Sta#4 (15)
JUL 26 1998

# ENGINEERING DATA TRANSMITTAL



1. EDT 622232

| | | |
|---|---|---|
| 2. To: (Receiving Organization) Distribution | 3. From: (Originating Organization) TWRS Projects/SST Retrieval | 4. Related EDT No.: n/a |
| 5. Proj./Prog./Dept./Div.: D2991 W-320 TWRS/TCPN # ~~D2MA1~~ | 6. Design Authority/ Design Agent/Cog. Engr.: JW Bailey, NHC | 7. Purchase Order No.: n/a |
| 8. Originator Remarks: For approval and release of a new supporting document. This document has been generated to ensure retrievability of the Project W-320 "Piping Calculations, Vol. 4". | | 9. Equip./Component No.: n/a |
| | | 10. System/Bldg./Facility: 241-C-106 |
| 11. Receiver Remarks: 11A. Design Baseline Document? [X] Yes [] No | | 12. Major Assm. Dwg. No.: n/a |
| | | 13. Permit/Permit Application No.: n/a |
| | | 14. Required Response Date: |

15. DATA TRANSMITTED

| (A) Item No. | (B) Document/Drawing No. | (C) Sheet No. | (D) Rev. No. | (E) Title or Description of Data Transmitted | (F) Approval Designator | (G) Reason for Transmittal | (H) Originator Disposition | (I) Receiver Disposition |
|---|---|---|---|---|---|---|---|---|
| 1 | HNF-2474 | - | 0 | Project W-320, 241-C-106 Sluicing, Piping Calculations, Vol. 4 | NA | | | - |
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16. KEY

| Approval Designator (F) | Reason for Transmittal (G) | | Disposition (H) & (I) | |
|---|---|---|---|---|
| E, S, Q, D or N/A (see WHC-CM-3-5, Sec.12.7) | 1. Approval | 4. Review | 1. Approved | 4. Reviewed no/comment |
| | 2. Release | 5. Post-Review | 2. Approved w/comment | 5. Reviewed w/comment |
| | 3. Information | 6. Dist. (Receipt Acknow. Required) | 3. Disapproved w/comment | 6. Receipt acknowledged |

17. SIGNATURE/DISTRIBUTION
(See Approval Designator for required signatures)

| (G) Reason | (H) Disp. | (J) Name | (K) Signature | (L) Date | (M) MSIN | (G) Reason | (H) Disp. | (J) Name | (K) Signature | (L) Date | (M) MSIN |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | 1 | Design Authority | JW Bailey | 7/23/98 | S2-48 | | | | | | |
| | | Design Agent | MC Davenport | 7/23/98 | | | | | | | |
| 2 | 1 | Cog.Eng. | ~~CE Graves~~ | | S2-48 | | | | | | |
| 2 | 1 | Cog. Mgr | JW Bailey | 7/23/98 | S2-48 | | | | | | |
| | | QA | | | | | | | | | |
| | | Safety | | | | | | | | | |
| | | Env. | | | | | | | | | |

| | | | |
|---|---|---|---|
| 18. MC Davenport ~~CE Graves~~ ~~3/24/98~~ 7/23/98 Signature of EDT Originator Date | 19. Authorized Representative for Receiving Organization Date | 20. JW Bailey ~~3/24/98~~ 7/23/98 J.W. Bailey Design Authority/ Cognizant Manager Date | 21. DOE APPROVAL (if required) Ctrl. No. [] Approved [] Approved w/comments [] Disapproved w/comments |

BD-7400-172-2 (05/96) GEF097

BD-7400-172-1

# Project W-320, 241-C-106 Sluicing Piping Calculations, Vol. 4

**John W. Bailey**
Numatec Hanford Co., Richland, WA 99352
U.S. Department of Energy Contract DE-AC09-96RL13200

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B&R Code: EW3130010 Total Pages: 337

Key Words: W-320, Sluicing, Tank 241-C-106, Tank 241-AY-102, WRSS, calculations, piping.

Abstract: This supporting document has been prepared to make the FDNW calculations for Project W-320, readily retrievable.

Product cut sheets in this document have been reviewed and are not Copyrighted

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DATE:
STA: #4
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Release Approval Date 7/24/98

Release Stamp

**Approved for Public Release**

# Project W-320, 241-C-106 Sluicing Piping Calculations, Vol. 4

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W320-27-015

Support Structural Analysis

| ICF KAISER HANFORD COMPANY | CALCULATION IDENTIFICATION AND INDEX | Page i of ii<br>Date 9/13/1996 |
|---|---|---|

This sheet shows the status and description of the attached Design Analysis sheets.

Discipline 27, Piping and Vessels WO/Job No. ER4319 Calculation No. W-320-27-015

Project No. & Name Project W 320 Waste Retrieval for Tank 241-C-106

Calculation Item Support Structural Analysis

These calculations apply to:

Dwg. No. H-2-818548 Shts 1 & 2 of 2 Rev. No. 0

Dwg. No. Rev. No.

Other (Study, CDR) Rev. No.

The status of these calculations is:

- ☐ Preliminary Calculations
- ☒ Final Calculations
- ☐ Check Calculations (On Calculation Dated )
- ☐ Void Calculation (Reason Voided )

Incorporated in Final Drawings? ☒ Yes ☐ No

This calculation verified by independent "check" calculation? ☐ Yes ☒ No

Original and Revised Calculation Approvals:

| | Rev. 0 Signature / Date | Rev. 1 Signature / Date | Rev. 2 Signature / Date |
|---|---|---|---|
| Originator | D. L Stone 5/20/94<br>J. R. Booth 5/31/94 | D. L Stone<br>8/8/95 | D. L Stone<br>10/3/96 |
| Checked by | M.M. Ahmed<br>5/20/94 | C.D. Jones<br>8/10/95 | 10/03/96 |
| Approved by | C.D. Jones<br>6/3/94 | C.D. Jones<br>8/10/95 | 10/03/96 |
| Checked Against Approved Vendor Data | | | |

INDEX


| Design Analysis Page No. | Description |
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| ii | Calculation Cross Index |
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| Appx A | "POP" Analysis |
| Appx B | Drawings |

| FLUOR DANIEL NORTHWEST INC. | CALCULATION IDENTIFICATION AND INDEX | Page ia of ii<br>Date 11/24/97 |
|---|---|---|

This sheet shows the status and description of the attached Design Analysis sheets.

Discipline: (27) Piping and Vessels WO/Job No.: ER4319 Calculation No.: W320-27-015

Project No. & Name: Project W-320 Waste Retrieval for Tank 241-C-106

Calculation Item: Support Structural Analysis

These calculations apply to:

Dwg. No.: See Calculation Cross Index Rev. No.

Dwg. No.: Rev. No.

Other (Study, CDR): Rev. No.

The status of these calculations is:

[] Preliminary Calculations

[X] Final Calculations

[] Check Calculations (On Calculation Dated)

[] Void Calculation (Reason Voided)

Incorporated in Final Drawings? [X] Yes [] No

This calculation verified by independent "check" calculations? [] Yes [X] No

Original and Revised Calculation Approvals:

| | Rev. 3 Signature/Date | Rev. 4 Signature/Date | Rev. 5 Signature/Date |
|---|---|---|---|
| Originator | Kelly K Hanson 11/24/97 | | |
| Checked by | M. Ahmed 3.13.98 | | |
| Approved by | D. L. Evans 4/9/98 | | |
| Checked Against Approved Vendor Data | M. Ahmed 4.10.98 | | |

INDEX

| Design Analysis Page No. | Description |
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| 3 - 29 | Caclulations |
| Appx A | "POP" Analysis |
| Appx B | Drawings |
| | |
| | Rev. 3 Incorporates As-Built Conditions. Page ia added. Pages ii, 1, 2, 6, and 16 revised. |
| | |

# CALCULATION CROSS INDEX (Typical)

Subject Calculation No.: W320-27-014



| Subject Calculation Revision No. | Superceded by Calculation No. | These interfacing calculation/documents provide input to the subject calculation, and if revised may require revision of the subject calculation. | | Results and conclusions of the subject calculation are used in these interfacing calculations and/or documents | | Does the output interface calculation/ documents require revision? | | Has the output interfacecalculation/ documents been revised? | | Discipline manager's signature and date indicating evaluation complete. |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Calculation/Document No. | Revision No. | Calculation/Document No. | Revision No. | Yes | No | Yes | No | |
| 3 | NA | H-2-818532, Sheet 1 | Ø 1 | | | | X | | X | X |
| | | H-2-818532, Sheet 2 | Ø 1 | | | | | | | |
| | | H-2-818548, Sheet 1 | Ø 1 | 3 | | | | | | D. L. Lemmo 7/16/98 |
| | | H-2-818548, Sheet 2 | Ø 1 | 3.13.98 | | | | | | |
| | | Calc # W320-27-013 | 3 | | | | | | | |
| | | Calc # W320-27-014 | 3 | | | | X | | X | X |

KEH 1975.00 (12/88)

| | | | | | |
|---|---|---|---|---|---|
| Client | WESTINGHOUSE HANFORD COMPANY | WO/Job No. | ER4319 | Filename | SSA-TEXT. WP |
| Subject | SUPPORT STRUCTURAL ANALYSIS | Date | 9 / 13 / 96 | By | D.L.STONE |
| PROJECT | W-320 WASTE RETRIEVAL for TANK 241-C-106 | Checked | 10 / 3 / 96 | By | N.J.JUPLO |
| Location | C TANK FARM - 200 W. AREA | Revised | 11 / 24 / 97 | By | K. Hoppe CHKD: [illegible] |

## OBJECTIVE:

The objective of this calculation is to perform the structural analysis of the Pipe Supports designed for Slurry & Supernate transfer pipe lines in order to meet the requirements of Code ASME Code B31.3.

## DESIGN INPUTS:

**Design Criteria:**

1. ASME Code B31.3-93 with B31.3a-93 Addenda.

2. Uniform Building Code, 1991 Edition.

3. Functional Design Criteria WHC-SD-W320-FDC-001, Rev ~~3~~ 4.

## DESIGN METHODOLOGY:

**Support Design Loads:**

The pipe support design loads are obtained from the piping stress calculations W320-27-14 (Ref.7) and W320-27-15 (Ref.8). These loads are the total summation of the gravity, pressure, thermal and seismic loads.

Since standard typical designs are used for each type of pipe support such as Y-Stop, Guide and Anchors, each type of support is evaluated for the maximum loads to which this type of supports are subjected. These loads are obtained from the AutoPipe analysis (Ref.7) and used to check the structural adequacy of these supports. These loads are tabulated on Page 3.

Since the intermediate anchor is designed to serve as an anchor for both primary pipe and encasement pipe, it is evaluated for the combined effect of the loads from the primary pipe (AutoPipe analysis) and encasement pipe loads. The only Encasement pipe load this anchor will be subjected to is a thermal axial load. This load is calculated on Page 3. In the event of earth quake, since anchor structure will move in tandem with ground motion, it will not experience any seismic loads.

## STRUCTURAL ANALYSIS:

The structural analysis (member stresses & weld stresses) is performed using the principles of statics as illustrated in "Design of Welded structures" by Blodgett (Ref.5) & "Formulas for Stress and Strain" by Roark (Ref.6).

The local stresses in the pipe wall due to welded attachments such as trunnions are computed based on Bjilaard principles promulgated in WRC Bulletin 107 (Ref.10). The "POP" computer program (Ref.11), a program based on WRC Bulletin, is used for computing the local stresses for Trunnion attachment. The calculated pipe local stresses are added to corresponding pipe stresses obtained from the AutoPipe analysis in order to satisfy the requirements of Code B31.3.

The base plates are analyzed using the moment of inertia method. The concrete anchors are qualified based on criteria in SDC 4.2, Rev-0, (Ref.14).

## CALCULATIONS:

See pages 3 thru 16 for calculations.
See Appendix-A for "POP" program results.

## REFERENCES:

1. ASME B31.3-93 Code and ASME B31.3.3a-93 Addenda for "Chemical and Petroleum Refinery".
2. Uniform Building Code, 1991 Edition.
3. Crane Technical Paper No: 410, 22nd Printing-1985.
4. AISC "Steel Construction Manual" 9th Edition.
5. "Design of Welded Structures" by Blodgett, 8th Printing.
6. "Formulas for Stress and Strain" by Roark & Young, 5th Edition.
7. Calculation: W320-27-14, ~~Rev-0~~ "Encasement Pipe Stress Analysis". Rev. 3 (3)
8. Calculation: W320-27-13, ~~Rev-0~~ " Process Pipe Stress Analysis". Rev. 3
9. Pipe Support Detail Drawings: H-2-818548 sh 1 & 2 of 2, Rev-0
10. WRC Bulletin no: 107, March 1979 "Local Stresses in Spherical and Cylindrical Shells due to External Loadings" by K.R. Wichman, A.G.Hopper and J.L. Mershon.
11. Computer program "POP" (PIPE ON PIPE) Version-0, Release Date: Feb 12, 1993.
12. W-~~030~~ 320 Project Specs: "WHC-SD-W320-FDC-001, Rev-~~2~~ 4" (3)
13. "Hand Book of Engineering Fundamentals" Third Edition by O. W. Eshback and M. Souders.
14. SDC 4.2, Rev-0, "Design & Installation of Expansion Anchors" (3)
(Now FOUW Practice # 134.215.1206, Design of Expansion Anchors)

## CONCLUSION:

The review of succeeding calculations indicates, pipe supports structures meet ASME Code B31.3 requirements.



Rev. 3 of this calculation verified the analysis against the as-built conditions. (3)
and found the changes does not have any adverse impact on analysis.

| | | | | | |
|---|---|---|---|---|---|
| Client | WESTINGHOUSE HANFORD CO. | WO/Job No. | ER4319 | Filename | FORCES.XLS |
| Subject | PROJECT W-320 WASTE RETRIEVAL | Date | 9/13/96 | By | D. L. STONE |
| for Tank 241-C-106 Support Structural Analysis | | Checked | 10/03/96 | By | N. J. JUPLO |
| Location C TANK FARM 200 EAST AREA | | Revised | | By | |

**SLURRY LINE** From Autopipe Analysis for Inner Process Pipe (Ref. 8)

| (Ref. W320-27-013 Appdx. A) | | FORCES (lb) | | | MOMENTS (ft-lb) | | |
|---|---|---|---|---|---|---|---|
| Anchor | Node | x | y | z | x | y | z |
| | A39 | 508 | 259 | 688 | 88 | 273 | 362 |
| Guide | Node | x | y | z | x | y | z |
| | A01 | 0 | 514 | 1218 | / | / | / |
| Incline | Node | x | y | z | x | y | z |
| | A74 | | 283 | | / | / | / |

**SUPERNATE LINE**

| (Ref. W320-27-013 Appdx. B) | | FORCES (lb) | | | MOMENTS (ft-lb) | | |
|---|---|---|---|---|---|---|---|
| Anchor | Node | x | y | z | x | y | z |
| | A39 | 422 | 259 | 612 | 88 | 227 | 362 |
| Guide | Node | x | y | z | x | y | z |
| | A41 | 670 | 532 | 670 | | | |
| Incline | Node | x | y | z | x | y | z |
| | A25 | | 286 | | / | / | / |

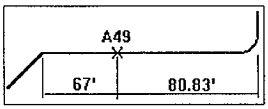
**ENCASEMENT PIPE AXIAL LOADS FOR INTERMEDIATE ANCHOR** (Ref. 7)

| (Ref. W320-27-013 Appdx. ) | | FORCES (lb) | | | MOMENTS (ft-lb) | | |
|---|---|---|---|---|---|---|---|
| Thermal | Node | x | y | z | x | y | z |
| Loads | A49 | | | 3844 * | | | |

* Note: Where Encasement Pipe segments on on either side of anchors are equal, axial friction forces at the anchor are equal in magnitude and opposite in direction, resulting in zero axial load on the anchors.
The maximum difference between pipe segment lengths on either side of an anchor occurs at Node A49.

Axial load at A49:

| ΔL = | F = | Fz = F x ΔL = |
|---|---|---|
| 13.82 | 23.18 | 3844.1712 |




(Ref. 7)

## DESIGN ANALYSIS

Client: WESTINGHOUSE HANFORD COMPANY
Subject: PROJECT W-320 WASTE RETRIEVAL
PIPE SUPPORT STRUCTURAL ANALYSIS
Location: C TANK FARM - 200 EAST AREA HANFORD

WO/Job No.: ER4319
Date: 9 / 13 / 96
Checked: 10/03/96
Revised:

Filename: SA-01.mcd
By: D.L. STONE
By: J. J. JUPLO
By:

---

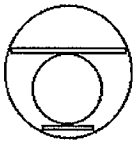
**DEAD WEIGHT SUPPORT ANALYSIS** (Details 2 and 4 Ref.9)

The purpose of this calculation is to determine a minimum plate thickness required for the Process Pipe Dead Weight Support.

Static bending analysis to determine maximum allowable stress for a minimum plate thickness.

Worst case loadings determined from *Autopipe* analysis. (See Page 3)

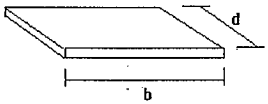
ASTM A36 — Plate Material (Ref. 9 )



$S_h := 16900 \cdot psi$ — Code B31.3 Allowable Stress at 200 deg F (Ref. 1 )

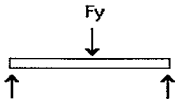
$F_y := 286 \cdot lbf$ — Worst case loading for Process Pipe Dead Weght Support.

$b := 3.3125 \cdot in$ — Design width of support plate. (Ref. 9 ) (Simple support beam span - conservative)




$d := 3 \cdot in$ — Plate Length

$M := F_y \cdot \frac{b}{4}$ — Moment at $F_y$ (Ref. 5 )




$M = 236.844 \cdot lbf \cdot in$

$t := 0.25 \cdot in$ — Design thickness of support plate.

$c := \left(\frac{t}{2}\right)$

$c = 0.125 \cdot in$ — Distance between centroid and outerfiber. (Ref. 5 )

$I := \left(\frac{d \cdot t^3}{12}\right)$

$I = 0.004 \cdot in^4$ — Moment of Inertia of the plate

$\sigma_{BpL} := \frac{M \cdot c}{I}$

$\sigma_{BpL} = 7.579 \cdot 10^3 \cdot psi$ — Calculated bending stress at $F_y$

## DESIGN ANALYSIS

Client: WESTINGHOUSE HANFORD COMPANY
Subject: PROJECT W-320 WASTE RETRIEVAL
PIPE SUPPORT STRUCTURAL ANALYSIS
Location: C TANK FARM - 200 EAST AREA HANFORD

WO/Job No.: ER4319
Date: 9 / 13 / 96 By: D.L. STONE
Checked: 10/03/96 By: J. J. JUPLO
Revised: By:

$\sigma_{all} := 1.33 \cdot S_h$ (Ref. 1)

$\sigma_{all} = 2.248 \cdot 10^4 \cdot psi$ Allowable stress for ASTM A-36 Plate

$$\left[\frac{M\left(\frac{t}{2}\right)}{\frac{d \cdot t_{min}^3}{12}}\right] \longrightarrow \frac{6 \cdot M}{d \cdot t_{min}^2}$$

Governing Equation (Ref. 5)

$t_{min} := \sqrt{\frac{6 \cdot M}{d \cdot \sigma_{all}}}$

$t_{min} = 0.145 \cdot in$ Minimum required plate thickness.

$t = 0.25 \cdot in$ Design Thickness (Ref. 9)

1/4" Plate is adequate for worst case loadings.

## DESIGN ANALYSIS

Client: WESTINGHOUSE HANFORD COMPANY
Subject: PROJECT W-320 WASTE RETRIEVAL
PIPE SUPPORT STRUCTURAL ANALYSIS
Location: C TANK FARM - 200 EAST AREA HANFORD

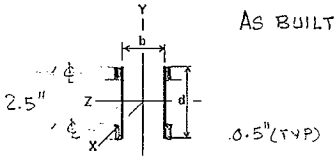
WO/Job No.: ER4319
Date: 9 / 13 / 96
Checked: 10/03/96
Revised: 11/24/97

By: D.L. STONE
By: N. J. JUPLO
By: K. Fayase CHK'D: L. Jupuo 3.139

WELD CALCULATIONS FOR JOINT BETWEEN ~~LUGS AND PROCESS PIPE:~~ Plate and Encasement Pipe

WELD PROPERTIES: (Ref. 5)

AS BUILT WELD: 1/2" INTERMITTENT GROOVE WELD @ 2½" [illegible]




$b := 3.313 \cdot in$ $\quad d = \cancel{3 \cdot in}$ 1 in

$Cy := \frac{b}{2}$ $\quad Cy = 1.656 \cdot in$

$Cz := \frac{d}{2}$ $\quad Cz = \cancel{1.5 \cdot in}$ 0.5 in

$Aw := 2 \cdot d$ $\quad Aw = \cancel{6 \cdot in}$ 2 in

$Swy := b \cdot d$ $\quad Swy = \cancel{9.939 \cdot in^2}$ 3 in²

$Swz := \frac{d^2}{3}$ $\quad Swz = \cancel{3 \cdot in^2}$ 0.33 in²

$\cancel{Jw := \frac{d \cdot (3 \cdot b^2 + d^2)}{6}}$ $\quad \cancel{Jw = 20.964 \cdot in^3}$

JOINT LOADS:

Tensile $Fx := F_y$ = 286 lbs $\quad Fy := 0 \cdot lbf \quad Fz := 0 \cdot lbf$

Moment $Mx := 0 \cdot in \cdot lbf \quad My := M$ = 237 in.lbs $\quad Mz := 0 \cdot in \cdot lbf$

WELD STRESS:

$$fw := \left[\left(\frac{Fx}{Aw} + \frac{My}{Swy} + \frac{Mz}{Swz}\right)^2 + \left(\frac{Fy}{Aw} + \frac{Mx \cdot Cy}{Jw}\right)^2 + \left(\frac{Fz}{Aw} + \frac{Mx \cdot Cz}{Jw}\right)^2\right]^{0.5} \qquad fw = \cancel{71.496} \ 222 \ \frac{lbf}{in}$$

FILLET WELD SIZE REQUIRED:

$S_h := 16700 \cdot psi$

$S := \cancel{1.2 \cdot 0.75 \cdot S_h}$ $\quad S = \cancel{1.503 \cdot 10^4} \ 1.33 \times 0.8 \times S_h \ 17981 \cdot psi$ Allowable Weld Stress per ASME Code B31.3 (Ref. 1)

$w := \frac{fw}{\cancel{0.707} \cdot S}$ $\quad w = \cancel{0.007 \cdot in}$ 0.013 Minimum ~~Fillet~~ GROOVE Weld Required

$w_{Design} := \left(\frac{1}{8} \cdot in\right)$ Design Fillet Weld Size

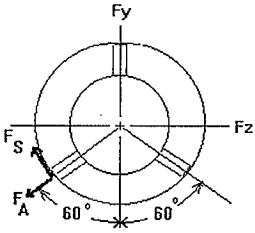
$SF_{fw} := \frac{w_{Design}}{w}$ $\quad SF_{fw} = \cancel{18.578}$ 9.6 Design exceeds requirement by a factor of ~~18.578~~ 9.6 - OK

**Process Pipe Guide Lug Design** (Detail 3 Ref. 9)

Assumptions: Lugs see Process Pipe Loads, only.

Each lug is subjected to total loading (conservative.) (Ref.8)
Critical Process Pipe Loads located at Nodepoint A41 on
Autopipe Model TRAN-SP are determined as critical.

Loads (See Page 3)




$F_x := 0 \cdot lbf$ Longitudinal Force

$F_y := 532 \cdot lbf$ Vertical Force

$F_z := \sqrt{670^2 + 670^2} \cdot lbf$ $F_z = 947.523 \cdot lbf$ Horizontal Force

$F_L := \frac{F_x}{3}$ $F_L = 0 \cdot lbf$ Longitudinal Loading

$F_A := F_y \cdot \cos(60 \cdot deg) + F_z \cdot \sin(60 \cdot deg)$ $F_A = 1.087 \cdot 10^3 \cdot lbf$ Axial Loading

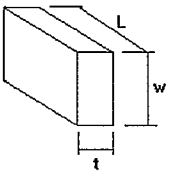
$F_S := F_y \cdot \sin(60 \cdot deg) + F_z \cdot \cos(60 \cdot deg)$ $F_S = 934.487 \cdot lbf$ Shear Loading

Properties

Material: ASTM A240 TP 304L (Ref. 9)

$S_h := 16700 \cdot psi$ Allowable Stress at 200 deg F (Ref.1)

$L := 4 \cdot in$ Lug Length




$w := 0.72 \cdot in$ Lug Width

$t := 0.375 \cdot in$ Lug thickness

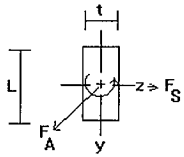
$c_y := \frac{t}{2}$

$c_z := \frac{L}{2}$ (Ref. 5)

$A := L \cdot t$ $A = 1.5 \cdot in^2$ Lug Area

$I_y := \frac{1}{12} \cdot t^3 \cdot L$ $\quad I_y = 0.018 \cdot in^4$ Moment of Area about y (Ref. 5)

$I_z := \frac{1}{12} \cdot t \cdot L^3$ $\quad I_z = 2 \cdot in^4$ Moment of Area about z




$z_y := \frac{I_y}{c_y}$ $\quad z_y = 0.094 \cdot in^3$ Section Modulus

$z_z := \frac{I_z}{c_z}$ $\quad z_z = 1 \cdot in^3$ Section Modulus

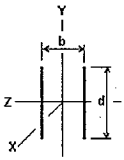
Tension and Bending

$\sigma_n := \frac{F_A}{A} + \frac{F_S \cdot w}{(z_y)}$ $\quad \sigma_n = 7.901 \cdot 10^3 \cdot psi$

$S_{all} := 1.33 \cdot S_h$ $\quad S_{all} = 2.221 \cdot 10^4 \cdot psi$

$|\sigma_n| = 7.901 \cdot 10^3 \cdot psi$ < $S_{all} = 2.221 \cdot 10^4 \cdot psi$ (Ref. 1)

WELD CALCULATIONS FOR JOINT BETWEEN LUGS AND PROCESS PIPE:




WELD PROPERTIES: (Ref. 5)

$b := 0.375 \cdot in$ $\quad d = 4 \cdot in$

$Cy := \frac{b}{2}$ $\quad Cy = 0.187 \cdot in$

$Cz := \frac{d}{2}$ $\quad Cz = 2 \cdot in$

$Aw := 2 \cdot d$ $\quad Aw = 8 \cdot in$

$Swy := b \cdot d$ $\quad Swy = 1.5 \cdot in^2$

$Swz := \frac{d^2}{3}$ $\quad Swz = 5.333 \cdot in^2$

$Jw := \frac{d \cdot (3 \cdot b^2 + d^2)}{6}$ $\quad Jw = 10.948 \cdot in^3$

## DESIGN ANALYSIS

Client: WESTINGHOUSE HANFORD COMPANY
Subject: PROJECT W-320 WASTE RETRIEVAL
PIPE SUPPORT STRUCTURAL ANALYSIS
Location: C TANK FARM - 200 EAST AREA HANFORD

WO/Job No.: ER4319
Date: 9 / 13 / 96
Checked: 10 / 03 / 96
Revised:

Filename: SA-03A.mcd
By: D.L. STONE
By: N.J. JUPLO
By:

**JOINT LOADS:**

| | | | |
|---|---|---|---|
| Tensile | $Fx := F_A$ | $Fy := 0 \cdot lbf$ | $Fz := 0 \cdot lbf$ |
| Moment | $Mx := 0 \cdot in \cdot lbf$ | $My := F_S \cdot w$ | $Mz := 0 \cdot in \cdot lbf$ |

**WELD STRESS:**

$$fw := \left[\left(\frac{Fx}{Aw} + \frac{My}{Swy} + \frac{Mz}{Swz}\right)^2 + \left(\frac{Fy}{Aw} + \frac{Mx \cdot Cy}{Jw}\right)^2 + \left(\frac{Fz}{Aw} + \frac{Mx \cdot Cz}{Jw}\right)^2\right]^{0.5} \qquad fw = 584.376 \cdot \frac{lbf}{in}$$

**FILLET WELD SIZE REQUIRED:**

$S_h := 16700 \cdot psi$

$S := 1.2 \cdot 0.75 \cdot S_h \qquad S = 1.503 \cdot 10^4 \cdot psi$ Allowable Weld Stress per ASME Code B31.3 (Ref. 1)

$w := \frac{fw}{0.707 \cdot S} \qquad w = 0.055 \cdot in$ Minimum Fillet Weld Required

$w_{Design} := \left(\frac{3}{16} \cdot in\right)$ Design Fillet Weld Size

$SF_{fw} := \frac{w_{Design}}{w} \qquad SF_{fw} = 3.409$ Design exceeds requirement by a factor of 3.409 - OK

PIPE LOCAL STRESSES DUE TO WELDED LUGS:

As is evident from above, since weld stresses are very low, local stresses in pipe will be insignificant.

Client: WESTINGHOUSE HANFORD COMPANY
Subject: PROJECT W-320 WASTE RETRIEVAL
PIPE SUPPORT STRUCTURAL ANALYSIS
Location: C TANK FARM - 200 EAST AREA HANFORD

WO/Job No.: ER4319
Date: 9 / 13 / 96
Checked: 10 / 03 / 96
Revised:

Filename: SA-07mcd
By: D.L. STONE
By: N. J. JUFLO
By:

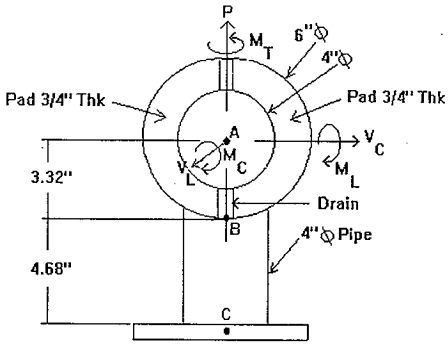
**INTERMEDIATE ANCHOR:** (Detail 1 Ref. 9)

**AUTOPIPE Loads for Process Pipe** (See Page 3)

$F_x := 508 \cdot lbf$ $M_x := 88 \cdot ft \cdot lbf$

$F_y := 259 \cdot lbf$ $M_y := 273 \cdot ft \cdot lbf$

$F_z := 688 \cdot lbf$ $M_z := 362 \cdot ft \cdot lbf$




**AUTOPIPE global axes oriented at 45 degree angle to pipe local axes.**

**PIPE LOADS at A**

| | | |
|---|---|---|
| $P := F_y$ | $P = 259 \cdot lbf$ | **Radial Load** |
| $V_C := F_z \cdot \cos(45 \cdot deg) + F_x \cdot \cos(45 \cdot deg)$ | $V_C = 845.7 \cdot lbf$ | **Circumferential Shear** |
| $V_L := F_x \cdot \sin(45 \cdot deg) + F_z \cdot \sin(45 \cdot deg)$ | $V_L = 845.7 \cdot lbf$ | **Longitudinal Shear** |
| $M_T := M_y$ | $M_T = 3.276 \cdot 10^3 \cdot in \cdot lbf$ | **Torsional Moment** |
| $M_C := M_x \cdot \cos(45 \cdot deg) + M_z \cdot \cos(45 \cdot deg)$ | $M_C = 3.818 \cdot 10^3 \cdot in \cdot lbf$ | **Circumferential Moment** |
| $M_L := M_x \cdot \sin(45 \cdot deg) + M_z \cdot \sin(45 \cdot deg)$ | $M_L = 3.818 \cdot 10^3 \cdot in \cdot lbf$ | **Longitudinal Moment** |
| $F_{AL} := 3844 \cdot lbf$ | | **Encased pipe Axial Load (See page 3)** |

**PIPE LOADS at B** **(Checking pipe local stresses and weld between pad and pipes.)**

| | |
|---|---|
| $P_B := P$ | $P_B = 259 \cdot lbf$ |
| $V_{CB} := V_C$ | $V_{CB} = 845.7 \cdot lbf$ |
| $V_{LB} := V_L + F_{AL}$ | $V_{LB} = 4.69 \cdot 10^3 \cdot lbf$ |
| $M_{TB} := M_T$ | $M_{TB} = 3.276 \cdot 10^3 \cdot in \cdot lbf$ |
| $M_{CB} := M_C + (3.32 \cdot in) \cdot V_C$ | $M_{CB} = 6.626 \cdot 10^3 \cdot in \cdot lbf$ |
| $M_{LB} := M_L + (3.32 \cdot in) \cdot V_{LB}$ | $M_{LB} = 1.999 \cdot 10^3 \cdot in \cdot lbf$ |

Client: WESTINGHOUSE HANFORD COMPANY
Subject: PROJECT W-320 WASTE RETRIEVAL
PIPE SUPPORT STRUCTURAL ANALYSIS
Location: C TANK FARM - 200 EAST AREA HANFORD

WO/Job No.: ER4319
Date: 9 / 13 / 96
Checked: 10 /03 /96
Revised:

Filename: SA-07mcd
By: D.L. STONE
By: J. J. JOFLO
By:

**PIPE LOADS at C** (Checking base plate and anchor bolts.)

$P_C := P$ $\qquad P_C = 259 \cdot lbf$

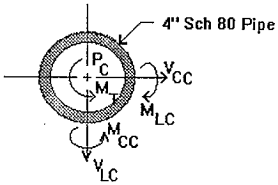
$V_{CC} := V_C$ $\qquad V_{CC} = 845.7 \cdot lbf$

$V_{LC} := V_L + F_{AL}$ $\qquad V_{LC} = 4.69 \cdot 10^3 \cdot lbf$

$M_{TC} := M_T$ $\qquad M_{TC} = 3.276 \cdot 10^3 \cdot in \cdot lbf$

$M_{CC} := M_C + (8 \cdot in) \cdot V_C$ $\qquad M_{CC} = 1.058 \cdot 10^4 \cdot in \cdot lbf$

$M_{LC} := M_L + (8 \cdot in) \cdot V_{LC}$ $\qquad M_{LC} = 4.134 \cdot 10^4 \cdot in \cdot lbf$




TRUNION STRESSES:

**Material:** **4" Schedule 80 A 106 GR-B Pipe**

$A := 4.407 \cdot in^2$ **Area of metal of 4" pipe.**

$z := 4.217 \cdot in^3$ **Section Modulus**

$$\sigma_n := \frac{P_C}{A} + \frac{M_{CC} + M_{LC}}{z} \qquad \sigma_n = 1.237 \cdot 10^4 \cdot psi$$

**Tension and Bending**

$S_h := 20000 \cdot psi$

$S_{all} := 1.33 \cdot S_h$

**Allowable Stress**

$\sigma_n = 1.237 \cdot 10^4 \cdot psi \quad < \quad S_{all} = 2.66 \cdot 10^4 \cdot psi$

**Shear stresses are insignificant.**

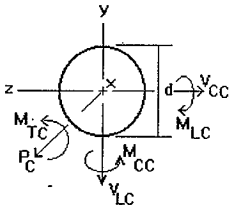
## DESIGN ANALYSIS

Client: WESTINGHOUSE HANFORD COMPANY
Subject: PROJECT W-320 WASTE RETRIEVAL
PIPE SUPPORT STRUCTURAL ANALYSIS
Location: C TANK FARM - 200 EAST AREA HANFORD

WO/Job No.: ER4319
Date: 9 / 13 / 96
Checked: 10 / 03 / 96
Revised:

Filename: SA-07.mcd
By: D.L. STONE
By: N.J. JUPLO
By:

### WELD CALCULATIONS FOR TRUNION TO BASEPLATE JOINT:




### WELD PROPERTIES:

$d := 4.5 \cdot in$ **(Ref. 5)**

$Cy := \frac{d}{2}$ $\quad Cy = 2.25 \cdot in$

$Cz := \frac{d}{2}$ $\quad Cz = 2.25 \cdot in$

$Aw := \pi \cdot d$ $\quad Aw = 14.137 \cdot in$

$Swy := \frac{\pi \cdot d^2}{4}$ $\quad Swy = 15.904 \cdot in^2$

$Swz := Swy$ $\quad Swz = 15.904 \cdot in^2$

$Jw := \frac{\pi \cdot d^3}{4}$ $\quad Jw = 71.569 \cdot in^3$

### JOINT LOADS at C:

$Fx := P_C$ $\quad Fx = 259 \cdot lbf$

$Fy := V_{LC}$ $\quad Fy = 4.69 \cdot 10^3 \cdot lbf$

$Fz := V_{CC}$ $\quad Fz = 845.7 \cdot lbf$

$Mx := M_{TC}$ $\quad Mx = 3.276 \cdot 10^3 \cdot in \cdot lbf$

$My := M_{CC}$ $\quad My = 1.058 \cdot 10^4 \cdot in \cdot lbf$

$Mz := M_{LC}$ $\quad Mz = 4.134 \cdot 10^4 \cdot in \cdot lbf$

### WELD STRESS:

$$fw := \left[\left(\frac{Fx}{Aw} + \frac{My}{Swy} + \frac{Mz}{Swz}\right)^2 + \left(\frac{Fy}{Aw} + \frac{Mx \cdot Cy}{Jw}\right)^2 + \left(\frac{Fz}{Aw} + \frac{Mx \cdot Cz}{Jw}\right)^2\right]^{0.5} \qquad fw = 3.315 \cdot 10^3 \cdot \frac{lbf}{in}$$ **(Ref. 5)**

### FILLET WELD SIZE REQUIRED:

$S_h := 17800 \cdot psi$ **ALLOWABLE WELD STRESS PER CODE B31.3 for A36 Plate**

$S := 1.2 \cdot 0.75 \cdot S_h \qquad S = 1.602 \cdot 10^4 \cdot psi$ **(Ref. 1)**

$w := \frac{fw}{0.707 \cdot S} \qquad w = 0.293 \cdot in$ **Minimum Fillet Weld Required**

$w_{Design} := \left(\frac{5}{16}\right) \cdot in$ **Design Fillet Weld Size**

$SF_{fw} := \frac{w_{Design}}{w} \qquad SF_{fw} = 1.068$ **Design exceeds requirement by a factor of 1.068 - *OK***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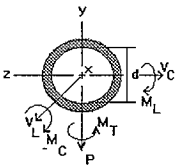
Page A-15

## DESIGN ANALYSIS

| | | | | | |
|---|---|---|---|---|---|
| Client: | WESTINGHOUSE HANFORD COMPANY | WO/Job No.: | ER4319 | Filename: | SA-07.mcd |
| Subject: | PROJECT W-320 WASTE RETRIEVAL | Date: | 9 / 13 / 96 | By: | D.L. STONE |
| | PIPE SUPPORT STRUCTURAL ANALYSIS | Checked: | 10 / 03 / 96 | By: | N. J. JUPLO |
| Location: | C TANK FARM - 200 EAST AREA HANFORD | Revised: | | By: | |

### WELD CALCULATIONS FOR JOINT BETWEEN PAD AND PIPES:

**Note: 1" gaps on top and bottom have been omitted to allow room to weld drain and vent. These gaps are insignificant compared to the total weld length and are, therefore, not considered in the analysis.**




**WELD PROPERTIES:**

$d := 4.5 \cdot in$ **(Ref. 5)**

$Cy := \frac{d}{2}$ $\quad Cy = 2.25 \cdot in$

$Cz := \frac{d}{2}$ $\quad Cz = 2.25 \cdot in$

$Aw := 2 \cdot (\pi \cdot d)$ $\quad Aw = 28.274 \cdot in$

$Swy := 2 \cdot \left(\frac{\pi \cdot d^2}{4}\right)$ $\quad Swy = 31.809 \cdot in^2$

$Swz := Swy$ $\quad Swz = 31.809 \cdot in^2$

$Jw := 2 \cdot \left(\frac{\pi \cdot d^3}{4}\right)$ $\quad Jw = 143.139 \cdot in^3$

**JOINT LOADS at B:**

$Fx := V_{LB}$ $\quad Fx = 4.69 \cdot 10^3 \cdot lbf$

$Fy := P_B$ $\quad Fy = 259 \cdot lbf$

$Fz := V_{CB}$ $\quad Fz = 845.7 \cdot lbf$

$Mx := M_{CB}$ $\quad Mx = 6.626 \cdot 10^3 \cdot in \cdot lbf$

$My := M_{TB}$ $\quad My = 3.276 \cdot 10^3 \cdot in \cdot lbf$

$Mz := M_{LB}$ $\quad Mz = 1.939 \cdot 10^4 \cdot in \cdot lbf$

**WELD STRESS:**

$$fw := \left[\left(\frac{Fx}{Aw} + \frac{My}{Swy} + \frac{Mz}{Swz}\right)^2 + \left(\frac{Fy}{Aw} + \frac{Mx \cdot Cy}{Jw}\right)^2 + \left(\frac{Fz}{Aw} + \frac{Mx \cdot Cz}{Jw}\right)^2\right]^{0.5} \qquad fw = 895.75 \cdot \frac{lbf}{in}$$ **(Ref. 5)**

**FILLET WELD SIZE REQUIRED:**

$S_h = 16700 \cdot psi$ **ALLOWABLE WELD STRESS PER CODE B31.3 for A312 TP306 Pipe** **(Ref. 1)**

$S = 1.2 \cdot 0.75 \cdot S_h \qquad S = 1.503 \cdot 10^4 \cdot psi$ **(Ref. 1)**

$w := \frac{fw}{0.707 \cdot S} \qquad w = 0.084 \cdot in$ **Minimum Fillet Weld Required**

$w_{Design} := \left(\frac{3}{16}\right) \cdot in$ **Design Fillet Weld Size**

HNF-2474, Rev. 0, Page A-16

$SF_{fw} := \frac{w_{Design}}{w} \qquad SF_{fw} = 2.224$ **Design exceeds requirement by a factor of 2.224 - *OK***

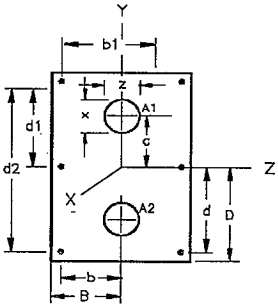
## DESIGN ANALYSIS

Client: WESTINGHOUSE HANFORD COMPANY
Subject: PROJECT W-320 WASTE RETRIEVAL
PIPE SUPPORT STRUCTURAL ANALYSIS
Location: C TANK FARM - 200 EAST AREA HANFORD

WO/Job No.: ER4319
Date: 9 / 13 / 96
Checked: 10/03/96
Revised:

Filename: SA-07.mcd
By: D.L. STONE
By: N.J. JUPLO
By:

### BASE PLATE ANALYSIS:




**DIMENSIONS:**

| | | |
|---|---|---|
| $b := 7.75 \cdot in$ | $B := 9 \cdot in$ | |
| $d := 11.75 \cdot in$ | $D := 13 \cdot in$ | |
| $c := 7 \cdot in$ | $t := 1 \cdot in$ | **Plate Thickness** |
| $x := 4.5 \cdot in$ | $z := 4.5 \cdot in$ | **Attachment Diam. (circular)** |
| $b1 := b + \frac{z}{2} + 2 \cdot t$ | $b1 = 12 \cdot in$ | |
| $d1 := c + \frac{x}{2} + 2 \cdot t$ | $d1 = 11.25 \cdot in$ | |
| $d2 := d + d1$ | $d2 = 23 \cdot in$ | |

### LOADS @ ATTACHMENT "A1" : (See Page 11)

$Fx1 := P_C$ $\quad Fx1 = 259 \cdot lbf$

$Fy1 := V_{CC}$ $\quad Fy1 = 845.7 \cdot lbf$

$Fz1 := V_{LC}$ $\quad Fz1 = 4.69 \cdot 10^3 \cdot lbf$

$Mx1 := M_{TC}$ $\quad Mx1 = 3.276 \cdot 10^3 \cdot in \cdot lbf$

$My1 := M_{LC}$ $\quad My1 = 4.134 \cdot 10^4 \cdot in \cdot lbf$

$Mz1 := M_{CC}$ $\quad Mz1 = 1.058 \cdot 10^4 \cdot in \cdot lbf$

### LOADS @ ATTACHMENT "A2" :

$Fx2 := P_C$ $\quad Fx2 = 259 \cdot lbf$

$Fy2 := V_{CC}$ $\quad Fy2 = 845.7 \cdot lbf$

$Fz2 := V_{LC}$ $\quad Fz2 = 4.69 \cdot 10^3 \cdot lbf$

$Mx2 := M_{TC}$ $\quad Mx2 = 3.276 \cdot 10^3 \cdot in \cdot lbf$

$My2 := M_{LC}$ $\quad My2 = 4.134 \cdot 10^4 \cdot in \cdot lbf$

$Mz2 := M_{CC}$ $\quad Mz2 = 1.058 \cdot 10^4 \cdot in \cdot lbf$

### LOADS @ CENTROID OF BOLT PATTEREN:

$Fx := Fx1 + Fx2$ $\quad Fx = 518 \cdot lbf$

$Fy := Fy1 + Fy2$ $\quad Fy = 1.691 \cdot 10^3 \cdot lbf$

$Fz := Fz1 + Fz2$ $\quad Fz = 9.379 \cdot 10^3 \cdot lbf$

$Mx := Mx1 + Mx2 + c \cdot (Fz1 + Fz2)$ $\quad Mx = 7.221 \cdot 10^4 \cdot in \cdot lbf$

$My := My1 + My2$ $\quad My = 8.267 \cdot 10^4 \cdot in \cdot lbf$

$Mz := Mz1 + Mz2 + c \cdot (Fx1 + Fx2)$ $\quad Mz = 2.479 \cdot 10^4 \cdot in \cdot lbf$

## DESIGN ANALYSIS

Client: WESTINGHOUSE HANFORD COMPANY
Subject: PROJECT W-320 WASTE RETRIEVAL
PIPE SUPPORT STRUCTURAL ANALYSIS
Location: C TANK FARM - 200 EAST AREA HANFORD

WO/Job No.: ER4319
Date: 9 / 13 / 96
Checked: 10 / 03 / 96
Revised:

Filename: SA-07.mcd
By: D.L. STONE
By: N.J. JUPLO
By:

### BOLT TENSION & SHEAR:

$$T := \frac{Fx}{6} + \frac{My}{3 \cdot b1} + \frac{Mz}{2 \cdot d1 + 2 \cdot d2} \qquad T = 2.745 \cdot 10^3 \cdot lbf$$

$$S := \left[\left[\frac{Fy}{6} + \frac{Mx}{4 \cdot \left(b^2 + d^2\right)^{0.5}}\right]^2 + \left[\frac{Fz}{6} + \frac{Mx}{4 \cdot \left(b^2 + d^2\right)^{0.5}}\right]^2\right]^{0.5} \qquad S = 3.247 \cdot 10^3 \cdot lbf$$

### BOLT INTERACTION ( I ) - BOLT SIZE & EMBEDMENT:

$A_s := 0.462$ — Tensile Stress Area for 7/8 Diam. Bolt (Ref. 4)

$Sh := 13700$ — Allowable Tensile stress for A307 Bolts at 200° F. Ref. AISC Pg. 4-3

$Ta := 1.33 \cdot A_s \cdot Sh \qquad Ta = 8.418 \cdot 10^3$ — TENSION Allowable

$Sa := 1.33 \cdot A_s \cdot 0.8 \cdot Sh \qquad Sa = 6.734 \cdot 10^3$ — SHEAR Allowable

$I := \frac{T}{Ta} + \frac{S}{Sa} \qquad I = 0.808 \cdot lbf \quad < \quad 1.0$ — BOLTS ARE ACCEPTABLE

### BASE PLATE STRESS:

$Mb := 3 \cdot T \cdot \left(b - \frac{z}{2}\right) \qquad Mb = 4.529 \cdot 10^4 \cdot in \cdot lbf$ — Maximum Bending Moment on Plate (Ref. 5)

$Z := \frac{2 \cdot B \cdot t^2}{6} \qquad Z = 3 \cdot in^3$

$\sigma b := \frac{Mb}{Z} \qquad \sigma b = 1.51 \cdot 10^4 \cdot psi$ — Maximum Bending Stress

$S_h := 17800 \cdot psi$ — For A36 Plate

$\sigma_{all} := 1.33 \cdot S_h \qquad \sigma_{all} = 2.367 \cdot 10^4 \cdot psi$ — Code B31.3 Allowable (Ref. 1)

$\sigma b = 1.51 \cdot 10^4 \cdot psi \quad < \quad \sigma_{all} = 2.367 \cdot 10^4 \cdot psi$ — MAXIMUM STRESS LEVEL ACCEPTABLE

# DESIGN ANALYSIS

Client: Numatec
Subject: Support Structural Analysis
Project W-320 Waste Retrieval for Tank 241-C-106
Location: C Tank Farm 200 East Area

WO/Job No.: ER4319/W-320
Date: 11/24/97 By: K. Hayase
Checked: 3.13.98 By: M. Ahmed
Revised: By:

TOTAL PIPE STRESSES

Includes local pipe stresses due to welded trunion. Assumes the same stress state in the process and encasement pipe due to the trunion.

Process Pipe: (ASTM A312 TP304L) $S_h = S_c = 16700$ psi

Max Sustained Stress (Autopipe, Ref. 8) 8128 psi
Appdx-A page 103
Local Stress (Sus. + Ther. + Occ.) 7813 psi
(From 'POP', Pg. 6, Appdx A) Total 15941 psi < 16700 psi allowable

Max Displacement Stress (Autopipe, Ref. 8) 16758 psi

Local Stress 7813 psi
Total 24571 psi < 25050 psi allowable
$= [1.25 S_h + 0.25 S_c]$

Max Occasional Stress (Autopipe, Ref. 8) 13427 psi
Appdx-A page 104
Local Stress 7813 psi
Total 21240 psi < 22211 psi allowable $= (1.33 S_h)$

Note: The allowable stress exceeds two-thirds of yield strength at temperature (Ref. B31.3 Para 302.3.6(a) and should be reduced slightly. However, the actual stresses at the intermediate anchor points are significantly less than the max occasional stress used here, therefore this is acceptable.

Encasement Pipe: (ASTM A53 Type-E GR-B) $S_h = 20000$ psi

Max Sustained Stress (STAB, Ref. 7) 1922 psi

Local Stress 7813 psi
Total 9735 psi < 20000 psi allowable $(S_h)$

Max Displacement Stress (STAB, Ref. 7) 23800 psi
(Page-10 of Rio Calcs)
Local Stress 7813 psi
Total 31613 psi < 40265 psi allowable

Note: allowable = 1.25(20000 psi + 20000 psi) - 9735 psi = 40265 psi (Ref. B31.3)

Max Occasional Stress (STAB, Ref. 7) 5904 psi

Local Stress 7813 psi
Total 13717 psi < 26600 psi allowable $(1.33 S_h)$

**KAISER ENGINEERS**
**HANFORD**

Calc. No. W320-27-[illegible]
Revision 0
Page No. 17 of 29

## DESIGN ANALYSIS

Client WHC
WO/Job No. E[illegible] / W-320
Subject Transfer Line - Concrete Base Design
Date 5/20/94 By [illegible]
Checked 5/20/94 By [illegible]
Location 200E
Revised By

Determine the Resteel Required in the Concrete Base for the Transfer Line Pipe Supports

1. Determine if size of footing is adequate to resist movement from forces imposed by the transfer lines.

$F_x = 2(905\ lb) = 1810\ lbs = 1.8\ kips$

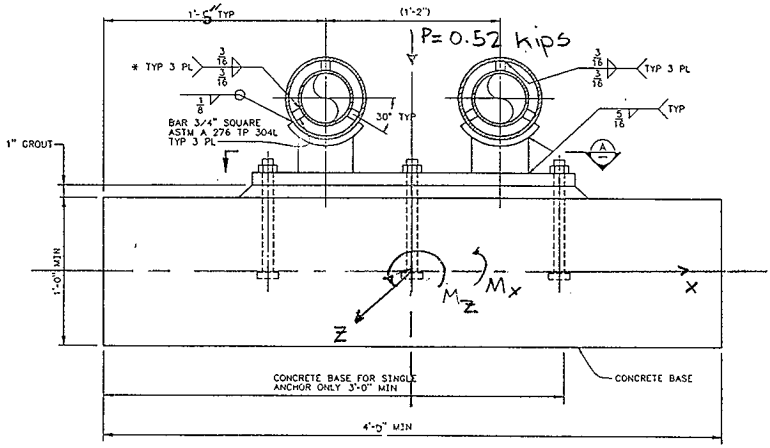
$M_x = 2(79850) = 159700\ in \cdot lb = 159.7\ in \cdot kips$

$F_y = 2(259\ lb) = 518\ lbs = 0.52\ kips$

$M_y = 2(6816) + 2(4752\ lb)(7\ in) = 80160\ in \cdot lb = 80.2\ in \cdot kips$

$F_z = 2(4752) = 9504\ lbs = 9.5\ kips$

$M_z = 2(18298) = 36596\ in \cdot lb = 36.6\ in \cdot kip$




a) $M_z = M_o = 36.6 + 0.57(7in) = 40.2\ in \cdot kip$ (Overturning Moment)

Determine if eccentricity is greater than Kern ($w/6$).

$w$ = width of footing = 4.17 ft.

a. continued

wt of footing = (1 ft)(3 ft)(4.2 ft)(150 pcf) = 1899 lbs
= 1.9 kip

P = D + L = 1.9 + 0.52 + 5.7 = 8.12 kip (Ws = wt. of soil = 5.7 kips)
$\gamma$ = 115 pcf, Table 2 of Shannon & Wilson report KEH-8008-2

$e = M/P = \frac{40.2 \text{ in-kip}}{8.12 \text{ kip}} = 5.0 \text{ in}$

$K = \frac{36 \text{ in}}{6} = 6 \text{ in}$

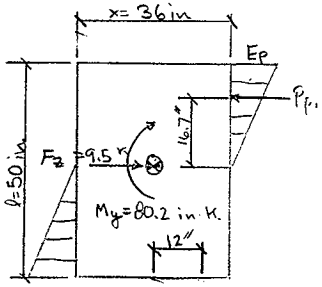
∴ Since e < K (kern) determine $q_{max} = \frac{P}{BL}\left(1 + \frac{6e}{B}\right)$

P = 8.12 kip
B = 3 ft
L = 4.2 ft
e = 5/12 ft
$q_A$ = 4000 psf

$q_{max} = \frac{8.12}{(3)(4.2)}\left(1 + \frac{6(5/12)}{3}\right) = 1.18 \text{ ksf} < 4 \text{ ksf}$ OK

* $q_A$ = 4000 psf from Shannon & Wilson Soil Report contract# KEH-8008-2

b. Check lateral resistance to sliding & rotation.




PLAN

Allowable Passive earth pressure.

$E_p = \frac{1}{2}(115 \text{ pcf})(4.5 \text{ ft})^2 (4/1.5)$ ← min depth
= 3105 lbs/ft

Assume $M_y$ is resisted by the 2 faces of the base.

$P_{p_1} = \left[\frac{E_p \cdot 1/2}{2}\right] = \left[\frac{3105(4.2/2)}{2}\right]$

= 3260 lbs

$P_{p_1}$ = 3.3 kip

Note: Ep is total force from soil acting against the footing at that depth and assumed triangular distribution from centroid.

b. Continued

$M_p \geq M_y$ ; required to resist torsion.

$M_p = P_p(16.7)2 = 110.2$ in·kip

$\therefore M_p > M_y$ , OK

Note: For the equation $q_p = \frac{1}{2}\gamma h^2 K_p$, $K_p = 4.0$ from S&W report. S&W recommended S.F. of 1.5. $E_p$ is Total force acting along the base. (lb/ft)

c. Check sliding resistance:

$F_z = 9.5$ kip

$F = \frac{F_r}{F_z} \geq 1.5$ , for cohesionless soils.

where

$F_r = R \tan\phi + E_p \ell$

where $\phi$ = friction ∠ ($\phi = 37°$, from S&W Report)
$R = W_c + W_s = 7.6$ kip

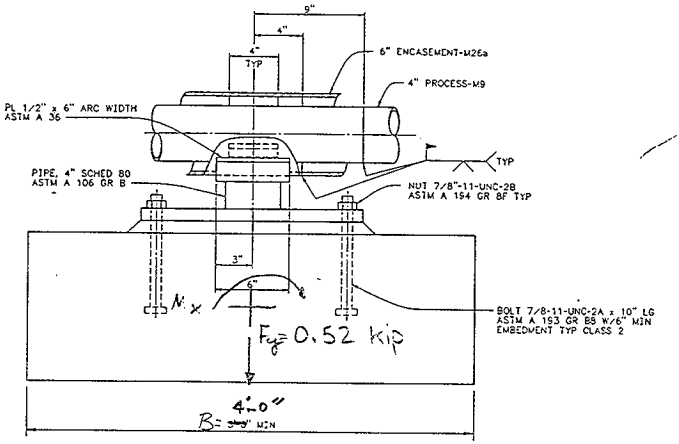
$W_c = 1.9$ kip

$W_s = 115\,pcf \times 4.2' \times 3.0' \times 3.92' = 5680$ lbs

$F_r = 7.6(\tan 37°) + 3.1(4.2) = 18.7$ kip

$\frac{F_r}{F_z} = \frac{18.7}{9.5} = 2.0 > 1.5$ $\therefore$ OK

d. Check moment from other view.




$M_o = M_x = 159.7$ in·kip

$P = F_y + W_c + W_s = 8.12$ kips

$e = M/P = \frac{159.7}{8.12 \text{ kip}} = 19.7$ in $\qquad k = \frac{50 \text{ in}}{6} = 8.3$ in

Increase B to 3'-6", which will increase P by 315 lb to P = 8.44 kips

$e = \frac{159.7}{8.44} = 18.9$ in

$q_{ult} = \frac{2P}{3L(B/2 - e)}$, since $e > k$

$q_{ult} = \frac{2(8.44)}{3(4.2)(3.5/2 - 18.9/12)} = 7.7$ ksf N.G

d. Continued:

Try $B = 4.0'$

P will increase by 315 lb to $P = 8.76$ Kip,

$$e = \frac{159.7}{8.76} = 18.23 \text{ in}$$

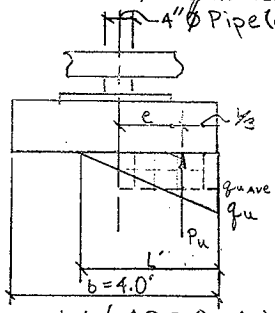
$$q_{u1+} = \frac{2(8.76)}{3(4.0)\left(4/2 - \frac{18.23}{12}\right)} = 3.0 \text{ ksf} < q_A \quad \text{OK}$$

Note: Stability not a concern since the pipe lines will prevent the footing from overturning.

From a constructibility stand point make concrete base square (4.0' x 4.0')

e. Determine Resteel Required for Slab.

$L' = (4/2 - e)3$
$= (4/2 - 18.23)3$
$= 17.31$ in
$= 1.44$ ft




$q_{max} = 3.0$ ksF
Use $q_A$ to determine bending for Resteel to take into account the small moment in the other direction.

Ave. the distributed load to be more conserv. and take the moment about the center.

$$q_u = 1.6\, q_A = 1.6(4000 \text{ plf}) = 6400 \text{ plf}$$

Averaging the $q_u$ into $q_{u\,ave}$.

$$q_{u\,ave} = \frac{\left(\frac{6.4}{1.44}\right)2}{2} + \left[6.4 - \left(\frac{6.4}{1.44}\right)2\right] = 6.4 \text{ pIF}$$

$$M_u = \frac{6.4(2)^2}{2} = 12.8 \text{ ft·kip}$$

e. Continued:

- Use design proceedure 3 of ACI SP-17(91) vol. 1, "ACI Design Handbook."

$d = 12 - 3 - \frac{0.625}{2} = 8.69''$ $\phi M_n \geq M_u$

$F = \frac{bd^2}{12000} = \frac{(12)(9)^2}{12000} = 0.081$

$K_n = M_u / F = 12.8 / 0.081 = 158.02$

$K_n < K_{n\,max}$, select $K_n$ based on $\frac{1}{3} f_{max} < \rho < \frac{2}{3} f_{max}$

$\therefore K_n = 370$

- Determine flexural steel required:

$A_s = \frac{12.8}{(9)(4.21)} = 0.35\ in^2/ft$

$A_{s\,min} = 0.0018(12)(12) = 0.26\ in^2/ft$ $\quad \therefore A_s > A_{s\,min}$

Use $A_s = 0.35\ in^2/ft$

- Check Shear: $\phi V_c \geq V_u$ @ d from face of support

$\phi V_c = \phi (2\sqrt{f'_c}) b_w d$
$= (0.85)(2)(4000)^{1/2}(12)(9) = 11.16$ kip

$V_u = q_u\left(\frac{b-a}{2} - d\right) = 6.4\left(\frac{4 - \frac{1}{3}}{2} - \frac{9}{12}\right) = 7$ kip $\quad \frac{1}{3}'$ is for 4" ø Pipe support

$\phi V_c > V_u$ OK for shear for one-way shear

Two-Way Shear (Punching): Compute $b_o$ required and compare to $b_o$ (supplied)

$b_o = 2(26 + 9) + 2(18 + 9) = 124$ in (Supplied)

e) Continued:

$\frac{K_{V6} V_u}{1.02} = 1.72$ for d = 8" conserv. $q_s = 6.67$ from SP-17, pg-259.

$a_b = 26.6$

$A_{FV} = (4)^2 - \left(\frac{26+9}{12} \times \frac{18+9}{12}\right) = 9.4\ ft^2$

$V_u = A_{FV} \cdot q_s = (9.4\ ft^2)(6.67\ ksf) = 62.7$ kips

$\beta_c = \frac{26}{18} = 1.44$ $K_{V6} = 1.0$ for $\beta_c \leq 2.0$

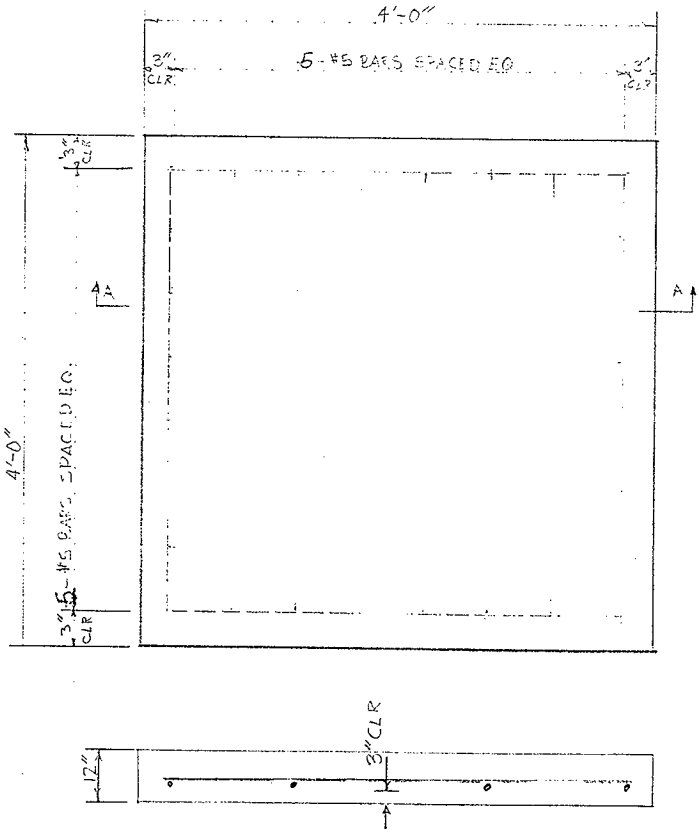
$b_o = \frac{(1)(62.7)}{1.72} = 36.5$ in

$b_o < b_o$ (supplied)

Bar Selection: Use 5 - #5 bars spaced equally EW w/ 3" clr on bottom and sides or at 10.5 in spacing.

| | | | |
|---|---|---|---|
| Client WHC | WO/Job No. ER4319 / W-320 | | |
| Subject Transfer Line - Concrete Base Design | Date 6/20/94 | By L. R. Booth | |
| | Checked 5/6/94 | By R. G. [illegible] | |
| Location 320 F | Revised | By | |

f. Plan View of Slab Dimensions [illegible]



g. Check Pull-Out Strength of Anchor Bolts:

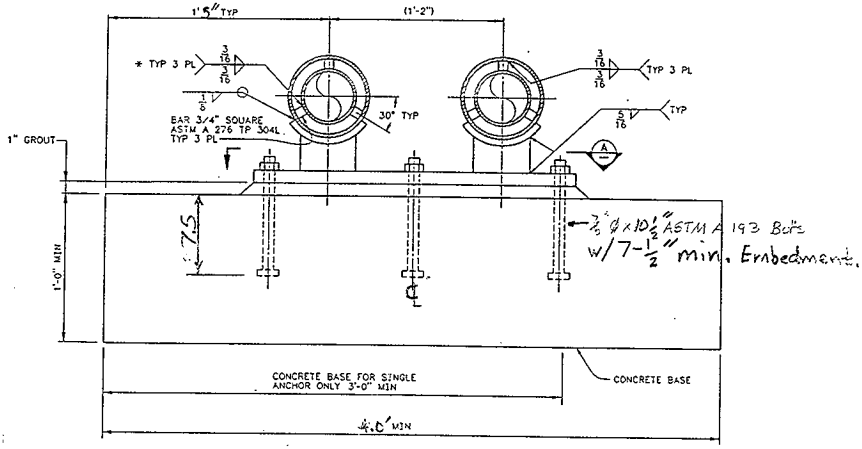
Unfactored loads from pg. 15 of calc.

T = 2786 lbs
S = 3467 lbs

Adequacy of bolt has already been determined.

Using method presented in A/E STD. # GC-ANCB-01.

Check embedment depth of anchor bolts




SECTION

$L_e = 7$ in
$C = 1.44$ in
$P_u = \pi(L_e^2 + C L_e)(4 \phi_c \sqrt{f'_c}) = 26431$ lb

$A_t = 0.462$ in$^2$
$\phi_c = 0.65$
$f'_c = 3000$
$F_u = \frac{26431}{0.462} = 57210$ psi

g. Continued:

$$L_e = \frac{\sqrt{C^2 + \frac{1.33\, F_u A_t}{\pi \phi_c \sqrt{f'_c}}} - C}{2}$$

$$= \frac{\sqrt{(1.44)^2 + \frac{1.3\,(57210)(0.462)}{\pi\,(0.65)\sqrt{3000}}} - 1.44\text{ in}}{2} = 8.04\text{ in}$$

$K_{ns} = 1.0$
$K_{\phi c} = 0.86$
$K_{f'c} = 0.93$

$L'_e = L_e\,(K_{ns}\ K_{\phi c}\ K_{f'c}) = (8.04)(1.0)(0.86)(0.93) = 6.43$ in

$L'_e > L_e$ embedment depth OK.

Edge Distance for Tension Load:

$F_u = 105$ ksi (ASME B31.3, Table A-2, 1993 ED.)
$F_y = 65$ ksi

$D = 7/8$ in
$F_{ult} = 105$ ksi
$F'_c = 4000$ psi

$$m_t = D\sqrt{\frac{F_{ult}}{56\sqrt{F'_c}}} = (7/8)\sqrt{\frac{105000}{56\sqrt{4000}}} = 4.76\text{ in}$$

$m_t$ is min. edge distance

($m_d$) Actual edge distance = 11.75 in OK

$V_D = 223.7\,(m_v)^2 = 223.7\,(13)^2 = 37805$ lbs

g. Continued:

Edge distance for Shear Load:

$$m_v = D\sqrt{\frac{f_{ult}}{7.5\sqrt{f'c}}} = (7/8)\sqrt{\frac{105000}{7.5\sqrt{4000}}} = 13 \text{ in}$$

$m_d < m_v$, N.G. Going to FIG. 4 $\quad V_c = 4\phi_c\sqrt{f'c}/2\pi m_v^2 = 46634$ lbs

$V_b/V_c = 0.8 \quad m_d/m_v = 0.9$, zone 1 $\quad$ OK for shear

Check anchor bolt spacing:

$$rm' = \text{min. anchor bolt spacing} = 2L_e + C = 2(7) + 1.44 = 15.44 \text{ in} > 11.75 \quad \underline{NG}$$

Re-evaluate $L'e$ $\quad p = 11.75''$ $\quad$ Note: Increase in min. embedment depth required because anchor bolt spacing less than min. req. w/ 7/8" ϕ bolts.

$$\frac{rm - p}{rm} = 0.24 \qquad K_{le} = 0.93$$

$$L'e = \sqrt{\frac{(7)^2}{(0.93)(}} = 7.3 \text{ in},$$

Go to 7/8"-11-UNC-2A x 10.5" LG ASTM A 193 Anchor bolts. (Min. emb. = 7.5")

---

Conclusions:

1) Concrete Base dimensions now 4'-0" x 4'-0" x 1'-0"

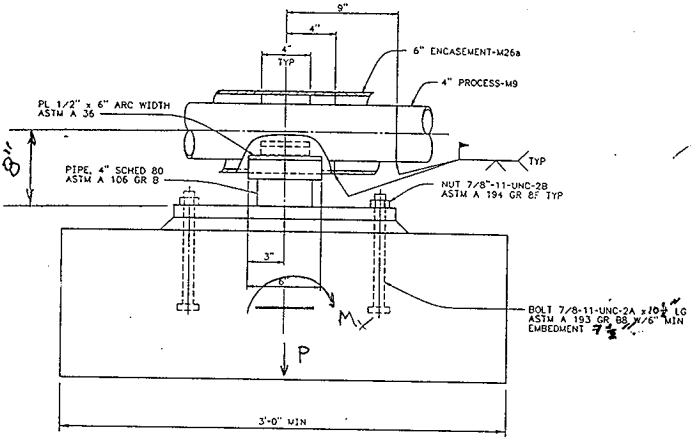
2) Resteel - 5 - #5 bars equally spaced w/ 3" clear spacing from sides & bottom.

3) Use 7/8" ϕ anchor bolts now 10½" long.

| | | | |
|---|---|---|---|
| Client | WHC | WO/Job No. | ER 4319 / W-320 |
| Subject | Transfer Line - Concrete Base Design | Date | 5/23/94 By S.R. Barth |
| | | Checked | 5/23/94 By [illegible] |
| Location | 200E | Revised | By |

Check Size Required for Concrete Base w/ Only One Pipe

a) Check Worst Case Overturning Moment:




$M_x = 79.85$ in·kip

$P = F_y + W_c + S$

where

$W_c = 150\,pcf(1 \times 3 \times 3) = 1350$ lb (Concrete Wt)

$S = 115\,pcf(3 \times 3 \times 3.92) = 4057$ lb (Soil Wt)

$F_y = 259$ lbs

$$P = \frac{259 + 1350 + 4057}{1000} = 5.67 \text{ kip}$$

$$e = \frac{79.85 \text{ in·kip}}{5.67} = 14.1 \text{ in} \qquad K = \frac{36 \text{ in}}{6} = 6 \text{ in}$$

since $e > K$, $q_{ult} = \dfrac{2P}{3L(B/2 - e)} = \dfrac{2(5.67)}{3(3)(3/2 - 1.18)} = 3.9$ ksf

$q_{ult} < q_A = 4.0$ ksf **OK**

Client WHC
Subject Transfer Line-Concrete Base Design
Location 200E

WO/Job No. ER4319 / W-320
Date 5/23/94 By [illegible]
Checked [illegible] By [illegible]
Revised 8/8/95 By [illegible]
10/3/94 [illegible]

b) For a concrete base supporting only one pipe the twisting action will not be a factor and maintaining approximately the same rebar spacing by inspection will be adequate.

The rebar will have 3" clear from the sides and bottom and be 4-#5 spaced equally in each direction or at 10 inches.

The base will be 3'x3'x1'.

//

Note: The loads used to design the footing were based on preliminary pipe stress information which were greater than the final values calculated by D.L. Stone. Therefore, no changes are necessary in the design of the footing.

[illegible] 8/8/95 1 Based upon revised loads presented in revision 1 of pages 1 thru 16, the above conclusion is still valid.

[illegible] 10/3/94 2 **Based upon the revised loads presented in revision 2 of this calculation, page 14, the conclusion provided in revision 0 is still valid. No further analysis is required.**

P O P

(PIPE ON PIPE)

PIPE WALL LOCAL STRESSES DUE TO WELDED TRUNNION

SOURCE:

WELDING RESEARCH COUNCIL BULLETIN NO. 107MARCH 1979 REVISION.LOCAL STRESSES IN SPHERICAL AND CYLINDRICAL SHELL DUE TO EXTERNAL LOADING" BY K.R. WICHMAN A.G. HOPPER AND J.L. MERSHON

PROGRAM AUTHOR: MOHAMMED M. AHMED

FILE NAME: W320POP. mcd

WORK ORDER/ JOB NO: ER4319

INPUT BY: Dianna L. Stone

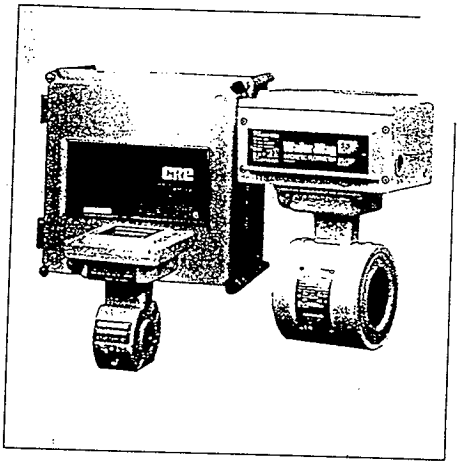
CHECKED BY:

# MODEL 7400

# WAFER-MAG™ ELECTROMAGNETIC FLOWMETER

## DESCRIPTION

The Brooks® Wafer-Mag electromagnetic flowmeter is a solid state, obstructionless flow rate measuring device which is capable of measuring a wide range of conductive liquids, clear or slurried.



The Wafer-Mag is comprised of two basic parts: a flow transmitter which becomes a part of the pipeline and a signal converter. A magnetic field is generated by compact high density field coils mounted to a short section of straight pipe. As a conductive liquid passes through the pipe section and its magnetic field, a voltage is generated that is directly proportional to the velocity of the conductive liquid. The voltage induced is sensed by electrodes mounted at right angles to the magnetic field and in contact with the conductive liquid or slurry. The electrodes are insulated from the pipe by a non-conductive liner that encapsulates all wetted parts of the pipe. From the electrodes, the voltage is transmitted to a signal conditioner where it is conditioned to the desired output signal(s).

The Brooks Wafer-Mag employs a keyed bi-directional dc magnetic field and digital electronics to establish new criteria in wide rangeability, high accuracy and low power consumption. The Wafer-Mag generates an open collector frequency (proportional to liquid velocity) of 10 kHz at maximum flow rate. Convenient terminal connections are provided to permit local or remote verification of proper meter operation. Optional analog current or factored/scaled pulse outputs are available for integral or remote mounting.

## DESIGN FEATURES

- *Accuracy* of ±0.5% of rate
- *Lay length*: wafer body design for installation between mating flanges of ANSI, DIN or BS bolt pattern, to 300 lb. ANSI rating. Minimum length for maximum ease of installation.
- *Light weight*: the wafer body design minimizes weight to maximize ease of handling.
- *Unobstructed flow*: no restrictions are in the liquid path. Pressure drop is equal to an equivalent length of pipe of the same inside diameter.
- *Stable operation*: flow measurement is unaffected by changes in temperature, pressure, specific gravity, viscosity and/or conductivity above a minimum of 3 micromhos/cm over a wide range of ambient temperatures.
- *DC magnetic field*: bi-directionally driven magnetic field.
- *Automatic zero*: no adjustments required. Signal voltage is dynamically verified each time the coil current reverses up to 75 times per second.
- *Low power consumption*: approximately 15 watts for sizes 0.15" to 8".
- *Interchangeable electronics*: all wafer-mag electronics are interchangeable. No test equipment required.
- *Potted coil housing*: coil housing internals are completely potted for maximum environmental and vibration resistance.
- *Separate sealed wiring compartments*: provide easy customer access for hook-up with maximum protection for electronics.
- *Digital analog span*: analog output has digital span setting for re-ranging without test equipment and no electrical power required for setting.
- *Optional Smart electronics (3580)*: configurable through local or remote operator interface.

Electrical Approvals:

- Flowheads with integral electronics: FM approved Class I, Division 2, Groups A, B, C and D, Class II, Division 1, Groups E, F and G and Class III.
- Flowheads for remote hook-up to 3560, 3570 or 3580 electronics: FM approved Class I, Division 2, Groups A, B, C and D, Class II, Division 1, Groups E, F and G and Class III.
- Optional: FM approved Class I, Division 1, Groups C and D. Flowhead can be used with Brooks remote electronics Models 3560, 3570 and 3580.

## SPECIFICATIONS

**WARNING: Do not operate this instrument in excess of the specifications listed below. Failure to heed this warning could result in personal injury and/or damage to the equipment.**

### Capacities

Full Scale Meter Range: 1 to 10 meters/sec or 1 to 10 feet/sec, jumper selectable with no special calibration required (refer to Table 1).

### Accuracy

System ±0.5% of the rate from one unit per second to ten units per second. (one unit = one foot or meter) and 0.005 units per second below one unit per second.

### Analog output

Add ±0.1% full scale to above accuracy specifications.

### Repeatability

0.25% of rate

### Pressure Limits

740 psig @ 100°F (40°C) Tefzel and Teflon tubes
285 psig @ 100°F (40°C) Ryton™ tubes (1" and smaller)
150 psig @ 100°F (40°C) Ryton tubes 1-1/2" and 2"

### Temperature

Ambient: 0 to 150°F (-18 to 65°C)
Process: Refer to Table 2.

### Power Requirements

Selectable by jumper plug -115 Vac or 230 Vac. ±15% 47-63 Hz, 10-30 Vdc

### Power Consumption

15 Watts maximum



**Table 1 Capacity Table - Velocity-to-Flow Conversion Factors 0.15" to 8" ***

| Meter Size | | Flow in gpm Units = Feet | | | | | | Flow in gpm Units = Meters | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1.000 ft/sec | | 10.00 ft/sec | | Low Flow Cut-off (2) | | 1.000 m/sec | | 10.000 m/sec | | Low Flow Cut-off (2) | | Guidelines Flow 6 ft/sec. | |
| Inches | mm | gpm | lpm | gpm | lpm | gpm | lpm | gpm | lpm | gpm | lpm | gpm | lpm | gpm | lpm |
| 0.15(1) | 4 | 0.055 | 0.21 | 0.55 | 2.1 | 0.001 | 0.004 | 0.18 | 0.68 | 1.8 | 6.8 | 0.004 | 0.02 | 0.33 | 1.3 |
| 0.3(1) | 8 | 0.22 | 0.83 | 2.2 | 8.3 | 0.005 | 0.02 | 0.72 | 2.7 | 7.2 | 27 | 0.02 | 0.06 | 1.3 | 4.9 |
| 1/2 | 15 | 0.86 | 3.3 | 8.6 | 33 | 0.02 | 0.08 | 2.8 | 10.6 | 28 | 106 | 0.06 | 0.23 | 5 | 19 |
| 1 | 25 | 2.3 | 8.7 | 23 | 87 | 0.05 | 0.20 | 7 | 28 | 75 | 284 | 0.16 | 0.6 | 14 | 53 |
| 1-1/2 | 40 | 5.5 | 21 | 55 | 208 | 0.13 | 0.48 | 18 | 68 | 180 | 681 | 0.41 | 1.6 | 36 | 136 |
| 2 | 50 | 9.1 | 34 | 91 | 344 | 0.21 | 0.79 | 30 | 113 | 300 | 1,136 | 0.69 | 2.6 | 55 | 208 |
| 3 | 80 | 21 | 80 | 213 | 806 | 0.48 | 1.8 | 70 | 265 | 700 | 2,650 | 1.6 | 6 | 128 | 485 |
| 4 | 100 | 37 | 138 | 365 | 1,382 | 0.85 | 3.2 | 120 | 454 | 1,200 | 4,542 | 2.8 | 10 | 220 | 833 |
| 6 | 150 | 83 | 314 | 830 | 3,142 | 1.9 | 7.2 | 270 | 1,022 | 2,700 | 10,220 | 6.2 | 24 | 495 | 1,874 |
| 8 | 200 | 152 | 575 | 1,520 | 5,753 | 3.5 | 13 | 500 | 1,893 | 5,000 | 18,925 | 11.5 | 44 | 915 | 3,463 |

* All Values are approximate — actual values will depend on flow tube K-factor

(1) These meter sizes are only offered with Ryton flow tubes, maximum pressure 285 psig at 100°F (40°C)

(2) Low flow cut-off is 2.3% of the selected analog setting adjustable from 23 Hz as listed in the above table through 230 Hz at the MAXIMUM FULL SCALE ANALOG SETTING AT 10 FEET OR 10M PER SECOND.

**Table 2 Maximum Working Pressures and Temperatures**

| Materials (Liner) | Characteristics (Liner) | Available in Meter Sizes | Pressure psig (kPa) 150/300 lb. Flanges | | | Maximum Allowable Liquid Temperature (1) |
|---|---|---|---|---|---|---|
| | | | 0-100°F (40°C) | 200°F (93°C) | 300°F (149°C) | |
| Tefzel | Chemical Resistant | 1/2 through 8 inch | 740 psig 5202 kPa | 675 psig 4745 kPa | 655 psig 4605 kPa | 300°F (149°C) |
| Teflon | 3A Food Services | 1/2 through 6 inch | 740 psig 5202 kPa | 575 psig 4745 kPa | 655 psig 4605 kPa | 350°F (149°C) |
| Ryton | Fractional Sizes | .15 and .30 inch | 285 psig 2004 kPa | 185 psig 1300 kPa | Not Applicable | 200°F (93°C) |
| Kynar | Consult Factory | Consult Factory | CF | CF | CF | CF |

Note (1): Temperature limits may vary depending on liquid being metered.

PROGRAMMED BY:
M. M. AHMED

VERSION: 0
PAGE NO: 2

INPUT DATA:
==========

1. APPLIED LOADS:
---

NOTE: THESE ARE THE LOADS ACTING AT PIPE WALL & ATTACHMENT JUNCTURE.

(Ref. File SA-07.mcd, "Pipe Loads at B")

| | |
|---|---|
| $P \equiv 259$ | RADIAL LOAD IN POUNDS |
| $M_c \equiv 6626$ | CIRCUMFERENTIAL MOMENT IN INCH-POUNDS |
| $M_l \equiv 19390$ | LONGITUDINAL MOMENT IN INCH-POUNDS |
| $M_t \equiv 3276$ | TORSIONAL MOMENT IN INCH-POUNDS |
| $V_c \equiv 846$ | SHEAR LOAD ACROSS PIPE LENGTH IN POUNDS |
| $V_l \equiv 4690$ | SHEAR LOAD ALONG PIPE LENGTH IN POUNDS |

2. GEOMETRY:
---

| | |
|---|---|
| $T \equiv 1.267$ | FROC.PIPE 0.237+ENC. PIPE 0.28+PAD 0.75=1.267" |
| $Rm \equiv 2.68$ | (ENC. OD 6.625 - T 1.267)/2 |
| $ro \equiv 2.25$ | ATTACHMENT PIPE (TRUNNION) RADIUS IN INCHES |
| $w \equiv 0.3125$ | FILLET WELD SIZE IN INCHES |
| $r \equiv 0.707 \cdot w$ | FILLET WELD RADIUS IN INCHES |

$r = 0.221$

3. GEOMETRIC PARAMETERS:
---

$\Gamma \equiv \frac{Rm}{T}$ PIPE/VESSEL PARAMETER

$\Gamma = 2.115$

$\beta \equiv (0.875) \cdot \frac{ro}{Rm}$ ATTACHMENT PARAMETER

$\beta = 0.735$

4. STRESS CONCENTRATION FACTORS:
---

$$Kn = 1 + \left(\frac{2 \cdot T}{5.6 \cdot r}\right)^{0.65}$$ TENSILE FACTOR

Kn = 2.594

$$Kb = 1 + \left(\frac{2 \cdot T}{9.4 \cdot r}\right)^{0.8}$$ BENDING FACTOR

Kb = 2.173

BIJLAARD'S NONDIMENSIONAL CURVES:
---

THESE CURVES ARE PLOTTED FOR 'β'VERSUS A NONDIMENSIONAL CONSTANTS FOR DIFFERENT VALUES OF 'Γ' AND APPLIED LOADS.THIS PROGRAM ADOPTS A SIMPLE AND CONSERVATIVE APPROACH FOR A SPECIFIC, MOST OFTEN USED RANGE OF VALUES FOR 'β' & 'Γ'. SINCE MOST OF THE PIPE ATTACHMENTS DESIGNED HAVE THE PARAMETERS 'β' & 'Γ' WITHIN THE RANGES LISTED BELOW, THE MOST CRITICAL NONDIMENSIONAL CONSTANTS ARE CHOSEN FROM THE APPLICABLE CURVES AND USED IN COMPUTING STRESSES CONSERVATIVELY. THUS ELIMINATING THE USE OF BIJLAARD CHARTS EACH TIME.

IF VALUE OF "Γ" IS BETWEÈN 5 AND 15 Γ = 2.115

AND "β" = OR > 0.5, β = 0.735

USE THE CONSTANTS GIVEN BELOW.

(IF Γ & β DO NOT FALL WITHIN ABOVE RANGE, READ CONSTANTS FROM SPECIFIC CURVES AND USE THEM IN PLACE OF CONSTANTS LISTED BELOW.)

SINCE "b

SINCE VALUES ARE OUT OF ABOVE RANGE , APPROPRIATE BJILAARD CONSTANTS ARE USED.

PROGRAMMED BY:
M.M. AHMED

VERSION. 0
PAGE NO: 4

CONSTANTS FOR CIRCUMFERENTIAL STRESSES:
---

| | |
|---|---|
| Aϕ = 0.70 | FROM FIG 4C: VALUE OF 'Nϕ/P/Rm' FOR 'P' |
| Bϕ = 0.04 | FROM FIG 2C-1: VALUE OF 'Mϕ/P' FOR 'P' |
| Cϕ = 0.20 | FROM FIG 3A: VALUE OF 'Nϕ/Mc/Rm^2.β' FOR Mc |
| Dϕ = 0.12 | FROM FIG 1A: VALUE OF 'Mϕ/Mc/Rm.β' FOR Mc |
| Eϕ = 0.50 | FROM FIG 3B: VALUE OF 'Nϕ/ML/Rm^2.β' FOR ML |
| Fϕ = 0.04 | FROM FIG 1B: VALUE OF 'Mϕ/ML/Rm.β' FOR ML |

CONSTANTS FOR LONGITUDINAL STRESSESS
---

| | |
|---|---|
| Ax = 0.60 | FROM FIG 4C: VALUE OF 'Nx/P/Rm' FOR 'P' |
| Bx = 0.08 | FROM FIG 1C-1: VALUE OF 'Nx/P' FOR 'P' |
| Cx = 0.30 | FROM FIG 4A: VALUE OF 'Nx/Mc/Rm^2.β' FOR Mc |
| Dx = 0.07 | FROM FIG 2A: VALUE OF 'Mx/Mc/Rm.β' FOR Mc |
| Ex = 0.15 | FROM FIG 4B: VALUE OF 'Nx/ML/Rm^2.β' FOR ML |
| Fx = 0.08 | FROM FIG 2B: VALUE OF 'Mx/ML/Rm.β' FOR ML |

CIRCUMFERENTIAL ( σϕ ) STRESSES:
---

$\sigma\phi a \equiv Kn \cdot A\phi \cdot \frac{P}{Rm \cdot T}$ $\sigma\phi a = 138.48$

$\sigma\phi b \equiv Kb \cdot B\phi \cdot 6 \cdot \frac{P}{T^2}$ $\sigma\phi b = 84.125$

$\sigma\phi c \equiv Kn \cdot C\phi \cdot \frac{M_c}{Rm^2 \cdot \beta \cdot T}$ $\sigma\phi c = 514.14$

$\sigma\phi d \equiv Kb \cdot D\phi \cdot 6 \cdot \frac{M_c}{(Rm \cdot \beta) \cdot T^2}$ $\sigma\phi d = 3.28 \cdot 10^3$

$\sigma\phi e \equiv Kn \cdot E\phi \cdot \frac{M_l}{Rm^2 \cdot \beta \cdot T}$ $\sigma\phi e = 3.761 \cdot 10^3$

$\sigma\phi f \equiv Kb \cdot F\phi \cdot 6 \cdot \frac{M_l}{(Rm \cdot \beta \cdot T^2)}$ $\sigma\phi f = 3.199 \cdot 10^3$

CIRCUMFERENTIAL STRESS (σϕ) SUMMATION:
---

NOTE: USE THE MOST CRITICAL STRESS OF THE FOLLOWING SUMMATIONS.

$\sigma\phi Cu \equiv \sigma\phi a + \sigma\phi b + \sigma\phi c + \sigma\phi d$ $\sigma\phi Cu = 4.016 \cdot 10^3$

OR

$\sigma\phi Au \equiv \sigma\phi a + \sigma\phi b + \sigma\phi e + \sigma\phi f$ $\sigma\phi Au = 7.183 \cdot 10^3$

PROGRAMMED BY:
M.M. AHMED



**LONGITUDINAL ( σx ) STRESSES:**

$\sigma xa \equiv Kn \cdot Ax \cdot \frac{P}{Rm \cdot T}$ $\sigma xa = 118.697$

$\sigma xb \equiv Kb \cdot Bx \cdot 6 \cdot \frac{P}{T^2}$ $\sigma xb = 168.25$

$\sigma xc \equiv Kn \cdot Cx \cdot \frac{M_c}{Rm^2 \cdot \beta \cdot T}$ $\sigma xc = 771.209$

$\sigma xd \equiv Kb \cdot Dx \cdot 6 \cdot \frac{M_c}{(Rm \cdot \beta \cdot T^2)}$ $\sigma xd = 1.913 \cdot 10^3$

$\sigma xe \equiv Kn \cdot Ex \cdot \frac{M_l}{Rm^2 \cdot \beta \cdot T}$ $\sigma xe = 1.128 \cdot 10^3$

$\sigma xf \equiv Kb \cdot Fx \cdot 6 \cdot \frac{M_l}{(Rm \cdot \beta \cdot T^2)}$ $\sigma xf = 6.398 \cdot 10^3$

**LONGITUDINAL (σx) STRESS SUMMATION:**

**NOTE: USE THE MOST CRITICAL OF THE FOLLOWING SUMMATIONS.**

$\sigma xCu \equiv \sigma xa + \sigma xb + \sigma xc + \sigma xd$ $\sigma xCu = 2.971 \cdot 10^3$

**OR**

$\sigma xAu \equiv \sigma xa + \sigma xb + \sigma xe + \sigma xf$ $\sigma xAu = 7.813 \cdot 10^3$

SHEAR ($\Gamma x\phi$) STRESSES:
---

$$\Gamma x\phi 1 \equiv \frac{M_t}{\left(2\cdot\pi\cdot ro^2\cdot T\right)}$$ SHEAR STRESS DUE TO TORSION 'MT'

$\Gamma x\phi 1 = 81.287$

$$\Gamma x\phi 2 \equiv \frac{V_c}{\pi\cdot ro\cdot T}$$ SHEAR STRESS DUE TO SHEAR 'VC'

$\Gamma x\phi 2 = 94.463$

$$\Gamma x\phi 3 \equiv \frac{V_l}{\pi\cdot ro\cdot T}$$ SHEAR STRESS DUE TO SHEAR 'VL'

$\Gamma x\phi 3 = 523.677$

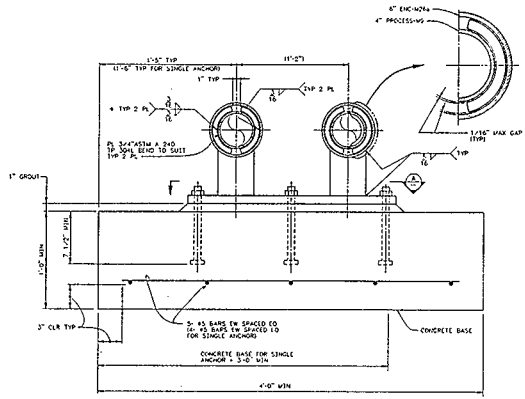
SHEAR STRESS ($\Gamma x\phi$) SUMMATION:
---

THE TWO COMPONENTS OF SHEAR STRESSES ARE:

$\Gamma x\phi Au \equiv (\Gamma x\phi 1 + \Gamma x\phi 2)$ $\Gamma x\phi Au = 175.75$

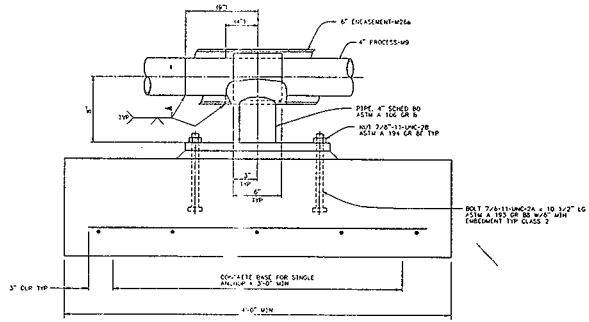
$\Gamma x\phi Du \equiv (\Gamma x\phi 1 + \Gamma x\phi 3)$ $\Gamma x\phi Du = 604.965$

NOTE: WHILE QUALIFYING THE PIPE STRESSES FOR ASME CODES B31.1 AND B31.3, THIS PROGRAM, "POP", SHALL BE RUN TWICE, ONCE FOR THERMAL LOADS AND ONCE FOR SUSTAINED + SEISMIC LOADS. THE HIGHEST OF THE LONGITUDINAL STRESSES ($\sigma xAu$ <u>or</u> $\sigma xCu$) COMPUTED ON PAGE-6 OF THIS PROGRAM SHALL BE ADDED TO THE "AUTOPIPE" PIPE STRESSES FOR RESPECTIVE LOAD CASE. THE SUMMATION PIPE NORMAL STRESSES (AUTOPIE) AND LOCAL LONGITUDINAL STRESSES (POP) SHALL BE WITHIN THE CODE ALLOWABLES FOR CORROSPONDING LOAD CASES.




ENCASED PIPE ANCHOR SYMBOL

DETAIL
H-2-818518 & H-2-818533
SCALE 3"=1'-0"



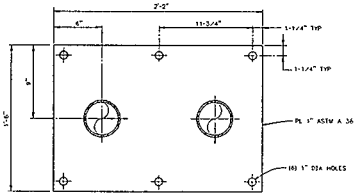




PLATE FOR DOUBLE ANCHOR

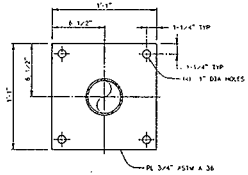



PLATE FOR SINGLE ANCHOR

SECTION
SCALE 3" = 1'-0"

NOTES:

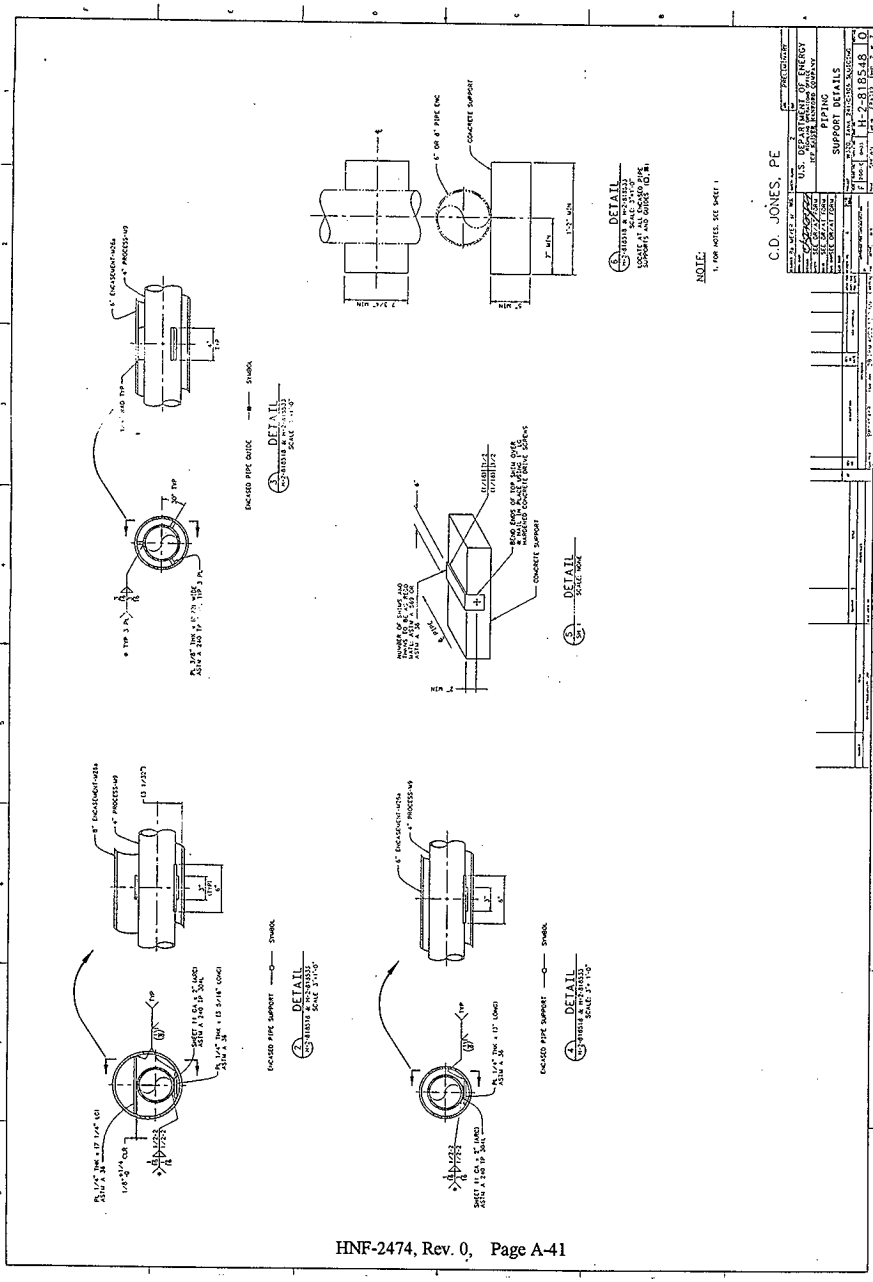
1. FOR GENERAL NOTES AND LEGEND, SEE DWG H-2-818518 AND H-2-818533
2. BREAK ALL SHARP EDGES AND REMOVE ALL BURRS
3. FOR LOCATION AND/OR SPACING OF SUPPORTS, GUIDES AND ANCHORS, SEE PIPING TRANSFER LINE PLANS.
4. DETAIL 5 ON SHEET 2 TO BE USED AS REQUIRED TO SHIM PIPE CENTER LINE TO ELEVATION REQUIRED

C.D. JONES, PE

| | |
|---|---|
| U.S. DEPARTMENT OF ENERGY<br>RICHLAND OPERATIONS OFFICE<br>ICF KAISER HANFORD COMPANY | PRELIMINARY |
| PIPING<br>SUPPORT DETAILS | |
| W320 TANK 241-C-106 SLUICING | |
| F 2006 0403 H-2-818548 10 | |



APPDX-B PAGE B1


DETAIL
DETAIL
DETAIL
DETAIL
DETAIL
DETAIL
ENCASED PIPE SUPPORT
SYMBOL
CONCRETE SUPPORT
NOTE:
1. FOR NOTES, SEE SHEET 1
C.D. JONES, PE
U.S. DEPARTMENT OF ENERGY
PIPING
SUPPORT DETAILS
H-2-818548

W320-27-016

C Farm Jumper Stress Analysis

| ICF KAISER HANFORD COMPANY | CALCULATION IDENTIFICATION AND INDEX | Page i of iii<br>Date 9/11/95 |
|---|---|---|

This sheet shows the status and description of the attached Design Analysis sheets.

Discipline 27,Piping and Vessels WO/Job No. ER4319 Calculation No. W320-27-016

Project No. & Name Project W-320 Waste Retrieval for Tank 241-C-106

Calculation Item C Farm Jumper Stress Analysis

These calculations apply to:

Dwg. No. H-2-818524, H-2-818505, and H-2-818508 Rev. No. 01

Dwg. No. H-2-818526 and H-2-818515 Rev. No. 01

Other (Study, CDR) Rev. No.

The status of these calculations is:

- [x] Preliminary Calculations
- [x] Final Calculations
- [ ] Check Calculations (On Calculation Dated )
- [ ] Void Calculation (Reason Voided

Incorporated in Final Drawings? [x] Yes [x] No

This calculation verified by independent "check" calculation? [ ] Yes [x] No

Original and Revised Calculation Approvals:

| | Rev. 0 Signature / Date | Rev. 1 Signature / Date | Rev. 2 Signature / Date |
|---|---|---|---|
| Originator | M. M. Ahmed 9-11-95 | M.M. Ahmed 6/28/96 | Kelly Harper 11/25/97 |
| Checked by | M. K. Pal 9-11-95 | D.L. Stone 7-1-96 | M. Ahmed 3.17.98 |
| Approved by | | CD Jones 7/1/96 | D.L. Evans 4/9/98 |
| Checked Against | | | M. Ahmed 4.10.98 |

RIVISION 1 SUMMARY: Revised pages 1, 5, 6, 7 & 8 , Appendices A & B.
Added page-9.

INDEX

| Design Analysis Page No. | Description |
|---|---|
| i - ii | Calculation Identification and Index |
| iii | Calculation Cross Index |
| 1 | Objective, Design Criteria ,Design Inputs |
| 2 - 3 | Design Methodology |
| 4 | Assumptions |
| 4 - 5 | References |
| 5 | Calculations and Conclusions |
| 6 | ISB Jumper Connectors qualification |
| 7 - 8 | Pit Wall Anchor Loads |
| 9 | Jumper piping Isometric 3D Model |

INDX-C.XLS

| ICF KAISER HANFORD COMPANY | CALCULATION IDENTIFICATION AND INDEX | Page ii of iii<br>Date 9 / 11 /95 |
|---|---|---|

Discipline 27,Piping and Vessels WO/Job No._ER4319__ Calculation No. W320-27-016

| | Rev. 0 Signature / Date | Rev. 1 Signature / Date | Rev. 2 Signature / Date |
|---|---|---|---|
| Originator | M. M. Ahmed 9-11-95 | M.M. Ahmed 6-28-96 | K. Hayes 11/25/97 |
| Checked by | M. K. Pal 9-11-95 | D.L. Stone 7-1-96 | M. Ahmed 3.17.98 |

INDEX

| Design Analysis Page No. | Description |
|---|---|
| ~~Appdx A~~ | ~~AutoPipe File no:MA-C06A, Stress Isometric & Drawings~~ |
| ~~Appdx B~~ | ~~AutoPipe File MA-C06AS Static & Hydrostatic analysis) \|\| Rev 1~~ |
| ~~Appdx C~~ | ~~AutoPipe File no:MA-J6A, Isometric & Piping Drawings \|\| REV 1~~ |
| ~~Appdx D C~~ | ~~Refrence Documentation \|\| Rev 1~~ |
| Appdx A | Autopipe File: MA-C06A, and drawings |
| Appdx B | Autopipe File: MA-C06AS |
| Appdx C | Autopipe File: MA-J6A, Isometric, and drawings |
| Appdx D | Reference Documentation |

2

2

Rev. 2 - Verify As-Built Conditions.
Page 5a added. Pages i, ii, iii, 1, and 4 revised.



INDX-C.XLS

# CALCULATION CROSS INDEX (Typical)

Subject Calculation No.: W320-27-016



| Subject Calculation Revision No. | Superceded by Calculation No. | These interfacing calculation/documents provide input to the subject calculation, and if revised may require revision of the subject calculation. | | Results and conclusions of the subject calculation are used in these interfacing calculations and/or documents | | Does the output interface calculation/ documents require revision? | | Has the output interfacecalculation/ documents been revised? | | Discipline manager's signature and date indicating evaluation complete. |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Calculation/Document No. | Revision No. | Calculation/Document No. | Revision No. | Yes | No | Yes | No | |
| 2 | NA | H-2-818505, Sheet 1 | ~~0~~ 1 | NA | | | X | | X | X |
| | | H-2-818505, Sheet 2 | ~~0~~ 1 | | | | | | | D. L. Evans 7/16/98 |
| | | H-2-818508, Sheet 1 | ~~0~~ 1 | | | | | | | |
| | | H-2-818515, Sheet 1 | ~~0~~ 1 | | | | | | | |
| | | H-2-818524, Sheet 1 | ~~0~~ 1 | 2 | | | | | | |
| | | H-2-818524, Sheet 2 | ~~0~~ 1 | NA 3.17.98 | | | | | | |
| | | H-2-818526, Sheet 1 | ~~0~~ 1 | | | | | | | |
| | | H-2-818526, Sheet 2 | ~~0~~ 1 | | | | X | | X | |

KEH 1975.00 (12/88)

## DESIGN ANALYSIS

Client WESTINGHOUSE HANFORD COMPANY
Subject AY FARM - JUMPER STRESS ANALYSIS
PROJECT W-320 WASTE RETRIEVAL for TANK 241-C-106
Location C TANK FARM - 200 W. AREA

WO/Job No. ER4319
Date 9-11-95
Checked 9/11/95
Revised / /

Filename: C06A.WP
By: M.M. Ahmed
By: M.K. Pal
By:

Rev. 2 By: K. Hayase 11/25/97
Chk. By: M. Ahmed 3.17.98

Rev-1: By: M. Ahmed 6-28-96
Chk'd By: D. L. Stout 7-1-96

**OBJECTIVE:**

The objectives of this calculation are:

1. Perform static and dynamic piping stress analysis of the "C- Tank Farm" Jumper Assemblies in order to be in compliance with the Code ASME B31.3 requirements.

2. Qualify the Integral Seal Block (ISB) Jumper connectors for loads exerted by piping in accordance with document WHC-SD-W236A-DA-002, Rev-0

3. Prepare a report on piping loads exerted on pit wall at pipe penetration location.

REV-1:

To incorporate the changes resulting from using a different Booster pump. I Rev-1
Rev-2: Verify As-built conditions 2

**DESIGN CRITERIA:**

1. ASME CODE B31.3-93 with Addenda up to 1994.
2. SDC 4.1, REV-12. (Now FDNW Practice # 134.215.1217) 2
3. PROJECT W-320 FDC: WHC-SD-W320-FDC-001, REV. ~~2~~ 4
4. WHC-SD-W236A-DA-002, Rev-0

**DESIGN INPUTS:**

GENERAL (Applicable to all Jumpers)

| | | |
|---|---|---|
| Ambient Temperature | 40°F | (Ref. 3) |
| Design Temperature: | 180°F | (Ref: 3) |
| Design Pressure: | 325 psig | (Ref: 10) |
| Hydrostatic Pressure | 490 psig | |
| Pipe Materials: | ASTM A312 TP304L | (Ref: 19) |
| Pipe Sizes: | 3 in. and 4 in. I Rev-1 | (Ref: 19) |
| Pipe Wall | Schedule 40 | (Ref: 5 & 19) |
| Safety Class category: | SC-3 | (Ref. 4) |
| Corrosion Allowance | 0.06 inches | (Ref. 7) |
| B31.3 Code Allowable stress | 16700 psi | (Ref: 1) |

JUMPER U9-A, B PUMP PIT 241-C-06A (Autopipe Filename: MA-C06A & ~~C06A-ST~~ MA-C06AS) 2

| | | | |
|---|---|---|---|
| Process Fluid: | 241-C-06A SLury | | (Ref: 20) |
| Specific gravity: | 1.20 | | (Ref: 8 ) |
| Piping Dimensions: | Dwg: H-2-818505 | | (Ref: 19) |
| Flanges | 300# ANSI rated | | (Ref. 21) |
| Connector weights | 4": 122 lbs 3": 77 lbs 2": 29 lbs | | (Ref: 9) |
| Nozzle weights | 4": 11 lbs 3": 6.5 lbs 2": 2.5 lbs | | (Ref: 9) |
| Kickplate weights | 4": 16.5 lbs 3": 12 lbs 2": 3.5 lbs | | (Ref: 9) |
| Pressure Element Weight | 4": 27 lbs N/A 2": 12 lbs | (Appx: C) | (Ref. 18) |
| Pump | $W_{Pump}$ = 1000 lbs | (Appx: C) | (Ref: 17) I Rev-1 |
| Pump Motor | $W_{Pump\ Motor}$ = 2250 lbs | (Appx: C) | (Ref: 17) I Rev-1 |
| Blank 2" Connector with Counter Weight | 86.98 lbs | (Appx: C) | (Ref. 22) |

JUMPER U6-A PUMP PIT 241-C-06C (Autopipe Filename: MA-J6A)

| | | |
|---|---|---|
| Process Fluid: | Tank 241-C-106 Supernate | (Ref: 20) |
| Specific gravity: | 1.12 | (Ref: 3) |
| Piping Dimensions: | Dwg: H-2-818515 | (Ref: 19) |
| Connector weight | 122 lbs | (Ref: 9) |
| Nozzle weight | 11 lbs | (Ref: 9) |
| Kickplate weight | 17 lbs | (Ref: 9) |
| Jumper Flushing Blank Head | 71.5 lbs | (Ref: 9) |

**DESIGN METHODOLOGY:**

C Farm Jumper Piping Assemblies include Jumper U9-A that is located in Pump Pit 241-c-06A and Jumper U6-A that is located in Pump Pit 241-C-06C.

The jumper assembly models include connectors and nozzles. The nozzles are considered to be rigidly anchored either to pit walls or cover plate for tanks (H-2-818524 and H-2-818526, Ref:19).

The jumper connectors are specified as Integral Seal Block (ISB) connectors (Ref:9) The document WHC-SD-W236A-DA-002 (Ref:22) provides all the analytical data such as connector stiffness, acceptable piping loads & seating forces for the ISB connectors. These connectors have been modeled in Autopipe as short radius elbows and flexible couplings with specified translation and rotational stiffness. The connector and nozzle weights are imposed at Flexible coupling.

The weights of structural steel assemblies and lifting bails used to connect jumper piping to nozzles during installation are calculated and imposed at appropriate points.

Stress analysis of the jumpers has been performed in accordance with ASME B31.3 for sustained, thermal and seismic loading (Ref. 1) using the computer program "Autopipe" Version-4.6 by "Engineering Design Automation" (EDA) (Ref. 11).

**SUSTAINED LOADS:**

The "AutoPipe" program checks the sustained stress (the summation of gravity and pressure stresses) against the B31.3 Code Allowable stress "S" for the material specified for each jumper piping.

**THERMAL (DISPLACEMENT) STRESS:**

The maximum design temperature for the pipe of 180°F and the ambient temperature of 40°F has been used in "AutoPipe" program to qualify the thermal expansion stress to the Code B31.3 allowable for displacement stress, "Sa".

**SEISMIC STRESSES:**

The jumper piping has been categorized as Safety Class 3. However the pit structure is classified as Safety Class 1 category. In order to perform Safety Class 3/1 analysis for this investigation, dynamic response spectra analysis is performed using Safety class-1, "Fig 3" seismic response spectra (5% Damping) of SDC 4.1, Rev-12 (Ref.2). This response spectra is created in "AutoPipe" as "SC1" and used in this dynamic analysis. Autopipe qualifies seismic stresses as occasional stress with the code allowable 1.33S.

The Jumper Connectors are qualified in accordance with WHC-SD-236A-DA-002, Rev-0 (Ref:22) Table 3.4 Acceptable piping loads. The acceptable axial force is limited to allowable seating forces for 50 ft-lb torque of Table 3.3 assuming all the actual axial loads tend to un-seat connector assembly. This results in conservative analysis. The acceptable loads are not increased by 1/3 as permitted on page-6 of Ref:22, which is conservative. The interaction of loads for critical connector is calculated (See page-6 of this calculations) as specified on page-7 of Ref:22.

**HYDROSTATIC PRESSURE:**

A hydrostatic pressure analysis is performed for 490 psig (1.5 times of Design pressure) and documented in Appendix-B.

The following describes the modelling and analysis techniques unique to individual jumpers.

**JUMPER U9-A**

Jumper U9-A includes the piping extending from the Tank C-06 Submersible Pump Assembly nozzle (A) to the Tank C-06 Booster Pump, and from the Booster Pump to the Transfer Line nozzle (U-9). The "Frame" feature of the "Autopipe" program has been used to assimilate the Booster Pump Assembly in order to consider the adequate stiffness of the pump in the system. The weight of the pump and motor is imposed at locations corresponding the centers of gravity of the pump and motor. The seismic stabilizer is represented in the model by two 3-inch schedule 40 pipes that connect to the lifting frame sub-assembly.

A Gravity support (Y-stop) has been modeled directly below the pump assembly (Node point#1) which is seated on concrete pedestal for the Sustained (Static) analysis only (See Appendix-B). The Y-stop is removed from the model for the dynamic analysis (See Appendix-A) in order to retain the linearity of the dynamic analysis and most accurately assimilate the effects of movement of the pump assembly in a Seismic event.

Weight of instrumentation has been applied at the instrument center on the pipe with flanges input as 400# ANSI rated in accordance with the 325 psig design pressure.

**PIPING LOADS AT BUILDING PENETRATION ANCHORS**
The spreadsheet program, "Excel" (Ref. 12), has been used to summarize Pipe Loading at Building Penetration Anchors and listed on pages 7 & 8.

**ASSUMPTIONS:**

1. Since the "Autopipe" program cannot perform non-linear dynamic analysis, Y-stops (No gap below and an infinite gap above the pipe) is ignored for the dynamic analysis. This results in a conservative analysis.

2. It is assumed that the lifting bail and structural steel assemblies designed to support the jumper piping during installation will be supported by the jumper during operation.

3. Assumed the ISB jumper connectors will be used and torqued to 50 ft-lbs.

4. Building structures and tank nozzles are structurally adequate to withstand pipe loads.

**REFERENCES:**

1. ASME Code B31.3 and B31.3a-1994 Addenda for "Chemical and Petroleum Refinery."

2. SDC 4.1, Rev. 12, "Standard Architecture & Civil Design Criteria."
(Now FDNW Practice # 134.215.1217, Design Loads for Facilities)
3. WHC-SD-W320-FDC-001, Rev-~~2~~ 4. "Functional Design Criteria for Tank 241-C-106 Waste Retrieval, Project W-320". 2

4. WHC-SD-WM-SEL-033, Rev-1, "Safety Equipment List for 241-C-106 Waste Retrieval Project W-230"

5. Construction specifications W-320-C5, Rev-0 , Section 15493 for piping materials.

6.Construction Specification No: B-131-C1, Section 15415 for piping materials.

7. Calculation No: W-030-011, Rev-1 for "Fouling factor and Corrosion rate."

8. *Data Compendium*, Bruce A. Castaing

9. Jumper Design Fabrication Drawings: H-2-821325, H-2-821326 & H-2-821404.

10. DSI from C.D.Jones dated March 28, 1994 "Design Pressure for Slurry and Sluice Pumps".

11. Computer program "AutoPipe" Version 4.6 by "Engineering Design Automation."

12. Computer Program "EXCEL" Version 4.0, by Microsoft.

13. Crane Technical Paper No: 410, 22nd Printing-1986.

14. Ryerson Stock List and Data Book, 1985-86 Edition, Joseph T. Ryerson & Son, Inc.

Rev-1: By: M. Ahmed 6.28.96
Checked By: D L - 7-1-96

15. PBM Reference Book Sec. II (SP Series) and Sec. IV (MP Series), PBM, Inc.

16. Fax Transmittal Memo from Micro Motion, Inc. Fax dated 6/22/94

17. Fax Transmittal Memo from C.D.Jones of Reliance Dimension Sheet 611740-503 and Goulds Catalog # GPM5, Page 134 for Pump Model 3900 , dated 1/23/95

18. Fax Transmittal Memo from Red Valve Co. Inc., on Series 40 Pressure Sensors.

19. Piping Arrangement and Detail drawings: H-2-818524, H-2-818505, H-2-818508, H-2-818526, and H-2-818515

20. Process Flow Diagrams: H-2-818558 H-2-818559, and H-2-818560

21. ASME/ANSI B16.5

22. WHC-SD-W236A-DA-002, Rev-0 "Stress Analysis of Single Port (ISB) Jumper Connectors for 2-, 3-, and 4-in Sizes".

23. Seismic Design White Paper Project W-320 Tank 241-C-106 Sluicing

## CALCULATIONS:

The calculations are documented in this package as shown below.

| | | |
|---|---|---|
| AutoPipe stress analysis results & Isometric models | Appendices A, B & C | |
| Jumper Connector load qualification | Page-6 | |
| Pit Wall Anchor Loads | Pages 7 & 8 | |
| Jumper 3D Isometrric Model for AutoPipe | Page-9 | I Rev-1 |

## CONCLUSION:

The review of the "AutoPipe" summary results attached as Appendices to this calculation indicates that all pipe stresses are in compliance with the requirements of ASME Code B31.3 requirements.

The Jumper qualification on page-6 indicates that ISB connectors are adequate for piping loads.

The Piping loads on Pit walls at piping penetrations are summarized on pages 7 & 8.

# DESIGN ANALYSIS

Client: Numatec
WO/Job No.: ER4319/W-320
Subject: C Farm Jumper Stress Analysis
Project W-320 Waste Retrieval for Tank 241-C-106
Date: 11/25/97 By: K Hayese
Checked: 3.17.98 By: R. Ahmed
Location: C Tank Farm 200 East Area
Revised: By:

**Rev. 2**

**CONCLUSION (CONTINUED)**

Rev. 2 of this calculation verified the analysis against the as-built conditions (~~as of 11/24/97~~). The analysis includes the weights of a flow meter and pressure sensors. These weights are not critical to the results of the analysis. Therefore, any differences between the weights used in the analysis and the approved vendor data are negligible.

AS-BUILT CHANGES ARE INSIGNIFICANT AND WILL NOT HAVE ANY ADVERSE IMPACT ON ANALYSIS.

Client WESTINGHOUSE HANFORD COMPANY
Subject AY FARM - JUMPER STRESS ANALYSIS
PROJECT W-320 WASTE RETRIEVAL for TANK 241-C-106
Location C TANK FARM - 200 W. AREA

WO/Job No. ER4319
Date 9-11-95
Checked 9/11/95
Revised / /

Filename: C06A.WP
By: M.M. Ahmed
By: M.K. Pal
By:

Rev-1: By: A. Ahmed 6.28.96
Checked By: D. Stone 7.1.96

## ISB JUMPER CONNECTOR LOADS QUALIFICATION

| CONNECTOR LOCATION | AUTOPIPE FILE NAME & NODE | SIZE | CONNECTOR ACTUAL LOADS I Rev-1 /ALLOWABLE LOADS | | | | | | REF NO: |
|---|---|---|---|---|---|---|---|---|---|
| | | | Axial X (lbs) | Shear Y (lbs) | Shear Z (lbs) | Torsion Mx (ft-lb) | Bend My (ft-lb) | Bend Mz (ft-lb) | |
| Connector-U9 Pump Pit C-06A | MA-C06A A03M | 4" | 520 | 276 | 381 | 180 | 197 | 236 | APDX-A |
| | | | 6310 | 2220 | 2220 | 780 | 1170 | 1170 | 22 |
| Connector A Pump Pit C-06A | MA-C06A A11M | 4" | 483 | 149 | 337 | 140 | 365 | 185 | APDX-A |
| | | | 6310 | 2220 | 2220 | 780 | 1170 | 1170 | 22 |
| Connector B Pump Pit C-06A | MA-C06A B04M | 4" | 269 | 258 | 333 | 30 | 100 | 84 | APDX-A |
| | | | 6310 | 2220 | 2220 | 780 | 1170 | 1170 | 22 |

SEATING FORCES BETWEEN CONNECTOR & NOZZLES:

The axial allowable load considered in table above are limited to seating forces for 4" Connectors for 50 ft-lb torque as specified in Table 3.3(Ref:22). Since the actual axial forces are less than the allowable seating forces, the connector will not be un-seated from the nozzle.

INTERACTION OF SHEAR, TORSION AND BENDING:

$I = fyz/Fyz + [mx]/Mx + myz/Myz < 1.0$ Ref:22, page-7

Review of actual loads and allowable loads in the table above indicates that the Connector-U9 in the pump pit is more critical for interaction. I Rev-1

fyz = 470 lbs (SRSS of fy=276 & fz=381). Increase Allowable by 1.33 for seismic I Rev-1

myz = 307 ft-lbs (SRSS of my=197 & mz=236) I Rev-1

I = 470/1.33x2220 + 180/1.33x780 + 307/1.33x1170 I Rev-1

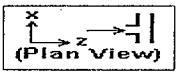
I = 0.53 < 1.00 As such Jumper Connectors are adequate. I Rev-1

| | | | | | |
|---|---|---|---|---|---|
| Client | WESTINGHOUSE HANFORD CO. | WO/Job N | ER4319 | Filename | U9.xls:2 |
| Subject | AY FARM JUMPER STRESS ANALYSIS | Date | 9/11/95 | By | M. M. AHMED |
| PROJECT W-320 WASTE RETRIEVAL for TANK 241-C-106 | | Checked | 9/11/95 | By | M. K. PAL |
| Location | C TANK FARM 200 EAST AREA | Revised | | By | |

REV-1: BY: M. Ahmed 6.28.96
CHECKED BY: D. L Stout 7-1-96

## ANCHOR LOADS AT PIT WALLS

NOTE: THESE ARE THE JUMPER PIPING LOADS EXERTED ON PIT WALL FROM INSIDE THE PIT. DOES NOT INCLUDE THE TRANSFER . PIPE LINE LOADS FROM OUT SIDE THE PIT.

| (Inside Pit) JUMPER LOADS | | Fx (lbs) | Fy (lbs) | Fz (lbs) | Mx (in-lb) | My (in-lb) | Mz (in-lb) |
|---|---|---|---|---|---|---|---|
| Identification: Dwg:H-2-818505 | (Seismic) (*1) | 132 | 128 | 295 | 1548 | 2352 | 948 |
| AutoPipe File: MA-C06A Node #: A00 Orientation: | (Thermal) (*2) | 23 | 321 | 233 | 3192 | 24 | 468 |
|   (*3) ABSOLUTE SUM | | 155 | 449 | 528 | 4740 | 2376 | 1416 |

| | | | | | |
|---|---|---|---|---|---|
| Client | WESTINGHOUSE HANFORD CO. | WO/Job N | ER4319 | Filename | U9.xls:2 |
| Subject | AY FARM JUMPER STRESS ANALYSIS | Date | 9/11/95 | By | M. M. AHMED |
| PROJECT W-320 WASTE RETRIEVAL for TANK 241-C-106 | | Checked | 9/11/95 | By | M. K. PAL |
| Location | C TANK FARM 200 EAST AREA | Revised | | By | |

REV:1 BY: M. Ahmed 6-28-96

CHECKED BY: D. L. Stone 7-1-96

NOTES:

(*1): SEISMIC LOADS COULD BE POSITIVE OR NEGATIVE.

(*2): THERMAL LOADS SPECIFIED ARE THE ALGEBRIC SUM OF GRAVITY AND THERMAL LOADS.

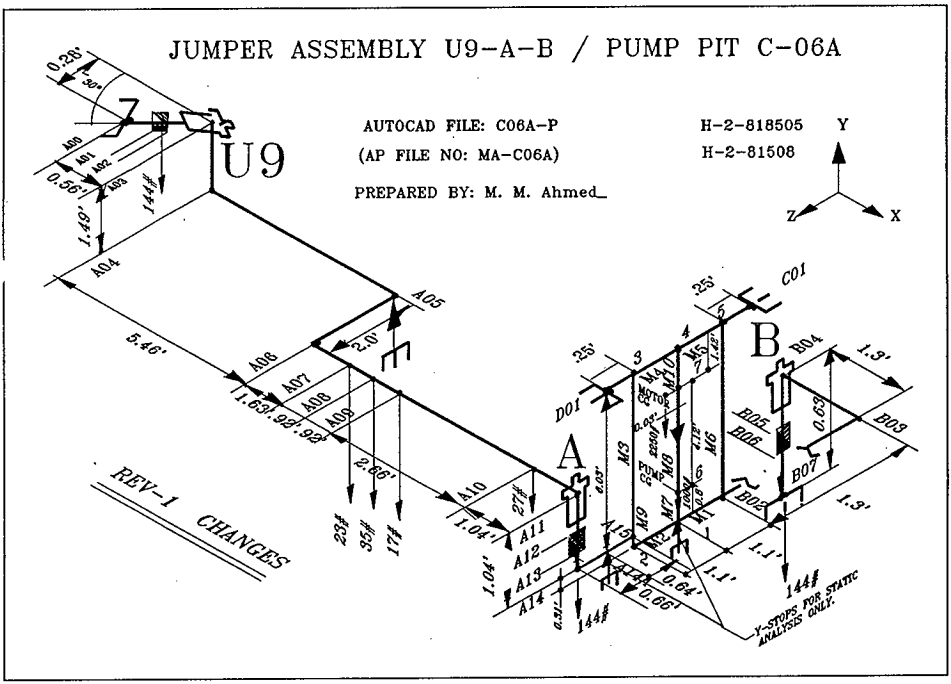
(*3): ABSOLUTE SUM IS THE TOTAL OF THERMAL AND SEISMIC DISREGARDING THE SIGNS.

**DESIGN ANALYSIS**

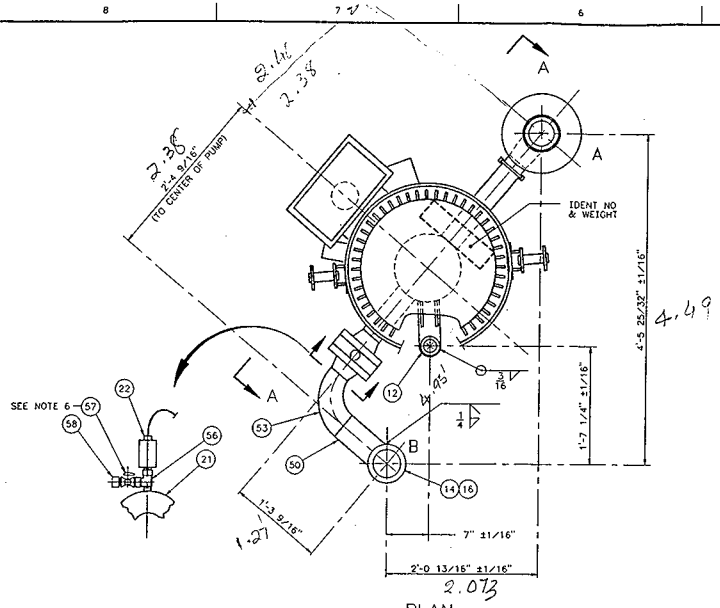
Client WESTINGHOUSE HANFORD COMPANY
Subject AY FARM - JUMPER STRESS ANALYSIS
PROJECT W-320 WASTE RETRIEVAL for TANK 241-C-106
Location C TANK FARM - 200 W. AREA

WO/Job No. ER4319 Filename: C06A.WP
Date 9-11-95 By: M.M. Ahmed
Checked 9/11/95 By: M.K. Pal
Revised / / By:

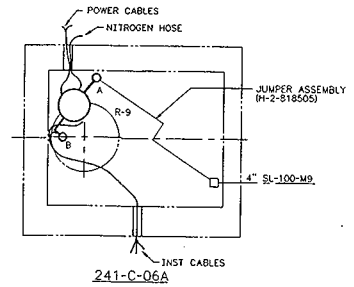
Rev-1: By: M. Ahmed 6-28-96
Checked By: [illegible] 7-1-96



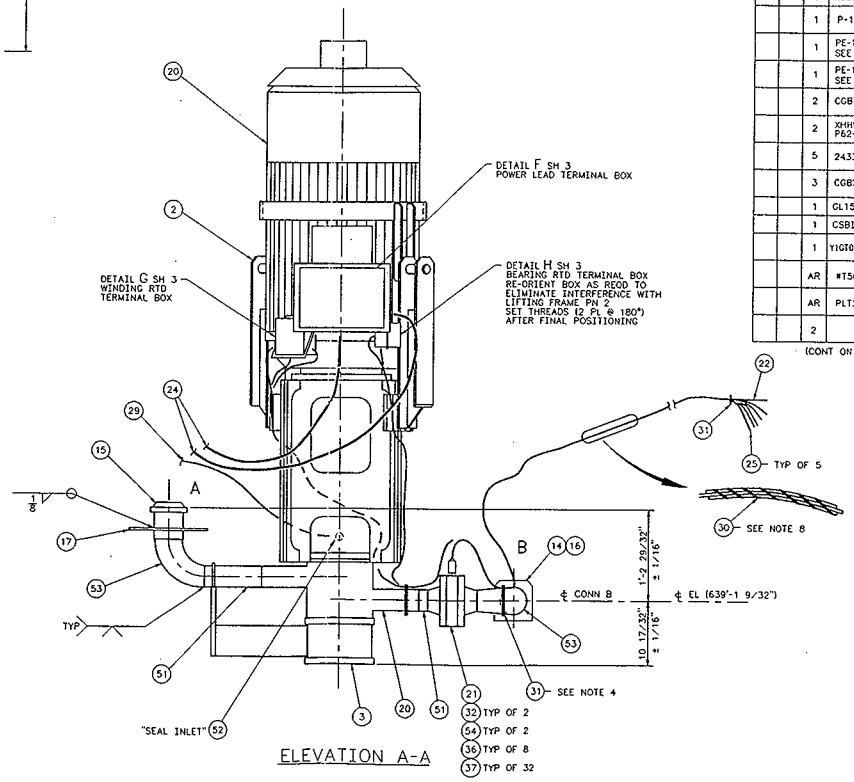
APPDX - A.




PLAN
(HOSES & WIRES NOT SHOWN FOR CLARITY)




241-C-06A
PUMP PIT
KEY PLAN
SCALE: NONE




ELEVATION A-A

1 ASSEMBLY
SCALE: 1 1/2" = 1'-0"

PARTS/MATERIAL LIST

| QUANTITY REQUIRED | | | PART/DASH NUMBER | NOMENCLATURE/DESCRIPTION | MATERIAL/REFERENCE | SHEET | ITEM NO. |
|---|---|---|---|---|---|---|---|
| | | X | -010 | ASSEMBLY | | | 1 |
| | X | 1 | -020 | LIFTING FRAME SUB-ASSY | | 2 | 2 |
| X | | 1 | -030 | PUMP BASE SUB-ASSY | | 2 | 3 |
| | | | | | | | 4 |
| | | | | | | | 5 |
| | 4 | | -001 | PLATE, 3/8" THK | ASTM A 36 | 3 | 6 |
| | 4 | | -002 | PLATE, 3/8" THK | ASTM A 36 | 3 | 7 |
| 2 | | | -003 | PLATE, 3/8" THK | ASTM A 36 | 3 | 8 |
| 1 | | | -004 | PLATE, 1/2" THK | ASTM A 36 | 3 | 9 |
| 2 | | | -005 | PLATE, 1" THK x 11 5/8" DIA | ASTM A 276 304L | 3 | 10 |
| | | | | | | 3 | 11 |
| | | 1 | -007 | PLATE, 3/8" THK | ASTM A 36 | 3 | 12 |
| | | | | | | | 13 |
| | | 1 | H-2-324+0-2 | CONN, VERT 4" | | | 14 |
| | | 1 | H-2-90187-2 | NOZZLE, MALE 4" | | | 15 |
| | | 1 | H-2-3997-8 | GASKET 4" TYPE III | | | 16 |
| | | 1 | H-2-3199-4 | KICK-OFF PL, 4" STD ROUND | | | 17 |
| | | | | | | | 18 |
| | | 1 | RB350-250 | CONDUIT RED BUSHING, 3 1/2" x 2 1/2" | APPLETON ELECTRIC | | 19 |
| | | 1 | P-1362 | PUMP, IN-LINE 3" INLET & 3" OUTLET | PROCUREMENT SPEC W-320-P17 | | 20 |
| | | 1 | PE-1363 SEE NOTE 6 & 9 | PRESSURE SENSOR, 3" | RED VALVE CO. INC | | 21 |
| | | 1 | PE-1363 SEE NOTE 7 | PRESSURE TRANSDUCER, (PE) 1/4" NPT | CONSTR SPEC W-320-C5 | | 22 |
| | | 2 | CGB791[illegible] | CABLE FITTING, 2 1/2" MNPT x 1.375/1.625 DIA | CROUSE-HINDS | | 23 |
| | | 2 | XHHW P62-0404 | CABLE, 3C, 4/0 AWG W/ GROUND, RATED FOR 90°C, 30' L | ROCKBESTOS FIREWALL III | | 24 |
| | | 5 | 2433C | CABLE, 3C, #16 AWG W/ OVERALL SHIELD x 25' L | ALPHA | | 25 |
| | | 3 | CGB293 | CABLE FITTING, 3/4" MNPT x .250/.375 DIA | CROUSE-HINDS | | 26 |
| | | 1 | GL150 | CABINET ADAPTER, 1 1/2" | O-Z/GEDNEY | | 27 |
| | | 1 | CSBI-150P-1 | CONDUIT SEALING BUSHING, 1 1/2" | O-Z/GEDNEY | | 28 |
| | | 1 | YIGT0404UCOAMC-300 | HOSE ASSY 1/4" ID FLEX x 25' L | IMPERIAL EASTMAN | | 29 |
| | | AR | #T50T | CABLE TEFLON SPRIAL WRAPPING x L AS REQD | PANDUIT | | 30 |
| | | AR | PLT2H-[illegible] | CABLE TIE, NYLON HVY CROSS SECTION x L AS REQD | PANDUIT | | 31 |
| | | 2 | | GASKET, 3" FLANGE, 1/8" THK | COMPRESSED FIBER GARLOCK BLUE GARD | | 32 |

(CONT ON SHEET 2)

NOTES:

1. FABRICATION AND TESTING SHALL BE IN ACCORDANCE WITH HANFORD SPECIFICATION HS-BS-0084, REV B.
2. HYDROSTATIC TEST AT 480 PSIG.
3. JUMPER WEIGHT IS 3750 LB APPROX.
4. ROUTE CABLES APPROXIMATELY AS SHOWN AND SECURE TO SUPPORT STEEL W/PN 31, AVOID IMPACT WRENCH AND LIFTING BAIL AREAS.
5. USE (1) COAT OF AMERLOCK 400 IN PLACE OF AMERCOAT 187 PRIMER AND AMERCOAT 33, WHERE REQUIRED BY JUMPER FABRICATION SPECIFICATION.
6. SEE CONSTRUCTION SPEC W-320-C5, SECTION 13440 FOR FILLING INSTRUCTION AFTER ASSEMBLY. AFTER FILLING, REMOVE HANDLE FROM BALL VALVE (PN 57).
7. TRIM CABLES FURNISHED WITH PN 22 TO 25' LONG PRIOR TO INSTALLATION.
8. TIE EACH END OF TEFLON SPIRAL WRAPPING (PN 30) WITH NYLON CABLE TIES (PN 31).
9. PRESSURE SENSOR (PN 21) SHALL BE SERIES 40, FOR CLASS 300 FLANGES, 316 SST, EPDM SLEEVES, WITH 1/4" NPT PRESSURE TAP. FURNISH WITH 100ML OF SILICONE OIL IN A SEPERATE CONTAINER.

STATE OF WASHINGTON
DAVID B. MEYER
18131
REGISTERED PROFESSIONAL ENGINEER
EXPIRES 5-3-96

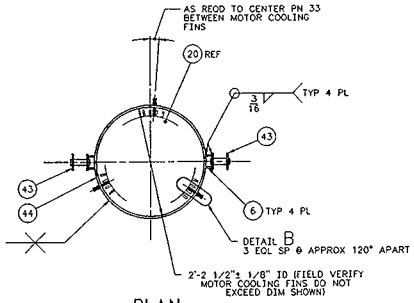
| | |
|---|---|
| USE | CONSTRUCTION |
| DESIGNED Ba MEYER 3/[illegible] | SAFETY CLASS 3 |
| DSGN ENGR | |
| CHECKED | U.S. DEPARTMENT OF ENERGY RICHLAND OPERATIONS OFFICE ICF KAISER HANFORD COMPANY |
| SAFETY SEE DR/AT FORM | JUMPER ASSEMBLY PUMP PIT C-06A-B-(A) |
| DWSP SEE DR/AT FORM | |
| DWG ENGR SEE DR/AT FORM | |
| LEAD ENGR | |
| REVIEW NO. 11 | PROJECT W-320 TANK 241-C-106 SLUICING |
| APPROVED FOR IMPLEMENTATION | SIZE F · SYSTEM 241-C · DWG NO. 8405 · DWG NO. B508AR1 · REV NO. 1 |
| BY WHC DATE | SCALE SHOWN · JOB NO. ER4319 · SHEET 1 OF 3 |

| NUMBER | TITLE | NUMBER | TITLE |
|---|---|---|---|
| DRAWING TRACEABILITY LIST | | H-2-818423 SH 7 | DRAWING LIST |
| | | NEXT USED ON H-2-818524 | |

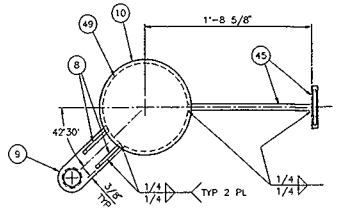
| REV BY | DATE | DESCRIPTION | REV BY DATE | SCH APPROVALS | APPR FOR IMPLEMENTATION BY DATE |
|---|---|---|---|---|---|
| | | REVISIONS | | | |

CAD FILE B508AR1 · CAD CODE 2B:18M:ACD2:12.0:NN · SHPS N · PDA

2 PLOT SCALE: 1=8 · KEHCAD · 1 · STIFFLEAF, 1994/03/03/0900




PLAN

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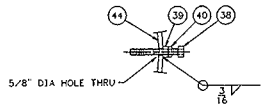
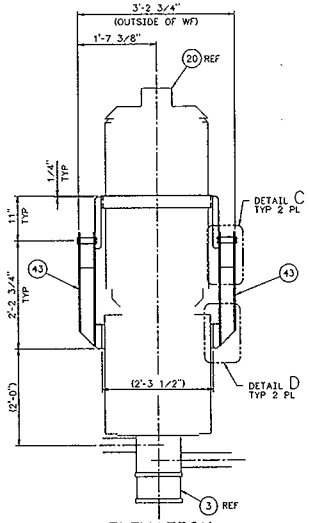


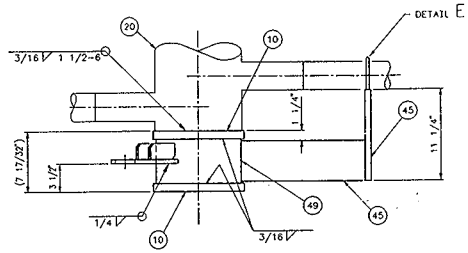

DETAIL B
SCALE: 3"=1'-0"

| QUANTITY REQUIRED | | | PART/DASH NUMBER | NOMENCLATURE/DESCRIPTION | MATERIAL/REFERENCE | SHEET | ITEM NO. |
|---|---|---|---|---|---|---|---|
| PARTS/MATERIAL LIST | | | | | | | |
| | | | | (CONT FROM SHEET 1) | | | |
| | | X | | ASSEMBLY | | 1 | 1 |
| | X | | | LIFTING FRAME SUB-ASSY | | | 2 |
| X | | | | PUMP BASE SUB-ASSY | | | 3 |
| | | | | | | | 33 |
| | | | | [illegible] | [illegible] | | 34 |
| | | | | [illegible] | [illegible] | | 35 |
| | | 8 | | STUD BOLT, 3/4"-10 UNC-2A x 7 1/2"L | ASTM A 193, GR B8 304 | | 36 |
| | | 32 | | NUT, HVY HEX, 3/4"-10 UNC-2B | ASTM A 194, GR 8F 303 | | 37 |
| | | 3 | | MACHINE SCREW, 1/2"-13 UNC-2A x 4 1/2"L | SAE J429 GR. 5 | | 38 |
| | | 3 | | NUT, HVY HEX, 1/2"-13 UNC-2B | ASTM A 563, GR B | | 39 |
| | | 3 | | NUT, JAM, 1/2"-13 UNC-2B | ASTM A 563, GR A | | 40 |
| | | | | | | | 41 |
| | | | | | | | 42 |
| | AR | | | W4 x 13 | ASTM A 36 | | 43 |
| | AR | | | FLAT BAR, 3" x 1/2" | ASTM A 36 | | 44 |
| AR | | | | FLAT BAR, 5" x 3/4" | ASTM A 36 | | 45 |
| | 2 | | | BAR, 1 1/2" DIA x 4 7/8" L | ASTM A 36 | | 46 |
| AR | | | | BAR, 3/8" DIA | ASTM A 36 | | 47 |
| | | | | | | | 48 |
| AR | | | | PIPE, 10" SCHED 40S | ASTM A 312 GR TP 304L | | 49 |
| | | AR | | PIPE, 4" SCHED 40S | ASTM A 312 GR TP 304L | | 50 |
| | | AR | | PIPE, 3" SCHED 40S | ASTM A 312 GR TP 304L | | 51 |
| | | 1 | SS-8-RB-4 | RED BUSHING, 1/2" NPT x 1/4" NPT | CAJON | | 52 |
| | | 2 | | RDCR ELB 90° LR, 4" x 3", SCHED 40S BW | ASTM A 403 WP-S 304L | | 53 |
| | | 2 | | FLANGE 3", 300# RF WN | ASTM A 182 GR F 304L | | 54 |
| | | 1 | | PLUG, 3/8" NPT | ASTM A 126 GCI | | 55 |
| | | 1 | SS-4-ST | STREET TEE, 1/4" NPT | CAJON | | 56 |
| | | 1 | SS-43M4 | BALL VALVE, 1/4" NPT | WHITEY | | 57 |
| | | 1 | SS-4-CP | PIPE CAP, 1/4" NPT | CAJON | | 58 |



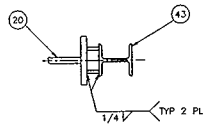

ELEVATION

2 LIFTING FRAME SUB-ASSY
SCALE: 1"= 1'-0"

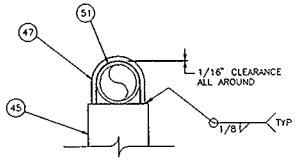



ELEVATION

3 PUMP BASE SUB-ASSY
SCALE: 2"= 1'-0"

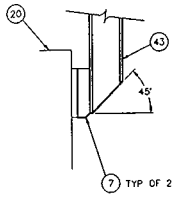



PLAN




ELEVATION

DETAIL E
SCALE: 3"=1'-0"

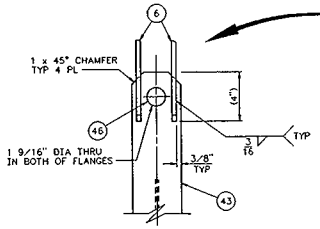



ELEVATION

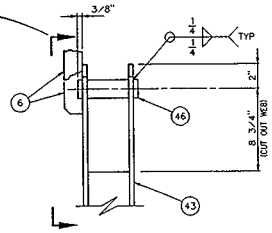
DETAIL D
SCALE: 2"=1'-0"

NOTE:

1. FOR NOTES, SEE SHEET 1




ELEVATION




ELEVATION

DETAIL C
SCALE: 3"=1'-0"

EXPIRES 5-3-96

| | | | |
|---|---|---|---|
| DESIGNED Bo MEYER Sr | DATE | SAFETY CLASS 3 | USE CONSTRUCTION |
| DRAWN BY | | | EST |
| CHECKED | | U.S. DEPARTMENT OF ENERGY RICHLAND OPERATIONS OFFICE ICF KAISER HANFORD COMPANY | |
| SAFETY SEE DR/AT FORM | | JUMPER ASSEMBLY PUMP PIT C-06A-B-(A) | |
| SHOP SEE DR/AT FORM | | | |
| QUAL CHECK SEE DR/AT FORM | | | |
| LEAD CHECK | | | |
| REVIEW NO. 12 | | PROJECT W-320 TANK 241-C-106 SLUICING | |
| APPROVED FOR IMPLEMENTATION | | SIZE F / BLDG NO. 241-C / DWG NO. B508BR1 | REV NO. 1 |
| BY | | | |
| FOR WHC | DATE | SCALE SHOWN / JOB NO. EP4319 | SHEET 2 OF 3 |

| NUMBER | TITLE | NUMBER | TITLE |
|---|---|---|---|
| DRAWING TRACEABILITY LIST | | NEXT USED ON | REFERENCES |

| NO. | REV BY DATE | DESCRIPTION | REV BY DATE | NEA APPROVALS | CPD FOR IMPLEMENT. | CPD DATE |
|---|---|---|---|---|---|---|
| | | REVISIONS | | | | |

CAD FILE B508BR1 CAD CODE 2B:IBM:ACD2:12.0:NN DPS N

2 PLOT SCALE: 1=12 KEHCAD 1

POINT DATA LISTING

| POINT NAME | TYPE | OFFSETS (ft) X | Y | Z | PIPE ID | DESCRIPTION |
|---|---|---|---|---|---|---|
| *** SEGMENT A | | | | | | |
| A00 | Run | 0 | 0 | 0 | 4PIPE | |
| A01 | Flex | 0.22 | 0 | -0.11 | | Wt= 144 lb , Ar= 3.2 sq.in<br>Axial= 23300000 Tors= 304.0<br>Y-Shear= RIGID Bend= 2080.0<br>Z-Shear= RIGID Bend= 2080.0 |
| A02 | Run | 0.04 | 0 | -0.02 | | |
| A03 | Bend | 0.30 | 0 | -0.15 | | Short Elbow, Radius = 4.00 inch<br>Bend angle change = 90.00 deg<br>Mid point at 50.00 percent<br>SIF - In 2.56, Out = 2.13<br>Flex = 7.908 |
| A04 | Bend | 0 | -1.49 | 0 | | Long Elbow, Radius = 6.00 inch<br>Bend angle change = 90.00 deg<br>Mid point at 50.00 percent<br>SIF - In 1.95, Out = 1.63<br>Flex = 5.272 |
| A05 | Bend | 5.46 | 0 | 0 | | Long Elbow, Radius = 6.00 inch<br>Bend angle change = 90.00 deg<br>Mid point at 50.00 percent<br>SIF - In 1.95, Out = 1.63<br>Flex = 5.272 |
| A06 | Bend | 0 | 0 | 2.00 | | Long Elbow, Radius = 6.00 inch<br>Bend angle change = 90.00 deg<br>Mid point at 50.00 percent<br>SIF - In 1.95, Out = 1.63<br>Flex = 5.272 |
| A07 | Run | 1.63 | 0 | 0 | | |
| A08 | Run | 0.92 | 0 | 0 | | |
| A09 | Run | 0.92 | 0 | 0 | | |
| A10 | Run | 2.66 | 0 | 0 | | |
| A11 | Bend | 1.04 | 0 | 0 | | Short Elbow, Radius = 4.00 inch<br>Bend angle change = 90.00 deg<br>Mid point at 50.00 percent<br>SIF - In 2.56, Out = 2.13<br>Flex = 7.908 |
| A12 | Flex | 0 | -0.40 | 0 | | Wt= 144 lb , Ar= 3.2 sq.in<br>Axial= 23300000 Tors= 304.0<br>Y-Shear= RIGID Bend= 2080.0<br>Z-Shear= RIGID Bend= 2080.0 |
| A13 | Run | 0 | -0.04 | 0 | | |
| A14 | Bend | 0 | -0.60 | 0 | | Long Elbow, Radius = 6.00 inch |





POINT DATA LISTING

| POINT NAME | TYPE | OFFSETS (ft) X | Y | Z | PIPE ID | DESCRIPTION |
|---|---|---|---|---|---|---|
| | | | | | | Bend angle change = 90.00 deg<br>Mid point at 50.00 percent<br>SIF - In 1.95, Out = 1.63<br>Flex = 5.272 |
| A14 F | Far | | | | 3PIPE | |
| A14A | Run | 0 | 0 | -0.66 | | |
| A15 | Run | 0 | 0 | -0.64 | | |
| *** SEGMENT B | | | | | | |
| B02 | Run | 13.19 | -2.84 | -1.78 | 3PIPE | |
| B03 | Bend | 0 | 0 | -1.30 | | Long Elbow, Radius = 4.50 inch<br>Bend angle change = 90.00 deg<br>Mid point at 50.00 percent<br>SIF - In 1.78, Out = 1.48<br>Flex = 4.577 |
| B03 F | Far | | | | 4PIPE | |
| B04 | Bend | -1.30 | 0 | 0 | | Short Elbow, Radius = 4.00 inch<br>Bend angle change = 90.00 deg<br>Mid point at 50.00 percent<br>SIF - In 2.56, Out = 2.13<br>Flex = 7.908 |
| B05 | Flex | 0 | -0.40 | 0 | | Wt= 144 lb , Ar= 3.2 sq.in<br>Axial= 23300000 Tors= 304.0<br>Y-Shear= RIGID Bend= 2080.0<br>Z-Shear= RIGID Bend= 2080.0 |
| B06 | Run | 0 | -0.04 | 0 | | |
| B07 | Run | 0 | -0.19 | 0 | | |
| *** SEGMENT C | | | | | | |
| 5 | Run | 13.19 | 3.50 | -1.78 | 3.5PIPE | |
| C01 | Run | 0 | 0 | -0.25 | | |
| *** SEGMENT D | | | | | | |
| 3 | Run | 13.19 | 3.50 | 0.42 | 3.5PIPE | |
| D01 | Run | 0 | 0 | 0.25 | | |

Total weight of empty pipes : 254 lb

C O M P O N E N T D A T A L I S T I N G

| POINT NAME | ---COORDINATE(ft X | Y | Z )--- | DATA TYPE | DESCRIPTION |
|---|---|---|---|---|---|
| *** SEGMENT A | | | | | |
| A00 | 0.00 | 0.00 | 0.00 | ANCHOR | Rigid<br>Thermal movements : None |
| A01 | 0.22 | 0.00 | -0.11 | | |
| A02 | 0.26 | 0.00 | -0.13 | | |
| A03 N | 0.26 | 0.00 | -0.13 | | |
| A03 | 0.56 | 0.00 | -0.28 | TI | |
| A03 M | 0.47 | -0.10 | -0.24 | | |
| A03 F | 0.56 | -0.33 | -0.28 | | |
| A04 N | 0.56 | -0.99 | -0.28 | | |
| A04 | 0.56 | -1.49 | -0.28 | TI | |
| A04 M | 0.71 | -1.34 | -0.28 | | |
| A04 F | 1.06 | -1.49 | -0.28 | | |
| A05 N | 5.52 | -1.49 | -0.28 | | |
| A05 | 6.02 | -1.49 | -0.28 | TI | |
| A05 M | 5.87 | -1.49 | -0.13 | | |
| A05 F | 6.02 | -1.49 | 0.22 | | |
| A06 N | 6.02 | -1.49 | 1.22 | | |
| A06 | 6.02 | -1.49 | 1.72 | TI | |
| A06 M | 6.17 | -1.49 | 1.57 | | |
| A06 F | 6.52 | -1.49 | 1.72 | | |
| A07 | 7.65 | -1.49 | 1.72 | WEIGHT | 23 lb , No offsets |
| A08 | 8.57 | -1.49 | 1.72 | WEIGHT | 35 lb , No offsets |
| | | | | FLANGE | Weld neck SIF = 1.00<br>Rating = 400, Weight = 35 lb |
| | | | | FLANGE | Weld neck SIF = 1.00<br>Rating = 400, Weight = 35 lb |
| A09 | 9.49 | -1.49 | 1.72 | WEIGHT | 17 lb , No offsets |
| A10 | 12.15 | -1.49 | 1.72 | WEIGHT | 27 lb , No offsets |
| | | | | FLANGE | Weld neck SIF = 1.00<br>Rating = 400, Weight = 35 lb |
| | | | | FLANGE | Weld neck SIF = 1.00<br>Rating = 400, Weight = 35 lb |
| A11 N | 12.86 | -1.49 | 1.72 | | |
| A11 | 13.19 | -1.49 | 1.72 | TI | |
| A11 M | 13.09 | -1.59 | 1.72 | | |
| A11 F | 13.19 | -1.82 | 1.72 | | |
| A12 | 13.19 | -1.89 | 1.72 | | |
| A13 | 13.19 | -1.93 | 1.72 | | |
| A14 N | 13.19 | -2.03 | 1.72 | | |
| A14 | 13.19 | -2.53 | 1.72 | TI | |
| A14 M | 13.19 | -2.38 | 1.57 | | |
| A14 F | 13.19 | -2.53 | 1.22 | | |
| A14A | 13.19 | -2.53 | 1.06 | | |
| A15 | 13.19 | -2.53 | 0.42 | | |
| *** SEGMENT B | | | | | |
| B02 | 13.19 | -2.84 | -1.78 | | |
| B03 N | 13.19 | -2.84 | -2.70 | | |





C O M P O N E N T D A T A L I S T I N G

| POINT NAME | ---COORDINATE(ft X | Y | Z )--- | DATA TYPE | DESCRIPTION |
|---|---|---|---|---|---|
| B03 | 13.19 | -2.84 | -3.08 | TI | |
| B03 M | 13.08 | -2.84 | -2.97 | | |
| B03 F | 12.81 | -2.84 | -3.08 | | |
| B04 N | 12.22 | -2.84 | -3.08 | | |
| B04 | 11.89 | -2.84 | -3.08 | TI | |
| B04 M | 11.99 | -2.94 | -3.08 | | |
| B04 F | 11.89 | -3.17 | -3.08 | | |
| B05 | 11.89 | -3.24 | -3.08 | | |
| B06 | 11.89 | -3.28 | -3.08 | | |
| B07 | 11.89 | -3.47 | -3.08 | ANCHOR | Rigid<br>Thermal movements : None |
| *** SEGMENT C | | | | | |
| 5 | 13.19 | 3.50 | -1.78 | ANCHOR | Translational stiffness lb/in<br>X= FREE Y= FREE Z= FREE<br>Rotational stiffness ft-lb/deg<br>X= RIGID Y= RIGID Z= RIGID<br>Thermal movements : None |
| C01 | 13.19 | 3.50 | -2.03 | ANCHOR | Rigid<br>Thermal movements : None |
| *** SEGMENT D | | | | | |
| 3 | 13.19 | 3.50 | 0.42 | ANCHOR | Translational stiffness lb/in<br>X= FREE Y= FREE Z= FREE<br>Rotational stiffness ft-lb/deg<br>X= RIGID Y= RIGID Z= RIGID<br>Thermal movements : None |
| D01 | 13.19 | 3.50 | 0.67 | ANCHOR | Rigid<br>Thermal movements : None |

Number of points in the system : 51

## P I P E  D A T A  L I S T I N G

| Pipe ID/ Material | Nom/ Sch | O.D. inch | -----Thickness(inch)----- W.Th. | Corr | Mill | Insu | Ling | Spec Grav | Weight(lb/ft ) Pipe | Other | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 4PIPE | 4 | 4.500 | 0.237 | 0.06 | 0.03 | 0 | 0 | 1.20 | 11.04 | 0 | 17.66 |
| AU | STD | | | | | | | | | | |
| 3.5PIPE | 3.500 | 4.000 | 0.226 | 0.06 | 0.03 | 0 | 0 | 0 | 9.32 | 0 | 9.32 |
| AU | STD | | | | | | | | | | |
| 3PIPE | 3.000 | 3.500 | 0.216 | 0.06 | 0.03 | 0 | 0 | 1.20 | 7.75 | 0 | 11.60 |
| AU | STD | | | | | | | | | | |



## M A T E R I A L  D A T A  L I S T I N G

| Material Name | Pipe ID | Density lb/cu.ft | Pois. Ratio | Temper. deg F | Modulus E6 psi | Expans. in/100ft | Allow. psi |
|---|---|---|---|---|---|---|---|
| AU | 4PIPE | 501.0 | 0.30 | 40.0 | 28.42 | | 16700.0 |
| | | | | 180.0 | | 1.5442 | 16700.0 |
| AU | 3PIPE | 501.0 | 0.30 | 40.0 | 28.42 | | 16700.0 |
| | | | | 180.0 | | 1.5442 | 16700.0 |
| AU | 3.5PIPE | 501.0 | 0.30 | 40.0 | 28.42 | | 16700.0 |
| | | | | 180.0 | | 1.5442 | 16700.0 |

## FRAME POINT DATA LISTING

| POINT NAME | ---COORDINATE(ft )--- X | Y | Z | DATA TYPE | DESCRIPTION |
|---|---|---|---|---|---|
| A15 | 13.19 | -2.53 | 0.42 | | |
| 1 | 13.19 | -2.84 | -0.68 | | |
| B02 | 13.19 | -2.84 | -1.78 | | |
| 5 | 13.19 | 3.50 | -1.78 | ANCHOR | Translational stiffness lb/in<br>X= FREE Y= FREE Z= FREE<br>Rotational stiffness ft-lb/deg<br>X= RIGID Y= RIGID Z= RIGID<br>Thermal movements : None |
| 4 | 13.19 | 3.50 | -0.68 | | |
| 3 | 13.19 | 3.50 | 0.42 | | |
| 6 | 13.19 | -2.04 | -0.68 | WEIGHT | 1000 lb , No offsets |
| 2 | 13.19 | -2.84 | 0.42 | | |
| 7 | 13.19 | 2.08 | -0.68 | WEIGHT | 2250 lb , Offsets in ft<br>DX = 0.00, DY = 0.00, DZ = 0.03 |



## BEAM DATA LISTING

| BEAM ID | | POINT NAME | LENGTH (ft ) | SECTION ID/ MATERIAL ID | BETA ANGLE | RIGID END(ft) | RELEASE Ax | Y-Y | Z-Z |
|---|---|---|---|---|---|---|---|---|---|
| M2 | From | 2 | 1.10 | W4X13 | 0.00 | 0.00 | N | N | N |
| | To | 1 | | A36 | | 0.00 | N | N | N |
| M9 | From | 2 | 0.31 | W4X13 | 0.00 | 0.00 | N | N | N |
| | To | A15 | | A36 | | 0.00 | N | N | N |
| M1 | From | 1 | 1.10 | W4X13 | 0.00 | 0.00 | N | N | N |
| | To | B02 | | A36 | | 0.00 | N | N | N |
| M6 | From | 5 | 6.34 | W4X13 | 0.00 | 0.00 | N | N | N |
| | To | B02 | | A36 | | 0.00 | N | N | N |
| M3 | From | A15 | 6.03 | W4X13 | 0.00 | 0.00 | N | N | N |
| | To | 3 | | A36 | | 0.00 | N | N | N |
| M4 | From | 3 | 1.10 | W4X13 | 0.00 | 0.00 | N | N | N |
| | To | 4 | | A36 | | 0.00 | N | N | N |
| M5 | From | 4 | 1.10 | W4X13 | 0.00 | 0.00 | N | N | N |
| | To | 5 | | A36 | | 0.00 | N | N | N |
| M7 | From | 1 | 0.80 | XS12 | 0.00 | 0.00 | N | N | N |
| | To | 6 | | A36 | | 0.00 | N | N | N |
| M8 | From | 6 | 4.12 | XS12 | 0.00 | 0.00 | N | N | N |
| | To | 7 | | A36 | | 0.00 | N | N | N |
| M10 | From | 4 | 1.42 | XS12 | 0.00 | 0.00 | N | N | N |
| | To | 7 | | A36 | | 0.00 | N | N | N |

CROSS SECTION LISTING

| Section ID ID | Area(sq.in ) Axial | Y-Shear | Z-Shear | Inertia (in**4 ) Torsion | Y-Y Bend | Z-Z Bend |
|---|---|---|---|---|---|---|
| W4X13 | 3.83 | 1.16 | 1.86 | 0.2 | 3.9 | 11.3 |
| XS12 | 19.20 | 9.60 | 9.60 | 724.0 | 362.0 | 362.0 |



BEAM MATERIAL LISTING

| MATERIAL ID | Elastic modulus E6 psi | Poissons ratio | Yield Stress psi | Density lb/cu.ft | Expansion E-6 /F | Ultimate stress psi |
|---|---|---|---|---|---|---|
| A36 | 29.000 | 0.250 | 36000 | 490.00 | 6.50000 | 58000 |





KCN4P81NT

TEMPERATURE AND PRESSURE DATA

| POINT NAME | -----CASE 1------ PRESS. psi | TEMPER deg F | EXPAN. in/100ft | -----CASE 2------ PRESS. psi | TEMPER deg F | EXPAN. in/100ft | -----CASE 3------ PRESS. psi | TEMPER deg F | EXPAN. in/100ft |
|---|---|---|---|---|---|---|---|---|---|
| *** SEGMENT A | | | | | | | | | |
| A00 | 325 | 180 | 1.544 | | | | | | |
| A14 F | 325 | 180 | 1.544 | | | | | | |
| A15 | 325 | 180 | 1.544 | | | | | | |
| *** SEGMENT B | | | | | | | | | |
| B02 | 325 | 180 | 1.544 | | | | | | |
| B03 F | 325 | 180 | 1.544 | | | | | | |
| B07 | 325 | 180 | 1.544 | | | | | | |
| *** SEGMENT C | | | | | | | | | |
| 5 | 490 | 180 | 1.544 | | | | | | |
| C01 | 490 | 180 | 1.544 | | | | | | |
| *** SEGMENT D | | | | | | | | | |
| 3 | 490 | 180 | 1.544 | | | | | | |
| D01 | 490 | 180 | 1.544 | | | | | | |





A N A L Y S I S S U M M A R Y

Current model revision number : 24

Static - Date and Time of analysis ..... Jun 26, 1996 11:08 AM
Model Revision Number ..... 23 ***
Number of load cases ..... 2
Load cases analyzed ..... GR T1
Gaps/Friction/Yielding considered ..... No
Hanger design run ..... No
Cut short included ..... No
Weight of contents included ..... Yes
Pressure stiffening case ..... 0
Water elevation for buoyancy loads .... Not considered

Modal - Date and Time of analysis ..... Jun 26, 1996 11:09 AM
Model Revision Number ..... 24
Number of modes ..... 6
Cutoff frequency (Hz) ..... 33.0
Weight of contents included ..... Yes
Pressure stiffening case ..... 0
Water elevation for buoyancy loads .... Not considered

Response - Date and Time of analysis ..... Jun 26, 1996 11:09 AM
Model Revision Number ..... 24
Number of load cases ..... 3
Load cases analyzed ..... R1 R2 R3
Date and time of modal analysis ..... Jun 26, 1996 11:09 AM
Number of modes ..... 6
Cutoff frequency (Hz) ..... 33.0
Model revision of modal analysis ..... 24
Weight of contents included ..... Yes
Pressure stiffening case ..... 0
Water elevation for buoyancy loads .... Not considered

*** W A R N I N G

Current model revision does not match analysis

CODE COMPLIANCE COMBINATIONS

| Combination | Category | Method | Load | Factor | Allowable | Remarks |
|---|---|---|---|---|---|---|
| GR + Max P | Sustain | Sum | Gravity | 1.00 | Automatic | Default |
| | | | Max Long | 1.00 | | |
| Cold to T1 | Expansion | Sum | Thermal 1 | 1.00 | Automatic | Default |
| Sus. + R1 | Occasion | Abs sum | Response 1 | 1.00 | Automatic | Default |
| | | | Max Sus | 1.00 | | |
| Sus. + R2 | Occasion | Abs sum | Response 2 | 1.00 | Automatic | Default |
| | | | Max Sus | 1.00 | | |
| Sus. + R3 | Occasion | Abs sum | Response 3 | 1.00 | Automatic | Default |
| | | | Max Sus | 1.00 | | |
| Max P | Hoop | | Max Hoop | 1.00 | Automatic | Default |
| SRSS | Occasion | SRSS | Response 1 | 1.00 | Automatic | User |
| | | | Response 2 | 1.00 | | |
| | | | Response 3 | 1.00 | | |

OTHER USER COMBINATIONS

| Combination | Method | Load | Factor | Remarks |
|---|---|---|---|---|
| GR | Sum | Gravity | 1.00 | Default |
| T1 | Sum | Thermal 1 | 1.00 | Default |
| R1 | Sum | Response 1 | 1.00 | Default |
| R2 | Sum | Response 2 | 1.00 | Default |
| R3 | Sum | Response 3 | 1.00 | Default |
| GR+T1 | Sum | Gravity | 1.00 | User |
| | | Thermal 1 | 1.00 | |
| RESPONSE | SRSS | Response 1 | 1.00 | User |
| | | Response 2 | 1.00 | |
| | | Response 3 | 1.00 | |
| TOTAL | Abs sum | GR+T1 | 1.00 | User |
| | | RESPONSE | 1.00 | |

CODE COMPLIANCE





Y - Factor ..... 0.40
Weld efficiency factor ..... 1.00
Range reduction factor ..... 1.00
Design Pressure Factor ..... 1.00
Minimum stress ratio used in reports... 0.00
Include corrosion in stress calcs. .... Y
Include torsion in code stress ..... N
Include axial force in code stress .... N
Longitudinal pressure calculation ..... PD/4t
Include rigorous pressure ..... Not analyzed

RESPONSE SPECTRUM LOAD CASES :

Number of load cases analysed : 3

Load case 1 - R1

Missing mass : Yes
ZPA : No

Combination method : SRSS

X- Spectrum : SC1
Multiplier : 1.00

SC1

| Freq(Hz) | Grav( ) | Freq(Hz) | Grav( ) | Freq(Hz) | Grav( ) |
|---|---|---|---|---|---|
| 0.100 | 0.01 | 0.160 | 0.03 | 0.250 | 0.06 |
| 0.400 | 0.10 | 0.600 | 0.16 | 1.100 | 0.28 |
| 1.640 | 0.42 | 8.000 | 0.42 | 12.000 | 0.34 |
| 20.000 | 0.26 | 33.000 | 0.20 | 100.000 | 0.20 |



Load case 2 - R2

Missing mass : Yes
ZPA : No

Combination method : SRSS

Y- Spectrum : SC1
Multiplier : 1.00

SC1

| Freq(Hz) | Grav( ) | Freq(Hz) | Grav( ) | Freq(Hz) | Grav( ) |
|---|---|---|---|---|---|
| 0.100 | 0.01 | 0.160 | 0.03 | 0.250 | 0.06 |
| 0.400 | 0.10 | 0.600 | 0.16 | 1.100 | 0.28 |
| 1.640 | 0.42 | 8.000 | 0.42 | 12.000 | 0.34 |
| 20.000 | 0.26 | 33.000 | 0.20 | 100.000 | 0.20 |

Load case 3 - R3

Missing mass : Yes
ZPA : No

Combination method : SRSS

Z- Spectrum : SC1
Multiplier : 1.00

SC1

| Freq(Hz) | Grav( ) | Freq(Hz) | Grav( ) | Freq(Hz) | Grav( ) |
|---|---|---|---|---|---|
| 0.100 | 0.01 | 0.160 | 0.03 | 0.250 | 0.06 |
| 0.400 | 0.10 | 0.600 | 0.16 | 1.100 | 0.28 |
| 1.640 | 0.42 | 8.000 | 0.42 | 12.000 | 0.34 |
| 20.000 | 0.26 | 33.000 | 0.20 | 100.000 | 0.20 |





D I S P L A C E M E N T S

| Point name | Load combination | TRANSLATIONS (in ) X | Y | Z | ROTATIONS (deg ) X | Y | Z |
|---|---|---|---|---|---|---|---|
| *** Segment A begin *** | | | | | | | |
| A00 | GR | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | T1 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | GR+T1 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | RESPONSE | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | TOTAL | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| A01 | GR | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | -0.002 |
| | T1 | 0.003 | 0.000 | -0.002 | 0.000 | 0.000 | -0.001 |
| | GR+T1 | 0.003 | 0.000 | -0.002 | 0.000 | 0.000 | -0.002 |
| | RESPONSE | 0.000 | 0.000 | 0.000 | 0.001 | 0.002 | 0.001 |
| | TOTAL | 0.003 | 0.000 | 0.002 | 0.001 | 0.002 | 0.004 |
| A02 | GR | 0.000 | 0.000 | 0.000 | 0.153 | -0.015 | -0.124 |
| | T1 | 0.003 | 0.000 | -0.002 | 0.058 | 0.000 | -0.076 |
| | GR+T1 | 0.003 | -0.001 | -0.002 | 0.210 | -0.015 | -0.200 |
| | RESPONSE | 0.000 | 0.000 | 0.000 | 0.161 | 0.078 | 0.097 |
| | TOTAL | 0.004 | 0.001 | 0.002 | 0.371 | 0.093 | 0.297 |
| A03 N | GR | 0.000 | 0.000 | 0.000 | 0.153 | -0.015 | -0.124 |
| | T1 | 0.003 | 0.000 | -0.002 | 0.058 | 0.000 | -0.076 |
| | GR+T1 | 0.003 | -0.001 | -0.002 | 0.210 | -0.015 | -0.200 |
| | RESPONSE | 0.000 | 0.000 | 0.000 | 0.161 | 0.078 | 0.097 |
| | TOTAL | 0.004 | 0.001 | 0.002 | 0.371 | 0.093 | 0.297 |
| A03 M | GR | -0.002 | -0.003 | -0.002 | 0.151 | -0.015 | -0.128 |
| | T1 | 0.005 | -0.004 | -0.004 | 0.055 | -0.002 | -0.082 |
| | GR+T1 | 0.003 | -0.007 | -0.007 | 0.206 | -0.017 | -0.211 |
| | RESPONSE | 0.003 | 0.004 | 0.006 | 0.164 | 0.088 | 0.102 |
| | TOTAL | 0.006 | 0.010 | 0.013 | 0.370 | 0.105 | 0.313 |
| A03 F | GR | -0.009 | -0.004 | -0.010 | 0.154 | -0.014 | -0.132 |
| | T1 | 0.002 | -0.009 | -0.008 | 0.051 | -0.003 | -0.085 |
| | GR+T1 | -0.006 | -0.012 | -0.017 | 0.205 | -0.018 | -0.217 |
| | RESPONSE | 0.008 | 0.005 | 0.015 | 0.167 | 0.091 | 0.106 |
| | TOTAL | 0.014 | 0.018 | 0.032 | 0.373 | 0.108 | 0.323 |
| A04 N | GR | -0.027 | -0.004 | -0.031 | 0.156 | -0.015 | -0.134 |
| | T1 | -0.010 | -0.019 | -0.015 | 0.050 | -0.005 | -0.083 |
| | GR+T1 | -0.036 | -0.022 | -0.046 | 0.206 | -0.020 | -0.217 |
| | RESPONSE | 0.022 | 0.005 | 0.037 | 0.168 | 0.095 | 0.105 |
| | TOTAL | 0.058 | 0.028 | 0.083 | 0.373 | 0.115 | 0.321 |

D I S P L A C E M E N T S

| Point name | Load combination | TRANSLATIONS (in ) X | Y | Z | ROTATIONS (deg ) X | Y | Z |
|---|---|---|---|---|---|---|---|
| A04 M | GR | -0.037 | -0.008 | -0.042 | 0.159 | -0.014 | -0.142 |
| | T1 | -0.013 | -0.026 | -0.018 | 0.045 | -0.008 | -0.063 |
| | GR+T1 | -0.050 | -0.034 | -0.060 | 0.204 | -0.023 | -0.205 |
| | RESPONSE | 0.029 | 0.008 | 0.051 | 0.166 | 0.097 | 0.097 |
| | TOTAL | 0.079 | 0.042 | 0.111 | 0.370 | 0.119 | 0.302 |
| A04 F | GR | -0.041 | -0.019 | -0.046 | 0.161 | -0.014 | -0.147 |
| | T1 | -0.009 | -0.032 | -0.019 | 0.041 | -0.014 | -0.037 |
| | GR+T1 | -0.050 | -0.051 | -0.064 | 0.202 | -0.029 | -0.184 |
| | RESPONSE | 0.032 | 0.014 | 0.060 | 0.165 | 0.101 | 0.091 |
| | TOTAL | 0.083 | 0.065 | 0.124 | 0.367 | 0.130 | 0.275 |
| A05 N | GR | -0.041 | -0.139 | -0.032 | 0.175 | -0.013 | -0.093 |
| | T1 | 0.060 | -0.046 | 0.005 | 0.025 | -0.041 | 0.004 |
| | GR+T1 | 0.018 | -0.185 | -0.027 | 0.200 | -0.054 | -0.089 |
| | RESPONSE | 0.032 | 0.087 | 0.131 | 0.158 | 0.083 | 0.060 |
| | TOTAL | 0.051 | 0.272 | 0.158 | 0.358 | 0.137 | 0.150 |
| A05 M | GR | -0.042 | -0.150 | -0.032 | 0.165 | -0.011 | -0.052 |
| | T1 | 0.063 | -0.046 | 0.011 | 0.020 | -0.058 | 0.015 |
| | GR+T1 | 0.022 | -0.196 | -0.021 | 0.185 | -0.069 | -0.036 |
| | RESPONSE | 0.033 | 0.092 | 0.135 | 0.153 | 0.069 | 0.038 |
| | TOTAL | 0.055 | 0.288 | 0.155 | 0.338 | 0.138 | 0.075 |
| A05 F | GR | -0.042 | -0.163 | -0.031 | 0.155 | -0.010 | -0.033 |
| | T1 | 0.061 | -0.046 | 0.018 | 0.013 | -0.070 | 0.021 |
| | GR+T1 | 0.018 | -0.209 | -0.013 | 0.169 | -0.080 | -0.012 |
| | RESPONSE | 0.036 | 0.099 | 0.136 | 0.147 | 0.067 | 0.030 |
| | TOTAL | 0.055 | 0.308 | 0.149 | 0.316 | 0.147 | 0.043 |
| A06 N | GR | -0.045 | -0.196 | -0.031 | 0.154 | -0.011 | -0.001 |
| | T1 | 0.046 | -0.049 | 0.034 | 0.012 | -0.068 | 0.027 |
| | GR+T1 | 0.001 | -0.244 | 0.003 | 0.166 | -0.079 | 0.027 |
| | RESPONSE | 0.048 | 0.118 | 0.136 | 0.145 | 0.065 | 0.021 |
| | TOTAL | 0.049 | 0.363 | 0.138 | 0.311 | 0.144 | 0.048 |
| A06 M | GR | -0.046 | -0.206 | -0.031 | 0.137 | -0.016 | 0.020 |
| | T1 | 0.044 | -0.049 | 0.041 | 0.009 | -0.047 | 0.032 |
| | GR+T1 | -0.002 | -0.255 | 0.010 | 0.146 | -0.063 | 0.052 |
| | RESPONSE | 0.052 | 0.125 | 0.135 | 0.135 | 0.057 | 0.024 |
| | TOTAL | 0.053 | 0.380 | 0.145 | 0.281 | 0.120 | 0.077 |





D I S P L A C E M E N T S

| Point name | Load combination | TRANSLATIONS (in ) X | Y | Z | ROTATIONS (deg ) X | Y | Z |
|---|---|---|---|---|---|---|---|
| A06 F | GR | -0.046 | -0.207 | -0.029 | 0.122 | -0.023 | 0.068 |
| | T1 | 0.048 | -0.046 | 0.046 | 0.007 | -0.020 | 0.040 |
| | GR+T1 | 0.002 | -0.253 | 0.016 | 0.129 | -0.043 | 0.108 |
| | RESPONSE | 0.053 | 0.126 | 0.132 | 0.128 | 0.062 | 0.045 |
| | TOTAL | 0.055 | 0.380 | 0.149 | 0.257 | 0.105 | 0.153 |
| A07 | GR | -0.046 | -0.187 | -0.024 | 0.117 | -0.026 | 0.098 |
| | T1 | 0.066 | -0.036 | 0.049 | 0.007 | -0.006 | 0.044 |
| | GR+T1 | 0.019 | -0.224 | 0.025 | 0.124 | -0.032 | 0.142 |
| | RESPONSE | 0.053 | 0.114 | 0.118 | 0.123 | 0.073 | 0.061 |
| | TOTAL | 0.072 | 0.338 | 0.143 | 0.247 | 0.105 | 0.203 |
| A08 | GR | -0.046 | -0.166 | -0.018 | 0.113 | -0.028 | 0.124 |
| | T1 | 0.080 | -0.028 | 0.049 | 0.007 | 0.004 | 0.046 |
| | GR+T1 | 0.034 | -0.194 | 0.031 | 0.120 | -0.024 | 0.170 |
| | RESPONSE | 0.053 | 0.101 | 0.104 | 0.119 | 0.084 | 0.075 |
| | TOTAL | 0.086 | 0.295 | 0.135 | 0.239 | 0.108 | 0.245 |
| A09 | GR | -0.046 | -0.140 | -0.013 | 0.109 | -0.030 | 0.147 |
| | T1 | 0.094 | -0.019 | 0.047 | 0.007 | 0.013 | 0.047 |
| | GR+T1 | 0.048 | -0.158 | 0.035 | 0.116 | -0.017 | 0.194 |
| | RESPONSE | 0.053 | 0.086 | 0.088 | 0.115 | 0.095 | 0.088 |
| | TOTAL | 0.101 | 0.244 | 0.122 | 0.231 | 0.112 | 0.282 |
| A10 | GR | -0.046 | -0.044 | 0.005 | 0.097 | -0.034 | 0.186 |
| | T1 | 0.135 | 0.007 | 0.034 | 0.008 | 0.033 | 0.042 |
| | GR+T1 | 0.089 | -0.038 | 0.039 | 0.105 | -0.001 | 0.228 |
| | RESPONSE | 0.053 | 0.030 | 0.033 | 0.103 | 0.115 | 0.108 |
| | TOTAL | 0.142 | 0.068 | 0.072 | 0.208 | 0.116 | 0.335 |
| A11 N | GR | -0.046 | -0.017 | 0.010 | 0.094 | -0.035 | 0.186 |
| | T1 | 0.146 | 0.013 | 0.029 | 0.008 | 0.037 | 0.039 |
| | GR+T1 | 0.100 | -0.004 | 0.039 | 0.102 | 0.002 | 0.225 |
| | RESPONSE | 0.053 | 0.015 | 0.022 | 0.101 | 0.116 | 0.107 |
| | TOTAL | 0.153 | 0.019 | 0.061 | 0.202 | 0.118 | 0.332 |
| A11 M | GR | -0.042 | -0.008 | 0.010 | 0.091 | -0.038 | 0.176 |
| | T1 | 0.150 | 0.013 | 0.026 | 0.011 | 0.046 | 0.029 |
| | GR+T1 | 0.108 | 0.005 | 0.037 | 0.102 | 0.007 | 0.205 |
| | RESPONSE | 0.052 | 0.010 | 0.019 | 0.098 | 0.117 | 0.102 |
| | TOTAL | 0.159 | 0.015 | 0.056 | 0.200 | 0.124 | 0.307 |

D I S P L A C E M E N T S

| Point name | Load combination | TRANSLATIONS (in ) X | Y | Z | ROTATIONS (deg ) X | Y | Z |
|---|---|---|---|---|---|---|---|
| A11 F | GR | -0.034 | -0.004 | 0.007 | 0.085 | -0.040 | 0.160 |
| | T1 | 0.153 | 0.010 | 0.025 | 0.013 | 0.049 | 0.023 |
| | GR+T1 | 0.119 | 0.005 | 0.032 | 0.098 | 0.008 | 0.183 |
| | RESPONSE | 0.050 | 0.008 | 0.016 | 0.093 | 0.118 | 0.094 |
| | TOTAL | 0.169 | 0.014 | 0.048 | 0.191 | 0.126 | 0.277 |
| A12 | GR | -0.032 | -0.004 | 0.006 | 0.085 | -0.040 | 0.160 |
| | T1 | 0.153 | 0.009 | 0.025 | 0.013 | 0.049 | 0.023 |
| | GR+T1 | 0.121 | 0.004 | 0.030 | 0.098 | 0.008 | 0.182 |
| | RESPONSE | 0.049 | 0.008 | 0.015 | 0.092 | 0.118 | 0.094 |
| | TOTAL | 0.171 | 0.013 | 0.046 | 0.190 | 0.126 | 0.276 |
| A13 | GR | -0.031 | -0.004 | 0.005 | 0.046 | -0.096 | 0.058 |
| | T1 | 0.153 | 0.009 | 0.025 | 0.009 | 0.418 | 0.016 |
| | GR+T1 | 0.122 | 0.004 | 0.030 | 0.054 | 0.323 | 0.074 |
| | RESPONSE | 0.049 | 0.008 | 0.015 | 0.053 | 0.134 | 0.043 |
| | TOTAL | 0.172 | 0.013 | 0.045 | 0.107 | 0.457 | 0.117 |
| A14 N | GR | -0.030 | -0.004 | 0.004 | 0.045 | -0.096 | 0.057 |
| | T1 | 0.153 | 0.007 | 0.024 | 0.008 | 0.419 | 0.016 |
| | GR+T1 | 0.124 | 0.003 | 0.028 | 0.054 | 0.323 | 0.073 |
| | RESPONSE | 0.049 | 0.008 | 0.014 | 0.053 | 0.135 | 0.043 |
| | TOTAL | 0.173 | 0.011 | 0.043 | 0.106 | 0.458 | 0.116 |
| A14 M | GR | -0.023 | -0.003 | 0.001 | 0.037 | -0.092 | 0.041 |
| | T1 | 0.142 | 0.002 | 0.022 | 0.007 | 0.420 | 0.020 |
| | GR+T1 | 0.119 | -0.001 | 0.023 | 0.044 | 0.329 | 0.061 |
| | RESPONSE | 0.046 | 0.007 | 0.013 | 0.044 | 0.134 | 0.036 |
| | TOTAL | 0.164 | 0.008 | 0.036 | 0.087 | 0.462 | 0.097 |
| A14 F | GR | -0.015 | -0.001 | 0.000 | 0.018 | -0.087 | 0.033 |
| | T1 | 0.111 | 0.000 | 0.016 | 0.003 | 0.419 | 0.024 |
| | GR+T1 | 0.096 | -0.001 | 0.016 | 0.022 | 0.332 | 0.057 |
| | RESPONSE | 0.038 | 0.004 | 0.013 | 0.030 | 0.132 | 0.034 |
| | TOTAL | 0.134 | 0.005 | 0.029 | 0.052 | 0.464 | 0.091 |
| A14A | GR | -0.013 | 0.000 | 0.000 | 0.013 | -0.086 | 0.028 |
| | T1 | 0.097 | 0.000 | 0.013 | 0.003 | 0.418 | 0.027 |
| | GR+T1 | 0.085 | 0.000 | 0.013 | 0.016 | 0.331 | 0.055 |
| | RESPONSE | 0.034 | 0.003 | 0.013 | 0.027 | 0.132 | 0.032 |
| | TOTAL | 0.119 | 0.003 | 0.027 | 0.043 | 0.463 | 0.087 |





D I S P L A C E M E N T S

| Point name | Load combination | TRANSLATIONS (in ) X | Y | Z | ROTATIONS (deg ) X | Y | Z |
|---|---|---|---|---|---|---|---|
| A15 | GR | -0.001 | 0.000 | 0.000 | 0.000 | -0.084 | 0.008 |
| | T1 | 0.042 | 0.000 | 0.004 | -0.001 | 0.407 | 0.040 |
| | GR+T1 | 0.041 | 0.000 | 0.004 | -0.001 | 0.323 | 0.049 |
| | RESPONSE | 0.025 | 0.001 | 0.013 | 0.011 | 0.129 | 0.029 |
| | TOTAL | 0.065 | 0.001 | 0.017 | 0.012 | 0.452 | 0.078 |

*** Segment A end ***

*** Segment B begin ***

| Point name | Load combination | TRANSLATIONS (in ) X | Y | Z | ROTATIONS (deg ) X | Y | Z |
|---|---|---|---|---|---|---|---|
| B02 | GR | 0.000 | 0.000 | 0.000 | -0.001 | 0.000 | 0.000 |
| | T1 | 0.033 | 0.000 | 0.004 | 0.003 | 0.029 | 0.028 |
| | GR+T1 | 0.033 | 0.000 | 0.004 | 0.002 | 0.029 | 0.028 |
| | RESPONSE | 0.016 | 0.001 | 0.013 | 0.003 | 0.048 | 0.016 |
| | TOTAL | 0.049 | 0.001 | 0.017 | 0.005 | 0.077 | 0.044 |
| B03 N | GR | 0.000 | 0.000 | 0.000 | -0.001 | 0.000 | 0.000 |
| | T1 | 0.026 | 0.002 | -0.011 | 0.011 | 0.040 | 0.003 |
| | GR+T1 | 0.026 | 0.002 | -0.011 | 0.010 | 0.040 | 0.003 |
| | RESPONSE | 0.005 | 0.001 | 0.013 | 0.001 | 0.058 | 0.012 |
| | TOTAL | 0.031 | 0.003 | 0.024 | 0.012 | 0.098 | 0.015 |
| B03 M | GR | 0.000 | 0.000 | 0.000 | -0.001 | 0.000 | -0.001 |
| | T1 | 0.022 | 0.003 | -0.014 | 0.015 | 0.054 | -0.007 |
| | GR+T1 | 0.022 | 0.002 | -0.014 | 0.015 | 0.054 | -0.008 |
| | RESPONSE | 0.002 | 0.001 | 0.012 | 0.004 | 0.053 | 0.009 |
| | TOTAL | 0.024 | 0.003 | 0.026 | 0.018 | 0.107 | 0.017 |
| B03 F | GR | 0.000 | 0.000 | 0.000 | -0.001 | 0.000 | -0.001 |
| | T1 | 0.016 | 0.004 | -0.012 | 0.017 | 0.066 | -0.024 |
| | GR+T1 | 0.017 | 0.004 | -0.012 | 0.017 | 0.065 | -0.025 |
| | RESPONSE | 0.001 | 0.001 | 0.010 | 0.007 | 0.049 | 0.004 |
| | TOTAL | 0.018 | 0.004 | 0.021 | 0.024 | 0.115 | 0.029 |
| B04 N | GR | 0.000 | 0.000 | 0.000 | -0.001 | 0.000 | -0.001 |
| | T1 | 0.007 | 0.007 | -0.004 | 0.015 | 0.067 | -0.026 |
| | GR+T1 | 0.007 | 0.007 | -0.004 | 0.015 | 0.067 | -0.027 |
| | RESPONSE | 0.001 | 0.000 | 0.004 | 0.008 | 0.049 | 0.003 |
| | TOTAL | 0.008 | 0.008 | 0.007 | 0.023 | 0.116 | 0.030 |
| B04 M | GR | 0.000 | 0.000 | 0.000 | -0.001 | 0.000 | -0.002 |
| | T1 | 0.003 | 0.007 | -0.001 | 0.014 | 0.068 | -0.026 |
| | GR+T1 | 0.003 | 0.007 | -0.001 | 0.013 | 0.068 | -0.027 |
| | RESPONSE | 0.001 | 0.000 | 0.001 | 0.010 | 0.049 | 0.008 |
| | TOTAL | 0.004 | 0.007 | 0.002 | 0.023 | 0.117 | 0.035 |

D I S P L A C E M E N T S

| Point name | Load combination | TRANSLATIONS (in ) X | Y | Z | ROTATIONS (deg ) X | Y | Z |
|---|---|---|---|---|---|---|---|
| B04 F | GR | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | -0.001 |
| | T1 | 0.000 | 0.004 | 0.000 | 0.011 | 0.069 | -0.023 |
| | GR+T1 | 0.000 | 0.004 | 0.000 | 0.011 | 0.069 | -0.024 |
| | RESPONSE | 0.000 | 0.000 | 0.000 | 0.011 | 0.048 | 0.011 |
| | TOTAL | 0.001 | 0.004 | 0.000 | 0.021 | 0.117 | 0.035 |
| B05 | GR | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | -0.001 |
| | T1 | 0.000 | 0.003 | 0.000 | 0.011 | 0.069 | -0.022 |
| | GR+T1 | 0.000 | 0.003 | 0.000 | 0.011 | 0.068 | -0.024 |
| | RESPONSE | 0.000 | 0.000 | 0.000 | 0.011 | 0.048 | 0.011 |
| | TOTAL | 0.000 | 0.003 | 0.000 | 0.021 | 0.117 | 0.035 |
| B06 | GR | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | T1 | 0.000 | 0.003 | 0.000 | 0.000 | 0.000 | 0.000 |
| | GR+T1 | 0.000 | 0.003 | 0.000 | 0.000 | 0.000 | 0.000 |
| | RESPONSE | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | TOTAL | 0.000 | 0.003 | 0.000 | 0.000 | 0.000 | 0.001 |
| B07 | GR | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | T1 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | GR+T1 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | RESPONSE | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | TOTAL | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |

*** Segment B end ***

*** Segment C begin ***

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 5 | GR | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | T1 | 0.000 | 0.000 | 0.003 | 0.000 | 0.000 | 0.000 |
| | GR+T1 | 0.000 | 0.000 | 0.003 | 0.000 | 0.000 | 0.000 |
| | RESPONSE | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | TOTAL | 0.000 | 0.000 | 0.003 | 0.000 | 0.000 | 0.000 |
| C01 | GR | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | T1 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | GR+T1 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | RESPONSE | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | TOTAL | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |

*** Segment C end ***

** Segment D begin ***





D I S P L A C E M E N T S

| Point name | Load combination | TRANSLATIONS (in ) X | Y | Z | ROTATIONS (deg ) X | Y | Z |
|---|---|---|---|---|---|---|---|
| 3 | GR | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | T1 | 0.000 | 0.000 | -0.003 | 0.000 | 0.000 | 0.000 |
| | GR+T1 | 0.000 | 0.000 | -0.003 | 0.000 | 0.000 | 0.000 |
| | RESPONSE | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | TOTAL | 0.000 | 0.000 | 0.003 | 0.000 | 0.000 | 0.000 |
| D01 | GR | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | T1 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | GR+T1 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | RESPONSE | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | TOTAL | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |

*** Segment D end ***

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| A15 | GR | -0.001 | 0.000 | 0.000 | 0.000 | -0.084 | 0.008 |
| | T1 | 0.042 | 0.000 | 0.004 | -0.001 | 0.407 | 0.040 |
| | GR+T1 | 0.041 | 0.000 | 0.004 | -0.001 | 0.323 | 0.049 |
| | RESPONSE | 0.025 | 0.001 | 0.013 | 0.011 | 0.129 | 0.029 |
| | TOTAL | 0.065 | 0.001 | 0.017 | 0.012 | 0.452 | 0.078 |
| 1 | GR | 0.000 | 0.000 | 0.000 | 0.000 | -0.001 | 0.000 |
| | T1 | 0.038 | 0.000 | 0.004 | -0.002 | 0.013 | 0.029 |
| | GR+T1 | 0.038 | 0.000 | 0.004 | -0.003 | 0.012 | 0.029 |
| | RESPONSE | 0.024 | 0.000 | 0.013 | 0.009 | 0.012 | 0.017 |
| | TOTAL | 0.062 | 0.000 | 0.017 | 0.011 | 0.025 | 0.046 |
| B02 | GR | 0.000 | 0.000 | 0.000 | -0.001 | 0.000 | 0.000 |
| | T1 | 0.033 | 0.000 | 0.004 | 0.003 | 0.029 | 0.028 |
| | GR+T1 | 0.033 | 0.000 | 0.004 | 0.002 | 0.029 | 0.028 |
| | RESPONSE | 0.016 | 0.001 | 0.013 | 0.003 | 0.048 | 0.016 |
| | TOTAL | 0.049 | 0.001 | 0.017 | 0.005 | 0.077 | 0.044 |
| 5 | GR | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | T1 | 0.000 | 0.000 | 0.003 | 0.000 | 0.000 | 0.000 |
| | GR+T1 | 0.000 | 0.000 | 0.003 | 0.000 | 0.000 | 0.000 |
| | RESPONSE | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | TOTAL | 0.000 | 0.000 | 0.003 | 0.000 | 0.000 | 0.000 |
| 4 | GR | 0.000 | 0.000 | 0.000 | 0.000 | -0.001 | 0.000 |
| | T1 | 0.000 | 0.000 | 0.000 | -0.002 | 0.009 | 0.029 |
| | GR+T1 | 0.000 | 0.000 | 0.000 | -0.002 | 0.008 | 0.029 |
| | RESPONSE | 0.000 | 0.000 | 0.000 | 0.009 | 0.008 | 0.018 |
| | TOTAL | 0.000 | 0.001 | 0.000 | 0.011 | 0.017 | 0.047 |

## D I S P L A C E M E N T S

| Point name | Load combination | TRANSLATIONS (in ) X | Y | Z | ROTATIONS (deg ) X | Y | Z |
|---|---|---|---|---|---|---|---|
| 3 | GR | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | T1 | 0.000 | 0.000 | -0.003 | 0.000 | 0.000 | 0.000 |
| | GR+T1 | 0.000 | 0.000 | -0.003 | 0.000 | 0.000 | 0.000 |
| | RESPONSE | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | TOTAL | 0.000 | 0.000 | 0.003 | 0.000 | 0.000 | 0.000 |
| 6 | GR | 0.000 | 0.000 | 0.000 | 0.000 | -0.001 | 0.000 |
| | T1 | 0.033 | 0.000 | 0.003 | -0.003 | 0.013 | 0.029 |
| | GR+T1 | 0.033 | 0.000 | 0.003 | -0.003 | 0.012 | 0.029 |
| | RESPONSE | 0.021 | 0.001 | 0.012 | 0.009 | 0.012 | 0.017 |
| | TOTAL | 0.054 | 0.001 | 0.015 | 0.012 | 0.024 | 0.046 |
| 2 | GR | -0.001 | 0.000 | 0.000 | -0.001 | -0.005 | 0.008 |
| | T1 | 0.044 | 0.000 | 0.004 | -0.001 | 0.039 | 0.040 |
| | GR+T1 | 0.044 | 0.000 | 0.004 | -0.001 | 0.034 | 0.049 |
| | RESPONSE | 0.026 | 0.001 | 0.013 | 0.005 | 0.016 | 0.029 |
| | TOTAL | 0.070 | 0.001 | 0.017 | 0.007 | 0.051 | 0.077 |
| 7 | GR | 0.000 | 0.000 | 0.000 | 0.000 | -0.001 | 0.000 |
| | T1 | 0.009 | 0.000 | 0.001 | -0.003 | 0.010 | 0.029 |
| | GR+T1 | 0.009 | 0.000 | 0.001 | -0.003 | 0.009 | 0.029 |
| | RESPONSE | 0.006 | 0.001 | 0.003 | 0.010 | 0.009 | 0.018 |
| | TOTAL | 0.014 | 0.001 | 0.004 | 0.013 | 0.019 | 0.047 |





## S U P P O R T F O R C E S

| Point/ Supp. ID | Connect/ Type | Load Combination | LOCAL Dirn | LOCAL Force | LOCAL Deform | GLOBAL Dirn | GLOBAL Force | GLOBAL Deform |
|---|---|---|---|---|---|---|---|---|

*** End of system , no supports encountered. ***

## RESTRAINT REACTIONS

| Point name | Load combination | FORCES (lb ) X | Y | Z | Result | MOMENTS (ft-lb ) X | Y | Z | Result |
|---|---|---|---|---|---|---|---|---|---|
| A00 | Anchor | | | | | | | | |
| | GR | 57 | -358 | 9 | 362 | -28 | -39 | -186 | 193 |
| | T1 | -290 | 37 | -32 | 294 | -11 | 41 | -80 | 91 |
| | GR+T1 | -233 | -321 | -23 | 397 | -39 | 2 | -266 | 269 |
| | RESPONSE | 295 | 128 | 132 | 347 | 79 | 196 | 129 | 248 |
| | TOTAL | 528 | 449 | 155 | 710 | 118 | 198 | 395 | 458 |
| B07 | Anchor | | | | | | | | |
| | GR | 5 | -167 | 2 | 167 | -1 | 0 | -4 | 4 |
| | T1 | 8 | -197 | -103 | 222 | 1 | 21 | -48 | 52 |
| | GR+T1 | 13 | -363 | -102 | 378 | 1 | 21 | -52 | 56 |
| | RESPONSE | 326 | 86 | 169 | 377 | 56 | 15 | 90 | 107 |
| | TOTAL | 339 | 450 | 270 | 625 | 56 | 35 | 142 | 156 |
| 5 | Anchor | | | | | | | | |
| | GR | 0 | 0 | 0 | 0 | 50 | 4 | 2 | 50 |
| | T1 | 0 | 0 | 0 | 0 | -4 | -72 | 284 | 293 |
| | GR+T1 | 0 | 0 | 0 | 0 | 46 | -69 | 286 | 298 |
| | RESPONSE | 0 | 0 | 0 | 0 | 94 | 60 | 123 | 166 |
| | TOTAL | 0 | 0 | 0 | 0 | 140 | 129 | 409 | 451 |
| C01 | Anchor | | | | | | | | |
| | GR | 22 | -231 | -6 | 232 | 29 | 3 | 0 | 29 |
| | T1 | -279 | -14 | -24319 | 24321 | 2 | -35 | 0 | 35 |
| | GR+T1 | -257 | -245 | -24325 | 24328 | 31 | -32 | 0 | 44 |
| | RESPONSE | 281 | 1062 | 314 | 1142 | 133 | 35 | 0 | 137 |
| | TOTAL | 538 | 1307 | 24639 | 24680 | 163 | 67 | 0 | 177 |
| 3 | Anchor | | | | | | | | |
| | GR | 0 | 0 | 0 | 0 | -80 | 13 | -134 | 156 |
| | T1 | 0 | 0 | 0 | 0 | -41 | -167 | 748 | 767 |
| | GR+T1 | 0 | 0 | 0 | 0 | -121 | -155 | 614 | 645 |
| | RESPONSE | 0 | 0 | 0 | 0 | 200 | 240 | 397 | 506 |
| | TOTAL | 0 | 0 | 0 | 0 | 321 | 395 | 1011 | 1132 |
| D01 | Anchor | | | | | | | | |
| | GR | -84 | 154 | -5 | 175 | 19 | 10 | 0 | 22 |
| | T1 | 561 | 262 | 24455 | 24463 | 33 | -70 | 0 | 77 |
| | GR+T1 | 477 | 416 | 24450 | 24458 | 52 | -60 | 0 | 79 |
| | RESPONSE | 560 | 1180 | 316 | 1344 | 148 | 70 | 0 | 163 |
| | TOTAL | 1037 | 1596 | 24766 | 24839 | 200 | 130 | 0 | 238 |



## RESTRAINT REACTIONS

| Point name | Load combination | FORCES (lb ) X | Y | Z | Result | MOMENTS (ft-lb ) X | Y | Z | Result |
|---|---|---|---|---|---|---|---|---|---|
| 5 | Anchor | | | | | | | | |
| | GR | 0 | 0 | 0 | 0 | 50 | 4 | 2 | 50 |
| | T1 | 0 | 0 | 0 | 0 | -4 | -72 | 284 | 293 |
| | GR+T1 | 0 | 0 | 0 | 0 | 46 | -69 | 286 | 298 |
| | RESPONSE | 0 | 0 | 0 | 0 | 94 | 60 | 123 | 166 |
| | TOTAL | 0 | 0 | 0 | 0 | 140 | 129 | 409 | 451 |

## G L O B A L F O R C E S & M O M E N T S

| Point name | Load combination | FORCES (lb ) X | Y | Z | Result | MOMENTS (ft-lb ) X | Y | Z | Result |
|---|---|---|---|---|---|---|---|---|---|
| *** Segment A begin *** | | | | | | | | | |
| A00 | GR | -57 | 358 | -9 | 362 | 28 | 39 | 186 | 193 |
| | T1 | 290 | -37 | 32 | 294 | 11 | -41 | 80 | 91 |
| | GR+T1 | 233 | 321 | 23 | 397 | 39 | -2 | 266 | 269 |
| | RESPONSE | 295 | 128 | 131 | 347 | 79 | 196 | 129 | 248 |
| | TOTAL | 528 | 448 | 155 | 710 | 118 | 198 | 395 | 458 |
| A01 | GR | -57 | 209 | -9 | 217 | -11 | 31 | 108 | 113 |
| | T1 | 290 | -37 | 32 | 294 | 15 | -2 | 88 | 89 |
| | GR+T1 | 233 | 172 | 23 | 291 | 4 | 29 | 196 | 198 |
| | RESPONSE | 290 | 115 | 121 | 335 | 75 | 161 | 118 | 213 |
| | TOTAL | 523 | 288 | 145 | 614 | 80 | 190 | 314 | 376 |
| A02 | GR | -57 | 209 | -9 | 217 | -16 | 29 | 97 | 103 |
| | T1 | 290 | -37 | 32 | 294 | 16 | 5 | 90 | 91 |
| | GR+T1 | 233 | 172 | 23 | 291 | -1 | 34 | 186 | 190 |
| | RESPONSE | 287 | 109 | 117 | 329 | 75 | 155 | 117 | 208 |
| | TOTAL | 520 | 281 | 140 | 608 | 76 | 190 | 303 | 366 |
| A03 N | GR | -57 | 209 | -9 | 217 | -17 | 29 | 97 | 102 |
| | T1 | 290 | -37 | 32 | 294 | 16 | 5 | 90 | 91 |
| | GR+T1 | 233 | 172 | 23 | 291 | -1 | 35 | 186 | 189 |
| | RESPONSE | 287 | 109 | 117 | 329 | 75 | 155 | 117 | 208 |
| | TOTAL | 520 | 281 | 140 | 608 | 76 | 190 | 303 | 365 |
| A03 M | GR | -57 | 205 | -9 | 212 | -39 | 21 | 58 | 74 |
| | T1 | 290 | -37 | 32 | 294 | 23 | 43 | 69 | 84 |
| | GR+T1 | 233 | 168 | 23 | 288 | -17 | 64 | 128 | 144 |
| | RESPONSE | 287 | 108 | 117 | 328 | 68 | 133 | 96 | 177 |
| | TOTAL | 520 | 276 | 140 | 605 | 85 | 197 | 223 | 309 |
| A03 F | GR | -57 | 200 | -9 | 208 | -50 | 18 | 54 | 76 |
| | T1 | 290 | -37 | 32 | 294 | 32 | 58 | 4 | 67 |
| | GR+T1 | 233 | 163 | 23 | 286 | -18 | 76 | 58 | 98 |
| | RESPONSE | 287 | 108 | 116 | 327 | 62 | 128 | 76 | 161 |
| | TOTAL | 520 | 271 | 139 | 602 | 80 | 204 | 134 | 257 |
| A04 N | GR | -57 | 188 | -9 | 197 | -56 | 18 | 91 | 109 |
| | T1 | 290 | -37 | 32 | 294 | 53 | 58 | -186 | 202 |
| | GR+T1 | 233 | 151 | 23 | 279 | -3 | 76 | -95 | 122 |
| | RESPONSE | 285 | 108 | 114 | 325 | 96 | 128 | 213 | 266 |
| | TOTAL | 518 | 259 | 137 | 595 | 99 | 204 | 308 | 383 |

U9





## G L O B A L F O R C E S & M O M E N T S

| Point name | Load combination | FORCES (lb ) X | Y | Z | Result | MOMENTS (ft-lb ) X | Y | Z | Result |
|---|---|---|---|---|---|---|---|---|---|
| A04 M | GR | -57 | 181 | -9 | 190 | -60 | 17 | 84 | 105 |
| | T1 | 290 | -37 | 32 | 294 | 65 | 63 | -283 | 297 |
| | GR+T1 | 233 | 145 | 23 | 275 | 5 | 80 | -199 | 215 |
| | RESPONSE | 284 | 107 | 111 | 323 | 129 | 118 | 298 | 346 |
| | TOTAL | 517 | 252 | 135 | 591 | 135 | 197 | 498 | 552 |
| A04 F | GR | -57 | 174 | -9 | 184 | -61 | 14 | 30 | 69 |
| | T1 | 290 | -37 | 32 | 294 | 70 | 74 | -313 | 329 |
| | GR+T1 | 233 | 138 | 23 | 272 | 9 | 88 | -283 | 297 |
| | RESPONSE | 276 | 104 | 100 | 312 | 144 | 101 | 314 | 360 |
| | TOTAL | 509 | 242 | 123 | 577 | 153 | 189 | 598 | 645 |
| A05 N | GR | -57 | 96 | -9 | 112 | -61 | -27 | -573 | 577 |
| | T1 | 290 | -37 | 32 | 294 | 70 | 219 | -148 | 273 |
| | GR+T1 | 233 | 59 | 23 | 242 | 9 | 192 | -721 | 746 |
| | RESPONSE | 268 | 83 | 73 | 290 | 144 | 417 | 354 | 565 |
| | TOTAL | 502 | 141 | 96 | 530 | 153 | 609 | 1075 | 1245 |
| A05 M | GR | -57 | 89 | -9 | 106 | -48 | -22 | -605 | 608 |
| | T1 | 290 | -37 | 32 | 294 | 64 | 188 | -135 | 240 |
| | GR+T1 | 233 | 52 | 23 | 240 | 17 | 166 | -741 | 759 |
| | RESPONSE | 267 | 80 | 68 | 287 | 135 | 417 | 371 | 574 |
| | TOTAL | 500 | 132 | 92 | 526 | 152 | 583 | 1112 | 1265 |
| A05 F | GR | -57 | 82 | -9 | 100 | -17 | -3 | -618 | 618 |
| | T1 | 290 | -37 | 32 | 294 | 51 | 90 | -130 | 166 |
| | GR+T1 | 233 | 45 | 23 | 239 | 34 | 87 | -748 | 754 |
| | RESPONSE | 264 | 77 | 61 | 282 | 117 | 377 | 378 | 547 |
| | TOTAL | 498 | 122 | 84 | 519 | 151 | 464 | 1126 | 1227 |
| A06 N | GR | -57 | 64 | -9 | 86 | 56 | 54 | -618 | 623 |
| | T1 | 290 | -37 | 32 | 294 | 14 | -200 | -130 | 239 |
| | GR+T1 | 233 | 27 | 23 | 236 | 70 | -146 | -748 | 765 |
| | RESPONSE | 260 | 70 | 54 | 274 | 98 | 354 | 378 | 527 |
| | TOTAL | 493 | 98 | 78 | 508 | 168 | 500 | 1126 | 1244 |
| A06 M | GR | -57 | 57 | -9 | 81 | 77 | 72 | -627 | 636 |
| | T1 | 290 | -37 | 32 | 294 | 1 | -297 | -124 | 322 |
| | GR+T1 | 233 | 20 | 23 | 235 | 78 | -225 | -751 | 788 |
| | RESPONSE | 257 | 66 | 51 | 270 | 104 | 392 | 383 | 558 |
| | TOTAL | 490 | 86 | 74 | 503 | 182 | 617 | 1134 | 1304 |

## G L O B A L F O R C E S & M O M E N T S

| Point name | Load combination | FORCES (lb ) X | Y | Z | Result | MOMENTS (ft-lb ) X | Y | Z | Result |
|---|---|---|---|---|---|---|---|---|---|
| A06 F | GR | -57 | 50 | -9 | 76 | 85 | 77 | -646 | 656 |
| | T1 | 290 | -37 | 32 | 294 | -4 | -328 | -111 | 347 |
| | GR+T1 | 233 | 13 | 23 | 235 | 81 | -251 | -757 | 802 |
| | RESPONSE | 250 | 58 | 45 | 261 | 107 | 414 | 393 | 581 |
| | TOTAL | 484 | 71 | 68 | 494 | 188 | 665 | 1150 | 1342 |
| A07 - | GR | -57 | 30 | -9 | 65 | 85 | 67 | -691 | 700 |
| | T1 | 290 | -37 | 32 | 294 | -4 | -292 | -70 | 300 |
| | GR+T1 | 233 | -7 | 23 | 235 | 81 | -225 | -761 | 798 |
| | RESPONSE | 250 | 58 | 45 | 261 | 107 | 419 | 420 | 603 |
| | TOTAL | 484 | 65 | 68 | 493 | 188 | 644 | 1181 | 1358 |
| A07 + | GR | -57 | 7 | -9 | 58 | 85 | 67 | -691 | 700 |
| | T1 | 290 | -37 | 32 | 294 | -4 | -292 | -70 | 300 |
| | GR+T1 | 233 | -30 | 23 | 236 | 81 | -225 | -761 | 798 |
| | RESPONSE | 232 | 42 | 38 | 239 | 107 | 419 | 420 | 603 |
| | TOTAL | 465 | 71 | 61 | 475 | 188 | 644 | 1181 | 1358 |
| A08 - | GR | -57 | -9 | -9 | 58 | 85 | 59 | -691 | 698 |
| | T1 | 290 | -37 | 32 | 294 | -4 | -262 | -36 | 264 |
| | GR+T1 | 233 | -46 | 23 | 239 | 81 | -203 | -726 | 758 |
| | RESPONSE | 232 | 42 | 38 | 239 | 107 | 407 | 420 | 595 |
| | TOTAL | 465 | 88 | 61 | 477 | 188 | 610 | 1146 | 1312 |
| A08 + | GR | -57 | -114 | -9 | 128 | 85 | 59 | -691 | 698 |
| | T1 | 290 | -37 | 32 | 294 | -4 | -262 | -36 | 264 |
| | GR+T1 | 233 | -151 | 23 | 279 | 81 | -203 | -726 | 758 |
| | RESPONSE | 179 | 83 | 76 | 212 | 107 | 407 | 420 | 595 |
| | TOTAL | 412 | 234 | 100 | 484 | 188 | 610 | 1146 | 1312 |
| A09 - | GR | -57 | -130 | -9 | 142 | 85 | 50 | -578 | 587 |
| | T1 | 290 | -37 | 32 | 294 | -4 | -232 | -2 | 232 |
| | GR+T1 | 233 | -167 | 23 | 288 | 81 | -182 | -580 | 613 |
| | RESPONSE | 179 | 83 | 76 | 212 | 107 | 339 | 347 | 497 |
| | TOTAL | 412 | 250 | 100 | 492 | 188 | 520 | 927 | 1080 |
| A09 + | GR | -57 | -147 | -9 | 158 | 85 | 50 | -578 | 587 |
| | T1 | 290 | -37 | 32 | 294 | -4 | -232 | -2 | 232 |
| | GR+T1 | 233 | -184 | 23 | 298 | 81 | -182 | -580 | 613 |
| | RESPONSE | 158 | 109 | 97 | 216 | 107 | 339 | 347 | 497 |
| | TOTAL | 392 | 294 | 120 | 504 | 188 | 520 | 927 | 1080 |





## G L O B A L F O R C E S & M O M E N T S

| Point name | Load combination | FORCES (lb ) X | Y | Z | Result | MOMENTS (ft-lb ) X | Y | Z | Result |
|---|---|---|---|---|---|---|---|---|---|
| A10 - | GR | -57 | -194 | -9 | 202 | 85 | 26 | -124 | 153 |
| | T1 | 290 | -37 | 32 | 294 | -4 | -146 | 96 | 175 |
| | GR+T1 | 233 | -231 | 23 | 329 | 81 | -120 | -28 | 147 |
| | RESPONSE | 158 | 109 | 97 | 216 | 107 | 92 | 88 | 166 |
| | TOTAL | 392 | 340 | 120 | 533 | 188 | 211 | 116 | 306 |
| A10 + | GR | -57 | -291 | -9 | 297 | 85 | 26 | -124 | 153 |
| | T1 | 290 | -37 | 32 | 294 | -4 | -146 | 96 | 175 |
| | GR+T1 | 233 | -328 | 23 | 403 | 81 | -120 | -28 | 147 |
| | RESPONSE | 108 | 136 | 124 | 213 | 107 | 92 | 88 | 166 |
| | TOTAL | 342 | 464 | 147 | 595 | 188 | 211 | 116 | 306 |
| A11 N | GR | -57 | -304 | -9 | 309 | 85 | 20 | 86 | 122 |
| | T1 | 290 | -37 | 32 | 294 | -4 | -123 | 123 | 174 |
| | GR+T1 | 233 | -341 | 23 | 413 | 81 | -103 | 208 | 246 |
| | RESPONSE | 105 | 137 | 125 | 214 | 107 | 30 | 78 | 136 |
| | TOTAL | 339 | 478 | 148 | 604 | 188 | 133 | 287 | 368 |
| A11 M | GR | -57 | -308 | -9 | 314 | 84 | 18 | 163 | 185 |
| | T1 | 290 | -37 | 32 | 294 | -1 | -115 | 103 | 155 |
| | GR+T1 | 233 | -345 | 23 | 417 | 83 | -98 | 266 | 296 |
| | RESPONSE | 104 | 138 | 126 | 213 | 101 | 42 | 99 | 148 |
| | TOTAL | 337 | 483 | 149 | 607 | 185 | 140 | 365 | 432 |
| A11 F | GR | -57 | -313 | -9 | 318 | 82 | 17 | 207 | 223 |
| | T1 | 290 | -37 | 32 | 294 | 7 | -112 | 38 | 119 |
| | GR+T1 | 233 | -350 | 23 | 421 | 89 | -96 | 245 | 278 |
| | RESPONSE | 103 | 138 | 126 | 213 | 93 | 51 | 115 | 156 |
| | TOTAL | 336 | 488 | 149 | 611 | 181 | 147 | 360 | 429 |
| A12 | GR | -57 | -458 | -9 | 462 | 82 | 17 | 211 | 227 |
| | T1 | 290 | -37 | 32 | 294 | 9 | -112 | 19 | 114 |
| | GR+T1 | 233 | -495 | 23 | 548 | 90 | -96 | 230 | 265 |
| | RESPONSE | 63 | 154 | 148 | 223 | 92 | 51 | 117 | 157 |
| | TOTAL | 296 | 649 | 172 | 733 | 182 | 147 | 347 | 418 |
| A13 | GR | -57 | -458 | -9 | 462 | 81 | 17 | 213 | 229 |
| | T1 | 290 | -37 | 32 | 294 | 10 | -112 | 7 | 113 |
| | GR+T1 | 233 | -495 | 23 | 548 | 91 | -96 | 220 | 257 |
| | RESPONSE | 92 | 176 | 178 | 267 | 92 | 51 | 119 | 159 |
| | TOTAL | 325 | 671 | 201 | 772 | 183 | 147 | 339 | 412 |

## G L O B A L F O R C E S & M O M E N T S

| Point name | Load combination | FORCES (lb ) X | Y | Z | Result | MOMENTS (ft-lb ) X | Y | Z | Result |
|---|---|---|---|---|---|---|---|---|---|
| A14 N | GR | -57 | -460 | -9 | 463 | 80 | 17 | 219 | 234 |
| | T1 | 290 | -37 | 32 | 294 | 13 | -112 | -22 | 115 |
| | GR+T1 | 233 | -497 | 23 | 549 | 93 | -96 | 197 | 238 |
| | RESPONSE | 94 | 176 | 179 | 268 | 95 | 51 | 124 | 164 |
| | TOTAL | 327 | 673 | 202 | 775 | 189 | 147 | 321 | 400 |
| A14 M | GR | -57 | -467 | -9 | 470 | 145 | 9 | 239 | 279 |
| | T1 | 290 | -37 | 32 | 294 | 30 | -70 | -124 | 146 |
| | GR+T1 | 233 | -504 | 23 | 556 | 175 | -61 | 115 | 218 |
| | RESPONSE | 96 | 177 | 180 | 270 | 143 | 40 | 144 | 207 |
| | TOTAL | 329 | 681 | 204 | 783 | 318 | 101 | 258 | 422 |
| A14 F | GR | -57 | -474 | -9 | 477 | 310 | -12 | 247 | 397 |
| | T1 | 290 | -37 | 32 | 294 | 48 | 33 | -167 | 176 |
| | GR+T1 | 233 | -511 | 23 | 562 | 358 | 21 | 80 | 367 |
| | RESPONSE | 97 | 178 | 181 | 272 | 204 | 23 | 154 | 256 |
| | TOTAL | 330 | 688 | 204 | 790 | 562 | 44 | 234 | 610 |
| A14A | GR | -57 | 549 | -9 | 552 | 386 | -21 | 247 | 459 |
| | T1 | 290 | -2 | 32 | 292 | 54 | 79 | -167 | 192 |
| | GR+T1 | 233 | 546 | 23 | 594 | 440 | 58 | 80 | 451 |
| | RESPONSE | 98 | 178 | 182 | 273 | 226 | 29 | 154 | 275 |
| | TOTAL | 331 | 725 | 205 | 823 | 666 | 87 | 234 | 711 |
| A15 | GR | -57 | 541 | -9 | 544 | 37 | -57 | 247 | 256 |
| | T1 | 290 | -2 | 32 | 292 | 55 | 265 | -167 | 317 |
| | GR+T1 | 233 | 539 | 23 | 588 | 93 | 208 | 80 | 241 |
| | RESPONSE | 98 | 178 | 182 | 273 | 326 | 83 | 154 | 370 |
| | TOTAL | 331 | 717 | 205 | 816 | 419 | 291 | 234 | 561 |

*** Segment A end ***

*** Segment B begin ***

| Point name | Load combination | X | Y | Z | Result | X | Y | Z | Result |
|---|---|---|---|---|---|---|---|---|---|
| B02 | GR | 5 | 19 | 2 | 20 | 13 | -5 | 4 | 15 |
| | T1 | 8 | -197 | -103 | 222 | -189 | -124 | 213 | 311 |
| | GR+T1 | 13 | -178 | -102 | 205 | -176 | -129 | 217 | 308 |
| | RESPONSE | 319 | 59 | 154 | 359 | 45 | 259 | 39 | 266 |
| | TOTAL | 332 | 237 | 255 | 481 | 221 | 388 | 256 | 515 |
| B03 N | GR | 5 | 8 | 2 | 10 | 1 | 0 | 4 | 4 |
| | T1 | 8 | -197 | -103 | 222 | -7 | -117 | 213 | 243 |
| | GR+T1 | 13 | -188 | -102 | 214 | -7 | -117 | 217 | 246 |
| | RESPONSE | 319 | 59 | 154 | 359 | 28 | 113 | 39 | 122 |
| | TOTAL | 332 | 247 | 256 | 487 | 35 | 229 | 256 | 345 |





## G L O B A L F O R C E S & M O M E N T S

| Point name | Load combination | FORCES (lb ) X | Y | Z | Result | MOMENTS (ft-lb ) X | Y | Z | Result |
|---|---|---|---|---|---|---|---|---|---|
| B03 M | GR | 5 | 5 | 2 | 7 | -1 | 1 | 5 | 5 |
| | T1 | 8 | -197 | -103 | 222 | 45 | -103 | 192 | 222 |
| | GR+T1 | 13 | -192 | -102 | 217 | 43 | -102 | 196 | 225 |
| | RESPONSE | 319 | 59 | 155 | 360 | 39 | 154 | 44 | 165 |
| | TOTAL | 332 | 251 | 257 | 489 | 83 | 256 | 241 | 361 |
| B03 F | GR | 5 | 2 | 2 | 5 | -2 | 1 | 5 | 6 |
| | T1 | 8 | -197 | -103 | 222 | 66 | -75 | 139 | 172 |
| | GR+T1 | 13 | -195 | -102 | 220 | 65 | -73 | 145 | 175 |
| | RESPONSE | 319 | 59 | 156 | 360 | 45 | 142 | 59 | 161 |
| | TOTAL | 332 | 254 | 257 | 491 | 109 | 216 | 204 | 316 |
| B04 N | GR | 5 | -9 | 2 | 10 | -2 | 0 | 3 | 4 |
| | T1 | 8 | -197 | -103 | 222 | 66 | -14 | 23 | 71 |
| | GR+T1 | 13 | -206 | -102 | 230 | 65 | -13 | 26 | 71 |
| | RESPONSE | 319 | 59 | 156 | 360 | 45 | 52 | 93 | 115 |
| | TOTAL | 333 | 264 | 258 | 497 | 109 | 65 | 119 | 174 |
| B04 M | GR | 5 | -13 | 2 | 14 | -1 | 0 | 0 | 1 |
| | T1 | 8 | -197 | -103 | 222 | 56 | 11 | -24 | 62 |
| | GR+T1 | 13 | -210 | -102 | 234 | 55 | 11 | -24 | 61 |
| | RESPONSE | 319 | 59 | 156 | 360 | 29 | 19 | 76 | 83 |
| | TOTAL | 333 | 269 | 258 | 500 | 84 | 30 | 100 | 134 |
| B04 F | GR | 5 | -18 | 2 | 19 | -1 | 0 | -2 | 3 |
| | T1 | 8 | -197 | -103 | 222 | 32 | 21 | -45 | 59 |
| | GR+T1 | 13 | -215 | -102 | 238 | 31 | 21 | -48 | 60 |
| | RESPONSE | 319 | 59 | 156 | 360 | 8 | 15 | 7 | 18 |
| | TOTAL | 333 | 274 | 258 | 502 | 39 | 35 | 55 | 76 |
| B05 | GR | 5 | -163 | 2 | 163 | -1 | 0 | -3 | 3 |
| | T1 | 8 | -197 | -103 | 222 | 25 | 21 | -46 | 56 |
| | GR+T1 | 13 | -360 | -102 | 374 | 24 | 21 | -49 | 58 |
| | RESPONSE | 321 | 67 | 160 | 365 | 18 | 15 | 16 | 28 |
| | TOTAL | 334 | 427 | 262 | 602 | 42 | 35 | 65 | 85 |
| B06 | GR | 5 | -163 | 2 | 163 | -1 | 0 | -3 | 3 |
| | T1 | 8 | -197 | -103 | 222 | 21 | 21 | -46 | 55 |
| | GR+T1 | 13 | -360 | -102 | 374 | 20 | 21 | -49 | 57 |
| | RESPONSE | 326 | 86 | 168 | 377 | 25 | 15 | 29 | 40 |
| | TOTAL | 339 | 446 | 270 | 622 | 44 | 35 | 78 | 96 |

## G L O B A L F O R C E S & M O M E N T S

| Point name | Load combination | FORCES (lb ) X | Y | Z | Result | MOMENTS (ft-lb ) X | Y | Z | Result |
|---|---|---|---|---|---|---|---|---|---|
| B07 | GR | 5 | -167 | 2 | 167 | -1 | 0 | -4 | 4 |
| | T1 | 8 | -197 | -103 | 222 | 1 | 21 | -48 | 52 |
| | GR+T1 | 13 | -363 | -102 | 378 | 1 | 21 | -52 | 56 |
| | RESPONSE | 326 | 86 | 168 | 377 | 56 | 15 | 90 | 107 |
| | TOTAL | 339 | 449 | 270 | 624 | 56 | 35 | 142 | 156 |
| *** Segment B end *** | | | | | | | | | |
| *** Segment C begin *** | | | | | | | | | |
| 5 | GR | 22 | -229 | -6 | 230 | -29 | -3 | 0 | 29 |
| | T1 | -279 | -14 | -24319 | 24321 | -2 | 35 | 0 | 35 |
| | GR+T1 | -257 | -243 | -24325 | 24328 | -30 | 32 | 0 | 44 |
| | RESPONSE | 281 | 1062 | 314 | 1142 | 133 | 35 | 0 | 137 |
| | TOTAL | 538 | 1304 | 24639 | 24679 | 163 | 67 | 0 | 176 |
| C01 | GR | 22 | -231 | -6 | 232 | 29 | 3 | 0 | 29 |
| | T1 | -279 | -14 | -24319 | 24321 | 2 | -35 | 0 | 35 |
| | GR+T1 | -257 | -245 | -24325 | 24328 | 31 | -32 | 0 | 44 |
| | RESPONSE | 281 | 1062 | 314 | 1142 | 133 | 35 | 0 | 137 |
| | TOTAL | 538 | 1307 | 24639 | 24679 | 163 | 67 | 0 | 177 |
| *** Segment C end *** | | | | | | | | | |
| *** Segment D begin *** | | | | | | | | | |
| 3 | GR | -84 | 156 | -5 | 177 | -19 | -10 | 0 | 22 |
| | T1 | 561 | 262 | 24455 | 24463 | -33 | 70 | 0 | 77 |
| | GR+T1 | 477 | 418 | 24450 | 24458 | -52 | 60 | 0 | 79 |
| | RESPONSE | 560 | 1180 | 316 | 1344 | 148 | 70 | 0 | 163 |
| | TOTAL | 1037 | 1598 | 24766 | 24839 | 200 | 130 | 0 | 238 |
| D01 | GR | -84 | 154 | -5 | 175 | 19 | 10 | 0 | 22 |
| | T1 | 561 | 262 | 24455 | 24463 | 33 | -70 | 0 | 77 |
| | GR+T1 | 477 | 416 | 24450 | 24458 | 52 | -60 | 0 | 79 |
| | RESPONSE | 560 | 1180 | 316 | 1344 | 148 | 70 | 0 | 163 |
| | TOTAL | 1037 | 1596 | 24766 | 24839 | 200 | 130 | 0 | 238 |
| *** Segment D end *** | | | | | | | | | |





## ASME B31.3c (1992) CODE COMPLIANCE

| Point name | Load combination | (Moments in ft-lb ) In-Pl. Moment | Out-Pl. Moment | Torsion Moment | S.I.F In | S.I.F Out | Eq. no. | (Stress in psi ) Load type | Code Stress | Code Allow. |
|---|---|---|---|---|---|---|---|---|---|---|
| *** Segment A begin *** | | | | | | | | | | |
| A00 | Max P | | | | | | (3a) | HOOP | 4844 | 16700 |
| | GR + Max P | 179 | 39 | | 1.00 | 1.00 | (18) | SUST | 2947 | 16700 |
| | Cold to T1 | 76 | 41 | 26 | 1.00 | 1.00 | (17) | DISP | 338 | 25050 |
| | SRSS | 141 | 196 | | 1.00 | 1.00 | (18) | OCC | 1162 | 22211 |
| A01 | Max P | | | | | | (3a) | HOOP | 4844 | 16700 |
| | GR + Max P | 92 | 31 | | 1.00 | 1.00 | (18) | SUST | 2531 | 16700 |
| | Cold to T1 | 85 | 2 | 26 | 1.00 | 1.00 | (17) | DISP | 334 | 25050 |
| | SRSS | 130 | 161 | | 1.00 | 1.00 | (18) | OCC | 992 | 22211 |
| A02 | Max P | | | | | | (3a) | HOOP | 4844 | 16700 |
| | GR + Max P | 79 | 29 | | 1.00 | 1.00 | (18) | SUST | 2472 | 16700 |
| | Cold to T1 | 87 | 5 | 26 | 1.00 | 1.00 | (17) | DISP | 340 | 25050 |
| | SRSS | 128 | 155 | | 1.00 | 1.00 | (18) | OCC | 967 | 22211 |
| A03 N- | Max P | | | | | | (3a) | HOOP | 4844 | 16700 |
| | GR + Max P | 79 | 29 | | 1.00 | 1.00 | (18) | SUST | 2470 | 16700 |
| | Cold to T1 | 87 | 5 | 26 | 1.00 | 1.00 | (17) | DISP | 340 | 25050 |
| | SRSS | 128 | 155 | | 1.00 | 1.00 | (18) | OCC | 966 | 22211 |
| A03 N+ | Max P | | | | | | (3a) | HOOP | 4844 | 16700 |
| | GR + Max P | 79 | 29 | | 2.56 | 2.13 | (18) | SUST | 3080 | 16700 |
| | Cold to T1 | 87 | 5 | 26 | 2.56 | 2.13 | (17) | DISP | 839 | 25050 |
| | SRSS | 128 | 155 | | 2.56 | 2.13 | (18) | OCC | 2235 | 22211 |
| A03 M | Max P | | | | | | (3a) | HOOP | 4844 | 16700 |
| | GR + Max P | 35 | 28 | | 2.56 | 2.13 | (18) | SUST | 2580 | 16700 |
| | Cold to T1 | 72 | 23 | 38 | 2.56 | 2.13 | (17) | DISP | 725 | 25050 |
| | SRSS | 108 | 99 | | 2.56 | 2.13 | (18) | OCC | 1674 | 22211 |
| A03 F- | Max P | | | | | | (3a) | HOOP | 4844 | 16700 |
| | GR + Max P | 26 | 69 | | 2.56 | 2.13 | (18) | SUST | 2842 | 16700 |
| | Cold to T1 | 18 | 27 | 58 | 2.56 | 2.13 | (17) | DISP | 349 | 25050 |
| | SRSS | 79 | 57 | | 2.56 | 2.13 | (18) | OCC | 1136 | 22211 |
| A03 F+ | Max P | | | | | | (3a) | HOOP | 4844 | 16700 |
| | GR + Max P | 50 | 54 | | 1.00 | 1.00 | (18) | SUST | 2420 | 16700 |
| | Cold to T1 | 32 | 4 | 58 | 1.00 | 1.00 | (17) | DISP | 248 | 25050 |
| | SRSS | 62 | 76 | | 1.00 | 1.00 | (18) | OCC | 469 | 22211 |

ASME B31.3c (1992) CODE COMPLIANCE

| Point name | Load combination | (Moments in ft-lb) In-Pl. Moment | Out-Pl. Moment | Torsion Moment | S.I.F In | S.I.F Out | Eq. no. | Load type | (Stress in psi) Code Stress | Code Allow. |
|---|---|---|---|---|---|---|---|---|---|---|
| A04 N- | Max P | | | | | | (3a) | HOOP | 4844 | 16700 |
| | GR + Max P | 56 | 91 | | 1.00 | 1.00 | (18) | SUST | 2580 | 16700 |
| | Cold to T1 | 53 | 186 | 58 | 1.00 | 1.00 | (17) | DISP | 755 | 25050 |
| | SRSS | 96 | 213 | | 1.00 | 1.00 | (18) | OCC | 1121 | 22211 |
| A04 N+ | Max P | | | | | | (3a) | HOOP | 4844 | 16700 |
| | GR + Max P | 91 | 56 | | 1.95 | 1.63 | (18) | SUST | 3027 | 16700 |
| | Cold to T1 | 186 | 53 | 58 | 1.95 | 1.63 | (17) | DISP | 1413 | 25050 |
| | SRSS | 213 | 96 | | 1.95 | 1.63 | (18) | OCC | 2132 | 22211 |
| A04 M | Max P | | | | | | (3a) | HOOP | 4844 | 16700 |
| | GR + Max P | 84 | 30 | | 1.95 | 1.63 | (18) | SUST | 2890 | 16700 |
| | Cold to T1 | 283 | 90 | 1 | 1.95 | 1.63 | (17) | DISP | 2137 | 25050 |
| | SRSS | 298 | 93 | | 1.95 | 1.63 | (18) | OCC | 2889 | 22211 |
| A04 F- | Max P | | | | | | (3a) | HOOP | 4844 | 16700 |
| | GR + Max P | 30 | 14 | | 1.95 | 1.63 | (18) | SUST | 2364 | 16700 |
| | Cold to T1 | 313 | 74 | 70 | 1.95 | 1.63 | (17) | DISP | 2339 | 25050 |
| | SRSS | 314 | 101 | | 1.95 | 1.63 | (18) | OCC | 3050 | 22211 |
| A04 F+ | Max P | | | | | | (3a) | HOOP | 4844 | 16700 |
| | GR + Max P | 30 | 14 | | 1.00 | 1.00 | (18) | SUST | 2223 | 16700 |
| | Cold to T1 | 313 | 74 | 70 | 1.00 | 1.00 | (17) | DISP | 1228 | 25050 |
| | SRSS | 314 | 101 | | 1.00 | 1.00 | (18) | OCC | 1585 | 22211 |
| A05 N- | Max P | | | | | | (3a) | HOOP | 4844 | 16700 |
| | GR + Max P | 573 | 27 | | 1.00 | 1.00 | (18) | SUST | 4818 | 16700 |
| | Cold to T1 | 148 | 219 | 70 | 1.00 | 1.00 | (17) | DISP | 1020 | 25050 |
| | SRSS | 354 | 417 | | 1.00 | 1.00 | (18) | OCC | 2624 | 22211 |
| A05 N+ | Max P | | | | | | (3a) | HOOP | 4844 | 16700 |
| | GR + Max P | 27 | 573 | | 1.95 | 1.63 | (18) | SUST | 6546 | 16700 |
| | Cold to T1 | 219 | 148 | 70 | 1.95 | 1.63 | (17) | DISP | 1850 | 25050 |
| | SRSS | 417 | 354 | | 1.95 | 1.63 | (18) | OCC | 4783 | 22211 |
| A05 M | Max P | | | | | | (3a) | HOOP | 4844 | 16700 |
| | GR + Max P | 22 | 395 | | 1.95 | 1.63 | (18) | SUST | 5153 | 16700 |
| | Cold to T1 | 188 | 141 | 50 | 1.95 | 1.63 | (17) | DISP | 1626 | 25050 |
| | SRSS | 417 | 254 | | 1.95 | 1.63 | (18) | OCC | 4381 | 22211 |
| A05 F- | Max P | | | | | | (3a) | HOOP | 4844 | 16700 |
| | GR + Max P | 3 | 17 | | 1.95 | 1.63 | (18) | SUST | 2205 | 16700 |
| | Cold to T1 | 90 | 51 | 130 | 1.95 | 1.63 | (17) | DISP | 873 | 25050 |
| | SRSS | 377 | 117 | | 1.95 | 1.63 | (18) | OCC | 3650 | 22211 |





ASME B31.3c (1992) CODE COMPLIANCE

| Point name | Load combination | (Moments in ft-lb) In-Pl. Moment | Out-Pl. Moment | Torsion Moment | S.I.F In | S.I.F Out | Eq. no. | Load type | (Stress in psi) Code Stress | Code Allow. |
|---|---|---|---|---|---|---|---|---|---|---|
| A05 F+ | Max P | | | | | | (3a) | HOOP | 4844 | 16700 |
| | GR + Max P | 17 | 3 | | 1.00 | 1.00 | (18) | SUST | 2151 | 16700 |
| | Cold to T1 | 51 | 90 | 130 | 1.00 | 1.00 | (17) | DISP | 620 | 25050 |
| | SRSS | 117 | 377 | | 1.00 | 1.00 | (18) | OCC | 1895 | 22211 |
| A06 N- | Max P | | | | | | (3a) | HOOP | 4844 | 16700 |
| | GR + Max P | 56 | 54 | | 1.00 | 1.00 | (18) | SUST | 2436 | 16700 |
| | Cold to T1 | 14 | 200 | 130 | 1.00 | 1.00 | (17) | DISP | 891 | 25050 |
| | SRSS | 98 | 354 | | 1.00 | 1.00 | (18) | OCC | 1763 | 22211 |
| A06 N+ | Max P | | | | | | (3a) | HOOP | 4844 | 16700 |
| | GR + Max P | 54 | 56 | | 1.95 | 1.63 | (18) | SUST | 2729 | 16700 |
| | Cold to T1 | 200 | 14 | 130 | 1.95 | 1.63 | (17) | DISP | 1537 | 25050 |
| | SRSS | 354 | 98 | | 1.95 | 1.63 | (18) | OCC | 3405 | 22211 |
| A06 M | Max P | | | | | | (3a) | HOOP | 4844 | 16700 |
| | GR + Max P | 72 | 498 | | 1.95 | 1.63 | (18) | SUST | 6011 | 16700 |
| | Cold to T1 | 297 | 89 | 87 | 1.95 | 1.63 | (17) | DISP | 2258 | 25050 |
| | SRSS | 392 | 300 | | 1.95 | 1.63 | (18) | OCC | 4355 | 22211 |
| A06 F- | Max P | | | | | | (3a) | HOOP | 4844 | 16700 |
| | GR + Max P | 77 | 646 | | 1.95 | 1.63 | (18) | SUST | 7161 | 16700 |
| | Cold to T1 | 328 | 111 | 4 | 1.95 | 1.63 | (17) | DISP | 2488 | 25050 |
| | SRSS | 414 | 393 | | 1.95 | 1.63 | (18) | OCC | 4946 | 22211 |
| A06 F+ | Max P | | | | | | (3a) | HOOP | 4844 | 16700 |
| | GR + Max P | 646 | 77 | | 1.00 | 1.00 | (18) | SUST | 5187 | 16700 |
| | Cold to T1 | 111 | 328 | 4 | 1.00 | 1.00 | (17) | DISP | 1295 | 25050 |
| | SRSS | 393 | 414 | | 1.00 | 1.00 | (18) | OCC | 2740 | 22211 |
| A07 | Max P | | | | | | (3a) | HOOP | 4844 | 16700 |
| | GR + Max P | 691 | 67 | | 1.00 | 1.00 | (18) | SUST | 5400 | 16700 |
| | Cold to T1 | 70 | 292 | 4 | 1.00 | 1.00 | (17) | DISP | 1120 | 25050 |
| | SRSS | 420 | 419 | | 1.00 | 1.00 | (18) | OCC | 2850 | 22211 |
| A08 | Max P | | | | | | (3a) | HOOP | 4844 | 16700 |
| | GR + Max P | 691 | 59 | | 1.00 | 1.00 | (18) | SUST | 5393 | 16700 |
| | Cold to T1 | 36 | 262 | 4 | 1.00 | 1.00 | (17) | DISP | 987 | 25050 |
| | SRSS | 420 | 407 | | 1.00 | 1.00 | (18) | OCC | 2807 | 22211 |
| A09 | Max P | | | | | | (3a) | HOOP | 4844 | 16700 |
| | GR + Max P | 578 | 50 | | 1.00 | 1.00 | (18) | SUST | 4852 | 16700 |
| | Cold to T1 | 2 | 232 | 4 | 1.00 | 1.00 | (17) | DISP | 867 | 25050 |
| | SRSS | 347 | 339 | | 1.00 | 1.00 | (18) | OCC | 2327 | 22211 |

ASME B31.3c (1992) CODE COMPLIANCE

| Point name | Load combination | (Moments in ft-lb ) In-Pl. Moment | Out-Pl. Moment | Torsion Moment | S.I.F In | S.I.F Out | (Stress in psi ) Eq. no. | Load type | Code Stress | Code Allow. |
|---|---|---|---|---|---|---|---|---|---|---|
| A10 | Max P | | | | | | (3a) | HOOP | 4844 | 16700 |
| | GR + Max P | 124 | 26 | | 1.00 | 1.00 | (18) | SUST | 2676 | 16700 |
| | Cold to T1 | 96 | 146 | 4 | 1.00 | 1.00 | (17) | DISP | 654 | 25050 |
| | SRSS | 88 | 92 | | 1.00 | 1.00 | (18) | OCC | 609 | 22211 |
| A11 N- | Max P | | | | | | (3a) | HOOP | 4844 | 16700 |
| | GR + Max P | 86 | 20 | | 1.00 | 1.00 | (18) | SUST | 2488 | 16700 |
| | Cold to T1 | 123 | 123 | 4 | 1.00 | 1.00 | (17) | DISP | 649 | 25050 |
| | SRSS | 78 | 30 | | 1.00 | 1.00 | (18) | OCC | 403 | 22211 |
| A11 N+ | Max P | | | | | | (3a) | HOOP | 4844 | 16700 |
| | GR + Max P | 86 | 20 | | 2.56 | 2.13 | (18) | SUST | 3138 | 16700 |
| | Cold to T1 | 123 | 123 | 4 | 2.56 | 2.13 | (17) | DISP | 1527 | 25050 |
| | SRSS | 78 | 30 | | 2.56 | 2.13 | (18) | OCC | 1010 | 22211 |
| A11 M | Max P | | | | | | (3a) | HOOP | 4844 | 16700 |
| | GR + Max P | 163 | 72 | | 2.56 | 2.13 | (18) | SUST | 4203 | 16700 |
| | Cold to T1 | 103 | 82 | 81 | 2.56 | 2.13 | (17) | DISP | 1220 | 25050 |
| | SRSS | 99 | 69 | | 2.56 | 2.13 | (18) | OCC | 1402 | 22211 |
| A11 F- | Max P | | | | | | (3a) | HOOP | 4844 | 16700 |
| | GR + Max P | 207 | 82 | | 2.56 | 2.13 | (18) | SUST | 4742 | 16700 |
| | Cold to T1 | 38 | 7 | 112 | 2.56 | 2.13 | (17) | DISP | 558 | 25050 |
| | SRSS | 115 | 93 | | 2.56 | 2.13 | (18) | OCC | 1699 | 22211 |
| A11 F+ | Max P | | | | | | (3a) | HOOP | 4844 | 16700 |
| | GR + Max P | 82 | 207 | | 1.00 | 1.00 | (18) | SUST | 3134 | 16700 |
| | Cold to T1 | 7 | 38 | 112 | 1.00 | 1.00 | (17) | DISP | 444 | 25050 |
| | SRSS | 93 | 115 | | 1.00 | 1.00 | (18) | OCC | 708 | 22211 |
| A12 | Max P | | | | | | (3a) | HOOP | 4844 | 16700 |
| | GR + Max P | 82 | 211 | | 1.00 | 1.00 | (18) | SUST | 3150 | 16700 |
| | Cold to T1 | 9 | 19 | 112 | 1.00 | 1.00 | (17) | DISP | 426 | 25050 |
| | SRSS | 92 | 117 | | 1.00 | 1.00 | (18) | OCC | 714 | 22211 |
| A13 | Max P | | | | | | (3a) | HOOP | 4844 | 16700 |
| | GR + Max P | 81 | 213 | | 1.00 | 1.00 | (18) | SUST | 3160 | 16700 |
| | Cold to T1 | 10 | 7 | 112 | 1.00 | 1.00 | (17) | DISP | 422 | 25050 |
| | SRSS | 92 | 119 | | 1.00 | 1.00 | (18) | OCC | 721 | 22211 |
| A14 N- | Max P | | | | | | (3a) | HOOP | 4844 | 16700 |
| | GR + Max P | 80 | 219 | | 1.00 | 1.00 | (18) | SUST | 3184 | 16700 |
| | Cold to T1 | 13 | 22 | 112 | 1.00 | 1.00 | (17) | DISP | 430 | 25050 |
| | SRSS | 95 | 124 | | 1.00 | 1.00 | (18) | OCC | 748 | 22211 |





ASME B31.3c (1992) CODE COMPLIANCE

| Point name | Load combination | (Moments in ft-lb ) In-Pl. Moment | Out-Pl. Moment | Torsion Moment | S.I.F In | S.I.F Out | (Stress in psi ) Eq. no. | Load type | Code Stress | Code Allow. |
|---|---|---|---|---|---|---|---|---|---|---|
| A14 N+ | Max P | | | | | | (3a) | HOOP | 4844 | 16700 |
| | GR + Max P | 80 | 219 | | 1.95 | 1.63 | (18) | SUST | 3932 | 16700 |
| | Cold to T1 | 13 | 22 | 112 | 1.95 | 1.63 | (17) | DISP | 450 | 25050 |
| | SRSS | 95 | 124 | | 1.95 | 1.63 | (18) | OCC | 1314 | 22211 |
| A14 M | Max P | | | | | | (3a) | HOOP | 4844 | 16700 |
| | GR + Max P | 145 | 163 | | 1.95 | 1.63 | (18) | SUST | 3927 | 16700 |
| | Cold to T1 | 30 | 38 | 137 | 1.95 | 1.63 | (17) | DISP | 604 | 25050 |
| | SRSS | 143 | 93 | | 1.95 | 1.63 | (18) | OCC | 1521 | 22211 |
| A14 F- | Max P | | | | | | (3a) | HOOP | 4844 | 16700 |
| | GR + Max P | 310 | 12 | | 1.95 | 1.63 | (18) | SUST | 4972 | 16700 |
| | Cold to T1 | 48 | 33 | 167 | 1.95 | 1.63 | (17) | DISP | 740 | 25050 |
| | SRSS | 204 | 23 | | 1.95 | 1.63 | (18) | OCC | 1919 | 22211 |
| A14 F+ | Max P | | | | | | (3a) | HOOP | 4279 | 16700 |
| | GR + Max P | 310 | 12 | | 1.00 | 1.00 | (18) | SUST | 4661 | 16700 |
| | Cold to T1 | 48 | 33 | 167 | 1.00 | 1.00 | (17) | DISP | 1228 | 25050 |
| | SRSS | 204 | 23 | | 1.00 | 1.00 | (18) | OCC | 1876 | 22211 |
| A14A | Max P | | | | | | (3a) | HOOP | 4279 | 16700 |
| | GR + Max P | 386 | 21 | | 1.00 | 1.00 | (18) | SUST | 5358 | 16700 |
| | Cold to T1 | 54 | 79 | 167 | 1.00 | 1.00 | (17) | DISP | 1337 | 25050 |
| | SRSS | 226 | 29 | | 1.00 | 1.00 | (18) | OCC | 2087 | 22211 |
| A15 | Max P | | | | | | (3a) | HOOP | 4279 | 16700 |
| | GR + Max P | 37 | 57 | | 1.00 | 1.00 | (18) | SUST | 2444 | 16700 |
| | Cold to T1 | 55 | 265 | 167 | 1.00 | 1.00 | (17) | DISP | 2210 | 25050 |
| | SRSS | 326 | 83 | | 1.00 | 1.00 | (18) | OCC | 3078 | 22211 |

*** Segment A end ***

*** Segment B begin ***

| Point name | Load combination | (Moments in ft-lb ) In-Pl. Moment | Out-Pl. Moment | Torsion Moment | S.I.F In | S.I.F Out | (Stress in psi ) Eq. no. | Load type | Code Stress | Code Allow. |
|---|---|---|---|---|---|---|---|---|---|---|
| B02 | Max P | | | | | | (3a) | HOOP | 4279 | 16700 |
| | GR + Max P | 13 | 5 | | 1.00 | 1.00 | (18) | SUST | 1952 | 16700 |
| | Cold to T1 | 189 | 124 | 213 | 1.00 | 1.00 | (17) | DISP | 2166 | 25050 |
| | SRSS | 45 | 259 | | 1.00 | 1.00 | (18) | OCC | 2407 | 22211 |
| B03 N- | Max P | | | | | | (3a) | HOOP | 4279 | 16700 |
| | GR + Max P | 1 | 0 | | 1.00 | 1.00 | (18) | SUST | 1828 | 16700 |
| | Cold to T1 | 7 | 117 | 213 | 1.00 | 1.00 | (17) | DISP | 1692 | 25050 |
| | SRSS | 28 | 113 | | 1.00 | 1.00 | (18) | OCC | 1063 | 22211 |

ASME B31.3c (1992) CODE COMPLIANCE

| Point name | Load combination | (Moments in ft-lb ) In-Pl. Moment | Out-Pl. Moment | Torsion Moment | S.I.F In | S.I.F Out | (Stress in psi ) Eq. no. | Load type | Code Stress | Code Allow. |
|---|---|---|---|---|---|---|---|---|---|---|
| B03 N+ | Max P | | | | | | (3a) | HOOP | 4279 | 16700 |
| | GR + Max P | 0 | 1 | | 1.78 | 1.48 | (18) | SUST | 1831 | 16700 |
| | Cold to T1 | 117 | 7 | 213 | 1.78 | 1.48 | (17) | DISP | 2071 | 25050 |
| | SRSS | 113 | 28 | | 1.78 | 1.48 | (18) | OCC | 1871 | 22211 |
| B03 M | Max P | | | | | | (3a) | HOOP | 4279 | 16700 |
| | GR + Max P | 1 | 4 | | 1.78 | 1.48 | (18) | SUST | 1881 | 16700 |
| | Cold to T1 | 103 | 104 | 167 | 1.78 | 1.48 | (17) | DISP | 2031 | 25050 |
| | SRSS | 154 | 51 | | 1.78 | 1.48 | (18) | OCC | 2594 | 22211 |
| B03 F- | Max P | | | | | | (3a) | HOOP | 4279 | 16700 |
| | GR + Max P | 1 | 5 | | 1.78 | 1.48 | (18) | SUST | 1899 | 16700 |
| | Cold to T1 | 75 | 139 | 66 | 1.78 | 1.48 | (17) | DISP | 1770 | 25050 |
| | SRSS | 142 | 59 | | 1.78 | 1.48 | (18) | OCC | 2450 | 22211 |
| B03 F+ | Max P | | | | | | (3a) | HOOP | 4844 | 16700 |
| | GR + Max P | 5 | 1 | | 1.00 | 1.00 | (18) | SUST | 2092 | 16700 |
| | Cold to T1 | 139 | 75 | 66 | 1.00 | 1.00 | (17) | DISP | 640 | 25050 |
| | SRSS | 59 | 142 | | 1.00 | 1.00 | (18) | OCC | 740 | 22211 |
| B04 N- | Max P | | | | | | (3a) | HOOP | 4844 | 16700 |
| | GR + Max P | 3 | 0 | | 1.00 | 1.00 | (18) | SUST | 2081 | 16700 |
| | Cold to T1 | 23 | 14 | 66 | 1.00 | 1.00 | (17) | DISP | 267 | 25050 |
| | SRSS | 93 | 52 | | 1.00 | 1.00 | (18) | OCC | 511 | 22211 |
| B04 N+ | Max P | | | | | | (3a) | HOOP | 4844 | 16700 |
| | GR + Max P | 3 | 0 | | 2.56 | 2.13 | (18) | SUST | 2106 | 16700 |
| | Cold to T1 | 23 | 14 | 66 | 2.56 | 2.13 | (17) | DISP | 349 | 25050 |
| | SRSS | 93 | 52 | | 2.56 | 2.13 | (18) | OCC | 1259 | 22211 |
| B04 M | Max P | | | | | | (3a) | HOOP | 4844 | 16700 |
| | GR + Max P | 0 | 1 | | 2.56 | 2.13 | (18) | SUST | 2077 | 16700 |
| | Cold to T1 | 24 | 32 | 47 | 2.56 | 2.13 | (17) | DISP | 387 | 25050 |
| | SRSS | 76 | 31 | | 2.56 | 2.13 | (18) | OCC | 980 | 22211 |
| B04 F- | Max P | | | | | | (3a) | HOOP | 4844 | 16700 |
| | GR + Max P | 2 | 1 | | 2.56 | 2.13 | (18) | SUST | 2098 | 16700 |
| | Cold to T1 | 45 | 32 | 21 | 2.56 | 2.13 | (17) | DISP | 507 | 25050 |
| | SRSS | 7 | 8 | | 2.56 | 2.13 | (18) | OCC | 123 | 22211 |
| B04 F+ | Max P | | | | | | (3a) | HOOP | 4844 | 16700 |
| | GR + Max P | 1 | 2 | | 1.00 | 1.00 | (18) | SUST | 2079 | 16700 |
| | Cold to T1 | 32 | 45 | 21 | 1.00 | 1.00 | (17) | DISP | 221 | 25050 |
| | SRSS | 8 | 7 | | 1.00 | 1.00 | (18) | OCC | 53 | 22211 |





ASME B31.3c (1992) CODE COMPLIANCE

| Point name | Load combination | (Moments in ft-lb ) In-Pl. Moment | Out-Pl. Moment | Torsion Moment | S.I.F In | S.I.F Out | (Stress in psi ) Eq. no. | Load type | Code Stress | Code Allow. |
|---|---|---|---|---|---|---|---|---|---|---|
| B05 | Max P | | | | | | (3a) | HOOP | 4844 | 16700 |
| | GR + Max P | 1 | 3 | | 1.00 | 1.00 | (18) | SUST | 2080 | 16700 |
| | Cold to T1 | 25 | 46 | 21 | 1.00 | 1.00 | (17) | DISP | 210 | 25050 |
| | SRSS | 18 | 16 | | 1.00 | 1.00 | (18) | OCC | 117 | 22211 |
| B06 | Max P | | | | | | (3a) | HOOP | 4844 | 16700 |
| | GR + Max P | 1 | 3 | | 1.00 | 1.00 | (18) | SUST | 2081 | 16700 |
| | Cold to T1 | 21 | 46 | 21 | 1.00 | 1.00 | (17) | DISP | 204 | 25050 |
| | SRSS | 25 | 29 | | 1.00 | 1.00 | (18) | OCC | 181 | 22211 |
| B07 | Max P | | | | | | (3a) | HOOP | 4844 | 16700 |
| | GR + Max P | 1 | 4 | | 1.00 | 1.00 | (18) | SUST | 2085 | 16700 |
| | Cold to T1 | 1 | 48 | 21 | 1.00 | 1.00 | (17) | DISP | 194 | 25050 |
| | SRSS | 56 | 90 | | 1.00 | 1.00 | (18) | OCC | 508 | 22211 |

*** Segment B end ***

*** Segment C begin ***

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 5 | Max P | | | | | | (3a) | HOOP | 6905 | 16700 |
| | GR + Max P | 29 | 3 | | 1.00 | 1.00 | (18) | SUST | 3140 | 16700 |
| | Cold to T1 | 2 | 35 | 0 | 1.00 | 1.00 | (17) | DISP | 175 | 25050 |
| | SRSS | 133 | 35 | | 1.00 | 1.00 | (18) | OCC | 895 | 22211 |
| C01 | Max P | | | | | | (3a) | HOOP | 6905 | 16700 |
| | GR + Max P | 29 | 3 | | 1.00 | 1.00 | (18) | SUST | 3140 | 16700 |
| | Cold to T1 | 2 | 35 | 0 | 1.00 | 1.00 | (17) | DISP | 175 | 25050 |
| | SRSS | 133 | 35 | | 1.00 | 1.00 | (18) | OCC | 895 | 22211 |

*** Segment C end ***

*** Segment D begin ***

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 3 | Max P | | | | | | (3a) | HOOP | 6905 | 16700 |
| | GR + Max P | 19 | 10 | | 1.00 | 1.00 | (18) | SUST | 3096 | 16700 |
| | Cold to T1 | 33 | 70 | 0 | 1.00 | 1.00 | (17) | DISP | 388 | 25050 |
| | SRSS | 148 | 70 | | 1.00 | 1.00 | (18) | OCC | 1065 | 22211 |
| D01 | Max P | | | | | | (3a) | HOOP | 6905 | 16700 |
| | GR + Max P | 19 | 10 | | 1.00 | 1.00 | (18) | SUST | 3095 | 16700 |
| | Cold to T1 | 33 | 70 | 0 | 1.00 | 1.00 | (17) | DISP | 388 | 25050 |
| | SRSS | 148 | 70 | | 1.00 | 1.00 | (18) | OCC | 1065 | 22211 |

*** Segment D end ***

## SYSTEM SUMMARY

### Maximum displacements (in)

| | | | |
|---|---|---|---|
| Maximum X : | 0.173 | Point : A14 N | Load Comb.: TOTAL |
| Maximum Y : | 0.380 | Point : A06 M | Load Comb.: TOTAL |
| Maximum Z : | 0.158 | Point : A05 N | Load Comb.: TOTAL |
| Max. total: | 0.411 | Point : A06 F | Load Comb.: TOTAL |

### Maximum rotations (deg)

| | | | |
|---|---|---|---|
| Maximum X : | 0.373 | Point : A04 N | Load Comb.: TOTAL |
| Maximum Y : | 0.464 | Point : A14 F | Load Comb.: TOTAL |
| Maximum Z : | 0.335 | Point : A10 | Load Comb.: TOTAL |
| Max. total: | 0.506 | Point : A04 N | Load Comb.: TOTAL |

### Maximum restraint forces(lb)

| | | | |
|---|---|---|---|
| Maximum X : | 1037 | Point : D01 | Load Comb.: TOTAL |
| Maximum Y : | 1596 | Point : D01 | Load Comb.: TOTAL |
| Maximum Z : | 24766 | Point : D01 | Load Comb.: TOTAL |
| Max. total: | 24839 | Point : D01 | Load Comb.: TOTAL |

### Maximum restraint moments(ft-lb)

| | | | |
|---|---|---|---|
| Maximum X : | 321 | Point : 3 | Load Comb.: TOTAL |
| Maximum Y : | 395 | Point : 3 | Load Comb.: TOTAL |
| Maximum Z : | 1011 | Point : 3 | Load Comb.: TOTAL |
| Max. total: | 1132 | Point : 3 | Load Comb.: TOTAL |





## SYSTEM SUMMARY

### Maximum pipe forces (lb)

| | | | |
|---|---|---|---|
| Maximum X : | 1037 | Point : 3 | Load Comb.: TOTAL |
| Maximum Y : | 1598 | Point : 3 | Load Comb.: TOTAL |
| Maximum Z : | 24766 | Point : 3 | Load Comb.: TOTAL |
| Max. total: | 24839 | Point : 3 | Load Comb.: TOTAL |

### Maximum pipe moments (ft-lb)

| | | | |
|---|---|---|---|
| Maximum X : | 666 | Point : A14A | Load Comb.: TOTAL |
| Maximum Y : | 665 | Point : A06 F | Load Comb.: TOTAL |
| Maximum Z : | 1181 | Point : A07 | Load Comb.: TOTAL |
| Max. total: | 1358 | Point : A07 | Load Comb.: TOTAL |

## S Y S T E M  S U M M A R Y

Maximum sustained stress

| | |
|---|---|
| Point | : A06 F |
| Stress psi | : 7161 |
| Allowable psi | : 16700 |
| Ratio | : 0.43 |
| Load combination | : GR + Max P |

Maximum displacement stress

| | |
|---|---|
| Point | : A06 F |
| Stress psi | : 2488 |
| Allowable psi | : 25050 |
| Ratio | : 0.10 |
| Load combination | : Cold to T1 |

Maximum occasional stress

| | |
|---|---|
| Point | : A06 F |
| Stress psi | : 4946 |
| Allowable psi | : 22211 |
| Ratio | : 0.22 |
| Load combination | : SRSS |

Maximum hoop stress

| | |
|---|---|
| Point | : 5 |
| Stress psi | : 6905 |
| Allowable psi | : 16700 |
| Ratio | : 0.41 |
| Load combination | : Max P |

Maximum sustained stress ratio

| | |
|---|---|
| Point | : A06 F |
| Stress psi | : 7161 |
| Allowable psi | : 16700 |
| Ratio | : 0.43 |
| Load combination | : GR + Max P |

Maximum displacement stress ratio

| | |
|---|---|
| Point | : A06 F |
| Stress psi | : 2488 |
| Allowable psi | : 25050 |
| Ratio | : 0.10 |
| Load combination | : Cold to T1 |





## S Y S T E M  S U M M A R Y

Maximum occasional stress ratio

| | |
|---|---|
| Point | : A06 F |
| Stress psi | : 4946 |
| Allowable psi | : 22211 |
| Ratio | : 0.22 |
| Load combination | : SRSS |

Maximum hoop stress ratio

| | |
|---|---|
| Point | : 5 |
| Stress psi | : 6905 |
| Allowable psi | : 16700 |
| Ratio | : 0.41 |
| Load combination | : Max P |

* * * The system satisfies ASME B31.3 code requirements * * *
* * * for the selected options * * *

APPDX - B

## P O I N T  D A T A  L I S T I N G

| POINT NAME | TYPE | -----OFFSETS (ft )----- X | Y | Z | PIPE ID | DESCRIPTION |
|---|---|---|---|---|---|---|
| *** SEGMENT A | | | | | | |
| A00 | Run | 0 | 0 | 0 | 4PIPE | |
| A01 | Flex | 0.22 | 0 | -0.11 | | Wt= 144 lb , Ar= 3.2 sq.in<br>Axial= 23300000 Tors= 304.0<br>Y-Shear= RIGID Bend= 2080.0<br>Z-Shear= RIGID Bend= 2080.0 |
| A02 | Run | 0.04 | 0 | -0.02 | | |
| A03 | Bend | 0.30 | 0 | -0.15 | | Short Elbow, Radius = 4.00 inch<br>Bend angle change = 90.00 deg<br>Mid point at 50.00 percent<br>SIF - In 2.56, Out = 2.13<br>Flex = 7.908 |
| A04 | Bend | 0 | -1.49 | 0 | | Long Elbow, Radius = 6.00 inch<br>Bend angle change = 90.00 deg<br>Mid point at 50.00 percent<br>SIF - In 1.95, Out = 1.63<br>Flex = 5.272 |
| A05 | Bend | 5.46 | 0 | 0 | | Long Elbow, Radius = 6.00 inch<br>Bend angle change = 90.00 deg<br>Mid point at 50.00 percent<br>SIF - In 1.95, Out = 1.63<br>Flex = 5.272 |
| A06 | Bend | 0 | 0 | 2.00 | | Long Elbow, Radius = 6.00 inch<br>Bend angle change = 90.00 deg<br>Mid point at 50.00 percent<br>SIF - In 1.95, Out = 1.63<br>Flex = 5.272 |
| A07 | Run | 1.63 | 0 | 0 | | |
| A08 | Run | 0.92 | 0 | 0 | | |
| A09 | Run | 0.92 | 0 | 0 | | |
| A10 | Run | 2.66 | 0 | 0 | | |
| A11 | Bend | 1.04 | 0 | 0 | | Short Elbow, Radius = 4.00 inch<br>Bend angle change = 90.00 deg<br>Mid point at 50.00 percent<br>SIF - In 2.56, Out = 2.13<br>Flex = 7.908 |
| A12 | Flex | 0 | -0.40 | 0 | | Wt= 144 lb , Ar= 3.2 sq.in<br>Axial= 23300000 Tors= 304.0<br>Y-Shear= RIGID Bend= 2080.0<br>Z-Shear= RIGID Bend= 2080.0 |
| A13 | Run | 0 | -0.04 | 0 | | |
| A14 | Bend | 0 | -0.60 | 0 | | Long Elbow, Radius = 6.00 inch |





## P O I N T  D A T A  L I S T I N G

| POINT NAME | TYPE | -----OFFSETS (ft )----- X | Y | Z | PIPE ID | DESCRIPTION |
|---|---|---|---|---|---|---|
| | | | | | | Bend angle change = 90.00 deg<br>Mid point at 50.00 percent<br>SIF - In 1.95, Out = 1.63<br>Flex = 5.272 |
| A14 F | Far | | | | 3PIPE | |
| A14A | Run | 0 | 0 | -0.66 | | |
| A15 | Run | 0 | 0 | -0.64 | | |
| *** SEGMENT B | | | | | | |
| B02 | Run | 13.19 | -2.84 | -1.78 | 3PIPE | |
| B03 | Bend | 0 | 0 | -1.30 | | Long Elbow, Radius = 4.50 inch<br>Bend angle change = 90.00 deg<br>Mid point at 50.00 percent<br>SIF - In 1.78, Out = 1.48<br>Flex = 4.577 |
| B03 F | Far | | | | 4PIPE | |
| B04 | Bend | -1.30 | 0 | 0 | | Short Elbow, Radius = 4.00 inch<br>Bend angle change = 90.00 deg<br>Mid point at 50.00 percent<br>SIF - In 2.56, Out = 2.13<br>Flex = 7.908 |
| B05 | Flex | 0 | -0.40 | 0 | | Wt= 144 lb , Ar= 3.2 sq.in<br>Axial= 23300000 Tors= 304.0<br>Y-Shear= RIGID Bend= 2080.0<br>Z-Shear= RIGID Bend= 2080.0 |
| B06 | Run | 0 | -0.04 | 0 | | |
| B07 | Run | 0 | -0.19 | 0 | | |
| *** SEGMENT C | | | | | | |
| 5 | Run | 13.19 | 3.50 | -1.78 | 3.5PIPE | |
| C01 | Run | 0 | 0 | -0.25 | | |
| *** SEGMENT D | | | | | | |
| 3 | Run | 13.19 | 3.50 | 0.42 | 3.5PIPE | |
| D01 | Run | 0 | 0 | 0.25 | | |

Total weight of empty pipes : 254 lb

## C O M P O N E N T D A T A L I S T I N G

```
POINT  ---COORDINATE(ft )---  DATA
NAME     X       Y       Z    TYPE  DESCRIPTION
-----  ------  ------  ------  ----  ----------------------------------------
*** SEGMENT A
A00      0.00    0.00    0.00 ANCHOR Rigid
                                     Thermal movements : None
A01      0.22    0.00   -0.11
A02      0.26    0.00   -0.13
A03 N    0.26    0.00   -0.13
A03      0.56    0.00   -0.28 TI
A03 M    0.47   -0.10   -0.24
A03 F    0.56   -0.33   -0.28
A04 N    0.56   -0.99   -0.28
A04      0.56   -1.49   -0.28 TI
A04 M    0.71   -1.34   -0.28
A04 F    1.06   -1.49   -0.28
A05 N    5.52   -1.49   -0.28
A05      6.02   -1.49   -0.28 TI
A05 M    5.87   -1.49   -0.13
A05 F    6.02   -1.49    0.22
A06 N    6.02   -1.49    1.22
A06      6.02   -1.49    1.72 TI
A06 M    6.17   -1.49    1.57
A06 F    6.52   -1.49    1.72
A07      7.65   -1.49    1.72 WEIGHT 23 lb    ,  No offsets
A08      8.57   -1.49    1.72 WEIGHT 35 lb    ,  No offsets
                                FLANGE Weld neck          SIF = 1.00
                                       Rating = 400, Weight = 35 lb
                                FLANGE Weld neck          SIF = 1.00
                                       Rating = 400, Weight = 35 lb
A09      9.49   -1.49    1.72 WEIGHT 17 lb    ,  No offsets
A10     12.15   -1.49    1.72 WEIGHT 27 lb    ,  No offsets
                                FLANGE Weld neck          SIF = 1.00
                                       Rating = 400, Weight = 35 lb
                                FLANGE Weld neck          SIF = 1.00
                                       Rating = 400, Weight = 35 lb
A11 N   12.86   -1.49    1.72
A11     13.19   -1.49    1.72 TI
A11 M   13.09   -1.59    1.72
A11 F   13.19   -1.82    1.72
A12     13.19   -1.89    1.72
A13     13.19   -1.93    1.72
A14 N   13.19   -2.03    1.72
A14     13.19   -2.53    1.72 TI
A14 M   13.19   -2.38    1.57
A14 F   13.19   -2.53    1.22
A14A    13.19   -2.53    1.06 Y-STOP ID : A14A 1, Connected to Ground
                                     Gap-Below = 0.00, Above = 1.00 inch
                                     Friction = 0.00
                                     Gaps set Weightless
A15     13.19   -2.53    0.42
```





## C O M P O N E N T D A T A L I S T I N G

```
POINT  ---COORDINATE(ft )---  DATA
NAME     X       Y       Z    TYPE  DESCRIPTION
-----  ------  ------  ------  ----  ----------------------------------------
*** SEGMENT B
B02     13.19   -2.84   -1.78
B03 N   13.19   -2.84   -2.70
B03     13.19   -2.84   -3.08 TI
B03 M   13.08   -2.84   -2.97
B03 F   12.81   -2.84   -3.08
B04 N   12.22   -2.84   -3.08
B04     11.89   -2.84   -3.08 TI
B04 M   11.99   -2.94   -3.08
B04 F   11.89   -3.17   -3.08
B05     11.89   -3.24   -3.08
B06     11.89   -3.28   -3.08
B07     11.89   -3.47   -3.08 ANCHOR Rigid
                                     Thermal movements : None

*** SEGMENT C
5       13.19    3.50   -1.78 ANCHOR Translational stiffness lb/in
                                     X= FREE      Y= FREE      Z= FREE
                                     Rotational stiffness ft-lb/deg
                                     X= RIGID     Y= RIGID     Z= RIGID
                                     Thermal movements : None
C01     13.19    3.50   -2.03 ANCHOR Rigid
                                     Thermal movements : None

*** SEGMENT D
3       13.19    3.50    0.42 ANCHOR Translational stiffness lb/in
                                     X= FREE      Y= FREE      Z= FREE
                                     Rotational stiffness ft-lb/deg
                                     X= RIGID     Y= RIGID     Z= RIGID
                                     Thermal movements : None
D01     13.19    3.50    0.67 ANCHOR Rigid
                                     Thermal movements : None

Number of points in the system : 51
```

## PIPE DATA LISTING

| Pipe ID/ Material | Nom/ Sch | O.D. inch | W.Th. | Thickness(inch) Corr | Mill | Insu | Ling | Spec Grav | Weight(lb/ft) Pipe | Other | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 4PIPE AU | 4 STD | 4.500 | 0.237 | 0.06 | 0.03 | 0 | 0 | 1.20 | 11.04 | 0 | 17.66 |
| 3.5PIPE AU | 3.500 STD | 4.000 | 0.226 | 0.06 | 0.03 | 0 | 0 | 0 | 9.32 | 0 | 9.32 |
| 3PIPE AU | 3.000 STD | 3.500 | 0.216 | 0.06 | 0.03 | 0 | 0 | 1.20 | 7.75 | 0 | 11.60 |



## MATERIAL DATA LISTING

| Material Name | Pipe ID | Density lb/cu.ft | Pois. Ratio | Temper. deg F | Modulus E6 psi | Expans. in/100ft | Allow. psi |
|---|---|---|---|---|---|---|---|
| AU | 4PIPE | 501.0 | 0.30 | 40.0 | 28.42 | | 16700.0 |
| | | | | 70.0 | | 0.3088 | 16700.0 |
| AU | 3PIPE | 501.0 | 0.30 | 40.0 | 28.42 | | 16700.0 |
| | | | | 70.0 | | 0.3088 | 16700.0 |
| AU | 3.5PIPE | 501.0 | 0.30 | 40.0 | 28.42 | | 16700.0 |
| | | | | 70.0 | | 0.3088 | 16700.0 |

FRAME POINT DATA LISTING

| POINT NAME | ---COORDINATE(ft )--- X | Y | Z | DATA TYPE | DESCRIPTION |
|---|---|---|---|---|---|
| A15 | 13.19 | -2.53 | 0.42 | | |
| 1 | 13.19 | -2.84 | -0.68 | Y-STOP | ID : 1 1, Connected to Ground<br>Gap-Below = 0.00, Above = 1.00 inch<br>Friction = 0.00<br>Gaps set Weightless |
| B02 | 13.19 | -2.84 | -1.78 | | |
| 5 | 13.19 | 3.50 | -1.78 | ANCHOR | Translational stiffness lb/in<br>X= FREE Y= FREE Z= FREE<br>Rotational stiffness ft-lb/deg<br>X= RIGID Y= RIGID Z= RIGID<br>Thermal movements : None |
| 4 | 13.19 | 3.50 | -0.68 | | |
| 3 | 13.19 | 3.50 | 0.42 | | |
| 6 | 13.19 | -2.04 | -0.68 | WEIGHT | 1000 lb , No offsets |
| 2 | 13.19 | -2.84 | 0.42 | | |
| 7 | 13.19 | 2.08 | -0.68 | WEIGHT | 2250 lb , Offsets in ft<br>DX = 0.00, DY = 0.00, DZ = 0.03 |





BEAM DATA LISTING

| BEAM ID | | POINT NAME | LENGTH (ft ) | SECTION ID/ MATERIAL ID | BETA ANGLE | RIGID END(ft) | RELEASE Ax | Y-Y | Z-Z |
|---|---|---|---|---|---|---|---|---|---|
| M2 | From | 2 | 1.10 | W4X13 | 0.00 | 0.00 | N | N | N |
| | To | 1 | | A36 | | 0.00 | N | N | N |
| M9 | From | 2 | 0.31 | W4X13 | 0.00 | 0.00 | N | N | N |
| | To | A15 | | A36 | | 0.00 | N | N | N |
| M1 | From | 1 | 1.10 | W4X13 | 0.00 | 0.00 | N | N | N |
| | To | B02 | | A36 | | 0.00 | N | N | N |
| M6 | From | 5 | 6.34 | W4X13 | 0.00 | 0.00 | N | N | N |
| | To | B02 | | A36 | | 0.00 | N | N | N |
| M3 | From | A15 | 6.03 | W4X13 | 0.00 | 0.00 | N | N | N |
| | To | 3 | | A36 | | 0.00 | N | N | N |
| M4 | From | 3 | 1.10 | W4X13 | 0.00 | 0.00 | N | N | N |
| | To | 4 | | A36 | | 0.00 | N | N | N |
| M5 | From | 4 | 1.10 | W4X13 | 0.00 | 0.00 | N | N | N |
| | To | 5 | | A36 | | 0.00 | N | N | N |
| M7 | From | 1 | 0.80 | XS12 | 0.00 | 0.00 | N | N | N |
| | To | 6 | | A36 | | 0.00 | N | N | N |
| M8 | From | 6 | 4.12 | XS12 | 0.00 | 0.00 | N | N | N |
| | To | 7 | | A36 | | 0.00 | N | N | N |
| M10 | From | 4 | 1.42 | XS12 | 0.00 | 0.00 | N | N | N |
| | To | 7 | | A36 | | 0.00 | N | N | N |





ICA14981JT

CROSS SECTION LISTING

| Section ID ID | Area(sq.in ) Axial | Y-Shear | Z-Shear | Inertia (in**4 ) Torsion | Y-Y Bend | Z-Z Bend |
|---|---|---|---|---|---|---|
| W4X13 | 3.83 | 1.16 | 1.86 | 0.2 | 3.9 | 11.3 |
| XS12 | 19.20 | 9.60 | 9.60 | 724.0 | 362.0 | 362.0 |



BEAM MATERIAL LISTING

| MATERIAL ID | Elastic modulus E6 psi | Poissons ratio | Yield Stress psi | Density lb/cu.ft | Expansion E-6 /F | Ultimate stress psi |
|---|---|---|---|---|---|---|
| A36 | 29.000 | 0.250 | 36000 | 490.00 | 6.50000 | 58000 |

TEMPERATURE AND PRESSURE DATA

| POINT NAME | -----CASE 1------ PRESS. psi | TEMPER deg F | EXPAN. in/100ft | -----CASE 2------ PRESS. psi | TEMPER deg F | EXPAN. in/100ft | -----CASE 3------ PRESS. psi | TEMPER deg F | EXPAN. in/100ft |
|---|---|---|---|---|---|---|---|---|---|
| *** SEGMENT A | | | | | | | | | |
| A00 | 490 | 70.00 | 0.309 | | | | | | |
| A14 F | 490 | 70.00 | 0.309 | | | | | | |
| A15 | 490 | 70.00 | 0.309 | | | | | | |
| *** SEGMENT B | | | | | | | | | |
| B02 | 490 | 70.00 | 0.309 | | | | | | |
| B03 F | 490 | 70.00 | 0.309 | | | | | | |
| B07 | 490 | 70.00 | 0.309 | | | | | | |
| *** SEGMENT C | | | | | | | | | |
| 5 | 490 | 70.00 | 0.309 | | | | | | |
| C01 | 490 | 70.00 | 0.309 | | | | | | |
| *** SEGMENT D | | | | | | | | | |
| 3 | 490 | 70.00 | 0.309 | | | | | | |
| D01 | 490 | 70.00 | 0.309 | | | | | | |





ANALYSIS SUMMARY

Current model revision number : 3

Static - Date and Time of analysis ..... Jun 28, 1996 11:05 AM
Model Revision Number ..... 3
Number of load cases ..... 3
Load cases analyzed ..... GR T1 P1
Gaps/Friction/Yielding considered ..... No
Hanger design run ..... No
Cut short included ..... No
Weight of contents included ..... Yes
Pressure stiffening case ..... 0
Water elevation for buoyancy loads .... Not considered





ICF-4PRINT

CODE COMPLIANCE COMBINATIONS

| Combination | Category | Method | Load | Factor | Allowable | Remarks |
|---|---|---|---|---|---|---|
| GR + Max P | Sustain | Sum | Gravity | 1.00 | Automatic | Default |
| | | | Max Long | 1.00 | | |
| Cold to T1 | Expansion | Sum | Thermal 1 | 1.00 | Automatic | Default |
| Max P | Hoop | | Max Hoop | 1.00 | Automatic | Default |

OTHER USER COMBINATIONS

| Combination | Method | Load | Factor | Remarks |
|---|---|---|---|---|
| GR | Sum | Gravity | 1.00 | Default |
| T1 | Sum | Thermal 1 | 1.00 | Default |
| P1 | Sum | Press 1 | 1.00 | Default |

CODE COMPLIANCE

Y - Factor ..... 0.40
Weld efficiency factor ..... 1.00
Range reduction factor ..... 1.00
Design Pressure Factor ..... 1.00
Minimum stress ratio used in reports... 0.00
Include corrosion in stress calcs. ..... Y
Include torsion in code stress ..... N
Include axial force in code stress .... N
Longitudinal pressure calculation ..... PD/4t
Include rigorous pressure ..... Y





D I S P L A C E M E N T S

| Point name | Load combination | TRANSLATIONS (in ) X | Y | Z | ROTATIONS (deg ) X | Y | Z |
|---|---|---|---|---|---|---|---|
| *** Segment A begin *** | | | | | | | |
| A00 | GR | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | T1 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | P1 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| A01 | GR | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | -0.002 |
| | T1 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | P1 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| A02 | GR | 0.000 | 0.000 | 0.000 | 0.153 | -0.015 | -0.124 |
| | T1 | 0.001 | 0.000 | 0.000 | 0.012 | 0.000 | -0.015 |
| | P1 | 0.000 | 0.000 | 0.000 | 0.001 | 0.000 | -0.002 |
| A03 N | GR | 0.000 | 0.000 | 0.000 | 0.153 | -0.015 | -0.124 |
| | T1 | 0.001 | 0.000 | 0.000 | 0.012 | 0.000 | -0.015 |
| | P1 | 0.000 | 0.000 | 0.000 | 0.001 | 0.000 | -0.002 |
| A03 M | GR | -0.002 | -0.003 | -0.002 | 0.151 | -0.015 | -0.128 |
| | T1 | 0.001 | -0.001 | -0.001 | 0.011 | 0.000 | -0.016 |
| | P1 | 0.000 | 0.000 | 0.000 | 0.001 | 0.000 | -0.002 |
| A03 F | GR | -0.009 | -0.004 | -0.010 | 0.154 | -0.014 | -0.132 |
| | T1 | 0.000 | -0.002 | -0.002 | 0.010 | -0.001 | -0.017 |
| | P1 | 0.000 | 0.000 | 0.000 | 0.001 | 0.000 | -0.002 |
| A04 N | GR | -0.027 | -0.004 | -0.031 | 0.156 | -0.015 | -0.134 |
| | T1 | -0.002 | -0.004 | -0.003 | 0.010 | -0.001 | -0.017 |
| | P1 | 0.000 | 0.000 | 0.000 | 0.001 | 0.000 | -0.002 |
| A04 M | GR | -0.037 | -0.008 | -0.042 | 0.159 | -0.014 | -0.142 |
| | T1 | -0.003 | -0.005 | -0.004 | 0.009 | -0.002 | -0.013 |
| | P1 | 0.000 | -0.001 | 0.000 | 0.001 | 0.000 | -0.001 |
| A04 F | GR | -0.041 | -0.019 | -0.046 | 0.161 | -0.014 | -0.147 |
| | T1 | -0.002 | -0.006 | -0.004 | 0.008 | -0.003 | -0.007 |
| | P1 | 0.000 | -0.001 | 0.000 | 0.001 | 0.000 | -0.001 |
| A05 N | GR | -0.041 | -0.139 | -0.032 | 0.175 | -0.013 | -0.093 |
| | T1 | 0.012 | -0.009 | 0.001 | 0.005 | -0.008 | 0.001 |
| | P1 | 0.001 | -0.001 | 0.000 | 0.000 | -0.001 | 0.000 |
| A05 M | GR | -0.042 | -0.150 | -0.032 | 0.165 | -0.011 | -0.052 |
| | T1 | 0.013 | -0.009 | 0.002 | 0.004 | -0.012 | 0.003 |
| | P1 | 0.001 | -0.001 | 0.000 | 0.000 | -0.001 | 0.000 |

D I S P L A C E M E N T S

| Point name | Load combination | TRANSLATIONS (in ) X | Y | Z | ROTATIONS (deg ) X | Y | Z |
|---|---|---|---|---|---|---|---|
| A05 F | GR | -0.042 | -0.163 | -0.031 | 0.155 | -0.010 | -0.033 |
| | T1 | 0.012 | -0.009 | 0.004 | 0.003 | -0.014 | 0.004 |
| | P1 | 0.001 | -0.001 | 0.000 | 0.000 | -0.001 | 0.000 |
| A06 N | GR | -0.045 | -0.196 | -0.031 | 0.154 | -0.011 | -0.001 |
| | T1 | 0.009 | -0.010 | 0.007 | 0.002 | -0.014 | 0.005 |
| | P1 | 0.001 | -0.001 | 0.001 | 0.000 | -0.001 | 0.001 |
| A06 M | GR | -0.046 | -0.206 | -0.031 | 0.137 | -0.016 | 0.020 |
| | T1 | 0.009 | -0.010 | 0.008 | 0.002 | -0.009 | 0.006 |
| | P1 | 0.001 | -0.001 | 0.001 | 0.000 | -0.001 | 0.001 |
| A06 F | GR | -0.046 | -0.207 | -0.029 | 0.122 | -0.023 | 0.068 |
| | T1 | 0.010 | -0.009 | 0.009 | 0.001 | -0.004 | 0.008 |
| | P1 | 0.001 | -0.001 | 0.001 | 0.000 | 0.000 | 0.001 |
| A07 | GR | -0.046 | -0.187 | -0.024 | 0.117 | -0.026 | 0.098 |
| | T1 | 0.013 | -0.007 | 0.010 | 0.001 | -0.001 | 0.009 |
| | P1 | 0.001 | -0.001 | 0.001 | 0.000 | 0.000 | 0.001 |
| A08 | GR | -0.046 | -0.166 | -0.018 | 0.113 | -0.028 | 0.124 |
| | T1 | 0.016 | -0.006 | 0.010 | 0.001 | 0.001 | 0.009 |
| | P1 | 0.002 | -0.001 | 0.001 | 0.000 | 0.000 | 0.001 |
| A09 | GR | -0.046 | -0.140 | -0.013 | 0.109 | -0.030 | 0.147 |
| | T1 | 0.019 | -0.004 | 0.009 | 0.001 | 0.003 | 0.009 |
| | P1 | 0.002 | 0.000 | 0.001 | 0.000 | 0.000 | 0.001 |
| A10 | GR | -0.046 | -0.044 | 0.005 | 0.097 | -0.034 | 0.186 |
| | T1 | 0.027 | 0.001 | 0.007 | 0.002 | 0.007 | 0.008 |
| | P1 | 0.003 | 0.000 | 0.001 | 0.000 | 0.001 | 0.001 |
| A11 N | GR | -0.046 | -0.017 | 0.010 | 0.094 | -0.035 | 0.186 |
| | T1 | 0.029 | 0.003 | 0.006 | 0.002 | 0.007 | 0.008 |
| | P1 | 0.003 | 0.000 | 0.001 | 0.000 | 0.001 | 0.001 |
| A11 M | GR | -0.042 | -0.008 | 0.010 | 0.091 | -0.038 | 0.176 |
| | T1 | 0.030 | 0.003 | 0.005 | 0.002 | 0.009 | 0.006 |
| | P1 | 0.003 | 0.000 | 0.001 | 0.000 | 0.001 | 0.001 |
| A11 F | GR | -0.034 | -0.004 | 0.007 | 0.085 | -0.040 | 0.160 |
| | T1 | 0.031 | 0.002 | 0.005 | 0.003 | 0.010 | 0.005 |
| | P1 | 0.003 | 0.000 | 0.000 | 0.000 | 0.001 | 0.001 |
| A12 | GR | -0.032 | -0.004 | 0.006 | 0.085 | -0.040 | 0.160 |
| | T1 | 0.031 | 0.002 | 0.005 | 0.003 | 0.010 | 0.005 |
| | P1 | 0.003 | 0.000 | 0.000 | 0.000 | 0.001 | 0.001 |





D I S P L A C E M E N T S

| Point name | Load combination | TRANSLATIONS (in ) X | Y | Z | ROTATIONS (deg ) X | Y | Z |
|---|---|---|---|---|---|---|---|
| A13 | GR | -0.031 | -0.004 | 0.005 | 0.046 | -0.096 | 0.058 |
| | T1 | 0.031 | 0.002 | 0.005 | 0.002 | 0.084 | 0.003 |
| | P1 | 0.003 | 0.000 | 0.000 | 0.000 | 0.009 | 0.000 |
| A14 N | GR | -0.030 | -0.004 | 0.004 | 0.045 | -0.096 | 0.057 |
| | T1 | 0.031 | 0.001 | 0.005 | 0.002 | 0.084 | 0.003 |
| | P1 | 0.003 | 0.000 | 0.000 | 0.000 | 0.009 | 0.000 |
| A14 M | GR | -0.023 | -0.003 | 0.001 | 0.037 | -0.092 | 0.041 |
| | T1 | 0.028 | 0.000 | 0.004 | 0.001 | 0.084 | 0.004 |
| | P1 | 0.003 | 0.000 | 0.000 | 0.000 | 0.009 | 0.000 |
| A14 F | GR | -0.015 | -0.001 | 0.000 | 0.018 | -0.087 | 0.033 |
| | T1 | 0.022 | 0.000 | 0.003 | 0.001 | 0.084 | 0.005 |
| | P1 | 0.002 | 0.000 | 0.000 | 0.000 | 0.009 | 0.000 |
| A14A | GR | -0.013 | 0.000 | 0.000 | 0.013 | -0.086 | 0.028 |
| | T1 | 0.019 | 0.000 | 0.003 | 0.001 | 0.084 | 0.005 |
| | P1 | 0.002 | 0.000 | 0.000 | 0.000 | 0.009 | 0.001 |
| A15 | GR | -0.001 | 0.000 | 0.000 | 0.000 | -0.084 | 0.008 |
| | T1 | 0.008 | 0.000 | 0.001 | 0.000 | 0.081 | 0.008 |
| | P1 | 0.001 | 0.000 | 0.000 | 0.000 | 0.008 | 0.001 |
| *** Segment A end *** | | | | | | | |
| *** Segment B begin *** | | | | | | | |
| B02 | GR | 0.000 | 0.000 | 0.000 | -0.001 | 0.000 | 0.000 |
| | T1 | 0.007 | 0.000 | 0.001 | 0.001 | 0.006 | 0.006 |
| | P1 | 0.001 | 0.000 | 0.000 | 0.000 | 0.001 | 0.001 |
| B03 N | GR | 0.000 | 0.000 | 0.000 | -0.001 | 0.000 | 0.000 |
| | T1 | 0.005 | 0.000 | -0.002 | 0.002 | 0.008 | 0.001 |
| | P1 | 0.001 | 0.000 | 0.000 | 0.000 | 0.001 | 0.000 |
| B03 M | GR | 0.000 | 0.000 | 0.000 | -0.001 | 0.000 | -0.001 |
| | T1 | 0.004 | 0.001 | -0.003 | 0.003 | 0.011 | -0.001 |
| | P1 | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 | 0.000 |
| B03 F | GR | 0.000 | 0.000 | 0.000 | -0.001 | 0.000 | -0.001 |
| | T1 | 0.003 | 0.001 | -0.002 | 0.003 | 0.013 | -0.005 |
| | P1 | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 | -0.001 |
| B04 N | GR | 0.000 | 0.000 | 0.000 | -0.001 | 0.000 | -0.001 |
| | T1 | 0.001 | 0.001 | -0.001 | 0.003 | 0.013 | -0.005 |
| | P1 | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 | -0.001 |

D I S P L A C E M E N T S

| Point name | Load combination | TRANSLATIONS (in ) X | Y | Z | ROTATIONS (deg ) X | Y | Z |
|---|---|---|---|---|---|---|---|
| B04 M | GR | 0.000 | 0.000 | 0.000 | -0.001 | 0.000 | -0.002 |
| | T1 | 0.001 | 0.001 | 0.000 | 0.003 | 0.014 | -0.005 |
| | P1 | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 | -0.001 |
| B04 F | GR | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | -0.001 |
| | T1 | 0.000 | 0.001 | 0.000 | 0.002 | 0.014 | -0.005 |
| | P1 | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 | -0.001 |
| B05 | GR | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | -0.001 |
| | T1 | 0.000 | 0.001 | 0.000 | 0.002 | 0.014 | -0.004 |
| | P1 | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 | -0.001 |
| B06 | GR | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | T1 | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 |
| | P1 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| B07 | GR | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | T1 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | P1 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| *** Segment B end *** | | | | | | | |
| *** Segment C begin *** | | | | | | | |
| 5 | GR | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | T1 | 0.000 | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 |
| | P1 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| C01 | GR | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | T1 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | P1 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| *** Segment C end *** | | | | | | | |
| *** Segment D begin *** | | | | | | | |
| 3 | GR | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | T1 | 0.000 | 0.000 | -0.001 | 0.000 | 0.000 | 0.000 |
| | P1 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| D01 | GR | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | T1 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | P1 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| *** Segment D end *** | | | | | | | |
| A15 | GR | -0.001 | 0.000 | 0.000 | 0.000 | -0.084 | 0.008 |
| | T1 | 0.008 | 0.000 | 0.001 | 0.000 | 0.081 | 0.008 |
| | P1 | 0.001 | 0.000 | 0.000 | 0.000 | 0.008 | 0.001 |





D I S P L A C E M E N T S

| Point name | Load combination | TRANSLATIONS (in ) X | Y | Z | ROTATIONS (deg ) X | Y | Z |
|---|---|---|---|---|---|---|---|
| 1 | GR | 0.000 | 0.000 | 0.000 | 0.000 | -0.001 | 0.000 |
| | T1 | 0.008 | 0.000 | 0.001 | 0.000 | 0.003 | 0.006 |
| | P1 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 |
| B02 | GR | 0.000 | 0.000 | 0.000 | -0.001 | 0.000 | 0.000 |
| | T1 | 0.007 | 0.000 | 0.001 | 0.001 | 0.006 | 0.006 |
| | P1 | 0.001 | 0.000 | 0.000 | 0.000 | 0.001 | 0.001 |
| 5 | GR | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | T1 | 0.000 | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 |
| | P1 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 4 | GR | 0.000 | 0.000 | 0.000 | 0.000 | -0.001 | 0.000 |
| | T1 | 0.000 | 0.000 | 0.000 | 0.000 | 0.002 | 0.006 |
| | P1 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 |
| 3 | GR | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | T1 | 0.000 | 0.000 | -0.001 | 0.000 | 0.000 | 0.000 |
| | P1 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 6 | GR | 0.000 | 0.000 | 0.000 | 0.000 | -0.001 | 0.000 |
| | T1 | 0.007 | 0.000 | 0.001 | -0.001 | 0.003 | 0.006 |
| | P1 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 |
| 2 | GR | -0.001 | 0.000 | 0.000 | -0.001 | -0.005 | 0.008 |
| | T1 | 0.009 | 0.000 | 0.001 | 0.000 | 0.008 | 0.008 |
| | P1 | 0.001 | 0.000 | 0.000 | 0.000 | 0.001 | 0.001 |
| 7 | GR | 0.000 | 0.000 | 0.000 | 0.000 | -0.001 | 0.000 |
| | T1 | 0.002 | 0.000 | 0.000 | -0.001 | 0.002 | 0.006 |
| | P1 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 |

## SUPPORT FORCES

| Point/ Supp. ID | Connect/ Type | Load Combination | LOCAL Dirn | LOCAL Force | LOCAL Deform | GLOBAL Dirn | GLOBAL Force | GLOBAL Deform |
|---|---|---|---|---|---|---|---|---|
| A14A | | GR | down | 1024 | 0.000 | X | | -0.013 |
| A14A 1 | Y - Stop | | | | | Y | -1024 | 0.000 |
| Stiff | :RIGID | | | | | Z | | 0.000 |
| | | T1 | down | 7 | 0.000 | X | | 0.019 |
| | | | | | | Y | -7 | 0.000 |
| | | | | | | Z | | 0.003 |
| | | P1 | down | 1 | 0.000 | X | | 0.002 |
| | | | | | | Y | -1 | 0.000 |
| | | | | | | Z | | 0.000 |
| 1 | | GR | down | 3293 | 0.000 | X | | 0.000 |
| 1 1 | Y - Stop | | | | | Y | -3293 | 0.000 |
| Stiff | :RIGID | | | | | Z | | 0.000 |
| | | T1 | down | 11 | 0.000 | X | | 0.008 |
| | | | | | | Y | -11 | 0.000 |
| | | | | | | Z | | 0.001 |
| | | P1 | down | 1 | 0.000 | X | | 0.001 |
| | | | | | | Y | -1 | 0.000 |
| | | | | | | Z | | 0.000 |



## RESTRAINT REACTIONS

| Point name | Load combination | FORCES (lb) X | FORCES (lb) Y | FORCES (lb) Z | FORCES (lb) Result | MOMENTS (ft-lb) X | MOMENTS (ft-lb) Y | MOMENTS (ft-lb) Z | MOMENTS (ft-lb) Result |
|---|---|---|---|---|---|---|---|---|---|
| A00 | Anchor | | | | | | | | |
| | GR | 57 | -358 | 9 | 362 | -28 | -39 | -186 | 193 |
| | T1 | -58 | 7 | -6 | 59 | -2 | 8 | -16 | 18 |
| | P1 | -6 | 1 | -1 | 6 | 0 | 1 | -2 | 2 |
| A14A | Y - Stop | | | | | | | | |
| | GR | 0 | -1024 | 0 | 1024 | 0 | 0 | 0 | 0 |
| | T1 | 0 | -7 | 0 | 7 | 0 | 0 | 0 | 0 |
| | P1 | 0 | -1 | 0 | 1 | 0 | 0 | 0 | 0 |
| B07 | Anchor | | | | | | | | |
| | GR | 5 | -167 | 2 | 167 | -1 | 0 | -4 | 4 |
| | T1 | 2 | -39 | -21 | 44 | 0 | 4 | -10 | 10 |
| | P1 | 0 | -5 | -2 | 5 | 0 | 0 | -1 | 1 |
| 5 | Anchor | | | | | | | | |
| | GR | 0 | 0 | 0 | 0 | 50 | 4 | 2 | 50 |
| | T1 | 0 | 0 | 0 | 0 | -1 | -14 | 57 | 59 |
| | P1 | 0 | 0 | 0 | 0 | 0 | -1 | 6 | 6 |
| C01 | Anchor | | | | | | | | |
| | GR | 22 | -231 | -6 | 232 | 29 | 3 | 0 | 29 |
| | T1 | -56 | -3 | -4864 | 4864 | 0 | -7 | 0 | 7 |
| | P1 | -5 | 2 | -435 | 435 | 0 | -1 | 0 | 1 |
| 3 | Anchor | | | | | | | | |
| | GR | 0 | 0 | 0 | 0 | -80 | 13 | -134 | 156 |
| | T1 | 0 | 0 | 0 | 0 | -8 | -33 | 150 | 153 |
| | P1 | 0 | 0 | 0 | 0 | -1 | -3 | 15 | 16 |
| D01 | Anchor | | | | | | | | |
| | GR | -84 | 154 | -5 | 175 | 19 | 10 | 0 | 22 |
| | T1 | 112 | 52 | 4891 | 4892 | 7 | -14 | 0 | 15 |
| | P1 | 11 | 5 | 437 | 438 | 1 | -1 | 0 | 2 |
| 1 | Y - Stop | | | | | | | | |
| | GR | 0 | -3293 | 0 | 3293 | 0 | 0 | 0 | 0 |
| | T1 | 0 | -11 | 0 | 11 | 0 | 0 | 0 | 0 |
| | P1 | 0 | -1 | 0 | 1 | 0 | 0 | 0 | 0 |
| 5 | Anchor | | | | | | | | |
| | GR | 0 | 0 | 0 | 0 | 50 | 4 | 2 | 50 |
| | T1 | 0 | 0 | 0 | 0 | -1 | -14 | 57 | 59 |
| | P1 | 0 | 0 | 0 | 0 | 0 | -1 | 6 | 6 |

## G L O B A L F O R C E S & M O M E N T S

| Point name | Load combination | FORCES (lb ) X | Y | Z | Result | MOMENTS (ft-lb ) X | Y | Z | Result |
|---|---|---|---|---|---|---|---|---|---|
| *** Segment A begin *** | | | | | | | | | |
| A00 | GR | -57 | 358 | -9 | 362 | 28 | 39 | 186 | 193 |
| | T1 | 58 | -7 | 6 | 59 | 2 | -8 | 16 | 18 |
| | P1 | 6 | -1 | 1 | 6 | 0 | -1 | 2 | 2 |
| A01 | GR | -57 | 209 | -9 | 217 | -11 | 31 | 108 | 113 |
| | T1 | 58 | -7 | 6 | 59 | 3 | 0 | 18 | 18 |
| | P1 | 6 | -1 | 1 | 6 | 0 | 0 | 2 | 2 |
| A02 | GR | -57 | 209 | -9 | 217 | -16 | 29 | 97 | 103 |
| | T1 | 58 | -7 | 6 | 59 | 3 | 1 | 18 | 18 |
| | P1 | 6 | -1 | 1 | 6 | 0 | 0 | 2 | 2 |
| A03 N | GR | -57 | 209 | -9 | 217 | -17 | 29 | 97 | 102 |
| | T1 | 58 | -7 | 6 | 59 | 3 | 1 | 18 | 18 |
| | P1 | 6 | -1 | 1 | 6 | 0 | 0 | 2 | 2 |
| A03 M | GR | -57 | 205 | -9 | 212 | -39 | 21 | 58 | 74 |
| | T1 | 58 | -7 | 6 | 59 | 5 | 9 | 14 | 17 |
| | P1 | 6 | -1 | 1 | 6 | 0 | 1 | 1 | 2 |
| A03 F | GR | -57 | 200 | -9 | 208 | -50 | 18 | 54 | 76 |
| | T1 | 58 | -7 | 6 | 59 | 6 | 12 | 1 | 13 |
| | P1 | 6 | -1 | 1 | 6 | 1 | 1 | 0 | 1 |
| A04 N | GR | -57 | 188 | -9 | 197 | -56 | 18 | 91 | 109 |
| | T1 | 58 | -7 | 6 | 59 | 11 | 12 | -37 | 40 |
| | P1 | 6 | -1 | 1 | 6 | 1 | 1 | -4 | 4 |
| A04 M | GR | -57 | 181 | -9 | 190 | -60 | 17 | 84 | 105 |
| | T1 | 58 | -7 | 6 | 59 | 13 | 13 | -57 | 59 |
| | P1 | 6 | -1 | 1 | 6 | 1 | 1 | -6 | 6 |
| A04 F | GR | -57 | 174 | -9 | 184 | -61 | 14 | 30 | 69 |
| | T1 | 58 | -7 | 6 | 59 | 14 | 15 | -63 | 66 |
| | P1 | 6 | -1 | 1 | 6 | 1 | 2 | -7 | 7 |
| A05 N | GR | -57 | 96 | -9 | 112 | -61 | -27 | -573 | 577 |
| | T1 | 58 | -7 | 6 | 59 | 14 | 44 | -30 | 55 |
| | P1 | 6 | -1 | 1 | 6 | 1 | 5 | -3 | 6 |
| A05 M | GR | -57 | 89 | -9 | 106 | -48 | -22 | -605 | 608 |
| | T1 | 58 | -7 | 6 | 59 | 13 | 38 | -27 | 48 |
| | P1 | 6 | -1 | 1 | 6 | 1 | 4 | -3 | 5 |





## G L O B A L F O R C E S & M O M E N T S

| Point name | Load combination | FORCES (lb ) X | Y | Z | Result | MOMENTS (ft-lb ) X | Y | Z | Result |
|---|---|---|---|---|---|---|---|---|---|
| A05 F | GR | -57 | 82 | -9 | 100 | -17 | -3 | -618 | 618 |
| | T1 | 58 | -7 | 6 | 59 | 10 | 18 | -26 | 33 |
| | P1 | 6 | -1 | 1 | 6 | 1 | 2 | -3 | 3 |
| A06 N | GR | -57 | 64 | -9 | 86 | 56 | 54 | -618 | 623 |
| | T1 | 58 | -7 | 6 | 59 | 3 | -40 | -26 | 48 |
| | P1 | 6 | -1 | 1 | 6 | 0 | -4 | -3 | 5 |
| A06 M | GR | -57 | 57 | -9 | 81 | 77 | 72 | -627 | 636 |
| | T1 | 58 | -7 | 6 | 59 | 0 | -59 | -25 | 64 |
| | P1 | 6 | -1 | 1 | 6 | 0 | -6 | -3 | 7 |
| A06 F | GR | -57 | 50 | -9 | 76 | 85 | 77 | -646 | 656 |
| | T1 | 58 | -7 | 6 | 59 | -1 | -66 | -22 | 69 |
| | P1 | 6 | -1 | 1 | 6 | 0 | -7 | -2 | 7 |
| A07 - | GR | -57 | 30 | -9 | 65 | 85 | 67 | -691 | 700 |
| | T1 | 58 | -7 | 6 | 59 | -1 | -58 | -14 | 60 |
| | P1 | 6 | -1 | 1 | 6 | 0 | -6 | -1 | 6 |
| A07 + | GR | -57 | 7 | -9 | 58 | 85 | 67 | -691 | 700 |
| | T1 | 58 | -7 | 6 | 59 | -1 | -58 | -14 | 60 |
| | P1 | 6 | -1 | 1 | 6 | 0 | -6 | -1 | 6 |
| A08 - | GR | -57 | -9 | -9 | 58 | 85 | 59 | -691 | 698 |
| | T1 | 58 | -7 | 6 | 59 | -1 | -52 | -7 | 53 |
| | P1 | 6 | -1 | 1 | 6 | 0 | -5 | -1 | 5 |
| A08 + | GR | -57 | -114 | -9 | 128 | 85 | 59 | -691 | 698 |
| | T1 | 58 | -7 | 6 | 59 | -1 | -52 | -7 | 53 |
| | P1 | 6 | -1 | 1 | 6 | 0 | -5 | -1 | 5 |
| A09 - | GR | -57 | -130 | -9 | 142 | 85 | 50 | -578 | 587 |
| | T1 | 58 | -7 | 6 | 59 | -1 | -46 | 0 | 46 |
| | P1 | 6 | -1 | 1 | 6 | 0 | -5 | 0 | 5 |
| A09 + | GR | -57 | -147 | -9 | 158 | 85 | 50 | -578 | 587 |
| | T1 | 58 | -7 | 6 | 59 | -1 | -46 | 0 | 46 |
| | P1 | 6 | -1 | 1 | 6 | 0 | -5 | 0 | 5 |
| A10 - | GR | -57 | -194 | -9 | 202 | 85 | 26 | -124 | 153 |
| | T1 | 58 | -7 | 6 | 59 | -1 | -29 | 19 | 35 |
| | P1 | 6 | -1 | 1 | 6 | 0 | -3 | 2 | 4 |
| A10 + | GR | -57 | -291 | -9 | 297 | 85 | 26 | -124 | 153 |
| | T1 | 58 | -7 | 6 | 59 | -1 | -29 | 19 | 35 |
| | P1 | 6 | -1 | 1 | 6 | 0 | -3 | 2 | 4 |

G L O B A L F O R C E S & M O M E N T S

| Point name | Load combination | FORCES (lb ) X | Y | Z | Result | MOMENTS (ft-lb ) X | Y | Z | Result |
|---|---|---|---|---|---|---|---|---|---|
| A11 N | GR | -57 | -304 | -9 | 309 | 85 | 20 | 86 | 122 |
| | T1 | 58 | -7 | 6 | 59 | -1 | -25 | 25 | 35 |
| | P1 | 6 | -1 | 1 | 6 | 0 | -3 | 3 | 4 |
| A11 M | GR | -57 | -308 | -9 | 314 | 84 | 18 | 163 | 185 |
| | T1 | 58 | -7 | 6 | 59 | 0 | -23 | 21 | 31 |
| | P1 | 6 | -1 | 1 | 6 | 0 | -2 | 2 | 3 |
| A11 F | GR | -57 | -313 | -9 | 318 | 82 | 17 | 207 | 223 |
| | T1 | 58 | -7 | 6 | 59 | 1 | -22 | 8 | 24 |
| | P1 | 6 | -1 | 1 | 6 | 0 | -2 | 1 | 2 |
| A12 | GR | -57 | -458 | -9 | 462 | 82 | 17 | 211 | 227 |
| | T1 | 58 | -7 | 6 | 59 | 2 | -22 | 4 | 23 |
| | P1 | 6 | -1 | 1 | 6 | 0 | -2 | 0 | 2 |
| A13 | GR | -57 | -458 | -9 | 462 | 81 | 17 | 213 | 229 |
| | T1 | 58 | -7 | 6 | 59 | 2 | -22 | 1 | 23 |
| | P1 | 6 | -1 | 1 | 6 | 0 | -2 | 0 | 2 |
| A14 N | GR | -57 | -460 | -9 | 463 | 80 | 17 | 219 | 234 |
| | T1 | 58 | -7 | 6 | 59 | 3 | -22 | -4 | 23 |
| | P1 | 6 | -1 | 1 | 6 | 0 | -2 | 0 | 2 |
| A14 M | GR | -57 | -467 | -9 | 470 | 145 | 9 | 239 | 279 |
| | T1 | 58 | -7 | 6 | 59 | 6 | -14 | -25 | 29 |
| | P1 | 6 | -1 | 1 | 6 | 1 | -1 | -3 | 3 |
| A14 F | GR | -57 | -474 | -9 | 477 | 310 | -12 | 247 | 397 |
| | T1 | 58 | -7 | 6 | 59 | 10 | 7 | -33 | 35 |
| | P1 | 6 | -1 | 1 | 6 | 1 | 1 | -3 | 4 |
| A14A - | GR | -57 | -476 | -9 | 479 | 386 | -21 | 247 | 459 |
| | T1 | 58 | -7 | 6 | 59 | 11 | 16 | -33 | 38 |
| | P1 | 6 | -1 | 1 | 6 | 1 | 2 | -3 | 4 |
| A14A + | GR | -57 | 549 | -9 | 552 | 386 | -21 | 247 | 459 |
| | T1 | 58 | 0 | 6 | 58 | 11 | 16 | -33 | 38 |
| | P1 | 6 | 0 | 1 | 6 | 1 | 2 | -3 | 4 |
| A15 | GR | -57 | 541 | -9 | 544 | 37 | -57 | 247 | 256 |
| | T1 | 58 | 0 | 6 | 58 | 11 | 53 | -33 | 63 |
| | P1 | 6 | 0 | 1 | 6 | 1 | 6 | -3 | 7 |

*** Segment A end ***

*** Segment B begin ***





G L O B A L F O R C E S & M O M E N T S

| Point name | Load combination | FORCES (lb ) X | Y | Z | Result | MOMENTS (ft-lb ) X | Y | Z | Result |
|---|---|---|---|---|---|---|---|---|---|
| B02 | GR | 5 | 19 | 2 | 20 | 13 | -5 | 4 | 15 |
| | T1 | 2 | -39 | -21 | 44 | -38 | -25 | 43 | 62 |
| | P1 | 0 | -5 | -2 | 5 | -5 | -2 | 5 | 7 |
| B03 N | GR | 5 | 8 | 2 | 10 | 1 | 0 | 4 | 4 |
| | T1 | 2 | -39 | -21 | 44 | -1 | -23 | 43 | 49 |
| | P1 | 0 | -5 | -2 | 5 | 0 | -2 | 5 | 6 |
| B03 M | GR | 5 | 5 | 2 | 7 | -1 | 1 | 5 | 5 |
| | T1 | 2 | -39 | -21 | 44 | 9 | -21 | 38 | 44 |
| | P1 | 0 | -5 | -2 | 5 | 1 | -2 | 5 | 5 |
| B03 F | GR | 5 | 2 | 2 | 5 | -2 | 1 | 5 | 6 |
| | T1 | 2 | -39 | -21 | 44 | 13 | -15 | 28 | 34 |
| | P1 | 0 | -5 | -2 | 5 | 1 | -1 | 3 | 4 |
| B04 N | GR | 5 | -9 | 2 | 10 | -2 | 0 | 3 | 4 |
| | T1 | 2 | -39 | -21 | 44 | 13 | -3 | 5 | 14 |
| | P1 | 0 | -5 | -2 | 5 | 1 | 0 | 0 | 2 |
| B04 M | GR | 5 | -13 | 2 | 14 | -1 | 0 | 0 | 1 |
| | T1 | 2 | -39 | -21 | 44 | 11 | 2 | -5 | 12 |
| | P1 | 0 | -5 | -2 | 5 | 1 | 0 | -1 | 2 |
| B04 F | GR | 5 | -18 | 2 | 19 | -1 | 0 | -2 | 3 |
| | T1 | 2 | -39 | -21 | 44 | 6 | 4 | -9 | 12 |
| | P1 | 0 | -5 | -2 | 5 | 1 | 0 | -1 | 2 |
| B05 | GR | 5 | -163 | 2 | 163 | -1 | 0 | -3 | 3 |
| | T1 | 2 | -39 | -21 | 44 | 5 | 4 | -9 | 11 |
| | P1 | 0 | -5 | -2 | 5 | 1 | 0 | -1 | 2 |
| B06 | GR | 5 | -163 | 2 | 163 | -1 | 0 | -3 | 3 |
| | T1 | 2 | -39 | -21 | 44 | 4 | 4 | -9 | 11 |
| | P1 | 0 | -5 | -2 | 5 | 1 | 0 | -1 | 2 |
| B07 | GR | 5 | -167 | 2 | 167 | -1 | 0 | -4 | 4 |
| | T1 | 2 | -39 | -21 | 44 | 0 | 4 | -10 | 10 |
| | P1 | 0 | -5 | -2 | 5 | 0 | 0 | -1 | 1 |

*** Segment B end ***

*** Segment C begin ***

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 5 | GR | 22 | -229 | -6 | 230 | -29 | -3 | 0 | 29 |
| | T1 | -56 | -3 | -4864 | 4864 | 0 | 7 | 0 | 7 |
| | P1 | -5 | 2 | -435 | 435 | 0 | 1 | 0 | 1 |

## GLOBAL FORCES & MOMENTS

| Point name | Load combination | FORCES (lb) X | Y | Z | Result | MOMENTS (ft-lb) X | Y | Z | Result |
|---|---|---|---|---|---|---|---|---|---|
| C01 | GR | 22 | -231 | -6 | 232 | 29 | 3 | 0 | 29 |
| | T1 | -56 | -3 | -4864 | 4864 | 0 | -7 | 0 | 7 |
| | P1 | -5 | 2 | -435 | 435 | 0 | -1 | 0 | 1 |
| *** Segment C end *** | | | | | | | | | |
| *** Segment D begin *** | | | | | | | | | |
| 3 | GR | -84 | 156 | -5 | 177 | -19 | -10 | 0 | 22 |
| | T1 | 112 | 52 | 4891 | 4892 | -7 | 14 | 0 | 15 |
| | P1 | 11 | 5 | 437 | 438 | -1 | 1 | 0 | 2 |
| D01 | GR | -84 | 154 | -5 | 175 | 19 | 10 | 0 | 22 |
| | T1 | 112 | 52 | 4891 | 4892 | 7 | -14 | 0 | 15 |
| | P1 | 11 | 5 | 437 | 438 | 1 | -1 | 0 | 2 |
| *** Segment D end *** | | | | | | | | | |





## ASME B31.3c (1992) CODE COMPLIANCE

| Point name | Load combination | (Moments in ft-lb) In-Pl. Moment | Out-Pl. Moment | Torsion Moment | S.I.F In | S.I.F Out | Eq. no. | (Stress in psi) Load type | Code Stress | Code Allow. |
|---|---|---|---|---|---|---|---|---|---|---|
| *** Segment A begin *** | | | | | | | | | | |
| A00 | Max P | | | | | | (3a) | HOOP | 7304 | 16700 |
| | GR + Max P | 181 | 38 | | 1.00 | 1.00 | (18) | SUST | 4000 | 16700 |
| | Cold to T1 | 15 | 8 | 5 | 1.00 | 1.00 | (17) | DISP | 68 | 25050 |
| A01 | Max P | | | | | | (3a) | HOOP | 7304 | 16700 |
| | GR + Max P | 94 | 31 | | 1.00 | 1.00 | (18) | SUST | 3586 | 16700 |
| | Cold to T1 | 17 | 0 | 5 | 1.00 | 1.00 | (17) | DISP | 67 | 25050 |
| A02 | Max P | | | | | | (3a) | HOOP | 7304 | 16700 |
| | GR + Max P | 81 | 29 | | 1.00 | 1.00 | (18) | SUST | 3527 | 16700 |
| | Cold to T1 | 17 | 1 | 5 | 1.00 | 1.00 | (17) | DISP | 68 | 25050 |
| A03 N- | Max P | | | | | | (3a) | HOOP | 7304 | 16700 |
| | GR + Max P | 81 | 29 | | 1.00 | 1.00 | (18) | SUST | 3525 | 16700 |
| | Cold to T1 | 17 | 1 | 5 | 1.00 | 1.00 | (17) | DISP | 68 | 25050 |
| A03 N+ | Max P | | | | | | (3a) | HOOP | 7304 | 16700 |
| | GR + Max P | 81 | 29 | | 2.56 | 2.13 | (18) | SUST | 4148 | 16700 |
| | Cold to T1 | 17 | 1 | 5 | 2.56 | 2.13 | (17) | DISP | 168 | 25050 |
| A03 M | Max P | | | | | | (3a) | HOOP | 7304 | 16700 |
| | GR + Max P | 36 | 28 | | 2.56 | 2.13 | (18) | SUST | 3639 | 16700 |
| | Cold to T1 | 14 | 5 | 8 | 2.56 | 2.13 | (17) | DISP | 145 | 25050 |
| A03 F- | Max P | | | | | | (3a) | HOOP | 7304 | 16700 |
| | GR + Max P | 26 | 69 | | 2.56 | 2.13 | (18) | SUST | 3887 | 16700 |
| | Cold to T1 | 4 | 5 | 12 | 2.56 | 2.13 | (17) | DISP | 70 | 25050 |
| A03 F+ | Max P | | | | | | (3a) | HOOP | 7304 | 16700 |
| | GR + Max P | 50 | 54 | | 1.00 | 1.00 | (18) | SUST | 3467 | 16700 |
| | Cold to T1 | 6 | 1 | 12 | 1.00 | 1.00 | (17) | DISP | 50 | 25050 |
| A04 N- | Max P | | | | | | (3a) | HOOP | 7304 | 16700 |
| | GR + Max P | 55 | 87 | | 1.00 | 1.00 | (18) | SUST | 3610 | 16700 |
| | Cold to T1 | 11 | 37 | 12 | 1.00 | 1.00 | (17) | DISP | 151 | 25050 |
| A04 N+ | Max P | | | | | | (3a) | HOOP | 7304 | 16700 |
| | GR + Max P | 87 | 55 | | 1.95 | 1.63 | (18) | SUST | 4039 | 16700 |
| | Cold to T1 | 37 | 11 | 12 | 1.95 | 1.63 | (17) | DISP | 283 | 25050 |
| A04 M | Max P | | | | | | (3a) | HOOP | 7304 | 16700 |
| | GR + Max P | 78 | 28 | | 1.95 | 1.63 | (18) | SUST | 3880 | 16700 |
| | Cold to T1 | 57 | 18 | 0 | 1.95 | 1.63 | (17) | DISP | 427 | 25050 |

ASME B31.3c (1992) CODE COMPLIANCE

| Point name | Load combination | In-Pl. Moment (Moments in ft-lb) | Out-Pl. Moment | Torsion Moment | S.I.F In | S.I.F Out | Eq. no. | Load type (Stress in psi) | Code Stress | Code Allow. |
|---|---|---|---|---|---|---|---|---|---|---|
| A04 F- | Max P | | | | | | (3a) | HOOP | 7304 | 16700 |
| | GR + Max P | 23 | 15 | | 1.95 | 1.63 | (18) | SUST | 3360 | 16700 |
| | Cold to T1 | 63 | 15 | 14 | 1.95 | 1.63 | (17) | DISP | 468 | 25050 |
| A04 F+ | Max P | | | | | | (3a) | HOOP | 7304 | 16700 |
| | GR + Max P | 23 | 15 | | 1.00 | 1.00 | (18) | SUST | 3245 | 16700 |
| | Cold to T1 | 63 | 15 | 14 | 1.00 | 1.00 | (17) | DISP | 246 | 25050 |
| A05 N- | Max P | | | | | | (3a) | HOOP | 7304 | 16700 |
| | GR + Max P | 576 | 22 | | 1.00 | 1.00 | (18) | SUST | 5878 | 16700 |
| | Cold to T1 | 30 | 44 | 14 | 1.00 | 1.00 | (17) | DISP | 204 | 25050 |
| A05 N+ | Max P | | | | | | (3a) | HOOP | 7304 | 16700 |
| | GR + Max P | 22 | 576 | | 1.95 | 1.63 | (18) | SUST | 7614 | 16700 |
| | Cold to T1 | 44 | 30 | 14 | 1.95 | 1.63 | (17) | DISP | 370 | 25050 |
| A05 M | Max P | | | | | | (3a) | HOOP | 7304 | 16700 |
| | GR + Max P | 18 | 397 | | 1.95 | 1.63 | (18) | SUST | 6221 | 16700 |
| | Cold to T1 | 38 | 28 | 10 | 1.95 | 1.63 | (17) | DISP | 325 | 25050 |
| A05 F- | Max P | | | | | | (3a) | HOOP | 7304 | 16700 |
| | GR + Max P | 1 | 16 | | 1.95 | 1.63 | (18) | SUST | 3242 | 16700 |
| | Cold to T1 | 18 | 10 | 26 | 1.95 | 1.63 | (17) | DISP | 175 | 25050 |
| A05 F+ | Max P | | | | | | (3a) | HOOP | 7304 | 16700 |
| | GR + Max P | 16 | 1 | | 1.00 | 1.00 | (18) | SUST | 3193 | 16700 |
| | Cold to T1 | 10 | 18 | 26 | 1.00 | 1.00 | (17) | DISP | 124 | 25050 |
| A06 N- | Max P | | | | | | (3a) | HOOP | 7304 | 16700 |
| | GR + Max P | 56 | 49 | | 1.00 | 1.00 | (18) | SUST | 3472 | 16700 |
| | Cold to T1 | 3 | 40 | 26 | 1.00 | 1.00 | (17) | DISP | 178 | 25050 |
| A06 N+ | Max P | | | | | | (3a) | HOOP | 7304 | 16700 |
| | GR + Max P | 49 | 56 | | 1.95 | 1.63 | (18) | SUST | 3750 | 16700 |
| | Cold to T1 | 40 | 3 | 26 | 1.95 | 1.63 | (17) | DISP | 307 | 25050 |
| A06 M | Max P | | | | | | (3a) | HOOP | 7304 | 16700 |
| | GR + Max P | 66 | 500 | | 1.95 | 1.63 | (18) | SUST | 7063 | 16700 |
| | Cold to T1 | 59 | 18 | 17 | 1.95 | 1.63 | (17) | DISP | 451 | 25050 |
| A06 F- | Max P | | | | | | (3a) | HOOP | 7304 | 16700 |
| | GR + Max P | 70 | 648 | | 1.95 | 1.63 | (18) | SUST | 8216 | 16700 |
| | Cold to T1 | 66 | 22 | 1 | 1.95 | 1.63 | (17) | DISP | 497 | 25050 |
| A06 F+ | Max P | | | | | | (3a) | HOOP | 7304 | 16700 |
| | GR + Max P | 648 | 70 | | 1.00 | 1.00 | (18) | SUST | 6241 | 16700 |
| | Cold to T1 | 22 | 66 | 1 | 1.00 | 1.00 | (17) | DISP | 259 | 25050 |



ASME B31.3c (1992) CODE COMPLIANCE

| Point name | Load combination | In-Pl. Moment (Moments in ft-lb) | Out-Pl. Moment | Torsion Moment | S.I.F In | S.I.F Out | Eq. no. | Load type (Stress in psi) | Code Stress | Code Allow. |
|---|---|---|---|---|---|---|---|---|---|---|
| A07 | Max P | | | | | | (3a) | HOOP | 7304 | 16700 |
| | GR + Max P | 693 | 61 | | 1.00 | 1.00 | (18) | SUST | 6450 | 16700 |
| | Cold to T1 | 14 | 58 | 1 | 1.00 | 1.00 | (17) | DISP | 224 | 25050 |
| A08 | Max P | | | | | | (3a) | HOOP | 7304 | 16700 |
| | GR + Max P | 691 | 53 | | 1.00 | 1.00 | (18) | SUST | 6440 | 16700 |
| | Cold to T1 | 7 | 52 | 1 | 1.00 | 1.00 | (17) | DISP | 197 | 25050 |
| A09 | Max P | | | | | | (3a) | HOOP | 7304 | 16700 |
| | GR + Max P | 578 | 46 | | 1.00 | 1.00 | (18) | SUST | 5896 | 16700 |
| | Cold to T1 | 0 | 46 | 1 | 1.00 | 1.00 | (17) | DISP | 173 | 25050 |
| A10 | Max P | | | | | | (3a) | HOOP | 7304 | 16700 |
| | GR + Max P | 122 | 23 | | 1.00 | 1.00 | (18) | SUST | 3710 | 16700 |
| | Cold to T1 | 19 | 29 | 1 | 1.00 | 1.00 | (17) | DISP | 131 | 25050 |
| A11 N- | Max P | | | | | | (3a) | HOOP | 7304 | 16700 |
| | GR + Max P | 88 | 17 | | 1.00 | 1.00 | (18) | SUST | 3544 | 16700 |
| | Cold to T1 | 25 | 25 | 1 | 1.00 | 1.00 | (17) | DISP | 130 | 25050 |
| A11 N+ | Max P | | | | | | (3a) | HOOP | 7304 | 16700 |
| | GR + Max P | 88 | 17 | | 2.56 | 2.13 | (18) | SUST | 4211 | 16700 |
| | Cold to T1 | 25 | 25 | 1 | 2.56 | 2.13 | (17) | DISP | 305 | 25050 |
| A11 M | Max P | | | | | | (3a) | HOOP | 7304 | 16700 |
| | GR + Max P | 166 | 70 | | 2.56 | 2.13 | (18) | SUST | 5269 | 16700 |
| | Cold to T1 | 21 | 16 | 16 | 2.56 | 2.13 | (17) | DISP | 244 | 25050 |
| A11 F- | Max P | | | | | | (3a) | HOOP | 7304 | 16700 |
| | GR + Max P | 208 | 82 | | 2.56 | 2.13 | (18) | SUST | 5801 | 16700 |
| | Cold to T1 | 8 | 1 | 22 | 2.56 | 2.13 | (17) | DISP | 112 | 25050 |
| A11 F+ | Max P | | | | | | (3a) | HOOP | 7304 | 16700 |
| | GR + Max P | 82 | 208 | | 1.00 | 1.00 | (18) | SUST | 4187 | 16700 |
| | Cold to T1 | 1 | 8 | 22 | 1.00 | 1.00 | (17) | DISP | 89 | 25050 |
| A12 | Max P | | | | | | (3a) | HOOP | 7304 | 16700 |
| | GR + Max P | 82 | 211 | | 1.00 | 1.00 | (18) | SUST | 4201 | 16700 |
| | Cold to T1 | 2 | 4 | 22 | 1.00 | 1.00 | (17) | DISP | 85 | 25050 |
| A13 | Max P | | | | | | (3a) | HOOP | 7304 | 16700 |
| | GR + Max P | 81 | 213 | | 1.00 | 1.00 | (18) | SUST | 4209 | 16700 |
| | Cold to T1 | 2 | 1 | 22 | 1.00 | 1.00 | (17) | DISP | 84 | 25050 |
| A14 N- | Max P | | | | | | (3a) | HOOP | 7304 | 16700 |
| | GR + Max P | 80 | 218 | | 1.00 | 1.00 | (18) | SUST | 4231 | 16700 |
| | Cold to T1 | 3 | 4 | 22 | 1.00 | 1.00 | (17) | DISP | 86 | 25050 |

ASME B31.3c (1992) CODE COMPLIANCE

| Point name | Load combination | (Moments in ft-lb) In-Pl. Moment | Out-Pl. Moment | Torsion Moment | S.I.F In | S.I.F Out | Eq. no. | Load type | (Stress in psi) Code Stress | Code Allow. |
|---|---|---|---|---|---|---|---|---|---|---|
| A14 N+ | Max P | | | | | | (3a) | HOOP | 7304 | 16700 |
| | GR + Max P | 80 | 218 | | 1.95 | 1.63 | (18) | SUST | 4978 | 16700 |
| | Cold to T1 | 3 | 4 | 22 | 1.95 | 1.63 | (17) | DISP | 90 | 25050 |
| A14 M | Max P | | | | | | (3a) | HOOP | 7304 | 16700 |
| | GR + Max P | 146 | 162 | | 1.95 | 1.63 | (18) | SUST | 4975 | 16700 |
| | Cold to T1 | 6 | 8 | 27 | 1.95 | 1.63 | (17) | DISP | 121 | 25050 |
| A14 F- | Max P | | | | | | (3a) | HOOP | 7304 | 16700 |
| | GR + Max P | 311 | 11 | | 1.95 | 1.63 | (18) | SUST | 6030 | 16700 |
| | Cold to T1 | 10 | 7 | 33 | 1.95 | 1.63 | (17) | DISP | 148 | 25050 |
| A14 F+ | Max P | | | | | | (3a) | HOOP | 6451 | 16700 |
| | GR + Max P | 311 | 11 | | 1.00 | 1.00 | (18) | SUST | 5595 | 16700 |
| | Cold to T1 | 10 | 7 | 33 | 1.00 | 1.00 | (17) | DISP | 246 | 25050 |
| A14A | Max P | | | | | | (3a) | HOOP | 6451 | 16700 |
| | GR + Max P | 387 | 19 | | 1.00 | 1.00 | (18) | SUST | 6294 | 16700 |
| | Cold to T1 | 11 | 16 | 33 | 1.00 | 1.00 | (17) | DISP | 267 | 25050 |
| A15 | Max P | | | | | | (3a) | HOOP | 6451 | 16700 |
| | GR + Max P | 38 | 51 | | 1.00 | 1.00 | (18) | SUST | 3334 | 16700 |
| | Cold to T1 | 11 | 53 | 33 | 1.00 | 1.00 | (17) | DISP | 442 | 25050 |
| *** Segment A end *** | | | | | | | | | | |
| *** Segment B begin *** | | | | | | | | | | |
| B02 | Max P | | | | | | (3a) | HOOP | 6451 | 16700 |
| | GR + Max P | 8 | 7 | | 1.00 | 1.00 | (18) | SUST | 2844 | 16700 |
| | Cold to T1 | 38 | 25 | 43 | 1.00 | 1.00 | (17) | DISP | 433 | 25050 |
| B03 N- | Max P | | | | | | (3a) | HOOP | 6451 | 16700 |
| | GR + Max P | 0 | 2 | | 1.00 | 1.00 | (18) | SUST | 2765 | 16700 |
| | Cold to T1 | 1 | 23 | 43 | 1.00 | 1.00 | (17) | DISP | 338 | 25050 |
| B03 N+ | Max P | | | | | | (3a) | HOOP | 6451 | 16700 |
| | GR + Max P | 2 | 0 | | 1.78 | 1.48 | (18) | SUST | 2779 | 16700 |
| | Cold to T1 | 23 | 1 | 43 | 1.78 | 1.48 | (17) | DISP | 414 | 25050 |
| B03 M | Max P | | | | | | (3a) | HOOP | 6451 | 16700 |
| | GR + Max P | 1 | 7 | | 1.78 | 1.48 | (18) | SUST | 2839 | 16700 |
| | Cold to T1 | 21 | 21 | 33 | 1.78 | 1.48 | (17) | DISP | 406 | 25050 |
| B03 F- | Max P | | | | | | (3a) | HOOP | 6451 | 16700 |
| | GR + Max P. | 0 | 9 | | 1.78 | 1.48 | (18) | SUST | 2866 | 16700 |
| | Cold to T1 | 15 | 28 | 13 | 1.78 | 1.48 | (17) | DISP | 354 | 25050 |





ASME B31.3c (1992) CODE COMPLIANCE

| Point name | Load combination | (Moments in ft-lb) In-Pl. Moment | Out-Pl. Moment | Torsion Moment | S.I.F In | S.I.F Out | Eq. no. | Load type | (Stress in psi) Code Stress | Code Allow. |
|---|---|---|---|---|---|---|---|---|---|---|
| B03 F+ | Max P | | | | | | (3a) | HOOP | 7304 | 16700 |
| | GR + Max P | 9 | 0 | | 1.00 | 1.00 | (18) | SUST | 3156 | 16700 |
| | Cold to T1 | 28 | 15 | 13 | 1.00 | 1.00 | (17) | DISP | 128 | 25050 |
| B04 N- | Max P | | | | | | (3a) | HOOP | 7304 | 16700 |
| | GR + Max P | 4 | 0 | | 1.00 | 1.00 | (18) | SUST | 3132 | 16700 |
| | Cold to T1 | 5 | 3 | 13 | 1.00 | 1.00 | (17) | DISP | 53 | 25050 |
| B04 N+ | Max P | | | | | | (3a) | HOOP | 7304 | 16700 |
| | GR + Max P | 4 | 0 | | 2.56 | 2.13 | (18) | SUST | 3159 | 16700 |
| | Cold to T1 | 5 | 3 | 13 | 2.56 | 2.13 | (17) | DISP | 70 | 25050 |
| B04 M | Max P | | | | | | (3a) | HOOP | 7304 | 16700 |
| | GR + Max P | 1 | 0 | | 2.56 | 2.13 | (18) | SUST | 3122 | 16700 |
| | Cold to T1 | 5 | 6 | 9 | 2.56 | 2.13 | (17) | DISP | 77 | 25050 |
| B04 F- | Max P | | | | | | (3a) | HOOP | 7304 | 16700 |
| | GR + Max P | 4 | 0 | | 2.56 | 2.13 | (18) | SUST | 3159 | 16700 |
| | Cold to T1 | 9 | 6 | 4 | 2.56 | 2.13 | (17) | DISP | 101 | 25050 |
| B04 F+ | Max P | | | | | | (3a) | HOOP | 7304 | 16700 |
| | GR + Max P | 0 | 4 | | 1.00 | 1.00 | (18) | SUST | 3131 | 16700 |
| | Cold to T1 | 6 | 9 | 4 | 1.00 | 1.00 | (17) | DISP | 44 | 25050 |
| B05 | Max P | | | | | | (3a) | HOOP | 7304 | 16700 |
| | GR + Max P | 0 | 4 | | 1.00 | 1.00 | (18) | SUST | 3132 | 16700 |
| | Cold to T1 | 5 | 9 | 4 | 1.00 | 1.00 | (17) | DISP | 42 | 25050 |
| B06 | Max P | | | | | | (3a) | HOOP | 7304 | 16700 |
| | GR + Max P | 0 | 4 | | 1.00 | 1.00 | (18) | SUST | 3133 | 16700 |
| | Cold to T1 | 4 | 9 | 4 | 1.00 | 1.00 | (17) | DISP | 41 | 25050 |
| B07 | Max P | | | | | | (3a) | HOOP | 7304 | 16700 |
| | GR + Max P | 0 | 5 | | 1.00 | 1.00 | (18) | SUST | 3138 | 16700 |
| | Cold to T1 | 0 | 10 | 4 | 1.00 | 1.00 | (17) | DISP | 39 | 25050 |
| *** Segment B end *** | | | | | | | | | | |
| *** Segment C begin *** | | | | | | | | | | |
| 5 | Max P | | | | | | (3a) | HOOP | 6905 | 16700 |
| | GR + Max P | 28 | 2 | | 1.00 | 1.00 | (18) | SUST | 2920 | 16700 |
| | Cold to T1 | 0 | 7 | 0 | 1.00 | 1.00 | (17) | DISP | 35 | 25050 |
| C01 | Max P | | | | | | (3a) | HOOP | 6905 | 16700 |
| | GR + Max P | 29 | 2 | | 1.00 | 1.00 | (18) | SUST | 2921 | 16700 |
| | Cold to T1 | 0 | 7 | 0 | 1.00 | 1.00 | (17) | DISP | 35 | 25050 |
| *** Segment C end *** | | | | | | | | | | |

ASME B31.3c (1992) CODE COMPLIANCE

| Point name | Load combination | In-Pl. Moment (Moments in ft-lb) | Out-Pl. Moment | Torsion Moment | S.I.F In | S.I.F Out | Eq. no. | Load type | Stress (Stress in psi) | Code Allow. |
|---|---|---|---|---|---|---|---|---|---|---|
| *** Segment D begin *** | | | | | | | | | | |
| 3 | Max P | | | | | | (3a) | HOOP | 6905 | 16700 |
| | GR + Max P | 20 | 9 | | 1.00 | 1.00 | (18) | SUST | 2876 | 16700 |
| | Cold to T1 | 7 | 14 | 0 | 1.00 | 1.00 | (17) | DISP | 78 | 25050 |
| D01 | Max P | | | | | | (3a) | HOOP | 6905 | 16700 |
| | GR + Max P | 20 | 9 | | 1.00 | 1.00 | (18) | SUST | 2876 | 16700 |
| | Cold to T1 | 7 | 14 | 0 | 1.00 | 1.00 | (17) | DISP | 78 | 25050 |
| *** Segment D end *** | | | | | | | | | | |



## SYSTEM SUMMARY

### Maximum displacements (in)

| | | | |
|---|---|---|---|
| Maximum X : | -0.046 | Point : A06 F | Load Comb.: GR |
| Maximum Y : | -0.207 | Point : A06 F | Load Comb.: GR |
| Maximum Z : | -0.046 | Point : A04 F | Load Comb.: GR |
| Max. total: | 0.214 | Point : A06 F | Load Comb.: GR |

### Maximum rotations (deg)

| | | | |
|---|---|---|---|
| Maximum X : | 0.175 | Point : A05 N | Load Comb.: GR |
| Maximum Y : | -0.096 | Point : A14 N | Load Comb.: GR |
| Maximum Z : | 0.186 | Point : A11 N | Load Comb.: GR |
| Max. total: | 0.218 | Point : A04 F | Load Comb.: GR |

### Maximum restraint forces(lb)

| | | | |
|---|---|---|---|
| Maximum X : | 112 | Point : D01 | Load Comb.: T1 |
| Maximum Y : | -3293 | Point : 1 | Load Comb.: GR |
| Maximum Z : | 4891 | Point : D01 | Load Comb.: T1 |
| Max. total: | 4892 | Point : D01 | Load Comb.: T1 |

### Maximum restraint moments(ft-lb)

| | | | |
|---|---|---|---|
| Maximum X : | -80 | Point : 3 | Load Comb.: GR |
| Maximum Y : | -39 | Point : A00 | Load Comb.: GR |
| Maximum Z : | -186 | Point : A00 | Load Comb.: GR |
| Max. total: | 193 | Point : A00 | Load Comb.: GR |

## SYSTEM SUMMARY

### Maximum pipe forces (lb)

| | | | |
|---|---|---|---|
| Maximum X : | 112 | Point : 3 | Load Comb.: T1 |
| Maximum Y : | 549 | Point : A14A | Load Comb.: GR |
| Maximum Z : | 4891 | Point : 3 | Load Comb.: T1 |
| Max. total: | 4892 | Point : 3 | Load Comb.: T1 |

### Maximum pipe moments (ft-lb)

| | | | |
|---|---|---|---|
| Maximum X : | 386 | Point : A14A | Load Comb.: GR |
| Maximum Y : | 77 | Point : A06 F | Load Comb.: GR |
| Maximum Z : | -691 | Point : A07 | Load Comb.: GR |
| Max. total: | 700 | Point : A07 | Load Comb.: GR |





## SYSTEM SUMMARY

### Maximum sustained stress

Point : A06 F
Stress psi : 8216
Allowable psi : 16700
Ratio : 0.49
Load combination : GR + Max P

### Maximum displacement stress

Point : A06 F
Stress psi : 497
Allowable psi : 25050
Ratio : 0.02
Load combination : Cold to T1

### Maximum hoop stress

Point : A00
Stress psi : 7304
Allowable psi : 16700
Ratio : 0.44
Load combination : Max P

### Maximum sustained stress ratio

Point : A06 F
Stress psi : 8216
Allowable psi : 16700
Ratio : 0.49
Load combination : GR + Max P

### Maximum displacement stress ratio

Point : A06 F
Stress psi : 497
Allowable psi : 25050
Ratio : 0.02
Load combination : Cold to T1

### Maximum hoop stress ratio

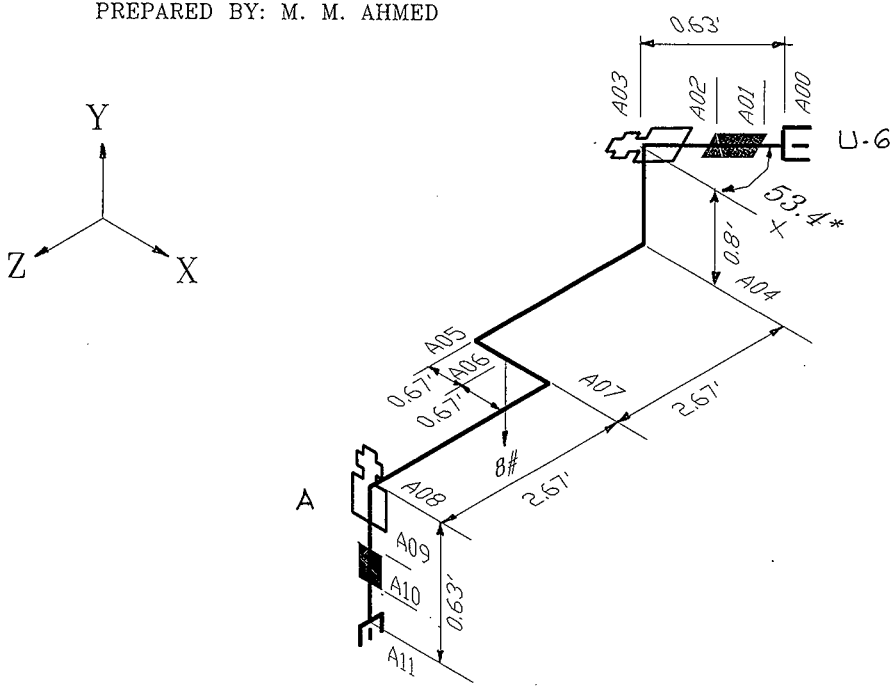
Point : A00
Stress psi : 7304
Allowable psi : 16700
Ratio : 0.44
Load combination : Max P

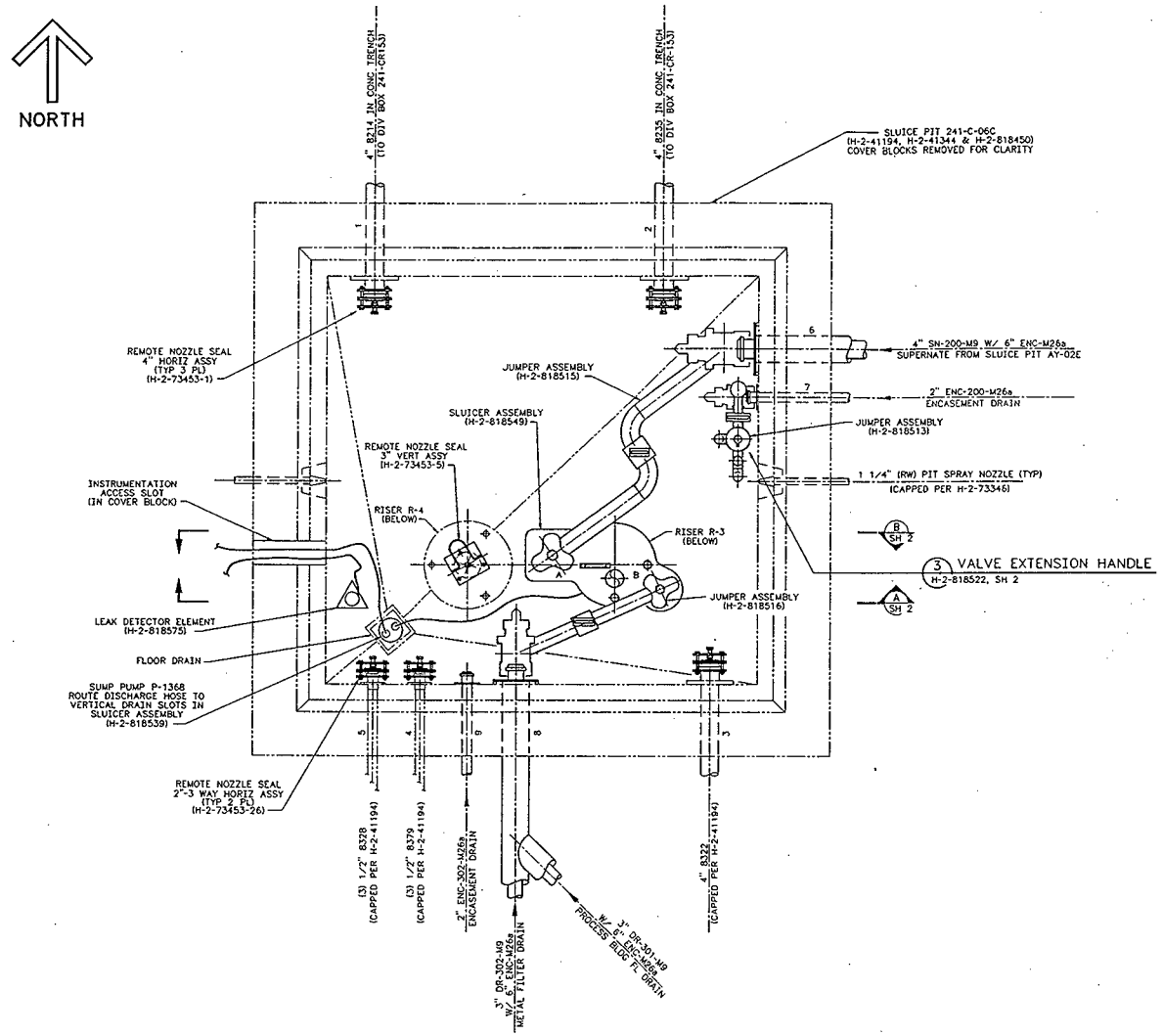
APPDX - C

# JUMPER ASSEMBLY U6-A / SLUICE PIT C-06C

DRAWING: H-2-818515 FILE NAME: J6A-S AP FILE NAME: MA-J6A

PREPARED BY: M. M. AHMED






PLAN
SLUICE PIT
241-C-06C

NOTES:

1. FOR GENERAL NOTES, LEGEND AND KEY PLAN SEE H-2-818518.

EXPIRES 3-3-96

| | |
|---|---|
| DESIGNED R. W. SCHROEDER | SAFETY CLASS 3 |
| DRAWN | |
| CHECKED | |
| SAFETY SEE DR/AT FORM | |
| DATA SEE DR/AT FORM | |
| Dwg Chkd SEE DR/AT FORM | |
| Lead Engr | |
| REVISION NO. 11 | |

USE CONSTRUCTION
IDF

U.S. DEPARTMENT OF ENERGY
RICHLAND OPERATIONS OFFICE
ICF KAISER HANFORD COMPANY

PIPING
JUMPER ARRANGEMENT
SLUICE PIT 241-C-06C

PROJECT W-320 TANK 241-C-105 SLUICING

| SIZE | BLDG NO. | SHEET NO. | DOC NO. | REV NO. |
|---|---|---|---|---|
| F | 241-C | 8404 | H-2-818526 | 0 |

SCALE 1"=1'-0" JOB NO. ER4319 SHEET 1 of 2

| | | | |
|---|---|---|---|
| H-2-818423 SH 7 | DRAWING LIST | | |
| NUMBER | TITLE | | |
| NUMBER | TITLE | | |

REVISIONS

| WF | REV NO | DESCRIPTION | REV BY DATE | EGA APPROVALS |
|---|---|---|---|---|

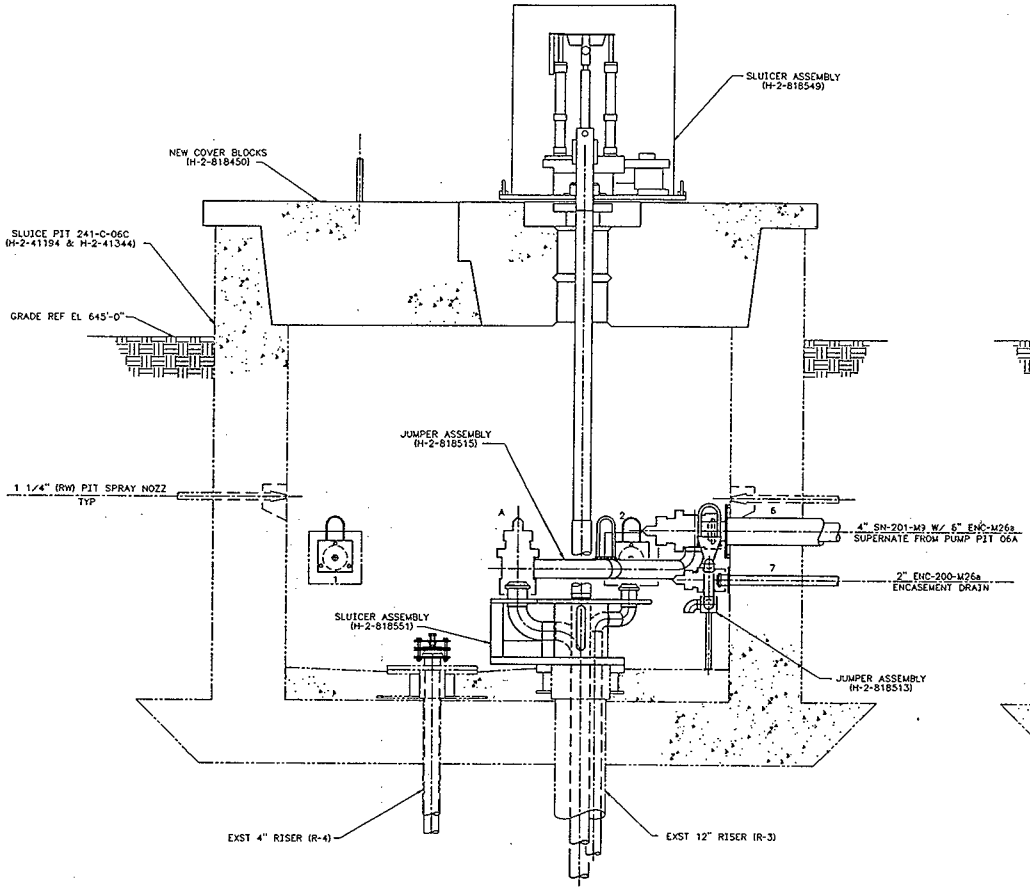
APVD FOR CONC FOR BLDG

APPROVED FOR IMPLEMENTATION
BY
FOR WHC DATE

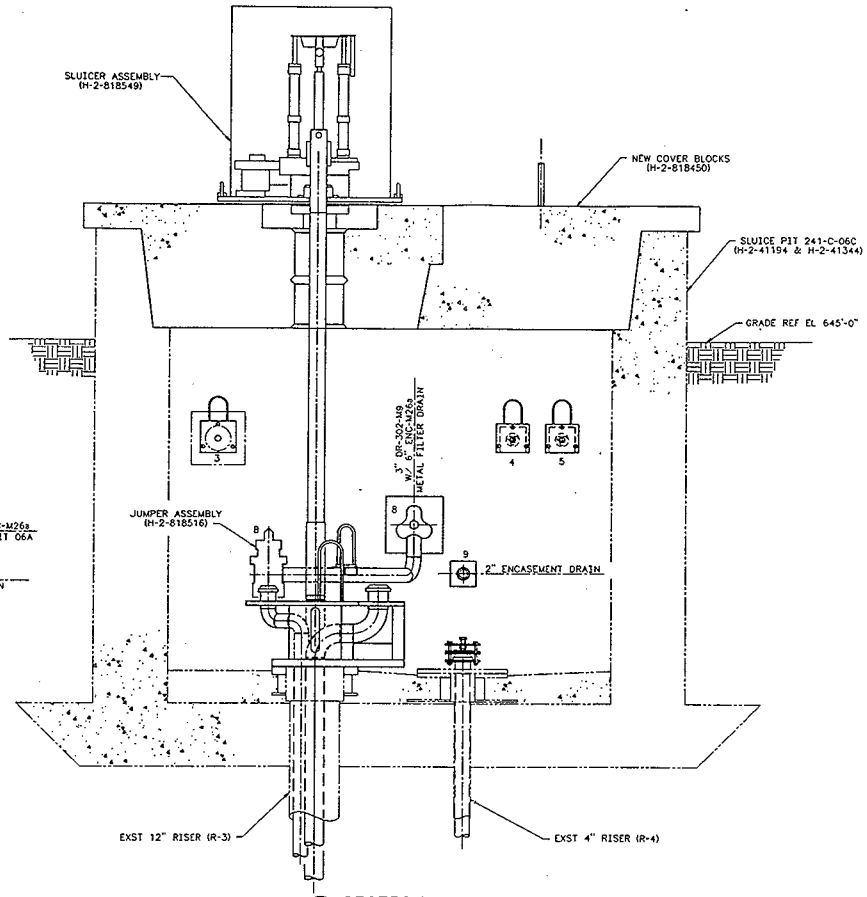
CAD FILE B818526A CAD CODE 2B:IBM:ACD2:12.0:NN UNITS N

PLOT SCALE: 1=12 KEHCAD

STA 6060 00 00/96
SYSDEF/ 1996/0000/0000




A SECTION
SH 1




B SECTION
SH 1

NOTES:

1. FOR NOTES, SEE SHEET 1.

STATE OF WASHINGTON 31633 REGISTERED PROFESSIONAL ENGINEER
EXPIRES 5-3-96

| | |
|---|---|
| DESIGNED R W SCHROEDER | SAFETY CLASS 3 |
| DRAWN CHAR | |
| CHECKED | |
| SAFETY SEE DR/AT FORM | |
| DRYER SEE DR/AT FORM | |
| DRN CHAR SEE DR/AT FORM | |
| LEAD CHEM | |
| REVISION NO. 10 | |
| APPROVED FOR IMPLEMENTATION | |
| DRAWN WHC | SCALE 1"=1'-0" |
| CAD FILE B818526B | CAD CODE 28:18M:ACD2:12.0:NN |
| SHEET N | PLOT SCALE: 1=12 |

SEC CONSTRUCTION
DIV

U.S. DEPARTMENT OF ENERGY
RICHLAND OPERATIONS OFFICE
ICF KAISER HANFORD COMPANY

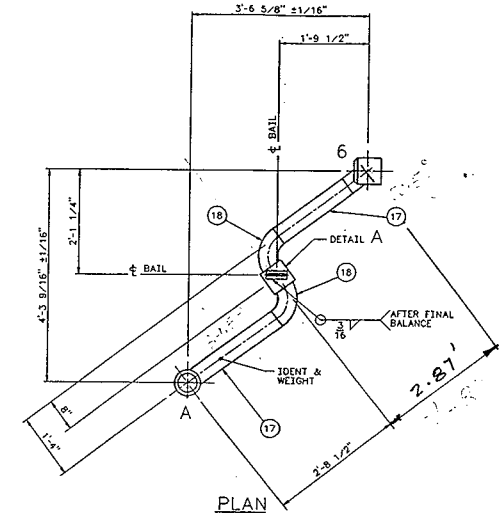
PIPING
JUMPER ARRANGEMENT
SLUICE PIT 241-C-06C

PROJECT W-320 TANK 241-C-106 SLUICING

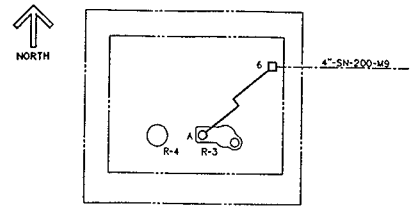
| DIST | BLDG NO | SHEET NO | DWG NO | REV NO |
|---|---|---|---|---|
| F | 241-C | 8404 | H-2-818526 | 0 |

JOB NO. ER4319 SHEET 2 OF 2

KEHCAD



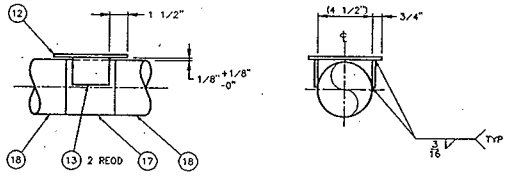

PLAN



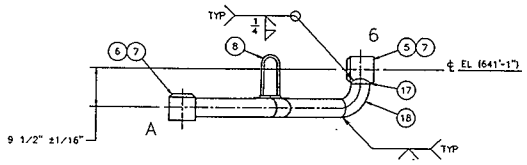

241-C-06C
SLUICE PIT
KEY PLAN
SCALE: NONE

| QTY REQD | PART/DASH NUMBER | NOMENCLATURE/DESCRIPTION | MATERIAL/REFERENCE | SHEET | ITEM NO. |
|---|---|---|---|---|---|
| | -010 | ASSEMBLY | | | 1 |
| | | | | | 2 |
| | | | | | 3 |
| | | | | | 4 |
| 1 | H-2-32440-1 | CONN, HORIZ 4" | | | 5 |
| 1 | H-2-32440-2 | CONN, VERT, 4" | | | 6 |
| 2 | H-2-3997-8 | GASKET 4" TYPE III | | | 7 |
| 1 | H-2-90161-3 | LIFTING BAIL | | | 8 |
| | | | | | 9 |
| | | | | | 10 |
| | | | | | 11 |
| 1 | | PLATE 1/4" THK x 6" x 6" | ASTM A 36 | | 12 |
| 2 | | BAR 1/4" THK x 2 1/4" x 3" | ASTM A 240 304L | | 13 |
| | | | | | 14 |
| | | | | | 15 |
| | | | | | 16 |
| AR | | PIPE, 4" SCHED 40S | ASTM A 312 GR TP 304L | | 17 |
| 3 | | ELBOW, 90° LR 4" SCHED 40S BW | ASTM A 403 WP-S 304L | | 18 |
| | | | | | 19 |
| | | | | | 20 |

PARTS/MATERIAL LIST




DETAIL A
SCALE: 3"= 1'-0"




ELEVATION

1 ASSEMBLY
SCALE: 1"= 1'-0"

NOTE:

1. FABRICATION AND TESTING SHALL BE IN ACCORDANCE WITH HANFORD SPECIFICATION HS-BS-0084 REV B.
2. HYDROSTATIC TEST AT 480 PSIG.
3. JUMPER WEIGHT IS 325 LB APPROX.
4. USE (1) COAT OF AMERLOCK 400 IN PLACE OF AMERCOAT 187 PRIMER AND AMERCOAT 33, WHERE REQUIRED BY JUMPER FABRICATION SPECIFICATION.

EXPIRES 5-3-96

| | |
|---|---|
| USE | CONSTRUCTION |
| DESIGNED Ba MEYER SR ENGR | SAFETY CLASS 3 |
| DRAWN BY | |
| CHECKED | U.S. DEPARTMENT OF ENERGY RICHLAND OPERATIONS OFFICE ICF KAISER HANFORD COMPANY |
| SURVEY SEE DR/AT FORM | JUMPER ASSEMBLY SLUICE PIT C-06C-6-A |
| DRAW SEE DR/AT FORM | |
| DWG CHK SEE DR/AT FORM | |
| LEAD DWR | |
| REVISION NO. 3 | PROJECT W-320 TANK 241-C-106 SLUICING |
| APPROVED FOR IMPLEMENTATION | SYSTEM F / BLDG NO. 241-C / SHEET NO. 8405 / DWG NO. H-2-818515 / REV NO. 0 |
| FOR WHC | SCALE SHOWN / JOB NO. ER4319 / SHEET 1 OF 1 |
| CAD FILE B818515A / CAD CODE 2B:IBM:ACD2:12.0:NN | SHEET 2 PLOT SCALE: 1=12 / KEHCAD |

| NUMBER | TITLE | NUMBER | TITLE |
|---|---|---|---|
| DRAWING TRACEABILITY LIST | | H-2-818473 SH 7 | DRAWING LIST |
| | | NEXT USED ON H-2-818526 | |

| REV NO. | DESCRIPTION | REV BY DATE | ECN APPROVALS |
|---|---|---|---|
| | | | |

REVISIONS

## POINT DATA LISTING

| POINT NAME | TYPE | OFFSETS (ft) X | Y | Z | PIPE ID | DESCRIPTION |
|---|---|---|---|---|---|---|
| *** SEGMENT A | | | | | | |
| A00 | Run | 0 | 0 | 0 | 4PIPE | |
| A01 | Flex | -0.11 | 0 | 0.15 | | Wt= 144 lb , Ar= 3.2 sq.in<br>Axial= 23300000 Tors= 304.0<br>Y-Shear= RIGID Bend= 2080.0<br>Z-Shear= RIGID Bend= 2080.0 |
| A02 | Run | -0.02 | 0 | 0.03 | | |
| A03 | Bend | -0.22 | 0 | 0.33 | | Short Elbow, Radius = 4.00 inch<br>Bend angle change = 90.00 deg<br>Mid point at 50.00 percent<br>SIF - In 2.56, Out = 2.13<br>Flex = 7.908 |
| A04 | Bend | 0 | -0.84 | 0 | | Long Elbow, Radius = 6.00 inch<br>Bend angle change = 90.00 deg<br>Mid point at 50.00 percent<br>SIF - In 1.95, Out = 1.63<br>Flex = 5.272 |
| A05 | Bend | 0 | 0 | 2.67 | | Long Elbow, Radius = 6.00 inch<br>Bend angle change = 90.00 deg<br>Mid point at 50.00 percent<br>SIF - In 1.95, Out = 1.63<br>Flex = 5.272 |
| A06 | Run | 0.67 | 0 | 0 | | |
| A07 | Bend | 0.67 | 0 | 0 | | Long Elbow, Radius = 6.00 inch<br>Bend angle change = 90.00 deg<br>Mid point at 50.00 percent<br>SIF - In 1.95, Out = 1.63<br>Flex = 5.272 |
| A08 | Bend | 0 | 0 | 2.67 | | Short Elbow, Radius = 4.00 inch<br>Bend angle change = 90.00 deg<br>Mid point at 50.00 percent<br>SIF - In 2.56, Out = 2.13<br>Flex = 7.908 |
| A09 | Flex | 0 | -0.40 | 0 | | Wt= 144 lb , Ar= 3.2 sq.in<br>Axial= 23300000 Tors= 304.0<br>Y-Shear= RIGID Bend= 2080.0<br>Z-Shear= RIGID Bend= 2080.0 |
| A10 | Run | 0 | -0.04 | 0 | | |
| A11 | Run | 0 | -0.19 | 0 | | |

Total weight of empty pipes : 104 lb





## COMPONENT DATA LISTING

| POINT NAME | COORDINATE(ft) X | Y | Z | DATA TYPE | DESCRIPTION |
|---|---|---|---|---|---|
| *** SEGMENT A | | | | | |
| A00 | 0.00 | 0.00 | 0.00 | ANCHOR | Rigid<br>Thermal movements : None |
| A01 | -0.11 | 0.00 | 0.15 | | |
| A02 | -0.13 | 0.00 | 0.18 | | |
| A03 N | -0.17 | 0.00 | 0.23 | | |
| A03 | -0.35 | 0.00 | 0.51 | TI | |
| A03 M | -0.30 | -0.10 | 0.43 | | |
| A03 F | -0.35 | -0.33 | 0.51 | | |
| A04 N | -0.35 | -0.34 | 0.51 | | |
| A04 | -0.35 | -0.84 | 0.51 | TI | |
| A04 M | -0.35 | -0.69 | 0.66 | | |
| A04 F | -0.35 | -0.84 | 1.01 | | |
| A05 N | -0.35 | -0.84 | 2.68 | | |
| A05 | -0.35 | -0.84 | 3.18 | TI | |
| A05 M | -0.21 | -0.84 | 3.04 | | |
| A05 F | 0.15 | -0.84 | 3.18 | | |
| A06 | 0.32 | -0.84 | 3.18 | WEIGHT 8 lb | , No offsets |
| A07 N | 0.49 | -0.84 | 3.18 | | |
| A07 | 0.99 | -0.84 | 3.18 | TI | |
| A07 M | 0.84 | -0.84 | 3.33 | | |
| A07 F | 0.99 | -0.84 | 3.68 | | |
| A08 N | 0.99 | -0.84 | 5.52 | | |
| A08 | 0.99 | -0.84 | 5.85 | TI | |
| A08 M | 0.99 | -0.94 | 5.75 | | |
| A08 F | 0.99 | -1.17 | 5.85 | | |
| A09 | 0.99 | -1.24 | 5.85 | | |
| A10 | 0.99 | -1.28 | 5.85 | | |
| A11 | 0.99 | -1.47 | 5.85 | ANCHOR | Rigid<br>Thermal movements : None |

Number of points in the system : 27

## P I P E  D A T A  L I S T I N G

| Pipe ID/ Material | Nom/ Sch | O.D. inch | -----Thickness(inch)----- W.Th. | Corr | Mill | Insu | Ling | Spec Grav | Weight(lb/ft ) Pipe | Other | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 4PIPE | 4 | 4.500 | 0.237 | 0.06 | 0.03 | 0 | 0 | 1.12 | 11.04 | 0 | 17.22 |
| AU | STD | | | | | | | | | | |



## M A T E R I A L  D A T A  L I S T I N G

| Material Name | Pipe ID | Density lb/cu.ft | Pois. Ratio | Temper. deg F | Modulus E6 psi | Expans. in/100ft | Allow. psi |
|---|---|---|---|---|---|---|---|
| AU | 4PIPE | 501.0 | 0.30 | 40.0 | 28.42 | | 16700.0 |
| | | | | 180.0 | | 1.5442 | 16700.0 |





ICF-4281SBT

TEMPERATURE AND PRESSURE DATA

| POINT NAME | -----CASE 1------ PRESS. psi | TEMPER deg F | EXPAN. in/100ft | -----CASE 2------ PRESS. psi | TEMPER deg F | EXPAN. in/100ft | -----CASE 3------ PRESS. psi | TEMPER deg F | EXPAN. in/100ft |
|---|---|---|---|---|---|---|---|---|---|
| *** SEGMENT A | | | | | | | | | |
| A00 | 325 | 180 | 1.544 | | | | | | |
| A11 | 325 | 180 | 1.544 | | | | | | |





ANALYSIS SUMMARY

Current model revision number : 1

Static - Date and Time of analysis ..... Sep 11, 1995 12:54 PM
Model Revision Number ..... 1
Number of load cases ..... 2
Load cases analyzed ..... GR T1
Gaps/Friction/Yielding considered ..... No
Hanger design run ..... No
Cut short included ..... No
Weight of contents included ..... Yes
Pressure stiffening case ..... 0
Water elevation for buoyancy loads .... Not considered

Modal - Date and Time of analysis ..... Sep 11, 1995 12:54 PM
Model Revision Number ..... 1
Number of modes ..... 1
Cutoff frequency (Hz) ..... 33.0
Weight of contents included ..... Yes
Pressure stiffening case ..... 0
Water elevation for buoyancy loads .... Not considered

Response - Date and Time of analysis ..... Sep 11, 1995 12:55 PM
Model Revision Number ..... 1
Number of load cases ..... 3
Load cases analyzed ..... R1 R2 R3
Date and time of modal analysis ..... Sep 11, 1995 12:54 PM
Number of modes ..... 1
Cutoff frequency (Hz) ..... 33.0
Model revision of modal analysis ..... 1
Weight of contents included ..... Yes
Pressure stiffening case ..... 0
Water elevation for buoyancy loads .... Not considered

CODE COMPLIANCE COMBINATIONS

| Combination | Category | Method | Load | Factor | Allowable | Remarks |
|---|---|---|---|---|---|---|
| GR + Max P | Sustain | Sum | Gravity | 1.00 | Automatic | Default |
| | | | Max Long | 1.00 | | |
| Cold to T1 | Expansion | Sum | Thermal 1 | 1.00 | Automatic | Default |
| Sus. + R1 | Occasion | Abs sum | Response 1 | 1.00 | Automatic | Default |
| | | | Max Sus | 1.00 | | |
| Sus. + R2 | Occasion | Abs sum | Response 2 | 1.00 | Automatic | Default |
| | | | Max Sus | 1.00 | | |
| Sus. + R3 | Occasion | Abs sum | Response 3 | 1.00 | Automatic | Default |
| | | | Max Sus | 1.00 | | |
| Max P | Hoop | | Max Hoop | 1.00 | Automatic | Default |

OTHER USER COMBINATIONS

| Combination | Method | Load | Factor | Remarks |
|---|---|---|---|---|
| GR | Sum | Gravity | 1.00 | Default |
| T1 | Sum | Thermal 1 | 1.00 | Default |
| R1 | Sum | Response 1 | 1.00 | Default |
| R2 | Sum | Response 2 | 1.00 | Default |
| R3 | Sum | Response 3 | 1.00 | Default |
| GR+T1 | Sum | Gravity | 1.00 | User |
| | | Thermal 1 | 1.00 | |
| SEIS | Abs sum | Response 1 | 1.00 | User |
| | | Response 2 | 1.00 | |
| | | Response 3 | 1.00 | |
| TOTAL | Abs sum | GR+T1 | 1.00 | User |
| | | SEIS | 1.00 | |

CODE COMPLIANCE

Y - Factor ..... 0.40
Weld efficiency factor ..... 1.00
Range reduction factor ..... 1.00





Design Pressure Factor ..... 1.00
Minimum stress ratio used in reports... 0.00
Include corrosion in stress calcs. .... Y
Include torsion in code stress ..... N
Include axial force in code stress .... N
Longitudinal pressure calculation ..... PD/4t
Include rigorous pressure ..... Not analyzed





ICF-4281INT

RESPONSE SPECTRUM LOAD CASES :

Number of load cases analysed : 3

Load case 1 - R1

Missing mass : No
ZPA : No

Combination method : SRSS

X- Spectrum : SC1
Multiplier : 1.00

SC1

| Freq(Hz) | Grav( ) | Freq(Hz) | Grav( ) | Freq(Hz) | Grav( ) |
|---|---|---|---|---|---|
| 0.100 | 0.01 | 0.160 | 0.03 | 0.250 | 0.06 |
| 0.400 | 0.10 | 0.600 | 0.16 | 1.100 | 0.28 |
| 1.640 | 0.42 | 8.000 | 0.42 | 12.000 | 0.34 |
| 20.000 | 0.26 | 33.000 | 0.20 | 100.000 | 0.20 |



Load case 2 - R2

Missing mass : No
ZPA : No

Combination method : SRSS

Y- Spectrum : SC1
Multiplier : 1.00

SC1

| Freq(Hz) | Grav( ) | Freq(Hz) | Grav( ) | Freq(Hz) | Grav( ) |
|---|---|---|---|---|---|
| 0.100 | 0.01 | 0.160 | 0.03 | 0.250 | 0.06 |
| 0.400 | 0.10 | 0.600 | 0.16 | 1.100 | 0.28 |
| 1.640 | 0.42 | 8.000 | 0.42 | 12.000 | 0.34 |
| 20.000 | 0.26 | 33.000 | 0.20 | 100.000 | 0.20 |

Load case 3 - R3

Missing mass : No
ZPA : No

Combination method : SRSS

Z- Spectrum : SC1
Multiplier : 1.00

SC1

| Freq(Hz) | Grav( ) | Freq(Hz) | Grav( ) | Freq(Hz) | Grav( ) |
|---|---|---|---|---|---|
| 0.100 | 0.01 | 0.160 | 0.03 | 0.250 | 0.06 |
| 0.400 | 0.10 | 0.600 | 0.16 | 1.100 | 0.28 |
| 1.640 | 0.42 | 8.000 | 0.42 | 12.000 | 0.34 |
| 20.000 | 0.26 | 33.000 | 0.20 | 100.000 | 0.20 |



F R E Q U E N C I E S

| Mode Number | Frequency (Rads/sec) | Frequency (Hertz) | Period (Sec) | Participation factors X | Y | Z |
|---|---|---|---|---|---|---|
| 1 | 207.2037 | 32.9775 | 0.030 | 0.497 | -0.054 | 0.000 |

## MODE SHAPES

| Point name | Mode | Frequency | TRANSLATIONS X | Y | Z | ROTATIONS (deg ) X | Y | Z |
|---|---|---|---|---|---|---|---|---|
| *** Segment A begin *** | | | | | | | | |
| A00 | 1 | 32.9775 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| A01 | 1 | 32.9775 | 0.001 | -0.001 | 0.001 | 0.030 | 0.040 | 0.030 |
| A02 | 1 | 32.9775 | 0.009 | -0.011 | 0.005 | 0.601 | 2.387 | 3.813 |
| A03 N | 1 | 32.9775 | 0.036 | -0.046 | 0.023 | 0.610 | 2.399 | 3.823 |
| A03 M | 1 | 32.9775 | 0.224 | -0.186 | 0.076 | 0.882 | 2.703 | 4.130 |
| A03 F | 1 | 32.9775 | 0.482 | -0.250 | 0.059 | 1.009 | 2.796 | 4.305 |
| A04 N | 1 | 32.9775 | 0.488 | -0.250 | 0.057 | 1.009 | 2.797 | 4.305 |
| A04 M | 1 | 32.9775 | 0.895 | -0.281 | -0.019 | 0.955 | 2.835 | 4.238 |
| A04 F | 1 | 32.9775 | 1.234 | -0.344 | -0.047 | 0.711 | 2.763 | 4.118 |
| A05 N | 1 | 32.9775 | 2.147 | -0.555 | -0.049 | 0.503 | 2.289 | 3.703 |
| A05 M | 1 | 32.9775 | 2.280 | -0.475 | -0.098 | 0.416 | 1.164 | 3.597 |
| A05 F | 1 | 32.9775 | 2.303 | -0.233 | -0.135 | 0.451 | -0.177 | 3.259 |
| A06 | 1 | 32.9775 | 2.303 | -0.117 | -0.127 | 0.433 | -0.303 | 3.220 |
| A07 N | 1 | 32.9775 | 2.302 | -0.003 | -0.115 | 0.415 | -0.437 | 3.178 |
| A07 M | 1 | 32.9775 | 2.253 | 0.202 | -0.023 | 0.489 | -2.227 | 2.738 |
| A07 F | 1 | 32.9775 | 2.015 | 0.245 | 0.065 | 0.533 | -4.064 | 2.539 |
| A08 N | 1 | 32.9775 | 0.227 | 0.044 | 0.063 | 0.550 | -4.927 | 1.838 |
| A08 M | 1 | 32.9775 | 0.013 | 0.014 | 0.050 | 0.668 | -5.135 | 1.651 |
| A08 F | 1 | 32.9775 | -0.022 | 0.000 | 0.014 | 0.689 | -5.226 | 1.328 |
| A09 | 1 | 32.9775 | -0.004 | 0.000 | 0.004 | 0.686 | -5.220 | 1.319 |
| A10 | 1 | 32.9775 | 0.001 | 0.000 | 0.001 | 0.018 | -0.016 | 0.011 |
| A11 | 1 | 32.9775 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| *** Segment A end *** | | | | | | | | |





## DISPLACEMENTS

| Point name | Load combination | TRANSLATIONS (in ) X | Y | Z | ROTATIONS (deg ) X | Y | Z |
|---|---|---|---|---|---|---|---|
| *** Segment A begin *** | | | | | | | |
| A00 | GR | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | T1 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | R1 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | R2 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | R3 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | GR+T1 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | SEIS | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | TOTAL | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| A01 | GR | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | T1 | -0.002 | 0.000 | 0.002 | 0.001 | -0.003 | 0.000 |
| | R1 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | R2 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | R3 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | GR+T1 | -0.002 | 0.000 | 0.002 | 0.001 | -0.003 | 0.000 |
| | SEIS | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | TOTAL | 0.002 | 0.000 | 0.002 | 0.001 | 0.003 | 0.000 |
| A02 | GR | 0.000 | 0.000 | 0.000 | 0.011 | 0.001 | 0.004 |
| | T1 | -0.002 | 0.000 | 0.002 | 0.209 | -0.128 | -0.211 |
| | R1 | 0.000 | 0.000 | 0.000 | 0.001 | 0.002 | 0.003 |
| | R2 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | R3 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | GR+T1 | -0.002 | 0.000 | 0.002 | 0.220 | -0.127 | -0.206 |
| | SEIS | 0.000 | 0.000 | 0.000 | 0.001 | 0.002 | 0.004 |
| | TOTAL | 0.002 | 0.000 | 0.002 | 0.221 | 0.129 | 0.210 |
| A03 N | GR | 0.000 | 0.000 | 0.000 | 0.011 | 0.001 | 0.004 |
| | T1 | -0.004 | -0.001 | 0.002 | 0.210 | -0.129 | -0.211 |
| | R1 | 0.000 | 0.000 | 0.000 | 0.001 | 0.002 | 0.003 |
| | R2 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | R3 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | GR+T1 | -0.004 | -0.001 | 0.002 | 0.220 | -0.127 | -0.206 |
| | SEIS | 0.000 | 0.000 | 0.000 | 0.001 | 0.002 | 0.004 |
| | TOTAL | 0.004 | 0.001 | 0.002 | 0.221 | 0.130 | 0.210 |
| A03 M | GR | 0.000 | -0.001 | 0.000 | 0.011 | 0.001 | 0.005 |
| | T1 | -0.016 | -0.006 | -0.004 | 0.220 | -0.126 | -0.202 |
| | R1 | 0.000 | 0.000 | 0.000 | 0.001 | 0.002 | 0.004 |
| | R2 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | R3 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | GR+T1 | -0.016 | -0.006 | -0.004 | 0.231 | -0.125 | -0.198 |
| | SEIS | 0.000 | 0.000 | 0.000 | 0.001 | 0.003 | 0.004 |
| | TOTAL | 0.016 | 0.007 | 0.004 | 0.232 | 0.128 | 0.202 |





ICF4SPRINT

D I S P L A C E M E N T S

| Point name | Load combination | TRANSLATIONS (in ) X | Y | Z | ROTATIONS (deg ) X | Y | Z |
|---|---|---|---|---|---|---|---|
| A03 F | GR | 0.000 | -0.001 | -0.001 | 0.011 | 0.001 | 0.004 |
| | T1 | -0.029 | -0.011 | -0.015 | 0.205 | -0.115 | -0.183 |
| | R1 | 0.000 | 0.000 | 0.000 | 0.001 | 0.003 | 0.004 |
| | R2 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | R3 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | GR+T1 | -0.028 | -0.012 | -0.015 | 0.216 | -0.114 | -0.179 |
| | SEIS | 0.000 | 0.000 | 0.000 | 0.001 | 0.003 | 0.004 |
| | TOTAL | 0.029 | 0.012 | 0.015 | 0.217 | 0.116 | 0.184 |
| A04 N | GR | 0.000 | -0.001 | -0.001 | 0.011 | 0.001 | 0.004 |
| | T1 | -0.029 | -0.011 | -0.015 | 0.205 | -0.114 | -0.183 |
| | R1 | 0.000 | 0.000 | 0.000 | 0.001 | 0.003 | 0.004 |
| | R2 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | R3 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | GR+T1 | -0.028 | -0.012 | -0.016 | 0.216 | -0.113 | -0.179 |
| | SEIS | 0.000 | 0.000 | 0.000 | 0.001 | 0.003 | 0.004 |
| | TOTAL | 0.029 | 0.012 | 0.016 | 0.217 | 0.116 | 0.184 |
| A04 M | GR | 0.001 | -0.001 | -0.002 | 0.012 | 0.001 | 0.003 |
| | T1 | -0.045 | -0.022 | -0.026 | 0.141 | -0.095 | -0.153 |
| | R1 | 0.001 | 0.000 | 0.000 | 0.001 | 0.003 | 0.004 |
| | R2 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | R3 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | GR+T1 | -0.044 | -0.023 | -0.028 | 0.152 | -0.094 | -0.149 |
| | SEIS | 0.001 | 0.000 | 0.000 | 0.001 | 0.003 | 0.004 |
| | TOTAL | 0.045 | 0.023 | 0.028 | 0.153 | 0.097 | 0.153 |
| A04 F | GR | 0.001 | -0.002 | -0.002 | 0.012 | 0.000 | 0.003 |
| | T1 | -0.055 | -0.030 | -0.024 | 0.041 | -0.049 | -0.129 |
| | R1 | 0.001 | 0.000 | 0.000 | 0.001 | 0.002 | 0.004 |
| | R2 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | R3 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | GR+T1 | -0.054 | -0.033 | -0.026 | 0.053 | -0.049 | -0.126 |
| | SEIS | 0.001 | 0.000 | 0.000 | 0.001 | 0.003 | 0.004 |
| | TOTAL | 0.055 | 0.033 | 0.026 | 0.053 | 0.052 | 0.130 |
| A05 N | GR | 0.001 | -0.006 | -0.002 | 0.009 | -0.001 | 0.002 |
| | T1 | -0.063 | -0.033 | 0.001 | -0.017 | 0.015 | -0.088 |
| | R1 | 0.002 | 0.000 | 0.000 | 0.000 | 0.002 | 0.003 |
| | R2 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | R3 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | GR+T1 | -0.062 | -0.039 | -0.001 | -0.009 | 0.014 | -0.086 |
| | SEIS | 0.002 | 0.001 | 0.000 | 0.000 | 0.002 | 0.004 |
| | TOTAL | 0.064 | 0.039 | 0.001 | 0.009 | 0.017 | 0.090 |





D I S P L A C E M E N T S

| Point name | Load combination | TRANSLATIONS (in ) X | Y | Z | ROTATIONS (deg ) X | Y | Z |
|---|---|---|---|---|---|---|---|
| A05 M | GR | 0.001 | -0.006 | -0.002 | 0.003 | -0.003 | 0.003 |
| | T1 | -0.055 | -0.032 | 0.004 | -0.057 | 0.125 | -0.066 |
| | R1 | 0.002 | 0.000 | 0.000 | 0.000 | 0.001 | 0.003 |
| | R2 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | R3 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | GR+T1 | -0.055 | -0.039 | 0.002 | -0.054 | 0.122 | -0.063 |
| | SEIS | 0.002 | 0.000 | 0.000 | 0.000 | 0.001 | 0.004 |
| | TOTAL | 0.057 | 0.039 | 0.002 | 0.054 | 0.124 | 0.067 |
| A05 F | GR | 0.000 | -0.006 | -0.002 | 0.001 | -0.004 | 0.004 |
| | T1 | -0.045 | -0.034 | -0.007 | -0.075 | 0.199 | -0.036 |
| | R1 | 0.002 | 0.000 | 0.000 | 0.000 | 0.000 | 0.003 |
| | R2 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | R3 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | GR+T1 | -0.044 | -0.040 | -0.009 | -0.074 | 0.196 | -0.032 |
| | SEIS | 0.002 | 0.000 | 0.000 | 0.000 | 0.000 | 0.003 |
| | TOTAL | 0.047 | 0.040 | 0.009 | 0.074 | 0.196 | 0.035 |
| A06 | GR | 0.000 | -0.006 | -0.001 | 0.000 | -0.004 | 0.004 |
| | T1 | -0.042 | -0.035 | -0.015 | -0.077 | 0.202 | -0.035 |
| | R1 | 0.002 | 0.000 | 0.000 | 0.000 | 0.000 | 0.003 |
| | R2 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | R3 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | GR+T1 | -0.042 | -0.041 | -0.016 | -0.077 | 0.198 | -0.030 |
| | SEIS | 0.002 | 0.000 | 0.000 | 0.000 | 0.000 | 0.003 |
| | TOTAL | 0.044 | 0.041 | 0.016 | 0.077 | 0.198 | 0.034 |
| A07 N | GR | 0.000 | -0.006 | -0.001 | 0.000 | -0.004 | 0.004 |
| | T1 | -0.040 | -0.036 | -0.022 | -0.080 | 0.202 | -0.034 |
| | R1 | 0.002 | 0.000 | 0.000 | 0.000 | 0.000 | 0.003 |
| | R2 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | R3 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | GR+T1 | -0.039 | -0.042 | -0.023 | -0.080 | 0.198 | -0.029 |
| | SEIS | 0.002 | 0.000 | 0.000 | 0.000 | 0.000 | 0.003 |
| | TOTAL | 0.041 | 0.042 | 0.023 | 0.081 | 0.198 | 0.033 |
| A07 M | GR | 0.000 | -0.005 | -0.001 | -0.003 | -0.003 | 0.006 |
| | T1 | -0.029 | -0.036 | -0.034 | -0.089 | 0.158 | -0.026 |
| | R1 | 0.002 | 0.000 | 0.000 | 0.000 | 0.002 | 0.002 |
| | R2 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | R3 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | GR+T1 | -0.028 | -0.041 | -0.035 | -0.092 | 0.154 | -0.020 |
| | SEIS | 0.002 | 0.000 | 0.000 | 0.000 | 0.002 | 0.003 |
| | TOTAL | 0.030 | 0.041 | 0.035 | 0.092 | 0.157 | 0.023 |

D I S P L A C E M E N T S

| Point name | Load combination | TRANSLATIONS (in ) X | Y | Z | ROTATIONS (deg ) X | Y | Z |
|---|---|---|---|---|---|---|---|
| A07 F | GR | 0.000 | -0.005 | -0.001 | -0.008 | -0.002 | 0.007 |
| | T1 | -0.018 | -0.029 | -0.033 | -0.099 | 0.078 | -0.025 |
| | R1 | 0.002 | 0.000 | 0.000 | 0.000 | 0.004 | 0.002 |
| | R2 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | R3 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | GR+T1 | -0.018 | -0.034 | -0.034 | -0.107 | 0.076 | -0.018 |
| | SEIS | 0.002 | 0.000 | 0.000 | 0.000 | 0.004 | 0.003 |
| | TOTAL | 0.020 | 0.034 | 0.034 | 0.107 | 0.080 | 0.020 |
| A08 N | GR | 0.000 | -0.001 | -0.001 | -0.011 | -0.001 | 0.006 |
| | T1 | 0.002 | 0.007 | -0.005 | -0.076 | 0.036 | -0.035 |
| | R1 | 0.000 | 0.000 | 0.000 | 0.000 | 0.004 | 0.002 |
| | R2 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | R3 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | GR+T1 | 0.001 | 0.006 | -0.006 | -0.087 | 0.035 | -0.029 |
| | SEIS | 0.000 | 0.000 | 0.000 | 0.000 | 0.005 | 0.002 |
| | TOTAL | 0.002 | 0.006 | 0.006 | 0.088 | 0.040 | 0.031 |
| A08 M | GR | 0.000 | 0.000 | -0.001 | -0.012 | -0.001 | 0.006 |
| | T1 | 0.002 | 0.008 | 0.000 | -0.019 | 0.027 | -0.039 |
| | R1 | 0.000 | 0.000 | 0.000 | 0.001 | 0.005 | 0.001 |
| | R2 | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 | 0.000 |
| | R3 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | GR+T1 | 0.002 | 0.007 | -0.001 | -0.031 | 0.025 | -0.033 |
| | SEIS | 0.000 | 0.000 | 0.000 | 0.001 | 0.005 | 0.002 |
| | TOTAL | 0.002 | 0.007 | 0.001 | 0.031 | 0.030 | 0.035 |
| A08 F | GR | 0.000 | 0.000 | 0.000 | -0.010 | -0.002 | 0.005 |
| | T1 | 0.001 | 0.004 | 0.001 | 0.014 | 0.025 | -0.040 |
| | R1 | 0.000 | 0.000 | 0.000 | 0.001 | 0.005 | 0.001 |
| | R2 | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 | 0.000 |
| | R3 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | GR+T1 | 0.001 | 0.004 | 0.000 | 0.003 | 0.024 | -0.035 |
| | SEIS | 0.000 | 0.000 | 0.000 | 0.001 | 0.005 | 0.001 |
| | TOTAL | 0.001 | 0.004 | 0.000 | 0.004 | 0.029 | 0.036 |
| A09 | GR | 0.000 | 0.000 | 0.000 | -0.010 | -0.002 | 0.005 |
| | T1 | 0.000 | 0.003 | 0.000 | 0.014 | 0.025 | -0.040 |
| | R1 | 0.000 | 0.000 | 0.000 | 0.001 | 0.005 | 0.001 |
| | R2 | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 | 0.000 |
| | R3 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | GR+T1 | 0.000 | 0.003 | 0.000 | 0.004 | 0.024 | -0.035 |
| | SEIS | 0.000 | 0.000 | 0.000 | 0.001 | 0.005 | 0.001 |
| | TOTAL | 0.000 | 0.003 | 0.000 | 0.004 | 0.029 | 0.036 |





D I S P L A C E M E N T S

| Point name | Load combination | TRANSLATIONS (in ) X | Y | Z | ROTATIONS (deg ) X | Y | Z |
|---|---|---|---|---|---|---|---|
| A10 | GR | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | T1 | 0.000 | 0.003 | 0.000 | 0.002 | 0.000 | -0.001 |
| | R1 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | R2 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | R3 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | GR+T1 | 0.000 | 0.003 | 0.000 | 0.002 | 0.000 | -0.001 |
| | SEIS | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | TOTAL | 0.000 | 0.003 | 0.000 | 0.002 | 0.000 | 0.001 |
| A11 | GR | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | T1 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | R1 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | R2 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | R3 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | GR+T1 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | SEIS | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | TOTAL | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |

*** Segment A end ***

## S U P P O R T  F O R C E S

| Point/ Supp. ID | Connect/ Type | Load Combination | LOCAL Dirn | LOCAL Force | LOCAL Deform | GLOBAL Dirn | GLOBAL Force | GLOBAL Deform |
|---|---|---|---|---|---|---|---|---|

*** End of system , no supports encountered. ***



## R E S T R A I N T  R E A C T I O N S

| Point name | Load combination | FORCES (lb ) X | Y | Z | Result | MOMENTS (ft-lb ) X | Y | Z | Result |
|---|---|---|---|---|---|---|---|---|---|
| A00 | Anchor | | | | | | | | |
| | GR | 6 | -222 | 29 | 224 | 55 | 7 | 38 | 67 |
| | T1 | -447 | 427 | -2062 | 2153 | 76 | -588 | -60 | 596 |
| | R1 | 9 | 1 | 7 | 12 | 4 | 5 | 3 | 7 |
| | R2 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 1 |
| | R3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | GR+T1 | -441 | 205 | -2034 | 2091 | 131 | -581 | -22 | 596 |
| | SEIS | 10 | 1 | 8 | 13 | 4 | 6 | 4 | 8 |
| | TOTAL | 451 | 206 | 2042 | 2101 | 135 | 586 | 26 | 602 |
| A11 | Anchor | | | | | | | | |
| | GR | -6 | -208 | -29 | 210 | -27 | 0 | 12 | 30 |
| | T1 | 447 | -427 | 2062 | 2153 | 458 | 8 | -175 | 491 |
| | R1 | 10 | 1 | 7 | 12 | 3 | 1 | 0 | 3 |
| | R2 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 |
| | R3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | GR+T1 | 441 | -635 | 2034 | 2175 | 431 | 7 | -163 | 461 |
| | SEIS | 11 | 1 | 8 | 14 | 3 | 2 | 0 | 3 |
| | TOTAL | 452 | 636 | 2042 | 2186 | 434 | 9 | 164 | 464 |

## G L O B A L F O R C E S & M O M E N T S

| Point name | Load combination | FORCES (lb ) X | Y | Z | Result | MOMENTS (ft-lb ) X | Y | Z | Result |
|---|---|---|---|---|---|---|---|---|---|
| *** Segment A begin *** | | | | | | | | | |
| A00 | GR | -6 | 222 | -29 | 224 | -55 | -7 | -38 | 67 |
| | T1 | 447 | -427 | 2062 | 2153 | -76 | 588 | 60 | 596 |
| | R1 | 9 | 1 | 7 | 12 | 4 | 5 | 3 | 7 |
| | R2 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 1 |
| | R3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | GR+T1 | 441 | -205 | 2034 | 2091 | -131 | 581 | 22 | 596 |
| | SEIS | 10 | 1 | 8 | 13 | 4 | 6 | 4 | 8 |
| | TOTAL | 451 | 206 | 2042 | 2101 | 135 | 586 | 26 | 602 |
| A01 | GR | -6 | 75 | -29 | 80 | -21 | -3 | -13 | 25 |
| | T1 | 447 | -427 | 2062 | 2153 | -141 | 287 | 12 | 320 |
| | R1 | 9 | 1 | 7 | 12 | 4 | 4 | 3 | 7 |
| | R2 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 1 |
| | R3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | GR+T1 | 441 | -352 | 2034 | 2110 | -162 | 284 | -1 | 327 |
| | SEIS | 10 | 1 | 8 | 13 | 4 | 5 | 4 | 7 |
| | TOTAL | 451 | 353 | 2042 | 2120 | 166 | 289 | 5 | 333 |
| A02 | GR | -6 | 75 | -29 | 80 | -17 | -2 | -10 | 20 |
| | T1 | 447 | -427 | 2062 | 2153 | -154 | 232 | 4 | 279 |
| | R1 | 9 | 1 | 7 | 12 | 4 | 4 | 3 | 6 |
| | R2 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 1 |
| | R3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | GR+T1 | 441 | -352 | 2034 | 2110 | -171 | 230 | -7 | 286 |
| | SEIS | 10 | 1 | 8 | 13 | 4 | 5 | 4 | 7 |
| | TOTAL | 451 | 353 | 2042 | 2120 | 175 | 235 | 10 | 293 |
| A03 N | GR | -6 | 73 | -29 | 79 | -13 | -1 | -8 | 15 |
| | T1 | 447 | -427 | 2062 | 2153 | -176 | 136 | -11 | 223 |
| | R1 | 9 | 1 | 7 | 12 | 4 | 4 | 3 | 6 |
| | R2 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 1 |
| | R3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | GR+T1 | 441 | -353 | 2034 | 2111 | -189 | 135 | -19 | 233 |
| | SEIS | 10 | 1 | 8 | 13 | 4 | 5 | 4 | 7 |
| | TOTAL | 451 | 354 | 2042 | 2121 | 193 | 140 | 23 | 239 |
| A03 M | GR | -6 | 69 | -29 | 75 | -2 | 4 | 2 | 5 |
| | T1 | 447 | -427 | 2062 | 2153 | -59 | -221 | -111 | 254 |
| | R1 | 9 | 1 | 7 | 12 | 3 | 3 | 2 | 5 |
| | R2 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 1 |
| | R3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | GR+T1 | 441 | -358 | 2034 | 2111 | -60 | -217 | -109 | 250 |
| | SEIS | 10 | 1 | 8 | 13 | 3 | 4 | 3 | 5 |
| | TOTAL | 451 | 359 | 2042 | 2121 | 63 | 221 | 111 | 255 |





## G L O B A L F O R C E S & M O M E N T S

| Point name | Load combination | FORCES (lb ) X | Y | Z | Result | MOMENTS (ft-lb ) X | Y | Z | Result |
|---|---|---|---|---|---|---|---|---|---|
| A03 F | GR | -6 | 64 | -29 | 71 | -3 | 6 | 7 | 10 |
| | T1 | 447 | -427 | 2062 | 2153 | 393 | -369 | -239 | 590 |
| | R1 | 9 | 1 | 7 | 12 | 1 | 3 | 0 | 3 |
| | R2 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 |
| | R3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | GR+T1 | 441 | -362 | 2034 | 2112 | 390 | -363 | -232 | 581 |
| | SEIS | 10 | 1 | 8 | 13 | 1 | 3 | 0 | 3 |
| | TOTAL | 451 | 363 | 2042 | 2122 | 391 | 366 | 232 | 584 |
| A04 N | GR | -6 | 64 | -29 | 71 | -3 | 6 | 7 | 10 |
| | T1 | 447 | -427 | 2062 | 2153 | 407 | -369 | -242 | 600 |
| | R1 | 9 | 0 | 7 | 12 | 1 | 3 | 0 | 3 |
| | R2 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 |
| | R3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | GR+T1 | 441 | -362 | 2034 | 2112 | 403 | -363 | -235 | 591 |
| | SEIS | 10 | 1 | 8 | 13 | 1 | 3 | 0 | 3 |
| | TOTAL | 451 | 363 | 2042 | 2122 | 404 | 366 | 235 | 594 |
| A04 M | GR | -6 | 58 | -29 | 65 | -5 | 7 | 9 | 12 |
| | T1 | 447 | -427 | 2062 | 2153 | 1073 | -434 | -400 | 1225 |
| | R1 | 8 | 0 | 7 | 11 | 2 | 2 | 3 | 4 |
| | R2 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 |
| | R3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | GR+T1 | 441 | -369 | 2034 | 2113 | 1068 | -428 | -391 | 1215 |
| | SEIS | 9 | 0 | 8 | 12 | 2 | 2 | 3 | 4 |
| | TOTAL | 450 | 370 | 2042 | 2123 | 1071 | 429 | 394 | 1219 |
| A04 F | GR | -6 | 51 | -29 | 59 | 10 | 9 | 10 | 17 |
| | T1 | 447 | -427 | 2062 | 2153 | 1224 | -592 | -466 | 1438 |
| | R1 | 6 | 0 | 7 | 9 | 3 | 1 | 4 | 5 |
| | R2 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 1 |
| | R3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | GR+T1 | 441 | -376 | 2034 | 2114 | 1234 | -583 | -455 | 1439 |
| | SEIS | 7 | 0 | 8 | 11 | 3 | 1 | 5 | 6 |
| | TOTAL | 448 | 376 | 2042 | 2124 | 1238 | 585 | 460 | 1444 |
| A05 N | GR | -6 | 22 | -29 | 37 | 71 | 19 | 10 | 74 |
| | T1 | 447 | -427 | 2062 | 2153 | 512 | -1339 | -466 | 1507 |
| | R1 | 2 | 1 | 7 | 8 | 3 | 11 | 4 | 12 |
| | R2 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 1 |
| | R3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | GR+T1 | 441 | -405 | 2034 | 2120 | 583 | -1320 | -455 | 1513 |
| | SEIS | 2 | 1 | 8 | 9 | 3 | 13 | 5 | 14 |
| | TOTAL | 443 | 406 | 2042 | 2128 | 585 | 1332 | 460 | 1526 |





ICF-4SPRINT

G L O B A L F O R C E S & M O M E N T S

| Point name | Load combination | FORCES (lb ) X | Y | Z | Result | MOMENTS (ft-lb ) X | Y | Z | Result |
|---|---|---|---|---|---|---|---|---|---|
| A05 M | GR | -6 | 15 | -29 | 33 | 78 | 17 | 8 | 80 |
| | T1 | 447 | -427 | 2062 | 2153 | 361 | -1195 | -403 | 1312 |
| | R1 | 1 | 2 | 7 | 7 | 2 | 13 | 4 | 14 |
| | R2 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 2 |
| | R3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | GR+T1 | 441 | -412 | 2034 | 2121 | 438 | -1178 | -396 | 1318 |
| | SEIS | 1 | 2 | 8 | 8 | 2 | 15 | 5 | 16 |
| | TOTAL | 442 | 413 | 2041 | 2129 | 441 | 1193 | 400 | 1333 |
| A05 F | GR | -6 | 8 | -29 | 31 | 80 | 8 | 4 | 80 |
| | T1 | 447 | -427 | 2062 | 2153 | 298 | -531 | -252 | 659 |
| | R1 | 0 | 2 | 7 | 7 | 2 | 16 | 5 | 17 |
| | R2 | 0 | 0 | 1 | 1 | 0 | 2 | 1 | 2 |
| | R3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | GR+T1 | 441 | -418 | 2034 | 2122 | 378 | -524 | -249 | 692 |
| | SEIS | 0 | 2 | 8 | 8 | 2 | 18 | 6 | 19 |
| | TOTAL | 441 | 420 | 2041 | 2130 | 380 | 541 | 254 | 708 |
| A06 - | GR | -6 | 6 | -29 | 30 | 80 | 3 | 2 | 80 |
| | T1 | 447 | -427 | 2062 | 2153 | 298 | -181 | -180 | 392 |
| | R1 | 0 | 2 | 7 | 7 | 2 | 17 | 5 | 18 |
| | R2 | 0 | 0 | 1 | 1 | 0 | 2 | 1 | 2 |
| | R3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | GR+T1 | 441 | -421 | 2034 | 2123 | 378 | -178 | -177 | 454 |
| | SEIS | 0 | 2 | 8 | 8 | 2 | 19 | 6 | 20 |
| | TOTAL | 441 | 423 | 2041 | 2131 | 380 | 197 | 183 | 465 |
| A06 + | GR | -6 | -2 | -29 | 30 | 80 | 3 | 2 | 80 |
| | T1 | 447 | -427 | 2062 | 2153 | 298 | -181 | -180 | 392 |
| | R1 | 3 | 2 | 7 | 8 | 2 | 17 | 5 | 18 |
| | R2 | 0 | 0 | 1 | 1 | 0 | 2 | 1 | 2 |
| | R3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | GR+T1 | 441 | -429 | 2034 | 2125 | 378 | -178 | -177 | 454 |
| | SEIS | 3 | 2 | 8 | 9 | 2 | 19 | 6 | 20 |
| | TOTAL | 444 | 431 | 2041 | 2133 | 380 | 197 | 183 | 465 |
| A07 N | GR | -6 | -5 | -29 | 30 | 80 | -2 | 3 | 80 |
| | T1 | 447 | -427 | 2062 | 2153 | 298 | 170 | -107 | 360 |
| | R1 | 4 | 2 | 7 | 8 | 2 | 18 | 6 | 19 |
| | R2 | 0 | 0 | 1 | 1 | 0 | 2 | 1 | 2 |
| | R3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | GR+T1 | 441 | -432 | 2034 | 2125 | 378 | 168 | -104 | 426 |
| | SEIS | 4 | 2 | 8 | 9 | 2 | 20 | 6 | 21 |
| | TOTAL | 445 | 434 | 2041 | 2134 | 380 | 188 | 110 | 438 |





G L O B A L F O R C E S & M O M E N T S

| Point name | Load combination | FORCES (lb ) X | Y | Z | Result | MOMENTS (ft-lb ) X | Y | Z | Result |
|---|---|---|---|---|---|---|---|---|---|
| A07 M | GR | -6 | -12 | -29 | 32 | 78 | -12 | 6 | 79 |
| | T1 | 447 | -427 | 2062 | 2153 | 236 | 834 | 44 | 867 |
| | R1 | 6 | 2 | 7 | 9 | 2 | 20 | 6 | 21 |
| | R2 | 1 | 0 | 1 | 1 | 0 | 2 | 1 | 2 |
| | R3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | GR+T1 | 441 | -439 | 2034 | 2127 | 314 | 822 | 50 | 881 |
| | SEIS | 6 | 2 | 8 | 10 | 2 | 22 | 7 | 23 |
| | TOTAL | 447 | 441 | 2041 | 2136 | 316 | 844 | 57 | 903 |
| A07 F | GR | -6 | -19 | -29 | 35 | 73 | -14 | 8 | 74 |
| | T1 | 447 | -427 | 2062 | 2153 | 85 | 978 | 106 | 987 |
| | R1 | 9 | 1 | 7 | 12 | 1 | 19 | 7 | 20 |
| | R2 | 1 | 0 | 1 | 1 | 0 | 2 | 1 | 2 |
| | R3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | GR+T1 | 441 | -446 | 2034 | 2128 | 157 | 964 | 114 | 983 |
| | SEIS | 10 | 1 | 8 | 13 | 1 | 21 | 7 | 22 |
| | TOTAL | 451 | 447 | 2041 | 2138 | 158 | 985 | 122 | 1005 |
| A08 N | GR | -6 | -51 | -29 | 58 | 9 | -2 | 8 | 12 |
| | T1 | 447 | -427 | 2062 | 2153 | -699 | 157 | 106 | 724 |
| | R1 | 10 | 1 | 7 | 12 | 1 | 2 | 7 | 7 |
| | R2 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 1 |
| | R3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | GR+T1 | 441 | -477 | 2034 | 2135 | -690 | 154 | 114 | 716 |
| | SEIS | 11 | 1 | 8 | 14 | 2 | 2 | 7 | 8 |
| | TOTAL | 452 | 479 | 2041 | 2145 | 692 | 156 | 122 | 719 |
| A08 M | GR | -6 | -55 | -29 | 62 | -6 | -1 | 9 | 11 |
| | T1 | 447 | -427 | 2062 | 2153 | -598 | 51 | 63 | 604 |
| | R1 | 10 | 1 | 7 | 12 | 1 | 0 | 6 | 6 |
| | R2 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 1 |
| | R3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | GR+T1 | 441 | -482 | 2034 | 2136 | -605 | 50 | 71 | 611 |
| | SEIS | 11 | 1 | 8 | 14 | 1 | 1 | 6 | 6 |
| | TOTAL | 452 | 483 | 2041 | 2146 | 606 | 51 | 77 | 613 |
| A08 F | GR | -6 | -60 | -29 | 66 | -19 | 0 | 10 | 21 |
| | T1 | 447 | -427 | 2062 | 2153 | -154 | 8 | -43 | 160 |
| | R1 | 10 | 1 | 7 | 12 | 1 | 1 | 3 | 4 |
| | R2 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 |
| | R3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | GR+T1 | 441 | -486 | 2034 | 2137 | -173 | 7 | -33 | 176 |
| | SEIS | 11 | 1 | 8 | 14 | 1 | 2 | 4 | 4 |
| | TOTAL | 452 | 488 | 2041 | 2147 | 173 | 9 | 36 | 177 |





ICF 4951HT

## G L O B A L F O R C E S & M O M E N T S

| Point name | Load combination | FORCES (lb ) X | Y | Z | Result | MOMENTS (ft-lb ) X | Y | Z | Result |
|---|---|---|---|---|---|---|---|---|---|
| A09 | GR | -6 | -205 | -29 | 207 | -21 | 0 | 11 | 23 |
| | T1 | 447 | -427 | 2062 | 2153 | -16 | 8 | -73 | 75 |
| | R1 | 10 | 1 | 7 | 12 | 1 | 1 | 3 | 3 |
| | R2 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 |
| | R3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | GR+T1 | 441 | -631 | 2034 | 2174 | -37 | 7 | -62 | 73 |
| | SEIS | 11 | 1 | 8 | 14 | 1 | 2 | 3 | 4 |
| | TOTAL | 452 | 633 | 2042 | 2185 | 38 | 9 | 65 | 76 |
| A10 | GR | -6 | -205 | -29 | 207 | -22 | 0 | 11 | 24 |
| | T1 | 447 | -427 | 2062 | 2153 | 66 | 8 | -91 | 112 |
| | R1 | 10 | 1 | 7 | 12 | 1 | 1 | 2 | 3 |
| | R2 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 |
| | R3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | GR+T1 | 441 | -631 | 2034 | 2174 | 44 | 7 | -80 | 91 |
| | SEIS | 11 | 1 | 8 | 14 | 2 | 2 | 2 | 3 |
| | TOTAL | 452 | 633 | 2042 | 2185 | 46 | 9 | 82 | 95 |
| A11 | GR | -6 | -208 | -29 | 210 | -27 | 0 | 12 | 30 |
| | T1 | 447 | -427 | 2062 | 2153 | 458 | 8 | -175 | 491 |
| | R1 | 10 | 1 | 7 | 12 | 3 | 1 | 0 | 3 |
| | R2 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 |
| | R3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | GR+T1 | 441 | -635 | 2034 | 2175 | 431 | 7 | -163 | 461 |
| | SEIS | 11 | 1 | 8 | 14 | 3 | 2 | 0 | 3 |
| | TOTAL | 452 | 636 | 2042 | 2186 | 434 | 9 | 164 | 464 |

*** Segment A end ***



## ASME B31.3c (1992) CODE COMPLIANCE

| Point name | Load combination | (Moments in ft-lb ) In-Pl. Moment | Out-Pl. Moment | Torsion Moment | S.I.F In | S.I.F Out | Eq. no. | (Stress in psi ) Load type | Code Stress | Code Allow. |
|---|---|---|---|---|---|---|---|---|---|---|
| *** Segment A begin *** | | | | | | | | | | |
| A00 | Max P | | | | | | (3a) | HOOP | 4844 | 16700 |
| | GR + Max P | 67 | 7 | | 1.00 | 1.00 | (18) | SUST | 2388 | 16700 |
| | Cold to T1 | 25 | 588 | 94 | 1.00 | 1.00 | (17) | DISP | 2225 | 25050 |
| | Sus. + R1 | 72 | 12 | | 1.00 | 1.00 | (18) | OCC | 2422 | 22211 |
| | Sus. + R2 | 67 | 8 | | 1.00 | 1.00 | (18) | OCC | 2391 | 22211 |
| | Sus. + R3 | 67 | 7 | | 1.00 | 1.00 | (18) | OCC | 2388 | 22211 |
| A01 | Max P | | | | | | (3a) | HOOP | 4844 | 16700 |
| | GR + Max P | 25 | 3 | | 1.00 | 1.00 | (18) | SUST | 2187 | 16700 |
| | Cold to T1 | 106 | 287 | 94 | 1.00 | 1.00 | (17) | DISP | 1195 | 25050 |
| | Sus. + R1 | 30 | 8 | | 1.00 | 1.00 | (18) | OCC | 2218 | 22211 |
| | Sus. + R2 | 25 | 4 | | 1.00 | 1.00 | (18) | OCC | 2190 | 22211 |
| | Sus. + R3 | 25 | 3 | | 1.00 | 1.00 | (18) | OCC | 2187 | 22211 |
| A02 | Max P | | | | | | (3a) | HOOP | 4844 | 16700 |
| | GR + Max P | 20 | 2 | | 1.00 | 1.00 | (18) | SUST | 2161 | 16700 |
| | Cold to T1 | 126 | 232 | 88 | 1.00 | 1.00 | (17) | DISP | 1040 | 25050 |
| | Sus. + R1 | 25 | 7 | | 1.00 | 1.00 | (18) | OCC | 2192 | 22211 |
| | Sus. + R2 | 20 | 3 | | 1.00 | 1.00 | (18) | OCC | 2165 | 22211 |
| | Sus. + R3 | 20 | 2 | | 1.00 | 1.00 | (18) | OCC | 2161 | 22211 |
| A03 N- | Max P | | | | | | (3a) | HOOP | 4844 | 16700 |
| | GR + Max P | 15 | 1 | | 1.00 | 1.00 | (18) | SUST | 2138 | 16700 |
| | Cold to T1 | 153 | 136 | 88 | 1.00 | 1.00 | (17) | DISP | 833 | 25050 |
| | Sus. + R1 | 20 | 5 | | 1.00 | 1.00 | (18) | OCC | 2168 | 22211 |
| | Sus. + R2 | 16 | 2 | | 1.00 | 1.00 | (18) | OCC | 2141 | 22211 |
| | Sus. + R3 | 15 | 1 | | 1.00 | 1.00 | (18) | OCC | 2138 | 22211 |
| A03 N+ | Max P | | | | | | (3a) | HOOP | 4844 | 16700 |
| | GR + Max P | 15 | 1 | | 2.56 | 2.13 | (18) | SUST | 2251 | 16700 |
| | Cold to T1 | 153 | 136 | 88 | 2.56 | 2.13 | (17) | DISP | 1850 | 25050 |
| | Sus. + R1 | 20 | 5 | | 2.56 | 2.13 | (18) | OCC | 2323 | 22211 |
| | Sus. + R2 | 16 | 2 | | 2.56 | 2.13 | (18) | OCC | 2259 | 22211 |
| | Sus. + R3 | 15 | 1 | | 2.56 | 2.13 | (18) | OCC | 2251 | 22211 |
| A03 M | Max P | | | | | | (3a) | HOOP | 4844 | 16700 |
| | GR + Max P | 0 | 5 | | 2.56 | 2.13 | (18) | SUST | 2113 | 16700 |
| | Cold to T1 | 110 | 198 | 114 | 2.56 | 2.13 | (17) | DISP | 1945 | 25050 |
| | Sus. + R1 | 4 | 7 | | 2.56 | 2.13 | (18) | OCC | 2163 | 22211 |
| | Sus. + R2 | 1 | 5 | | 2.56 | 2.13 | (18) | OCC | 2119 | 22211 |
| | Sus. + R3 | 0 | 5 | | 2.56 | 2.13 | (18) | OCC | 2113 | 22211 |

ASME B31.3c (1992) CODE COMPLIANCE

| Point name | Load combination | (Moments in ft-lb ) In-Pl. Moment | Out-Pl. Moment | Torsion Moment | S.I.F In | S.I.F Out | (Stress in psi ) Eq. no. | Load type | Code Stress | Code Allow. |
|---|---|---|---|---|---|---|---|---|---|---|
| A03 F- | Max P | | | | | | (3a) | HOOP | 4844 | 16700 |
| | GR + Max P | 1 | 8 | | 2.56 | 2.13 | (18) | SUST | 2146 | 16700 |
| | Cold to T1 | 194 | 417 | 369 | 2.56 | 2.13 | (17) | DISP | 4043 | 25050 |
| | Sus. + R1 | 2 | 8 | | 2.56 | 2.13 | (18) | OCC | 2157 | 22211 |
| | Sus. + R2 | 2 | 8 | | 2.56 | 2.13 | (18) | OCC | 2148 | 22211 |
| | Sus. + R3 | 1 | 8 | | 2.56 | 2.13 | (18) | OCC | 2146 | 22211 |
| A03 F+ | Max P | | | | | | (3a) | HOOP | 4844 | 16700 |
| | GR + Max P | 3 | 7 | | 1.00 | 1.00 | (18) | SUST | 2103 | 16700 |
| | Cold to T1 | 393 | 239 | 369 | 1.00 | 1.00 | (17) | DISP | 2201 | 25050 |
| | Sus. + R1 | 4 | 7 | | 1.00 | 1.00 | (18) | OCC | 2107 | 22211 |
| | Sus. + R2 | 3 | 7 | | 1.00 | 1.00 | (18) | OCC | 2104 | 22211 |
| | Sus. + R3 | 3 | 7 | | 1.00 | 1.00 | (18) | OCC | 2103 | 22211 |
| A04 N- | Max P | | | | | | (3a) | HOOP | 4844 | 16700 |
| | GR + Max P | 3 | 7 | | 1.00 | 1.00 | (18) | SUST | 2104 | 16700 |
| | Cold to T1 | 407 | 242 | 369 | 1.00 | 1.00 | (17) | DISP | 2240 | 25050 |
| | Sus. + R1 | 4 | 7 | | 1.00 | 1.00 | (18) | OCC | 2108 | 22211 |
| | Sus. + R2 | 3 | 7 | | 1.00 | 1.00 | (18) | OCC | 2104 | 22211 |
| | Sus. + R3 | 3 | 7 | | 1.00 | 1.00 | (18) | OCC | 2104 | 22211 |
| A04 N+ | Max P | | | | | | (3a) | HOOP | 4844 | 16700 |
| | GR + Max P | 3 | 7 | | 1.95 | 1.63 | (18) | SUST | 2130 | 16700 |
| | Cold to T1 | 407 | 242 | 369 | 1.95 | 1.63 | (17) | DISP | 3583 | 25050 |
| | Sus. + R1 | 4 | 7 | | 1.95 | 1.63 | (18) | OCC | 2138 | 22211 |
| | Sus. + R2 | 3 | 7 | | 1.95 | 1.63 | (18) | OCC | 2131 | 22211 |
| | Sus. + R3 | 3 | 7 | | 1.95 | 1.63 | (18) | OCC | 2130 | 22211 |
| A04 M | Max P | | | | | | (3a) | HOOP | 4844 | 16700 |
| | GR + Max P | 5 | 11 | | 1.95 | 1.63 | (18) | SUST | 2165 | 16700 |
| | Cold to T1 | 1073 | 590 | 24 | 1.95 | 1.63 | (17) | DISP | 8604 | 25050 |
| | Sus. + R1 | 7 | 12 | | 1.95 | 1.63 | (18) | OCC | 2184 | 22211 |
| | Sus. + R2 | 5 | 12 | | 1.95 | 1.63 | (18) | OCC | 2167 | 22211 |
| | Sus. + R3 | 5 | 11 | | 1.95 | 1.63 | (18) | OCC | 2165 | 22211 |
| A04 F- | Max P | | | | | | (3a) | HOOP | 4844 | 16700 |
| | GR + Max P | 10 | 9 | | 1.95 | 1.63 | (18) | SUST | 2183 | 16700 |
| | Cold to T1 | 1224 | 592 | 466 | 1.95 | 1.63 | (17) | DISP | 9777 | 25050 |
| | Sus. + R1 | 13 | 10 | | 1.95 | 1.63 | (18) | OCC | 2214 | 22211 |
| | Sus. + R2 | 10 | 9 | | 1.95 | 1.63 | (18) | OCC | 2187 | 22211 |
| | Sus. + R3 | 10 | 9 | | 1.95 | 1.63 | (18) | OCC | 2183 | 22211 |
| A04 F+ | Max P | | | | | | (3a) | HOOP | 4844 | 16700 |
| | GR + Max P | 10 | 9 | | 1.00 | 1.00 | (18) | SUST | 2130 | 16700 |
| | Cold to T1 | 1224 | 592 | 466 | 1.00 | 1.00 | (17) | DISP | 5367 | 25050 |
| | Sus. + R1 | 13 | 10 | | 1.00 | 1.00 | (18) | OCC | 2146 | 22211 |
| | Sus. + R2 | 10 | 9 | | 1.00 | 1.00 | (18) | OCC | 2132 | 22211 |
| | Sus. + R3 | 10 | 9 | | 1.00 | 1.00 | (18) | OCC | 2130 | 22211 |





ASME B31.3c (1992) CODE COMPLIANCE

| Point name | Load combination | (Moments in ft-lb ) In-Pl. Moment | Out-Pl. Moment | Torsion Moment | S.I.F In | S.I.F Out | (Stress in psi ) Eq. no. | Load type | Code Stress | Code Allow. |
|---|---|---|---|---|---|---|---|---|---|---|
| A05 N- | Max P | | | | | | (3a) | HOOP | 4844 | 16700 |
| | GR + Max P | 71 | 19 | | 1.00 | 1.00 | (18) | SUST | 2418 | 16700 |
| | Cold to T1 | 512 | 1339 | 466 | 1.00 | 1.00 | (17) | DISP | 5626 | 25050 |
| | Sus. + R1 | 73 | 30 | | 1.00 | 1.00 | (18) | OCC | 2474 | 22211 |
| | Sus. + R2 | 71 | 20 | | 1.00 | 1.00 | (18) | OCC | 2424 | 22211 |
| | Sus. + R3 | 71 | 19 | | 1.00 | 1.00 | (18) | OCC | 2418 | 22211 |
| A05 N+ | Max P | | | | | | (3a) | HOOP | 4844 | 16700 |
| | GR + Max P | 19 | 71 | | 1.95 | 1.63 | (18) | SUST | 2648 | 16700 |
| | Cold to T1 | 1339 | 512 | 466 | 1.95 | 1.63 | (17) | DISP | 10387 | 25050 |
| | Sus. + R1 | 30 | 73 | | 1.95 | 1.63 | (18) | OCC | 2756 | 22211 |
| | Sus. + R2 | 20 | 71 | | 1.95 | 1.63 | (18) | OCC | 2659 | 22211 |
| | Sus. + R3 | 19 | 71 | | 1.95 | 1.63 | (18) | OCC | 2648 | 22211 |
| A05 M | Max P | | | | | | (3a) | HOOP | 4844 | 16700 |
| | GR + Max P | 17 | 49 | | 1.95 | 1.63 | (18) | SUST | 2483 | 16700 |
| | Cold to T1 | 1195 | 540 | 30 | 1.95 | 1.63 | (17) | DISP | 9307 | 25050 |
| | Sus. + R1 | 30 | 51 | | 1.95 | 1.63 | (18) | OCC | 2607 | 22211 |
| | Sus. + R2 | 18 | 50 | | 1.95 | 1.63 | (18) | OCC | 2497 | 22211 |
| | Sus. + R3 | 17 | 49 | | 1.95 | 1.63 | (18) | OCC | 2483 | 22211 |
| A05 F- | Max P | | | | | | (3a) | HOOP | 4844 | 16700 |
| | GR + Max P | 8 | 4 | | 1.95 | 1.63 | (18) | SUST | 2142 | 16700 |
| | Cold to T1 | 531 | 252 | 298 | 1.95 | 1.63 | (17) | DISP | 4310 | 25050 |
| | Sus. + R1 | 23 | 9 | | 1.95 | 1.63 | (18) | OCC | 2296 | 22211 |
| | Sus. + R2 | 9 | 4 | | 1.95 | 1.63 | (18) | OCC | 2159 | 22211 |
| | Sus. + R3 | 8 | 4 | | 1.95 | 1.63 | (18) | OCC | 2142 | 22211 |
| A05 F+ | Max P | | | | | | (3a) | HOOP | 4844 | 16700 |
| | GR + Max P | 4 | 8 | | 1.00 | 1.00 | (18) | SUST | 2106 | 16700 |
| | Cold to T1 | 252 | 531 | 298 | 1.00 | 1.00 | (17) | DISP | 2462 | 25050 |
| | Sus. + R1 | 9 | 23 | | 1.00 | 1.00 | (18) | OCC | 2186 | 22211 |
| | Sus. + R2 | 4 | 9 | | 1.00 | 1.00 | (18) | OCC | 2115 | 22211 |
| | Sus. + R3 | 4 | 8 | | 1.00 | 1.00 | (18) | OCC | 2106 | 22211 |
| A06 | Max P | | | | | | (3a) | HOOP | 4844 | 16700 |
| | GR + Max P | 2 | 3 | | 1.00 | 1.00 | (18) | SUST | 2083 | 16700 |
| | Cold to T1 | 180 | 181 | 298 | 1.00 | 1.00 | (17) | DISP | 1464 | 25050 |
| | Sus. + R1 | 8 | 20 | | 1.00 | 1.00 | (18) | OCC | 2169 | 22211 |
| | Sus. + R2 | 3 | 5 | | 1.00 | 1.00 | (18) | OCC | 2092 | 22211 |
| | Sus. + R3 | 2 | 3 | | 1.00 | 1.00 | (18) | OCC | 2083 | 22211 |
| A07 N- | Max P | | | | | | (3a) | HOOP | 4844 | 16700 |
| | GR + Max P | 3 | 2 | | 1.00 | 1.00 | (18) | SUST | 2084 | 16700 |
| | Cold to T1 | 107 | 170 | 298 | 1.00 | 1.00 | (17) | DISP | 1343 | 25050 |
| | Sus. + R1 | 9 | 20 | | 1.00 | 1.00 | (18) | OCC | 2175 | 22211 |
| | Sus. + R2 | 4 | 4 | | 1.00 | 1.00 | (18) | OCC | 2094 | 22211 |
| | Sus. + R3 | 3 | 2 | | 1.00 | 1.00 | (18) | OCC | 2084 | 22211 |

ASME B31.3c (1992) CODE COMPLIANCE

| Point name | Load combination | (Moments in ft-lb ) In-Pl. Moment | Out-Pl. Moment | Torsion Moment | S.I.F In | S.I.F Out | (Stress in psi ) Eq. no. | Load type | Code Stress | Code Allow. |
|---|---|---|---|---|---|---|---|---|---|---|
| A07 N+ | Max P | | | | | | (3a) | HOOP | 4844 | 16700 |
| | GR + Max P | 2 | 3 | | 1.95 | 1.63 | (18) | SUST | 2097 | 16700 |
| | Cold to T1 | 170 | 107 | 298 | 1.95 | 1.63 | (17) | DISP | 1789 | 25050 |
| | Sus. + R1 | 20 | 9 | | 1.95 | 1.63 | (18) | OCC | 2274 | 22211 |
| | Sus. + R2 | 4 | 4 | | 1.95 | 1.63 | (18) | OCC | 2116 | 22211 |
| | Sus. + R3 | 2 | 3 | | 1.95 | 1.63 | (18) | OCC | 2097 | 22211 |
| A07 M | Max P | | | | | | (3a) | HOOP | 4844 | 16700 |
| | GR + Max P | 12 | 51 | | 1.95 | 1.63 | (18) | SUST | 2478 | 16700 |
| | Cold to T1 | 834 | 136 | 198 | 1.95 | 1.63 | (17) | DISP | 6176 | 25050 |
| | Sus. + R1 | 32 | 54 | | 1.95 | 1.63 | (18) | OCC | 2668 | 22211 |
| | Sus. + R2 | 14 | 51 | | 1.95 | 1.63 | (18) | OCC | 2498 | 22211 |
| | Sus. + R3 | 12 | 51 | | 1.95 | 1.63 | (18) | OCC | 2478 | 22211 |
| A07 F- | Max P | | | | | | (3a) | HOOP | 4844 | 16700 |
| | GR + Max P | 14 | 73 | | 1.95 | 1.63 | (18) | SUST | 2646 | 16700 |
| | Cold to T1 | 978 | 85 | 106 | 1.95 | 1.63 | (17) | DISP | 7155 | 25050 |
| | Sus. + R1 | 33 | 73 | | 1.95 | 1.63 | (18) | OCC | 2825 | 22211 |
| | Sus. + R2 | 16 | 73 | | 1.95 | 1.63 | (18) | OCC | 2666 | 22211 |
| | Sus. + R3 | 14 | 73 | | 1.95 | 1.63 | (18) | OCC | 2646 | 22211 |
| A07 F+ | Max P | | | | | | (3a) | HOOP | 4844 | 16700 |
| | GR + Max P | 73 | 14 | | 1.00 | 1.00 | (18) | SUST | 2420 | 16700 |
| | Cold to T1 | 85 | 978 | 106 | 1.00 | 1.00 | (17) | DISP | 3685 | 25050 |
| | Sus. + R1 | 73 | 33 | | 1.00 | 1.00 | (18) | OCC | 2512 | 22211 |
| | Sus. + R2 | 73 | 16 | | 1.00 | 1.00 | (18) | OCC | 2430 | 22211 |
| | Sus. + R3 | 73 | 14 | | 1.00 | 1.00 | (18) | OCC | 2420 | 22211 |
| A08 N- | Max P | | | | | | (3a) | HOOP | 4844 | 16700 |
| | GR + Max P | 9 | 2 | | 1.00 | 1.00 | (18) | SUST | 2109 | 16700 |
| | Cold to T1 | 699 | 157 | 106 | 1.00 | 1.00 | (17) | DISP | 2703 | 25050 |
| | Sus. + R1 | 10 | 4 | | 1.00 | 1.00 | (18) | OCC | 2121 | 22211 |
| | Sus. + R2 | 9 | 3 | | 1.00 | 1.00 | (18) | OCC | 2111 | 22211 |
| | Sus. + R3 | 9 | 2 | | 1.00 | 1.00 | (18) | OCC | 2109 | 22211 |
| A08 N+ | Max P | | | | | | (3a) | HOOP | 4844 | 16700 |
| | GR + Max P | 9 | 2 | | 2.56 | 2.13 | (18) | SUST | 2176 | 16700 |
| | Cold to T1 | 699 | 157 | 106 | 2.56 | 2.13 | (17) | DISP | 6803 | 25050 |
| | Sus. + R1 | 10 | 4 | | 2.56 | 2.13 | (18) | OCC | 2202 | 22211 |
| | Sus. + R2 | 9 | 3 | | 2.56 | 2.13 | (18) | OCC | 2179 | 22211 |
| | Sus. + R3 | 9 | 2 | | 2.56 | 2.13 | (18) | OCC | 2176 | 22211 |
| A08 M | Max P | | | | | | (3a) | HOOP | 4844 | 16700 |
| | GR + Max P | 6 | 5 | | 2.56 | 2.13 | (18) | SUST | 2162 | 16700 |
| | Cold to T1 | 598 | 80 | 8 | 2.56 | 2.13 | (17) | DISP | 5749 | 25050 |
| | Sus. + R1 | 7 | 9 | | 2.56 | 2.13 | (18) | OCC | 2201 | 22211 |
| | Sus. + R2 | 7 | 6 | | 2.56 | 2.13 | (18) | OCC | 2167 | 22211 |
| | Sus. + R3 | 6 | 5 | | 2.56 | 2.13 | (18) | OCC | 2162 | 22211 |





ASME B31.3c (1992) CODE COMPLIANCE

| Point name | Load combination | (Moments in ft-lb ) In-Pl. Moment | Out-Pl. Moment | Torsion Moment | S.I.F In | S.I.F Out | (Stress in psi ) Eq. no. | Load type | Code Stress | Code Allow. |
|---|---|---|---|---|---|---|---|---|---|---|
| A08 F- | Max P | | | | | | (3a) | HOOP | 4844 | 16700 |
| | GR + Max P | 19 | 10 | | 2.56 | 2.13 | (18) | SUST | 2319 | 16700 |
| | Cold to T1 | 154 | 43 | 8 | 2.56 | 2.13 | (17) | DISP | 1508 | 25050 |
| | Sus. + R1 | 19 | 13 | | 2.56 | 2.13 | (18) | OCC | 2353 | 22211 |
| | Sus. + R2 | 19 | 11 | | 2.56 | 2.13 | (18) | OCC | 2322 | 22211 |
| | Sus. + R3 | 19 | 10 | | 2.56 | 2.13 | (18) | OCC | 2319 | 22211 |
| A08 F+ | Max P | | | | | | (3a) | HOOP | 4844 | 16700 |
| | GR + Max P | 19 | 10 | | 1.00 | 1.00 | (18) | SUST | 2168 | 16700 |
| | Cold to T1 | 154 | 43 | 8 | 1.00 | 1.00 | (17) | DISP | 597 | 25050 |
| | Sus. + R1 | 19 | 13 | | 1.00 | 1.00 | (18) | OCC | 2184 | 22211 |
| | Sus. + R2 | 19 | 11 | | 1.00 | 1.00 | (18) | OCC | 2170 | 22211 |
| | Sus. + R3 | 19 | 10 | | 1.00 | 1.00 | (18) | OCC | 2168 | 22211 |
| A09 | Max P | | | | | | (3a) | HOOP | 4844 | 16700 |
| | GR + Max P | 21 | 11 | | 1.00 | 1.00 | (18) | SUST | 2177 | 16700 |
| | Cold to T1 | 16 | 73 | 8 | 1.00 | 1.00 | (17) | DISP | 279 | 25050 |
| | Sus. + R1 | 22 | 13 | | 1.00 | 1.00 | (18) | OCC | 2191 | 22211 |
| | Sus. + R2 | 21 | 11 | | 1.00 | 1.00 | (18) | OCC | 2179 | 22211 |
| | Sus. + R3 | 21 | 11 | | 1.00 | 1.00 | (18) | OCC | 2177 | 22211 |
| A10 | Max P | | | | | | (3a) | HOOP | 4844 | 16700 |
| | GR + Max P | 22 | 11 | | 1.00 | 1.00 | (18) | SUST | 2183 | 16700 |
| | Cold to T1 | 66 | 91 | 8 | 1.00 | 1.00 | (17) | DISP | 420 | 25050 |
| | Sus. + R1 | 23 | 13 | | 1.00 | 1.00 | (18) | OCC | 2195 | 22211 |
| | Sus. + R2 | 22 | 11 | | 1.00 | 1.00 | (18) | OCC | 2184 | 22211 |
| | Sus. + R3 | 22 | 11 | | 1.00 | 1.00 | (18) | OCC | 2183 | 22211 |
| A11 | Max P | | | | | | (3a) | HOOP | 4844 | 16700 |
| | GR + Max P | 27 | 12 | | 1.00 | 1.00 | (18) | SUST | 2209 | 16700 |
| | Cold to T1 | 458 | 175 | 8 | 1.00 | 1.00 | (17) | DISP | 1831 | 25050 |
| | Sus. + R1 | 30 | 12 | | 1.00 | 1.00 | (18) | OCC | 2222 | 22211 |
| | Sus. + R2 | 28 | 12 | | 1.00 | 1.00 | (18) | OCC | 2210 | 22211 |
| | Sus. + R3 | 27 | 12 | | 1.00 | 1.00 | (18) | OCC | 2209 | 22211 |

*** Segment A end ***





ICF4-PRINT

## S Y S T E M  S U M M A R Y

### Maximum displacements (in)

| | | | |
|---|---|---|---|
| Maximum X : | 0.064 | Point : A05 N | Load Comb.: TOTAL |
| Maximum Y : | 0.042 | Point : A07 N | Load Comb.: TOTAL |
| Maximum Z : | 0.035 | Point : A07 M | Load Comb.: TOTAL |
| Max. total: | 0.075 | Point : A05 N | Load Comb.: TOTAL |

### Maximum rotations (deg)

| | | | |
|---|---|---|---|
| Maximum X : | 0.232 | Point : A03 M | Load Comb.: TOTAL |
| Maximum Y : | 0.202 | Point : A07 N | Load Comb.: T1 |
| Maximum Z : | -0.211 | Point : A03 N | Load Comb.: T1 |
| Max. total: | 0.333 | Point : A03 M | Load Comb.: TOTAL |

### Maximum restraint forces(lb)

| | | | |
|---|---|---|---|
| Maximum X : | 452 | Point : A11 | Load Comb.: TOTAL |
| Maximum Y : | 636 | Point : A11 | Load Comb.: TOTAL |
| Maximum Z : | -2062 | Point : A00 | Load Comb.: T1 |
| Max. total: | 2186 | Point : A11 | Load Comb.: TOTAL |

### Maximum restraint moments(ft-lb)

| | | | |
|---|---|---|---|
| Maximum X : | 458 | Point : A11 | Load Comb.: T1 |
| Maximum Y : | -588 | Point : A00 | Load Comb.: T1 |
| Maximum Z : | -175 | Point : A11 | Load Comb.: T1 |
| Max. total: | 602 | Point : A00 | Load Comb.: TOTAL |





## S Y S T E M  S U M M A R Y

### Maximum pipe forces (lb)

| | | | |
|---|---|---|---|
| Maximum X : | 452 | Point : A08 M | Load Comb.: TOTAL |
| Maximum Y : | 636 | Point : A11 | Load Comb.: TOTAL |
| Maximum Z : | 2062 | Point : A00 | Load Comb.: T1 |
| Max. total: | 2186 | Point : A11 | Load Comb.: TOTAL |

### Maximum pipe moments (ft-lb)

| | | | |
|---|---|---|---|
| Maximum X : | 1238 | Point : A04 F | Load Comb.: TOTAL |
| Maximum Y : | -1339 | Point : A05 N | Load Comb.: T1 |
| Maximum Z : | -466 | Point : A04 F | Load Comb.: T1 |
| Max. total: | 1526 | Point : A05 N | Load Comb.: TOTAL |

## S Y S T E M  S U M M A R Y

Maximum sustained stress

| | |
|---|---|
| Point | : A05 N |
| Stress psi | : 2648 |
| Allowable psi | : 16700 |
| Ratio | : 0.16 |
| Load combination | : GR + Max P |

Maximum displacement stress

| | |
|---|---|
| Point | : A05 N |
| Stress psi | : 10387 |
| Allowable psi | : 25050 |
| Ratio | : 0.41 |
| Load combination | : Cold to T1 |

Maximum occasional stress

| | |
|---|---|
| Point | : A07 F |
| Stress psi | : 2825 |
| Allowable psi | : 22211 |
| Ratio | : 0.13 |
| Load combination | : Sus. + R1 |

Maximum hoop stress

| | |
|---|---|
| Point | : A00 |
| Stress psi | : 4844 |
| Allowable psi | : 16700 |
| Ratio | : 0.29 |
| Load combination | : Max P |

Maximum sustained stress ratio

| | |
|---|---|
| Point | : A05 N |
| Stress psi | : 2648 |
| Allowable psi | : 16700 |
| Ratio | : 0.16 |
| Load combination | : GR + Max P |

Maximum displacement stress ratio

| | |
|---|---|
| Point | : A05 N |
| Stress psi | : 10387 |
| Allowable psi | : 25050 |
| Ratio | : 0.41 |
| Load combination | : Cold to T1 |





## S Y S T E M  S U M M A R Y

Maximum occasional stress ratio

| | |
|---|---|
| Point | : A07 F |
| Stress psi | : 2825 |
| Allowable psi | : 22211 |
| Ratio | : 0.13 |
| Load combination | : Sus. + R1 |

Maximum hoop stress ratio

| | |
|---|---|
| Point | : A00 |
| Stress psi | : 4844 |
| Allowable psi | : 16700 |
| Ratio | : 0.29 |
| Load combination | : Max P |

* * * The system satisfies ASME B31.3 code requirements * * *
* * * for the selected options * * *



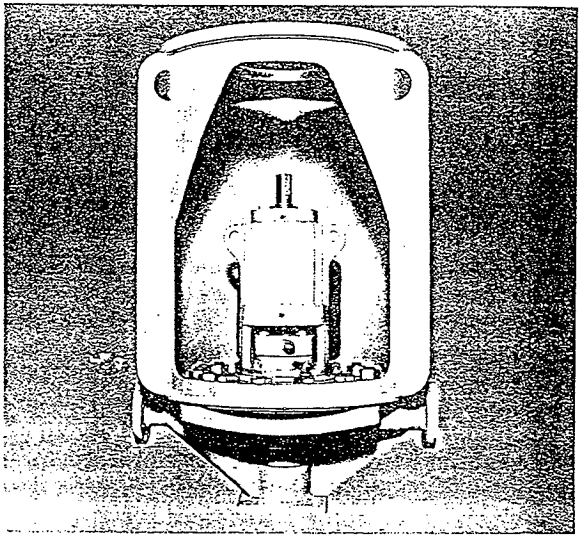


KCA-PRINT

(NEW PUMP IN SUMP) as of 4/6/95
PIT

# Series 1400
# In-Line Bearing Frame True Line Pumps

- Partial emissions hydraulics for optimum efficiency
  - Heads to 700 FT (213m) at 3550 RPM with a single stage
- 700 lb. casing
- Back Pullout feature
- Mag Drive option
- High speed designs available
- Variable speed options available



*Series 1400 2" x 2" - 13" Vertical In-Line Pump* Figure 1

## Optimized Low Flow, High Head Performance

True Line pumps from Lawrence Pumps Inc. are designed to deliver long term mechanical and hydraulic reliability for your low flow, high head applications.

- Designed to API-610 Standards
- Mechanical seal life is extended because the robust shaft design, combined with low radial loads minimizes shaft deflection
- Alignment between the pump and motor is guaranteed by a precision machined fit
- Liberal internal clearances and reduced radial thrust virtually eliminate the potential for any internal metal to metal contact
- Extreme temperature designs available (-50°F/-45°C to 700°F/370°C)
- Back Pullout feature allows ease of maintenance without disturbing the motor or connecting piping
- Seal chamber design accommodates Single, Double and Tandem mechanical seals
- Complete seal flush piping arrangements available

There are no close clearance wear rings or stuffing box bushing, and the axial clearances on both the front and back of the impeller are typically 0.035". Ultimately, the True Line design will withstand prolonged process upsets, or loss of suction, if seal lubrication is maintained.

## Improved Process Pump Performance. Reduced Total Cost of Ownership.

- High efficiency at low flows
- Stable operations at all design points
- Minimum shaft deflection at off-design flows
- Reliable performance through process upsets
- Low maintenance from high seal reliability
- True In-Line with suction and discharge flanges on same plane
- Low NPSH characteristics

LAWRENCE PUMPS INC.

## NEMA FRAMES 182HP - 449HP — (See drawings below.) - Dimensions in inches/millimeters

| FRAME | P | T | CAST IRON TERMINAL BOX AA | AB | AC | AF | AJ | AX(2) | BB | BD | BE | BF | AG STD | AG LG(5) | AH(4) | BY STD | BY LG(5) | SHAFT AND KEY Y | U(1) | EU(3) | EM(MIN) | LGTH | SQ.KEY STD. | SQ.KEY LG(5) | WT. LBS./KG. STD. | WT. LBS./KG. LG(5) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 182HP | 9.50 241 | 1.44 36.5 | .75 19 | 7.75 197 | 6.31 150 | 1.94 49.3 | 9.12 232 | 8.250 210 | .19 4.8 | 10.00 254 | .62 15.9 | .44 11.1 | 17.55 446 | 19.06 484 | 2.750 69.85 | 9.38 238 | 10.12 257 | 2.75 69.8 | 1.1250 28.575 | .875 22.22 | 1.16 29.5 | 1.28 32.5 | .250 6.35 | 120 54 | 145 65 |
| L184HP | 9.50 241 | 1.44 36.5 | .75 19 | 7.75 197 | 6.31 150 | 1.94 49.3 | 9.12 232 | 8.250 210 | .19 4.8 | 10.00 254 | .62 15.9 | .44 11.1 | 18.56 471 | 20.06 509 | 2.750 69.85 | 9.88 251 | 10.62 270 | 2.75 69.8 | 1.1250 28.575 | .875 22.22 | 1.16 29.5 | 1.28 32.5 | .250 6.35 | 130 59 | 155 70 |
| 213HP | 10.50 267 | 1.44 36.5 | 1.00 25.4 | 9.75 248 | 7.75 197 | 2.50 63.5 | 9.12 232 | 8.250 210 | .19 4.8 | 10.00 254 | .62 15.9 | .44 11.1 | 19.50 495 | 21.25 540 | 2.750 69.85 | 9.75 248 | 10.62 270 | 2.75 69.8 | 1.1250 28.575 | .875 22.22 | 1.38 35.0 | 1.28 32.5 | .250 6.35 | 175 79 | 190 86 |
| L215HP | 10.50 267 | 1.44 36.5 | 1.00 25.4 | 9.75 248 | 7.75 197 | 2.50 63.5 | 9.12 232 | 8.250 210 | .19 4.8 | 10.00 254 | .62 15.9 | .44 11.1 | 21.00 533 | 21.88 555 | 2.750 69.85 | 10.50 267 | 10.94 278 | 2.75 69.8 | 1.1250 28.575 | .875 22.22 | 1.38 35.0 | 1.28 32.5 | .250 6.35 | 200 91 | 215 97 |
| 254HP | 13.88 352 | 2.25 57.2 | 1.25 31.8 | 10.19 259 | 8.22 209 | 2.50 63.5 | 9.12 232 | 8.250 210 | .19 4.8 | 10.00 254 | .62 15.9 | .44 11.1 | 20.94 532 | — | 2.750 69.85 | 10.81 275 | — | 2.75 69.8 | 1.1250 28.575 | .875 22.22 | 1.75 44.4 | 1.28 32.5 | .250 6.35 | 215 98 | — |
| 256HP | 13.88 352 | 2.25 57.2 | 1.25 31.8 | 10.19 259 | 8.22 209 | 2.50 63.5 | 9.12 232 | 8.250 210 | .19 4.8 | 10.00 254 | .62 15.9 | .44 11.1 | 24.69 627 | — | 2.750 69.85 | 11.69 297 | — | 2.75 69.8 | 1.1250 28.575 | .875 22.22 | 1.75 44.4 | 1.28 32.5 | .250 6.35 | 245 111 | — |
| 284HP | 15.50 394 | 2.25 57.2 | 1.5 38 | 12.00 305 | 9.56 243 | 3.00 76.2 | 9.12 232 | 8.250 210 | .25 6.4 | 10.00 254 | .69 17.5 | .44 11.1 | 25.88 657 | — | 2.750 69.85 | 12.25 311 | — | 2.75 69.8 | 1.1250 28.575 | .875 22.22 | 1.75 44.4 | 1.28 32.5 | .250 6.35 | 270 122 | — |
| 286HP | 15.50 394 | 2.25 57.2 | 1.5 38 | 12.00 305 | 9.56 243 | 3.00 76.2 | 9.12 232 | 8.250 210 | .25 6.4 | 10.00 254 | .69 17.5 | .44 11.1 | 27.38 695 | — | 2.750 69.85 | 13.00 330 | — | 2.75 69.8 | 1.1250 28.575 | .875 22.22 | 1.75 44.4 | 1.28 32.5 | .250 6.35 | 320 145 | — |
| 284HPH | 15.50 394 | 2.25 57.2 | 1.5 38 | 12.00 305 | 9.56 243 | 3.00 76.2 | 14.75 375 | 13.500 343 | .25 6.4 | 16.50 419 | .88 22.2 | .69 17.5 | 25.88 657 | — | 4.500 114 | 12.25 311 | — | 4.50 114 | 1.6250 41.3 | 1.250 31.8 | 1.75 44.4 | 1.28 32.5 | .375 9.5 | 300 136 | — |
| 286HPH | 15.50 394 | 2.25 57.2 | 1.5 38 | 12.00 305 | 9.56 243 | 3.00 76.2 | 14.75 375 | 13.500 343 | .25 6.4 | 16.50 419 | .88 22.2 | .69 17.5 | 27.38 695 | — | 4.500 114 | 13.00 330 | — | 4.50 114 | 1.6250 41.3 | 1.250 31.8 | 1.75 44.4 | 1.28 32.5 | .375 9.5 | 350 159 | — |
| 324HP | 17.75 451 | 2.25 57.2 | 2 50.8 | 14.69 373 | 10.94 278 | 3.63 92.1 | 14.75 375 | 13.500 343 | .25 6.4 | 16.50 419 | .88 22.2 | .69 17.5 | 29.06 738 | — | 4.500 114 | 13.50 343 | — | 4.50 114 | 1.6250 41.275 | 1.250 31.75 | 2.12 53.8 | 3.03 77.0 | .375 9.52 | 480 218 | — |
| 326HP | 17.75 451 | 2.25 57.2 | 2 50.8 | 14.69 373 | 10.94 278 | 3.63 92.1 | 14.75 375 | 13.500 343 | .25 6.4 | 16.50 419 | .88 22.2 | .69 17.5 | 30.56 776 | — | 4.500 114 | 14.25 362 | — | 4.50 114 | 1.6250 41.275 | 1.250 31.75 | 2.12 53.8 | 3.03 77.0 | .375 9.52 | 530 240 | — |
| 364HP | 20.50 521 | 2.25 57.2 | 3 76 | 17.94 456 | 13.75 349 | 4.13 105 | 14.75 375 | 13.500 343 | .25 6.4 | 16.50 419 | .88 22.2 | .69 17.5 | 33.38 847 | — | 4.500 114 | 15.38 390 | — | 4.50 114 | 1.6250 41.275 | 1.250 31.75 | 2.25 57.2 | 3.03 77.0 | .375 9.52 | 660 299 | — |
| 365HP | 20.50 521 | 2.25 57.2 | 3 76 | 17.94 456 | 13.75 349 | 4.13 105 | 14.75 375 | 13.500 343 | .25 6.4 | 16.50 419 | .88 22.2 | .69 17.5 | 33.38 847 | — | 4.500 114 | 15.38 390 | — | 4.50 114 | 1.6250 41.275 | 1.250 31.75 | 2.25 57.2 | 3.03 77.0 | .375 9.52 | 710 322 | — |
| 404HP | 22.62 575 | 2.50 63.5 | 3 76 | 19.19 487 | 15.00 381 | 4.13 105 | 14.75 375 | 13.500 343 | .25 6.4 | 16.50 419 | .94 23.8 | .69 17.5 | 35.19 893 | — | 4.500 114 | 15.12 384 | — | 4.50 114 | 1.6250 41.275 | 1.250 31.75 | 2.25 57.2 | 3.03 77.0 | .375 9.52 | 950 431 | — |
| 405HP | 22.62 575 | 2.50 63.5 | 3 76 | 19.19 487 | 15.00 381 | 4.13 105 | 14.75 375 | 13.500 343 | .25 6.4 | 16.50 419 | .94 23.8 | .69 17.5 | 35.19 893 | — | 4.500 114 | 15.12 384 | — | 4.50 114 | 1.6250 41.275 | 1.250 31.75 | 2.25 57.2 | 3.03 77.0 | .375 9.52 | 1075 488 | — |
| 444HP | 25.50 648 | 2.50 63.5 | 3 76 | 22.13 562 | 17.37 441 | 6.00 152 | 14.75 375 | 13.500 343 | .25 6.4 | 16.50 419 | 1.06 27.0 | .69 17.5 | 40.88 1038 | — | 4.500 114 | 18.00 457 | — | 4.50 114 | 1.6250 53.975 | 1.750 44.45 | 2.25 57.2 | 3.03 77.0 | .500 12.70 | 1405 637 | — |
| 445HP | 25.50 648 | 2.50 63.5 | 3 76 | 22.13 562 | 17.37 441 | 6.00 152 | 14.75 375 | 13.500 343 | .25 6.4 | 16.50 419 | 1.06 27.0 | .69 17.5 | 40.88 1038 | — | 4.500 114 | 18.00 457 | — | 4.50 114 | 1.6250 53.975 | 1.750 44.45 | 2.25 57.2 | 3.03 77.0 | .500 12.70 | 1555 705 | — |
| 447HP | 25.25 641 | 2.50 63.5 | (5) | 23.37 594 | 18.12 460 | 7.00 178 | 14.75 375 | 13.500 343 | .25 6.4 | 16.50 419 | 1.06 27.0 | .69 17.5 | 49.38 1254 | — | 4.500 114 | 22.25 565 | — | 4.50 114 | 1.6250 53.975 | 1.750 44.45 | 2.25 57.2 | 3.03 77.0 | .500 12.70 | 2900 1314 | — |
| 449HP | 25.25 641 | 2.50 63.5 | (5) | 23.37 594 | 18.12 460 | 7.00 178 | 14.75 375 | 13.500 343 | .25 6.4 | 16.50 419 | 1.06 27.0 | .69 17.5 | 49.38 1254 | — | 4.500 114 | 22.25 565 | — | 4.50 114 | 1.6250 53.975 | 1.750 44.45 | 2.25 57.2 | 3.03 77.0 | .500 12.70 | 2900 1314 | — |

(1) "U" Varies { — up to 2.125 +.0000, −.0005 / — 2.125 and larger +.000, −.001 } 53.975 +.000, −.013 / 53.975 and larger +.00, −.03

(2) "AK" Varies { — 180 HP, — 250HP, +.003, −.000 / — 250HP, — 440HP +.005, −.000 } +.08, −.00 / +.13, −.00

Face runout and Eccentricity { — 182HP — 445HP, .004 Max. T.I.R. / — 447HP — 449HP, .007 Max. T.I.R. } .10 / .18

(3) "EU" Varies +.000, −.005 +.00, −.13

(4) "AH" Varies +.030, −.030 +.76, −.76

(5) "AA" Varies with full load amps: 4" (120 mm) @ 201 amps, 5" (127 mm) @ 335 amps, 6" (152 mm) @ 600 amps.

Maximum permissible shaft runout when measured at end of shaft extension is .002 inches (.051 mm) Max. T.I.R. (.003 inches, .076 mm on 447HP — 449HP).

If mounting clearance is required, consult factory.

# NORMAL THRUST, TEFC Above-NEMA, 350 — 400 HP

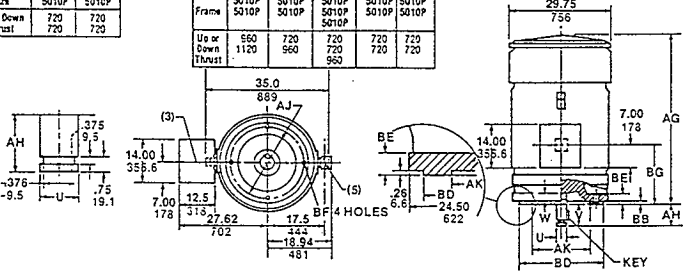
### 5010P Frame, 460 Volts

| HP | 350 | 400 |
|---|---|---|
| Full Load Speed | 3560 1773 | 3558 1773 |
| Frame Size | 5010P 5010P | 5010P 5010P |
| Up or Down Thrust | 720 720 | 720 720 |

### 5010P Frame, 2300, 4000 Volts

| HP | 200 | 250 | 300 | 350 | 400 |
|---|---|---|---|---|---|
| Full Load Speed | 1189 890 | 1783 1189 | 3571 1783 1188 | 3570 1784 | 3579 1784 |
| Frame | 5010P 5010P | 5010P 5010P | 5010P 5010P 5010P | 5010P 5010P | 5010P 5010P |
| Up or Down Thrust | 960 1120 | 720 960 | 720 720 960 | 720 720 | 720 720 |

- 5010P Frames
- 460, 2300, 4000 Volts
- 3-Phase, 60 Hz
- 1.0 S.F., Continuous Duty
- 40°C. Ambient
- Class B Insulation
- Ball Bearing
- Solid Shaft




## ABOVE NEMA 5010P — Dimensions in inches/millimeters

| FRAME | RPM (MAX.) | U(2) | V | AG | AH | AJ | AX(1) | BB | BD | BE | BG | W | BF | KEY SQ. | KEY LGTH. | WT. (LBS/KG) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5010P 5610P | 3600 3600 | 2.375 60.33 | 6.75 171 | 62.5 1587 | 6.75 171 | 14.75 374 | 13.500 343 | .26 6.4 | 20.00 508 | 1.75 45 | 17.94 456 | 4.44 113 | .687 18 | .625 15.88 | 4.00 102 | 6200 2360 |
| 5010P 110P | 1800 1800 | 3.375 85.73 | 6.75 171 | 62.5 1587 | 6.75 171 | 14.75 374 | 13.500 343 | .25 6.4 | 20.00 508 | 1.75 45 | 17.94 456 | 4.44 113 | .687 18 | .875 22.23 | 5.0 127 | 6200 2360 |

(1) This Dimension Varies +.005 −.000 +.13, −.00

(2) This Varies +.000, −.001, +.00 −.03

(3) Customer to drill hole in Conduit Box.

(4) Face Runout and Eccentricity .007 (.18 mm) max. T.I.R.

(5) 3/4 N.P.T. for space heater leads.

Conduit Box can be rotated 360° in 90° steps.

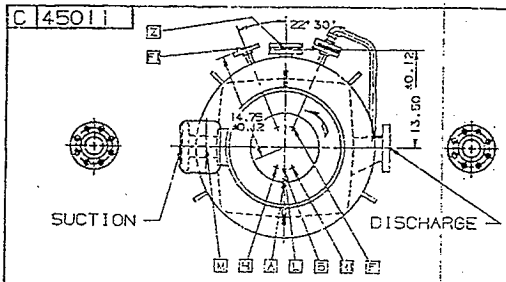
If mounting clearance details are required, consult factory.

Maximum permissible shaft runout when measured at end of std. shaft extension is .003 (.08 mm) T.I.R.

| MAXIMUM FULL LOAD AMPERES | AA (4X6) PIPE TAP* |
|---|---|
| 201 | 4 |
| 335 | 5 |
| 600 | 6 |

* On 5010P frame, customer to drill hole in conduit box.

C 45011




CONNECTIONS:

- A 1/4-18 NPT - ALTERNATE LUBRICANT INLET TO THRUST BEARING (PLUGGED)
- B 1/4-18 NPT - OIL OUTLET FROM BEARING HOUSING
- F 1/2-14 NPT - INLET TO SEAL THRU API PLAN 11 FROM PUMP DISCHARGE
- J 1/2-300 LB. R.F. S.W. FLANGE - CASING VENT
- H 1/2-14 NPT - SEAL VENT
- H 1/2-14 NPT - SEAL DRAIN
- L 1/4-18 NPT - OIL MIST INLET TO BEARING HOUSING
- M MOTOR CONNECTION FOR POWER LEADS
- Z 3/4-300 LB. R.F. S.W. FLANGE - CASING DRAIN (COVERED WITH BLIND FLANGE)

WEIGHTS:

① PUMP 800 LBS.
MOTOR 2700 ~~400~~ LBS.
TOTAL 3500 ~~1200~~ LBS. APPROXIMATE

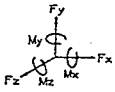
DRIVER DATA:

① 250 HP - 3600 RPM, T.E.F.C., VERTICAL ELECTRIC MOTOR, RELIANCE FRAME NO. 326TC

NOZZLE LOADS:

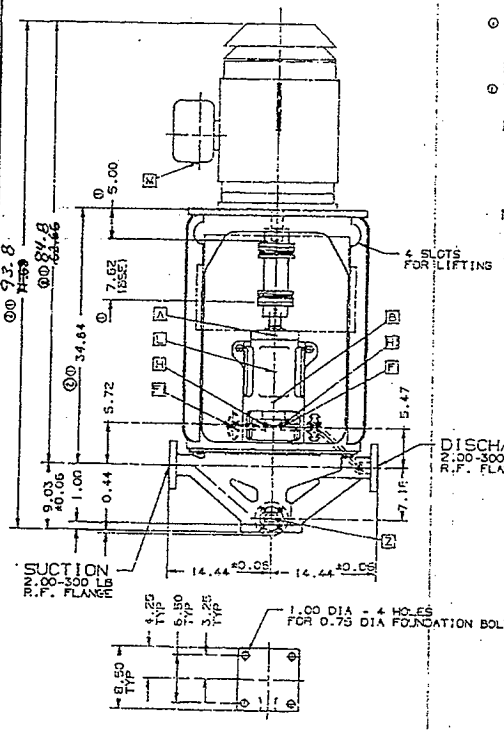
SUCTION & DISCHARGE

Fx 200 LBS. Mx 340 FT-LBS.
Fy 130 LBS. My 250 FT-LBS.
Fz 160 LBS. Mz 170 FT-LBS.




NOTES:

1. FOR ASSEMBLY SEE DRAWING NO.C45010.
2. FOR PARTS LIST SEE "LIST OF COMPONENTS".
3. ALL FLANGE CONNECTIONS TO CONFORM TO A FACE FINISH OF 125 RMS.




| NO. | BY | DATE | CHK.BY | DESCRIPTION |
|---|---|---|---|---|
| 2 | RM | [illegible] | RAM | DIMS DECREASED 0.50 |
| 1 | MO | [illegible] | RAM | MOTOR WAS 325 HP FRAME |

REVISIONS

LAWRENCE PUMPS INC.

# TRUE-LINE SERIES

PUMP SIZE: [illegible]
SERIES: 1400
MODEL: 14-4A
DR.BY: [illegible]
CHK.BY: RAM 11/28/88
APPV.BY:
DATE: 21 NOV 88

CUSTOMER:
PURCHASE ORDER NO.:
PUMP SERIAL NO.:
PUMP ITOU NO.:
CERTIFIED BY:
DATE:

PUMP ASSEMBLY:
PUMP PARTS LIST:

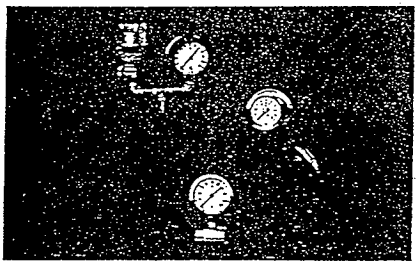
PUMP ELEVATION

DRAWING NO.: C 45011

# Pressure Sensors

F-03-23

- Protects and isolates instrumentation
- Full 360° pressure reading
- Self cleaning, flexing action
- Won't clog like traditional diaphragm seals
- Excellent pump protection
- Accuracy, ±2% of installed instrument



Materials of Construction

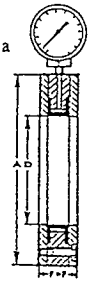
- Carbon Steel, Stainless Steel, or PVC body
- Sleeves available in Pure Gum Rubber, Neoprene, Hypalon, Chlorobutyl, Polyurethane, Buna-N, Viton and EPDM
- ANSI Class 150, 300, 600#

Red Valve's complete line of Pressure Sensors isolate and protect instrumentation from the process line, providing accurate, repeatable instrument measurement.

Reliable, accurate instrument readings are often difficult or even impossible to obtain on pipelines carrying slurries, solids, or chemical process slurries.

With Series 40 and 42 Pressure Sensors, line pressure is sensed 360° through the flexible rubber sleeve. The captive fluid is displaced through the pressure sensor body to the instrument's bourdon tube. Instruments are isolated and protected from the process assuring positive and accurate readings.

The thru-bolted Series 40 can be mounted in any flow direction, submerged in a tank, or mounted with a blind flange as a dead end to monitor tank levels.



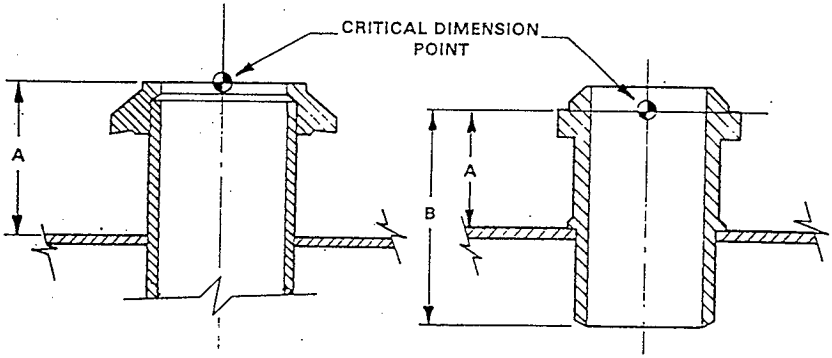

The threaded end model Series 42 is available in sizes 1/2"-2".

Two Pressure Sensors with a differential pressure switch can be used to monitor pressure drop across a filter or pump. They can also be used to send a signal to shut a pump or open a by-pass valve.

## Series 40

| VALVE SIZE D | LENGTH F to F | BODY O.D. A | WORKING PRESSURE (psi) | VALVE WEIGHT (lbs) |
|---|---|---|---|---|
| 1" | 1-7/8" | 4-1/2" | 200 | 6 |
| 1-1/2" | 1-7/8" | 5" | 200 | 8 |
| 2" | 1-7/8" | 6" | 200 | 12 |
| 2-1/2" | 1-7/8" | 7" | 200 | 16 |
| 3" | 1-7/8" | 7-1/2" | 200 | 18 |
| 4" | 2-1/8" | 9" | 200 | 27 |
| 5" | 2-1/4" | 10" | 200 | 32 |
| 6" | 2-1/4" | 11" | 200 | 37 |
| 8" | 2-1/2" | 13-1/2" | 200 | 58 |
| 10" | 2-3/4" | 16" | 200 | 79 |
| 12" | 3" | 19" | 200 | 125 |
| 14" | 3" | 21" | 200 | 157 |
| 16" | 3" | 23-1/2" | 200 | 190 |
| 18" | 3" | 25" | 200 | 250 |
| 20" | 3" | 27-1/2" | 200 | 185 |
| 24" | 3" | 32" | 200 | 220 |

## 8.3 PUREX and Hanford Nozzle



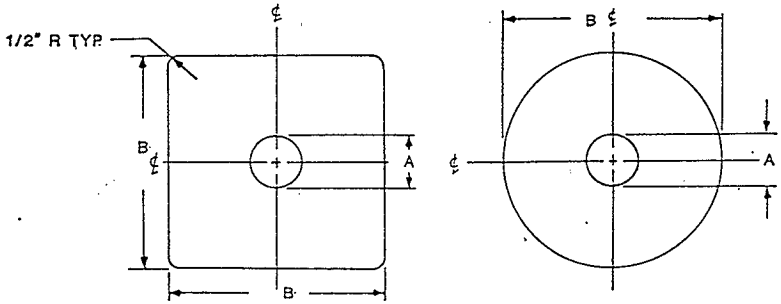

HANFORD NOZZLE PUREX NOZZLE

| Size | Type | A | B | Weight (lbs.) | Drawing No. |
|---|---|---|---|---|---|
| 2" | Hanford | 3-5/8 | | 5 | H-2-32705-9 |
| 3" | Hanford | 3-5/8 | | 3.5 | H-2-32705-8 |
| 4-Way | Hanford | 3-5/8 | | 6 | H-2-32705-* |
| | | | | | |
| 1" | Purex | 1-7/8 | | 1.5 | H-2-90184-2 |
| 2" | Purex | 2-1/4 | 3-29/32 | 2.5 | H-2-90185-2 |
| 3-Way | Purex | 2-9/32 | | 5 | H-2-32447-1 |
| 3" | Purex | 3 [illegible] | 4-13/16 | 6.5 | H-2-90186-2 |
| 4[illegible] | Purex | 3-3/8 | 5-5/32 | 11[illegible] | H-2-90187-2 |

*See Drawing for Dash Number.

4 13/16
3 9/16
3 [illegible]/16
11 [illegible]/16

## 8.4 .Kick-Off Plate




| TYPE | SHAPE | SIZE | WT# | A | B | THK. | C.S. P.N. | SST. P.N. |
|---|---|---|---|---|---|---|---|---|
| PUREX | SQ. | 1 | 4 | 1-25/32 | 6-1/4 | 3/8 | H-2-30600-2 | H-2-30600-1 |
| PUREX | SQ. | 2 | 3.5 | 2-21/32 | 6-1/4 | 3/8 | H-2-30600-4 | H-2-30600-3 |
| PUREX | SQ. | 3 | 12 | 3-25/32 | 11 | 3/8 | H-2-30600-6 | H-2-30600-5 |
| PUREX | SQ. | 4 | 16.5 | 4-27/32 | 13 | 3/8 | H-2-30600-8 | H-2-30600-7 |
| PUREX | RD. | 1 | 3 | 1-25/32 | 6 | 3/8 | H-2-3194-1 TYPE II | H-2-3194-1 TYPE I |
| PUREX | RD. | 2 | 2.5 | 2-21/32 | 6-1/4 | 3/8 | H-2-3194-2 TYPE II | H-2-3194-2 TYPE I |
| PUREX | RD. | 3 | 9 | 3-25/32 | 11 | 3/8 | H-2-3194-3 TYPE II | H-2-3194-3 TYPE I |
| PUREX | RD. | 4 | 12.5 | 4-27/32 | 13 | 3/8 | H-2-3194-4 TYPE II | H-2-3194-4 TYPE I |
| | | | | | | | | |
| HANFORD | SQ. | 2 | 12.5 | 2-7/16 | 11 | 3/8 | H-2-74755-11 | H-2-74755-1 |
| HANFORD | SQ. | 3 | 12 | 3-9/16 | 11 | 3/8 | H-2-74755-12 | H-2-74755-2 |
| HANFORD | SQ. | 4-WAY | 13 | ? | 11 | 3/8 | H-2-74755-? | H-2-74755-? |
| HANFORD | RD. | 2 | 9.5 | 2-7/16 | 11 | 3/8 | H-2-74755-16 | H-2-74755-6 |
| HANFORD | RD. | 3 | 9 | 3-9/16 | 11 | 3/8 | H-2-74755-17 | H-2-74755-7 |
| HANFORD | RD. | 4-WAY | 10 | ? | 11 | 3/8 | H-2-74755-? | H-2-74755-? |

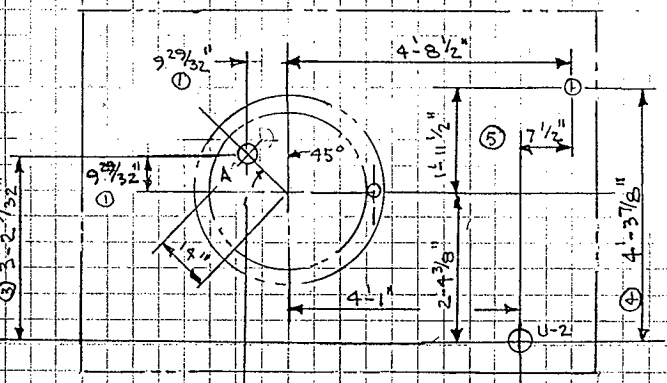
**KAISER ENGINEERS**
**HANFORD**

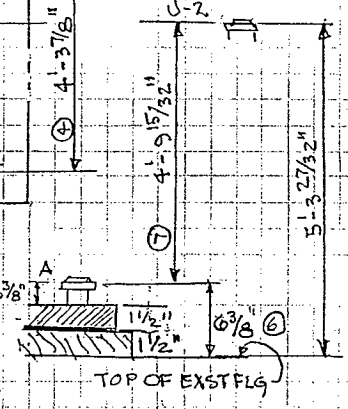
# DESIGN ANALYSIS

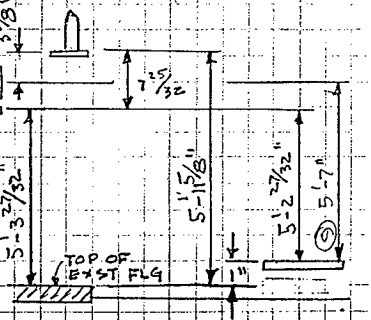
Calc. No. _____
Revision 0
Page No. 1 of 1

Client WHC
WO/Job No. W-320 /
Subject JUMPER CRITICALS FOR H-2-818503
Date 6-20-95 By D. PECK
Checked By
Location SLUCE PIT 241-AY-02E
Revised By

REF: H-2-818543, SH1 (REVIEW 14)
H-2-818494, SH1 (REVIEW 14)
H-2-818498, SH1 (REVIEW 15)
H-2-818499, SH2 (REVIEW 8)




① SIN 45° × 14" = 9.90" ≈ 9 29/32"

② 4'-1"
+ 9 29/32"
4'-10 29/32"

③ 2'-4 3/8 = 12
+ 9 29/32" +29
3'-2 9/32 41
·32
9

④ 2'-4 3/8
+ 1'-11 1/2
4'-3 7/8

⑤ 4'-8 1/2
- 4'-1"
7 1/2"

⑥ 3 3/8"
1 1/2"
1 1/2"
6 3/8"

⑦ 5'-3 27/32" 27
- 6 3/8 12
4'-9 15/32" 15

⑧ 5'-11 5/8" 20 32 52
- 5'-3 27/32 - 27
2.5

7 25/32
- 4 5/32
3 5/8"

⑨ 5'-2 27/32
+ 4 5/32
5'-7"


37.00 (06/9

# KAISER ENGINEERS
## HANFORD

## JUMPER CALCULATION

| JOB NO. | DWG. NO. | DATE | PAGE |
|---|---|---|---|
| ER4319 | H-2-818503 | 6-13-95 | 4/4 |
| BLDG. NO. 241-AY | | BY BAM / CHKD. | |

720 Y X

| PART | DESCRIPTION | WEIGHT LBS. | X-X AXIS MOM. ARM IN. | X-X AXIS MOMENT IN. LBS. | Y-Y AXIS MOM. ARM IN. | Y-Y AXIS MOMENT IN. LBS. |
|---|---|---|---|---|---|---|
| A | 2" BLK CONN | 86.98 | 2,187 | 190,22 | 19.62 | 1706,55 |
| B | 2 BARS | 2.03 | 48 | 97,44 | 12.87 | 26,12 |
| C | | | | | | |
| D | | | | | | |
| E | | | | | | |
| F | | | | | | |
| G | | 4297 | | 127796 | | 62380 |
| H | SH 3/4 | ~~4277.62~~ | | 127341.33 | | ~~61056.82~~ |
| J | | | | | | |
| K | 8x8x1/2 ? | 9.09 | 31.5 | 286.33 | 12.87 | 116.99 |
| L | | | | | | |
| M | | | | | | |
| N | | | | | | |
| P | | | | | | |
| Q | | | | | | |
| R | | | | | | |
| S | | | | | | |
| T | | | | | | |
| U | | 4380 | | | | |
| V | | ~~4378~~ | | 128238 | | 65373 |

$\Sigma W = 4375.72$ $\Sigma Mx = 127915.32$ $\Sigma My = 62906.48$

$\bar{x} = \frac{\Sigma Mx}{\Sigma W} =$ 29.239 29.27" 29 1/4

$\bar{y} = \frac{\Sigma My}{\Sigma W} =$ 14.376 14.92" 14 3/8"

| | COEFF. OF. EXP. / °F | Δt °F | ΔX EXPANDING LENGTH | ΔX EXPANSION | ΔY EXPANDING LENGTH | ΔY EXPANSION | ΔZ EXPANDING LENGTH | ΔZ EXPANSION |
|---|---|---|---|---|---|---|---|---|
| JUMPER | | | | | | | | |
| VESSEL | | | | | | | | |
| DUNNAGE | | | | | | | | |
| TOLERANCE | | | | | | | | |
| | | | ΔX = | | ΔY = | | ΔZ = | |



KEH-63 (3-82)

# KAISER ENGINEERS
## HANFORD

## JUMPER CALCULATION

| JOB NO. | DWG. NO. | DATE | PAGE |
|---|---|---|---|
| ER 4319 | H-2-818503 | 6-9-95 | 1/4 |
| BLDG. NO. 241-AY | | BY BAM / CHKD. D. PECK | |

| PART | DESCRIPTION | WEIGHT LBS. | X-X AXIS (Y) MOM. ARM IN. | X-X AXIS (Y) MOMENT IN.LBS. | Y-Y AXIS (X) MOM. ARM IN. | Y-Y AXIS (X) MOMENT IN. LBS. |
|---|---|---|---|---|---|---|
| A | 4" ~~HORIZ~~ VERT CONN | 12 | Ø | Ø | Ø | Ø |
| B | 4" ~~HORIZ~~ VERT CONN | 12 | 38.25 | 4590.0 | 58.87 | 7064.4 |
| C | 2" MALE CONN | 2.5 | Ø | Ø | 18.37 | 45.92 |
| D | 2" KP (Round) | 2.5 | Ø | Ø | 18.37 | 45.92 |
| E | 4" PIPE (14 3/16") | 12.87 | 48.62 | 625.74 | 58.87 | 757.65 |
| F | 4" PIPE 2'-7 3/8" | 28.2 | 55.37 | 1561.43 | 43.19 | 1217.96 |
| G | 4" x 2" RDCR | 3 | 55.37 | 166.11 | 25.5 | 76.5 |
| H | 2" FLG | | | | | |
| | 2" FLG | 36 | 55.37 | ~~1716.47~~ | 19.69 | ~~610.39~~ |
| K | PRES IND | 36 | | 1993 | | 709 |
| L | PRES GAGE | | | | | |
| M | 2" PIPE 3" | .91 | 54.25 | 49.37 | 14.37 | 13.07 |
| | 2" PIPE 6 15/16 | 2.1 | 52.31 | 109.85 | 12.87 | 27.03 |
| P | 2" FLG 9# | 18 | 31.5 | ~~567~~ | 12.87 | ~~231.66~~ |
| Q | 2" FLG 9# | 23 | 2 | 726 | | 296 |
| R | 2" x 4" RDCR | 3 | 12.19 | 36.57 | 12.87 | 38.61 |
| S | 4" PIPE 10 1/4" | 9.21 | 5.12 | 47.15 | 12.87 | 118.53 |
| T | 4" PIPE 6" | 5.39 | Ø | Ø | 12.87 | 69.37 |
| U | (2) 4" FLG | 50 | Ø | Ø | 12.87 | ~~643.5~~ 77 |
| V | PRES IND | 27 | Ø | Ø | 12.87 | 347.49 |
| | | $\Sigma W =$ 435.68 | | $\Sigma Mx =$ 9469.69 | | $\Sigma My =$ 11308.0 |

$\bar{x} = \frac{\Sigma Mx}{\Sigma W} =$ 455.68 9924

$\bar{y} = \frac{\Sigma My}{\Sigma W} =$ 11601

| | COEFF. OF. EXP. / °F | Δt °F | ΔX EXPANDING LENGTH | ΔX EXPANSION | ΔY EXPANDING LENGTH | ΔY EXPANSION | ΔZ EXPANDING LENGTH | ΔZ EXPANSION |
|---|---|---|---|---|---|---|---|---|
| JUMPER | | | | | | | | |
| VESSEL | | | | | | | | |
| DUNNAGE | | | | | | | | |
| TOLERANCE | | | | | | | | |
| | | | ΔX = | | ΔY = | | ΔZ = | |



KEH-63 (3-82)

# KAISER ENGINEERS
## HANFORD

## JUMPER CALCULATION

| JOB NO. | DWG. NO. | DATE | PAGE |
|---|---|---|---|
| ER4319 | H-2-818503 | 6-9-95 | 2/4 |
| BLDG. NO. 241-AY | | BY BAM | CHKD. |

| PART | DESCRIPTION | WEIGHT LBS. | X – X AXIS (Y) MOM. ARM IN. | X – X AXIS (Y) MOMENT IN.LBS. | Y – Y AXIS (X) MOM. ARM IN. | Y – Y AXIS (X) MOMENT IN. LBS. |
|---|---|---|---|---|---|---|
| A | PRES GAGE | 1 | Ø | Ø | 12.87 | 12.87 |
| B | 4" PIPE 14 1/8" | 12.7 | Ø | Ø | 12.87 | 163.43 |
| C | FLOW METER | 35 | Ø | Ø | 12.87 | 450.45 |
| D | 4" FLG (2) | (50) 60 | Ø | Ø | 12.87 | 643.5 |
| E | 4" PIPE 14 1/4" | 12.8 | Ø | Ø | 12.87 | 164.73 |
| F | 4" PIPE 9 11/16" | 8.71 | Ø | Ø | 8.0 | 69.68 |
| G | 2" PIPE 3 1/4" | .99 | Ø | Ø | 16.75 | 16.58 |
| H | 2" PIPE 3" | .91 | Ø | Ø | 18.37 | 16.71 |
| J | PUMP W/ MTR | 3500 | 31.5 | 110250.0 | 12.87 | 45045.1 |
| K | | 455.68 | | 9924 | | 11601 |
| L | SH 1 | ( ~~435.68~~ ) | | ( 9469.69 ) | | ( 11308.0 ) |
| M | | ~~435.68~~ | | | | |
| N | | | | | | |
| P | | | | | | |
| Q | | | | | | |
| R | | | | | | |
| S | | | | | | |
| T | | | | | | |
| U | | | | | | |
| V | | | | | | |

$\Sigma W =$ 4057.79 4077.79

$\Sigma Mx =$ 119719.69 120174

$\Sigma My =$ 57890.9 58312

$\bar{x} = \frac{\Sigma Mx}{\Sigma W} = 29.50$

$\bar{y} = \frac{\Sigma My}{\Sigma W} = 14.266$

| | COEFF. OF. EXP. / °F | Δt °F | ΔX EXPANDING LENGTH | ΔX EXPANSION | ΔY EXPANDING LENGTH | ΔY EXPANSION | ΔZ EXPANDING LENGTH | ΔZ EXPANSIO |
|---|---|---|---|---|---|---|---|---|
| JUMPER | | | | | | | | |
| VESSEL | | | | | | | | |
| DUNNAGE | | | | | | | | |
| TOLERANCE | | | | | | | | |
| | | | ΔX = | | ΔY = | | ΔZ = | |



KEH-63 (3

Y ← (B)

HANFORD

# JUMPER CALCULATION

| JOB NO. | DWG. NO. | DATE | PAGE |
|---|---|---|---|
| ER4319 | H-2-818503 | 6-11-95 | 3/4 |
| BLDG. NO. 241-AY | | BY BAM / CHKD. | |

| | PART | DESCRIPTION | WEIGHT LBS. | X – X AXIS (Y) MOM. ARM IN. | X – X AXIS (Y) MOMENT IN.LBS. | Y – Y AXIS (X) MOM. ARM IN. | Y – Y AXIS (X) MOMENT IN. LBS. |
|---|---|---|---|---|---|---|---|
| L | A | W4x13 | 60.7 | 50.75 | 3080.5 | 12.87 | 781.21 |
| R | B | W4x13 | 60.7 | 12.25 | 743.57 | 12.87 | 781.21 |
| L | C | 1½ Ø BAR | 2.4 | 50.75 | 121.8 | 12.87 | 30.89 |
| R | D | 1½ Ø BAR | 2.4 | 12.25 | 29.4 | 12.87 | 30.89 |
| | E | MTR RING | 30.20 | 31.5 | 951.3 | 12.87 | 405.40 389 |
| | F | C3x4.1 | 3.03 | 47.69 | 144.5 | -.25 | -.75 .075 |
| | G | C3x4.1 | 3.03 | 44.62 | 135.2 | -2.62 | -7.94 |
| | H | C3x4.1 | 23.2 | 48 | 1113.6 | (25) -36 | 580.0 835 |
| | J | SUPPORT | 5.5 | 46.87 | 257.78 | 58.87 | 323.78 |
| L | K | 2 BARS 2½x⅜ | .79 | 47.94 | 37.87 | 12.87 | 10.17 |
| R | L | " " | .79 | 15.06 | 11.9 | 12.87 | 10.17 |
| | M | ~~BAR~~ PLATE 3/8 11 THK | 1.52 | 51.87 | 78.84 | -7.5 | -11.4 |
| | N | ~~BAR~~ PLATE 3/8 | 1.2 | 49.75 | 59.7 | -5.37 | -6.4 |
| L | P | 2" FLG BKT | 6.04 | 47.06 | 284.24 | 12.87 | 77.73 |
| R | Q | 2" FLG BKT | 6.04 | 15.87 | 95.85 | 12.87 | 77.73 |
| | R | 2 BARS | 2.03 | (15.19) 15.2 | 30.83 | 12.87 | 26.12 |
| | S | Mounting PL | 10.26 | 31.5 | 323.19 | 12.87 | 132.04 |
| | T | | 219.83 | | 7621.64 | 40.60 | 3165.85 |
| | U | SH 2 OF 3 4077 | 4057.79 | 120.174 | 11971.69 | 58.320 | 57890.97 |
| | V | | | | | | |

$\Sigma W$ = ~~4277.62~~ 4297

$\Sigma Mx$ = ~~12734.33~~ 127795

$\Sigma My$ = ~~61056.82~~ 62380

$\bar{x} = \frac{\Sigma Mx}{\Sigma W}$ = 29.769 @ 29¾"

$\bar{y} = \frac{\Sigma My}{\Sigma W}$ = 14.273 1'-2¼"

| | COEFF. OF. EXP. / °F | Δt °F | ΔX EXPANDING LENGTH | ΔX EXPANSION | ΔY EXPANDING LENGTH | ΔY EXPANSION | ΔZ EXPANDING LENGTH | ΔZ EXPANSION |
|---|---|---|---|---|---|---|---|---|
| JUMPER | | | | | | | | |
| VESSEL | | | | | | | | |
| DUNNAGE | | | | | | | | |
| TOLERANCE | | | | | | | | |
| | | | ΔX = | | ΔY = | | ΔZ = | |

KEH-63 (3-82)

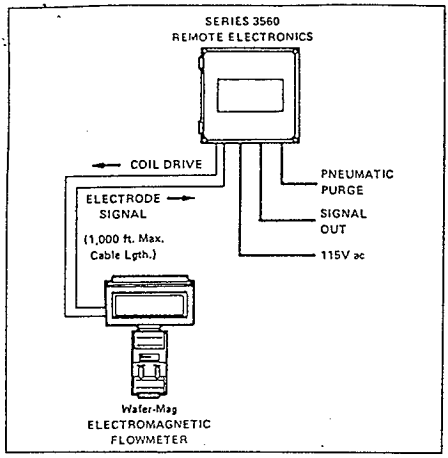



Figure 4 Typical Installation — Series 3560 Remote Electronics With Wafer-Mag Magnetic Flowmeter

3. For accurate operation, it is mandatory that the flowmeter be installed so that the flow tube will be completely full of process liquid under all operating conditions. When the meter is only partially filled, even though the electrodes are covered, an inaccurate measurement will result. Refer to Figure 5.

   It is desirable that the meter be installed in a vertical pipe run with flow upward, refer to Figure 6. In slurry applications, the vertical position insures a more even distribution of solids under all flow conditions and minimizes the chances of suspended solids adhering to the flow tube.

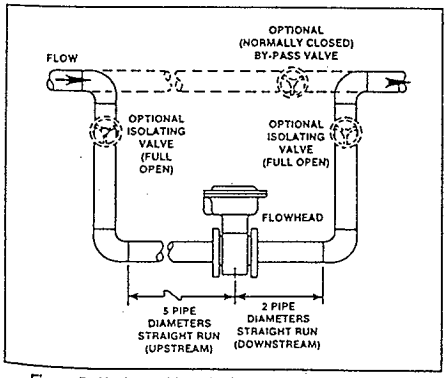



Figure 5 Horizontal Installation Piping (Meter shown In Optional Line Drop)

4. The position of the flow tube in relation to other devices in the system is also important in assuring system accuracy. Any upstream tee, elbows, valves, etc., should be placed at least five pipe diameters from the flowhead to minimize any obstructions or flow disturbances.

### Liquid Flow Characteristics

The characteristics of the liquid to be metered, the liquid flow parameters and the environment of the meter are determining factors in the accuracy of a particular meter.

1. Conductivity - electrical conductivity is simply a way of expressing the ability of a liquid to conduct electricity. Just as copper wire is a better conductor that steel wire, some liquids are better conductors than others. Of even greater importance, however, is the fact that some liquids have little or no conductivity.

   The conductivity of a metered liquid must be at least 3 micromhos/cm for use with the flowmeter. The conductivity of the liquid can change throughout the process operation as long as it is homogenous and remains above the 3 micromhos/cm threshold.

2. Acids/Caustics - the chemical composition of the product to be measured must be compatible with the meter liner and electrodes to assure maximum service life from the meter.

   Refer to a publication such as the Corrosion Survey, National Association of Corrosion Engineers, etc., to determine the compatibility of the liner with the process liquid. Many process slurries or liquids are designated by a generic name but may contain other



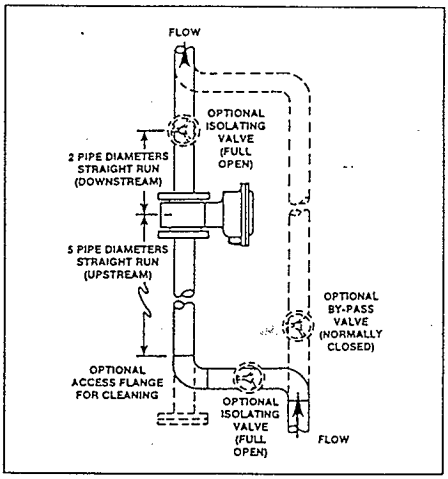



Figure 6 Vertical Installation

## ORDERING INFORMATION

1. Meter Size
2. Liner Material
3. Electrode Material
4. Pressure and Temperature Requirements (Ambient and Process)
5. Flow Rate (Normal, Maximum, Minimum)
6. Electrical Requirements
7. Output(s) Required
8. Liquid to be metered (name, conductivity)
9. Meter Orientation (horizontal or vertical).
10. Accessories Required

See Wafer Mag Model Code Table 6.

### Purchase Specification

The magnetic flowmeter shall be of the wafer body construction utilizing the pulsed direct current field coil excitation to eliminate manual zero verification.

The flowmeter transmitter shall produce an output signal of 0-10 kHz proportional to flow rate and provide a factored and/or scaled pulse output. Factoring, to convert to engineering unit output (gpm, liters per minute, m³/hr. etc.), is accomplished by dividing the pulse output frequency by 1.000 to 15.000 using direct reading detent switches (1.000 to F.000). Scaling is accomplished by setting a field selectable DIP switch for divide by 1, 10, 100, 1,000 or 10,000.

Table 5 Dimensions (Meter Sizes 0.15" through 8") with Remote Electronics

| Meter Size | | Flange Size | | A | | B | | C | | D | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Inch | mm | Inch | mm | Inch | mm | Inch | mm | Inch | mm | Inch | mm |
| 0.15 | 4 | | | | | | | | | | |
| 0.30 | 8 | 1/2 | 15 | 4-15/16 | 125 | 6-3/8 | 162 | 3-9/16 | 90 | 2-3/16 | 56 |
| 1/2 | 15 | | | | | | | | | | |
| 1 | 25 | 1 | 25 | 9 | 132 | 6-15/16 | 176 | 4-1/2 | 114 | 2-3/16 | 56 |
| 1-1/2 | 40 | 1-1/2 | 40 | 9 | 133 | 6-7/8 | 175 | 3-1/4 | 83 | 2-3/4 | 70 |
| 2 | 50 | 2 | 50 | 9-5/16 | 141 | 7-1/2 | 191 | 3-7/8 | 98 | 3-1/4 | 83 |
| 3 | 76 | 3 | 76 | 9-15/16 | 157 | 8-3/4 | 222 | 5-1/8 | 130 | 4-11/16 | 119 |
| 4 | 102 | 4 | 102 | 10-5/8 | 175 | 10-1/8 | 257 | 6-1/2 | 165 | 5-7/8 | 149 |
| 6 | 152 | 6 | 152 | 11-11/16 | 202 | 12-1/4 | 311 | 8-9/16 | 218 | 6-7/8 | 175 |
| 8 | 203 | 8 | 203 | 12-3/4 | 229 | 14-3/8 | 365 | 10-11/16 | 272 | 8-7/8 | 225 |

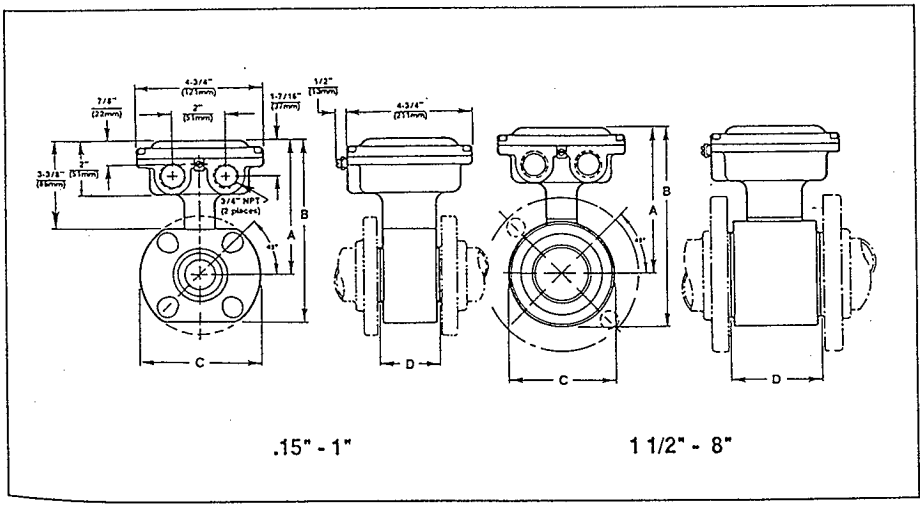


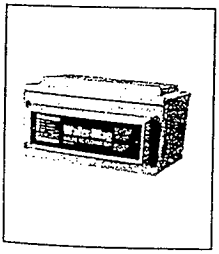

Figure 8 Dimensions (Meter Sizes 0.15" through 8") with Remote Electronics

Table 6 Wafer-Mag Electronics — Outputs, Performance Options

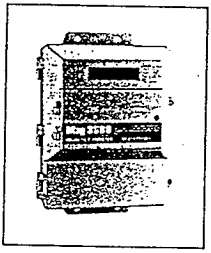
| Outputs, Performance Options | | Electronics Model | | | |
|---|---|---|---|---|---|
| | | Integral Series III | Remote 3560 CRE Series III | 3570 Integral/Remote (MagLite) | 3580 SMART |
| Accuracy: | ±0.5% Rate | Yes | Yes | Optional | Yes |
| | ±1% Rate 0.5% Optional | N/A | N/A | Yes | N/A |
| Output Range: (For above stated accuracy) | 1-10 m/Sec. | Yes | Yes | Yes | |
| | 1-10 ft/Sec. | Yes | Yes | N/A | N/A |
| | 1-30 ft/Sec. | N/A | N/A | N/A | Yes |
| Electrical Outputs: | 4-20 mA Analog | Yes | Yes | Yes | Yes |
| | 0-20 mA Analog | Yes | Yes | Yes | N/A |
| | 0-10 kHz Unfactored | Note (3) | Note (3) | Yes | N/A |
| | 0-10 kHz Scaled | Yes | Yes | N/A | N/A |
| | 0-1 kHz Scaled | Note (2) | Note (2) | N/A | Yes |
| Repeatability: | 0.25% Rate | Yes | Yes | Yes | 0.2% |
| Power Consumption: | less than 15 Watts | Yes | Yes | Yes | |
| | less than 20 Watts | | | | Yes |
| Input Voltage: (Note 1) | 10-30 Vdc | Yes | Yes | Yes | N/A |
| | 115 Vac 50-60 Hz | Yes | Yes | Yes | Yes |
| | 220 Vac 50-60 Hz | Yes | Yes | Yes | N/A |
| Communications: | Hart Protocol | N/A | N/A | N/A | Yes |
| Bi-Directional Flow Option: | | N/A | Yes | N/A | Standard |
| Integral Mounting: | | Yes | No | N/A | Note 4 |
| Remote Mounting: | | No | Yes | N/A | Yes |
| Universal: | Integral/Remote | No | No | Yes | No |
| Class I, Division 2, NEMA 4X (FM Approved) | | Yes | Yes | Yes | Yes |
| Features: | | Most Flexible Integral | Most Flexible Remote | Best Value All Flowheads | All Flowheads Digital Keypad Micro Processor |

NOTES:
(1) Series III Integral and 3560/3570 have jumper-selected power inputs 10-30 Vdc 115 Vac and 230 Vac.
(2) Can use divide-by 10 scaler function to reduce 10 kHz to 1,000 Hz.
(3) 0-10- kHz unfactored output when factor option board is removed (two-board module).
(4) Integral mounting with adaptor

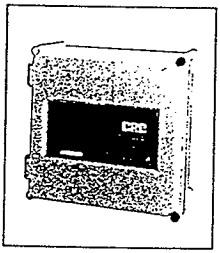




The Series III Integral Electronics represents the most versatile unit in the Brooks family of Mag electronics. Multitude of user-selectable output signals.



The newest member of the Brooks group is the Model 3580 "Smart" Electronics. This microprocessor-based magnetic flow transmitter offers keypad entry and display of selectable information, aids in flow-tube and transmitter testing and provides diagnostic helps in operation and maintenance of the system and communications.

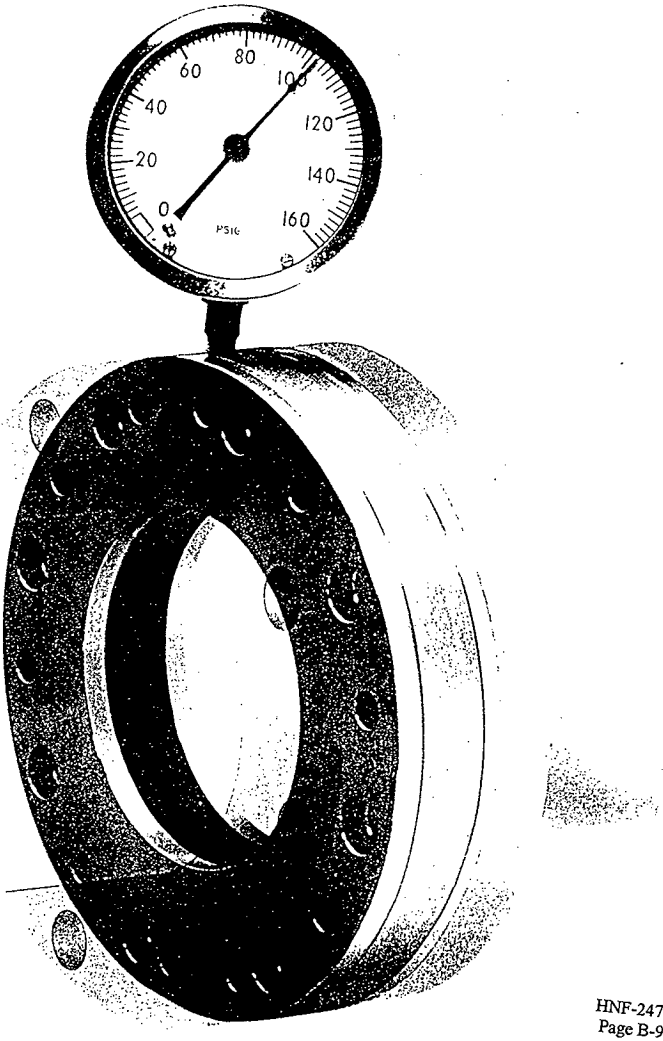



The Model 3560 Complete Remote Electronics "CRE" eliminates the need for supplying line voltage at the flowmeter elements and allows for convenient, accessible location. It can be mounted up to 1,000 feet from the flowmeter and offers many selectable features. (Models 3561, 3562, 3563 and 3564.)

The Model 3570, possibly Brooks' best value in electronic instrumentation, is used on all flowheads 0.15" - 8" and exclusively on the MagLite. Mounting may be integral or remote.

Figure 9 Wafer-Mag Electronics

# RED VALVE
## Pressure Sensors



# SERIES 40

**RED VALVE PRESSURE SENSORS** provide a full 360° circumferential reading of line fluids, while isolating them from the gauge. The flexible rubber sleeve provides accurate pressure readings of slurries and other hard to gauge corrosive fluids. Plugging or chemical attack of the gauge is eliminated.

A full circumferential reading eliminates pressure reading changes from trapped air or sediment deposits in the line. Readings taken at one point with a pipe tap are prone to bridge or clog from sediment.

Accuracy is dependent on the gauge. Red Valve's standard gauge has an accuracy of 2%. Gauges with greater accuracy are also available.

Pressure sensors can be mounted in any flow direction. Flow pressure is transferred from the flexible rubber sleeve to the gauge through a captive fluid. The sensor cannot clog because there are no line obstructions inducing buildup. Build up is fully eliminated by the flexing action of the sleeve which can break off adhering substances.

**Series 40 FLANGED SENSORS** conform to ANSI #125 flange drilling specifications. Class #300, #600, #900, #1200 flanges are also available. The small liquid chamber eliminates inaccurate readings due to thermal expansion of the fluid. Large chamber volumes are available on request.

The Series 40 is bolted directly in the line during installation and removal, eliminating costly welding associated with diaphragm seals.

The Series 40 can be mounted in any flow direction or it can be mounted with a blind flange as a dead end. End flange mounting can monitor tank levels.

**FEATURES** The Standard Red Valve Series "40" Sensor is manufactured with a very small chamber for the sensing liquid (less than ¼ of cubic inch). The volume of liquid in the Sensor Body is kept at a minimum because the pressure reading of the Sensor is effected by the thermal expansion or contraction of the sensing liquid. If a larger volume is required for bellows type instrumentation, it can be furnished on request.

In many applications the process is brought from atmospheric to over 100 degrees. A large volume of sensing liquid would expand and cause an increase of pressure because of the thermal expansion of the sensing liquid.

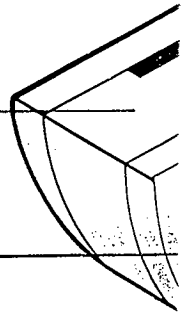
Red Valve Series "40" Sensors have less than ¼ of a cubic inch of liquid.

**Instrumentation**
**GAUGE, TRANSMITTER, PRESSURE SWITCH**

**Epoxy Seal**

**Fluid Chamber**

**360° Sensing Sleeve**



**Solid Center Flange**

**Thru Flange Bolting**

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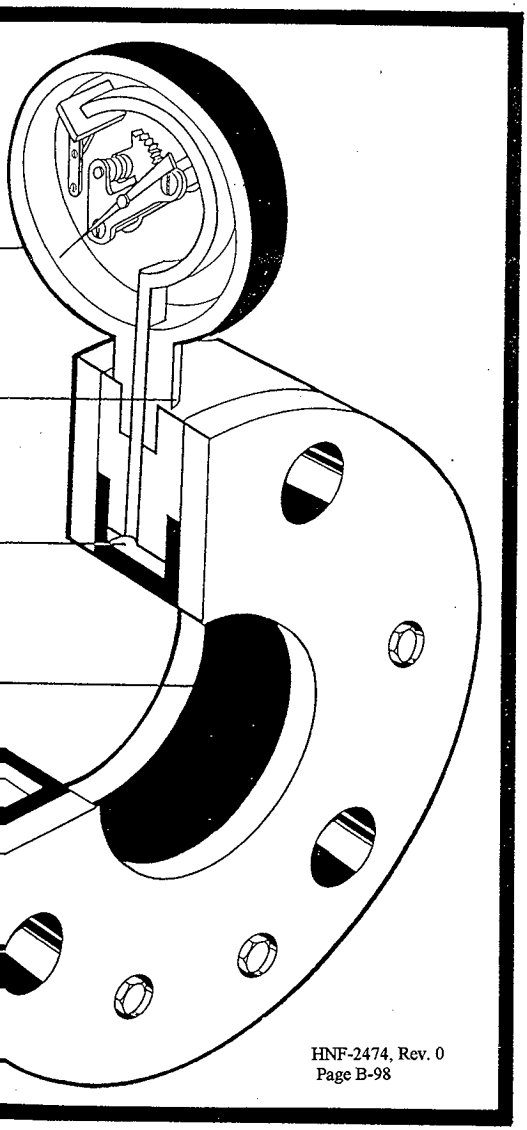
Page B-97




EXCEPTIONS: WHEN USING INSTRUMENTATION THAT REQUIRES A LARGE VOLUME OF SENSING LIQUID AS NEEDED BY CERTAIN MAKES OF PRESSURE SWITCHES, DIFFERENTIAL PRESSURE METERS, ETC., USER SHOULD SPECIFIY THIS ON HIS PURCHASE ORDER. (We will then furnish a Sensor with a larger volume.)

**EPOXY SEAL-FILL CONNECTION** Red Valve Pressure Sensors are now being furnished with the **Cap Fill Connection** covered with an epoxy plastic seal. Precision workmanship and caution is exercised in filling the Pressure Sensors at the factory. All air pockets are removed with a vacuum pump after which the fill connection is sealed with a fill plug. The epoxy plastic over the hole makes the fill plug tamper-proof. The epoxy plastic can be chipped out very easily with a nail setting tool or drilled out if necessary in the future.

**SOLID CONSTRUCTION** Pressure Sensors are now being furnished with double the "holding screws" to hold the unit firmly together. This prevents overcompressing in installation which could change the pressure reading.

**Full flange to the O.D. of the pipe guarantees that the Series 40 Sensor is centered when installed and makes installation easier, particularly for large diameter sensors.**

THE CENTER FLANGE IS FURNISHED SOLID AT THE CIRCUMFERENCE TO PREVENT COMPRESSION.

## Filling Instructions

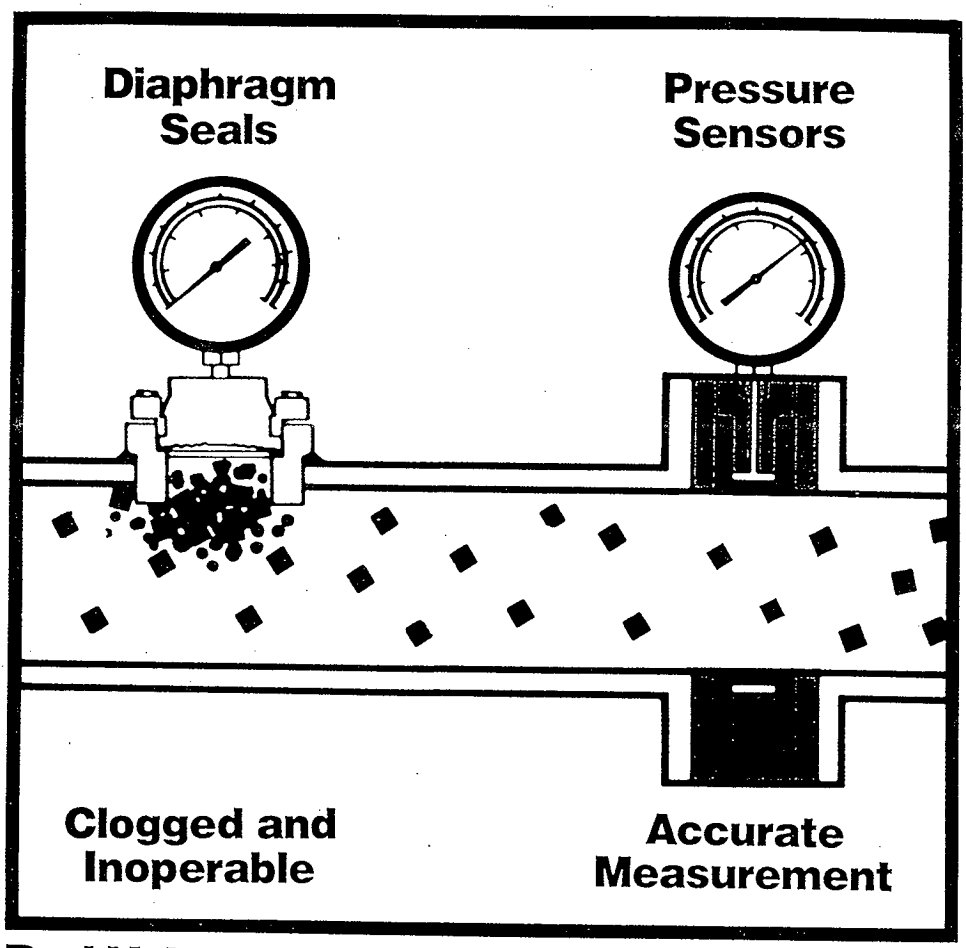
Red Valve Pressure Sensors should be refilled with a vacuum pump after the instrument is assembled to assure that all air is removed from the cavity of the sensor and instruments. If the sensor can not be removed from the line or a portable vacuum is not available, the alternate method is to gravity fill the sensor.

**Following are simple instructions:**

Gravity fill the sensor and lightly tap it to eliminate air bubbles. The gauge can also be gravity filled or filled separately under vacuum in the instrument shop.

After the gauge is filled, a piece of Saran Wrap should be placed over the threads of the pressure gauge to keep the liquid in the gauge from spilling when the gauge is inverted to thread into the sensor. The Saran Wrap should be left on when inverting the sensor because the Saran Wrap breaks very easily when the gauge is threaded into the sensor. This will prevent fill liquid from dripping out.

Gravity fill is not as good as vacuum fill but if care is exercised, it can work.




# Red Valve Pressure Sensors will not clog!

**Assuring accurate measurement and dependable systems control.**

GPS-501 3/85

Red Valve Company, Inc.
P.O. Box 548 600 N. Bell Ave.
CARNEGIE, PA 15106
(412) 279-0044 Telex 86-6138
FAX (412) 279-7878

# SPECIFICATIONS

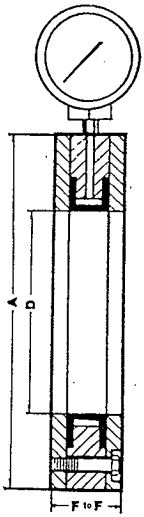
**SIZES** Series 40 Pressure Sensors are available in sizes 1" to 48". Pressure Sensors have an inside diameter equal to Schedule 40 Pipe.

**PRESSURES** Standard operating pressures are equivalent to the pressure rating of the flange. Standard Series 40 Sensors are manufactured to A.N.S.I. Class 125/150 pound flange and bolting dimensions.

Sensors can be supplied with Class 300, 600, 900 and 1200 pound flanges with comparable pressure ratings of 740, 1480, 2220, and 2960 PSI. Higher pressure ratings up to 20,000 PSI with raised faces or ring-grooves are also available.

**MATERIALS** Standard body and end flanges are Carbon Steel. Optional Materials include Stainless Steel, P.V.C. and Teflon.

**ACCURACY** The accuracy is equal to the gauge installed on the sensor. A ±2% of the gauge reading is common with off-the-shelf gauges. Higher accuracy and sensitivity is obtainable with more precise instrumentation.




| SIZE "D" | LENGTH F TO F* | O.D. "A" | STEEL (LBS). |
|---|---|---|---|
| 1" | 1⅞" | 4½" | 6 |
| 1½" | 1⅞" | 5" | 8 |
| 2" | 1⅞" | 6" | 12 |
| 2½" | 1⅞" | 7" | 16 |
| 3" | 1⅞" | 7½" | 18 |
| 4" | 2⅛" | 9" | 27 |
| 5" | 2¼" | 10" | 32 |
| 6" | 2¼" | 11" | 37 |
| 8" | 2½" | 13½" | 58 |
| 10" | 2¾" | 16" | 79 |
| 12" | 3" | 19" | 125 |
| 14" | 3" | 21" | 157 |
| 16" | 3" | 23½" | 190 |
| 18" | 3" | 25" | 250 |
| 20" | 3" | 27½" | 185 |
| 24" | 3" | 32" | 220 |
| 30" | 3" | 38¾" | 295 |
| 36" | 4" | 46" | 380 |
| 42" | 4" | 53" | 475 |
| 48" | 4" | 59½" | 610 |

*F to F of Teflon® Sensors is different.

**GAUGES** All standard ranges are available. A 0-100 psi gauge is furnished as standard unless otherwise specified. 0-60 psi and 0-200 psi gauges are also furnished at no extra charge.

**LIQUIDS** Standard sensing liquid is a 50% mixture of ethylene glycol (anti-freeze) and water. Special fluids can be supplied on request.

| | | | |
|---|---|---|---|
| Mineral Oil | 220°F | Vegetable Oil | 230°F |
| Distilled | 200°F | Silicone Oil (FDA Approved) | 450°F |

**ELASTOMERS** The standard Sensing Sleeve material is Buna-N. Other materials available include Pure Gum Rubber, Neoprene, Butyl, Hypalon, EPT, Food Grade Rubber and TEFLON. Other elastomers are available on request.

**SPECIFICATIONS FOR FLANGED PRESSURE SENSORS** This specification covers; Pressure Sensors and Gauge Isolator devices designed for isolating pipe-line flow media from a gauge or instrument. The Sensor shall be flanged and bolted directly into ANSI flanged pipelines. Face-to-face shall be no greater than a wafer style of a butterfly valve. The flanges shall have thru bolt holes to enable positive alignment in the pipeline. Inside diameter of the sensor shall be the same as the mating pipe with a full thru uninterrupted flow. There shall be no dead ends or crevices and flow passage shall make the sensor self-cleaning.

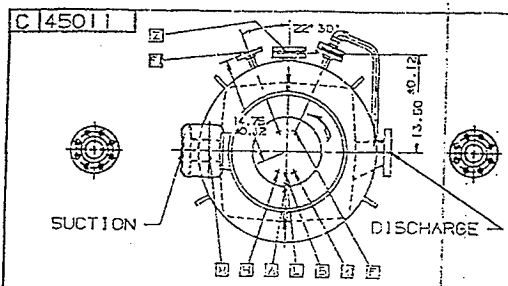
The Pressure Sensing Ring shall measure pressure for 360° around the full inside circumference of the pipeline. The sensing ring shall also be clamped into the body for the full radial width of the sensor. Pressure shall be transmitted to the gauge by a locked in and sealed fluid such as ethylene glycol or silicone oil. The Sensor shall have an auxiliary tapped and plugged port to allow filling connection of other equipment.

Red Valve Pressure Sensors are also available with capillary tubing for remote locations of instrumentation. Capillary tubing is available in various materials and sizes per your specifications. Red Valve can also fill and mount your instrumentation on our Pressure Sensors.

**All Sensors shall be as the Series 40, as manufactured by the Red Valve Co., of Carnegie, PA, 600 N. Bell Ave.**

® Teflon is Du Pont trademark for TFE flourocarbon resins

C 45011




CONNECTIONS:

- A 1/4-18 NPT - ALTERNATE LUBRICANT INLET TO THRUST BEARING (PLUGGED)
- B 1/4-18 NPT - OIL OUTLET FROM BEARING HOUSING
- E 1/2-14 NPT - INLET TO SEAL THRU API PLAN 11 FROM PUMP DISCHARGE
- F 1/2-300 LB. R.F. S.W. FLANGE - CASING VENT
- H 1/2-14 NPT - SEAL VENT
- H 1/2-14 NPT - SEAL DRAIN
- L 1/4-18 NPT - OIL MIST INLET TO BEARING HOUSING
- M MOTOR CONNECTION FOR POWER LEADS
- Z 3/4-300 LB. R.F. S.W. FLANGE - CASING DRAIN (COVERED WITH BLIND FLANGE)

WEIGHTS:

| | | |
|---|---|---|
| ① | PUMP | 800 LBS. |
| | MOTOR | 2700 ~~450~~ LBS. |
| | TOTAL | 3500 ~~1250~~ LBS. APPROXIMATE |

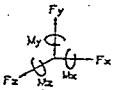
DRIVER DATA:

① 250 HP - 3600 RPM, T.E.F.C., VERTICAL ELECTRIC MOTOR, RELIANCE FRAME NO. 326TC

NOZZLE LOADS:

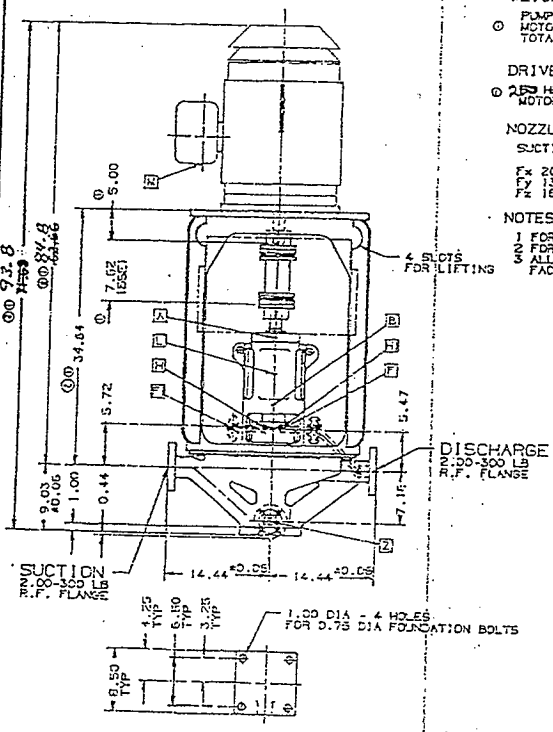
SUCTION & DISCHARGE

| | | | |
|---|---|---|---|
| Fx | 200 LBS. | Mx | 340 FT-LBS. |
| Fy | 130 LBS. | My | 250 FT-LBS. |
| Fz | 160 LBS. | Mz | 170 FT-LBS. |




NOTES:

1. FOR ASSEMBLY SEE DRAWING NO.C45010.
2. FOR PARTS LIST SEE "LIST OF COMPONENTS".
3. ALL FLANGE CONNECTIONS TO CONFORM TO A FACE FINISH OF 125 RMS.




| NO. | BY | DATE | CHK.BY | DESCRIPTION |
|---|---|---|---|---|
| 2 | KM | 4/24 | RAM | DIMS DECREASED 0.50 |
| 1 | MD | 4/24 | RAM | MOTOR WAS 325 HP FRAME |

REVISIONS

LAWRENCE PUMPS INC.

TRUE-LINE SERIES

PUMP SIZE: 2x3x10 2x3x8 1x3
SERIES: 1400
MODEL: 14-4A
DR.BY: TJ
CHK.BY: RAM 11/28/88
APPV.BY:
DATE: 21 NOV 88

CUSTOMER:
PURCHASE ORDER NO.:
PUMP SERIAL NO.:
PUMP ITEM NO.:
CERTIFIED BY:

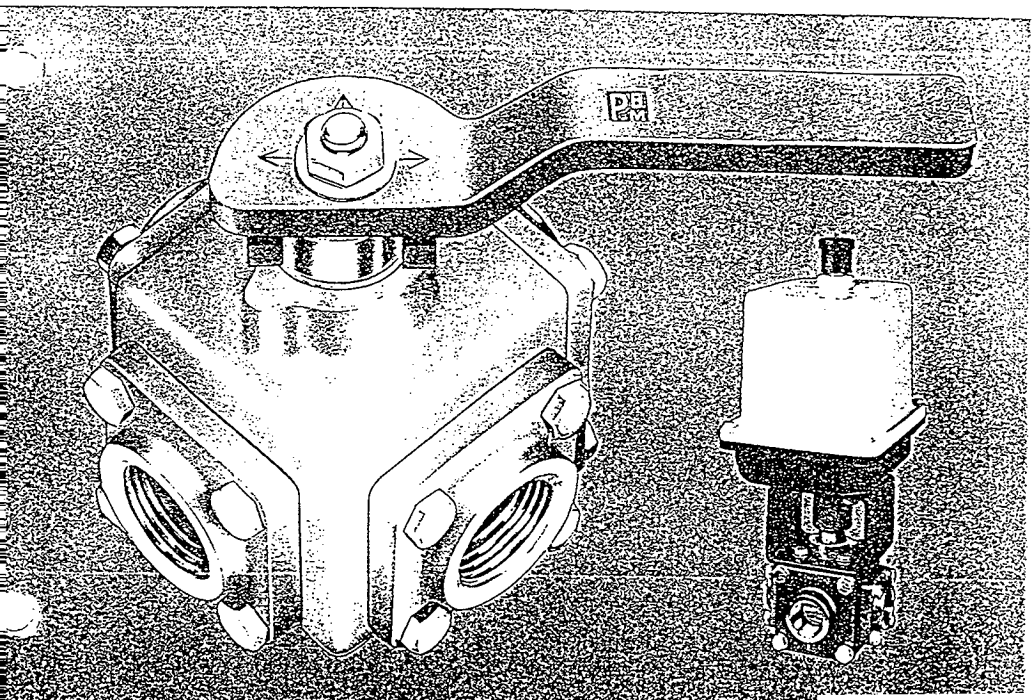
PUMP ASSEMBLY:
PUMP PARTS LIST:

PUMP ELEVATION

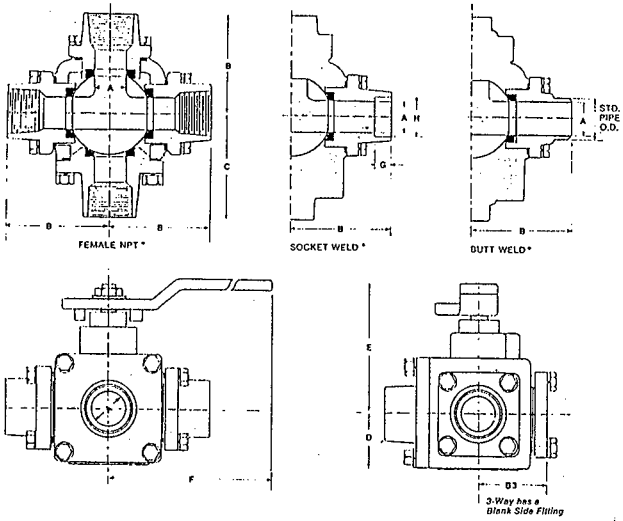
DRAWING NO.: C 45011

# Multi-Port Ball Valves

## Three, Four, and Five-Way

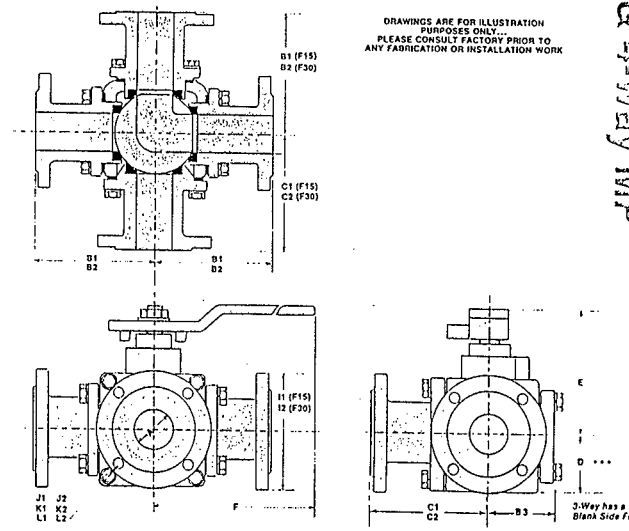


RBM INC. • P.O. BOX 397-A Sandy Hill Road • Irwin, PA 15642-0397 • 412-863-0550 • FAX




# Dimensions for 3 & 4-Way MP

DRAWINGS ARE FOR ILLUSTRATION PURPOSES ONLY... PLEASE CONSULT FACTORY PRIOR TO ANY FABRICATION OR INSTALLATION WORK




## Female NPT • Socket • Butt Weld

| PIPE SIZE (Inch) | A Port Dia. | B CL to Side Face | B3 CL to Blank Face | C CL to End Face | D Center to Bottom | E Center to Top | F Handle Length | G Socket Weld Depth | H Socket Weld Dia. | 3-Way Wt. (Lbs.) S/S & C/S** |
|---|---|---|---|---|---|---|---|---|---|---|
| ½" | .62" | 2.00" | 1.47" | 2.00" | 2.00" | 4.56" | 5.50" | .81" | .86" | 8 |
| ¾" | .62" | 2.00" | 1.47" | 2.00" | 2.00" | 4.56" | 5.50" | .81" | 1.06" | 8 |
| 1" | 1.00" | 2.36" | 2.00" | 2.36" | 1.56" | 3.72" | 6.00" | .94" | 1.34" | 12 |
| 1¼" | 1.00" | 2.38" | 2.00" | 2.38" | 1.56" | 3.72" | 6.00" | .62"‡ | 1.69" | 12 |
| 1½" | 1.50" | 3.28" | 2.88" | 3.28" | 2.25" | 5.17" | 8.00" | 1.16" | 1.92" | 28 |
| 2" | 2.00" | 3.88" | 3.30" | 3.88" | 2.62" | 5.61" | 8.00" | 1.12" | 2.41" | 40 |
| 3" | 2.25" | 5.53" | 3.75" | 5.53" | 3.75" | 9.56" | 11.62" | 1.88" | 3.55" | 65 |

*1 Port shown. See Flow Charts, pages 5 & 6, for other possibilities.
**Weights for other metals and for 4-Way supplied upon request.
‡ NOT STANDARD BORE DEPTH.

## 150# RF Flange (F15)

| PIPE SIZE (Inch) | A Port Dia. | B1 CL to Side | B3 Blank Side | C1 CL to End | D CL to Bottom | E CL to Top | I1 Flg. O.D. | F Handle Length | J1 Dia. B.C. | K1 No. Bolt Holes | L1 Bolt Dia. | 3-Way Wt. (Lbs.)** S/S & C/S |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1½" | 1.50" | 5.28" | 2.88" | 5.28" | 2.25" | 5.17" | 5.00" | 8.00" | 3.88" | 4 | .50" | 46 |
| 2"* | 2.00" | 5.97" | 3.30" | 5.97" | 2.62" | 5.61" | 6.00" | 8.00" | 4.75" | 4 | .62" | 64 |
| 3" | 2.25" | 7.28" | 3.75" | 7.28" | 3.75" | 9.56" | 7.50" | 11.62" | 6.00" | 4 | .62" | 105 |
| 4" | 3.00" | 8.50" | 5.00" | 8.50" | 5.00" | 11.25" | 9.00" | 13.75" | 7.50" | 8 | .62" | 220 |

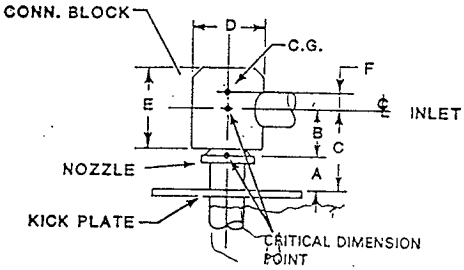
## 300# RF Flange (F30)

| PIPE SIZE (Inch) | A Port Dia. | B2 CL to Side | B3 Blank Side | C2 CL to End | D CL to Bottom | E CL to Top | I2 Flg. O.D. | F Handle Length | J2 Dia. B.C. | K2 No. Bolt Holes | L2 Bolt Dia. | 3-Way Wt. (Lbs.)** S/S & C/S |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1½" | 1.50" | 5.41" | 2.88" | 5.41" | 2.25" | 5.17" | 6.12" | 8.00" | 4.50" | 4 | .75" | 57 |
| 2" | 2.00" | 6.09" | 3.30" | 6.09" | 2.62" | 5.61" | 6.50" | 8.00" | 5.00" | 8 | .62" | 76 |
| 3" | 2.25" | 7.47"* | 3.75" | 7.47"* | 3.75" | 9.56" | 8.25" | 11.62" | 6.62" | 8 | .75" | 117 |
| 4" | 3.00" | 8.81" | 5.00" | 8.81" | 5.00" | 11.25" | 10.00" | 13.75" | 7.88" | 8 | .75" | 252 |

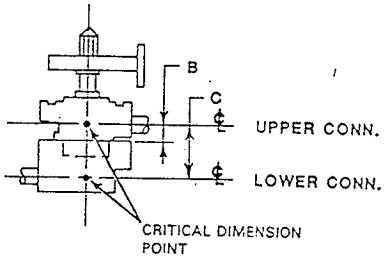
Note: Consult factory for 6" MP valve.

# 8.0 DESIGN DATA

## 8.1 PUREX Connector




PROCESS CONNECTOR




ELECTRICAL CONNECTOR

| Connector Block | | Dimensions (inches) | | | | | | Horizontal | | Vertical | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Size | Type | A | B | C | D | E | F | Weight (lbs.) | Drawing No. | Weight (lbs.) | Drawing No. |
| 1 | 1×1 | 1-7/8 | 1-23/32 | 3-19/32 | 2-1/2 | 2-1/2 | | 15.5 | H-2-32410-1 | 15.5 | H-2-32410-2 |
| 1 | Blank | 1-7/8 | 1-23/32 | 3-19/32 | 2-1/2 | 2-1/2 | | 16 | H-2-32410-3 | 16.5 | H-2-32410-4 |
| | | | | | | | | | | | |
| 2 | 2 × 2 | 2-1/4 | 2-7/16 | 4-11/16 | 3-3/8 | 3-5/8 | 1-1/8 | 29 | H-2-32420-1 | 29 | H-2-32420-2 |
| 2 | 2 × 1½ Dip tube | 2-1/4 | 2-7/16 | 4-11/16 | 3-3/8 | 3-5/8 | | | | 29 | H-2-32420-5 |
| 2 | 3 Way 3 1/2 | 2-9/32 | 2-13/32 | 4-11/16 | 3-3/8 | 3-5/8 | 1-1/8 | 31.5 | H-2-32427-1 | 32 | H-2-32427-2 |
| 2 | Recirculation | | | | | | | | | 31.5 | H-2-32427-7 |
| 2 | Thermowell | 2-1/4 | 2-7/8 | 5-1/8 | 3-3/8 | | | | | * | H-2-90154 |
| 2 | Blank | 2-1/4 | 2-7/8 | 4-11/16 | 3-3/8 | 3-5/8 | 1-1/8 | 32 | H-2-32420-3 | 34.5 | H-2-32420-4 |
| | | | | | | | | | | | |
| 3 | 3 × 3 | 3 | 3-9/13 | 6-9/16 | 5 | 5-9/16 | 1-7/16 | 76 | H-2-32430-1 | 77 | H-2-32430-2 |
| 3 | 3 × 2 Dip Tube | 3 | 3-9/13 | 6-9/16 | 5 | 5-9/16 | | | | 80 | H-2-32430-5 |
| 3 | 2 × 3 | 3 | 3-9/13 | 6-9/16 | 5 | 5-9/16 | 1-7/16 | 76 | H-2-32430-3 | 77 | H-2-32430-4 |
| 3 | 2 × 2 Dip Tube | 3 | 3-9/13 | 6-9/16 | 5 | 5-9/16 | | | | 83 | H-2-32430-6 |
| 3 | 3-Way 3 1/2 | 3 | 3-9/13 | 6-9/16 | 5 | 5-9/16 | | | | 87.5 | H-2-32437-1 |
| 3 | Thermowell | 3 | 3-9/13 | 6-9/16 | 5 | 5-9/16 | | | | * | H-2-90156 |
| 3 | Blank | 3 | 3-9/13 | 6-9/16 | 5 | 5-9/16 | 1-7/16 | 87.5 | H-2-32430-7 | 93 | H-2-32430-8 |
| | | | | | | | | | | | |
| 4 | 4 × 4 | 3-3/8 | 4-5/32 | 7-17/32 | 6-3/8 | 6-1/2 | 1-11/16 | 120 | H-2-32440-1 | 122 | H-2-32440-2 |
| 4 | 4 × 3 Dip Tube | 3-3/8 | 4-5/32 | 7-17/32 | 6-3/8 | 6-1/2 | | | | 126 | H-2-32440-3 |
| 4 | 3 × 3 Dip Tube | 3-3/8 | 4-5/32 | 7-17/32 | 6-3/8 | 6-1/2 | | | | 131 | H-2-32440-4 |
| 4 | 2 × 3 Dip Tube | 3-3/8 | 4-5/32 | 7-17/32 | 6-3/8 | 6-1/2 | | | | 135 | H-2-32440-5 |
| 4 | Blank | 3-3/8 | 4-5/32 | 7-17/32 | 6-3/8 | 6-1/2 | 1-11/16 | 150 | H-2-32440-6 | 153 | H-2-32440-7 |
| | | | | | | | | | | | |
| | Elec. Upper | | 1-11/16 | | | | | 56 | H-2-32400-2 | 7-Point | |
| | Eqpt. Conn. Lower | | | 5-19/32 | | | | 29 | H-2-32401-2 | 7-Point | |
| | Wall Conn. Lower | | | 5-27/32 | | | | | H-2-32408-1 | 7-Point | |

*Establish Weight from Drawing

Author: Dianna L Stone at ~KEH10
Date: 06/25/96 03:18 PM
Priority: Normal
TO: Mohammed M Ahmed at ~WHC4
Subject: Datum

---------- Message Contents ----------

Hi Mo,

The top side of the plate to which the seismic restraint is welded is located 6' - 0 9/32" above the centerline of the Pump Discharge (shown as Detail 2, Lifting Frame Sub-Assy, on Dwg H-2-818508, Sht 2).

Hope that works for you.
Dianna

W320-27-017

Distributor Stress Analysis

| KAISER ENGINEERS HANFORD | CALCULATION IDENTIFICATION AND INDEX | Page i of iii<br>Date |
|---|---|---|

This sheet shows the status and description of the attached Design Analysis sheets.

Discipline 27 - Piping WO/Job No. ER4319 / W320 Calculation No. W320 - 27 - 017

Project No. & Name W320, 241-C106 Sluicing

Calculation Item Distributor Stress Analysis

These calculations apply to:

Dwg. No. H-2-818527 Rev. No. D

Dwg. No. _____ Rev. No. _____

Other (Study, CDR) _____

_____ Rev. No. _____

The status of these calculations is:

- ☐ Preliminary Calculations
- ☒ Final Calculations
- ☐ Check Calculations (On Calculation Dated _____)
- ☐ Void Calculation (Reason Voided _____)

Incorporated in Final Drawings? ☒ Yes ☐ No

This calculation verified by independent "check" calculations? ☐ Yes ☒ No

Original and Revised Calculation Approvals:

| | Rev. 0 Signature/Date | Rev. 1 Signature/Date | Rev. 2 Signature/Date |
|---|---|---|---|
| Originator | [illegible] 4-20-98 | | |
| Checked by | A. Ahmed 8-26-98 | | |
| Approved by | CD Jones 8/31/94 | | |
| Checked Against Approved Vendor Data | A. Ahmed 4.10.98 | | |

CARROLL D. JONES STATE OF WASHINGTON REGISTERED PROFESSIONAL ENGINEER EXPIRES: 5/3/98

10/19/94

INDEX

| Design Analysis Page No. | Description |
|---|---|
| i | Calculation Identification and Index |
| ii | Calculation Cross Index |
| iii | Design Verification Screening Criteria |
| 1. | Objectives, Criteria, Given Data, Assumptions, Methods, References, Calculation |
| 2. | Conclusions |
| Appendix A | Autopipe Analysis |



KEH 0378.00 (06/92)

# CALCULATION CROSS INDEX (Typical)

Subject Calculation No. D320-27-017



| Subject Calculation Revision No. | Superceded by Calculation No. | These interfacing calculation/documents provide input to the subject calculation, and if revised may require revision of the subject calculation. | | Results and conclusions of the subject calculation are used in these interfacing calculations and/or documents. | | Does the output interface calculation/ documents require revision? | | Has the output interface calculation/ documents been revised? | | Discipline manager's signature and date indicating evaluation complete. |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Calculation/Document No. | Revision No. | Calculation/Document No. | Revision No. | Yes | No | Yes | No | |
| 0 | | H-2-918537 | 01 | H-2-818537 | 01 | | X | | X | D.L. Evans 7/16/98 |
| | | | | | | | | | | |
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KEH 1975 00 (12/88)

SFS No. _____

# DESIGN VERIFICATION SCREENING CRITERIA

Pg. iii of iii

Project/Document No. W320/ W320-27-016

When the design or design change affects hardware, formal design verification must be performed if one or more of the following questions must be answered affirmatively (YES).

| YES | NO | |
|---|---|---|
| | ✓ | 1. Does the design or design change involved meet the established criteria to be considered Safety Class 1? |
| | ✓ | 2. Does this design or design change cause or permit changes to Safety Class 1 instrument or alarm setpoints outside of previously approved operational limits? |
| | ✓ | 3. Does this design or design change significantly affect the nuclear or environmental safety consequences of a malfunction or failure of the structure, system, or component? |
| | ✓ | 4. Does this design or design change involve or change design that has previously undergone formal design verification? |

Carroll D. Jones — 8/31/94
Assigned Lead Engineer — Date

Danny L. Evans — 9/28/98
Responsible Discipline Manager — Date

Original Design Package Distribution:

Project Manager

Design Verification Officer

Engineering Document Control

Design Change Distribution:

Attach to Engineering Change Notice

**Client** WHC
**Subject** Distributor Stress Analysis
**Location:** 241-AY-02

**WO/Job No.** ER4319/W320
**Date** 7-19-94 **By** Rodney Campbell
**Checked** 8-24-94 **By** [illegible]
**Revised** **By**

**OBJECTIVE:**
The objective of this calculation is to verify that the design of the distributor meets ASME B31.3 code stress requirements.

**CRITERIA:**
1. Functional Design Criteria WHC-SD-W320-FDC-001, Rev. 2.
2. ASME B31.3-1993, Chemical Plant and Petroleum Refinery Piping, With Addenda.

**GIVEN DATA:**
1. Specific Gravity of fluid: 1.25
2. Ambient temperature: 40°F.
3. Maximum temperature: 180°F.

**ASSUMPTIONS:**
1. The same volume of material flows throughs the four nozzles at the same velocity, causing static equilibrium.
2. There is no damping from the fluid in the tank, on the distributor during an earthquake.

**METHODS:**

1. Autopipe→ Version 4.50
2. Hand calculations

**REFERENCES:**
1. Drawing H-2-818537, Rev. 0.
2. ASME B31.3-1993, Chemical Plant and Petroleum Refinery Piping, With Addenda.

**CALCULATION:**

1. Calculate the Stress Intensification Factors of the tee required for the analysis. (Ref. 2, Appendix D, Unreinforced Fabricated Tee)

$T := .337 \cdot in$ Average wall thickness of pipe being welded to.

$r_2 := 2.25 \cdot in$ Radius of pipe being welded to.

$$h := \frac{T}{r_2}$$

$$h = 0.15$$

$$i_o := \frac{0.9}{h^{\frac{2}{3}}}$$ Out of plane Stress Intensification Factor.

$$i_o = 3.19$$

$$i_i := \frac{3}{4} \cdot i_o + \frac{1}{4}$$ In plane Stress Intensification Factor.

$$i_i = 2.64$$

According to the AutoPipe calculation (Appendix A), the piping meets ASME B31.3-1993. The piping system is built from 4", schedule 80 pipe and 2", schedule 80 nozzles.

**Client** WHC
**Subject** Distributor Stress Analysis

**Location:** 241-AY

**WO/Job No.** ER4319/W320
**Date** 7-19-94 **By** Rodney Campbell
**Checked** 8-24-94 **By** Ahmed
**Revised** **By**

**CONCLUSIONS:**

The distributor as designed meets ASME B31.3.

APPENDIX A

## P O I N T D A T A L I S T I N G

| POINT NAME | TYPE | OFFSETS (ft) X | Y | Z | PIPE ID | DESCRIPTION |
|---|---|---|---|---|---|---|
| *** SEGMENT A | | | | | | |
| A00 | Run | 0 | 0 | 0 | 4SCHED80 | |
| A01 | Run | 0 | -2.54 | 0 | | |
| A02 | Tee | 0 | -35.15 | 0 | | |
| A03 | Run | 0 | -0.42 | 0 | | |
| *** SEGMENT B | | | | | | |
| A02 | Tee | 0 | -37.69 | 0 | 2SCHED80 | |
| B01 | Run | 0.50 | 0 | 0 | | |
| *** SEGMENT C | | | | | | |
| A02 | Tee | 0 | -37.69 | 0 | 2SCHED80 | |
| C01 | Run | -0.50 | 0 | 0 | | |
| *** SEGMENT D | | | | | | |
| A02 | Tee | 0 | -37.69 | 0 | 2SCHED80 | |
| D01 | Run | 0 | 0 | 0.50 | | |
| * SEGMENT E | | | | | | |
| A02 | Tee | 0 | -37.69 | 0 | 2SCHED80 | |
| E01 | Run | 0 | 0 | -0.50 | | |

Total weight of empty pipes : 595 lb

## C O M P O N E N T  D A T A  L I S T I N G

| POINT NAME | COORDINATE(ft) X | Y | Z | DATA TYPE | DESCRIPTION |
|---|---|---|---|---|---|
| *** SEGMENT A | | | | | |
| A00 | 0.00 | 0.00 | 0.00 | ANCHOR | Rigid<br>Thermal movements : None |
| A01 | 0.00 | -2.54 | 0.00 | | |
| A02 | 0.00 | -37.69 | 0.00 | TEE | Other<br>SIF - In = 2.60, Out = 3.14 |
| A03 | 0.00 | -38.10 | 0.00 | | |
| *** SEGMENT B | | | | | |
| A02 | 0.00 | -37.69 | 0.00 | TEE | Other<br>SIF - In = 2.60, Out = 3.14 |
| B01 | 0.50 | -37.69 | 0.00 | | |
| *** SEGMENT C | | | | | |
| A02 | 0.00 | -37.69 | 0.00 | TEE | Other<br>SIF - In = 2.60, Out = 3.14 |
| C01 | -0.50 | -37.69 | 0.00 | | |
| * SEGMENT D | | | | | |
| A02 | 0.00 | -37.69 | 0.00 | TEE | Other<br>SIF - In = 2.60, Out = 3.14 |
| D01 | 0.00 | -37.69 | 0.50 | | |
| *** SEGMENT E | | | | | |
| A02 | 0.00 | -37.69 | 0.00 | TEE | Other<br>SIF - In = 2.60, Out = 3.14 |
| E01 | 0.00 | -37.69 | -0.50 | | |

Number of points in the system : 12

## P I P E D A T A L I S T I N G

| Pipe ID/ Material | Nom/ Sch | O.D. inch | Thickness(inch) W.Th. | Corr | Mill | Insu | Ling | Spec Grav | Weight(lb/ft) Pipe | Other | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 4SCHED80 A312-TP304L | 4 80S | 4.500 | 0.337 | 0.06 | 0.04 | 0 | 0 | 1.25 | 15.33 | 0 | 21.56 |
| 2SCHED80 A312-TP304L | 2.000 80S | 2.375 | 0.218 | 0.06 | 0.03 | 0 | 0 | 1.25 | 5.14 | 0 | 6.74 |

## M A T E R I A L  D A T A  L I S T I N G

| Material Name | Pipe ID | Density lb/cu.ft | Pois. Ratio | Temper. deg F | Modulus E6 psi | Expans. in/100ft | Allow. psi |
|---|---|---|---|---|---|---|---|
| A312-TP304L | 4SCHED80 | 501.0 | 0.30 | 40.0 | 28.42 | | 16700.0 |
| | | | | 180.0 | | 1.5442 | 16700.0 |
| A312-TP304L | 2SCHED80 | 501.0 | 0.30 | 40.0 | 28.42 | | 16700.0 |
| | | | | 180.0 | | 1.5442 | 16700.0 |

TEMPERATURE AND PRESSURE DATA

| POINT NAME | -----C A S E 1------ PRESS. psi | TEMPER deg F | EXPAN. in/100ft | -----C A S E 2------ PRESS. psi | TEMPER deg F | EXPAN. in/100ft | -----C A S E 3------ PRESS. psi | TEMPER deg F | EXPAN. in/100ft |
|---|---|---|---|---|---|---|---|---|---|
| *** SEGMENT A | | | | | | | | | |
| A00 | 320 | 180 | 1.544 | | | | | | |
| A03 | 320 | 180 | 1.544 | | | | | | |
| *** SEGMENT B | | | | | | | | | |
| A02 | 320 | 180 | 1.544 | | | | | | |
| B01 | 320 | 180 | 1.544 | | | | | | |
| *** SEGMENT C | | | | | | | | | |
| A02 | 320 | 180 | 1.544 | | | | | | |
| C01 | 320 | 180 | 1.544 | | | | | | |
| *** SEGMENT D | | | | | | | | | |
| A02 | 320 | 180 | 1.544 | | | | | | |
| D01 | 320 | 180 | 1.544 | | | | | | |
| *** SEGMENT E | | | | | | | | | |
| 2 | 320 | 180 | 1.544 | | | | | | |
| E01 | 320 | 180 | 1.544 | | | | | | |

# A N A L Y S I S  S U M M A R Y

Current model revision number : 32

```
  Static - Date and Time of analysis ............ Aug 11, 1994   7:03 AM
           Model Revision Number ................ 32
           Number of load cases ................. 3
           Load cases analyzed .................. GR T1 P1
           Gaps/Friction/Yielding considered ..... No
           Hanger design run .................... No
           Cut short included ................... No
           Weight of contents included .......... Yes
           Pressure stiffening case ............. 0
           Water elevation for buoyancy loads .... Not considered

   Modal - Date and Time of analysis ............ Aug 11, 1994   7:03 AM
           Model Revision Number ................ 32
           Number of modes ...................... 2
           Cutoff frequency (Hz) ................ 33.0
           Weight of contents included .......... Yes
           Pressure stiffening case ............. 0
           Water elevation for buoyancy loads .... Not considered

Response - Date and Time of analysis ............ Aug 11, 1994   7:04 AM
           Model Revision Number ................ 32
           Number of load cases ................. 3
           Load cases analyzed .................. R1 R2 R3
           Date and time of modal analysis ...... Aug 11, 1994   7:03 AM
           Number of modes ...................... 2
           Cutoff frequency (Hz) ................ 33.0
           Model revision of modal analysis ..... 32
           Weight of contents included .......... Yes
           Pressure stiffening case ............. 0
           Water elevation for buoyancy loads .... Not considered
```

CODE COMPLIANCE COMBINATIONS

| Combination | Category | Method | Load | Factor | Allowable | Remarks |
|---|---|---|---|---|---|---|
| GR + Max P | Sustain | Sum | Gravity | 1.00 | Automatic | Default |
| | | | Max Long | 1.00 | | |
| Cold to T1 | Expansion | Sum | Thermal 1 | 1.00 | Automatic | Default |
| Sus. + R1 | Occasion | Abs sum | Response 1 | 1.00 | Automatic | Default |
| | | | Max Sus | 1.00 | | |
| Sus. + R2 | Occasion | Abs sum | Response 2 | 1.00 | Automatic | Default |
| | | | Max Sus | 1.00 | | |
| Sus. + R3 | Occasion | Abs sum | Response 3 | 1.00 | Automatic | Default |
| | | | Max Sus | 1.00 | | |
| Max P | Hoop | | Max Hoop | 1.00 | Automatic | Default |
| RTOTAL | Occasion | SRSS | Response 1 | 1.00 | Automatic | User |
| | | | Response 2 | 1.00 | | |
| | | | Response 3 | 1.00 | | |

OTHER USER COMBINATIONS

| Combination | Method | Load | Factor | Remarks |
|---|---|---|---|---|
| GR | Sum | Gravity | 1.00 | Default |
| T1 | Sum | Thermal 1 | 1.00 | Default |
| P1 | Sum | Press 1 | 1.00 | Default |
| R1 | Sum | Response 1 | 1.00 | Default |
| R2 | Sum | Response 2 | 1.00 | Default |
| R3 | Sum | Response 3 | 1.00 | Default |
| GR+T1 | Sum | Gravity | 1.00 | User |
| | | Thermal 1 | 1.00 | |
| RT | Abs sum | Response 1 | 1.00 | User |
| | | Response 2 | 1.00 | |
| | | Response 3 | 1.00 | |
| GR+T1+RT | Abs sum | GR+T1 | 1.00 | User |
| | | RT | 1.00 | |

CODE COMPLIANCE

Y - Factor ..... 0.40
Weld efficiency factor ..... 1.00
Range reduction factor ..... 1.00
Design Pressure Factor ..... 1.00
Minimum stress ratio used in reports... 0.00
Include corrosion in stress calcs. .... Y
Include torsion in code stress ..... N
Include axial force in code stress .... N
Longitudinal pressure calculation ..... PD/4t
Include rigorous pressure ..... N

RESPONSE SPECTRUM LOAD CASES :

Number of load cases analysed : 3

Load case 1 - R1

Missing mass : No
ZPA : No

Combination method : SRSS

X- Spectrum : SC2&3
Multiplier : 1.00

SC2&3

| Freq(Hz) | Grav( ) | Freq(Hz) | Grav( ) | Freq(Hz) | Grav( ) |
|---|---|---|---|---|---|
| 0.100 | 0.01 | 0.160 | 0.02 | 0.250 | 0.04 |
| 0.400 | 0.06 | 0.600 | 0.09 | 1.100 | 0.17 |
| 1.640 | 0.25 | 8.000 | 0.25 | 12.000 | 0.20 |
| 20.000 | 0.16 | 33.000 | 0.12 | 100.000 | 0.12 |

Load case 2 - R2

Missing mass : No
ZPA : No

Combination method : SRSS

Y- Spectrum : SC2&3
Multiplier : 1.00

SC2&3

| Freq(Hz) | Grav( ) | Freq(Hz) | Grav( ) | Freq(Hz) | Grav( ) |
|---|---|---|---|---|---|
| 0.100 | 0.01 | 0.160 | 0.02 | 0.250 | 0.04 |
| 0.400 | 0.06 | 0.600 | 0.09 | 1.100 | 0.17 |
| 1.640 | 0.25 | 8.000 | 0.25 | 12.000 | 0.20 |
| 20.000 | 0.16 | 33.000 | 0.12 | 100.000 | 0.12 |

Load case 3 - R3

Missing mass : No
ZPA : No

Combination method : SRSS

Z- Spectrum : SC2&3
Multiplier : 1.00

SC2&3

| Freq(Hz) | Grav( ) | Freq(Hz) | Grav( ) | Freq(Hz) | Grav( ) |
|---|---|---|---|---|---|
| 0.100 | 0.01 | 0.160 | 0.02 | 0.250 | 0.04 |
| 0.400 | 0.06 | 0.600 | 0.09 | 1.100 | 0.17 |
| 1.640 | 0.25 | 8.000 | 0.25 | 12.000 | 0.20 |
| 20.000 | 0.16 | 33.000 | 0.12 | 100.000 | 0.12 |

D I S P L A C E M E N T S

| Point name | Load combination | TRANSLATIONS (in ) X | Y | Z | ROTATIONS (deg ) X | Y | Z |
|---|---|---|---|---|---|---|---|
| *** Segment A begin *** | | | | | | | |
| A00 | GR | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | T1 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | P1 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | R1 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | R2 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | R3 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | GR+T1 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | RT | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | GR+T1+RT | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| A01 | GR | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | T1 | 0.000 | -0.039 | 0.000 | 0.000 | 0.000 | 0.000 |
| | P1 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | R1 | 0.022 | 0.000 | 0.000 | 0.000 | 0.000 | 0.081 |
| | R2 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | R3 | 0.000 | 0.000 | 0.022 | 0.081 | 0.000 | 0.000 |
| | GR+T1 | 0.000 | -0.039 | 0.000 | 0.000 | 0.000 | 0.000 |
| | RT | 0.022 | 0.000 | 0.022 | 0.081 | 0.000 | 0.081 |
| | GR+T1+RT | 0.022 | 0.039 | 0.022 | 0.081 | 0.000 | 0.081 |
| A02 | GR | 0.000 | -0.002 | 0.000 | 0.000 | 0.000 | 0.000 |
| | T1 | 0.000 | -0.582 | 0.000 | 0.000 | 0.000 | 0.000 |
| | P1 | 0.000 | -0.005 | 0.000 | 0.000 | 0.000 | 0.000 |
| | R1 | 3.286 | 0.000 | 0.000 | 0.000 | 0.000 | 0.624 |
| | R2 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | R3 | 0.000 | 0.000 | 3.286 | 0.624 | 0.000 | 0.000 |
| | GR+T1 | 0.000 | -0.584 | 0.000 | 0.000 | 0.000 | 0.000 |
| | RT | 3.286 | 0.000 | 3.286 | 0.624 | 0.000 | 0.624 |
| | GR+T1+RT | 3.286 | 0.584 | 3.286 | 0.624 | 0.000 | 0.624 |
| A03 | GR | 0.000 | -0.002 | 0.000 | 0.000 | 0.000 | 0.000 |
| | T1 | 0.000 | -0.588 | 0.000 | 0.000 | 0.000 | 0.000 |
| | P1 | 0.000 | -0.005 | 0.000 | 0.000 | 0.000 | 0.000 |
| | R1 | 3.341 | 0.000 | 0.000 | 0.000 | 0.000 | 0.624 |
| | R2 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | R3 | 0.000 | 0.000 | 3.341 | 0.624 | 0.000 | 0.000 |
| | GR+T1 | 0.000 | -0.590 | 0.000 | 0.000 | 0.000 | 0.000 |
| | RT | 3.341 | 0.000 | 3.341 | 0.624 | 0.000 | 0.624 |
| | GR+T1+RT | 3.341 | 0.590 | 3.341 | 0.624 | 0.000 | 0.624 |
| *** Segment A end *** | | | | | | | |
| * Segment B begin *** | | | | | | | |

D I S P L A C E M E N T S

| Point name | Load combination | TRANSLATIONS (in ) X | Y | Z | ROTATIONS (deg ) X | Y | Z |
|---|---|---|---|---|---|---|---|
| A02 | GR | 0.000 | -0.002 | 0.000 | 0.000 | 0.000 | 0.000 |
| | T1 | 0.000 | -0.582 | 0.000 | 0.000 | 0.000 | 0.000 |
| | P1 | 0.000 | -0.005 | 0.000 | 0.000 | 0.000 | 0.000 |
| | R1 | 3.286 | 0.000 | 0.000 | 0.000 | 0.000 | 0.624 |
| | R2 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | R3 | 0.000 | 0.000 | 3.286 | 0.624 | 0.000 | 0.000 |
| | GR+T1 | 0.000 | -0.584 | 0.000 | 0.000 | 0.000 | 0.000 |
| | RT | 3.286 | 0.000 | 3.286 | 0.624 | 0.000 | 0.624 |
| | GR+T1+RT | 3.286 | 0.584 | 3.286 | 0.624 | 0.000 | 0.624 |
| B01 | GR | 0.000 | -0.002 | 0.000 | 0.000 | 0.000 | 0.000 |
| | T1 | 0.008 | -0.582 | 0.000 | 0.000 | 0.000 | 0.000 |
| | P1 | 0.000 | -0.005 | 0.000 | 0.000 | 0.000 | 0.000 |
| | R1 | 3.286 | 0.065 | 0.000 | 0.000 | 0.000 | 0.624 |
| | R2 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | R3 | 0.000 | 0.000 | 3.286 | 0.624 | 0.000 | 0.000 |
| | GR+T1 | 0.008 | -0.584 | 0.000 | 0.000 | 0.000 | 0.000 |
| | RT | 3.286 | 0.065 | 3.286 | 0.624 | 0.000 | 0.624 |
| | GR+T1+RT | 3.294 | 0.649 | 3.286 | 0.624 | 0.000 | 0.624 |

*** Segment B end ***

*** Segment C begin ***

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| A02 | GR | 0.000 | -0.002 | 0.000 | 0.000 | 0.000 | 0.000 |
| | T1 | 0.000 | -0.582 | 0.000 | 0.000 | 0.000 | 0.000 |
| | P1 | 0.000 | -0.005 | 0.000 | 0.000 | 0.000 | 0.000 |
| | R1 | 3.286 | 0.000 | 0.000 | 0.000 | 0.000 | 0.624 |
| | R2 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | R3 | 0.000 | 0.000 | 3.286 | 0.624 | 0.000 | 0.000 |
| | GR+T1 | 0.000 | -0.584 | 0.000 | 0.000 | 0.000 | 0.000 |
| | RT | 3.286 | 0.000 | 3.286 | 0.624 | 0.000 | 0.624 |
| | GR+T1+RT | 3.286 | 0.584 | 3.286 | 0.624 | 0.000 | 0.624 |
| C01 | GR | 0.000 | -0.002 | 0.000 | 0.000 | 0.000 | 0.000 |
| | T1 | -0.008 | -0.582 | 0.000 | 0.000 | 0.000 | 0.000 |
| | P1 | 0.000 | -0.005 | 0.000 | 0.000 | 0.000 | 0.000 |
| | R1 | 3.286 | 0.065 | 0.000 | 0.000 | 0.000 | 0.624 |
| | R2 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | R3 | 0.000 | 0.000 | 3.286 | 0.624 | 0.000 | 0.000 |
| | GR+T1 | -0.008 | -0.584 | 0.000 | 0.000 | 0.000 | 0.000 |
| | RT | 3.286 | 0.065 | 3.286 | 0.624 | 0.000 | 0.624 |
| | GR+T1+RT | 3.294 | 0.649 | 3.286 | 0.624 | 0.000 | 0.624 |

*** Segment C end ***

*** Segment D begin ***

D I S P L A C E M E N T S

| Point name | Load combination | TRANSLATIONS (in ) X | Y | Z | ROTATIONS (deg ) X | Y | Z |
|---|---|---|---|---|---|---|---|
| A02 | GR | 0.000 | -0.002 | 0.000 | 0.000 | 0.000 | 0.000 |
| | T1 | 0.000 | -0.582 | 0.000 | 0.000 | 0.000 | 0.000 |
| | P1 | 0.000 | -0.005 | 0.000 | 0.000 | 0.000 | 0.000 |
| | R1 | 3.286 | 0.000 | 0.000 | 0.000 | 0.000 | 0.624 |
| | R2 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | R3 | 0.000 | 0.000 | 3.286 | 0.624 | 0.000 | 0.000 |
| | GR+T1 | 0.000 | -0.584 | 0.000 | 0.000 | 0.000 | 0.000 |
| | RT | 3.286 | 0.000 | 3.286 | 0.624 | 0.000 | 0.624 |
| | GR+T1+RT | 3.286 | 0.584 | 3.286 | 0.624 | 0.000 | 0.624 |
| D01 | GR | 0.000 | -0.002 | 0.000 | 0.000 | 0.000 | 0.000 |
| | T1 | 0.000 | -0.582 | 0.008 | 0.000 | 0.000 | 0.000 |
| | P1 | 0.000 | -0.005 | 0.000 | 0.000 | 0.000 | 0.000 |
| | R1 | 3.286 | 0.000 | 0.000 | 0.000 | 0.000 | 0.624 |
| | R2 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | R3 | 0.000 | 0.065 | 3.286 | 0.624 | 0.000 | 0.000 |
| | GR+T1 | 0.000 | -0.584 | 0.008 | 0.000 | 0.000 | 0.000 |
| | RT | 3.286 | 0.065 | 3.286 | 0.624 | 0.000 | 0.624 |
| | GR+T1+RT | 3.286 | 0.649 | 3.294 | 0.624 | 0.000 | 0.624 |

*** Segment D end ***

*** Segment E begin ***

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| A02 | GR | 0.000 | -0.002 | 0.000 | 0.000 | 0.000 | 0.000 |
| | T1 | 0.000 | -0.582 | 0.000 | 0.000 | 0.000 | 0.000 |
| | P1 | 0.000 | -0.005 | 0.000 | 0.000 | 0.000 | 0.000 |
| | R1 | 3.286 | 0.000 | 0.000 | 0.000 | 0.000 | 0.624 |
| | R2 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | R3 | 0.000 | 0.000 | 3.286 | 0.624 | 0.000 | 0.000 |
| | GR+T1 | 0.000 | -0.584 | 0.000 | 0.000 | 0.000 | 0.000 |
| | RT | 3.286 | 0.000 | 3.286 | 0.624 | 0.000 | 0.624 |
| | GR+T1+RT | 3.286 | 0.584 | 3.286 | 0.624 | 0.000 | 0.624 |
| E01 | GR | 0.000 | -0.002 | 0.000 | 0.000 | 0.000 | 0.000 |
| | T1 | 0.000 | -0.582 | -0.008 | 0.000 | 0.000 | 0.000 |
| | P1 | 0.000 | -0.005 | 0.000 | 0.000 | 0.000 | 0.000 |
| | R1 | 3.286 | 0.000 | 0.000 | 0.000 | 0.000 | 0.624 |
| | R2 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | R3 | 0.000 | 0.065 | 3.286 | 0.624 | 0.000 | 0.000 |
| | GR+T1 | 0.000 | -0.584 | -0.008 | 0.000 | 0.000 | 0.000 |
| | RT | 3.286 | 0.065 | 3.286 | 0.624 | 0.000 | 0.624 |
| | GR+T1+RT | 3.286 | 0.649 | 3.294 | 0.624 | 0.000 | 0.624 |

*** Segment E end ***

S U P P O R T  F O R C E S

| Point/ Supp. ID | Connect/ Type | Load Combination | LOCAL Dirn | LOCAL Force | LOCAL Deform | GLOBAL Dirn | GLOBAL Force | GLOBAL Deform |
|---|---|---|---|---|---|---|---|---|

*** End of system , no supports encountered. ***

## R E S T R A I N T  R E A C T I O N S

| Point name | Load combination | FORCES (lb ) X | Y | Z | Result | MOMENTS (ft-lb ) X | Y | Z | Result |
|---|---|---|---|---|---|---|---|---|---|
| A00 | Anchor | | | | | | | | |
| | GR | 0 | -835 | 0 | 835 | 0 | 0 | 0 | 0 |
| | T1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | P1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | R1 | 29 | 0 | 0 | 29 | 0 | 0 | 1097 | 1097 |
| | R2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | R3 | 0 | 0 | 29 | 29 | 1097 | 0 | 0 | 1097 |
| | GR+T1 | 0 | -835 | 0 | 835 | 0 | 0 | 0 | 0 |
| | RT | 29 | 0 | 29 | 41 | 1097 | 0 | 1097 | 1552 |
| | GR+T1+RT | 29 | 835 | 29 | 836 | 1097 | 0 | 1097 | 1552 |

## G L O B A L F O R C E S & M O M E N T S

| Point name | Load combination | FORCES (lb ) X | Y | Z | Result | MOMENTS (ft-lb ) X | Y | Z | Result |
|---|---|---|---|---|---|---|---|---|---|
| *** Segment A begin *** | | | | | | | | | |
| A00 | GR | 0 | 835 | 0 | 835 | 0 | 0 | 0 | 0 |
| | T1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | P1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | R1 | 29 | 0 | 0 | 29 | 0 | 0 | 1097 | 1097 |
| | R2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | R3 | 0 | 0 | 29 | 29 | 1097 | 0 | 0 | 1097 |
| | GR+T1 | 0 | 835 | 0 | 835 | 0 | 0 | 0 | 0 |
| | RT | 29 | 0 | 29 | 41 | 1097 | 0 | 1097 | 1552 |
| | GR+T1+RT | 29 | 835 | 29 | 836 | 1097 | 0 | 1097 | 1552 |
| A01 | GR | 0 | 780 | 0 | 780 | 0 | 0 | 0 | 0 |
| | T1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | P1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | R1 | 29 | 0 | 0 | 29 | 0 | 0 | 1023 | 1023 |
| | R2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | R3 | 0 | 0 | 29 | 29 | 1023 | 0 | 0 | 1023 |
| | GR+T1 | 0 | 780 | 0 | 780 | 0 | 0 | 0 | 0 |
| | RT | 29 | 0 | 29 | 41 | 1023 | 0 | 1023 | 1447 |
| | GR+T1+RT | 29 | 780 | 29 | 781 | 1023 | 0 | 1023 | 1447 |
| A02 - | GR | 0 | 22 | 0 | 22 | 0 | 0 | 0 | 0 |
| | T1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | P1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | R1 | 29 | 0 | 0 | 29 | 0 | 0 | 0 | 0 |
| | R2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | R3 | 0 | 0 | 29 | 29 | 0 | 0 | 0 | 0 |
| | GR+T1 | 0 | 22 | 0 | 22 | 0 | 0 | 0 | 0 |
| | RT | 29 | 0 | 29 | 41 | 0 | 0 | 0 | 0 |
| | GR+T1+RT | 29 | 22 | 29 | 47 | 0 | 0 | 0 | 0 |
| A02 + | GR | 0 | 9 | 0 | 9 | 0 | 0 | 0 | 0 |
| | T1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | P1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | R1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | R2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | R3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | GR+T1 | 0 | 9 | 0 | 9 | 0 | 0 | 0 | 0 |
| | RT | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | GR+T1+RT | 0 | 9 | 0 | 9 | 0 | 0 | 0 | 0 |

G L O B A L F O R C E S & M O M E N T S

| Point name | Load combination | FORCES (lb ) X | Y | Z | Result | MOMENTS (ft-lb ) X | Y | Z | Result |
|---|---|---|---|---|---|---|---|---|---|
| A03 | GR | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | T1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | P1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | R1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | R2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | R3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | GR+T1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | RT | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | GR+T1+RT | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *** Segment A end *** | | | | | | | | | |
| *** Segment B begin *** | | | | | | | | | |
| A02 | GR | 0 | 3 | 0 | 3 | 0 | 0 | 1 | 1 |
| | T1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | P1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | R1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | R2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | R3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | GR+T1 | 0 | 3 | 0 | 3 | 0 | 0 | 1 | 1 |
| | RT | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | GR+T1+RT | 0 | 3 | 0 | 3 | 0 | 0 | 1 | 1 |
| B01 | GR | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | T1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | P1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | R1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | R2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | R3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | GR+T1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | RT | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | GR+T1+RT | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *** Segment B end *** | | | | | | | | | |
| *** Segment C begin *** | | | | | | | | | |
| A02 | GR | 0 | 3 | 0 | 3 | 0 | 0 | -1 | 1 |
| | T1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | P1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | R1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | R2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | R3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | GR+T1 | 0 | 3 | 0 | 3 | 0 | 0 | -1 | 1 |
| | RT | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | GR+T1+RT | 0 | 3 | 0 | 3 | 0 | 0 | 1 | 1 |

G L O B A L F O R C E S & M O M E N T S

| Point name | Load combination | FORCES (lb ) X | Y | Z | Result | MOMENTS (ft-lb ) X | Y | Z | Result |
|---|---|---|---|---|---|---|---|---|---|
| C01 | GR | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | T1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | P1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | R1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | R2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | R3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | GR+T1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | RT | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | GR+T1+RT | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *** Segment C end *** | | | | | | | | | |
| *** Segment D begin *** | | | | | | | | | |
| A02 | GR | 0 | 3 | 0 | 3 | -1 | 0 | 0 | 1 |
| | T1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | P1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | R1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | R2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | R3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | GR+T1 | 0 | 3 | 0 | 3 | -1 | 0 | 0 | 1 |
| | RT | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | GR+T1+RT | 0 | 3 | 0 | 3 | 1 | 0 | 0 | 1 |
| D01 | GR | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | T1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | P1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | R1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | R2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | R3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | GR+T1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | RT | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | GR+T1+RT | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *** Segment D end *** | | | | | | | | | |
| *** Segment E begin *** | | | | | | | | | |
| A02 | GR | 0 | 3 | 0 | 3 | 1 | 0 | 0 | 1 |
| | T1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | P1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | R1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | R2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | R3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | GR+T1 | 0 | 3 | 0 | 3 | 1 | 0 | 0 | 1 |
| | RT | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | GR+T1+RT | 0 | 3 | 0 | 3 | 1 | 0 | 0 | 1 |

G L O B A L F O R C E S & M O M E N T S

| Point name | Load combination | FORCES (lb ) X | Y | Z | Result | MOMENTS (ft-lb ) X | Y | Z | Result |
|---|---|---|---|---|---|---|---|---|---|
| E01 | GR | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | T1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | P1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | R1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | R2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | R3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | GR+T1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | RT | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | GR+T1+RT | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

*** Segment E end ***

G E N E R A L P I P E S T R E S S R E P O R T
(Stress in psi )

| Point name | Load combination | Hoop Stress | Longitudinal Max | Longitudinal Min | Tors. Shear | Principal Max | Principal Min | Max Shear | Loc | Oct Shear |
|---|---|---|---|---|---|---|---|---|---|---|
| *** Segment A begin *** | | | | | | | | | | |
| A00 | SIFI= 1.00 | SIFO= 1.00 | | | | | | | | |
| | GR | 0 | 227 | 227 | 0 | 227 | 0 | 114 | NA | 227 |
| | T1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | NA | 0 |
| | P1 | 2936 | 1001 | 1001 | 0 | 2936 | 1001 | 1468 | NA | 2585 |
| | R1 | 0 | 3601 | -3601 | 0 | 3601 | -3601 | 1801 | MT | 3601 |
| | R2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | NA | 0 |
| | R3 | 0 | 3601 | -3601 | 0 | 3601 | -3601 | 1801 | MT | 3601 |
| | GR+T1 | 0 | 227 | 227 | 0 | 227 | 0 | 114 | NA | 227 |
| | RT | 0 | 5093 | -5093 | 0 | 5093 | -5093 | 2547 | MT | 5093 |
| | GR+T1+RT | 0 | 4866 | -5320 | 0 | 4866 | -5320 | 2660 | MC | 5320 |
| A01 | SIFI= 1.00 | SIFO= 1.00 | | | | | | | | |
| | GR | 0 | 212 | 212 | 0 | 212 | 0 | 106 | NA | 212 |
| | T1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | MT | 0 |
| | P1 | 2936 | 1001 | 1001 | 0 | 2936 | 1001 | 1468 | NA | 2585 |
| | R1 | 0 | 3357 | -3357 | 0 | 3357 | -3357 | 1678 | MT | 3357 |
| | R2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | NA | 0 |
| | R3 | 0 | 3357 | -3357 | 0 | 3357 | -3357 | 1678 | MT | 3357 |
| | GR+T1 | 0 | 212 | 212 | 0 | 212 | 0 | 106 | NA | 212 |
| | RT | 0 | 4748 | -4748 | 0 | 4748 | -4748 | 2374 | MT | 4748 |
| | GR+T1+RT | 0 | 4535 | -4960 | 0 | 4535 | -4960 | 2480 | MC | 4960 |
| A02 - | SIFI= 2.60 | SIFO= 3.14 | | | | | | | | |
| | GR | 0 | 6 | 6 | 0 | 6 | 0 | 3 | NA | 6 |
| | T1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | MT | 0 |
| | P1 | 2936 | 1001 | 1001 | 0 | 2936 | 1001 | 1468 | NA | 2585 |
| | R1 | 0 | 1 | -1 | 0 | 1 | -1 | 1 | MT | 1 |
| | R2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | NA | 0 |
| | R3 | 0 | 1 | -1 | 0 | 1 | -1 | 1 | MT | 1 |
| | GR+T1 | 0 | 6 | 6 | 0 | 6 | 0 | 3 | NA | 6 |
| | RT | 0 | 2 | -2 | 0 | 2 | -2 | 1 | MT | 2 |
| | GR+T1+RT | 0 | -4 | -8 | 0 | 0 | -8 | 4 | MC | 8 |
| A02 + | SIFI= 2.60 | SIFO= 3.14 | | | | | | | | |
| | GR | 0 | 2 | 2 | 0 | 2 | 0 | 1 | NA | 2 |
| | T1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | MC | 0 |
| | P1 | 2936 | 1001 | 1001 | 0 | 2936 | 1001 | 1468 | NA | 2585 |
| | R1 | 0 | 1 | -1 | 0 | 1 | -1 | 1 | MT | 1 |
| | R2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | NA | 0 |
| | R3 | 0 | 1 | -1 | 0 | 1 | -1 | 1 | MT | 1 |
| | GR+T1 | 0 | 2 | 2 | 0 | 2 | 0 | 1 | NA | 2 |
| | RT | 0 | 2 | -2 | 0 | 2 | -2 | 1 | MT | 2 |
| | GR+T1+RT | 0 | -1 | -4 | 0 | 0 | -4 | 2 | MC | 4 |

G E N E R A L P I P E S T R E S S R E P O R T
(Stress in psi )

| Point name | Load combination | Hoop Stress | Longitudinal Max | Longitudinal Min | Tors. Shear | Principal Max | Principal Min | Max Shear | Loc | Oct Shear |
|---|---|---|---|---|---|---|---|---|---|---|
| A03 | SIFI= 1.00 | SIFO= 1.00 | | | | | | | | |
| | GR | 0 | 0 | 0 | 0 | 0 | 0 | 0 | NA | 0 |
| | T1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | MC | 0 |
| | P1 | 2936 | 1001 | 1001 | 0 | 2936 | 1001 | 1468 | NA | 2585 |
| | R1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | NA | 0 |
| | R2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | NA | 0 |
| | R3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | NA | 0 |
| | GR+T1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | MC | 0 |
| | RT | 0 | 0 | 0 | 0 | 0 | 0 | 0 | NA | 0 |
| | GR+T1+RT | 0 | 0 | 0 | 0 | 0 | 0 | 0 | MC | 0 |

*** Segment A end ***

*** Segment B begin ***

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| A02 | SIFI= 2.60 | SIFO= 3.14 | | | | | | | | |
| | GR | 0 | 46 | -46 | 0 | 46 | -46 | 23 | MT | 46 |
| | T1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | MT | 0 |
| | P1 | 2773 | 859 | 859 | 0 | 2773 | 859 | 1386 | NA | 2459 |
| | R1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | MC | 0 |
| | R2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | NA | 0 |
| | R3 | 0 | 4 | -4 | 0 | 4 | -4 | 2 | MT | 4 |
| | GR+T1 | 0 | 46 | -46 | 0 | 46 | -46 | 23 | MT | 46 |
| | RT | 0 | 4 | -4 | 0 | 4 | -4 | 2 | MC | 4 |
| | GR+T1+RT | 0 | 46 | -46 | 0 | 46 | -46 | 23 | MC | 46 |
| B01 | SIFI= 1.00 | SIFO= 1.00 | | | | | | | | |
| | GR | 0 | 0 | 0 | 0 | 0 | 0 | 0 | MT | 0 |
| | T1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | MT | 0 |
| | P1 | 2773 | 859 | 859 | 0 | 2773 | 859 | 1386 | NA | 2459 |
| | R1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | NA | 0 |
| | R2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | NA | 0 |
| | R3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | NA | 0 |
| | GR+T1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | MT | 0 |
| | RT | 0 | 0 | 0 | 0 | 0 | 0 | 0 | NA | 0 |
| | GR+T1+RT | 0 | 0 | 0 | 0 | 0 | 0 | 0 | MC | 0 |

*** Segment B end ***

*** Segment C begin ***

# G E N E R A L  P I P E  S T R E S S  R E P O R T

(Stress in psi )

| Point name | Load combination | Hoop Stress | Longitudinal Max | Longitudinal Min | Tors. Shear | Principal Max | Principal Min | Max Shear | Loc | Oct Shear |
|---|---|---|---|---|---|---|---|---|---|---|
| A02 | SIFI= 2.60 | SIFO= 3.14 | | | | | | | | |
| | GR | 0 | 46 | -46 | 0 | 46 | -46 | 23 | MT | 46 |
| | T1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | MT | 0 |
| | P1 | 2773 | 859 | 859 | 0 | 2773 | 859 | 1386 | NA | 2459 |
| | R1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | MC | 0 |
| | R2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | NA | 0 |
| | R3 | 0 | 4 | -4 | 0 | 4 | -4 | 2 | MT | 4 |
| | GR+T1 | 0 | 46 | -46 | 0 | 46 | -46 | 23 | MT | 46 |
| | RT | 0 | 4 | -4 | 0 | 4 | -4 | 2 | MC | 4 |
| | GR+T1+RT | 0 | 46 | -46 | 0 | 46 | -46 | 23 | MC | 46 |
| C01 | SIFI= 1.00 | SIFO= 1.00 | | | | | | | | |
| | GR | 0 | 0 | 0 | 0 | 0 | 0 | 0 | MT | 0 |
| | T1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | MT | 0 |
| | P1 | 2773 | 859 | 859 | 0 | 2773 | 859 | 1386 | NA | 2459 |
| | R1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | NA | 0 |
| | R2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | NA | 0 |
| | R3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | NA | 0 |
| | GR+T1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | MT | 0 |
| | RT | 0 | 0 | 0 | 0 | 0 | 0 | 0 | NA | 0 |
| | GR+T1+RT | 0 | 0 | 0 | 0 | 0 | 0 | 0 | MC | 0 |

*** Segment C end ***

*** Segment D begin ***

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| A02 | SIFI= 2.60 | SIFO= 3.14 | | | | | | | | |
| | GR | 0 | 46 | -46 | 0 | 46 | -46 | 23 | MT | 46 |
| | T1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | MT | 0 |
| | P1 | 2773 | 859 | 859 | 0 | 2773 | 859 | 1386 | NA | 2459 |
| | R1 | 0 | 4 | -4 | 0 | 4 | -4 | 2 | MT | 4 |
| | R2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | NA | 0 |
| | R3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | MC | 0 |
| | GR+T1 | 0 | 46 | -46 | 0 | 46 | -46 | 23 | MT | 46 |
| | RT | 0 | 4 | -4 | 0 | 4 | -4 | 2 | MC | 4 |
| | GR+T1+RT | 0 | 46 | -46 | 0 | 46 | -46 | 23 | MC | 46 |
| D01 | SIFI= 1.00 | SIFO= 1.00 | | | | | | | | |
| | GR | 0 | 0 | 0 | 0 | 0 | 0 | 0 | MT | 0 |
| | T1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | MT | 0 |
| | P1 | 2773 | 859 | 859 | 0 | 2773 | 859 | 1386 | NA | 2459 |
| | R1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | NA | 0 |
| | R2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | NA | 0 |
| | R3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | NA | 0 |
| | GR+T1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | MT | 0 |
| | RT | 0 | 0 | 0 | 0 | 0 | 0 | 0 | NA | 0 |
| | GR+T1+RT | 0 | 0 | 0 | 0 | 0 | 0 | 0 | MC | 0 |

*** Segment D end ***

G E N E R A L  P I P E  S T R E S S  R E P O R T
(Stress in psi )

| Point name | Load combination | Hoop Stress | Longitudinal Max | Longitudinal Min | Tors. Shear | Principal Max | Principal Min | Max Shear | Loc | Oct Shear |
|---|---|---|---|---|---|---|---|---|---|---|
| *** Segment E begin *** | | | | | | | | | | |
| A02 | SIFI= 2.60 | SIFO= 3.14 | | | | | | | | |
| | GR | 0 | 46 | -46 | 0 | 46 | -46 | 23 | MT | 46 |
| | T1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | MT | 0 |
| | P1 | 2773 | 859 | 859 | 0 | 2773 | 859 | 1386 | NA | 2459 |
| | R1 | 0 | 4 | -4 | 0 | 4 | -4 | 2 | MT | 4 |
| | R2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | NA | 0 |
| | R3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | MC | 0 |
| | GR+T1 | 0 | 46 | -46 | 0 | 46 | -46 | 23 | MT | 46 |
| | RT | 0 | 4 | -4 | 0 | 4 | -4 | 2 | MC | 4 |
| | GR+T1+RT | 0 | 46 | -46 | 0 | 46 | -46 | 23 | MC | 46 |
| E01 | SIFI= 1.00 | SIFO= 1.00 | | | | | | | | |
| | GR | 0 | 0 | 0 | 0 | 0 | 0 | 0 | MT | 0 |
| | T1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | MT | 0 |
| | P1 | 2773 | 859 | 859 | 0 | 2773 | 859 | 1386 | NA | 2459 |
| | R1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | NA | 0 |
| | R2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | NA | 0 |
| | R3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | NA | 0 |
| | GR+T1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | MT | 0 |
| | RT | 0 | 0 | 0 | 0 | 0 | 0 | 0 | NA | 0 |
| | GR+T1+RT | 0 | 0 | 0 | 0 | 0 | 0 | 0 | MC | 0 |
| *** Segment E end *** | | | | | | | | | | |

ASME B31.3c (1992) CODE COMPLIANCE

| Point name | Load combination | (Moments in ft-lb ) In-Pl. Moment | Out-Pl. Moment | Torsion Moment | S.I.F In | Out | Eq. no. | (Stress in psi ) Load type | Code Stress | Code Allow. |
|---|---|---|---|---|---|---|---|---|---|---|
| *** Segment A begin *** | | | | | | | | | | |
| A00 | Max P | | | | | | (3a) | HOOP | 2936 | 16700 |
| | GR + Max P | 0 | 0 | | 1.00 | 1.00 | (18) | SUST | 1300 | 16700 |
| | Cold to T1 | 0 | 0 | 0 | 1.00 | 1.00 | (17) | DISP | 0 | 25050 |
| | Sus. + R1 | 0 | 1097 | | 1.00 | 1.00 | (18) | OCC | 4901 | 22211 |
| | Sus. + R2 | 0 | 0 | | 1.00 | 1.00 | (18) | OCC | 1300 | 22211 |
| | Sus. + R3 | 1097 | 0 | | 1.00 | 1.00 | (18) | OCC | 4901 | 22211 |
| | RTOTAL | 1097 | 1097 | | 1.00 | 1.00 | (18) | OCC | 5093 | 22211 |
| A01 | Max P | | | | | | (3a) | HOOP | 2936 | 16700 |
| | GR + Max P | 0 | 0 | | 1.00 | 1.00 | (18) | SUST | 1300 | 16700 |
| | Cold to T1 | 0 | 0 | 0 | 1.00 | 1.00 | (17) | DISP | 0 | 25050 |
| | Sus. + R1 | 0 | 1023 | | 1.00 | 1.00 | (18) | OCC | 4657 | 22211 |
| | Sus. + R2 | 0 | 0 | | 1.00 | 1.00 | (18) | OCC | 1300 | 22211 |
| | Sus. + R3 | 1023 | 0 | | 1.00 | 1.00 | (18) | OCC | 4657 | 22211 |
| | RTOTAL | 1023 | 1023 | | 1.00 | 1.00 | (18) | OCC | 4748 | 22211 |
| 2 - | Max P | | | | | | (3a) | HOOP | 2936 | 16700 |
| | GR + Max P | 0 | 0 | | 2.60 | 3.14 | (18) | SUST | 1300 | 16700 |
| | Cold to T1 | 0 | 0 | 0 | 2.60 | 3.14 | (17) | DISP | 0 | 25050 |
| | Sus. + R1 | 0 | 0 | | 2.60 | 3.14 | (18) | OCC | 1301 | 22211 |
| | Sus. + R2 | 0 | 0 | | 2.60 | 3.14 | (18) | OCC | 1300 | 22211 |
| | Sus. + R3 | 0 | 0 | | 2.60 | 3.14 | (18) | OCC | 1301 | 22211 |
| | RTOTAL | 0 | 0 | | 2.60 | 3.14 | (18) | OCC | 2 | 22211 |
| A02 + | Max P | | | | | | (3a) | HOOP | 2936 | 16700 |
| | GR + Max P | 0 | 0 | | 2.60 | 3.14 | (18) | SUST | 1300 | 16700 |
| | Cold to T1 | 0 | 0 | 0 | 2.60 | 3.14 | (17) | DISP | 0 | 25050 |
| | Sus. + R1 | 0 | 0 | | 2.60 | 3.14 | (18) | OCC | 1301 | 22211 |
| | Sus. + R2 | 0 | 0 | | 2.60 | 3.14 | (18) | OCC | 1300 | 22211 |
| | Sus. + R3 | 0 | 0 | | 2.60 | 3.14 | (18) | OCC | 1301 | 22211 |
| | RTOTAL | 0 | 0 | | 2.60 | 3.14 | (18) | OCC | 2 | 22211 |
| A03 | Max P | | | | | | (3a) | HOOP | 2936 | 16700 |
| | GR + Max P | 0 | 0 | | 1.00 | 1.00 | (18) | SUST | 1300 | 16700 |
| | Cold to T1 | 0 | 0 | 0 | 1.00 | 1.00 | (17) | DISP | 0 | 25050 |
| | Sus. + R1 | 0 | 0 | | 1.00 | 1.00 | (18) | OCC | 1300 | 22211 |
| | Sus. + R2 | 0 | 0 | | 1.00 | 1.00 | (18) | OCC | 1300 | 22211 |
| | Sus. + R3 | 0 | 0 | | 1.00 | 1.00 | (18) | OCC | 1300 | 22211 |
| | RTOTAL | 0 | 0 | | 1.00 | 1.00 | (18) | OCC | 0 | 22211 |

*** Segment A end ***

*** Segment B begin ***

ASME B31.3c (1992) CODE COMPLIANCE

| Point name | Load combination | In-Pl. Moment | Out-Pl. Moment | Torsion Moment | S.I.F In | S.I.F Out | Eq. no. | Load type | Code Stress | Code Allow. |
|---|---|---|---|---|---|---|---|---|---|---|
| | | (Moments in ft-lb ) | | | | | (Stress in psi ) | | | |
| LA02 | Max P | | | | | | (3a) | HOOP | 2773 | 16700 |
| | GR + Max P | 1 | 0 | | 2.60 | 3.14 | (18) | SUST | 1227 | 16700 |
| | Cold to T1 | 0 | 0 | 0 | 2.60 | 3.14 | (17) | DISP | 0 | 25050 |
| | Sus. + R1 | 1 | 0 | | 2.60 | 3.14 | (18) | OCC | 1227 | 22211 |
| | Sus. + R2 | 1 | 0 | | 2.60 | 3.14 | (18) | OCC | 1227 | 22211 |
| | Sus. + R3 | 1 | 0 | | 2.60 | 3.14 | (18) | OCC | 1229 | 22211 |
| | RTOTAL | 0 | 0 | | 2.60 | 3.14 | (18) | OCC | 2 | 22211 |
| B01 | Max P | | | | | | (3a) | HOOP | 2773 | 16700 |
| | GR + Max P | 0 | 0 | | 1.00 | 1.00 | (18) | SUST | 1203 | 16700 |
| | Cold to T1 | 0 | 0 | 0 | 1.00 | 1.00 | (17) | DISP | 0 | 25050 |
| | Sus. + R1 | 0 | 0 | | 1.00 | 1.00 | (18) | OCC | 1203 | 22211 |
| | Sus. + R2 | 0 | 0 | | 1.00 | 1.00 | (18) | OCC | 1203 | 22211 |
| | Sus. + R3 | 0 | 0 | | 1.00 | 1.00 | (18) | OCC | 1203 | 22211 |
| | RTOTAL | 0 | 0 | | 1.00 | 1.00 | (18) | OCC | 0 | 22211 |

*** Segment B end ***

*** Segment C begin ***

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| LA02 | Max P | | | | | | (3a) | HOOP | 2773 | 16700 |
| | GR + Max P | 1 | 0 | | 2.60 | 3.14 | (18) | SUST | 1248 | 16700 |
| | Cold to T1 | 0 | 0 | 0 | 2.60 | 3.14 | (17) | DISP | 0 | 25050 |
| | Sus. + R1 | 1 | 0 | | 2.60 | 3.14 | (18) | OCC | 1249 | 22211 |
| | Sus. + R2 | 1 | 0 | | 2.60 | 3.14 | (18) | OCC | 1248 | 22211 |
| | Sus. + R3 | 1 | 0 | | 2.60 | 3.14 | (18) | OCC | 1252 | 22211 |
| | RTOTAL | 0 | 0 | | 2.60 | 3.14 | (18) | OCC | 4 | 22211 |
| C01 | Max P | | | | | | (3a) | HOOP | 2773 | 16700 |
| | GR + Max P | 0 | 0 | | 1.00 | 1.00 | (18) | SUST | 1203 | 16700 |
| | Cold to T1 | 0 | 0 | 0 | 1.00 | 1.00 | (17) | DISP | 0 | 25050 |
| | Sus. + R1 | 0 | 0 | | 1.00 | 1.00 | (18) | OCC | 1203 | 22211 |
| | Sus. + R2 | 0 | 0 | | 1.00 | 1.00 | (18) | OCC | 1203 | 22211 |
| | Sus. + R3 | 0 | 0 | | 1.00 | 1.00 | (18) | OCC | 1203 | 22211 |
| | RTOTAL | 0 | 0 | | 1.00 | 1.00 | (18) | OCC | 0 | 22211 |

*** Segment C end ***

*** Segment D begin ***

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| LA02 | Max P | | | | | | (3a) | HOOP | 2773 | 16700 |
| | GR + Max P | 0 | 1 | | 2.60 | 3.14 | (18) | SUST | 1255 | 16700 |
| | Cold to T1 | 0 | 0 | 0 | 2.60 | 3.14 | (17) | DISP | 0 | 25050 |
| | Sus. + R1 | 0 | 1 | | 2.60 | 3.14 | (18) | OCC | 1258 | 22211 |
| | Sus. + R2 | 0 | 1 | | 2.60 | 3.14 | (18) | OCC | 1255 | 22211 |
| | Sus. + R3 | 0 | 1 | | 2.60 | 3.14 | (18) | OCC | 1255 | 22211 |
| | RTOTAL | 0 | 0 | | 2.60 | 3.14 | (18) | OCC | 3 | 22211 |

ASME B31.3c (1992) CODE COMPLIANCE

| Point name | Load combination | In-Pl. Moment (Moments in ft-lb) | Out-Pl. Moment | Torsion Moment | S.I.F In | S.I.F Out | Eq. no. | Load type | Code Stress (Stress in psi) | Code Allow. |
|---|---|---|---|---|---|---|---|---|---|---|
| D01 | Max P | | | | | | (3a) | HOOP | 2773 | 16700 |
| | GR + Max P | 0 | 0 | | 1.00 | 1.00 | (18) | SUST | 1203 | 16700 |
| | Cold to T1 | 0 | 0 | 0 | 1.00 | 1.00 | (17) | DISP | 0 | 25050 |
| | Sus. + R1 | 0 | 0 | | 1.00 | 1.00 | (18) | OCC | 1203 | 22211 |
| | Sus. + R2 | 0 | 0 | | 1.00 | 1.00 | (18) | OCC | 1203 | 22211 |
| | Sus. + R3 | 0 | 0 | | 1.00 | 1.00 | (18) | OCC | 1203 | 22211 |
| | RTOTAL | 0 | 0 | | 1.00 | 1.00 | (18) | OCC | 0 | 22211 |

*** Segment D end ***

*** Segment E begin ***

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| A02 | Max P | | | | | | (3a) | HOOP | 2773 | 16700 |
| | GR + Max P | 0 | 1 | | 2.60 | 3.14 | (18) | SUST | 1258 | 16700 |
| | Cold to T1 | 0 | 0 | 0 | 2.60 | 3.14 | (17) | DISP | 0 | 25050 |
| | Sus. + R1 | 0 | 1 | | 2.60 | 3.14 | (18) | OCC | 1261 | 22211 |
| | Sus. + R2 | 0 | 1 | | 2.60 | 3.14 | (18) | OCC | 1258 | 22211 |
| | Sus. + R3 | 0 | 1 | | 2.60 | 3.14 | (18) | OCC | 1258 | 22211 |
| | RTOTAL | 0 | 0 | | 2.60 | 3.14 | (18) | OCC | 3 | 22211 |
| E01 | Max P | | | | | | (3a) | HOOP | 2773 | 16700 |
| | GR + Max P | 0 | 0 | | 1.00 | 1.00 | (18) | SUST | 1203 | 16700 |
| | Cold to T1 | 0 | 0 | 0 | 1.00 | 1.00 | (17) | DISP | 0 | 25050 |
| | Sus. + R1 | 0 | 0 | | 1.00 | 1.00 | (18) | OCC | 1203 | 22211 |
| | Sus. + R2 | 0 | 0 | | 1.00 | 1.00 | (18) | OCC | 1203 | 22211 |
| | Sus. + R3 | 0 | 0 | | 1.00 | 1.00 | (18) | OCC | 1203 | 22211 |
| | RTOTAL | 0 | 0 | | 1.00 | 1.00 | (18) | OCC | 0 | 22211 |

*** Segment E end ***

## S Y S T E M  S U M M A R Y

### Maximum displacements (in)

| | | | |
|---|---|---|---|
| Maximum X : | 3.341 | Point : A03 | Load Comb.: R1 |
| Maximum Y : | 0.649 | Point : B01 | Load Comb.: GR+T1+RT |
| Maximum Z : | 3.341 | Point : A03 | Load Comb.: R3 |
| Max. total: | 4.761 | Point : A03 | Load Comb.: GR+T1+RT |

### Maximum rotations (deg)

| | | | |
|---|---|---|---|
| Maximum X : | 0.624 | Point : D01 | Load Comb.: GR+T1+RT |
| Maximum Z : | 0.624 | Point : B01 | Load Comb.: GR+T1+RT |
| Max. total: | 0.883 | Point : D01 | Load Comb.: GR+T1+RT |

### Maximum restraint forces(lb)

| | | | |
|---|---|---|---|
| Maximum X : | 29 | Point : A00 | Load Comb.: R1 |
| Maximum Y : | -835 | Point : A00 | Load Comb.: GR |
| Maximum Z : | 29 | Point : A00 | Load Comb.: R3 |
| Max. total: | 836 | Point : A00 | Load Comb.: GR+T1+RT |

### Maximum restraint moments(ft-lb)

| | | | |
|---|---|---|---|
| Maximum X : | 1097 | Point : A00 | Load Comb.: R3 |
| Maximum Z : | 1097 | Point : A00 | Load Comb.: R1 |
| Max. total: | 1552 | Point : A00 | Load Comb.: RT |

## S Y S T E M  S U M M A R Y

### Maximum pipe forces (lb)

| | | | |
|---|---|---|---|
| Maximum X : | 29 | Point : A00 | Load Comb.: R1 |
| Maximum Y : | 835 | Point : A00 | Load Comb.: GR |
| Maximum Z : | 29 | Point : A00 | Load Comb.: R3 |
| Max. total: | 836 | Point : A00 | Load Comb.: GR+T1+RT |

### Maximum pipe moments (ft-lb)

| | | | |
|---|---|---|---|
| Maximum X : | 1097 | Point : A00 | Load Comb.: R3 |
| Maximum Y : | 0 | Point : A02 | Load Comb.: R3 |
| Maximum Z : | 1097 | Point : A00 | Load Comb.: R1 |
| Max. total: | 1552 | Point : A00 | Load Comb.: RT |

## S Y S T E M  S U M M A R Y

Maximum sustained stress

```
Point            : A00
Stress    psi    : 1300
Allowable psi    : 16700
Ratio            : 0.08
Load combination : GR + Max P
```

Maximum displacement stress

```
Point            : A02
Stress    psi    : 0
Allowable psi    : 25050
Ratio            : 0.00
Load combination : Cold to T1
```

Maximum occasional stress

```
Point            : A00
Stress    psi    : 5093
Allowable psi    : 22211
Ratio            : 0.23
Load combination : RTOTAL
```

Maximum hoop stress

```
Point            : A00
Stress    psi    : 2936
Allowable psi    : 16700
Ratio            : 0.18
Load combination : Max P
```

Maximum sustained stress ratio

```
Point            : A00
Stress    psi    : 1300
Allowable psi    : 16700
Ratio            : 0.08
Load combination : GR + Max P
```

Maximum displacement stress ratio

```
Point            : A02
Stress    psi    : 0
Allowable psi    : 25050
Ratio            : 0.00
Load combination : Cold to T1
```

## S Y S T E M  S U M M A R Y

Maximum occasional stress ratio

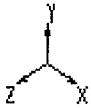
| | |
|---|---|
| Point | : A00 |
| Stress psi | : 5093 |
| Allowable psi | : 22211 |
| Ratio | : 0.23 |
| Load combination | : RTOTAL |

Maximum hoop stress ratio

| | |
|---|---|
| Point | : A00 |
| Stress psi | : 2936 |
| Allowable psi | : 16700 |
| Ratio | : 0.18 |
| Load combination | : Max P |

* * * The system satisfies ASME B31.3 code requirements * * *
* * * for the selected options * * *

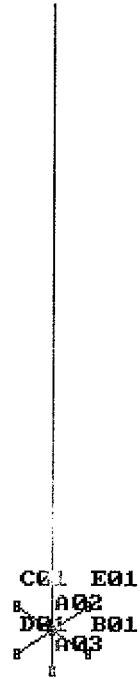
Point A01 A




AY FARM DISTRIBUTOR ANALYSIS

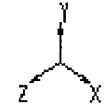
W320 TANK 241-C-106 SLUICING ER4319

Point A02 A

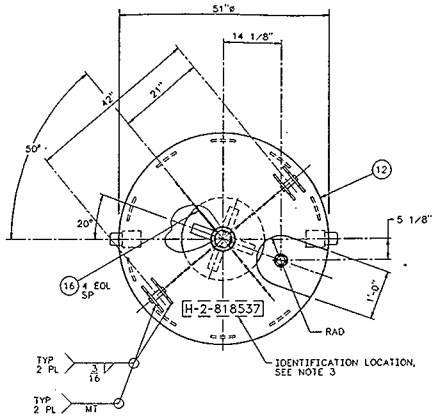


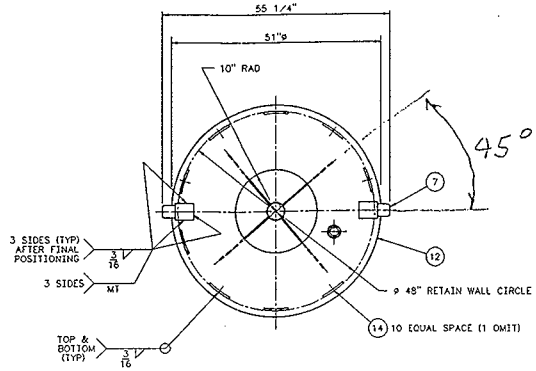

AY FARM DISTRIBUTOR ANALYSIS

W320 TANK 241-C-106 SLUICING ER4319

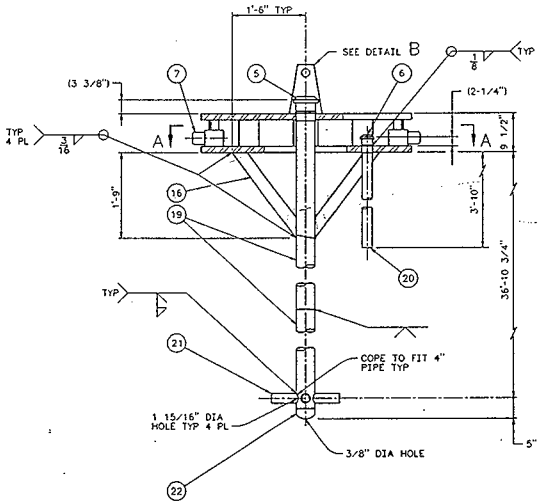


| QTY REQD | PART/DASH NUMBER | NOMENCLATURE/DESCRIPTION | MATERIAL/REFERENCE | SHEET | ITEM NO. |
|---|---|---|---|---|---|
| | -010 | ASSEMBLY | | | 1 |
| | | | | | 2 |
| | | | | | 3 |
| | | | | | 4 |
| 1 | H-2-90187-3 | NOZZLE, MALE CONN 4" SCHED 80 | | | 5 |
| 1 | H-2-90185-2 | NOZZLE, MALE CONN 2" | | | 6 |
| 2 | H-2-64426-1 | TRUNNION | | | 7 |
| 1 | H-2-90161-5 | LIFTING BAIL | | | 8 |
| | | | | | 9 |
| | | | | | 10 |
| | | | | | 11 |
| AR | | PL 1 1/2" | ASTM A 36 | | 12 |
| AR | | PL 1/2" | ASTM A 36 | | 13 |
| 9 | | PL 1/2" x 6" x 6 1/2" | ASTM A 36 | | 14 |
| 2 | | BAR ø2" x 5" LG | ASTM A 36 | | 15 |
| AR | | BAR 3" x 3/8" | ASTM A 276 304L | | 16 |
| | | | | | 17 |
| | | | | | 18 |
| AR | | PIPE, 4" SCHED 80S | ASTM A 312 GR TP 304L | | 19 |
| AR | | PIPE, 2" SCHED 40S | ASTM A 312 GR TP 304L | | 20 |
| 4 | | PIPE, 2" SCHED 80S x 6" LG | ASTM A 312 GR TP 304L | | 21 |
| 1 | | CAP, 4" SCHED 80 BW | ASTM A 403 WP-S 304L | | 22 |

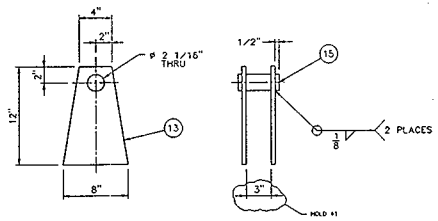



SECTION A-A
SCALE: 1 1/2"= 1'-0




1 FLANGE ASSEMBLY
SCALE: 1"= 1'-0"
(FOR TRUE ORIENTATION SEE PLAN)




DETAIL B
SCALE: 3"= 1'-0

NOTES:

1. FOR GENERAL NOTES, LEGEND AND KEY PLAN, SEE DWG H-2-818518
2. ASSEMBLY, WELDING, PROTECTIVE COATING AND PAINTING SHALL BE CONFORMANCE WITH SPEC W-320-C3.
3. PAINT 2" HIGH BLACK LETTERS ON YELLOW BACKGROUND.
4. DIMENSIONS ARE IN INCHES. TOLERANCE ARE AS FOLLOW UNLESS OTHERWISE NOTED:
   FRACTIONAL ±1/8" DECIMALS ±.06" ANGLES ±2°

C.D. JONES, PE

| | | | |
|---|---|---|---|
| DESIGNER Ba MEYER sr | SAFETY CLASS 3 | USE PRELIMINARY | |
| U.S. DEPARTMENT OF ENERGY<br>RICHLAND OPERATIONS OFFICE<br>ICP KAISER HANFORD COMPANY | | | |
| SAFETY SEE DR/AT FORM | PIPING<br>DISTRIBUTOR ASSEMBLY<br>02A-R6-(A)-(B) | | |
| CHKR SEE DR/AT FORM | | | |
| SYSTEM NO. 3 | PROJECT W320, TANK 241-C-106 SLUICING | | |
| SCALE SHOWN | JOB NO. ER4319 | SHEET 1 OF 1 | REV. NO. 0 |
| F | 241-AY | 8405 | H-2-818537 |

| NUMBER | TITLE |
|---|---|
| H-2-818433 | DRAWING LIST |

| REV NO. | DESCRIPTION | REV BY & DATE | REV APPROVALS |
|---|---|---|---|
| 3 | | | |

CAD FILE B818537A CAD CODE 2B:IBM:ACD2:12.0:NN SHEET N FOR WHC DATE

HNF-2474, Rev. 0
Page C-40

112501 27100

PLOT SCALE: 1=12 KEHCAD

W320-27-019

Winch Analysis -Slurry/Sluice Pump

| ICF KAISER HANFORD COMPANY | CALCULATION IDENTIFICATION AND INDEX | Page i of ii<br>Date 9 / 8 /95 |
|---|---|---|

This sheet shows the status and description of the attached Design Analysis sheets.

Discipline 27,Piping and Vessels WO/Job No. ER4319 Calculation No. W320-27-019

Project No. & Name Project W-320 Waste Retrieval for Tank 241-C-106

Calculation Item WINCH ANALYSIS - Slurry/Sluice Pump

These calculations apply to:

Dwg. No. H-2-818442, -443, -444, -494, -495, -496, Rev. No. 0

Dwg. No. -497, -498, -499 Rev. No. 0

Other (Study, CDR) Rev. No.

The status of these calculations is:

- ☐ Preliminary Calculations
- ☒ Final Calculations
- ☐ Check Calculations (On Calculation Dated )
- ☐ Void Calculation (Reason Voided )

Incorporated in Final Drawings? ☒ Yes ☐ No

This calculation verified by independent "check" calculation? ☐ Yes ☒ No

Original and Revised Calculation Approvals:

| | Rev. 0 Signature / Date | Rev. 1 Signature / Date | Rev. 2 Signature / Date |
|---|---|---|---|
| Originator | D. L. Stone 9/8/95 | | |
| Checked by | Michael L. Cooley 9/8/95 | | |
| Approved by | CD Jones 9/8/95 [redacted] | | |
| Checked Against Approved Vendor Data | R. Ahmed 4.10.98 | | |

INDEX

| Design Analysis Page No. | Description |
|---|---|
| i | Calculation Identification and Index |
| ii | Calculation Cross Index |
| 1 | Objective, Design Criteria ,Design Inputs and Assumptions |
| 2-3 | References |
| 4- 78 | Calculations and Conclusion |
| Appendix | Supporting Documentation |

INDX-W.XLS

# CALCULATION CROSS INDEX (Typical)

Subject Calculation No. W320-27-~~028~~ 019



| Subject Calculation Revision No. | Superceded by Calculation No. | These interfacing calculation/documents provide input to the subject calculation, and if revised may require revision of the subject calculation. | | Results and conclusions of the subject calculation are used in these interfacing calculations and/or documents. | | Does the output interface calculation/ documents require revision? | | Has the output interface calculation/ documents been revised? | | Discipline manager's signature and date indicating evaluation complete. |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Calcualtion/Document No. | Revision. No. | Calcualtion/Document No. | Revision. No. | Yes | No | Yes | No | |
| 0 | NA | Calc.# W320-27-016 | 0 | NA | | | X | | X | D.L. Evans 7/17/98 |
| 0 | NA | Calc.# W320-27-028 | 0 | NA | | | X | | X | D.L. Evans 7/19/98 |
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KEH 1975.00 (12/88)

**DESIGN ANALYSIS**

| | | | | | |
|---|---|---|---|---|---|
| Client | WESTINGHOUSE HANFORD COMPANY | WO/Job No. | ER4319 | Filename | WIN-01.mcd |
| Subject | WINCH ANALYSIS - SLURRY/SLUICE PUMP | Date | 9 / 8 / 95 | By | D.L. Stoll |
| | PROJECT W-320 WASTE RETRIEVAL for TANK 241-C-106 | Checked | 9/8/95 | By | M.R. Coster MRC |
| Location | C TANK FARM - HANFORD 200 EAST AREA | Revised | | By | |

## OBJECTIVES:

The objective of this calculation is to provide a detailed design for a winch, to raise and lower submersible pumps inside tanks 241-C-106 and 241-AY-102. The pumps will transfer the contents of Tank 241-C-106 to Tank 241-AY-102, and provide supernate to the sluicing process.

## DESIGN CRITERIA:

1. Project W320, Tank 241-C-106 Sluicing, Functional Design Criteria (WSC document No. WHC-SD-W320-FDC-001, Rev. 0 ).
2. SDC 4.1, Rev. 11, Design Loads For Facilities.
3. DOE-RL-92-36, *Hanford Site Hoisting and Rigging Manual* , Section 9.2.3.2, January 15, 1993
4. Project 93L-EWW-320, Tank 241-C-106, Letter of Instruction, Addendum 14

## DESIGN INPUTS:

### Design Methodology :

| | |
|---|---|
| Seismic analysis was performed according to SDC 4.1, Rev. 11, Design Loads For Facilities. | (Ref. 2) |
| Standard engineering methods were used to determine Shear, Tensile, Bearing and Bending stresses. | |
| Weld analysis uses Blodgetts's method for analysis of a weld as a line | (Ref. 9) |
| Moment Distribution Method for Indeterminent Beams is used to determine reaction forces on Axle 12. | (Ref. 13) |
| Shaft design methods include torsion analysis for shafts of varying diameters, and minimum shaft diameter equation. | (Ref. 14)<br>(Ref. 8) |
| Bearing loads were determined using Equivalent Load equations provided in bearing vendor catalogs. | (Ref. 26 & 27) |
| Stress on Reel Hub is determined by standard beam analysis and correction for a curved beam. | (Ref. 8) |
| Gear Strength is determined using the AGMA Strength Formula and Lewis Beam Strength Formula. | (Ref. 12) |

### Data:

Safety factor will be 3 to 1, ($SF_y = 3$), against Yield Strength ,
or 5 to 1, ($SF_u = 5$) against Ultimate Strength. Ref. 3

### Assumptions:

1. Pit and winch are both rigid structures and are rigidly connected.
2. Hose/Pipe connection at plate is assumed as a hinged joint and that the pipe will be allowed to deflect with movement of the pump and assemblies.
3. Pump and motor weight = 3000 lbs. (Ref. 23 & 24)

**DESIGN ANALYSIS**

| | | | | | |
|---|---|---|---|---|---|
| Client | WESTINGHOUSE HANFORD COMPANY | WO/Job No. | ER4319 | Filename | WIN-02.mcd |
| Subject | WINCH ANALYSIS - SLURRY/SLUICE PUMP | Date | 9 / 8 / 95 | By | D.L. STONE |
| | PROJECT W-320 WASTE RETRIEVAL for TANK 241-C-106 | Checked | 9/8/95 | By | M.R. CUSTER MRC |
| Location | C TANK FARM - HANFORD 200 EAST AREA | Revised | | By | |

**References :**

1. Project W320, Tank 241-C-106 Slucing, Functional Design Criteria (WSC document No. WHC-SD-W320-FDC-001, Rev. 2 ).
2. SDC 4.1, Rev. 12, Design Loads For Facilities.
3. NUREG-0800, U.S. Nuclear Regulatory Commission Standard Review Plan, Section 3.7.2, Rev.2 (8/89)
4. DOE-RL-92-36, *Hanford Site Hoisting and Rigging Manual* , Section 9.2.3.2, January 15, 1993
5. ANSI B16.9
6. ANSI B16.5
7. Steel Construction Manual, Ninth edition.
8. Machinery's Handbook, 24th edition
9. Design of Welded Structures, Homer Blodgett.
10. Formulas for Stress and Strain, R.J. Roark and W.C. Young, Edition 5
11. Machine Design, Shigley & Miscke, Edition 5, 1989
12. Machine Design, Shigley & Miscke, Edition 1
13. Structural Analysis, Jack. C McCormac, 4th Edition, 1984
14. Mechanics and Materials, I.J. Levinson, 2nd Edition.
15. Crane Technical Paper No. 410, *Flow of Fluids Through Pipes, Fittings and Valves, 25th Printing*
16. Joseph T. Ryerson, Inc., *Stock List and Data Book*, 1994
17. T-M Swivel Joint Catalog.
18. Gates Hose Catalog, No.39496-000, Dated 3/30/92
19. Catalog sheets by Fax from American Hose & Fitting Co., 7/6/95
20. Boston Gear Catalog, 1995.
21. Associated Spring Catalog
22. Mc White Wire Rope Catalog, 4th Edition, 1991
23. Lawrence Pump information sheets, dated June 6, 1995.
24. Reliance Motor information sheets, dated June 6, 1995.
25. Crucible Materials Corporation, *ARMCO Product Data Bulletin No. S-45*
26. Timkin Bearing Selection Handbook for Tapered Roller Bearings, Revised 1986
27. Torrington Bearing Catalog Form # 100-889-50M, 1st Edition, Second Printing
28. Journal Entry, June 6, 1995. Teleconference with Torrington Bearing Co.
29. *Mathcad , Version 4.0*, by MathSoft, Inc.
30. *Excel , Version 4.0*, by Microsoft.
31. *Autocad* , Release 12 , Autodesk, inc, 1993, Inc.
32. Calculation #W320-27-016 Stress Analysis for W-320 C-Farm Jumpers

33.0. Project W320 Drawing No. H-2-818442, Rev. 0

33.1. Project W320 Drawing No. H-2-818443, Rev. 0

33.2. Project W320 Drawing No. H-2-818444, Rev. 0

33.3. Project W320 Drawing No. H-2-818494, Rev. 0

33.4. Project W320 Drawing No. H-2-818495, Rev. 0

33.5. Project W320 Drawing No. H-2-818496, Rev. 0

33.6. Project W320 Drawing No. H-2-818497, Rev. 0

33.7. Project W320 Drawing No. H-2-818498, Rev. 0

33.8. Project W320 Drawing No. H-2-818499, Rev. 0

**DESIGN ANALYSIS**

| | | | | | |
|---|---|---|---|---|---|
| Client | WESTINGHOUSE HANFORD COMPANY | WO/Job No. | ER4319 | Filename | WIN-01.mcd |
| Subject | WINCH ANALYSIS - SLURRY/SLUICE PUMP | Date | 9 / 8 / 95 | By | J. C. Stone |
| | PROJECT W-320 WASTE RETRIEVAL for TANK 241-C-106 | Checked | 9/8/95 | By | H. R. Coster, PE |
| Location | C TANK FARM - HANFORD 200 EAST AREA | Revised | | By | |

## CALCULATIONS:

Page:

5 - 8 Seismic Evaluation

9 - 20 Analysis of Pump and Sheave Assembly Components

21 - 25 Analysis of Retrieval Cable Assembly

26 - 40 Axle 12 - Component Design

41 - 46 Design of Reel Hub

47 - 50 Gear Analysis

51 - 54 Axle 11 - Component Design

55 - 60 Axle 15 - Component Design

61 - 62 Analysis of Winch Housing Stresses

63 - 67 Upper Driveshaft Analysis

68 - 70 Guide Idler Component Analysis

71 - 75 Plate Stress and Bolt Analysis

76 - 78 Analysis of Lifting Brackets

## CONCLUSIONS:

The results of this analysis indicate that the components of of the Winch Assembly meet, exceed or fall within acceptable limits of the Safety Factor requirements set forth in DOE-RL-92-36, *Hanford Site Hoisting and Rigging Manual* , Section 9.2.3.2, January 15, 1993.

## Seismic Analysis of Winch and Pump Assembly to Safety Class 1 Criteria

The winch / pump assembly is classified as Safety Class 3 per the Functional Design Criteria for the project. Based on the SDC 4.1, Rev. 11, the design for the winch / pump assembly is required to be analyzed to Safety Class 1 criteria, due to the potential structural failure and impact of the winch/ pump assembly on the Safety Class 1 structure (the tank structure). Safety Class 1 design requires a dynamic analysis to be performed using the response spectra per SDC 4.1, Rev.11 (Figure 3) as the seismic input for the design. Conservatively, an equivalent static load method is used in the evaluation since the winch may be represented by a single model configuration. A factor of 1.5 is applied to the peak acceleration of the appropriate response spectrum per SDC 4.1, Rev.11.

The upper, winch structure is rigidly attached to the top of the base slab of the pump pit in both horizontal directions. The pump pit is considered a rigid structure, therefore, the ground acceleration is used as the seismic input.

The lower winch structure consists of a cable and sheave assembly suspending the process pump and includes the associated hose and connections. The configuration of the lower structure, therefore can be represented as a single mass suspended by a flexible cable, subjected to seismic loading.

The primary concern for the tank structure is the potential impact of the pump with the tank wall. The maximum displacement of the pump will be evaluated based on the seismic input and a comparison made as to the proximity of the pump relative to the tank wall.

The remaining concern is the structural adequacy of the winch plate, which supports the winch/ pump assembly, spanning the penetration opening in the tank. The magnitude of the vertical, seismic response required to be used is defined in SDC 4.1, Rev. 11, as 2/3 of the peak, horizontal response.

**Seismic Components**: (Assume 2 % damping, conservative) (Ref. 4, Section 3.7.2, II - 1.b)

$g := 386.4 \cdot \frac{in}{sec^2}$ Acceleration of gravity (Ref. 2, Table 7)

$LF := 1.5$ Load Factor

$ag := 0.2 \cdot g$ Peak Horizontal Free-field Ground Acceleration (Ref. 4, Section 3.7.2, II - 1.b.iii) (Ref. 2, Fig.3)

$A := 2.74$ Acceleration Amplifcation at 2% damping (Ref. 2, Table 7, 2 % Damping)

$a_{maxh} := ag \cdot A \cdot 1.5$ $a_{maxh} = 317.621 \cdot \frac{in}{sec^2} = 0.822 \cdot g$ Horizontal seismic component

$a_{maxv} := \left(\frac{2}{3}\right) \cdot a_{maxh}$ $a_{maxv} = 211.747 \cdot \frac{in}{sec^2} = 0.548 \cdot g$ Vertical seismic component (Ref. 2, B.3.3 )

**Potential Impact of the Pump with the Tank Wall**

The primary concern to be addressed in this evaluation is the potential interaction of the pump with the tank wall, due to pendulum action of the pump/ cable system.

Determine the maximum, horizontal displacement of the pump relative to the tank wall:

| | | | |
|---|---|---|---|
| $L := 26 \cdot ft$ | $L = 312 \cdot in$ | (Maximum "L" USED, conservative) | |
| $f := \left(\frac{1}{2 \cdot \pi}\right) \cdot \sqrt{\frac{g}{L}}$ | $f = 0.177 \cdot time^{-1}$ | Natural Frequency | |
| $T := \frac{1}{f}$ | $T = 5.646 \cdot sec$ | Natural Period | |
| $d := 13 \cdot in$ | | Displacement | Ref. 2, Fig.3 |
| $D := 1.63$ | | Spectrum Amplification Factor at 2% damping | Ref. 2, Table 7 |
| $d_{SDC4.1} := D \cdot d$ | $d_{SDC4.1} = 21.19 \cdot in$ | Based on engineering judgement, displacement of 21" is considered to be negligible. | |

**Hose / Pipe Assembly**

| | | | |
|---|---|---|---|
| $SG := 1.2$ | | Specific Gravity of Process Fluid | Ref. 1 |
| $\rho_w := 62.41 \cdot \frac{lbf}{ft^3}$ | | Density of water at Minimum Operating Temperature | Ref. 15, Pg. A6 |
| $\rho := SG \cdot \rho_w$ | $\rho = 74.892 \cdot \frac{lbf}{ft^3}$ | Density of Process Fluid at Minimum Operating Temperature | |
| $W_f := 7.5 \cdot \frac{lbf}{ft}$ | | Weight per foot of hose. | Ref. F, Pg. 69 |
| $L_{hose} := (9.8 + 10.8) \cdot ft$ | | Combined length of hoses | |
| $R_h := 2 \cdot in$ | | Inner Radius of hose. | Ref. 18, Pg. 69 |
| $W_{hose} := W_f L_{hose}$ | $W_{hose} = 154.5 \cdot lbf$ | Weight of 4" hose. | Ref. 33.2, Sh.2 |
| $V_h := \pi \cdot R_h^2 \cdot L_{hose}$ | $V_h = 1.798 \cdot ft^3$ | Volume of hose. | |
| $Hose_{contents} := V_h \cdot \rho$ | $Hose_{contents} = 134.633 \cdot lbf$ | Weight of Process Fluid fluid in combined length of hose. | |

**DESIGN ANALYSIS**

| | | | | | |
|---|---|---|---|---|---|
| Client | WESTINGHOUSE HANFORD COMPANY | WO/Job No. | ER4319 | Filename | WIN-03.mcd |
| Subject | WINCH ANALYSIS - SLURRY/SLUICE PUMP | Date | 9 / 8 / 95 | By | D.L. STONE |
| | PROJECT W-320 WASTE RETRIEVAL for TANK 241-C-106 | Checked | 9/8/95 | By | M.R. CUSTER MRC |
| Location | C TANK FARM - HANFORD 200 EAST AREA | Revised | | By | |

**Hose / Pipe Assembly (continued....)**

$W_p := 10.79 \cdot \frac{lbf}{ft}$ — Weight per foot of pipe. Ref. 15

$pipe_L := 114 \cdot in$ — Pipe Length

$W_{pipe} := W_p \cdot pipe_L$ $\quad W_{pipe} = 102.505 \cdot lbf$ — Weight of 93.8" of 4" pipe.

$R_p := 2.013 \cdot in$ — Inner Radius of pipe.

$V_p := \pi \cdot R_p^2 \cdot pipe_L$ $\quad V_p = 0.84 \cdot ft^3$ — Volume of pipe.

$Pipe_{contents} := V_p \cdot \rho$ $\quad Pipe_{contents} = 62.898 \cdot lbf$ — Weight of Process Fluid fluid in pipe.

$Coupling := 4 \cdot (27 \cdot lbf)$ — Est. Weight of 4 Hose Couplings Ref. 19, Pg. 399

$Swivel_{joint} := 36 \cdot lbf + 2 \cdot (72 \cdot lbf)$ — Weight of 1, 3" and 2, 4" swivel joints Ref. 17, Pg. 11

$pipe_{CG} := \frac{pipe_L}{2}$ $\quad pipe_{CG} = 57 \cdot in$ — Center of Gravity of Pipe

$$Mass_{pipe} := \frac{W_{pipe} + Pipe_{contents}}{g}$$

$Mass_{pipe} = 165.269 \cdot lb$ — Mass of the Pipe

$$Mass_{hose} := \frac{W_{hose} + Hose_{contents} + Coupling + Swivel_{joint}}{g}$$

$Mass_{hose} = 576.668 \cdot lb$ — Mass of the Hose

$F_{pipeH} := Mass_{pipe} \cdot a_{maxh}$ $\quad F_{pipeH} = 135.961 \cdot lbf$ — Horizontal Seismic Force due to Pipe

$F_{hoseH} := Mass_{hose} \cdot a_{maxh}$ $\quad F_{hoseH} = 474.403 \cdot lbf$ — Horizontal Seismic Force due to Hose Assembly

$F_V := (Mass_{pipe} + 2 \cdot Mass_{hose}) \cdot (g + a_{maxv})$ $\quad F_V = 2.043 \cdot 10^3 \cdot lbf$ — Vertical Seismic Force due to Pipe/Hose Assembly

$M := (F_{pipeH}) \cdot (pipe_{CG}) + (F_{hoseH}) \cdot (pipe_L)$ $\quad M = 6.183 \cdot 10^4 \cdot lbf \cdot in$ — Moment due to Pipe/Hose Assembly

**DESIGN ANALYSIS**

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**Stress at Pipe Connection to Winch Plate**

*Shear Stress due to Horizontal Seismic Force*

$A := 3.174 \cdot in^2$ — Area of Shear plane (Metal Area of pipe)

$S_y := 30000 \cdot \frac{lbf}{in^2}$ — Yield strength of Schedule 40S, ASTM A-312 Gr Tp 304 Pipe

$S_{all} := (0.40) \cdot S_y$ $\quad S_{all} = 1.2 \cdot 10^4 \cdot \frac{lbf}{in^2}$ — Allowable Shear Stress — Ref. 7, Part 5, Chap. D.3.1

$S_{act} := \frac{F_{pipeH} + F_{hoseH}}{A}$ $\quad S_{act} = 192.301 \cdot \frac{lbf}{in^2}$ — Calculated stress on pipe.

$SF := \frac{S_{all}}{S_{act}}$ $\quad SF = 62.402$ — Safety factor > 3 OK

*Tensile Stress due to Vertical Seismic Force*

$T_{all} := (0.45) \cdot S_y$ $\quad T_{all} = 1.35 \cdot 10^4 \cdot \frac{lbf}{in^2}$ — Allowable Stress in Tension — Ref. 11, Page 12

$T_{act} := \frac{F_V}{A}$ $\quad T_{act} = 643.619 \cdot psi$ — Calculated Tensile Stress on Pipe resulting from Bending Moment at Plate

$\frac{T_{all}}{T_{act}} = 20.975$ — Safety factor > 3 OK — See Assumptions, #2

**DESIGN ANALYSIS**

| | | | | | |
|---|---|---|---|---|---|
| Client | WESTINGHOUSE HANFORD COMPANY | WO/Job No. | ER4319 | Filename | WIN-04.mcd |
| Subject | WINCH ANALYSIS - SLURRY/SLUICE PUMP | Date | 9 / 8 / 95 | By | D.L. STONE |
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| Location | C TANK FARM -- HANFORD 200 EAST AREA | Revised | | By | |

**WEIGHT of PUMP ASSEMBLY (Supported by the Sheave Assembly)**

*(Most conservative configuraiton considered as the pump in the fully elevated position.)* Ref. 33.4

*Weight of Pump* Ref. 33.6, Sh. 1&2

$W_{pump} := 3000 \cdot lbf$ Weight of pump. Ref. 23

*Weight of Hose and Contents* Ref. 33.2

$W_{hose} := 81 \cdot lbf$ Weight of 10.8' of 4" hose.

$W_{contents} := 70.584 \cdot lbf$ Weight of Process Fluid fluid in 8 feet of hose.

*Weight of pipe fittings (on pump discharge).*

| | | | |
|---|---|---|---|
| $W_C := 2 \cdot (27 \cdot lbf)$ | Weight of Hose Couplings | Ref. 33.0, Sh. 1, Item 1 | Ref. 19 |
| $Flange3 := 13 \cdot lbf$ | 3", 300 lb, slip on flange | Ref. 33.4, Sh. 1, Item 27 | Ref. 6 |
| $E_{90} := 4.58 \cdot lbf$ | 3" elbow (90) | Ref. 33.4, Sh. 1, Item 24 | Ref. 5 |
| $SJ_3 := 37 \cdot lbf$ | 3" swivel joint | Ref. 33.4, Sh. 1, Item 11 | Ref. 17, Pg. 11 |
| $SJ_4 := 1.5 \cdot (72 \cdot lbf)$ | 1-1/2 4" swivel joints | Ref. 33.4, Sh. 1, Item 12 | Ref. 17, Pg. 11 |
| $Reducer := 3.5 \cdot lbf$ | 3 x 4 Standard Reducer | Ref. 33.4, Sh. 1, Item 26 | Ref. 5 |
| $Pipe_3 := 7.58 \cdot \frac{lbf}{ft}$ | Attached 3 inch pipe | Ref. 33.4, Sh. 1, Item 30 | Ref. 15, Pg. B-16 |
| $Pipe_4 := 10.79 \cdot \frac{lbf}{ft}$ | Attached 4 inch pipe | Ref. 33.4, Sh. 1, Item 29 | Ref. 15, Pg. B-17 |
| $L_{pipe} := 2.25 \cdot in$ | Length of attached pipes (typ) | | |

$RE_{3x4} := L_{pipe} \cdot (Pipe_3 + Pipe_4) + Reducer$ $RE_{3x4} = 6.944 \cdot lbf$

$W_{fj} := Flange3 + E_{90} + SJ_3 + SJ_4 + RE_{3x4}$ $W_{fj} = 169.524 \cdot lbf$ Combined Weight of fittings and joints

*Total Weight of Pump Assembly :*

$W_P := W_{pump} + W_{hose} + W_{contents} + W_{fj} + W_C$ $W_P = 3.375 \cdot 10^3 \cdot lbf$ Pump Assembly

$W_{PA} := 1.2 \cdot W_P$ $W_{PA} = 4.05 \cdot 10^3 \cdot lbf$ Impact Loading Considered
Ref. 7, Pg. 5-29, Section A4.2

DESIGN ANALYSIS

| | | | | | |
|---|---|---|---|---|---|
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| Subject | WINCH ANALYSIS - SLURRY/SLUICE PUMP | Date | 9 / 8 / 95 | By | D.L. STONE |
| | PROJECT W-320 WASTE RETRIEVAL for TANK 241-C-106 | Checked | 9/8/95 | By | M.R. CUSTER MRC |
| Location | C TANK FARM - HANFORD 200 EAST AREA | Revised | | By | |

## CHECK of PUMP / WINCH SUPPORT SYSTEM COMPONENTS

### *3/4" Diam. Pump Support BOLTS*

Ref. 33.4, Pg. 1, Item 33

*(Assume A307 structural bolts, worst case.)*

$n_b := 8$ — Number of bolts used

$A_{blt} := 0.442 \cdot in^2$ — Cross sectional area of bolt

$F_v := 10000 \cdot \frac{lbf}{in^2}$ — Allowable shear strength of bolts — Ref. 7, Pg 4-5, Table I-D

$S_{act} := \frac{\frac{(W_{PA} - W_{pump})}{n_b}}{A_{blt}}$ $\quad S_{act} = 296.982 \cdot \frac{lbf}{in^2}$ — Calculated shear stress

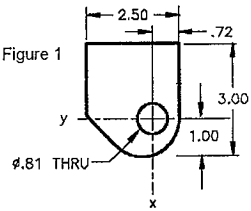
$SF := \frac{F_v}{S_{act}}$ $\quad SF = 33.672$ — Safety factor > 5 — OK

### *Pump Support Brackets welded to the 3"x3" square tube plates.*

Ref. 33.6, Sh. 2, Detail A.

$w := \left[\left(1 - \frac{0.81}{2}\right) \cdot in\right]$ $\quad w = 0.595 \cdot in$ — Width of Shear plane.

Figure 1




$th := \left(\frac{3}{8}\right) \cdot in$ $\quad th = 0.375 \cdot in$ — Plate thickness

$AR_b := 4 \cdot w \cdot th$ $\quad AR_b = 0.892 \cdot in^2$ — Area of brackets loaded by the bolt.

$S_y := 25000 \cdot \frac{lbf}{in^2}$ — Yield strength of ASTM A240 Type 304L

$S_{all} := (0.45) \cdot S_y$ $\quad S_{all} = 1.125 \cdot 10^4 \cdot \frac{lbf}{in^2}$ — Allowable Stress — Ref.7, Pg 5, Chap. D.3.1

$S_{act} := \frac{W_{PA}}{AR_b}$ $\quad S_{act} = 4.538 \cdot 10^3 \cdot \frac{lbf}{in^2}$ — Calculated stress on brackets.

$SF := \frac{S_y}{S_{act}}$ $\quad SF = 5.509$ — Safety factor > 3 — OK

**DESIGN ANALYSIS**

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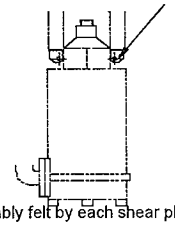
***Sizing of Bolts connecting Pump to Sheave Assembly Brackets*** Ref. 33.6, Pg 2



Shear stress

$D := \left(0.81 - \frac{1}{16}\right) \cdot in$ Bolt Diameter

$A_a := \frac{\pi \cdot D^2}{4}$ $A_a = 0.439 \cdot in^2$ Cross Sectional Area

$F_{bolt} := \left(\frac{W_{PA}}{4}\right)$ $F_{bolt} = 1.013 \cdot 10^3 \cdot lbf$ Force of Pump Assembly felt by each shear plane.

$S_{act} := \frac{F_{bolt}}{A_a}$ $S_{act} = 2.307 \cdot 10^3 \cdot \frac{lbf}{in^2}$ Calculated Shear Stress per Bolt.

$S_y := 100000 \cdot \frac{lbf}{in^2}$ Yield strength for ASTM A 193, Class 2, B8T

$S_{all} := 0.22 \cdot S_y$ $S_{all} = 2.2 \cdot 10^4 \cdot \frac{lbf}{in^2}$ Allowable Shear Stress Ref. 7, Pg. 4.5

$SF_S := \frac{S_{all}}{S_{act}}$ $SF_S = 9.535$ Safety factor > 3 OK

## DESIGN ANALYSIS

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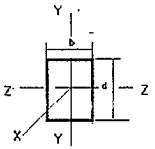
| Location | C TANK FARM - HANFORD 200 EAST AREA | Revised | | By | |

***Welds connecting pump support brackets to the 3" x 3" plate.*** Ref. 33.6, Sh. 2, Detail A.

$Fx := \frac{W_{PA}}{4}$ Weld Tensile Load
*("x" direction on subroutine sketch, below)*

$M_{arm} := \left(\frac{2.50}{2} - 0.72\right) \cdot in$ Moment arm (Moment about Z )
(distance from weld centerline to load application point)

**WELD PROPERTIES:**




$b := 0.375 \cdot in$ Weld Outline Dimension - short side Ref. 9, Pg. 7.4 6 &7

$d := 2.5 \cdot in$ Weld Outline Dimension - long side

$Cy := \frac{b}{2}$ $Cy = 0.188 \cdot in$ Location of center of gravity with respect to y axis.

$Cz := \frac{d}{2}$ $Cz = 1.25 \cdot in$ Location of center of gravity with respect to z axis.

$Aw := 2 \cdot (b + d)$ $Aw = 5.75 \cdot in$ Weld length (1 Bracket)

$Swy := b \cdot d + \frac{b^2}{3}$ $Swy = 0.984 \cdot in^2$ Section modulus about y axis

$Swz := b \cdot d + \frac{d^2}{3}$ $Swz = 3.021 \cdot in^2$ Section modulus about z axis

$Jw := \frac{(b + d)^3}{6}$ $Jw = 3.961 \cdot in^3$ Polar Moment of Inertia

**JOINT LOADS:**

| | | | |
|---|---|---|---|
| Tensile | $Fx = 1.013 \cdot 10^3 \cdot lbf$ | $Fy := 0 \cdot lbf$ | $Fz := 0 \cdot lbf$ |
| Moment | $Mx := 0 \cdot in \cdot lbf$ | $My := 0 \cdot in \cdot lbf$ | $Mz := (Fx \cdot M_{arm})$ |

**WELD STRESS:**

$$fw := \left[\left(\frac{Fx}{Aw} + \frac{My}{Swy} + \frac{Mz}{Swz}\right)^2 + \left(\frac{Fy}{Aw} + \frac{Mx \cdot Cy}{Jw}\right)^2 + \left(\frac{Fz}{Aw} + \frac{Mx \cdot Cz}{Jw}\right)^2\right]^{0.5} \qquad fw = 353.74 \cdot \frac{lbf}{in}$$

**FILLET WELD SIZE REQUIRED:**

$S := 15800 \cdot psi$ Allowable Weld Stress per AWS & AISC Ref. 9, Pg. 7.4-8

$w := \frac{fw}{0.707 \cdot S}$ $w = 0.032 \cdot in$ Minimum Allowable Fillet Weld Required by Design

$w_{Code} := \left(\frac{3}{16} \cdot in\right)$ Minimum Size Fillet Weld Required by Code for material thickness of 3/8". Ref. 7, Part 5, Section J.2.2, Table J2.4

$w_{act} := \left(\frac{1}{4} \cdot in\right)$ Weld size specified in design drawings. Ref. 33.6, Pg. 2

$SF_{fw} := \frac{w_{act}}{w}$ $SF_{fw} = 7.895$ Safety factor based on a 1/4" weld > 3 *OK*

## DESIGN ANALYSIS

| | | | | | |
|---|---|---|---|---|---|
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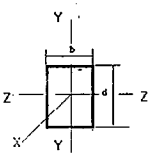
**Weld on the two 3" x 3" x 3/8" plates attached to the 3" square tubes.**

$Fx := \frac{W_{PA}}{2}$ Weld Tensile Load *(In "x" direction on subroutine sketch, below)* Ref. 33.6, Sh. 1&2, Item 17

$M_{arm} := \left(\frac{2.50}{2} - 0.72\right) \cdot in$ Moment arm (Moment about Z imposed by eccentric bracket loading.

Ref. 9, Pg. 7.4 6 &7

**WELD PROPERTIES:**




$b := 3 \cdot in$ Weld Outline Dimension - short side

$d := 3 \cdot in$ Weld Outline Dimension - long side

$Cy := \frac{b}{2}$ $Cy = 1.5 \cdot in$ Location of center of gravity with respect to y axis.

$Cz := \frac{d}{2}$ $Cz = 1.5 \cdot in$ Location of center of gravity with respect to z axis.

$Aw := 2 \cdot (b + d)$ $Aw = 12 \cdot in$ Weld length (1 Tube)

$Swy := b \cdot d + \frac{b^2}{3}$ $Swy = 12 \cdot in^2$ Section modulus about y axis

$Swz := b \cdot d + \frac{d^2}{3}$ $Swz = 12 \cdot in^2$ Section modulus about z axis

$Jw := \frac{(b + d)^3}{6}$ $Jw = 36 \cdot in^3$ Polar Moment of Inertia

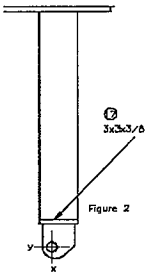


Figure 2

**JOINT LOADS:**

| | | | |
|---|---|---|---|
| Tensile | $Fx = 2.025 \cdot 10^3 \cdot lbf$ | $Fy := 0 \cdot lbf$ | $Fz := 0 \cdot lbf$ |
| Moment | $Mx := 0 \cdot in \cdot lbf$ | $My := 0 \cdot in \cdot lbf$ | $Mz := (Fx \cdot M_{arm})$ |

**WELD STRESS:**

$$fw := \left[\left(\frac{Fx}{Aw} + \frac{My}{Swy} + \frac{Mz}{Swz}\right)^2 + \left(\frac{Fy}{Aw} + \frac{Mx \cdot Cy}{Jw}\right)^2 + \left(\frac{Fz}{Aw} + \frac{Mx \cdot Cz}{Jw}\right)^2\right]^{0.5} \qquad fw = 258.196 \cdot \frac{lbf}{in}$$

**FILLET WELD SIZE REQUIRED:**

$S := 15800 \cdot psi$ Allowable Weld Stress per AWS & AISC Ref. 9, Pg. 7.4-8

$w := \frac{fw}{0.707 \cdot S}$ $w = 0.023 \cdot in$ Minimum Allowable Fillet Weld Required by Design

$w_{Code} := \left(\frac{3}{16} \cdot in\right)$ Minimum Size Fillet Weld Required by Code for material thickness of 3/8". Ref. 7, Part 5, Section J.2.2, Table J2.4

$w_{act} := \left(\frac{5}{16} \cdot in\right)$ Weld size specified in design drawings. Ref. 33.6, Pg. 2

$SF_{fw} := \frac{w_{act}}{w}$ $SF_{fw} = 13.52$ Safety factor based on a 5/16" weld > 3 *OK*

**DESIGN ANALYSIS**

| | | | | | |
|---|---|---|---|---|---|
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**WEIGHT of SHEAVE ASSEMBLY (Supported by Axles)**

$W_{steel} := 490.8 \cdot \frac{lbf}{ft^3}$ (Ref.7, Page 6-8)

Weight of 2 Sheaves

$V_{sheavs} := 4 \cdot \left[ (0.25 \cdot in) \cdot \left[ \frac{\pi \cdot (9.5 \cdot in)^2}{4} - \frac{\pi \cdot (1.508 \cdot in)^2}{4} \right] \right] + 2 \cdot \left[ (2 \cdot in) \cdot \left[ \frac{\pi \cdot (7.25 \cdot in)^2}{4} - \frac{\pi \cdot (1.508 \cdot in)^2}{4} \right] \right]$ Volume

(Ref. 33.6, Item 3)

$W_{sheavs} := (V_{sheavs} \cdot W_{steel})$ $W_{sheavs} = 64.498 \cdot lbf$ Weight

Weight of 2 Square Tubing Support Arms

$w_{tube} := 8.81 \cdot \frac{lbf}{ft}$ Weight of 3 x 3 x 1/4 Square Carbon Steel Tubing : (Ref. 16)

$L_{tube} := 2 \cdot (17.875 \cdot in)$ Total Length of 2 Support Arms (Ref. 33.6, Item 2)

$W_{tube} := L_{tube} \cdot w_{tube}$ $W_{tube} = 26.246 \cdot lbf$ Weight

$w_{psf} := 15.32 \cdot \frac{lbf}{ft^2}$ Weight of 3/8 in. Hot Rolled Carbon Steel plate per square foot: (Ref. 16)

Weight of 4 Support Brackets

$A_{plate} := 4 \cdot \left[ (2.5) \cdot (3) - 1 - \frac{\pi \cdot (0.81)^2}{4} \right] \cdot in^2$ $A_{plate} = 23.939 \cdot in^2$ Area of 4 Brackets (Ref. 33.6, Item A)

$W_{brackets} := A_{plate} \cdot w_{psf}$ $W_{brackets} = 2.547 \cdot lbf$ Weight

Weight of 2, 3 x 3 x 3/8 End Plates (Ref. 33.6, Item 2)

$A_{plate} := 2 \cdot (3 \cdot 3 \cdot in^2)$ $A_{plate} = 18 \cdot in^2$ Area of 2 Plates

$W_{ends} := A_{plate} \cdot w_{psf}$ $W_{ends} = 1.915 \cdot lbf$ Weight

Sheave housing walls (Ref. 33.6, Detail 2

$A_{plate} := 2 \cdot \left[ ((21) \cdot (11)) - (2 \cdot 2) - 2 \cdot \left[ \frac{\pi \cdot (1.505)^2}{4} \right] \right] \cdot in^2$ $A_{plate} = 446.884 \cdot in^2$ Area of Wall Plate

$W_{housing} := A_{plate} \cdot w_{psf}$ $W_{housing} = 47.544 \cdot lbf$ Weight

**DESIGN ANALYSIS**

| | | | | | |
|---|---|---|---|---|---|
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| Location | C TANK FARM - HANFORD 200 EAST AREA | Revised | | By | |

Sheave housing cross brace (Ref. 33.6, Item 2)

$A_{plate} := 2\cdot(((8.625)\cdot(11)) - (3\cdot3) - (4.5\cdot4.5))\cdot in^2$ $A_{plate} = 131.25\cdot in^2$ Area of Cross Brace Plate

$W_{brace} := A_{plate}\cdot w_{psf}$ $W_{brace} = 13.964\cdot lbf$ Weight

Sheave housing Stabilizer Braces (Ref. 33H.6, Item 2)

$A_{plate} := 4\cdot((1.5)\cdot(7))\cdot in^2$ $A_{plate} = 42\cdot in^2$ Area of Bracket Plates

$W_{braces} := A_{plate}\cdot w_{psf}$ $W_{braces} = 4.468\cdot lbf$ Weight

Sheave Assembly Support Bracket

$A_{plate} := \left[\left[\frac{\pi}{2}\cdot(1.5^2) + (3\cdot3)\right] - \frac{\pi}{4}\cdot(1.5^2)\right]\cdot in^2$ $A_{plate} = 10.767\cdot in^2$ Area of Bracket Plates

(Ref. 33.6, Item 2)

$W_{sab} := A_{plate}\cdot w_{psf}$ $W_{sab} = 1.146\cdot lbf$ Weight

Retrieval Cable Bracket (Ref. 33H.6, Item 6)

$$V_{cb} := \left[2\cdot(0.47)\cdot\left[\left[\frac{\pi\cdot(1.25^2)}{2} + (1.25\cdot3)\right] - \frac{\pi}{4}\cdot(0.75^2)\right] + (0.25\cdot1.5\cdot3) + 2\cdot(2\cdot3\cdot0.54)\right]\cdot in^3$$

$V_{cb} = 13.022\cdot in^3$ Metal Volume of Bracket

$w_{240} := 0.284\cdot\frac{lbf}{in^3}$ Weight of ASTM A-240 Tp 304 SST

$W_{cb} := V_{cb}\cdot w_{240}$ $W_{cb} = 3.698\cdot lbf$ Weight

Retrieval Cable

$w_{rope} := 24.3\cdot\frac{lbf}{100\cdot ft}$ Weight per 100 ft of 3/8", 7 x 19 in Strand Core Wire Rope Ref. 33.4, Item 20

$L_{rope} := (638.33 - 608)\cdot ft$ $L_{rope} = 30.33\cdot ft$ Total Length of Wire Rope

$W_{rope} := w_{rope}\cdot L_{rope}$ $W_{rope} = 7.37\cdot lbf$ Weight of 75 ft of Wire Rope Ref. 22

Sheave Assembly Base Plate

$A_{plate} := ((20.5)\cdot(3.5))\cdot in^2$ $A_{plate} = 71.75\cdot in^2$ Area of Plate (Ref. 33.6, Item 2)

$w_{psf} := 20.42\cdot\frac{lbf}{ft^2}$ Weight of 1/2 in. Hot Rolled Carbon Steel plate per square foot: (Ref. 16)

$W_{base} := A_{plate}\cdot w_{psf}$ $W_{base} = 10.175\cdot lbf$ Weight

**DESIGN ANALYSIS**

| | | | | | |
|---|---|---|---|---|---|
| Client | WESTINGHOUSE HANFORD COMPANY | WO/Job No. | ER4319 | Filename | WIN-04.mcd |
| Subject | WINCH ANALYSIS - SLURRY/SLUICE PUMP | Date | 9 / 8 / 95 | By | D.L. STONE |
| | PROJECT W-320 WASTE RETRIEVAL for TANK 241-C-106 | Checked | 9/5/95 | By | M.R. CUSTER MRC |
| Location | C TANK FARM - HANFORD 200 EAST AREA | Revised | | By | |

Weight of Axles

$w_{N60} := \left(6.01 \cdot \frac{lbf}{ft}\right)$ Weight per ft of 1-1/2 Inch Diameter Nitronic 60 Round Stock (Ref. 16)

$L_{axle} := 2 \cdot (5.0 \cdot in)$ Total Length of 2 Axles (Ref. 33.6, Item 2)

$W_{axle} := L_{axle} \cdot w_{N60}$ $W_{axle} = 5.008 \cdot lbf$ Weight

*Total Weight of Sheave Assembly*

$$W_{SA} := W_{sheavs} + W_{tube} + W_{brackets} + W_{ends} + W_{housing} + W_{brace} \cdots + W_{braces} + W_{sab} + W_{cb} + W_{rope} + W_{base} + W_{axle}$$

$W_{SA} = 188.578 \cdot lbf$

## DESIGN ANALYSIS

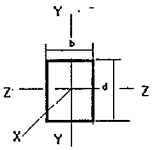
| | | | | | |
|---|---|---|---|---|---|
| Client | WESTINGHOUSE HANFORD COMPANY | WO/Job No. | ER4319 | Filename | WIN-04.mcd |
| Subject | WINCH ANALYSIS - SLURRY/SLUICE PUMP | Date | 9 / 8 / 95 | By | D.L. STONE |
| | PROJECT W-320 WASTE RETRIEVAL for TANK 241-C-106 | Checked | 9/8/95 | By | M.R. CUSTER MRC |
| Location | C TANK FARM - HANFORD 200 EAST AREA | Revised | | By | |

***Weld Strength of the welds attaching the 3"square tube to the Sheave Assembly Baseplate.***

$Fx := \frac{W_{PA} + W_{tube} + W_{brackets} + W_{ends}}{2}$ Weight of Sheave Assembly components below baseplate. Ref. 33.6, Sh. 2.

$M_{arm} := \left(\frac{2.50}{2} - 0.72\right) \cdot in$ Moment arm (Moment about Z imposed by eccentric bracket loading.

**WELD PROPERTIES:**




$b := 3 \cdot in$ Weld Outline Dimension - short side Ref. 9, Pg. 7.4 6 &7

$d := 3 \cdot in$ Weld Outline Dimension - long side

$Cy := \frac{b}{2}$ $Cy = 1.5 \cdot in$ Location of center of gravity with respect to y axis.

$Cz := \frac{d}{2}$ $Cz = 1.5 \cdot in$ Location of center of gravity with respect to z axis.

$Aw := 2 \cdot (b + d)$ $Aw = 12 \cdot in$ Weld length (1 Tube)

$Swy := b \cdot d + \frac{b^2}{3}$ $Swy = 12 \cdot in^2$ Section modulus about y axis

$Swz := b \cdot d + \frac{d^2}{3}$ $Swz = 12 \cdot in^2$ Section modulus about z axis

$Jw := \frac{(b + d)^3}{6}$ $Jw = 36 \cdot in^3$ Polar Moment of Inertia

**JOINT LOADS:**

| | | | |
|---|---|---|---|
| Tensile | $Fx = 2.04 \cdot 10^3 \cdot lbf$ | $Fy := 0 \cdot lbf$ | $Fz := 0 \cdot lbf$ |
| Moment | $Mx := 0 \cdot in \cdot lbf$ | $My := 0 \cdot in \cdot lbf$ | $Mz := (Fx \cdot M_{arm})$ |

**WELD STRESS:**

$$fw := \left[\left(\frac{Fx}{Aw} + \frac{My}{Swy} + \frac{Mz}{Swz}\right)^2 + \left(\frac{Fy}{Aw} + \frac{Mx \cdot Cy}{Jw}\right)^2 + \left(\frac{Fz}{Aw} + \frac{Mx \cdot Cz}{Jw}\right)^2\right]^{0.5} \qquad fw = 260.153 \cdot \frac{lbf}{in}$$

**FILLET WELD SIZE REQUIRED:**

$S := 15800 \cdot psi$ Allowable Weld Stress per AWS & AISC Ref. 9, Pg. 7.4-8

$w := \frac{fw}{0.707 \cdot S}$ $w = 0.023 \cdot in$ Minimum Allowable Fillet Weld Required by Design

$w_{Code} := \left(\frac{3}{16} \cdot in\right)$ Minimum Size Fillet Weld Required by Code for material thickness of 1/2". Ref. 7, Part 5, Section J.2.2, Table J2.4

$SF_{fw} := \frac{w_{Code}}{w}$ $SF_{fw} = 8.051$ Safety factor based on a 3/16" weld > 3 OK

| | | | | | |
|---|---|---|---|---|---|
| Client | WESTINGHOUSE HANFORD COMPANY | WO/Job No. | ER4319 | Filename | WIN-04.mcd |
| Subject | WINCH ANALYSIS - SLURRY/SLUICE PUMP | Date | 9 / 8 / 95 | By | D.L. STONE |
| | PROJECT W-320 WASTE RETRIEVAL for TANK 241-C-106 | Checked | 9/8/95 | By | M.R. CUSTER MRC |
| Location | C TANK FARM - HANFORD 200 EAST AREA | Revised | | By | |

**Stress on sheave axles** — Ref. 33.6, Pg 2, Item 44

Shear stress

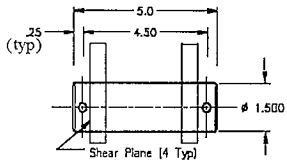


Figure 3

$D := 1.5 \cdot in$ — Axle Diameter

$A_a := \frac{\pi \cdot D^2}{4}$ $\quad A_a = 1.767 \cdot in^2$ — Cross Sectional Area

$F_{axle} := \left[\frac{(W_{SA} - W_{axle}) + W_{PA}}{8}\right]$ $\quad F_{axle} = 529.212 \cdot lbf$ — Force of sheave assembly felt by each shear plane.

$S_{actS} := \frac{F_{axle}}{A_a}$ $\quad S_{actS} = 299.473 \cdot \frac{lbf}{in^2}$ — Calculated Shear Stress at each shear plane.

$S_y := 44400 \cdot \frac{lbf}{in^2}$ — Yield Strength of ASTM A-276, *ARMCO Nitronic 60* Stainless Steel (1.5" not listed. Stress used is conservative for 1") — Ref. 25, Table 36

$S_{allS} := 0.4 \cdot S_y$ $\quad S_{allS} = 1.776 \cdot 10^4 \cdot \frac{lbf}{in^2}$ — Allowable Shear Stress — Ref. 11, Sec.1.8

$SF_S := \frac{S_{allS}}{S_{actS}}$ $\quad SF_S = 59.304$ — Safety factor > 3 *OK*

Bending stress

$D_m := 0.18 \cdot in$ — Thrust Washer Thickness (Moment arm on axle between sheave and housing.) — Ref. 33H.6, Pg. 2, Item 5

$M := F_{axle} \cdot D_m$ — Moment applied to axle

$y := \frac{1.5}{2} \cdot in$ — Distance from centroidal axis to outside fiber.

$I := \frac{\pi \cdot D^4}{64}$ — Axle Moment of Inertia

$S_{actB} := \frac{M \cdot y}{I}$ $\quad S_{actB} = 287.494 \cdot \frac{lbf}{in^2}$ — Calculated Maximum Bending Stress per axle. — Ref. 8, Pg. 177 (*Table of Simple Stresses*)

$S_{allB} := 0.75 \cdot S_y$ $\quad S_{allB} = 3.33 \cdot 10^4 \cdot \frac{lbf}{in^2}$ — Allowable Bending Stress — Ref. 7, Pg 5-48 (F2-1)

$SF_B := \frac{S_{allB}}{S_{actB}}$ $\quad SF_B = 115.828$ — Safety factor > 3 *OK*

**DESIGN ANALYSIS**

| | | | | | |
|---|---|---|---|---|---|
| Client | WESTINGHOUSE HANFORD COMPANY | WO/Job No. | ER4319 | Filename | WIN-04.mcd |
| Subject | WINCH ANALYSIS - SLURRY/SLUICE PUMP | Date | 9 / 8 / 95 | By | D.L. STONE |
| | PROJECT W-320 WASTE RETRIEVAL for TANK 241-C-106 | Checked | 9/8/95 | By | M.R. CUSTER MRC |
| Location | C TANK FARM - HANFORD 200 EAST AREA | Revised | | By | |

**Shear Stress of Sheave Housing at Axles**

Calculation considers two plates in double shear at each axle.

$D := 5 \cdot in$ — Depth of Housing Plate section — Ref. 33H.6, Pg. 2, Item 2

$Th := \frac{3}{8} \cdot in$ — Thickness of Sheave Housing Plate

$A_a := D \cdot Th \cdot 4 \qquad A_a = 7.5 \cdot in^2$ — Area of metal supported by axles

$F_{SH} := W_{PA} + W_{tube} + W_{brackets} + W_{ends} + W_{housing} + W_{brace} + W_{braces} + W_{sub} + W_{cb} + W_{base}$

$F_{SH} = 4.162 \cdot 10^3 \cdot lbf$ — Force on sheave Housing

$S_y := 25000 \cdot \frac{lbf}{in^2}$ — Yield strength of ASTM A240 Type 304L

$S_{all} := (0.45) \cdot S_y \qquad S_{all} = 1.125 \cdot 10^4 \cdot \frac{lbf}{in^2}$ — Allowable Stress — Ref.7, Chap. D.3.1

$S_{act} := \frac{F_{SH}}{A_a} \qquad S_{act} = 554.911 \cdot \frac{lbf}{in^2}$ — Calculated Shear stress on Housing.

$SF := \frac{S_{all}}{S_{act}} \qquad SF = 20.274$ — Safety factor > 3 OK

**DESIGN ANALYSIS**

| | | | | | |
|---|---|---|---|---|---|
| Client | WESTINGHOUSE HANFORD COMPANY | WO/Job No. | ER4319 | Filename | WIN-04.mcd |
| Subject | WINCH ANALYSIS - SLURRY/SLUICE PUMP | Date | 9 / 8 / 95 | By | D.L. STONE |
| | PROJECT W-320 WASTE RETRIEVAL for TANK 241-C-106 | Checked | 9/8/95 | By | M.R. CUSTER MRC |
| Location | C TANK FARM - HANFORD 200 EAST AREA | Revised | | By | |

**Strength of Weld between housing walls and 1/2" base plate.**

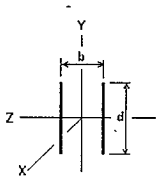
$Fx := W_{PA} + W_{tube} + W_{brackets} + W_{ends} + W_{base}$

$Fx = 4.091 \cdot 10^3 \cdot lbf$ Weld Tensile Load *(In "x" direction on subroutine sketch, below)*

**WELD PROPERTIES:**

$b := 3.5 \cdot in$ Weld Outline Dimension - short side Ref. 9, Pg. 7.4 6 &7

$d := 20.5 \cdot in$ Weld Outline Dimension - long side




$Cy := \frac{b}{2}$ $Cy = 1.75 \cdot in$ Location of center of gravity with respect to y axis.

$Cz := \frac{d}{2}$ $Cz = 10.25 \cdot in$ Location of center of gravity with respect to z axis.

$Aw := 2 \cdot d$ $Aw = 41 \cdot in$ Weld length

$Swy := b \cdot d$ $Swy = 71.75 \cdot in^2$ Section modulus about y axis

$Swz := \frac{d^2}{3}$ $Swz = 140.083 \cdot in^2$ Section modulus about z axis

$Jw := \frac{d \cdot (3 \cdot b^2 + d^2)}{6}$ $Jw = 1.561 \cdot 10^3 \cdot in^3$ Polar Moment of Inertia

**JOINT LOADS:**

| | | | |
|---|---|---|---|
| Tensile | $Fx = 4.091 \cdot 10^3 \cdot lbf$ | $Fy := 0 \cdot lbf$ | $Fz := 0 \cdot lbf$ |
| Moment | $Mx := 0 \cdot in \cdot lbf$ | $My := 0 \cdot in \cdot lbf$ | $Mz := 0 \cdot in \cdot lbf$ |

**WELD STRESS:**

$$fw := \left[\left(\frac{Fx}{Aw} + \frac{My}{Swy} + \frac{Mz}{Swz}\right)^2 + \left(\frac{Fy}{Aw} + \frac{Mx \cdot Cy}{Jw}\right)^2 + \left(\frac{Fz}{Aw} + \frac{Mx \cdot Cz}{Jw}\right)^2\right]^{0.5} \qquad fw = 99.781 \cdot \frac{lbf}{in}$$

**FILLET WELD SIZE REQUIRED:**

$S := 15800 \cdot psi$ Allowable Weld Stress per AWS & AISC Ref. 9, Pg. 7.4-8

$w := \frac{fw}{0.707 \cdot S}$ $w = 0.009 \cdot in$ Minimum Allowable Fillet Weld Required by Design

$w_{Code} := \left(\frac{3}{16} \cdot in\right)$ Minimum Size Fillet Weld Required by Code for material thickness of 1/2". Ref. 7, Part 5, Section J.2.2, Table J2.4

$SF_{fw} := \frac{w_{Code}}{w}$ $SF_{fw} = 20.991$ Safety factor based on a 3/16" weld > 3 *OK*

**DESIGN ANALYSIS**

| | | | | | |
|---|---|---|---|---|---|
| Client | WESTINGHOUSE HANFORD COMPANY | WO/Job No. | ER4319 | Filename | WIN-05.mcd |
| Subject | WINCH ANALYSIS - SLURRY/SLUICE PUMP | Date | 9 / 8 / 95 | By | D.L. STONE |
| | PROJECT W-320 WASTE RETRIEVAL for TANK 241-C-106 | Checked | 9/8/95 | By | M.R. CUSTER MRC |
| Location | C TANK FARM - HANFORD 200 EAST AREA | Revised | | By | |

## Check of Retrieval Cable and Brackets

*Check of Retrieval Cable*

$W_{PA} := 3375 \cdot lbf$ Total Weight of Pump Assembly , impact loading not considered.

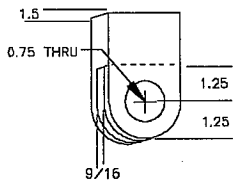
$W_{SA} := 188.578 \cdot lbf$ Total Weight of Sheave Assembly

$W_{PA} + W_{SA} = 3.564 \cdot 10^3 \cdot lbf$

$S_{cable} := 22800 \cdot lbf$ Breaking Strength of Type 304 Stainless Steel, 1/2", 6 x 19 IWRC Cable

$SF := \frac{S_{cable}}{(W_{PA} + W_{SA})}$ $SF = 6.398$ Safety factor > 5 OK

*Cable Support Brackets welded to the Winch Plate* Ref. 33.7, Sh. 2, Detail 3




*Shear*

$w := \left(1.25 - \frac{0.75}{2}\right) \cdot in$ $w = 0.875 \cdot in$ Width of Shear plane.

$th := (.4687) \cdot in$ $th = 0.469 \cdot in$ Plate thickness

$A := 2 \cdot (w \cdot th)$ $A = 0.82 \cdot in^2$ Area of bracket loaded by the clevis pin.

$S_y := 30000 \cdot \frac{lbf}{in^2}$ Yield strength of ASTM A240 Type 304

$S_{all} := (0.45) \cdot S_y$ $S_{all} = 1.35 \cdot 10^4 \cdot \frac{lbf}{in^2}$ Allowable Stress Ref.7, Part 5, Chap. D.3.1

$S_{act} := \frac{(W_{PA} + W_{SA})}{A}$ $S_{act} = 4.345 \cdot 10^3 \cdot \frac{lbf}{in^2}$ Calculated stress on brackets.

$SF := \frac{S_{all}}{S_{act}}$ $SF = 3.107$ Safety factor > 3 OK

*Cable Support Brackets (continued...)*

*Bearing Stress*

$d := 0.75 \cdot in$ — Hole Diameter

$A := \left(\frac{\pi \cdot d}{2} \cdot th\right)$ $\quad A = 0.552 \cdot in^2$ — Bearing Surface Area.

$S_y := 30000 \cdot \frac{lbf}{in^2}$ — Yield strength of ASTM A240 Type 304

$S_{all} := (0.9) \cdot S_y$ $\quad S_{all} = 2.7 \cdot 10^4 \cdot \frac{lbf}{in^2}$ — Allowable Stress — Ref.11, Pg 12

$S_{act} := \frac{W_{PA} + W_{SA}}{A}$ $\quad S_{act} = 6.454 \cdot 10^3 \cdot \frac{lbf}{in^2}$ — Calculated stress on brackets.

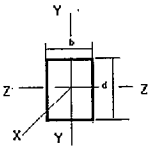
$SF := \frac{S_{all}}{S_{act}}$ $\quad SF = 4.184$ — Safety factor > 3 — OK

## DESIGN ANALYSIS

| | | | | | |
|---|---|---|---|---|---|
| Client | WESTINGHOUSE HANFORD COMPANY | WO/Job No. | ER4319 | Filename | WIN-05.mcd |
| Subject | WINCH ANALYSIS - SLURRY/SLUICE PUMP | Date | 9 / 8 / 95 | By | D.L. STONE |
| | PROJECT W-320 WASTE RETRIEVAL for TANK 241-C-106 | Checked | 9/8/95 | By | M.R. CUSTER MRC |
| Location | C TANK FARM - HANFORD 200 EAST AREA | Revised | | By | |

*Weld connecting Support Bracket to the Winch Plate.* Ref. 33.7, Sh. 2, Detail 3

**WELD PROPERTIES:**




$b := 1.5 \cdot in$ Weld Outline Dimension - short side Ref. 9, Pg. 7.4 6 &7

$d := 3 \cdot in$ Weld Outline Dimension - long side

$Cy := \frac{b}{2}$ $Cy = 0.75 \cdot in$ Location of center of gravity with respect to y axis.

$Cz := \frac{d}{2}$ $Cz = 1.5 \cdot in$ Location of center of gravity with respect to z axis.

$Aw := 2 \cdot (b + d)$ $Aw = 9 \cdot in$ Weld length (1 Bracket)

$Swy := b \cdot d + \frac{b^2}{3}$ $Swy = 5.25 \cdot in^2$ Section modulus about y axis

$Swz := b \cdot d + \frac{d^2}{3}$ $Swz = 7.5 \cdot in^2$ Section modulus about z axis

$Jw := \frac{(b + d)^3}{6}$ $Jw = 15.187 \cdot in^3$ Polar Moment of Inertia

**JOINT LOADS:**

| | | | |
|---|---|---|---|
| Tensile | $Fx := W_{PA} + W_{SA}$ | $Fy := 0 \cdot lbf$ | $Fz := 0 \cdot lbf$ |
| Moment | $Mx := 0 \cdot in \cdot lbf$ | $My := 0 \cdot in \cdot lbf$ | $Mz := 0 \cdot in \cdot lbf$ |

**WELD STRESS:**

$$fw := \left[\left(\frac{Fx}{Aw} + \frac{My}{Swy} + \frac{Mz}{Swz}\right)^2 + \left(\frac{Fy}{Aw} + \frac{Mx \cdot Cy}{Jw}\right)^2 + \left(\frac{Fz}{Aw} + \frac{Mx \cdot Cz}{Jw}\right)^2\right]^{0.5} \qquad fw = 395.953 \cdot \frac{lbf}{in}$$

**FILLET WELD SIZE REQUIRED:**

$S := 15800 \cdot psi$ Allowable Weld Stress per AWS & AISC Ref. 9, Pg. 7.4-8

$w := \frac{fw}{0.707 \cdot S}$ $w = 0.035 \cdot in$ Minimum Allowable Fillet Weld Required by Design

$w_{Code} := \left(\frac{5}{16} \cdot in\right)$ Minimum Size Fillet Weld Required by Code for material thickness of over 3/4". Ref. 7, Part 5, Section J.2.2, Table J2.4

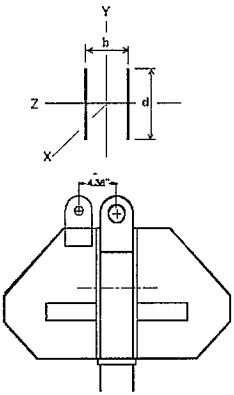
$SF_{fw} := \frac{w_{Code}}{w}$ $SF_{fw} = 8.816$ Safety factor based on a 5/16" weld > 3 OK

## DESIGN ANALYSIS

| | | | | | |
|---|---|---|---|---|---|
| Client | WESTINGHOUSE HANFORD COMPANY | WO/Job No. | ER4319 | Filename | WIN-05.mcd |
| Subject | WINCH ANALYSIS - SLURRY/SLUICE PUMP | Date | 9 / 8 / 95 | By | D.L. STONE |
| | PROJECT W-320 WASTE RETRIEVAL for TANK 241-C-106 | Checked | 9/8/95 | By | M.R. CUSTER MRC |
| Location | C TANK FARM - HANFORD 200 EAST AREA | Revised | | By | |

*Weld connecting Eye Tabs to Sheave Housing* — Ref. 33.6, Sh. 2, Detail 3

**WELD PROPERTIES:**




$b := 3 \cdot in$ — Weld Outline Dimension - short side — Ref. 9, Pg. 7.4 6 &7

$d := 2 \cdot in$ — Weld Outline Dimension - long side

$Cy := \frac{b}{2}$ $\quad Cy = 1.5 \cdot in$ — Location of center of gravity with respect to y axis.

$Cz := \frac{d}{2}$ $\quad Cz = 1 \cdot in$ — Location of center of gravity with respect to z axis.

$Aw := 2 \cdot d$ $\quad Aw = 4 \cdot in$ — Weld length

$Swy := b \cdot d$ $\quad Swy = 6 \cdot in^2$ — Section modulus about y axis

$Swz := \frac{d^2}{3}$ $\quad Swz = 1.333 \cdot in^2$ — Section modulus about z axis

$Jw := \frac{d \cdot (3 \cdot b^2 + d^2)}{6}$ $\quad Jw = 10.333 \cdot in^3$ — Polar Moment of Inertia

**JOINT LOADS:**

Tensile $\quad Fx := 0 \cdot lbf \quad Fy := \frac{W_{PA} + W_{SA}}{2} \quad Fz := 0 \cdot lbf$

Moment $\quad Mx := 0 \cdot in \cdot lbf \quad My := 0 \cdot in \cdot lbf \quad Mz := 0 \cdot in \cdot lbf$

**WELD STRESS:**

$$fw := \left[\left(\frac{Fx}{Aw} + \frac{My}{Swy} + \frac{Mz}{Swz}\right)^2 + \left(\frac{Fy}{Aw} + \frac{Mx \cdot Cy}{Jw}\right)^2 + \left(\frac{Fz}{Aw} + \frac{Mx \cdot Cz}{Jw}\right)^2\right]^{0.5} \qquad fw = 445.447 \cdot \frac{lbf}{in}$$

**FILLET WELD SIZE REQUIRED:**

$S := 15800 \cdot psi$ — Allowable Weld Stress per AWS & AISC — Ref. 9, Pg. 7.4-8

$w := \frac{fw}{0.707 \cdot S}$ $\quad w = 0.04 \cdot in$ — Minimum Allowable Fillet Weld Required by Design

$w_{Code} := \left(\frac{3}{16} \cdot in\right)$ — Minimum Size Fillet Weld Required by Code for material thickness of 3/8". — Ref. 7, Part 5, Section J.2.2, Table J2.4

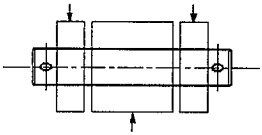
$w_{act} := \left(\frac{1}{4} \cdot in\right)$ — Weld size specified in design drawings. — Ref. H.6, Pg. 2

$SF_{fw} := \frac{w_{act}}{w}$ $\quad SF_{fw} = 6.269$ — Safety factor based on a 3/16" weld — > 3 — *OK*

## DESIGN ANALYSIS

| | | | | | |
|---|---|---|---|---|---|
| Client | WESTINGHOUSE HANFORD COMPANY | WO/Job No. | ER4319 | Filename | WIN-05.mcd |
| Subject | WINCH ANALYSIS - SLURRY/SLUICE PUMP | Date | 9 / 8 / 95 | By | D.L. STONE |
| | PROJECT W-320 WASTE RETRIEVAL for TANK 241-C-106 | Checked | 9/8/95 | By | M.R. CUSTER MRC |
| Location | C TANK FARM - HANFORD 200 EAST AREA | Revised | | By | |

*Shear on Eye Bolt* Ref. 33.6, Pg 2



$D := \left(\frac{45}{64}\right) \cdot in$ $\quad D = 0.703 \cdot in$ Axle Diameter

$A_a := \frac{\pi \cdot D^2}{4}$ $\quad A_a = 0.388 \cdot in^2$ Cross Sectional Area

$F_{axle} := \left(\frac{W_{SA} + W_{PA}}{2}\right)$ $\quad F_{axle} = 1.782 \cdot 10^3 \cdot lbf$ Force of sheave assembly felt by each shear plane.

$S_{actS} := \frac{F_{axle}}{A_a}$ $\quad S_{actS} = 4.589 \cdot 10^3 \cdot \frac{lbf}{in^2}$ Calculated Shear Stress per axle.

$S_y := 100000 \cdot \frac{lbf}{in^2}$ Yield Strength of ASTM 193, Class 2, B8T

$S_{allS} := 0.4 \cdot S_y$ $\quad S_{allS} = 4 \cdot 10^4 \cdot \frac{lbf}{in^2}$ Allowable Shear Stress Ref. 11, Sec.1.8

$SF_S := \frac{S_{allS}}{S_{actS}}$ $\quad SF_S = 8.717$ Safety factor > 3 *OK*

**DESIGN ANALYSIS**

| | | | | | |
|---|---|---|---|---|---|
| Client | WESTINGHOUSE HANFORD COMPANY | WO/Job No. | ER4319 | Filename | WIN-06.mcd |
| Subject | WINCH ANALYSIS - SLURRY/SLUICE PUMP | Date | 9 / 8 / 95 | By | D.L. STONE |
| | PROJECT W-320 WASTE RETRIEVAL for TANK 241-C-106 | Checked | 9/8/95 | By | M.R. CUSTER MRC |
| Location | C TANK FARM - HANFORD 200 EAST AREA | Revised | | By | |

***Weight of Reel Axle (12) Supported Components***

$W_{PA} := 4050 \cdot lbf$ Weight of Pump Assembly (Impact Considered)

$W_{SA} := 188.578 \cdot lbf$ Weight of Sheave Assembly

Weight of Reel (Ref. 33.5, Sh. 2&4)

*Weight of 2 Flanges*

$w_{psf} := 15.32 \cdot \frac{lbf}{ft^2}$ Weight of 3/8 in. Hot Rolled Carbon Steel plate per square foot: (Ref. 16)

$A_{plate} := 2 \cdot \left[\frac{\pi}{4} \cdot \left(28^2 - 3.25^2\right)\right] \cdot in^2$ $A_{plate} = 1.215 \cdot 10^3 \cdot in^2$ Area of 2 Flanges

$W_{flanges} := A_{plate} \cdot w_{psf}$ $W_{flanges} = 129.253 \cdot lbf$ Flange Weight

*Weight of Inner (Axle) Hub*

$w_{r3} := 24.03 \cdot \frac{lbf}{ft}$ Weight per ft of 3 Inch Diameter 304L Round Stock Ref.16

$w_{r1.938} := 10.02 \cdot \frac{lbf}{ft}$ Weight per ft of 1-15/16 Inch Diameter 304L Round Stock Ref. 16

$L_{hub} := (3.75 \cdot in)$ Total Length of Hub

$W_{hubA} := L_{hub} \cdot \left(w_{r3} - w_{r1.938}\right)$ $W_{hubA} = 4.378 \cdot lbf$ Inner Hub Weight

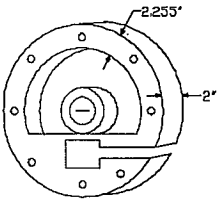
*Weight of Outer (Reel) Hub* (Ref. 33.5, Sh. 6)

(Ref. 7, Page 6-8)

$W_{steel} := 490.8 \cdot \frac{lbf}{ft^3}$

$r_{solid} := \left(\frac{11.75}{2}\right) \cdot in$ $r_{solid} = 5.875 \cdot in$

$A_{solid} := \pi \cdot r_{solid}^2$ $r_{cutout} := 3.62 \cdot in$




$$A_{cutout} := \left(\frac{\pi \cdot r_{cutout}^2}{2}\right) + 2 \cdot \left[(1.5 \cdot in) \cdot r_{cutout}\right] + \left[(1.5 \cdot 2.25) \cdot in^2\right] + \left[\left(\frac{3}{8} \cdot 5\right) \cdot in^2\right]$$

$A_{cutout} = 36.694 \cdot in^2$ Approximation of Semicircular Cutout Area.

$w := 2 \cdot in$ Hub Length

$V_{hub} := (w) \cdot \left(A_{solid} - A_{cutout}\right)$ $V_{hub} = 143.479 \cdot in^3$ Metal Volume of Hub

$W_{hubB} := \left(V_{hub} \cdot W_{steel}\right)$ $W_{hubB} = 40.752 \cdot lbf$ Approximate weight

**DESIGN ANALYSIS**

| | | | | | |
|---|---|---|---|---|---|
| Client | WESTINGHOUSE HANFORD COMPANY | WO/Job No. | ER4319 | Filename | WIN-06.mcd |
| Subject | WINCH ANALYSIS - SLURRY/SLUICE PUMP | Date | 9 / 8 / 95 | By | D.L. STONE |
| | PROJECT W-320 WASTE RETRIEVAL for TANK 241-C-106 | Checked | 9/8/95 | By | M.R. CUSTER MRC |
| Location | C TANK FARM - HANFORD 200 EAST AREA | Revised | | By | |

*TOTAL Weight of Reel*

$W_{reel} := W_{flanges} + W_{hubA} + W_{hubB}$ $\quad W_{reel} = 174.383 \cdot lbf$

*Weight of Gear*

$W_{gear25} := 105 \cdot lbf$ — *Weight of 54 tooth 18 PD, 3 DP, 3" Spur Gear obtained by telecon from Boston Gear, 8 / 15 / 95.* Ref. 20

*Weight of Wire Rope*

$w_{rope} := 0.69 \cdot \frac{lbf}{ft}$ — Weight per ft of 1/4 x 1-1/2 in Flat Wire Rope Ref. 8, Pg. 332, Tbl 7

$L_{rope} := 75 \cdot ft$ — Total Length of Wire Rope Ref. 33.1

$W_{rope} := w_{rope} \cdot L_{rope}$ $\quad W_{rope} = 51.75 \cdot lbf$ — Weight of 75 ft of Wire Rope

*Weight of Reel / Spur Gear Shaft (Axle)*

$w_2 := 10.68 \cdot \frac{lbf}{ft}$ — Weight per ft of 2 Inch Diameter 4140 Round Stock Ref. 16

$w_{1.938} := 10.02 \cdot \frac{lbf}{ft}$ — Weight per ft of 1-15/16 Inch Diameter 4140 Round Stock Ref. 16

$w_{1.25} := 4.17 \cdot \frac{lbf}{ft}$ — Weight per ft of 1-1/4 Inch Diameter 4140 Round Stock Ref. 16

$W_{shaft} := \left[(10.55 \cdot in) \cdot w_{1.938}\right] + \left[(5.44 \cdot in) \cdot w_2\right] + \left[(5.5 \cdot in) \cdot w_{1.25}\right]$ $\quad W_{shaft} = 15.562 \cdot lbf$ Axle Weight

***Weight of Pump, Sheave and Rope Assemblies on Reel Hub***

$W_{Hub} := W_{PA} + W_{SA} + W_{rope}$ $\quad W_{Hub} = 4.29 \cdot 10^3 \cdot lbf$

***Weight of Loaded Reel on Axle (12)***

$W_{Reel} := W_{PA} + W_{SA} + W_{reel} + W_{rope}$ $\quad W_{Reel} = 4.465 \cdot 10^3 \cdot lbf$

***Total Weight of Reel / Spur Gear Assembly on Bearings***

$W_{RA} := W_{PA} + W_{SA} + W_{reel} + W_{gear25} + W_{rope} + W_{shaft}$ $\quad W_{RA} = 4.585 \cdot 10^3 \cdot lbf$

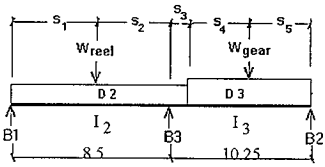
**DESIGN ANALYSIS**

| | | | | | |
|---|---|---|---|---|---|
| Client | WESTINGHOUSE HANFORD COMPANY | WO/Job No. | ER4319 | Filename | WIN-07.mcd |
| Subject | WINCH ANALYSIS - SLURRY/SLUICE PUMP | Date | 9 / 8 / 95 | By | D.L. STONE |
| | PROJECT W-320 WASTE RETRIEVAL for TANK 241-C-106 | Checked | 9/8/95 | By | M.R. CUSTER MRC |
| Location | C TANK FARM - HANFORD 200 EAST AREA | Revised | | By | |

**Shear on Reel Axle (12) Bearings**

$D2 := \left(10.032 \cdot \frac{lbf}{ft}\right)$ $D3 := \left(10.69 \cdot \frac{lbf}{ft}\right)$ Weight per foot of Shaft

Ref. C, Page 1-108




$s_1 := 3.89 \cdot in$ Span 1 = Axle Length between Bearing 1 and Reel. Ref. 33.5, Pages 1 & 5

$s_2 := 4.61 \cdot in$ Span 2 = Axle Length between Reel and Center Bearing (Bearing 3).

$s_3 := 3.435 \cdot in$ Span 3 = Axle Length between Bearing 3 and Diameter change.

$s_4 := 1.625 \cdot in$ Span 4 = Axle Length between Diameter Change and Gear 25.

$s_5 := 5.19 \cdot in$ Span 5 = Axle Length between Gear25 and Bearing 2.

Ref. 8, Page 191

$d_2 := 1.9375 \cdot in$ $I_2 := \frac{\pi \cdot d_2^4}{64}$ $I_2 = 0.6917 \cdot in^4$ Moment of Inertia for shaft diameter = 1.9375 in

$d_3 := 2 \cdot in$ $I_3 := \frac{\pi \cdot d_3^4}{64}$ $I_3 = 0.7854 \cdot in^4$ Moment of Inertia for shaft diameter = 2 in

$K_1 := \frac{I_2}{(s_1 + s_2)} \cdot \left(\frac{3}{4}\right)$ $K_1 = 0.061 \cdot in^3$ Stiffness Factor adjusted for simple supports. Ref. 13, Page 530

$K_2 := \frac{I_3}{(s_3 + s_4 + s_5)} \cdot \left(\frac{3}{4}\right)$ $K_2 = 0.057 \cdot in^3$ Stiffness Factor adjusted for simple supports.

$DF_{K1} := \frac{K_1}{K_1 + K_2}$ $DF_{K1} = 0.515$ Distribution Factor Ref. 13, Page 528

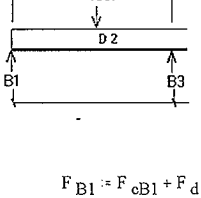
$DF_{K2} := \frac{K_2}{K_1 + K_2}$ $DF_{K2} = 0.485$ Distribution Factor

**DESIGN ANALYSIS**

| | | | | | |
|---|---|---|---|---|---|
| Client | WESTINGHOUSE HANFORD COMPANY | WO/Job No. | ER4319 | Filename | WIN-07.mcd |
| Subject | WINCH ANALYSIS - SLURRY/SLUICE PUMP | Date | 9 / 8 / 95 | By | D.L. STONE |
| | PROJECT W-320 WASTE RETRIEVAL for TANK 241-C-106 | Checked | 9/8/95 | By | M.R. CUSTER MRC |
| Location | C TANK FARM - HANFORD 200 EAST AREA | Revised | | By | |

Loading on Axle from Bearings B1 to B3

$W_{reel} := 4465 \cdot lbf$ Ref. 13, Page 528




$F_{cB1} := \frac{W_{reel} \cdot (s_2)}{(s_1 + s_2)}$ $F_{cB1} = 2.422 \cdot 10^3 \cdot lbf$ Concentrated vertical Load at B1

$F_{cB3} := \frac{W_{reel} \cdot (s_1)}{(s_1 + s_2)}$ $F_{cB3} = 2.043 \cdot 10^3 \cdot lbf$ Concentrated vertical Load at B3

$F_d := \frac{D2 \cdot (s_1 + s_2)}{2}$ $F_d = 3.553 \cdot lbf$ Distributed vertical Load from B1 to B3

$F_{B1} := F_{cB1} + F_d$ $F_{B1} = 2425.159 \cdot lbf$ Combined vertical Loading at B1.

$F_{B3} := F_{cB3} + F_d$ $F_{B3} = 2046.947 \cdot lbf$ Combined vertical Loading at B3.

Fixed End Moments (Span B1 - B3) Ref. 13, Page 528
Ref. 33.5, Pages 1 & 5

$P := W_{reel}$ Concentrated Load

$l := s_1 + s_2$ Total Spacing

$w := D2$ Distributed Load (Conservatively assumed as spanning full length of beam.)

$FEM_{cB1} := \frac{P \cdot s_1 \cdot s_2^2}{l^2}$ $FEM_{cB1} = 5.109 \cdot 10^3 \cdot lbf \cdot in$ Left Fixed End Moment resulting from Concentrated Load

$FEM_{cB3} := \frac{P \cdot s_1^2 \cdot s_2}{l^2}$ $FEM_{cB3} = 4.311 \cdot 10^3 \cdot lbf \cdot in$ Right Fixed End Moment resulting from Concentrated Load

$M_d := \frac{w \cdot l^2}{12}$ $M_d = 5.033 \cdot lbf \cdot in$ Fixed End Moment resulting from Uniformly Distrbuted Load

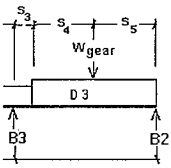
$FEM_L := FEM_{cB1} + M_d$ $FEM_L = 5114.024 \cdot lbf \cdot in$

$FEM_R := FEM_{cB3} + M_d$ $FEM_R = 4316.09 \cdot lbf \cdot in$

**DESIGN ANALYSIS**

| | | | | | |
|---|---|---|---|---|---|
| Client | WESTINGHOUSE HANFORD COMPANY | WO/Job No. | ER4319 | Filename | WIN-07.mcd |
| Subject | WINCH ANALYSIS - SLURRY/SLUICE PUMP | Date | 9 / 8 / 95 | By | D.L. STONE |
| | PROJECT W-320 WASTE RETRIEVAL for TANK 241-C-106 | Checked | 9/8/95 | By | M.R. CUSTER MRC |
| Location | C TANK FARM - HANFORD 200 EAST AREA | Revised | | By | |

Loading on Axle from Bearings B3 to B2 — Ref. 13, Page 528




$W_{gear} := 105 \cdot lbf$

$F_{cB3} := \frac{W_{gear} \cdot (s_5)}{(s_3 + s_4 + s_5)}$ $\quad F_{cB3} = 53.166 \cdot lbf$ Concentrated vertical Load felt at B3

$F_{cB2} := \frac{W_{gear} \cdot (s_3 + s_4)}{(s_3 + s_4 + s_5)}$ $\quad F_{cB2} = 51.834 \cdot lbf$ Concentrated vertical Load felt at B2

$F_d := \frac{(D2 \cdot s_3) + [D3 \cdot (s_4 + s_5)]}{2}$ $\quad F_d = 4.471 \cdot lbf$ Distributed vertical Load from B1 and B2

$F_{B2} := F_{cB2} + F_d$ $\quad F_{B2} = 56.305 \cdot lbf$ Combined vertical Loading at B2.

$F_{B3} := F_{cB3} + F_d$ $\quad F_{B3} = 57.637 \cdot lbf$ Combined vertical Loading at B3.

---

Fixed End Moments (Span B3 - B2) — Ref. 13, Page 528

$P := W_{gear}$ Concentrated Load

$l := (s_3 + s_4 + s_5)$ Total Spacing

$w := D3$ Distributed Load (Conservatively assumed as spanning full length of beam.)

$FEM_{cB3} := \frac{P \cdot (s_3 + s_4) \cdot (s_5)^2}{l^2}$ $\quad FEM_{cB3} = 136.216 \cdot lbf \cdot in$ Left Fixed End Moment resulting from Concentrated Load

$FEM_{cB2} := \frac{P \cdot (s_3 + s_4)^2 \cdot (s_5)}{l^2}$ $\quad FEM_{cB2} = 132.804 \cdot lbf \cdot in$ Right Fixed End Moment resulting from Concentrated Load

$M_d := \frac{w \cdot l^2}{12}$ $\quad M_d = 7.799 \cdot lbf \cdot in$ Moment resulting from Distrbuted Load

$FEM_R := FEM_{cB2} + M_d$ $\quad FEM_R = 140.603 \cdot lbf \cdot in$

$FEM_L := FEM_{cB3} + M_d$ $\quad FEM_L = 144.015 \cdot lbf \cdot in$

## REEL SHAFT FORCES AND MOMENTS

Determined by Moment Distribution Method for Beams

| | | 0.515 | 0.485 | |
|---|---|---|---|---|
| Fixed End Moments | -5114.02 | 4316.09 | -144.02 | 140.60 |
| Reaction Due to Unbalanced Moment | 5114.02 | 2557.01 | -70.30 | -140.60 |
| Distributed Reactions | 0.00 | -3429.27 | -3229.51 | 0.00 |
| Sum | | 3443.83 | -3443.83 | |
| Simple Support Reactions of: | | | | |
| Vertical Load, P/L + wL/2 (AISC) | 2425.16 | 2046.95 | 57.64 | 56.31 |
| Distributed Moments , M/L | -405.16 | 405.16 | 335.98 | -335.98 |
| Sum | 2020.00 | 2452.10 | 393.62 | -279.68 |
| Total Vertical Reactions at Supports | 2020.00 lb | 2845.72 lbs | | -279.68 lbs |

**DESIGN ANALYSIS**

| | | | | | |
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| Client | WESTINGHOUSE HANFORD COMPANY | WO/Job No. | ER4319 | Filename | WIN-07.mcd |
| Subject | WINCH ANALYSIS - SLURRY/SLUICE PUMP | Date | 9 / 8 / 95 | By | D.L. STONE |
| | PROJECT W-320 WASTE RETRIEVAL for TANK 241-C-106 | Checked | 9/8/95 | By | M.R. CUSTER MRC. |
| Location | C TANK FARM - HANFORD 200 EAST AREA | Revised | | By | |

## Reel Shaft Forces

Determined by Moment Distribution Method for Indeterminant Beams

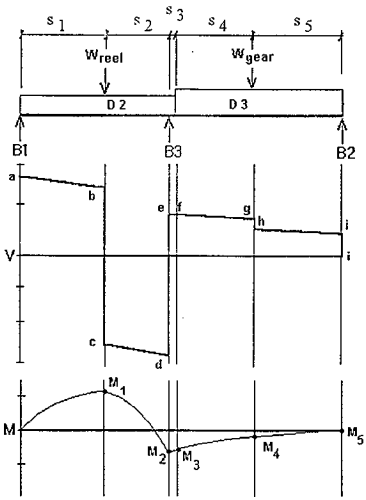
$B1 := 2020.00 \cdot lbf$ $\quad B3 := 2845.72 \cdot lbf$ $\quad B2 := -279.68 \cdot lbf$

## Bending Moments for Reel Axle (12)

$D2 = 10.032 \cdot \frac{lbf}{ft}$ $\quad D3 = 10.69 \cdot \frac{lbf}{ft}$ Weight per foot of Shaft

$W_{reel} = 4.465 \cdot 10^3 \cdot lbf$ $\quad W_{gear} = 105 \cdot lbf$

| | |
|---|---|
| $a := B1$ | $a = 2.02 \cdot 10^3 \cdot lbf$ |
| $b := a - (s_1) \cdot D2$ | $b = 2.017 \cdot 10^3 \cdot lbf$ |
| $c := b - W_{reel}$ | $c = -2.448 \cdot 10^3 \cdot lbf$ |
| $d := c - (s_2) \cdot D2$ | $d = -2.452 \cdot 10^3 \cdot lbf$ |
| $e := d + B3$ | $e = 393.614 \cdot lbf$ |
| $f := e - (s_3) \cdot D2$ | $f = 390.742 \cdot lbf$ |
| $g := f - (s_4) \cdot D3$ | $g = 389.295 \cdot lbf$ |
| $h := g - W_{gear}$ | $h = 284.295 \cdot lbf$ |
| $i := h - (s_5) \cdot D3$ | $i = 279.671 \cdot lbf$ |
| $j := i + B2$ | $j = 0 \cdot lbf$ |




### Maximum Bending Moment on the Shaft

$$M_1 := b \cdot (s_1) + \frac{(a - b) \cdot (s_1)}{2} \qquad M_1 = 7.851 \cdot 10^3 \cdot lbf \cdot in$$ <---------- Maximum Bending Moment

$$M_2 := M_1 + \left[ c \cdot (s_2) + \frac{(d - c) \cdot (s_2)}{2} \right] \qquad M_2 = -3.444 \cdot 10^3 \cdot lbf \cdot in$$

$$M_3 := M_2 + \left[ f \cdot (s_3) + \frac{(e - f) \cdot (s_3)}{2} \right] \qquad M_3 = -2.097 \cdot 10^3 \cdot lbf \cdot in$$

$$M_4 := M_3 + \left[ g \cdot (s_4) + \frac{(f - g) \cdot (s_4)}{2} \right] \qquad M_4 = -1.463 \cdot 10^3 \cdot lbf \cdot in$$

$$M_5 := M_4 + \left[ i \cdot (s_5) + \frac{(h - i) \cdot (s_5)}{2} \right] \qquad M_5 = 0.554 \cdot lbf \cdot in \approx 0 \cdot (lbf \cdot in)$$

**DESIGN ANALYSIS**

| | | | | | |
|---|---|---|---|---|---|
| Client | WESTINGHOUSE HANFORD COMPANY | WO/Job No. | ER4319 | Filename | WIN-07.mcd |
| Subject | WINCH ANALYSIS - SLURRY/SLUICE PUMP | Date | 9 / 8 / 95 | By | D.L. STONE |
| | PROJECT W-320 WASTE RETRIEVAL for TANK 241-C-106 | Checked | 9/8/95 | By | M.R. CUSTER MRC |
| Location | C TANK FARM - HANFORD 200 EAST AREA | Revised | | By | |

***Equivalent Radial load - Radial Ball Bearings***

*Shaft End (B1 and B2) Bearings*

Pillow Block, RSAO (1-1/4" Shaft Diameter) — Ref. 27, Pg 174
Bearing, GN104KRRB — Ref. 27, Pg 144

$C_o := 4500 \cdot lbf$ — Published STATIC LOAD RATING (Maximum Permissible Radial Load) Ref. 27, Pg. 174

$i_B := 1$ — Number of adjacently mounted bearings.

$R := B1$ — Maximum APPLIED RADIAL LOAD on Bearings

$Thr := 0 \cdot lbf$ — APPLIED THRUST LOAD on Bearing

$K_{Thr} := \frac{Thr}{i_B \cdot C_o}$ $\quad K_{Thr} = 0$ — Relative Thrust Load Factor for Ball Bearings — Ref. 27, Pg. E-50, Table 1.1

$Y_1 := 0$ — Thrust Load Factor for Ball Bearings (from Table 2) — Ref. 27, Pg. E-51, Table 2

Formula for Single Row *WIDE INNER RING BALL BEARINGS*

Equivalent Radial Load on Bearing is the Larger result of the two following Formulas

$P := 0.56 \cdot R + Y_1 \cdot Thr \quad P = 1.131 \cdot 10^3 \cdot lbf$ — Ref. 27, Pg. E-50, Table 1.2

$P := R \quad P = 2.02 \cdot 10^3 \cdot lbf$

$SF := \frac{2.5 \cdot C_o}{P} = \frac{F_{all}}{F_{act}} \quad SF = 5.569$

Given that actual bearing failure (ball fracture or disintegration) would require 2 to 3 times the Static Load Rating, a factor of 2.5 times Co has been assumed to represent Ultimate Strength. Ref. 28

Safety > 5 ***OK***

**DESIGN ANALYSIS**

| | | | | | |
|---|---|---|---|---|---|
| Client | WESTINGHOUSE HANFORD COMPANY | WO/Job No. | ER4319 | Filename | WIN-07.mcd |
| Subject | WINCH ANALYSIS - SLURRY/SLUICE PUMP | Date | 9 / 8 / 95 | By | D.L. STONE |
| | PROJECT W-320 WASTE RETRIEVAL for TANK 241-C-106 | Checked | 9/8/95 | By | M.R. CUSTER MRC |
| Location | C TANK FARM - HANFORD 200 EAST AREA | Revised | | By | |

*Center Bearings (B3)*

Flanges, RCJO (1-15/16" Shaft Diameter) — Ref. 27, Pg 186
Bearing, GN115KRRB — Ref. 27, Pg 144

$C_o := 8000 \cdot lbf$ — Published STATIC LOAD RATING (Maximum Permissible Radial Load)

$i_B := 2$ — Number of adjacently mounted bearings. — Ref. 27, Pg. 174

$R := B3$ — Maximum APPLIED RADIAL LOAD on Bearings

$Thr := 0 \cdot lbf$ — APPLIED THRUST LOAD on Bearing

$K_{Thr} := \frac{Thr}{i_B \cdot C_o}$ $\quad K_{Thr} = 0$ — Relative Thrust Load Factor for Ball Bearings — Ref. 27, Pg. E-50, Table 1.1

$Y_1 := 0$ — Thrust Load Factor for Ball Bearings (from Table 2) — Ref. 27, Pg. E-51, Table 2

Formula for Single Row *WIDE INNER RING BALL BEARINGS*

Equivalent Radial Load on Bearing is the Larger result of the two following Formulas

$P := 0.56 \cdot R + Y_1 \cdot Thr \quad P = 1.594 \cdot 10^3 \cdot lbf$

$P := R \quad P = 2.846 \cdot 10^3 \cdot lbf$

Ref. 27, Pg. E-50 Table 1.2

$SF := \frac{i_B \cdot 2.5 \cdot C_o}{P} = \frac{F_{all}}{F_{act}} \quad SF = 14.056$ — Safety factor > 5 ***OK*** — Ref. 28

DESIGN ANALYSIS

| | | | | | |
|---|---|---|---|---|---|
| Client | WESTINGHOUSE HANFORD CO. | WO/Job No. | ER4319 | Filename | WIN-9.XLS |
| Subject | WINCH ANALYSIS | Date | 9/8/95 | By | D. L. STONE |
| PROJECT W-320 WASTE RETRIEVAL for Tank 241-106-C | | Checked | 9/8/95 | By | M.R. CUSTER MRC- |
| Location | C TANK FARM- HANFORD 200 EAST AREA | Revised | | By | |

Radial Distance from Reel Axis to Outermost Coil of Wire Rope on Reel

| | Wrap Diameter d | Circumference c | Radius |
|---|---|---|---|
| Hub Diameter | 11.75 | 36.91 | 5.875 |
| Wrap 1 | 12.25 | 38.48 | 0.25 |
| Wrap 2 | 12.75 | 40.06 | 0.25 |
| Wrap 3 | 13.25 | 41.63 | 0.25 |
| Wrap 4 | 13.75 | 43.20 | 0.25 |
| Wrap 5 | 14.25 | 44.77 | 0.25 |
| Wrap 6 | 14.75 | 46.34 | 0.25 |
| Wrap 7 | 15.25 | 47.91 | 0.25 |
| Wrap 8 | 15.75 | 49.48 | 0.25 |
| Wrap 9 | 16.25 | 51.05 | 0.25 |
| Wrap 10 | 16.75 | 52.62 | 0.25 |
| Wrap 11 | 17.25 | 54.19 | 0.25 |
| Wrap 12 | 17.75 | 55.76 | 0.25 |
| Wrap 13 | 18.25 | 57.33 | 0.25 |
| Wrap 14 | 18.75 | 58.90 | 0.25 |
| Wrap 15 | 19.25 | 60.48 | 0.25 |
| Wrap 16 | 19.75 | 62.05 | 0.25 |
| Wrap 17 | 20.25 | 63.62 | 0.25 |
| Wrap 18 | 20.75 | 65.19 | 0.25 |
| | Sum | 933.05 | 10.375 |

| | | |
|---|---|---|
| Length of Wire Rope | 933.05 | inches |
| (Length of Wire Rope | 77.75 | feet) |

**DESIGN ANALYSIS**

| | | | | | |
|---|---|---|---|---|---|
| Client | WESTINGHOUSE HANFORD COMPANY | WO/Job No. | ER4319 | Filename | WIN-10.mcd |
| Subject | WINCH ANALYSIS - SLURRY/SLUICE PUMP | Date | 9 / 8 / 95 | By | D.L. STONE |
| | PROJECT W-320 WASTE RETRIEVAL for TANK 241-C-106 | Checked | 9/8/95 | By | M.R. CUSTER MRC |
| Location | C TANK FARM - HANFORD 200 EAST AREA | Revised | | By | |

***Axle 12 Center Bearing Stresses*** Ref. 33.5

$B3 := 2845.72 \cdot lbf$ Vertical loading at Center Bearings

$M2 := 3444 \cdot lbf \cdot in$ Moment at Center Bearings

*Bearing Stress on Wall at the Screws*

$th := \frac{1}{2} \cdot in$ Plate Thickness Ref. 33.5, Sh. 3

$d := \left(\frac{11}{16}\right) \cdot in$ Hole Diameter Ref. 33.5, Sh. 3

$A := \left(\frac{\pi \cdot d}{2} \cdot th\right)$ $A = 0.54 \cdot in^2$ Bearing Surface Area.

$S_y := 36000 \cdot \frac{lbf}{in^2}$ Yield strength of ASTM A36

$S_{all} := (0.9) \cdot S_y$ $S_{all} = 3.24 \cdot 10^4 \cdot \frac{lbf}{in^2}$ Allowable Stress Ref. 11, Page12

$S_{act} := \frac{B3}{4 \cdot A}$ $S_{act} = 1.318 \cdot 10^3 \cdot \frac{lbf}{in^2}$ Calculated stress on 1/2" wall plate.

$SF := \frac{S_{all}}{S_{act}}$ $SF = 24.591$ Safety factor > 3 *OK*

***Check stress on 5/8 - 11 - UNC - 2B Hex Head Screws***

*Shear*

$n_b := 4$ — Number of Screws per Housing — Ref. 33.5, Sh. 3

$n_B := 1$ — Number of Bearings

$n := 11$ — Number of threads per inch

$D := \frac{5}{8} \cdot in$ — Major Diameter of Screw

$A_T := 0.7854 \cdot \left[\left[D - \left(\frac{0.9743}{n}\right) \cdot in\right]\right]^2$ $\quad A_T = 0.226 \cdot in^2$ — Tensile Stress Area of Screw — Ref. 7, Pg. 4-147

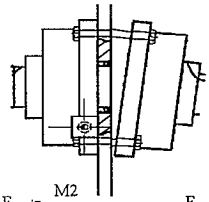
$F_u := 100000 \cdot psi$ — Ultimate Tensile Strength of A193 Class2 B8T Stainless Steel Fasteners

$S_{all} := 0.17 \cdot F_u$ $\quad S_{all} = 1.7 \cdot 10^4 \cdot psi$ — Allowable shear strength of screws — Ref. 7, Pg. 4-5

$S_{act} := \frac{B3}{n_b \cdot A_T}$ $\quad S_{act} = 3.148 \cdot 10^3 \cdot psi$ — Calculated shear stress

$\frac{S_{all}}{S_{act}} = 5.4$ — Safety factor > 5 *OK*

*Tensile*



$n_b := 2$ — Number of Screws stressed by Moment — Ref. 33.5, Sh. 3

$d := 5.125 \cdot in$ — Center to center distance of housing bolts. — Ref. 27, Page 186

$y := \frac{d}{2}$ — Housing base edge to screw $C_L$ distance to determine maximum prying stress.

$F_T := \frac{M2}{n_B \cdot y}$ $\quad F_T = 1.344 \cdot 10^3 \cdot lbf$ — Tension on Screws resulting from combined moment on housing

$T_{act} := \frac{F_T}{n_b \cdot A_T}$ $\quad T_{act} = 2.973 \cdot 10^3 \cdot psi$ — Calculated Tensile stress at each screw

$T_{all} := 0.33 \cdot F_u$ — Allowable Yield Strength in Tension — Ref. 7, Pg. 4-3

$\frac{T_{all}}{T_{act}} = 11.098$ — Safety factor > 5 *OK*

## Design of Reel Axle

$W_{Hub} := 4290 \cdot lbf$ — Weight on the Reel Hub

$R := 10.375 \cdot in$ — Outer radius of reel plus 18 layers of 1/4" x 1- 1/2" flat wire rope wraped on the reel.

$T := W_{Hub} \cdot R \qquad T = 4.451 \cdot 10^4 \cdot in \cdot lbf$ — Applied Torsional Moment on winch axle

$M_b := 7851 \cdot lbf \cdot in$ — Maximum Bending Moment

### *Determination of Torsion on a Shaft of Varying Diameters*

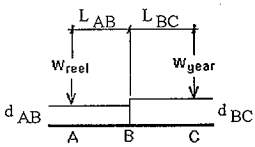
Ref. 14, Page 74.

$L_{AB} := (4.61 + 3.435) \cdot in \qquad L_{BC} := 1.625 \cdot in$ — Shaft Section Lengths

$d_{AB} := 1.9375 \cdot in \qquad d_{BC} := 2 \cdot in$ — Shaft Diameters

$Gs = Gb$ — Modulus of Rigidity

$\theta = \left(\frac{T \cdot L}{G} \cdot \frac{32}{\pi \cdot d^4}\right)$ — Twist Angle




**Equation 1**

$$\theta_{AB} = \theta_{BC}$$

$$\left(\frac{T_{AB} \cdot L_{AB}}{Gs} \cdot \frac{32}{\pi \cdot d_{AB}^4}\right) = \left(\frac{T_{BC} \cdot L_{BC}}{Gb} \cdot \frac{32}{\pi \cdot d_{BC}^4}\right)$$

$$\left(\frac{T_{AB} \cdot L_{AB}}{d_{AB}^4}\right) = \left(\frac{T_{BC} \cdot L_{BC}}{d_{BC}^4}\right)$$

$$\frac{T_{AB}}{T_{BC}} = x := \left(\frac{L_{BC}}{L_{AB}}\right) \cdot \left(\frac{d_{AB}^4}{d_{BC}^4}\right) \qquad x = 0.178$$

$$T_{AB} = T_{BC} \cdot x$$

**Equation 2**

$$T_{AB} + T_{BC} = T = 4.451 \cdot 10^4 \cdot lbf \cdot in$$

$$T_{AB} = T - T_{BC}$$

---

$$T_{AB} = T_{AB}$$

$$T_{BC} \cdot x = T_{applied} - T_{BC}$$

$$(T_{BC} \cdot x) + T_{BC} = T_{applied}$$

$$T_{BC} \cdot (x + 1) = T_{applied}$$

$T_{BC} := \frac{T}{(x + 1)} \qquad T_{BC} = 3.779 \cdot 10^4 \cdot lbf \cdot in$ — Torsion on Section B

$T_{AB} := T_{BC} \cdot x \qquad T_{AB} = 6.722 \cdot 10^3 \cdot lbf \cdot in$ — Torsion on Section A

**DESIGN ANALYSIS**

| | | | | | |
|---|---|---|---|---|---|
| Client | WESTINGHOUSE HANFORD COMPANY | WO/Job No. | ER4319 | Filename | WIN-11.mcd |
| Subject | WINCH ANALYSIS - SLURRY/SLUICE PUMP | Date | 9 / 8 / 95 | By | D.L. STONE |
| | PROJECT W-320 WASTE RETRIEVAL for TANK 241-C-106 | Checked | 9/8/95 | By | M.R. CUSTER MRC |
| Location | C TANK FARM - HANFORD 200 EAST AREA | Revised | | By | |

**Design of Reel Axle ,** ***(continued.....)***

$S_y := 120000 \cdot \frac{lbf}{in^2}$ — Yield Strength of ASTM A291-92, Class B Steel

$S_{allC} := 0.30 \cdot S_y$ $\quad S_{allC} = 3.6 \cdot 10^4 \cdot \frac{lbf}{in^2}$ — Maximum Allowable Shearing Stress for Combined Torsion and Bending — Ref. 8, Pg 270 ((b), Below Table 2)

$P_t := 0.75 \cdot S_{allC}$ $\quad P_t = 2.7 \cdot 10^4 \cdot \frac{lbf}{in^2}$ — Maximum Allowable Stress for Solid Shafts using Keyways — Ref. 8, Pg 270

$B := 1$ — B defines hollow shafts and is assumed as 1 for solid shafts. — Ref, 8, Pg 270 (Below Table 3)

$K_t := 1.0$

$K_m := 1.5$ — Combined Shock and Fatigue factors for Steady, gradually applied, loading — Ref. 8, Pg 270, Table 1

$$D_c := B \cdot \left[ \frac{5.1}{P_t} \cdot \left[ (K_m \cdot M_b)^2 + (K_t \cdot T_{BC})^2 \right]^{\frac{1}{2}} \right]^{\frac{1}{3}}$$

$D_c = 1.955 \cdot in$ — Minimum Required Shaft Diameter for Combined Bending and Torsional Loading — Ref. 8, Pg. 269,(3a)

$D_{act} := 1.9375 \cdot in$ — Design Shaft Diameter

$D_{act} \geq D_c$ ***OK*** — Acceptance Criteria for Minimum Shaft Diameter

DESIGN ANALYSIS

| | | | | | |
|---|---|---|---|---|---|
| Client | WESTINGHOUSE HANFORD COMPANY | WO/Job No. | ER4319 | Filename | WIN-11.mcd |
| Subject | WINCH ANALYSIS - SLURRY/SLUICE PUMP | Date | 9 / 8 / 95 | By | D.L. STONE |
| | PROJECT W-320 WASTE RETRIEVAL for TANK 241-C-106 | Checked | 9/8/95 | By | M.R. CUSTER MRC |
| Location | C TANK FARM - HANFORD 200 EAST AREA | Revised | | By | |

**Key stress**

Key, Reel and Spur Gear (typical) = 1/2 " x 1/2" x 4.75 ". Ref. 33.5, Page 5

$F_{ky} := 100000 \cdot \frac{lbf}{in^2}$ Yield Strength for (ASTM A 276-94b, Type 304, Condiiton B)

$SA_{ky} := 0.577 \cdot F_{ky}$ $SA_{ky} = 5.77 \cdot 10^4 \cdot psi$ Allowable Shear Stress Ref. 11, Page 370

| Reel | Spur Gear | |
|---|---|---|
| $A_{kyr} := (0.50 \cdot in) \cdot (3.75 \cdot in)$ | $A_{kyg} := (0.50 \cdot in) \cdot (4.75 \cdot in)$ | |
| $A_{kyr} = 1.875 \cdot in^2$ | $A_{kyg} = 2.375 \cdot in^2$ | Area of key cross section |
| $d_{AB} := 1.9375 \cdot in$ | $d_{BC} := 2 \cdot in$ | Shaft Diameters |
| $r_r := \frac{d_{AB}}{2}$ | $r_g := \frac{d_{BC}}{2}$ | Shaft Radius |
| $F_{kyr} := \frac{T_{AB}}{r_r}$ $F_{kyr} = 6.939 \cdot 10^3 \cdot lbf$ | $F_{kyg} := \frac{T_{BC}}{r_g}$ $F_{kyg} = 3.779 \cdot 10^4 \cdot lbf$ | Force on key |
| $S_{kyr} := \frac{F_{kyr}}{A_{kyr}}$ $S_{kyr} = 3.701 \cdot 10^3 \cdot \frac{lbf}{in^2}$ | $S_{kyg} := \frac{F_{kyg}}{A_{kyg}}$ $S_{kyg} = 1.591 \cdot 10^4 \cdot \frac{lbf}{in^2}$ | Stress on key |
| $SF_r := \frac{SA_{ky}}{S_{kyr}}$ | $SF_g := \frac{SA_{ky}}{S_{kyg}}$ | |
| $SF_r = 15.591$ > 3 ***OK*** | $SF_g = 3.627$ > 3 ***OK*** | Safety factor |

**DESIGN ANALYSIS**

| | | | | | |
|---|---|---|---|---|---|
| Client | WESTINGHOUSE HANFORD COMPANY | WO/Job No. | ER4319 | Filename | WIN-12.mcd |
| Subject | WINCH ANALYSIS - SLURRY/SLUICE PUMP | Date | 9 / 8 / 95 | By | D.L. STONE |
| | PROJECT W-320 WASTE RETRIEVAL for TANK 241-C-106 | Checked | 9/8/95 | By | M.R. CUSTER MRC |
| Location | C TANK FARM - HANFORD 200 EAST AREA | Revised | | By | |

## Loading on Circular Hub

### Forces / Moments on Reel Hub

$W_{Hub} := 4290 \cdot lbf$ — Weight on Reel Hub

$T := 44510 \cdot lbf \cdot in$ — Torsional Moment

---

$Tension := W_{Hub}$ — $Tension = 4.29 \cdot 10^3 \cdot lbf$ — Tension on Rope

$d := 1.5 \cdot in$ — Rope Diameter (Width of Flat Wire Rope) — Ref. 33.1

$D := 11.75 \cdot in$ — Hub (Drum) Diameter — Ref. 33.5, Page 6

$P := \frac{2 \cdot Tension}{D \cdot d}$ — $P = 486.809 \cdot \frac{lbf}{in^2}$ — Radial Pressure — Ref. 8, Pg. 334

$h := (2.255) \cdot in$ — Hub Thickness (Radial)

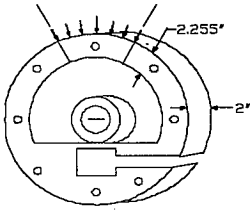
$D_m := (11.75 \cdot in - h)$ — $D_m = 9.495 \cdot in$ — Hub Mean Diameter

$circ := \pi \cdot D_m$ — $circ = 29.829 \cdot in$ — Hub Circumference at mean Diameter

$F_{rad} := P \cdot d$ — $F_{rad} = 730.213 \cdot \frac{lbf}{in}$ — Distributed Force due to Radial Pressure — Ref. 33.5, Sh. 4

### Forces and Moment on Reel Hub

Stresses on curved beam are calculated using the standard straight beam formula, S = Mc / I , multiplied by a Stress Correction Factor, K . This calculation considers the initial straight beam length to be the distance between bolts, or 1/8 of the hub circumference.




$$+\uparrow \sum F = 0 = \quad W_{Hub} + F_{rad} \cdot \left(\frac{circ}{8}\right) - R_1 - R_2$$

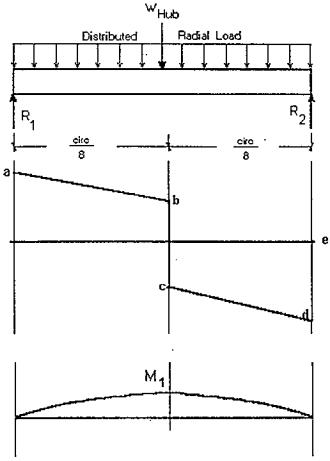
$$\circlearrowleft + \sum M = 0 = \quad R_2 \cdot \left(\frac{circ}{8}\right) - W_{Hub} \cdot \left(\frac{circ}{16}\right) - F_{rad} \cdot \left(\frac{circ}{8}\right) \cdot \left(\frac{circ}{16}\right)$$

$R_1$

$$R_2 := \frac{W_{Hub} \cdot \left(\frac{circ}{16}\right) + F_{rad} \cdot \left(\frac{circ}{8}\right) \cdot \left(\frac{circ}{16}\right)}{\left(\frac{circ}{8}\right)} \qquad R_2 = 3.506 \cdot 10^3 \cdot lbf$$

$$R_1 := W_{Hub} + F_{rad} \cdot \left(\frac{circ}{8}\right) - R_2 \qquad R_1 = 3.506 \cdot 10^3 \cdot lbf$$

## Bending Moments for Hub as a Straight Beam




$a := R_1$ $\quad a = 3.506 \cdot 10^3 \cdot lbf$

$b := a - F_{rad} \cdot \left(\frac{circ}{16}\right)$ $\quad b = 2.145 \cdot 10^3 \cdot lbf$

$c := b - W_{Hub}$ $\quad c = -2.145 \cdot 10^3 \cdot lbf$

$d := c - F_{rad} \cdot \left(\frac{circ}{16}\right)$ $\quad d = -3.506 \cdot 10^3 \cdot lbf$

$e := d + R_2$ $\quad e = 0 \cdot lbf$

Maximum Bending Moment for Hub as a Straight Beam

$$M_1 := b \cdot \left(\frac{circ}{16}\right) + \frac{(a - b) \cdot \left(\frac{circ}{16}\right)}{2} \qquad M_1 = 5.268 \cdot 10^3 \cdot lbf \cdot in$$

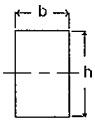
Ref 8, Page 242

Calculated Straight Beam Stress

$b := 2 \cdot in$ Hub "Length" (Axial)

$h = 2.255 \cdot in$ Hub Width (Radial)

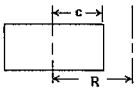
$I := \frac{b \cdot h^3}{12}$ $\quad I = 1.911 \cdot in^4$ Moment of Inertia




Parameters for determination of Stress Correction Factor, K

Ref 8, Page 243

$c := \frac{h}{2}$ $\quad R := \frac{D}{2} - c$ $\quad \frac{R}{c} = 4.211$




Interpolation of correction factor for inside fiber

$A_i = 4$ $\quad a_i = 1.2$ $\quad x_i := \frac{A_i - B_i}{A_i - C_i} \cdot (a_i - c_i)$

$B_i = 4.211$ $\quad b_i$

$C_i = 6$ $\quad c_i = 1.12$ $\quad b_i := a_i - x_i$ $\quad b_i = 1.192$

Ref 8, Page 242

**DESIGN ANALYSIS**

| | | | | | |
|---|---|---|---|---|---|
| Client | WESTINGHOUSE HANFORD COMPANY | WO/Job No. | ER4319 | Filename | WIN-12.mcd |
| Subject | WINCH ANALYSIS - SLURRY/SLUICE PUMP | Date | 9 / 8 / 95 | By | D.L. STONE |
| | PROJECT W-320 WASTE RETRIEVAL for TANK 241-C-106 | Checked | 9/8/95 | By | M.R. CUSTER MRC. |
| Location | C TANK FARM - HANFORD 200 EAST AREA | Revised | | By | |

Calculated Curved Beam Stress

$S := \frac{M_1 \cdot c}{I}$ $\quad S = 3.108 \cdot 10^3 \cdot psi$

$S_{act} := b_i \cdot S$ $\quad S_{act} = 3.703 \cdot 10^3 \cdot psi$ Maximum Stress for inner fiber of a Curved Beam

$S_y := 120000 \cdot psi$ Yield Stress for ASTM A-291-92, Class 6, (BHN = 321)

$S_{all} := 0.45 \cdot S_y$ $\quad S_{all} = 5.4 \cdot 10^4 \cdot psi$ Allowable Tensile Stress Ref. 11, Page 12

$\frac{S_{all}}{S_{act}} = 14.581$ Safety Factor > 3 ***OK***

**DESIGN ANALYSIS**

| | | | | | |
|---|---|---|---|---|---|
| Client | WESTINGHOUSE HANFORD COMPANY | WO/Job No. | ER4319 | Filename | WIN-13.mcd |
| Subject | WINCH ANALYSIS - SLURRY/SLUICE PUMP | Date | 9 / 8 / 95 | By | D.L. STONE |
| | PROJECT W-320 WASTE RETRIEVAL for TANK 241-C-106 | Checked | 9/8/95 | By | M.R. CUSTER MRC |
| Location | C TANK FARM - HANFORD 200 EAST AREA | Revised | | By | |

## Analysis of Reel Hub Connections

$W_{Hub} := 4290 \cdot lbf$ — Concentrated Vertical Load on Reel Hub

$P := 486.809 \cdot \frac{lbf}{in^2}$ — Radial Pressure

$F_{rad} := 730.213 \cdot \frac{lbf}{in}$ — Distributed Force due to Radial Pressure

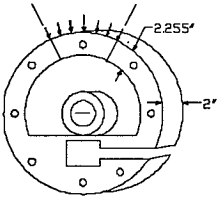
$T := 44510 \cdot lbf \cdot in$ — Torsional Moment

$b := 2 \cdot in$ — Hub Length (Axial)

$h := (2.255) \cdot in$ — Hub Thickness (Radial)

$D_m := (11.75 \cdot in - h)$ $\quad D_m = 9.495 \cdot in$ — Hub Mean Diameter

$circ := \pi \cdot D_m$ $\quad circ = 29.829 \cdot in$ — Hub Circumference



**DESIGN ANALYSIS**

| | | | | | |
|---|---|---|---|---|---|
| Client | WESTINGHOUSE HANFORD COMPANY | WO/Job No. | ER4319 | Filename | WIN-13.mcd |
| Subject | WINCH ANALYSIS - SLURRY/SLUICE PUMP | Date | 9 / 8 / 95 | By | D.L. STONE |
| | PROJECT W-320 WASTE RETRIEVAL for TANK 241-C-106 | Checked | 9/8/95 | By | M.R. CUSTER MRC |
| Location | C TANK FARM - HANFORD 200 EAST AREA | Revised | | By | |

*Check stress on 1/2 - 13 - UNC - 2A x 1-1/4 L Hex Head Screws*

Ref. 33.4, Pg. 4, Item 63

$n_b := 8$ — Number of Screws

$n := 13$ — Number of threads per inch

$D := \frac{1}{2} \cdot in$ — Major Diameter of Screw

$A_T := 0.7854 \cdot \left[\left[D - \left(\frac{0.9743}{n}\right) \cdot in\right]\right]^2$ $\quad A_T = 0.142 \cdot in^2$ — Tensile Stress Area of Screw — Ref. 7, Pg. 4-147

$F_u := 125000 \cdot psi$ — Ultimate Tensile Strength of A193 Class2 B8T Stainless Steel Fasteners

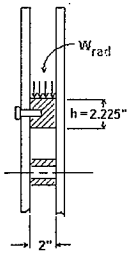
$S_{all} := 0.17 \cdot F_u$ $\quad S_{all} = 2.125 \cdot 10^4 \cdot psi$ — Allowable shear strength of screws — Ref. 7, Pg. 4-147

$W_{rad} := \frac{P \cdot circ}{n_b}$ $\quad W_{rad} = 1.815 \cdot 10^3 \cdot \frac{lbf}{in}$ — Uniform Load resulting from Radial Pressure, per screw.

$S_{act} := \frac{W_{Hub} + W_{rad} \cdot b}{n_b \cdot A_T}$ $\quad S_{act} = 6.977 \cdot 10^3 \cdot psi$ — Calculated Shear Stress — Ref. 7, Pg. 4-147

$M_{rad} := \frac{W_{rad} \cdot b^2}{12}$ $\quad M_{rad} = 605.051 \cdot lbf \cdot in$ — Moment due to radial loading.

$M_{con} := \frac{\frac{W_{Hub}}{8} \cdot b}{8}$ $\quad M_{con} = 134.063 \cdot lbf \cdot in$ — Moment due to concentrated loading.




$W_T := \frac{M_{rad} + M_{con}}{\left(\frac{h}{2}\right)}$ $\quad W_T = 655.533 \cdot lbf$ — Tensile Force on Screw

$T_{act} := \frac{W_T}{A_T}$ $\quad S_{act} = 6.977 \cdot 10^3 \cdot psi$ — Calculated Tensile stress

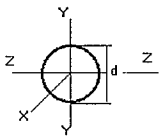
$T_{all} := .33 \cdot F_u$ $\quad T_{all} = 4.125 \cdot 10^4 \cdot psi$ — Allowable Yield Strength in Tension

$SF := \frac{S_{all}}{S_{act}} + \frac{T_{all}}{T_{act}}$ $\quad SF = 11.975$ — Safety factor > 5 — *OK*

**DESIGN ANALYSIS**

| | | | | | |
|---|---|---|---|---|---|
| Client | WESTINGHOUSE HANFORD COMPANY | WO/Job No. | ER4319 | Filename | WIN-13.mcd |
| Subject | WINCH ANALYSIS - SLURRY/SLUICE PUMP | Date | 9 / 8 / 95 | By | D.L. STONE |
| | PROJECT W-320 WASTE RETRIEVAL for TANK 241-C-106 | Checked | 9/8/95 | By | M.R. CUSTER MRC |
| Location | C TANK FARM - HANFORD 200 EAST AREA | Revised | | By | |

## Weld Stresses Resulting from Radial and Vertical Loading




**WELD PROPERTIES:** Ref. 9, Pg. 7.4 6 &7

| | | |
|---|---|---|
| $d := 11.75 \cdot in$ | | Weld Diameter |
| $Cy := \frac{d}{2}$ | $Cy = 5.875 \cdot in$ | Location of center of gravity wrt b. |
| $Cz := \frac{d}{2}$ | $Cz = 5.875 \cdot in$ | Location of center of gravity wrt d. |
| $Aw := \pi \cdot d$ | $Aw = 36.914 \cdot in$ | Weld length |
| $Swy := \frac{\pi \cdot d^2}{4}$ | $Swy = 108.434 \cdot in^2$ | Section modulus |
| $Swz := Swy$ | $Swz = 108.434 \cdot in^2$ | Section modulus |
| $Jw := \frac{\pi \cdot d^3}{4}$ | $Jw = 1.274 \cdot 10^3 \cdot in^3$ | Polar Moment of Inertia |

**JOINT LOADS:**

| | | | |
|---|---|---|---|
| Tensile | $Fx := \frac{F_{rad} \cdot 1 \cdot in}{2}$ | $Fy := W_{Hub} \cdot \sin(61.1 \cdot deg)$ | $Fz := W_{Hub} \cdot \cos(61.1 \cdot deg)$ |
| Moment | $Mx := \frac{T}{2}$ | $My := Fz \cdot \left(\frac{b}{2}\right)$ | $Mz := Fy \cdot \left(\frac{b}{2}\right)$ |

**WELD STRESS:**

$$fw := \left[\left(\frac{Fx}{Aw} + \frac{My}{Swy} + \frac{Mz}{Swz}\right)^2 + \left(\frac{Fy}{Aw} + \frac{Mx \cdot Cy}{Jw}\right)^2 + \left(\frac{Fz}{Aw} + \frac{Mx \cdot Cz}{Jw}\right)^2\right]^{0.5} \qquad fw = 266.512 \cdot \frac{lbf}{in}$$

**FILLET WELD SIZE REQUIRED:**

$S := 15800 \cdot psi$ — Allowable Weld Stress per AWS & AISC — Ref. 9, Pg. 7.4-8

$w := \frac{fw}{0.707 \cdot S}$ $\quad w = 0.024 \cdot in$ — Minimum Allowable Fillet Weld Required by Design

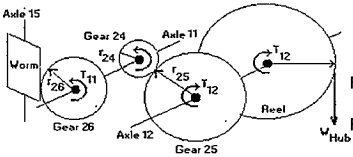
$w_{Code} := \left(\frac{5}{16} \cdot in\right)$ — Minimum Size Fillet Weld Required by Code for material thickness > 3/4". — Ref. 7, Part 5, Section J.2, Table J2.4

$SF_{fw} := \frac{w_{Code}}{w}$ $\quad SF_{fw} = 13.098$ — Safety factor > 3 — OK

**DESIGN ANALYSIS**

| | | | | | |
|---|---|---|---|---|---|
| Client | WESTINGHOUSE HANFORD COMPANY | WO/Job No. | ER4319 | Filename | WIN-14.mcd |
| Subject | WINCH ANALYSIS - SLURRY/SLUICE PUMP | Date | 9 / 8 / 95 | By | D.L. STONE |
| | PROJECT W-320 WASTE RETRIEVAL for TANK 241-C-106 | Checked | 9/8/95 | By | M.R. CUSTER MRC |
| Location | C TANK FARM - HANFORD 200 EAST AREA | Revised | | By | |

***Tooth Loading on Gears*** Ref: 33.5, Sh. 1




$r_{reel} := 10.375 \cdot in$ Maximum Radius of Coil on Reel

$r_{25} := 9 \cdot in$ Pitch Radius of Gear 25 Ref. 20, Page A 83

$r_{24} := 2 \cdot in$ Pitch Radius of Gear 24 Ref. 20, Page A 83

$r_{26} := 6 \cdot in$ Pitch Radius of Gear 26 (Worm Gear) Ref. 20, Page A 83

$r_{worm} := 2.00 \cdot in$ Pitch Radius of the WORM

$W_{Hub} := 4290 \cdot lbf$ Weight on Reel Hub

$T_{12} := W_{Hub} \cdot r_{reel}$ $T_{12} = 4.451 \cdot 10^4 \cdot lbf \cdot in$ Torsional Moment on Axle 12 imposed by Winch Reel

$F_{tran} := \frac{T_{12}}{r_{25}}$ $F_{tran} = 4.945 \cdot 10^3 \cdot lbf$ Force transmitted to Gear 24 by Gear 25

$T_{11} := F_{tran} \cdot r_{24}$ $T_{11} = 9.891 \cdot 10^3 \cdot lbf \cdot in$ Torsional Moment on Axle 11 Gear 25

$F_{worm} := \frac{T_{11}}{r_{26}}$ $F_{worm} = 1.648 \cdot 10^3 \cdot lbf$ Axial force on Worm by Gear 25

**********

*AGMA Strength Formula* Ref. 12, Page 407

$S_y := 120000$ Yield Strength for ASTM A-291-92, Class 6, BHN = 321

Interpolation of $K_L$

$A_i = 250$ $a_i = 2.4$ $x_i := \frac{A_i - B_i}{A_i - C_i} \cdot (a_i - c_i)$

$B_i = 321$ $b_i$

$C_i = 450$ $c_i = 3.4$ $b_i := a_i - x_i$ $b_i = 2.755$

$K_L := b_i$ $K_L = 2.755$ Life cycle Requirement

$Temp := 220$ Operating Temparature

$K_T := \frac{460 + Temp}{620}$ Temperature Requirement

$K_R := 1.5$ Reliability Requirement

$S := \frac{S_y \cdot K_L}{K_T K_R}$ $S = 2.01 \cdot 10^5$ Calculated Allowable Strength for Gear Teeth

**DESIGN ANALYSIS**

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| Client | WESTINGHOUSE HANFORD COMPANY | WO/Job No. | ER4319 | Filename | WIN-14.mcd |
| Subject | WINCH ANALYSIS - SLURRY/SLUICE PUMP | Date | 9 / 8 / 95 | By | D.L. STONE |
| | PROJECT W-320 WASTE RETRIEVAL for TANK 241-C-106 | Checked | 9/8/95 | By | M.R. CUSTER MRC |
| Location | C TANK FARM - HANFORD 200 EAST AREA | Revised | | By | |

Lewis Beam Strength Formula (Barth Revision) for Tooth Loading on Spur Gears

Gear 25 - *54 tooth Spur Gear on Reel Axle (12)*

$D_{25} := 18$ in — Pitch Diameter — Ref. 20. Pg. 15

$F := 3$ in — Face Width

$P := 3$ — Diametral Pitch

$Y := 0.352$ — Tooth Form Factor — Ref. 20. Pg. 137

$rpm := 1.08$ — Reel Speed

$V := 0.262 \cdot D_{25} \cdot rpm \quad V = 5.093 \frac{ft}{min}$ — Pitch Line Velocity — Ref. 20. Pg. 137

$c := 600$ — Material Constant for Metallic Gears

$W := \left[\frac{S \cdot F \cdot Y}{P} \cdot \left(\frac{c}{c+V}\right)\right] \quad W = 7.014 \cdot 10^4$ lbf — Maximum Safe (Allowable) Loading — Ref. 20. Pg. 137

$F_{all} := W \cdot lbf$

$F_{act} := \frac{T_{12}}{r_{25}} \quad F_{act} = 4.945 \cdot 10^3 \cdot lbf$

$SF := \frac{F_{all}}{F_{act}} \quad SF = 14.183$ — Safety factor > 3 OK

Lewis Beam Strength Formula (Barth Revision) for Tooth Loading on Spur Gears

Gear 24 - *12 tooth Spur Gear on Axle (11)*

$D_{24} := 4$ in — Pitch Diameter — Ref. 20. Pg. 15

$GR := \frac{54}{12}$ — Gear Ratio

$F := 4$ in — Face Width

$P := 3$ — Diametral Pitch

$Y := 0.210$ — Tooth Form Factor — Ref. 20. Pg. 137

$V := 0.262 \cdot D_{24} \cdot (GR \cdot rpm) \quad V = 5.093 \frac{ft}{min}$ — Pitch Line Velocity — Ref. 20. Pg. 137

$c := 600$ — Material Constant

$W := \frac{S \cdot F \cdot Y}{P} \cdot \left(\frac{c}{c+V}\right) \quad W = 5.579 \cdot 10^4$ lbf — Maximum Safe (Allowable) Loading — Ref. 20. Pg. 137

$F_{all} := W \cdot lbf$

$F_{act} := \frac{T_{11}}{r_{24}} \quad F_{act} = 4.945 \cdot 10^3 \cdot lbf$ — Actual Loading on Gear 24

$SF := \frac{F_{all}}{F_{act}} \quad SF = 11.282$ — Safety factor > 3 OK

**DESIGN ANALYSIS**

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|---|---|---|---|---|---|
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| Location | C TANK FARM - HANFORD 200 EAST AREA | Revised | | By | |

Worm and Worm Gear Analysis — Ref. 11

| | | | |
|---|---|---|---|
| $l := 4.767 \cdot deg$ | | Lead Angle | Ref. 20, Page A 83 |
| $f_n := 14.5 \cdot deg$ | | Pressure Angle | Ref. 20, Page A 83 |
| $m := 0.06$ | | Coefficient of friction | Ref. 11, Fig. 13-42 |
| $W_{Gt} := \frac{T_{11}}{r_{26}}$ <br> $W := W_{Gt}$ | $W_{Gt} = 1.648 \cdot 10^3 \cdot lbf$ | Transmitted Load onto the GEAR Normal to the worm-tooth profile, neglecting friction. | Ref. 11, Edition 1, Page 453 |
| $W_x := W \cdot \cos(f_n) \cdot \sin(l)$ | $W_x = 132.631 \cdot lbf$ | Tangential component of force onto the worm. | Ref. 11, Edition 5, Page 565 |
| $W_y := W \cdot \sin(f_n)$ | $W_y = 412.744 \cdot lbf$ | Radial component of force onto the worm. | |
| $W_z := W \cdot \cos(f_n) \cdot \cos(l)$ | $W_z = 1.59 \cdot 10^3 \cdot lbf$ | Axial component of force onto the worm. | |
| $W_{gt} := W \cdot (\cos(f_n) \cdot \cos(l) - m \cdot \sin(l))$ | $W_{gt} = 1.582 \cdot 10^3 \cdot lbf$ | Transmitted Load onto the GEAR Normal to the worm-tooth profile, friction considered. | Ref. 11, Edition 1, Page 454 |
| $W_{wa} := W_z - m \cdot W \cdot \sin(l)$ | $W_{wa} = 1.582 \cdot 10^3 \cdot lbf$ | Axial force on the WORM. | |
| $W_{wt} := W_x + m \cdot W \cdot \cos(l)$ | $W_{wt} = 231.197 \cdot lbf$ | Tangential force acting on the WORM. | |
| $W_{ga} := -W_{wt}$ | $W_{ga} = -231.197 \cdot lbf$ | Axial force acting on the GEAR. | Ref. 11, Edition 5, Page 565 |
| $W_{gr} := W_y = -W_{wr}$ | $W_{gr} = 412.744 \cdot lbf$ | Radial force acting on the GEAR. | |
| $W_{gt} := -W_{wa}$ | $W_{gt} = -1.582 \cdot 10^3 \cdot lbf$ | Tangential force acting on the GEAR. | |
| $T_w := r_{worm} \cdot W_{wt}$ | $T_w = 462.394 \cdot lbf \cdot in$ | Required Torsional input to the WORM. | Ref. 11, Edition 1, Page 454 |

* Due to the greater contact area and inherent strength of the worm teeth over the gear teeth, a comparative analysis of the worm Gear will be considered as a conservative comparison for the worm for this calculation.

**DESIGN ANALYSIS**

| | | | | | |
|---|---|---|---|---|---|
| Client | WESTINGHOUSE HANFORD COMPANY | WO/Job No. | ER4319 | Filename | WIN-14.mcd |
| Subject | WINCH ANALYSIS - SLURRY/SLUICE PUMP | Date | 9 / 8 / 95 | By | D.L. STONE |
| | PROJECT W-320 WASTE RETRIEVAL for TANK 241-C-106 | Checked | 9/8/95 | By | M.R. CUSTER MRC |
| Location | C TANK FARM - HANFORD 200 EAST AREA | Revised | | By | |

*Gear 26 - 36 tooth Worm Gear on Gear Axle (11)*

*Lewis Beam Strength Formula (Barth Revision)* for Tooth Loading on Spur Gears

| | | | |
|---|---|---|---|
| $D_{26} := 12$ in | | Pitch Diameter | Ref. 20, Page A 83 |
| $F := 2$ in | | Face Width | Ref. 20, Page A 83 |
| $P := 3$ | | Diametral Pitch | Ref. 20, Page A 83 |
| $Y := 0.223$ | | Tooth Form Factor | Ref. 20. Pg. 137 |
| $V := 0.262 \cdot \bar{D}_{26} \cdot (GR \cdot rpm)$ | $V = 15.28 \ \frac{ft}{min}$ | Pitch Line Velocity | Ref. 20. Pg. 137 |
| $c := 600$ | | Material Constant | |
| $W := \frac{S \cdot F \cdot Y}{P} \cdot \left(\frac{c}{c+V}\right)$ | $W = 2.913 \cdot 10^4$ lbf | Maximum Safe (Allowable) Loading | Ref. 20. Pg. 137 |
| $F_{all} := W \cdot lbf$ | | | |
| $F_{act} := \frac{T_{11}}{r_{26}}$ | $F_{act} = 4.945 \cdot 10^3 \cdot lbf$ | Actual Loading on Gear 26 | |
| $SF := \frac{F_{all}}{F_{act}}$ | $SF = 11.282$ | Safety factor > 3 OK | |

**DESIGN ANALYSIS**

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|---|---|---|---|---|---|
| Client | WESTINGHOUSE HANFORD COMPANY | WO/Job No. | ER4319 | Filename | WIN-15.mcd |
| Subject | WINCH ANALYSIS - SLURRY/SLUICE PUMP | Date | 9 / 8 / 95 | By | D.L. STONE |
| | PROJECT W-320 WASTE RETRIEVAL for TANK 241-C-106 | Checked | 9/8/95 | By | M.R. CUSTER MRC |
| Location | C TANK FARM - HANFORD 200 EAST AREA | Revised | | By | |

## Shear on Gear Axle *(11)* Bearings

$D2 := \left(6.01 \cdot \frac{lbf}{ft}\right)$ $D3 := \left(3.77 \cdot \frac{lbf}{ft}\right)$ Weight per foot of Shaft Ref. 7, Page 1-108

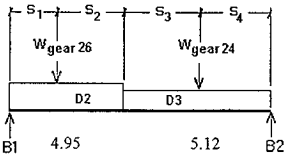
$s_1 := 3.815 \cdot in$

$s_2 := 1.135 \cdot in$

$s_3 := 1.46 \cdot in$

$s_4 := 3.66 \cdot in$

$W_{gear26} := 40 \cdot lbf$ $W_{gear24} := 11 \cdot lbf$




## Gear Shaft Forces

$+\uparrow \Sigma F = 0 = \quad B1 + B2 - D2 \cdot (4.95 \cdot in) - D3 \cdot (5.12 \cdot in) - W_{gear24} - W_{gear26}$

$\circlearrowleft \Sigma M_{B1} = 0 = (B2 \cdot 10.07 \cdot in) - \left[D2 \cdot \left(\frac{4.95 \cdot in}{2}\right)^2\right] - (D3 \cdot (5.12 \cdot in) \cdot (7.51 \cdot in)) - W_{gear24} \cdot (6.41 \cdot in) - \left(W_{gear26} \cdot 3.815 \cdot in\right)$

$$B2 := \frac{\left[D2 \cdot \left(\frac{4.95 \cdot in}{2}\right)^2\right] + D3 \cdot (5.12 \cdot in) \cdot ((7.51 \cdot in)) + W_{gear24} \cdot (6.41 \cdot in) + W_{gear26} \cdot (3.815 \cdot in)}{10.07 \cdot in}$$ $B2 = 23.66 \cdot lbf$

$B1 := D2 \cdot (4.95 \cdot in) + D3 \cdot (5.12 \cdot in) + W_{gear24} + W_{gear26} - B2$ $B1 = 31.427 \cdot lbf$

## Shear

$a := B1$ $a = 31.427 \cdot lbf$

$b := a - (s_1) \cdot D2$ $b = 29.517 \cdot lbf$

$c := b - W_{gear26}$ $c = -10.483 \cdot lbf$

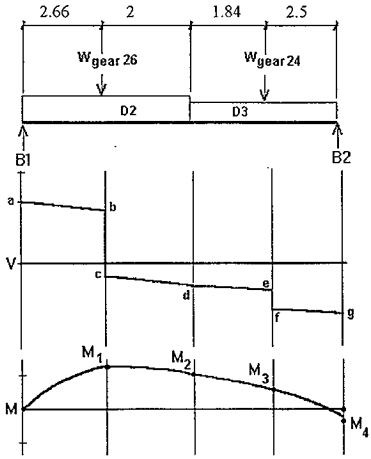
$d := c - (s_2) \cdot D2$ $d = -11.052 \cdot lbf$

$e := d - (s_3) \cdot D3$ $e = -11.51 \cdot lbf$

$f := e - W_{gear24}$ $f = -22.51 \cdot lbf$

$g := f - (s_4) \cdot D3$ $g = -23.66 \cdot lbf$

$h := -(g + B2)$ $h = -3.534 \cdot 10^{-15} \cdot lbf \approx 0$



DESIGN ANALYSIS

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|---|---|---|---|---|---|
| Client | WESTINGHOUSE HANFORD COMPANY | WO/Job No. | ER4319 | Filename | WIN-15.mcd |
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Maximum Bending Moment on the Shaft

$$M_1 := b\cdot(s_1) + \left[\frac{(a-b)\cdot s_1}{2}\right] \qquad M_1 = 116.251\cdot lbf\cdot in$$ <---------- Maximum Bending Moment

$$M_2 := M_1 + \left[c\cdot(s_2) + \frac{(d-c)\cdot(s_2)}{2}\right] \qquad M_2 = 104.03\cdot lbf\cdot in$$

$$M_3 := M_2 + \left[d\cdot(s_3) + \frac{(e-d)\cdot(s_3)}{2}\right] \qquad M_3 = 87.56\cdot lbf\cdot in$$

$$M_4 := M_3 + \left[f\cdot(s_4) + \frac{(g-f)\cdot(s_4)}{2}\right] \qquad M_4 = 3.068\cdot lbf\cdot in$$

Equivalent Radial load - Radial Ball Bearings

Pillow Block, RSAO (1-3/16" Shaft Diameter) — Ref. 27, Pg. 174

Bearing, GN103KRRB — Ref. 27, Pg. 144

$C_o := 3550\cdot lbf$ — Published STATIC LOAD RATING (Maximum Permissible Radial Load) Ref. 27, Pg. 174

$i_B := 1$ — Number of adjacently mounted bearings.

$\frac{221}{2} = 110.5$

$R := B1$ — Maximum APPLIED RADIAL LOAD on Bearings

$Thr := \frac{231.197}{2}\cdot lbf$ — APPLIED THRUST LOAD on Bearing

$K_{Thr} := \frac{Thr}{i_B\cdot C_o}$ $\quad K_{Thr} = 0.033$ — Relative Thrust Load Factor for Ball Bearings — Ref. 27, Pg. E-50, Table 1

$Y_1 := 2.00$ — Thrust Load Factor for Ball Bearings (from Table 2) — Ref. 27, Pg. E-51, Table 2

For Single Row WIDE INNER RING BALL BEARINGS

Equivalent Radial Load on Bearing is the Larger result of the two following Formulas

$P := R \qquad P = 31.427\cdot lbf$

$P := 0.56\cdot R + Y_1\cdot Thr \qquad P = 248.796\cdot lbf$

Ref. 27, Pg. E-50 Table 1

$$SF := \frac{C_o}{P} = \frac{F_{all}}{F_{act}} \qquad SF = 14.269$$ Safety factor >3 ***OK***

Due to low reactions at shaft ends, bearing stress on the wall at the Flange and bolt prying stresses have been considered negligible relative to material tensile strengths.

DESIGN ANALYSIS

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**Design of Gear Axle *(11)***

$T_{11} := 9891 \cdot lbf \cdot in$ $\quad T_{11} = 9.891 \cdot 10^3 \cdot in \cdot lbf$ — Applied Torsional Moment on Axle 11

$M_b := M_1$ $\quad M_b = 116.251 \cdot lbf \cdot in$ — Maximum Bending Moment on Winch Axle

$S_y := 120000 \cdot \frac{lbf}{in^2}$ — Yield Strength for (ASTM A-291-92, Class 6, BHN = 321)

$S_{allC} := 0.30 \cdot S_y$ $\quad S_{allC} = 3.6 \cdot 10^4 \cdot \frac{lbf}{in^2}$ — Maximum Allowable Shearing Stress for Combined Torsion and Bending — Ref. 8, Pg 270 ((b), Below Table 2)

$P_t := 0.75 \cdot S_{allC}$ $\quad P_t = 2.7 \cdot 10^4 \cdot \frac{lbf}{in^2}$ — Maximum Allowable Stress for Solid Shafts using Keyways — Ref. 8, Pg 270

$B := 1$ — B factor defines hollow shafts and is assumed as 1 for solid shafts. — Ref, 8, Pg 270 (Below Table 3)

$K_t := 1.0$ $\quad K_m := 1.5$ — Combined Shock and Fatigue factors for Steady, gradually applied, loading — Ref. 8, Pg 270, Table 1

$$D_c := B \cdot \left[ \frac{5.1}{P_t} \cdot \left[ (K_m \cdot M_b)^2 + (K_t \cdot T_{11})^2 \right]^{\frac{1}{2}} \right]^{\frac{1}{3}} \quad D_c = 1.232 \cdot in$$

Required Shaft Diameter for Combined Bending and Torsional Loading — Ref. 8, Pg. 269,(3a)

$D_{act} := 1.313 \cdot in$ — Design Shaft Diameter

$D_{act} \geq D_c$ ***OK*** — Acceptance Criteria for Minimum Shaft Diameter

**DESIGN ANALYSIS**

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|---|---|---|---|---|---|
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**Key stress**

Key, Spur and Worm Gear (typical) = 3/8 " x 3/8" x 2.375 ".

$A_k := \left(\frac{3}{8}\cdot in\right)\cdot 2.375\cdot in$ $\quad A_k = 0.891\cdot in^2$ — Area of key cross section — Ref. 33.5, Sh. 5, Item 11, Sh. 1, Item 78

$F_y := 100000\cdot\frac{lbf}{in^2}$ — Yield Strength for (ASTM A 276-94b, Condiiton B, Type 304)

$S_{all} := 0.577\cdot F_y$ $\quad S_{all} = 5.77\cdot 10^4\cdot\frac{lbf}{in^2}$ — Allowable Shear Stress — Ref. 11, Pg. 370

| Worm Gear (26) | | Spur Gear (24) | | |
|---|---|---|---|---|
| $r_w := \frac{1.5}{2}\cdot in$ | | $r_s := \frac{1.1875}{2}\cdot in$ | | Shaft Radius |
| $F_{kw} := \frac{T_{11}}{r_w}$ | $F_{kw} = 1.319\cdot 10^4\cdot lbf$ | $F_{ks} := \frac{T_{11}}{r_s}$ | $F_{ks} = 1.666\cdot 10^4\cdot lbf$ | Force on key |
| $S_{kw} := \frac{F_{kw}}{A_k}$ | $S_{kw} = 1.481\cdot 10^4\cdot\frac{lbf}{in^2}$ | $S_{ks} := \frac{F_{ks}}{A_k}$ | $S_{ks} = 1.87\cdot 10^4\cdot\frac{lbf}{in^2}$ | Stress on key |
| $SF_w := \frac{S_{all}}{S_{kw}}$ | | $SF_s := \frac{S_{all}}{S_{ks}}$ | | Safety factor |
| $SF_w = 3.897$ | > 3 OK | $SF_s = 3.085$ | > 3 OK | |

**DESIGN ANALYSIS**

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|---|---|---|---|---|---|
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| Subject | WINCH ANALYSIS - SLURRY/SLUICE PUMP | Date | 9 / 8 / 95 | By | D.L. STONE |
| | PROJECT W-320 WASTE RETRIEVAL for TANK 241-C-106 | Checked | 9/8/95 | By | M.R. CUSTER MRC |
| Location | C TANK FARM - HANFORD 200 EAST AREA | Revised | | By | |

***Design of Worm Axle (15)***

$W_{gt} := 1582 \cdot lbf$ Transmitted Load onto the GEAR normal to the worm-tooth profile.

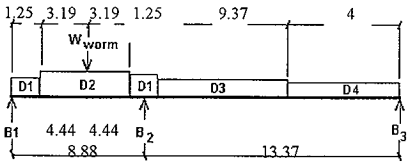
$W_w := 17 \cdot lbf$ Weight of the worm

$W_{wa} := 1582 \cdot lbf$ Axial force on the worm.

$W_{ax.max} := W_{wa} + W_w$ Maximum Thrust loading on Bearing

$W_{wt} := 231.197 \cdot lbf$ Tangential force acting on the worm

$W_{wr} := 412.744 \cdot lbf$ Radial force acting on the worm.




Load acting on bearings.

By inspection:

$M_b := 0.5 \cdot W_{wr} \cdot (4.44 \cdot in)$ $M_b = 916.292 \cdot lbf \cdot in$ Maximum Bending Moment on the Shaft

$R_w := 2 \cdot in$ Pitch Radius of the Worm

$T_w := R_w \cdot W_{wt}$ $T_w = 462.394 \cdot lbf \cdot in$ Applied Torsional Moment on the Axle

Determine Minimum Diameter of Axle Required

$S_y := 120000 \cdot \frac{lbf}{in^2}$ Safe Static Stress for.40 C. Alloy (Heat Treated) (ASTM A-291-92, Class 6, BHN = 321)

$S_{allC} := 0.3 \cdot S_y$ $S_{allC} = 3.6 \cdot 10^4 \cdot \frac{lbf}{in^2}$ Maximum Allowable Shearing Stress for Combined Torsion and Bending Ref. 8, Pg 271 ((b), Below Table 2)

$P_t := 0.75 \cdot S_{allC}$ $P_t = 2.7 \cdot 10^4 \cdot \frac{lbf}{in^2}$ Maximum Allowable Stress for Solid Shafts using Keyways Ref. 8, Pg 270

$B := 1$ B factor defines hollow shafts and is assumed as 1 for solid shafts. Ref, 8, Pg 270 (Below Table 3)

$K_t := 1.0$ $K_m := 1.0$ Combined Shock and Fatigue factors for Steady, gradually applied, loading Ref. 8, Pg 270, Table 1

$$D_c := B \cdot \left[ \frac{5.1}{P_t} \cdot \left[ (K_m \cdot M_b)^2 + (K_t \cdot T_w)^2 \right]^{\frac{1}{2}} \right]^{\frac{1}{3}}$$

$D_c = 0.579 \cdot in$ Required Shaft Diameter for Combined Bending and Torsional Loading Ref. 8, Pg. 269, (3a)

$D_{act} := (1.50) \cdot in$ Shaft Design Diameter at Worm Centerline

$D_{act} \geq D_c$ ***OK*** Acceptance Criteria for Minimum Shaft Diameter

**DESIGN ANALYSIS**

| | | | | | |
|---|---|---|---|---|---|
| Client | WESTINGHOUSE HANFORD COMPANY | WO/Job No. | ER4319 | Filename | WIN-16.mcd |
| Subject | WINCH ANALYSIS - SLURRY/SLUICE PUMP | Date | 9 / 8 / 95 | By | D.L. STONE |
| | PROJECT W-320 WASTE RETRIEVAL for TANK 241-C-106 | Checked | 9/8/95 | By | M.R. CUSTER MRC |
| Location | C TANK FARM - HANFORD 200 EAST AREA | Revised | | By | |

***Allowable Loads for Radial Tapered Roller Bearings***

Bearing: Timken TDI , Cone: 17116D, Cup: 17244, Bore Diam. 1.1875", (Ref. 26, Pg 212)

$F_t := W_{wt}$ $\quad F_t = 231.197 \cdot lbf$

$F_r := W_{wr}$ $\quad F_r = 412.744 \cdot lbf$

$F_a := \frac{W_{ax.max}}{2}$ $\quad F_a = 799.5 \cdot lbf$ APPLIED THRUST LOAD per Bearing

**********

(Ref. 26, Pg 49, 50)

$F_{rA} := \sqrt{\left(\frac{F_t \cdot 3.815 \cdot in}{7.63 \cdot in}\right)^2 + \left[\frac{F_r \cdot 3.815 \cdot in}{7.63 \cdot in} + \frac{F_a \cdot 4 \cdot in}{2 \cdot (7.63) \cdot in}\right]^2}$ $\quad F_{rA} = 431.704 \cdot lbf$ Bearing Reactions (Typical)

$K := 1.53$ Relative Thrust Load Factor for Bearings

$F_A := \frac{0.6 \cdot F_{rA}}{K} + F_a$

$P := 0.5 \cdot F_{rA} + 0.83 \cdot K \cdot F_A$ $\quad P = 1.446 \cdot 10^3 \cdot lbf$ Equivalent Radial Load for ~~Single~~ DOUBLE MRC DLS Row RADIAL TAPERED ROLLER BEARINGS (Ref. 26, Pg 40)

$P_{all} := 1.374 \cdot (18100 \cdot lbf)$ Maximum Permissible Radial Load at 175 rpm

$SF := \frac{P_{all}}{P}$ $\quad SF = 17.197$ Safety factor > 3 ***OK***

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Key stress

Key = 3/8 " x 3/8" x 2.00 ".

$A_k := \left(\frac{3}{8}\cdot in\right)\cdot 2.00\cdot in \qquad A_k = 0.75\cdot in^2$ — Area of key cross section — Ref. 33.5, Sh. 5, Item 15 and Sh. 1, Item 78

$F_y := 100000\cdot \frac{lbf}{in^2}$ — Yield Strength for (ASTM A 276-94b, Condiiton B, Type 304)

$S_{all} := 0.577\cdot F_y \qquad S_{all} = 5.77\cdot 10^4\cdot \frac{lbf}{in^2}$ — Allowable Shear Stress — Ref. 11, Pg. 370

$r_w := \frac{1.5}{2}\cdot in$ — Shaft Radius

$F_{kw} := \frac{T_w}{r_w} \qquad F_{kw} = 616.525\cdot lbf$ — Force`on key

$S_{kw} := \frac{F_{kw}}{A_k} \qquad S_{kw} = 822.034\cdot \frac{lbf}{in^2}$ — Stress on key

$SF_w := \frac{S_{all}}{S_{kw}} \qquad SF_w = 70.192$ > 3 OK — Safety factor

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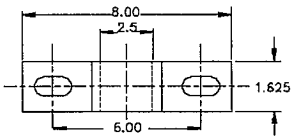
Stress on the worm axle Support Bracket

Ref. 33.5, Pg. 5, Item 20



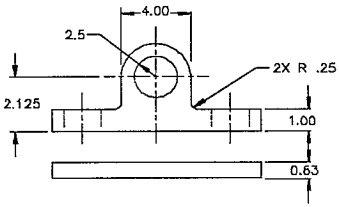

$W_{wa} = 1.582 \cdot 10^3 \cdot lbf$ Axial force transmitted to shaft at the worm

$F_{housing} := \frac{W_{wa}}{2}$ Force divided by number of bearings.

$w := 1.625 \cdot in$ Width of Housing base.

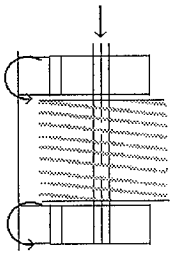
$t := 1.00 \cdot in$ Height of Housing base.

$b := 6 \cdot in$ Distance between bolts




$C_L := 2.125 \cdot in$ Distance from Mounting Block to Bearing Center Line (Moment Arm)

$M_B := W_{wa} \cdot C_L$ $M_B = 3.362 \cdot 10^3 \cdot lbf \cdot in$ Moment on the worm axle pillow blocks.



Check Stress on Bearing Housings

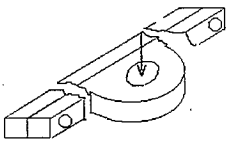
Torsion at Base

$T := \frac{M_B}{2}$ Torsion per section

$S_{act} := \frac{T}{w \cdot t^2} \cdot \left(3 + 1.8 \cdot \frac{t}{w}\right)$ $S_{act} = 4.249 \cdot 10^3 \cdot psi$ Formula to approximate torsional stress on a rectangular area. Ref. 11, Pg 55

$S_u := 145000 \cdot psi$ Ultimate stress for ASTM A291

$S_{sy} := 0.35 \cdot S_u$ Ref. P, Pg 423



$SF := \frac{S_{sy}}{S_{act}}$ $SF = 11.944$ Safety factor > 5 OK

**DESIGN ANALYSIS**

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| Location | C TANK FARM - HANFORD 200 EAST AREA | Revised | | By | |

Shear and Bending at Housing Ring

$cup := 2.46 \cdot in$ — Bearing cup Outer Diameter

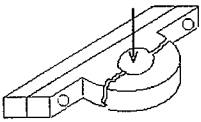
$H_D := 4.00 \cdot in$ — Bearing Housing Ring Outer Diameter

$th := \left(\frac{H_D - cup}{2}\right)$ $\quad th = 0.77 \cdot in$ — Metal Thickness at thinnest section of the bracket

$A_b := (w \cdot th) \cdot 2$ $\quad A_b = 2.502 \cdot in^2$ — Cross sectional Area at thinnest section of the bracket

$S_y := 120000 \cdot \frac{lbf}{in^2}$ — Yield stress for ASTM A291

$S_{all} := 0.4 \cdot S_y$ $\quad S_{all} = 4.8 \cdot 10^4 \cdot \frac{lbf}{in^2}$ — Allowable Shear Stress



$S_{act} := \frac{F_{housing}}{A_b}$ $\quad S_{act} = 316.084 \cdot \frac{lbf}{in^2}$ — Calculated Shear Stress

$Z := \frac{th \cdot w^2}{6}$ — Section modulus of minimum Cross sectional area

$T_{act} := \frac{M_B + M_b}{2 \cdot Z}$ $\quad T_{act} = 6.312 \cdot 10^3 \cdot psi$ — Tensile stress due to bending.

$T_{all} := 0.45 \cdot S_y$ $\quad T_{all} = 5.4 \cdot 10^4 \cdot psi$

$\frac{T_{all}}{T_{act}} = 8.555$ $\quad \frac{S_{all}}{S_{act}} = 151.858$ — Safety factor > 3 OK

**DESIGN ANALYSIS**

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***Check stress on 1/2 - 13 - UNC - 2A x 1-5/8 L Hex Head Screws***

***Shear***

Ref. 33.4, Pg. 1, Item 32

$n_b := 2$ — Number of Screws per Housing

$n_B := 2$ — Number of Bearing Housings

$n := 13$ — Number of threads per inch

$D := \frac{5}{8} \cdot in$ — Major Diameter of Screw

$A_T := 0.7854 \cdot \left[\left[D - \left(\frac{0.9743}{n}\right) \cdot in\right]\right]^2$ $\quad A_T = 0.238 \cdot in^2$ — Tensile Stress Area of Screw — Ref. 7, Pg. 4-147

$F_u := 125000 \cdot psi$ — Ultimate Tensile Strength of A193 Class2 B8T Stainless Steel Fasteners

$S_{all} := 0.17 \cdot F_u$ $\quad S_{all} = 2.125 \cdot 10^4 \cdot psi$ — Allowable shear strength of screws — Ref. 7, Pg. 4-5

$S_{act} := \frac{F_{housing}}{n_b \cdot A_T}$ $\quad S_{act} = 1.664 \cdot 10^3 \cdot psi$ — Calculated shear stress — Ref. 7, Pg. 4-147

$\frac{S_{all}}{S_{act}} = 12.768$ — Safety factor > 3 OK

Tensile

$w = 1.625 \cdot in$ — Width of Housing base.

$y := \frac{w}{2}$ — Housing base edge to screw $C_L$ distance to determine maximum prying stress.

$F_T := \frac{(M_B + M_b)}{n_B \cdot y}$ $\quad F_T = 2.633 \cdot 10^3 \cdot lbf$ — Tension on Screws resulting from combined moment on housing

$T_{act} := \frac{F_T}{n_b \cdot A_T}$ $\quad T_{act} = 5.539 \cdot 10^3 \cdot psi$ — Calculated Tensile stress at screw

$T_{all} := 0.33 \cdot F_u$ $\quad T_{all} = 4.125 \cdot 10^4 \cdot psi$ — Allowable Yield Strength in Tension — Ref. 7, Pg. 4-3

$\frac{T_{all}}{T_{act}} = 7.447$ — Safety factor > 5 OK

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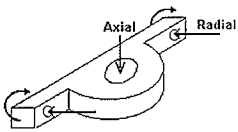
**Check Stresses in Gear Housing at Axle #15 Bearing Housings**

$W_a := 1582 \cdot lbf$ Axial force on the WORM.

$W_t := 231.197 \cdot lbf$ Tangential force acting on the WORM.

$W_r := 412.744 \cdot lbf$ Radial force .




$Base_w := 1.625 \cdot in$ Width of Bearing Housing Base Ref. 33.5, Sh.5, Item 2

$Base_L := 8.00 \cdot in$ Length of Bearing Housing Base

$th := \left(\frac{1}{2} + 0.63\right) \cdot in$ Plate Thickness

$M := W_a \cdot (3.00 \cdot in)$ $M = 4.746 \cdot 10^3 \cdot lbf \cdot in$

Shear on Housing wall due to Radial Loading

$A := Base_w \cdot th$ $A = 1.836 \cdot in^2$ Minimum Cross Sectional Area of Plate

$S_{act} := \frac{\left(\frac{W_r}{2}\right)}{A}$ $S_{act} = 112.388 \cdot psi$ Calculated shear at plate resulting due to radial load on worm.

$S_y := 36000 \cdot psi$ Yield Strength of A36 plate at at 250° F.

$S_{all} := 0.4 \cdot S_y$ $S_{all} = 1.44 \cdot 10^4 \cdot psi$ Allowable shear stress

$SF := \left(\frac{S_{all}}{S_{act}}\right)$ $SF = 128.128$ Safety factor > 3 OK

Stress in Housing Wall due to Torsional Moment resulting from axial force. Ref. 7, Pg. 4-147

$y := \frac{Base_w}{2}$ Block edge to $C_L$ distance to determine maximum prying stress.

$I := \frac{Base_L \cdot Base_w^3}{12}$ Moment of Inertia of Housing base

$B_1 := \frac{M \cdot y}{I}$ $B_1 = 1.348 \cdot 10^3 \cdot psi$ Calculated compressive shear at plate due to moment.

**DESIGN ANALYSIS**

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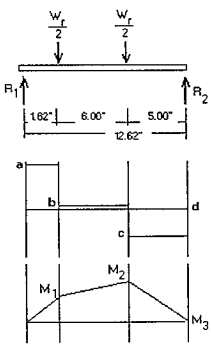
Stress in Housing Wall due to Bending Moment resulting from radial force.

$$+\uparrow \sum F = 0 = W_r - R_1 - R_2$$

$$\circlearrowleft + \sum_{R_1} M = 0 = \left(R_2 \cdot 12.62 \cdot in\right) - \left(\frac{W_r}{2}\right) \cdot 1.62 \cdot in - \left(\frac{W_r}{2}\right) \cdot 7.62 \cdot in$$

$$R_2 := \frac{\left(\frac{W_r}{2}\right) \cdot 1.62 \cdot in + \left(\frac{W_r}{2}\right) \cdot 7.62 \cdot in}{12.62 \cdot in} \qquad R_2 = 151.1 \cdot lbf$$

$$R_1 := W_r - R_2 \qquad R_1 = 261.644 \cdot lbf$$




$$a := R_1 \qquad a = 261.644 \cdot lbf$$

$$b := a - \left(\frac{W_r}{2}\right) \qquad b = 55.272 \cdot lbf$$

$$c := b - \left(\frac{W_r}{2}\right) \qquad c = -151.1 \cdot lbf$$

$$d := c + R_2 \qquad d = 0 \cdot lbf$$

Maximum Bending Moment on the Wall

$$M_1 := (a \cdot 1.62 \cdot in) \qquad M_1 = 423.864 \cdot lbf \cdot in$$

$$M_2 := M_1 + (b \cdot 6.00 \cdot in) \qquad M_2 = 755.498 \cdot lbf \cdot in$$ <---------- Maximum Bending Moment

$$M_3 := M_2 + (c \cdot 5.00 \cdot in) \qquad M_3 = -1.258 \cdot 10^{-13} \cdot lbf \cdot in \approx 0$$

$$B_{all} := 0.6 \cdot S_y \qquad B_{all} = 2.16 \cdot 10^4 \cdot psi$$ Allowable stress due to Bending — Ref. 7, Pg. 4-147

$$y := \frac{th}{2} \qquad y = 0.565 \cdot in$$ $C_L$ of plate.

$$I := \frac{th^3 \cdot (10.01 \cdot in)}{12} \qquad I = 1.204 \cdot in^4$$ Moment of Inertia of Plate cross section

$$B_2 := \frac{M_2 \cdot y}{I} \qquad B_2 = 354.645 \cdot psi$$ Calculated stress at plate due to bending

$$SF := \left(\frac{B_{all}}{B_1 + B_2}\right) \qquad SF = 12.686$$ Safety factor > 5 OK

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***Design of Drive Assembly Shaft***

$T_w := 462.394 \cdot lbf \cdot in$ — Applied Torsional Moment on the Axle

$M_b := 0 \cdot in \cdot lbf$ — Maximum Bending Moment on the Shaft

Determine Minimum Diameter of Axle Required

$S_y := 120000 \cdot \frac{lbf}{in^2}$ — Safe Static Stress for.40 C. Alloy (Heat Treated) (ASTM A-291-92, Class 6, BHN = 321)

$S_{allC} := 0.3 \cdot S_y$ $\quad S_{allC} = 3.6 \cdot 10^4 \cdot \frac{lbf}{in^2}$ — Maximum Allowable Shearing Stress for Combined Torsion and Bending — Ref. 8, Pg 270 ((b), Below Table 2)

$P_t := 0.75 \cdot S_{allC}$ $\quad P_t = 2.7 \cdot 10^4 \cdot \frac{lbf}{in^2}$ — Maximum Allowable Stress for Solid Shafts using Keyways — Ref. 8, Pg 271

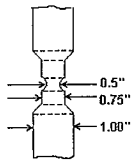
$B := 1$ — B factor defines hollow shafts and is assumed as 1 for solid shafts. — Ref, 8, Pg 270 (Below Table 3)

$K_t := 1.0$ $\quad K_m := 1.0$ — Combined Shock and Fatigue factors for Steady, gradually applied, loading — Ref. 8, Pg 270, Table 1

Ref. 8, Pg. 269,(3a)

$$D_c := B \cdot \left[ \frac{5.1}{P_t} \cdot \left[ (K_m \cdot M_b)^2 + (K_t \cdot T_w)^2 \right]^{\frac{1}{2}} \right]^{\frac{1}{3}}$$

$D_c = 0.444 \cdot in$ — Required Shaft Diameter for Combined Bending and Torsional Loading




$D_{act} := 0.75 \cdot in$ — Shaft Shaft Design Diameter

$D_{act} \geq D_c$ ***OK*** — Acceptance Criteria for Minimum Shaft Diameter

**DESIGN ANALYSIS**

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***Calculation of Force Required to Compress Nut Lock Springs***

***Weight of Upper Shaft Assembly***

$w_{1.5} := 6.01 \cdot \frac{lbf}{ft}$ Weight per ft of 1.5" A36 Rod Ref. 16

$L_{sec5} := 14.44 \cdot in$ Length of Upper Shaft Ref. 33.3, Sh. 3, Item 5

$W_1 := w_{1.5} \cdot L_{sec5}$ $W_1 = 7.232 \cdot lbf$ Weight of Upper Shaft

Weight of Drive Assembly

$w_2 := 2.67 \cdot \frac{lbf}{ft}$ Weight per ft of 1" A36 Rod Ref. 16

$L_{sec6} := 80.13 \cdot in$ Length of Drive Assembly Shaft Ref. 33.3, Sh. 3, Item 7

$W_2 := w_2 \cdot L_{sec6}$ $W_2 = 17.829 \cdot lbf$ Weight of Drive Assembly Shaft

Estimated weight of Socket

$w_{1.25} := 4.17 \cdot \frac{lbf}{ft}$ $W_3 := \left[(0.783 + 0.358) \cdot in \cdot w_{1.25}\right]$ $W_3 = 0.396 \cdot lbf$ Upper Diameter of Socket

$w_2 := 10.68 \cdot \frac{lbf}{ft}$ $W_4 := \left[(2.358 \cdot in) \cdot w_2\right]$ $W_4 = 2.099 \cdot lbf$ Lower Diameter of Socket

$W_{socket} := W_3 + W_4$ $W_{socket} = 2.495 \cdot lbf$

Weight of Nut Lock Ref. 33.5, Sh.5, Item 19

$w_{pl.375} := 16.5 \cdot \frac{lbf}{ft^2}$ Weight of 3/8" Stainless Steel Plate Ref. 16

$d := 4 \cdot in$ Nut Lock Diameter

$c := 3.91 \cdot in^2$ Hex Cutout

$A_{NL} := \frac{p \cdot d^2}{4} - c$ Total Plate Area of Nut Lock

$W_{NL} := w_{pl.375} \cdot A_{NL}$ $W_{NL} = 0.992 \cdot lbf$

Weight of Drive Guide Assembly — Ref. 33.5, Sh. 6, Item 21

$R_{cone} := 5 \cdot in$ — Cone Large Radius

$r_{cone} := 1.5 \cdot in$ — Cone Small Radius

$h_{cone} := 7.5 \cdot in$ — Cone Height

$A_{cone} := p \cdot \sqrt{(R_{cone} - r_{cone})^2 + h_{cone}^2} \cdot (R_{cone} + r_{cone})$ — Cone Area — Ref. 8, Pg 64

$A_{cone} = 169.008 \cdot in^2$

$d_{cyl} := 4 \cdot in$ — Support Cylinder Diameter

$h_{cyl} := 3.71 \cdot in$ — Support Cylinder Height

$A_{cyl} := p \cdot d_{cyl} \cdot h_{cyl}$ $\quad A_{cyl} = 46.621 \cdot in^2$ — Support Cylinder Area

$A_{SecKK} := p \cdot (4^2 - 2^2) \cdot in^2$ $\quad A_{SecKK} = 37.699 \cdot in^2$ — Area of Section K-K

$A_{DG} := A_{cone} + A_{cyl} + A_{SecKK}$ $\quad A_{DG} = 253.329 \cdot in^2$ — Total Area of Guide Assembly

$w_{569pl} := 7.5 \cdot \frac{lbf}{ft^2}$ — Weight per square ft of ASTM 569 Plate — Ref.16

$W_{DG} := A_{DG} \cdot w_{569pl}$ $\quad W_{DG} = 13.194 \cdot lbf$ — Total Weight of Guide Assembly

$W_{DA} := W_1 + W_2 + W_{socket} + W_{NL} + W_{DG}$ $\quad W_{DA} = 41.742 \cdot lbf$ — Total Weight of Drive Assembly

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| Subject | WINCH ANALYSIS - SLURRY/SLUICE PUMP | Date | 9 / 8 / 95 | By | D.L. STONE |
| | PROJECT W-320 WASTE RETRIEVAL for TANK 241-C-106 | Checked | 9/8/95 | By | M.R. CUSTER MRC |
| Location | C TANK FARM - HANFORD 200 EAST AREA | Revised | | By | |

***Spring Force***

Ref. 33.5, Pgs 1, Item 36
Pgs 5, Item 19

$L := 2.25 \cdot in$ — Length of 1/2 -13 UNC-2B x 2-1/4 L Hex Screws

$th_{bp} := 0.5 \cdot in$ — Thickness of baseplate.

$th_{nl} := 0.375 \cdot in$ — Thickness of nutlock.

$SL_{req} := L - th_{bp} - th_{nl}$ $\quad SL_{req} = 1.375 \cdot in$ — Minimum Spring length required.

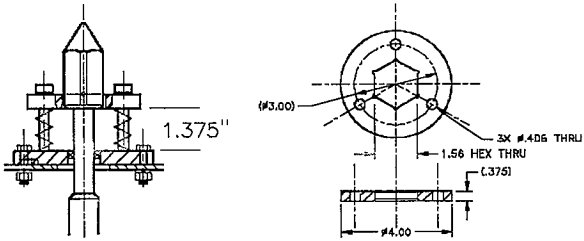
$k := 0.833 \cdot \left(53 \cdot \frac{lbf}{in}\right)$ $\quad k = 44.149 \cdot \frac{lbf}{in}$ — Spring Rate, Cat # CO600-081-2000S — Ref. 21, Page 19
Multiply Spring Rate by 0.833 for Stainless Steel

$y := \frac{3}{8} \cdot in$ $\quad y = 0.375 \cdot in$ — Length of compression (Plate thickness)

$n_s := 3$ — Number of Springs

$F := n_s \cdot k \cdot y$ $\quad F = 49.668 \cdot lbf > W_{DA}$ — Force required to compress n Springs y inches — Ref. 11, Page 9

Strength of Nutlock Bolts




$T := 0.5 \cdot T_w$ $\quad T = 231.197 \cdot lbf \cdot in$ — Estimated Torsional Moment applied at the drive shaft due to the transfer of load from Shaft 15 to the drive assembly.

$W := \frac{T}{1.5 \cdot in}$ $\quad W = 154.131 \cdot lbf$ — Force at bolt ring

$M := W \cdot (1.375 \cdot in)$ $\quad M = 211.931 \cdot lbf \cdot in$ — Applied Moment on Bolts

**DESIGN ANALYSIS**

| | | | | | |
|---|---|---|---|---|---|
| Client | WESTINGHOUSE HANFORD COMPANY | WO/Job No. | ER4319 | Filename | WIN-18.mcd |
| Subject | WINCH ANALYSIS - SLURRY/SLUICE PUMP | Date | 9 / 8 / 95 | By | D.L. STONE |
| | PROJECT W-320 WASTE RETRIEVAL for TANK 241-C-106 | Checked | 9/8/95 | By | M.R. CUSTER MRC |
| Location | C TANK FARM - HANFORD 200 EAST AREA | Revised | | By | |

***Check stress on 1/2 - 13 - UNC - 2B Fasteners***

Ref. 33.5, Pg. 5, Item 14

Shear

$n_b := 3$ — Number of Fasteners Sharing Load

$n := 13$ — Number of threads per inch

$D := \frac{1}{2} \cdot in$ — Major Diameter of Fastener

$A_T := 0.7854 \cdot \left[\left[D - \left(\frac{0.9743}{n}\right) \cdot in\right]\right]^2$ $\quad A_T = 0.142 \cdot in^2$ — Tensile Stress Area of Fastener — Ref. 7, Pg. 4-147

$F_u := 125000 \cdot psi$ — Ultimate Tensile Strength of A193 Class2 B8T Stainless Steel Fasteners

$S_{all} := 0.17 \cdot F_u$ $\quad S_{all} = 2.125 \cdot 10^4 \cdot psi$ — Allowable shear strength of Fasteners — Ref. 7, Pg. 4-5

$S_{act} := \frac{W}{n_b \cdot A_T}$ $\quad S_{act} = 362.069 \cdot psi$ — Calculated shear stress

$\frac{S_{all}}{S_{act}} = 58.691$ — Safety factor > 5 OK

Tensile Stress due to bending moment

$D := \left(\frac{1}{2}\right) \cdot in$ — Major diameter of bolt

$y := \frac{D}{2}$ — Radius of Bolt

$I := \frac{p \cdot D^4}{64}$ $\quad I = 0.003 \cdot in^4$ — Moment of Inertia of bolt

$T_{act} := \frac{M \cdot y}{n_b \cdot I}$ $\quad T_{act} = 5.757 \cdot 10^3 \cdot psi$ — Calculated Tensile stress at Fasteners

$T_{all} := 0.33 \cdot F_u$ — Allowable Yield Strength in Tension — Ref. 7, Pg. 4-3

$\frac{T_{all}}{T_{act}} = 7.166$ — Safety factor > 5 OK

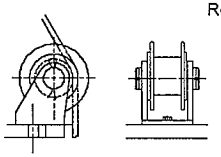
**DESIGN ANALYSIS**

| | | | | | |
|---|---|---|---|---|---|
| Client | WESTINGHOUSE HANFORD COMPANY | WO/Job No. | ER4319 | Filename | WIN-19.mcd |
| Subject | WINCH ANALYSIS - SLURRY/SLUICE PUMP | Date | 9 / 8 / 95 | By | D.L. STONE |
| | PROJECT W-320 WASTE RETRIEVAL for TANK 241-C-106 | Checked | 9/8/95 | By | M.R. CUSTER MRC |
| Location | C TANK FARM - HANFORD 200 EAST AREA | Revised | | By | |

## Design of Guide Idler

Ref. 33.5, Pg 1, View A-A

$W_T := 4290 \cdot lbf$ Tension on Wire Rope



Resolution of forces on idler axle due to loading from winch cable.
Dimension obtained from Autocad.

Ref. 31

$FH_{empty} := W_T \cdot \cos(61.1 \cdot deg)$ $FH_{empty} = 2.073 \cdot 10^3 \cdot lbf$ Maximum load condition at empty reel

$FV_{empty} := W_T \cdot \sin(61.1 \cdot deg)$ $FV_{empty} = 3.756 \cdot 10^3 \cdot lbf$

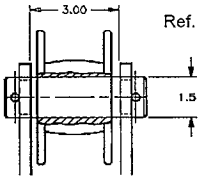
$FH_{full} := W_T \cdot \cos(76.66 \cdot deg)$ $FH_{full} = 989.828 \cdot lbf$

$FV_{full} := W_T \cdot \sin(76.66 \cdot deg)$ $FV_{full} = 4.174 \cdot 10^3 \cdot lbf$ Maximum load condition at full reel

$M_b := FH_{empty} \cdot 3.88 \cdot in$ $M_b = 8.044 \cdot 10^3 \cdot lbf \cdot in$ Moment on Bracket

## Stress on sheave axles

Ref. 33.5, Pg. 4, Item 8




Shear stress

$D := 1.5 \cdot in$ Axle Diameter

$A_a := \frac{p \cdot D^2}{4}$ $A_a = 1.767 \cdot in^2$ Cross Sectional Area

$W_{axle} := \left(\frac{W_T}{2}\right)$ $W_{axle} = 2.145 \cdot 10^3 \cdot lbf$ Force of sheave assembly felt by each shear plane.

$S_{actS} := \frac{W_{axle}}{A_a}$ $S_{actS} = 1.214 \cdot 10^3 \cdot \frac{lbf}{in^2}$ Calculated Shear Stress per axle.

$S_y := 120000 \cdot \frac{lbf}{in^2}$ Yield Strength for ASTM 291

$S_{allS} := 0.4 \cdot S_y$ $S_{allS} = 4.8 \cdot 10^4 \cdot \frac{lbf}{in^2}$ Allowable Shear Stress Ref. 11, Sec.1.8

$SF_S := \frac{S_{allS}}{S_{actS}}$ $SF_S = 39.545$ Safety factor > 3 OK

## DESIGN ANALYSIS

| | | | | | |
|---|---|---|---|---|---|
| Client | WESTINGHOUSE HANFORD COMPANY | WO/Job No. | ER4319 | Filename | WIN-19.mcd |
| Subject | WINCH ANALYSIS - SLURRY/SLUICE PUMP | Date | 9 / 8 / 95 | By | D.L. STONE |
| | PROJECT W-320 WASTE RETRIEVAL for TANK 241-C-106 | Checked | 9/8/95 | By | M.R. CUSTER MRC |
| Location | C TANK FARM - HANFORD 200 EAST AREA | Revised | | By | |

Bending stress

$D_m := 0.18 \cdot in$ — Thrust Washer Thickness (Moment arm on axle between sheave and housing.) — Ref. 33.5, Pg. 4, Item 7

$M := W_{axle} \cdot D_m$ — Moment applied to axle

$y := \frac{1.5}{2} \cdot in$ — Distance from centroidal axis to inside fiber.

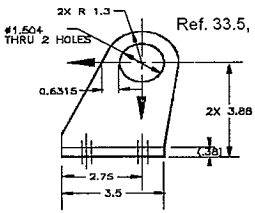
$I := \frac{p \cdot D^4}{64}$ — Axle Moment of Inertia

$B_{act} := \frac{M \cdot y}{I}$ $\quad B_{act} = 1.165 \cdot 10^3 \cdot \frac{lbf}{in^2}$ — Calculated Maximum Bending Stress per axle. — Ref.8B, Pg. 177 (Table of Simple Stresses)

$B_{all} := 0.75 \cdot S_y$ $\quad B_{all} = 9 \cdot 10^4 \cdot \frac{lbf}{in^2}$ — Allowable Bending Stress — Ref. 7, Pg 5-48 (F2-1)

$SF_B := \frac{B_{all}}{B_{act}}$ $\quad SF_B = 77.235$ — Safety factor > 3 OK

Stress on Bracket — Ref. 33.5, Pg. 4, Item 5




Shear, Horizontal

$w := 0.672 \cdot in$ — Width of Shear plane.

$th := \left(\frac{3}{8}\right) \cdot in$ $\quad th = 0.375 \cdot in$ — Plate thickness

$A := 2 \cdot (w \cdot th)$ $\quad A = 0.504 \cdot in^2$ — Area of bracket loaded by the axle.

$S_y := 30000 \cdot \frac{lbf}{in^2}$ — Yield strength of ASTM A240 Type 304

$S_{all} := (0.45) \cdot S_y$ $\quad S_{all} = 1.35 \cdot 10^4 \cdot \frac{lbf}{in^2}$ — Allowable Stress — Ref.7, Part 5, Chap. D.3.1

$S_{act} := \frac{(FH_{empty})}{A}$ $\quad S_{act} = 4.114 \cdot 10^3 \cdot \frac{lbf}{in^2}$ — Calculated stress on brackets.

$SF := \frac{S_{all}}{S_{act}}$ $\quad SF = 3.282$ — Safety factor > 3 OK

**DESIGN ANALYSIS**

| | | | | | |
|---|---|---|---|---|---|
| Client | WESTINGHOUSE HANFORD COMPANY | WO/Job No. | ER4319 | Filename | WIN-19.mcd |
| Subject | WINCH ANALYSIS - SLURRY/SLUICE PUMP | Date | 9 / 8 / 95 | By | D.L. STONE |
| | PROJECT W-320 WASTE RETRIEVAL for TANK 241-C-106 | Checked | 9/8/95 | By | M.R. CUSTER MRC |
| Location | C TANK FARM - HANFORD 200 EAST AREA | Revised | | By | |

Bearing

Ref. 33.5, Pg. 4, Item 5

$d := 1.054 \cdot in$ — Hole Diameter

$A := 2 \cdot \left(\frac{p \cdot d}{2} \cdot th\right)$ $\quad A = 1.242 \cdot in^2$ — Bearing Surface Area.

$S_y := 30000 \cdot \frac{lbf}{in^2}$ — Yield strength of ASTM A240 Type 304

$S_{all} := (0.9) \cdot S_y$ $\quad S_{all} = 2.7 \cdot 10^4 \cdot \frac{lbf}{in^2}$ — Allowable Stress

$S_{act} := \frac{FV_{full}}{A}$ $\quad S_{act} = 3.362 \cdot 10^3 \cdot \frac{lbf}{in^2}$ — Calculated stress on brackets.

$SF := \frac{S_{all}}{S_{act}}$ $\quad SF = 8.032$ — Safety factor > 3 OK

**DESIGN ANALYSIS**

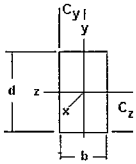
| | | | | | |
|---|---|---|---|---|---|
| Client | WESTINGHOUSE HANFORD COMPANY | WO/Job No. | ER4319 | Filename | WIN-19.mcd |
| Subject | WINCH ANALYSIS - SLURRY/SLUICE PUMP | Date | 9 / 8 / 95 | By | D.L. STONE |
| | PROJECT W-320 WASTE RETRIEVAL for TANK 241-C-106 | Checked | 9/8/95 | By | M.R. CUSTER MRC |
| Location | C TANK FARM - HANFORD 200 EAST AREA | Revised | | By | |

**Weld Strength at Base / Wall Connection**

**WELD PROPERTIES:** Ref. 9, Pg. 7.4 6 &7

$b := 0.38 \cdot in$ Weld Outline Dimension - short side

$d := 3.5 \cdot in$ Weld Outline Dimension - long side




$Cy := \frac{b}{2}$ $Cy = 0.19 \cdot in$ Location of center of gravity with respect to y axis.

$Cz := \frac{d}{2}$ $Cz = 1.75 \cdot in$ Location of center of gravity with respect to z axis.

$Aw := b \cdot d$ $Aw = 1.33 \cdot in^2$ Weld length

$Iy := \frac{b^3 \cdot d}{12}$ $Iy = 0.016 \cdot in^4$ Moment of Inertia about y axis

$Iz := \frac{b \cdot d^3}{12}$ $Iz = 1.358 \cdot in^4$ Moment of Inertia about z axis

JOINT LOADS:

Tensile $Fx := \frac{FV_{full}}{2}$ $Fy := \frac{FH_{empty}}{2}$ $Fz := 0 \cdot lbf$

Moment $Mx := 0 \cdot in \cdot lbf$ $My := 0 \cdot in \cdot lbf$ $Mz := \frac{M_b}{2}$

WELD STRESS:

$$S_{act} := \left[\left(\frac{Fx}{Aw}\right)^2 + \left(\frac{Fy}{Aw}\right)^2 + \left(\frac{Mz \cdot Cz}{Iz}\right)^2\right]^{0.5} \qquad S_{act} = 5.472 \cdot 10^3 \cdot psi$$

FILLET WELD SIZE REQUIRED:

$S_{all} := 15800 \cdot psi$ Allowable Weld Stress per AWS & AISC Ref. 9, Pg. 7.4-8

$SF := \frac{S_{all}}{S_{act}}$ $SF = 2.887$ Safety factor based on full pennetration weld $\approx$ > 3 OK

**DESIGN ANALYSIS**

| | | | | | |
|---|---|---|---|---|---|
| Client | WESTINGHOUSE HANFORD COMPANY | WO/Job No. | ER4319 | Filename | WIN-19.mcd |
| Subject | WINCH ANALYSIS - SLURRY/SLUICE PUMP | Date | 9 / 8 / 95 | By | D.L. STONE |
| | PROJECT W-320 WASTE RETRIEVAL for TANK 241-C-106 | Checked | 9/8/95 | By | M.R. CUSTER MRC |
| Location | C TANK FARM - HANFORD 200 EAST AREA | Revised | | By | |

Check stress on 3/4 - 10 - UNC - 2B Screws — Ref. 33.5, Pg. 3, Sec.C-C

Shear

$n_b := 2$ — Number of Screws per Bracket

$n := 10$ — Number of threads per inch

$D := \left(\frac{3}{4}\right)\cdot in$ — Major Diameter of Screw

$A_T := 0.7854\cdot\left[\left[D - \left(\frac{0.9743}{n}\right)\cdot in\right]\right]^2$ $\quad A_T = 0.334\cdot in^2$ — Tensile Stress Area of Screw — Ref. 7, Pg. 4-147

$F_u := 125000\cdot psi$ — Ultimate Tensile Strength of A193 Class2 B8T Stainless Steel Fasteners

$S_{all} := 0.17\cdot F_u$ $\quad S_{all} = 2.125\cdot 10^4\cdot psi$ — Allowable shear strength of screws — Ref. 7, Pg. 4-5

$S_{act} := \frac{FH_{empty}}{n_b\cdot A_T}$ $\quad S_{act} = 3.099\cdot 10^3\cdot psi$ — Calculated shear stress — Ref. 7, Pg. 4-147

$\frac{S_{all}}{S_{act}} = 6.856$ — Safety factor > 5 OK

Tensile

$y := 1.75\cdot in$ — Bracket base edge to screw $C_L$ distance to determine maximum prying stress. — Ref. 33.5, Pg. 4, Item 5

$M_b = 8.044\cdot 10^3\cdot lbf\cdot in$ — Moment on Bracket

$F_T := \frac{M_b}{y}$ $\quad F_T = 4.597\cdot 10^3\cdot lbf$ — Tension on Screws resulting from combined moment on housing

$T_{act} := \frac{F_T}{n_b\cdot A_T}$ $\quad T_{act} = 6.872\cdot 10^3\cdot psi$ — Calculated Tensile stress at screw

$T_{all} := 0.33\cdot F_u$ — Allowable Yield Strength in Tension — Ref. 7, Pg. 4-3

$\frac{T_{all}}{T_{act}} = 6.003$ — Safety factor > 5 OK

**DESIGN ANALYSIS**

| | | | | | |
|---|---|---|---|---|---|
| Client | WESTINGHOUSE HANFORD COMPANY | WO/Job No. | ER4319 | Filename | WIN-20.mcd |
| Subject | WINCH ANALYSIS - SLURRY/SLUICE PUMP | Date | 9 / 8 / 95 | By | D.L. STONE |
| | PROJECT W-320 WASTE RETRIEVAL for TANK 241-C-106 | Checked | 9/8/95 | By | M.R. CUSTER MRC |
| Location | C TANK FARM - HANFORD 200 EAST AREA | Revised | | By | |

## Forces and Moments on Winch Baseplate

Weights of winch and winch housing components.

Ref. 33.5. Pg 3

$T := 4290 \cdot lbf$ Weight of Pump and Sheave Assembly

$Axle_{12} := 610 \cdot lbf$

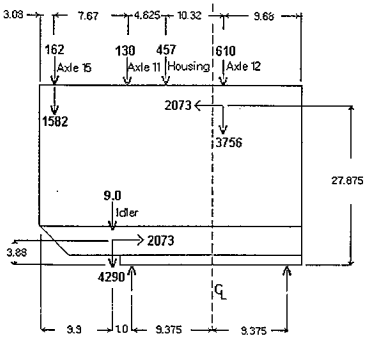
$Axle_{11} := 130 \cdot lbf$

$Axle_{15} := 162 \cdot lbf$

$Housing := 457 \cdot lbf$

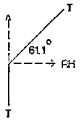
$Idler := 9 \cdot lbf$

$F_{worm} := 1582 \cdot lbf$




$RH := T \cdot \cos(61.1 \cdot deg)$ $RH = 2.073 \cdot 10^3$

$RV := T \cdot \sin(61.1 \cdot deg)$ $RV = 3.756 \cdot 10^3 \cdot lbf$




$+\downarrow \sum F = 0 =$ $F_y := F_{worm} + T + Axle_{12} + Axle_{11} + Axle_{15} + Housing + Idler$

$F_y = 7.24 \cdot 10^3 \cdot lbf$

$\circlearrowleft + \sum M = 0 =$ $M_{cL} := (T + Idler) \cdot (10.375 \cdot in) + ((RH) \cdot (27.375 - 3.88) \cdot in) + (Housing \cdot 5.945 \cdot in) \ldots$
$+ \left[ (Axle_{11} \cdot 8.37 \cdot in) + \left[ (Axle_{15} + F_{worm}) \cdot 16.04 \cdot in \right] \right] - \left[ \left[ Axle_{12} + (RV) \right] \cdot 1.95 \cdot in \right]$

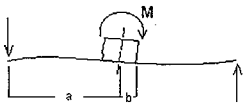
$M_{cL} = 1.166 \cdot 10^5 \cdot lbf \cdot in$

## Analysis for Stress due to central couple on a simply supported plate.

**Roark - Table 24 Case 20**

Ref. 10, Page 369

(Moment produced by eccentricity of winch is considered centrally located for this portion of the analysis and will produce conservative results.)




$a := 22.5 \cdot in$ Radius to plate edge

$b := 9.375 \cdot in$ Radial distance to winch baseplate edge

$\frac{b}{a} = 0.417$ Ratio for determination of proportionality constants.

**DESIGN ANALYSIS**

| | | | | | |
|---|---|---|---|---|---|
| Client | WESTINGHOUSE HANFORD COMPANY | WO/Job No. | ER4319 | Filename | WIN-20.mcd |
| Subject | WINCH ANALYSIS - SLURRY/SLUICE PUMP | Date | 9 / 8 / 95 | By | D.L. STONE |
| | PROJECT W-320 WASTE RETRIEVAL for TANK 241-C-106 | Checked | 9/8/95 | By | M.R. CUSTER MRC |
| Location | C TANK FARM - HANFORD 200 EAST AREA | Revised | | By | |

**Analysis for Stress due to central couple ( continued...)**

$b := 1.73$ Proportionality constant

$a := 0.167$ Proportionality constant

$M := M_{cL}$ Moment at winch baseplate centerline

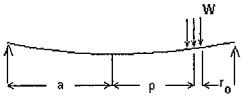
$t := 1.5 \cdot in$ Plate thickness

$E := 29 \cdot 10^6 \cdot psi$ Modlus of Elasticity of Stainless Steel

$s_w := \frac{b \cdot M}{a \cdot t^2}$ $s_w = 3.984 \cdot 10^3 \cdot psi$ Stress Resulting from moment imposed by Winch

**Analysis for Stress due to uniform loading over a small eccentric circular area of radius, $r_o$, for a simply supported plate.** Ref. 10, Page 367

**Roark - Table 24 Case 18**




$a = 22.5 \cdot in$ Radius to plate edge

$n := 0.3$ Poisson's Ratio

$p := 14 \cdot in$ Distance ffrom plate center to center of eccentric circle

$r_o := 3 \cdot in$ Radius of eccentric circle

$W := (453 + 635) \cdot lbf$ Weight at eccentric circle (Weight of hose assembly and Vertical Jumper Nozzle loading. Ref. 32

$C := 2 \cdot p \cdot a$ Winch plate Circumference

$$M_r := \frac{W}{4 \cdot p} \cdot \left[ 1 + (1 + n) \cdot \ln\left[\frac{(a - p)}{r_o}\right] - \frac{(1 - n) \cdot r_o^2}{4 \cdot (a - p)^2} \right]$$

$M_r = 201.913 \cdot \frac{lbf \cdot in}{in}$ Maximum Moment at the load.

$s_n := \frac{6 \cdot M_r}{t^2}$ $s_n = 538.435 \cdot psi$ Stress resulting from Bending moment imposed at nozzle

$S_y := 25000 \cdot (psi)$ Yield strength of ASTM A240 Type 304L

$B_{all} := 0.6 \cdot S_y$ $B_{all} = 1.5 \cdot 10^4 \cdot psi$ Allowable stress due to Bending Ref. 7, Pg. 5-49

$SF := \left(\frac{B_{all}}{s_w + s_n}\right)$ $SF = 3.317$ Safety factor > 3 OK

**DESIGN ANALYSIS**

| | | | | | |
|---|---|---|---|---|---|
| Client | WESTINGHOUSE HANFORD COMPANY | WO/Job No. | ER4319 | Filename | WIN-20.mcd |
| Subject | WINCH ANALYSIS - SLURRY/SLUICE PUMP | Date | 9 / 8 / 95 | By | D.L. STONE |
| | PROJECT W-320 WASTE RETRIEVAL for TANK 241-C-106 | Checked | 9/8/95 | By | M.R. CUSTER MRC |
| Location | C TANK FARM - HANFORD 200 EAST AREA | Revised | | By | |

Check Tensile Stress on 3/4 - 10 - UNC - 2B Fasteners

Ref. 33.4, Pg. 1, Item 33

$n_b := 2$ — Number of Fasteners

$n := 10$ — Number of threads per inch

$D := \frac{3}{4} \cdot in$ — Major Diameter of Fasteners

$A_T := 0.7854 \cdot \left[\left[D - \left(\frac{0.9743}{n}\right) \cdot in\right]\right]^2$ $\quad A_T = 0.334 \cdot in^2$ — Tensile Stress Area of Fasteners — Ref. 7, Pg. 4-147

$F_u := 125000 \cdot psi$ — Ultimate Tensile Strength of A193 Class2 B8T Stainless Steel Fasteners

$y := 18.75 \cdot in$ — Distance between fasteners to determine maximum prying stress. — Ref. 33.5, Pg.3

$F_T := \frac{(M_{cL})}{n_b \cdot y}$ $\quad F_T = 3.109 \cdot 10^3 \cdot lbf$ — Tension on each fastener resulting from combined moment on housing.

$T_{act} := \frac{F_T}{A_T}$ $\quad T_{act} = 9.295 \cdot 10^3 \cdot psi$ — Calculated Tensile stress at each fastener

$T_{all} := 0.33 \cdot F_u$ $\quad T_{all} = 4.125 \cdot 10^4 \cdot psi$ — Allowable Tensile Strength of threaded fastener — Ref. 7, Pg. 4-3

$SF := \frac{T_{all}}{T_{act}}$ $\quad SF = 4.438$ — Safety factor $\approx$ 5 OK

**DESIGN ANALYSIS**

| | | | | | |
|---|---|---|---|---|---|
| Client | WESTINGHOUSE HANFORD COMPANY | WO/Job No. | ER4319 | Filename | WIN-21.mcd |
| Subject | WINCH ANALYSIS - SLURRY/SLUICE PUMP | Date | 9 / 8 / 95 | By | D.L. STONE |
| | PROJECT W-320 WASTE RETRIEVAL for TANK 241-C-106 | Checked | 9/8/95 | By | M.R. CUSTER MRC |
| Location | C TANK FARM - HANFORD 200 EAST AREA | Revised | | By | |

## Winchplate Lifting Brackets

| | | |
|---|---|---|
| $W_{Hub} := 4290 \cdot lbf$ | Weight of Pump and Sheave Assembly | Ref. 33.5. Pg 3 |
| $Winch := 1365 \cdot lbf$ | Weight of Winch Assembly | |
| $Hose := 494 \cdot lbf$ | Weight of hose and pipe assembly at Nozzle | |
| $Winchplate := 700 \cdot lbf$ | Weight of Winchplate | |
| $Shieldplate := 453 \cdot lbf$ | Weight of Shielding plate | |

$W := W_{Hub} + Winch + Hose + Winchplate + Shieldplate \qquad W = 7.302 \cdot 10^{3} \cdot lbf$

## Stress on Lifting Bracket Bars

### Shear stress in Lifting Pins

Ref. 33.7, Pg. 2, Item 13

| | | | |
|---|---|---|---|
| $D := 2 \cdot in$ | | Bar Diameter | |
| $A_a := \frac{p \cdot D^2}{4}$ | $A_a = 3.142 \cdot in^2$ | Cross Sectional Area | |
| $W_{shear} := \left(\frac{W}{4}\right)$ | $W_{shear} = 1.826 \cdot 10^{3} \cdot lbf$ | Force of sheave assembly felt by each shear plane. | |
| $S_{actS} := \frac{W_{shear}}{A_a}$ | $S_{actS} = 581.075 \cdot psi$ | Calculated Shear Stress per axle. | |
| $S_y := 100000 \cdot \frac{lbf}{in^2}$ | | Yield Strength for ASTM 276 | |
| $S_{allS} := 0.4 \cdot S_y$ | $S_{allS} = 4 \cdot 10^{4} \cdot psi$ | Allowable Shear Stress | Ref. 11, Sec.1.8 |
| $SF_S := \frac{S_{allS}}{S_{actS}}$ | $SF_S = 68.838$ | Safety factor > 3 OK | |

**DESIGN ANALYSIS**

| | | | | | |
|---|---|---|---|---|---|
| Client | WESTINGHOUSE HANFORD COMPANY | WO/Job No. | ER4319 | Filename | WIN-21.mcd |
| Subject | WINCH ANALYSIS - SLURRY/SLUICE PUMP | Date | 9 / 8 / 95 | By | D.L. STONE |
| | PROJECT W-320 WASTE RETRIEVAL for TANK 241-C-106 | Checked | 9/8/95 | By | M.R. CUSTER MRC |
| Location | C TANK FARM - HANFORD 200 EAST AREA | Revised | | By | |

Bending stress in Lifting Pin

$L := 3.0 \cdot in$ — Span of Lifting Pin Bracket — Ref. 33.7, Pg. 2, Item 2

$M := \left(\frac{W}{2}\right) \cdot \left(\frac{L}{2}\right)$ — Maximum Moment potentially applied to axle

$y := 1 \cdot in$ — Distance from centroidal axis to inside fiber.

$I := \frac{p \cdot D^4}{64}$ — Axle Moment of Inertia

$B_{act} := \frac{M \cdot y}{I}$ $\quad B_{act} = 6.973 \cdot 10^3 \cdot \frac{lbf}{in^2}$ — Calculated Maximum Bending Stress per axle. — Ref. 8, Pg. 177 (Table of Simple Stresses)

$B_{all} := 0.75 \cdot S_y$ $\quad B_{all} = 7.5 \cdot 10^4 \cdot \frac{lbf}{in^2}$ — Allowable Bending Stress — Ref. 7, Pg 5-48, (F2-1)

$SF_B := \frac{B_{all}}{B_{act}}$ $\quad SF_B = 10.756$ — Safety factor > 3 OK

Stress on Bracket — Ref. I, Pg. 4, Item 5

Shear

$w := 0.97 \cdot in$ — Width of Shear plane.

$th := \left(\frac{1}{2}\right) \cdot in$ $\quad th = 0.5 \cdot in$ — Plate thickness

$A := 2 \cdot (w \cdot th)$ $\quad A = 0.97 \cdot in^2$ — Area of bracket loaded by the axle.

$S_y := 25000 \cdot \frac{lbf}{in^2}$ — Yield strength of ASTM A240 Type 304L

$S_{all} := (0.45) \cdot S_y$ $\quad S_{all} = 1.125 \cdot 10^4 \cdot psi$ — Allowable Stress — Ref. 7, Part 5, Chap. D.3.1

$S_{act} := \frac{W}{2 \cdot A}$ $\quad S_{act} = 3.764 \cdot 10^3 \cdot \frac{lbf}{in^2}$ — Calculated stress on brackets.

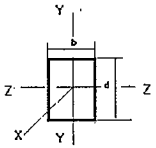
$SF := \frac{S_{all}}{S_{act}}$ $\quad SF = 2.989$ — Safety factor $\approx$ 3 OK

**DESIGN ANALYSIS**

| | | | | | |
|---|---|---|---|---|---|
| Client | WESTINGHOUSE HANFORD COMPANY | WO/Job No. | ER4319 | Filename | WIN-21.mcd |
| Subject | WINCH ANALYSIS - SLURRY/SLUICE PUMP | Date | 9 / 8 / 95 | By | D.L. STONE |
| | PROJECT W-320 WASTE RETRIEVAL for TANK 241-C-106 | Checked | 9/8/95 | By | M.R. CUSTER MRC |
| Location | C TANK FARM - HANFORD 200 EAST AREA | Revised | | By | |

**Weld Strength at Lifting Bracket Base**

**WELD PROPERTIES:**




$b := 0.5 \cdot in$ Weld Outline Dimension - short side Ref. 9, Pg. 7.4 6 &7

$d := 8 \cdot in$ Weld Outline Dimension - long side

$Aw := 2 \cdot 2 \cdot (b + d)$ $Aw = 34 \cdot in$ Weld length (2 Plates)

JOINT LOADS:

Tensile $Fx := \frac{W}{2}$ $Fy := 0 \cdot lbf$ $Fz := 0 \cdot lbf$

Moment $Mx := 0 \cdot in \cdot lbf$ $My := 0 \cdot in \cdot lbf$ $Mz := 0 \cdot in \cdot lbf$

WELD STRESS:

$fw := \left(\frac{Fx}{Aw}\right)$ $fw = 107.382 \cdot \frac{lbf}{in}$

FILLET WELD SIZE REQUIRED:

$S := 15800 \cdot psi$ Allowable Weld Stress per AWS & AISC Ref. 9, Pg. 7.4-8

$w := \frac{fw}{0.707 \cdot S}$ $w = 0.01 \cdot in$ Minimum Allowable Fillet Weld Required by Design

$w_{Code} := \left(\frac{3}{16} \cdot in\right)$ Minimum Size Fillet Weld Required by Code for material thickness of 1/2". Ref. 7, Part 5, Section J.2.2, Table J2.4

$w_{act} := \left(\frac{1}{4} \cdot in\right)$ Weld size specified in design drawings. Ref. 33.6, Pg. 2

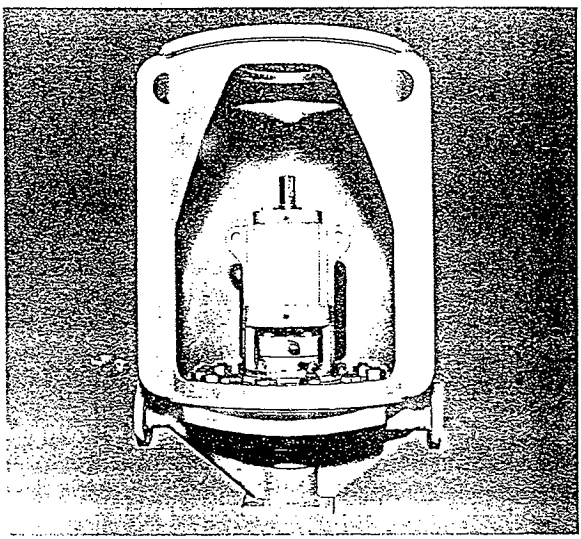
$SF_{fw} := \frac{w_{act}}{w}$ $SF_{fw} = 26.007$ Safety factor based on a 1/4" weld > 3 OK

# APPENDIX A

(NEW PUMP IN SUMP PIT) as of 6/6/95

# Series 1400
# In-Line Bearing Frame True Line Pumps

- Partial emissions hydraulics for optimum efficiency
  - Heads to 700 FT (213m) at 3550 RPM with a single stage
- 700 lb. casing
- Back Pullout feature
- Mag Drive option
- High speed designs available
- Variable speed options available



*Series 1400 2" x 2" - 13" Vertical In-Line Pump* Figure 1

## Optimized Low Flow, High Head Performance

True Line pumps from Lawrence Pumps Inc. are designed to deliver long term mechanical and hydraulic reliability for your low flow, high head applications.

- Designed to API-610 Standards
- Mechanical seal life is extended because the robust shaft design, combined with low radial loads minimizes shaft deflection
- Alignment between the pump and motor is guaranteed by a precision machined fit
- Liberal internal clearances and reduced radial thrust virtually eliminate the potential for any internal metal to metal contact
- Extreme temperature designs available (-50°F/-45°C to 700°F/370°C)
- Back Pullout feature allows ease of maintenance without disturbing the motor or connecting piping
- Seal chamber design accommodates Single, Double and Tandem mechanical seals
- Complete seal flush piping arrangements available

There are no close clearance wear rings or stuffing box bushing, and the axial clearances on both the front and back of the impeller are typically 0.035". Ultimately, the True Line design will withstand prolonged process upsets, or loss of suction, if seal lubrication is maintained.

### Improved Process Pump Performance, Reduced Total Cost of Ownership.

- High efficiency at low flows
- Stable operations at all design points
- Minimum shaft deflection at off-design flows
- Reliable performance through process upsets
- Low maintenance from high seal reliability
- True In-Line with suction and discharge flanges on same plane
- Low NPSH characteristics

LAWRENCE PUMPS INC.

## NEMA FRAMES 182HP - 449HP — (See drawings below.) - Dimensions in inches/millimeters

| FRAME | P | T | CAST IRON TERMINAL BOX AA | AB | AC | AF | AJ | AX(2) | BB | BO | BE | BF | AG STD | AG LG(5) | AH(4) | BY STD | BY LG(5) | SHAFT AND KEY Y | U(1) | EU(3) | EP(MIN) | LGTH | SQ.KEY | WT. LBS./KG. STD. | WT. LBS./KG. LG(5) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 182HP | 9.50 241 | 1.44 36.5 | .75 19 | 7.75 197 | 6.31 160 | 1.94 49.3 | 9.12 232 | 8.250 210 | .19 4.8 | 10.00 254 | .62 15.9 | .44 11.1 | 17.56 446 | 19.06 484 | 2.750 69.85 | 9.38 238 | 10.12 257 | 2.75 69.8 | 1.1250 28.575 | .875 22.22 | 1.16 29.5 | 1.28 32.5 | .250 6.35 | 120 54 | 145 65 |
| 184HP | 9.50 241 | 1.44 36.5 | .75 19 | 7.75 197 | 6.31 160 | 1.94 49.3 | 9.12 232 | 8.250 210 | .19 4.8 | 10.00 254 | .62 15.9 | .44 11.1 | 18.56 471 | 20.06 509 | 2.750 69.85 | 9.88 251 | 10.62 270 | 2.75 69.8 | 1.1250 28.575 | .875 22.22 | 1.16 29.5 | 1.28 32.5 | .250 6.35 | 130 59 | 155 70 |
| 213HP | 10.50 267 | 1.44 36.5 | 1.00 25.4 | 9.75 248 | 7.75 197 | 2.50 63.5 | 9.12 232 | 8.250 210 | .19 4.8 | 10.00 254 | .62 15.9 | .44 11.1 | 19.50 495 | 21.25 540 | 2.750 69.85 | 9.75 248 | 10.62 270 | 2.75 69.8 | 1.1250 28.575 | .875 22.22 | 1.38 35.0 | 1.28 32.5 | .250 6.35 | 175 79 | 190 86 |
| 215HP | 10.50 267 | 1.44 36.5 | 1.00 25.4 | 9.75 248 | 7.75 197 | 2.50 63.5 | 9.12 232 | 8.250 210 | .19 4.8 | 10.00 254 | .62 15.9 | .44 11.1 | 21.00 533 | 21.88 555 | 2.750 69.85 | 10.50 267 | 10.94 273 | 2.75 69.8 | 1.1250 28.575 | .875 22.22 | 1.38 35.0 | 1.28 32.5 | .250 6.35 | 200 91 | 215 97 |
| 254HP | 13.88 352 | 2.25 57.2 | 1.25 31.8 | 10.19 259 | 8.22 209 | 2.50 63.5 | 9.12 232 | 8.250 210 | .19 4.8 | 10.00 254 | .62 15.9 | .44 11.1 | 22.94 582 | — | 2.750 69.85 | 10.81 275 | — | 2.75 69.8 | 1.1250 28.575 | .875 22.22 | 1.75 44.4 | 1.28 32.5 | .250 6.35 | 215 98 | — |
| 256HP | 13.88 352 | 2.25 57.2 | 1.25 31.8 | 10.19 259 | 8.22 209 | 2.50 63.5 | 9.12 232 | 8.250 210 | .19 4.8 | 10.00 254 | .62 15.9 | .44 11.1 | 24.69 627 | — | 2.750 69.85 | 11.69 297 | — | 2.75 69.8 | 1.1250 28.575 | .875 22.22 | 1.75 44.4 | 1.28 32.5 | .250 6.35 | 245 111 | — |
| 284HP | 15.50 394 | 2.25 57.2 | 1.5 38 | 12.00 305 | 9.56 243 | 3.00 76.2 | 9.12 232 | 8.250 210 | .25 6.4 | 10.00 254 | .69 17.5 | .44 11.1 | 25.88 657 | — | 2.750 69.85 | 12.25 311 | — | 2.75 69.8 | 1.1250 28.575 | .875 22.22 | 1.75 44.4 | 1.28 32.5 | .250 6.35 | 270 122 | — |
| 286HP | 15.50 394 | 2.25 57.2 | 1.5 38 | 12.00 305 | 9.56 243 | 3.00 76.2 | 9.12 232 | 8.250 210 | .25 6.4 | 10.00 254 | .69 17.5 | .44 11.1 | 27.38 695 | — | 2.750 69.85 | 13.00 330 | — | 2.75 69.8 | 1.1250 28.575 | .875 22.22 | 1.75 44.4 | 1.28 32.5 | .250 6.35 | 320 145 | — |
| 284HPH | 15.50 394 | 2.25 57.2 | 1.5 38 | 12.00 305 | 9.56 243 | 3.00 76.2 | 14.75 375 | 13.500 343 | .25 6.4 | 16.50 492 | .88 22.2 | .69 17.5 | 25.88 657 | — | 4.500 114 | 12.25 311 | — | 4.50 114 | 1.6250 41.3 | 1.250 31.8 | 1.75 44.4 | 1.28 32.5 | .375 9.5 | 300 136 | — |
| 286HPH | 15.50 394 | 2.25 57.2 | 1.5 38 | 12.00 305 | 9.56 243 | 3.00 76.2 | 14.75 375 | 13.500 343 | .25 6.4 | 16.50 492 | .88 22.2 | .69 17.5 | 27.38 695 | — | 4.500 114 | 13.00 330 | — | 4.50 114 | 1.6250 41.3 | 1.250 31.8 | 1.75 44.4 | 1.28 32.5 | .375 9.5 | 350 159 | — |
| 324HP | 17.75 451 | 2.25 57.2 | 2 50.8 | 14.69 373 | 10.94 278 | 3.63 92.1 | 14.75 375 | 13.500 343 | .25 6.4 | 16.50 419 | .88 22.2 | .69 17.5 | 29.06 738 | — | 4.500 114 | 13.50 343 | — | 4.50 114 | 1.6250 41.275 | 1.250 31.75 | 2.12 53.8 | 3.03 77.0 | .375 9.52 | 480 218 | — |
| 326HP | 17.75 451 | 2.25 57.2 | 2 50.8 | 14.69 373 | 10.94 278 | 3.63 92.1 | 14.75 375 | 13.500 343 | .25 6.4 | 16.50 419 | .88 22.2 | .69 17.5 | 30.56 776 | — | 4.500 114 | 14.25 362 | — | 4.50 114 | 1.6250 41.275 | 1.250 31.75 | 2.12 53.8 | 3.03 77.0 | .375 9.52 | 530 240 | — |
| 364HP | 20.50 521 | 2.25 57.2 | 3 76 | 17.94 456 | 13.75 349 | 4.13 105 | 14.75 375 | 13.500 343 | .25 6.4 | 16.50 419 | .88 22.2 | .69 17.5 | 33.38 847 | — | 4.500 114 | 15.38 390 | — | 4.50 114 | 1.6250 41.275 | 1.250 31.75 | 2.25 57.2 | 3.03 77.0 | .375 9.52 | 660 299 | — |
| 365HP | 20.50 521 | 2.25 57.2 | 3 76 | 17.94 456 | 13.75 349 | 4.13 105 | 14.75 375 | 13.500 343 | .25 6.4 | 16.50 419 | .88 22.2 | .69 17.5 | 33.38 847 | — | 4.500 114 | 15.38 390 | — | 4.50 114 | 1.6250 41.275 | 1.250 31.75 | 2.25 57.2 | 3.03 77.0 | .375 9.52 | 710 322 | — |
| 404HP | 22.62 575 | 2.50 63.5 | 3 76 | 19.19 487 | 15.00 381 | 4.13 105 | 14.75 375 | 13.500 343 | .25 6.4 | 16.50 419 | .94 23.8 | .69 17.5 | 35.19 893 | — | 4.500 114 | 15.12 384 | — | 4.50 114 | 1.6250 41.275 | 1.250 31.75 | 2.25 57.2 | 3.03 77.0 | .375 9.52 | 950 431 | — |
| 405HP | 22.62 575 | 2.50 63.5 | 3 76 | 19.19 487 | 15.00 381 | 4.13 105 | 14.75 375 | 13.500 343 | .25 6.4 | 16.50 419 | .94 23.8 | .69 17.5 | 35.19 893 | — | 4.500 114 | 15.12 384 | — | 4.50 114 | 1.6250 41.275 | 1.250 31.75 | 2.25 57.2 | 3.03 77.0 | .375 9.52 | 1075 488 | — |
| 444HP | 25.50 648 | 2.50 63.5 | 3 76 | 22.13 562 | 17.37 441 | 6.00 152 | 14.75 375 | 13.500 343 | .25 6.4 | 16.50 419 | 1.06 27.0 | .69 17.5 | 40.88 1038 | — | 4.500 114 | 18.00 457 | — | 4.50 114 | 2.125 53.975 | 1.750 44.45 | 2.25 57.2 | 3.03 77.0 | .500 12.70 | 1405 637 | — |
| 445HP | 25.50 648 | 2.50 63.5 | 3 76 | 22.13 562 | 17.37 441 | 6.00 152 | 14.75 375 | 13.500 343 | .25 6.4 | 16.50 419 | 1.06 27.0 | .69 17.5 | 40.88 1038 | — | 4.500 114 | 18.00 457 | — | 4.50 114 | 2.125 53.975 | 1.750 44.45 | 2.25 57.2 | 3.03 77.0 | .500 12.70 | 1555 705 | — |
| 447HP | 25.25 641 | 2.50 63.5 | (5) | 23.37 594 | 18.12 460 | 7.00 178 | 14.75 375 | 13.500 343 | .25 6.4 | 16.50 419 | 1.06 27.0 | .69 17.5 | 49.38 1254 | — | 4.500 114 | 22.25 565 | — | 4.50 114 | 2.125 53.975 | 1.750 44.45 | 2.25 57.2 | 3.03 77.0 | .500 12.70 | 2900 1314 | — |
| 449HP | 25.25 641 | 2.50 63.5 | (5) | 23.37 594 | 18.12 460 | 7.00 178 | 14.75 375 | 13.500 343 | .25 6.4 | 16.50 419 | 1.06 27.0 | .69 17.5 | 49.38 1254 | — | 4.500 114 | 22.25 565 | — | 4.50 114 | 2.125 53.975 | 1.750 44.45 | 2.25 57.2 | 3.03 77.0 | .500 12.70 | 2900 1314 | — |

(1) "U" Varies { — up to 2.125 +.0000, —.0005 / — 2.125 and larger +.000, —.001 } 53.975 +.000, —.013 / 53.975 and larger +.00, —.03

(2) "AK" Varies { — 180 HP, —250HP, +.003, —.000 / — 280HP, —440HP +.005, —.000 } +.08, —.00 / +.13, —.00

Face runout and Eccentricity { — 182HP —445HP, .004 Max. T.I.R. / — 447HP —449HP, .007 Max. T.I.R. } .10 / .18

(3) "EU" Varies +.000, —.005 +.00, —.13

(4) "AH" Varies +.030, —.030 +.76, —.76

(5) "AA" Varies with full load amps: 4" (120 mm) @ 201 amps, 5" (127 mm) @ 335 amps, 6" (152 mm) @ 600 amps.

Maximum permissible shaft runout when measured at end of shaft extension is .002 inches (.051 mm) Max. T.I.R. (.003 inches, .076 mm on 447HP — 449HP).

If mounting clearance is required, consult factory.

# NORMAL THRUST, TEFC Above-NEMA, 350 — 400 HP

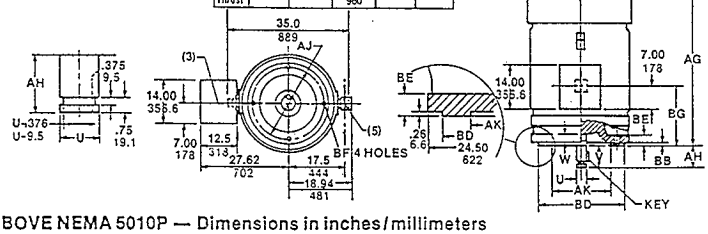
### 5010P Frame, 460 Volts

| HP | 350 | 400 |
|---|---|---|
| Full Load Speed | 3560 1773 | 3558 1773 |
| Frame Size | 5010P 5010P | 5010P 5010P |
| Up or Down Thrust | 720 720 | 720 720 |

### 5010P Frame, 2300, 4000 Volts

| HP | 200 | 250 | 300 | 350 | 400 |
|---|---|---|---|---|---|
| Full Load Speed | 1189 890 | 1783 1189 | 3571 1783 1188 | 3570 1784 | 3579 1784 |
| Frame | 5010P 5010P | 5010P 5010P | 5010P 5010P 5010P | 5010P 5010P | 5010P 5010P |
| Up or Down Thrust | 560 1120 | 720 960 | 720 720 960 | 720 720 | 720 720 |

- 5010P Frames
- 460, 2300, 4000 Volts
- 3-Phase, 60 Hz
- 1.0 S.F., Continuous Duty
- 40°C. Ambient
- Class B Insulation
- Ball Bearing
- Solid Shaft




## ABOVE NEMA 5010P — Dimensions in inches/millimeters

| FRAME | RPM (MAX.) | U(2) | V | AG | AH | AJ | AX(1) | BB | BO | BE | BG | W | BF | KEY SQ. | KEY LGTH. | WT. (LBS/KG) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5010P | 3600 | 2.375 | 6.75 | 62.5 | 6.75 | 14.75 | 13.500 | .26 | 20.00 | 1.75 | 17.94 | 4.44 | .687 | .625 | 4.00 | 6200 |
| 5010P | 3600 | 60.33 | 171 | 1587 | 171 | 374 | 343 | 6.4 | 508 | 45 | 456 | 113 | 18 | 15.88 | 102 | 2360 |
| 5010P | 1800 | 3.375 | 6.75 | 62.5 | 6.75 | 14.75 | 13.500 | .25 | 20.00 | 1.75 | 17.94 | 4.44 | .687 | .875 | 5.0 | 6200 |
| 310P | 1800 | 85.73 | 171 | 1587 | 171 | 374 | 343 | 6.4 | 508 | 45 | 456 | 113 | 18 | 22.23 | 127 | 2360 |

(1) This Dimension Varies +.005 —.000 — 13, — 00

(2) This Varies +.000, —.001, — 00 — 03

(3) Customer to drill hole in Conduit Box.

(4) Face Runout and Eccentricity .007 (.18 mm) max. T.I.R.

(5) 3/4 N.P.T. for space heater leads.

Conduit Box can be rotated 360° in 90° steps.

If mounting clearance details are required, consult factory.

Maximum permissible shaft runout when measured at end of std. shaft extension is .003 (.08 mm) T.I.R.

| MAXIMUM FULL LOAD AMPERES | AA (4)(6) PIPE TAP* |
|---|---|
| 201 | 4 |
| 335 | 5 |
| 600 | 6 |

* On 5010P frame, customer to drill hole in conduit box.

HNF-2474, Rev. 0
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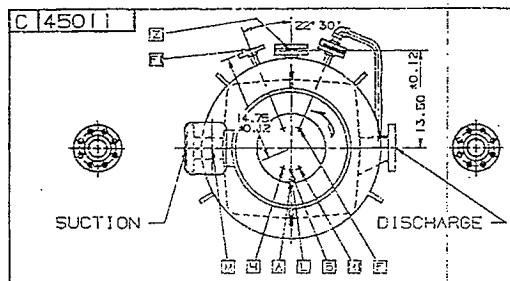
C 45011




CONNECTIONS:

- A 1/4-18 NPT - ALTERNATE LUBRICANT INLET TO THRUST BEARING (PLUGGED)
- B 1/4-18 NPT - OIL OUTLET FROM BEARING HOUSING
- F 1/2-14 NPT - INLET TO SEAL THRU API PLAN 11 FROM PUMP DISCHARGE
- E 1/2-300 LB. R.F. S.W. FLANGE - CASING VENT
- H 1/2-14 NPT - SEAL VENT
- H 1/2-14 NPT - SEAL DRAIN
- L 1/4-18 NPT - OIL MIST INLET TO BEARING HOUSING
- M MOTOR CONNECTION FOR POWER LEADS
- Z 3/4-300 LB. R.F. S.W. FLANGE - CASING DRAIN (COVERED WITH BLIND FLANGE)

WEIGHTS:

| | | |
|---|---|---|
| ① | PUMP | 800 LBS. |
| | MOTOR | 2,700 ~~1400~~ LBS. |
| | TOTAL | 3500 ~~1200~~ LBS. APPROXIMATE |

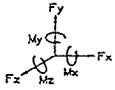
DRIVER DATA:

① 250 HP - 3500 RPM, T.E.F.C., VERTICAL ELECTRIC MOTOR, RELIANCE FRAME NO. 326TC

NOZZLE LOADS:

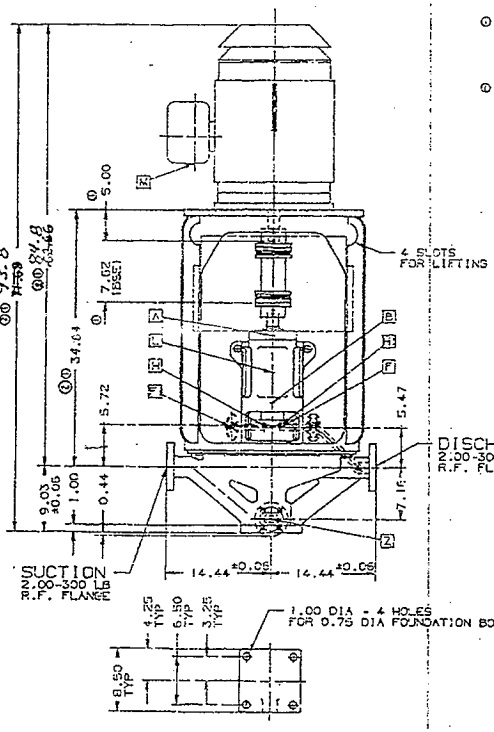
SUCTION & DISCHARGE

| | |
|---|---|
| Fx 200 LBS. | Mx 340 FT-LBS. |
| Fy 130 LBS. | My 250 FT-LBS. |
| Fz 160 LBS. | Mz 170 FT-LBS. |




NOTES:

1. FOR ASSEMBLY SEE DRAWING NO.C45010.
2. FOR PARTS LIST SEE "LIST OF COMPONENTS".
3. ALL FLANGE CONNECTIONS TO CONFORM TO A FACE FINISH OF 125 RMS.




| NO. | BY | DATE | CHK.BY | DESCRIPTION |
|---|---|---|---|---|
| 2 | RM | | BAM | DIM.S DECREASED 0.50 |
| 1 | MO | | RAM | MOTOR WAS 325 HP FRAME |

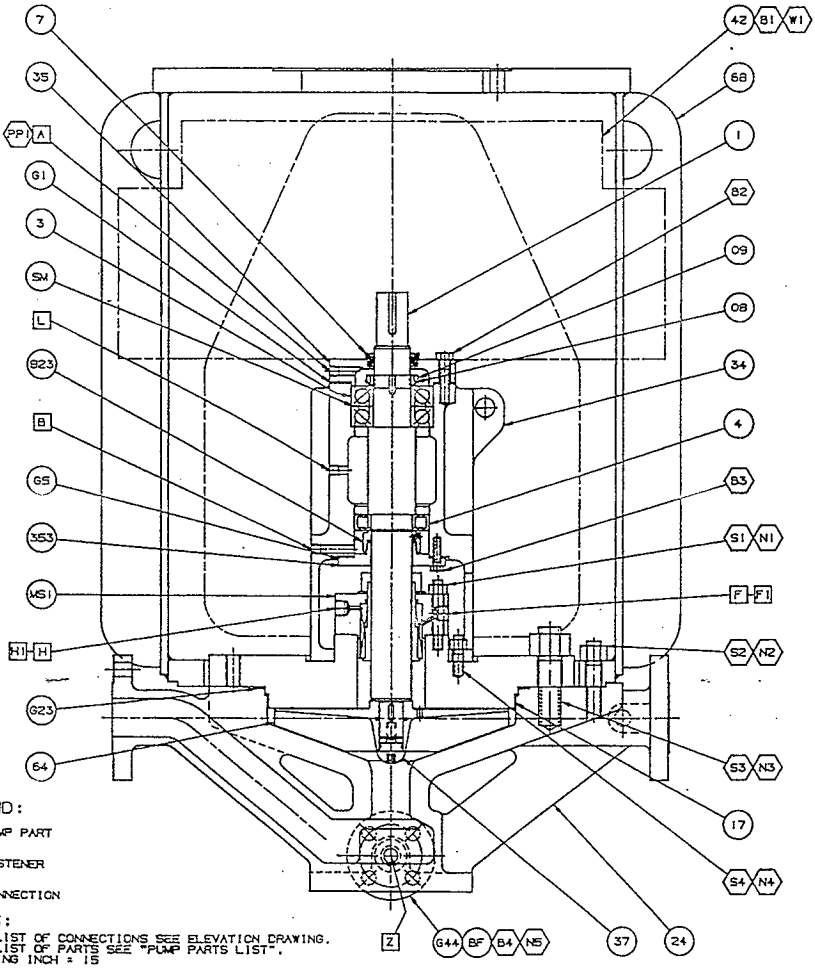
REVISIONS

LAWRENCE PUMPS INC.

TRUE-LINE SERIES

| | | |
|---|---|---|
| PUMP SIZE 2x3x10 2x3x8 1.0 | CUSTOMER: | PUMP ASSEMBLY: |
| SERIES: 1400 | PURCHASE ORDER NO.: | PUMP PARTS LIST: |
| MODEL: 14-4A | PUMP SERIAL NO.: | |
| DR.BY: TJ | PUMP ITEM NO.: | PUMP ELEVATION |
| CHK.BY: RAM 11/28/88 | | |
| APPV.BY: | CERTIFIED BY: | DRAWING NO.: C 45011 |
| DATE: 21 NOV 88 | DATE: | |

C 45010




LEGEND:

- PUMP PART
- FASTENER
- CONNECTION

NOTES:

1 FOR LIST OF CONNECTIONS SEE ELEVATION DRAWING.
2 FOR LIST OF PARTS SEE "PUMP PARTS LIST".
3 BEARING INCH = 15

| NO | BY | DATE | CHK BY | DESCRIPTION |
|---|---|---|---|---|
| 1 | DRS | 7/3 93 | REA | PT NO. SM ADDED |

REVISIONS

LAWRENCE PUMPS INC.

TRUE-LINE SERIES

| | | |
|---|---|---|
| PUMP SIZE: 2x2x13D 2x2x4 1/2D | CUSTOMER: | PUMP ELEVATION: |
| SERIES: 1400 | PURCHASE ORDER NO.: | PUMP PARTS LIST: |
| MODEL: 14-4A | PUMP SERIAL NO.: | CROSS-SECTIONAL PUMP ASSEMBLY |
| DR.BY: DT | PUMP ITEM NO.: | |
| CHK.BY: RAW 11/28/88 | | |
| APPV.BY: | CERTIFIED BY: | |
| DATE: 21, NOV 88 | DATE: | DRAWING NO.: C 45010 |

| REL. S.O. | FRAME | HP | TYPE | PHASE/ HERTZ | RPM | VOLTS |
|---|---|---|---|---|---|---|
| | [redacted] | 250 | P | 3/60 | 1785 | 460 |

| AMPS | DUTY | AMB°C/ INSUL. | S.F. | NEMA DESIGN | CODE LETTER | ENCL. FCXP-1D |
|---|---|---|---|---|---|---|
| 273 | CONT | 40/F | 1.15 | B | G | [redacted] |

| E/S | ROTOR | TEST S.O. | TEST DATE | STATOR RES.@25°C OHMS (BETWEEN LINES) |
|---|---|---|---|---|
| 533698 | 418143-31-GE | --- | --- | .0124 |

PERFORMANCE

| LOAD | HP | AMPERES | RPM | % POWER FACTOR | % EFFICIENCY |
|---|---|---|---|---|---|
| NO LOAD | 0 | 75.6 | 1800 | 3.92 | 0 |
| 1/4 | 62.5 | 100 | 1796 | 61.6 | 94.6 |
| 2/4 | 125 | 150 | 1793 | 80.8 | 96.4 |
| 3/4 | 187 | 209 | 1789 | 86.9 | 96.6 |
| 4/4 | 250 | 273 | 1784 | 89.0 | 96.4 |
| 5/4 | 312 | 341 | 1780 | 89.4 | 95.9 |
| | | | | | |

SPEED TORQUE

| | RPM | TORQUE % FULL LOAD | TORQUE LB.-FT. | AMPERES |
|---|---|---|---|---|
| LOCKED ROTOR | 0 | 158 | 1160 | 1820 |
| PULL UP | 700 | 143 | 1052 | 1660 |
| BREAKDOWN | 1728 | 247 | 1816 | 1037 |
| FULL LOAD | 1784 | 100 | 736 | 273 |

AMPERES SHOWN FOR 460. VOLT CONNECTION. IF OTHER VOLTAGE CONNECTIONS ARE AVAILABLE, THE AMPERES WILL VARY INVERSELY WITH THE RATED VOLTAGE

REMARKS: XE MOTOR-TYPICAL DATA-NEMA NOM. EFF. 96.2 PCT.
GUARANTEED MIN. EFF 95.8 PCT.

RELIANCE ELECTRIC
CLEVELAND, OHIO 44117 U.S.A.

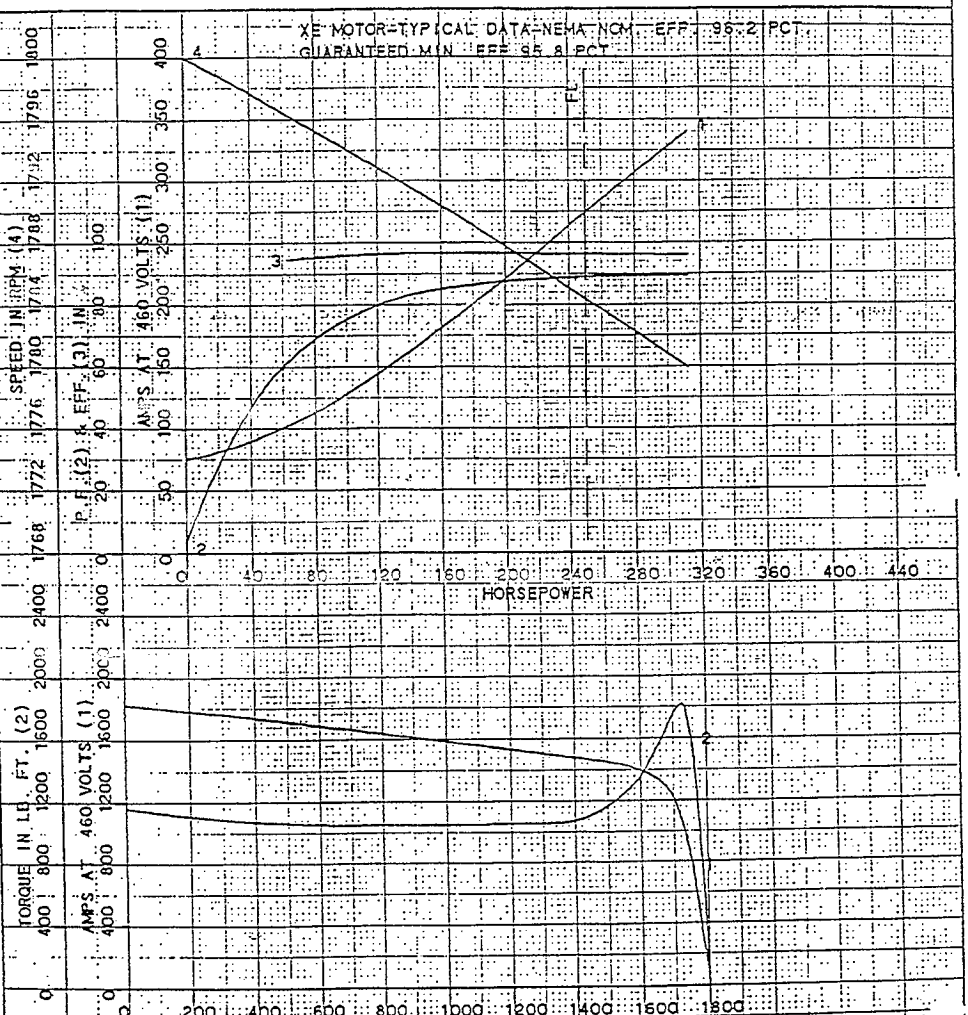
DR. BY D. MAY
CK. BY J.P. TSAO
APP. BY J.P. TSAO
DATE 01/21/81

A-C MOTOR PERFORMANCE DATA

E06854-A-A001
ISSUE DATE 06/05/84

C/R 279416

| | | | |
|---|---|---|---|
| REL S.O. | RPM 1785 | S.F. 1.15 | ROTOR 418143-31-GE |
| FRAME [redacted] | VOLTS 460 | NEMA DESIGN B | TEST S.O. --- |
| HP 250 | AMPS 273 | CODE LETTER G | TEST DATE --- |
| TYPE P | DUTY CONT | ENCLOSURE TEFC | STATOR RES.@ 25°C .0124 |
| PHASE/HERTZ 3/60 | AMB°C/INSUL 40/F | E/S 533698 | OHMS (BETWEEN LINES) |




AMPERES SHOWN FOR 460 VOLT CONNECTION, IF OTHER VOLTAGE CONNECTIONS ARE AVAILABLE, THE AMPERES WILL VARY INVERSELY WITH THE RATED VOLTAGE.

**RELIANCE ELECTRIC**
CLEVELAND, OHIO 44117 U.S.A.

DR. BY D. MAY
CK. BY J.P. TSAO
APP. BY J.P. TSAO
DATE 01/21/81

A-C MOTOR PERFORMANCE CURVES

E06854-A-A001

ISSUE DATE 06/05/84

G-33-05

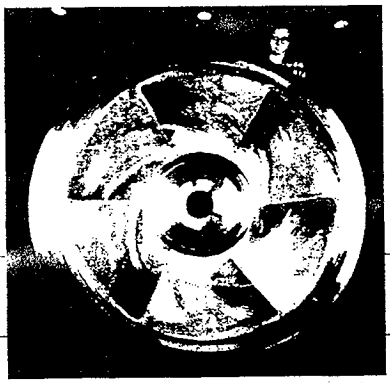
# Armco NITRONIC 60 Stainless Steel

## FIGHTS WEAR AND GALLING

- **Best galling resistance of *all* stainless steels.**
- **Corrosion resistance better than Type 304.**
- **Pitting resistance better than Type 316.**

### Applications Potential

Outstanding galling resistance at both ambient and elevated temperatures makes patented Armco NITRONIC 60 Stainless Steel a valuable material for valve stems, seats and trim; fastening systems, including nuts and bolts; screening; chain-drive systems; pins, bushings and roller bearings; and pump components such as wear rings and lobes.



*Atlas Impeller Casting of Armco NITRONIC 60 Stainless Steel.*

# ARMCO NITRONIC 60 STAINLESS STEEL (UNS S21800)

ARMCO Product Data Bulletin No. S-45

# Oxidation Resistance

NITRONIC 60 offers far superior oxidation resistance compared to AISI Types 304 and 316, and about the same oxidation resistance as AISI Type 309.

Table 28
**Static Oxidation Resistance***

| Test Temperature, F (C) | | Weight Loss, mg/cm² RA 333 | Type 310 | NITRONIC 60 | Type 304 |
|---|---|---|---|---|---|
| 2100 (1149) | Before Descaling | 3.1 | 4.6 | 16.5 | 1220 |
| | After Descaling | 12.2 | 15.7 | 23 2 | 1284 |
| 2200 (1204) | Before Descaling | 10.1 | 10.1 | 26 1 | 2260 |
| | After Descaling | 16.7 | 20.6 | 35 4 | 2265 |

*240 hours at temperature, duplicate tests

Table 29
**Cyclic Oxidation Resistance**

| Cycle | Alloy | Weight Change, mg/in², at number of cycles indicated 134 cycles | 275 cycles | 467 cycles | 200 cycles | 304 cycles | 400 cycles |
|---|---|---|---|---|---|---|---|
| 1600-1700 F (871-927 C) | RA 330 | + 3.4 | + 4 9 | + 6 4 | | — | — |
| 25 minutes heat, | Type 310 | + 4 0 | + 6 7 | · 22.7 | — | — | — |
| 5 minutes cool - | Type 309 | + 3 0 | · 41 6 | · 100 4 | — | — | — |
| duplicate tests | NITRONIC 60 | + 1 5 | · 69.2 | · 167.6 | — | — | — |
| | Type 316 | -473.0 | -970 8 | -1287.0 | — | — | — |
| | | Weight Loss, mg/cm² | | | | | |
| 1900 F (1038 C) | Type 446 | — | — | | 1.47 | 1.72 | 1 97 |
| 30 minutes heat, | Type 310 | — | — | — | 2.70 | 15.95 | 17 22 |
| 30 minutes cool | Type 309 | — | — | — | 22 53 | 26 34 | 33:69 |
| | NITRONIC 60 | — | — | — | 42 99 | 60 40 | 74.80 |
| | Type 316 | — | — | — | 93 04 | 135 34 | 178.27 |

# Mechanical Properties

Table 30
**Typical Room Temperature Tensile Properties***

| Condition | Size | Hardness | UTS ksi (MPa) | 0.2% YS ksi (MPa) | Elongation % in 4XD | Reduction of Area, % |
|---|---|---|---|---|---|---|
| Annealed | 1" (25.4 mm) ø | 95 HRB | 103 (710) | 60 (414) | 64 | 74 |
| Annealed | 1-3/4" (44.4 mm) ø | 100 HRB | 101 (696) | 56 (386) | 62 | 73 |
| Annealed | 2-1/4" (57.2 mm) ø | 100 HRB | 101 (696) | 60 (414) | 60 | 76 |
| Annealed | 3" (76.2 mm) ø | 97 HRB | 113 (779) | 65 (448) | 55 | 67 |
| Annealed | 4-1/8" (104.8 mm) ø | 95 HRB | 106 (731) | 56 (386) | 57 | 67 |
| 10% Cold Drawn | 442" (11.2 mm) ø | 24 HRC | 120 (827) | 91 (627) | 51 | 68 |
| 20% Cold Drawn | Start Size | 31 HRC | 140 (965) | 112 (772) | 35 | 65 |
| 30% Cold Drawn | | 34 HRC | 161 (1110) | 132 (910) | 26 | 62 |
| 40% Cold Drawn | | 37.5 HRC | 195 (1344) | 153 (1055) | 20 | 57 |
| 50% Cold Drawn | | 41 HRC | 217 (1496) | 174 (1200) | 15 | 53 |
| 60% Cold Drawn | | 43 HRC | 240 (1655) | 195 (1344) | 12 | 48 |
| 70% Cold Drawn | | 46 HRC | 263 (1813) | 217 (1496) | 10 | 40 |

*Data based on duplicate tests.
(1) CG bar

Table 31
**Typical Room Temperature Torsion and Shear Properties***

| Condition | Size | Hardness HRB | Torsional Modulus, G ksi (MPa) | 0.2% Torsional YS ksi (MPa) γ | 0.2% Torsional YS ksi (MPa) ε | Modulus of Rupture ksi (MPa) | Double Shear Strength ksi (MPa) |
|---|---|---|---|---|---|---|---|
| Annealed | 1" ø (25.4 mm) | 95 | $8.83 \times 10^3$ ($61 \times 10^3$) | 48.9 (337) | 50.7 (350) | 124 (855) | – |
| Annealed | 3/8" ø (9.6 mm) | 95 | – | – | – | – | 86 (593) |

*Data based on duplicate tests

Table 32
**Double Shear Strength***
**(Cold Drawn — 0.442" [11.23 mm] start size)**

| % Cold Drawn | Shear Strength, ksi (MPa) |
|---|---|
| 10 | 89 (614) |
| 20 | 98 (676) |
| 30 | 106 (731) |
| 40 | 113 (779) |
| 50 | 122 (841) |
| 60 | 130 (896) |

*Triplicate tests

Table 33
**Fatigue Strength**
**(R.R. Moore Machine)**

| Condition | Size | Hardness | Fatigue Limit, ksi (MPa) $10^8$ Cycles |
|---|---|---|---|
| Annealed | 1" (25.4 mm) ø | 95 HRB | 37.5 (258) |
| Cold Worked 54.6% | 0.70" (17.8 mm) ø | 44 HRC | 72.5 (500) |

Table 34
**Room Temperature Compression Strength**

| Condition | Size | 0.2% Compressive YS, ksi (MPa) |
|---|---|---|
| Annealed | 0.500" ø (12.7 mm) | 67.6 (466) |
| Cold Drawn 39% | 0.440" ø (11.2 mm) | 121.0 (834) |

Table 35
**Properties Acceptable for Material Specification**
**(Bar and Wire)**

| Condition | Size | UTS ksi (MPa) | 0.2% YS ksi (MPa) | Elongation % in 4XD | Reduction of Area, % | Hardness HRB |
|---|---|---|---|---|---|---|
| Annealed | 1/2" ø + under (12.7 mm) | 105 min (724) | 55 min (379) | 35 min | 55 min | 85 min |
| Annealed | Over 1/2" ø (12.7 mm) | 95 min (655) | 50 min (345) | 35 min | 55 min | 85 min |

G-33-05

Table 36
**Typical Elevated Temperature Mechanical Properties***
**(Annealed 3/4" and 1" [19.05 and 25.4 mm] Diameter Bar Stock)**

| Test Temperature F (C) | UTS ksi (MPa) | 0.2% YS ksi (MPa) | Elongation % in 4XD | Reduction of Area % | Hardness Brinell |
|---|---|---|---|---|---|
| Room Temperature | 106.5 (734) | 56.5 (389) | 61.7 | 71.9 | 200 |
| 200 (93) | 98.2 (677) | 44.4 (306) | 63.3 | 72.4 | 187 |
| 300 (149) | 89.9 (620) | 37.8 (260) | 64.4 | 73.7 | -- |
| 400 (204) | 84.4 (580) | 32.8 (227) | 64.0 | 73.7 | 168 |
| 500 (260) | 82.1 (566) | 32.1 (222) | 61.5 | 73.0 | — |
| 600 (316) | 80.5 (555) | 29.7 (205) | 59.6 | 73.1 | 155 |
| 700 (371) | 79.5 (548) | 29.2 (201) | 59.1 | 72.6 | — |
| 800 (427) | 78.3 (540) | 29.0 (200) | 56.5 | 72.1 | 148 |
| 900 (482) | 77.1 (532) | 28.3 (195) | 53.9 | 71.6 | — |
| 1000 (538) | 75.4 (520) | 28.0 (193) | 52.2 | 70.4 | 145 |
| 1100 (593) | 71.6 (494) | 28.7 (198) | 48.7 | 70.0 | -- |
| 1200 (649) | 66.6 (459) | 28.1 (194) | 48.2 | 69.6 | 144 |
| 1300 (704) | 59.0 (407) | 27.5 (189) | 41.4 | 50.0 | — |
| 1400 (760) | 49.8** (344) | 25.3 (174) | 47.1 | 53.9 | 143 |
| 1500 (816) | 37.0** (255) | 23.8 (164) | 72.8 | 75.0 | |
| 1600 (871) | 30.2** (208) | 16.4 (113) | 72.8 | | 110 |

*Triplicate tests of 2 heats and single tests of 1 heat
**Single tests of 1 heat

Table 37
**Elevated Temperature Tensile Properties**
**(Cold Swaged 54% to 0.700" [17.8 mm] ø)**

| Test Temp. F (C) | UTS ksi (MPa) | 0.2% YS ksi (MPa) | Elongation % in 4XD | Reduction of Area, % |
|---|---|---|---|---|
| RT | 230 (1586) | 216 (1489) | 12 | 55 |
| 200 (93) | 215 (1482) | 205 (1413) | 12 | 54 |
| 300 (149) | 206 (1420) | 199 (1372) | 11 | 52 |
| 400 (204) | 200 (1379) | 194 (1338) | 11 | 51 |
| 500 (260) | 195 (1344) | 191 (1317) | 11 | 48 |
| 600 (316) | 193 (1331) | 188 (1296) | 11 | 47 |
| 700 (371) | 191 (1317) | 176 (1213) | 10 | 47 |
| 800 (427) | 190 (1310) | 184 (1269) | 9 | 46 |
| 900 (482) | 187 (1289) | 177 (1220) | 11 | 44 |
| 1000 (538) | 179 (1234) | 166 (1145) | 11 | 47 |
| 1100 (593) | 162 (1117) | 144 (993) | 13 | 52 |
| 1200 (649) | 112 (772) | 72 (496) | 11 | 25 |

Table 38
**Elevated Temperature Stress Rupture Strength**
**(Annealed Bars 5/8" to 1" [16.0 to 25.4 mm] Diameter)**

| Temperature F (C) | Number of Heats | Stress Rupture Strength, ksi (MPa) | | |
|---|---|---|---|---|
| | | 100 hr. life | 1000 hr. life | 10,000 hr. life |
| 1000 (538) | 3 | 72 (496) | 52 (359) | 35 (241) |
| 1100 (593) | 3 | 49 (338) | 31 (214) | 20 (138) |
| 1200 (649) | 4 | 29 (200) | 17 (117) | 10* (69) |
| 1350 (732) | 1 | 14 (97) | 8 (55) | — |
| 1500 (816) | 1 | 6.7 (46) | 4 (28) | — |

*Extrapolated

Table 39
**Cryogenic Tensile Properties***

| Condition | Size | Temperature, F (C) | UTS ksi (MPa) | 0.2% YS ksi (MPa) | Elongation % in 4XD | Reduction of Area, % |
|---|---|---|---|---|---|---|
| Annealed | 3/8" (9.5 mm) ø | -100 ( -73) | 155 (1069) | 76 (524) | 57 | 69 |
| | 3/8" (9.5 mm) ø | -200 (-129) | 170 (1172) | 87 (600) | 56 | 71 |
| | 1"(25.4 mm) ø | -320 (-196) | 213 (1469) | 109 (752) | 60 | 67 |
| Cold Swaged 54% | .700" (17.8 mm) ø | -320 (-196) | 322 (2220) | 272 (1875) | 10 | 53 |
| | .700" (17.8 mm) ø | -200 (-129) | 287 (1979) | 250 (1724) | 13 | 62 |

*Duplicate tests

Table 40
**Low Temperature Mechanical Properties of NITRONIC 60 Stainless Steel Longitudinal Tensile Specimens***

| Test Temperature F (C) | UTS ksi (MPa) | 0.2% Offset YS ksi (MPa) | Elongation % in 1" (25.4 mm) or 4XD | Reduction of Area % | Fracture Strength ksi (MPa) | Modulus psi (MPa) | N/U** Tensile Ratio | Charpy V-Notch Impact ft-lbs (J) |
|---|---|---|---|---|---|---|---|---|
| 75 (24) | 109.3 (754) | 58.1 (400) | 66.4 | 79.0 | 336.1 (2317) | 24.0x10⁶ (165,000) | 1.44 | 231 (310) |
| 0 (-18) | 128.1 (883) | 67.3 (464) | 71.3 | 79.7 | 433.4 (2988) | 23.7x10⁶ (163,000) | 1.37 | 216 (292) |
| -100 (-73) | 148.4 (1023) | 77.9 (537) | 70.5 | 80.9 | 447.1 (3083) | 24.2x10⁶ (167,000) | 1.45 | 197 (267) |
| -200 (-129) | 167.6 (1155) | 87.4 (602) | 62.4 | 79.4 | 457.0 (3151) | 24.2x10⁶ (167,000) | 1.46 | 170 (231) |
| -320 (-196) | 217.9 (1502) | 101.4 (699) | 59.5 | 65.8 | 594.0 (4095) | 24.8x10⁶ (171,000) | 1.26 | 138 (188) |
| -423 (-253) | 203.8 (1405) | 125.3 (864) | 23.5 | 26.6 | 277.6 (1914) | 24.8x10⁶ (171,000) | 1.33 | — — |

*0.250" (6.35 mm) diameter, machined from a 1" (25.4 mm) diameter annealed and straightened bar. Four specimen average.
**Average Stress Concentration Factor $K_t = 7.0$
Data taken with permission from NASA TM X-73359, Jan. 1977.

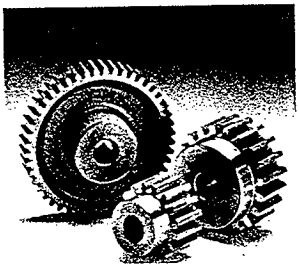
Table 41
**Impact Properties****

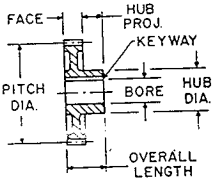
| Condition | Size | Test Temperature, F (C) | Charpy V-Notch Impact, ft-lbs (J) |
|---|---|---|---|
| Annealed | 1" ø (25.4 mm) | Room Temperature | 240* (325) |
| | | -100 (-73) | 229 (310) |
| | | -320 (-196) | 144 (195) |
| Annealed | 2-1/4" ø (54.2 mm) | Room Temperature | 240* (325) |
| | | -100 (-73) | 240* (325) |
| | | -320 (-196) | 160 (217) |
| Cold Swaged 18% Hardness $R_C$ 29 | .932" ø (23.7 mm) | -320 (-196) | 67 (91) |
| Cold Swaged 40% Hardness $R_C$ 37 | .795" ø (20.2 mm) | -320 (-196) | 40 (54) |
| Cold Swaged 54% Hardness $R_C$ 42 | .700" ø (17.8 mm) | -320 (-196) | 26 (35) |
| Cold Swaged 18% Hardness $R_C$ 29 | .932" ø (23.7 mm) | -200 (-129) | 90 (122) |
| Cold Swaged 40% Hardness $R_C$ 37 | .795" ø (20.2 mm) | -200 (-129) | 44 (60) |
| Cold Swaged 54% Hardness $R_C$ 42 | .700" ø (17.8mm) | -200 (-129) | 30 (41) |

*Did not fracture completely
**Data based on duplicate tests

## 4 AND 3 DIAMETRAL PITCH
## STEEL AND CAST IRON

**14½° PRESSURE ANGLE**
*(Will not operate with 20° spurs)*






ALL DIMENSIONS IN INCHES
ORDER BY CATALOG NUMBER OR ITEM CODE

| No. of Teeth | Pitch Dia. | Bore | Hub Dia. | Hub Proj. | Style See Page A93 | Without Keyway or Setscrew Catalog Number | Without Keyway or Setscrew Item Code |
|---|---|---|---|---|---|---|---|
| **4 DIAMETRAL PITCH** — FACE = 2" · OUTSIDE DIA. = PITCH DIA. + .500" · OVERALL LENGTH = 2" + HUB PROJ. | | | | | | | |
| **STEEL** | | | | | | | |
| 11 | 3.000* | 1-1/8 | 2-17/64 | 7/8 | A | NL11B | 09860 |
| 12 | 3.000 | | 2-17/64 | | | NL12B | 09862 |
| 14 | 3.500 | | 2-49/64 | | | NL14B | 09864 |
| 15 | 3.750 | | 3-1/64 | | | NL15B | 09866 |
| 16 | 4.000 | | 3-17/64 | | | NL16B | 09868 |
| 18 | 4.500 | | 3-49/64 | | | NL18B | 09870 |
| 20 | 5.000 | | 4-17/64 | | | NL20B | 09872 |
| 22 | 5.500 | | 4-49/64 | | | NL22B | 09874 |
| **CAST IRON** | | | | | | | |
| 24 | 6.000 | 1-1/8 | 3-1/2 | 1-1/2 | A | NL24B | 10484 |
| 28 | 7.000 | 1-1/4 | | | | NL28B | 10486 |
| 30 | 7.500 | | | | B | NL30B | 10488 |
| 32 | 8.000 | | | | | NL32B | 10490 |
| 36 | 9.000 | | | | | NL36B | 10492 |
| 40 | 10.000 | | 4 | | C | NL40B | 10494 |
| 42 | 10.500 | | | | | NL42 | 10496 |
| 44 | 11.000 | | | | | NL44B | 10498 |
| 48 | 12.000 | | | | D | NL48B | 10500 |
| 54 | 13.500 | | | | | NL54 | 10502 |
| 56 | 14.000 | | | | | NL56B | 10504 |
| 60 | 15.000 | | | | | NL60 | 10506 |
| 64 | 16.000 | | | | | NL64B | 10508 |
| 72 | 18.000 | | | | | NL72B | 10510 |
| 80 | 20.000 | 1-3/8 | 4-1/2 | 1-1/2 | | NL80B | 10512 |
| 84 | 21.000 | | | | | NL84 | 10514 |
| 88 | 22.000 | | | 1-3/4 | | NL88B | 10516 |
| 96 | 24.000 | | | | | NL96B | 10518 |
| **3 DIAMETRAL PITCH** — FACE = 4" · OUTSIDE DIA. = PITCH DIA. + .667" · OVERALL LENGTH = FACE + HUB PROJ. | | | | | | | |
| **STEEL** | | | | | | | |
| 11 | 4.000* | 1-5/16 | — | — | A | NO11B† | 09876 |
| 12 | 4.000 | | | | | NO12B† | 09878 |
| 14 | 4.667 | | | | | NO14B | 09880 |
| 15 | 5.000 | | | | | NO15B | 09882 |
| 16 | 5.333 | | | | | NO16B | 09884 |
| 18 | 6.000 | | | | | NO18B | 09886 |
| 20 | 6.667 | | | | | NO20 | 09888 |
| 21 | 7.000 | | | | | NO21B | 09890 |
| **CAST IRON** | | | | | | | |
| 24 | 8.000 | 1-7/16 | 4-1/2 | 1-1/4 | B | NO24B | 10524 |
| 30 | 10.000 | | 5-1/4 | | | NO30B | 10526 |
| 36 | 12.000 | | | 1-3/4 | | NO36B | 10528 |
| 42 | 14.000 | | | | C | NO42 | 10530 |
| 48 | 16.000 | 1-9/16 | 5-1/4 | 1-3/4 | D | NO48B | 10532 |
| 54 | 18.000 | | | | | NO54 | 10534 |
| 60 | 20.000 | | | | | NO60B | 10536 |
| 72 | 24.000 | 1-11/16 | 5-1/2 | 1-3/4 | | NO72B | 10538 |
| 84 | 28.000 | | 5-3/4 | | | NO84B | 10540 |
| 96 | 32.000 | 1-15/16 | 5-3/4 | 1-3/4 | | NO96B | 10542 |
| 108 | 36.000 | | | | | NO108B | 10544 |

*Special Pitch Diameter, used for calculating Center Distance only, not Ratio.
†NO11B and NO12B have 4" Face.

### STANDARD TOLERANCES

| DIMENSION | | TOLERANCE |
|---|---|---|
| BORE | All | ± .0005 |

### REFERENCE PAGES

Alterations—A92
Horsepower Ratings—A9, A10
Lubrication—A92
Materials—A93
Selection Procedure—A2



BOSTON Gear®
INCOM INTERNATIONAL INC.

# SPUR GEARS

## *APPROXIMATE HORSEPOWER AND TORQUE* RATINGS FOR CLASS I SERVICE (Service Factor = 1.0)*

**4 DIAMETRAL PITCH CAST IRON** — 14½° PRESSURE ANGLE — 2" FACE — REFERENCE PAGE A25.

| Pitch | 25 RPM | | 50 RPM | | 100 RPM | | 200 RPM | | 300 RPM | | 600 RPM | | 900 RPM | | 1200 RPM | | 1800 RPM | | 3600 RPM | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | H.P. | Torque | H.P. | Torque | H.P. | Torque | H.P. | Torque | H.P. | Torque | H.P. | Torque | H.P. | Torque | H.P. | Torque | H.P. | Torque | H.P. | Torque |
| | 2.00 | 5042 | 3.77 | 4750 | 6.75 | 4257 | 11.19 | 3525 | 14.32 | 3008 | 19.88 | 2089 | 22.84 | 1600 | | | | | | |
| | 2.43 | 6129 | 4.54 | 5723 | 8.02 | 5053 | 12.99 | 4094 | 16.38 | 3441 | 22.16 | 2328 | | | | | | | | |
| | 2.62 | 6599 | 4.87 | 6135 | 8.53 | 5378 | 13.69 | 4314 | 17.14 | 3601 | 22.92 | 2408 | | | | | | | | |
| | 2.86 | 7211 | 5.30 | 6675 | 9.22 | 5811 | 14.65 | 4616 | 18.22 | 3829 | 24.11 | 2534 | | | | | | | | |
| | 3.25 | 8187 | 5.96 | 7514 | 10.24 | 6454 | 15.98 | 5034 | 19.64 | 4126 | 25.49 | 2677 | | | | | | | | |
| | 3.64 | 9177 | 6.63 | 8354 | 11.24 | 7085 | 17.24 | 5433 | 20.97 | 4406 | 26.77 | 2812 | | | | | | | | |
| | 3.80 | 9588 | 6.90 | 8694 | 11.63 | 7328 | 17.69 | 5575 | 21.42 | 4499 | 27.12 | 2849 | | | | | | | | |
| | 4.04 | 10161 | 7.29 | 9195 | 12.22 | 7703 | 18.46 | 5816 | 22.24 | 4672 | 27.97 | 2938 | | | | | | | | |
| | 4.35 | 10999 | 7.82 | 9858 | 12.95 | 8163 | 19.28 | 6074 | 23.02 | 4837 | 28.58 | 3002 | | | | | | | | |
| | 4.97 | 12530 | 8.81 | 11104 | 14.35 | 9045 | 20.94 | 6598 | 24.72 | 5193 | | | | | | | | | | |
| | 5.13 | 12933 | 9.06 | 11419 | 14.68 | 9253 | 21.29 | 6708 | 25.04 | 5261 | | | | | | | | | | |
| | 5.44 | 13727 | 9.55 | 12034 | 15.32 | 9652 | 21.94 | 6915 | 25.65 | 5388 | | | | | | | | | | |
| | 5.86 | 14763 | 10.20 | 12852 | 16.20 | 10209 | 22.95 | 7233 | 26.65 | 5601 | | | | | | | | | | |
| | 6.47 | 16305 | 11.11 | 14005 | 17.33 | 10923 | 24.07 | 7585 | 27.65 | 5810 | | | | | | | | | | |
| | 7.18 | 18101 | 12.18 | 15350 | 18.68 | 11772 | 25.48 | 8029 | | | | | | | | | | | | |
| | 7.47 | 18838 | 12.60 | 15877 | 19.17 | 12079 | 25.93 | 8170 | | | | | | | | | | | | |
| | 7.76 | 19561 | 13.00 | 16387 | 19.63 | 12372 | 26.35 | 8304 | | | | | | | | | | | | |
| | 8.32 | 20970 | 13.78 | 17365 | 20.50 | 12922 | 27.13 | 8548 | | | | | | | | | | | | |

**3 DIAMETRAL PITCH STEEL** — 14½° PRESSURE ANGLE — 3" FACE — REFERENCE PAGE A25.

| Pitch | 25 RPM | | 50 RPM | | 100 RPM | | 200 RPM | | 300 RPM | | 600 RPM | | 900 RPM | | 1200 RPM | | 1800 RPM | | 3600 RPM | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | H.P. | Torque | H.P. | Torque | H.P. | Torque | H.P. | Torque | H.P. | Torque | H.P. | Torque | H.P. | Torque | H.P. | Torque | H.P. | Torque | H.P. | Torque |
| | 2.94 | 7421 | 5.67 | 7146 | 10.56 | 6652 | 18.55 | 5846 | 24.82 | 5213 | 37.47 | 3936 | 45.15 | 3162 | 50.30 | 2642 | | | | |
| | 3.20 | 8067 | 6.14 | 7743 | 11.37 | 7167 | 19.80 | 6239 | 26.30 | 5524 | 39.14 | 4111 | 46.74 | 3273 | 51.78 | 2719 | | | | |
| | 4.15 | 10462 | 7.92 | 9979 | 14.49 | 9134 | 24.79 | 7812 | 32.48 | 6824 | 47.09 | 4947 | 55.40 | 3880 | | | | | | |
| | 4.61 | 11618 | 8.76 | 11046 | 15.96 | 10056 | 27.06 | 8528 | 35.24 | 7403 | 50.49 | 5304 | 59.01 | 4132 | | | | | | |
| | 5.09 | 12825 | 9.64 | 12156 | 17.47 | 11008 | 29.38 | 9259 | 38.03 | 7989 | 53.89 | 5661 | 62.60 | 4383 | | | | | | |
| | 6.03 | 15214 | 11.37 | 14333 | 20.38 | 12845 | 33.75 | 10637 | 43.20 | 9076 | 60.00 | 6303 | 68.93 | 4827 | | | | | | |
| | 6.97 | 17570 | 13.05 | 16454 | 23.16 | 14599 | 37.80 | 11913 | 47.89 | 10062 | 65.33 | 6863 | | | | | | | | |
| | 7.46 | 18795 | 13.92 | 17549 | 24.59 | 15495 | 39.64 | 12556 | 50.24 | 10554 | 67.96 | 7139 | | | | | | | | |

**3 DIAMETRAL PITCH CAST IRON** — 14½° PRESSURE ANGLE — 3" FACE — REFERENCE PAGE A25.

| Pitch | 25 RPM | | 50 RPM | | 100 RPM | | 200 RPM | | 300 RPM | | 600 RPM | | 900 RPM | | 1200 RPM | | 1800 RPM | | 3600 RPM | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | H.P. | Torque | H.P. | Torque | H.P. | Torque | H.P. | Torque | H.P. | Torque | H.P. | Torque | H.P. | Torque | H.P. | Torque | H.P. | Torque | H.P. | Torque |
| | 5.23 | 13175 | 9.67 | 12195 | 16.84 | 10617 | 26.76 | 8433 | 33.30 | 6995 | 44.05 | 4627 | | | | | | | | |
| | 6.81 | 17164 | 12.40 | 15626 | 21.03 | 13251 | 32.25 | 10162 | 39.23 | 8241 | 50.07 | 5259 | | | | | | | | |
| | 8.41 | 21199 | 15.07 | 18998 | 24.96 | 15732 | 37.15 | 11707 | 44.37 | 9322 | 55.08 | 5786 | | | | | | | | |
| | 9.81 | 24721 | 17.32 | 21828 | 28.06 | 17687 | 40.69 | 12822 | 47.87 | 10056 | | | | | | | | | | |
| | 11.20 | 28241 | 19.50 | 24586 | 30.99 | 19530 | 43.91 | 13838 | 51.00 | 10715 | | | | | | | | | | |
| | 12.71 | 32043 | 21.83 | 27523 | 34.06 | 21466 | 47.30 | 14906 | 54.35 | 11417 | | | | | | | | | | |
| | 13.87 | 34965 | 23.52 | 29651 | 36.08 | 22740 | 49.22 | 15509 | | | | | | | | | | | | |
| | 16.35 | 41223 | 27.08 | 34136 | 40.30 | 25402 | 53.32 | 16803 | | | | | | | | | | | | |
| | 18.76 | 47293 | 30.40 | 38322 | 44.08 | 27782 | 56.87 | 17923 | | | | | | | | | | | | |
| | 20.75 | 52300 | 32.96 | 41545 | 46.71 | 29437 | 59.02 | 18597 | | | | | | | | | | | | |
| | 22.99 | 57968 | 35.87 | 45212 | 49.81 | 31395 | 61.64 | 19486 | | | | | | | | | | | | |

Ratings are based on strength calculation. Basic static strength rating, or for hand operation of above gears is approximately 3 times the 100 RPM rating.

NOTE: Ratings to right of heavy line are not recommended, as pitch line velocity exceeds 1000 feet per minute. They should be used for interpolation purposes only.

*Torque Rating (Lb. Ins.).



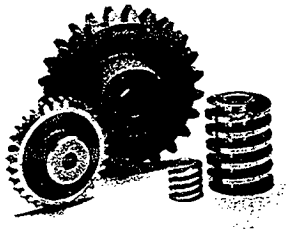
BOSTON Gear®
INCOM INTERNATIONAL INC.

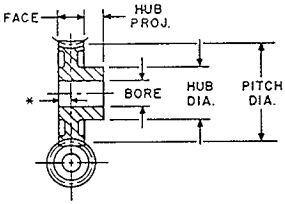
## 3 DIAMETRAL PITCH
## CAST IRON WORM GEARS
## STEEL WORMS — UNHARDENED AND HARDENED

PRESSURE ANGLE – 14½°

RATIO = Gear Teeth ÷ Worm Threads
All Worm and Worm Gears stocked RIGHT HAND ONLY

54/12 =






ALL DIMENSIONS IN INCHES
ORDER BY CATALOG NUMBER OR ITEM CODE

| 3 DIAMETRAL PITCH WORM GEARS (FACE = 2 × CENTER LINE WORM TO FLUSH END − 1.000") | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| No. of Teeth | Pitch Dia. | Bore | Hub Dia. | Hub Proj. | Style See Page A93 | SINGLE Thread Catalog Number | SINGLE Thread Item Code | DOUBLE Thread Catalog Number | DOUBLE Thread Item Code | FOUR Thread Catalog Number | FOUR Thread Item Code |
| 18 | 6.000 | 1 | 3 | 1-1/2 | B | G1110 | 13248 | — | — | — | — |
| 24 | 8.000 | 1-1/2 | 3-1/2 | 1-1/2 | B | G1111 | 13250 | — | — | — | — |
| 30 | 10.000 | | | | B | G1112 | 13252 | — | — | — | — |
| 36 | 12.000 | | | | B | G1113 | 13254 | — | — | — | — |
| 48 | 16.000 | | 4 | | C | G1114 | 13256 | — | — | — | — |
| 54 | 18.000 | | | | D | G1115 | 13258 | — | — | — | — |

#26

### STANDARD TOLERANCES

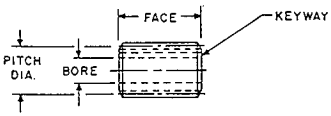
| DIMENSION | | TOLERANCE |
|---|---|---|
| Bore | All | ± .0005 |

### WORM LEAD and LEAD ANGLE

| | |
|---|---|
| LEAD | 1.0472" |
| LEAD ANGLE | 4°46' |

| 3 DIAMETRAL PITCH WORMS FOR ABOVE GEARS | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Pitch Dia. | Face | Bore | Hub Dia. | Hub Proj. | SINGLE Thread Catalog Number* | SINGLE Thread Item Code | DOUBLE Thread Catalog Number | DOUBLE Thread Item Code | QUAD Thread Catalog Number | QUAD Thread Item Code |
| UNHARDENED | | | | | | | | | | |
| 4.000 | 4 | 1-1/2 | — | — | G1116K | 12880 | — | — | — | — |
| | 5-1/2 | | | | L1116 | 12910 | — | — | — | — |
| HARDENED | | | | | | | | | | |
| 4.000 | 4 | 1-1/2 | — | — | H1116 | 12978 | — | — | — | — |
| | 5-1/2 | | | | HL1116 | 13016 | — | — | — | — |

#27




*All Worms furnished with 3/8" keyway.
Hardened Worms have ground and polished threads.

### REFERENCE PAGES
Alterations—A92
Horsepower Ratings—A66, A67
Lubrication—A92
Materials—A93
Selection Procedure—A65



BOSTON Gear
INCOM INTERNATIONAL INC.

## STEEL-HARDENED, GROUND AND POLISHED WORMS
## BRONZE WORM GEARS

### APPROXIMATE HORSEPOWER AND TORQUE* RATINGS FOR CLASS I SERVICE (Service Factor = 1.0)

| Worm RPM | | 1800 | | 600 | | 100 | | Worm Cat. No. | Gear Cat. No. | |
|---|---|---|---|---|---|---|---|---|---|---|
| Ratio | Center Distance | Input HP | Output Torque | Input HP | Output Torque | Input HP | Output Torque | | | DP |
| 5 | 1.000 | .52 | 50 | .27 | 72 | .06 | 83 | H1607 | QB1212 | 12 |
| | 1.500 | 1.19 | 109 | .66 | 183 | .15 | 227 | H1627 | QB812 | 8 |
| 6 | 1.167 | .78 | 99 | .40 | 143 | .08 | 166 | H1607 | QB1216 | 12 |
| | 1.425 | 1.11 | 142 | .61 | 223 | .13 | 267 | H1618 | QB1016 | 10 |
| | 1.750 | 1.77 | 216 | .98 | 361 | .22 | 454 | H1627 | QB816 | 8 |
| | 2.333 | 3.01 | 392 | 1.84 | 689 | .45 | 933 | H1638 | QB616 | 6 |
| 7.5 | 1.333 | .68 | 109 | .34 | 158 | .07 | 180 | H1607 | DB1600 | 12 |
| | 1.625 | 1.03 | 165 | .57 | 257 | .12 | 309 | H1618 | DB1610 | 10 |
| | 2.000 | 1.73 | 264 | .96 | 441 | .22 | 551 | H1627 | DB1620 | 8 |
| | 2.667 | 3.92 | 639 | 2.40 | 1124 | .59 | 1512 | H1638 | DB620 | 6 |
| 7.64 | 3.000 | 3.82 | 746 | 2.34 | 1317 | .57 | 1777 | H1638 | DB1630 | 6 |
| 10 | 1.750 | 1.04 | 247 | .53 | 355 | .11 | 411 | H1607 | DB1601 | 12 |
| | 2.125 | 1.59 | 381 | .87 | 599 | .19 | 714 | H1618 | DB1611 | 10 |
| | 2.625 | 2.65 | 607 | 1.47 | 1016 | .33 | 1276 | H1627 | DB1621 | 8 |
| | 3.500 | 4.80 | 1174 | 2.94 | 2064 | .72 | 2789 | H1638 | DB1631 | 6 |
| 12 | 1.333 | .44 | 130 | .23 | 189 | .05 | 208 | H1407 | DB1400 | 12 |
| | 1.625 | .67 | 196 | .38 | 305 | .09 | 366 | H1418 | DB1410 | 10 |
| | 2.000 | 1.05 | 318 | .63 | 525 | .15 | 649 | H1427 | DB1420 | 8 |
| | 2.167 | 1.39 | 441 | .71 | 641 | .15 | 756 | H1607 | DB1602 | 12 |
| | 2.667 | 2.01 | 616 | 1.26 | 1071 | .32 | 1450 | H1438 | DB620 | 6 |
| | 2.625 | 2.11 | 672 | 1.16 | 1061 | .25 | 1267 | H1618 | DB1612 | 10 |
| | 3.250 | 3.54 | 1082 | 1.96 | 1806 | .44 | 2270 | H1627 | DB1622 | 8 |
| | 4.333 | 6.43 | 2094 | 3.94 | 3685 | .96 | 4980 | H1638 | DB1632 | 6 |
| 12.24 | 3.000 | 2.39 | 882 | 1.50 | 1537 | .38 | 2042 | H1438 | DB1430 | 6 |
| 15 | 2.583 | 1.72 | 683 | .87 | 985 | .18 | 1134 | H1607 | DB1603 | 12 |
| | 3.125 | 2.61 | 1042 | 1.44 | 1641 | .33 | 1961 | H1618 | DB1613 | 10 |
| | 3.875 | 4.40 | 1681 | 2.44 | 2810 | .55 | 3466 | H1627 | DB1623 | 8 |
| 20 | 1.750 | .64 | 284 | .33 | 410 | .07 | 463 | H1407 | DB1401 | 12 |
| | 2.125 | .98 | 436 | .55 | 678 | .13 | 804 | H1418 | DB1411 | 10 |
| | 2.625 | 1.54 | 699 | .92 | 1150 | .22 | 1428 | H1427 | DB1421 | 8 |
| | 3.000 | 2.04 | 966 | 1.03 | 1402 | .22 | 1617 | H1607 | QB1260 | 12 |
| | 3.500 | 2.94 | 1355 | 1.84 | 2364 | .47 | 3120 | H1438 | DB1431 | 6 |
| 24.5 | 3.000† | 2.27 | 1038 | 1.33 | 2373 | .41 | 4198 | H1116 | G1110† | 3 |
| 25 | 1.333 | .28 | 140 | .15 | 210 | .04 | 227 | H1056 | GB1050 | 12 |
| | 1.625 | .42 | 217 | .25 | 336 | .06 | 391 | H1066 | GB1060 | 10 |
| | 2.000 | .65 | 343 | .41 | 567 | .10 | 706 | H1076 | GB1070 | 8 |
| | 2.167 | .83 | 483 | .43 | 693 | .09 | 794 | H1407 | DB1402 | 12 |
| | 2.667 | 1.22 | 655 | .80 | 1156 | .22 | 1550 | H1086 | GB1077 | 6 |
| | 2.625 | 1.25 | 742 | .71 | 1156 | .16 | 1374 | H1418 | DB1412 | 10 |
| | 3.250 | 1.98 | 1191 | 1.18 | 1974 | .28 | 2433 | H1427 | DB1422 | 8 |
| | 3.833 | 2.61 | 1660 | 1.32 | 2395 | .28 | 2773 | H1607 | DB1604 | 12 |
| | 4.000 | 2.92 | 1667 | 1.99 | 3025 | .64 | 4663 | H1106 | GB1100 | 4 |
| | 4.333 | 3.77 | 2318 | 2.36 | 4034 | .60 | 5420 | H1438 | DB1432 | 6 |
| 30.24 | 3.000 | 1.42 | 933 | .93 | 1613 | .26 | 2163 | H1086 | GB1080 | 6 |
| | 6.000† | 3.23 | 2218 | 1.81 | 4020 | .53 | 7109 | H1116 | G1111† | 3 |
| | 4.500 | 3.41 | 2336 | 2.32 | 4235 | .75 | 6504 | H1106 | GB1101 | 4 |
| 35 | 2.583 | .99 | 726 | .52 | 1048 | .11 | 1197 | H1407 | DB1403 | 12 |
| | 3.125 | 1.50 | 1112 | .85 | 1730 | .19 | 2048 | H1418 | DB1413 | 10 |
| | 3.875 | 2.39 | 1794 | 1.43 | 2962 | .34 | 3671 | H1427 | DB1423 | 8 |
| | 4.667 | 3.14 | 2495 | 1.59 | 3591 | .33 | 4096 | H1607 | DB1605 | 12 |
| | 5.167 | 4.53 | 3475 | 2.84 | 6055 | .72 | 8035 | H1438 | DB1433 | 6 |
| 40 | 1.750 | .40 | 294 | .21 | 410 | .05 | 473 | H1056 | GB1051 | 12 |
| | 2.125 | .59 | 452 | .35 | 693 | .09 | 831 | H1066 | DB1061 | 10 |
| | 2.625 | .90 | 725 | .57 | 1197 | .13 | 1286 | H1076 | GB1071 | 8 |
| | 3.000 | 1.15 | 1008 | .60 | 1450 | .13 | 1663 | H1407 | DB1260 | 12 |
| | 3.500 | 1.69 | 1386 | 1.12 | 2426 | .31 | 3233 | H1086 | GB1081 | 6 |
| | 3.625 | 1.74 | 1544 | .98 | 2395 | .22 | 2836 | H1418 | DB1414 | 10 |
| | 4.500 | 2.75 | 2489 | 1.65 | 4128 | .39 | 5105 | H1427 | DB860 | 8 |
| | 7.000† | 4.23 | 3326 | 2.53 | 6002 | .76 | 10683 | H1116 | G1112† | 3 |
| 48 | 5.500 | 4.26 | 3909 | 2.92 | 7092 | .94 | 10890 | H1106 | GB1102 | 4 |
| 60 | 4.000 | 1.95 | 1915 | 1.29 | 3366 | .36 | 4470 | H1086 | GB1082 | 6 |
| | 8.000† | 3.87 | 3990 | 1.33 | 4130 | .68 | 12816 | H1116 | G1113† | 3 |

* Torque in Lb. Ins.

†Cast Iron Gear Rating with Hardened Worm shown.

All Worm and Worm Gear Ratings are based on a Hardened Steel Worm used with a Bronze Worm Gear.

1. For a Hardened Steel Worm used with a Cast Iron Gear, multiply the listed Rating by .50.
2. For an Unhardened Steel Worm used with a Cast Iron Gear, multiply the listed Rating by .25.

**Table 7. Weights and Strengths of Standard Flat Wire Rope, Not Preformed**

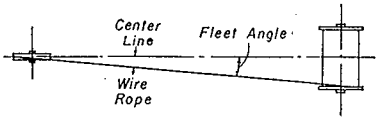
Flat Wire Rope

This rope consists of a number of 4-strand rope units placed side by side and stitched together with soft steel sewing wire.

| Width and Thickness, Inches | No. of Ropes | Approx. Weight per Ft., Pounds | Breaking Strength, Tons of 2000 Lbs. | | Width and Thickness, Inches | No. of Ropes | Approx. Weight per Ft., Pounds | Breaking Strength, Tons of 2000 Lbs. | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Plow Steel | Mild Plow Steel | | | | Plow Steel | Mild Plow Steel |
| ¼ × 1½ | 7 | 0.69 | 16.8 | 14.6 | ½ × 4 | 9 | 3.16 | 81.8 | 71.2 |
| ¼ × 2 | 9 | 0.88 | 21.7 | 18.8 | ½ × 4½ | 10 | 3.82 | 90.9 | 79.1 |
| ¼ × 2½ | 11 | 1.15 | 26.5 | 23.0 | ½ × 5 | 12 | 4.16 | 109. | 94.9 |
| ¼ × 3 | 13 | 1.34 | 31.3 | 27.2 | ½ × 5½ | 13 | 4.50 | 118. | 103. |
| | | | | | ½ × 6 | 14 | 4.85 | 127. | 111. |
| 5/16 × 1½ | 5 | 0.77 | 18.5 | 16.0 | ½ × 7 | 16 | 5.85 | 145. | 126. |
| 5/16 × 2 | 7 | 1.05 | 25.8 | 22.4 | | | | | |
| 5/16 × 2½ | 9 | 1.33 | 33.2 | 28.8 | ⅝ × 3½ | 6 | 3.40 | 85.8 | 74.6 |
| 5/16 × 3 | 11 | 1.61 | 40.5 | 35.3 | ⅝ × 4 | 7 | 3.95 | 100. | 87.1 |
| 5/16 × 3½ | 13 | 1.89 | 47.9 | 41.7 | ⅝ × 4½ | 8 | 4.50 | 114. | 99.5 |
| 5/16 × 4 | 15 | 2.17 | 55.3 | 48.1 | ⅝ × 5 | 9 | 5.04 | 129. | 112. |
| | | | | | ⅝ × 5½ | 10 | 5.59 | 143. | 124. |
| ⅜ × 2 | 6 | 1.25 | 31.4 | 27.3 | ⅝ × 6 | 11 | 6.14 | 157. | 137. |
| ⅜ × 2½ | 8 | 1.64 | 41.8 | 36.4 | ⅝ × 7 | 13 | 7.23 | 186. | 162. |
| ⅜ × 3 | 9 | 1.84 | 47.1 | 40.9 | ⅝ × 8 | 15 | 8.32 | 214. | 186. |
| ⅜ × 3½ | 11 | 2.23 | 57.5 | 50.0 | | | | | |
| ⅜ × 4 | 12 | 2.44 | 62.7 | 54.6 | ¾ × 5 | 8 | 6.50 | 165. | 143. |
| ⅜ × 4½ | 14 | 2.83 | 73.2 | 63.7 | ¾ × 6 | 9 | 7.31 | 185. | 161. |
| ⅜ × 5 | 15 | 3.03 | 78.4 | 68.2 | ¾ × 7 | 10 | 8.13 | 206. | 179. |
| ⅜ × 5½ | 17 | 3.42 | 88.9 | 77.3 | ¾ × 8 | 11 | 9.70 | 227. | 197. |
| ⅜ × 6 | 18 | 3.63 | 94.1 | 81.9 | | | | | |
| | | | | | ⅞ × 5 | 7 | 7.50 | 190. | 165. |
| ½ × 2½ | 6 | 2.13 | 54.5 | 47.4 | ⅞ × 6 | 8 | 8.56 | 217. | 188. |
| ½ × 3 | 7 | 2.47 | 63.6 | 55.4 | ⅞ × 7 | 9 | 9.63 | 244. | 212. |
| ½ × 3½ | 8 | 2.82 | 72.7 | 63.3 | ⅞ × 8 | 10 | 10.7 | 271. | 236. |

*Source:* Rope diagram, Bethlehem Steel Co.; all data, U. S. Simplified Practice Recommendation 198–50.

When the rope is underwound on the drum, a right lay rope should be started from the left flange and a left lay rope from the right flange. When this is done, the rope will spool evenly and the turns will lie snugly together.




Sheaves and drums should be properly aligned to prevent undue wear. The proper position of the main or lead sheave for the rope as it comes off the drum is governed by what is called the fleet angle or angle between the rope as it stretches from drum



to sheave and an imaginary center-line passing through the center of the sheave groove and a point halfway between the ends of the drum. When the rope is at one end of the drum, this angle should not exceed one and a half to two degrees. With the lead sheave mounted with its groove on this center-line, a safe fleet angle is obtained by allowing 30 feet of lead for each two feet of drum width.

*Sheave and Drum Dimensions:* Sheaves and drums should be as large as possible to obtain maximum rope life. However, factors such as the need for lightweight equipment for easy transport and use at high speeds, may call for relatively small sheaves with consequent sacrifice in rope life in the interest of over-all economy. No hard and fast rules can be laid down for any particular rope if the utmost in economical performance is to be obtained. Where maximum rope life is of prime importance, the following recommendations of Federal Specification RR–R–571a for minimum sheave or drum diameters $D$ in terms of rope diameter $d$ will be of interest. For 6 × 7 rope (six strands of 7 wires each) $D = 72\,d$; for 6 × 19 rope, $D = 45\,d$; for 6 × 25 rope, $D = 45\,d$; for 6 × 29 rope, $D = 30\,d$; for 6 × 37 rope, $D = 27\,d$; and for 8 × 19 rope, $D = 31\,d$.

Too small a groove for the rope it is to carry will prevent proper seating of the rope in the bottom of the groove and consequently uneven distribution of load on the rope will result. Too large a groove will not give the rope sufficient side support. Federal specifications RR–R–571a recommend that sheave groove diameters be larger than the nominal rope diameters by the following minimum amounts: For ropes of ¼- to 5/16-inch diameters, 1/64 inch larger; for ⅜- to ⅝-inch diameter ropes, 1/32 inch larger; for 13/16- to 1⅛-inch diameter ropes, 3/64 inch larger; for 1 3/16- to 1 15/16-inch ropes, 1/16 inch larger; for 1 15/16- to 2¼-inch ropes, 3/32 inch larger; and for 2 5/16 and larger diameter ropes, ⅛ inch larger. For new or regrooved sheaves these values should be doubled; in other words for ¼- to 5/16-inch diameter ropes, the groove diameter should be 1/32 inch larger, etc.

*Drum or Reel Capacity:* The length of wire rope, in feet, that can be spooled onto a drum or reel, is computed by the following formula, where

**Table 8. Factors K Used in Calculating Wire Rope Drum and Reel Capacities**

| Rope Diam., In. | Factor K | Rope Diam., In. | Factor K | Rope Diam., In. | Factor K |
|---|---|---|---|---|---|
| 3/32 | 23.4 | ¾ | 0.925 | 1⅜ | 0.127 |
| ⅛ | 13.6 | 13/16 | 0.741 | 1½ | 0.107 |
| 3/64 | 10.8 | ⅞ | 0.607 | 1⅝ | 0.0886 |
| 1/32 | 8.72 | 1 1/16 | 0.506 | 1¾ | 0.0770 |
| 1/16 | 6.14 | 1⅛ | 0.428 | 1⅞ | 0.0675 |
| 3/32 | 4.59 | 1 3/16 | 0.354 | 2 | 0.0597 |
| ¼ | 3.29 | 1¼ | 0.308 | 2⅛ | 0.0532 |
| 5/16 | 2.21 | 1 | 0.239 | 2¼ | 0.0476 |
| ⅜ | 1.58 | 1⅜ | 0.191 | 2⅜ | 0.0419 |
| 7/16 | 1.19 | 1½ | 0.152 | 2½ | 0.0380 |

*Note:* The values of "K" allow for normal oversize of ropes, and the fact that it is practically impossible to "thread-wind" ropes of small diameter. However, the formula is based on uniform rope winding and will not give correct figures if rope is wound non-uniformly on the reel. The amount of tension applied when spooling the rope will also affect the length. The formula is based on the same number of wraps of rope in each layer, which is not strictly correct, but which does not result in appreciable error unless the width (B) of the reel is quite small compared with the flange diameter (H).

# STEEL-HARDENED, GROUND AND POLISHED WORMS BRONZE WORM GEARS

## APPROXIMATE HORSEPOWER AND TORQUE * RATINGS FOR CLASS I SERVICE (Service Factor = 1.0)

| Worm RPM ➡ | | 1800 | | 600 | | 100 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Ratio | Center Distance | Input HP | Output Torque | Input HP | Output Torque | Input HP | Output Torque | Worm Cat. No. | Gear Cat. No. | DP |
| 40 | 2.167 | .48 | 490 | .26 | 672 | .06 | 782 | H1056 | GB1052 | 12 |
| | 2.625 | .72 | 742 | .43 | 1134 | .11 | 1361 | H1066 | GB1062 | 10 |
| | 3.250 | 1.12 | 1190 | .71 | 1974 | .18 | 2420 | H1076 | GB1072 | 8 |
| | 3.833 | 1.43 | 1680 | .74 | 2395 | .16 | 2748 | H1047 | DB1404 | 12 |
| | 4.333 | 2.11 | 2310 | 1.39 | 4034 | .38 | 5345 | H1086 | GB1078 | 6 |
| | 4.625 | 2.16 | 2562 | 1.22 | 3991 | .28 | 4790 | H1418 | DB1080 | 10 |
| | 5.750 | 3.42 | 4130 | 2.05 | 6807 | .48 | 8319 | H1427 | DB1424 | 8 |
| 48 | 3.750 | 1.26 | 1614 | .79 | 2622 | .20 | 3267 | H1076 | GB1073 | 8 |
| | 5.000 | 2.37 | 3110 | 1.56 | 5445 | .43 | 7260 | H1086 | GB1083 | 6 |
| | 10.000† | 4.06 | 5320 | 1.68 | 6608 | .72 | 17088 | H1116 | G1114† | 3 |
| 50 | 2.583 | .55 | 700 | .30 | 998 | .07 | 1134 | H1056 | GB1053 | 12 |
| | 3.125 | .83 | 1068 | .51 | 1733 | .12 | 1954 | H1066 | GB1063 | 10 |
| | 3.875 | 1.30 | 1716 | .82 | 2836 | .21 | 3498 | H1076 | GB850 | 8 |
| | 5.167 | 2.43 | 3327 | 1.60 | 5777 | .44 | 7563 | H1086 | GB1079 | 6 |
| 54 | 11.000† | 4.34 | 5985 | 1.79 | 7434 | .77 | 19224 | H1116 | G1115† | 3 |
| 60 | 3.000 | .60 | 924 | .33 | 1323 | .08 | 1664 | H1056 | GB1260 | 12 |
| | 3.625 | .91 | 1408 | .54 | 2142 | .13 | 2571 | H1066 | GB1064 | 10 |
| | 4.500 | 1.42 | 2269 | .89 | 3718 | .23 | 4538 | H1076 | GB860 | 8 |
| | 6.000 | 2.66 | 4370 | 1.75 | 7625 | .49 | 10210 | H1086 | GB1087 | 6 |
| 72 | 7.000 | 2.79 | 5521 | 1.84 | 9605 | .51 | 12705 | H1086 | GB1084 | 6 |
| 80 | 3.833 | .64 | 1288 | .35 | 1849 | .08 | 2118 | H1056 | GB1054 | 12 |
| | 4.625 | .96 | 1961 | .57 | 3042 | .14 | 3630 | H1066 | GB1067 | 10 |
| | 5.750 | 1.49 | 3165 | .94 | 5210 | .24 | 6555 | H1076 | GB1074 | 8 |
| 100 | 4.667 | .60 | 1505 | .33 | 2206 | .08 | 2458 | H1056 | GB1055 | 12 |
| | 5.625 | .90 | 2310 | .54 | 3571 | .13 | 4223 | H1066 | GB1065 | 10 |
| | 7.000 | 1.40 | 3711 | .88 | 6092 | .22 | 7563 | H1076 | GB8100 | 8 |

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* Torque in Lb. Ins.

†Cast Iron Gear Rating with Hardened Worm shown.

All Worm and Worm Gear Ratings are based on a Hardened Steel Worm used with a Bronze Worm Gear.
1. For a Hardened Steel Worm used with a Cast Iron Gear, multiply the listed Rating by .50.
2. For an Unhardened Steel Worm used with a Cast Iron Gear, multiply the listed Rating by .25.

## CENTER DISTANCES AND RATIOS AVAILABLE WITH STOCK WORM GEARING

| Center Distance (Inches) | Pitch | No. of Teeth in Gear | Worm Thread Ratio: Single | Double | Quad |
|---|---|---|---|---|---|
| 1.875 | 48 | 20 | 20 | 10 | 5 |
| 1.917 | 48 | 30 | 30 | 15 | 7.5 |
| 2.000 | 32 | 20 | 20 | 10 | 5 |
| 2.083 | 48 | 40 | 40 | 20 | 10 |
| 2.125 | 24 | 20 | 20 | 10 | 5 |
| 2.167 | 48 | 50 | 50 | 25 | 12.5 |
| 2.188 | 32 | 30 | 30 | 15 | 7.5 |
| 2.250 | 48 | 60 | 60 | 30 | 15 |
| 2.333 | 32 | 40 | 40 | 20 | 10 |
| 2.375 | 24 | 30 | 30 | 15 | 7.5 |
| 2.583 | 16 | 20 | 20 | 10 | 5 |
| 2.625 | 48 | 80 | 80 | 40 | 20 |
| 2.667 | 32 | 50 | 50 | 25 | 12.5 |
| 2.833 | 24 | 40 | 40 | 20 | 10 |
| 2.875 | 32 | 60 | 60 | 30 | 15 |
| 2.917 | 48 | 100 | 100 | 50 | 25 |
| 3.000 | 16 | 30 | 30 | 15 | 7.5 |
| 3.083 | 24 | 50 | 50 | 25 | 12.5 |
| 3.125 | 12 | 20 | 20 | 10 | 5 |
| 3.167 | 32 | 80 | 80 | 40 | 20 |
| 3.250 | 24 | 60 | 60 | 30 | 15 |
| 3.333 | 16 | 40 | 40 | 20 | 10 |
| 3.375 | 10 | 20 | 20 | 10 | 5 |
| 3.417 | 32 | 96 | 96 | 48 | 24 |
| 3.500 | 24 | 72 | 72 | 36 | 18 |
| 3.583 | 12 | 30 | 30 | 15 | 7.5 |

| Center Distance (Inches) | Pitch | No. of Teeth in Gear | Worm Thread Ratio: Single | Double | Quad |
|---|---|---|---|---|---|
| 3.781 | 32 | 100 | 100 | 50 | 25 |
| 3.875 | 16 | 50 | 50 | 25 | 12.5 |
| 3.917 | 24 | 80 | 80 | 40 | 20 |
| 3.000 | 8 | 20 | 20 | 10 | 5 |
| 3.125 | 10 | 30 | 30 | 15 | 7.5 |
| 3.167 | 12 | 40 | 40 | 20 | 10 |
| 3.188 | 16 | 60 | 60 | 30 | 15 |
| 3.250 | 24 | 96 | 96 | 48 | 24 |
| 3.333 | 24 | 100 | 100 | 50 | 25 |
| 3.583 | 12 | 50 | 50 | 25 | 12.5 |
| 3.625 | 10 | 40 | 40 | 20 | 10 |
| 3.625 | 8 | 30 | 30 | 15 | 7.5 |
| 3.667 | 6 | 20 | 20 | 10 | 5 |
| 3.812 | 16 | 80 | 80 | 40 | 20 |
| 3.000 | 12 | 60 | 60 | 30 | 15 |
| 3.000 | 6 | 24 | 24 | 12 | 6 |
| 3.125 | 10 | 50 | 50 | 50 | 12.5 |
| 3.250 | 8 | 40 | 40 | 20 | 10 |
| 3.438 | 16 | 100 | 100 | 50 | 25 |
| 3.500 | 6 | 30 | 30 | 15 | 7.5 |
| 3.625 | 10 | 60 | 60 | 30 | 15 |
| 3.750 | 8 | 48 | 48 | — | — |
| 3.833 | 12 | 80 | 80 | 40 | 20 |
| 3.875 | 8 | 50 | 50 | 25 | 12.5 |
| 4.000 | 6 | 36 | 36 | — | — |
| 4.000 | 4 | 20 | 20 | — | — |

| Center Distance (Inches) | Pitch | No. of Teeth in Gear | Worm Thread Ratio: Single | Double | Quad |
|---|---|---|---|---|---|
| 4.333 | 6 | 40 | 40 | 20 | 10 |
| 4.500 | 8 | 60 | 60 | 30 | 15 |
| 4.500 | 4 | 24 | 24 | — | — |
| 4.625 | 10 | 80 | 80 | 40 | 20 |
| 4.667 | 12 | 100 | 100 | — | — |
| 5.000 | 6 | 48 | 48 | — | — |
| 5.000 | 3 | 18 | 18 | — | — |
| 5.167 | 6 | 50 | 50 | 25 | 12.5 |
| 5.500 | 4 | 32 | 32 | — | — |
| 5.625 | 10 | 100 | 100 | 50 | 25 |
| 5.750 | 8 | 80 | 80 | 40 | 20 |
| 6.000 | 6 | 60 | 60 | 30 | 15 |
| 6.000 | 3 | 24 | 24 | — | — |
| 6.500 | 4 | 40 | 40 | — | — |
| 6.750 | 8 | 96 | 96 | — | — |
| 7.000 | 8 | 100 | 100 | 50 | 25 |
| 7.000 | 6 | 72 | 72 | 36 | 18 |
| 7.000 | 3 | 30 | 30 | — | — |
| 7.500 | 4 | 48 | 48 | — | — |
| 7.667 | 6 | 80 | 80 | 40 | 20 |
| 8.000 | 3 | 36 | 36 | — | — |
| 9.000 | 6 | 96 | 96 | — | — |
| 9.333 | 6 | 100 | 100 | 50 | 25 |
| 9.500 | 4 | 64 | 64 | — | — |
| 10.000 | 3 | 48 | 48 | — | — |
| 11.000 | 3 | 54 | 54 | — | — |

Example: Given a center distance of 2.625", Table lists Worm and Worm Gear Ratios available:
10 Pitch, 40 tooth, single = 40 to 1
10 Pitch, 40 tooth, double = 20 to 1
10 Pitch, 40 tooth, quad = 10 to 1
8 pitch, 30 tooth, single = 30 to 1
8 pitch, 30 tooth, double = 15 to 1
8 pitch, 30 tooth, quad = 7.5 to 1

# SPUR GEARS

## LEWIS FORMULA (Barth Revision)

Gear failure can occur due to tooth breakage (tooth stress) or surface failure (surface durability) as a result of fatigue and wear. Strength is determined in terms of tooth-beam stresses for static and dynamic conditions, following well established formula and procedures. Satisfactory results may be obtained by the use of Barth's Revision to the Lewis Formula, which considers beam strength but not wear. The formula is satisfactory for commercial gears at Pitch Circle velocities of up to 1500 FPM. It is this formula that is the basis for all Boston Spur Gear ratings.

METALLIC SPUR GEARS

Safe

$$W = \frac{SFY}{P}\left(\frac{600}{600 + V}\right)$$

W = Tooth Load, Lbs. (along the Pitch Line)
S = Safe Material Stress (static) Lbs. per Sq. In. (Table II)
F = Face Width, In.
Y = Tooth Form Factor (Table I)
P = Diametral Pitch
D = Pitch Diameter
V = Pitch Line Velocity, Ft. per Min. = .262 × PD × RPM

For NON-METALLIC GEARS, the modified Lewis Formula shown below may be used with (S) values of 6000 PSI for Phenolic Laminated material.

$$W = \frac{SFY}{P}\left(\frac{150}{200 + V} + .25\right)$$

TABLE II – VALUES OF SAFE STATIC STRESS (s)

| Material | | (s) Lb. per Sq. In. |
|---|---|---|
| Bronze | | 10000 |
| Cast Iron | | 12000 |
| Steel | .20 Carbon (Untreated) | 20000 |
| | .20 Carbon (Case-hardened) | 25000 |
| | .40 Carbon (Untreated) | 25000 |
| | .40 Carbon (Heat-treated) | 30000 |
| | .40 C. Alloy (Heat-treated) | 40000 |

Max. allowable torque (T) that should be imposed on a gear will be the safe tooth load (W) multiplied by $\frac{D}{2}$ or $T = \frac{W \times D}{2}$

The safe horsepower capacity of the gear (at a given RPM) can be calculated from $HP = \frac{T \times RPM}{63{,}025}$ or directly from (W) and (V);

$$HP = \frac{WV}{33{,}000}$$

For a known HP, $T = \frac{63025 \times HP}{RPM}$

TABLE I Y FACTORS

| Number of Teeth | 14½° Full Depth Involute | 20° Full Depth Involute |
|---|---|---|
| 10 | 0.176 | 0.201 |
| 11 | 0.192 | 0.226 |
| 12 | 0.210 | 0.245 |
| 13 | 0.223 | 0.264 |
| 14 | 0.236 | 0.276 |
| 15 | 0.245 | 0.289 |
| 16 | 0.255 | 0.295 |
| 17 | 0.264 | 0.302 |
| 18 | 0.270 | 0.308 |
| 19 | 0.277 | 0.314 |
| 20 | 0.283 | 0.320 |
| 22 | 0.292 | 0.330 |
| 24 | 0.302 | 0.337 |
| 26 | 0.308 | 0.344 |
| 28 | 0.314 | 0.352 |
| 30 | 0.318 | 0.358 |
| 32 | 0.322 | 0.364 |
| 34 | 0.325 | 0.370 |
| 36 | 0.329 | 0.377 |
| 38 | 0.332 | 0.383 |
| 40 | 0.336 | 0.389 |
| 45 | 0.340 | 0.399 |
| 50 | 0.346 | 0.408 |
| 55 | 0.352 | 0.415 |
| 60 | 0.355 | 0.421 |
| 65 | 0.358 | 0.425 |
| 70 | 0.360 | 0.429 |
| 75 | 0.361 | 0.433 |
| 80 | 0.363 | 0.436 |
| 90 | 0.366 | 0.442 |
| 100 | 0.368 | 0.446 |
| 150 | 0.375 | 0.458 |
| 200 | 0.378 | 0.463 |
| 300 | 0.382 | 0.471 |
| Rack | 0.390 | 0.484 |



BOSTON Gear
INCOM INTERNATIONAL INC.

# SPUR GEARS

## BACKLASH

Stock spur gears are cut to operate at standard center distances. The standard center distance being defined by:

$$\text{Standard Center Distance} = \frac{\text{Pinon PD} + \text{Gear PD}}{2}$$

When mounted at this center distance, stock spur gears will have the following average backlash:

| Diametral Pitch | Backlash (Inches) | Diametral Pitch | Backlash (Inches) |
|---|---|---|---|
| 3 | .013 | 8-9 | .005 |
| 4 | .010 | 10-13 | .004 |
| 5 | .008 | 14-32 | .003 |
| 6 | .007 | 33-64 | .0025 |
| 7 | .006 | | |

An increase or decrease in center distance will cause an increase or decrease in backlash.

Since, in practice, some deviation from the theoretical standard center distance is inevitable and will alter the backlash, such deviation should be as small as possible. For most applications, it would be acceptable to limit the deviation to an increase over the nominal center distance of one half the average backlash. Varying the center distance may afford a practical means of varying the backlash to a limited extent.

The approximate relationship between center distance and backlash change of 14½° and 20° pressure angle gears is shown below:

For 14½° — Change in Center Distance = 1.933 × Change in Backlash
For 20° — Change in Center Distance = 1.374 × Change in Backlash

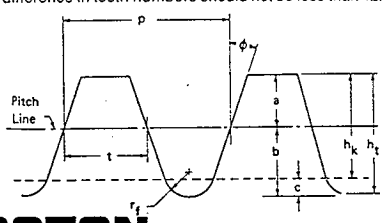
From this, it is apparent that a given change in center distance, 14½° gears will have a smaller change in backlash than 20° gears. This fact should be considered in cases where backlash is critical.

## UNDERCUT

When the number of teeth in a gear is small, the tip of the mating gear tooth may interfere with the lower portion of the tooth profile. To prevent this, the generating process removes material at this point. This results in loss of a portion of the involute adjacent to the tooth base, reducing tooth contact and tooth strength.

On 14½°PA gears undercutting occurs where number of teeth is less than 32 and for 20°PA less than 18. Since this condition becomes more severe as tooth numbers decrease, it is recommended that the minimum number of teeth be 16 for 14½°PA and 13 for 20°PA.

In a similar manner INTERNAL Spur Gear teeth may interfere when the pinion gear is too near the size of its mating internal gear. The following may be used as a guide to assure proper operation of the gear set. For 14½°PA, the difference in tooth numbers between the gear and pinion should not be less than 15. For 20°P.A. the difference in tooth numbers should not be less than 12.




a = Addendum
b = Dedendum
c = Clearance
$h_k$ = Working Depth
$h_t$ = Whole Depth
p = Circular Pitch
$r_f$ = Fillet Radius
t = Circular Tooth Thickness
ϕ = Pressure Angle

## SPUR GEAR FORMULAS

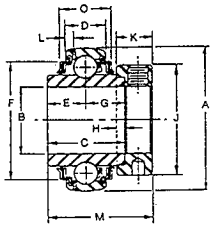
FOR FULL DEPTH INVOLUTE TEETH

| To Obtain | Having | Formula |
|---|---|---|
| Diametral Pitch (P) | Circular Pitch (p) | $P = \frac{3.1416}{p}$ |
| | Number of Teeth (N) & Pitch Diameter (D) | $P = \frac{N}{D}$ |
| | Number of Teeth (N) & Outside Diameter ($D_o$) | $P = \frac{N + 2}{D_o}$ (Approximate) |
| Circular Pitch (p) | Diametral Pitch (P) | $p = \frac{3.1416}{P}$ |
| Pitch Diameter (D) | Number of Teeth (N) & Diametral Pitch (P) | $D = \frac{N}{P}$ |
| | Outside Diameter (D) & Diametral Pitch (P) | $D = D_o - \frac{2}{P}$ |
| Base Diameter ($D_b$) | Pitch Diameter And Pressure Angle | $D_b = D\cos\phi$ |
| Number of Teeth (N) | Diametral Pitch (P) & Pitch Diameter (D) | $N = P \times D$ |
| Tooth Thickness (t) @Pitch Diameter (D) | Diametral Pitch (P) | $t = \frac{1.5708}{P}$ |
| Addendum (a) | Diametral Pitch (P) | $a = \frac{1}{P}$ |
| Outside Diameter ($D_o$) | Pitch Diameter (D) & Addendum (a) | $D_o = D + 2a$ |
| Whole Depth ($h_t$) (20P & Finer) | Diametral Pitch (P) | $h_t = \frac{2.2}{P} + .002$ |
| Whole Depth ($h_t$) (Coarser than 20P) | Diametral Pitch (P) | $h_t = \frac{2.157}{P}$ |
| Working Depth ($h_K$) | Addendum | $h_K = 2(a)$ |
| Clearance (c) | Whole Depth ($h_t$) Addendum (a) | $c = h_t - 2a$ |
| Dedendum (b) | Whole Depth ($h_t$) & Addendum (a) | $b = h_t - a$ |
| Contact Ratio ($M_c$) | Outside Radii, Base Radii, Center Distance and Pressure Angle | $M_c = \frac{\sqrt{R_o^2 - R_b^2} + \sqrt{r_p^2 - r_b^2} - C\sin\phi}{P_c\cos\phi}$ * |
| Root Diameter ($D_r$) | Pitch Diameter and Dedendum | $D_r = D - 2b$ |
| Center Distance (C) | Pitch Diameter or No. of Teeth and Pitch | $C = \frac{D_1 + D_2}{2}$ or $\frac{N_1 + N_2}{2P}$ |

*$R_o$ = Outside Radius, Gear
$r_o$ = Outside Radius, Pinion
$R_b$ = Base Circle Radius, Gear
$r_b$ = Base Circle Radius, Pinion

# N-KRRB Heavy Series Relubricatable Type

he heavy series R-Seal wide inner ring bearings are similar to the stan-
ard series described on page 141 but are capable of withstanding con-
nuous, heavy or shock loads. The GN-KRRB series utilizes a heavier
uter ring than the standard series, as well as, a considerably thicker
aling member in the contact-type diaphragm seal. This design assures
omplete retention of the lubricant and positive exclusion of all
ontaminants. These bearings are especially effective at slow-to-
oderate speeds under the severest conditions of dirt and corrosion.




commended shaft tolerances: 1/2"-2 9/16", nominal to -.0005", -.013 mm;
2 9/16"-3 15/16", nominal to -.001", -.025 mm.

■ ORDER, SPECIFY BEARING NUMBER FOLLOWED BY "AND COLLAR." Example: GN303KRRB and Collar.

| Bearing Number | Collar Number | Basic Outer Ring Size | Bore[1] B | O.D. A | Ring Widths Inner | Ring Widths Outer | E | G | H | J | K | L | M | F | O | Brg. & Collar WL | | Static Load Rating $C_o$ | Extended Dynamic Load Rating $C_E$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | in. | in. mm | in. mm | in. mm | in. mm | in. mm | in. mm | in. mm | in. mm | in. mm | in. mm | in. mm | in. mm | lbs. | kg | lbs. N | lbs. N |
| N103KRRB | SN103K | G306 | 1 3/16 | 2.8346 72 | 1 7/16 36.51 | .787 20 | 11/16 17.5 | 3/4 19.1 | 5/32 4.0 | 1 19/16 45.2 | 11/16 17.5 | .142 3.61 | 1 31/32 50.0 | 2.369 60.17 | .925 23.50 | 1.22 | .553 | 3550 15600 | 7500 33500 |
| N104KRRB | SN104K | | 1 1/4 | | | | | | | | | | | | | 1.68 | .762 | | |
| N105KRRB | SN105K | | 1 5/16 | 3.1496 80 | 1 1/2 38.10 | .866 22 | 23/32 18.3 | 25/32 19.8 | 5/32 4.0 | 2 3/16 55.6 | 11/16 17.5 | .156 3.96 | 2 1/32 51.6 | 2.638 67.01 | 1.063 27.00 | 1.64 1.60 | .744 .726 | 4500 20000 | 9150 45500 |
| N106KRRB | SN106K | G307 | 1 3/8 | | | | | | | | | | | | | 1.56 | .708 | | |
| N107KRB | SN107K | | 1 7/16 | | | | | | | | | | | | | | | | |
| N108KRRB | SN108K | G308 | 1 1/2 | 3.5433 90 | 1 3/8 41.28 | .984 25 | 29/32 19.8 | 27/32 21.4 | 3/16 4.8 | 2 1/2 63.5 | 13/16 20.6 | .182 4.62 | 2 1/4 57.2 | 2.955 75.06 | 1.050 26.67 | 2.54 | 1.152 | 5500 24500 | 11000 49000 |
| N110KRRB | SN110K | | 1 5/8 | 3.9370 100 | 1 11/16 42.86 | 1.063 27 | 29/32 19.8 | 29/32 23.0 | 3/16 4.8 | 2 3/4 69.9 | 13/16 20.6 | .197 5.00 | 2 5/16 58.7 | 3.251 82.58 | 1.123 28.52 | 3.65 3.21 2.95 | 1.656 1.456 1.388 | 6700 30000 | 13200 56500 |
| N111KRRB | SN111K | G309 | 1 11/16 | | | | | | | | | | | | | | | | |
| N112KRRB[2] | SN112K | | 1 3/4 | | | | | | | | | | | | | | | | |
| N114KRRB | SN114K | G310 | 1 7/8 | 4.3307 110 | 1 15/16 49.21 | 1.142 29 | 31/32 24.6 | 31/32 24.6 | 3/16 4.8 | 2 63/64 75.8 | 7/8 22.2 | .211 5.36 | 2 5/8 66.7 | 3.654 92.87 | 1.215 30.86 | 4.35 4.20 | 1.973 1.935 | 8000 35500 | 15300 68000 |
| N115KRRB | SN115K | | 1 15/16 | | | | | | | | | | | | | | | | |
| N200KRRB | SN200K | G311 | 2 | 4.7244 120 | 2 3/16 55.56 | 1.220 31 | 1 3/32 27.8 | 1 3/32 27.8 | 3/16 4.8 | 3 1/4 82.6 | 7/8 22.2 | .216 5.49 | 2 7/8 73.0 | 4.007 101.78 | 1.475 37.47 | 4.70 5.22 | 2.132 2.398 | 9300 41500 | 18000 80000 |
| N203KRRB | SN203K | | 2 3/16 | | | | | | | | | | | | | | | | |
| N207KRRB | SN207K | G312 | 2 7/16 | 5.1181 130 | 2 7/16 61.91 | 1.299 33 | 1 7/32 31.0 | 1 7/32 31.0 | 1/4 6.4 | 3 1/2 88.9 | 15/16 23.8 | .230 5.84 | 3 1/8 79.4 | 4.312 109.52 | 1.535 38.99 | 6.26 | 2.839 -- | 10800 48000 | 20400 90000 |
| N211KRRB | SN211K | G314 | 2 11/16 | 5.9055 150 | 2 11/16 68.26 | 1.457 37 | 1 11/32 34.1 | 1 11/32 34.1 | 1/4 6.4 | 4 101.6 | 1 1/16 27.0 | .255 6.73 | 3 1/2 88.9 | 4.973 126.31 | 1.770 44.96 | 9.54 | 4.509 | 14300 63000 | 26000 116000 |
| N215KRRB | SN215K | G315 | 2 15/16 | 6.2992 160 | 2 15/16 74.61 | 1.535 39 | 1 15/32 37.3 | 1 15/32 37.3 | 1/4 6.4 | 4 7/16 112.7 | 1 1/4 31.8 | .255 6.48 | 3 15/16 100.00 | 5.273 133.92 | 2.013 51.13 | 12.42 | 5.634 | 16000 71000 | 28500 125000 |
| N303KRRB | SN303K | G316 | 3 3/16 | 6.6929 170 | 3 3/16 80.95 | 1.614 41 | 1 15/32 40.5 | 1 15/32 40.5 | 1/4 6.4 | 4 11/16 119.1 | 1 1/4 31.8 | .266 7.26 | 4 3/16 106.4 | 5.623 142.82 | 2.010 51.05 | 15.71 | 7.126 | 18000 80000 | 30500 137000 |
| N307KRRB | SN307K | G318 | 3 7/16 | 7.4803 190 | 3 7/16 87.31 | 1.772 45 | 1 21/32 42.1 | 1 21/32 42.1 | 5/16 7.9 | 5 1/4 133.4 | 1 7/16 36.5 | .322 8.18 | 4 9/16 115.9 | 6.353 161.37 | 2.072 52.63 | 20.26 | 9.190 | 22400 98000 | 35500 156000 |
| N315KRRB | SN315K | G320 | 3 15/16 | 8.4646 215 | 3 15/16 100.01 | 1.929 49 | 1 31/32 50.0 | 1 31/32 50.0 | 5/16 7.9 | 5 3/4 146.1 | 1 7/16 36.5 | .338 7.62 | 5 1/16 129.6 | 7.199 182.85 | 2.337 59.36 | 26.97 | 12.233 | 29000 132000 | 43000 193000 |

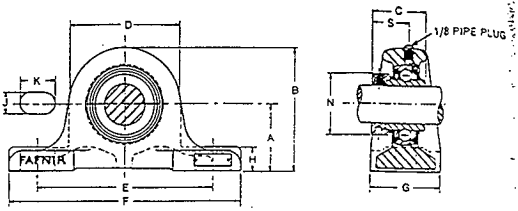
ore tolerances: 1 3/16"- 2 3/16", nominal to -.0005", -.013 mm; 2 7/16"- 3 3/16", nominal to -.0006", -.015 mm
7/16"- 3 15/16", nominal to -.0007", -.018 mm.

lso available with cylindrical O.D. Delete suffix "B" Example: GN106KRR

# RSAO Heavy Series

Fafnir RSAO units are ideally suited for installations where the load is heavy in proportion to the shaft diameter or where considerable shock loads exist. Incorporating a high capacity GN-KRRB (R-Seal) wide inner ring bearing, these units have the same base-to-center height and bolt hole spacing as Fafnir heavy series SAO pillow blocks.

These pillow blocks are prelubricated and ready for immediate use. For wet or extremely dirty conditions, a grease fitting installed in place of the standard 1/8 pipe plug will provide means of relubrication through a groove in the inside surface of the housing. All units are supplied with self-locking collars.




Recommended shaft tolerances: 11/16"-1 15/16", nominal to -.0005", -.013 mm;
2"-2 15/16", nominal to -.0010", -.025 mm.

**Bearing Data**

| Unit | Bearing Number | Dimensions and Load Ratings |
|---|---|---|
| RSAO | GN . . . KRRB | Page 144 |

TO ORDER, SPECIFY UNIT AND SHAFT DIAMETER. Example: RSAO 17/16".

| Unit | Shaft Diam. | A | B | C | D | E | F | G | H | J | K | N | S | Bolt Size | Bearing Number | Collar Number | Housing Number | Unit Wt. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | in. | in. mm | in. mm | in. mm | in. mm | in. mm | in. mm | in. mm | in. mm | in. mm | in. mm | in. mm | in. mm | in. mm | | | | lbs. kg |
| RSAO 1 1/16 | | 2 3/8 | 4 1/4 | 1 31/32 | 3 3/4 | 6 5/8 | 8 1/4 | 2 3/8 | 7/8 | 5/8 | 1 | 1 15/16 | 1 9/32 | 1/2 | GN101KRRB | SN101K | T-22678 | 6.47 |
| RSAO 1 1/8 | | 60.33 | 108.0 | 50.0 | 95.2 | 168.3 | 209.6 | 60.3 | 22.2 | 15.9 | 25.4 | 49.2 | 32.5 | 12.7 | GN102KRRB | SN102K | T-22678 | 2.937 |
| RSAO 1 3/16 | | | | | | | | | | | | | | | GN103KRRB | SN103K | T-22678 | |
| RSAO 1 1/4 | | | | | | | 6.37 | | 1.88 | | | | | | GN104KRRB | SN104K | T-22496 | |
| RSAO 1 5/16 | | 2 3/4 | 4 13/16 | 2 1/32 | 4 1/8 | 8 1/4 | 10 5/8 | 2 3/4 | 15/16 | 3/4 | 1 1/8 | 2 1/16 | 1 5/16 | 5/8 | GN105KRRB | SN105K | T-22496 | 5.15 |
| RSAO 1 3/8 | | 69.85 | 122.2 | 51.6 | 104.8 | 209.6 | 269.9 | 69.8 | 23.8 | 19.0 | 28.6 | 53.6 | 33.3 | 15.9 | GN106KRRB | SN106K | T-22496 | 2.134 |
| RSAO 1 7/16 | | | | | | | | | | | | | | | GN107KRRB | SN107K | T-22496 | |
| RSAO 1 1/2 | | 3 1/8 | 5 3/8 | 2 1/4 | 4 1/2 | 9 | 11 3/8 | 3 1/8 | 1 1/16 | 3/4 | 1 1/8 | 2 1/2 | 1 15/32 | 5/8 | GN108KRRB | SN108K | T-22672 | 12.90 |
| RSAO 1 9/16 | | 79.38 | 136.5 | 57.2 | 114.3 | 228.6 | 288.9 | 79.4 | 27.0 | 19.0 | 28.6 | 63.5 | 37.3 | 15.9 | GN109KRRB | SN109K | T-22672 | 5.857 |
| RSAO 1 5/8 | | 3 1/8 | 5 5/8 | 2 9/16 | 5 | 9 | 11 3/8 | 3 1/8 | 1 3/16 | 3/4 | 1 1/8 | 2 3/4 | 1 17/32 | 5/8 | GN110KRRB | SN110K | T-22498 | 14.45 |
| RSAO 1 11/16 | | 79.38 | 142.9 | 65.7 | 127.0 | 228.6 | 288.9 | 79.4 | 30.2 | 19.0 | 28.6 | 69.8 | 38.9 | 15.9 | GN111KRRB | SN111K | T-22498 | 6.560 |
| RSAO 1 3/4 | | | | | | | | | | | | | | | GN112KRRB | SN112K | T-22498 | |
| RSAO 1 13/16 | | 3 1/8 | 5 27/32 | 2 5/8 | 5 7/16 | 9 | 11 3/8 | 3 1/8 | 1 3/16 | 3/4 | 1 1/8 | 3 | 1 21/32 | 5/8 | GN113KRRB | SN113K | T-22502 | 15.96 |
| RSAO 1 7/8 | | 79.38 | 145.4 | 66.7 | 138.1 | 228.6 | 288.9 | 79.4 | 33.3 | 19.0 | 28.6 | 76.2 | 42.1 | 15.9 | GN114KRRB | SN114K | T-22502 | 7.245 |
| RSAO 1 15/16 | | | | | | | | | | | | | | | GN115KRRB | SN115K | T-22502 | |
| RSAO 2 | | | | | | | | | | | | | | | GN200KRRB | SN200K | T-22500 | |
| RSAO 2 1/16 | | 3 9/16 | 6 29/32 | 2 7/8 | 5 15/16 | 10 1/4 | 12 5/8 | 3 1/2 | 1 7/16 | 7/8 | 1 3/8 | 3 1/4 | 1 29/32 | 3/4 | GN201KRRB | SN201K | T-22500 | 22.45 |
| RSAO 2 1/8 | | 90.25 | 176.7 | 73.0 | 150.8 | 260.4 | 320.7 | 88.9 | 36.5 | 22.2 | 34.9 | 82.6 | 45.2 | 19.0 | GN202KRRB | SN202K | T-22500 | 10.192 |
| RSAO 2 3/16 | | | | | | | | | | | | | | | GN203KRRB | SN203K | T-22500 | |
| RSAO 2 1/4 | | | | | | | | | | | | | | | GN204KRRB | SN204K | T-22454 | |
| RSAO 2 5/16 | | 4 1/8 | 7 11/32 | 3 1/8 | 6 7/16 | 11 1/4 | 13 3/4 | 4 | 1 1/2 | 7/8 | 1 3/8 | 3 1/2 | 1 29/32 | 3/4 | GN205KRRB | SN205K | T-22454 | 33.56 |
| RSAO 2 3/8 | | 104.78 | 185.5 | 79.4 | 163.5 | 285.8 | 349.2 | 101.6 | 38.1 | 22.2 | 34.9 | 88.9 | 48.4 | 19.0 | GN206KRRB | SN206K | T-22454 | 15.144 |
| RSAO 2 7/16 | | | | | | | | | | | | | | | GN207KRRB | SN207K | T-22454 | |
| RSAO 2 5/8 | | 4 9/16 | 8 9/32 | 3 1/2 | 7 7/16 | 12 | 15 3/8 | 4 3/8 | 1 3/4 | 1 | 1 3/8 | 4 | 2 5/32 | 7/8 | GN210KRRB | SG210K | T-22492 | 42.50 |
| RSAO 2 11/16 | | 115.89 | 210.3 | 88.9 | 188.9 | 304.8 | 390.5 | 111.1 | 44.4 | 25.4 | 34.9 | 101.6 | 54.8 | 22.2 | GN211KRRB | SG211K | T-22492 | 19.295 |
| RSAO 2 3/4 | | | | | | | | | | | | | | | GN212KRRB | SG212K | T-22492 | |
| RSAO 2 13/16 | | 4 9/16 | 8 9/16 | 3 15/16 | 8 | 12 3/8 | 15 3/8 | 4 3/8 | 1 7/8 | 1 | 1 3/8 | 4 7/16 | 2 15/32 | 7/8 | GN213KRRB | SN213K | T-22490 | 44.25 |
| RSAO 2 7/8 | | 115.89 | 217.5 | 100.0 | 203.2 | 314.3 | 390.5 | 111.1 | 47.6 | 25.4 | 34.9 | 112.7 | 62.7 | 22.2 | GN214KRRB | SN214K | T-22490 | 20.090 |
| RSAO 2 15/16 | | | | | | | | | | | | | | | GN215KRRB | SN215K | T-22490 | |
| RSAO 3 3/16 | | 4 9/16 | 8 29/32 | 4 3/16 | 8 7/16 | 12 3/8 | 15 3/8 | 4 3/8 | 1 15/16 | 1 | 1 3/4 | 4 11/16 | 2 15/32 | 7/8 | GN303KRRB | SN303K | T-22444 | 50.25 |
| | | 115.89 | 223.0 | 106.4 | 214.3 | 314.3 | 390.5 | 111.1 | 49.2 | 25.4 | 44.4 | 119.1 | 63.9 | 22.2 | | | | 22.814 |
| RSAO 3 7/16 | | 5 1/8 | 9 7/8 | 4 9/16 | 9 1/2 | 13 3/8 | 16 3/8 | 4 3/4 | 2 3/4 | 1 1/8 | 2 1/8 | 5 1/4 | 2 27/32 | 1 | GN307KRRB | SN307K | T-22446 | 68.25 |
| | | 130.18 | 250.8 | 115.5 | 241.3 | 339.7 | 415.9 | 120.6 | 57.2 | 28.6 | 54.0 | 133.4 | 72.2 | 25.4 | | | | 30.986 |
| RSAO 3 15/16 | | 5 11/16 | 11 1/16 | 5 1/16 | 10 3/4 | 14 3/4 | 17 5/16 | 5 1/8 | 2 9/16 | 1 1/8 | 1 3/4 | 5 3/4 | 3 3/32 | 1 | GN315KRRB | SN315K | T-22448 | 85.50 |
| | | 144.45 | 281.0 | 128.6 | 273.0 | 374.6 | 439.7 | 130.2 | 65.1 | 28.6 | 44.4 | 146.0 | 78.6 | 25.4 | | | | 41.633 |

# RCJO Heavy Series

RCJO type heavy series flange cartridges are similar in design to the standard series. They are for applications where a minimum amount of machining is to be done and are supplied completely assembled, being mounted in place by means of bolts through the flange.

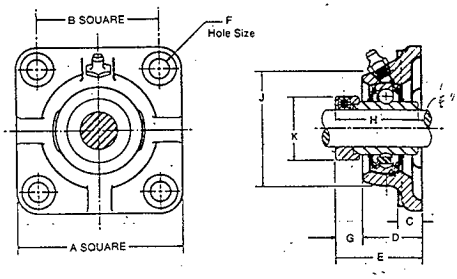
RCJO units are equipped with GN-KRRB (R-Seal) wide inner ring bearings.

A grease fitting provides for relubrication if required. Units are supplied with self-locking collars and are dimensionally interchangeable.

Recommended shaft tolerances: 1 3/16"-1 15/16", nominal to -.0005", -.013 mm;
2"-3 15/16", nominal to -.0010", -.025 mm.

Bearing Data

| Unit | Bearing Number | Dimensions and Load Ratings |
|---|---|---|
| RCJO | GN . . . KRRB | Page 144 |




TO ORDER, SPECIFY UNIT AND SHAFT DIAMETER. Example: RCJO 1 7/16".

| Unit | Shaft Diam. | A | B | C | D | E | F | G | H | J | K | Bolt (4 req'd) | Bearing Number | Collar Number | Housing Number | Unit Wt. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | in. | in.<br>mm | in.<br>mm | in.<br>mm | in.<br>mm | in.<br>mm | in.<br>mm | in.<br>mm | in.<br>mm | in.<br>mm | in.<br>mm | in. | | | | lbs.<br>kg |
| RCJO | 1 3/16 | 4 3/4<br>120.6 | 3 5/8<br>92.08 | 9/16<br>14.3 | 1 1/2<br>38.1 | 2 31/32<br>73.2 | 9/16<br>14.3 | 19/32<br>15.1 | 1 31/32<br>50.0 | 3 13/16<br>96.8 | 1 15/16<br>49.2 | 1/2 | GN103KRRB | SN103K | T-19165 | 4.00<br>1.816 |
| RCJO | 1 7/16 | 5 1/8<br>130.2 | 4<br>101.60 | 5/8<br>15.9 | 1 13/32<br>40.5 | 2 5/32<br>54.8 | 9/16<br>14.3 | 9/16<br>14.3 | 2 1/32<br>51.6 | 4 1/8<br>104.8 | 2 3/16<br>56.7 | 1/2 | GN107KRRB | SN107K | T-19167 | 5.50<br>2.497 |
| RCJO | 1 1/2 | 5 3/8<br>136.5 | 4 1/8<br>104.78 | 5/8<br>15.9 | 1 3/4<br>44.4 | 2 3/8<br>60.3 | 5/8<br>15.9 | 5/8<br>15.9 | 2 1/4<br>57.2 | 4 1/2<br>114.3 | 2 1/2<br>63.5 | 9/16 | GN108KRRB | SN108K | T-19169 | 6.90<br>3.133 |
| RCJO | 1 11/16 | 5 5/8<br>142.9 | 4 3/8<br>111.12 | 11/16<br>17.5 | 1 27/32<br>45.3 | 2 7/16<br>61.9 | 5/8<br>15.9 | 19/32<br>15.1 | 2 9/16<br>56.7 | 4 7/8<br>123.8 | 2 3/4<br>69.8 | 9/16 | GN111KRRB | SN111K | T-19171 | 7.87<br>3.573 |
| RCJO | 1 15/16 | 6 1/2<br>165.1 | 5 1/8<br>130.18 | 11/16<br>17.5 | 2 9/32<br>53.2 | 2 3/4<br>69.8 | 11/16<br>17.5 | 21/32<br>16.7 | 2 5/8<br>66.7 | 5 5/16<br>141.3 | 3<br>76.2 | 5/8 | GN115KRRB | SN115K | T-19173 | 11.42<br>5.185 |
| RCJO | 2 3/16 | 7<br>177.8 | 5 5/8<br>142.88 | 11/16<br>17.5 | 2 9/16<br>56.7 | 3<br>76.2 | 11/16<br>17.5 | 11/16<br>17.5 | 2 7/8<br>73.0 | 6 1/16<br>154.0 | 3 1/4<br>82.6 | 5/8 | GN203KRRB | SN203K | T-19175 | 14.15<br>6.424 |
| RCJO | 2 7/16 | 7 1/2<br>190.5 | 5 7/8<br>149.22 | 3/4<br>19.0 | 2 9/16<br>65.1 | 3 5/16<br>84.1 | 13/16<br>20.6 | 3/4<br>19.0 | 3 1/8<br>79.4 | 6 5/16<br>160.3 | 3 1/2<br>88.9 | 3/4 | GN207KRRB | SN207K | T-19177 | 16.32<br>7.409 |
| RCJO | 2 11/16 | 8 7/8<br>225.4 | 7<br>177.80 | 7/8<br>22.2 | 2 27/32<br>72.2 | 3 11/16<br>93.7 | 15/16<br>23.8 | 27/32<br>21.4 | 3 1/2<br>88.9 | 7 5/16<br>185.7 | 4<br>101.6 | 7/8 | GN211KRRB | SN211K | T-19179 | 21.00<br>9.534 |
| RCJO | 2 15/16 | 9 7/8<br>251.8 | 7 1/4<br>184.15 | 7/8<br>22.2 | 3 1/16<br>77.8 | 4 1/8<br>104.8 | 15/16<br>23.8 | 1 1/16<br>27.0 | 3 15/16<br>100.0 | 7 13/16<br>198.4 | 4 7/16<br>112.7 | 7/8 | GN215KRRB | SN215K | T-19181 | 31.12<br>14.128 |
| RCJO | 3 7/16 | 11<br>279.4 | 8 1/2<br>215.90 | 1 1/8<br>28.6 | 3 5/16<br>84.1 | 4 3/4<br>120.6 | 1 1/16<br>27.0 | 1 7/16<br>36.5 | 4 9/16<br>115.9 | 9<br>228.6 | 5 13/64<br>132.2 | 1 | GN307KRRB | SN307K | T-24475 | 47.30<br>21.474 |
| RCJO | 3 15/16 | 12 1/2<br>317.5 | 9 1/2<br>241.30 | 1 1/4<br>31.8 | 3 13/16<br>96.8 | 5 1/4<br>133.4 | 1 3/16<br>30.2 | 1 7/16<br>36.5 | 5 1/16<br>128.6 | 10 1/2<br>266.7 | 5 47/64<br>145.7 | 1 1/8 | GN315KRRB | SN315K | T-24477 | 67.50<br>30.645 |

# LM67000 SERIES

**BORE RANGE**
**31.750**
**1.2500**

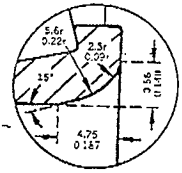
d R B

Any cone in this series may be used with any cup in this series.

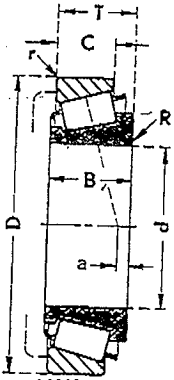
| [redacted] | | | | | cup no. LM67010 | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | outside diameter D | max housing fillet radius r | width C | bearing width T |
| 31.750<br>1.2500 | ** | LM67048 | 16.764<br>0.6600 | -3.0<br>-0.12 | 59.131<br>2.3280 | 1.3<br>0.05 | 11.811<br>0.4650 | 15.875<br>0.6250 |

a

** Compound radius—see illustration




Compound Radius




LM67010

LM67010
(half size)

LM67010
(1:2.5 size)

**THE TIMKEN COMPANY**

No. of Pages 1

| To MIKE CUSTER | From JIM LEE |
|---|---|
| Co. | Co. |
| Dept. | Phone No. |
| Fax No. | Fax No. |

x 1.374 for 175 RPM

| basic rating @ 500 rpm for 3000 hours $L_{10}$ | |
|---|---|
| radial | 9460 N<br>2130 lbf |
| thrust | 6680 N<br>1500 lbf |
| K | 1.42 |

use modifying factors to compare Timken bearing capacity-ratings with other makes of bearings.

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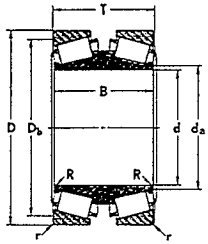
# TWO-ROW ASSEMBLY - DOUBLE CONE; SINGLE CUPS




| | | width | | rating at 500 rpm for 3000 hours $L_{10}$ | | | factor | part numbers | | cone | | cup | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | over cups T - | | one-row radial N lbf | thrust N lbf | two-row radial N lbf | K | | | | | | |
| 30.162<br>1.1875 | 62.000<br>2.4409 | 33.797<br>1.3306 | 34.925<br>1.3750 | 10400<br>2330 | 6800<br>1530 | 18100<br>4060 | 1.53 | 17116D | 17244 | 0.8<br>0.03 | 35.5<br>1.40 | 1.5<br>0.06 | 54.0<br>2.13 |
| 36.512<br>1.4375 | 68.262<br>2.6875 | 36.810<br>1.4492 | 38.100<br>1.5000 | 12200<br>2740 | 9260<br>2080 | 21200<br>4760 | 1.31 | 19145D | 19268 | 0.8<br>0.03 | 42.5<br>1.67 | 1.5<br>0.06 | 61.0<br>2.40 |
| 36.512<br>1.4375 | 71.438<br>2.8125 | 36.810<br>1.4492 | 38.100<br>1.5000 | 12200<br>2740 | 9260<br>2080 | 21200<br>4760 | 1.31 | 19145D | 19281 | 0.8<br>0.03 | 42.5<br>1.67 | 1.0<br>0.04 | 63.0<br>2.48 |
| 36.512<br>1.4375 | 72.000<br>2.8346 | 39.096<br>1.5392 | 38.100<br>1.5000 | 12200<br>2740 | 9260<br>2080 | 21200<br>4760 | 1.31 | 19145D | 19283 | 0.8<br>0.03 | 42.5<br>1.67 | 1.5<br>0.06 | 63.0<br>2.48 |
| 42.862<br>1.6875 | 85.000<br>3.3465 | 50.267<br>1.9790 | 52.375<br>2.0620 | 19600<br>4420 | 10300<br>2320 | 34200<br>7690 | 1.91 | 358D | 354A | 1.5<br>0.06 | 51.0<br>2.01 | 1.3<br>0.05 | 77.0<br>3.03 |
| 42.862<br>1.6875 | 90.119<br>3.5480 | 54.991<br>2.1650 | 52.375<br>2.0620 | 19600<br>4420 | 10300<br>2320 | 34200<br>7690 | 1.91 | 358D | 352 | 1.5<br>0.06 | 51.0<br>2.01 | 2.3<br>0.09 | 78.0<br>3.07 |
| 44.450<br>1.7500 | 80.962<br>3.1875 | 34.925<br>1.3750 | 31.750<br>1.2500 | 12200<br>2740 | 11000<br>2480 | 21200<br>4770 | 1.11 | 13176D | 13318 | SPCL | 50.0<br>1.97 | 1.5<br>0.06 | 72.0<br>2.83 |
| 50.800<br>2.0000 | 93.264<br>3.6718 | 50.013<br>1.9690 | 53.188<br>2.0940 | 21100<br>4750 | 12200<br>2750 | 36800<br>8260 | 1.73 | 375D | 374 | 0.8<br>0.03 | 57.0<br>2.24 | 1.3<br>0.05 | 85.0<br>3.35 |
| †54.988<br>†2.1649 | 136.525<br>5.3750 | 66.091<br>2.6020 | 65.989<br>2.5980 | 41100<br>9230 | 60900<br>13700 | 71500<br>16100 | 0.67 | 78216D | 78537 | 2.3<br>0.09 | 79.0<br>3.11 | 3.3<br>0.13 | 115.0<br>4.53 |
| †54.988<br>†2.1649 | 140.030<br>5.5130 | 66.091<br>2.6020 | 65.989<br>2.5980 | 41100<br>9230 | 60900<br>13700 | 71500<br>16100 | 0.67 | 78216D | 78551 | 2.3<br>0.09 | 79.0<br>3.11 | 2.3<br>0.09 | 117.0<br>4.61 |
| 61.912<br>2.4375 | 110.000<br>4.3307 | 55.550<br>2.1870 | 55.550<br>2.1870 | 23700<br>5340 | 16300<br>3670 | 41300<br>9290 | 1.45 | 399D | 394A | 0.8<br>0.03 | 70.0<br>2.76 | 1.3<br>0.05 | 101.0<br>3.98 |
| 61.912<br>2.4375 | 110.000<br>4.3307 | 55.550<br>2.1870 | 55.550<br>2.1870 | 23700<br>5340 | 16300<br>3670 | 41300<br>9290 | 1.45 | 399D | 394AS | 0.8<br>0.03 | 70.0<br>2.76 | 3.3<br>0.13 | 99.0<br>3.90 |
| 63.500<br>2.5000 | 112.712<br>4.4375 | 60.325<br>2.3750 | 60.325<br>2.3750 | 40100<br>9010 | 23300<br>5230 | 69800<br>15700 | 1.72 | 39585D | 39520 | 0.8<br>0.03 | 72.0<br>2.83 | 3.3<br>0.13 | 101.0<br>3.98 |
| 63.500<br>2.5000 | 112.712<br>4.4375 | 60.325<br>2.3750 | 60.325<br>2.3750 | 40100<br>9010 | 23300<br>5230 | 69800<br>15700 | 1.72 | 39585D | 39521 | 0.8<br>0.03 | 72.0<br>2.83 | 0.8<br>0.03 | 103.0<br>4.06 |
| 63.500<br>2.5000 | 136.525<br>5.3750 | 66.091<br>2.6020 | 65.989<br>2.5980 | 41100<br>9230 | 60900<br>13700 | 71500<br>16100 | 0.67 | 78251D | 78537 | 2.3<br>0.09 | 79.0<br>3.10 | 3.3<br>0.13 | 115.0<br>4.53 |
| 63.500<br>2.5000 | 140.030<br>5.5130 | 66.091<br>2.6020 | 65.989<br>2.5980 | 41100<br>9230 | 60900<br>13700 | 71500<br>16100 | 0.67 | 78251D | 78551 | 2.3<br>0.09 | 79.0<br>3.10 | 2.3<br>0.09 | 117.0<br>4.61 |
| †64.988<br>†2.5586 | 136.525<br>5.3750 | 66.091<br>2.6020 | 65.989<br>2.5980 | 41100<br>9230 | 60900<br>13700 | 71500<br>16100 | 0.67 | 78255D | 78537 | 1.5<br>0.06 | 79.0<br>3.11 | 3.3<br>0.13 | 115.0<br>4.53 |
| †64.988<br>†2.5586 | 140.030<br>5.5130 | 66.091<br>2.6020 | 65.989<br>2.5980 | 41100<br>9230 | 60900<br>13700 | 71500<br>16100 | 0.67 | 78255D | 78551 | 1.5<br>0.06 | 79.0<br>3.11 | 2.3<br>0.09 | 117.0<br>4.61 |
| 76.200<br>3.0000 | 115.888<br>4.5625 | 53.975<br>2.1250 | 53.975<br>2.1250 | 29900<br>6720 | 13900<br>3130 | 52100<br>11700 | 2.15 | LM114848D | LM114811 | 0.8<br>0.03 | 83.0<br>3.27 | 1.5<br>0.06 | 107.0<br>4.21 |

① These maximum fillet radii will be cleared by the bearing corners.

† For standard class ONLY, the maximum metric size is a whole millimetre value.

* Cone is extended on one side.

# LOAD RATINGS AND E CALCULATIONS

## BALL BEARINGS

### Fatigue Life

Because of the dispersion in life of identical bearings operating under dentical conditions, a statistical result will be obtained for bearing Fatigue life. For most calculations life is expressed as the number of hours that 90% of a group of identical bearings will exceed under a given set of conditions, and is referred to as the $L_{10}$ life. For life values of greater reliability than 90% refer to Table 4.

The basic life equation for radial ball bearings is:

$$L_n = \frac{16667 \times a_1 \times a_2 \times a_3}{N} \left[ \frac{f_B \times C_E}{P} \right]^3 \text{ Hours} \quad \boxed{1}$$

The basic life equation for radial roller bearings is:

$$L_n = \frac{16667 \times a_1 \times a_2 \times a_3}{N} \left[ \frac{f_B \times C}{P} \right]^{10/3} \text{ Hours} \quad \boxed{2}$$

**Notations Used in this Section:**

C = Basic Dynamic Load Rating — Radial Roller Bearings
Pounds or Newtons
$C_E$ = Extended Basic Dynamic Load Rating — Radial Ball Bearings
Pounds or Newtons
$C_o$ = Basic Static Load Rating — Radial Bearings
Pounds or Newtons
$C_{oa}$ = Basic Static Thrust Load Rating
Pounds or Newtons
= Basic Thrust Dynamic Load Rating — Ball and Roller Bearings
= Thrust Rating Calculation Factor
$K_T$ = Relative Thrust Load Factor — Ball Bearings
$L_f$ = Life Factor
$L_n$ = Fatigue Life for Reliability Level "r" — Hours
N = Operating Speed — R.P.M.
$N_f$ = Speed Factor
R = Applied Radial Load on Bearing
Pounds or Newtons
P = Equivalent Radial Load on Bearing
Pounds or Newtons
$T_e$ = Equivalent Thrust Load — Thrust Ball and Roller Bearings
Pounds or Newtons
T = Applied Thrust Load on Bearing
Pounds or Newtons
X = Radial Load Factor
$Y, Y_1, Y_2, Y_3$ = Thrust Load Factors
$a_1$ = Life Adjustment Factor for Reliability
$a_2$ = Life Adjustment Factor for Bearing Material
$a_3$ = Life Adjustment Factor for Application Conditions
$f_B$ = Dynamic Load Rating Adjustment Factor for Number of Adjacently Mounted Bearings
$i_B$ = Number of Adjacently Mounted Bearings
$P_1 \ldots P_n$ = Proportion of Time at Load/Speed Conditions 1 through n
r = Percent reliability of Survival Life
$\mu$ = Operating Viscosity — Centistokes
$\mu_R$ = Reference Viscosity — Centistokes

### d Ratings — Radial Ball Bearings

The load ratings published in this catalog are based on AFBMA Standard 9, but are increased to reflect improvements in materials and processing. These new ratings are referred to as EXTENDED BASIC DYNAMIC LOAD RATINGS, $C_E$. Care must be taken that the EXTENDED BASIC DYNAMIC LOAD RATINGS only be used in equations containing $C_E$, and should not be used in any equations in prior published Fafnir catalogs.

**NOTE: $C_E$ does not represent the maximum permissible radial load which in general is equal to $C_o$ the Static Radial Load Ratings.**

### Life — Radial Ball Bearings

Equation 1 in the case of single row bearings and where $a_1$, $a_2$, $a_3$ can be considered each equal to one, may be simplified for general purpose as follows:

$$L_{10} = \frac{16667}{N} \left[ \frac{C_E}{P} \right]^3 \text{ Hours} \quad \boxed{3}$$

### Equivalent Radial Load — Radial Ball Bearings

Calculate equivalent radial load (P) by using Table 1 and required Y factors from Table 2.

Table 1

| Bearing Description | Single Row Bearings and Tandem Mountings | Double Row Bearings and Preload Pair Mountings |
|---|---|---|
| Bearing Type and/or Series | $K_T = \frac{T}{i_B C_o}$ | $K_T = \frac{T}{C_o}$ |
| RADIAL TYPE BALL BEARINGS | Use larger of Resulting "P" Value | |
| M9300K, MM9300K<br>M9100K, MM9100K<br>M200K, MM200K<br>M300K, MM300K | P = R<br>or<br>P = 0.56R + $Y_1$T | P = R + 1.20$Y_1$T<br>or<br>P = 0.78R + 1.625$Y_1$T |
| Small inch and Metric 9300, 9100, 200, 300 and derivatives "XLS" Large Inch "W" and "GW" Tri-Ply Seal | P = R<br>or<br>P = 0.56R + $Y_1$T | |
| WIDE INNER RING BALL BEARINGS HOUSED UNITS | P = R<br>or<br>P = 0.56R + $Y_1$T | |
| ANGULAR CONTACT BALL BEARINGS | | |
| 7201K-7202W-7206W<br>7303W<br>5200K-5205K, 5218W, 5220W<br>5302K-5305K<br>5311W-5318W, 5320W<br>5322W, 5326W | P = R<br>or<br>P = 0.43R + T | P = R + 1.09T<br>or<br>P = 0.70R + 1.63T |
| 5206K-5208K,<br>5206W-5212W<br>5213-5217, 5219, 5222<br>5306W-5310W, 5319, 5324 | P = R<br>or<br>P = 0.35R + 0.76T | P = R + 0.76T<br>or<br>P = 0.63R + 1.24T |
| 7215WN-7232WN<br>7315WN-7330WN | P = R<br>or<br>P = 0.36R + 0.62T | P = R + 0.60T<br>or<br>P = 0.58R + 1.01T |
| 7207WN-7218WN<br>7304WN-7218WN<br>7412WN-7415WN | P = R<br>or<br>P = 0.35R + 0.57T | P = R + 0.55T<br>or<br>P = 0.57R + 0.96T |
| 2M9300WI<br>2M9100WI, 2MM9100WI<br>2M200WI, 2MM200WI<br>2MM300WI<br>2MMF9500WI | P = R<br>or<br>P = 0.44R + $Y_2$T | P = R + 1.124$Y_2$T<br>or<br>P = 0.72R + 1.625$Y_2$T |
| 2MM9100WO | P = R<br>or<br>P = 0.44R + $Y_3$T | P = R + 1.124$Y_3$T<br>or<br>P = 0.72R + 1.625$Y_3$T |
| 2MM9300WO | P = R<br>or<br>P = 0.43R + 1.06T | P = R + 1.16T<br>or<br>P = 0.70R + 1.72T |
| 3MMF9500WI<br>3M9300WI<br>3M9100WI, 3MM9100WI<br>3M200WI, 3MM200WI<br>3MM300WI | P = R<br>or<br>P = 0.41R + 0.87T | P = R + 0.92T<br>or<br>P = 0.67R + 1.41T |

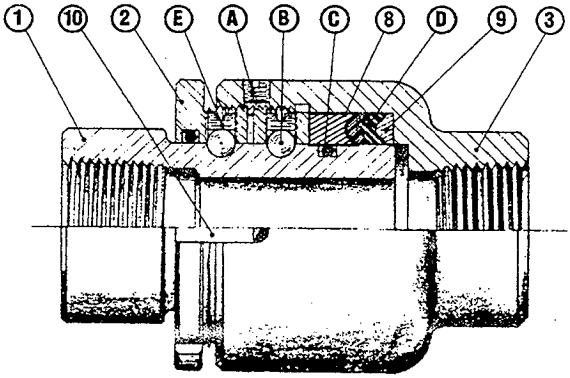
Date: * June 6, 1995

Teleconference with engineer (Jim Good) at Torrington Bearing Co., 206-455-4466 regarding Safety factor incorporated into their published Static Load Ratings.
Loading less than the Static Load Rating will result in less than 1/10 inch deformation of the ball, and would correspond to a yield strength. Actual bearing failure (ball fracture or disintegration) would require 2 to 3 times that force, which would correspond to ultimate strength. Since we are designing to safety factors of 5 to ultimate and 3 to yield, a calculated SF of 3 based on the Static Load Rating should be sufficient.
- OK but still require heavy duty bearings, resulting in enlargement of winch box.

New pumps issued - Submersible pump now weighs 3000 lbs. Three bearings will be required.

E-21-15

# T-M SWIVEL JOINTS ENGINEERING SPECIFICATIONS




Manufactured in eight styles. Sizes from 3/8" through 16" pipe size in steel, and 3/8" to 4" in aluminum and stainless steel. The basic components of T-M Union Assembly Joints are as follows:

**1** Swivel Nipple: Rotates on 2 rows of chrome alloy steel balls to ensure ease of rotation under severe thrust and radial loads.

**2** Holding Nut: Provides half of bearing race and utility of (1) Providing initial compression on packing (2) Take-up on worn packing (3) Quick disassembly for repacking. Ball races of 6000 PSI and 15,000 PSI series are through hardened to 42 to 58 Rockwell "C" scale, for maximum strength and wear.

**3** Body: Parts 1 and 3 are changed in configuration to provide eight different styles.

**8** Back-up Ring: Furnished in similar metal to part 1 to back up packing and act as outboard bearing during severe radial loads. Optional materials: Aluminum, stainless steel, teflon.

**9** Male Adaptor: Acts as wedge to expand chevron packing and effect seal. Furnished in Buna N as standard, but may be furnished in aluminum, steel, stainless steel or aramid fiber.

**10** Lock Bar: Locks assembly of parts 1 and 2 to part 3. Removal of lock bar allows holding nut to be rotated to (1) Take-up on packing in increments of .005" or (2) Remove assembly of parts 1 and 2 from body for repacking.

**A** Grease Plug: Hole is tapped to receive Alemite fitting but since T-M joints usually do not require lubrication until repacked, a flush set screw is inserted at factory.

E-21-15

Basic Components:

(B) Balls: Hardened chrome alloy steel balls are furnished as standard. Optional material: stainless steel.

(C) "O" Rings: Act as grease seals to (1) Seal grease in assembly to insure proper lubrication of bearings (2) Seal against grit and dirt from outside sources (3) Seal bearings against line contaminants. Standard 6227 and 6230 sizes used. Optional materials: Silicone, teflon, viton.

(D) Chevron Packing: The most effective packing design known, used in standard JIC and AN-6225 sizes in Buna N. Optional materials: teflon, aramid fiber, viton.

(E) Ball Plugs: Retain balls in races. Assembly of parts 1 and 2 is made at factory and need not be disassembled to repack the joint. The T-M joints can be repacked without handling balls.

---

When ordering specify Size, Style, Material, e.g.: steel, stainless steel, etc., working pressure, working temperature, material to be handled, and end connections.

Standard end connections are threaded, (TE), bored for welding, (BR), or flanged (F); see price list for prices. Other end connections on special order.

Component parts can be ordered to suit individual requirements, e.g.: 2" style 100 1000 PSI MWP, steel with bronze male adaptor (9) teflon packing (D), bronze back-up ring (8), and stainless steel balls (B).

---

T-M Swivel Joints Out-perform All Others:

They can be repacked in the line or in the field without the handling of balls. Result: Less down time.

Union Assembly allows for take up on worn packing. Result: Up to 400% longer packing life. Provides positive pressure on packing to insure against low pressure and low temperature leaks. Result: No leaks, less maintenance.

Bearing assembly is protected against outside and inside contaminants, and grease is sealed in. Result: Longer life, less maintenance.

They will withstand heavier radial loads and thrust loads while maintaining seal due to high quality bearing races, outboard bearing, and modern engineering design. Result: Lower final cost.

All packing, "O" rings, used in T-M Swivel Joints are standard to JIC and AN sizes. Commercially available. Relult: Less inventory.

T-M

E-21-15

# SWIVEL JOINTS

## ESTIMATED WEIGHTS

| STYLE | 100 | 200 | 300 | 400 | 500 | 600 | 700 | 800 |
|---|---|---|---|---|---|---|---|---|
| 3/8" & 1/2" Alum. | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 |
| Steel | 2 | 2 | 2 | 3 | 4 | 4 | 5 | 6 |
| 1" & 3/4" Alum. | 2 | 2 | 2 | 3 | 4 | 4 | 6 | 6 |
| Steel | 4 | 5 | 6 | 9 | 9 | 10 | 13 | 13 |
| 1 1/4" Alum. | 2 | 3 | 3 | 4 | 5 | 5 | 7 | 7 |
| Steel | 5 | 6 | 7 | 10 | 11 | 12 | 15 | 16 |
| 1 1/2" Alum. | 3 | 4 | 4 | 5 | 6 | 6 | 8 | 9 |
| Steel | 9 | 11 | 12 | 16 | 18 | 19 | 23 | 24 |
| 2" Alum. | 6 | 8 | 9 | 12 | 13 | 15 | 18 | 19 |
| Steel | 13 | 19 | 23 | 31 | 34 | 38 | 48 | 51 |
| 15000 PSI Steel | 18 | 21 | 24 | 34 | 39 | 44 | 52 | 57 |
| 2 1/2" Alum. | 8 | 9 | 12 | 15 | 17 | 19 | 23 | 25 |
| Steel | 21 | 25 | 31 | 38 | 43 | 47 | 59 | 65 |
| 3" Alum. | 10 | 12 | 15 | 21 | 23 | 26 | 30 | 33 |
| Steel | 25 | 29 | 37 | 49 | 57 | 65 | 82 | 90 |
| 4" Alum. | 19 | 23 | 27 | 31 | 42 | 47 | 58 | 62 |
| Steel | 52 | 60 | 72 | 85 | 98 | 110 | 136 | 144 |
| 6" Steel | 95 | 110 | 125 | 205 | 220 | 235 | 315 | 330 |
| 8" Steel | 115 | 146 | 177 | 262 | 292 | 323 | 407 | 438 |
| 10" Steel | 140 | 195 | 250 | 335 | 390 | 445 | 530 | 585 |
| 12" Steel | 155 | 233 | 311 | 388 | 466 | 544 | 621 | 699 |

Note: All weights given in pounds for threaded or welded ends. (Flanged weights not included.)

## TERMS AND CONDITIONS OF SALES:

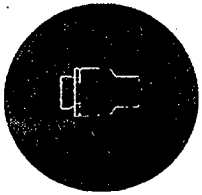
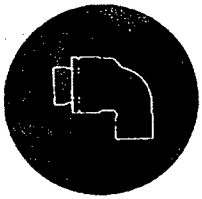
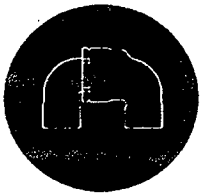
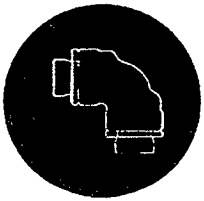
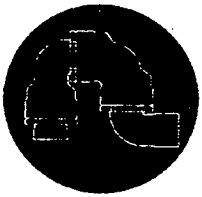
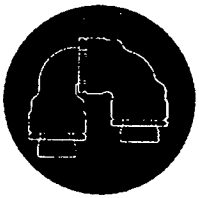
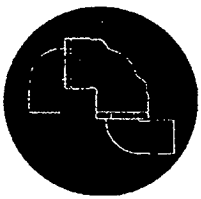
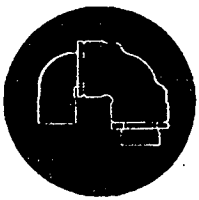
Prices and conditions of sale are subject to change without notice. Prices of all T-M Products are f. o. b., Sunnyvale, California. All material for export is subject to a 4% charge for export boxing. Material will be accepted for credit when returned with permission, and material returned for credit is subject to a restocking charge. Orders for products incorporating variations from catalog listed items are special; are subject to cancellation at extra charge and cannot be accepted for credit upon return. We insure to the common carrier but not normally beyond the point of delivery to the common carrier unless otherwise instructed. We maintain responsibility to the extent of the insurance carried . . . to the common carrier . . . or beyond when so instructed.

## GUARANTEE:

All T-M Products are unconditionally guaranteed for one year against defective material or workmanship. Materials returned, f. o. b. Sunnyvale, if found defective will be repaired. Material found damaged, but not defective, will be repaired at nominal service charge.

## WHEN ORDERING SPECIFY:

1. Pipe Size.
2. Style number of joints.
3. Material (aluminum, steel, stainless steel).
4. Product to be handled
5. Operating pressure.
6. Operating temperature.
7. End connections (threaded, flanged, bored or beveled for weld).

- THE FINAL COST OF AN ITEM IS DETERMINED BY ITS PERFORMANCE
- T-M SWIVEL JOINTS ARE OUTPERFORMING ALL OTHERS
- SPECIFY AND BUY T-M SWIVEL JOINTS FROM

| REPRESENTATIVE |
| --- |
| |

T-M

SWIVEL JOINTS

T-M MFG. CO.. 695 E. ARQUES AVE.. SUNNYVALE. CALIF. 94086 (408) 736-5202 FAX (408) 736-3743

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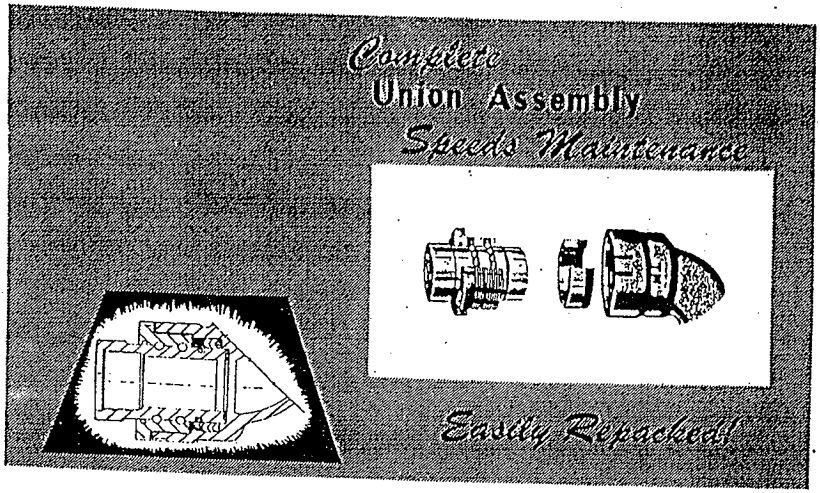



The T-M Swivel Joints are the result of modern engineering methods applied to the design and manufacture of Ball-Bearing Swivel Joints. Over 400 different types, styles, and sizes have been developed for pressures and services from 28" vacuum to 15,000 p.s.i., and temperatures to 550degrees F.

Along with the development of new types of Swivel Joints for many different services, T-M also carries on continuous research for the purpose of developing and perfecting Swivel Joints which will meet your performance specifications.

All T-M Ball Bearing Swivel Joints employ the basic principle that all turning movement takes place on double rows of Ball-Bearings. Although each rotating member turns in a single plane, unlimited flexibility is secured by combining swivels in the proper sequence.

The T-M Swivel Joint arrangement bridges the gap between the working parts so that abrasives are filtered out. Packing seals last longer, lubrication is sealed in, which maintains the life of the Ball-Bearings. T-M swivel joints are grease packed when assembled, and no further greasing is required unless the joint is in constant rotation.

T-M Swivel Joints are superior because:

They will withstand greater radial and thrust loads while maintaining seal.

The union assembly allows for repacking in minutes, while in the line.

Union assembly allows take-up for worn packing, thus extending the usable life of packing.

Union assembly allows take-up for pressure variances and for extremely volatile materials.

Union assembly permits repacking without the handling of balls.

Standard packing is used throughout T-M Swivel Joints. Available from T-M Manufacturing, their Dealers, or from your local supplier.

**T-M**

**SWIVEL JOINTS**

T-M MFG. CO., 695 E. ARQUES AVE., SUNNYVALE, CALIF. 94086 (408) 736-5202

# Lovejoy Universal Joints

## Pin and Block

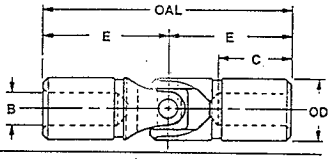
### D Type

Standard industrial type universal joint with pin and block design. The special tapered shape of the yolks provide exceptional strength for long life, while allowing full free movement of the joint.

Ideal for applications with angles up to 25° and speeds up to 1750 RPM.* Available with your choice of round, hex, splined, or keyway bores. Boot retaining grooves are standard.

*Operation of all universal joints is determined by the angle/speed combinations of the application. Consult Lovejoy Engineering for specific limitations and recommendations.

D Type



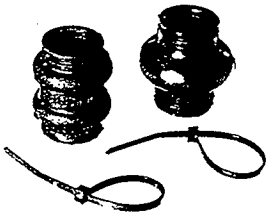

D Type Dimensional Data

| Catalog Number Solid | Catalog Number Bored | O.D. | Overall Length OAL | Dimensions in Inches Bore Diameter** B Std. | B Max. | E | Bore Depth C | Max. Bore with Keyway | Max. Square Hole | Static Breaking Torque In.-Lb. | Approx. Weight Lbs. Solid | Bored |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| D-1 | D-1B | 3/8 | 1 3/4 | 3/16 | 1/4 | 7/8 | 9/16 | — | 3/16 | 110 | .05 | .04 |
| D-2 | D-2B | 1/2 | 2 | 1/4 | 3/8 | 1 | 5/8 | — | 1/4 | 378 | .10 | .08 |
| D-3 | D-3B | 5/8 | 2 1/4 | 5/16 | 1/2 | 1 1/8 | 11/16 | 1/8 | 5/16 | 540 | .17 | .15 |
| D-4 | D-4B | 3/4 | 2 11/16 | 3/8 | 5/8 | 1 11/32 | 7/8 | 7/16 | 3/8 | 768 | .30 | .25 |
| D-5 | D-5B | 7/8 | 3 | 7/16 | 13/16 | 1 1/2 | 7/8 | 1/2 | 7/16 | 1,176 | .45 | .37 |
| D-6 | D-6B | 1 | 3 3/8 | 1/2 | 3/4 | 1 11/16 | 1 | 9/16 | 1/2 | 1,560 | .65 | .55 |
| D-7 | D-7B | 1 1/8 | 3 1/2 | 9/16 | 7/8 | 1 3/4 | 1 | 5/8 | 9/16 | 2,880 | .85 | .71 |
| D-8 | D-8B | 1 1/4 | 3 3/4 | 5/8 | 1 | 1 7/8 | 1 1/16 | 3/4 | 5/8 | 5,220 | 1.11 | .94 |
| D-10 | D-10B | 1 1/2 | 4 1/4 | 3/4 | 1 1/8 | 2 1/8 | 1 3/16 | 7/8 | 3/4 | 7,920 | 1.8 | 1.5 |
| D-11 | D-11B | 1 3/4 | 5 | 7/8 | 1 1/4 | 2 1/2 | 1 3/8 | 1 | 13/16 | 10,680 | 3.0 | 2.5 |
| D-12 | D-12B | 2 | 5 7/16 | 1 | 1 1/2 | 2 23/32 | 1 1/2 | 1 3/16 | 7/8 | 15,600 | 4.2 | 3.5 |
| D-13 | D-13B | 2 1/2 | 7 | 1 1/4 | 1 3/4 | 3 1/2 | 2 | 1 1/2 | 1 1/8 | 33,120 | 8.5 | 7.2 |
| D-14 | D-14B | 3 | 9 1/16 | 1 1/2 | 2 | 4 17/32 | 2 3/4 | 1 13/16 | 1 3/8 | 65,400 | 16.0 | 13.0 |
| D-15 | D-15B | 4 | 10 5/8 | 2 | 2 1/2 | 5 5/16 | 3 1/4 | 2 1/2 | 1 3/4 | 138,000 | 33.0 | 26.0 |

NOTE: Maximum operating angle for transmission of power is 25°.
Dimensions subject to change without notice.
**Applications which fall outside the limitations of these tables should be referred to our technical design staff.
Keyways, set screws, pin holes, special materials, or bores other than standard available at additional charge.

## Universal Joint Boots

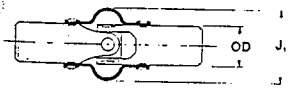
The life of a universal joint can be extended substantially if booted. Wear areas of the universal joint are protected from dirt and contaminants, while lubrication is retained. Lovejoy on-site replaceable boots ensure proper lubrication for up to 5 times longer universal joint life. Installation and replacement is fast and easy. Your machine can be back in operation in minutes. Lovejoy universal joints: D, D-SS, DD, DDX, HD, NB and LOJ come pre-grooved to accommodate on-site replaceable boots.



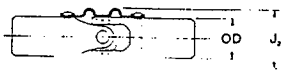
| Boot Size | O.D. | Upper $J_1$ | Lower $J_2$ |
|---|---|---|---|
| D-1 | 3/8 | 23/32 | 5/8 |
| D-2 | 1/2 | 29/32 | 3/4 |
| D-3 | 5/8 | 1 3/32 | 15/16 |
| D-4 | 3/4 | 1 11/32 | 1 1/16 |
| D-5 | 7/8 | 1 1/2 | 1 1/4 |
| D-6 | 1 | 1 3/4 | 1 3/8 |
| D-7 | 1 1/8 | 2 1/32 | 1 1/2 |
| D-8 | 1 1/4 | 2 1/32 | 1 11/16 |
| D-10 | 1 1/2 | 2 9/16 | 1 15/16 |
| D-11* | 1 3/4 | — | 2 3/16 |
| D-12* | 2 | — | 2 19/32 |
| D-13* | 2 1/2 | — | 3 1/4 |
| D-14* | 3 | — | 4 1/4 |
| D-15* | 4 | — | 5 1/2 |

Boots are available separately.
Specify boot size and if upper or lower
(ex. D-1 Upper Boot)

Upper Type Boot (U)



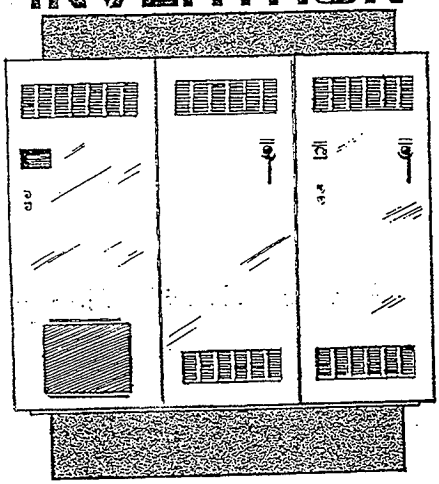

Lower Type Boot (L)




When possible use the larger diameter Upper Type boots. If sufficient space is not available then use the smaller diameter Lower Type boots. Standard boots are packaged two to a bag.

250VP AC Drive

# INVERTRON



VGI and VCI
Digital PWM Inverters

RELIANCE ELECTRIC

# INVERTRON
A-C DRIVES

250HP AC DRIVE

## Standard Specifications

| Inverter Model | VGI | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | Sales Order Engineering Models | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | VCI | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | | | | | | | |
| Output Ratings | HP Rating @ 460V | 150 | 200 | 250 | 300 | 350 | 400 | 500 | 600 | 700 | 800 | 900 | 1000 | 1200 |
| | Output Current | 180 | 240 | 300 | 360 | 420 | 480 | 625 | 750 | 875 | 960 | 1080 | 1200 | 1380 |
| Output Ratings | Overload Capacity | Up to 150% for 1 minute | | | | 125% | 110% | 110% of 936 A | | | | | | |
| | Output Frequency | 0–200 Hertz | | | | | | | | | | | | |
| Input Ratings | Power Supply | 3-Phase 380/400/415/460V | | | | | | | | | | | | |
| | Allow. Variation | Plus or minus 10 percent | | | | | | | | | | | | |
| Control Specs. | Control Method | VGI: Flux Regulated Sine Wave<br>VCI: Flux Vector Regulation | | | | | | | | | | | | |
| | Speed Regulation | VGI: 0.5% of base frequency with slip compensation<br>VCI: 0.05% of base frequency | | | | | | | | | | | | |
| | Freq. Regulation | 0.1 Hertz | | | | | | | | | | | | |
| | Volts/Hertz Ratio | VGI: Multi-point V/Hz curve shaping either linear or quadratic<br>VCI: Programmable motor voltage regulation | | | | | | | | | | | | |
| | Torque Boost | VGI: Up to 30 Volts at a programmable output frequency VCI: Calculated from motor input data | | | | | | | | | | | | |
| | Carrier Frequency | Full-spectrum switching carrier frequency (between 800 Hz and 4 KHz) to lower motor noise | | | | | | | | | | | | |
| | Auxiliary Functions | VGI: Three critical frequency avoidance bands, D-C braking, Start into a rotating motor, Slip compensation<br>VCI: 8 selectable preset speeds, Torque limit, Programmable for winder applications | | | | | | | | | | | | |
| Operating Specs. | Operating Method | Keypad, or hardwired pilot devices connected to control terminal strip | | | | | | | | | | | | |
| | Speed Reference/ Input Signals | Up/Down arrow keys on keypad; 0–10 VDC (+/–), 0–20 or 4–20 mA analog signals wired to terminal strip, Static MOP inputs wired to terminal strip, 0–1 MHz (Pulse Train), and preset speeds | | | | | | | | | | | | |
| | Accel. and Decel. Time | VGI: Linear or "J" curve 1 to 3277 seconds; acceleration and deceleration set independently<br>VCI: Linear 0.1 to 3277 seconds, acceleration and deceleration set independently | | | | | | | | | | | | |
| | External Output Signals (analog) | 0–10 VDC analog outputs proportional to motor voltage, motor current, and motor speed; Optional 4–20 mA output signals | | | | | | | | | | | | |
| | Digital Outputs | Fault contact, 1–N.O.; Run contact, 1–N.O.; 2–Programmable output relay contracts each 1–N.O. | | | | | | | | | | | | |
| | Serial Communications | RS232C serial port with optional MMI software provides ability to upload/download drive parameters, and monitor register values | | | | | | | | | | | | |
| Protective Functions | Inverter Trip | Run permissive open, heatsink overtemperature, line dip ride-through time exceeded, Overspeed, D-C bus overcurrent, Motoring overcurrent, Ground fault current, Microprocessor fault, Motor overcurrent | | | | | | | | | | | | |
| | Fault Warning | D-C Bus Voltage less than 85%, plus two programmable input contacts from user. | | | | | | | | | | | | |
| | Ride Through | Six cycles with a programmable voltage ride-through level | | | | | | | | | | | | |
| | Fault Reset | Fault reset by contact closure or keypad | | | | | | | | | | | | |
| Indication and Keypad | Display Mode | Motor RPM, Input Speed Reference, Motor Voltage, Motor Current, D-C Bus Voltage, Slip Frequency, and Output Frequency; Units are scalable | | | | | | | | | | | | |
| | Reference Mode | Displays the method of speed reference input such as analog input, MOP, preset speeds or speed pot | | | | | | | | | | | | |
| | Control Mode | Displays the method of drive control either keypad, or terminal strip | | | | | | | | | | | | |
| | Diagnostic Mode | Fault codes with English messages are displayed; As each fault occurs it is stored with an occurrence time in NVRAM; If several faults occur at once, they will be shown flashing | | | | | | | | | | | | |
| | Code Mode | Provides the ability to enter and display the three levels of password protection | | | | | | | | | | | | |
| Operating Condi-tions | Storage Temp. | –40° C to 65° C (–40° F to 149° F) | | | | | | | | | | | | |
| | Ambient Temp. | 0° C to 40° C (32° F to 104° F) | | | | | | | | | | | | |
| | Humidity | Non-condensing, relative humidity to 95% | | | | | | | | | | | | |
| | Installation | Indoor not more than 1000 m (3300 ft.) above sea level | | | | | | | | | | | | |
| | Enclosure | NEMA I force-ventilated | | | | | | | | | | | | |
| | Weight (kg) | 980 | 980 | 980 | 980 | 980 | 980 | 2000 | 2000 | 2000 | 2000 | 3000 | 3000 | 3000 |
| | | Up to 400 HP | | | | | | 500–800 HP | | | | 900–1200 HP | | |

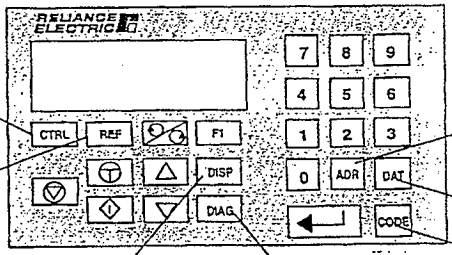
RELIANCE ELECTRIC

250 HP AC DRIVE

# INVERTRON
A-C DRIVES

## A multi-function alphanumeric keypad and display provides operation, programming, and monitoring of running condition.

The VGI/VCI keypad display is comprised of two lines and 40 characters. This backlit, LCD, English message display is easily visible when viewing – even from a distance.




**CONTROL MODE:** – Shows the selection and status of the control source (keypad, or remote operation) and any faults, alarms or other status indications.

**REFERENCE MODE:** – Displays which speed reference sources are configured and which one is active.

**DISPLAY MODE:** – Shows actual system values, such as voltage, current, frequency and speed.

**DIAGNOSTIC MODE:** – Clear text indications of fault, alarm, and emergency conditions. Keeps an error log of faults coinciding with the working hours counter.

**REGISTER MODE:** Displays values in registers with proper address and ability to modify data (with proper passwords when necessary.)

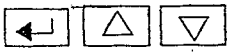
**DATA MODE:**

**CODE MODE:** In this mode, passwords and password levels can be defined.

### OPERATOR KEYS:

Start Stop Reverse Jog

### NON-STATE KEYS:



Enter Up Down

### RS232 PROGRAMMING PORT IS ALSO AVAILABLE – AS STANDARD.

Using Reliance MMI Software all parameters can be downloaded, uploaded, monitored, and saved as a file for transfering to future additional drives.

### FAULT DISPLAYS (Sample List)

| DISPLAY | DESCRIPTION |
|---|---|
| LOW_LINE_FLT | Line Dip Ride Thru Exceeded |
| BUS_OVERVOLT | Bus Overvoltage |
| OVERTEMP_INV | Overtemperature on Heatsink |
| BASE_DRV_FAULT | Power Supply Fault |
| BUS_OVERCURR | Bus Overcurrent Trip |
| MOT_OVERCURR | Motor Overcurrent |
| EARTH_CURRNT | Ground Fault Trip |
| LVOLT_TIMOUT | Coast Thru too Long |
| PROC:A-B_FAULT | Processor 'A' Fault |
| MCR_KPS_OPEN | Main Contactor Auxiliary Open |
| MCR_KPS_CLSD | Main Contactor Auxiliary Closed |
| ±15/5V_FAULT | Logic Power Not Ready |
| PROC: B_W. DOG | Processor Watchdog Time Out |
| BUS_ASYM_VLT | D-C Bus Asym. Charged |

(NEW PUMP IN TANK) as of 6/6/95

D1 499334

(HOLE 36" Ø (±))

33

ROTATION

CONNECTIONS:
M MAIN POWER LEADS TO MOTOR

WEIGHTS:
PUMP 1500 LBS.
MOTOR 1500 LBS.
TOTAL 3000 LBS.(APPROXIMATE)

DRIVER DATA

NOTES:

7

DISCHARGE

M

LC

LS

WHL SUBMERGENCE LENGTH

ELECTRIC MOTOR

65

M1

W1 V1 U1

B1

T1

B2

W1 U1

A2

Z2

W1 U1

W1 U1

P2

P1

REF NOTE 2

D2

W1 U1 V1

B1

T1

B1

4

15

10

6

3

1

SCREENED SUCTION

PRELIMINARY

| | | | | | |
|---|---|---|---|---|---|
| 90754-2 | 16047-311-E2 | 2 | | | 30-PP-404-02 |
| 90754-1 | | 1 | | | 30-PP-404-01 |
| PUMP SERIAL NUMBER | MODEL NUMBER | UNIT NUMBER | EQUIPMENT NAME | EQUIPMENT NUMBER | |

OWNER:

PROJECT:

LEGEND
- PUMP PART
- FASTENER
- CONNECTION

| NO | BY | DATE | CHECKED | DESCRIPTION |
|---|---|---|---|---|
| | | | | REVISIONS |

3 X 4 X 13

DATE 7/1 DRAWN R.A.M.
DATE 15 OCT 90 CHKD
SCALE 3 R.A.M.

LAWRENCE PUMPS INC.
LAWRENCE, MASS.

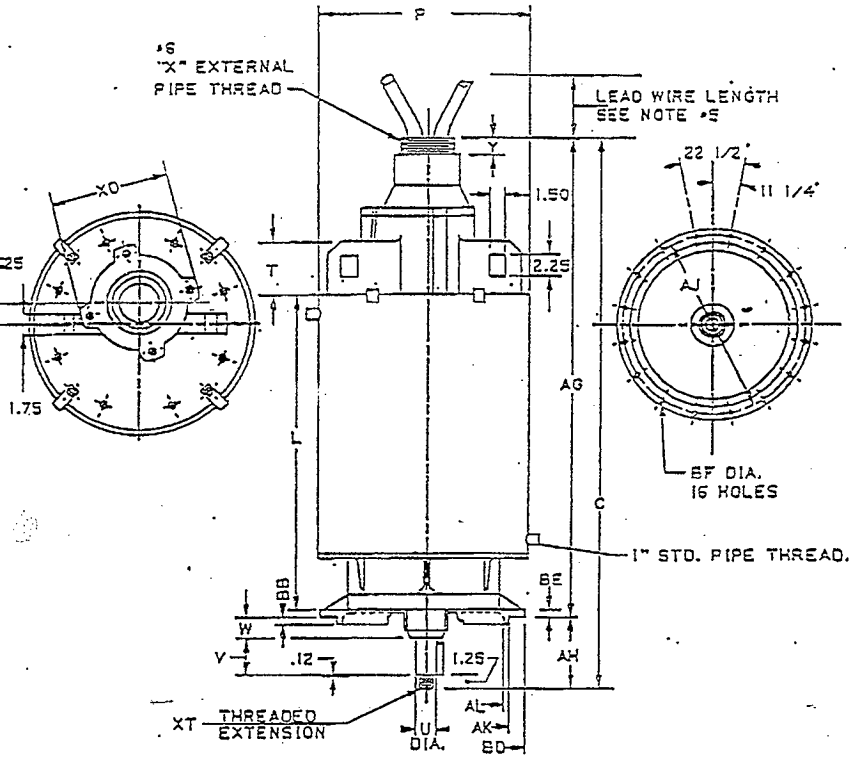
D1 499334 1 of 1

# TY MASTER ALTERNATING CURRENT MOTORS

SQUIRREL-CAGE INDUCTION

ENCLOSURE: TOTALLY ENCLOSED SUBMERSIBLE

FRAME L360TY




DIMENSIONS ARE IN INCHES

| FRAME | C | L | P | T | U (3) | V | W | AG | AH | AJ | AK (4) | AL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 360TY | 51.81 | 33.25 | 20.38 | 4.25 | 2.4997 | 3.19 | 2.12 | 45.25 | 6.56 | 18.75 | 17.500 | 15.25 |
| 1.) | | | | | | | | | | | | |

| FRAME | BB | BD (2) | BE | BF | XT | LEAD CONNECTION X | LEAD CONNECTION Y | B.E. KEY XO | B.E. KEY SQ. | B.E. KEY LGTH. |
|---|---|---|---|---|---|---|---|---|---|---|
| 360TY | .25 | 20.25 | 1.12 | .69 | 1-1/2-12 | 3 - 8 | 1.25 | 10.88 | .50 | 3.00 |
| 1.) | | | | | | | | | | |

1.) SPECIAL DIMENSIONS APPLYING TO THIS ORDER ON THIS LINE.
2.) "BD" VARIES ±.010.
3.) "U" VARIES +.0000, -.0005.
4.) "AK" VARIES +.000, -.002
5.) LEAD WIRE LENGTH AS SPECIFIED ON SALES ORDER.
6.) 3 1/2 - 8 PIPE THREAD SUPPLIED WITH CABLE SIZES LARGER THAN #1/0

FACE RUNOUT AND ECCENTRICITY .005 MAX. T.I.R.

PROTECTIVE CONDUIT FURNISHED BY CUSTOMER.

TYPE- L360TY TYPE- TENV CERTIFIED FOR-

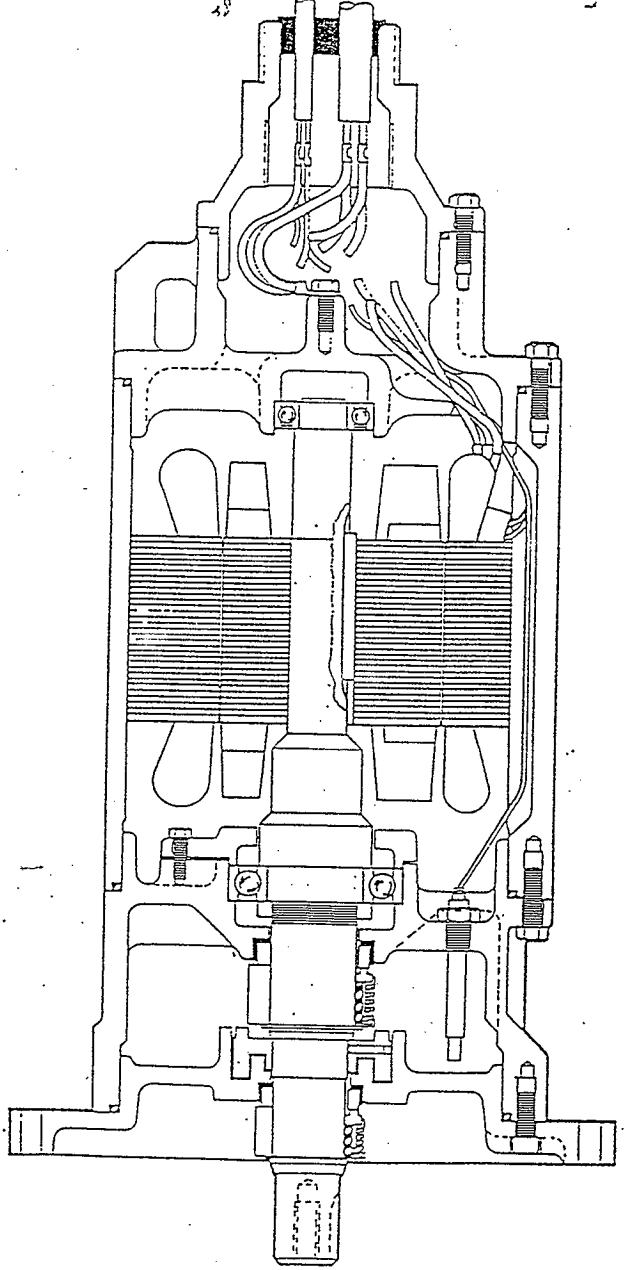
ORDER- ITEM- XP- XPR- PH- 3 HZ 60 VOLTS 460

RELIANCE SALES ORDER- APPROVED BY- MMW DATE 7-15-92

RELIANCE ELECTRIC

DR. BY R.S. MUELLER
CK. BY R.R. MONTANEZ

DIMENSION 66930-120 SHEET



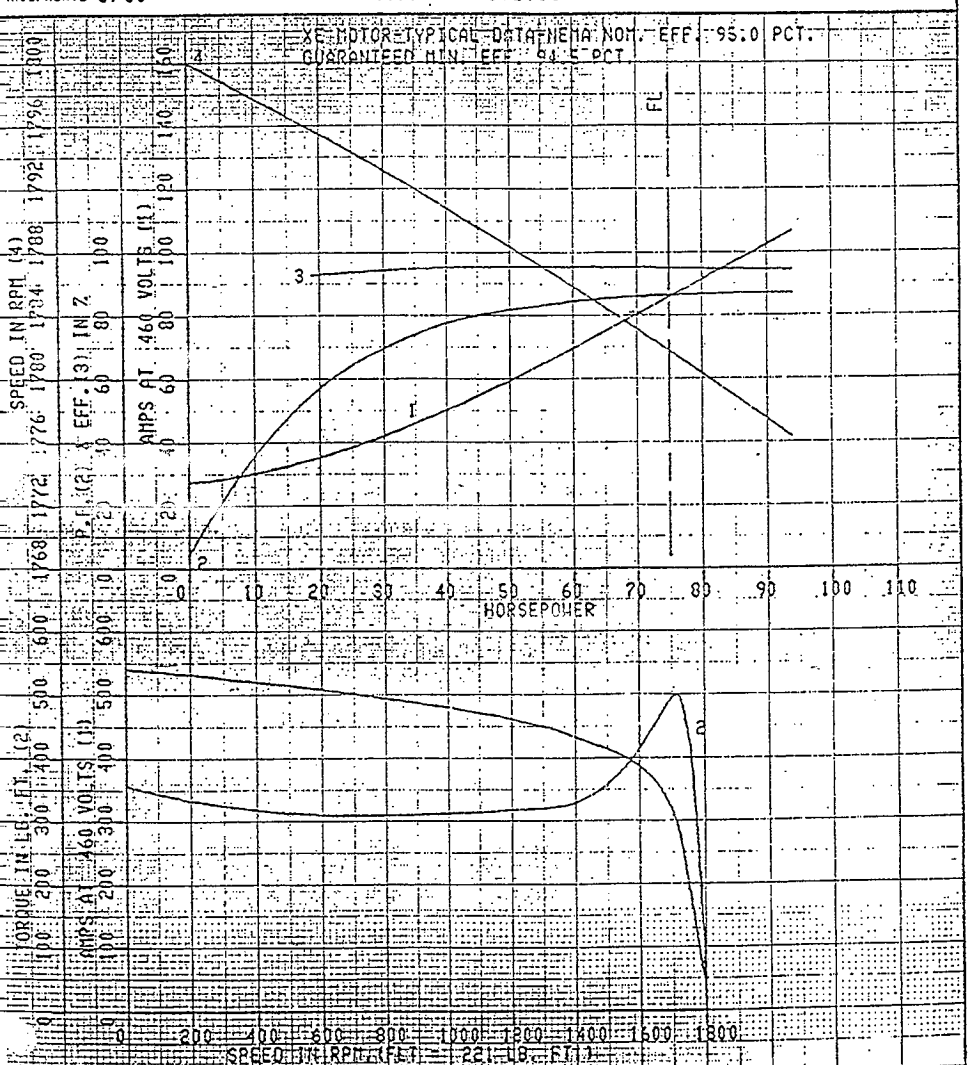
matl

EL S.O.-
AME [redacted]
5
YPE P
HASE/HERTZ 3/60

RPM 1780
VOLTS 460
AMPS 85.5
DUTY CONT
AMBºC/INSUL 40/F

S.F. 1.15
NEMA DESIGN B
CODE LETTER G
ENCLOSURE TEFC-XT
E/S 592966

ROTOR 418141-33-RE
TEST S.O. ---
TEST DATE ---
STATOR RES.@ 25ºC .0806
OHMS (BETWEEN LINES)




AMPERES SHOWN FOR 460 VOLT CONNECTION. IF OTHER VOLTAGE CONNECTIONS ARE AVAILABLE, THE AMPERES WILL VARY INVERSELY WITH THE RATED VOLTAGE.

RELIANCE ELECTRIC

DR. BY P.B. GREENE
CK. BY D. M. GYRO
APP. BY D. M. GYRO

A-C MOTOR PERFORMANCE CURVES

E3669A-A-002

ISSUE DATE 09/13/84

| REL. S.O. | FRAME | HP | TYPE | PHASE/ HERTZ | RPM | VOLTS |
|---|---|---|---|---|---|---|
| - | [redacted] | 75 | P | 3/60 | 1780 | 460 |

| AMPS | DUTY | AMB°C/ INSUL. | S.F. | NEMA DESIGN | CODE LETTER | ENCL. |
|---|---|---|---|---|---|---|
| 85.5 | CONT | 40/F | 1.15 | B | G | TEFC-XT |

| E/S | ROTOR | TEST S.O. | TEST DATE | STATOR RES.@25°C OHMS (BETWEEN LINES) |
|---|---|---|---|---|
| 592966 | 418141-33-RE | --- | --- | .0806 |

PERFORMANCE

| LOAD | HP | AMPERES | RPM | % POWER FACTOR | % EFFICIENCY |
|---|---|---|---|---|---|
| NO LOAD | 0 | 27.5 | 1800 | 4.41 | 0 |
| 1/4 | 18.8 | 34.3 | 1796 | 55.3 | 92.8 |
| 2/4 | 37.5 | 48.6 | 1791 | 76.0 | 95.1 |
| 3/4 | 56.2 | 66.1 | 1787 | 83.6 | 95.4 |
| 4/4 | 74.9 | 85.5 | 1782 | 86.4 | 95.0 |
| 5/4 | 93.8 | 107 | 1776 | 87.0 | 94.4 |
| | | | | | |

SPEED TORQUE

| | RPM | TORQUE % FULL LOAD | TORQUE LB.-FT. | AMPERES |
|---|---|---|---|---|
| LOCKED ROTOR | 0 | 162 | 357 | 540 |
| PULL UP | 700 | 140 | 309 | 501 |
| BREAKDOWN | 1715 | 226 | 499 | 290 |
| FULL LOAD | 1782 | 100 | 221 | 85.5 |

AMPERES SHOWN FOR 460. VOLT CONNECTION. IF OTHER VOLTAGE CONNECTIONS ARE AVAILABLE, THE AMPERES WILL VARY INVERSELY WITH THE RATED VOLTAGE

REMARKS: XE MOTOR-TYPICAL DATA-NEMA NOM. EFF. 95.0 PCT.
GUARANTEED MIN. EFF. 94.5 PCT.

RELIANCE ELECTRIC
CLEVELAND, OHIO 44117 U.S.A.

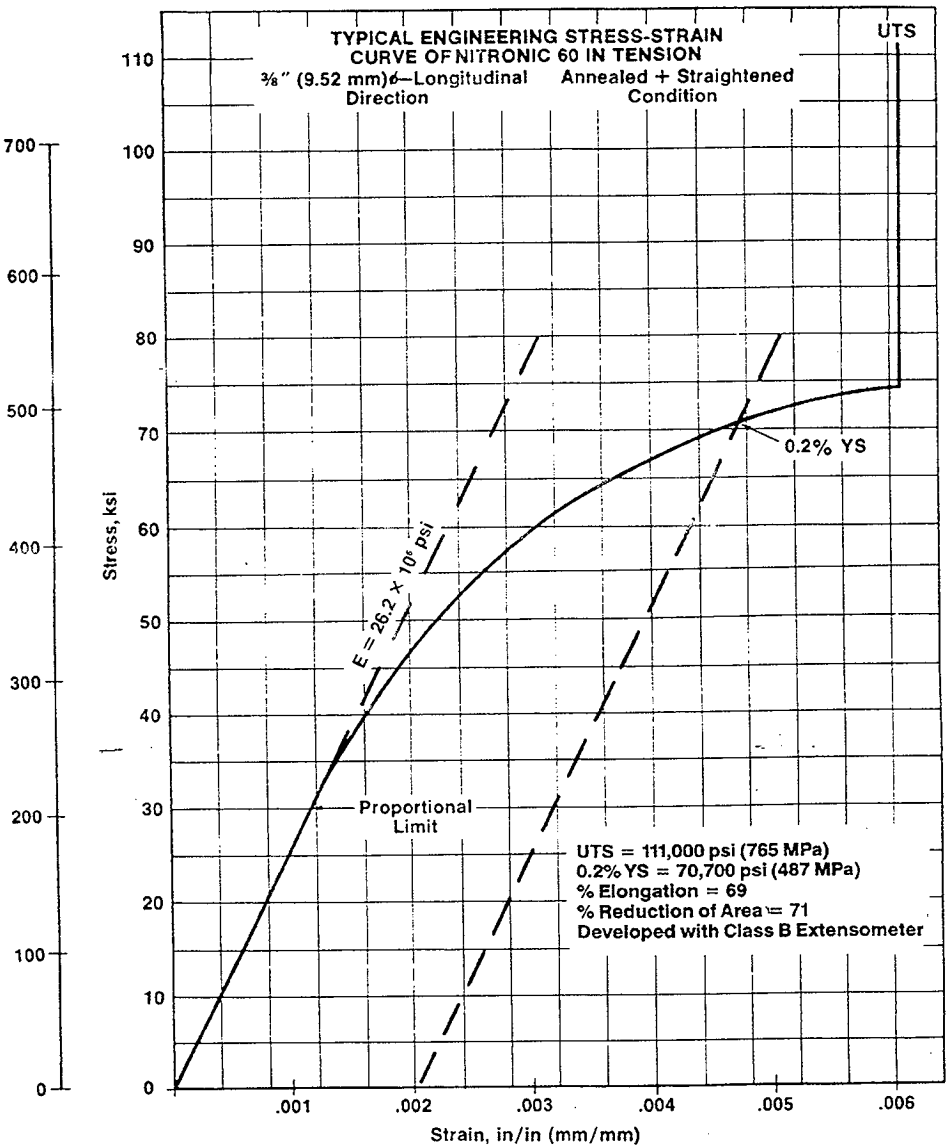
DR. BY P.B. GREENE
CK. BY U. M. BYRU
APP. BY U. M. BYRU
DATE 09/17/84

A-C MOTOR PERFORMANCE DATA

E3669A-A-002
ISSUE DATE 09/13/84

FIGURE 7

G-33-05



# WIRE ROPE Stainless Steel

## Stainless Steel Wire Rope

Stainless steel wire rope is especially suited for frequent, continuous exposure to extremely corrosive conditions. Stainless steel provides high resistance to corrosion from marine environments, petrochemicals, oxidizing acids, and food processing. It is available in the following five grades. TYPE 316—Provides chemical resistance along with low magnetic properties ideal for use around sensitive instruments. TYPE 302 AND TYPE 304—Breaking strength conforms to the latest revision to applicable Federal Specification RR-W-410 (except 1 x 7 Type 304 construction) or Mil-W-83420. Controlled chemistry of Type 302 provides exceptionally high fa resistance, resulting in a high performance cable that far exc the endurance requirements of the applicable specification. ST LESS-PLUS SUPER ALLOY WIRE ROPE—See page 491. Deve to combat spreading crevice corrosion and pitting that attacks conventional Type 302 and Type 304 stainless steel in a marine sphere. TYPE 305 NONMAGNETIC—See page 494. Meets Fe Specification Mil-C-18375A and is ideal for applications whic quire good corrosion resistance and low magnetic permeabil

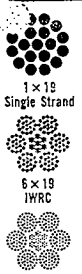
## Type 316 Stainless Steel Wire Rope

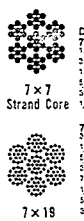
| Dia. | Breaking Strength Lbs. | No. | NET/FOOT 1-99 | 100-299 | 300-Up |
|---|---|---|---|---|---|
| 1 x 19 SINGLE STRAND | | | | | |
| 1/8" | 1,750 | 8908T12 | $0.68 | $0.55 | $0.46 |
| 3/16" | 4,000 | 8908T16 | 1.13 | 0.91 | 0.76 |
| 1/4" | 6,900 | 8908T22 | 1.60 | 1.28 | 1.07 |
| 5/16" | 10,600 | 8908T24 | 2.14 | 1.72 | 1.44 |
| 3/8" | 14,500 | 8908T26 | 3.41 | 2.53 | 2.45 |
| 6 x 19 IWRC | | | | | |
| 1/2" | 18,300 | 8908T58 | $6.57 | $5.80 | $4.85 |

| Dia. | Breaking Strength Lbs. | No. | NET/FOOT 1-99 | 100-299 | 300-Up |
|---|---|---|---|---|---|
| 7 x 7 STRAND CORE | | | | | |
| 1/16" | 360 | 8908T32 | $0.38 | $0.30 | |
| 3/32" | 700 | 8908T34 | .61 | .49 | |
| 1/8" | 1,360 | 8908T36 | .86 | .69 | |
| 7 x 19 STRAND CORE | | | | | |
| 1/8" | 1,300 | 8908T44 | $1.38 | $1.11 | |
| 3/16" | 2,900 | 8908T48 | 1.54 | 1.24 | |
| 1/4" | 4,900 | 8908T52 | 2.35 | 1.89 | |
| 5/16" | 7,600 | 8908T54 | 3.64 | 2.93 | |
| 3/8" | 11,000 | 8908T56 | 4.56 | 3.67 | |

| Construction | Core | Characteristics: Strength | Abrasion Resistance | Flexibility | Corrosion Resistance | Applications: Light Hoisting | Heavy Hoisting | Small Drums and Sheaves | Signal and Control | Guy |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 x 19 | Strand | Excellent | Very Good | Low | Excellent | | | | | X |
| 7 x 7 | Strand | Moderate | Very Good | Moderate | Excellent | X | | | X | |
| 6 x 19 | IWRC | Moderate | Good | Good | Excellent | X | X | X | X | |
| 7 x 19 | Strand | Moderate | Good | Good | Excellent | X | X | X | X | |

## Type 304 Stainless Steel—Wire Rope




| Dia. | Breaking Strength Lbs. | No. | NET/FOOT 1-99 | 100-299 | 300-Up |
|---|---|---|---|---|---|
| 1 x 19 SINGLE STRAND | | | | | |
| 1/16" | 500 | 3461T14 | $0.16 | $0.13 | $0.11 |
| 3/32" | 1,200 | 3461T15 | .30 | .25 | .21 |
| 1/8" | 2,100 | 3461T16 | .49 | .40 | .34 |
| 5/32" | 3,300 | 3461T17 | .62 | .51 | .43 |
| 3/16" | 4,700 | 3461T18 | .85 | .69 | .59 |
| 1/4" | 8,200 | 3461T21 | 1.30 | 1.06 | .90 |
| 5/16" | 12,500 | 3461T23 | 1.87 | 1.53 | 1.29 |
| 3/8" | 17,500 | 3461T24 | 2.72 | 2.23 | 1.89 |
| 6 x 19 IWRC | | | | | |
| 3/8" | 16,300 | 3461T74 | $4.06 | $3.32 | $2.81 |
| 1/2" | 22,800 | 3461T75 | 5.04 | 4.12 | 3.49 |
| 5/8" | 35,000 | 3461T77 | 7.17 | 5.87 | 4.96 |
| 6 x 37 IWRC | | | | | |
| 1/2" | 5,400 | 3375T31 | $2.10 | $1.72 | $1.45 |
| 5/8" | 8,300 | 3375T32 | 2.99 | 2.44 | 2.07 |
| 3/4" | 11,700 | 3375T33 | 3.71 | 3.03 | 2.57 |

| Dia. | Breaking Strength Lbs. | No. | NET/FOOT 1-99 | 100-299 | 300-Up |
|---|---|---|---|---|---|
| 7 x 7 STRAND CORE | | | | | |
| 1/16" | 480 | 3461T44 | $0.26 | $0.21 | |
| 3/32" | 920 | 3461T45 | .40 | .32 | |
| 1/8" | 1,700 | 3461T46 | .59 | .49 | |
| 5/32" | 2,400 | 3461T47 | .70 | .57 | |
| 3/16" | 3,700 | 3461T48 | .98 | .80 | |
| 1/4" | 6,100 | 3461T51 | 1.37 | 1.12 | |
| 7 x 19 STRAND CORE | | | | | |
| 3/32" | 920 | 3461T64 | $0.73 | $0.64 | |
| 1/8" | 1,760 | 3461T65 | .91 | .75 | |
| 5/32" | 2,400 | 3461T66 | .97 | .79 | |
| 3/16" | 3,700 | 3461T67 | 1.08 | .88 | |
| 1/4" | 6,000 | 3461T68 | 1.44 | 1.18 | |
| 5/16" | 6,400 | 3461T69 | 1.61 | 1.32 | |
| 3/8" | 9,000 | 3461T72 | 2.41 | 1.97 | |
| 3/8" | 12,000 | 3461T73 | 3.11 | 2.55 | |

| Construction | Core | Characteristics: Strength | Abrasion Resistance | Flexibility | Corrosion Resistance | Applications: Light Hoisting | Heavy Hoisting | Small Drums and Sheaves | Signal and Control | Guy |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 x 19 | Strand | Excellent | Very Good | Low | Very Good | | | | | X |
| 7 x 7 | Strand | Excellent | Very Good | Moderate | Very Good | | | | X | X |
| 6 x 19 | IWRC | Very Good | Moderate | Very Good | Very Good | X | X | | | X |
| 7 x 19 | Strand | Excellent | Moderate | Good | Very Good | X | X | X | | X |
| 6 x 37 | IWRC | Good | Moderate | Very Good | Very Good | X | X | | | X |

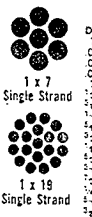
All descriptions of the wire rope applications listed on this page are general, and are provided with the intention of making it easier you to select the proper wire rope for your individual needs. To select wire rope correctly, be sure to apply sound engineering practi

McMASTER-CAR

# Stainless

## Type 302 Stainless St

osion resistant type 302 stainless steel provides excellent mity in strength and elongation properties, plus high fatigue ance. The breaking strength conforms to the latest revision of al Specification RR-W-410, MIL-W-83420, and MIL-W-87161 to it applies. This high performance cable far exceeds the rance requirements of the applicable specification. ly used in the chemical, food processing, petroleum, and




| Dia. | Breaking Strength Lbs. | No. | NET/FOOT 1-99 | 100-299 | 300-Up |
|---|---|---|---|---|---|
| SINGLE STRAND—Miniature sizes are used al cable and standard sizes for guy wire. | | | | | |
| ure Sizes | | | | | |
| 25 | | 3458T141 | $0.07 | $0.06 | $0.05 |
| 65 | | 3458T142 | .06 | .05 | .04 |
| 50 | | 3458T143 | .06 | .05 | .04 |
| 100 | | 3458T144 | .06 | .05 | .04 |
| 125 | | 3458T145 | .07 | .06 | .05 |
| 250 | | 3458T146 | .09 | .08 | .06 |
| ard Sizes | | | | | |
| 40 | | 3458T11 | $0.05 | $0.05 | $0.04 |
| 150 | | 3458T12 | .08 | .06 | .05 |
| 500 | | 3458T14 | .14 | .12 | .10 |
| 1,200 | | 3458T16 | .24 | .19 | .16 |
| 2,100 | | 3458T17 | .40 | .33 | .27 |
| 3,300 | | 3458T171 | .69 | .57 | .47 |
| 4,700 | | 3458T19 | .82 | .67 | .55 |
| 19 SINGLE STRAND—Used for guying, brac and as standing rigging. | | | | | |
| 150 | | 3458T21 | $0.10 | $0.09 | $0.07 |
| 325 | | 3458T22 | .12 | .10 | .08 |
| 500 | | 3458T23 | .18 | .16 | .13 |
| 800 | | 3458T24 | .27 | .23 | .19 |
| 1,200 | | 3458T25 | .35 | .30 | .25 |
| 2,100 | | 3458T26 | .59 | .50 | .42 |
| 3,300 | | 3458T27 | .75 | .64 | .53 |
| 4,700 | | 3458T28 | .99 | .84 | .70 |
| 6,200 | | 3458T91 | 1.40 | 1.18 | .99 |
| 12,500 | | 3458T93 | 1.87 | 1.59 | 1.33 |
| 17,500 | | 3458T94 | 3.16 | 2.68 | 2.24 |

| | | NET/FOOT 1-99 | 100-Up |
|---|---|---|---|
| 7 HOLLOW CORE | | | |
| 110 | 3458T51 | $0.16 | $0.13 |
| 6 x 19 IWRC | | | |
| 16,300 | 3458T121 | $5.28 | $4.60 |
| 22,800 | 3458T122 | 6.03 | 5.26 |

| | | NET/FOOT 1-99 | 100-299 | 300-Up |
|---|---|---|---|---|
| 7 IWRC—More flexible than 6 x 19 construc- though it is not as durable. | | | | |
| 3,000 | 3458T111 | $1.94 | $1.61 | $1.34 |
| 5,400 | 3458T54 | 3.10 | 2.56 | 2.14 |
| 6,300 | 3458T55 | 4.28 | 3.53 | 2.95 |
| 11,700 | 3458T56 | 5.27 | 4.35 | 3.64 |
| 20,400 | 3458T57 | 7.38 | 6.09 | 5.10 |

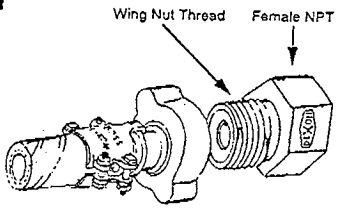
| | | Characteristics: Strength | Abrasion Resistance | Flexibility | Corrosion Resistance |
|---|---|---|---|---|---|
| truction | Core | | | | |
| x 7 | Strand | Excellent | Very Good | Low | Excellen |
| x 19 | Strand | Excellent | Very Good | Low | Excellen |
| x 7 | Hollow | Very Good | Good | Excellent | Excellen |
| x 3 | Hollow | Very Good | Good | Excellent | Excellen |
| x 7 | Strand | Excellent | Good | Good | Excellen |
| x 7 | Strand | Very Good | Moderate | Very Good | Excellen |
| x 19 | IWRC | Excellent | Excellent | Very Good | Excellen |
| x 19 | Strand | Excellent | Good | Excellent | Excellen |
| x 37 | IWRC | Good | Very Good | Excellent | Excellen |
| x 42 | Fiber | Moderate | Low | Excellent | Excellen |

escriptions of wire rope applications listed on this are general, and are the proper wire rope for your individual needs. To select wire rope co

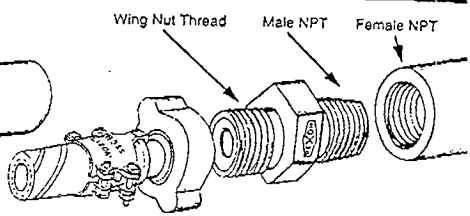
HNF-2474, Rev. 0
Page D-124

# BOSS COUPLINGS

## A "BOSS" ASSEMBLY DIAGRAM

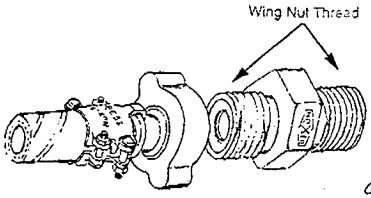



FEMALE SPUD COUPLING with CLAMP




MALE SPUD COUPLING with CLAMP

MALE COUPLING FOR HOSE 3" (RNS36) 7.5#
4" (RNS46) 12.0#
CATALOG #




Catalog # { BS39 3" BOSS CLAMP 12.100#
BS45 4" BOSS 15.045#

Wing Nut, Stem, "Boss" Clamp

DOUBLE SPUD COUPLING with CLAMP

## "EZ-BOSS" GROUND JOINT SEAL

"EZ-Boss" non-metallic polymer seal is not subject to corrosion and offers resistance to chemicals and steam found in manufacturing facilities. A precisely machined recess holds the seal firmly in place, allowing it to absorb harsh punishment. Recommended for steam service up to 450°F; easy to seal; works with existing "Boss" Ground Joint Stems; Made in the USA. Fittings will be supplied with Polymer seats as stock is depleted

PLATED STEEL &/or MALLEABLE IRON

| | Coupling With Female Spud | | Stem | | | Wing Nut | | | Female Spud | | | Male Spud | | Double Spud | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sizes | Part # | Price | Part # | Price | Pkg Qty | Part # | Price | Pkg Qty | Part # | Price | Pkg Qty | Part # | Price | Part # | Price |
| 1/4" | GF1 | $24.25 | GBA | $7.75 | 100 | BA2 | $6.00 | 100 | GBC | $10.50 | 100 | GMB | $10.50 | | |
| 3/8" | GF3 | 22.25 | GCA | 5.25 | 100 | CB | 6.00 | 100 | GCC | 11.00 | 100 | GMC | 10.50 | | |
| 1/2" | GF6 | 15.40 | GB1 | 4.00 | 100 | B2 | 3.75 | 100 | GB3 | 7.65 | 100 | GM3 | 12.00 | GDB3 | $20.00 |
| 3/4" | GF26 | 21.85 | GB6 | 9.00 | 50 | B12 | 4.70 | 25 | GB6 | 7.95 | 50 | GM6 | 13.00 | GDB13 | 23.15 |
| 1" | GF36 | 22.20 | GB11 | 9.25 | 50 | B12 | 4.70 | 25 | GB13 | 8.25 | 50 | GM13 | 14.00 | GDB13 | 23.15 |
| 1 1/4" | GF51 | 36.80 | GB16 | 11.00 | 25 | B17 | 8.00 | 25 | GB18 | 17.80 | 25 | GM18 | 30.00 | GDB23 | 40.00 |
| 1 1/2" | GF61 | 37.05 | GB21 | 11.25 | 25 | B17 | 8.00 | 25 | GB23 | 17.80 | 25 | GM23 | 28.30 | GDB23 | 40.00 |
| 2" | GF81 | 43.80 | GB26 | 12.00 | 10 | B27 | 14.00 | 10 | GB28 | 17.80 | 10 | GM28 | 30.85 | GDB28 | 41.00 |
| 2 1/2" | GF96 | 123.15 | GB31 | 32.15 | 5 | B32 | 35.00 | 5 | GB33 | 56.00 | 5 | GM33 | 80.00 | GDB33 | 80.00 |
| 3" | GF111 | 132.00 | GB36 | 36.00 | 5 | B37 | 35.00 | 5 | GB38 | 61.00 | 5 | GM38 | 85.00 | GDB38 | 90.00 |
| 4" | GF141 | 292.00 | GB46 | 87.00 | 5 | B47 | 95.00 | 5 | GB48 | 110.00 | 5 | | | | |
| 5" | GF171 | 765.00 | GB56 | $40.00 | 2 | B57 | 175.00 | 2 | GB58 | 250.00 | 2 | | | | |
| 6" | GF201 | 875.00 | GB66 | 250.00 | 2 | B67 | 175.00 | 2 | GB68 | 400.00 | 2 | | | | |

1/4", 3/8", 5" & 6" come with Copper seat spuds. Copper seats are available in other sizes - consult the Factory for pricing and availability.

**"Boss" Couplings And The Steam Quick Disconnects On P. 6 Are The Only Dixon Couplings Recommended For Steam Service**

# Industrial Hose Products/List Prices

[redacted]

39496-000
March 30, 1992
Supersedes 39496-000
January 2, 1990

Steam Hose

## 200MB Steam Pile Driver

(Specification 3601)

| Item No. | Nom. I.D. (In.) | Nom. O.D. (In.) | Maximum W.P. (psi) | Suction (In. Hg) | Min. Bend Radius (In.) | Wt. Per Ft. (Lbs.) | Standard Pack | Stock (X) or Minimum Order Qty. | Gates Prod. No. | List Price Per Ft. |
|---|---|---|---|---|---|---|---|---|---|---|
| 303500 | 2 | 2.95 | 200 | 10.0 | 25.0 | 3.43 | 50 ft | 500 ft | 3601-0410 | $48.438 |
| 303501 | 2½ | 3.45 | 200 | 10.0 | 30.0 | 3.88 | 50 ft | 500 ft | 3601-0420 | 68.209 |
| 303502 | 3 | 3.97 | 200 | 10.0 | 36.0 | 4.47 | 50 ft | X | 3601-0430 | 77.516 |
| 303503 | 4 | 5.20 | 200 | 10.0 | 48.0 | 7.47 | 50 ft | X | 3601-0440 | 125.364 |

RECOMMENDED FOR: Saturated steam up to 200 PSI and 388° F for pile driver applications.
Service life will be severely shortened if steam without lubricating oil is used.
**NOTE: NOT FOR USE WITH STEAM ONLY.**

TEMPERATURE: Maximum to 388°F (198°C) continuous service.

CONSTRUCTION: **Tube:** Type A (Neoprene) Black.
**Reinforcement:** Braided, high tensile steel wire.
**Cover:** Type A (Neoprene) Black. All sizes are perforated.

COUPLINGS: 14 or 15. Reference pages 130-141.

PACKAGING: 50' coiled in a carton.

BRANDING: Rubber patch label every 5-10 ft. Example; "Gates 200MB Steam Pile Driver 200 PSI (1.38MPa) WP at 388 Degrees F Made In U.S.A. Caution: Tighten Clamps Before Using."

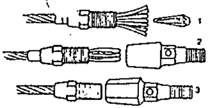
SPECIAL ORDER REQUIREMENTS: Special production runs require minimum order quantities of 500 feet per size.

REMNANT LENGTHS: Not Available.

Due to continual product improvements, Gates reserves the right to alter specs and prices without prior notice.

Gates. The world's most trusted name in belts and hose.

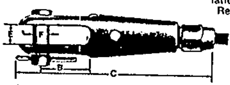
# Positive Grip Wire Rope Fittings




## Positive Grip Wire Rope Fitting Information

Fittings consist of three parts: A sleeve, plug and covering socket. To assemble: (1) Slip sleeve over end of wire rope. (2) Open rope strands and drive fluted plug into sleeve. (3) Close strands over plug and screw on covering socket. For safety, covering socket on fittings has inspection hole for checking correct installation. Fittings are reusable by replacing plug. Recommend use of kit listed below for easier, more efficient assembly of fitting.

Note: All Positive Grip Fittings can be used with all 6 strand fibre core wire rope, except tiller and extra improved plow steel wire rope. Fittings equipped with plugs to accommodate 6 strand IWRC, 7×7 and 7×19 wire rope, plugs for other type of wire rope and fittings for use with extra improved plow steel wire rope are available. Prices on Request.



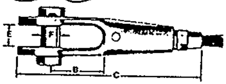
## Machined Standard Clevis End Fittings

Material: Machined from bar stock.
Special Feature: Positive grip socket equipped with clevis pin for easy, quick removal and changing of end fittings.
Uses: Ideal for all standard industrial rigging jobs.

Spark resistant Bronze in sizes listed available, specify 3473T999. Prices on Request.

♦ Note: Nos. 3473T, 3480T, 3511T and 3474T are for 6 strand fiber core wire rope. Fittings for other construction see top of this page.

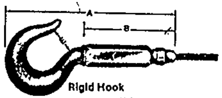
| Wire Rope Dia. | Center of Pin To Socket B | Approx. Overall Length C | Jaw Opening E | Pin Dia. F | Self-Colored Steel No. | NET EACH | Cadmium-Plated Steel No. | NET EACH | Stainless Steel No. | NET EACH |
|---|---|---|---|---|---|---|---|---|---|---|
| 1/16" | 3/8" | 2 1/16" | 3/16" | 3/16" | 3473T14 | $12.76 | 3473T34 | $15.95 | 3473T74 | [illegible] |
| 3/32" | 1/2" | 2 7/16" | 1/4" | 1/4" | 3473T15 | 12.96 | 3473T35 | 16.20 | 3473T75 | [illegible] |
| 1/8" | 1/2" | 2 7/16" | 1/4" | 1/4" | 3473T16 | 13.15 | 3473T36 | 16.44 | 3473T76 | [illegible] |
| 5/32" | 5/8" | 2 31/32" | 5/16" | 5/16" | 3473T17 | 15.76 | 3473T37 | 19.70 | 3473T77 | [illegible] |
| 3/16" | 5/8" | 2 31/32" | 5/16" | 5/16" | 3473T18 | 18.39 | 3473T38 | 22.99 | 3473T78 | [illegible] |
| 1/4" | 3/4" | 3 23/32" | 3/8" | 3/8" | 3473T21 | 25.26 | 3473T41 | 31.58 | 3473T81 | [illegible] |
| 5/16" | 7/8" | 4 1/4" | 3/8" | 7/16" | 3473T23 | 32.59 | 3473T43 | 40.74 | 3473T83 | [illegible] |
| 3/8" | 1" | 4 27/32" | 7/16" | 1/2" | 3473T24 | 40.88 | 3473T44 | 51.09 | 3473T84 | [illegible] |
| 1/2" | 1 3/8" | 6 11/32" | 1/2" | 11/16" | 3473T26 | 53.73 | 3473T46 | 67.16 | 3473T86 | [illegible] |



## Forged Heavy Duty Clevis End Fittings

Material: Drop forged steel. Finishes: Self-colored or galvanized.
Special Feature: Positive socket equipped with clevis pin for easy, quick removal and changing of end fittings. Uses: Ideal for tough rigging jobs which demand maximum strength and durability.
See ♦ with No. 3473.

| Wire Rope Dia. | Center of Pin To Socket B | Approx. Overall Length C | Jaw Opening E | Pin Dia. F | Self-Colored Steel No. | NET EACH | Galvanized Steel No. | NET EACH |
|---|---|---|---|---|---|---|---|---|
| 1/4" | 1 1/4" | 4 1/2" | 17/32" | 1/2" | 3480T14 | $23.70 | 3480T31 | [illegible] |
| 5/16" | 1 1/2" | 5 3/8" | 11/16" | 9/16" | 3480T15 | 26.20 | 3480T32 | [illegible] |
| 3/8" | 1 1/2" | 5 1/2" | 11/16" | 5/8" | 3480T16 | 30.69 | 3480T33 | [illegible] |
| 7/16" | 2" | 7 3/16" | 1" | 3/4" | 3480T17 | 41.46 | 3480T34 | [illegible] |
| 1/2" | 2" | 7 3/16" | 1" | 7/8" | 3480T18 | 44.33 | 3480T35 | [illegible] |
| 5/8" | 2 1/2" | 8 5/8" | 1 1/4" | 1" | 3480T19 | 67.10 | 3480T36 | [illegible] |
| 3/4" | 3" | 10 3/16" | 1 1/2" | 1 1/8" | 3480T21 | 74.45 | 3480T37 | [illegible] |
| 7/8" | 2 5/8" | 11" | 1 9/16" | 1 1/2" | 3480T22 | 126.44 | 3480T38 | [illegible] |
| 1" | 3" | 12 11/16" | 1 7/8" | 1 1/2" | 3480T23 | 181.84 | 3480T39 | [illegible] |




## Machined Standard Duty Hook Assemblies

Material: Machined from bar stock. Available in alloy steel. Socket assembly machined from alloy steel. Hook forged alloy steel. Finish: Self-colored.
Special Features: Available with rigid or swivel hook. Uses: For hoisting and lifting operations.

Zinc-plated finish is available, specify 3511T999—Prices On Request.
See ♦ with No. 3473.

| Wire Rope Dia. | Hook Opening E | Rigid Hooks Overall Length A | Rigid Hooks Socket Length B | No. | NET EACH | Swivel Hooks Overall Length A | Swivel Hooks Socket Length B | No. | NET EACH | Safety Latches No. | NET EACH |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1/4" | 1 1/16" | 5 7/8" | 2 1/2" | 3511T14 | $41.53 | 7 7/16" | 4 3/16" | 3511T34 | $48.86 | 8944T12 | [illegible] |
| 3/8" | 1 1/4" | 7 19/32" | 3 13/32" | 3511T16 | 65.76 | 9 5/16" | 5 5/16" | 3511T36 | 81.78 | 8944T14 | [illegible] |
| 1/2" | 1 1/2" | 9 23/32" | 4 1/2" | 3511T18 | 87.04 | 11 13/16" | 6 13/16" | 3511T38 | 114.76 | 8944T16 | [illegible] |

## Machined Standard Eye End Fittings

Material: Machined from bar stock.
Special Features: Positive Grip Sockets are ideal for most industrial applications especially where a smooth machined finish is desired for ease of handling and better appearance.

Spark Resistant Bronze in sizes listed available, specify 3474T999—Prices On Request.

See ♦ with No. 3473.

| Wire Rope Dia. | Approx. Overall Length C | Socket Dia. D | Pin Hole Dia. F | Eye Width E | Self-Colored Steel No. | NET EACH | Zinc Plated Steel No. | NET EACH | Stainless Steel No. | NET EACH |
|---|---|---|---|---|---|---|---|---|---|---|
| 1/16" | 2 1/16" | 1/2" | 13/64" | 11/64" | 3474T14 | $10.04 | 3474T34 | $12.55 | 3474T74 | [illegible] |
| 3/32" | 2 15/32" | 3/8" | 13/64" | 15/64" | 3474T15 | 10.28 | 3474T35 | 12.84 | 3474T75 | [illegible] |
| 1/8" | 2 15/32" | 5/8" | 17/64" | 15/64" | 3474T16 | 10.51 | 3474T36 | 13.14 | 3474T76 | [illegible] |
| 5/32" | 3" | 3/4" | 21/64" | 19/64" | 3474T17 | 11.56 | 3474T37 | 14.45 | 3474T77 | [illegible] |
| 3/16" | 3" | 3/4" | 21/64" | 19/64" | 3474T18 | 12.61 | 3474T38 | 15.77 | 3474T78 | [illegible] |
| 1/4" | 3 3/4" | 15/16" | 25/64" | 23/64" | 3474T21 | 14.75 | 3474T41 | 18.44 | 3474T81 | [illegible] |
| 5/16" | 4 9/32" | 1 1/16" | 29/64" | 23/64" | 3474T23 | 22.08 | 3474T43 | 27.59 | 3474T83 | [illegible] |
| 3/8" | 4 7/8" | 1 3/16" | 33/64" | 27/64" | 3474T24 | 24.15 | 3474T44 | 30.19 | 3474T84 | [illegible] |
| 1/2" | 6 3/8" | 1 9/16" | 45/64" | 31/64" | 3474T26 | 44.66 | 3474T46 | 55.83 | 3474T86 | [illegible] |

## Assembly Kits for Use with Positive Grip Wire Rope Fittings

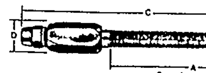
Material: Extruded alloy steel. Finish: Self-colored.
Special Features: Provide easier, more efficient assembly of Positive Grip Wire Rope Fittings listed on this page and on the following pages.
How It Works: Steel block holds wire strands firmly so that plug can be driven to a solid seat. Assembly block prevents wires of the rope strands from being nicked by the jaws of the vise. Note: Hollow tubing is used for terminating IWRC wire rope.

| Wire Rope Dia. | No. | NET EACH |
|---|---|---|
| 1/8-9/16" | 8929T12 | [illegible] |
| 5/8-1" | 8929T14 | [illegible] |

# Positive Grip Wire Rope Fittings

## Machined Standard Stud End Fittings

Material: Machined from bar stock. Special Feature: Positive grip socket has threaded stud end. Uses: Ideal for most industrial rigging jobs requiring a quick method of attaching lines to beams, equipment or to various lifting devices.

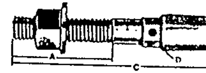


| Stud Size | Threaded Stud Length A | Approx. Overall Length C | Socket Dia. D | Self-Colored Steel No. | NET EACH | Cadmium Plated Steel No. | NET EACH | Stainless Steel No. | NET EACH |
|---|---|---|---|---|---|---|---|---|---|
| 10-32 | 1 19/32" | 3 1/32" | 7/16" | 3475T14 | $11.00 | 3475T31 | $13.75 | 3475T71 | $23.10 |
| 1/4"-28 | 1 7/8" | 3 1/2" | 9/16" | 3475T15 | 12.85 | 3475T32 | 16.06 | 3475T72 | 26.99 |
| 1/4"-28 | 1 7/8" | 3 1/2" | 9/16" | 3475T16 | 14.71 | 3475T33 | 18.39 | 3475T73 | 30.90 |
| 3/8"-24 | 2 3/16" | 4 3/16" | 11/16" | 3475T18 | 17.35 | 3475T35 | 21.69 | 3475T75 | 36.44 |
| 1/2"-20 | 4 9/16" | 7 1/16" | 7/8" | 3475T21 | 20.98 | 3475T37 | 26.22 | 3475T77 | 44.05 |
| 5/8"-18 | 4 9/16" | 7 1/2" | 1" | 3475T23 | 28.91 | 3475T39 | 36.14 | 3475T79 | 60.72 |
| 3/4"-16 | 4 15/16" | 8 3/16" | 1 1/8" | 3475T24 | 33.38 | 3475T41 | 41.72 | 3475T81 | 70.09 |
| 7/8"-14 | 6 15/16" | 11" | 1 1/2" | 3475T26 | 49.88 | 3475T43 | 62.34 | 3475T83 | 104.74 |

Spark Bronze St... fittings avail... fy 3475T... on request.
♦ Nos. 34... 3477T, 34... 3470T and ... for 6 strand ... wire rope. ... other const... top of page...

## Forged Heavy Duty Stud End Fittings

Stud End Fittings for wire rope diameter up to 1 1/2" available, specify 3479T999—Prices on Request.



| Stud Size | Threaded Stud Length A | Approx. Overall Length C | Socket Dia. D | Self-Colored Steel No. | EACH | Galvanized Steel No. | NET EACH |
|---|---|---|---|---|---|---|---|
| 1/2"-13 | 4 3/16" | 7 3/8" | 1" | 3479T11 | $21.50 | 3479T31 | $26.88 |
| 1/2"-13 | 4 3/16" | 7 9/16" | 1" | 3479T12 | 24.05 | 3479T32 | 30.06 |
| 5/8"-11 | 4 1/2" | 8 1/4" | 1 1/8" | 3479T13 | 28.39 | 3479T33 | 35.49 |
| 3/4"-10 | 6 3/8" | 10 15/16" | 1 1/2" | 3479T15 | 35.18 | 3479T35 | 43.97 |
| 7/8"-9 | 8 1/8" | 13 7/8" | 1 13/16" | 3479T16 | 63.08 | 3479T36 | 78.84 |
| 1 1/8"-7 | 8 5/8" | 15 1/4" | 2 1/4" | 3479T17 | 77.56 | 3479T37 | 96.95 |

Material: Drop forged steel. Finish: Self-colored and galvanized. Special Feature: ... duty for long dependable service under severe operating conditions. Uses: For m... industrial rigging.
See ♦ with No. 3475.

## Machined Standard Duty Turnbuckles

Machined Turnbuckles made of Bronze are available—Prices on Request. See ♦ with No. 3475.

Socket & Jaw Turnbuckles

| B | E | F | Rated Takeup G | Extended Length C | Self-Colored Alloy Steel No. | NET EACH | Stainless Steel No. | NET EACH |
|---|---|---|---|---|---|---|---|---|
| 3/8" | 3/16" | 3/16" | 2 1/2" | 8 1/4" | 3476T11 | $32.43 | 3476T71 | $68.09 |
| 1/2" | 1/4" | 1/4" | 2 7/8" | 9 5/8" | 3476T13 | 41.41 | 3476T73 | 86.97 |
| 5/8" | 5/16" | 5/16" | 3 1/8" | 11 3/32" | 3476T15 | 47.43 | 3476T75 | 99.59 |
| 3/4" | 3/8" | 3/8" | 4 13/16" | 15 3/4" | 3476T17 | 55.20 | 3476T77 | 115.92 |
| 1" | 7/16" | 1/2" | 5 5/16" | 18 9/16" | 3476T21 | 79.70 | 3476T81 | 167.37 |
| 1 3/8" | 1/2" | 11/16" | 8 1/16" | 25 13/16" | 3476T23 | 137.01 | 3476T83 | 287.73 |

Jaw & Jaw Type Turnbuckles

| Extended Length C | Self-Colored Alloy Steel No. | NET EACH | Stainless Steel No. | NET EACH |
|---|---|---|---|---|
| 7 21/32" | 3477T11 | $32.43 | 3477T51 | |
| 9 1/8" | 3477T13 | 41.41 | 3477T53 | |
| 10 7/16" | 3477T15 | 47.43 | 3477T55 | |
| 14 3/16" | 3477T17 | 55.20 | 3477T57 | |
| 17 5/16" | 3477T21 | 79.70 | 3477T61 | |
| 24 9/32" | 3477T23 | 137.01 | 3477T63 | |

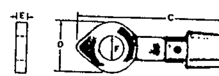
DOUBLE SOCKET TYPE TURNBUCKLES

| Extended Length C | Rated Takeup G | Self-Colored Alloy Steel No. | NET EACH | Stainless Steel No. | NET EACH |
|---|---|---|---|---|---|
| 8 7/8" | 2 1/2" | 3478T11 | $29.56 | 3478T71 | $62.08 |
| 10 1/8" | 2 7/8" | 3478T13 | 34.69 | 3478T73 | 72.84 |
| 11 3/4" | 3 1/8" | 3478T15 | 45.20 | 3478T75 | 94.92 |

| Wire Rope Dia. | Extended Length C | Rated Takeup G | Self-Colored Alloy Steel No. | NET EACH | Stainless Steel No. |
|---|---|---|---|---|---|
| 1/4" | 16 11/16" | 4 13/16" | 3478T17 | $56.23 | 3478T77 |
| 3/8" | 19 13/16" | 5 5/16" | 3478T21 | 90.09 | 3478T81 |
| 1/2" | 27 5/16" | 8 1/16" | 3478T23 | 140.06 | 3478T83 |

## Forged Heavy Duty Eye End Fittings

Eye end fittings for wire rope diameter up to 1" available, specify 3482T999—Prices on Request. See ♦ with No. 3475.



| Approx. Overall Length C | Eye Dia. D | Pin Hole Dia. F | Eye Width E | Self-Colored Steel No. | NET EACH | Galvanized Steel No. | NET EACH |
|---|---|---|---|---|---|---|---|
| 4 3/8" | 1 5/32" | 17/32" | 1/2" | 3482T11 | $18.76 | 3482T31 | $22.55 |
| 5 1/2" | 1 5/16" | 21/32" | 9/16" | 3482T13 | 23.23 | 3482T33 | 27.92 |
| 6 7/8" | 1 3/4" | 29/32" | 3/4" | 3482T15 | 33.88 | 3482T35 | 40.72 |

Material: Drop forged steel. Finishes: Self-colored or galvanized. Special Feature: H... thickness of metal at bearing point. Uses: ... rugged rigging operations.

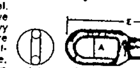
## Machined Standard Duty Drum Sockets

Material: Alloy steel. Machined from bar stock. Special Feature: Provides an extra strong terminal for wire rope ends. Uses: Used for attaching winch lines to slotted drums, etc.
See ♦ with No. 3475.

| Overall Length A | Hex Size B | Self-Colored Steel No. | NET EACH | Zinc Plated Steel No. | NET EACH |
|---|---|---|---|---|---|
| 1 9/16" | 9/16" | 3470T14 | $9.00 | 3470T31 | $11.25 |
| 1 15/16" | 5/8" | 3470T15 | 10.43 | 3470T32 | 13.03 |
| 1 15/16" | 3/4" | 3470T16 | 11.75 | 3470T33 | 14.69 |
| 2 3/8" | 7/8" | 3470T17 | 12.93 | 3470T34 | 16.16 |
| 2 3/4" | 15/16" | 3470T18 | 13.68 | 3470T35 | 17.09 |
| 3 1/4" | 1 1/8" | 3470T19 | 17.64 | 3470T36 | 22.05 |
| 3 3/4" | 1 1/4" | 3470T21 | 31.40 | 3470T37 | 39.25 |

## Forged Heavy Duty Oval Eye Fitt...

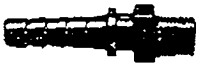
Material: Drop forged steel.
Special Feature: Oval shape eye for quick attachment of heavy hooks. Oval eye fittings for wire rope diameter up to 1 1/2" and galvanized finish are available, specify 3481T999—Prices on Request. See ♦ with No. 3475.



| Wire Rope Dia. | Inside Eye Width A | Inside Eye Length B | Eye Thickness D | Approx. Overall Length E | Self-Colored Steel No. | NET EACH |
|---|---|---|---|---|---|---|
| 1/4" | 7/8" | 1 15/16" | 5/8" | 5 1/2" | 3481T14 | |
| 3/8" | 7/8" | 1 15/16" | 5/8" | 5 13/16" | 3481T16 | |
| 1/2" | 1" | 2 1/16" | 7/8" | 6 7/8" | 3481T18 | |
| 3/4" | [illegible] | [illegible] | [illegible] | | | |

## "BOSS" MALE STEM





### STEEL BAR STOCK

| Hose x NPT Size | Part # | Price | Pkg Qty |
|---|---|---|---|
| 1/4" x 1/8" | MS4X2 | $5.00 | 25 |
| 1/4" x 1/4" | MSA | 4.15 | 50 |
| 1/4" x 3/8" | MSB | 4.50 | 25 |
| 3/8" x 1/4" | MS6X4 | 4.25 | 25 |
| 3/8" x 3/8" | MSC | 3.50 | 100 |
| 3/8" x 1/2" | MS6X8 | 4.40 | 25 |
| 1/2" x 1/4" | MS8X4 | 4.40 | 25 |
| 1/2" x 3/8" | MS8X6 | 4.40 | 50 |
| 1/2" x 1/2" | MS1 | 3.25 | 25 |
| 1/2" x 3/4" | MS8X12 | 8.95 | 25 |
| 3/4" x 1/2" | MS12X8 | 7.75 | 25 |
| 3/4" x 3/4" | MS6 | 5.50 | 25 |
| 3/4" x 1" | MS12X16 | 13.50 | 25 |
| 1" x 3/4" | MS16X12 | 13.50 | 25 |
| 1" | MS11 | 8.70 | 25 |

### MALLEABLE IRON

| Size | Part # | Price | Pkg Qty |
|---|---|---|---|
| 1 1/4" | MS16 | $11.00 | 20 |
| 1 1/2" | MS21 | 11.25 | 20 |
| 2" | MS26 | 16.80 | 10 |
| 2 1/2" | MS31 | 36.00 | 5 |
| 3" | MS36 | 48.00 | 5 |
| 4" | MS46 | 84.00 | 2 |

### 316 STAINLESS STEEL

| Size | Part # | Price |
|---|---|---|
| 1/2" | RMS1 | $40.00 |
| 3/4" | RMS6 | 47.00 |
| 1" | RMS11 | 47.00 |
| 1 1/4" | RMS16 | 105.00 |
| 1 1/2" | RMS21 | 105.00 |
| 2" | RMS26 | 110.00 |
| 2 1/2" | RMS31 | 300.00 |
| 3" | RMS36 | 390.00 |

### BRASS

| Size | Part # | Price |
|---|---|---|
| 3/4" | BMS6 | $13.50 |
| 1" | BMS11 | 25.00 |
| 1 1/4" | BMS16 | 31.00 |
| 1 1/2" | BMS21 | 42.00 |
| 2" | BMS26 | 58.00 |
| 3" | BMS36 | 145.00 |

## "LP-BOSS" MALE STEM

Non-porous tubular steel for volatile materials

| Size | Plated, Male NPT End Part # | Plated, Male NPT End Price | Unplated, Beveled End Part # | Unplated, Beveled End Price |
|---|---|---|---|---|
| 1 1/4" | LP16 | $35.00 | | |
| 1 1/2" | LP21 | 35.00 | | |
| 2" | LP26 | 24.00 | LPB26 | $28.00 |
| 2 1/2" | LP31 | 80.00 | | |
| 3" | LP36 | 80.00 | LPB36 | 82.00 |
| 4" | LP46 | 80.00 | | |
| 6" | LP66 | 175.00 | | |

## "BOSS" WASHER SEAL

### PLATED STEEL &/or MALLEABLE IRON

| Sizes | Coupling With Female Spud Part # | Coupling With Female Spud Price | Stem Part # | Stem Price | Stem Pkg Qty | Wing Nut Part # | Wing Nut Price | Wing Nut Pkg Qty | Female Spud Part # | Female Spud Price | Female Spud Pkg Qty | Male Spud Part # | Male Spud Price | Double Spud Part # | Double Spud Price | Washer* Part # | Washer* Price |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3/8" | WF3 | $15.00 | CA | $3.50 | 100 | CB | 36.00 | 100 | CC | $5.50 | 100 | WMC | $10.00 | | | WBC | $.35 |
| 1/2" | WF6 | 12.00 | B1 | 4.25 | 100 | B2 | 3.75 | 100 | B3 | 4.00 | 100 | WM3 | 10.00 | DB3 | $15.00 | W2 | .35 |
| 3/4" | WF26 | 19.45 | B6 | 9.00 | 50 | B12 | 4.70 | 25 | B8 | 5.75 | 25 | WM8 | 11.50 | DB13 | 18.00 | W12 | .45 |
| 1" | WF36 | 19.70 | B11 | 9.25 | 50 | B12 | 4.70 | 25 | B13 | 5.75 | 50 | WM13 | 12.00 | DB13 | 18.00 | W12 | .45 |
| 1 1/4" | WF51 | 35.50 | B16 | 12.50 | 25 | B17 | 8.00 | 25 | B18 | 15.00 | 25 | WM18 | 28.00 | DB23 | 27.00 | W17 | .75 |
| 1 1/2" | WF61 | 35.00 | B21 | 12.50 | 25 | B17 | 8.00 | 25 | B23 | 14.50 | 25 | WM23 | 28.00 | DB23 | 27.00 | W17 | .75 |
| 2" | WF81 | 43.00 | B26 | 12.50 | 10 | B27 | 14.00 | 10 | B28 | 16.50 | 10 | WM28 | 32.00 | DB28 | 30.00 | W27 | .85 |
| 2 1/2" | WF96 | 99.00 | B31 | 30.00 | 5 | B32 | 36.00 | 5 | B33 | 34.00 | 5 | WM33 | 60.00 | DB33 | 60.00 | W32 | 1.10 |
| 3" | WF111 | 124.00 | B36 | 39.00 | 5 | B37 | 35.00 | 5 | B38 | 50.00 | 5 | WM38 | 60.00 | DB38 | 77.00 | W37 | 1.10 |
| 4" | WF141 | 292.00 | B46 | 105.00 | 5 | B47 | 95.00 | 5 | B48 | 92.00 | 5 | | | | | W47 | 5.25 |
| 5" | WF171 | 735.00 | B56 | 340.00 | 2 | B67 | 175.00 | 2 | B58 | 220.00 | 2 | | | | | W67 | 5.25 |
| 6" | WF201 | 860.00 | B66 | 265.00 | 2 | B67 | 175.00 | 2 | B69 | 220.00 | 2 | | | | | W67 | 5.25 |

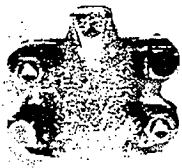
* Washer is Klinger nylon, Nitrile bonded, Kevlar reinforced material.

# BOSS COUPLINGS

## "BOSS" CLAMPS

A

2-BOLT TYPE



4-BOLT TYPE
2 GRIPPING FINGERS

4-BOLT TYPE
*4 GRIPPING FINGERS

| Hose I.D. Size | Hose O.D. From: | To: | Plated Malleable Iron Part # | Price | Qty | Brass (Shipped from factory only.) Part # | Price | Stainless Steel (Shipped from factory only.) Part # | Price | Torque** |
|---|---|---|---|---|---|---|---|---|---|---|
| 1/4" | 9/16" | 21/32" | *BD* | $3.95 | 100 | | | | | 6 |
| 3/8" | 11/16" | 7/8" | *CD* | 3.95 | 100 | | | | | 6 |
| 1/2" | 13/16" | 15/16" | *DD* | 3.95 | 100 | | | | | 6 |
| 1/2" | 15/16" | 1 1/16" | *B4* | 3.95 | 25 | *BB4* | $13.00 | *RB4* | $90.00 | 12 |
| 1/2" | 1 1/16" | 1 3/16" | *B5* | 4.25 | 25 | | | | | 12 |
| 3/4" | 1 5/32" | 1 9/32" | *BU9S* | 5.30 | 50 | | | | | 21 |
| 3/4" | 1 3/16" | 1 5/16" | *BU9* | 5.30 | 50 | *BBU9* | 16.00 | *RBU9* | 99.00 | 21 |
| 3/4" | 1 5/16" | 1 1/2" | *B9* | 5.30 | 25 | *BB9* | 16.00 | *RB9* | 99.00 | 21 |
| 3/4" | 1 1/2" | 1 11/16" | *B10* | 6.00 | 25 | | | | | 21 |
| 1/2" | 29/32" | 1 1/32" | *968* | 6.00 | 50 | | | | | 6 |
| 1" | 1 13/32" | 1 9/16" | *156** | 9.45 | 20 | | | | | 21 |
| 1" | 1 17/32" | 1 23/32" | *BU14* | 9.45 | 25 | *BBU14* | 45.00 | *RBU14* | 126.00 | 21 |
| 1" | 1 11/16" | 1 15/16" | *B14* | 9.65 | 25 | *BB14* | 49.00 | *RB14* | 126.00 | 21 |
| 1" | 1 15/16" | 2 1/8" | *B15* | 11.00 | 20 | | | | | 21 |
| 1 1/4" | 1 1/2" | 1 25/32" | *BU18* | 18.00 | 10 | | | | | 40 |
| 1 1/4" | 1 11/16" | 1 7/8" | *187** | 12.50 | 10 | | | | | 21 |
| 1 1/4" | 1 25/32" | 2 3/32" | *BU19* | 18.00 | 10 | | | | | 40 |
| 1 1/4" | 1 7/8" | 2 1/16" | *206** | 13.00 | 20 | | | | | 21 |
| 1 1/4" | 2 1/8" | 2 3/8" | *B19* | 14.00 | 10 | *BB19* | 49.00 | *RB19* | 128.00 | 40 |
| 1 1/2" | 1 13/16" | 2" | *BU22* | 17.50 | 10 | | | | | 40 |
| 1 1/2" | 2" | 2 7/32" | *B22* | 18.00 | 10 | | | | | 40 |
| 1 1/2" | 2" | 2 1/6" | *212** | 15.00 | 10 | | | | | 21 |
| 1 1/2" | 2 1/16" | 2 1/4" | *225** | 16.50 | 10 | | | | | 40 |
| 1 1/2" | 2 3/16" | 2 3/8" | *BU24* | 15.00 | 10 | *BBU24* | 90.00 | *RBU24* | 135.00 | 40 |
| 1 1/2" | 2 3/8" | 2 9/16" | *B24* | 15.00 | 10 | *BB24* | 90.00 | *RB24* | 135.00 | 40 |
| 1 1/2" | [illegible] | 2 3/4" | *B25* | 17.50 | 10 | | | | | 40 |
| 2" | 2 1/4" | 2 1/2" | *250** | 17.50 | 10 | | | | | 40 |
| 2" | 2 11/32" | 2 17/32" | *BU28* | 18.00 | 10 | | | | | 60 |
| 2" | 2 1/2" | 2 3/4" | *275** | 21.50 | 10 | | | | | 40 |
| 2" | 2 1/2" | 2 25/32" | *BU29* | 17.50 | 10 | *BBU29* | 90.00 | *RBU29* | 200.00 | 60 |
| 2" | 2 3/4" | 3 1/16" | *B29* | 18.50 | 10 | *BB29* | 90.00 | *RB29* | 200.00 | 60 |
| 2" | 2 3/4" | 3 1/16" | *306** | 24.00 | 10 | | | | | 60 |
| 2" | 3 3/32" | 3 7/16" | *B30* | 35.50 | 5 | | | | | 60 |
| 2 1/2" | 3 1/16" | 3 1/2" | *350** | 25.00 | 5 | | | | | 60 |
| 2 1/2" | 3 3/32" | 3 7/16" | *BU34* | 40.00 | 5 | | | | | 60 |
| 2 1/2" | 3 1/2" | 3 15/16" | *B34* | 40.00 | 5 | | | | | 150 |
| 3" | 3 1/2" | 3 3/4" | *375** | 35.50 | 5 | | | | | 60 |
| 3" | 3 1/2" | 3 15/16" | *BU35* | 63.00 | 5 | | | | | 150 |
| 3" | 3 3/4" | 4" | *401** | 57.00 | 5 | | | | | 150 |
| 3" | 3 13/16" | 4 1/16" | *B35* | 45.00 | 5 | | | | | 150 |
| 3" | 4" | 4 3/16" | *418** | 76.50 | 4 | | | | | 200 |
| 3" | 4 1/16" | 4 7/16" | *B39* | 70.00 | 5 | | | | | 200 |
| 3" | 4 3/16" | 4 1/2" | *450** | 70.00 | 2 | | | | | 200 |

THREE-PIECE
8-BOLT TYPE

| Hose I.D. Size | Hose O.D. From: | To: | Plated Malleable Iron Part # | Price | Qty | Torque** |
|---|---|---|---|---|---|---|
| 3" | 4 1/4" | 4 13/16" | *BS39* | $130.00 | 2 | 150 |
| 4" | 4 5/8" | 5" | *B45* | 140.00 | 2 | 150 |
| 4" | 4 7/8" | 5 1/4" | *BS49* | 190.00 | 2 | 200 |
| 4" | 5 1/4" | 5 19/32" | *BU49* | 200.00 | 2 | 200 |
| 4" | 5 17/32" | 5 15/16" | *B49* | 200.00 | 2 | 200 |
| 6" | 6 7/8" | 7 3/8" | *750* | 240.00 | 1 | 200 |
| 6" | 7 1/2" | 8" | *850* | 240.00 | 1 | 200 |

* 4 Gripping Fingers
**Recommended torque rating in FT. LBS. (for malleable iron & stainless steel clamps only)

## How To Use The Coupling Section

Couplings are designated by Block Numbers, and are described as to construction and source. Adapters and fittings are available for special applications.

Each coupling has a pressure rating of Low, Medium or High. These terms have a general meaning as follows:

Low Pressure — 400 psi maximum
Medium Pressure — 425 psi maximum
High Pressure — 800 psi maximum

Coupling ratings apply only where the recommended clamps or bands are used. Use this information as a guide since different tube stocks affect coupling retension.

Common shank couplings or nipples with bands or clamps should be used only on straight or plain end water or material handling hoses up to the following rated working pressures:

| | |
|---|---|
| 1/2 - 1 1/2" I.D. — 315 psi | |
| 2 -3" I.D. — 100 psi | 6" I.D. — 50 psi |
| 4" I.D. — 75 psi | 8" I.D. — 40 psi |
| 5" I.D. — 60 psi | 10" I.D. — 30 psi |

NOTE: Shank or water hose nipples are for combination nipples only. They are available plated or stainless steel. Use only for water and air service. They are available in the following styles: Tapered Pipe, Thread Tube, Combination Gasketing, Stainless Steel with Tapered Pipe, Thread Tube, Combination Gasketing.

Listed are all of the clamps, bands and ferrules used to secure the couplings to the hose. The proper clamp size should be selected carefully, since many clamps will fit only one hose size or a narrow range of sizes.

For certain critical fluids, specific couplings are used, as follows:

### Critical Applications

1. Use only the couplings recommended in this catalog for conveying:
   - Steam
   - LP Gas
   - Corrosive Chemicals
   - Petroleum Products
2. For any high temperature application, use only interlocking type couplings— [14] or [15].
3. For conveying flammable fluids, use couplings made of nonsparking materials, such as brass or aluminum.
4. For ground fueling of aircraft, use certified coupled assemblies only.

When you have selected a hose from the Hose Section, you will have found one or more coupling recommendations for that hose. The following procedure will help you make the final selection.

A. If more than one coupling is recommended, make a final selection for type of coupling on basis of cost, sizes available, thread type available and application.

B. Determine how the coupling is to be fastened to the hose--ferrule, band or clamp.

Due to continual product improvements, Gates reserves the right to alter specs and prices without prior notice.

## Coupling Installation

Before making any hose assembly, check over these general instructions and precautions:

1. **Square Ends**—Before attaching a coupling to the hose, make sure the end is cut square. This will help prevent leakage of the coupling.
2. **Proper Fit of Ferrules and Clamps—This is important.** Make sure you are using the correct sizes for the hose being coupled. Never buff the cover, except when specified for certain hydraulic hose couplings, and you should not enlarge the hose tube in any way to make the coupling insert fit. Occasionally, a nipple pusher tool will be helpful in pushing the insert into the hose.
3. **Installation Lubricants**—Use of lubricants on coupling inserts and ferrules will simplify coupling installation and reduce possibility of damage to the hose. Some lubricants to use are water, soap solution or lactol. Or, you can use a solution of glycerin and alcohol made up of one (1) part glycerin and 15 parts wood alcohol by volume.
4. **Appearance of the Hose Assembly**—A properly installed coupling significantly improves customer acceptance of the product. It also provides added assurance of satisfactory service and safety of assembly.
5. **Seal the Ends**—Where the hose is intended for use in petroleum transfer applications and hose ends will be exposed after couplings are attached, apply a sufficient amount of quality Neoprene cement or shellac to seal the ends.
6. **Critical Applications.**

   (a) Use only the couplings recommended on pages 134-140 for conveying:
   - Steam
   - LP Gas
   - Corrosive Chemicals
   - Petroleum Products
   - Edible Products

   (b) For any high temperature applications, use only interlocking type couplings—[14] or [15].

   (c) For conveying flammable fluids, use couplings made of nonsparking materials; i.e., brass or aluminum.

   (d) For aircraft ground fueling hose, use factory coupled assemblies only.

NOTE: For a complete listing of coupling seal installation information, refer to Gates Couplings Manual #9505.

E-14-41-01
E-14-41-03
E-14-41-05

# Industrial Hose Products/List Prices

39496-000
March 30, 1992
Supersedes 39496-000
January 2, 1990

E-14-41-07
E-14-41-09
E-14-41-11

## Couplings for Gates Hoses

### 1 Long Shank

**Description:** Cast brass, serrated shank, set has hex male and hex swivel female couplings, with a washer seal. Threads are GHT or NPSM.
**Sources:** Dixon Valve & Coupling Co.
John W. Moon, Inc.
H.B. Sherman Mfg. Co.
Seal-Fast Bobo, Inc.

### 2 Lightweight Water Hose

**Description:** Spun or wrought brass serrated shank, round swivel female and solid male, both GHT, washer seal.
**Sources:** American Coupling Co.
L.R. Nelson Corp.
H.B. Sherman Mfg. Co.

### 3 Cast Brass Short Shank

**Description:** Cast brass, serrated shank, hex swivel female with washer, solid male, GHT threads, ¾-11½.
**Sources:** J.C. Gadd Co.
John W. Moon, Inc.
H.B. Sherman Mfg. Co.
Seal-Fast Bobo, Inc.
Stayput Clamp & Coupling Co.

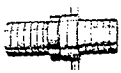
### 4 Machined Brass Short Shank

**Description:** Machined brass, serrated shank. Each set has round swivel female and solid male, GHT, washer seal. Octagon nut male and female.
**Sources:** American Coupling Co.
Anchor-Lenz Div.
Royal Brass, Inc.
H.B. Sherman Mfg. Co.

### 5 Brass Pin-Lug

**Description:** Cast brass shank and swivel, shank is serrated. NPSM threads in female and male, with washer seal. Sizes under 3" have lugs on female only.
**Sources:** John W. Moon, Inc.
Dixon Valve & Coupling Co.

### 6 Malleable Iron Pin Lug



**Description:** Malleable iron shank and swivel with serrated shank, cadmium plated. NPSM threads in male and female, washer seal. Pin lugs on female only.
**Sources:** Dixon Valve & Coupling Co.
H.B. Sherman Mfg. Co.
Seal-Fast Bobo, Inc.

### 7 Combination Nipple

Victaulic Nipple

**Description:** Swaged steel with scored or serrated shank, NPT threads same nominal size as I.D. of hose. Special plastic materials available.
**Sources:** Band-It
Dixon Valve & Coupling Co.
Martin Brass Works, Inc.
Screw Machine Products Co.
Seal-Fast Bobo, Inc.
Stayput Clamp & Coupling Co.

MS-46

### 8 Tri-Lokt

**Description:** Machined steel insert, male NPT threads only. Held in place with steel yoke and Band-It Jr. clamps. Insert is reusable—can be reinstalled with new yoke and clamps.
**Source:** Band-It

### 10 Single or Double Bolt Malleable Iron Clamp

**Description:** Cast malleable iron, cadmium plated.
**Source:** Dixon Valve & Coupling Co.

### 14 Interlocking, Ground Joint

Part # S650
BU49 clamp

Boss coupling

**Description:** Malleable iron swivel. Inserts and spud may be either steel or malleable iron. All parts are cadmium plated. Male and female threads both NPT with same nominal size as hose I.D. Ground joint between spud and female insert. Available with 2- and 4-bolt clamps.
**Sources:** Dixon Valve & Coupling Co.
Seal-Fast Bobo, Inc.

### 15 Interlocking, Washer Joint

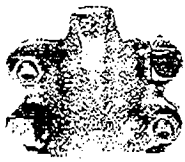
**Description:** Malleable iron swivel. Insert and spud may be either malleable iron or steel. All parts are cadmium plated. Female thread in spud is NPT with same nominal size as hose I.D. Washer joint between insert and spud. Available with 2- and 4-bolt clamps.
**Source:** Dixon Valve & Coupling Co.

Due to continual product improvements, Gates reserves the right to alter specs and prices without prior notice.

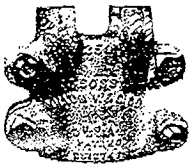
# BOSS COUPLINGS

## "BOSS" CLAMPS

2-BOLT TYPE



4-BOLT TYPE
2 GRIPPING FINGERS



4-BOLT TYPE
*4 GRIPPING FINGERS

| Hose I.D. | Hose O.D. | | Plated Malleable Iron | | | Brass (Shipped from factory only.) | | Stainless Steel (Shipped from factory only.) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Size | From: | To: | Part # | Price | Qty | Part # | Price | Part # | Price | Torque** |
| 1/4" | 9/16" | 21/32" | BD | $3.95 | 100 | | | | | 6 |
| 3/8" | 11/16" | 7/8" | CD | 3.95 | 100 | | | | | 6 |
| 1/2" | 13/16" | 15/16" | DD | 3.95 | 100 | | | | | 6 |
| 1/2" | 15/16" | 1 1/16" | B4 | 3.95 | 25 | BB4 | $13.00 | RB4 | $90.00 | 12 |
| 1/2" | 1 1/16" | 1 3/16" | B5 | 4.25 | 25 | | | | | 12 |
| 3/4" | 1 5/32" | 1 9/32" | BU9S | 5.30 | 50 | | | | | 21 |
| 3/4" | 1 3/16" | 1 5/16" | BU9 | 5.30 | 50 | BBU9 | 16.00 | RBU9 | 99.00 | 21 |
| 3/4" | 1 5/16" | 1 1/2" | B9 | 5.30 | 25 | BB9 | 16.00 | RB9 | 99.00 | 21 |
| 3/4" | 1 1/2" | 1 11/16" | B10 | 6.00 | 25 | | | | | 21 |
| 1/2" | 29/32" | 1 1/32" | 968 | 6.00 | 50 | | | | | 6 |
| 1" | 1 13/32" | 1 9/16" | 156* | 9.45 | 20 | | | | | 21 |
| 1" | 1 17/32" | 1 23/32" | BU14 | 9.45 | 25 | BBU14 | 45.00 | RBU14 | 126.00 | 21 |
| 1" | 1 11/16" | 1 15/16" | B14 | 9.65 | 25 | BB14 | 49.00 | RB14 | 126.00 | 21 |
| 1" | 1 15/16" | 2 1/8" | B15 | 11.00 | 20 | | | | | 21 |
| 1 1/4" | 1 1/2" | 1 25/32" | BU18 | 18.00 | 10 | | | | | 40 |
| 1 1/4" | 1 11/16" | 1 7/8" | 187* | 12.50 | 10 | | | | | 21 |
| 1 1/4" | 1 25/32" | 2 3/32" | BU19 | 18.00 | 10 | | | | | 40 |
| 1 1/4" | 1 7/8" | 2 1/16" | 206* | 13.00 | 20 | | | | | 21 |
| 1 1/4" | 2 1/8" | 2 3/8" | B19 | 14.00 | 10 | BB19 | 49.00 | RB19 | 126.00 | 40 |
| 1 1/2" | 1 13/16" | 2" | BU22 | 17.50 | 10 | | | | | 40 |
| 1 1/2" | 2" | 2 7/32" | B22 | 18.00 | 10 | | | | | 40 |
| 1 1/2" | 2" | 2 1/8" | 212* | 15.00 | 10 | | | | | 21 |
| 1 1/2" | 2 1/16" | 2 1/4" | 225* | 16.50 | 10 | | | | | 40 |
| 1 1/2" | 2 3/16" | 2 3/8" | BU24 | 15.00 | 10 | BBU24 | 90.00 | RBU24 | 135.00 | 40 |
| 1 1/2" | 2 3/8" | 2 9/16" | B24 | 15.00 | 10 | BB24 | 90.00 | RB24 | 135.00 | 40 |
| 1 1/2" | 2 9/16" | 2 3/4" | B25 | 17.50 | 10 | | | | | 40 |
| 2" | 2 1/4" | 2 1/2" | 250* | 17.50 | 10 | | | | | 40 |
| 2" | 2 11/32" | 2 17/32" | BU28 | [illegible] | 10 | | | | | 60 |
| 2" | 2 1/2" | 2 3/4" | 275* | 21.50 | 10 | | | | | 40 |
| 2" | 2 1/2" | 2 25/32" | BU29 | 17.50 | 10 | BBU29 | 90.00 | RBU29 | 200.00 | 60 |
| 2" | 2 3/4" | 3 1/16" | B29 | [illegible] | 10 | BB29 | 90.00 | RB29 | 200.00 | 60 |
| 2" | 2 3/4" | 3 1/16" | 306* | 24.00 | 10 | | | | | 60 |
| 2" | 3 3/32" | 3 7/16" | B30 | 35.50 | 5 | | | | | 60 |
| 2 1/2" | 3 1/16" | 3 1/2" | 350* | 25.00 | 5 | | | | | 60 |
| 2 1/2" | 3 3/32" | 3 7/16" | BU34 | 40.00 | 5 | | | | | 60 |
| 2 1/2" | 3 1/2" | 3 15/16" | B34 | 40.00 | 5 | | | | | 150 |
| 3" | 3 1/2" | 3 3/4" | 375* | 35.50 | 5 | | | | | 60 |
| 3" | 3 1/2" | 3 15/16" | BU35 | 63.00 | 5 | | | | | 150 |
| 3" | 3 3/4" | 4" | 401* | 57.00 | 5 | | | | | 150 |
| 3" | 3 13/16" | 4 1/16" | B35 | 45.00 | 5 | | | | | 150 |
| 3" | 4" | 4 3/16" | 418* | 76.50 | 4 | | | | | 200 |
| 3" | 4 1/16" | 4 7/16" | B39 | 70.00 | 5 | | | | | 200 |
| 3" | 4 3/16" | 4 1/2" | 450* | 70.00 | 2 | | | | | 200 |

THREE-PIECE
6-BOLT TYPE

| Hose I.D. | Hose O.D. | | Plated Malleable Iron | | | |
|---|---|---|---|---|---|---|
| Size | From: | To: | Part # | Price | Qty | Torque** |
| 3" | 4 1/4" | 4 13/16" | BS39 | $130.00 | 2 | 150 |
| 4" | 4 5/8" | 5" | B45 | 140.00 | 2 | 150 |
| 4" | 4 7/8" | 5 1/4" | BS49 | 190.00 | 2 | 200 |
| 4" | 5 1/4" | 5 19/32" | BU49 | 200.00 | 2 | 200 |
| 4" | 5 17/32" | 5 15/16" | B49 | 200.00 | 2 | 200 |
| 6" | 6 7/8" | 7 3/8" | 750 | 240.00 | 1 | 200 |
| 6" | 7 1/2" | 8" | 850 | 240.00 | 1 | 200 |

GF-141 (4")
WF-141 (4")

* 4 Gripping Fingers
**Recommended torque rating in FT. LBS. (for malleable iron & stainless steel clamps only)

**FAX MEMO**

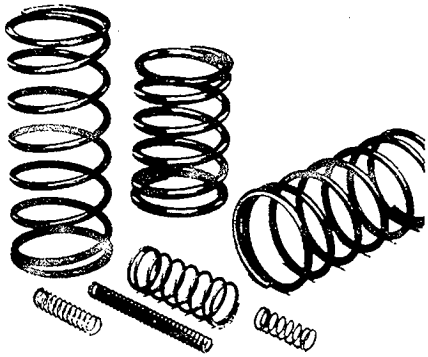
#PAGES 3 DATE 7/6 FAX#
CO.
ATTN: Mike Custer
FROM AMERICAN HOSE & FITTINGS
PH# (206) 872-8080 FAX# (206) 395-3410



JUL-06-1995 15:07 FROM AMERICAN-HOSE-FITTGS TO 31

J-25-05

# Compression Springs



## Stock sizes in music wire and stainless steel

Associated Spring offers a broad variety of helical compression springs in the SPEC selection. They are reliable, inexpensive and efficient — the right combination for general-purpose use throughout industry.

COMPRESSION SPRINGS

## Material

Music wire
ASTM-A228 or AMS 5112

Stainless steel
Commercial Type 302, ASTM-A313 or
AMS 5688 spring temper. (chemical & physical only)

No charge for certificate of compliance when requested; certificate of chemical analysis available, see price book.

Music wire will be furnished unless stainless steel is specified. When inquiring or ordering, use letter "M" or letter "S" as suffix on catalog numbers to designate music wire or stainless steel wire, respectively.

Music wire springs are not recommended for applications where the temperature exceeds 250 deg F (121 deg C). Stainless steel springs are not recommended for applications where the temperature exceeds 500 deg F (260 deg C).

## Direction of Helix

Right hand.

## Ends

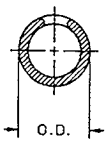
Squared and ground. Ends to be square within 3° with axis O.D. sizes 0.057-0.088 in (1.45-2.24 mm) squared ends not ground.

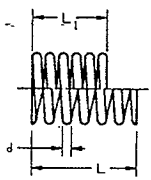
Free length L is for reference use only. Load P is attained at length $L_1$. For stainless steel multiply P by 0.833.

Load values shown are for music wire.

For normal service, springs should not be compressed below $L_1$.

To determine load P at any length other than $L_1$, multiply the proposed deflection by the rate R. *[P + (L-Lx) x R] When stainless steel is used the value for rate R must be corrected by multiplying R by 0.833.




## Finishes

Standard finish is that of the normal wire. Shot-peened and plated finishes furnished on request. Allow sufficient additional time for special finishes.

## Tolerances

| O.D. (English) | O.D. (Metric) |
|---|---|
| 0.057 to 0.119 in ± 0.003 in | 1.45 to 3.02 mm ± 0.08 mm |
| 0.120 to 0.240 in ± 0.005 in | 3.05 to 6.10 mm ± 0.13 mm |
| 0.241 to 0.500 in ± 0.008 in | 6.12 to 12.70 mm ± 0.20 mm |
| 0.501 to 1.000 in ± 0.015 in | 12.73 to 25.40 mm ± 0.38 mm |
| 1.001 to 1.225 in ± 0.020 in | 25.43 to 31.12 mm ± 0.51 mm |
| 1.226 to 1.460 in ± 0.030 in | 31.14 to 37.08 mm ± 0.76 mm |
| 1.461 to 2.000 in ± 0.040 in | 37.11 to 50.80 mm ± 1.02 mm |

# STOCK COMPRESSION SPRINGS
## Music Wire and Stainless Steel

Associated Spring Raymond BARNES GROUP INC

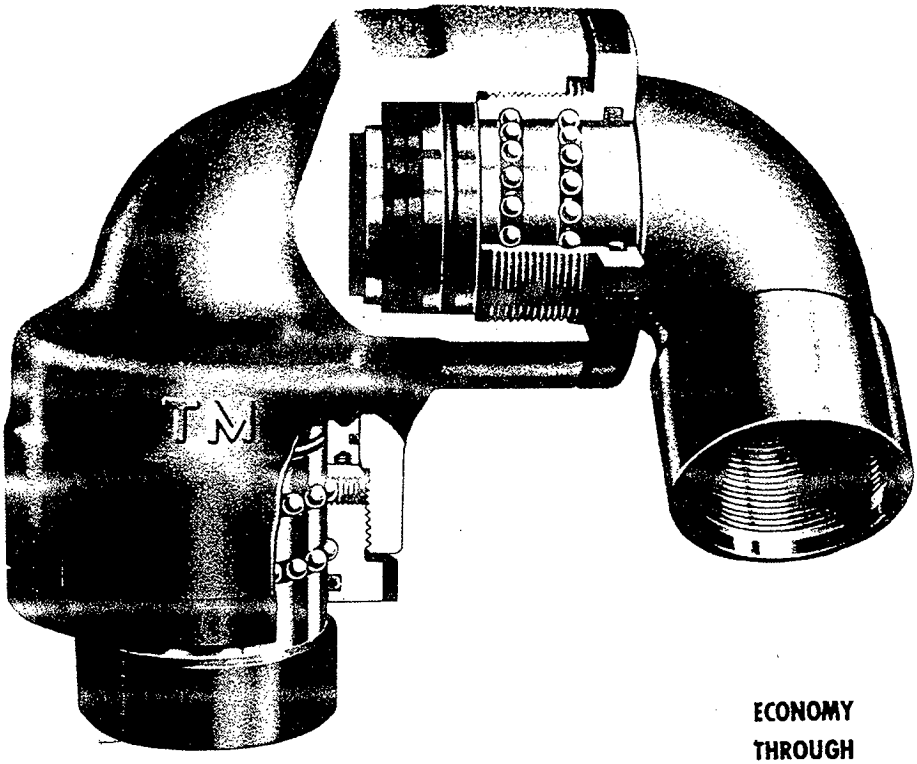
| CATALOG NUMBER* | Outside Diameter in | Outside Diameter mm | Wire Diameter in | Wire Diameter mm | Free Length L, Approx. in | Free Length L, Approx. mm | Load, P at $L_1$ lb† | Load, P at $L_1$ N† | Length, $L_1$ in | Length, $L_1$ mm | Solid Height, Approx. in | Solid Height, Approx. mm | Spring Rate, R lb/in† | Spring Rate, R N/mm† |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| C0600-063-2000 | | | | | 2.00 | 50.80 | | | 1.059 | 26.90 | 0.700 | 17.78 | 18.0 | 3.15 |
| C0600-063-2250 | | | | | 2.25 | 57.15 | | | 1.184 | 30.07 | 0.768 | 19.51 | 15.9 | 2.78 |
| C0600-063-2500 | | | 0.063 | 1.60 | 2.50 | 63.50 | 18.00 | 80.07 | 1.308 | 33.22 | 0.836 | 21.23 | 14.2 | 2.49 |
| C0600-063-2750 | | | | | 2.75 | 69.85 | | | 1.433 | 36.40 | 0.863 | 21.92 | 13.7 | 2.40 |
| C0600-063-3000 | | | | | 3.00 | 76.20 | | | 1.558 | 39.57 | 0.927 | 23.55 | 12.5 | 2.19 |
| C0600-063-3500 | | | | | 3.50 | 88.90 | | | 1.807 | 45.90 | 1.055 | 26.80 | 10.6 | 1.856 |
| C0600-067-0625 | | | | | 0.62 | 15.75 | | | 0.360 | 9.14 | 0.300 | 7.62 | 80.0 | 14.01 |
| C0600-067-0750 | | | | | 0.75 | 19.05 | | | 0.430 | 10.92 | 0.336 | 8.53 | 66.0 | 11.56 |
| C0600-067-0880 | | | | | 0.88 | 22.35 | | | 0.455 | 11.56 | 0.401 | 10.19 | 50.0 | 8.76 |
| C0600-067-1000 | | | | | 1.00 | 25.40 | | | 0.530 | 13.46 | 0.430 | 10.92 | 45.0 | 7.88 |
| C0600-067-1250 | | | | | 1.25 | 31.75 | | | 0.665 | 16.89 | 0.505 | 12.83 | 36.0 | 6.30 |
| C0600-067-1500 | | | 0.067 | 1.70 | 1.50 | 38.10 | 21.00 | 93.41 | 0.780 | 19.81 | 0.594 | 15.09 | 29.0 | 5.08 |
| C0600-067-1750 | | | | | 1.75 | 44.45 | | | 0.830 | 21.08 | 0.715 | 18.16 | 23.0 | 4.03 |
| C0600-067-2000 | | | | | 2.00 | 50.80 | | | 1.106 | 28.09 | 0.771 | 19.58 | 22.5 | 3.94 |
| C0600-067-2250 | | | | | 2.25 | 57.15 | | | 1.236 | 31.39 | 0.847 | 21.51 | 19.8 | 3.47 |
| C0600-067-2500 | | | | | 2.50 | 63.50 | | | 1.366 | 34.70 | 0.923 | 23.44 | 17.7 | 3.10 |
| C0600-067-2750 | | | | | 2.75 | 69.85 | | | 1.496 | 38.00 | 0.966 | 24.54 | 16.7 | 2.92 |
| C0600-067-3000 | | | | | 3.00 | 76.20 | | | 1.626 | 41.30 | 1.040 | 26.42 | 15.3 | 2.68 |
| C0600-072-0620 | | | | | 0.62 | 15.75 | | | 0.405 | 10.29 | 0.381 | 9.68 | 114.5 | 20.05 |
| C0600-072-0750 | | | | | 0.75 | 19.05 | | | 0.445 | 11.30 | 0.396 | 10.06 | 78.0 | 13.66 |
| C0600-072-0880 | | | | | 0.88 | 22.35 | | | 0.520 | 13.21 | 0.433 | 11.00 | 68.0 | 11.91 |
| C0600-072-1000 | | | | | 1.00 | 25.40 | | | 0.565 | 14.35 | 0.502 | 12.75 | 55.0 | 9.63 |
| C0600-072-1250 | | | | | 1.25 | 31.75 | | | 0.710 | 18.03 | 0.581 | 14.76 | 45.0 | 7.88 |
| C0600-072-1500 | | | 0.072 | 1.83 | 1.50 | 38.10 | 24.00 | 106.76 | 0.830 | 21.08 | 0.691 | 17.55 | 36.0 | 6.30 |
| C0600-072-1750 | | | | | 1.75 | 44.45 | | | 0.950 | 24.13 | 0.801 | 20.35 | 30.0 | 5.25 |
| C0600-072-2000 | | | | | 2.00 | 50.80 | | | 1.140 | 28.96 | 0.848 | 21.54 | 28.0 | 4.90 |
| C0600-072-2250 | | | | | 2.25 | 57.15 | | | 1.301 | 33.05 | 0.946 | 24.03 | 25.9 | 4.54 |
| C0600-072-2500 | | | | | 2.50 | 63.50 | | | 1.438 | 36.53 | 1.033 | 26.24 | 23.1 | 4.05 |
| C0600-072-2750 | | | | | 2.75 | 69.85 | | | 1.601 | 40.67 | 1.119 | 28.42 | 20.9 | 3.66 |
| C0600-072-3000 | 0.600 | 15.24 | | | 3.00 | 76.20 | | | 1.742 | 44.25 | 1.206 | 30.63 | 19.1 | 3.34 |
| C0600-081-0620 | | | | | 0.62 | 15.75 | | | 0.466 | 11.84 | 0.412 | 10.46 | 212.6 | 37.23 |
| C0600-081-0750 | | | | | 0.75 | 19.05 | | | 0.553 | 14.05 | 0.459 | 11.66 | 165.6 | 29.00 |
| C0600-081-0880 | | | | | 0.88 | 22.35 | | | 0.639 | 16.23 | 0.507 | 12.88 | 135.6 | 23.74 |
| C0600-081-1000 | | | | | 1.00 | 25.40 | | | 0.719 | 18.26 | 0.552 | 14.02 | 116.2 | 20.35 |
| C0600-081-1250 | | | | | 1.25 | 31.75 | | | 0.885 | 22.48 | 0.644 | 16.36 | 89.5 | 15.67 |
| C0600-081-1500 | | | | | 1.50 | 38.10 | | | 1.051 | 26.70 | 0.736 | 18.69 | 72.8 | 12.75 |
| C0600-081-1750 | | | | | 1.75 | 44.45 | | | 1.217 | 30.91 | 0.828 | 21.03 | 61.3 | 10.73 |
| C0600-081-2000 | | | | | 2.00 | 50.80 | | | 1.383 | 35.13 | 0.920 | 23.37 | 53.0 | 9.28 |
| C0600-081-2250 | | | 0.081 | 2.06 | 2.25 | 57.15 | 32.69 | 145.41 | 1.549 | 39.34 | 1.012 | 25.70 | 46.6 | 8.16 |
| C0600-081-2500 | | | | | 2.50 | 63.50 | | | 1.715 | 43.56 | 1.104 | 28.04 | 41.7 | 7.30 |
| C0600-081-2750 | | | | | 2.75 | 69.85 | | | 1.881 | 47.78 | 1.196 | 30.38 | 37.6 | 6.58 |
| C0600-081-3000 | | | | | 3.00 | 76.20 | | | 2.047 | 51.99 | 1.288 | 32.72 | 34.3 | 6.01 |
| C0600-081-3250 | | | | | 3.25 | 82.55 | | | 2.213 | 56.21 | 1.380 | 35.05 | 31.5 | 5.52 |
| C0600-081-3500 | | | | | 3.50 | 88.90 | | | 2.379 | 60.43 | 1.472 | 37.39 | 29.2 | 5.11 |
| C0600-081-3750 | | | | | 3.75 | 95.25 | | | 2.545 | 64.64 | 1.564 | 39.73 | 27.1 | 4.75 |
| C0600-081-4000 | | | | | 4.00 | 101.60 | | | 2.711 | 68.86 | 1.656 | 42.06 | 25.4 | 4.45 |
| C0600-085-0620 | | | | | 0.62 | 15.75 | | | 0.477 | 12.12 | 0.433 | 11.00 | 262.5 | 45.96 |
| C0600-085-0750 | | | | | 0.75 | 19.05 | | | 0.565 | 14.35 | 0.484 | 12.29 | 203.6 | 35.65 |
| C0600-085-0880 | | | | | 0.88 | 22.35 | | | 0.654 | 16.61 | 0.536 | 13.61 | 166.4 | 29.14 |
| C0600-085-1000 | | | | | 1.00 | 25.40 | | | 0.736 | 18.69 | 0.583 | 14.81 | 142.3 | 24.92 |
| C0600-085-1250 | | | | | 1.25 | 31.75 | | | 0.906 | 23.01 | 0.682 | 17.32 | 109.4 | 19.16 |
| C0600-085-1500 | | | | | 1.50 | 38.10 | | | 1.076 | 27.33 | 0.781 | 19.84 | 88.8 | 15.55 |
| C0600-085-1750 | | | | | 1.75 | 44.45 | | | 1.247 | 31.67 | 0.880 | 22.35 | 74.8 | 13.10 |
| C0600-085-2000 | | | | | 2.00 | 50.80 | | | 1.417 | 35.99 | 0.978 | 24.84 | 64.5 | 11.29 |
| C0600-085-2250 | | | 0.085 | 2.16 | 2.25 | 57.15 | 37.62 | 167.33 | 1.588 | 40.34 | 1.077 | 27.36 | 56.8 | 9.95 |
| C0600-085-2500 | | | | | 2.50 | 63.50 | | | 1.758 | 44.65 | 1.176 | 29.87 | 50.7 | 8.88 |
| C0600-085-2750 | | | | | 2.75 | 69.85 | | | 1.928 | 48.97 | 1.275 | 32.39 | 45.8 | 8.02 |
| C0600-085-3000 | | | | | 3.00 | 76.20 | | | 2.099 | 53.31 | 1.374 | 34.90 | 41.7 | 7.30 |
| C0600-085-3250 | | | | | 3.25 | 82.55 | | | 2.269 | 57.63 | 1.473 | 37.41 | 38.3 | 6.71 |
| C0600-085-3500 | | | | | 3.50 | 88.90 | | | 2.439 | 61.95 | 1.572 | 39.93 | 35.5 | 6.22 |
| C0600-085-3750 | | | | | 3.75 | 95.25 | | | 2.610 | 66.29 | 1.670 | 42.42 | 33.0 | 5.78 |
| C0600-085-4000 | | | | | 4.00 | 101.60 | | | 2.780 | 70.61 | 1.769 | 44.93 | 30.8 | 5.39 |
| C0600-092-0750 | | | | | 0.75 | 19.05 | | | 0.591 | 15.01 | 0.524 | 13.31 | 291.5 | 51.04 |
| C0600-092-0880 | | | 0.092 | 2.34 | 0.88 | 22.35 | 46.46 | 206.65 | 0.684 | 17.37 | 0.581 | 14.76 | 237.0 | 41.50 |
| C0600-092-1000 | | | | | 1.00 | 25.40 | | | 0.770 | 19.56 | 0.633 | 16.08 | 202.2 | 35.41 |

*†For stainless steel, multiply values by 0.833.*
**When inquiring or ordering, use letter "M" or letter "S" as suffix on catalog numbers to designate music wire or stainless-steel wire, respectively.*

COMPRESSION SPRINGS

PHONE (408) 736-5202 VE 7954

— NPT (NATIONAL PIPE THREAD)
(SINGLE POINT THREAD) E-21-15




ECONOMY
THROUGH
QUALITY

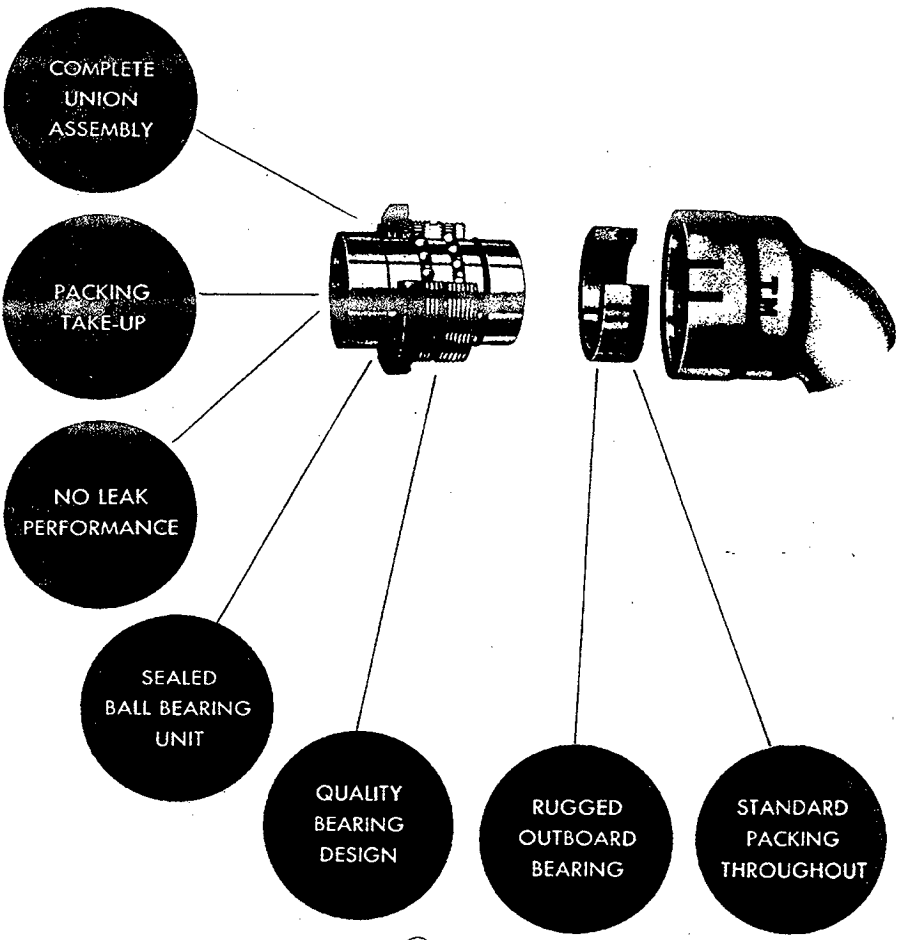
# T-M SWIVEL JOINTS

**T-M MFG. CO.** 695 E. ARQUES AVE., SUNNYVALE, CALIF. 94086-3832

A

E-21-15

# T-M SWIVEL JOINTS




B

## COMPLETE UNION ASSEMBLY

Repack anywhere, anytime, without handling ball bearings, even when welded into the line. Reduces service and maintenance to an absolute minimum.

## PACKING TAKE-UP

Chevron packing compensates for normal wear, varying temperatures, extremely volatile materials. Extends packing life as much as 400%.

## NO-LEAK PERFORMANCE

Superior engineering design enable guaranteed, no-leak performance from gases to acids to drilling cement.

## SEALED BALL BEARING UNIT

Factory assembled rotating unit sealed from outside contaminants and line fluids by "o" rings. Lubricants are sealed in and foreign matter sealed out. Reduces maintenance costs by eliminating daily lubrication. Quality design will cut costs, extend life of joints.

## QUALITY BEARING DESIGN

The finest alloy steels used in manufacture of T-M Joints. Through hardened ball races in 6000 and 15,000 steel series coupled with hardened chrome alloy steel balls assure longer life, lower maintenance costs and fewer replacements.

## RUGGED OUTBOARD BEARING

The packing backup ring acts as a solid bearing during severe or shock loads. Protects the ball races from brinnelling. Eliminates misalignment leaks. Guarantees top performance under all conditions.

## STANDARD PACKING THROUGHOUT

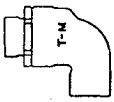
No special packing worries with T-M. Packing for all services is available in standard sizes and materials.

# T-M SWIVEL JOINTS

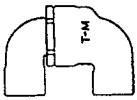
E-21-15
STYLES

No. 100
STRAIGHT SINGLE SWIVEL

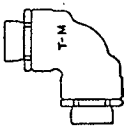
No. 200
ELL SINGLE SWIVEL




No. 300
2 ELL SINGLE SWIVEL




No. 400
1 ELL DOUBLE SWIVEL




## MATERIALS

125 PSI Aluminum Alloy
Color Code: Aluminum

1000 PSI Steel
Color Code: Blue

6000 PSI Steel
Color Code: Red

15,000 PSI Steel
Color Code: Yellow

125 PSI Type 316 Stainless Steel
Color Code: #316

Special Alloys
Color Code by Type

PSI = Maximum Working Pressure

## TEMPERATURES

225° Hycar Packing
450° Aramid Fiber
550° Aramid Fiber
300° Teflon
400° Viton

## SIZES

3/8" – Thru 16" Pipe Size
Larger on request

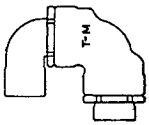
## END CONNECTIONS

Threaded Ends (TE) (Female)
Beveled for Weld (BV) (Beveled)
Bored for Weld (BR) (Bored)
Flanged
Special ---On Order

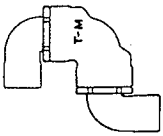
## SPECIAL ORDERS

We will be pleased to submit prices on your special requirements. Manufactured on Order.

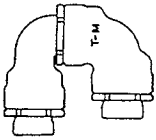
No. 500
2 ELL DOUBLE SWIVEL



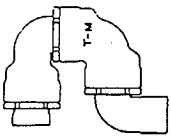

No. 600
3 ELL DOUBLE SWIVEL




No. 700
2 ELL TRIPLE SWIVEL

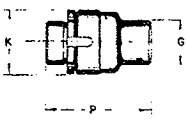



No. 800
3 ELL TRIPLE SWIVEL



E-21-15

# THREADED AND BORED FOR WELDING

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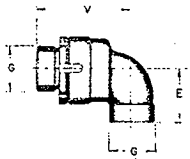


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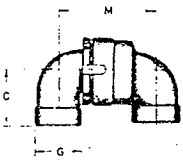
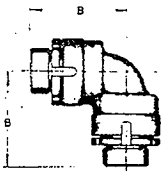



STYLE 300

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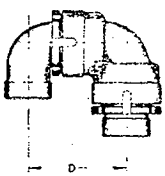


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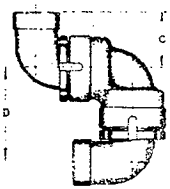


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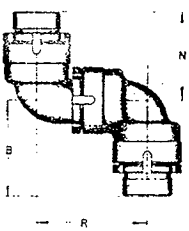


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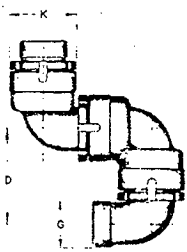



STYLE 800

| DIMENSIONS | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SIZES | B | C | D | E | G | K | M | N | P | R | V | SIZE |
| 3/8 & 1/2 | 3 1/2 | 2 | 3 3/8 | 1 7/8 | 1 1/4 | 2 | 3 | 3 1/8 | 3 7/8 | 3 5/8 | 3 7/8 | 3/8 & 1/2 |
| 3/4 & 1 | 4 1/4 | 2 3/8 | 4 1/4 | 2 1/4 | 1 3/4 | 2 7/8 | 4 1/8 | 4 1/8 | 4 3/8 | 5 | 4 1/8 | 3/4 & 1 |
| 1 1/4 | 4 3/4 | 2 3/4 | 4 3/4 | 2 3/4 | 2 1/8 | 3 1/8 | 4 5/8 | 4 5/8 | 5 1/8 | 5 3/16 | 5 1/4 | 1 1/4 |
| 1 1/2 | 5 1/2 | 3 | 6 | 3 1/4 | 2 1/2 | 3 1/2 | 6 | 5 1/4 | 5 3/4 | 5 15/16 | 5 1/8 | 1 1/2 |
| 2 | 6 3/8 | 3 1/2 | 6 5/8 | 4 1/4 | 3 1/8 | 4 3/8 | 6 5/8 | 6 | 6 3/8 | 7 3/8 | 6 1/4 | 2 |
| 2 1/2 | 6 7/8 | 4 | 7 3/8 | 4 | 3 3/4 | 5 1/4 | 6 7/8 | 6 3/8 | 6 7/8 | 8 1/4 | 6 3/8 | 2 1/2 |
| 3 | 7 3/4 | 4 7/8 | 9 1/8 | 4 1/4 | 4 1/4 | 5 7/8 | 8 1/8 | 7 1/4 | 7 5/16 | 10 1/8 | 7 | 3 |
| 4 | 9 1/4 | 5 1/2 | 10 1/8 | 5 1/2 | 5 1/2 | 7 1/4 | 10 1/8 | 9 1/4 | 8 3/4 | 11 1/2 | 8 5/8 | 4 |

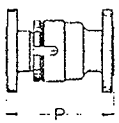
All dimensions given in inches ±1/8"

For sizes larger than 4" refer to section on fabricated joints.

E-21-15

# T-M SWIVEL JOINTS

FLANGED (SERIES 15)

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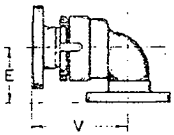


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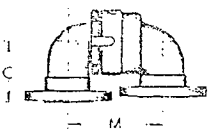


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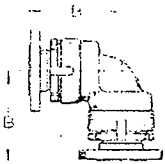


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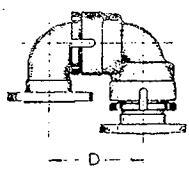


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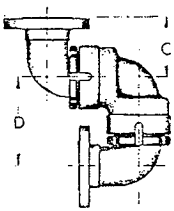


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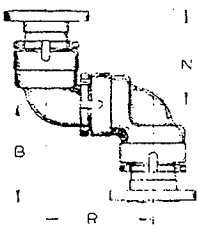


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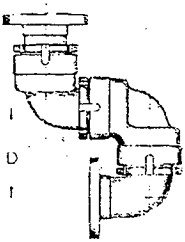


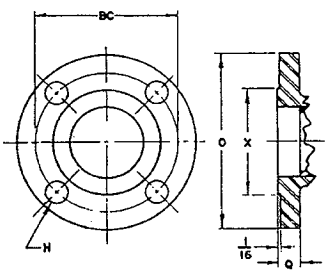

STYLE 800

| JOINT DIMENSIONS | | | | | | | | | | FLANGE DIMENSIONS | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SIZES | B | C | D | E | M | N | P | R | V | No. Holes | BC | H | Bolt Size | O | Q | X | SIZES |
| 2 | 6⅞ | 4 | 6⅝ | 4¾ | 6⅝ | 6½ | 7⅜ | 7⅜ | 6¾ | 4 | 4¾ | ¾ | ⅝ | 6 | ¾ | 3⅝ | 2 |
| 2½ | 7½ | 4⅝ | 7⅜ | 4⅝ | 6⅞ | 7 | 8⅛ | 8¼ | 7 | 4 | 5½ | ¾ | ⅝ | 7 | ⅞ | 4⅛ | 2½ |
| 3 | 8½ | 5½ | 9⅛ | 4⅞ | 8⅛ | 7⅞ | 8¾ | 10⅛ | 7⅝ | 4 | 6 | ¾ | ⅝ | 7½ | 15/16 | 5 | 3 |
| 4 | 9⅞ | 6¼ | 10⅛ | 6¼ | 10⅛ | 10 | 10¼ | 11 7/16 | 9⅜ | 8 | 7½ | ¾ | ⅝ | 9 | 15/16 | 6 7/16 | 4 |

All dimensions given in inches ±1/8"

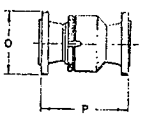
For sizes larger than 4" refer to section on fabricated joints.

For dimensions of other series flanged joints consult factory.



E-21-15

# FABRICATED

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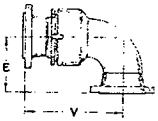


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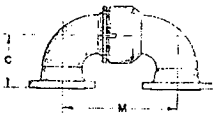


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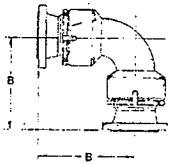


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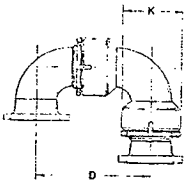


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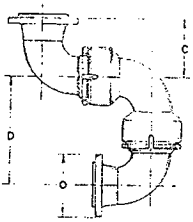


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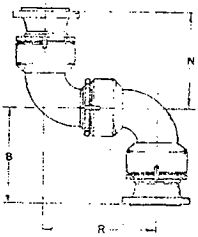


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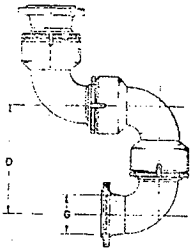



STYLE 800

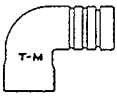
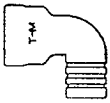
| | SIZES | B | C | D | E | G | K | M | N | O | P | R | V | SIZES |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | DIMENSIONS | | | | | | | | | | | | |
| BEVELED FOR WELDING | 6 | 13¼ | 6 | 19½ | 6 | — | 9⅞ | 19¾ | 13½ | — | 7¼ | 19¾ | 13½ | 6 |
| | 8 | 16 | 8 | 24¼ | 8 | — | 12 | 24¼ | 16 | — | 7¾ | 24¼ | 16 | 8 |
| | 10 | 18 | 10 | 28¼ | 10 | — | 14 | 28¼ | 18 | — | 7¾ | 28¼ | 18 | 10 |
| | 12 | 20 | 12 | 32¼ | 12 | — | 16 | 32¼ | 20 | — | 7¾ | 32¼ | 20 | 12 |
| THREADED | 6 | 16 | 8¾ | 19 | 8¾ | 7½ | 9⅞ | 19¾ | 16¼ | — | 12¾ | 19¾ | 16¼ | 6 |
| | 8 | 19 | 11 | 24¼ | 11 | 9⅝ | 12 | 24¼ | 19 | — | 13¾ | 24¼ | 19 | 8 |
| FLANGED (SERIES 15) | 6 | 17¼ | 9¾ | 19½ | 9¾ | — | 9⅞ | 19¾ | 17 | 11 | 14¾ | 19¾ | 17¼ | 6 |
| | 8 | 20¼ | 12¼ | 24¼ | 12¼ | — | 12 | 24¼ | 20¼ | 13½ | 16¼ | 24¼ | 20¼ | 8 |
| | 10 | 22¼ | 14¼ | 28¼ | 14¼ | — | 14 | 28¼ | 22¼ | 16 | 16¼ | 28¼ | 22¼ | 10 |
| | 12 | 24¾ | 16¾ | 33¼ | 16¾ | — | 16 | 32¼ | 24¾ | 19 | 17¼ | 32¼ | 24¾ | 12 |

All dimensions given in inches ±1/8"
For dimensions of other series flanged joints consult factory.

E-21-15

REPLACEMENT PARTS

# SWIVEL JOINTS

| | | | |
|---|---|---|---|
| Part 1<br>STRAIGHT SWIVEL NIPPLE<br> | Part 2<br>HOLDING NUT<br> | Part 3<br>STRAIGHT ONE SWIVEL BODY<br> | Part 4<br>ELL SWIVEL NIPPLE<br>  |
| Part 5<br>ELL TWO SWIVEL BODY<br> | Part 6<br>ELL ONE SWIVEL BODY<br> | Part 7<br>ELL TWO SWIVEL NIPPLE<br>  | ACCESSORIES:<br>Ball Bearings<br>Lock Bar<br>O-Ring - V-Ring<br>Adapters (Upper and Lower)<br>Counterbalance Lug; designated by "X" after part number. |

## SERVICING

(1) T-M Swivel Joints are greased at the factory and require only occasional greasing unless joint is in constant rotation or high temperature service. When greasing, remove slotted plug on outside of body, and insert alemite fitting.

(2) Provision has been made for take-up on the packing. After packing wears, remove lock bar, turn nut clockwise to next locking slot and reinstall lock bar. Process may be repeated until packing has worn too badly to effect seal.

## REPACKING

(1) Remove lock bar.
(2) Remove nut and nipple assembly from body by turning nut counter clockwise.
(3) Remove back-up ring from body.
(4) Remove 2 packing rings.
(5) Remove male adaptor.
(6) Clean packing chamber and reinstall (1) male adaptor (2) new packing and (3) back-up ring. Grease all parts thoroughly.
(7) Insert nut and nipple assembly in body and reassemble. Rotate nipple occasionally as the nipple passes through the packing.
(8) Screw nut clockwise until compression on packing causes nipple to rotate with a mild amount of torque.
(9) You do not need to handle the balls or disassemble the nut and nipple to repack the T-M Swivel Joint.

T-M

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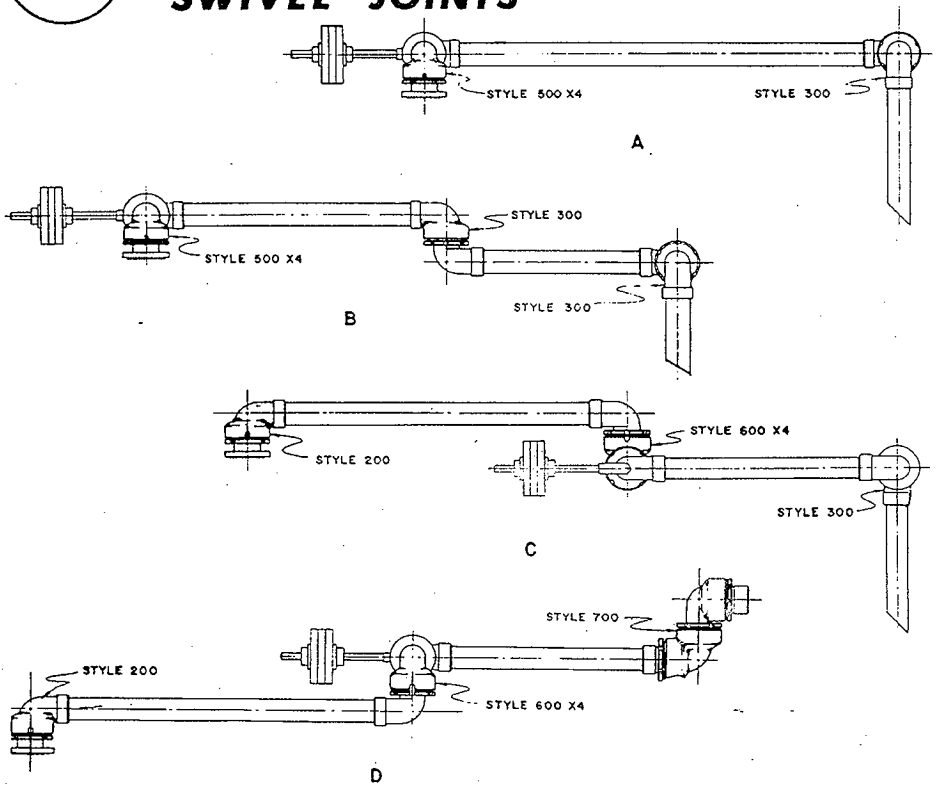
LOADING RACKS

# SWIVEL JOINTS




T-M Swivel Joints assembled into the 4 basic tank car and tank truck designs will enable you to transfer your product with economy and safety.

Even when welded into the line T-M Swivel Joints can be taken up to compensate for packing wear or separated for repacking. Overhung loads do not cause leaks on T-M loading arms due to the rugged design.

Furnished in aluminum, steel and stainless steel and packed to fit your individual requirements. Other designs on request.

## COUNTER BALANCE DESIGN

Since counterbalance design necessarily varies with each installation, we have shown no standard design.

Please consult the factory for prices and furnish the following information (1) Clearance restrictions and (2) Overhung loading.

E-21-15

# PACKING AND COMPONENT PARTS

| SWIVEL JOINT SIZE | 3/8" & 1/2" | 3/4" & 1" | 1 1/4" | 1 1/2" | 2" | 2 1/2" | 3" | 4" | 6" | 8" | 10" | 12" |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SIZE 6225 CHEVRON PACKING | -20 | -28 | -30 | -32 | -39 | -44 | -49 | -54 | -63 | -68 | -72 | -76 |
| SIZE 6229 MALE ADAPTOR | -20 | -28 | -30 | -32 | -39 | -44 | -49 | -54 | -63 | -68 | -72 | -76 |
| FEMALE ADAPTOR p/n 8 | 50-8 | 100-8 | 125-8 | 150-8 | 200-8 | 250-8 | 300-8 | 400-8 | 600-8 | 800-8 | 1000-8 | 1200-8 |
| *SIZE 6227 AND 6230 "O" RING p/n-1 | 7-15 | 7-25 | 0-01 | 0-03 | 0-09 | 0-14 | 0-18 | 0-28 | 0-40 | 30-47 | 7-77 | 7-81 |
| *SIZE 6227 AND 6230 "O" RING p/n 2 | 7-19 | 0-01 | 0-03 | 0-05 | 0-11 | 0-16 | 0-20 | 0-30 | 0-41 | 30-49 | 7-79 | 7-83 |
| BALL SIZE | 3/16 | 1/4 | 1/4 | 5/16 | 5/16 | 3/8 | 3/8 | 7/16 | 9/16 | 9/16 | 9/16 | 9/16 |
| NUMBER OF BALLS PER ROTATING ELEMENT | 32 | 40 | 46 | 42 | 56 | 58 | 66 | 74 | 80 | 104 | 126 | 148 |
| SIZE DESIGNATION LOCK BAR p/n 10 | 1/4 | 1/4 | 1/4 | 3/8 | 3/8 | 3/8 | 3/8 | 3/8 | 1/2 | 1/2 | 1/2 | 1/2 |
| SIZE DESIGNATION BALL PLUGS | 1/4 | 5/16 | 5/16 | 3/8 | 3/8 | 7/16 | 7/16 | 1/2 | 5/8 | 5/8 | 5/8 | 5/8 |

* ALL "O" RINGS PRECEDED BY 7 INDICATES 6227 SERIES; PRECEDED BY O INDICATES 6230 SERIES.

## STANDARD AND OPTIONAL MATERIALS

### CHEVRON PACKING

Standard Hycar: To 225°F working temperature
Optional Teflon: To + 300°F Acid Services
Optional Aramid Fiber: To 450°F working temp.
Optional Aramid Fiber: To 550°F working temp.
Optional Viton: To 400°F working temperature

### MALE ADAPTOR

Standard Buna N: To 225°F working temperature
Optional Aluminum: Acid and corrosive services
Optional Teflon: Acid Services
Optional Stainless Steel: Alloy to suit application
Optional Hi-Temp: To 550°F working temperature

### FEMALE ADAPTOR

Standard Steel: To 550°F working temperature
Optional Aluminum: Acid and corrosive services
Optional Stainless Steel: Alloy to suit application

### ALL "O" RINGS

Standard Buna-N: To 225°F working temperature
Optional Teflon: Acid Services
Optional Silicon: To 450°F working temperature
Optional Viton: To 450°F working temperature

# DISTRIBUTION SHEET

| To | From | Page 1 of 1 |
|---|---|---|
| Distribution | JW Bailey | Date 23 July 1998 |
| Project Title/Work Order | | EDT No. 622232 |
| Project W-320 Tank 106-C, HNF-2474, Piping Calculations, Vol. 4 | | ECN No. n/a |

| Name | MSIN | Text With All Attach. | Text Only | Attach./ Appendix Only | EDT/ECN Only |
|---|---|---|---|---|---|
| JW Bailey | S2-48 | | | | |
| W-320 Project Files | R1-29 | | | | |