D-Zero Cryobridge Structural Analysis

Engineering Note #3740.510-EN-240

Issued: February 2, 1990

Appended: April 20, 1990

Originator: Jeff Western

Checked: Al Jaques

Appended: Al Jaques

D-Zero Cryobridge Structural Analysis

*CG calculations and Lifting stresser
appended to Report on 4/6/90

Engineering Note #3740.510-EN-240

REF: DWG. No. 9220.740-ME-284211 REV. C
2 SHTS
(RESEARCH DIV. MECH. SUPP.)

Issued: April 6
~~February 2~~, 1990

Originator: Jeff Western

Checked: Al Jaques

E740

D0 CRYO BRIDGE
STRUCTURAL
CALCULATIONS

JEFFREY L. WESTERN
SEPTEMBER 1, 1989

PER TONY PARKER
8-10-89

NOTE: - LIVE LOAD IS THE
CRYOPIPING LOADING
- DEAD LOAD IS WEIGHT OF FRAME

LIVE LOAD	-	500	1000	1000	1000
DEAD LOAD	325 + 4500	650	650	650	325 + 4500

TOTAL LOAD	4825*	1150*	1650*	1650*	5825*
------------	-------	-------	-------	-------	-------

1	ITEM 1, 10	I = 41,245	A = 134	
2	ITEM 2, 9	I = 5801	A = 49.9	LOWER COLUMN
3	ITEM 3, 8	I = 3,511	A = 37.3	UPPER COLUMN
4	ITEMS 4, 5, 6, 7	I = 1,030	A = 25.2	HORIZ. MEMBER

HORIZONTAL BEAM (MC18x42.7 W/ MC18x42.7 ON TOP FLANGE) MAX POS MOMENT LOCATION

$$M = 338,720 \text{ IN-LB} \quad \text{MEMBER 4/5} \quad \text{LOAD CASE 1}$$

$$F_{b+} = M/S = 338,720 / 72.9 = 4,646 \text{ PSI}$$

$$F_{b+} = \frac{12 \times 10^3}{L d / A_F} = \frac{12000}{33(12)(18.5/8.1)} = 13,268 \text{ PSI}$$

$$13,268 \text{ PSI} > 4,646 \text{ PSI} \therefore \text{ADEQUATE}$$

MAX. NEG. MOMENT LOCATION

$$M = 298,730 \text{ IN-LB} \quad \text{MEMBER 7} \quad \text{LOAD CASE 1}$$

$$F_{b+} = M/S = 298,730 / 72.9 = 4,098 \text{ PSI}$$

$$F_{b+} = \frac{12 \times 10^3}{L d / A_F} = \frac{12000}{33(12)(7.29)} = 4,157 \text{ PSI}$$

$$4,157 \text{ PSI} > 4,098 \text{ PSI} \therefore \text{ADEQUATE}$$

UPPER COLUMN (W27x84 w/ MC18x42.7 ONE FLANGE ONLY)

$$\left. \begin{array}{l} P = 9621 \text{ LB} \\ M = 484,430 \text{ IN-LB} \end{array} \right\} \text{ MEMBER 8 LOAD CASE 1}$$

$$F_a = P/A = 9621/37.3 = 258 \text{ PSI}$$

$$F_u = 7,200 \text{ PSI}$$

$$\leftarrow \frac{KL}{r} = \frac{8.124(12)}{4.2} = 144$$

$$F_{bx} = 484,430/220 = 2,202 \text{ PSI}$$

$$F_{bx} = 12000 / \frac{30(12)(4.19)}{1} = 6,630 \text{ PSI}$$

$$F_{bx}/F_{bx} + F_a/F_u \leq 1.0$$

$$2,202/6,630 + 258/7200 = .37 \leq 1.0$$

∴ ADEQUATE

LOWER COLUMN (W27x84 w/ MC18x42.7 BOTH FLANGES)

$$\left. \begin{array}{l} P = 9621 \text{ LB} \\ M = 577,280 \text{ IN-LB} \end{array} \right\} \text{ MEMBER 9 LOAD CASE 1}$$

$$F_a = P/A = 9621/49.9 = 193 \text{ PSI}$$

$$F_u = 4300 \text{ PSI}$$

$$\leftarrow \frac{KL}{r} = \frac{2036(12)}{4.9} = 185$$

$$F_{bx} = M/S = 577,280/464 = 1,244 \text{ PSI}$$

$$F_{bx} = 12 \times 10^3 / \frac{Ld/r}{30(12)(17/8.1)} = 11,842 \text{ PSI}$$

$$1,244/11,842 + 193/4300 = .15 \leq 1.0$$

∴ ADEQUATE

UPPER COLUMN 24' HEIGHT

W27x84 W/ MC18x42.7 ONE FLANGE ONLY

$$KL/r_y = \frac{(2.1)(24)(12)}{42} = 144 \leq 200$$

LOWER COLUMN 30' HEIGHT

W27x84 W/ MC18x42.7 BOTH FLANGES

$$KL/r_y = \frac{2.1(30)(12)}{4.9} = 185 \leq 200$$

NOTE: W27x84 W/ MC18x42.7 ONE FLANGE ONLY

$$KL/r_y = \frac{2.1(30)(12)}{4.2} = 210 \neq 200 \therefore \text{CHANNEL BOTH FLANGES REQUIRED}$$

UPPER COLUMN

FROM COMPUTER OUTPUT

$$I_x = 3511 \text{ IN}^4 \quad r_x = 9.7 \text{ IN}$$

$$I_y = 640 \text{ IN}^4 \quad r_y = 4.2 \text{ IN}$$

$$A = 37.3 \text{ IN}^2$$

$$S_x = \frac{3511}{15.78} = 220$$

$$S_y = \frac{640}{9} = 73$$

LOWER COLUMN

FROM COMPUTER OUTPUT

$$I_x = 5801 \text{ IN}^4 \quad r_x = 10.8$$

$$I_y = 1214 \text{ IN}^4 \quad r_y = 4.9$$

$$A = 49.9 \text{ IN}^2$$

$$S_x = \frac{5801}{12.05 + .45} = 464$$

$$S_y = \frac{1214}{9} = 135$$

Module A-1: Properties of Plane Sections

FILE FOR SECTION: 1.
2.

AR1=24.7	a1=12.05	b1=0
AR2=12.6	a2=23.67	b2=0
Ix1=2370	Iy1=106	E1=2.9E+07
Ix2=14.4	Iy2=554	E2=2.9E+07

Area= 3.7300E+01	[As material-1]
y = 1.5975E+01	x = 0.0000E+00
Iaa = 3.5110E+03	ra = 9.7019E+00
Ibb = 6.5999E+02	rb = 4.2064E+00
ex = 0.0000E+00	ey = 2.1803E+01

30. Arbitrary Assembly
of n sections

2 SECTIONS

ENTER F7 FOR SECTION MENU

F2PRINT F3DISP

F7MENU F8REDO F9SAVE

Module A-1: Properties of Plane Sections

FILE FOR SECTION: 1.
2. 3.

AR1=24.7	a1=0	b1=0
AR2=12.6	a2=11.62	b2=0
AR3=12.6	a3=-11.62	b3=0
Ix1=2370	Iy1=106	E1=2.9E+07
Ix2=14.4	Iy2=554	E2=2.9E+07
Ix3=14.4	Iy3=554	E3=2.9E+07

Area= 4.9900E+01	[As material-1]
y = 0.0000E+00	x = 0.0000E+00
Iaa = 5.8014E+03	ra = 1.0782E+01
Ibb = 1.2140E+03	rb = 4.9324E+00
ex = 0.0000E+00	ey = 0.0000E+00

30. Arbitrary Assembly
of n sections

3 SECTIONS

ENTER F7 FOR SECTION MENU

F2PRINT F3DISP

F7MENU F8REDO F9SAVE

REV. 1 9-5-89 gju

x 50" 27" REV. 1 gju

$$I_x = \frac{19(50)^3 - 17(48)^3}{12} = \frac{9,029}{12} = 4,124.5 \text{ IN}^4 \quad \text{REV. 1 gju}$$

$$S_x = \frac{19(50)^3 - 17(48)^3}{6(50)} = \frac{669}{6} = 1,115 \text{ IN}^3 \quad \text{REV. 1 gju}$$

$$A = 19(50) - 17(48) = \frac{88}{134} \text{ IN}^2 \quad \text{REV. 1 gju}$$

REV. 1 9-5-89 9TW

STRESSES AT B-B SEE SH. 1 BENDING STRESS (TOP FLANGE)

$$F_{br} = M/S = 577,280 \cdot \frac{863}{11,450} = 350 \text{ PSI}$$

REV 1 9TW

$$F_{br} = 21,600 \text{ PSI}$$

$$21,600 > \frac{863}{350} \therefore \text{ADEQUATE}$$

SHEAR STRESS

$$F_v = F_v/A = 9,621 \cdot \frac{178}{241(50)} = 76 \text{ PSI}$$

REV 1 9TW

$$F_v = .4(30) = 14,400 \text{ PSI}$$

$$14,400 > \frac{178}{76} \therefore \text{ADEQUATE}$$

BOLT STRESSES AT C-C SEE SHT. 1 REV. 1 9-5-89 g/w

$V = 9,621 \text{ LB}$

$M = 577,280 \text{ IN-LB}$

FROM COMPUTER OUTPUT
LOAD CASE 1 MOM. 10

$$\Sigma y^2 = 4 \left(15\right)^2 + 4 \left(7\frac{1}{2}\right)^2 + 4 \left(1\frac{3}{4}\right)^2 \quad \text{REV. 1 g/w}$$

$$= \frac{284}{1134} \text{ IN}^2$$

$$\Sigma x^2 = 12(6)^2$$

$$= 432 \text{ IN}^2$$

$$F_{xv} = \frac{9,621}{12} = 801 \text{ LB}$$

$$F_{xm} = \frac{577,280 (15)}{\frac{1134 + 432}{284}} = \frac{12,004}{5,530} \text{ LB} \quad \text{REV. 1 g/w}$$

$$F_{ym} = \frac{577,280 (6)}{\frac{1134 + 432}{284}} = \frac{4,838}{2,212} \text{ LB} \quad \text{REV. 1 g/w}$$

BOLT STRESS

$$F = \sqrt{\left(801 + \frac{5530}{12,004}\right)^2 + \frac{2212^2}{4838}} = \frac{13,773}{6,766} \text{ LB} \quad \text{REV. 1 g/w}$$

$$F_v = \frac{13,773}{6,766} = \frac{8,773}{2,690} \text{ PSI} \quad \frac{1}{3/4"} \phi \text{ A325 BOLTS. REV. 1 g/w}$$

$$F_t = 17,500 \text{ PSI} \geq \frac{7,500}{8,773} \text{ PSI} \quad \therefore \text{ADEQUATE REV. 1 g/w}$$

715.4418(2) ← LOAD ON 12 BOLTS

WELD ALLOWABLE AT C-C SEE SHT. 1

$$L = 21"$$

$$K = \frac{12}{21} = .6$$

$$e = \frac{577,280}{9,621}$$

$$= 60 \text{ IN}$$

$$a = \frac{e}{L} = \frac{60}{21} = 2.85$$

$$P_{\text{ACT}} = V = 9,621 \text{ LB}$$

FROM AISC 7TH EDITION P. 4-75

$$P_{\text{ALL}} = C C_1 D L$$

$$C = .242 \quad \alpha = 2.85 \quad K = .6$$

$$C_1 = 1$$

$$D = 10 \quad \text{5/16" WELD (TWO PLATES) } 2 \times 5 = 10$$

$$L = 21"$$

$$P_{\text{ALL}} = (.242)(1)(10)(21) = 50.8 \text{ KIP} = 50,800 \text{ LB}$$

$$P_{\text{ACT}} = V = 9,621 \text{ LB} \leq \frac{50,800 \text{ LB}}{2} = 25,400 \text{ LB}$$

DIVIDE BY 2 (5/16" WELD 30 @ 6)

NOTE:

THIS PAGE FOLLOWS PAGE 4.
PREVIOUS PAGE 4A BECOMES
PAGE 4B.

DETERMINE LOCAL STRESS ON PLATFORM WEB DUE TO BRACKET LOADING.

Dφ PLATFORM

- COUPLE:

$$P_L = \frac{M}{27"} = \frac{577,280}{27} = 21,381 \text{ LB}$$

$$M = \frac{21,381 (16.75)(21)^2}{37.75^2} = 110,827 \text{ IN-LB}$$

19" WIDTH OF BRACKET

$$S = \frac{bd^2}{6} = \frac{19 (1.5)^2}{6} = 7.13 \text{ IN}^3$$

$$F_{b+} = \frac{M}{S} = \frac{110,827}{7.13} = 15,544 \text{ PSI} \leq 27,000 \text{ PSI}$$

∴ ADEQUATE

Module C-5: General Two-Dimensional Frames

JOINT	FORCE-X	FORCE-Y	MOMENT-Z
4	0	-4825	0
5	0	-1150	0
6	0	-1650	0
7	0	-1650	0
8	750	-5825	0

ENTER JOINT LOAD FOR 5 JOINTS OR
F7 FOR RESTRAINT SELECTION MENU

F7MENU

F8REDO

F10TOP

Module C-5: General Two-Dimensional Frames

ENTER F6 FOR MOMENT DIAGRAM OR
 F7 FOR LOAD SELECTION MENU

F2PRINT F3DISP F6NEXT F7MENU F8REDO F9SAVE F10TOP

3/4

DE/CAASE Version 3.1
Module C-5 v3.1: General Two-Dimensional Frames
Developed by DVSE Inc. in cooperation with MSC
Copyright (C)1985,1987 All Rights Reserved

..... INPUT VARIABLES

NO. OF JOINTS =11 NO. OF MEMBERS =10
NO. OF JOINTS WITH RESTRAINTS = 2 NO. OF JOINTS WITH APPLIED LOAD= 5
NO. OF DIFFERENT MEMBER PROPERTIES= 4

JOINT	X-COORD	Y-COORD	BOUNDARY TYPE	FORCE-X	FORCE-Y	MOMENT-Z
1	6.000E+01	0.000E+00	3	0.000E+00	0.000E+00	0.000E+00
2	0.000E+00	0.000E+00	0	0.000E+00	0.000E+00	0.000E+00
3	0.000E+00	1.440E+02	0	0.000E+00	0.000E+00	0.000E+00
4	0.000E+00	4.320E+02	0	0.000E+00	-4.825E+03	0.000E+00
5	9.900E+01	4.320E+02	0	0.000E+00	-1.150E+03	0.000E+00
6	1.980E+02	4.320E+02	0	0.000E+00	-1.650E+03	0.000E+00
7	2.970E+02	4.320E+02	0	0.000E+00	-1.650E+03	0.000E+00
8	3.960E+02	4.320E+02	0	7.500E+02	-5.825E+03	0.000E+00
9	3.960E+02	1.440E+02	0	0.000E+00	0.000E+00	0.000E+00
10	3.960E+02	0.000E+00	0	0.000E+00	0.000E+00	0.000E+00
11	3.360E+02	0.000E+00	3	0.000E+00	0.000E+00	0.000E+00

MEMBER	JOINT-1	JOINT-2	PROP NO.
1	1	2	1
2	2	3	2
3	3	4	3
4	4	5	4
5	5	6	4
6	6	7	4
7	7	8	4
8	8	9	3
9	9	10	2
10	10	11	1

PROPERTY NO.	AREA	MOMENT OF INERTIA	ELASTIC MODULUS
1	4.990E+01	5.801E+03	2.900E+07
2	4.990E+01	5.801E+03	2.900E+07
3	4.990E+01	5.801E+03	2.900E+07
4	4.990E+01	5.801E+03	2.900E+07

..... RESULTS

MAXIMUM DEFLECTION	Xmax = 3.0017E-01	JOINT = 8
	Ymax = -8.6001E-02	JOINT = 8
MAXIMUM BENDING MOMENT	= 5.7728E+05	MEMBER = 9 JOINT = 10
MAXIMUM AXIAL FORCE	= -9.6213E+03	MEMBER = 8
MAXIMUM SHEAR FORCE	= -9.6213E+03	MEMBER = 10
MAXIMUM REACTION Rx	= -1.3952E+03	JOINT = 1
MAXIMUM REACTION Ry	= 9.6213E+03	JOINT = 11
MAXIMUM REACTION Rmz	= 1.0000E+00	JOINT = 11

JOINT	Deflections.....			Reactions.....		
	X-DEFLECTION	Y-DEFLECTION	Z-ROTATION	Rx	Ry	Rmz
1	0.0000E+00	0.0000E+00	-4.7111E-04	-1.40E+03	5.48E+03	0.00E+00
2	5.7848E-05	2.9439E-02	-5.2973E-04	0.00E+00	0.00E+00	0.00E+00

3	9.2470E-02	2.8894E-02	-7.2511E-04	0.00E+00	0.00E+00	0.00E+00
4	2.9979E-01	2.7804E-02	-5.9999E-04	0.00E+00	0.00E+00	0.00E+00
5	2.9989E-01	-2.2986E-02	-4.1972E-04	0.00E+00	0.00E+00	0.00E+00
6	2.9998E-01	-5.5149E-02	-2.3486E-04	0.00E+00	0.00E+00	0.00E+00
7	3.0008E-01	-7.2028E-02	-1.2697E-04	0.00E+00	0.00E+00	0.00E+00
8	3.0017E-01	-8.6001E-02	-1.9217E-04	0.00E+00	0.00E+00	0.00E+00
9	1.5593E-01	-8.4086E-02	-8.6249E-04	0.00E+00	0.00E+00	0.00E+00
10	-2.6734E-05	-8.3129E-02	-1.3169E-03	0.00E+00	0.00E+00	0.00E+00
11	0.0000E+00	0.0000E+00	-1.4198E-03	6.45E+02	9.62E+03	1.00E+00

MEMBER	AXIAL FORCE	SHEAR FORCE	MOMENT JOINT-1	MOMENT JOINT-2
1	-1.3952E+03	5.4787E+03	0.0000E+00	3.2872E+05
2	-5.4788E+03	-1.3952E+03	-3.2872E+05	1.2782E+05
3	-5.4787E+03	-1.3952E+03	-1.2782E+05	-2.7400E+05
4	1.3955E+03	-6.5373E+02	2.7400E+05	-3.3872E+05
5	1.3950E+03	4.9627E+02	3.3872E+05	-2.8959E+05
6	1.3950E+03	2.1463E+03	2.8959E+05	-7.7105E+04
7	1.3950E+03	3.7963E+03	7.7104E+04	2.9873E+05
8	-9.6213E+03	6.4479E+02	-2.9873E+05	4.8443E+05
9	-9.6213E+03	6.4479E+02	-4.8443E+05	5.7728E+05
10	-6.4479E+02	-9.6213E+03	-5.7728E+05	-1.0000E+00

Module C-5: General Two-Dimensional Frames

JOINT	FORCE-X	FORCE-Y	MOMENT-Z
4	0	-4825	0
5	0	-1150	0
6	0	-1650	0
7	0	-1650	0
8	0	-5825	0

ENTER JOINT LOAD FOR 5 JOINTS OR
F7 FOR RESTRAINT SELECTION MENU

F7MENU F8REDO

F10TOP

E1140 W
CRYO BRIDGE

FRAME ANALYSIS
LOAD CASE 2
VERTICAL LOADS ONLY

J. L. WESTERN
AUG 23, 1989

Module C-5: General Two-Dimensional Frames

ENTER F6 FOR MOMENT DIAGRAM OR
 F7 FOR LOAD SELECTION MENU
 F2PRINT F3DISP F6NEXT F7MENU F8REDO F9SAVE F10TOP

DE/CAASE Version 3.1
Module C-5 v3.1: General Two-Dimensional Frames
Developed by DVSE Inc. in cooperation with MSC
Copyright (C)1985,1987 All Rights Reserved

..... INPUT VARIABLES

NO. OF JOINTS =11 NO. OF MEMBERS =10
NO. OF JOINTS WITH RESTRAINTS = 2 NO. OF JOINTS WITH APPLIED LOAD= 5
NO. OF DIFFERENT MEMBER PROPERTIES= 4

JOINT	X-COORD	Y-COORD	BOUNDARY		FORCE-X	FORCE-Y	MOMENT-Z
			TYPE				
1	6.000E+01	0.000E+00	3		0.000E+00	0.000E+00	0.000E+00
2	0.000E+00	0.000E+00	0		0.000E+00	0.000E+00	0.000E+00
3	0.000E+00	1.440E+02	0		0.000E+00	0.000E+00	0.000E+00
4	0.000E+00	4.320E+02	0		0.000E+00	-4.825E+03	0.000E+00
5	9.900E+01	4.320E+02	0		0.000E+00	-1.150E+03	0.000E+00
6	1.980E+02	4.320E+02	0		0.000E+00	-1.650E+03	0.000E+00
7	2.970E+02	4.320E+02	0		0.000E+00	-1.650E+03	0.000E+00
8	3.960E+02	4.320E+02	0		0.000E+00	-5.825E+03	0.000E+00
9	3.960E+02	1.440E+02	0		0.000E+00	0.000E+00	0.000E+00
10	3.960E+02	0.000E+00	0		0.000E+00	0.000E+00	0.000E+00
11	3.360E+02	0.000E+00	3		0.000E+00	0.000E+00	0.000E+00

MEMBER	JOINT-1	JOINT-2	PROP NO.
1	1	2	1
2	2	3	2
3	3	4	3
4	4	5	4
5	5	6	4
6	6	7	4
7	7	8	4
8	8	9	3
9	9	10	2
10	10	11	1

PROPERTY NO.	AREA	MOMENT OF INERTIA	ELASTIC MODULUS
1	4.990E+01	5.801E+03	2.900E+07
2	4.990E+01	5.801E+03	2.900E+07
3	4.990E+01	5.801E+03	2.900E+07
4	4.990E+01	5.801E+03	2.900E+07

..... RESULTS

MAXIMUM DEFLECTION Xmax = 6.8823E-02 JOINT = 8
Ymax = -5.5147E-02 JOINT = 6
MAXIMUM BENDING MOMENT = 5.0681E+05 MEMBER = 9 JOINT = 10
MAXIMUM AXIAL FORCE = -8.4469E+03 MEMBER = 8
MAXIMUM SHEAR FORCE = -8.4468E+03 MEMBER = 10
MAXIMUM REACTION Rx = -1.0202E+03 JOINT = 1
MAXIMUM REACTION Ry = 8.4468E+03 JOINT = 11
MAXIMUM REACTION Rmz = -1.0000E+00 JOINT = 11

.....Deflections.....				Reactions.....		
JOINT	X-DEFLECTION	Y-DEFLECTION	Z-ROTATION	Rx	Ry	Rmz
1	0.0000E+00	0.0000E+00	2.3651E-04	-1.02E+03	6.65E+03	1.25E-01
2	4.2299E-05	-1.2767E-02	1.6533E-04	0.00E+00	0.00E+00	0.00E+00

3	-2.1827E-03	-1.3429E-02	-1.1347E-04	0.00E+00	0.00E+00	0.00E+00
4	6.8544E-02	-1.4753E-02	-2.9386E-04	0.00E+00	0.00E+00	0.00E+00
5	6.8614E-02	-4.0879E-02	-2.1618E-04	0.00E+00	0.00E+00	0.00E+00
6	6.8684E-02	-5.5147E-02	-6.5490E-05	0.00E+00	0.00E+00	0.00E+00
7	6.8754E-02	-5.4128E-02	7.6641E-05	0.00E+00	0.00E+00	0.00E+00
8	6.8823E-02	-4.3427E-02	1.1409E-04	0.00E+00	0.00E+00	0.00E+00
9	6.1239E-02	-4.1746E-02	-2.5058E-04	0.00E+00	0.00E+00	0.00E+00
10	-4.2295E-05	-4.0905E-02	-6.2150E-04	0.00E+00	0.00E+00	0.00E+00
11	0.0000E+00	0.0000E+00	-7.1188E-04	1.02E+03	8.45E+03	-1.00E+00

MEMBER	AXIAL FORCE	SHEAR FORCE	MOMENT JOINT-1	MOMENT JOINT-2
1	-1.0202E+03	6.6531E+03	-1.2500E-01	3.9919E+05
2	-6.6531E+03	-1.0202E+03	-3.9919E+05	2.5228E+05
3	-6.6531E+03	-1.0202E+03	-2.5228E+05	-4.1526E+04
4	1.0201E+03	-1.8281E+03	4.1526E+04	-2.2251E+05
5	1.0201E+03	-6.7813E+02	2.2251E+05	-2.8945E+05
6	1.0201E+03	9.7188E+02	2.8945E+05	-1.9343E+05
7	1.0201E+03	2.6219E+03	1.9343E+05	6.6138E+04
8	-8.4469E+03	1.0201E+03	-6.6139E+04	3.5992E+05
9	-8.4469E+03	1.0201E+03	-3.5992E+05	5.0681E+05
10	-1.0201E+03	-8.4468E+03	-5.0681E+05	1.0000E+00

Cryobridge Splice

5/1

Moment of Inertia

$$\bar{x} = \frac{3(.5)(.25) + 14(.5)(9.5) + 2(3)(.5)(17.0) + 14(.5)(19.25)}{1.5 + 7 + 2(1.5) + 7}$$

$$= 13.655"$$

$$I_{\bar{x}} = \frac{3(.5)^3}{12} + \frac{.5(14)^3}{12} + \frac{2(.5)(3)^3}{12} + \frac{14(.5)^3}{12}$$

$$+ 3(.5)(13.655 - 0.25)^2 + 14(.5)(13.655 - 9.5)^2$$

$$+ 2(3)(.5)(13.655 - 17)^2 + 14(.5)(13.655 - 19.25)^2$$

$$= 759.8 \text{ in}^4 \quad C = 13.655"$$

*All 1/2" Thick

SECTION A-A

Bending stress at Splice

$$f_b = \frac{Mc}{I} = \frac{338\,720 (13.655)}{759.8} = \boxed{6087 \text{ psi}}$$

OK

Bolt Shear

* In a conservative approach we will assume the 12 bolts in the vertical 14" plate bear the total load.

$$F' = \frac{V}{n} = \frac{653.7}{6} = \underline{\underline{109 \text{ lbs}}}$$

$$F'' = \frac{Mr_o}{\sum_{1,3,4,6} r_i^2 + r_2^2 + r_3^2 + r_4^2 + r_5^2 + r_6^2} = \frac{338\,720 (5.83)}{4(5.83)^2 + 2(5)^2} = \underline{\underline{10620 \text{ lbs}}}$$

$$F_{2,5} = \frac{338\,720 (5)}{4(5.83)^2 + 2(5)^2} = \underline{\underline{9108 \text{ lbs}}}$$

$$\vec{F}_{max} = \vec{F}' + \vec{F}''_{1,6} = 9108 \hat{i} + 5573 \hat{j}$$

$$F_{max} = \sqrt{9108^2 + 5573^2} = \underline{\underline{10678 \text{ lbs}}}$$

$$\tau_{bolt} = \frac{F}{A} = \frac{10670}{\pi(5)^2} = \boxed{13.6 \text{ ksi}} \quad \underline{\underline{OK}}$$

SUBJECT

NAME

DATE

REVISION DATE

Cryobridge CG Calculations

East Leg of Cryobridge

Part #	Weight (lbs.)	Horizontal Distance from east edge (in.)
1	$4\left[\left(\frac{1}{4}\right)4(22)\right]$ $\times (.283) = \underline{23}^\#$	<u>13.5625"</u>
2	$(42.7)10 = \underline{427}^\#$	<u>26.75"</u>
3	$\left(\frac{426}{12}\right)(42.7) = \underline{1516}^\#$	<u>0.877"</u>
4	$\left(\frac{411.5}{12}\right)(84) = \underline{2880}^\#$	<u>13.80"</u>
5	$\left(\frac{3}{8}\right)\left(3\frac{1}{6}\right)(18)$ $\times (.283) = \underline{7}^\#$	<u>0.1875"</u>
6	$4\left[\left(\frac{1}{4}\right)(4)16\right](.283) +$ $2\left[\left(\frac{1}{4}\right)(4)(18)\right](.283)$ $= \underline{28}^\#$	$27.16 + \left[\frac{4(18)(11.5) + 4(16)(10.5)}{4(18) + 2(4)(16)}\right]$ $= \underline{26.4}"$
7	$\left(\frac{30(10+4)}{2}\right)\left(\frac{1}{2}\right)(.283)$ $= \underline{30}^\#$	<u>36.25"</u>
8	$\frac{7}{16}\left((18)^2 - \frac{(14.5)^2}{2} - \frac{(1.5)^2}{2}\right)$ $\times (.283) = \underline{27}^\#$	$27.16 + \frac{1}{3}\left(21\frac{7}{32}\right)$ $= \underline{34.2}"$
9b	$\frac{260.5}{12}(2(42.7)) = \underline{1854}^\#$	<u>130.25"</u>
11	$-\pi\left(\frac{7.25}{2}\right)^2(.45)(.283)$ $= \underline{-5.26}^\#$	<u>240.375"</u>

SUBJECT

NAME

DATE

REVISION DATE

Cryobridge CG Calculations

East Leg (cont)Part #Weight
(lbs.)Horiz. distance from
east edge (in.)

$$12 \quad -(\pi(2)^2 + 2(2)(2))(.45)(.283) \\ = -2.62\#$$

$$226.625''$$

$$13 \quad -(.625)(3.95 - .45)(47.93)(.283) \\ = -29.67\#$$

$$24.4''$$

$$\bar{x}_e = \frac{23(13.5625) + 427(26.75) + 1516(.877) + 2880(13.8) + 7(0.1875) + 28(26.4) + 30(36.25) + 27(34.2) + 1854(130.25) - 5.26(240.375) - 2.62(226.625) - 29.67(24.4)}{23 + 427 + 1516 + 2880 + 7 + 28 + 30 + 27 + 1854 - 5.26 - 2.62 - 29.67}$$

$$\bar{x}_e = 43.60'' \text{ from East outer edge}$$

6751.15

SUBJECT

NAME

DATE

REVISION DATE

Cryobridge CG Calculations

West Leg of Cryobridge

<u>Part #</u>	<u>Weight (lbs.)</u>	<u>Horizontal distance from west edge (in.)</u>
1	<u>23#</u>	<u>13.5625"</u>
2	<u>427#</u>	<u>26.75"</u>
3	<u>1516#</u>	<u>0.877"</u>
4	<u>2880#</u>	<u>13.80"</u>
5	<u>7#</u>	<u>0.1875"</u>
6	<u>28#</u>	<u>26.4"</u>
7	<u>30#</u>	<u>36.25"</u>
8	<u>27#</u>	<u>34.2"</u>
9	$\frac{165}{12} (85.4)$ <u>= 1174.#</u>	$\frac{165}{2} = \underline{82.5}"$
10	$2(\frac{1}{4}) [(20)^2 - \frac{(20-2)^2}{2}] (1.283)$ <u>= 33.677#</u>	$1 + \frac{(20)^2(10) - \frac{(20-2)^2}{2}(20-6)}{(20)^2 - \frac{(20-2)^2}{2}}$ <u>= 8.28"</u>
13	<u>-29.67#</u>	<u>24.2"</u>

$$\bar{X}_w = \frac{23(13.5625) + 427(26.75) + 1516(0.877) + 2880(13.8) + 7(0.1875) + 28(26.4) + 30(36.25) + 27(34.2) + 1174(82.5) + 33.677(8.28) - 29.67(24.2)}{23 + 427 + 1516 + 2880 + 7 + 28 + 30 + 27 + 1174 + 33.677 - 29.67}$$

$$\boxed{\bar{X}_w = 24.85"} \text{ from west outer edge}$$

SUBJECT

NAME

DATE

REVISION DATE

Cryobridge CG Calculations

East Leg of Cryobridge

Part #	Weight (lbs.)	Vertical distance from top edge (in.)
1	<u>23</u> #	<u>417</u> "
2	<u>427</u> #	<u>370</u> "
3	<u>1516</u> #	<u>215</u> "
4	<u>2880</u> #	<u>224.5</u> "
5	<u>7</u> #	<u>2.22</u> "
6	<u>28</u> #	<u>21.9</u> "
7	<u>30</u> #	<u>30</u> "
8	<u>27</u> #	<u>25.5</u> "
9b	<u>1854</u> #	<u>5.15</u> "
11	<u>- 5.26</u> #	<u>18.13</u> "
12	<u>- 2.62</u> #	<u>7.375</u> "
13	<u>- 29.67</u> #	<u>14.375</u> "

$$\bar{y}_e = \frac{23(417) + 427(370) + 1516(215) + 2880(224.5) + 7(2.22) + 28(21.9) + 30(30) + 27(25.5) + 1854(5.15) - 5.26(18.13) - 2.62(7.375) - 29.67(14.375)}{23 + 427 + 1516 + 2880 + 7 + 28 + 30 + 27 + 1854 - 5.26 - 2.62 - 29.67}$$

$\bar{y}_e = 170.13$ "

From Top surface of Cryobridge

SUBJECT

NAME

DATE

REVISION DATE

Lifting Stress Analysis

$T = W = 6754.5 \#$

W_{CG}

$W_{CG} = 6754.5 \#$

$R = \emptyset$

$M_c = 6754.5 (145.65)$
 $= \underline{983769.5 \text{ in-lb}}$

$\cos 51.93^\circ = \frac{d}{236.2}$
 $d = \underline{145.65''}$

$V_h = \cos(38.07^\circ) 6754.5$
 $= 5318 \#$
 $= 5.318 \text{ K}$
 $V_v = \sin(38.07^\circ) 6754.5$
 $= 4165 \#$
 $= 4.165 \text{ K}$

SUBJECT

NAME

DATE

REVISION DATE

Lifting Stress Analysis

$$w = \frac{3}{16}''$$

$$T = \frac{m_c}{2} = \underline{492 \text{ k-in.}}$$

(plates on both sides)

Weld
pattern
(Both
sides)

at 1

$$C_v = 20.5 - 15.1 = \underline{5.4 \text{ in}}$$

$$C_h = \underline{19.8 \text{ in}}$$

$$\bar{x} = \frac{2(18)(9) + 4(18) + 16(18.5) + 2(4)(20.5) + 16(22.5) + 4(23) + 2(16)(31) + 4(39)}{4 + 2(18) + 4 + 16 + 2(4) + 16 + 4 + 2(16) + 4}$$

$$= \underline{19.8''}$$

$$\bar{y} = \frac{2(16)(8) + 4(16) + 18(16.5) + 16(16.5) + 4(4)(18.5) + 18(20.5) + 16(20.5)}{4 + 2(18) + 4 + 16 + 2(4) + 16 + 4 + 2(16) + 4}$$

$$= \underline{15.1''}$$

$$J_w = \frac{J}{w} = \frac{I_x}{w} + \frac{I_y}{w} = \frac{[(4)\frac{1}{12}(\cancel{\frac{3}{16}})(4)^3 + (2)\frac{1}{12}(\cancel{\frac{3}{16}})(16)^3 + \frac{1}{12}(2(18) + 2(16) + 2(4))(\cancel{\frac{3}{16}})^3] + \frac{3}{16}[(2(4) + 2(18))(18.5 - 15.1)^2 + (2(4) + 2(16))(18.5 - 15.1)^2 + (2(4) + 2(16))(15.1 - 8)^2]}{}$$

$$+ \frac{[(2)\frac{1}{12}(\cancel{\frac{3}{16}})(18)^3 + (2)\frac{1}{12}(\cancel{\frac{3}{16}})(4)^3 + (2)\frac{1}{12}(\cancel{\frac{3}{16}})(16)^3 + \frac{1}{12}(4(4) + 2(16))(\cancel{\frac{3}{16}})^3] + \frac{3}{16}[(2(4) + 2(18))(19.8 - 9)^2 + (2(4) + 2(16))(20.5 - 19.8)^2 + (2(4) + 2(16))(20.5 - 19.8)^2]}{}$$

$$= \underline{15526.5 \text{ in}^3}$$

$$W_h = \frac{T_{c_v}}{J_w} = \frac{492(5.4)}{15526.5} = 0.17 \frac{\text{kips}}{\text{lin. in.}}$$

$$W_v = \frac{T_{c_h}}{J_w} = \frac{492(19.8)}{15526.5} = 0.63 \frac{\text{kips}}{\text{lin. in.}}$$

SUBJECT

Lifting Stress Analysis

NAME

DATE

REVISION DATE

$$W_{s_v} = \frac{V_v}{A_w} = \frac{4.165}{6(4) + 4(16) + 2(18)} = 0.034 \frac{\text{kips}}{\text{lin. in.}}$$

$$W_{s_h} = \frac{V_h}{A_w} = \frac{5.318}{6(4) + 4(16) + 2(18)} = 0.043 \frac{\text{kips}}{\text{lin. in.}}$$

$$\begin{aligned} W &= \sqrt{(W_h + W_{s_h})^2 + (W_v + W_{s_v})^2} \\ &= \sqrt{(0.17 + 0.043)^2 + (0.63 + 0.034)^2} \\ &= 0.7 \frac{\text{kips}}{\text{line in.}} = 700 \frac{\text{lbs}}{\text{line in. of weld}} \end{aligned}$$

$$= \frac{3}{16} \left(\frac{1}{\sqrt{2}} \right) = 0.13''$$

$$\text{shear stress in weld} = f_v = \frac{700}{0.13} = 5385 \text{ psi}$$

OK

DETAIL A' DETAIL A' 0000

K