AUG 26 1999

ENGINEERING DATA TRANSMITTAL

1. EDT 625110

2. To: (Receiving Organization) Distribution	3. From: (Originating Organization) Operation Equipment Engineering	4. Related EDT No.: N/A
5. Proj./Prog./Dept./Div.: TWRS Interim Stabilization Engineering	6. Design Authority/ Design Agent/Cog. Engr.: H. H. Ziada	7. Purchase Order No.:
8. Originator Remarks: This EDT Transmits the Release of the Supporting Document HNF-3286, Rev. 0		9. Equip./Component No.:
		10. System/Bldg./Facility:
11. Receiver Remarks: 11A. Design Baseline Document? [X] Yes [] No		12. Major Assm. Dwg. No.:
		13. Permit/Permit Application No.:
		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-3286		0	Design Analysis of 2,000 lb. Jib Crane for Chemical Lab	SQ	2		

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 2. Release 3. Information	4. Review 5. Post-Review 6. Dist. (Receipt Acknow. Required)	1. Approved 2. Approved w/comment 3. Disapproved w/comment	4. Reviewed no/comment 5. Reviewed 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
1	1	Design Authority W. F. Zuroff	[signature]	2/8/99	S7-20	1	1	Peer Reviewer L. J. Julyk	[signature]	2/2/99	R1-56
1	1	Design Agent H. H. Ziada	[signature]	2-2-99	R1-56	3	3	S. H. Rifaey	[signature]		R1-56
1	1	Cog.Eng. J. J. Elsen	[signature]	2-8-99	S7-20	3	3	C. W. Peoples	[signature]	8-18-99	S7-20
1	1	~~Cog.~~ HNF Mgr. R. L. Schlosser	[signature]	2-2-99	R1-56						
1	1	QA M. C. Tipps	[signature]	5/11/99	S7-34						
1	1	Safety O. M. Jaka	[signature]	7/29/99	S7-34						
		Env.									

18. [signature] H. H. Ziada 2-2-99 Signature of EDT Originator / Date	19. M. R. Koch [signature] 2/8/99 Authorized Representative for Receiving Organization / Date	20. M. R. Koch [signature] 2/8/99 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

S

HNF-3286, Rev. 0

Design Analysis of 2,000 Lb. Jib Crane for Chemical Lab

H. H. Ziada
Numatec Hanford Corporation, Richland, WA 99352
U.S. Department of Energy Contract DE-AC06-96RL13200

EDT/ECN: 625110 UC: 2000
Org Code: 82600 Charge Code: 103352/EF00
B&R Code: EW3120071 Total Pages: 20

Key Words: Jib Crane, Chemical Lab, 200 East, Design Analysis, Hoisting and Rigging, Tank Farms.

Abstract: This design analysis provides a design (Materials, sizes, and dimensions) of a 2,000 lb. Jib Crane to be installed in the 200 East Tank Farms Chemical Lab (MO-733) to replace an existing 1,0001b. Jib Crane.

8/26/99

Release Approval Date

DATE: HANFORD RELEASE ID: 2
STA: 4
AUG 26 1999

Release Stamp

Approved for Public Release

A-6400-073 (01/97) GEF321

CHECKLIST FOR INDEPENDENT REVIEW

Document Reviewed Design Analysis of 2,000lb$_f$ Jib Crane for Chemical Lab

Document No. HNF-3286 - Rev. 0

Author H. H. Ziada

Yes	No	N/A	
[X]	[ ]	[ ]	Problem completely defined.
[X]	[ ]	[ ]	Necessary assumptions explicitly stated and supported.
[ ]	[ ]	[X]	Computer codes and data files documented.
[X]	[ ]	[ ]	Data used in calculations explicitly stated in document.
[X]	[ ]	[ ]	Data checked for consistency with original source information as applicable.
[X]	[ ]	[ ]	Mathematical derivations checked including dimensional consistency of results.
[X]	[ ]	[ ]	Models appropriate and used within range of validity or use outside range of established validity justified.
[X]	[ ]	[ ]	Hand calculations checked for errors.
[ ]	[ ]	[X]	Code run streams correct and consistent with analysis documentation.
[ ]	[ ]	[X]	Code output consistent with input and with results reported in analysis documentation.
[X]	[ ]	[ ]	Acceptability limits on analytical results applicable and supported. Limits checked against sources.
[X]	[ ]	[ ]	Safety margins consistent with good engineering practices.
[X]	[ ]	[ ]	Conclusions consistent with analytical results and applicable limits.
[X]	[ ]	[ ]	Results and conclusions address all points required in the problem statement.

L. J. Julyk (signature)
Reviewer

2/2/99
Date

HNF-3286, Rev. 0

Design Analysis of 2,000 lb. Jib Crane for Chemical Lab

H. H. Ziada
January 1999

TABLE OF CONTENTS

DESIGN ANALYSIS OF 2,000 lbf JIB CRANE FOR CHEMICAL LAB

1.0 INTRODUCTION AND OBJECTIVE

A 2,000 lbf jib crane is needed to replace an existing 1,000 lbf jib crane in the Chemical Lab (Building MO-733).

The existing 1,000 lbf jib crane (to be replaced) has a 17-ft boom (I-beam). The crane is attached to the wall through two brackets (about 8 1/2-ft apart). The boom is attached to the lower bracket, and a supporting rod is attached to the upper bracket. The supporting rod is attached to the boom at about 8-ft from the free end.

After preliminary studies and discussions, it was decided to construct the new jib crane from two perpedicular I-beams (L-shape) without a supporting rod (see Figure 1). The crane is to be supported on the wall through the two lower existing brackets (about 5-ft apart). The boom is to be 20-ft long cantilever (the horizontal I-beam). The vertical I-beam is to be attached to the lower two existing brackets to support the jib crane to the wall. This construction is to be similar to another existing 1,000 lbf jib crane (L-shape) in the lab.

The purpose of this document is to perform a design analysis for the proposed 2,000 lbf jib crane to determine suitable sizes of members and configuration of the new jib crane assembly.

After construction, if the as-built assembly differs from the 2,000 lbf jib crane as proposed in this document, a revision of this analysis needs to be performed to confirm the acceptability of the as-built assembly.

2.0 CONCLUSIONS AND RECOMMENDATIONS

The following recommended materials, sizes, and dimensions are based on the design factor of 5 specified in DOE (1993), and the guidelines provided in AISC (1989).

1- All structural materials are recommended to be carbon steel A36 (ASTM 1997) and the pin material to be A325 steel.

2- The L-shaped jib crane is recommended to be constructed from I-beam size W 12x40 (as minimum size).

3- The assembly of the L-shaped I-beams and hinge connections shall be similar to that of the other existing 1,000 lbf jib crane (L-shape) or stiffer (see Figure 1) .

4- The existing lower two brackets of the 1,000 lbf jib crane to be replaced (about 5-ft apart) shall be used in connecting the new jib crane to the wall. The thickness of the upper and lower brackets of each support should be strengthened by a 1/2-in. thick plate at the hole region. This will provide a total thickness of 1-in. for each bracket to satisfy the DOE (1993) stress allowable (see Figure 2) .

5- The pin of each hinge shall be a minimum of 1-in. diameter and made of A325 material.

6- All welds shall be fillet welds with the sizes shown in Figures 1-4, or stronger. The recommended weld material is E70XX.

Sketches of the proposed jib crane assembly are shown in Figures 1-4. Final drawings should be developed and approved. If the final as-built assembly is different from the proposed sizes, dimensions, and configuration; a revision of this analysis needs to be performed to confirm the acceptability of the as-built structure.

3.0 CONFIGURATION AND MATERIAL

The configuration of the proposed L-shaped 2,000lbf jib crane is illustrated in Figure 1. The crane is constructed of two perpendicular I-beams, which are selected to be size W 12x40 (stronger sizes can also be used but the beam weight should not exceed 70 lbf/ft). The boom (horizontal part) has a 20-ft effective arm. The jib crane is attached to the two existing lower hinge brackets. A sketch of the modified bracket is illustrated in Figure 2. The existing hinge brackets are made of 1/2-in. thick plate. The brackets are welded to the wall by a 1/4-in. all around fillet weld. The brackets are modified by the addition of a 1/2-in. thick plate at the hole region on the outer upper and lower horizontal surfaces .

The structural material of the new components is selected to be carbon steel A36, and the pin material is to be A325 (ASTM 1997). The yield strength of the A36 material is 36,000 lbf/in^2, and the minimum ultimate tensile strength is 58,000 lbf/in^2. The yield and ultimate strengths of the A325 material are 92,000 lbf/in^2 and 120,000 lbf/in^2, respectively.

4.0 LOADING AND CRITERIA

The evaluation is based on the general construction and installation requirements of Hanford Site Hoisting and Rigging Manual (DOE 1993), and the guidelines provided in the Manual of Steel Construction, Allowable Stress Design (AISC 1989).

4.1 LOADING

The loading on the 20-ft boom (cantilever) is the jib crane rated load of 2,000 lbf, and the boom (W 12x40 I-beam) distributed weight of 40 lbf/ft (3.333 lbf/in). The boom weight is considered because it has significant contribution to the bending moment.

4.2 ALLOWABLE STRESSES AND LOADS

The allowable stresses and loads are based on the design factor of 5 on the ultimate tensile strength of the material (DOE 1993). The shear strength is taken as 0.577 of the tensile strength (Von-Mises criteria), which is consistent with ductile material behavior, and gives allowable shear stress more conservative than the AISC ratio of 0.66 (see below).

Because the the jib crane is a steel structure, thus, the ratios between the different stress allowables in AISC (1989) can be applied to determine the shear and bearing stress allowables in comparison to the tensile stress allowable.

From AISC (1989); the allowable tensile stress (Ft) is 0.6 of the yield strength, the allowable shear stress (Fv) is 0.4 the yield strength, and the allowable bearing stress (Fp) is 0.9 the yield strength.

Ratio of shear stress to tensile stress allowables = Fv/Ft = 0.4/0.6 = 0.66 > 0.577 (thus 0.577 is used to obtain Fv).

Ratio of bearing stress to tensile stress allowables = Fp/Ft = 0.9/0.6 =1.5

4.2.1 Allowable Stresses for Structural Components (A36 Material)

$Fu := 58000 \cdot \frac{lbf}{in^2}$ $\quad Ft := \frac{Fu}{5}$ $\quad Ft = 11600 \cdot \frac{lbf}{in^2}$ Allowable bending stress (tensile and compressive, see next page)

$Fv := 0.577 \cdot Ft$ $\quad Fv = 6693 \cdot \frac{lbf}{in^2}$ Allowable shear stress

$Fp := 1.5 \cdot Ft$ $\quad Fp = 17400 \cdot \frac{lbf}{in^2}$ Allowable bearing stress

The allowable compressive bending stress depends on the slenderness ratio (l/r_T) of the flexural member (I-beam). The AISC (1989), Section F1.3, provides formulas for different cases of slenderness ratio. When the unbraced length L is greater than a specified L_c value (defined below), the allowable compressive bending stress for the W 12x40 I-beam is calculated in accordance with the following formulas of AISC (1989).

$b_f := 8 \cdot in$ Flange width $Fy := 36000 \cdot \frac{lbf}{in^2}$ Yield strength

$L_c := \frac{76 \cdot b_f}{\sqrt{Fy}}$ Lc = 76x8/6 = 101.33 in (where Fy is 36 kips)

$L := 240 \cdot in$ Beam length, greater than L_c of 101.33-in.

$r_T := 2.14 \cdot in$ Radius of gyration of compression flange plus 1/3 of compression web, from I-beam properties tables in AISC (1989).

$\frac{L}{r_T} = 112$

For flexural members with compact or noncompact sections, and with unbraced lengths greater than Lc with an axis of symmetryin, and loaded in the plane of their web, the allowable bending stress in compression (F_{bc}) is shown below.

$C_b := 1$ For cantilever beams; coefficient depends on end moments ratio.

The beam satisfies the following condition, $\sqrt{\frac{102000 \cdot C_b}{Fy}} < \frac{L}{r_T} < \sqrt{\frac{510000 \cdot C_b}{Fy}}$; (53.23 < 112.15 < 119.02).

When L (240-in.) exceeds L_c (101.33-in.) and l/r_T (112.15) is between the above values, the allowable compressive bending stress is determined as the larger value from the following two equations.

$\sigma := 1530000000 \cdot \frac{lbf}{in^2}$ Dummy units for a constant given in the following equation.

$$F_{bc1} := Fy \cdot \left[\frac{2}{3} - \frac{Fy \cdot \left(\frac{L}{r_T} \right)^2}{\sigma \cdot C_b} \right] \quad \text{-------------(1)}$$

$F_{bc1} = 13346 \cdot \frac{lbf}{in^2}$ First compressive bending stress allowable.

For any value of L/r_T:

$C1 := 2.9 \cdot \frac{1}{in}$ C1=d/Af, ratio of depth to flange area (AISC 1989).

$C2 := 12000000 \cdot \frac{lbf}{in^2}$ Dummy units for a constant given in the following equation.

$F_{bc2} := \frac{C2 \cdot C_b}{L \cdot C1}$ -----(2) $F_{bc2} = 17241 \cdot \frac{lbf}{in^2}$ Second compressive bending stress allowable

Both F_{bc1} and F_{bc2} values of the above two equations are greater than Ft. Therefore, Ft of 11,600 lbf/in² is used for allowable tension and compression bending stresses.

4.2.2 Allowable Shear Stress for Fillet Weld

Assume the weld electrode material is E70XX. The AISC (1989), Table J2.5, specifies the following shear stress allowables for fillet welds.

Allowable shear stress for shear on effective area = 0.3 x Fu weld = 0.3 x 70,000 = 21,000 lbf/in^2

Allowable shear stress for tension or compression parallel to axis of weld = same as base metal

To be consistent with DOE (1993) and the derivation of the base metal allowables in the preceding sections, the allowable shear stress for welds will be taken as the base metal allowables (conservative).

$Fvw := Fv$ $\quad Fvw = 6693 \cdot \frac{lbf}{in^2}$ Allowable shear stress for weld

$t_w := 0.25 \cdot in$

$F_w := 0.707 \cdot t_w \cdot Fvw$ $\quad F_w = 1183 \cdot \frac{lbf}{in}$ Allowable shear stress (per linear inch) for 1/4-in. fillet weld.

4.2.3 Allowable Stresses for Pin (A325 Material)

$fup := 120000 \cdot \frac{lbf}{in^2}$ Ultimate strength of pin material

$Ftp := \frac{fup}{5}$ $\quad Ftp = 24000 \cdot \frac{lbf}{in^2}$ Allowable bending stress for pin

$Fvp := 0.577 \cdot Ftp$ $\quad Fvp = 13848 \cdot \frac{lbf}{in^2}$ Allowable shear stress for pin

5.0 ANALYSIS

The analysis was performed by conventional hand calculations using formulas from Roark (1975), Bruhn (1965), Ricker (1991), Shigley, and Blodgett (1982).

5.1 JIB CRANE BOOM (W 12x 40 I-BEAM)

The bending moment is calculated for the 2,000 lbf at 240-in. (from the wall), and for the distributed weight of the boom (w=3.33 lbf/in for the I-beam). This moment is conservative for the boom and its weld connection to the box.

$P := 2000 \cdot lbf$ $\quad w := 3.333333 \cdot \frac{lbf}{in}$ (40 lbf/ft of I-beam) $\quad L := 240 \cdot in$

$M := P \cdot L + \frac{w \cdot L^2}{2}$ $\quad M = 576000 \cdot in \cdot lbf$ Moment at fixed end

$S := 51.9 \cdot in^3$ Modulus of section

$\sigma_b := \frac{M}{S}$

$\sigma_b = 11098 \cdot \frac{lbf}{in^2}$ Bending stress is less than bending stress allowable of 11,600 lbf/in^2.

5.2 HINGE BRACKETS

The results of a preliminary analysis indicated that the brackets (at the pin hole region) need to be thicker than the original thickness of 0.5-in. in order to satisfy the shear and bearing stress allowables. It is recommended to strengthen the brackets by welding (0.25-in. fillet weld) a 0.5-in. plate to the upper and lower outermost horizontal surfaces of each bracket at the hole region. The welded plates need to follow the contour of the brackets and to allow sufficient distances from the outside edges to facilitate the welding on the outside of the added plate (no weld on the hole surface). The modified bracket configuration is presented in Figure 2.

The moment M (576,000 in.lbf) produces a couple that generates action and reaction forces (F) in the two brackets. The distance between the centerlines of the brackets is 5-ft (60-in.).

The bracket at the hole region should be checked for the following failure modes.

1- Tension failure at sides of hole.

2- Double shear failure.

3- Bearing failure.

4- Tearing tension failure or hoop tension failure.

5- Compliance with dishing failure.

Bruhn (1965), Ricker (1991), and Shigley (1983) have slightly different approaches in dealing with shear, bearing, and tearing tension failures.

5.2.1 Tension Failure

The modified bracket is 1.0-in. thick, and the side distance from the hole to the edge is about 1.0-in. (see figure below).

$t := 1.0 \cdot in$ Plate thickness

$L_t := 1.0 \cdot in$ Side length for tension stress

$A_{pt} := 2 \cdot t \cdot L_t$

$A_{pt} = 2 \cdot in^2$ Tension area

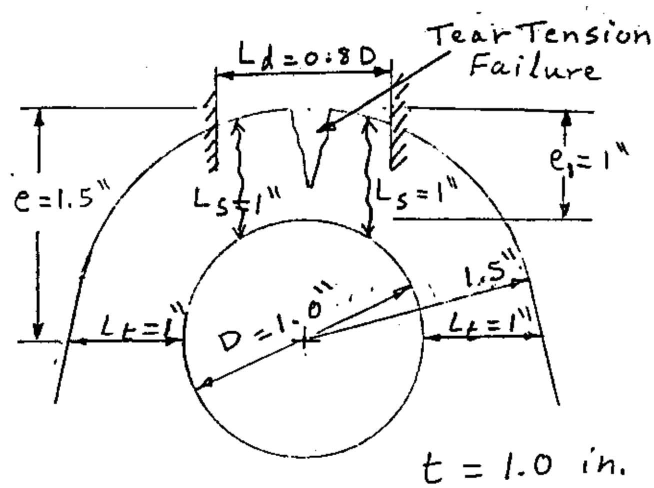
$L_1 := 60 \cdot in$ Distance between brackets

$F := \dfrac{M}{L_1}$

$F = 9600 \cdot lbf$ Force on bracket

$f_t := \dfrac{F}{A_{pt}}$

$f_t = 4800 \cdot \dfrac{lbf}{in^2}$ Tensile stress is less than 11,600 lbf/in² allowable stress.



5.2.2 Double Shear Failure

$L_s := 1.0 \cdot in$ Shear distance to edge

$A_{ps} := 2 \cdot t \cdot L_s$

$A_{ps} = 2 \cdot in^2$ Shear area

$f_v := \dfrac{F}{A_{ps}}$

$f_v = 4800 \cdot \dfrac{lbf}{in^2}$ Shear stress is less than allowable shear stress of 6,693 lbf/in^2.

5.2.3 Bearing Failure

$D := 1.0 \cdot in$ Pin diameter

$A_{pb} := D \cdot t$

$A_{pb} = 1 \cdot in^2$ Bearing area

$f_p := \dfrac{F}{A_{pb}}$

$f_p = 9600 \cdot \dfrac{lbf}{in^2}$ Bearing stress is less than 17,400 lbf/in2 allowable bearing stress.

5.2.4 Tearing Tension Failure

This failure occurs when the pin diameter is smaller than the hole diameter.

a) Shigley (19830 states that this failure is avoided by spacing the hole at least 1.5 diameter from the margin (edge).

1.5 x d = 1.5 x 1.0 = 1.5 in, this is more than 1.0-in. distance from the edge. Thus, check the tearing tension failure.

b) Ricker (1991) assumes that the tear resulted from a bending stress in section between the hole and the boundary. Assume that a block of 0.8xd in length, e in height, and have the same plate thickness. The block performs as a fixed-ends beam (see sketch on previous page) .

$e_1 := 1.0 \cdot in$ Height or distance to edge

$L_d := 0.8 \cdot D$ $L_d = 1 \cdot in$ Beam length

$S := \dfrac{t \cdot e_1^{\,2}}{6}$ $S = 0 \cdot in^3$ Modulus of section

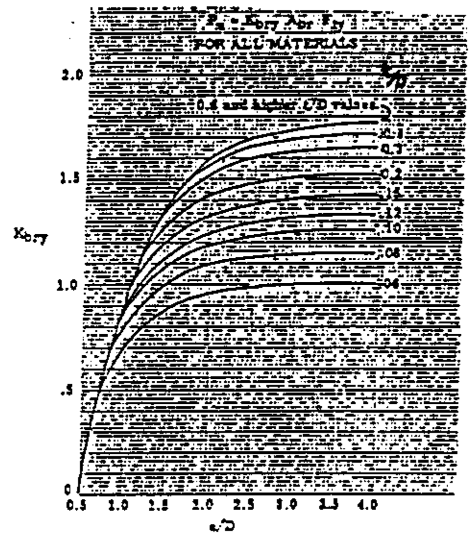
$M1 := \dfrac{F \cdot L_d}{8}$

$M1 = 960 \cdot in \cdot lbf$ Bending moment

$f_t := \frac{M1}{S}$

$f_t = 5760 \cdot \frac{lbf}{in^2}$ Bending stress is less than allowable stress of 11,600 lbf/in².

c) Bruhn (1965) states that failure due to shear out and bearing (tearing) are closely related and are covered by a single calculation based on empirical curves. The allowable load (P_{ta}) may be expressed as a function of the allowable stress



$A_{pb} = 1 \cdot in^2$ Bearing area

$K_{bry} := 1.4$ Shear bearing factor based on t/D=1.0, and e/D=1.5 (see curve).

$Ft = 11600 \cdot \frac{lbf}{in^2}$ Allowable tensile stress

$P_{ta} := K_{bry} \cdot A_{pb} \cdot Ft$

$P_{ta} = 16240 \cdot lbf$ Allowable load is greater than the acting load of 9,600 lbf.

5.2.5 Dishing Failure (Out-of-Plane Buckling)

Ricker (1991) stated that dishing can be prevented by having the plate thickness equal or greater than 0.25 the diameter, but never less than 0.5-in. The bracket satisfies this condition. Therefore, dishing is not a concern.

5.3 HINGE PIN

The existing pin has 1-in. diameter. The bracket does not have enough distance to the front edge to increase the pin diameter. Besides, it is not easy to machine the bracket hole because it is welded to the wall structure. Therefore, the pin diameter is restricted to 1-in. diameter.

Each pin is subjected to a force of 9,600 lbf. The pin is checked for shear and bending stresses (the bearing stress is enveloped by the bracket). Preliminary calculations indicated that the pin should be made out of material stronger than A36 carbon steel. Thus, the pin material needs to be A325 or stronger.

5.3.1 Shear Stress

First assume the pin will fail under double shear.

$A_p := \frac{\pi \cdot D^2}{4}$ $A_p = 1 \cdot in^2$ Pin area

$f_{sp} := \frac{F}{2 \cdot A_p}$

$f_{sp} = 6112 \cdot \frac{lbf}{in^2}$ Double shear stress is not conservative, because the load is not uniform.

Second, assume that the rotation of the crane (due to the bending moment) will cause the 9,600 lbf load to act as a concentrated load on the pin, see sketch below. ***Therefore, the pin will be under single shear.*** **This is a conservative representation for this application.**

$$f_{spd} := \frac{F}{A_p}$$

$$f_{spd} = 12223 \cdot \frac{lbf}{in^2}$$

Single shear stress is less than 13,848 lbf/in² allowable shear stress.

5.3.2 Bending stress

In general static tests of single bolt fittings will not show a failure due to bolt bending failure. Besides, it is not known exactly how the load is distributed to the pin nor the relative deformations of the pin and the members. However, it is important that sufficient bending strength is provided to prevent permanent bending deformation so that bolts can be readily removed in maintenance operations.

Assume simply supported beam with concentrated load as shown in the sketch below, with a maximum clearance of 0.125-in applied on one side, and the gap between the pin and the hinge on the left is not closed.

$a := 0.125 \cdot in$ — Distance from close support (Clearance)

$b := 5.375 \cdot in$ — Distance from far support

$L_p := 5.5 \cdot in$ — Length of pin between supports (inside of the bracket)

$$R := F \cdot \frac{b}{L_p}$$

$R = 9382 \cdot lbf$ — Reaction force

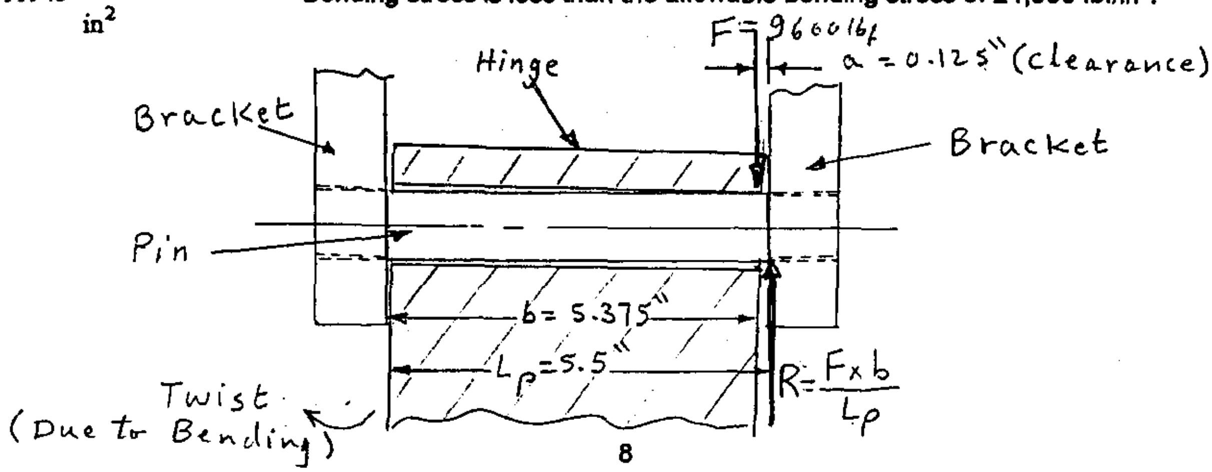
$$M_p := R \cdot a$$

$M_p = 1173 \cdot in \cdot lbf$ — Maximum bending moment at point of load

$$f_{bp} := \frac{32 \cdot M_p}{\pi \cdot D^3}$$

$$f_{bp} = 11945 \cdot \frac{lbf}{in^2}$$

Bending stress is less than the allowable bending stress of 24,000 lbf/in².



5.4 WELDS

This section evaluates the welds of the crane assembly. The weld that joins the the hinge bracket to the wall is an existing 1/4-in. fillet weld. The other welds are to be sized to support the crane loads. The welds were evaluated according to formulas obtained from Blodgett (1982) and the guidelines of AISC (1989).

5.4.1 Welds of Hinge Support

This is an existing 1/4-in. fillet weld (see Figure 2).

The normal load on the weld is 9,600 lbf (load per bracket to react the moment).

$A_w := 22.75 \cdot in$ Weld area per unit thickness (5+5+6.375+6.375)

$f_{hw} := \dfrac{F}{A_w}$

$f_{hw} = 422 \cdot \dfrac{lbf}{in}$ Shear stress (per linear length) for tension load

The shear load (V) on the weld is the 2,000 lbf plus the beam weight (see Section 5.1).

$V := P + w \cdot L$

$V = 2800 \cdot lbf$ Shear force, assuming only one support carries the shear load

$f_{vw} := \dfrac{V}{A_w}$

$f_{vw} = 123 \cdot \dfrac{lbf}{in}$ Shear stress (per linear length) for shear load

$f_w := \sqrt{f_{hw}^2 + f_{vw}^2}$

$f_w = 440 \cdot \dfrac{lbf}{in}$ Resultant shear stress (per linear length) is less than 1,183 lbf/in allowable weld stress for 0.25-in. fillet weld.

5.4.2 Welds Connecting Boom (I-Beam) to Box

The two I-beams are connected together through a box-shaped structure as shown in Figure 1. The boom is welded to one side of the box-shape structure around its contour. A 3/4-in. thick plate is welded to the top surface of the box and the I-beam by a 3/8-in. fillet weld around the plate sides (on the bottom). The box-shape is constructed from 3/4-in. thick plates with the web plate welded to the four side plates by a 5/8-in. fillet welds on both sides.

The weld dimensions and section properties appear in Figure 3. Bottom weld (at point "a") is the critical location.

$A_{w1} := 24.32 \cdot in^2$ Total weld area

$J_w := 945.6 \cdot in^4$ Polar moment of inertia

$C_y := 9.0 \cdot in$ Vertical distance from point "a" to neutral axis

$C_x := 3.33 \cdot in$ Horizontal distance from point "a" to neutral axis

$f_{sh} := \frac{M \cdot C_y}{J_w}$ M = 576,000 in.lbf (Section 5.1)

$f_{sh} = 5482 \cdot \frac{lbf}{in^2}$ Horizontal torsional shear stress

$f_{sv} := \frac{M \cdot C_x}{J_w}$

$f_{sv} = 2028 \cdot \frac{lbf}{in^2}$ Vertical torsional shear stress

$f_{v1} := \frac{V}{A_{w1}}$ Vertical shear stress

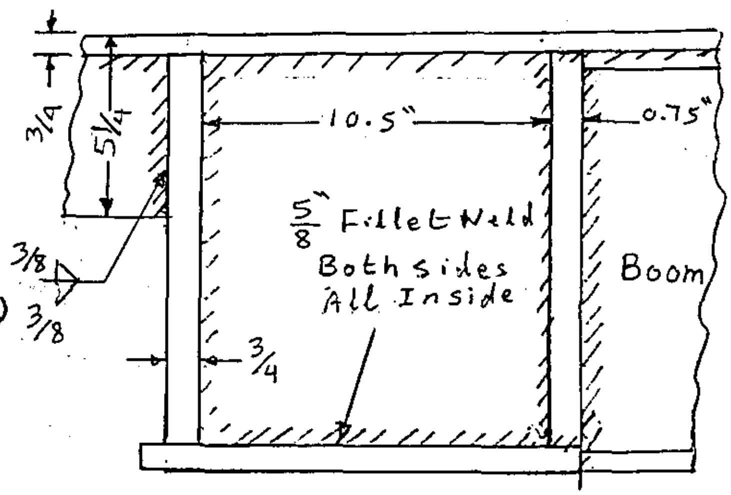
$f_{v1} = 115 \cdot \frac{lbf}{in^2}$

$f_{wr} := \sqrt{f_{sh}^2 + (f_{sv} + f_{v1})^2}$

$f_{wr} = 5886 \cdot \frac{lbf}{in^2}$ Shear stress on weld is less than the 6,693 lbf/in^2 allowable shear stress.

5.4.3 Welds in Box-Shaped Connection

The web plate is welded to the side plates by a 5/8-in. fillet weld. All plates are 3/4-in. thick. The length of each side is 12-in. long. Assume the length of the welds on each internal side is 10.5-in. long (see sketch below).



$d_h := 10.5 \cdot in$ Weld horizontal length

$d_v := 10.5 \cdot in$ Weld vertical length (coservative)

$V_h := \frac{M}{d_v}$

$V_h = 54857 \cdot lbf$ Shear force in weld (V_v=V_h)

$t_{w1} := 0.625 \cdot in$ Fillet weld size

$f_{hbox} := \frac{V_h}{2 \cdot d_h} \cdot \frac{1}{t_{w1} \cdot 0.707}$

$f_{hbox} = 5912 \cdot \frac{lbf}{in^2}$ Shear stress in weld is less than 6,693 lbf/in^2 allowable shear stress.

5.4.4 WELD OF HINGE PLATE

The loads are the same as those in Section 5.4.1 above. Take the plate thickness to be 3/4-in. and the fillet weld size to be 3/8-in. (to be in proportion with other plates). The depth of the plate should not be less than 5.25-in. long to allow for the 1/8-in. maximum clearance between the hinge and the inside space of the support plates (5.375-in. distance).

$t_{w2} := 0.375 \cdot in$ Weld size $L_{w2} := 4.5 \cdot in$ Length of vertical welds only (conservative, because it neglects the effect of the horizontal plate), see sketch on previous page.

$A_{w2} := 2 \cdot t_{w2} \cdot L_{w2} \cdot 0.707$

$A_{w2} = 2 \cdot in^2$ Area of weld

$f_{hw2} := \frac{F}{A_{w2}}$

$f_{hw2} = 4023 \cdot \frac{lbf}{in^2}$ Shear stress for tension load

$f_{vw2} := \frac{V}{A_{w2}}$

$f_{vw2} = 1173 \cdot \frac{lbf}{in^2}$ Shear stress for shear load

$f_{w2} := \sqrt{f_{hw2}^2 + f_{vw2}^2}$

$f_{w2} = 4191 \cdot \frac{lbf}{in^2}$ Shear stress is less than 6,693 lbf/in^2 allowable shear stress.

5.5 ANALYSIS RESULTS

The stress analysis results show that all proposed component sizes and dimensions (as shown in Figures 1-4) are acceptable. The proposed sizes of I-beams and welds are minimum requirements. Any sizes larger than those proposed are acceptable (provided that the weight of the beam does not exceed 70 lbf/ft) and will provide larger margins of safety beyond the factor of 5 on ultimate strength.

The existing wall support brackets should be modified by welding a 1/2-in. thick plate on each of the top surface of the upper bracket and the bottom surface of the lower bracket at the pin hole region. The existing 1/2-in. thick brackets can not satisfy the allowable shear and bearing stresses developed from the 2,000 lbf and the weight of the jib crane boom.

The hinge pins need to be made of steel A325 or stronger to satisfy the required allowable stresses that are based on a factor of 5 on the ultimate strength of the material.

Figures 1-4 represent the main features and dimensions of the proposed jib crane. The conclusions and recommendations are presented in Section 2.0.

Final drawings need to be developed. If the final as built structure is different from the proposed design, a revised stress analysis needs to be performed to verify the changes.

5.5 REFERENCES

AISC, 1989," Manual of Steel Construction, Allowable Stress Design," American Institute of Steel Construction, Inc., 9 th. edition, Chicago, Illinois.

ASTM, 1997," Annual Book of ASTM Standards," American Society of Testing and Materials," Philadelphia, Pennsylvania.

Blodgett, O. W., 1982," Design of Welded Structures," The James F. Lincoln Arc Welding Foundation, 12 th. Printing, Cleveland, Ohio.

Bruhn, E. F., 1965," Analysis and Design of Flight Vehicle Structures," Tri-State Offset Company, Cincinnati, Ohio.

DOE, 1993," Hanford Site Hoisting and Rigging Manual," DOE-RL-92-36, Section 12.0, Richland, Washington.

Ricker, David t., 1991," Design and Construction of Lifting Beams," Journal of American Institute of Steel Construction, Fourth Quarter, p. 149-158.

Roark, R. J., 1975," Formulas for Stress and Strain," Fifth Edition, McGrow-Hill Book Company, New York, New York.

Shigley, J. E., 1983," Mechanical Engineering Design," 4 th. Edition, McGrow-Hill Company, New York, New York.

Figure 1: Configuration of the Proposed 2, 000 lbf Jib Crane.

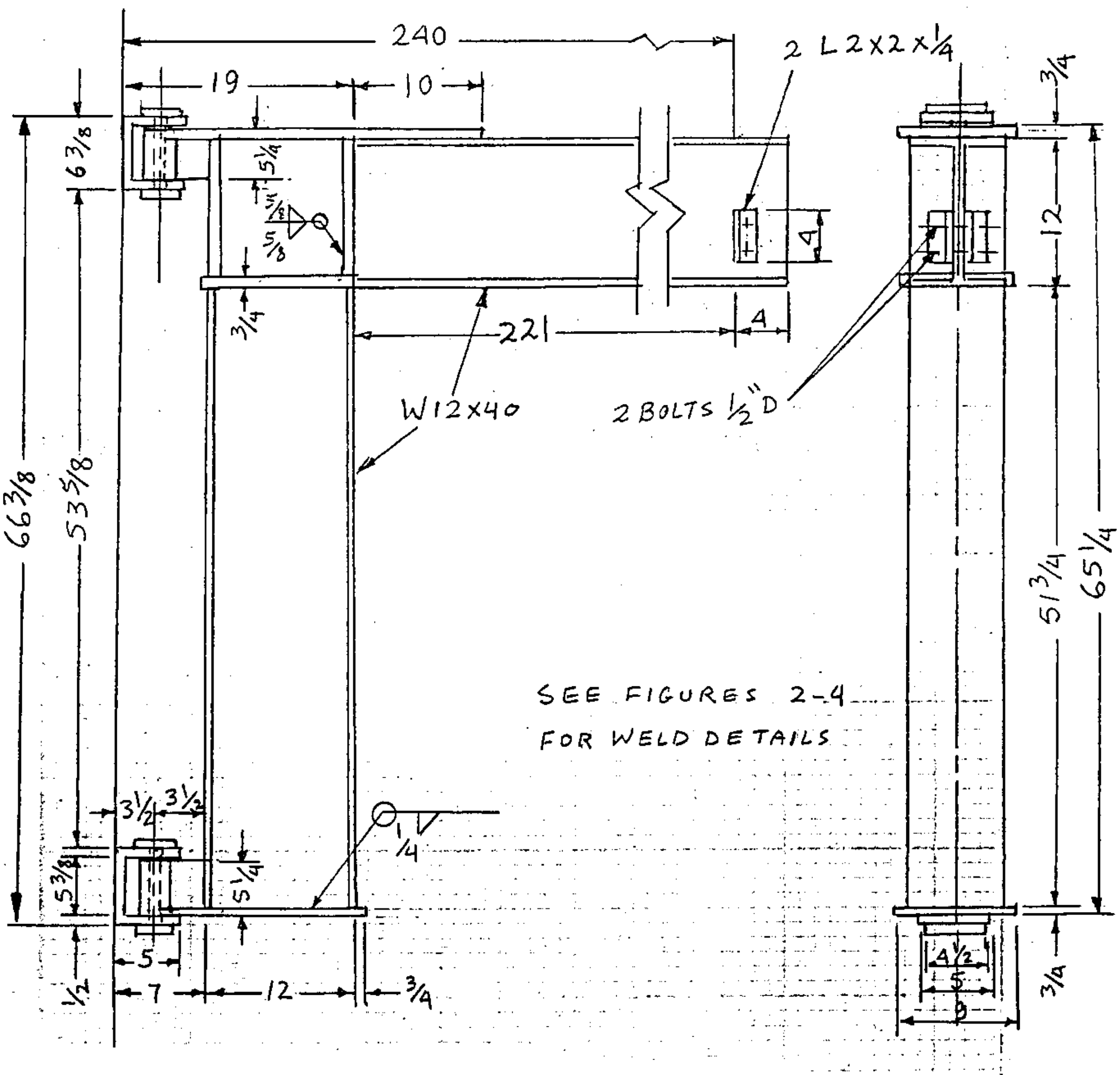
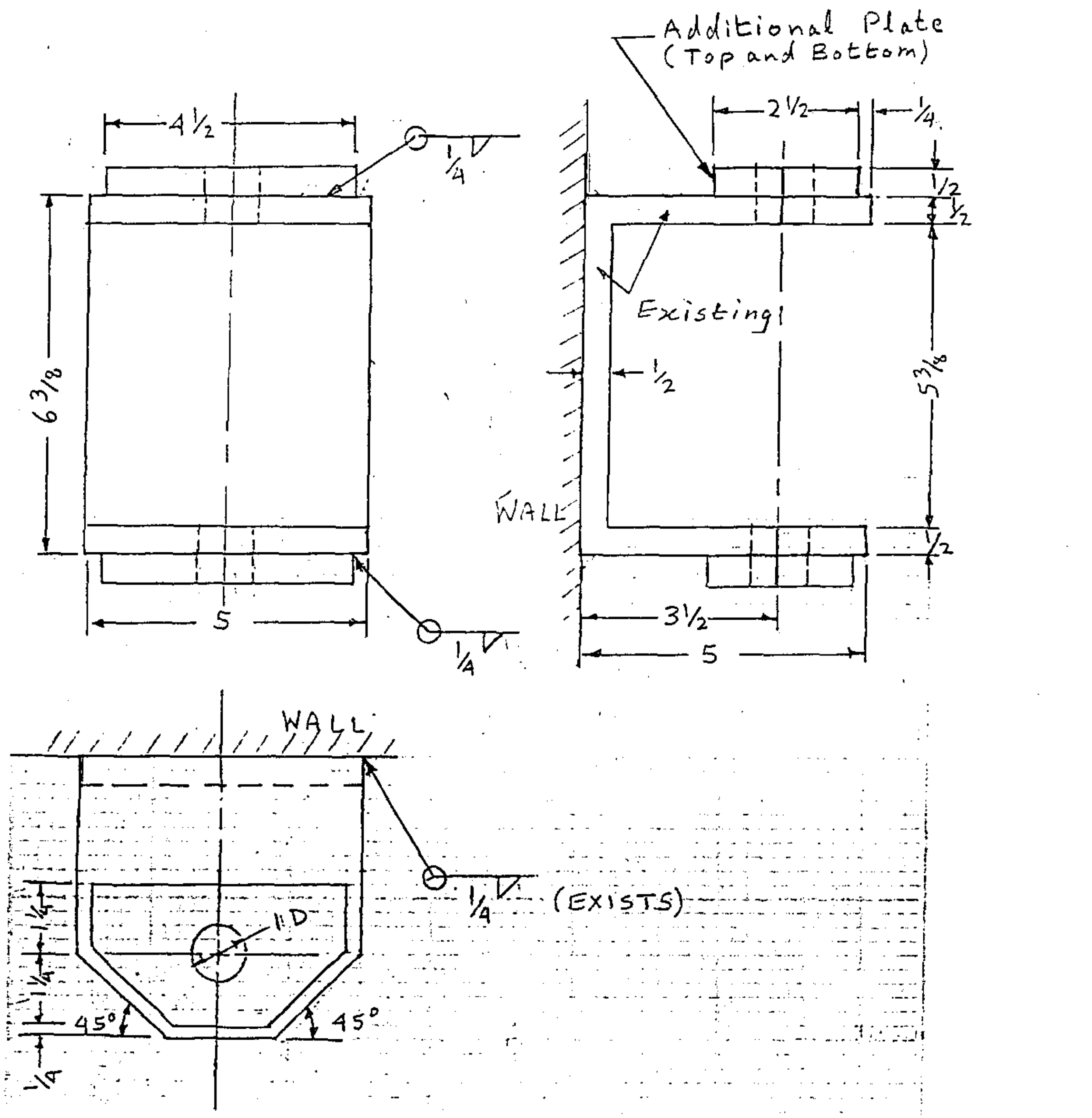
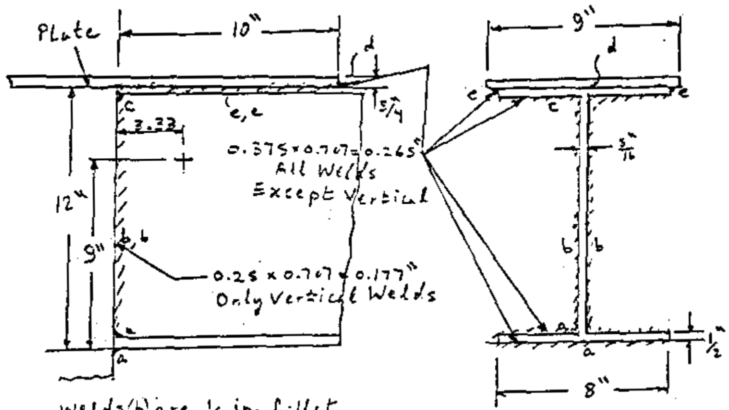


Figure 2: Modified Bracket Configuration.



Client: Lockheed Martin Hanford, Corp. | WO/Job No. N1WGD
Subject: Design Analysis of 2,000 lbf Jib Crane in Chemical Lab in Building MO-733. | Date: 10/19/98 | By: H. H. Zieda
Checked: 11/19/98 | By: L. J. Julyk
Location: Building MO-733 lab, 200E Area Hanford, Washington | Revised: | By:

Figure 3: Proprties of Weld Connecting Boom (I-Beam) to Box.



welds(b) are 1/4 in. fillet
welds(a, c, d, e) are 3/8 in. fillet

I_{xx}

Item	Size	Area (in²) A	Distance x (in)	M (in³) A×x	I_x (in⁴) M×X	I_g (in⁴)
a	2×8×0.265	4.24	0	0	0	34.70
b	2×11×0.177	3.89	6.00	23.34	140.04	—
c	1×8×0.265	2.12	11.50	24.38	280.37	—
d	1×8×0.265	2.12	12.00	25.44	305.28	—
e	2×10×0.265	5.20	12.00	62.40	748.80	—
Plate	1×9×0.75	6.75	12.375	83.53	1033.70	0.10
Total		24.32		219.09	2508.19	34.80

$$n_{ay} = \frac{M}{A} = \frac{219.09}{24.32} = 9.0 \text{ in}$$

$$I_{xx} = I_x + I_g - \frac{M^2}{A} = 2508.19 + 34.80 - \frac{(219.09)^2}{24.32} \approx 569.3 \text{ in}^4$$

I_{yy}

Item	Size	Area (in²) A	Distance x (in)	M (in³) A×x	I_y (in⁴) M×X	I_g (in⁴)
a	2×8×0.265	4.24	0	0	0	22.61
b	2×11×0.177	3.89	0	0	0	—
c	1×8×0.265	2.12	0	0	0	11.31
d	1×8×0.265	2.12	10	21.20	212.00	11.31
e	2×10×0.265	5.20	5	26.00	130.00	44.17
Plate	1×9×0.75	6.75	5	33.75	168.75	45.56
Total		24.32		80.95	510.75	134.96

$$n_{ax} = \frac{M}{A} = \frac{80.95}{24.32} = 3.33 \text{ in}$$

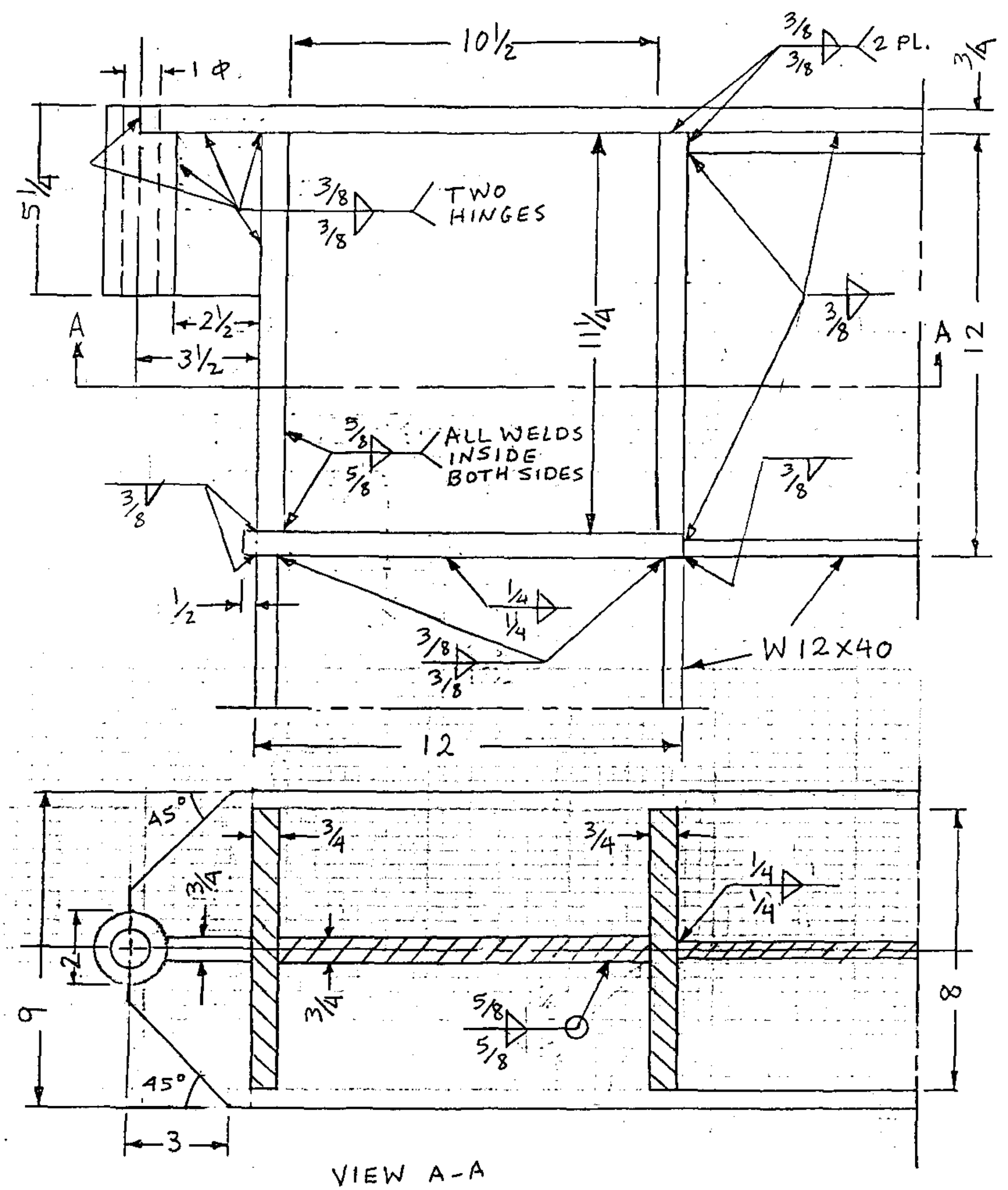
$$I_{yy} = I_y + I_g - \frac{M^2}{A} = 510.75 + 134.96 - \frac{(80.95)^2}{24.32} = 376.3 \text{ in}^4$$

$$J_W = I_{xx} + I_{yy} = 569.3 + 376.3 = 945.6 \text{ in}^4$$

Client: Lockheed Martin Hanford, Corp.
Subject: Design Analysis of 2,000 lbf Jib Crane in Chemical Lab in Building MO-733.
Location: Building MO-733 lab, 200E Area Hanford, Washington

WO/Job No. N1WGD
Date: 10/21/98 By: H. H. Ziada *Hom H. Ziada*
Checked: *11/19/98* By: L. J. Julyk *LJJ*
Revised: By:

Figure 4: Configuration of Hinge and Box.



DISTRIBUTION SHEET

To	From	
Distribution	Operational Equipment Engineering	Page 1 of 1
Project Title/Work Order		Date August 25, 1999
Design Analysis of 2,000 lb. Crane for Chemical Laboratory		EDT No. 625110
		ECN No. N/A

Name	MSIN	Text With All Attach.	Text Only	Attach./ Appendix Only	EDT/ECN Only
Lockheed Martin Hanford Corporation					
J. J. Elsen	S7-24	X			
O. M. Jaka	S7-24			X	
L. J. Julyk	R1-56	X			
M. R. Koch	S7-54	X			
C. W. Peoples	S7-20	X			
S. H. Rifaey	R1-56			X	
R. L. Schlosser	R1-56			X	
M. C. Tipps	S7-34			X	
W. G. Zuroff	S7-24	X			
Numatec Hanford Corporation					
H. H. Ziada	R1-56	X			