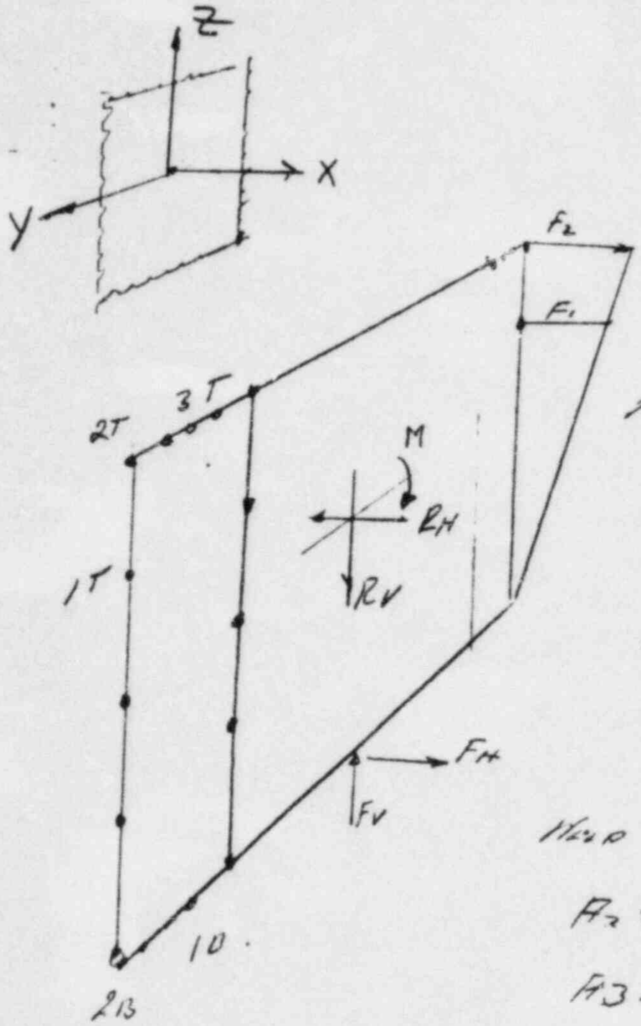
$$F_1 = \frac{0.36}{3.96}(95.65E\text{-}03\ F_H) = 8.695E\text{-}03 F_H$$

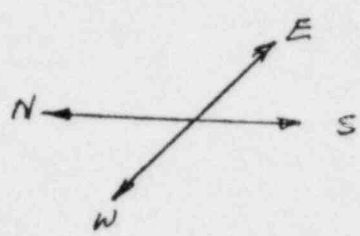
6.6 - CONT -

6.6.2 SUMMARY

| | | STANDARD RACK LBS | | CONSOLIDATED RACK LBS | |
|---|---|---|---|---|---|
| | | OBE | SSE | OBE | SSE |
| | $F_H$ | 156,200 | 164,300 | 153,000 | 184,700 |
| | $F_V$ | 185,110 | 173,410 | 64,140 | 171,040 |
| WELD #1 | $F_X$ | 0 | 0 | 0 | 0 |
| | $F_Y$ = 8.695 E-03 $F_H$ | 1358 | 1428 | 1330 | 1606 |
| | $F_Z$ = 25.08 E-03 $F_V$ | 4643 | 4349 | 1609 | 4290 |
| WELD #2 | $F_X$ | 0 | 0 | 0 | 0 |
| | $F_Y$ = 17.391 E-03 $F_H$ | 2716 | 2857 | 2661 | 3212 |
| | $F_Z$ = 25.08 E-03 $F_V$ | 4643 | 4349 | 1609 | 4290 |
| WELD #3 | $F_X$ | 0 | 0 | 0 | 0 |
| | $F_Y$ 8.695 E-03 $F_H$ | 1358 | 1428 | 1330 | 1606 |
| | $F_Z$ = 11.28 E-03 $F_V$ | 2088 | 1956 | 723 | 1929 |

## 6.7 NORTH-SOUTH LOAD – E-W PLANE




$A_{TOTAL} F_2$  $A_{2T} = A_{3T} = 9.36 in^2$

$F_1$  $A_1 = 3.96 in^2$

FROM 5.2.2  FOR $R_H$ & $R_V$

$A_T = 30.6 in^2$

WELD AREA RESISTING FORCE

$A_2 = A_1 = 0.36$

$A_3 = 0.18 in^2$

WELD #1

$F_x = {}^*0(R_H) + \frac{0.36}{3.96} F_1 = 0.091 F_1$

$F_Y = 0$

$F_Z = \frac{0.36}{30.6} R_V = 0.012 R_V$

* COMPRESSIVE STRESSES ACT ON BOXES, NOT THE WELDS

6. 7 - CONT -

N-S LOAD, E-W PLANE

WELD # 2

$$F_x = 0(R_V) + \frac{0.36}{9.36} F_z = 0.038 F_z$$

$$F_Y = 0$$

$F_z$: SAME AS #1 $= -0.012 R_V$

WELD # 5

$$F_x = 0(R_V) + \frac{0.18 \; F_z}{9.36} = 0.019 F_z$$

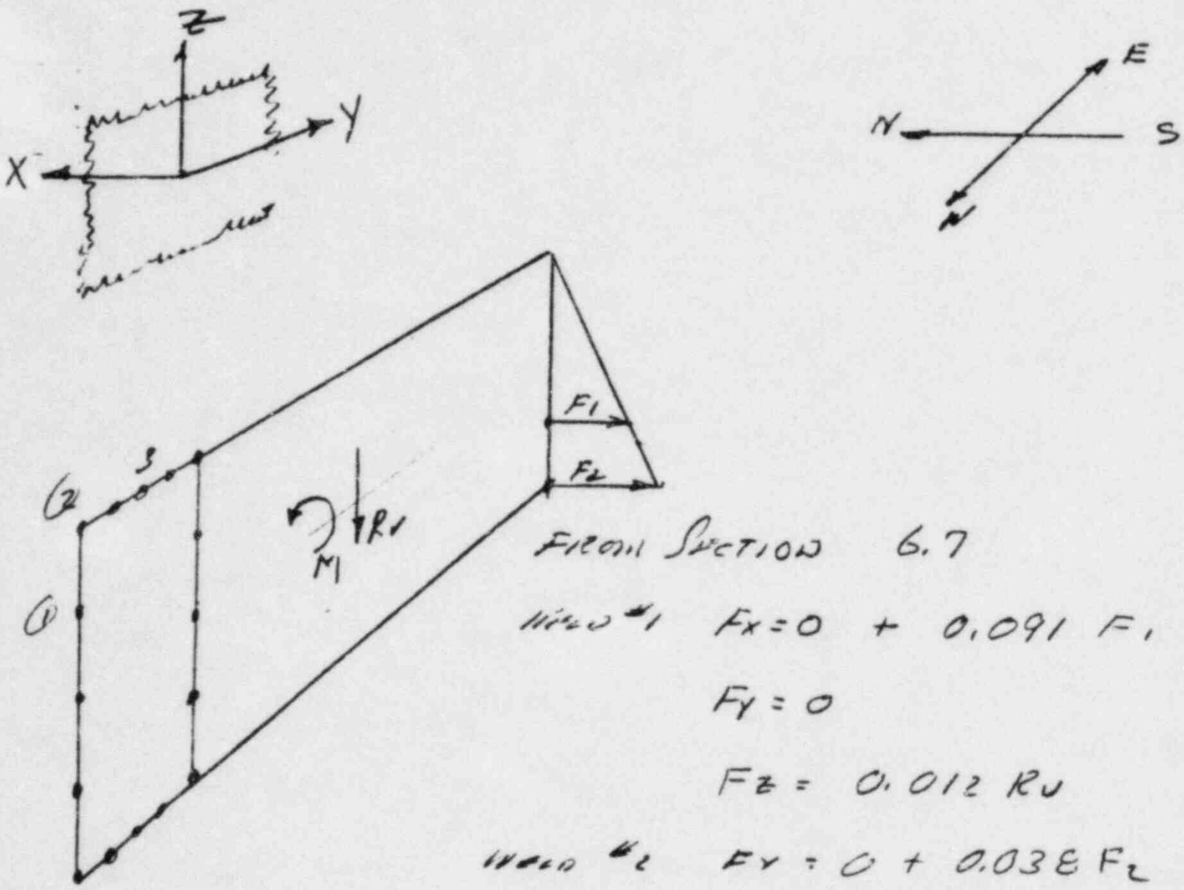
$$F_Y = 0$$

$$F_z = \frac{0.18}{30.6} R_V = 0.006 R_V$$

## 6.7 - SUMMARY - NORTH-SOUTH LOAD - E-W PLANE

| | | STANDARD RACK | | CONSOLIDATED RACK | |
|---|---|---|---|---|---|
| | | OBE LBS | SSE LBS | OBE LBS | SSE LBS |
| Sect 5.9.3 | RH | 133,600 | 181,900 | 125,900 | 188,000 |
| | RV | 49,900 | 154,400 | 0.0 | 90,000 |
| WELD #1 | FX | 0 | 0 | 0 | 0 |
| | FY | 0 | 0 | 0 | 0 |
| | FZ=0.012RV | 598 | 1853 | 0.0 | 1080 |
| | F1(m) | 15,300 | 20,200 | 14,700 | 21,400 |
| | FX 0.091 F1 | 1329 | 1838 | 1338 | 1915 |
| | FY | 0 | 0 | 0 | 0 |
| | FZ | 0 | 0 | 0 | 0 |
| WELD #2 | FX | 0 | 0 | 0 | 0 |
| | FY | 0 | 0 | 0 | 0 |
| | FZ 0.012RV | 617 | 1853 | 0.0 | 1080 |
| | F2(m) | 48,100 | 63,800 | 46,200 | 67,300 |
| | FX 0.038F2 | 1828 | 2424 | 1756 | 2557 |
| | FY | 0 | 0 | 0 | 0 |
| | FZ | 0 | 0 | 0 | 0 |
| WELD #3 | FX | 0 | 0 | 0 | 0 |
| | FY | 0 | 0 | 0 | 0 |
| | FZ 0.006RV | 300 | 926 | 0.0 | 540 |
| | F2(m) | 48100 | 63,800 | 46,200 | 67,300 |
| | FX 0.019(F2) | 914 | 1212 | 878 | 1278 |
| | FY | 0 | 0 | 0 | 0 |
| | FZ | 0 | 0 | 0 | 0 |

6.8. VERTICAL LOAD - E-W - PLANE




FROM SECTION 6.7

WELD #1 $F_X = 0 + 0.091\ F_1$

$F_Y = 0$

$F_Z = 0.012\ R_V$

WELD #2 $F_X = 0 + 0.038\ F_2$

$F_Y = 0$

$F_Z = 0.012\ R_V$

WELD #3 $F_X = 0 + 0.019\ F_2$

$F_Y = 0$

$F_Z = 0.006\ R_V$

6.8 Summary - Vertical - E-W- Plane.

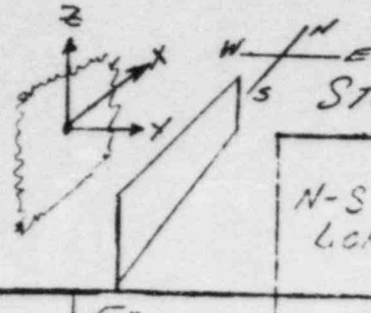
| | | Standard Rack OBE | Standard Rack SSE | Consolidated Rack OBE | Consolidated Rack SSE |
|---|---|---|---|---|---|
| | RH | 0 | 0 | 0 | 0 |
| | RV | 44477 | 44477 | 74066 | 74066 |
| Weld #1 | Fx | 0 | 0 | 0 | 0 |
| | Fy | 0 | 0 | 0 | 0 |
| | Fz 0.012RV | 533 | 533 | 888 | 888 |
| A=0.36 | F1(M) | 275 | 275 | 458 | 458 |
| | Fx 0.091F1 | 25 | 25 | 42 | 42 |
| | Fy | 0 | 0 | 0 | 0 |
| | Fz | 0 | 0 | 0 | 0 |
| Weld #2 | Fx | 0 | 0 | 0 | 0 |
| | Fy | 0 | 0 | 0 | 0 |
| | Fz 0.012 RV | 533 | 533 | 888 | 888 |
| | F1 M | 866 | 866 | 1442 | 1442 |
| | Fx 0.038F1 | 33 | 33 | 55 | 55 |
| | Fy 0 | 0 | 0 | 0 | 0 |
| | Fz | 0 | 0 | 0 | 0 |
| Weld #3 | Fx | 0 | 0 | 0 | 0 |
| | Fy | 0 | 0 | 0 | 0 |
| | Fz 0.006RV | 267 | 267 | 445 | 445 |
| | F1 M1 | 866 | 866 | 1442 | 1442 |
| | Fx 0.038F1 | 33 | 33 | 55 | 55 |
| | Fy | 0 | 0 | 0 | 0 |
| | Fz | 0 | 0 | 0 | 0 |

6.9 SWT LOADING - E-W PLANE

THE FX, FY & FZ'S ARE SAME FORMULA AS 6.8

| | | STANDARD, RACK | | CONSOLIDATED RACK | |
|---|---|---|---|---|---|
| | | OBE | SSE | OBE | SSE |
| | RV ✓ | 145730 | 145730 | 238740 | 238740 |
| | FX | 0 | 0 | 0 | 0 |
| WELD #1 | FY | 0 | 0 | 0 | 0 |
| | FZ 0.012RV | 1749 | 1749 | 2864 | 2864 |
| | F1 (M) | 1093 | 1093 | 1791 | 1791 |
| | FX 0.091 F1 | 100 | 100 | 163 | 163 |
| | FY | 0 | 0 | 0 | 0 |
| | FZ | 0 | 0 | 0 | 0 |
| | | | | | |
| | FX | 0 | 0 | 0 | 0 |
| WELD #2 | FY | 0 | 0 | 0 | 0 |
| | FZ 0.012RV | 1749 | 1749 | 2864 | 2864 |
| | F1 M | 3445 | 3445 | 5644 | 5644 |
| | FX 0.038F1 | 130 | 130 | 215 | 215 |
| | FY | 0 | 0 | 0 | 0 |
| | FZ | 0 | 0 | 0 | 0 |
| | | | | | |
| WELD #3 | FX | 0 | 0 | 0 | 0 |
| | FY | 0 | 0 | 0 | 0 |
| | FZ 0.006RV | 875 | 875 | 1432 | 1432 |
| | F1 M | 3445 | 3445 | 5644 | 5644 |
| | FX 0.019F1 | | | | |
| | FY | 0 | 0 | 0 | 0 |
| | FZ | 0 | 0 | 0 | 0 |

6.10

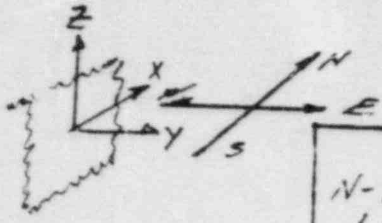



# SUMMARY - LOADS AND STRESSES
## STANDARD RACK - NORTH - SOUTH PLANE - OBE

| Weld | | N-S LOAD | E-W LOAD | VERT LOAD | SWC LOAD | FOR $(F_x^2+F_z^2)^{1/2}$ $F_S = SWT \pm (F_{NS}^2 + F_{EW}^2 + F_V^2)^{1/2}$ | $\tau = F_S / A$ | * $S = F_T / A$ |
|---|---|---|---|---|---|---|---|---|
| WELD #1 A= 0.196 | Fx | ±847 | 0 | 0 | 0 | | | T 1374 |
| | FY | 0 | T+1354 B+970 | T .4.2 B 12.5 | T+20 B+42 | | | ST 7010 |
| | Fz | ±550 | −778 | −301 | −981 | | | B 1012 |
| | $(F_x^2+F_z^2)^{1/2}$ | 1009 | 778 | 301 | 981 | 2290 | 11,680 | S 5164 |
| WELD #2 A= 0.36 | Fx | ±3111 | 0 | 0 | 0 | | | T 2787 S = 7742 |
| | Fy | 0 | T 2672 B 0 | T = 0 B = 7 | 115 | | | |
| | Fz | ±1387 | −1296 | −502 | −1645 | | | |
| | $(F_x^2+F_z^2)^{1/2}$ | 3406 | 1296 | +502 | 1645 | 5325 | 14,800 | |
| WELD #3 A= 0.18 | Fx | ±778 | 0 | 0 | 0 | | | T 1412 S = 7844 |
| | FY | 0 | T 1412 B 0 | T = 0 B = 16.4 | T 0 B 40 | | | |
| | Fz | ±650 | 648 | 212 | −822 | | | |
| | $(F_x+F_z)^{1/2}$ | 1013 | 648 | 212 | 822 | 2043 | 13,350 | |

* THE "T" OR "B" NO IS $F_{TOP}$ OR $F_{BOTTOM} = SWC \pm \sqrt{F_{Z\,N\text{-}S} + F_{Z\,E\text{-}W} + F_{Z\,VT}}$

6.11




# SUMMARY - LOADS AND STRESSES
## STANDARD RACK - N-S PLANE - SSE

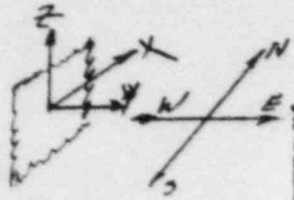
| | | N-S LOAD | E-W LOAD | VERT LOAD | SWC LOAD | FOR $(F_x^2+F_z^2)^{1/2}$ $F_S = SWT + (F_{NS}^2 + F_{EW}^2 + F_{VT}^2)^{1/2}$ | $\tau = F_S/A$ | * $S = F_T/A$ |
|---|---|---|---|---|---|---|---|---|
| WELD #1 A= 0.196 | $F_X$ | N+ 1153 S- | 0 | 0 | 0 | | | T 1838 B 931 ST 9378 SB 1862 |
| | $F_Y$ | 0 | T+ 1396 B+ 930 | T 4.2 B 12.5 | T + 502 B 1506 | | | |
| | $F_Z$ | N+ 1700 S- | -728 | -301 | -981 | | | |
| | $(F_X^2+F_Z^2)^{1/2}$ | 2051 | 728 | 301 | 981 | 3178 | 16210 | |
| WELD #2 A= 0.36 | $F_X$ | N+ 4236 S- | 0 | 0 | 0 | | | T 2782 ST = 7728 |
| | $F_Y$ | 0 | T+ 2667 B 0 | 6.9 | 115 | | | |
| | $F_Z$ | N+ 4296 S- | -1214 | -502 | -1645 | | | |
| | $(F_X^2+F_Z^2)^{1/2}$ | 6033 | 1214 | 502 | 1645 | 7819 | 21720 | |
| WELD #3 A= 0.18 | $F_X$ | N+ 1059 S- | 0 | 0 | 0 | | | T 1342 ST = 7456 |
| | $F_Y$ | 0 | T 1342 B 0 | T - 0 B + 16.4 | T - 0 B - 40 | | | |
| | $F_Z$ | N+ 2015 S- | 607 | 212 | 822 | | | |
| | $(F_X^2+F_Z^2)^{1/2}$ | 2274 | 607 | 212 | 822 | 3187 | 17,710 | |

* SEE 6.10.1

6.12

# SUMMARY - LOADS AND STRESSES

## CONSOLIDATED RACK - NORTH-SOUTH PLANE - OBE

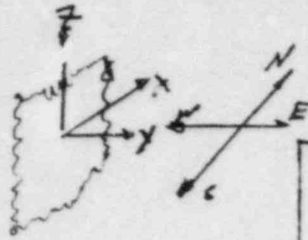



| | | N-S LOAD ** | E-W LOAD | VERT LOAD | SWC LOAD | FOR $(F_x^2+F_z^2)^{1/2}$ $F_S = SWT + (F_{NS}^2 + F_{EW}^2 + F_{V}^2)^{1/2}$ | $\tau = F_S/A$ | * $S = F_Y/A$ |
|---|---|---|---|---|---|---|---|---|
| WELD #1 $A = 0.196$ | $F_X$ | 798 | 0 | 0 | 0 | - | | T 920 B 878 |
| | $F_Y$ | 0 | T + 867 B + 467 | T 216 B 646 | T 26 B 79 | | | ST - 4694 SO - 4478 |
| | $F_Z$ | 0 * | 269 | - 501 | 584 | | | |
| | $(F_X^2+F_Z^2)^{1/2}$ | 798 | 269 | 501 | 584 | 1564 | 7980 | |
| WELD #2 $A = 0.36$ | $F_X$ | 2932 | 0 | 0 | 0 | | | T 1872 |
| | $F_Y$ | 0 | T 1872 B 0 | T 0 B 12 | T 0 B 206 | | | ST = 5200 |
| | $F_Z$ | 0 | -449 | 836 | 974 | | | |
| | $(F_X^2+F_Z^2)^{1/2}$ | 2932 | 449 | 836 | 974 | 4061 | 11,280 | |
| WELD #3 $A = 0.16$ | $F_X$ | 733 | 0 | 0 | 0 | | | T 1264 |
| | $F_Y$ | 0 | T 1264 B 0 | T 0 B 277 | T 0 B 67 | | | ST = 7022 |
| | $F_Z$ | 0 | 225 | 353 | 1347 | | | |
| | $(F_X^2+F_Z^2)^{1/2}$ | 733 | 225 | 353 | 1347 | 2191 | 12170 | |

* SEE 6.10.1

** NO LIFT OFF

6.13

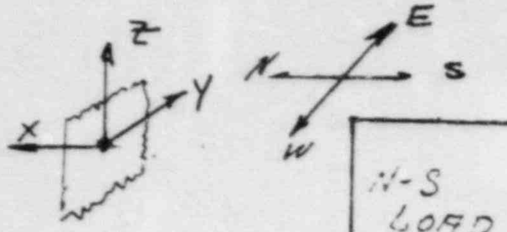



# SUMMARY - LOADS AND STRESSES
## CONSOLIDATED RACK - NORTH-SOUTH PLANE - SSE

| Weld | | N-S LOAD | E-W LOAD | VERT LOAD | SWC LOAD | FOR $(F_X^2+F_Z^2)^{1/2}$ $F_S = SWT + (F_{NS}^2 + F_{EW}^2 + F_{VT}^2)^{1/2}$ | $\tau = F_S/A$ | * $S = F_r/A$ |
|---|---|---|---|---|---|---|---|---|
| WELD #1 A = 0.196 | Fx | 1192 | 0 | 0 | 0 | | | T 1417 B 1022 ST = 7230 SB = 5214 |
| | Fy | .0 | T 1391 B 943 | T 7 B 14 | T 26 B 79 | | | |
| | Fz | 989 | 719 | 501 | 1617 | | | |
| | $(F_X^2+F_Z^2)^{1/2}$ | 1549 | 719 | 501 | 1617 | 3397 | 17,330 | |
| WELD #2 A = 0.36 | Fx | 4379 | 0 | 0 | 0 | | | T 2802 ST = 7783 |
| | Fy | 0 | T 2802 B 0 | T 0 B 12 | T 0 B 208 | | | |
| | Fz | 2504 | 1198 | 836 | 2695 | | | |
| | $(F_X^2+F_Z^2)^{1/2}$ | 5044 | 1198 | 836 | 2695 | 7946 | 22,070 | |
| WELD #3 A = 0.18 | Fx | 1095 | 0 | 0 | 0 | | | T 620 ST = 3444 |
| | Fy | 0 | T 620 B 0 | T 0 B 27 | T 0 B 67 | | | |
| | Fz | 1175 | 599 | 343 | -1347 | | | |
| | $(F_X^2+F_Z^2)^{1/2}$ | 1606 | 599 | 343 | 1347 | 3095 | 17,200 | |

* SEE 6.10.1

6.14

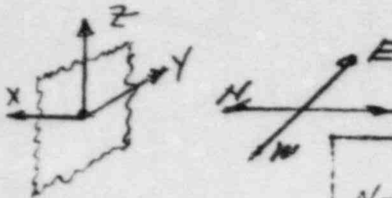



SUMMARY - LOADS AND STRESSES
STANDARD RACK - EAST WEST PLANE OBE

| | | N-S LOAD | E-W LOAD | VERT LOAD | SWC LOAD | FOR $(F_y^2+F_z^2)^{1/2}$ $F_S = SWT + (F_{NS}^2 + F_{EW}^2 + F_{VT}^2)^{1/2}$ | $\tau = F_S/A$ | * $S = F_T/A$ |
|---|---|---|---|---|---|---|---|---|
| WELD #1 A= 0.36 | Fx | T -1392 B 464 | 0 | T 7 B 32 | T 65 B 194 | | | T 1457 ST= 4047 |
| | Fy | 0 | T B -1358 | 0 | 0 | | | |
| | Fz | T&B - 598 | T B -4643 | - 533 | 1749 | | | |
| | $(F_y^2+F_z^2)^{1/2}$ | 598 | 4878 | 533 | 1749 | 6653 | 18480 | |
| WELD #2 A= 0.36 | Fx | T - 1828 B - 0 | 0 | T 0 B 28 | T 0 B 255 | | | T 1828 ST= 5078 |
| | Fy | 0 | T B -2716 | 0 | 0 | | | |
| | Fz | T&B - 617 | T B -4642 | 533 | 1749 | | | |
| | $(F_y^2+F_z^2)^{1/2}$ | 617 | 5378 | 533 | 1749 | 7188 | 19,970 | |
| WELD #3 A= 0.18 | Fx | T - 914 B - 0 | 0 | T 0 B 14 | T 0 B 1000 | | | B 1014 SB= 5633 |
| | Fy | 0 | T B -1358 | 0 | 0 | | | |
| | Fz | T B - 300 | -2088 | 266 | 875 | | | |
| | $(F_y+F_z)^{1/2}$ | 300 | 2491 | 266 | 875 | 3397 | 18876 | |

* SEE 6.10.1

6.15




# SUMMARY - LOADS AND STRESSES
## STANDARD RACK - EAST WEST PLANE - SSE

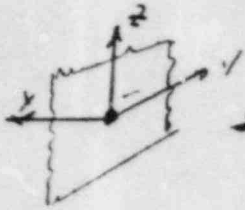
| | | N-S LOAD | E-W LOAD | VERT LOAD | SWC LOAD | FOR $(F^2+F^2)^{1/2}$ $F_S = SWT + (F_{NS}^2 + F_{EW}^2 + F_{PT}^2)^{1/2}$ | $\tau = F_S/A$ | * $S = F_T/A$ |
|---|---|---|---|---|---|---|---|---|
| Weld [illegible] A= 0.36 | $F_x$ | T 1866 B 619 | 0 | T 7 B 32 | T 65 B 191 | | | T 1936 ST - 5378 |
| | $F_y$ | 0 | T/B 1428 | 0 | 0 | | | |
| | $F_z$ | 1853 | T/B 4349 | 533 | 1749 | | | |
| | $(F_y^2+F_z^2)^{1/2}$ | 1853 | 4577 | 533 | 1749 | 6715 | 18,660 | |
| Weld [illegible] A= 0.36 | $F_x$ | T 2451 B 0 | 0 | T 0 B 25 | T 0 B 255 | | | T 2451 ST=6800 |
| | $F_y$ | | T/B -2857 | 0 | 0 | | | |
| | $F_z$ | 1853 | T/B -4349 | 533 | 1749 | | | |
| | $(F_y^2+F_z^2)^{1/2}$ | 1853 | 5203 | 533 | 1749 | 7298 | 20,270 | |
| Weld [illegible] A= 0.18 | $F_x$ | T 914 B 0 | 0 | T 0 B 14 | T 0 B 1000 | | | T - 914 B - 1014 SB = 5633 |
| | $F_y$ | 0 | T/B - 1428 | 0 | 0 | | | |
| | $F_z$ | 308 | T/B - 1952 | 266 | 875 | | | |
| | $(F_y^2+F_z^2)^{1/2}$ | 926 | 2418 | 266 | 875 | 3478 | 19,320 | |

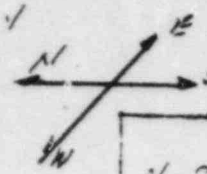
SEE 6.10.1

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

BY [illegible] DATE 1/30/84 SUBJECT SUMMARY LOAD & STRESSES SECT. 6 SHEET 29 OF 34
CHKD. BY JLD DATE 2/23/84 PROJ. NO. 6369

6.16



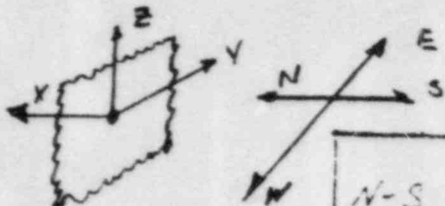




SUMMARY - LOADS AND STRESSES
CONSOLIDATED RACK - EAST WEST PLANE - OBE

| | | N-S LOAD ** | E-W LOAD | VERT LOAD | SWC LOAD | FOR $(F_y^2+F_z^2)^{1/2}$ $F_S = SWT + (F_{NS}^2 + F_{EW}^2 + F_{VT}^2)^{1/2}$ | $\tau = F_S/A$ | * $S = F_r/A$ |
|---|---|---|---|---|---|---|---|---|
| WELD #1 A = 0.36 | $F_x$ | T - 1338 B - 446 | 0 | T -131 B 379 | T -106 B -318 | | | T 1455 |
| | $F_y$ | 0 | T/B 1330 | 0 | 0 | | | ST = 4043 |
| | $F_z$ | 0 | T/B -1609 | 888 | -2864 | | | |
| | $(F_y^2+F_z^2)^{1/2}$ | 0 | 2058 | 888 | 2864 | 5132 | 14,260 | |
| WELD #2 A = 0.36 | $F_x$ | T -1756 B - 0 | 0 | T 0 B 47 | T 0 C 418 | | | T 1756 |
| | $F_y$ | 0 | T/B -2661 | 0 | 0 | | | ST = 4878 |
| | $F_z$ | 0 | T/B 1609 | 888 | -2864 | | | |
| | $(F_y^2+F_z^2)^{1/2}$ | 0 | 3110 | 888 | 2864 | 6098 | 16,940 | |
| WELD #3 A = 0.18 | $F_x$ | T - 878 B 0 | 0 | T 0 B 7 | T 0 C 1000 | | | B 1000 |
| | $F_y$ | 0 | 1330 | 0 | 0 | | | SB = 2778 |
| | $F_z$ | 0 | -723 | -445 | 1432 | | | |
| | $(F_y^2+F_z^2)^{1/2}$ | 0 | 1514 | 445 | 1432 | 3009 | 16,720 | |

* SEE 6.10.1
** NO LIFTOFF

6.17

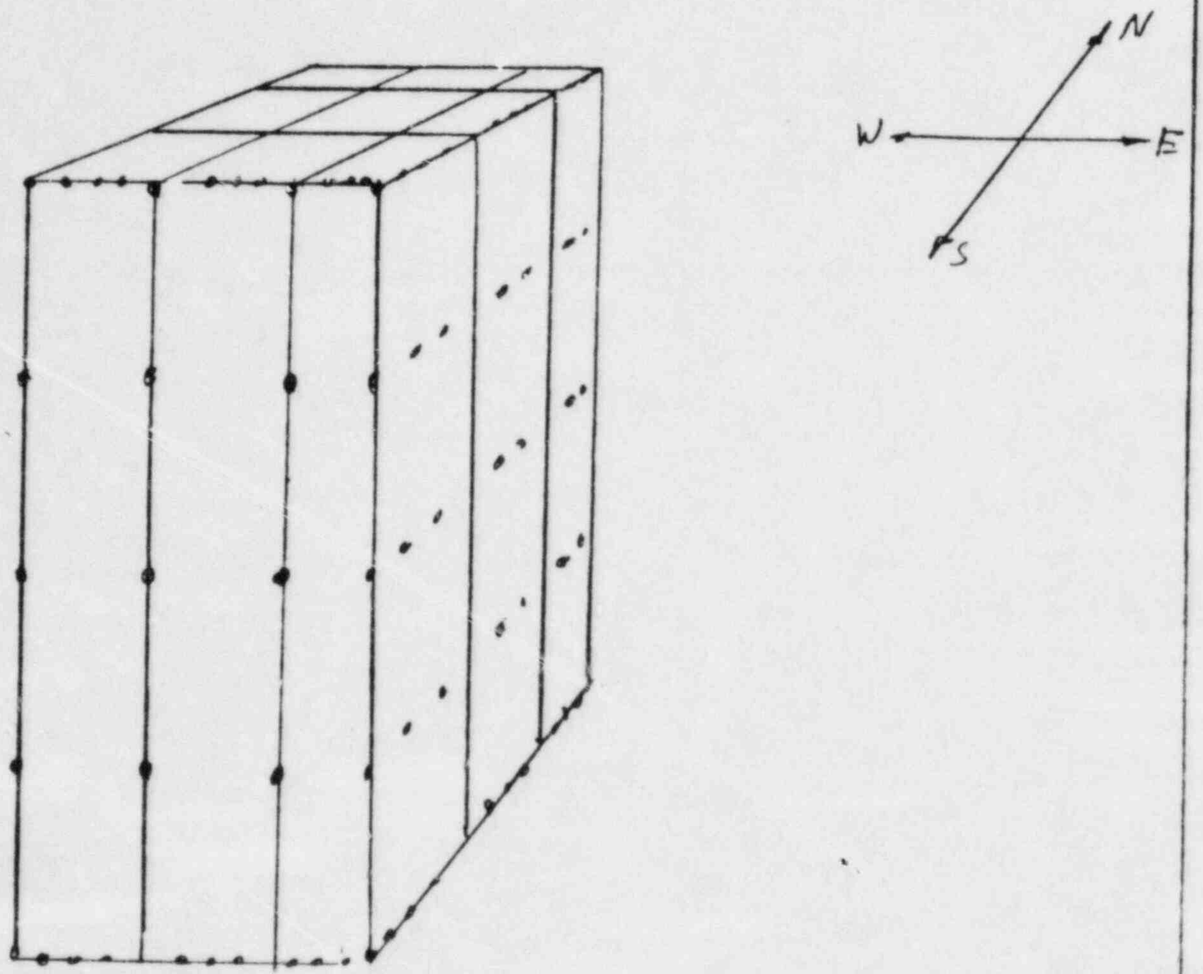



SUMMARY - LOADS AND STRESSES
CONSOLIDATED RACK - EAST-WEST PLANE - SSE

| | | N-S LOAD | E-W LOAD | VERT LOAD | SWC LOAD | FOR $(F^2+F^2)^{1/2}$ $F_S$ = SWT + $(F_{NS}^2 + F_{EW}^2 + F_{VT}^2)^{1/2}$ | $\tau = F_S/A$ | * $S = F_T/A$ |
|---|---|---|---|---|---|---|---|---|
| WELD #1 A= 0.36 | Fx | T-1993 B-655 | 0 | T-131 B-379 | T-106 B-318 | | | T 2043 ST= 5676 |
| | Fy | 0 | T/B 1606 | 0 | 0 | | | |
| | Fz | 1080 | T/B 4290 | 888 | -2864 | | | |
| | $(F_y^2+F_z^2)^{1/2}$ | 1080 | 4581 | 888 | 2864 | 7653 | 21260 | |
| WELD #2 A= 0.36 | Fx | T-2573 B-0 | 0 | T 0 B 47 | T=0 B=418 | | | T 2573 ST= 7147 |
| | Fy | 0 | T/B 3212 | 0 | 0 | | | |
| | Fz | 1080 | T/B 4290 | 888 | 2864 | | | |
| | $(F_y^2+F_z^2)^{1/2}$ | 1080 | 5359 | 888 | 2864 | 8402 | 23340 | |
| WELD #3 A= 0.18 | Fx | T-1286 B-0 | 0 | T 0 B 7 | T 0 B 1000 | | | T= 1268 ST= 7044 |
| | Fy | 0 | T/B 1606 | 0 | 0 | | | |
| | Fz | 540 | T/B 1929 | -445 | 1432 | | | |
| | $(F_y+F_z)^{1/2}$ | 540 | 2510 | 445 | 1432 | 4037 | 22,430 | |

* SEE 6.10.1

## 6.18 SHEAROUT STRESSES AT CORNERS.




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

WELD AREA

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

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

4 SETS OF 5-2in FILLET WELD - 0.18 TK

$A = (4)(5)(2)(0.18) = 7.20 \text{ IN}^2$

3 SETS OF 6 - FUSION WELDS $A = 0.196 \text{ in}^2$

$A = (3)(6)(0.196) = 3.53 \text{ in}^2$

6.18 - CONT -

TOTAL WELD AREA =

$A_T = 6.48 + 7.70 + 3.[illegible]3 = 17.21 \text{ in}^2$

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 |
| Y = F/A | 11,945 | 13,821 | 13107 | 16431 |

F.S. - OBE

F.S. = 24,000/13,110

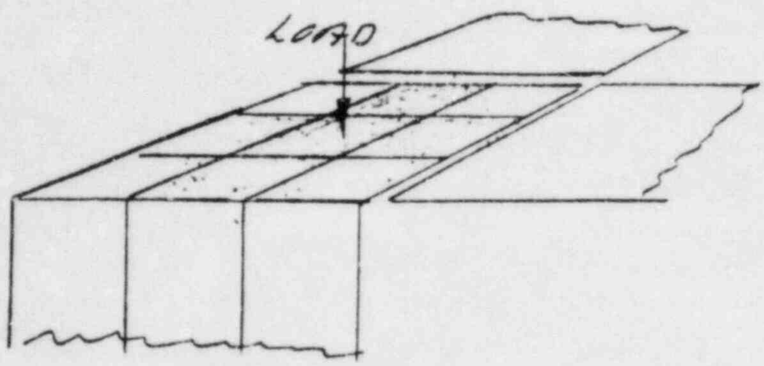
F.S. = 1.83

F.S. - SSE

F.S. = 36,000/16450

F.S. = 2.2

## 6.19 - 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 BOX)

EXTERNAL - 2 SIDES

TOTAL AREA -

30 SIDES × 8.64 in LONG PER SIDE × 0.09 in TK.

= 23.33 $in^2$

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 = 28E06
$\mu$ = POISSONS RATIO = 0.3
K = CONSTANT - (FIXED-FIXED) = 6.97

$$\sigma_{CR} = \frac{(6.97)(\pi)^2(28E06)}{10.92}\left(\frac{0.09}{8.64}\right)^2 = 19,140$$

6.19 - Cont

| | Standard Rack | | Consolidated Rack | |
|---|---|---|---|---|
| | OBE | SSE | OBE | SSE |
| Load = F RMS Sort^4 | 205,567 | 237,862 | 225,573 | 282,762 |
| S = F/A | 8811 | 10196 | 9670 | 12120 |

$\sigma_{cr}$ = 19,140 psi

∴ F.S. = 19,140 psi / 12,120 = 1.58

# 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 in X 11 in X 3/4 in = 121 in² (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 | 225,573 | 282,782 |
| BEARING STRESS | 1700 | 1965 | 1864 | 2337 |

ALLOWABLE CONCRETE BEARING STRESS

$S_B = 0.85 \phi f'_c = (0.85)(0.7)(3000\text{ Psi})$ (REF. 6)

$S_B = 1785$ 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

$\therefore S_B = (1785\text{ Psi})(2)$ 3570 Psi

MIN. F.S. = $3570\text{ PSI}/2337 = 1.53$

△1

# 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.