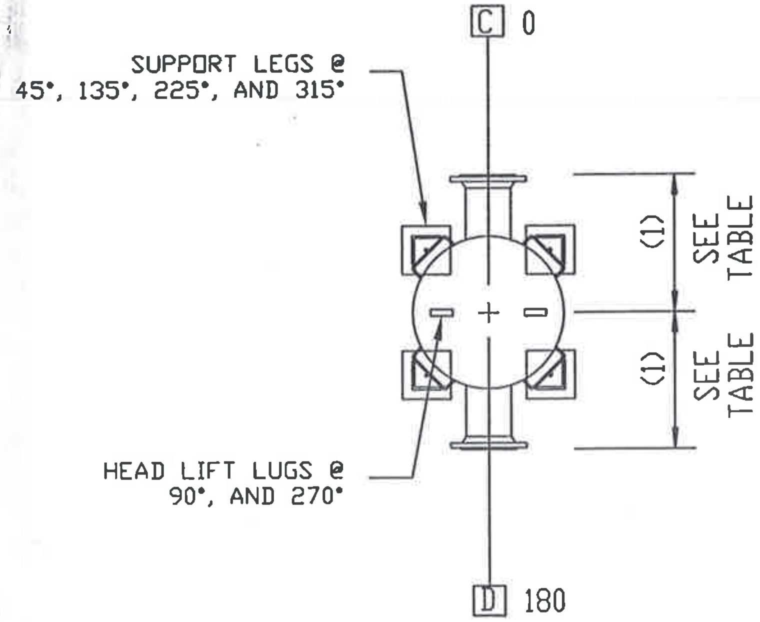
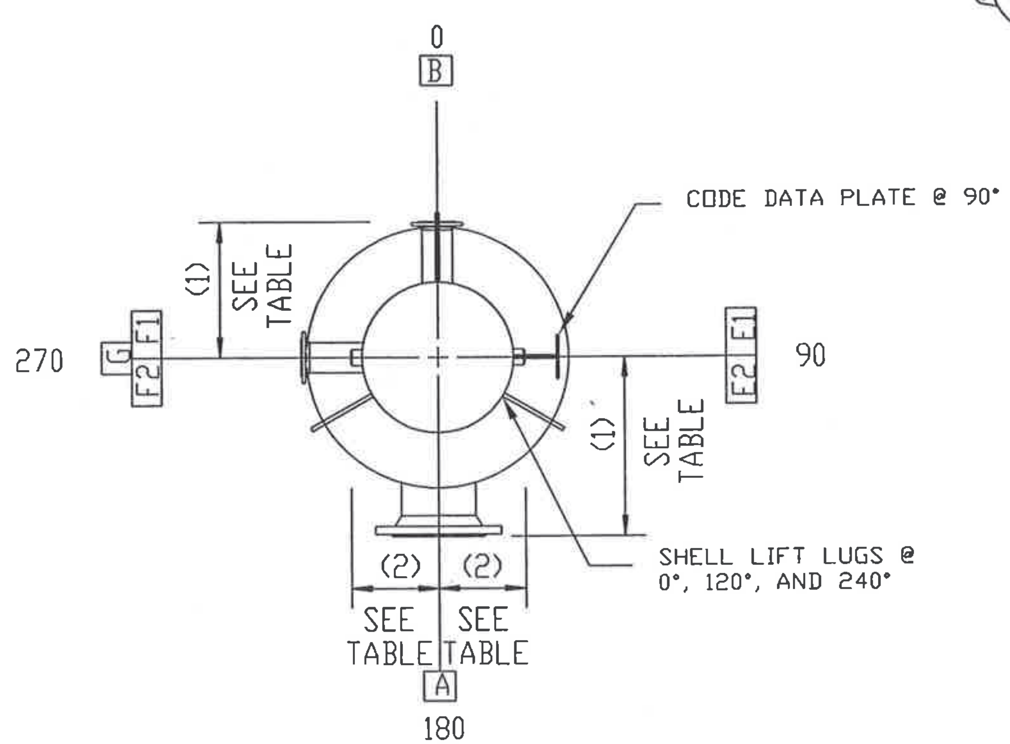
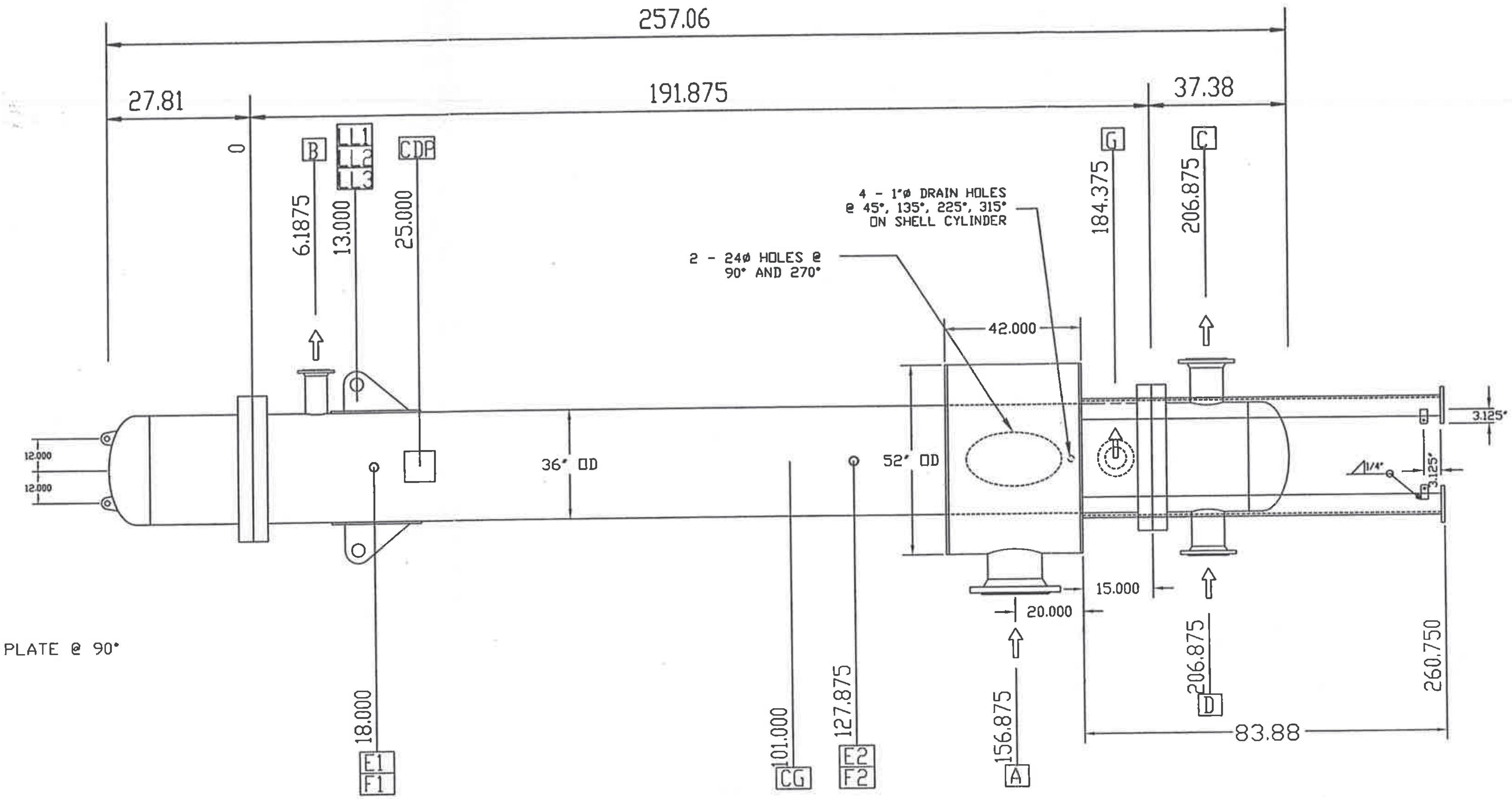
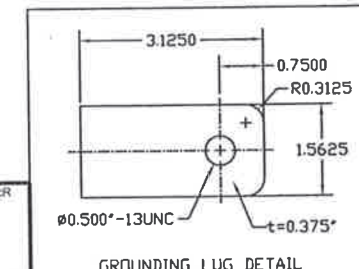
Dimensions: in









HT/DCR Engineering, Inc.
2830 Parkway Street • Lakeland, FL 33811
Phone: 863-904-2880 • Fax: 863-913-1091
Florida Engineering Business License No. 26522

Nozzles (1)

Label	Size:	Description	Project.
A	24"	150 # ANSI S.O.RF	32
B	2"	150 # ANSI S.O.RF	24
C	10"	150 # ANSI S.O.RF	24
D	10"	150 # ANSI S.O.RF	24
G	6"	150 # ANSI S.O.RF	24

Couplings / Supports (2)

Label	Size: Description	Project.
E1	0.5 3000 # Half Length	18.9375
E2	0.5 3000 # Half Length	18.9375
F1	0.75 3000 # Half Length	19
F2	0.75 3000 # Half Length	19
LL1	Lifting Lug 1	22.5 To Hole
LL2	Lifting Lug 2	22.5 To Hole
LL3	Lifting Lug 3	22.5 To Hole

Design Specifications

Design Specifications		Shell	Tube
Design Pressure	psig	75/FV	150/FV
Test Pressure	psig	98	195
Min. Design Temperature	F	-20	-20
Max. Design Temperature	F	300	300
Number of Passes		1	4
Corrosion Allowance	in	0.0	0.0625
Radiographing		None	None
Post-Weld Heat Treatment		None	None

Wt Empty: 13911 Full: 22005 Bundle: 8881 lb

Rev:	Date:	Description	Dwg	Ckd	Appd
2	12-04-07	Certified As-Built	AGB	DGB	PW

Company: DCR
Location: Bunge-Ergon
Product Condenser
Item No.: E-4401
Date: February 26, 2007 Job No.: 7793

DCR Construction, Inc.
Lakeland, Florida

ASME VIII-1 2004 A06
TEMA Type: BEM
Size: 35-192
TEMA Class: C

Setting Plan

Dwg No.: E-4401 01
Rev: 2

Dimensions: in

Component		O.D.	Thk.	Materials of Construction
Nozzle A Vapor	Inlet	24.0	0.375	150 # ANSI S.O.RF Flg SA-182 on SA-312 S30400 Grd TP304 Wld. pipe
Nozzle B Vapor	Outlet	2.375	0.154	150 # ANSI S.O.RF Flg SA-182 on SA-312 S30400 Grd TP304 Wld. pipe
Nozzle C Cooling Water	Inlet	10.75	0.365	150 # ANSI S.O.RF Flg SA-105 on SA-53 K03005 Grd. E/B Wld. pipe
Nozzle D Cooling Water	Outlet	10.75	0.365	150 # ANSI S.O.RF Flg SA-105 on SA-53 K03005 Grd. E/B Wld. pipe
Nozzle G Liquid	Outlet	6.625	0.134	150 # ANSI S.O.RF Flg SA-182 on SA-312 S30400 Grd TP304 Wld. pipe
Coupling E1 PI		0.5		3000 # Half Length SA-182 S30400 Grd F304 Forgings
Coupling E2 PI		0.5		3000 # Half Length SA-182 S30400 Grd F304 Forgings
Coupling F1 TI		0.75		3000 # Half Length SA-182 S30400 Grd F304 Forgings
Coupling F2 TI		0.75		3000 # Half Length SA-182 S30400 Grd F304 Forgings
Shell Cylinder		36	0.25	SA-240 S30400 Grd 304 Plate
Head Cylinders		36	0.375	SA-516 K02700 Grd 70 Plate
Head Covers		36	0.375	SA-516 K02700 Grd 70 Plate (Ellipsoidal Cover)
Tubesheets		39.5	2.5	SA-240 S30400 Grd 304 Plate
Head Flanges at Tbshts		39.5	2.0625	SA-516 K02700 Grd 70 Plate (Ring Flange)
Head Gaskets at Tbshts		37.25	0.125	Solid Teflon 1/8in Thickness (Periph. Width 0.5625 in)
Head Bolting at Tbshts		0.5		SA-193 G41400 Grd B7 Bolt (60 Bolts on 38.25 in B.C.)
Tubes		0.75	0.049	SA-249 S30400 Grd TP304 Wld. tube (Plain Tubes)
Baffles		35.313	0.3125	SA-240 S30400 Grd 304 Plate
Leg Bracket			0.375	SA-240 S30400 Grd 304 Plate
Support Legs			0.5	SA-516 Grd. 70 or SA-36 - 6 x 6 x 1/2" Angle
Base Plate			0.5	SA-516 Grd. 70 or SA-36 - 10 x 10 x 1/2" Plate
Vapor Belt		52.000	0.500	SA-240 S30400 Grd 304 Plate
Vapor Belt - Upper Ring		53.000	0.625	SA-240 S30400 Grd 304 Plate
Vapor Belt - Lower Ring		53.000	0.625	SA-240 S30400 Grd 304 Plate
Nameplate			0.1046	SA-240 S30400 Grd 304 Plate
Nameplate Bracket			0.25	SA-240 S30400 Grd 304 Plate
Head Lift Lugs			0.500	SA-36 K02600 Plate
Shell Lift Lugs			0.500	SA-36 K02600 Plate
Shell Lift Lug Pad			0.500	SA-240 S30400 Grd 304 Plate
Tie Rods		0.50		SA-479 S30400 Grd 304 Bar
Spacers		0.75		SA-249 S30400 Grd TP 304 Wld. Tube
FH Partitions			0.50	SA-516 K02700 Grd 70 Plate 27.81 x 35.25 (2) Each
RH Partition			0.50	SA-516 K02700 Grd 70 Plate 37.38 x 35.25 (1) Each
RH Partitions			0.50	SA-516 K02700 Grd 70 Plate 37.38 x 17.62 (2) Each

HT/DCR Engineering, Inc.
2830 Parkway Street • Lakeland, FL 33811
Phone: 863-904-2880 • Fax: 863-913-1091
Florida Engineering Business License No. 26522

Design Specifications

		Shell Side	Tube Side
Design Pressure	psig	75/FV	150/FV
Test Pressure	psig	98	195
Design Temperature	F	300	300
Number of Passes		1	4
Corrosion Allowance	in	0.0	0.0625
Radiographing		None	None

TEMA Type: BEM Size: 35-192 Area: 3541 ft2
Tube Type: Plain # Holes: 1127 Length: 192 in
Layout: 0.9375 in (30) Tube-Ts Joint: Str. Weld
Baffle Type: Triple Seg. Cut: 13% V No: 9
Baffle Spacing (C-C): 16.75 Inlet: 42 in
Impingement Protection: None
Code: ASME VIII-1 2004 A06 TEMA Class: C
Wt Empty: 13911 Full: 22005 Bundle: 8881 lb
Drawn By: Ckd By: Apvd By:
Dwg No.: Rev: 3 Date: 12-04-07

Company: DCR
Location: Plymouth
Product Condenser
Item No.: E-4401
Date: May 26, 2007 Job No.: 7793

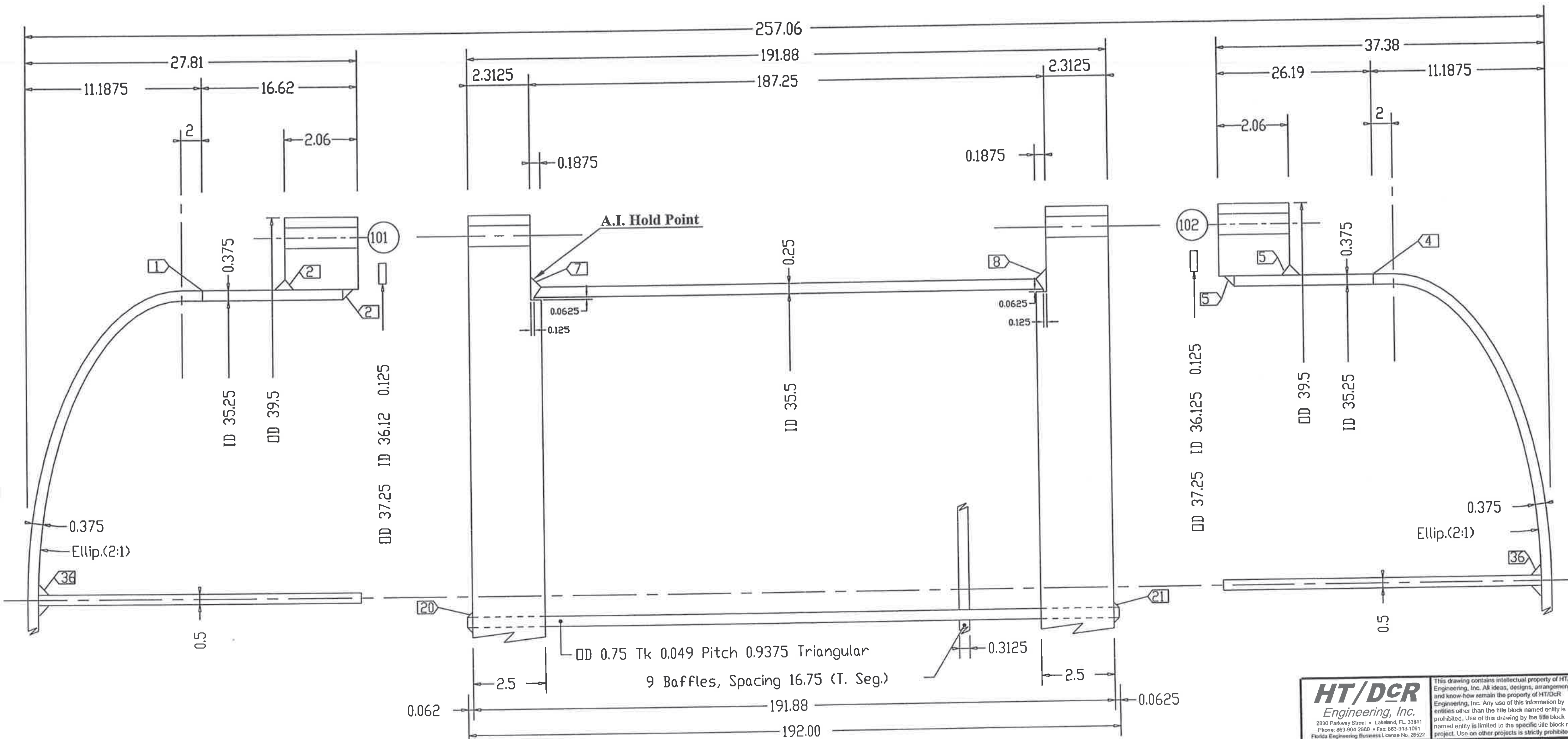
DCR Construction, Inc
Lakeland, FL

Rev1 Corrected Nozzle A Flange Material
Rev2 Issued for Construction
Rev3 Certified As-Built

Bill Of Material

Dwg No.: E-4401 02 Rev: 3

All Dimensions
In Inches



Notes:

Company: DCR
Location: Bunge-Ergon
Product Condenser
Item No.: E-4401
Date: March 13, 2007 Job No.: 7793

DCR Construction, Inc
Lakeland, FL

Scale: NTS

Rev:	Date:	Description	Dwg	Ckd	Appd
1	08-23-07	Issued for Construction	KFF	DGB	PW
2	12-04-07	Certified As-Built	AGB	DGB	PW

ASME VIII-1 2004 A06
TEMA Type: BEM
Size: 35-192
TEMA Class: C

Sectional Plan

Dwg No.: E-4401 03

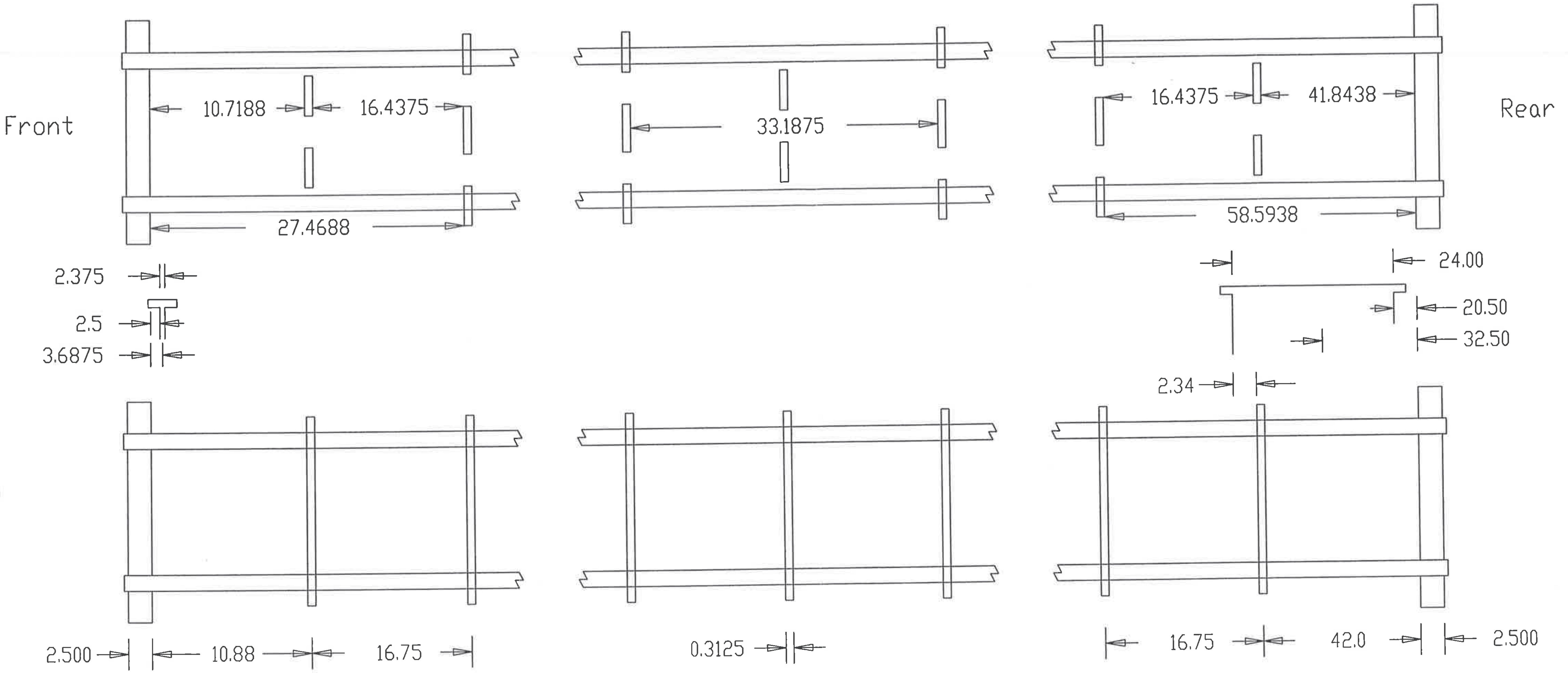
Rev: 2

Ref	No	Bolt Dia.	Bolt Length	Bolt Circle	Bolt Hole
102	60	0.5	7	38.25	0.625
101	60	0.5	7	38.25	0.625

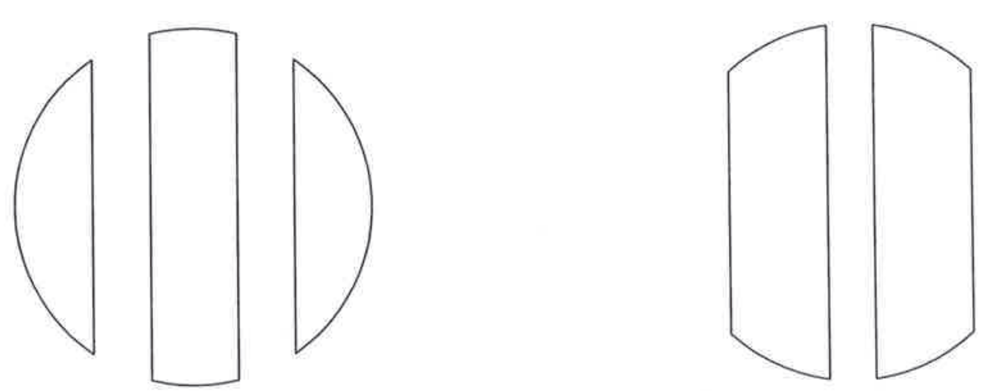
Bolting

Dimensions: in

TEMA Type: E



Side View



Baffles

HT/DCR Engineering, Inc.
2830 Parkway Street • Lakeland, FL 33811
Phone: 863-904-2880 • Fax: 863-913-1091
Florida Engineering Business License No. 26522

Notes:

Company: DCR
Location: Bunge-Ergon
Product Condenser
Item No.: E-4401
Date: February 26, 2007 Job No.: 7793

DCR Construction, Inc.
Lakeland, Florida

Scale: NTS

Rev:	Date:	Description	Dwg	Ckd	Appd
1	08-23-07	Issued For Construction	KFF	DGB	PW
2	12-04-07	Certified As-Built	AGB	DGB	PW

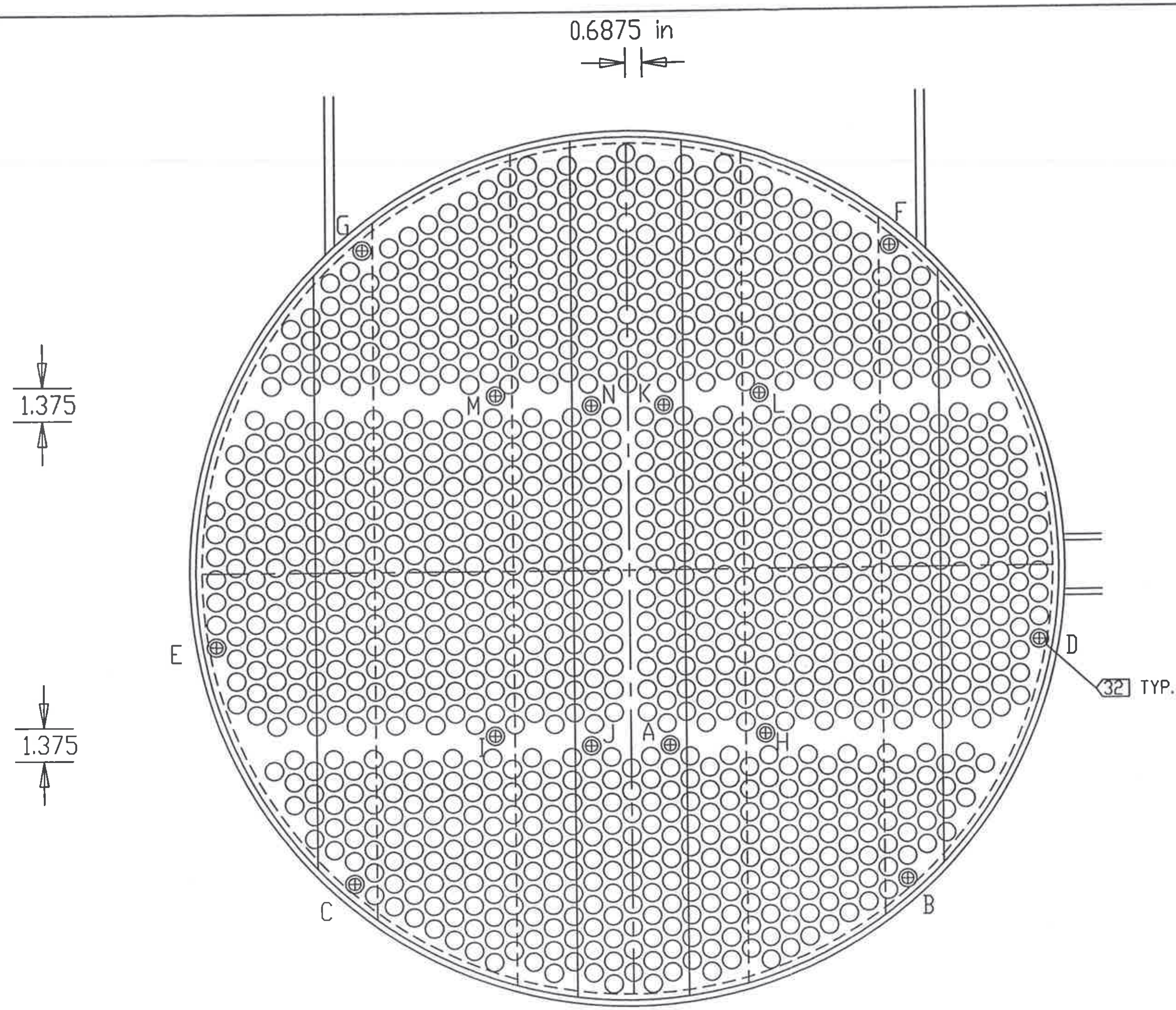
ASME VIII-1 2004 A06
TEMA Type: BEM
Size: 35-192
TEMA Class: C

Bundle Detail

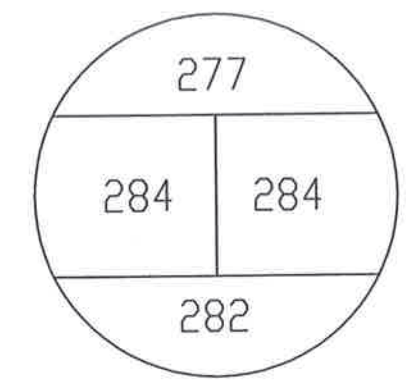
Dwg No.: E-4401 04

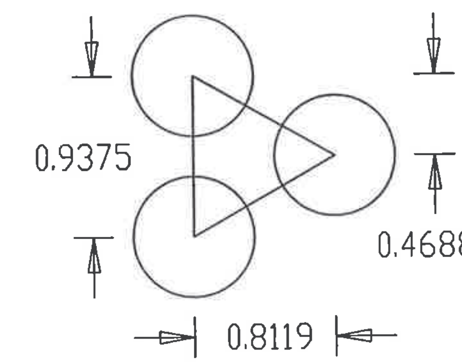
Rev: 2

Row	Holes
70	1
69	6
68	7
67	8
66	9
65	10
64	11
63	12
62	13
61	12
60	15
59	16
58	15
57	16
56	17
55	18
54	17
53	18
52	19
51	18
50	19
49	20
48	18
47	20
46	20
45	20
44	20
43	20
42	20
41	22
40	20
39	22
38	20
37	22
36	20
35	22
34	20
33	22
32	20
31	22
30	20
29	20
28	20
27	20
26	20
25	20
24	20
23	20
22	18
21	18
20	19
19	18
18	17
17	18
16	17
15	16
14	17
13	16
12	15
11	14
10	13
9	14
8	13
7	12
6	11
5	10
4	9
3	8
2	5
1	2
	1127



Shell ID 35.5 in
O.T.L. 35 in
Baffle cut to C/L 2.311 in
4.747 in
10.43 in
12.866 in





HT/DCR Engineering, Inc.
2830 Parkway Street • Lakeland, FL 33811
Phone 863-904-2880 • Fax 863-913-1091
Florida Engineering Business License No. 26522

Design Specifications

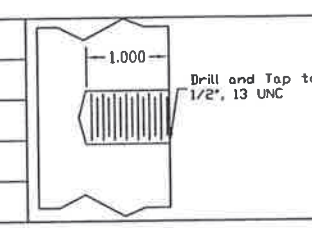
Number of Tube Holes	1127
Tube Outside Diameter	0.75 in
Tube Pitch	0.9375 in
Tube Pattern	Triangular
Tube Passes	4 Mixed
Number of Tie Rods	6
Tie Rod Diameter	0.5 in
Baffle Diameter	35.3125 in
Baffle Type	Triple Segmental
Baffle Cut	13%
Tube Thickness	0.049 in

Tie Rod Locations

A	1.6238	-7.266
B	11.3666	-12.8594
C	-11.3666	-12.8594
D	16.9255	-3.0469
E	-16.9255	-3.0469
F	10.5547	12.8594
G	-10.5547	12.8594
H	3.9351	-6.7973
I	-3.9351	-6.7973
J	-1.6238	-7.266

Tie Rod Locations Cont.

K	1.4994	6.765
L	4.0595	7.2338
M	-4.0595	7.2338
N	-1.4994	6.765



Drill and Tap Tie Rods A, H, I, J, K, L, M, N From Shell Side

Scale: NTS

Rev:	Date:	Description	Dwg	Ckd	Appd
1	08-23-07	Issued for Construction	KFF	DGB	PW
2	12-04-07	Certified As-Built	AGB	DGB	PW

Company: DCR
Location: Bunge-Ergon
Product Condenser
Item No.: E-4401
Date: March 6, 2007 Job No.: 7793

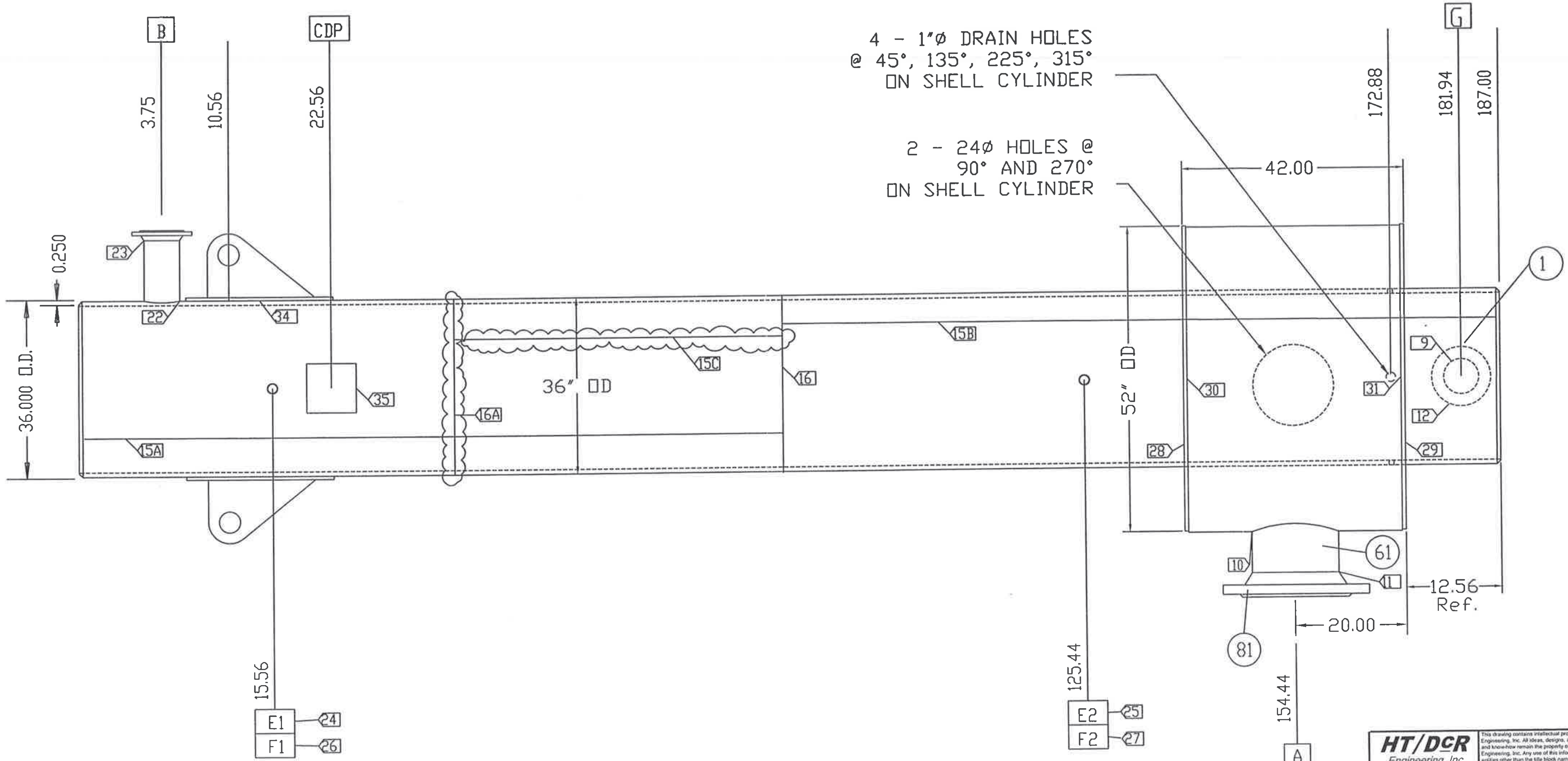
DCR Construction, Inc.
Lakeland, Florida

ASME VIII-1 2004 A06
TEMA Type: BEM
Size: 35-192
TEMA Class: C

Tube Layout

Dwg No.: E-4401 05

Rev: 2



Side View

HT/DCR Engineering, Inc.

Notes:
All Dimensions In Inches
Bolt holes to straddle centerlines
Weld joint details per drawing 20

Company: DCR
Location: Bunge-Ergon
Product Condenser
Item No.: E-4401
Date: March 13, 2007 Job No.: 7793

DCR Construction, Inc
Lakeland, FL

Scale: NTS

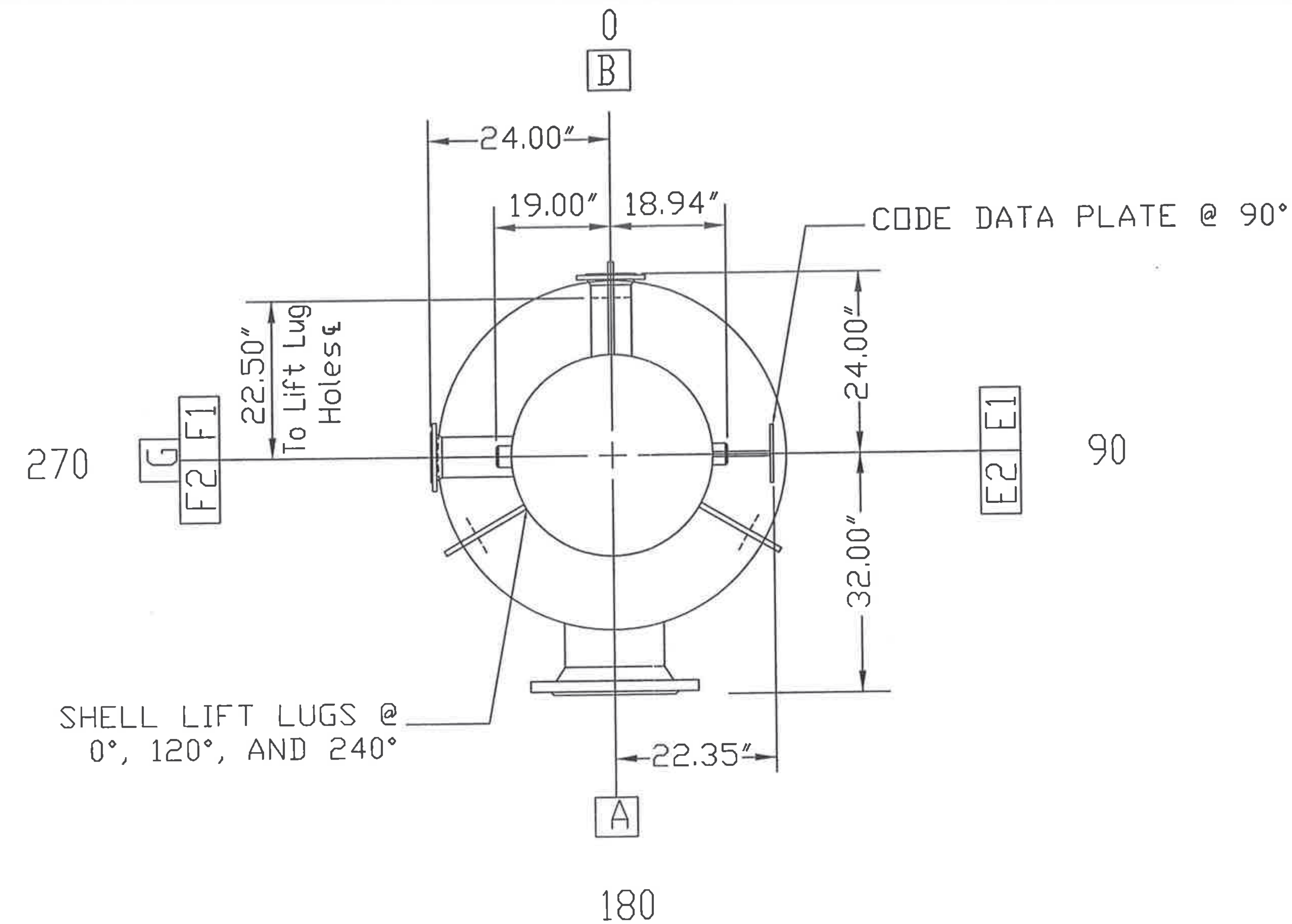
Rev:	Date:	Description	Dwg	Ckd	Appd
1	08-23-07	Issued for Construction	KFF	DGB	PW
2	10-4-07	Added Weld Seam	KFF	DGB	PW
3	12-04-07	Certified As-Built	AGB	DGB	PW

ASME VIII-1 2004 A06
TEMA Type: BEM
Size: 35-192
TEMA Class: C

Shell Detail

Dwg No.: E-4401 06A

Rev: 3



Front End View

HT/DcR Engineering, Inc.
2830 Parkway Street • Lakeland, FL 33811
Phone: 863-904-2880 • Fax: 863-913-1091
Florida Engineering Business License No. 26522

Notes:
All Dimensions In Inches
Bolt holes to straddle centerlines
Weld joint details per drawing 20

Company: DCR
Location: Bunge-Ergon
Product Condenser
Item No.: E-4401
Date: February 26, 2007 Job No.: 7793

DCR Construction, Inc
Lakeland, FL

Scale: NTS

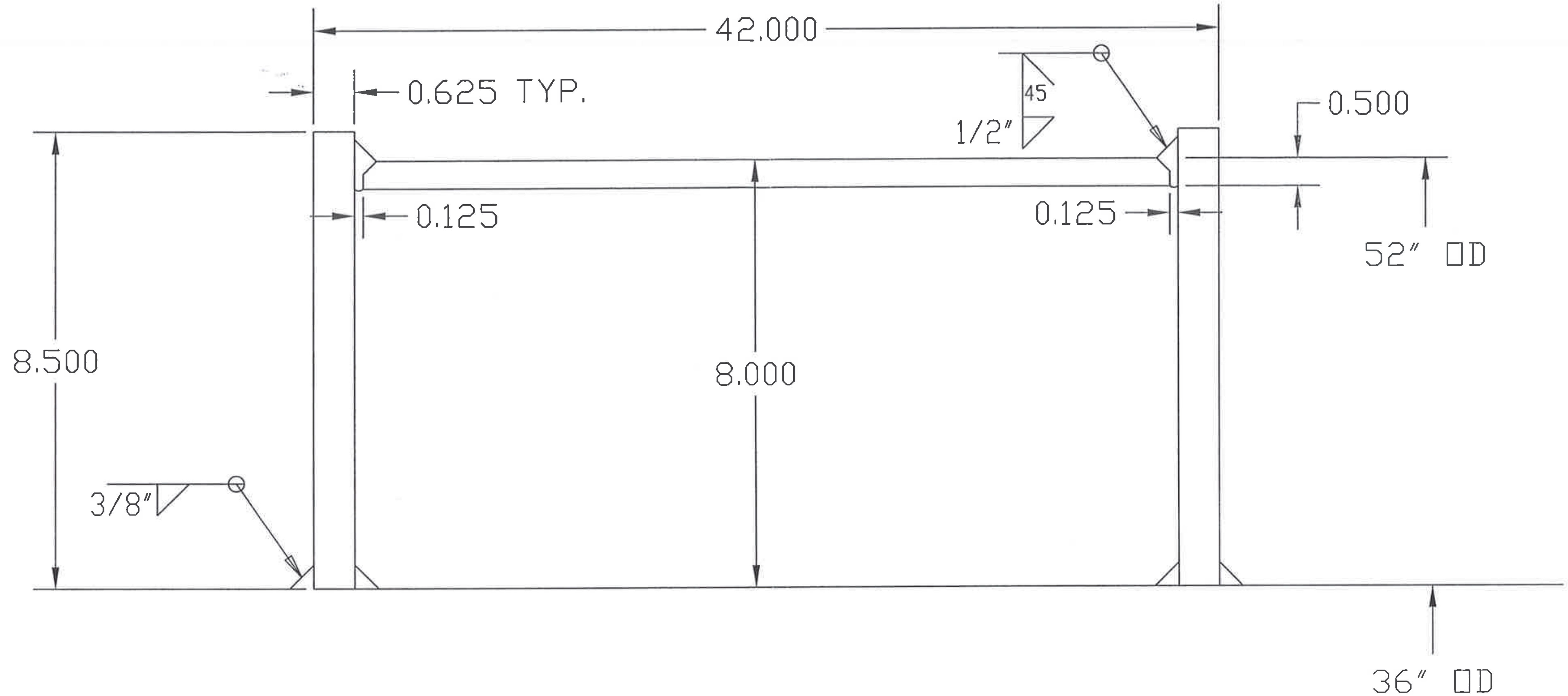
Rev:	Date:	Description	Dwg	Ckd	Appd
1	08-23-07	Issued for Construction	KFF	DGB	PW
2	12-04-07	Certified As-Built	AGB	DGB	PW

ASME VIII-1 2004 A06
TEMA Type: BEM
Size: 35-192
TEMA Class: C

Shell Detail

Dwg No.: E-4401 06B

Rev: 2



HT/DCR Engineering, Inc.

Notes:
All Dimensions In Inches

Company: DCR
Location: Bunge-Ergon
Product Condenser
Item No.: E-4401
Date: April 16, 2007 Job No.: 7790

DCR Construction, Inc
Lakeland, FL

Scale: NTS

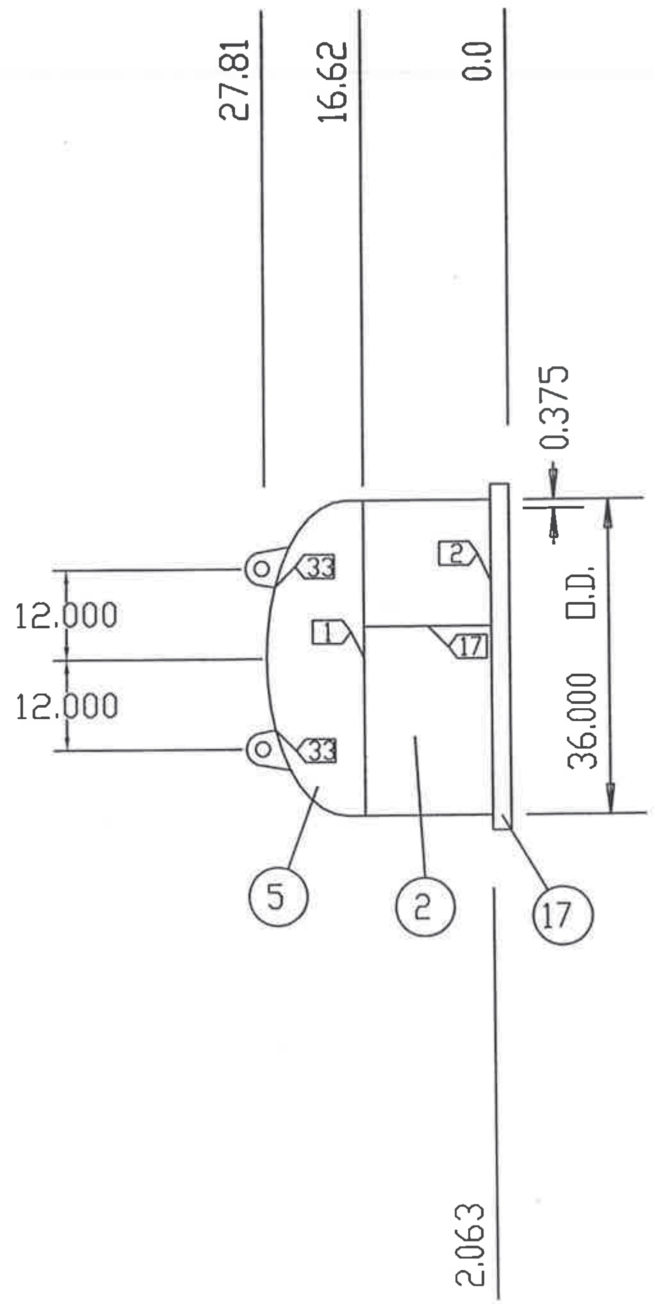
Rev:	Date:	Description	Dwg	Ckd	Appd
1	08-23-07	Issued for Construction	KFF	DGB	PW
2	12-04-07	Certified As-Built	AGB	DGB	PW

ASME VIII-1 2004 A06
TEMA Type: BEM
Size: 35-192
TEMA Class: C

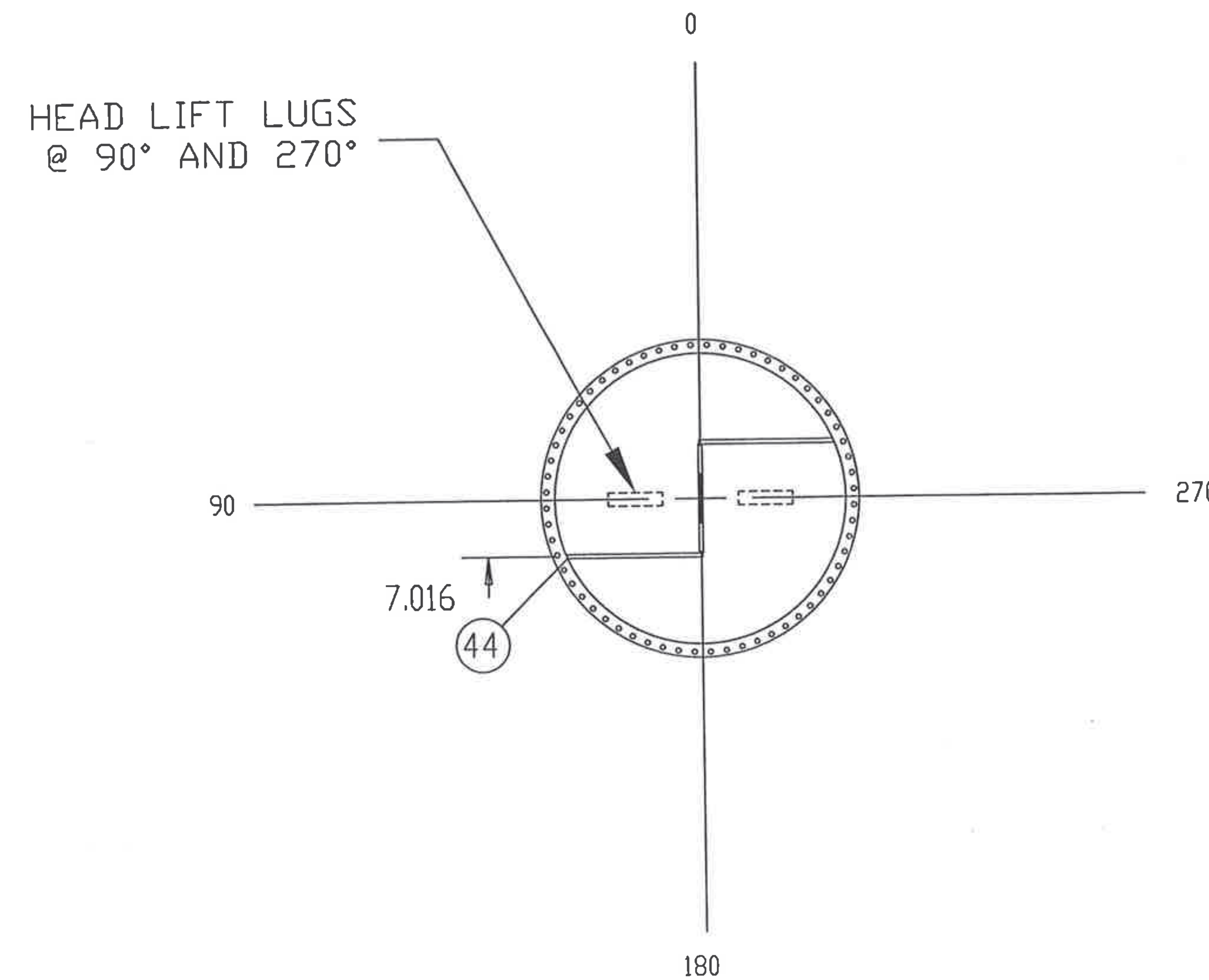
Vapor Belt Detail

Dwg No.: E-4401 07

Rev: 2



Side View



Rear End View

HT/DCR Engineering, Inc.

2830 Parkway Street • Lakeland, FL 33811
Phone: 863-904-2880 • Fax: 863-913-1891
Florida Engineering Business License No. 26322

Notes:
All Dimensions In Inches
Bolt holes to straddle centerlines
Weld joint details per drawing 20

Company: DCR
Location: Bunge-Ergon
Product Condenser
Item No.: E-4401
Date: February 26, 2007 Job No.: 7793

DCR Construction, Inc
Lakeland, FL

Scale: NTS

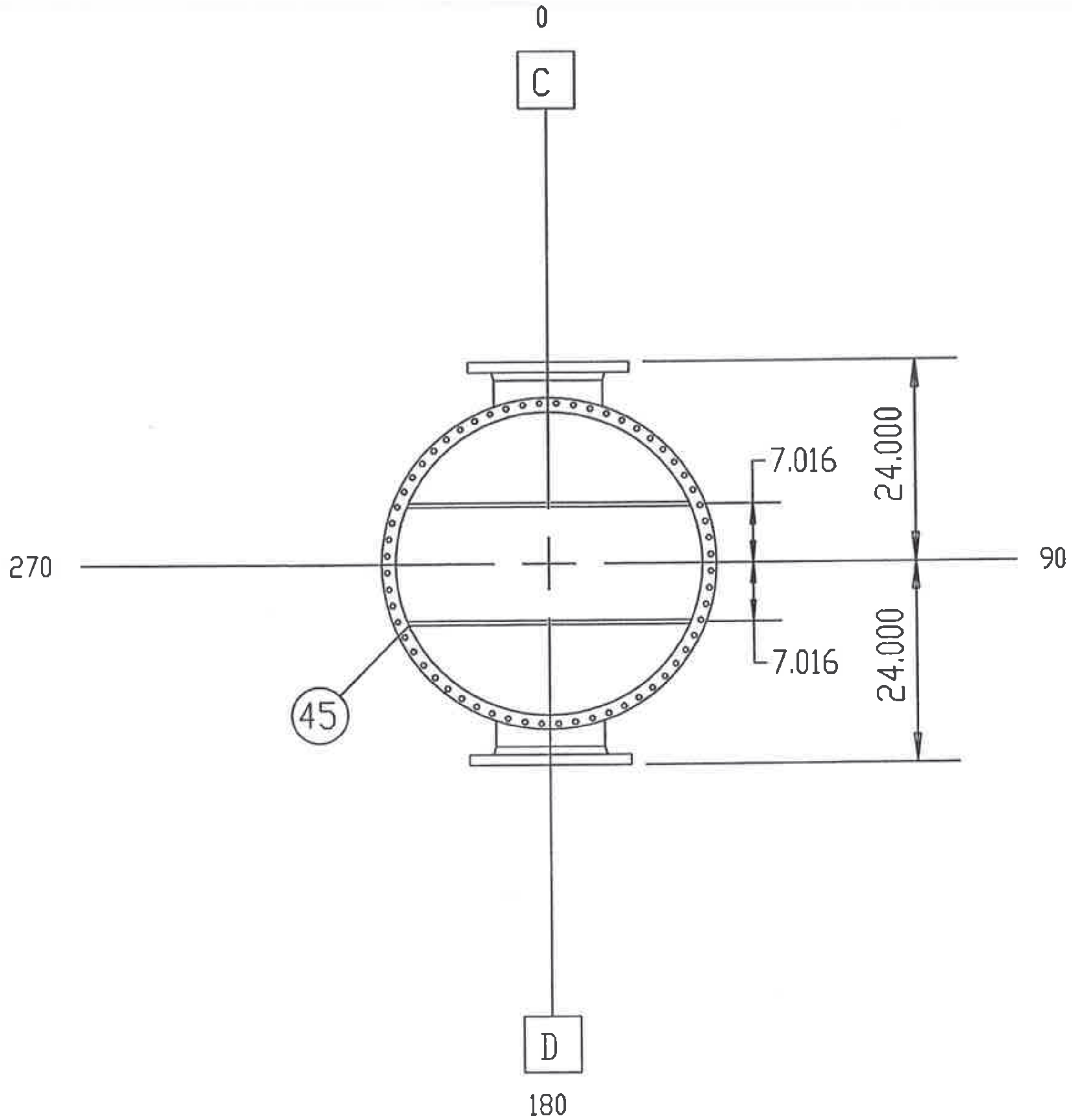
Rev:	Date:	Description	Dwg	Ckd	Appd
1	08-23-07	Issued For Construction	KFF	DGB	PW
2	12-04-07	Certified As-Built	AGB	DGB	PW

ASME VIII-1 2004 A06
TEMA Type: BEM
Size: 35-192
TEMA Class: C

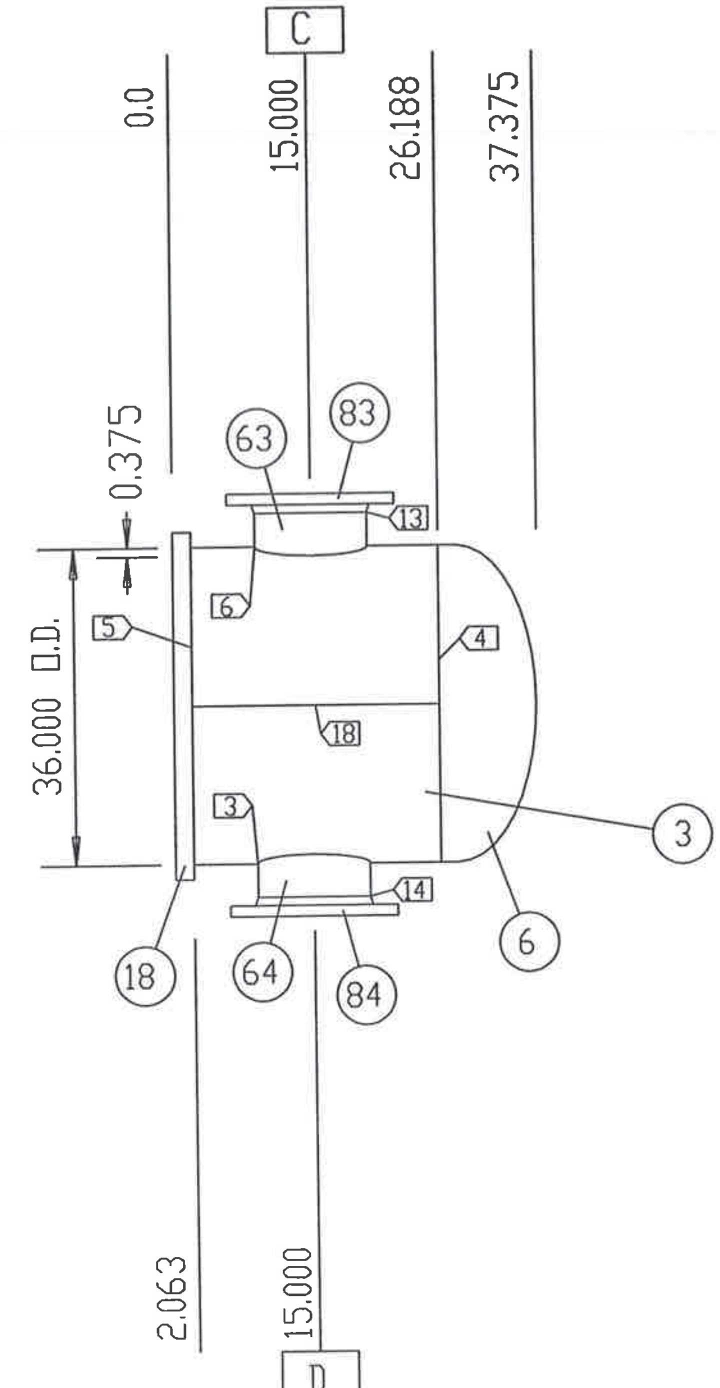
Front Head Detai

Dwg No.: E-4401 08

Rev: 2



Front End View



Side View

HT/DCR Engineering, Inc.
2830 Parkway Street • Lakeland, FL 33811
Phone: 863-904-2880 • Fax: 863-913-1091
Florida Engineering Business License No. 25522

Notes:
All Dimensions In Inches
Bolt holes to straddle centerlines
Weld joint details per drawing 20

Company: DCR
Location: Bunge-Ergon
Product Condenser
Item No.: E-4401
Date: February 26, 2007 Job No.: 7793

DCR Construction, Inc
Lakeland, FL

Scale: NTS

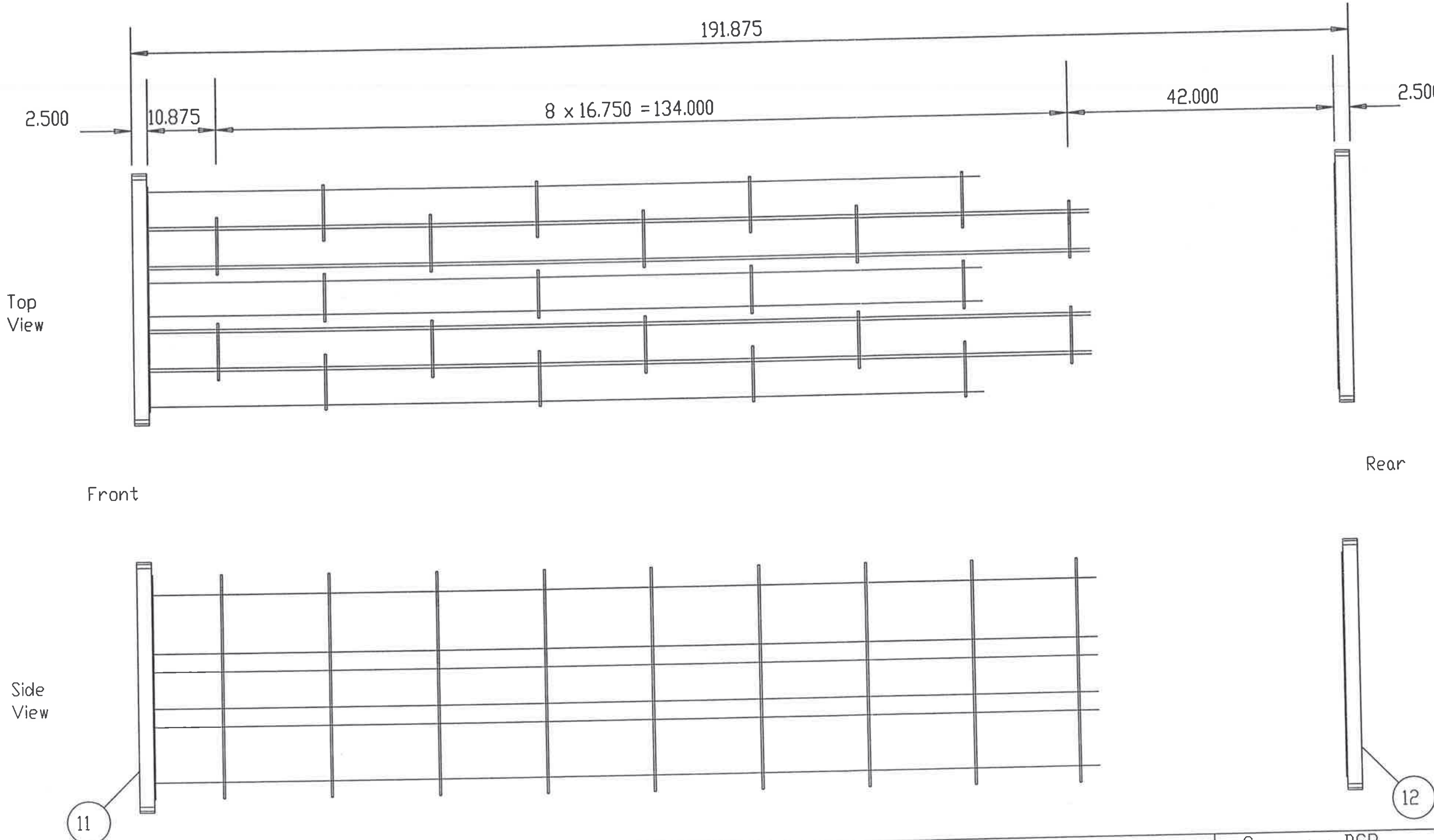
Rev:	Date:	Description	Dwg	Ckd	Appd
1	08-23-07	Issued for Construction	KFF	DGB	PW
2	12-04-07	Certified As-Built	AGB	DGB	PW

ASME VIII-1 2004 A06
TEMA Type: BEM
Size: 35-192
TEMA Class: C

Rear Head Detail

Dwg No.: E-4401 09

Rev: 2



# of Spacers	Length (in.)
16	16.438
3	33.188
2	10.719
1	27.469

Notes:
All Dimensions In Inches
Bolt holes to straddle centerlines
Weld joint details per drawing 20

HT/DCR Engineering, Inc.
2830 Parkway Street • Lakeland, FL 33811
Phone: 863-904-2880 • Fax: 863-913-1091
Florida Engineering Business License No. 26522

Company: DCR
Location: Bunge-Ergon
Product: Condenser
Item No.: E-4401
Date: February 26, 2007 Job No.: 7793

DCR Construction, Inc.
Lakeland, Florida

Scale: NTS

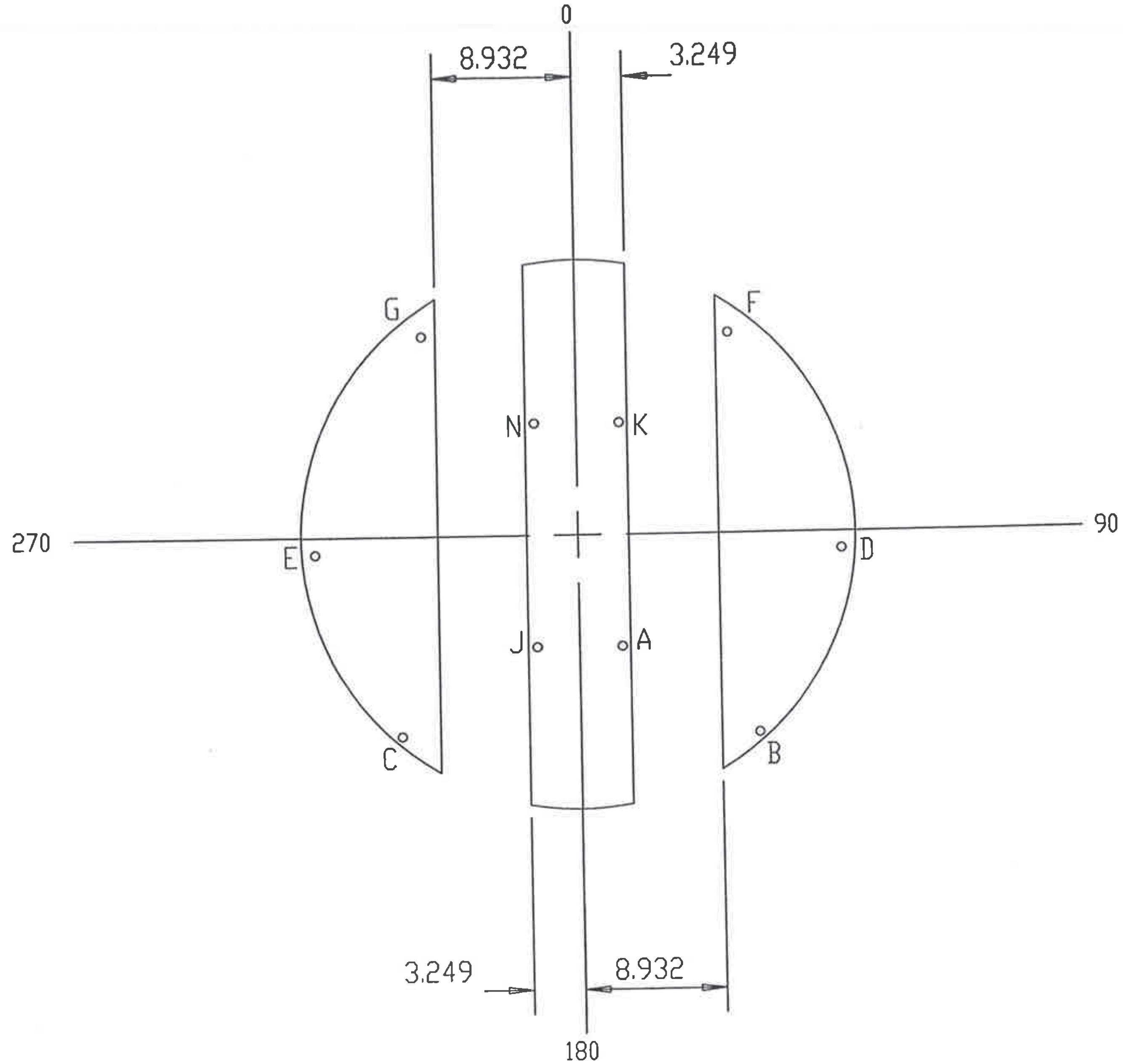
Rev:	Date:	Description	Dwg	Ckd	Appd
1	08-23-07	Issued for Construction	KFF	DGB	PW
2	12-04-07	Certified As-Built	AGB	DGB	PW

ASME VIII-1 2004 A06
TEMA Type: BEM
Size: 35-192
TEMA Class: C

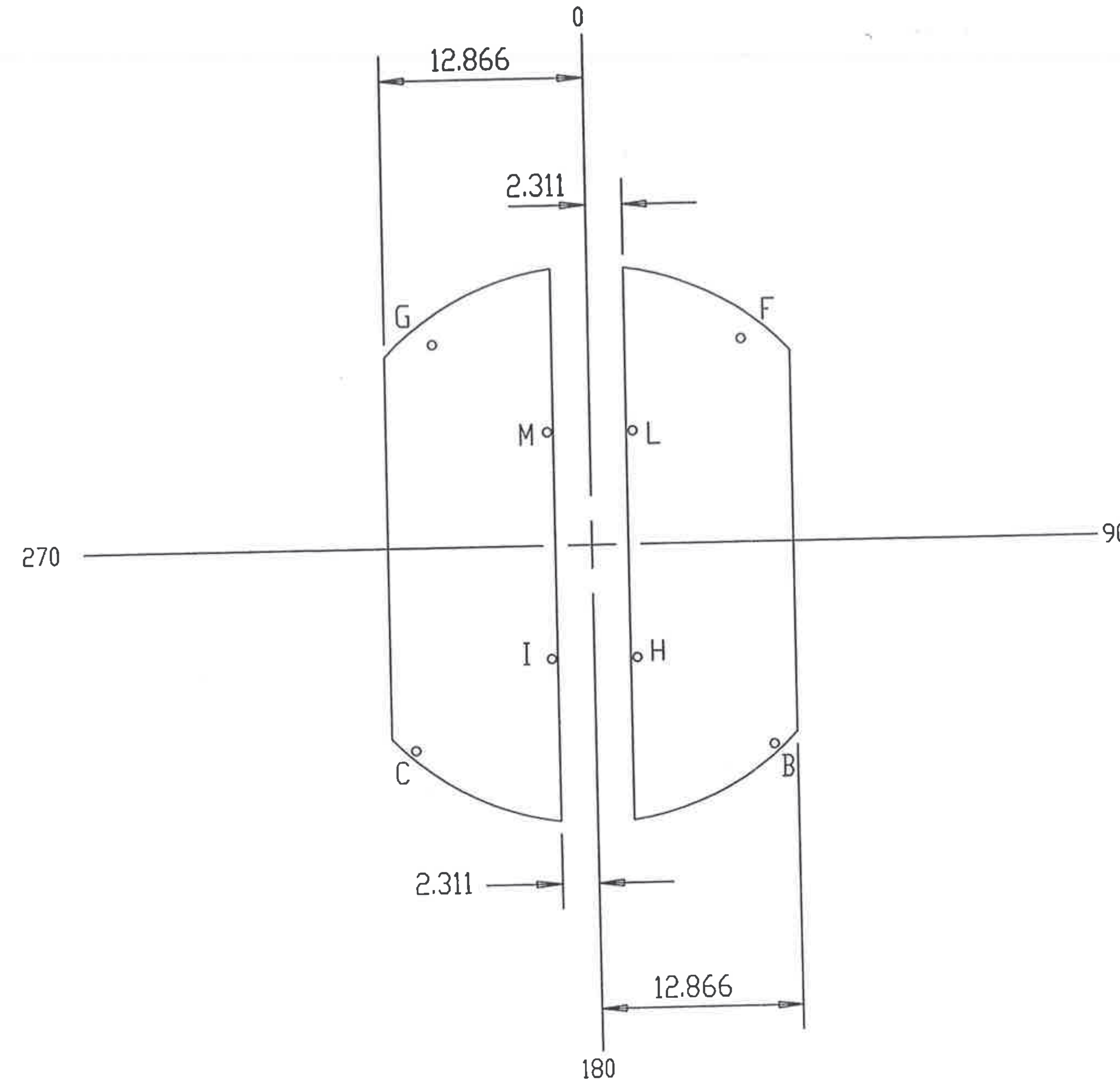
Bundle Detail

Dwg No.: E-4401 11

Rev: 2



39 A 4 Baffles 35.313 O.D. 0.313 Tk



39 B 5 Baffles 35.313 O.D. 0.313 Tk

Notes:
All Dimensions In Inches
Weld joint details per drawing 20

Company: DCR
Location: Bunge-Ergon
Product Condenser
Item No.: E-4401
Date: February 26, 2007 Job No.: 7793

HT/DCR Engineering, Inc.
2830 Parkway Street • Lakeland, FL 33811
Phone: 863-904-2880 • Fax: 863-913-1091
Florida Engineering Business License No. 26522

DCR Construction, Inc.
Lakeland, Florida

Scale: NTS

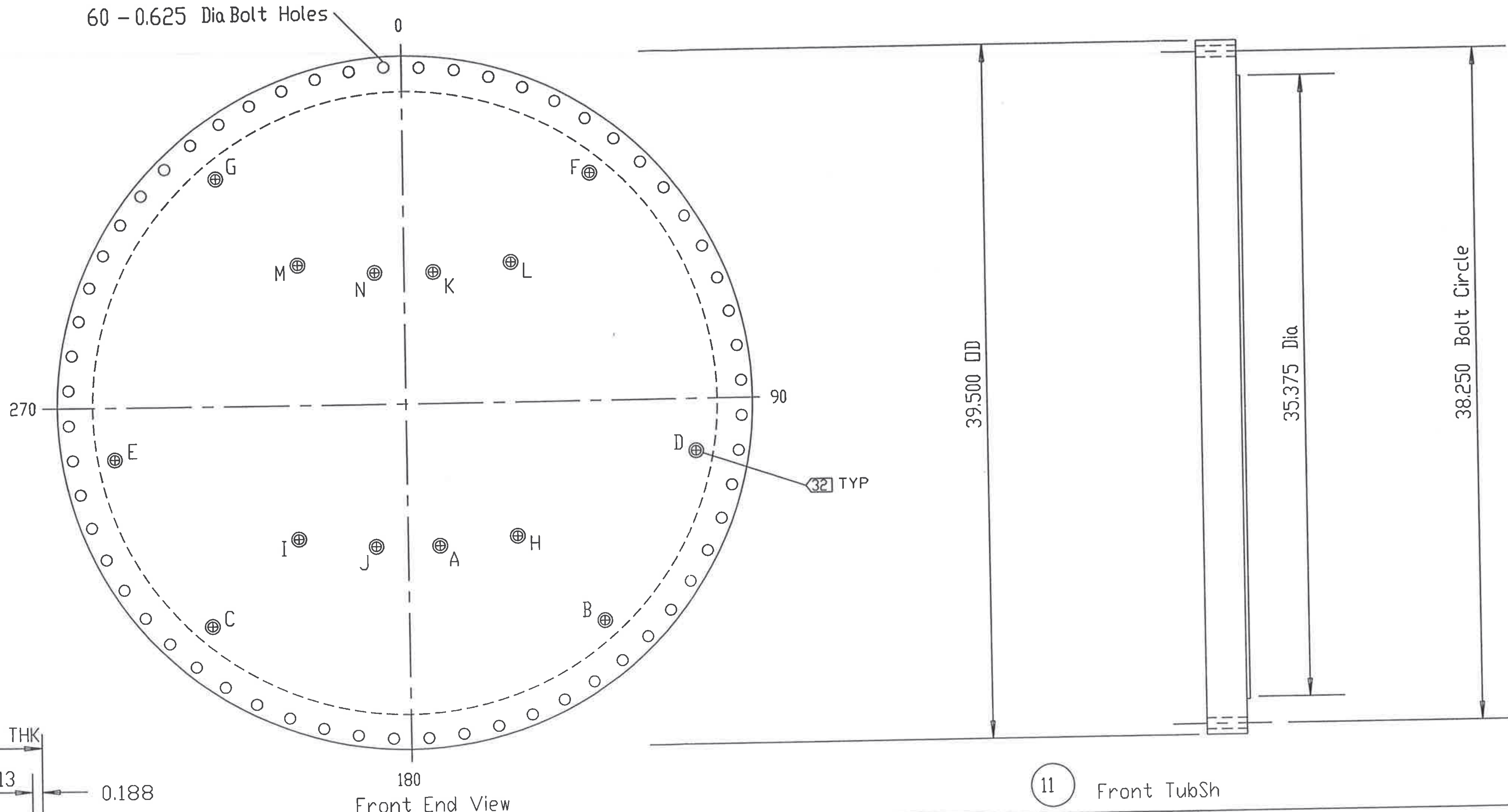
Rev:	Date:	Description	Dwg	Ckd	Appd
1	08-23-07	Issued for Construction	KFF	DGB	PW
2	12-04-07	Certified As-Built	AGB	DGB	PW

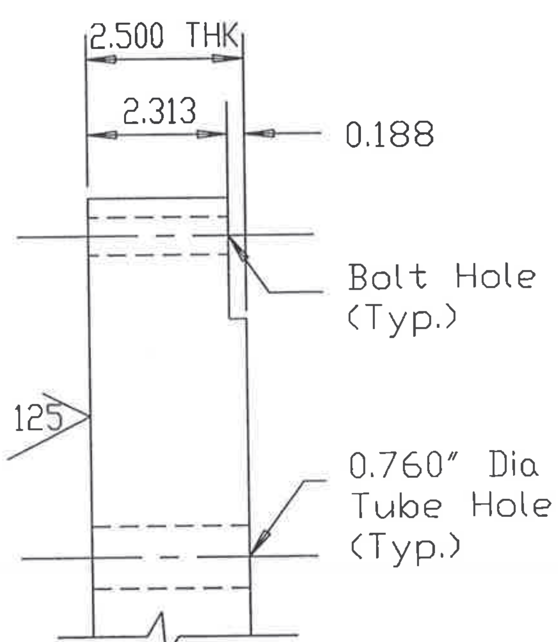
ASME VIII-1 2004 A06
TEMA Type: BEM
Size: 35-192
TEMA Class: C

Baffle Detail

Dwg No.: E-4401 12

Rev: 2





Notes:
All Dimensions In Inches
Bolt holes to straddle centerlines
See Tube Layout E-4401 05 For Tube Hole Locations

HT/DCR Engineering, Inc.
2830 Parkway Street • Lakeland, FL 33811
Phone: 863-904-2980 • Fax: 863-913-1091
Florida Engineering Business License No. 26522

Company: DCR
Location: Bunge-Ergon
Product Condenser
Item No.: E-4401
Date: February 26, 2007 Job No.: 7793

DCR Construction, Inc
Lakeland, FL

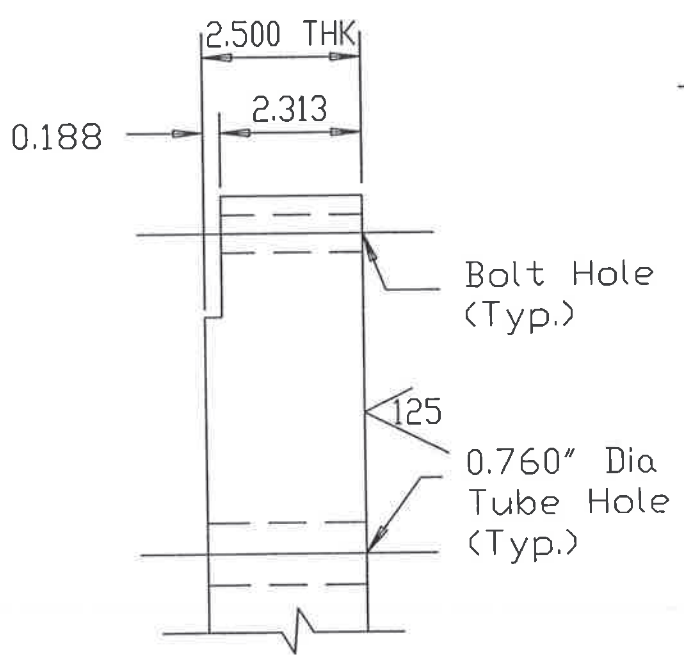
Scale: NTS

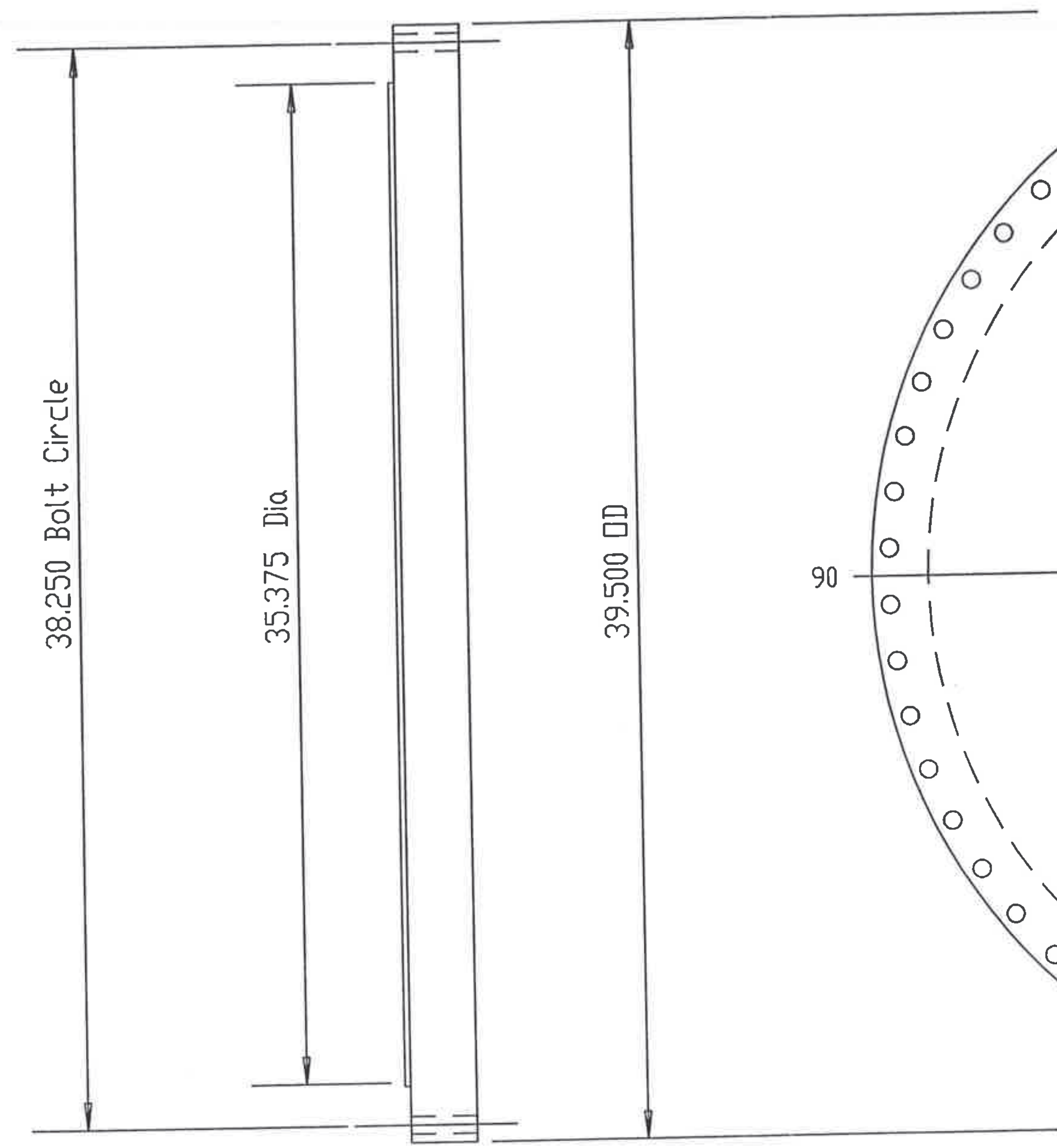
Rev:	Date:	Description	Dwg	Ckd	Appd
1	08-23-07	Issued for Construction	KFF	DGB	PW
2	12-04-07	Certified As-Built	AGB	DGB	PW

ASME VIII-1 2004 A06
TEMA Type: BEM
Size: 35-192
TEMA Class: C

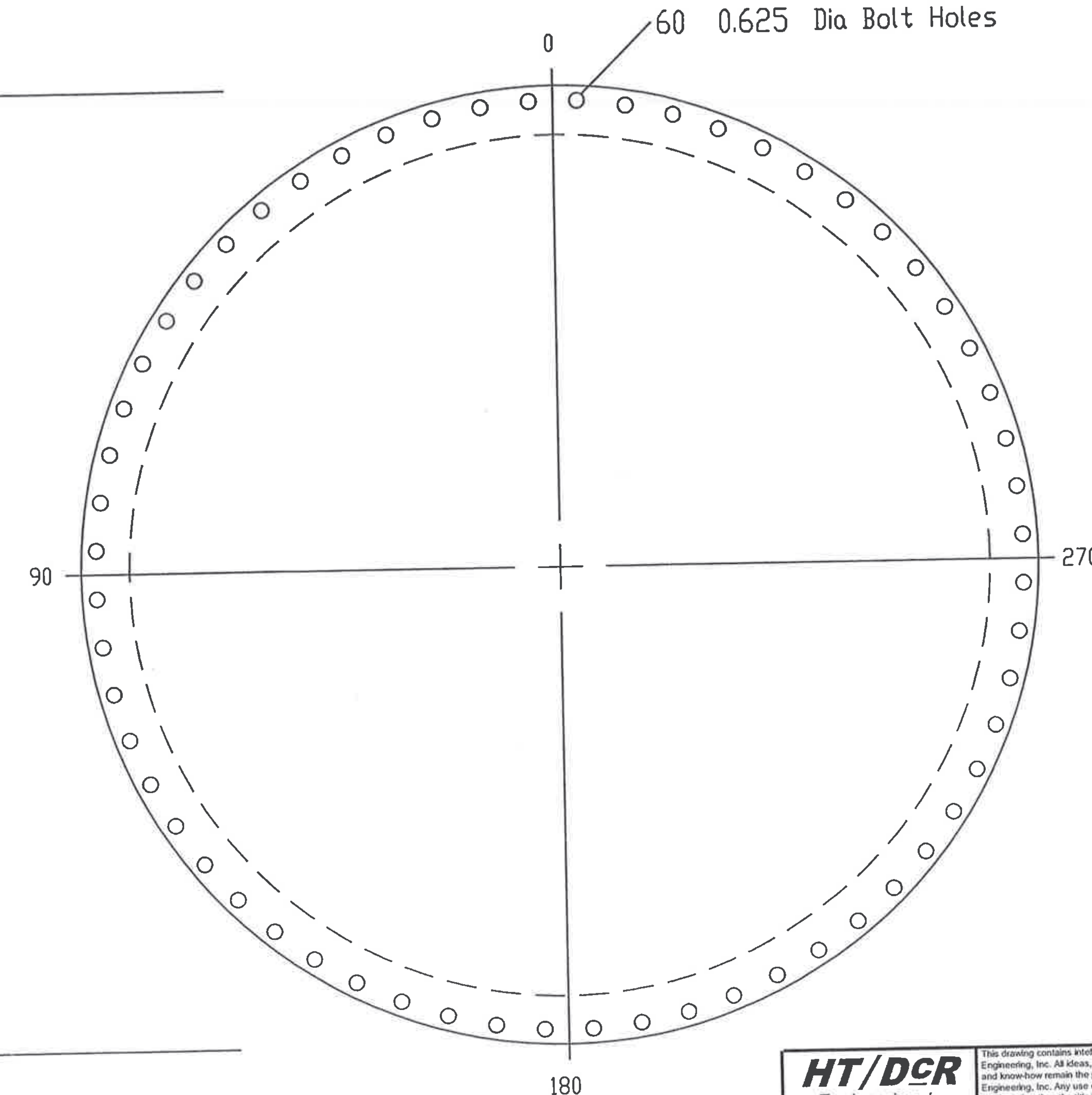
Front Tubesheet Detail

Dwg No.: E-4401 14
Rev: 2





12 Rear TubSh



Rear End View

HT/DCR Engineering, Inc.

2830 Parkway Street • Lakeland, FL 33811
Phone: 863-904-2880 • Fax: 863-913-1091
Florida Engineering Business License No. 26522

Notes:
All Dimensions In Inches
Bolt holes to straddle centerlines
See Tube Layout E-4401 05 For Tube Hole Locations

Company: DCR
Location: Bunge-Ergon
Product: Condenser
Item No.: E-4401
Date: February 26, 2007 Job No.: 7793

DCR Construction, Inc
Lakeland, FL

Scale: NTS

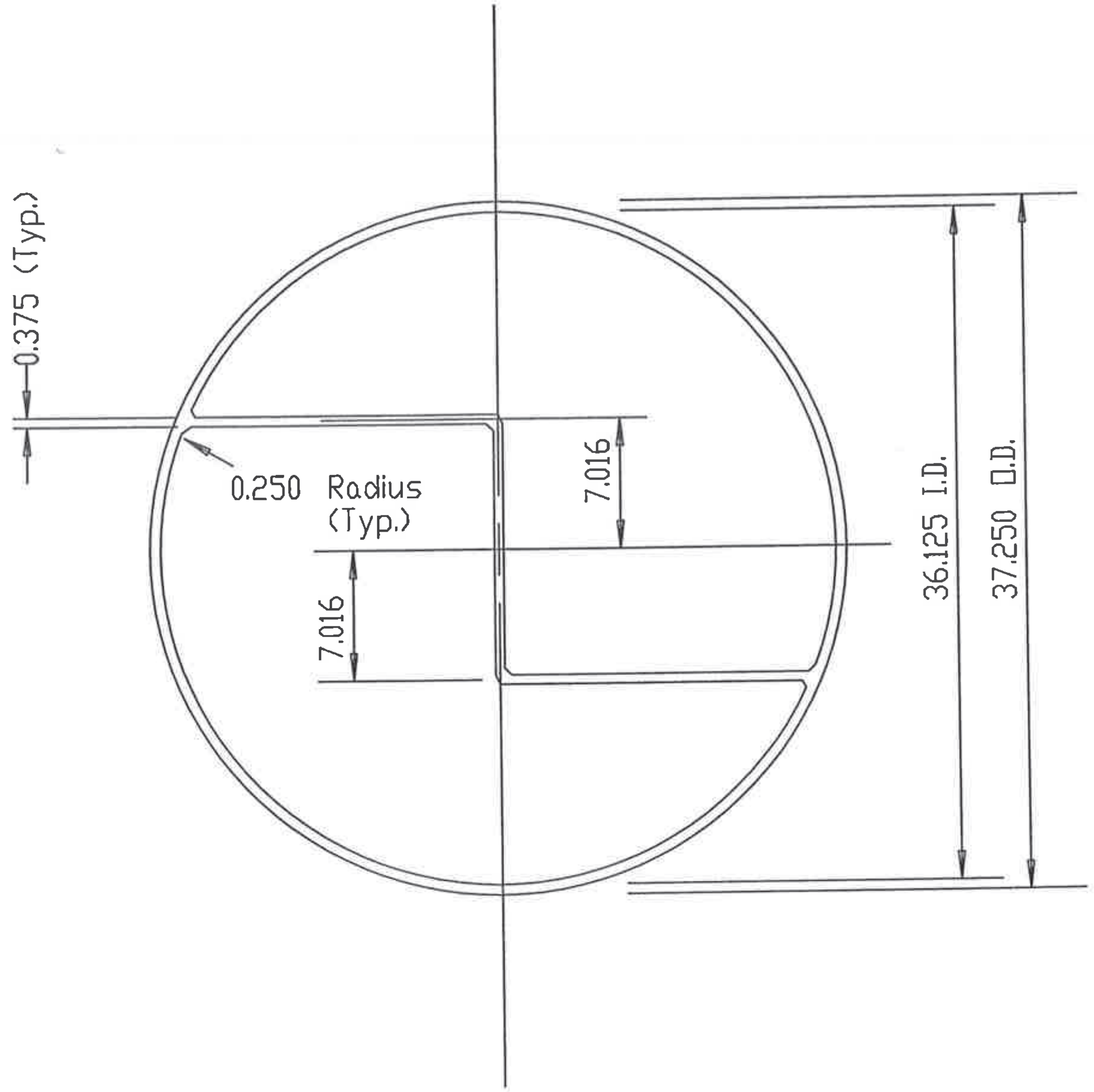
Rev:	Date:	Description	Dwg	Ckd	Appd
1	08-23-07	Issued for Construction	KFF	DGB	PW
2	12-04-07	Certified As-Built	AGB	DGB	PW

ASME VIII-1 2004 A06
TEMA Type: BEM
Size: 35-192
TEMA Class: C

Rear Tubesheet Detail

Dwg No.: E-4401 15

Rev: 2



(31) Front Head Gaskets at Tbshts

0.125 Thk.

HT/DCR
Engineering, Inc.
2830 Parkway Street • Lakeland, FL 33811
Phone: 863-904-2880 • Fax: 863-913-1091
Florida Engineering Business License No. 26522

Notes:
All Dimensions In Inches
Bolt holes to straddle centerlines

Company: DCR
Location: Bunge-Ergon
Product Condenser
Item No.: E-4401
Date: February 26, 2007 Job No.: 7793

DCR Construction, Inc
Lakeland, FL

Scale: NTS

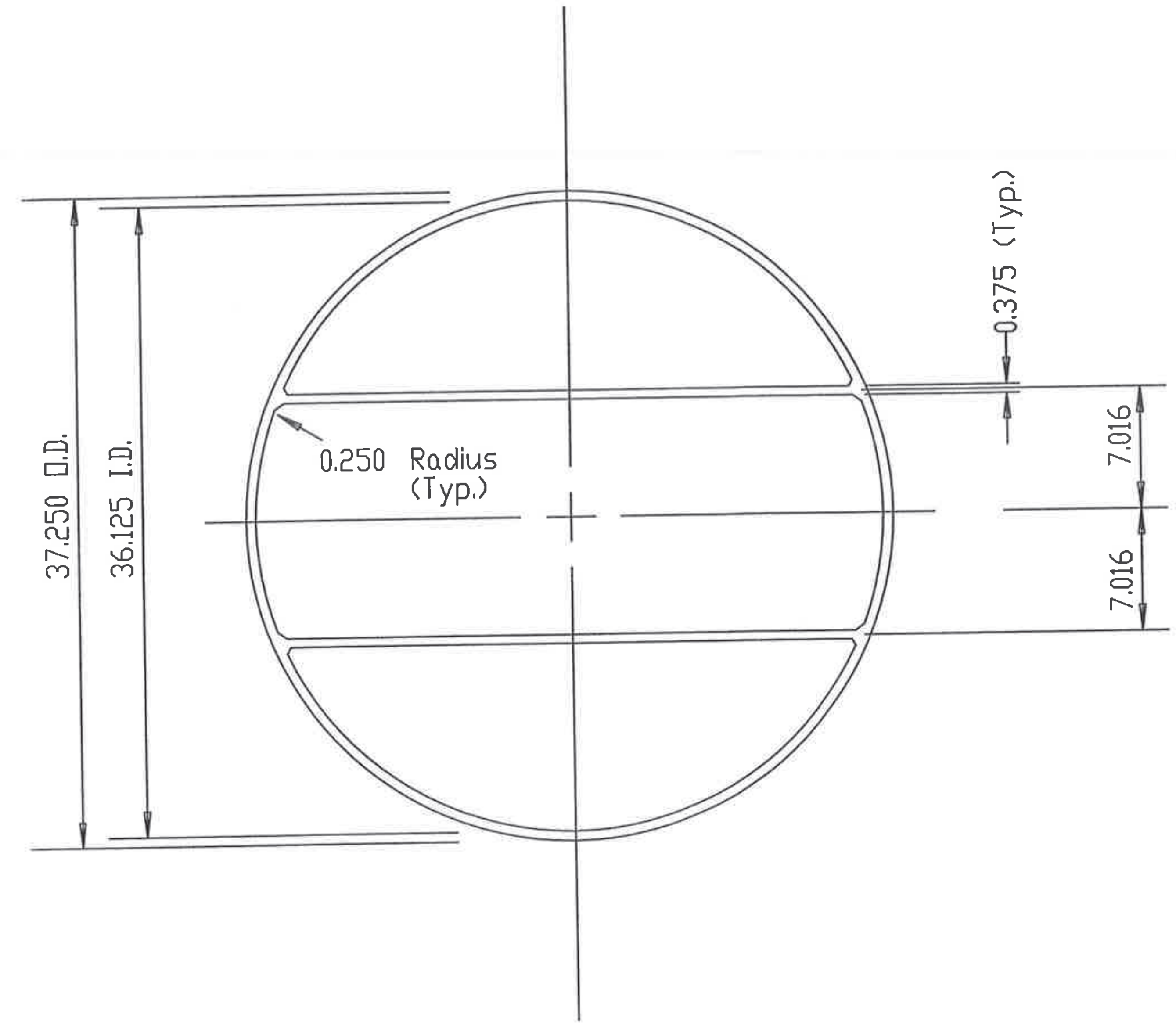
Rev:	Date:	Description	Dwg	Ckd	Appd
1	08-23-07	Issued For Construction	KFF	DGB	PW
2	12-04-07	Certified As-Built	AGB	DGB	PW

ASME VIII-1 2004 A06
TEMA Type: BEM
Size: 35-192
TEMA Class: C

Gasket Detail

Dwg No.: E-4401 17A

Rev: 2



(32) Rear Head Gaskets at Tbshts

0.125 Thk.

HT/DCR Engineering, Inc.

Notes:
All Dimensions In Inches
Bolt holes to straddle centerlines

Company: DCR
Location: Bunge-Ergon
Product Condenser
Item No.: E-4401
Date: February 26, 2007 Job No.: 7793

DCR Construction, Inc
Lakeland, FL

Scale: NTS

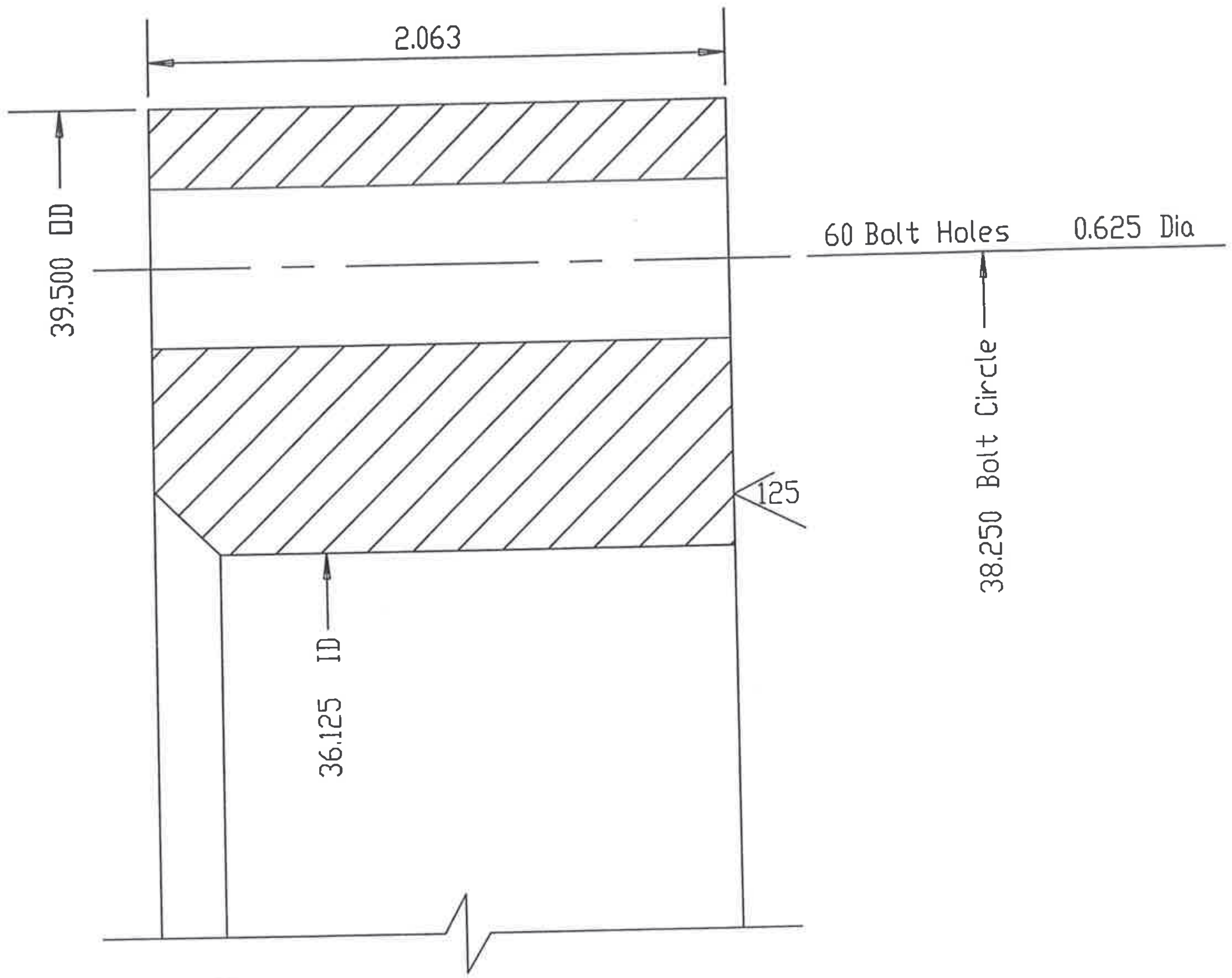
Rev:	Date:	Description	Dwg	Ckd	Appd
1	08-23-07	Issued For Construction	KFF	DGB	PW
2	12-04-07	Certified As-Built	AGB	DGB	PW

ASME VIII-1 2004 A06
TEMA Type: BEM
Size: 35-192
TEMA Class: C

Gasket Detail

Dwg No.: E-4401 17B

Rev: 2



17 Fr Hd Flng TubSh

Notes:
All Dimensions In Inches
Bolt holes to straddle centerlines

Company: DCR
Location: Bunge-Ergon
Product Condenser
Item No.: E-4401
Date: March 14, 2007 Job No.: 7793

DCR Construction, Inc.
Lakeland, Florida

HT/DCR Engineering, Inc.
2830 Parkway Street • Lakeland, FL 33811
Phone: 863-904-2880 • Fax: 863-913-1091
Florida Engineering Business License No. 26522

Scale: NTS

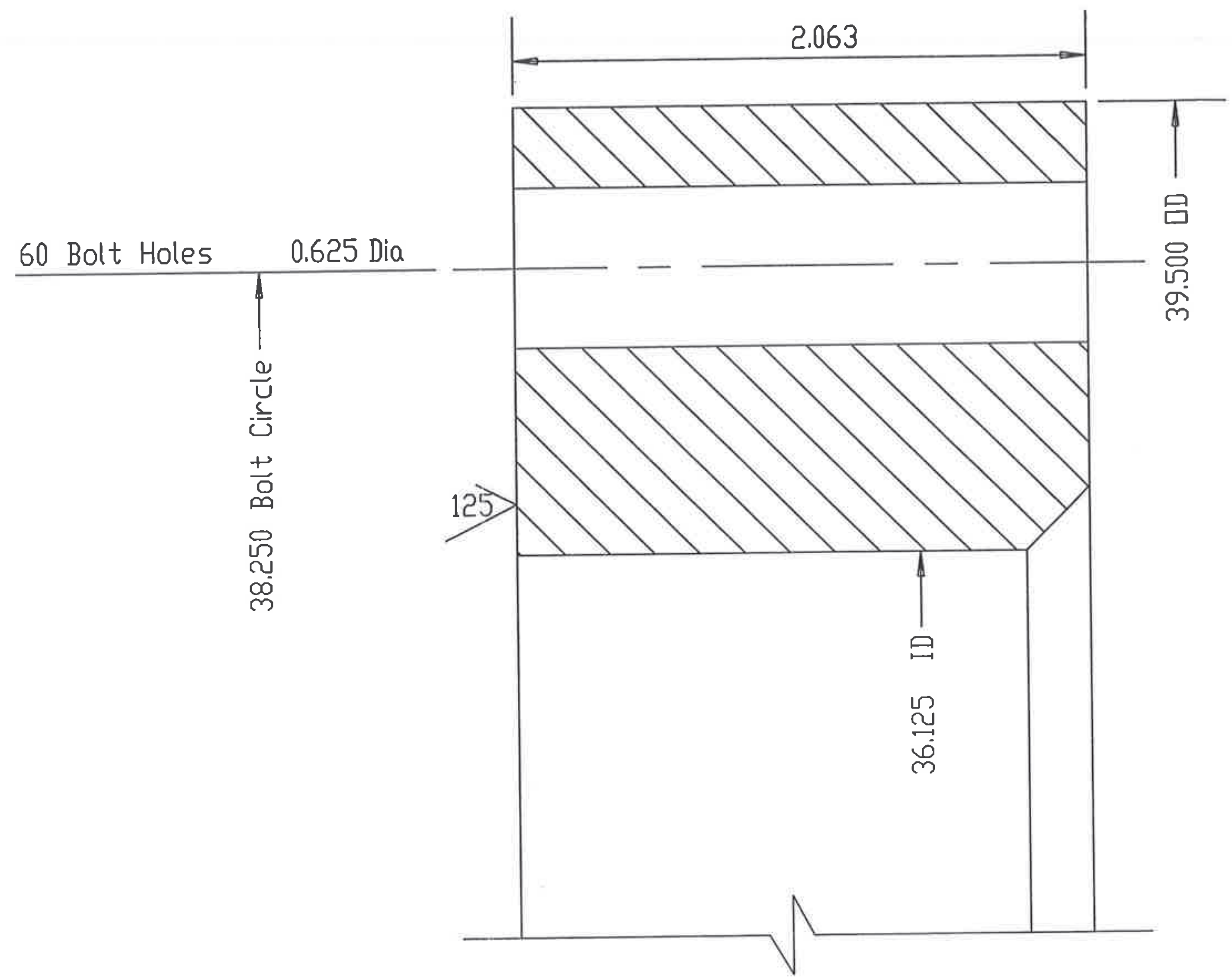
Rev:	Date:	Description	Dwg	Ckd	Appd
1	08-23-07	Issued for Construction	KFF	DGB	PW
2	12-04-07	Certified As-Built	AGB	DGB	PW

ASME VIII-1 2004 A06
TEMA Type: BEM
Size: 35-192
TEMA Class: C

Flange Detail

Dwg No.: E-4401 18A

Rev: 2



(18) Re Hd Flng TubSh

HT/DCR Engineering, Inc.
2830 Parkway Street • Lakeland, FL 33811
Phone: 863-904-2880 • Fax: 863-913-1091
Florida Engineering Business License No 26522

Notes:
All Dimensions In Inches
Bolt holes to straddle centerlines

Company: DCR
Location: Bunge-Ergon
Product Condenser
Item No.: E-4401
Date: March 14, 2007 Job No.: 7793

DCR Construction, Inc.
Lakeland, Florida

Scale: NTS

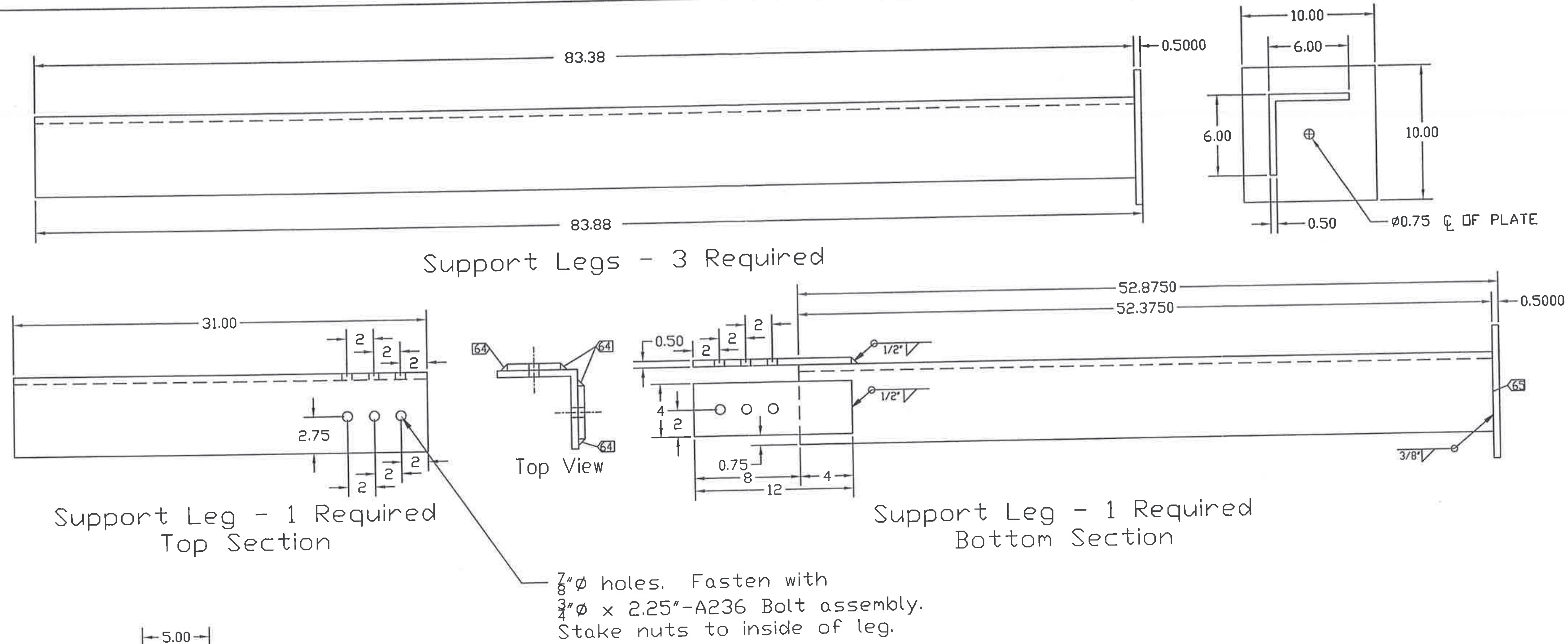
Rev:	Date:	Description	Dwg	Ckd	Appd
1	08-23-07	Issued For Construction	KFF	DGB	PW
2	12-04-07	Certified As-Built	AGB	DGB	PW

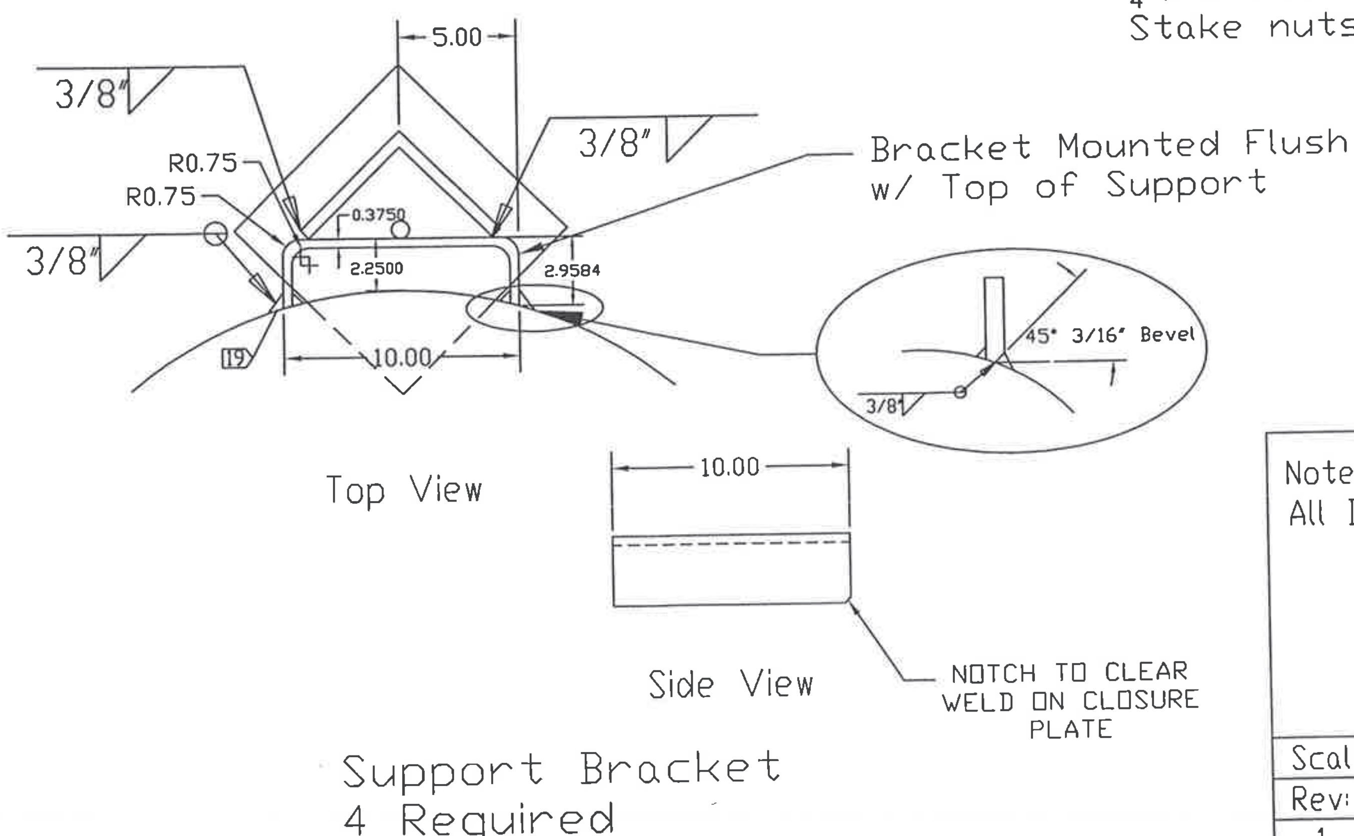
ASME VIII-1 2004 A06
TEMA Type: BEM
Size: 35-192
TEMA Class: C

Flange Detail

Dwg No.: E-4401 18B

Rev: 2





HT/DcR Engineering, Inc.

Notes:
All Dimensions In Inches

Company: DCR
Location: Bunge-Ergon
Product Condenser
Item No.: E-4401
Date: February 26, 2007 Job No.: 7793

DCR Construction, Inc
Lakeland, FL

Scale: NTS

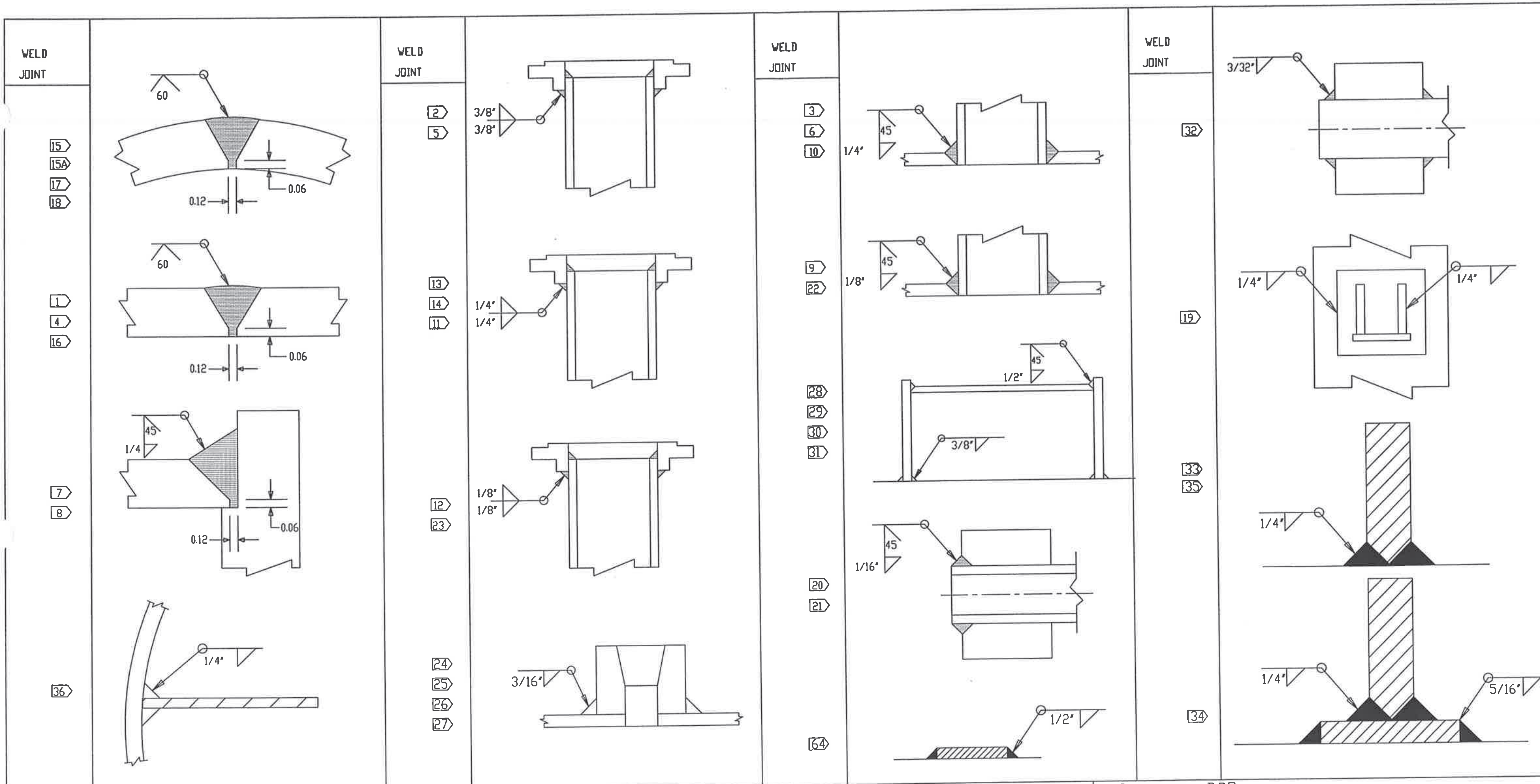
Rev:	Date:	Description	Dwg	Ckd	Appd
1	08-23-07	Issued for Construction	KFF	DGB	PW
2	12-04-07	Certified As-Built	AGB	DGB	PW

ASME VIII-1 2004 A06
TEMA Type: BEM
Size: 35-192
TEMA Class: C

Leg Support

Dwg No.: E-4401 19

Rev: 2



Notes:
All Dimensions In Inches
Welding in accordance with Code

HT/DCR Engineering, Inc.
2830 Parkway Street • Lakeland, FL 33811
Phone: 863-904-2880 • Fax: 863-913-1091
Florida Engineering Business License No. 26522

Company: DCR
Location: Bunge-Ergon
Product Condenser
Item No.:E-4401
Date: February 26, 2007 Job No.: 7793

DCR Construction, Inc
Lakeland, FL

Scale: NTS

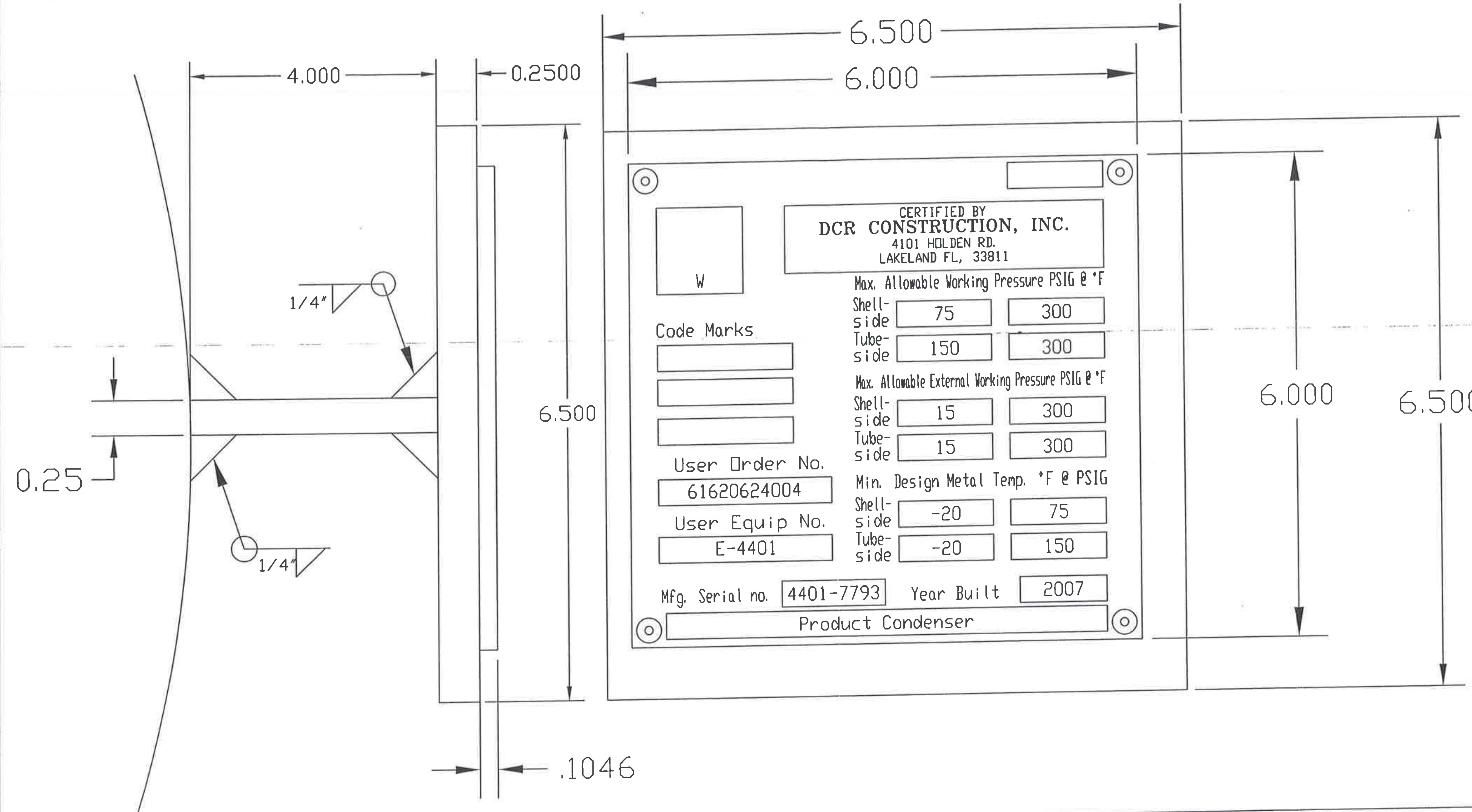
Rev:	Date:	Description	Dwg	Ckd	Appd
1	08-23-07	Issued for Construction	KFF	DGB	PW
2	12-04-07	Certified As-Built	AGB	DGB	PW

ASME VIII-1 2004 A06
TEMA Type: BEM
Size: 35-192
TEMA Class: C

Weld Joint Detail

Dwg No.: E-4401 20

Rev: 2



Notes:
All Dimensions In Inches

Company: DCR
Location: Bunge-Ergon
Product Condenser
Item No.: E-4401
Date: February 17, 2007 Job No.: 7793

HT/DCR Engineering, Inc.
2830 Parkway Street • Lakeland, FL 33811
Phone: 863-904-2880 • Fax: 863-913-1091
Florida Engineering Business License No. 26522

This drawing contains intellectual property of HT/DcR Engineering, Inc. All ideas, designs, arrangements and know-how remain the property of HT/DcR Engineering, Inc. Any use of this information by entities other than the title block named entity is prohibited. Use of this drawing by the title block named entity is limited to the specific title block named project. Use on other projects is strictly prohibited.

DCR Construction, Inc
Lakeland, FL

Scale: NTS

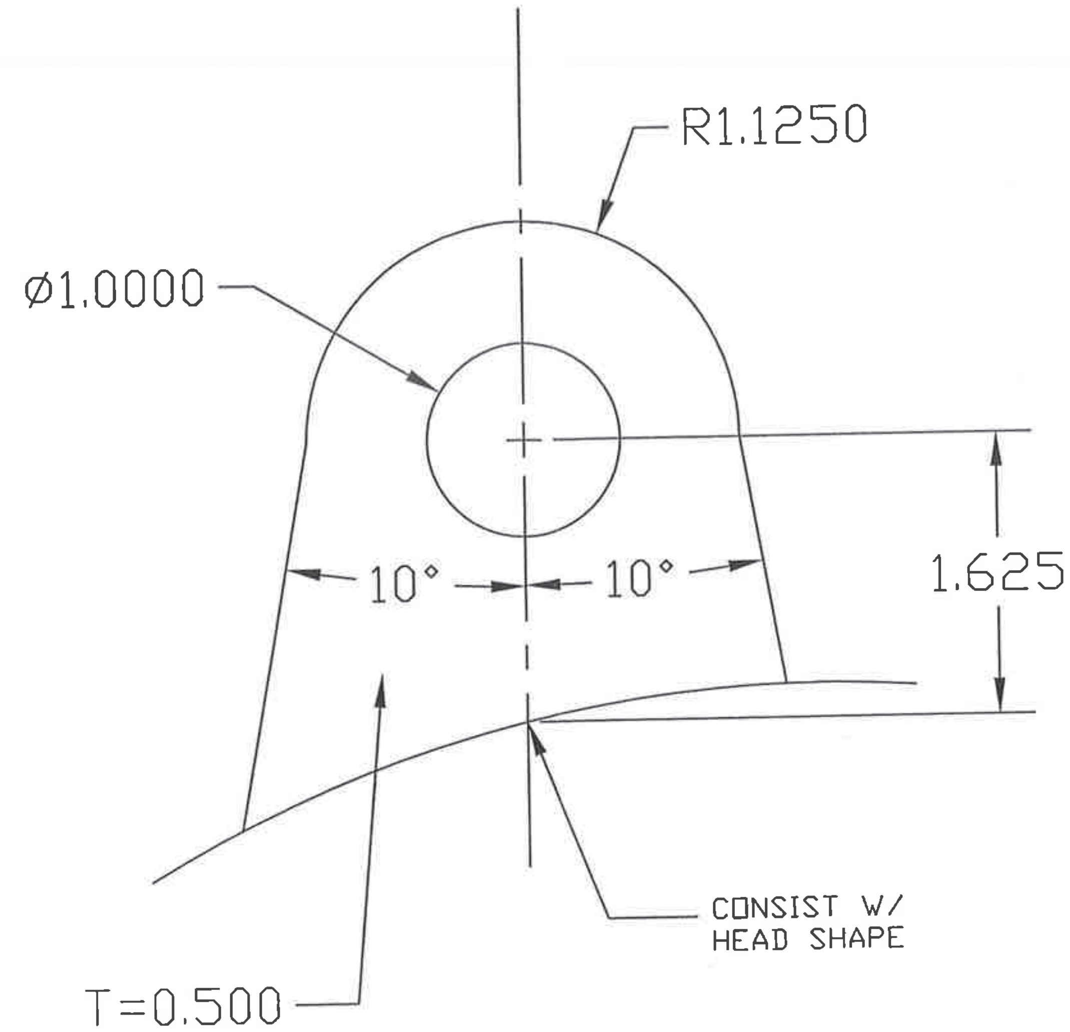
Rev:	Date:	Description	Dwg	Ckd	Appd
0	08-24-07	ISSUED FOR CONSTRUCTION	KFF	DGB	PW
1	12-04-07	CERTIFIED AS-BUILT	AGB	DGB	PW

ASME VIII-1 2004 A06
TEMA Type: BEM
Size: 71-264
TEMA Class: C

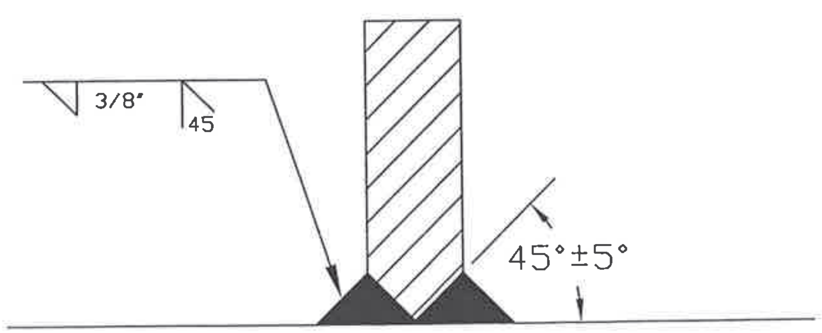
Code Data Plate

Dwg No.: E-4401 22

Rev: 1



TOP LIFTING LUG
2 REQUIRED



HT/DCR Engineering, Inc.
2830 Parkway Street • Lakeland, FL 33811
Phone: 863-904-2880 • Fax: 863-913-1091
Florida Engineering Business License No. 26522

Notes:
All Dimensions In Inches

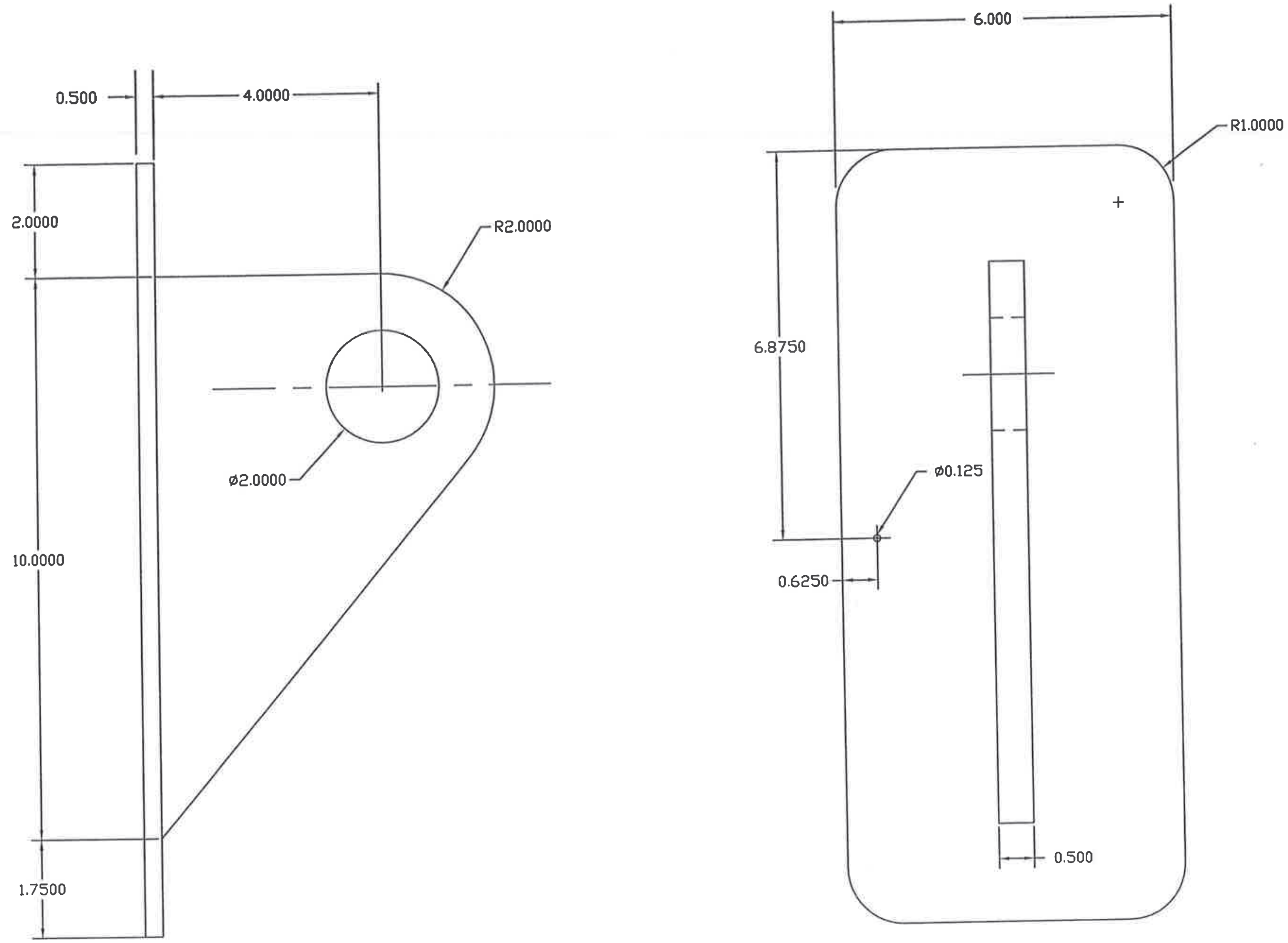
Company: DCR
Location: Bunge-Ergon
Product Condenser
Item No.: E-4401
Date: February 26, 2007 Job No.: 7793

DCR Construction, Inc
Lakeland, FL

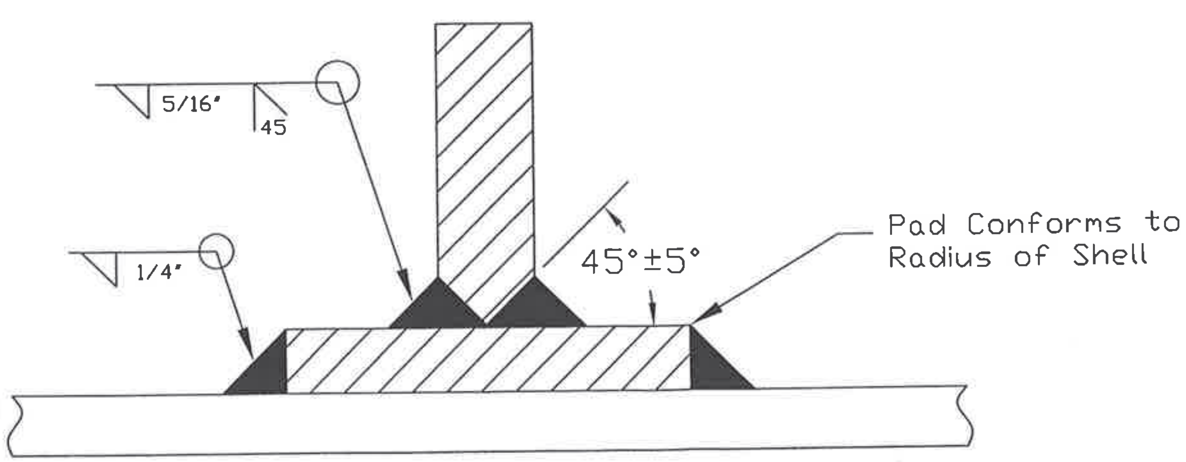
Scale: NTS

Rev:	Date:	Description	Dwg	Ckd	Appd
1	08-23-07	Issued for Construction	KFF	DGB	PW
2	12-04-07	Certified As-Built	AGB	DGB	PW

ASME VIII-1 2004 A06	Lifting Lug Detail
TEMA Type: BEM	
Size: 35-192	Dwg No.: E-4401 23A
TEMA Class: C	Rev: 2



LIFTING LUG
3 REQUIRED



HT/DCR Engineering, Inc.
2830 Parkway Street • Lakeland, FL 33811
Phone: 863-904-2880 • Fax: 863-913-1091
Florida Engineering Business License No. 26522

Notes:
All Dimensions In Inches

Company: DCR
Location: Bunge-Ergon
Product Condenser
Item No.: E-4401
Date: March 13, 2007 Job No.: 7793

DCR Construction, Inc
Lakeland, FL

Scale: NTS

Rev:	Date:	Description	Dwg	Ckd	Appd
1	08-23-07	Issued for Construction	KFF	DGB	PW
2	12-04-07	Certified As-Built	AGB	DGB	PW

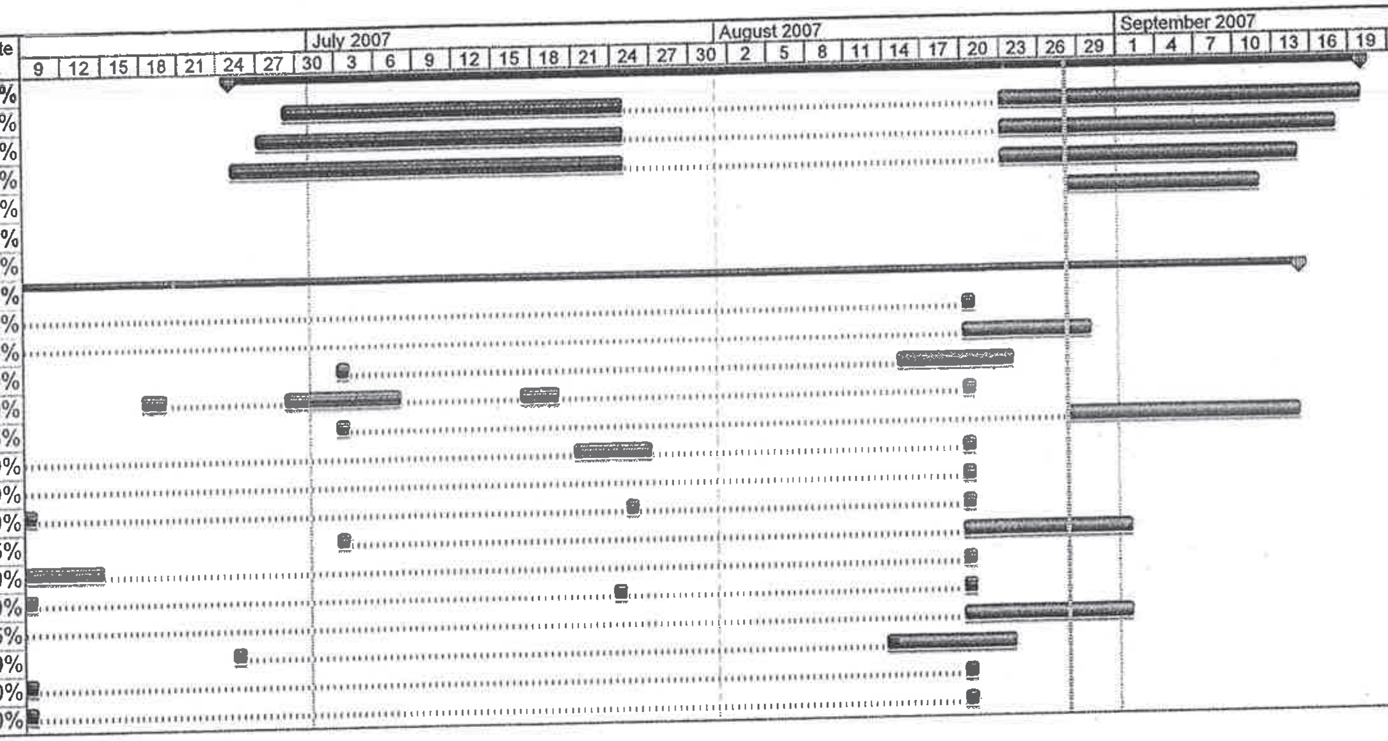
ASME VIII-1 2004 A06
TEMA Type: BEM
Size: 35-192
TEMA Class: C

Lifting Lug Detail

Dwg No.: E-4401 23B

Rev: 2

ID	Task Name	Start	Finish	% Complete
1	**Bunge-Ergon #4500142848 (DCR in KY)**	**Mon 6/25/07**	**Wed 9/19/07**	**58%**
2	E-4501 1st Effect Evaporator	Fri 6/29/07	Wed 9/19/07	59%
3	E-4502 2nd Effect Evaporator	Wed 6/27/07	Mon 9/17/07	62%
4	E-4503 3rd Effect Evaporator	Mon 6/25/07	Fri 9/14/07	66%
5	E-4504 Evaporator Condenser	Tue 8/28/07	Tue 9/11/07	0%
6	**Bunge-Ergon #4500142848- Change Order #1**	**Mon 4/23/07**	**Mon 4/23/07**	**100%**
7	Ladders and Platforms	Mon 4/23/07	Mon 4/23/07	100%
8	**Bunge-Ergon #4500142970 (DCR in TX)**	**Thu 5/31/07**	**Fri 9/14/07**	**55%**
9	E-2101 Slurry Mix Tank Vent Condenser	Thu 5/31/07	Mon 8/20/07	100%
10	E-4101 Beer Column Reboiler	Thu 5/31/07	Wed 8/29/07	25%
11	E-4102 Beer Column Vent Condenser	Tue 7/3/07	Thu 8/23/07	10%
12	E-4103 Beer Column Feed Heater	Mon 6/18/07	Mon 8/20/07	100%
13	E-4201 Reflux Condenser	Tue 7/3/07	Fri 9/14/07	5%
14	E-4202 Stripper Column Reboiler	Thu 5/31/07	Mon 8/20/07	100%
15	E-4203 Reflux Vent Condenser	Thu 5/31/07	Mon 8/20/07	100%
16	E-4301 Superheater	Thu 5/31/07	Mon 8/20/07	100%
17	E-4303 Regen Vacuum Condenser	Tue 7/3/07	Sat 9/1/07	5%
18	E-4304 Regen Preheater	Fri 6/8/07	Mon 8/20/07	100%
19	E-4305 DD&E Condensate Preheater	Thu 5/31/07	Mon 8/20/07	100%
20	E-4401 Product Condenser	Fri 6/8/07	Sat 9/1/07	5%
21	E-7201 Flash Recovery Condenser	Mon 6/25/07	Thu 8/23/07	20%
22	E-7601 Process Condensate Heater	Thu 5/31/07	Mon 8/20/07	100%
23	E-7602 Dilute Caustic Heater	Thu 5/31/07	Mon 8/20/07	100%



Heat Exchanger Specification Sheet

Company: DELTA-T CORPORATION Phone: (757) 220-2955
Location: WILLIAMSBURG, VIRGINIA Fax: (757) 229-1705
L2357 REV C
Service of Unit: PRODUCT CONDENSER
Item No.: E4401 Your Reference: 50MM GPY Job No.: 61310 Bunge-Ergon Vicksburg, LLC
Date: 6 February 2007 Prepared by: RS Checked by: AC
Size 35 / 192 in Type BEM vert Connected in 1 parallel 1 series
Surf/unit(eff.) 3482.9 ft2 Shells/unit 1 Surf/shell (eff.) 3482.9 ft2

PERFORMANCE OF ONE UNIT

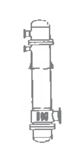
		Shell Side		Tube Side	
Fluid allocation		Shell Side		Tube Side	
Fluid name		FINAL PRODUCT VAPOR		COOLING WATER	
Fluid quantity, Total	lb/h	5711		124185	
Vapor (In/Out)	lb/h	5709	4		
Liquid	lb/h		5705	124185	124185
Noncondensable	lb/h	2			
Temperature (In/Out)	F	250	115	85	105
Dew / Bubble point	F	134.78			
Density	lb/ft3	0.036	47.453	62.264	62.064
Viscosity	cp	0.011	0.754	0.81	0.648
Molecular wt, Vap		45.79	45.23		
Molecular wt, NC		44.01			
Specific heat	BTU/(lb*F)	0.4507	0.6568	1.0008	1.0002
Thermal conductivity	BTU/(ft*h*F)	0.013	0.097	0.35	0.359
Latent heat	BTU/lb	371.3	379		
Pressure	psi	6		40	
Velocity	ft/s	14.52		0.85	
Pressure drop, allow./calc.	psi	1	0.028	15	0.214
Fouling resist. (min)	ft2*h*F/BTU	0.0005		0.001	

Heat exchanged 2484845 BTU/h MTD corrected 30.89 F
Transfer rate, Service 23.09 Dirty 97.51 Clean 116.21 BTU/(h*ft2*F)

CONSTRUCTION OF ONE SHELL

		Shell Side	Tube Side
Design/Test pressure	psi	75 / Code	150 / Code
Design temperature	F	300	300
Number passes per shell		1	4
Corrosion allowance	in		0.0625
Connections Size/rating in	In	24 / 150 ANSI	10 / 150 ANSI
	Out	2 / 150 ANSI	10 / 150 ANSI
	Intermediate	/ 150 ANSI	/ 150 ANSI

Sketch



Tube No. 1127 OD 0.75 Tks 0.049 in Length 16 ft Pitch 0.9375 in
Tube type Plain Material SS304 Tube pattern 30
Shell SS304 ID OD 36 in Shell cover
Channel or bonnet CS Channel cover
Tubesheet-stationary SS304 Tubesheet-floating
Floating head cover Impingement protection None
Baffle-crossing SS304 Type triple seg Cut(%d) 13 vert Spacing: c/c 16.75 in
Baffle-long Seal type Inlet 42 in
Supports-tube U-bend Type
Bypass seal Tube-tubesheet joint strength weld
Expansion joint Type
RhoV2-Inlet nozzle 8 Bundle entrance 6 Bundle exit 0 lb/(ft*s2)
Gaskets - Shell side Tube Side
Floating head
Code requirements ASME Code Sec VIII Div 1 TEMA class C
Weight/Shell 12481.1 Filled with water 20525.8 Bundle 8739.7 lb
Remarks Design is based on 120% of nominal flow, assuming both upstream preheaters are in service.

FORM U-1 MANUFACTURER'S DATA REPORT FOR PRESSURE VESSELS

As Required by the Provisions of the ASME Code Rules, Section VIII, Division 1

1. Manufactured and certified by: DCR Construction, Inc. 4101 Holden Rd. Lakeland, FL 33811
(Name and address of Manufacturer)

2. ...nufactured for: Delta-T Corporation 133 Waller Mill Rd. Williamsburg, VA 23185
(Name and address of Purchaser)

3. Location of installation: Bunge Ergon Vicksburg, LLC 1833 Haining Rd. Vicksburg, MS 39183
(Name and address)

4. Type: Vertical (Horiz, vert., or sphere) — Condenser (Tank, separator, jkt. vessel, heat exh, etc.) — 4401-7793 (Mfr's serial No.)

N/A (CRN) — 4401-01 to 4401-23B (See Details) (Drawing No.) — 223 (Nat'l Bd No.) — 2007 (Year built)

5. ASME Code Section VIII Div 1 — Edition 2004, Addenda 2006 [Edition and Addenda (date)] — N/A (Code Case No.) — N/A [Special Service per UG-120(d)]

Items 6-11 incl. to be completed for single wall vessels, jackets of jacketed vessels, shell of heat exchangers, or chamber of multi-chamber vessels.

6. Shell (a) No. of course (s): 3 (b) Overall Length (ft & in.): 15' 7 ¼"

Course(s)			Material	Thickness		Long. Joint (Cat. A)			Circum. Joint (Cat. A, B, & C)			Heat Treatment	
No.	Diameter	Length (ft & in.)	Spec./Grade or Type	Nom.	Corr.	Type	Full, Spot, None	Eff.	Type	Full, Spot, None	Eff	Temp.	Time
1	36"	5'	SA-240 GR304	0.250	0	1	None	0.70	1	None	0.70		
1	36"	5' 7 ½"	SA-240 GR304	0.250	0	1	None	0.70	1	None	0.70		
1	36"	4' 11 ¼"	SA-240 GR304	0.250	0	1	None	0.70	1	None	0.70		

7. Heads: (a) ______ (Matl. Spec. No., Grade or Type) (H.T. – Time & Temp) (b) ______ (Matl. Spec. No., Grade or Type) (H.T. – Time & Temp)

	Location (Top, Bottom, Ends)	Thickness		Radius		Elliptical Ratio	Conical Apex Angle	Hemispherical Radius	Flat Diameter	Side to Pressure		Category A		
		Min.	Corr.	Crown	Knuckle					Convex	Concave	Type	Full, Spot, None	Eff.
(a)														
(b)														

If removable, bolts used (describe other fastenings) ______ (Mat'l Spec. No., Grade, Size, No.)

8. Type of jacket ______ Jacket closure ______ (Describe as ogee & weld, bar, etc.)

...ar, give dimensions ______ If bolted, describe or sketch

9. ...WP 75 psig (internal) 15 psig (external) psig at max temp. 300 (internal) °F 300 (external) °F Min. design metal temp. -20 °F at 75 psig

10. Impact Test No Per UHA-51 [Indicate yes or no and the component(s) impact tested] at test temperature of N/A °F

11. Hydro., Pneu., or comb. test press. 98 psig Proof Test N/A

Items 12 and 13 to be completed for tube sections.

12. Tubesheet SA-240 GR304 [Stationary (Mat'l Spec. No.)] — 39.5" [Dia., In. (subject to press.)] — 2.5" (Nom. thk., in.) — 0 (Corr. Allow., in.) — Welded [Attachment (welded or bolted)]

______ Floating (Mat'l Spec. No.)] — ______ (Dia., in.) — ______ (Nom. thk., in.) — ______ (Corr. Allow., in.) — ______ (Attachment)

13. Tubes SA-249 GR304 Wld Tube (Mat'l Spec. No., Grade or Type) — 0.75" (O.D., in.) — 0.049" (Nom. thk., in. or gauge) — 1127 (Number) — Straight [Type (Straight or U)]

Items 14-18 incl. To be completed for inner chambers of jacketed vessels or channels of heat exchangers.

14. Shell (a) No. of course (s): 2 (b) Overall Length (ft & in.): 3' 6 13/16"

Courses			Material	Thickness		Long. Joint (Cat A)			Circum. Joint (Cat. A, B, & C)			Heat Treatment	
No.	Diameter	Length (ft & in.)	Spec./Grade or Type	Nom.	Corr.	Type	Full, Spot, None	Eff.	Type	Full, Spot, None	Eff	Temp.	Time
1	35.25	1' 4 5/8"	SA-516 GR70	0.375	0.0625	1	None	0.70	1	None	0.70		
1	35.25	2' 2 3/16"	SA-516 GR70	0.375	0.0625	1	None	0.70	1	None	0.70		

15. Heads: (a) SA-516 GR70 (Matl. Spec. No., Grade or Type) (H.T. – Time & Temp) (b) SA-516 GR70 (Matl. Spec. No., Grade or Type) (H.T. – Time & Temp)

	Location (Top, Bottom, Ends)	Thickness		Radius		Elliptical Ratio	Conical Apex Angle	Hemispherical Radius	Flat Diameter	Side to Pressure		Category A		
		Min.	Corr.	Crown	Knuckle					Convex	Concave	Type	Full, Spot, None	Eff.
(a)	Top	0.1341	0.0625			2:1					X	1	None	0.70
(b)	Bottom	0.1341	0.0625			2:1					X	1	None	0.70

If removable, bolts used (describe other fastenings) SA-193 GRB7 0.5" (60) (Mat'l Spec. No. Grade, size, No.)

FORM U-4 MANUFACTURER'S DATA REPORT SUPPLEMENTARY SHEET
As Required by the Provisions of the ASME Boiler and Pressure Vessel Code Rules, Section VIII, Division 1

1. Manufactured and certified by DCR Construction, Inc. 4101 Holden Rd. Lakeland, FL 33811
(Name and address of Manufacturer)
2. Manufactured for Delta-T Corporation 133 Waller Mill Rd. Williamsburg, VA 23185
(Name and address of Purchaser)
3. Location of installation Bunge Ergon Vicksburg, LLC 1833 Haining Rd. Vicksburg, MS 39183
(Name and address)
4. Type Vertical (Horizontal vertical, or sphere) — Condenser (Tank, separator, heat exch., etc.) — 4401-7793 (Manufacturer's serial number)

N/A (CRN) — 4401-01 to 4401-23B (Drawing No.) — 223 (National Board number.) — 2007 (Year built)

Data Report Item Number	Remarks
#6	Vapor Belt sections diameter 52", length 42", material SA-240 GR304 Thickness 0.500"
	Long. joint Cat. A Type 1, None, 0.70 circumference joint Cat. A, B & C, type 1 & 2*, none, 0.70
	Includes closure ring material SA-240 GR304 Thickness 0.625" Joint UW 31.1C

Certificate of Authorization: Type: U No. 35010 Expires 3-17-08

Date 11/29/07 Name DCR Construction, Inc. (Manufacturer) Signed [signature] (Representative)

Date 11-29-07 Name [signature] (Authorized Inspector) Commission 5789 AYB FL #412 [National Board (incl. Endorsement), State, Province and number.)

DCR Construction, Inc.

EXHIBIT 11

PRESSURE TEST REPORT

Utility/Plant 7793-4401 Shell Side Job No. 7793

Material Specification SA-240, Gr. 304

Pipe Size Range 36" Diameter (O.D.) Wall Thickness Range 0.250"

Design Pressure 75 psig PSI Test Pressure 98 psig

Decrease the test pressure to the design pressure during examination unless the procedure requires a lower pressure.

Pressure Gauges Serial No. W506-α (VA06054) Max. Range 300 PSI ☆ Calibration Date 7/3/07

Pressure Gauges Serial No. N/A Max. Range N/A PSI ☆ Calibration Date N/A

☆ The calibration date must be less than twelve (12) months prior to the test date.

Testing Medium [X] Plant Water [ ] Condensate [ ] Treated Water

[ ] Demineralized Water [ ] Other ____________

Duration at Test Pressure ____________ Hours 0 Minutes 15

Remarks ____________

Test Results Acceptable

Project Manager/Superintendent ____________ Date ____________

Q.C. Inspector [signature] Date 11/28/07

Authorized Inspector [signature] Date 11/28/07

Customer Inspector [signature] Date 11/28/07

DCR Construction, Inc.

EXHIBIT 11

PRESSURE TEST REPORT

Utility/Plant 7793-4401 Tube Side   Job No. 7793

Material Specification SA-249, Gr. 304

Pipe Size Range 0.75" Diameter   Wall Thickness Range 0.049"

Design Pressure 150 psig   PSI Test Pressure 195 psig

* Tubesheets = (2)@ 39.5" x 2.5", SA-240, Gr. 304

Decrease the test pressure to the design pressure during examination unless the procedure requires a lower pressure.

Pressure Gauges Serial No. W508-08 Max. Range 300 PSI ☆ Calibration Date 7/17/07

Pressure Gauges Serial No. N/A Max. Range N/A PSI ☆ Calibration Date N/A

☆ The calibration date must be less than twelve (12) months prior to the test date.

Testing Medium [X] Plant Water [ ] Condensate [ ] Treated Water

[ ] Demineralized Water [ ] Other ______

Duration at Test Pressure ______ Hours 0 Minutes 15

Remarks ______

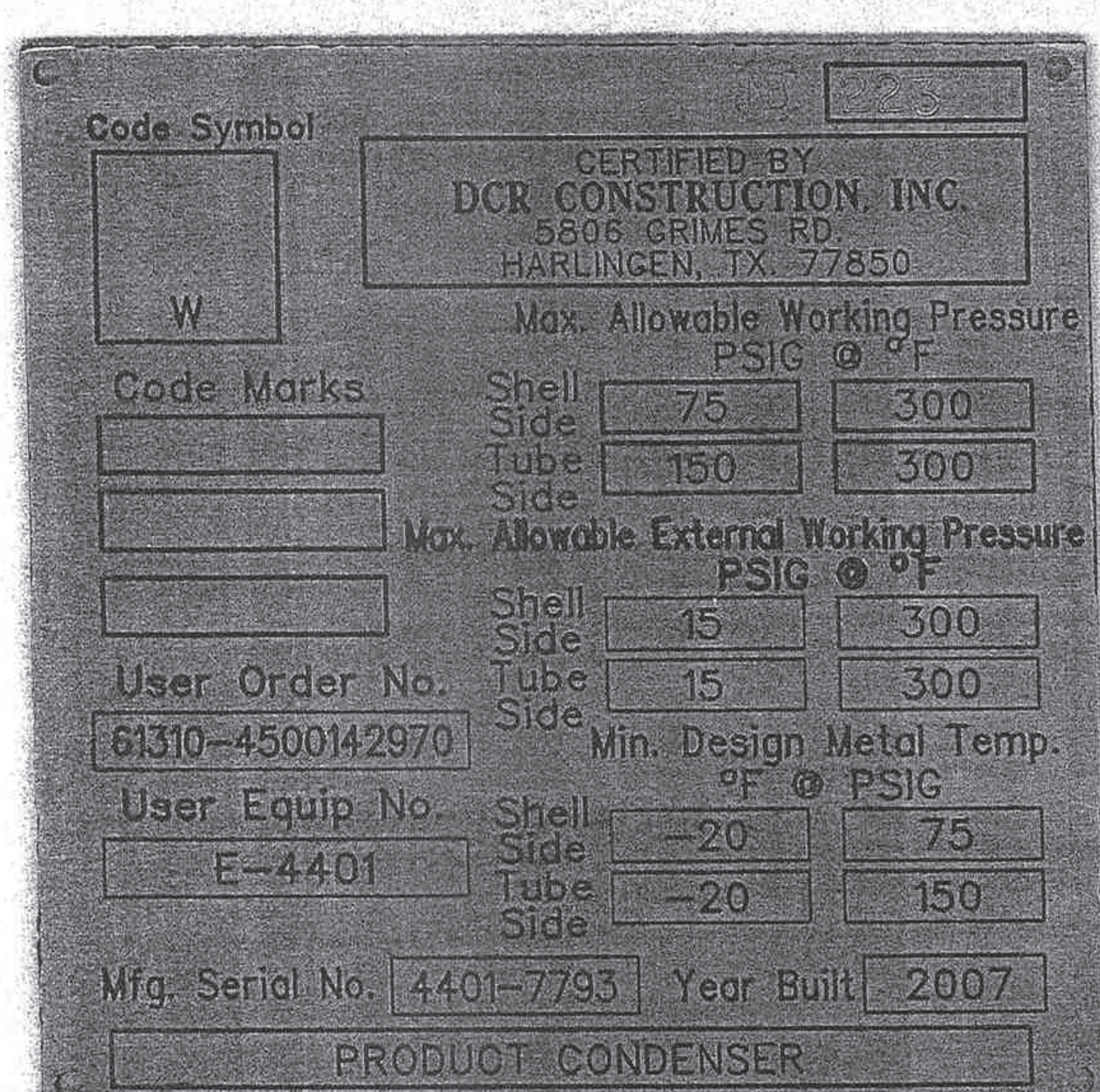
Test Results Acceptable

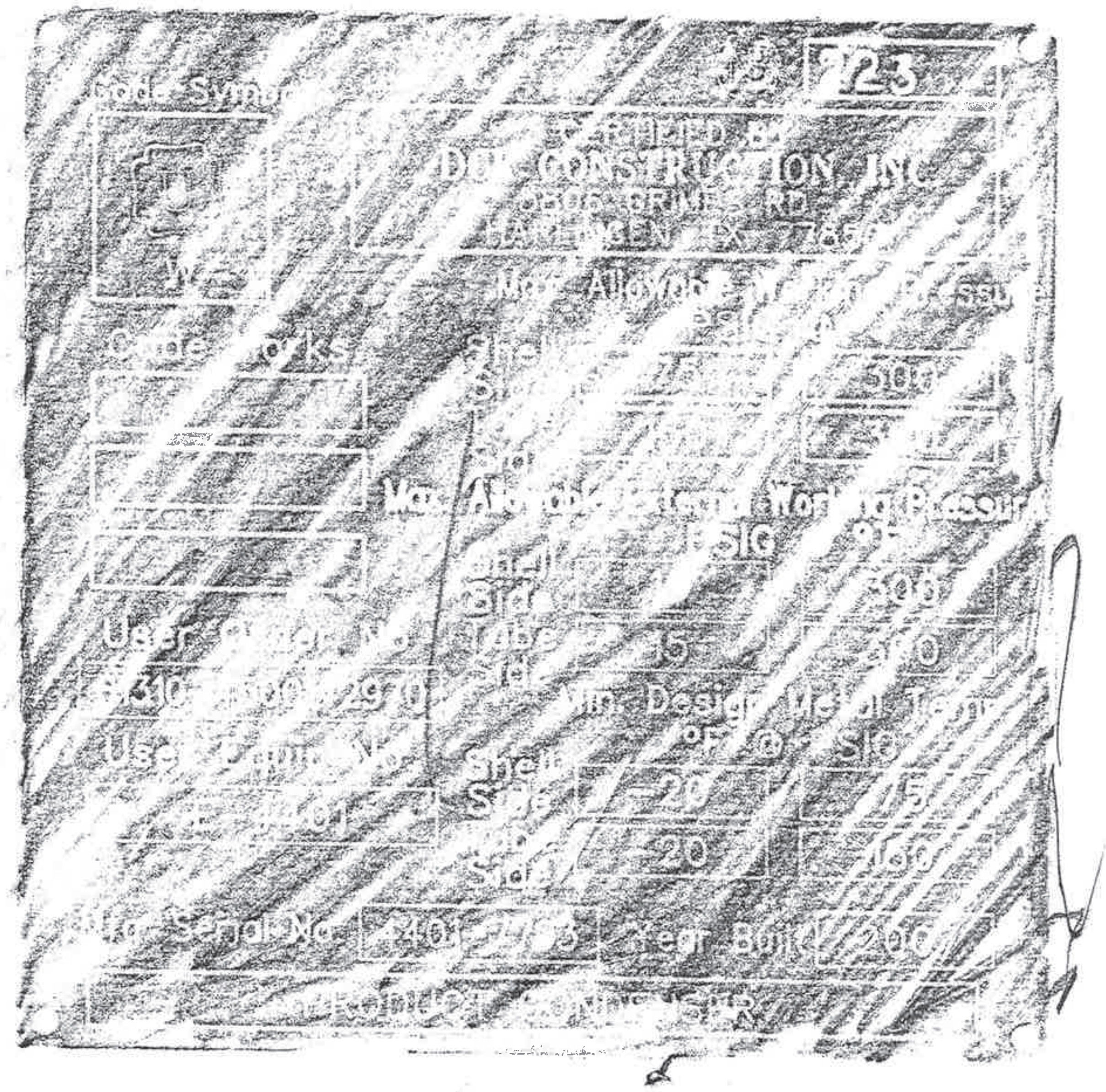
Project Manager/Superintendent ______ Date ______

Q.C. Inspector [signature] Date 11/28/07

Authorized Inspector [signature] Date 11-28-07

Customer Inspector [signature] Date 11/28/07


Code Symbol
W
CERTIFIED BY
DCR CONSTRUCTION, INC.
5806 GRIMES RD.
HARLINGEN, TX. 77850
Max. Allowable Working Pressure
PSIG @ °F
Shell Side 75 300
Tube Side 150 300
Code Marks
Max. Allowable External Working Pressure
PSIG @ °F
Shell Side 15 300
Tube Side 15 300
User Order No.
61310-4500142970
Min. Design Metal Temp.
°F @ PSIG
User Equip No.
E-4401
Shell Side -20 75
Tube Side -20 150
Mfg. Serial No. 4401-7793
Year Built 2007
PRODUCT CONDENSER



Code Symbol
723
Code Marks
Shell Side
Tube Side
Max Allowable External Working Pressure
PSIG
User Order No
User Equip No
Min. Design Metal Temp
°F @ PSIG
Mfg Serial No
Year Built

File name: E-4401-7793.BJT Date: 8/24/2007 Time: 9:11:34 AM

Design Specifications

TEMA Class		Shell Side	Tube Side	Tubesheets
Design pressure	psi	75	150	
Vacuum design pressre	psi	15	15	
Test pressure	psi	97.5	195	
Design temperature	F	300	300	300
Average metal temperature	F	128.65	114.45	128.65
Corrosion allowance	in		0.0625	
Front tubesheet corrosion allow	in			
Rear tubesheet corrosion allow	in			
Radiographing		None	None	
Number of passes		1	4	
Nozzle flange rating		150	150	
Post weld heat treatment		No	No	
Code	ASME Section VIII Div.1 2004 A06		TEMA Eighth Edition 1999	
Weights	Empty:13911	Full:22005	Bundle:8881	lbf

Cylinders/Covers

		Front Head		Shell	Rear Head		Shell Cover		Tubes
		Cover	Cyl.	Cyl.	Cyl.	Cover	Cyl.	Cover	
Head type		Ellipsoidal				Ellipsoidal			
Outside diameter	in	36	36	36	36	36			0.75
Calculated thk.	in	0.2201	0.2545	0.1018	0.2545	0.2201			0.0048
TEMA minimum thk.	in	0.375	0.375	0.25	0.375	0.375			
Actual thickness	in	0.375	0.375	0.25	0.375	0.375			0.049
X-ray		None	None	None	None	None			
Joint efficiency		None	None	None	None	None			
Corrosion allowance	in	0.0625	0.0625		0.0625	0.0625			
External pressure	psi	15	15	15	15	15			90
Length Ext.Press.	in		16.625	75	26.1875				192
Maximum Ext.Press.	psi	125.159	181.789	43.953	161.509	125.159			956.011
Minimum thk. Ext.Press.	in	0.157	0.148	0.162	0.164	0.157			0.013
Max.length Ext.Press.	in		483.5	204	483.5				580

Nozzles

Nozzle designator		A	B	C	D	G
Vessel side		Shell	Shell	Tube	Tube	Shell
Outside diameter	in	24	2.375	10.75	10.75	6.625
Calculated thickness	in	0.1173	0.0262	0.1728	0.1728	0.0362
Code minimum thk	in	0.1499	0.113	0.2427	0.2427	0.1105
Actual thickness	in	0.375	0.154	0.365	0.365	0.134
Reinf.pad OD	in					
Reinf.pad thickness	in					
Corrosion allowance	in			0.0625	0.0625	
External pressure	psi	15	15	15	15	15
Length ext. press.	in	6	6	6	6	6
Maximum ext. press.	psi	215.029	858.476	553.348	553.348	249.047

Nozzle

Flanges

Nozzle designator		A	B	C	D	G
Flange type		Slip on	Slip on	Slip on	Slip on	Slip on
Flange rating		150	150	150	150	150
Flange OD	in	32	6	16	16	11
Bolt circle	in	29.5	4.75	14.25	14.25	9.5
Bolt diameter	in	1.25	0.625	0.875	0.875	0.75
Bolt number	in	20	4	12	12	8
Gasket OD	in	27.25	3.62	12.75	12.75	8.5
Gasket width	in	1.62	0.62	1	1	0.94
Gasket thickness	in	0.125	0.125	0.125	0.125	0.125
Flange calc. thk.	in					
Flange actual thk.	in	1.88	0.75	1.19	1.19	1
Lap jnt ring OD	in					
Hub length	in					
Hub slope	in					
Weld height	in					

Body Flanges

		Front Head		Shell		Rear Head		Shell
		Cover	at TbSh	Front	Rear	at TbSh	Cover	Cover
Flange type			Ring			Ring		
Flange OD	in		39.5			39.5		
Bolt circle	in		38.25			38.25		
Bolt diameter	in		0.5			0.5		
Bolt number			60			60		
Gasket OD	in		37.25			37.25		
Gasket width	in		0.5625			0.5625		
Gasket thk.	in		0.125			0.125		
Flange calc. thk.	in		2.0625			2.0625		
Flange overlay	in							
Recess	in							
Flange act. thk.	in		2.0625			2.0625		
Lap jnt ring OD	in							
Hub length	in							
Hub slope	in							
Weld height	in		0.5			0.5		

Tubesheets

		Front	Rear
Tubesheet diameter	in	39.5	39.5
TEMA minimum thickness	in	0.5625	0.5625
TEMA bending thickness	in	1.6325	1.6325
TEMA shear thickness	in	0.223	0.223
TEMA flange extension thk	in	0.8079	0.8079
TEMA effective thickness	in	1.6875	1.6875
Code thickness	in	2.5	2.5
Corrosion allowance - shell	in		
Corrosion allowance - tube	in		
Recess	in		
Actual thickness	in	2.5	2.5
Clad thickness (not included above)	in		

Tube Details

Tube type		Plain
Tube OD	in	0.75
Tube wall thickness	in	0.049
Number of tubes		1127
Tube length	in	192
Tube pitch	in	0.9375
Tube pattern		30
Outer tube limit diameter	in	35

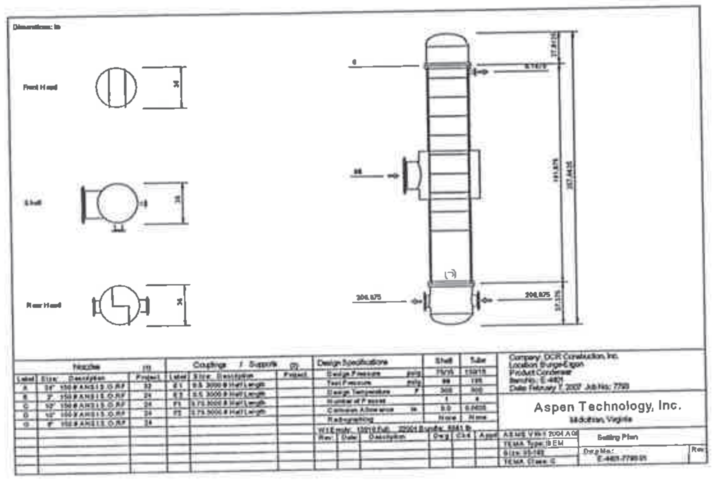
Materials of Construction

Component	Material
Shell Cylinder	SA-240 S30400 Grd 304 Plate(G5)
Front Head Cylinder	SA-516 K02700 Grd 70 Plate
Rear Head Cylinder	SA-516 K02700 Grd 70 Plate
Front Head Cover	SA-516 K02700 Grd 70 Plate
Rear Head Cover	SA-516 K02700 Grd 70 Plate
Shell Lifting Lugs	SA-36 K02600 Plate
Front Tubesheet	SA-240 S30400 Grd 304 Plate
Rear Tubesheet	SA-240 S30400 Grd 304 Plate
Front Head Flng At TS	SA-516 K02700 Grd 70 Plate
Rear Head Flng At TS	SA-516 K02700 Grd 70 Plate
Front Head Gasket At TS	Solid Teflon 1/8in Thickness
Rear Head Gasket At TS	Solid Teflon 1/8in Thickness
Tubes	SA-249 S30400 Grd TP304 Wld. tube
Baffles	SA-240 S30400 Grd 304 Plate
Tie Rods	SA-479 S30400 Grd 304 Bar
Spacers	SA-249 S30400 Grd TP304 Wld. tube(G5)
Front Head Partitions	SA-516 K02700 Grd 70 Plate
Rear Head Partitions	SA-516 K02700 Grd 70 Plate
Coupling	SA-182 S30400 Grd F304 Forgings(<= 5)(G5)
Coupling	SA-182 S30400 Grd F304 Forgings(<= 5)(G5)
Coupling	SA-182 S30400 Grd F304 Forgings(<= 5)(G5)
Coupling	SA-182 S30400 Grd F304 Forgings(<= 5)(G5)
Nozzle A	SA-312 S30400 Grd TP304 Wld. pipe
Nozzle B	SA-312 S30400 Grd TP304 Wld. pipe
Nozzle C	SA-53 K03005 Grd E/B Wld. pipe
Nozzle D	SA-53 K03005 Grd E/B Wld. pipe
Nozzle G	SA-312 S30400 Grd TP304 Wld. pipe
Nozzle Flng A	SA-182 S30400 Grd F304 Forgings(> 5)
Nozzle Flng B	SA-182 S30400 Grd F304 Forgings(> 5)
Nozzle Flng C	SA-105 K03504 Forgings
Nozzle Flng D	SA-105 K03504 Forgings
Nozzle Flng G	SA-182 S30400 Grd F304 Forgings(> 5)
Front Hd Bolting At TS	SA-193 G41400 Grd B7 Bolt(<= 2 1/2)
Rear Hd Bolting At TS	SA-193 G41400 Grd B7 Bolt(<= 2 1/2)
Distributor Belt A	SA-240 S30400 Grd 304 Plate(G5)
Nozzle Flng Bolting A	SA-193 G41400 Grd B7 Bolt(<= 2 1/2)
Nozzle Flng Bolting B	SA-193 G41400 Grd B7 Bolt(<= 2 1/2)
Nozzle Flng Bolting C	SA-193 G41400 Grd B7 Bolt(<= 2 1/2)
Nozzle Flng Bolting D	SA-193 G41400 Grd B7 Bolt(<= 2 1/2)
Nozzle Flng Bolting G	SA-193 G41400 Grd B7 Bolt(<= 2 1/2)
Nozzle Flg Gasket A	Solid Teflon 1/8in Thickness
Nozzle Flg Gasket B	Solid Teflon 1/8in Thickness

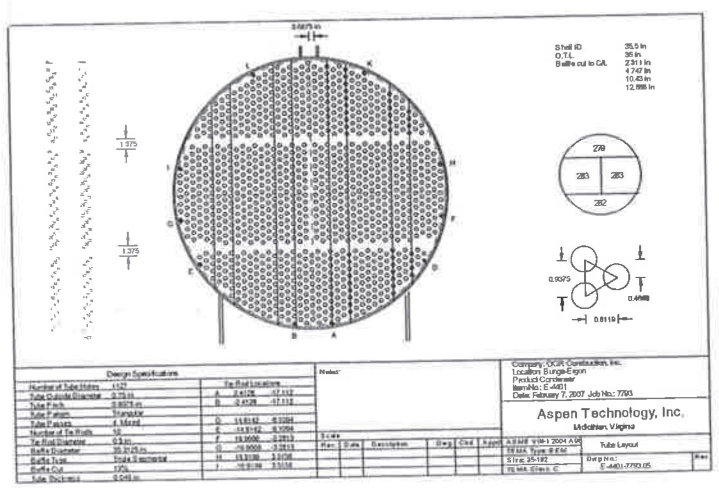
Nozzle Flg Gasket C	Solid Teflon 1/8in Thickness
Nozzle Flg Gasket D	Solid Teflon 1/8in Thickness
Nozzle Flg Gasket G	Solid Teflon 1/8in Thickness

File name: E-4401-7793.BJT Date: 8/24/2007 Time: 9:11:34 AM

Part #	Component Name	Material	Qnty	Dim1		Dim2		Thks	Wght	Cost/Unit	Mat Cost
				in		In		In	lbf	Dollar(US)	Dollar(US)
1	Shell Cylinder	SA-240 S30400 Grd 304 Plate(G5	1	112.5	ci	120	lg	0.25	1514	2.55	3865
1	Shell Cylinder	SA-240 S30400 Grd 304 Plate(G5	1	112.5	ci	67.5	lg	0.25	0	2.55	0
2	Fr Hd Cylinder	SA-516 K02700 Grd 70 Plate	1	112	ci	17	lg	0.375	202	0.45	91
3	Re Hd Cylinder	SA-516 K02700 Grd 70 Plate	1	112	ci	26.5	lg	0.375	315	0.45	141
5	Fr Hd Cover Ellip.	SA-516 K02700 Grd 70 Plate	1	47.625	lg	47.625	wi	0.4375	281	0.45	788
6	Re Hd Cover Ellip.	SA-516 K02700 Grd 70 Plate	1	47.625	lg	47.625	wi	0.4375	281	0.45	788
9	Shell Lift Lugs	SA-36 K02600 Plate	3	4	od	0		1.5	10	0.37	4
11	Front TubSh	SA-240 S30400 Grd 304 Plate	1	40.25	od	0		2.75	1005	2.55	2565
12	Rear TubSh	SA-240 S30400 Grd 304 Plate	1	40.25	od	0		2.75	1005	2.55	2565
17	Fr Hd Flng TubSh	SA-516 K02700 Grd 70 Plate	1	40.25	lg	40.25	wi	2.5	1147	0.45	515
18	Re Hd Flng TubSh	SA-516 K02700 Grd 70 Plate	1	40.25	lg	40.25	wi	2.5	1147	0.45	515
31	Fr Hd Gskt TubSh	Solid Teflon 1/8in Thickness	1	38	od	38	id	0.125	14	23	330
32	Re Hd Gskt TubSh	Solid Teflon 1/8in Thickness	1	38	od	38	id	0.125	14	23	330
38	Tubes (min wall)	SA-249 S30400 Grd TP304 Wld. t	1127	0.75	od	192	lg	0.049	7200	3.35	60475
39	Baffles	SA-240 S30400 Grd 304 Plate	9	36.0625	lg	36.063	wi	0.3125	1050	2.55	2681
40	Tie Rods	SA-479 S30400 Grd 304 Bar	14	0.5	od	176	lg	0	139	2.13	296
41	Spacers	SA-249 S30400 Grd TP304 Wld. t	104	0.75	od	33.5	lg	0.109	279	1.66	463
41	Spacers	SA-249 S30400 Grd TP304 Wld. t	18	0.75	od	16.75	lg	0.109	0	1.66	0
44	FH Partitions	SA-516 K02700 Grd 70 Plate	2	28.5625	lg	36	wi	0.5	291	0.45	131
45	RH Partitions	SA-516 K02700 Grd 70 Plate	1	38.125	lg	36	wi	0.5	393	0.45	176
45	RH Partitions	SA-516 K02700 Grd 70 Plate	2	38.125	od	18.375	lg	0.5	0	0.45	0
51	Coupling A	SA-182 S30400 Grd F304 Forging	1	0.5	od	0		0	0	20.21	7
52	Coupling B	SA-182 S30400 Grd F304 Forging	1	0.5	od	0		0	0	20.21	7
53	Coupling C	SA-182 S30400 Grd F304 Forging	1	0.75	od	0		0	1	20.21	13
54	Coupling D	SA-182 S30400 Grd F304 Forging	1	0.75	od	0		0	1	20.21	13
61	Nozzle A	SA-312 S30400 Grd TP304 Wld. p	1	24	od	6	lg	0.375	48	8.92	428
62	Nozzle B	SA-312 S30400 Grd TP304 Wld. p	1	2.375	od	6	lg	0.154	2	8.92	17
63	Nozzle C	SA-53 K03005 Grd E/B Wld. pipe	1	10.75	od	6	lg	0.365	20	0.7	14
64	Nozzle D	SA-53 K03005 Grd E/B Wld. pipe	1	10.75	od	6	lg	0.365	20	0.7	14
65	Nozzle G	SA-312 S30400 Grd TP304 Wld. p	1	6.625	od	6	lg	0.134	5	8.92	42
81	Nozzle Flng A Slip On	SA-182 S30400 Grd F304 Forging	1	150	AN	24	di	0	185	9.2	1700
82	Nozzle Flng B Slip On	SA-182 S30400 Grd F304 Forging	1	150	AN	2.375	di	0	5	9.2	47
83	Nozzle Flng C Slip On	SA-105 K03504 Forgings	1	150	AN	10.75	di	0	36	1.58	57
84	Nozzle Flng D Slip On	SA-105 K03504 Forgings	1	150	AN	10.75	di	0	36	1.58	57
85	Nozzle Flng G Slip On	SA-182 S30400 Grd F304 Forging	1	150	AN	6.625	di	0	17	9.2	157
101	Fr Hd Blts TubSh	SA-193 G41400 Grd B7 Bolt(<= 2	60	0.5	od	7	lg	0	23	2.48	58
102	Re Hd Blts TubSh	SA-193 G41400 Grd B7 Bolt(<= 2	60	0.5	od	7	lg	0	23	2.48	58
115	Distrib. Belt A	SA-240 S30400 Grd 304 Plate(G5	1	163.361	lg	42	wi	0.5	2092	2.55	5340
122	Dist.Belt An.Rng	SA-240 S30400 Grd 304 Plate(G5	2	52		0		0.625	0	0	0



Tubesheet Layout



```
Component:  Shell Cylinder
ASME Section VIII-1 2004 A06 UG-27 Thickness of Shells under Int. Pressure
--- Calculations --- Cylinder Internal Pressure
Material:  SA-240 S30400 Grd 304 Plate(G5)
Design pressure        P = 75 psi          Design temperature     T = 300 F
Radiography              = None            Joint eff.circ str.    E = 0.7
Design stress          S = 18900 psi       Joint eff.long str.    E = 0.7
Design stress, long    S = 18900 psi       (circum. butt welds)
Inside corr.allow.  CAI = 0.0 in           Outside corr. all.  CAO = 0.0 in
Material tolerance  Tol = 0.0 in           TEMA min. thickness tm = 0.25 in
Outside diameter     OD = 36.0 in          Corroded radius     OR = 18.0 in
Required wall thickness of the cylinder , greater of:
  Circumferential stress
            t = (P*OR / (S*E+0.4*P))+cai+cao+tol = 0.1018 in   APP.1-1(A)
  Longitudinal stress
          t = (P*IR / (2*S*E+0.4*P))+cai+cao+tol = 0.0503 in   UG-27(c)(2)
Actual wall thickness of cylinder:                tnom = 0.25 in
  (Required wall tks. for nozzle attachments, E=1    ,   tri = 0.0713 in )
ASME Section VIII-1 2004 A06 UG-28 Thickness of Shells under Ext. Pressure
--- Calculations --- Cylinder External Pressure
Material:  SA-240 S30400 Grd 304 Plate(G5)
Design pressure      PE = 15 psi           Design temperature   T = 300 F
Inside corr. allow. CAI = 0 in             Corrosion allow.   CAO = 0 in
Radiography             = None             Material tol.      Tol = 0 in
Cyl. outside dia.    Do = 36 in            Cylinder length EP   L = 75 in
Nominal thickness  tnom = 0.25 in          (tnom-CAI-CAO-Tol)   t = 0.25 in
L/Do ratio          Ldo = 2.0833           Do/t               Dot = 144.0
(2*S) or (0.9*yield) SE = -                Mod. of elasticity  ME = 27000000 psi
A factor SII-D-FigG   A = 0.00036          B factor HA-1        B = 4747
Max allowed external pressure: Pa = 4*B / (3*Dot)                 = 43.95 psi
Actual external design pressure:                                PE = 15 psi
   (Required cyl. tks. for nozzle attachments at PE, tre = 0.162 in  )
```

```
Component:  Front Head Cylinder
ASME Section VIII-1 2004 A06 UG-27 Thickness of Shells under Int. Pressure
--- Calculations --- Cylinder Internal Pressure
Material:  SA-516 K02700 Grd 70 Plate
Design pressure         P = 150 psi        Design temperature    T = 300 F
Radiography               = None           Joint eff.circ str.   E = 0.7
Design stress           S = 20000 psi      Joint eff.long str.   E = 0.7
Design stress, long     S = 20000 psi      (circum. butt welds)
Inside corr.allow.    CAI = 0.0625 in      Outside corr. all.  CAO = 0.0 in
Material tolerance    Tol = 0.0 in         TEMA min. thickness  tm = 0.375 in
Outside diameter       OD = 36.0 in        Corroded radius      OR = 18.0 in
Required wall thickness of the cylinder , greater of:
  Circumferential stress
        t = (P*OR / (S*E+0.4*P))+cai+cao+tol = 0.2545 in    APP.1-1(A)
  Longitudinal stress
        t = (P*IR / (2*S*E+0.4*P))+cai+cao+tol = 0.1571 in    UG-27(c)(2)
Actual wall thickness of cylinder:                tnom = 0.375 in
  (Required wall tks. for nozzle attachments, E=1    ,  tri = 0.1346 in )
ASME Section VIII-1 2004 A06 UG-28 Thickness of Shells under Ext. Pressure
--- Calculations --- Cylinder External Pressure
Material:  SA-516 K02700 Grd 70 Plate
Design pressure       PE = 15 psi          Design temperature  T = 300 F
Inside corr. allow. CAI = 0.0625 in        Corrosion allow.  CAO = 0 in
Radiography              = None            Material tol.     Tol = 0 in
Cyl. outside dia.     Do = 36 in           Cylinder length EP  L = 16.625 in
Nominal thickness   tnom = 0.375 in        (tnom-CAI-CAO-Tol)  t = 0.3125 in
L/Do ratio           Ldo = 0.4618          Do/t              Dot = 115.2
(2*S) or (0.9*yield) SE = -                Mod. of elasticity ME = 28100000 psi
A factor SII-D-FigG    A = 0.002549        B factor CS-2       B = 15707
Max allowed external pressure: Pa = 4*B / (3*Dot)                = 181.79 psi
Actual external design pressure:                              PE = 15 psi
   (Required cyl. tks. for nozzle attachments at PE, tre = 0.0855 in )
```

```
Component:  Rear Head Cylinder
ASME Section VIII-1 2004 A06 UG-27 Thickness of Shells under Int. Pressure
--- Calculations --- Cylinder Internal Pressure
Material:  SA-516 K02700 Grd 70 Plate
Design pressure        P = 150 psi          Design temperature    T = 300 F
Radiography              = None             Joint eff.circ str.   E = 0.7
Design stress          S = 20000 psi        Joint eff.long str.   E = 0.7
Design stress, long    S = 20000 psi        (circum. butt welds)
Inside corr.allow.   CAI = 0.0625 in        Outside corr. all.  CAO = 0.0 in
Material tolerance   Tol = 0.0 in           TEMA min. thickness  tm = 0.375 in
Outside diameter      OD = 36.0 in          Corroded radius      OR = 18.0 in
Required wall thickness of the cylinder , greater of:
  Circumferential stress
          t = (P*OR / (S*E+0.4*P))+cai+cao+tol = 0.2545 in    APP.1-1(A)
  Longitudinal stress
          t = (P*IR / (2*S*E+0.4*P))+cai+cao+tol = 0.1571 in    UG-27(c)(2)
Actual wall thickness of cylinder:             tnom = 0.375 in
  (Required wall tks. for nozzle attachments, E=1    ,  tri = 0.1346 in )
ASME Section VIII-1 2004 A06 UG-28 Thickness of Shells under Ext. Pressure
--- Calculations --- Cylinder External Pressure
Material:  SA-516 K02700 Grd 70 Plate
Design pressure        PE = 15 psi          Design temperature    T = 300 F
Inside corr. allow.   CAI = 0.0625 in       Corrosion allow.    CAO = 0 in
Radiography               = None            Material tol.       Tol = 0 in
Cyl. outside dia.      Do = 36 in           Cylinder length EP    L = 26.1875 in
Nominal thickness    tnom = 0.375 in        (tnom-CAI-CAO-Tol)    t = 0.3125 in
L/Do ratio            Ldo = 0.7274          Do/t                Dot = 115.2
(2*S) or (0.9*yield)  SE = -                Mod. of elasticity ME = 28100000 psi
A factor SII-D-FigG    A = 0.001554         B factor CS-2         B = 13954
Max allowed external pressure: Pa = 4*B / (3*Dot)                   = 161.51 psi
Actual external design pressure:                                 PE = 15 psi
  (Required cyl. tks. for nozzle attachments at PE, tre = 0.1015 in )
```

```
Component:  Front Head Cover
ASME Section VIII-1 2004 A06 UG-32 Formed Heads, and Sections,
                                Pressure on Concave Side
--- Calculations --- Ellipsoidal Cover Internal Pressure with t/L >= 0.002
Material:  SA-516 K02700 Grd 70 Plate
Design pressure        P = 150 psi         Design temperature  T = 300 F
Radiography              = None            Joint efficiency    E = 0.85
Design stress          S = 20000 psi       TEMA min. thk      tm = 0.375 in
Inside corr.all.     CAI = 0.0625 in       Outside corr.all. CAO = 0.0 in
Major/minor rat.    D/2h = 2.0             Forming tolerance Tol = 0.0 in
Corroded min. thk      t = 0.1341 in       Equiv.dish radius   L = 31.8375 in
Ratio t/L                = 0.00982         Material tol.     Tol = 0.0 in
Outside diameter      OD = 36.0 in         Corroded diameter  OD = 36.0 in
Proportion factor      K = 0.1667*(2+(D/2h)**2) = 1.0002
Required wall thickness of the cover:
     t = (P*OD*K / (2*S*E+2*P*(K-0.1)))+cai+cao+tol = 0.2201 in  App. 1-4(c)
Actual wall thickness of cover:                tnom = 0.375 in
   (Required wall tks. for nozzle attachments, E=1    ,  tri = 0.1341 in )
   (If opening & reinf. are within 80% of head diameter, tri = 0.1211 in )
ASME Section VIII-1 2004 A06 UG-33 Formed Heads, Pressure on Convex Side
--- Calculations --- Ellipsoidal Cover External Pressure
Material:  SA-516 K02700 Grd 70 Plate
Design pressure        PE = 15 psi        Design temperature   T = 300 F
Inside corr. allow.   CAI = 0.0625 in     Outside corr. all. CAO = 0 in
Radiography               = None          Forming tolerance  Tol = 0 in
                                          Material tolerance Tol = 0 in
Cover outside dia.     Do = 36 in         Outside sph.radius  Ro = 32.4 in
Nominal thickness    tnom = 0.375 in      tnom-CAI-CAO-Tol     t = 0.3125 in
Ko factor (UG-33.1)    Ko = 0.9           Ro/t ratio         Rot = 103.68
UG-33(a)     352.73/1.67 = 211.22 psi     Mod. of elasticity  ME = 28100000 psi
A factor = 0.125/Rot     = 0.001206       B factor CS-2        B = 12976
Maximum allowed external pressure:        Pa = B / Rot           = 125.16 psi
Actual external design pressure:                              PE = 15 psi
   (Required cov. tks. for nozzle attachments at PE, tre = 0.0945 in )
```

```
Component:  Rear Head Cover
ASME Section VIII-1 2004 A06 UG-32 Formed Heads, and Sections,
                                Pressure on Concave Side
--- Calculations --- Ellipsoidal Cover Internal Pressure with t/L >= 0.002
Material:  SA-516 K02700 Grd 70 Plate
Design pressure        P = 150 psi          Design temperature  T = 300 F
Radiography              = None             Joint efficiency    E = 0.85
Design stress          S = 20000 psi        TEMA min. thk      tm = 0.375 in
Inside corr.all.     CAI = 0.0625 in        Outside corr.all. CAO = 0.0 in
Major/minor rat.    D/2h = 2.0              Forming tolerance Tol = 0.0 in
Corroded min. thk      t = 0.1341 in        Equiv.dish radius   L = 31.8375 in
Ratio t/L                = 0.00982          Material tol.     Tol = 0.0 in
Outside diameter      OD = 36.0 in          Corroded diameter  OD = 36.0 in
Proportion factor      K = 0.1667*(2+(D/2h)**2) = 1.0002
Required wall thickness of the cover:
      t = (P*OD*K / (2*S*E+2*P*(K-0.1)))+cai+cao+tol = 0.2201 in  App. 1-4(c)
Actual wall thickness of cover:                tnom = 0.375 in
   (Required wall tks. for nozzle attachments, E=1    ,  tri = 0.1341 in )
   (If opening & reinf. are within 80% of head diameter, tri = 0.1211 in )
ASME Section VIII-1 2004 A06 UG-33 Formed Heads, Pressure on Convex Side
--- Calculations --- Ellipsoidal Cover External Pressure
Material:  SA-516 K02700 Grd 70 Plate
Design pressure        PE = 15 psi          Design temperature   T = 300 F
Inside corr. allow. CAI = 0.0625 in         Outside corr. all. CAO = 0 in
Radiography               = None            Forming tolerance  Tol = 0 in
                                            Material tolerance Tol = 0 in
Cover outside dia.    Do = 36 in            Outside sph.radius  Ro = 32.4 in
Nominal thickness   tnom = 0.375 in         tnom-CAI-CAO-Tol     t = 0.3125 in
Ko factor (UG-33.1)   Ko = 0.9              Ro/t ratio         Rot = 103.68
UG-33(a)     352.73/1.67 = 211.22 psi       Mod. of elasticity  ME = 28100000 psi
A factor = 0.125/Rot     = 0.001206         B factor CS-2        B = 12976
Maximum allowed external pressure:          Pa = B / Rot           = 125.16 psi
Actual external design pressure:                                PE = 15 psi
   (Required cov. tks. for nozzle attachments at PE, tre = 0.0945 in )
```

Component: Distributor Belt A

```
ASME Section VIII Div.1 2004 A06, Appendix 9 - Jacketed Vessels
--- Calculations --- Closure Member per Type 1 Figure 9-2.
OD of dist. belt       OD = 52.0 in       ID of dist. belt      ID = 51.0 in
Corroded jacket space  j = 7.5 in         Min. fillet weld       Y = 0.38 in
Corrosion allowance    c = 0.0 in         Min. thk.outer wall trj = 0.157 in
Required minimum thickness of closure member, trc
Figure 9-5 type:  (f-1), (f-2), (f-3)
trc = 2 * trj                             trc = 0.334 in
Actual thickness, tc                      tc  = 0.625 in
```

```
Component:  Distributor Belt A
ASME Section VIII-1 2004 A06 UG-27 Thickness of Shells under Int. Pressure
--- Calculations --- Cylinder Internal Pressure
Material:  SA-240 S30400 Grd 304 Plate(G5)
Design pressure        P = 75 psi        Design temperature    T = 300 F
Radiography              = None          Joint eff.circ str.   E = 0.7
Design stress          S = 18900 psi     Joint eff.long str.   E = 0.7
Design stress, long    S = 18900 psi     (circum. butt welds)
Inside corr.allow.   CAI = 0.0 in        Outside corr. all.  CAO = 0.0 in
Material tolerance   Tol = 0.0 in        TEMA min. thickness  tm = 0.0 in
Outside diameter      OD = 52.0 in       Corroded radius      OR = 26.0 in
Required wall thickness of the cylinder , greater of:
  Circumferential stress
           t = (P*OR / (S*E+0.4*P))+cai+cao+tol = 0.1471 in   APP.1-1(A)
  Longitudinal stress
         t = (P*IR / (2*S*E+0.4*P))+cai+cao+tol = 0.0722 in   UG-27(c)(2)
Actual wall thickness of cylinder:             tnom = 0.5 in
  (Required wall tks. for nozzle attachments, E=1    ,  tri = 0.103 in  )
ASME Section VIII-1 2004 A06 UG-28 Thickness of Shells under Ext. Pressure
--- Calculations --- Cylinder External Pressure
Material:  SA-240 S30400 Grd 304 Plate(G5)
Design pressure       PE = 15 psi          Design temperature   T = 300 F
Inside corr. allow. CAI = 0 in             Corrosion allow.   CAO = 0 in
Radiography              = None            Material tol.      Tol = 0 in
Cyl. outside dia.     Do = 52 in           Cylinder length EP   L = 42 in
Nominal thickness   tnom = 0.5 in          (tnom-CAI-CAO-Tol)   t = 0.5 in
L/Do ratio           Ldo = 0.8077          Do/t               Dot = 104.0
(2*S) or (0.9*yield) SE = -                Mod. of elasticity ME = 27000000 psi
A factor SII-D-FigG   A = 0.001605         B factor HA-1        B = 8716
Max allowed external pressure: Pa = 4*B / (3*Dot)                 = 111.74 psi
Actual external design pressure:                               PE = 15 psi
   (Required cyl. tks. for nozzle attachments at PE, tre = 0.157 in  )
```

```
Component:  Tubes
ASME Section VIII-1 2004 A06 UG-27 Thickness of Shells under Int. Pressure
--- Calculations --- Cylinder Internal Pressure
Material:  SA-249 S30400 Grd TP304 Wld. tube
Design pressure         P = 165 psi        Design temperature    T = 300 F
Radiography               = -              Joint eff.circ str.   E = 1
Design stress           S = 12700 psi      Joint eff.long str.   E = -
Design stress, long     S = -              (circum. butt welds)
Inside corr.allow.    CAI = 0.0 in         Outside corr. all.  CAO = 0.0 in
Material tolerance    Tol = 0.0 in         TEMA min. thickness  tm = 0.0 in
Outside diameter       OD = 0.75 in        Corroded radius      OR = 0.375 in
Required wall thickness of the cylinder , greater of:
  Circumferential stress
           t = (P*OR / (S*E+0.4*P))+cai+cao+tol = 0.0048 in    APP.1-1(A)
  Longitudinal stress
          t = (P*IR / (2*S*E+0.4*P))+cai+cao+tol = -             UG-27(c)(2)
Actual wall thickness of cylinder:              tnom = 0.049 in
  (Required wall tks. for nozzle attachments, E=-    ,  tri = -         )
ASME Section VIII-1 2004 A06 UG-28 Thickness of Shells under Ext. Pressure
--- Calculations --- Cylinder External Pressure
Material:  SA-249 S30400 Grd TP304 Wld. tube
Design pressure        PE = 90 psi         Design temperature    T = 300 F
Inside corr. allow. CAI = 0 in             Corrosion allow.    CAO = 0 in
Radiography               = Full           Material tol.       Tol = 0 in
Cyl. outside dia.      Do = 0.75 in        Cylinder length EP    L = 192 in
Nominal thickness    tnom = 0.049 in       (tnom-CAI-CAO-Tol)    t = 0.049 in
L/Do ratio            Ldo = 256.0          Do/t                Dot = 15.3061
(2*S) or (0.9*yield) SE = -                Mod. of elasticity   ME = 27000000 psi
A factor SII-D-FigG    A = 0.004768        B factor HA-1         B = 10975
Max allowed external pressure: Pa = 4*B / (3*Dot)                 = 956.01 psi
Actual external design pressure:                                PE = 90 psi
  (Required cyl. tks. for nozzle attachments at PE, tre = 0.013 in  )
```

```
Component: Tube-to-Tubesheet Welds
ASME Section VIII Div.1 2004 A06  UW-20 Tube-To-Tubesheet Welds
--- Calculations ---            Fig UW-20.1 Sketch (c) Full Strength
Tubesheet material:  SA-240 S30400 Grd 304 Plate
Tubesheet clad mtl:  -
Tubes material:      SA-249 S30400 Grd TP304 Wld. tube
Allowable stress TubS St = 15000 psi    All. stress tubes      Sa = 14941 psi
Allowable stress weld Sw = 14941 psi    Tube OD                do = 0.75 in
                                        Tube thickness          t = 0.049 in
Design temperature TubSh = 300 F        Design temp. tubes        = 300 F
Fille weld leg       af = 0.0625 in     Groove weld leg        ag = 0.0625 in
Minimum length ac  acmin = 0.0635 in    Total length ac = af+ag = 0.125 in
Fillet weld strength = Ff = 0.55*Pi*af*(do+0.67*af)*Sw        Ff = 1278 lbf
Groove weld strength = Fg = 0.85*Pi*ag*(do+0.67*ag)*Sw        Fg = 1975 lbf
Tube strength          Ft = Pi * t * (do - t) * Sa            Ft = 1612 lbf
Design Strength        Fd                                     Fd = 1612 lbf
Fillet weld strength, Ff = min (Ff, Ft)                       Ff = 1278 lbf
Groove weld strength, Fg = min (Fg, Ft)                       Fg = 1612 lbf
Weld strength factor fw = Sa / Sw                             fw = 1
Ratio fd = Fd / Ft                                            fd = 1
Ratio ff = 1 - Fg / (fd * Ft)                                 ff = 0
Minimum required length of the weld leg(s), ar
ar = 2*(SQRT((0.75*do)**2 + 1.07*t(do-t)*fw*fd) - 0.75*do)    ar = 0.0635 in
UW-18(d) - Allowable load on fillet/groove welds       Weld Leg = 0.125 in
               Allowable Load = PI * do * Weld Leg * Sw * 0.55 = 2420 lbf
Maximum Allowable Axial Loads, Lmax
  Pressure only = LmaxP = Ft                               LmaxP = 1612 lbf
  Other loads   = LmaxO = 2*Ft                             LmaxO = 3225 lbf
  Total weld throat dimension = 0.0885 in
```

Component: Front Pass Partition

Pass Partition Plate Max. Allowed Pressure Differential (TEMA 1999 RCB-9.132)
Pass plate material: SA-516 K02700 Grd 70 Plate

Thickness	t = 0.5 in	Allow. pressure drop	qa = 0 psi
TEMA min thk	tmin = 0.5 in		
Corrosion allowance	c = 0.0 in	Minimum thickness, tm	
Design stress	S = 20000 psi	tm = b*SQRT((qa*B)/(1.5*S))	

Max. allowable pressure drop: q = (1.5*S*((t-c)/b)**2)/B = see table below

Sides fixed	Dim a in	Dim b in	a/b	B factor	q psi	tm in	Selected
a & b	35.25	27.8125	1.267	0.431	22.5	0.0	*
a	35.25	27.8125	1.267	0.47	20.6	0.0	
b	35.25	27.8125	1.267	0.547	17.7	0.0	

Component: Rear Pass Partition

Pass Partition Plate Max. Allowed Pressure Differential (TEMA 1999 RCB-9.132)
Pass plate material: SA-516 K02700 Grd 70 Plate

Thickness	t = 0.5 in	Allow. pressure drop	qa = 0 psi
TEMA min thk	tmin = 0.5 in		
Corrosion allowance	c = 0.0 in	Minimum thickness, tm	
Design stress	S = 20000 psi	tm = b*SQRT((qa*B)/(1.5*S))	

Max. allowable pressure drop: q = (1.5*S*((t-c)/b)**2)/B = see table below

Sides fixed	Dim a in	Dim b in	a/b	B factor	q psi	tm in	Selected
a & b	37.375	35.25	1.06	0.335	18	0.0	*
a	37.375	35.25	1.06	0.432	14	0.0	
b	37.375	35.25	1.06	0.449	13.4	0.0	

```
Component:  Front Head Flng At TS
ASME Section VIII-1 2004 A06 App. 2 Bolted Flange With Ring Type Gaskets
Flange type: Optional type ring - code fig.2-4(8)
Flange material: SA-516 K02700 Grd 70 Plate
Int. design pressure   PI = 150 psi      Design temperature      T = 300 F
Ext. design pressure   PE = 15 psi       B1 = B+g1 or B+go      B1 = -
Inside corr. allow    CAI = 0.0625 in    Outside corr. all.    CAO = 0.0 in
Stress (operating)    SFO = 20000 psi    Stress (atmos.)       SFA = 20000 psi
Outside diameter        A = 39.5 in      Inside spherical rad.  L = -
Inside diameter         B = 35.375 in    Hub thickness          g1 = 0.8125 in
Bolt circle diameter    C = 38.25 in     Hub tks. at attach.    go = 0.3125 in
Mean gasket diameter    G = 36.7197 in   Weld leg/hub length     h = 0.5 in
Hub to bolt circle      R = 0.625 in     Bolt circle to OD       E = 0.625 in
Flange thickness        t = 2.0625 in
Note: Optional Type Flanges use the smaller of integral or loose calculation.
Gasket material: Solid Teflon 1/8in Thickness
Gasket outside dia.  ODG = 37.25 in      Gasket width          Wth = 0.5625 in
Gasket thickness     tks = 0.125 in      Gasket factor           m = 2.0
Gasket seating stress  y = 1600 psi      Gasket eff. width       b = 0.2652 in
Gasket rib length    Rib = 72.25 in      Seating width          bo = 0.2813 in
Gasket rib eff width  Br = 0.1875 in      (Table 2-5.2  facing 1a/1b  Col. II )
Bolt material: SA-193 G41400 Grd B7 Bolt(<= 2 1/2)
Bolt diameter        Dia = 0.5 in        No. of bolts          No. = 60
Bolt root area      Area = 0.126 in2
Stress (operating)    SB = 25000 psi     Stress (atmos.)        SA = 25000 psi
Joint-contact compr. load   HP = 6.2832*b*G*PI*m+2*Br*m*PI*RIB =    26482 lbf
Hydrostatic end force        H = 0.7854*G*G*PI                 =   158847 lbf
Hydrostatic end force       He= 0.7854*G*G*PE                  =    15885 lbf
Operating conditions:
Min. calc. bolt load       WM1 = HP+H                          =   185329 lbf
Min. used bolt load        WM1 = max of 2 mating flanges       =   185329 lbf
Bolting up conditions:
Minimum bolt load          WM2 = b*3.1416*G*Y+Br*Y*RIB         =    70617 lbf
Min. used bolt load        WM2 = max of 2 mating flanges       =    70617 lbf
Required bolt area          AM = WM2/SA or WM1/SB              =     7.41 in2
Available bolt area         AB = No.Bolt*Area                  =     7.56 in2
Design bolt load             W = 0.5*(AM+AB)*SA                =   187164 lbf
Minimum gasket width      NMIN = AB*SA/(6.283*y*G)             =    0.512 in
Gasket compression stress Gcst = AB*SA/(Pi*G*Wth)              =     2913 psi
```

```
Loads:                          Integral Flange Calculations
Operating conditions:
Hydrostatic end load             HD = 0.785*B*B*PI     = 147426 lbf
Hydrostatic end load             HDe= 0.785*B*B*PE     =  14743 lbf
Gasket load                      HG = WM1-H            =  26482 lbf
Result. hydrostatic force        HT = H-HD             =  11421 lbf
Result. hydrostatic force        HTe= He-HDe           =   1142 lbf
Bolting up conditions:
Gasket load                      HG = W                = 187164 lbf
Operating conditions:
Hydrostatic lever arm            hd = R+0.5*g1         = 1.0313 in
Gasket load lever arm            hg = (C-G)/2          = 0.7652 in
Result. hydro. lever arm         ht = (R+g1+hg)/2.0    = 1.1013 in
Bolting up conditions:
Gasket load lever arm            hg = (C-G)/2          = 0.7652 in
Operating conditions:
Hydrostatic moment               MD = HD*hd            = 152033 lbf*in
Gasket moment                    MG = HG*hg            =  20263 lbf*in
Result. hydro. moment            MT = HT*ht            =  12578 lbf*in
Total operating moment          MOP = MD+MG+MT         = 184874 lbf*in
Total operating mom. MOPe= HDe(hd-hg)+HTe(ht-hg)       =   4307 lbf*in
Bolting up conditions:
Bolt up moment                 MATM = W*hg             = 143212 lbf*in
Effective bolt moment            MB = MATM*SFO/SFA     = 143212 lbf*in
Total moment                     MO = MOP  or MB       = 184874 lbf*in
Bolt spacing correction           M = MO*Cf            = 184874 lbf*in
 (TEMA 1999 RCB-11.23) Cf= 1
Flange shape constants:
       K = A/B               = 1.1166       ho = SQ(B*G0)     = 3.3249
      TF = Fig.2-7.1         = 1.8712     h/ho = h/ho         = 0.1504
       Z = Fig.2-7.1         = 9.1033        F = Fig.2-7.2    = 0.899
       Y = Fig.2-7.1         = 17.5958       V = Fig.2-7.3    = 0.3721
       U = Fig.2-7.1         = 19.336        f = Fig.2-7.6    = 4.9874
   G1/G0 = G1/Go             = 2.6           e = F/ho         = 0.2704
       t =                   = 2.0625 in
       D = U*ho*g0*g0/V      = 16.872    Alpha = t*e+1.0      = 1.5577
    Beta = 1.333*t*e+1.0     = 1.7434    Gamma = Alpha/TF     = 0.8324
   Delta = t*t*t/D           = 0.52     Lambda = Gamma+Delta  = 1.3524
Stress calculations:                                      Allowable stress:
Long. hub      SH = (f*M)/(Lambda*g1**2*B)   =   29194 psi 1.5*SFO =   30000 psi
Radial         SR = Beta*M/(Lambda*t**2*B)   =    1584 psi     SFO =   20000 psi
Tangential    ST1 = M*Y/(t**2*B)-(Z*SR)      =    7201 psi     SFO =   20000 psi
  (greater)   ST2 = (SH+SR)/2 or (SH+ST1)/2  =   18197 psi     SFO =   20000 psi
```

Loose Flange Calculations

```
Loads:
Operating conditions:
Hydrostatic end load          HD = 0.785*B*B*PI        = 153744 lbf
Hydrostatic end load          HDe= 0.785*B*B*PE        =  15374 lbf
Gasket load                   HG = WM1-H               =  26482 lbf
Result. hydrostatic force     HT = H-HD                =   5103 lbf
Result. hydrostatic force     HTe= He-HDe              =    510 lbf
Bolting up conditions:
Gasket load                   HG = W                   = 187164 lbf
Operating conditions:
Hydrostatic lever arm         hd = (C-B)/2.0           = 1.0625 in
Gasket load lever arm         hg = (C-G)/2             = 0.7652 in
Result. hydro. lever arm      ht = (hd+hg)/2.0         = 0.9138 in
Bolting up conditions:
Gasket load lever arm         hg = (C-G)/2             = 0.7652 in
Operating conditions:
Hydrostatic moment            MD = HD*hd               = 163353 lbf*in
Gasket moment                 MG = HG*hg               =  20263 lbf*in
Result. hydro. moment         MT = HT*ht               =   4664 lbf*in
Total operating moment       MOP = MD+MG+MT            = 188279 lbf*in
Total operating mom. MOPe= HDe(hd-hg)+HTe(ht-hg)       =   4647 lbf*in
Bolting up conditions:
Bolt up moment              MATM = W*hg                = 143212 lbf*in
Effective bolt moment         MB = MATM*SFO/SFA        = 143212 lbf*in
Total moment                  MO = MOP  or MB          = 188279 lbf*in
Bolt spacing correction        M = MO*Cf               = 188279 lbf*in
 (TEMA 1999 RCB-11.23) Cf= 1
Flange shape constants:
       B =                = 36.125 in
       K = A/B            = 1.0934
       Y = Fig.2-7.1      = 21.6647
Flange calculated thickness:      t = (M*Y/SFO*B)**0.5 = 2.3761 in
Flange nominal thickness:                   tnom = 2.0625 in
Stress calculations:                           Allowable stess:
Tangential, ST = MO*Cf*Y/(B*tnom**2) = 19005 psi      SFO = 20000 psi
```

Component: Front Head Flng At TS

```
ASME Section VIII Div.1 2004 A06, Appendix 2, 2-14 Flange Rigidity
--- Calculations ---
Operating moment,     Mo = 184874 lbf*in Gasket seat. moment Ma = 143212 lbf*in
Factor V               V = 0.372         Factor L                L = 1.3524
Mod. elast.design T   Ed = 28100000 psi  Mod.elast.atm. temp Ea = 29300000 psi
Thickness g0          g0 = 0.3125 in     Factor h0              h0 = 3.3249 in
Factor KI             KI = 0.3           Factor KL              KL = 0.2
Corrosion allowance   ca = 0.0625 in     Factor K                K = 1.1166
Thickness, T           T = 2.0625 in
Rigidity index, J, loose flange type
Gasket seating    J = 109.4 * Ma / (E * T ** 3 * Ln(K) * KL) = -
Operating         J = 109.4 * Mo / (E * T ** 3 * Ln(K) * KL) = -
Rigidity index, J, integral flange type
Gasket seating    J = 52.14 * Ma * V / (L * E * G0 ** 2 * ho * KI) = 0.7199
Operating         J = 52.14 * Mo * V / (L * E * G0 ** 2 * ho * KI) = 0.969
```

```
Component:  Rear Head Flng At TS
ASME Section VIII-1 2004 A06 App. 2 Bolted Flange With Ring Type Gaskets
Flange type: Optional type ring - code fig.2-4(8)
Flange material: SA-516 K02700 Grd 70 Plate
Int. design pressure  PI = 150 psi       Design temperature      T = 300 F
Ext. design pressure  PE = 15 psi        B1 = B+g1 or B+go      B1 = -
Inside corr. allow   CAI = 0.0625 in     Outside corr. all.    CAO = 0.0 in
Stress (operating)   SFO = 20000 psi     Stress (atmos.)       SFA = 20000 psi
Outside diameter       A = 39.5 in       Inside spherical rad.  L = -
Inside diameter        B = 35.375 in     Hub thickness         g1 = 0.8125 in
Bolt circle diameter   C = 38.25 in      Hub tks. at attach.   go = 0.3125 in
Mean gasket diameter   G = 36.7197 in    Weld leg/hub length    h = 0.5 in
Hub to bolt circle     R = 0.625 in      Bolt circle to OD      E = 0.625 in
Flange thickness       t = 2.0625 in
Note: Optional Type Flanges use the smaller of integral or loose calculation.
Gasket material: Solid Teflon 1/8in Thickness
Gasket outside dia.  ODG = 37.25 in      Gasket width          Wth = 0.5625 in
Gasket thickness     tks = 0.125 in      Gasket factor           m = 2.0
Gasket seating stress  y = 1600 psi      Gasket eff. width       b = 0.2652 in
Gasket rib length    Rib = 72.25 in      Seating width          bo = 0.2813 in
Gasket rib eff width  Br = 0.1875 in      (Table 2-5.2  facing 1a/1b  Col. II )
Bolt material: SA-193 G41400 Grd B7 Bolt(<= 2 1/2)
Bolt diameter        Dia = 0.5 in        No. of bolts          No. = 60
Bolt root area      Area = 0.126 in2
Stress (operating)    SB = 25000 psi     Stress (atmos.)        SA = 25000 psi
Joint-contact compr. load   HP = 6.2832*b*G*PI*m+2*Br*m*PI*RIB =   26482 lbf
Hydrostatic end force        H = 0.7854*G*G*PI                =  158847 lbf
Hydrostatic end force       He= 0.7854*G*G*PE                 =   15885 lbf
Operating conditions:
Min. calc. bolt load       WM1 = HP+H                         =  185329 lbf
Min. used bolt load        WM1 = max of 2 mating flanges      =  185329 lbf
Bolting up conditions:
Minimum bolt load          WM2 = b*3.1416*G*Y+Br*Y*RIB        =   70617 lbf
Min. used bolt load        WM2 = max of 2 mating flanges      =   70617 lbf
Required bolt area          AM = WM2/SA or WM1/SB             =    7.41 in2
Available bolt area         AB = No.Bolt*Area                 =    7.56 in2
Design bolt load             W = 0.5*(AM+AB)*SA               =  187164 lbf
Minimum gasket width      NMIN = AB*SA/(6.283*y*G)            =   0.512 in
Gasket compression stress Gcst = AB*SA/(Pi*G*Wth)             =    2913 psi
```

```
Loads:                    Integral Flange Calculations
Operating conditions:
Hydrostatic end load        HD = 0.785*B*B*PI      = 147426 lbf
Hydrostatic end load        HDe= 0.785*B*B*PE      =  14743 lbf
Gasket load                 HG = WM1-H             =  26482 lbf
Result. hydrostatic force   HT = H-HD              =  11421 lbf
Result. hydrostatic force   HTe= He-HDe            =   1142 lbf
Bolting up conditions:
Gasket load                 HG = W                 = 187164 lbf
Operating conditions:
Hydrostatic lever arm       hd = R+0.5*g1          = 1.0313 in
Gasket load lever arm       hg = (C-G)/2           = 0.7652 in
Result. hydro. lever arm    ht = (R+g1+hg)/2.0     = 1.1013 in
Bolting up conditions:
Gasket load lever arm       hg = (C-G)/2           = 0.7652 in
Operating conditions:
Hydrostatic moment          MD = HD*hd             = 152033 lbf*in
Gasket moment               MG = HG*hg             =  20263 lbf*in
Result. hydro. moment       MT = HT*ht             =  12578 lbf*in
Total operating moment     MOP = MD+MG+MT          = 184874 lbf*in
Total operating mom. MOPe= HDe(hd-hg)+HTe(ht-hg)   =   4307 lbf*in
Bolting up conditions:
Bolt up moment            MATM = W*hg              = 143212 lbf*in
Effective bolt moment       MB = MATM*SFO/SFA      = 143212 lbf*in
Total moment                MO = MOP  or MB        = 184874 lbf*in
Bolt spacing correction      M = MO*Cf             = 184874 lbf*in
 (TEMA 1999 RCB-11.23) Cf= 1
Flange shape constants:
       K = A/B           = 1.1166       ho = SQ(B*G0)     = 3.3249
      TF = Fig.2-7.1     = 1.8712    h/ho = h/ho          = 0.1504
       Z = Fig.2-7.1     = 9.1033        F = Fig.2-7.2    = 0.899
       Y = Fig.2-7.1     = 17.5958       V = Fig.2-7.3    = 0.3721
       U = Fig.2-7.1     = 19.336        f = Fig.2-7.6    = 4.9874
   G1/G0 = G1/Go         = 2.6           e = F/ho         = 0.2704
       t =               = 2.0625 in
       D = U*ho*g0*g0/V  = 16.872     Alpha = t*e+1.0     = 1.5577
    Beta = 1.333*t*e+1.0 = 1.7434     Gamma = Alpha/TF    = 0.8324
   Delta = t*t*t/D       = 0.52      Lambda = Gamma+Delta = 1.3524
Stress calculations:                               Allowable stress:
Long. hub      SH = (f*M)/(Lambda*g1**2*B)  =   29194 psi 1.5*SFO =   30000 psi
Radial         SR = Beta*M/(Lambda*t**2*B)  =    1584 psi     SFO =   20000 psi
Tangential    ST1 = M*Y/(t**2*B)-(Z*SR)     =    7201 psi     SFO =   20000 psi
  (greater)   ST2 = (SH+SR)/2 or (SH+ST1)/2 =   18197 psi     SFO =   20000 psi
```

Loads: **Loose Flange Calculations**

```
Operating conditions:
Hydrostatic end load          HD = 0.785*B*B*PI      = 153744 lbf
Hydrostatic end load          HDe= 0.785*B*B*PE      =  15374 lbf
Gasket load                   HG = WM1-H             =  26482 lbf
Result. hydrostatic force     HT = H-HD              =   5103 lbf
Result. hydrostatic force     HTe= He-HDe            =    510 lbf
Bolting up conditions:
Gasket load                   HG = W                 = 187164 lbf
Operating conditions:
Hydrostatic lever arm         hd = (C-B)/2.0         = 1.0625 in
Gasket load lever arm         hg = (C-G)/2           = 0.7652 in
Result. hydro. lever arm      ht = (hd+hg)/2.0       = 0.9138 in
Bolting up conditions:
Gasket load lever arm         hg = (C-G)/2           = 0.7652 in
Operating conditions:
Hydrostatic moment            MD = HD*hd             = 163353 lbf*in
Gasket moment                 MG = HG*hg             =  20263 lbf*in
Result. hydro. moment         MT = HT*ht             =   4664 lbf*in
Total operating moment       MOP = MD+MG+MT          = 188279 lbf*in
Total operating mom. MOPe= HDe(hd-hg)+HTe(ht-hg)     =   4647 lbf*in
Bolting up conditions:
Bolt up moment              MATM = W*hg              = 143212 lbf*in
Effective bolt moment         MB = MATM*SFO/SFA      = 143212 lbf*in
Total moment                  MO = MOP  or MB        = 188279 lbf*in
Bolt spacing correction        M = MO*Cf             = 188279 lbf*in
 (TEMA 1999 RCB-11.23) Cf= 1
Flange shape constants:
      B =               = 36.125 in
      K = A/B           = 1.0934
      Y = Fig.2-7.1     = 21.6647
Flange calculated thickness:     t = (M*Y/SFO*B)**0.5 = 2.3761 in
Flange nominal thickness:                      tnom = 2.0625 in
Stress calculations:                               Allowable stess:
Tangential, ST = MO*Cf*Y/(B*tnom**2) = 19005 psi    SFO = 20000 psi
```

Component: Rear Head Flng At TS

```
ASME Section VIII Div.1 2004 A06, Appendix 2, 2-14 Flange Rigidity
--- Calculations ---
Operating moment,    Mo = 184874 lbf*in Gasket seat. moment Ma = 143212 lbf*in
Factor V              V = 0.372         Factor L              L = 1.3524
Mod. elast.design T  Ed = 28100000 psi  Mod.elast.atm. temp Ea = 29300000 psi
Thickness g0         g0 = 0.3125 in     Factor h0            h0 = 3.3249 in
Factor KI            KI = 0.3           Factor KL            KL = 0.2
Corrosion allowance  ca = 0.0625 in     Factor K              K = 1.1166
Thickness, T          T = 2.0625 in
Rigidity index, J, loose flange type
Gasket seating  J = 109.4 * Ma / (E * T ** 3 * Ln(K) * KL) = -
Operating       J = 109.4 * Mo / (E * T ** 3 * Ln(K) * KL) = -
Rigidity index, J, integral flange type
Gasket seating  J = 52.14 * Ma * V / (L * E * G0 ** 2 * ho * KI) = 0.7199
Operating       J = 52.14 * Mo * V / (L * E * G0 ** 2 * ho * KI) = 0.969
```

Component: Tubesheets

Tubesheet Details - TEMA 1999 Design

Materials of construction

Shell:	SA-240 S30400 Grd 304 Plate(G5)
Channel:	SA-516 K02700 Grd 70 Plate
Tubesheet:	SA-240 S30400 Grd 304 Plate
Tubes:	SA-249 S30400 Grd TP304 Wld. tube

Design conditions		Shell	Channel	Tubesheet	Tubes
Design pressure	psi	90	165		
Design temperature	F	300	300	300	300
Allowable stress	psi	18900		15000	14941
Mean metal temp.	F	128.6		128.6	114.4
Mod.of elas/M.M.T.	psi	27984192		27984192	28060654
Coef.th.exp/M.M.T.	in/in/F	0.0000087			0.0000086
Corrosion allowance	in	0.0	0.0625		
Yield stress, Sy	psi				22400

RCB-7.134 Tubesheet Formula - Tubesheet Flange Extension
RCB-7.1341 Fixed Tubesheet or Floating Tubesheet Exchangers

Design temperature TS	= 300 F	TS allowable stress	S = 15000 psi
Tubesheet OD	A = 39.5 in	Reaction diameter	G = 35.5 in
Ratio A/G	r = 1.1127		
Equivalent diameter	DL = 22.9244 in	Flange moment	M = 184874 lbf*in

```
                ( M * (r**2 - 1 + 3.71 * r**2 * Ln(r)   )**1/2
Tr = 0.98 *     (--------------------------------------  )          = 0.8079 in
                (   S * (A - G) * (1 + 1.86 * r**2)      )
```

Relative expansion between shell and tubes (TEMA T-4.5)
Shell metal temp. Thetas = 58.6 F   Tube metal temp. Thetat = 44.4 F
Tube length   L = 192.0 in
DeltaL = (Alphas*Thetas-Alphat*Thetat)*L = 0.0242 in

Component: Tubesheets

Tubesheet Details - TEMA 1999 Design
RCB-7.13 Required Effective Tubesheet Thickness
Tubesheet details with effective thicknesses (no corrosion added), in
Effective thickness definition as per TEMA 1999 RCB-7.12
Corroded conditions refer to head and shell dimensions only
Bending : T = (F*G/3)*Sqrt(P/Eta*S) Factor Eta = 0.4195
Shear : T = 0.31*DL*(P/S)/(1-do/Pitch)

	-Without exp.joint-		-- With exp.joint --	
	Uncorroded	Corroded	Uncorroded	Corroded
User specified thickness	2.5	2.5	2.5	2.5
Effective thickness, T :	1.6875	1.6875	0.0	0.0
Req. tks. shell side (bending):	0.8679	0.8679	0.0	0.0
Req. tks. tube side (bending) :	1.6325	1.6325	0.0	0.0
Req. tks. shell side (shear) :	0.0798	0.0798	0.0	0.0
Req. tks. tube side (shear) :	0.223	0.223	0.0	0.0

Shell and tube stresses, tube-to-TS loads and effective pressures
Stresses, psi (* means stress exceeds allowable)

	-Without exp.joint-		-- With exp.joint --	
	Uncorroded	Corroded	Uncorroded	Corroded
Shell longitudinal stress =	3737	3737	0	0
Shell compressive stress =	-1711	-1711	0	0
Tube longitudinal stress =	2811	2811	0	0
Tube compressive stress =	-939	-939	0	0
Tube-to-tubesheet load, lbf				
Tube-to-tubesheet load Wj =	303	303	0	0
Effective pressures P, psi				
Eff.pres.shell side (bend.)=	33.9	33.9	0	0
Eff.pres.tube side (bend.) =	119.8	119.8	0	0
Eff.pres.shell side (shear)=	33.7	33.7	0	0
Eff.pres.tube side (shear) =	94.2	94.2	0	0

Component: Tubesheets
Tubesheet Details - TEMA 1999 Design
RCB-7.161 Equivalent Differential Expansion Pressure, Pd, psi

Tube OD	do = 0.75 in	Tube thickness	tt = 0.049 in
Tube Number	N = 1127	Tube pitch	pitch = 0.9375 in
Tube Length	Lt = 192.0 in	Mod.of Elasticity	E = 27984192 psi
Mod.of Elasticity	Es = 27984192 psi	Mod.of Elasticity	Et = 28060654 psi

Pd = 4*J*Es*ts*(DeltaL/Lt)/(Do-3*ts)*(1+J*K*Fq)
J = Sj*L/Sj*L+Pi*(Do-ts)*ts*Es K = Es*ts*(Do-ts)/Et*tt*N*(do-tt)
Fq = 0.25+(F-0.6)*((300*ts*Es/K*L*E)*(G/T)**3)**0.25

Units: in		-Without exp.joint- Uncorroded	Corroded	-- With exp.joint -- Uncorroded	Corroded
Factor F shell side	F = Fs =	1.0	1.0	1.0	1.0
Factor F tube side	F = Ft =	1.0	1.0	1.0	1.0
Dia. G shell side	G = Gs =	35.5	35.5	35.5	35.5
Dia. G tube side	G = Gt =	35.5	35.5	35.5	35.5
Shell OD	Do =	36.0	36.0	36.0	36.0
Shell thickness	ts =	0.25	0.25	0.25	0.25
Spring rate, lbf/in	Sj =	-	-	0	0
Stiffness multiplier	K =	-	-	0	0
Effective tube length	L =	188.6	188.6	0	0
J=1;w/o Exp.Joint	J =	1.0	1.0	0.0	0.0
J=0;Sj< (Do-ts)*ts*Es/10*L	=	0	0	0	0
Rigidity factor K	K =	0.2302	0.2302	0.2302	0.2302
	Fq =	4.7542	4.7542	0.0	0.0
	Pd =	47.9	47.9	0	0

Component: Tubesheets
Tubesheet Details - TEMA 1999 Design
RCB-7.162 Equivalent Bolting Pressure, Pb, psi

	-Without exp.joint-		-- With exp.joint --	
	Uncorroded	Corroded	Uncorroded	Corroded
Equiv. bolting pressure Pbt =	25.6	25.6	25.6	25.6
Equiv. bolting pressure Pbs =	19.8	19.8	19.8	19.8

Operating moment M1 = 184874 lbf*in Bolting-up moment M2 = 143212 lbf*in

```
                     6.2 * M1                             6.2 * M2
Operating - Pbt = ------------        Bolting up - Pbs = -------------
                  F**2 * Gs**3                           F**2 * Gs**3
```

RCB-7.163 Effective Shell Side Design Pressure, P, psi

	-Without exp.joint-		-- With exp.joint --	
	Uncorroded	Corroded	Uncorroded	Corroded
P = (Ps'-Pd)/2	-7.1	-7.1	0	0
P = Ps'	33.7	33.7	0	0
P = PBs	19.8	19.8	0	0
P = (Ps'-Pd-PBs)/2	-17	-17	0	0
P = (PBs+Pd)/2	33.9	33.9	0	0
P = Ps'-PBs	13.8	13.8	0	0
G = Gs = Shell I.D., in	35.5	35.5	35.5	35.5
fs = 1-N*(do/G)**2	0.497	0.497	0.497	0.497
Dj = expansion joint ID, in	35.5	35.5	0.0	0.0
Ps' =	33.7	33.7	0	0

```
            0.4*J*(1.5+K*(1.5+fs))-((1-J)/2)*(Dj**2/G**2-1))
Ps' = Ps * ------------------------------------------------
                          1 + J * K * Fq
```

Component: Tubesheets

Tubesheet Details - TEMA 1999 Design

RCB-7.164 Effective Tube Side Design Pressure, P, psi

	-Without exp.joint- Uncorroded	Corroded	-- With exp.joint -- Uncorroded	Corroded
If Ps' is positive:				
P = (Pt'+PBt+Pd)/2	83.8	83.8	0	0
P = Pt'+PBt	119.8	119.8	0	0
If Ps' is negative:				
P = (Pt'-Ps'+PBt+Pd)/2	67	67	0	0
P = Pt'-Ps'+PBt	86.1	86.1	0	0
When J=0 and Ps and Pt are both positive:				
P = Pt+(Ps/2)*((Dj/G)**2-1)+PBt	0	0	0	0
G = Gs = shell I.D., in	35.5	35.5	35.5	35.5
ft = 1-N*((do-2*tt)/G)**2	0.6198	0.6198	0.6198	0.6198
Pt' =	94.2	94.2	0	0

$$Pt' = Pt * \frac{1 + 0.4 * J * K * (1.5 + ft)}{1 + J * K * Fq}$$

RCB-7.22 Shell Longitudinal Stress, Ss, psi

Ss = (Cs * (Do - ts) * (Ps*)) / 4 * ts

	-Without exp.joint- Uncorroded	Corroded	-- With exp.joint -- Uncorroded	Corroded
Tensile stress (shell), psi				
Allowable stress	18900	18900	18900	18900
Tensile stress Ss =	3737	3737	0	0
Compressive stress (shell), psi				
Allowable stress	8920	8920	8920	8920
Compressive stress Ss =	-1711	-1711	0	0
Effective pressure, Ps*, psi				
Ps* = Pt-Pt'	70.8	70.8	0	0
Ps* = Ps'	33.7	33.7	0	0
Ps* = -Pd	-47.9	-47.9	0	0
Ps* = Pt-Pt'+Ps'	104.5	104.5	0	0
Ps* = Pt-Pt'-Pd	23	23	0	0
Ps* = Ps'-Pd	-14.2	-14.2	0	0
Ps* = Pt-Pt'+Ps'-Pd	56.7	56.7	0	0

Component: Tubesheets

Tubesheet Details - TEMA 1999 Design

RCB-7.23 Tube Longitudinal Stress-Periphery of Bundle, St, psi

St = (Ct * Fq * (Pt*) * G**2) / 4 * N * tt * (do-tt)

	-Without exp.joint- Uncorroded	Corroded	-- With exp.joint -- Uncorroded	Corroded
G = Gs = Shell I:D., in	35.5	35.5	35.5	35.5
Fs = 3.25-0.5*Fq	1.25	1.25	0	0
Tensile stress (tubes), psi				
Allowable stress	14941	14941	14941	14941
Tensile stress St =	2810.6	2810.6	0	0
Compressive stress (tubes), psi				
Allowable stress Sc =	6191	6191	0	0
Compressive stress St =	-939.3	-939.3	0	0
Intermediate pressures, P2 and P3, psi				
P2 = Pt'-(ft*Pt/Fq)	72.6	72.6	0	0
P3 = Ps'-(fs*Ps/Fq)	24.3	24.3	0	0

RCB-7.23 Tube Longitudinal Stress-Periphery of Bundle (Continued), St, psi

Effective pressure, Pt*, psi	-Without exp.joint- Uncorroded	Corroded	-- With exp.joint -- Uncorroded	Corroded
Pt* = P2	72.6	72.6	0	0
Pt* = -P3	-24.3	-24.3	0	0
Pt* = Pd	47.9	47.9	0	0
Pt* = P2-P3	48.4	48.4	0	0
Pt* = P2+Pd	120.5	120.5	0	0
Pt* = -P3+Pd	23.6	23.6	0	0
Pt* = P2-P3+Pd	96.2	96.2	0	0

RCB-7.24 Allowable Tube Compressive Stress-Periphery of Bundle, Sc, psi

Sc = Pi**2 * Et/(Fs*(kl/r)**2 when Cc <= kl/r k = 0.80
Sc = (Sy/Fs)*(1-(kl/r)/(2*Cc)) when Cc > kl/r l = 58.75 in
Cc = Sqrt(2*Pi**2*Et/Sy) Cc = 157.3 kl/r = 189.18
r = 0.25*Sqrt(do**2+(do-2*tt)**2) = 0.2484 in

Component: Tubesheets

Tubesheet Details - TEMA 1999 Design

RCB-7.25 Tube-to-Tubesheet Joint Loads-Periphery of Bundle, Wj, lbf

Wj = Pi * Fq * (Pt*) G**2 / (4 * N)

	-Without exp.joint-		-- With exp.joint --	
	Uncorroded	Corroded	Uncorroded	Corroded
G = Gs = Shell I.D., in	35.5	35.5	35.5	35.5
Tube-to-tubesheet load, Wj	303.3	303.3	0	0
Effective pressure, Pt*, psi				
Pt* = P2	72.6	72.6	0	0
Pt* = -P3	-24.3	-24.3	0	0
Pt* = P2-P3	48.4	48.4	0	0

RCB-7.25 Tube-to-Tubesheet Joint Loads-Periphery of Bundle (cont.), Wj, lbf

Allowable Loads per ASME Section VIII Div. 1 2004 A06 Appendix A

Type	Joint description	No Test fr	No Test Lmax	Test fr	Test Lmax
a	Strength welded only	0.8	1290	1	1612
b	Seal welded only	0.55	887	0.7	1129
e	Strength welded and expanded	0.8	1290	1	1612
f	Seal welded and exp.with 2 grooves	0.75	1209	0.95	1532
g	Seal welded and exp.with 1 groove	0.65	1048	0.85	1370
h	Seal welded and exp.with no grooves	0.5	806	0.7	1129
i	Expanded with 2 grooves	0.7	1129	0.9	1451
j	Expanded with 1 groove	0.65	1048	0.8	1290
k	Expanded with no grooves	0.5	806	0.6	967

* = Wj calculated exceeds code allowable for this joint type.

For joints types a,b,b-1,c,d,e : Lmax = At*Sa*fr

For joints types f,g,h, : Lmax = At*Sa*fe*fr*fy

For joints types i,j,k : Lmax = At*Sa*fe*fr*fy,ft

Cross-sectional area	At = 0.1079 in2	Tube allowable stress	Sa = 14941 psi
Factor fe (1/do or 1)	fe = 1	Ratio fy	fy = 1
ft = (Po+Pt)/Po	ft = 1	Min Yield Str	SigmaM = 30000 psi
(ft = 1 if max exceeded)			
Tube OD	do = 0.75 in	Tube thickness	tt = 0.049 in
Tubes yield str(min)	st = 30000 psi	TubSh mean metal tmp	T = 128.6 F
Tubes Mod.Elasticity	EtT = 27984192 psi	TubSh Mod.Elast.	EsT = 27984192 psi
Tubes Coef.Th.Exp.	at = 0.0000087	TubSh Coef.Th.Exp.	as = 0.0000087

Po = (4*(do*t-t**2)*st)/do**2 Po = 7328 psi

Pt = ((T-Tamb)*(at-as)*(EtT*EsT)/(EtT+EsT) Pt = -

For joint types i, j, k: Po + Pt <= 0.58*SigmaM

7328 psi <= 17400 psi

```
Component: Tubesheets        Rules for the Design of Fixed Tubesheets
ASME VIII-1 2004 A06 UHX-13 Fig.UHX-13.1(b)  Controlling Case: UHX-13.4(a)(1)
*** Tubesheet material:      SA-240 S30400 Grd 304 Plate
Design temp. tubesheet T = 300 F         TubSh metal tmp at rim T'= 128.6 F
TubSh allowable stress S = 15000 psi    *TubSh th.ex.coe. alpha  = 9.2
TubSh mod.elasticity   E = 27000000 psi *TubSh th.ex.coe. alpha' = 8.7146
Poisson's rat. tubSh   v = 0.3            *(th.exp.coef * 10**6)
*** Shell material:          SA-240 S30400 Grd 304 Plate(G5)
Design temp. shell    Ts = 300 F         Shell metal tmp/TubS T's = 128.6 F
Shell allowable str.  Ss = 18900 psi    *Shell th.ex.coe.alpha's = 8.7146
Shell mod.elasticity  Es = 27000000 psi Shell mean metal tmp Tsm = 128.6 F
Poisson's ratio shell vs = 0.3          *Shell th.ex.coe.alphasm = 8.7146
*** Tube material:           SA-249 S30400 Grd TP304 Wld. tube
Design temp. tubes    Tt = 300 F         Tubes mean metal tmp Ttm = 114.4 F
Tube allow.Str. at Tt St = 14941.2 psi  Tube allow.Str. at T Stt = 14941.2 psi
Tube mod.elas. at Tt  Et = 27000000 psi Tube mod.elas. at T  Ett = 27000000 psi
Poisson's rat. tubes  vt = 0.3          *Tube th.ex.coe.alphatm  = 8.6578
Tube yield stress    Syt = 22400 psi      *(th.exp.coef * 10**6)
*** Channel material:        SA-516 K02700 Grd 70 Plate
Design temp. channel  Tc = 300 F         Channel metal tmp TS T'c = 114.4 F
Channel all. stress   Sc = 20000 psi    *Chan.th.ex.coe.alpha'c  = 6.5289
Channel mod.elast.    Ec = 28100000 psi   *(th.exp.coef * 10**6)
Poisson's rat.channel vc = 0.3
*** Adjacent shell matl:     -
Adj Shell all. str. Ss,1 = -            *Shell th.ex.coe.alpha's1= 0.0
                                        *Shell th.ex.coe.alpha'sm1=0.0
Tubesheet thickness     h = 2.5 in      Actual tubesheet thk  ha = 2.5 in
Shell side corr allow   c = 0.0 in      Tube side cor.allow.   c = 0.0625 in
SS TubSh corr allow    cs = 0.0 in      TS TubSh corr allow   ct = 0.0 in
                                  Corroded case    Uncorroded case
Shell diameter, Ds                  35.5 in          35.5 in
Channel diameter, Dc                35.375 in        35.25 in
Shell thickness, ts                 0.25 in          0.25 in
Adjacent shell thk  ts,1            0.0 in           0.0 in
Channel thickness, tc               0.3125 in        0.375 in
Minimum TubSh thk, hmin             1.5462 in        1.5462 in
Thickness h used                    2.5 in           2.5 in
Tubesheet OD            A = 39.5 in     Bolt circle diam.      C = 38.25 in
```

```
Shell gasket diam.    Gs = -                 Channel gasket diam.  Gc = 36.7197 in
Gasket reaction diam.  G = 36.7197 in       Gasket reaction diam. Gl = 36.7197 in
Number of tubes       Nt = 1127              Flange load            W = 187164 lbf
Pass partition groove hg = 0.0 in            Eff.tube side groove h'g = 0.0 in
Tube outside diam.    dt = 0.75 in           Tube thickness        tt = 0.049 in
Tube pitch             p = 0.9375 in         Center-to-center dis  UL = 1.375 in
Tube projection      tpr = 0.0625 in         Tube corrosion allow.  c = -
Tube length L          L = 186.875 in        Tube length Lt        Lt = 191.875 in
Tube expanded depth  ltx = 2.375 in          Tube exp.depth ratio rho = 0.95
Tube buckling factor   k = 0.8               Unsupported tube span  l = 58.75 in
Outermost tube rad.   ro = 17.125 in         Unsupp.length lt=k*l  lt = 47.0 in
Shell radius          as = 17.75 in          Channel radius        ac = 18.3598 in
Shell design pressure Ps = 0 psi             Tube design pressure Pt  = 165 psi
Exp.joint spring rate kj = -                        EJ diameter    Dj = -
Component: Tubesheets
           Fig.UHX-13.1(b)  Controlling Case: UHX-13.4(a)(1)
UHX-13.5.1 Step 1.  Determine Do, Mu, Mu* and h'g from UHX-11.5.1.
                                                               Do = 35.0 in
  Do = 2 * ro + dt                                             mu = 0.2
  mu = (p - dt) / p                                            d* = 0.6573 in
  d* = MAX(dt-2*tt*(Ett/E)*(Stt/S)*Rho),(dt-2*tt))        4*Do*p = 131.25 in2
  Pass lane area limit                                         AL = 112.24 in2
  Actual pass lane area, AL                                    p* = 0.9975 in
  Effective pitch = p/SQRT(1-(4*MIN[AL,4*Do*p]/Pi*Do**2))     mu* = 0.3411
  mu* = (p* - d*) / p*                                        h'g = 0.0 in
  h'g = MAX[(hg-ct),(0)]
  Calculate ao, rhos, rhoc, xs and xt
  ao = radius of the perforated region = Do / 2                ao = 17.5 in
  rhos = as/ao                                               rhos = 1.0143
  rhoc = ac/ao                                               rhoc = 1.0491
  xs = 1 - Nt(dt/(2*ao))**2                                    xs = 0.4825
  xt = 1 - Nt((dt-2*tt)/(2*ao))**2                             xt = 0.6089
```

```
UHX-13.5.2 Step 2.  Calculate the shell axial stiffness Ks, tube axial
  stiffness Kt, and stiffness factors Ks,t and J
  Shell axial stiffness, Ks = PI*ts(Ds+ts)*Es/L          Ks = 4056752 lbf/in
  Ks* = PI*(Ds+ts)/((L-2*l1)/(Es*ts)+(2*l1/(Es,1*ts,1))  Ks* = -
  Tube axial stiffness,  Kt = PI*tt(dt-tt)*Et/L          Kt = 15591 lbf/in
  Factor Ks,t = Ks/(Nt*Kt) or Ks*/(Nt*Kt)              Ks,t = 0.2309
  J = 1 / (1 + (Ks/Kj))                                   J = 1.0
  Calculate shell coefficients betas, ks, lambdas and deltas
  betas = (12*(1-vs**2))**0.25 / ((Ds+ts)*ts)**0.5      betas = 0.6081
  ks = betas*(Es*ts**3)/(6*(1-vs**2)                       ks = 46983
  lambdas=(6*Ds/h**3)*ks*(1+h*betas+(h**2*betas**2)/2) lambdas = 2354102
  deltas = (Ds**2/(4*Es*ts))*(1-vs/2)                  deltas = 0.0000396
  Calculate channel coefficients betac, kc, lambdac and deltac
  betac = (12*(1-vc**2))**0.25 / ((Dc+tc)*tc)**0.5      betac = 0
  kc = betac*(Ec*tc**3)/(6*(1-vc**2)                       kc = 0
  lambdac=(6*Dc/h**3)*kc*(1+h*betac+(h**2*betac**2)/2) lambdac = 0
  deltac = (Dc**2/(4*Ec*tc))*(1-vc/2)                  deltac = 0
  NOTE: If the effect of plasticity used, Es or Ec will be Es* or Ec*
Component: Tubesheets
           Fig.UHX-13.1(b)  Controlling Case: UHX-13.4(a)(1)
UHX-13.5.3 Step 3. Calculate h/p.  If rho changes, recalculate d* and mu*
  from UHX-11.5.1.  Determine E*/E and v* relative to h/p from UHX-11.5.2
  Layout: Triangular                  Tubesheet thickness    h = 2.5 in
  From fig. UHX-11.2 or UHX-11.3 - E*/E = 0.3353            v* = 0.3304
                                   h/p = 2.6667            mu* = 0.3411
  Effective Tubsheet Mod.Elasticity  E* = 9054420 psi
  Parameter Xa = (24*(1-v*(**2))*Nt*(Et*tt*(dt-tt)*
               ao**2)/((E*)*L*h**3))**0.25                  Xa = 4.011
UHX-13.5.4 Step 4. Calculate diameter ratio K and coefficient F.
  K = A / Do                                                 K = 1.129
  F = ((1-v*)/E*)*(lambdas+lambdac+E*Ln(K))                  F = 0.416
```

```
  Parameters Zd, Zv and Zm from Table UHX-13.1
  Psi1(Xa)=bei(Xa)+(1-v*)/Xa*ber'(Xa)                  Psi1(Xa) = 1.7611
  Psi2(Xa)=ber(Xa)-(1-v*)/Xa*bei'(Xa)                  Psi2(Xa) = -2.5117
  Za = bei'(Xa)*Psi2(Xa)-ber'(Xa)*Psi1(Xa)                   Za = 6.8515
  Zd = (ber(Xa)*Psi2(Xa)+ bei(Xa)*Psi1(Xa))/(Xa**3*Za)       Zd = 0.0239
  Zv = (ber'(Xa)*Psi2(Xa)+ bei'(Xa)*Psi1(Xa))/(Xa**2*Za)     Zv = 0.0635
  Zm = (ber'(Xa)**2+bei'(Xa)**2)/(Xa*Za)                     Zm = 0.3711
  Calculate Q1, Qz1, Qz2 and U
  Phi = (1+v*) * F                                          Phi = 0.5529
  Q1 = (rhos-1-Phi*Zv)/(1+Phi*Zm)                            Q1 = -0.0173
  Qz1 = ((Zd+Q1*Zv)*Xa**4)/2                                Qz1 = 2.9471
  Qz2 = ((Zv+Q1*Zm)*Xa**4)/2                                Qz2 = 7.391
  U = ((Zv+(rhos-1)*Zm)*Xa**4)/(1+Phi*Zm)                     U = 14.7819
UHX-13.5.5 Step 5.
UHX-13.5.5(a) Calculate gamma
  gamma = (alphatm*(Ttm-Tamb)-alphasm*(Tsm-Tamb))*L       gamma = 0.0 in
        (=0 for load cases 1, 2, 3)
UHX-13.5.5(b) Calculate omegas, omegas*, omegac, omegac*
  omegas = rhos*ks*betas*deltas*(1+h*betas)               omegas = 2.8972
  omegas* = ao**2*((rhos**2-1)*(rhos-1))/4-omegas        omegas* = -2.8658
  omegac = rhoc*kc*betac*deltac*(1+h*betac)               omegac = 0.0
  omegac* = ao**2*((rhoc**2+1)*(rhoc-1))/4-
                (rhos-1)/2-omegac                        omegac* = 5.7148
UHX-13.5.5(c) Calculate gammab
  gammab = (Gc-C)/Do                                     gammab = -0.0437
```

```
UHX-13.8.4 Calculate Ps* and Pc*.
UHX-13.8.4(a) Determine the average temperature of the unperforated rim Tr
  Tr  = (T'+T's)/2                                        Tr = 128.6 F
UHX-13.8.4(b) Determine the average temperature of the shell Ts* and
  channel Tc* at their junction to the tubesheet as follows:
  Ts* = (T's+Tr)/2                                       Ts* = 128.6 F
  Tc* = (T'c+Tr)/2                                       Tc* = 121.5 F
UHX-13.8.4(c) Calculate Ps* and Pc*
  Ps* = (Es*ts/as)*(alphas'*(Ts*-70)-alpha'*(Tr-70))     Ps* = 0 psi
  Pc* = (Ec*tc/ac)*(alphac'*(Tc*-70)-alpha'*(Tr-70))     Pc* = 0 psi
UHX-13.8.4(d) Calculate Pomega
  Pomega = (U/ao**2)(ws*(P*s)-wc*(P*c))               Pomega = 0 psi
Component: Tubesheets
         Fig.UHX-13.1(b)  Controlling Case: UHX-13.4(a)(1)
UHX-13.5.6 Step 6.  For each loading case calculate Ps', Pt', Pgamma, Pw,
  Prim, and effective pressure Pe.
  Ps' = (xs+2*(1-xs)*vt+(2/Kst)*(Ds/Do)**2*vs-            Ps' = 0 psi
        (Rhos**2-1)/(J*Kst)-((1-J)/(2*J*Kst))*
        (DJ**2-(2*as)**2)/Do**2 ) * Ps
  Pt' = (xt+2*(1-xt)*vt+1/(J*Kst))*Pt                     Pt' = 853.86 psi
  Pgamma  = (Nt*Kt/(Pi*ao**2))*gamma                   Pgamma = 0 psi
  PW      = -(U/ao**2)(gammab/(2*Pi))*W                    PW = 62.87 psi
  Prim    = -(U/ao**2)*((omegas*)(Ps)-(omegac*)(Pt))     Prim = 45.51 psi
  Effective pressure, Pe
  Pe = (J*Kst/(1+J*Kst(Qz1+(rhos-1)Qz2))
       * (Ps'-Pt'+Pgamma+Pomega+PW+Prim)                   Pe = -100.96 psi
```

UHX-13.5.7 Step 7. For each loading case calculate Q2 and Q3.

```
  Q2 = ((omegas*)*Ps-(omegac*)*Pt)-
       ((omegas*(Ps*)-omegac*(Pc*))+
       (gammab/(2*Pi))*W)/(1+Phi*Zm)                        Q2 = -1863.0881
  Q3 = Q1 + 2*Q2 / Pe*ao**2                                  Q3 = 0.1032
  Using Xa and Q3, determine coefficient Fm for each loading case from
  either Table UHX-13.1 or Figs. UHX-13.3.-1 and UHX-13.3.-2.
                                                 Controlling x = 3.1286 in
Calculate functions Psi1 and Psi2 relative to x
  Psi1(x) = bei(x) + (1-v*)/x * ber'(x)                 Psi1(x) = 1.6702
  Psi2(x) = ber(x) - (1-v*)/x * bei'(x)                 Psi2(x) = -0.6071
Calculate functions Qm, Qv and Fm relative to x
  Qm(x) = (bei'(Xa)*Psi2(x)-ber'(Xa)*Psi1(x))/Za          Qm(x) = 0.8141
  Qv(x) = (Psi1(Xa)*Psi2(x)-Psi2(Xa)*Psi1(x))/(Xa*Za)     Qv(x) = 0.1137
  Controlling Fm relative to x
  Fm(x) = (Qv(x) + Q3 * Qm(x)) / 2                        Fm(x) = 0.0989
  Fm = MAX|Fm(x)|                                            Fm = 0.0989
  For each loading case, calculate the bending stress in the tubesheet
  sigma = (1.5*Fm/mu*)*(2*ao/(h-h'g))**2 * Pe           sigma = -8606 psi
                                                     |sigma| <= 1.5*S
                                                    8606 psi <= 22500 psi
UHX-13.5.8 Step 8. For each loading case, calculate the average shear
  stress in the tubesheet at the outer edge of the perforated region
  Area enclosed by perimeter                                AL = 859.02 in2
  Perimeter of the tube layout                              CL = 149.8884 in
  Shear diameter DL = 4*AL/CL or Do                         Do = 35.0 in
  Ligament efficiency, mu                      mu = (p-dt)/p = 0.2
  Shear stress, tau = (1/(4*mu)*(Do/h)* Pe                 tau = -1767 psi
                                                       |tau| <= 0.8*S
                                                    1767 psi <= 12000 psi
```

```
UHX-13.5.9 Step 9. Perform this step for each loading case.
  UHX-13.5.9(a) Calculate coefficient Fq and the axial tube stress sigmat,o
  in the outermost tube row
                          Factor Fq = (Zd + Q3*Zv)*Xa**4/2    = 3.9379
                      sigmato = ((Ps*xs-Ptxt)-Pe*Fq)/(xt-xs) = 2350 psi
                                                sigmato <= St
                                              2350 psi <= 14941 psi

  UHX-13.5.9(b) Check the tubes for buckling.
  Ct = SQRT(2*PI**2*(Et/Syt)                           Ct = 154.2491
  rt = SQRT(dt**2+(dt-2*tt)**2)/4                      rt = 0.2484 in
  Ft = lt/rt                                           Ft = 189.1762
  Fs = MAX((1.25,(3.25-0.5*Fq),2)                      Fs = 1.2811
  For Ct <= Ft  Stb = MIN[(1/Fs)*(PI**2*Et/(Ft**2),St]  Stb = -5812 psi
  For Ct >  Ft  Stb = MIN[(Syt/Fs)*(1-(Ft/2*Ct))  ,St]  Stb = -
                                                sigmato <= Stb
                                                      - <= -5812 psi

UHX-Tube stresses at the interior of the bundle.
  Maximum tube compressive stress at the interior of the bundle
  Ft(x) = Zdx+Q3*Zwx*(Xa**4/2)
  Fi = ft(x)                                           Fi = -1.1164
  sigmati = ((Ps*xs-Ptxt)-Pe*Fi)/(xt-xs)          sigmati = -1686 psi
                                                sigmati <= Stb
                                             -1686 psi <= -5812 psi
```

UHX-13.5.10 Step 10. For each loading case, calculate the stresses in the shell and /or channel integral with the tubesheet.

```
Calculate the axial membrane stress sigmasm, axial bending stress sigmasb
and total axial stress sigmas in the shell at its junction to the tubesheet
sigmasm = ao**2/ts*(2*as+ts)*[Pe+(rhos**2-1)
          *(Ps-Pt)] + as**2/ts*(2*as+ts)*Pt          sigmasm = 2194 psi
sb1 = (6/ts**2)*ks
sb2 = betas*(deltas*Ps-vs*(as/Es)*sigmasm)
sb3 = 6*(1-(v*)**2)/(E*)*(ao**3/h**3)*(1+(h*betas/2)
sb4 = Pe*(Zv+Zm*Q1)+(2/ao**2)*Zm*Q2
sigmasb = sb1*(sb2+sb3*sb4)                          sigmasb = -17712 psi
sigmas = |sigmasm| + |sigmasb|                        sigmas = 19907 psi
                                                      sigmas <= 1.5*S
                                                   19907 psi <= 28350 psi
```

ASME VIII-1 2004 A06 UHX-13 - Rules for the Design of Fixed Tubesheets
ASME Fig.UHX-13.1(b) All Load Cases
Controlling case:

Load case:	1	2	3	4	5	6	7
Tube-side press, Pt	165	0	165	0	165	0	165
Shell-side press, Ps	0	90	90	0	0	90	90
Axial diff.Th.Exp	0.0	0.0	0.0	-0.0236	-0.0236	-0.0236	-0.0236
TubSh Bending stress	-8606	4024	-7372	-4915	-11760	-3978	-10303
Max TubSh Bending st	22500	22500	22500	57164	57164	57164	57164
Min TubSh thk	1.5462	1.0572	1.431	0.7331	1.1339	0.6595	1.0613
TubSh Shear stress	-1767	891	-1024	-900	-2801	-162	-2063
Max TubSh Shear str	12000	12000	12000	15244	15244	15244	15244
Min TubSh thk	0.3681	0.1857	0.2134	0.1476	0.4594	0.0265	0.3383
Tubesheet thickness	2.5	2.5	2.5	2.5	2.5	2.5	2.5

Component: Tubesheets
ASME Fig.UHX-13.1(b) All Load Cases
Controlling case:

Load case:	1	2	3	4	5	6	7
Tubes stress	2350	-294	1796	1691	3812	1129	3249
Max Tubes stress	14941	14941	14941	39048	39048	39048	39048
Max buckling stress	-	-3723	-	-	-	-	-
Total shell stress	19907	10266	9430	10073	22969	3992	12430
Max shell stress	28350	28350	28350	60000	60000	60000	60000
Max shell stress EP	56700	56700	56700				
Total channel stress	4806	0	4806	0	4806	0	4806
Max channel stress	30000	30000	30000	67200	67200	67200	67200
Max channel str. EP	67200	67200	67200				
EP factor - Facts(*)	1.0	1.0	1.0				
EP factor - Factc(*)	1.0	1.0	1.0	(*) <= 1 used in calculations			

Tube compressive stresses at the interior of the bundle

Load case:	1	2	3	4	5	6	7
Tubes stress	-1686	-297	-1159	-473	-1991	-	-1462
Max buckling stress	-5812	-3723	-5957	-6191	-5407	-	-6114

ASME VIII-1 2004 A06 UHX-13 - Fixed Tubesheets - All Cases

Load case	Ps psi	Pt psi	Gamma in	Ps* psi	Pc* psi
- 1 -	0	165	0	0	0
- 2 -	90	0	0	0	0
- 3 -	90	165	0	0	0
- 4 -	0	0	-0.0236	0	0
- 5 -	0	165	-0.0236	0	0
- 6 -	90	0	-0.0236	0	0
- 7 -	90	165	-0.0236	0	0

Load case	P's psi	P't psi	Pgamma psi	Pomega psi	Pw psi	Prim psi	Pe psi
- 1 -	0	853.9	0	0	62.9	45.5	-101
- 2 -	300.8	0	0	0	62.9	12.4	50.9
- 3 -	300.8	853.9	0	0	62.9	58	-58.5
- 4 -	0	0	-447.9	0	64.8	0	-51.4
- 5 -	0	855.8	-447.9	0	64.8	46.9	-160.1
- 6 -	301.4	0	-447.9	0	64.8	12.8	-9.2
- 7 -	301.4	855.8	-447.9	0	64.8	59.8	-117.9

Load case	Q2	Q3	Fm	Sigma psi	Sigma All psi	Tau psi	Tau All psi
- 1 -	-1863.1	0.1032	0.0989	-8606	22500	-1767	12000
- 2 -	-1294.7	-0.1833	0.0916	4024	22500	891	12000
- 3 -	-2077.1	0.2144	0.1461	-7372	22500	-1024	12000
- 4 -	-1070.3	0.1177	0.1036	-4915	57164	-900	15244
- 5 -	-1845.2	0.0571	0.0796	-11760	57164	-2801	15244
- 6 -	-1282.3	0.8879	0.4666	-3978	57164	-162	15244
- 7 -	-2057.1	0.0958	0.0948	-10303	57164	-2063	15244

ASME VIII-1 2004 A06 UHX-13 - Fixed Tubesheets - All Cases

Load case	Fq	Fs	Sigto psi	Sigto All psi	Stb psi
- 1 -	3.9379	1.2811	2350	14941	-5812
- 2 -	1.5823	2	-294	14941	-3723
- 3 -	4.8521	1.25	1796	14941	-5957
- 4 -	4.1556	1.25	1691	39048	-6191
- 5 -	3.6377	1.4312	3812	39048	-5407
- 6 -	10.7387	-	1129	39048	-
- 7 -	3.9684	1.2658	3249	39048	-6114

Load case	Sigsm psi	Sigsb psi	|Sigs| psi	Sigsall psi	Sigcm psi	Sigcb psi	|Sigc| psi	Sigcall psi
- 1 -	2194	-17712	19907	28350	4806	0	4806	30000
- 2 -	1834	8432	10266	28350	0	0	0	30000
- 3 -	3737	-5694	9430	28350	4806	0	4806	30000
- 4 -	-1763	-8310	10073	60000	0	0	0	67200
- 5 -	169	-22800	22969	60000	4806	0	4806	67200
- 6 -	-228	3764	3992	60000	0	0	0	67200
- 7 -	1704	-10726	12430	60000	4806	0	4806	67200

Type of tube-to-TS joint: expanded & strength welded

Load case:	1	2	3	4	5	6	7
Tube-to-TS Load, lbf	254	32	194	182	411	122	351
Allowable no-test	1290	1290	1290	2580	2580	2580	2580
Allowable test	1612	1612	1612	3225	3225	3225	3225

Allowable Loads per ASME Section VIII Div. 1 2004 A06 Appendix A

Type	Joint description	No Test fr	No Test Lmax	Test fr	Test Lmax
a	Strength welded only	0.8	1290	1	1612
b	Seal welded only	0.55	887	0.7	1129
e	Strength welded and expanded	0.8	1290	1	1612
f	Seal welded and exp.with 2 grooves	0.75	1209	0.95	1532
g	Seal welded and exp.with 1 groove	0.65	1048	0.85	1370
h	Seal welded and exp.with no grooves	0.5	806	0.7	1129
i	Expanded with 2 grooves	0.7	1129	0.9	1451
j	Expanded with 1 groove	0.65	1048	0.8	1290
k	Expanded with no grooves	0.5	806	0.6	967

* = Load calculated exceeds code allowable for this joint type.

```
For joints types a,b,b-1,c,d,e :            Lmax = At*Sa*fr
For joints types f,g,h,         :           Lmax = At*Sa*fe*fr*fy
For joints types i,j,k          :           Lmax = At*Sa*fe*fr*fy,ft
Cross-sectional area  At = 0.1079 in2  Tube allowable stress Sa = 14941 psi
Factor fe (1/do or 1) fe = 1           Ratio fy                fy = 1
ft = (Po+Pt)/Po       ft = 1           Min Yield Str     SigmaM = 30000 psi
 (ft = 1 if max exceeded)
Tube OD               do = 0.75 in     Tube thickness        tt = 0.049 in
Tubes yield str(min)  st = 30000 psi   TubSh mean metal tmp   T = 128.6 F
Tubes Mod.Elasticity EtT = 27984192 psi TubSh Mod.Elast.     EsT = 27984192 psi
Tubes Coef.Th.Exp.    at = 0.0000087   TubSh Coef.Th.Exp.    as = 0.0000087
Po = (4*(do*t-t**2)*st)/do**2                                Po = 7328 psi
Pt = ((T-Tamb)*(at-as)*(EtT*EsT)/(EtT+EsT)                   Pt = -
           For joint types i, j, k:                    Po + Pt <= 0.58*SigmaM
                                                    7328 psi <= 17400 psi
UHX-9 Tubesheet Flanged Extension
G  = diameter of gasket load reaction                 G = 36.7197 in
hG = gasket moment arm                               hG = 0.7652 in
Sa = allowable stress for tubesheet extension
        at ambient temperature                       Sa = 20000 psi
Sd = allowable stress for tubesheet extension
        at design temperature                        Sd = 15000 psi
Ta = ambient temperature                             Ta = 70 F
Td = design temperature                              Td = 300 F
Wo = flange design bolt load, opeating conditions    Wo = 185329 lbf
Wg = flange design bolt load, gasket seating         Wg = 187164 lbf
Minimum required thickness of the tubesheet flanged extension
hro = SQRT(1.9 * Wo * hG) / (Sd * G)                hro = 0.6994 in
hrg = SQRT(1.9 * Wg * hG) / (Sa * G)                hro = 0.6087 in
hr = MAX[hro, hrg]                                   hr = 0.6994 in
```

```
Component:  Nozzle A
ASME VIII-1 2004 A06 UG-27 Thickness of Cylinders under Internal Pressure
--- Calculations --- Cylinder Internal Pressure
Material:  SA-312 S30400 Grd TP304 Wld. pipe
Design pressure      P = 75 psi          Design temperature   T = 300 F
Radiography            = None            Joint efficiency     E = 0.85
Design stress        S = 15000 psi
Inside corr.allow. cai = 0.0 in          Outside corr. all. cao = 0.0 in
Material tolerance tol = 0.0469 in       Minimum thickness tmin = 0.1499 in
Outside diameter    OD = 24.0 in         Corroded radius     OR = 12.0 in
- Min. thk. not less than UG-45(a), UG-16(b), UG-45(b):
  - UG-45(a) Internal pressure:
              t = (P*OR / (S*E+0.4*P))+cai+cao+tol = 0.1173 in   APP.1-1(A)
  - UG-45(a) external pressure+cai+cao+tol       t = 0.094 in
  - UG-16(b) minimum thickness+cai+cao+tol       t = 0.1406 in
    UG-45(b) Smaller of:                         t = 0.1499 in
    UG-45(b)(4) std pipe*0.875+cai+cao+tol = 0.375 in
      - UG-45(b) Greater of:             t = 0.1499 in
        - UG-45(b)(1)+cai+cao+tol = 0.1499 in
        - UG-45(b)(2)+cai+cao+tol = 0 in
                        Minimum thickness:              tmin = 0.1499 in
                        Nominal thickness:              tnom = 0.375 in
ASME Section VIII-1 2004 A06 UG-28 Thickness of Shells under Ext. Pressure
--- Calculations --- Cylinder External Pressure
Material:  SA-312 S30400 Grd TP304 Wld. pipe
Design pressure      PE = 15 psi          Design temperature  T = 300 F
Inside corr. allow. CAI = 0 in            Corrosion allow.  CAO = 0 in
Radiography             = None            Material tol.     Tol = 0 in
Cyl. outside dia.    Do = 24 in           Cylinder length EP  L = 6 in
Nominal thickness  tnom = 0.375 in        (tnom-CAI-CAO-Tol)  t = 0.3281 in
L/Do ratio          Ldo = 0.25            Do/t              Dot = 73.1429
(2*S) or (0.9*yield) SE = -               Mod. of elasticity ME = 27000000 psi
A factor SII-D-FigG   A = 0.010953        B factor HA-1       B = 11796
Max allowed external pressure: Pa = 4*B / (3*Dot)             = 215.03 psi
Actual external design pressure:                           PE = 15 psi
   (Required cyl. tks. for nozzle attachments at PE, tre = 0.0471 in )
```

Component: Reinforcement Nozzle A

```
ASME Section VIII-1 2004 A06 UG-37  Reinforcement Required for Openings in
                                Shells and Formed Heads
--- Design Conditions:
Int. design pressure PI = 75 psi         Ext. design press.  PE = 15 psi
Design temperature    T = 300 F          Fig.UW-16.1 Sketch (c)
Vessel material: SA-240 S30400 Grd 304 Plate(G5)
Inside corr. allow. CAI = 0.0 in         Outside corr.allow.CAO = 0.0 in
Vessel design stress Sv = 18900 psi      Joint efficiency     E = 1
Vessel outside dia   Do = 52.0 in        Corroded radius     OR = 26.0 in
Nominal thickness  tnom = 0.5 in         Reinforcement limit lp = 23.25 in
Req. tks. int.pres.  tr = 0.103 in       Req. tks.ext.pres. tre = 0.157 in
Corroded thickness    t = 0.5 in         Reinf. efficiency   E1 = 1.0
Attachment Material: SA-312 S30400 Grd TP304 Wld. pipe
Inside corr. allow. CAI = 0.0 in         Outside corr.allow.CAO = 0.0 in
Nozzle design stress Sn = 15000 psi      Joint efficiency     E = 0.85
Nozzle outside dia. Don = 24.0 in        Corroded radius     OR = 12.0 in
Nominal thickness  tnom = 0.375 in       Reinforcement limit ln = 0.9375 in
Req.tks. int.pres.  trn = 0.0704 in      Req.tks.ext.pres. trne = 0.0471 in
Corroded thickness   tn = 0.375 in       Nozzle Projection    h = 0.0 in
Reinforcement element material:
Limit of reinf.      Dp = 0.0 in         Nominal thickness   te = 0.0 in
Outside diameter        = 0.0 in         Design stress       Se = 0 psi
Minimum weld size tmin  = 0.375 in       Leg size(1/2*tmin)(Act)= 0.0 in
1/2 * tmin (minimum)    = 0.0 in         1/2 * tmin  (actual)  = 0.0 in
Weld tw    (minimum)    = 0.2625 in      Weld tw     (actual)  = 0.0 in
Weld tc    (minimum)    = 0.25 in        Weld tc     (actual)  = 0.25 in
    smaller |0.25 in   |                 Leg size tw (actual)  = 0.0 in
 tc   of    |0.7 * tmin|                 Leg size tc (actual)  = 0.3571 in
Outward nozzle weld   L1 = 0.3571 in     fr1 = Sn/Sv              = 0.7937
Outer element weld    L2 = 0.0 in        fr2 = Sn/Sv              = 0.7937
Inward nozzle weld    L3 = 0.0 in        fr3 = Sn/Sv or Se/Sv     = 0.7937
Inward nozzel weld new   = 0.0 in        fr4 = Se/Sv              = 1.0
Corroded int.proj.thk ti = 0.0 in
```

```
Corroded inside diameter                                    d = 23.25 in
Vessel wall length available for reinforcement    2*Lp-d = 23.25 in
Plane correction factor (Fig.UG-37)                    F = 1.0
Offset distance from centerline                     doff = 0.0 in
Reinforcement areas (internal pressure condition) ASME 2004 UG-37
A1 = Vessel wall.  Larger of:
 |(2*Lp-d)*(E1*t-F*tr)-2*tn*(E1*t-F*tr)*(1-fr1)| = 9.1686 in2
 |2*(t+tn)*(E1*t-F*tr)-2*tn*(E1*t-F*tr)*(1-fr1)| = 0.6333 in2
                                                       A1 = 9.1686 in2
A2 = Nozzle wall outward  | 5*(tn-trn)*fr2*t    | = 0.6043 in2
     Smaller of:          | 5*(tn-trn)*fr2*tn   | = 0.4532 in2
                                                       A2 = 0.4532 in2
A3 = Nozzle wall inward   | 5*t*ti*fr2  | = 0.0 in2
     Smallest of:         | 5*ti*ti*fr2 | = 0.0 in2
                          | 2*h*ti*fr2  | = 0.0 in2
                                                       A3 = 0.0 in2
A41 = Outward nozzle weld = (L1**2)*fr3 = 0.1012 in2
A42 = Outer element weld  = (L2**2)*fr4 = 0.0 in2
A43 = Inward nozzle weld  = (L3**2)*fr2 = 0.0 in2
                                                       A4 = 0.1012 in2
A5 = Reinforcement pad Area = (Dp-d-2*tn)*te*fr4       A5 = 0.0 in2
Aa = Area Available = A1+A2+A3+A4+A5                   Aa = 9.723 in2
A = Area required   = (d*tr*F)+2*tn*tr*F*(1-f1)         A = 2.411 in2
For large nozzles per 1-7:
  Reinforcement limit Dp2 = MIN(Dp, 1-7(a)(1))        Dp2 = 34.875 in
  A52 = Reinforcement pad Area = (Dp2-d-2*tn)*te*fr4  A52 = 0.0 in2
  A12 = Vessel wall.  Larger of:
    |(1.5Lp-d)*(E1*t-F*tr)-2*tn*(E1*t-F*tr)*(1-fr1)| = 4.5536 in
    |2*(t+tn)*(E1*t-F*tr)-2*tn*(E1*t-F*tr)*(1-fr1)|  = 0.6333 in
  Aa2= Area Available     = A12+A2+A3+A4+A52          Aa2 = 5.108 in2
  A = (2/3)Area required = (2/3)*((d*tr*F)+2*tn*tr*F*(1-f1)) A = 1.6073 in2
Note: Parallel and normal limits per 1-7(a)(1) and 1-7(a)(2).  Calculations
      per 1-7(b) only shown if required (see 1-7(b)(1)(a),(b),(c)).
ASME VIII-1 2004 A06 Reinforcement areas (external pressure) UG-37(d)
A1 = Vessel wall.  Larger of:
 |(2*Lp-d)*(E1*t-F*tre)-2*tn*(E1*t-F*tre)*(1-fr1)| = 7.9217 in2
 |2*(t+tn)*(E1*t-F*tre)-2*tn*(E1*t-F*tre)*(1-fr1)| = 0.5472 in2
                                                       A1 = 7.9217 in2
A2 = Nozzle wall outward  | 5*(tn-trne)*fr2*t  | = 0.6505 in2
     Smaller of:          | 5*(tn-trne)*fr2*tn | = 0.4879 in2
                                                       A2 = 0.4879 in2
A3 = Nozzle wall inward   | 5*t*ti*fr2  | = 0.0 in2
     Smallest of:         | 5*ti*ti*fr2 | = 0.0 in2
                          | 2*h*ti*fr2  | = 0.0 in2
                                                       A3 = 0.0 in2
A41 = Outward nozzle weld =   (L1**2)*fr3 = 0.1012 in2
A42 = Outer element weld  =   (L2**2)*fr4 = 0.0 in2
A43 = Inward nozzle weld  =   (L3**2)*fr2 = 0.0 in2
                                                       A4 = 0.1012 in2
A5 = Reinforcement pad Area = (Dp-d-2*tn)*te*fr4       A5 = 0.0 in2
Aa = Area Available = A1+A2+A3+A4+A5                   Aa = 8.5108 in2
A = Area required   = 0.5*(d*tre*F+2*tn*tre*F*(1-fr1))  A = 1.8373 in2
```

Nozzle attachment weld loads - UG-41 - Strength of reinforcement

```
  ASME - Weld strength calculations not required per UW-15(b).
Total weld load (UG-41(b)(2))
  W = (A-A1+2*tn*fr1(E1*t-F*tr))*Sv                          W = -
Weld load for strength path 1-1 (UG-41(b)(1)
  W(1-1) = (A2+A5+A41+A42)*Sv                      W(1-1) = 10480 lbf
Weld load for strength path 2-2 (UG-41(b)(1)
  W(2-2) = (A2+A3+A41+A43+2*tn*t*fr1)*Sv           W(2-2) = 16105 lbf
Weld load for strength path 3-3 (UG-41(b)(1)
  W(3-3) = (A2+A3+A5+A41+A42+A43+2*tn*t*fr1)*Sv    W(3-3) = -
Reinforcing element strength = A5 * Se                    = -
Nozzle attachment weld loads - ASME 2004 UG-41 - Strength of reinforcement
 Unit stresses - UW15(c)and UG-45(c)
    Inner fillet weld shear            =   7350 psi
    Outer fillet weld shear            =   -
    Groove weld tension                =   11100 psi
    Groove weld shear                  =   -
    Nozzle wall shear                  =   10500 psi
 Strength of connection elements
    Inner fillet weld shear            =   98911 lbf
    Nozzle wall shear                  =   146047 lbf
    Groove weld tension                =   149375 lbf
    Outer fillet weld shear            =   -
 Possible paths of failure
    1-1       146047 + 98911           =   244958 lbf
    2-2        98911 + 149375          =   248286 lbf
    3-3            - + -               =   -
 Welds strong enough if path greater than the smaller of W or W(path)
                           Path 1-1 > W or W11
                         244958 lbf > 10480 lbf               OK
                           Path 2-2 > W or W22
                         248286 lbf > 16105 lbf               OK
                           Path 3-3 > W or W33
                                  - > -
```

```
Component:  Nozzle B
ASME VIII-1 2004 A06 UG-27 Thickness of Cylinders under Internal Pressure
--- Calculations --- Cylinder Internal Pressure
Material:  SA-312 S30400 Grd TP304 Wld. pipe
Design pressure       P = 75 psi         Design temperature   T = 300 F
Radiography             = None           Joint efficiency     E = 0.85
Design stress         S = 15000 psi
Inside corr.allow. cai = 0.0 in          Outside corr. all. cao = 0.0 in
Material tolerance tol = 0.0192 in       Minimum thickness tmin = 0.113 in
Outside diameter    OD = 2.375 in        Corroded radius     OR = 1.1875 in
- Min. thk. not less than UG-45(a), UG-16(b), UG-45(b):
  - UG-45(a) Internal pressure:
              t = (P*OR / (S*E+0.4*P))+cai+cao+tol = 0.0262 in   APP.1-1(A)
  - UG-45(a) external pressure+cai+cao+tol       t = 0.031 in
  - UG-16(b) minimum thickness+cai+cao+tol       t = 0.113 in
    UG-45(b) Smaller of:                         t = 0.0906 in
    UG-45(b)(4) std pipe*0.875+cai+cao+tol = 0.154 in
      - UG-45(b) Greater of:             t = 0.0906 in
        - UG-45(b)(1)+cai+cao+tol = 0.0906 in
        - UG-45(b)(2)+cai+cao+tol = 0.0335 in
                        Minimum thickness:                tmin = 0.113 in
                        Nominal thickness:                tnom = 0.154 in
ASME Section VIII-1 2004 A06 UG-28 Thickness of Shells under Ext. Pressure
--- Calculations --- Cylinder External Pressure
Material:  SA-312 S30400 Grd TP304 Wld. pipe
Design pressure      PE = 15 psi          Design temperature  T = 300 F
Inside corr. allow. CAI = 0 in            Corrosion allow.  CAO = 0 in
Radiography             = None            Material tol.     Tol = 0 in
Cyl. outside dia.    Do = 2.375 in        Cylinder length EP  L = 6 in
Nominal thickness  tnom = 0.154 in        (tnom-CAI-CAO-Tol)  t = 0.1347 in
L/Do ratio          Ldo = 2.5263          Do/t              Dot = 17.6252
(2*S) or (0.9*yield) SE = -               Mod. of elasticity ME = 27000000 psi
A factor SII-D-FigG   A = 0.006845        B factor HA-1       B = 11348
Max allowed external pressure: Pa = 4*B / (3*Dot)             = 858.48 psi
Actual external design pressure:                           PE = 15 psi
   (Required cyl. tks. for nozzle attachments at PE, tre = 0.0118 in )
```

```
Component: Reinforcement Nozzle B
ASME Section VIII-1 2004 A06 UG-37  Reinforcement Required for Openings in
                                Shells and Formed Heads
--- Design Conditions:
Int. design pressure PI = 75 psi        Ext. design press.  PE = 15 psi
Design temperature    T = 300 F         Fig.UW-16.1 Sketch (c)
Vessel material: SA-240 S30400 Grd 304 Plate(G5)
Inside corr. allow. CAI = 0.0 in        Outside corr.allow.CAO = 0.0 in
Vessel design stress Sv = 18900 psi     Joint efficiency     E = 1
Vessel outside dia   Do = 36.0 in       Corroded radius     OR = 18.0 in
Nominal thickness  tnom = 0.25 in       Reinforcement limit lp = 2.067 in
Req. tks. int.pres.  tr = 0.0713 in     Req. tks.ext.pres. tre = 0.162 in
Corroded thickness    t = 0.25 in       Reinf. efficiency   E1 = 1.0
Attachment Material: SA-312 S30400 Grd TP304 Wld. pipe
Inside corr. allow. CAI = 0.0 in        Outside corr.allow.CAO = 0.0 in
Nozzle design stress Sn = 15000 psi     Joint efficiency     E = 0.85
Nozzle outside dia. Don = 2.375 in      Corroded radius     OR = 1.1875 in
Nominal thickness  tnom = 0.154 in      Reinforcement limit ln = 0.385 in
Req.tks. int.pres.  trn = 0.007 in      Req.tks.ext.pres. trne = 0.0118 in
Corroded thickness   tn = 0.154 in      Nozzle Projection    h = 0.0 in
Reinforcement element material:
Limit of reinf.      Dp = 0.0 in        Nominal thickness   te = 0.0 in
Outside diameter        = 0.0 in        Design stress       Se = 0 psi
Minimum weld size tmin  = 0.154 in      Leg size(1/2*tmin)(Act)= 0.0 in
1/2 * tmin (minimum)    = 0.0 in        1/2 * tmin  (actual)   = 0.0 in
Weld  tw   (minimum)    = 0.1078 in     Weld tw     (actual)   = 0.0 in
Weld  tc   (minimum)    = 0.1078 in     Weld tc     (actual)   = 0.1078 in
    smaller |0.25 in   |                Leg size tw (actual)   = 0.0 in
 tc   of    |0.7 * tmin|                Leg size tc (actual)   = 0.154 in
Outward nozzle weld   L1 = 0.154 in     fr1 = Sn/Sv             = 0.7937
Outer element weld    L2 = 0.0 in       fr2 = Sn/Sv             = 0.7937
Inward nozzle weld    L3 = 0.0 in       fr3 = Sn/Sv or Se/Sv    = 0.7937
Inward nozzel weld new   = 0.0 in       fr4 = Se/Sv             = 1.0
Corroded int.proj.thk ti = 0.0 in
```

```
Corroded inside diameter                                  d = 2.067 in
Vessel wall length available for reinforcement    2*Lp-d = 2.067 in
Plane correction factor (Fig.UG-37)                    F = 1.0
Offset distance from centerline                     doff = 0.0 in
Reinforcement areas (internal pressure condition) ASME 2004 UG-37
A1 = Vessel wall.  Larger of:
 |(2*Lp-d)*(E1*t-F*tr)-2*tn*(E1*t-F*tr)*(1-fr1)| = 0.358 in2
 |2*(t+tn)*(E1*t-F*tr)-2*tn*(E1*t-F*tr)*(1-fr1)| = 0.133 in2
                                                          A1 = 0.358 in2
A2 = Nozzle wall outward   | 5*(tn-trn)*fr2*t    | = 0.1459 in2
     Smaller of:           | 5*(tn-trn)*fr2*tn   | = 0.0899 in2
                                                          A2 = 0.0899 in2
A3 = Nozzle wall inward    | 5*t*ti*fr2  | = 0.0 in2
     Smallest of:          | 5*ti*ti*fr2 | = 0.0 in2
                           | 2*h*ti*fr2  | = 0.0 in2
                                                          A3 = 0.0 in2
A41 = Outward nozzle weld = (L1**2)*fr3 = 0.0188 in2
A42 = Outer element weld  = (L2**2)*fr4 = 0.0 in2
A43 = Inward nozzle weld  = (L3**2)*fr2 = 0.0 in2
                                                          A4 = 0.0188 in2
A5 = Reinforcement pad Area = (Dp-d-2*tn)*te*fr4          A5 = 0.0 in2
Aa = Area Available = A1+A2+A3+A4+A5                      Aa = 0.4667 in2
A = Area required    = (d*tr*F)+2*tn*tr*F*(1-f1)           A = 0.1519 in2
Per UG-36(c)(3)(a), this opening does NOT required additional reinforcement
                    other than the inherent in the construction.
ASME VIII-1 2004 A06 Reinforcement areas (external pressure) UG-37(d)
A1 = Vessel wall.  Larger of:
 |(2*Lp-d)*(E1*t-F*tre)-2*tn*(E1*t-F*tre)*(1-fr1)| = 0.1763 in2
 |2*(t+tn)*(E1*t-F*tre)-2*tn*(E1*t-F*tre)*(1-fr1)| = 0.0655 in2
                                                          A1 = 0.1763 in2
A2 = Nozzle wall outward   | 5*(tn-trne)*fr2*t   | = 0.1411 in2
     Smaller of:           | 5*(tn-trne)*fr2*tn  | = 0.0869 in2
                                                          A2 = 0.0869 in2
A3 = Nozzle wall inward    | 5*t*ti*fr2  | = 0.0 in2
     Smallest of:          | 5*ti*ti*fr2 | = 0.0 in2
                           | 2*h*ti*fr2  | = 0.0 in2
                                                          A3 = 0.0 in2
A41 = Outward nozzle weld =   (L1**2)*fr3 = 0.0188 in2
A42 = Outer element weld  =   (L2**2)*fr4 = 0.0 in2
A43 = Inward nozzle weld  =   (L3**2)*fr2 = 0.0 in2
                                                          A4 = 0.0188 in2
A5 = Reinforcement pad Area = (Dp-d-2*tn)*te*fr4          A5 = 0.0 in2
Aa = Area Available = A1+A2+A3+A4+A5                      Aa = 0.2821 in2
A = Area required   = 0.5*(d*tre*F+2*tn*tre*F*(1-fr1))     A = 0.1726 in2
```

Nozzle attachment weld loads - UG-41 - Strength of reinforcement

```
  ASME - Weld strength calculations not required per UW-15(b).
Total weld load (UG-41(b)(2))
  W = (A-A1+2*tn*fr1(E1*t-F*tr))*Sv                          W = -
Weld load for strength path 1-1 (UG-41(b)(1)
  W(1-1) = (A2+A5+A41+A42)*Sv                           W(1-1) = 2054 lbf
Weld load for strength path 2-2 (UG-41(b)(1)
  W(2-2) = (A2+A3+A41+A43+2*tn*t*fr1)*Sv                W(2-2) = 3209 lbf
Weld load for strength path 3-3 (UG-41(b)(1)
  W(3-3) = (A2+A3+A5+A41+A42+A43+2*tn*t*fr1)*Sv         W(3-3) = -
Reinforcing element strength = A5 * Se                         = -
Nozzle attachment weld loads - ASME 2004 UG-41 - Strength of reinforcement
 Unit stresses - UW15(c)and UG-45(c)
    Inner fillet weld shear            =   7350 psi
    Outer fillet weld shear            =   -
    Groove weld tension                =   11100 psi
    Groove weld shear                  =   -
    Nozzle wall shear                  =   10500 psi
 Strength of connection elements
    Inner fillet weld shear            =   4221 lbf
    Nozzle wall shear                  =   5639 lbf
    Groove weld tension                =   6374 lbf
    Outer fillet weld shear            =   -
 Possible paths of failure
    1-1         5639 + 4221            =   9860 lbf
    2-2         4221 + 6374            =   10595 lbf
    3-3            - + -               =   -
 Welds strong enough if path greater than the smaller of W or W(path)
                           Path 1-1 > W or W11
                           9860 lbf > 2054 lbf                 OK
                           Path 2-2 > W or W22
                          10595 lbf > 3209 lbf                 OK
                           Path 3-3 > W or W33
                                  - > -
```

```
Component:  Nozzle C
ASME VIII-1 2004 A06 UG-27 Thickness of Cylinders under Internal Pressure
--- Calculations --- Cylinder Internal Pressure
Material:  SA-53 K03005 Grd E/B Wld. pipe
Design pressure       P = 150 psi         Design temperature    T = 300 F
Radiography             = None            Joint efficiency      E = 0.85
Design stress         S = 14600 psi
Inside corr.allow. cai = 0.0625 in        Outside corr. all. cao = 0.0 in
Material tolerance tol = 0.0456 in        Minimum thickness tmin = 0.2427 in
Outside diameter    OD = 10.75 in         Corroded radius     OR = 5.375 in
- Min. thk. not less than UG-45(a), UG-16(b), UG-45(b):
  - UG-45(a) Internal pressure:
              t = (P*OR / (S*E+0.4*P))+cai+cao+tol = 0.1728 in   APP.1-1(A)
  - UG-45(a) external pressure+cai+cao+tol       t = 0.136 in
  - UG-16(b) minimum thickness+cai+cao+tol       t = 0.2019 in
    UG-45(b) Smaller of:                         t = 0.2427 in
    UG-45(b)(4) std pipe*0.875+cai+cao+tol = 0.4275 in
      - UG-45(b) Greater of:                t = 0.2427 in
        - UG-45(b)(1)+cai+cao+tol = 0.2427 in
        - UG-45(b)(2)+cai+cao+tol = 0.1216 in
                        Minimum thickness:                tmin = 0.2427 in
                        Nominal thickness:                tnom = 0.365 in
ASME Section VIII-1 2004 A06 UG-28 Thickness of Shells under Ext. Pressure
--- Calculations --- Cylinder External Pressure
Material:  SA-53 K03005 Grd E/B Wld. pipe
Design pressure      PE = 15 psi          Design temperature  T = 300 F
Inside corr. allow. CAI = 0.0625 in       Corrosion allow.  CAO = 0 in
Radiography             = None            Material tol.     Tol = 0 in
Cyl. outside dia.    Do = 10.75 in        Cylinder length EP  L = 6 in
Nominal thickness  tnom = 0.365 in        (tnom-CAI-CAO-Tol)  t = 0.2569 in
L/Do ratio          Ldo = 0.5581          Do/t              Dot = 41.8491
(2*S) or (0.9*yield) SE = -               Mod. of elasticity ME = 28100000 psi
A factor SII-D-FigG   A = 0.009869        B factor CS-2       B = 17368
Max allowed external pressure: Pa = 4*B / (3*Dot)             = 553.35 psi
Actual external design pressure:                          PE = 15 psi
   (Required cyl. tks. for nozzle attachments at PE, tre = 0.0279 in )
```

```
Component: Reinforcement Nozzle C
ASME Section VIII-1 2004 A06 UG-37  Reinforcement Required for Openings in
                                Shells and Formed Heads
--- Design Conditions:
Int. design pressure PI = 150 psi       Ext. design press.  PE = 15 psi
Design temperature    T = 300 F         Fig.UW-16.1 Sketch (c)
Vessel material: SA-516 K02700 Grd 70 Plate
Inside corr. allow. CAI = 0.0625 in     Outside corr.allow.CAO = 0.0 in
Vessel design stress Sv = 20000 psi     Joint efficiency     E = 1
Vessel outside dia   Do = 36.0 in       Corroded radius     OR = 18.0 in
Nominal thickness  tnom = 0.375 in      Reinforcement limit lp = 10.145 in
Req. tks. int.pres.  tr = 0.1346 in     Req. tks.ext.pres. tre = 0.1015 in
Corroded thickness    t = 0.3125 in     Reinf. efficiency   E1 = 1.0
Attachment Material: SA-53 K03005 Grd E/B Wld. pipe
Inside corr. allow. CAI = 0.0625 in     Outside corr.allow.CAO = 0.0 in
Nozzle design stress Sn = 14600 psi     Joint efficiency     E = 0.85
Nozzle outside dia. Don = 10.75 in      Corroded radius     OR = 5.375 in
Nominal thickness  tnom = 0.365 in      Reinforcement limit ln = 0.7563 in
Req.tks. int.pres.  trn = 0.0647 in     Req.tks.ext.pres. trne = 0.0279 in
Corroded thickness   tn = 0.3025 in     Nozzle Projection    h = 0.0 in
Reinforcement element material:
Limit of reinf.      Dp = 0.0 in        Nominal thickness   te = 0.0 in
Outside diameter        = 0.0 in        Design stress       Se = 0 psi
Minimum weld size tmin  = 0.3025 in     Leg size(1/2*tmin)(Act)= 0.0 in
1/2 * tmin (minimum)    = 0.0 in        1/2 * tmin  (actual)   = 0.0 in
Weld  tw   (minimum)    = 0.2118 in     Weld tw     (actual)   = 0.0 in
Weld  tc   (minimum)    = 0.2118 in     Weld tc     (actual)   = 0.2118 in
    smaller |0.25 in   |                Leg size tw (actual)   = 0.0 in
 tc    of   |0.7 * tmin|                Leg size tc (actual)   = 0.3025 in
Outward nozzle weld   L1 = 0.3025 in    fr1 = Sn/Sv              = 0.73
Outer element weld    L2 = 0.0 in       fr2 = Sn/Sv              = 0.73
Inward nozzle weld    L3 = 0.0 in       fr3 = Sn/Sv or Se/Sv     = 0.73
Inward nozzel weld new   = 0.0 in       fr4 = Se/Sv              = 1.0
Corroded int.proj.thk ti = 0.0 in
```

```
Corroded inside diameter                                    d = 10.145 in
Vessel wall length available for reinforcement    2*Lp-d = 10.145 in
Plane correction factor (Fig.UG-37)                    F = 1.0
Offset distance from centerline                      doff = 0.0 in
Reinforcement areas (internal pressure condition) ASME 2004 UG-37
A1 = Vessel wall.  Larger of:
 |(2*Lp-d)*(E1*t-F*tr)-2*tn*(E1*t-F*tr)*(1-fr1)| = 1.7758 in2
 |2*(t+tn)*(E1*t-F*tr)-2*tn*(E1*t-F*tr)*(1-fr1)| = 0.1898 in2
                                                        A1 = 1.7758 in2
A2 = Nozzle wall outward   | 5*(tn-trn)*fr2*t   | = 0.2713 in2
     Smaller of:           | 5*(tn-trn)*fr2*tn  | = 0.2626 in2
                                                        A2 = 0.2626 in2
A3 = Nozzle wall inward    | 5*t*ti*fr2  | = 0.0 in2
     Smallest of:          | 5*ti*ti*fr2 | = 0.0 in2
                           | 2*h*ti*fr2  | = 0.0 in2
                                                        A3 = 0.0 in2
A41 = Outward nozzle weld = (L1**2)*fr3 = 0.0668 in2
A42 = Outer element weld  = (L2**2)*fr4 = 0.0 in2
A43 = Inward nozzle weld  = (L3**2)*fr2 = 0.0 in2
                                                        A4 = 0.0668 in2
A5 = Reinforcement pad Area = (Dp-d-2*tn)*te*fr4        A5 = 0.0 in2
Aa = Area Available = A1+A2+A3+A4+A5                    Aa = 2.1052 in2
A = Area required   = (d*tr*F)+2*tn*tr*F*(1-f1)          A = 1.3875 in2
ASME VIII-1 2004 A06 Reinforcement areas (external pressure) UG-37(d)
A1 = Vessel wall.  Larger of:
 |(2*Lp-d)*(E1*t-F*tre)-2*tn*(E1*t-F*tre)*(1-fr1)| = 2.1061 in2
 |2*(t+tn)*(E1*t-F*tre)-2*tn*(E1*t-F*tre)*(1-fr1)| = 0.2251 in2
                                                        A1 = 2.1061 in2
A2 = Nozzle wall outward   | 5*(tn-trne)*fr2*t   | = 0.3132 in2
     Smaller of:           | 5*(tn-trne)*fr2*tn  | = 0.3032 in2
                                                        A2 = 0.3032 in2
A3 = Nozzle wall inward    | 5*t*ti*fr2  | = 0.0 in2
     Smallest of:          | 5*ti*ti*fr2 | = 0.0 in2
                           | 2*h*ti*fr2  | = 0.0 in2
                                                        A3 = 0.0 in2
A41 = Outward nozzle weld =   (L1**2)*fr3 = 0.0668 in2
A42 = Outer element weld  =   (L2**2)*fr4 = 0.0 in2
A43 = Inward nozzle weld  =   (L3**2)*fr2 = 0.0 in2
                                                        A4 = 0.0668 in2
A5 = Reinforcement pad Area = (Dp-d-2*tn)*te*fr4        A5 = 0.0 in2
Aa = Area Available = A1+A2+A3+A4+A5                    Aa = 2.4761 in2
A = Area required   = 0.5*(d*tre*F+2*tn*tre*F*(1-fr1))   A = 0.5231 in2
```

```
Nozzle attachment weld loads - UG-41 - Strength of reinforcement
  ASME - Weld strength calculations not required per UW-15(b).
Total weld load (UG-41(b)(2))
  W = (A-A1+2*tn*fr1(E1*t-F*tr))*Sv                          W = -
Weld load for strength path 1-1 (UG-41(b)(1)
  W(1-1) = (A2+A5+A41+A42)*Sv                           W(1-1) = 6588 lbf
Weld load for strength path 2-2 (UG-41(b)(1)
  W(2-2) = (A2+A3+A41+A43+2*tn*t*fr1)*Sv                W(2-2) = 9349 lbf
Weld load for strength path 3-3 (UG-41(b)(1)
  W(3-3) = (A2+A3+A5+A41+A42+A43+2*tn*t*fr1)*Sv         W(3-3) = -
Reinforcing element strength = A5 * Se                         = -
Nozzle attachment weld loads - ASME 2004 UG-41 - Strength of reinforcement
 Unit stresses - UW15(c)and UG-45(c)
    Inner fillet weld shear            =   7154 psi
    Outer fillet weld shear            =   -
    Groove weld tension                =   10804 psi
    Groove weld shear                  =   -
    Nozzle wall shear                  =   10220 psi
 Strength of connection elements
    Inner fillet weld shear            =   36525 lbf
    Nozzle wall shear                  =   50710 lbf
    Groove weld tension                =   55160 lbf
    Outer fillet weld shear            =   -
 Possible paths of failure
    1-1        50710 + 36525           =   87235 lbf
    2-2        36525 + 55160           =   91685 lbf
    3-3            - + -               =   -
 Welds strong enough if path greater than the smaller of W or W(path)
                            Path 1-1 > W or W11
                           87235 lbf > 6588 lbf                 OK
                            Path 2-2 > W or W22
                           91685 lbf > 9349 lbf                 OK
                            Path 3-3 > W or W33
                                   - > -
```

Component: Nozzle D

```
ASME VIII-1 2004 A06 UG-27 Thickness of Cylinders under Internal Pressure
--- Calculations --- Cylinder Internal Pressure
Material:  SA-53 K03005 Grd E/B Wld. pipe
Design pressure      P = 150 psi        Design temperature   T = 300 F
Radiography            = None           Joint efficiency     E = 0.85
Design stress        S = 14600 psi
Inside corr.allow. cai = 0.0625 in      Outside corr. all. cao = 0.0 in
Material tolerance tol = 0.0456 in      Minimum thickness tmin = 0.2427 in
Outside diameter    OD = 10.75 in       Corroded radius     OR = 5.375 in
- Min. thk. not less than UG-45(a), UG-16(b), UG-45(b):
  - UG-45(a) Internal pressure:
              t = (P*OR / (S*E+0.4*P))+cai+cao+tol = 0.1728 in   APP.1-1(A)
  - UG-45(a) external pressure+cai+cao+tol       t = 0.136 in
  - UG-16(b) minimum thickness+cai+cao+tol       t = 0.2019 in
    UG-45(b) Smaller of:                         t = 0.2427 in
    UG-45(b)(4) std pipe*0.875+cai+cao+tol = 0.4275 in
      - UG-45(b) Greater of:             t = 0.2427 in
        - UG-45(b)(1)+cai+cao+tol = 0.2427 in
        - UG-45(b)(2)+cai+cao+tol = 0.1216 in
                        Minimum thickness:                tmin = 0.2427 in
                        Nominal thickness:                tnom = 0.365 in
ASME Section VIII-1 2004 A06 UG-28 Thickness of Shells under Ext. Pressure
--- Calculations --- Cylinder External Pressure
Material:  SA-53 K03005 Grd E/B Wld. pipe
Design pressure      PE = 15 psi         Design temperature  T = 300 F
Inside corr. allow. CAI = 0.0625 in      Corrosion allow.  CAO = 0 in
Radiography             = None           Material tol.     Tol = 0 in
Cyl. outside dia.    Do = 10.75 in       Cylinder length EP  L = 6 in
Nominal thickness  tnom = 0.365 in       (tnom-CAI-CAO-Tol)  t = 0.2569 in
L/Do ratio          Ldo = 0.5581         Do/t              Dot = 41.8491
(2*S) or (0.9*yield) SE = -              Mod. of elasticity ME = 28100000 psi
A factor SII-D-FigG   A = 0.009869       B factor CS-2       B = 17368
Max allowed external pressure: Pa = 4*B / (3*Dot)            = 553.35 psi
Actual external design pressure:                            PE = 15 psi
   (Required cyl. tks. for nozzle attachments at PE, tre = 0.0279 in )
```

Component: Reinforcement Nozzle D

```
ASME Section VIII-1 2004 A06 UG-37  Reinforcement Required for Openings in
                                Shells and Formed Heads
--- Design Conditions:
Int. design pressure PI = 150 psi       Ext. design press.  PE = 15 psi
Design temperature    T = 300 F         Fig.UW-16.1 Sketch (c)
Vessel material: SA-516 K02700 Grd 70 Plate
Inside corr. allow. CAI = 0.0625 in     Outside corr.allow.CAO = 0.0 in
Vessel design stress Sv = 20000 psi     Joint efficiency     E = 1
Vessel outside dia   Do = 36.0 in       Corroded radius     OR = 18.0 in
Nominal thickness  tnom = 0.375 in      Reinforcement limit lp = 10.145 in
Req. tks. int.pres.  tr = 0.1346 in     Req. tks.ext.pres. tre = 0.1015 in
Corroded thickness    t = 0.3125 in     Reinf. efficiency   E1 = 1.0
Attachment Material: SA-53 K03005 Grd E/B Wld. pipe
Inside corr. allow. CAI = 0.0625 in     Outside corr.allow.CAO = 0.0 in
Nozzle design stress Sn = 14600 psi     Joint efficiency     E = 0.85
Nozzle outside dia. Don = 10.75 in      Corroded radius     OR = 5.375 in
Nominal thickness  tnom = 0.365 in      Reinforcement limit ln = 0.7563 in
Req.tks. int.pres.  trn = 0.0647 in     Req.tks.ext.pres. trne = 0.0279 in
Corroded thickness   tn = 0.3025 in     Nozzle Projection    h = 0.0 in
Reinforcement element material:
Limit of reinf.      Dp = 0.0 in        Nominal thickness   te = 0.0 in
Outside diameter        = 0.0 in        Design stress       Se = 0 psi
Minimum weld size tmin  = 0.3025 in     Leg size(1/2*tmin)(Act)= 0.0 in
1/2 * tmin (minimum)    = 0.0 in        1/2 * tmin  (actual)   = 0.0 in
Weld  tw   (minimum)    = 0.2118 in     Weld tw     (actual)   = 0.0 in
Weld  tc   (minimum)    = 0.2118 in     Weld tc     (actual)   = 0.2118 in
    smaller |0.25 in   |                Leg size tw (actual)   = 0.0 in
 tc    of   |0.7 * tmin|                Leg size tc (actual)   = 0.3025 in
Outward nozzle weld   L1 = 0.3025 in    fr1 = Sn/Sv              = 0.73
Outer element weld    L2 = 0.0 in       fr2 = Sn/Sv              = 0.73
Inward nozzle weld    L3 = 0.0 in       fr3 = Sn/Sv or Se/Sv     = 0.73
Inward nozzel weld new   = 0.0 in       fr4 = Se/Sv              = 1.0
Corroded int.proj.thk ti = 0.0 in
```

```
Corroded inside diameter                                          d = 10.145 in
Vessel wall length available for reinforcement     2*Lp-d = 10.145 in
Plane correction factor (Fig.UG-37)                     F = 1.0
Offset distance from centerline                      doff = 0.0 in
Reinforcement areas (internal pressure condition) ASME 2004 UG-37
A1 = Vessel wall.  Larger of:
 |(2*Lp-d)*(E1*t-F*tr)-2*tn*(E1*t-F*tr)*(1-fr1)| = 1.7758 in2
 |2*(t+tn)*(E1*t-F*tr)-2*tn*(E1*t-F*tr)*(1-fr1)| = 0.1898 in2
                                                           A1 = 1.7758 in2
A2 = Nozzle wall outward  | 5*(tn-trn)*fr2*t   | = 0.2713 in2
     Smaller of:          | 5*(tn-trn)*fr2*tn  | = 0.2626 in2
                                                           A2 = 0.2626 in2
A3 = Nozzle wall inward   | 5*t*ti*fr2  | = 0.0 in2
     Smallest of:         | 5*ti*ti*fr2 | = 0.0 in2
                          | 2*h*ti*fr2  | = 0.0 in2
                                                           A3 = 0.0 in2
A41 = Outward nozzle weld = (L1**2)*fr3 = 0.0668 in2
A42 = Outer element weld  = (L2**2)*fr4 = 0.0 in2
A43 = Inward nozzle weld  = (L3**2)*fr2 = 0.0 in2
                                                           A4 = 0.0668 in2
A5 = Reinforcement pad Area = (Dp-d-2*tn)*te*fr4           A5 = 0.0 in2
Aa = Area Available = A1+A2+A3+A4+A5                       Aa = 2.1052 in2
A = Area required   = (d*tr*F)+2*tn*tr*F*(1-f1)             A = 1.3875 in2
ASME VIII-1 2004 A06 Reinforcement areas (external pressure) UG-37(d)
A1 = Vessel wall.  Larger of:
 |(2*Lp-d)*(E1*t-F*tre)-2*tn*(E1*t-F*tre)*(1-fr1)| = 2.1061 in2
 |2*(t+tn)*(E1*t-F*tre)-2*tn*(E1*t-F*tre)*(1-fr1)| = 0.2251 in2
                                                           A1 = 2.1061 in2
A2 = Nozzle wall outward  | 5*(tn-trne)*fr2*t  | = 0.3132 in2
     Smaller of:          | 5*(tn-trne)*fr2*tn | = 0.3032 in2
                                                           A2 = 0.3032 in2
A3 = Nozzle wall inward   | 5*t*ti*fr2  | = 0.0 in2
     Smallest of:         | 5*ti*ti*fr2 | = 0.0 in2
                          | 2*h*ti*fr2  | = 0.0 in2
                                                           A3 = 0.0 in2
A41 = Outward nozzle weld =   (L1**2)*fr3 = 0.0668 in2
A42 = Outer element weld  =   (L2**2)*fr4 = 0.0 in2
A43 = Inward nozzle weld  =   (L3**2)*fr2 = 0.0 in2
                                                           A4 = 0.0668 in2
A5 = Reinforcement pad Area = (Dp-d-2*tn)*te*fr4           A5 = 0.0 in2
Aa = Area Available = A1+A2+A3+A4+A5                       Aa = 2.4761 in2
A = Area required   = 0.5*(d*tre*F+2*tn*tre*F*(1-fr1))      A = 0.5231 in2
```

```
Nozzle attachment weld loads - UG-41 - Strength of reinforcement
  ASME - Weld strength calculations not required per UW-15(b).
Total weld load (UG-41(b)(2))
  W = (A-A1+2*tn*fr1(E1*t-F*tr))*Sv                          W = -
Weld load for strength path 1-1 (UG-41(b)(1)
  W(1-1) = (A2+A5+A41+A42)*Sv                           W(1-1) = 6588 lbf
Weld load for strength path 2-2 (UG-41(b)(1)
  W(2-2) = (A2+A3+A41+A43+2*tn*t*fr1)*Sv                W(2-2) = 9349 lbf
Weld load for strength path 3-3 (UG-41(b)(1)
  W(3-3) = (A2+A3+A5+A41+A42+A43+2*tn*t*fr1)*Sv         W(3-3) = -
Reinforcing element strength = A5 * Se                         = -
Nozzle attachment weld loads - ASME 2004 UG-41 - Strength of reinforcement
 Unit stresses - UW15(c)and UG-45(c)
    Inner fillet weld shear                =   7154 psi
    Outer fillet weld shear                =   -
    Groove weld tension                    =   10804 psi
    Groove weld shear                      =   -
    Nozzle wall shear                      =   10220 psi
 Strength of connection elements
    Inner fillet weld shear                =   36525 lbf
    Nozzle wall shear                      =   50710 lbf
    Groove weld tension                    =   55160 lbf
    Outer fillet weld shear                =   -
 Possible paths of failure
    1-1        50710 + 36525               =   87235 lbf
    2-2        36525 + 55160               =   91685 lbf
    3-3            - + -                   =   -
 Welds strong enough if path greater than the smaller of W or W(path)
                            Path 1-1 > W or W11
                           87235 lbf > 6588 lbf                OK
                            Path 2-2 > W or W22
                           91685 lbf > 9349 lbf                OK
                            Path 3-3 > W or W33
                                   - > -
```

```
Component:  Nozzle G
ASME VIII-1 2004 A06 UG-27 Thickness of Cylinders under Internal Pressure
--- Calculations --- Cylinder Internal Pressure
Material:  SA-312 S30400 Grd TP304 Wld. pipe
Design pressure       P = 75 psi          Design temperature    T = 300 F
Radiography             = None            Joint efficiency      E = 0.85
Design stress         S = 15000 psi
Inside corr.allow. cai = 0.0 in           Outside corr. all. cao = 0.0 in
Material tolerance tol = 0.0168 in        Minimum thickness tmin = 0.1105 in
Outside diameter    OD = 6.625 in         Corroded radius     OR = 3.3125 in
- Min. thk. not less than UG-45(a), UG-16(b), UG-45(b):
  - UG-45(a) Internal pressure:
              t = (P*OR / (S*E+0.4*P))+cai+cao+tol = 0.0362 in   APP.1-1(A)
  - UG-45(a) external pressure+cai+cao+tol       t = 0.038 in
  - UG-16(b) minimum thickness+cai+cao+tol       t = 0.1105 in
    UG-45(b) Smaller of:                         t = 0.0881 in
    UG-45(b)(4) std pipe*0.875+cai+cao+tol = 0.2618 in
      - UG-45(b) Greater of:              t = 0.0881 in
        - UG-45(b)(1)+cai+cao+tol = 0.0881 in
        - UG-45(b)(2)+cai+cao+tol = 0.031 in
                        Minimum thickness:                tmin = 0.1105 in
                        Nominal thickness:                tnom = 0.134 in
ASME Section VIII-1 2004 A06 UG-28 Thickness of Shells under Ext. Pressure
--- Calculations --- Cylinder External Pressure
Material:  SA-312 S30400 Grd TP304 Wld. pipe
Design pressure       PE = 15 psi          Design temperature  T = 300 F
Inside corr. allow. CAI = 0 in             Corrosion allow.  CAO = 0 in
Radiography              = None            Material tol.     Tol = 0 in
Cyl. outside dia.     Do = 6.625 in        Cylinder length EP  L = 6 in
Nominal thickness   tnom = 0.134 in        (tnom-CAI-CAO-Tol)  t = 0.1173 in
L/Do ratio           Ldo = 0.9057          Do/t              Dot = 56.5032
(2*S) or (0.9*yield) SE = -                Mod. of elasticity ME = 27000000 psi
A factor SII-D-FigG   A = 0.003604         B factor HA-1       B = 10554
Max allowed external pressure: Pa = 4*B / (3*Dot)                = 249.05 psi
Actual external design pressure:                              PE = 15 psi
   (Required cyl. tks. for nozzle attachments at PE, tre = 0.0213 in )
```

```
Component: Reinforcement Nozzle G
ASME Section VIII-1 2004 A06 UG-37  Reinforcement Required for Openings in
                                Shells and Formed Heads
--- Design Conditions:
Int. design pressure PI = 75 psi        Ext. design press.  PE = 15 psi
Design temperature    T = 300 F         Fig.UW-16.1 Sketch (c)
Vessel material: SA-240 S30400 Grd 304 Plate(G5)
Inside corr. allow. CAI = 0.0 in        Outside corr.allow.CAO = 0.0 in
Vessel design stress Sv = 18900 psi     Joint efficiency     E = 1
Vessel outside dia   Do = 36.0 in       Corroded radius     OR = 18.0 in
Nominal thickness  tnom = 0.25 in       Reinforcement limit lp = 6.357 in
Req. tks. int.pres.  tr = 0.0713 in     Req. tks.ext.pres. tre = 0.162 in
Corroded thickness    t = 0.25 in       Reinf. efficiency   E1 = 1.0
Attachment Material: SA-312 S30400 Grd TP304 Wld. pipe
Inside corr. allow. CAI = 0.0 in        Outside corr.allow.CAO = 0.0 in
Nozzle design stress Sn = 15000 psi     Joint efficiency     E = 0.85
Nozzle outside dia. Don = 6.625 in      Corroded radius     OR = 3.3125 in
Nominal thickness  tnom = 0.134 in      Reinforcement limit ln = 0.335 in
Req.tks. int.pres.  trn = 0.0194 in     Req.tks.ext.pres. trne = 0.0213 in
Corroded thickness   tn = 0.134 in      Nozzle Projection    h = 0.0 in
Reinforcement element material:
Limit of reinf.      Dp = 0.0 in        Nominal thickness   te = 0.0 in
Outside diameter        = 0.0 in        Design stress       Se = 0 psi
Minimum weld size tmin  = 0.134 in      Leg size(1/2*tmin)(Act)= 0.0 in
1/2 * tmin (minimum)    = 0.0 in        1/2 * tmin  (actual)   = 0.0 in
Weld  tw   (minimum)    = 0.0938 in     Weld tw     (actual)   = 0.0 in
Weld  tc   (minimum)    = 0.0938 in     Weld tc     (actual)   = 0.0938 in
    smaller |0.25 in   |                Leg size tw (actual)   = 0.0 in
 tc    of   |0.7 * tmin|                Leg size tc (actual)   = 0.134 in
Outward nozzle weld   L1 = 0.134 in     fr1 = Sn/Sv              = 0.7937
Outer element weld    L2 = 0.0 in       fr2 = Sn/Sv              = 0.7937
Inward nozzle weld    L3 = 0.0 in       fr3 = Sn/Sv or Se/Sv     = 0.7937
Inward nozzel weld new   = 0.0 in       fr4 = Se/Sv              = 1.0
Corroded int.proj.thk ti = 0.0 in
```

```
Corroded inside diameter                                      d = 6.357 in
Vessel wall length available for reinforcement    2*Lp-d = 6.357 in
Plane correction factor (Fig.UG-37)                       F = 1.0
Offset distance from centerline                        doff = 0.0 in
Reinforcement areas (internal pressure condition) ASME 2004 UG-37
A1 = Vessel wall.  Larger of:
 |(2*Lp-d)*(E1*t-F*tr)-2*tn*(E1*t-F*tr)*(1-fr1)| = 1.126 in2
 |2*(t+tn)*(E1*t-F*tr)-2*tn*(E1*t-F*tr)*(1-fr1)| = 0.1273 in2
                                                           A1 = 1.126 in2
A2 = Nozzle wall outward  | 5*(tn-trn)*fr2*t   | = 0.1137 in2
     Smaller of:          | 5*(tn-trn)*fr2*tn  | = 0.0609 in2
                                                           A2 = 0.0609 in2
A3 = Nozzle wall inward   | 5*t*ti*fr2  | = 0.0 in2
     Smallest of:         | 5*ti*ti*fr2 | = 0.0 in2
                          | 2*h*ti*fr2  | = 0.0 in2
                                                           A3 = 0.0 in2
A41 = Outward nozzle weld = (L1**2)*fr3 = 0.0143 in2
A42 = Outer element weld  = (L2**2)*fr4 = 0.0 in2
A43 = Inward nozzle weld  = (L3**2)*fr2 = 0.0 in2
                                                           A4 = 0.0143 in2
A5 = Reinforcement pad Area = (Dp-d-2*tn)*te*fr4           A5 = 0.0 in2
Aa = Area Available = A1+A2+A3+A4+A5                       Aa = 1.2012 in2
A = Area required   = (d*tr*F)+2*tn*tr*F*(1-f1)             A = 0.4573 in2
ASME VIII-1 2004 A06 Reinforcement areas (external pressure) UG-37(d)
A1 = Vessel wall.  Larger of:
 |(2*Lp-d)*(E1*t-F*tre)-2*tn*(E1*t-F*tre)*(1-fr1)| = 0.5545 in2
 |2*(t+tn)*(E1*t-F*tre)-2*tn*(E1*t-F*tre)*(1-fr1)| = 0.0627 in2
                                                           A1 = 0.5545 in2
A2 = Nozzle wall outward  | 5*(tn-trne)*fr2*t  | = 0.1119 in2
     Smaller of:          | 5*(tn-trne)*fr2*tn | = 0.06 in2
                                                           A2 = 0.06 in2
A3 = Nozzle wall inward   | 5*t*ti*fr2  | = 0.0 in2
     Smallest of:         | 5*ti*ti*fr2 | = 0.0 in2
                          | 2*h*ti*fr2  | = 0.0 in2
                                                           A3 = 0.0 in2
A41 = Outward nozzle weld =   (L1**2)*fr3 = 0.0143 in2
A42 = Outer element weld  =   (L2**2)*fr4 = 0.0 in2
A43 = Inward nozzle weld  =   (L3**2)*fr2 = 0.0 in2
                                                           A4 = 0.0143 in2
A5 = Reinforcement pad Area = (Dp-d-2*tn)*te*fr4           A5 = 0.0 in2
Aa = Area Available = A1+A2+A3+A4+A5                       Aa = 0.6288 in2
A = Area required   = 0.5*(d*tre*F+2*tn*tre*F*(1-fr1))      A = 0.5194 in2
```

Nozzle attachment weld loads - UG-41 - Strength of reinforcement

```
  ASME - Weld strength calculations not required per UW-15(b).
Total weld load (UG-41(b)(2))
  W = (A-A1+2*tn*fr1(E1*t-F*tr))*Sv                        W = -
Weld load for strength path 1-1 (UG-41(b)(1)
  W(1-1) = (A2+A5+A41+A42)*Sv                         W(1-1) = 1421 lbf
Weld load for strength path 2-2 (UG-41(b)(1)
  W(2-2) = (A2+A3+A41+A43+2*tn*t*fr1)*Sv              W(2-2) = 2426 lbf
Weld load for strength path 3-3 (UG-41(b)(1)
  W(3-3) = (A2+A3+A5+A41+A42+A43+2*tn*t*fr1)*Sv       W(3-3) = -
Reinforcing element strength = A5 * Se                       = -
Nozzle attachment weld loads - ASME 2004 UG-41 - Strength of reinforcement
 Unit stresses - UW15(c)and UG-45(c)
    Inner fillet weld shear            =   7350 psi
    Outer fillet weld shear            =   -
    Groove weld tension                =   11100 psi
    Groove weld shear                  =   -
    Nozzle wall shear                  =   10500 psi
 Strength of connection elements
    Inner fillet weld shear            =   10245 lbf
    Nozzle wall shear                  =   14339 lbf
    Groove weld tension                =   15471 lbf
    Outer fillet weld shear            =   -
 Possible paths of failure
    1-1        14339 + 10245           =   24584 lbf
    2-2        10245 + 15471           =   25716 lbf
    3-3            - + -               =   -
 Welds strong enough if path greater than the smaller of W or W(path)
                            Path 1-1 > W or W11
                           24584 lbf > 1421 lbf                 OK
                            Path 2-2 > W or W22
                           25716 lbf > 2426 lbf                 OK
                            Path 3-3 > W or W33
                                   - > -
```

```
Component:  Nozzle B
Method: Local Stresses in Cylindrical Shell Due to External Loadings per
        Heat Exchange Institute (HEI 'Std For Power Plant Hx', First Edition)
Vessel:  Shell Cylinder                     SA-240 S30400 Grd 304 Plate(G5)
Design pressure        Pr = 75 psi          Design temperature     T = 300 F
Joint efficiency        E = 1.00
Vessel design stress    S = 18900 psi       Vessel yield stress  Sy = 22400 psi
Inside corr. allow.  CAI = 0.0 in           Outside corr. all.  CAO = 0.0 in
Vessel outside dia.   OD = 36.0 in          Vessel mean radius   Rm = 17.875 in
Vessel thickness    tnom = 0.25 in
Nozzle:
Nozzle outside dia.  ODn = 2.375 in         Nozzle outside rad.  ro = 1.1875 in
Reinf. pad:
Pad thickness       Prtk = 0.0 in           Vessel + pad tks.     T = 0.25 in
Shape factors and Coefficients:
 Gamma = Rm/T = 71.5                      Beta = 0.875*ro/Rm = 0.0581
 Alpha =       = 4876.22     Sigma = 3202.91        Delta = 2029.70
Conversion factor               Cf = 1
Maximum load & moment
S    = 2*pr*(Rm-T/2)/t            = 10650 psi
Sa   = shell allowable stress     = 18900 psi
Sig  = minimum of S & Sa          = 10650 psi
Frrf = Rm*Rm*(sy-sig)/alpha       = 770 lbf
Mrcm = Rm*Rm*ro*sy*cf/sigma       = 2654 lbf*in
Mrlm = Rm*Rm*ro*(sy-sig)*cf/delta = 2197 lbf*in
Frf  = maximum resultant force    = 770 lbf
Mrm  = maximum resultant moment   = 2197 lbf*in
          |  Interaction diagram:
          |                                Applied loads:
          |                                    Radial load    P = 0 lbf
      FRF-+                                    Circ. moment  Mc = 0 lbf*in
      770 |                                    Long. moment  Ml = 0 lbf*in
          |                                Maximum allowable loads:
          |                                    Radial Load P,Mc = 770 lbf
          |                                    Radial Load P,Ml = 770 lbf
          |                                    Mc or Ml (from P)= 2197 lbf*in
          +
          |                                    Note: Couples (P,Mc) & (P,Ml)
          |                                          must be located within
          |                                          the triangle limited by
          |                                          0, FRF, MRM.
          |
          ----------+---------+----
         0                  MRM
                            2197
```

```
Component:  Nozzle C
Method: Local Stresses in Cylindrical Shell Due to External Loadings per
        Heat Exchange Institute (HEI 'Std For Power Plant Hx', First Edition)
Vessel:  Rear Head Cylinder              SA-516 K02700 Grd 70 Plate
Design pressure       Pr = 150 psi      Design temperature    T = 300 F
Joint efficiency       E = 1.00
Vessel design stress   S = 20000 psi    Vessel yield stress  Sy = 33600 psi
Inside corr. allow.  CAI = 0.0625 in    Outside corr. all.  CAO = 0.0 in
Vessel outside dia.   OD = 36.0 in      Vessel mean radius   Rm = 17.8438 in
Vessel thickness    tnom = 0.375 in
Nozzle:
Nozzle outside dia.  ODn = 10.75 in     Nozzle outside rad.  ro = 5.375 in
Reinf. pad:
Pad thickness       Prtk = 0.0 in       Vessel + pad tks.     T = 0.3125 in
Shape factors and Coefficients:
 Gamma = Rm/T = 57.1                  Beta = 0.875*ro/Rm = 0.2636
 Alpha =      = 854.67      Sigma = 1405.13        Delta = 559.85
Conversion factor              Cf = 1
Maximum load & moment
S    = 2*pr*(Rm-T/2)/t             = 16980 psi
Sa   = shell allowable stress      = 20000 psi
Sig  = minimum of S & Sa           = 16980 psi
Frrf = Rm*Rm*(sy-sig)/alpha        = 6192 lbf
Mrcm = Rm*Rm*ro*sy*cf/sigma        = 40923 lbf*in
Mrlm = Rm*Rm*ro*(sy-sig)*cf/delta  = 50806 lbf*in
Frf  = maximum resultant force     = 6192 lbf
Mrm  = maximum resultant moment    = 40923 lbf*in
          |  Interaction diagram:
          |                         Applied loads:
          |                             Radial load    P = 0 lbf
      FRF-+                             Circ. moment  Mc = 0 lbf*in
     6192 |                             Long. moment  Ml = 0 lbf*in
          |                         Maximum allowable loads:
          |                             Radial Load P,Mc = 6192 lbf
          |                             Radial Load P,Ml = 6192 lbf
          |                             Mc or Ml (from P)= 40923 lbf*in
          +
          |                             Note: Couples (P,Mc) & (P,Ml)
          |                                   must be located within
          |                                   the triangle limited by
          |                                   0, FRF, MRM.
          |
         ----------+----------+----
         0                   MRM
                            40923
```

```
Component:  Nozzle D
Method: Local Stresses in Cylindrical Shell Due to External Loadings per
          Heat Exchange Institute (HEI 'Std For Power Plant Hx', First Edition)
Vessel:  Rear Head Cylinder                     SA-516 K02700 Grd 70 Plate
Design pressure          Pr = 150 psi           Design temperature     T = 300 F
Joint efficiency          E = 1.00
Vessel design stress      S = 20000 psi         Vessel yield stress   Sy = 33600 psi
Inside corr. allow.     CAI = 0.0625 in         Outside corr. all.   CAO = 0.0 in
Vessel outside dia.      OD = 36.0 in           Vessel mean radius    Rm = 17.8438 in
Vessel thickness       tnom = 0.375 in
Nozzle:
Nozzle outside dia.     ODn = 10.75 in          Nozzle outside rad.   ro = 5.375 in
Reinf. pad:
Pad thickness          Prtk = 0.0 in            Vessel + pad tks.      T = 0.3125 in
Shape factors and Coefficients:
 Gamma = Rm/T = 57.1                        Beta = 0.875*ro/Rm = 0.2636
 Alpha =      = 854.67       Sigma = 1405.13          Delta = 559.85
Conversion factor                 Cf = 1
Maximum load & moment
S    = 2*pr*(Rm-T/2)/t                 = 16980 psi
Sa   = shell allowable stress          = 20000 psi
Sig  = minimum of S & Sa               = 16980 psi
Frrf = Rm*Rm*(sy-sig)/alpha            = 6192 lbf
Mrcm = Rm*Rm*ro*sy*cf/sigma            = 40923 lbf*in
Mrlm = Rm*Rm*ro*(sy-sig)*cf/delta      = 50806 lbf*in
Frf  = maximum resultant force         = 6192 lbf
Mrm  = maximum resultant moment        = 40923 lbf*in
           |  Interaction diagram:
           |                                   Applied loads:
           |                                       Radial load    P = 0 lbf
     FRF-+                                         Circ. moment  Mc = 0 lbf*in
     6192 |                                        Long. moment  Ml = 0 lbf*in
           |                                   Maximum allowable loads:
           |                                       Radial Load P,Mc = 6192 lbf
           |                                       Radial Load P,Ml = 6192 lbf
           |                                       Mc or Ml  (from P)= 40923 lbf*in
           +
           |                                       Note: Couples (P,Mc) & (P,Ml)
           |                                             must be located within
           |                                             the triangle limited by
           |                                             0, FRF, MRM.
           |
           ----------+---------+----
          0                    MRM
                              40923
```

```
Component:  Nozzle G
Method: Local Stresses in Cylindrical Shell Due to External Loadings per
          Heat Exchange Institute (HEI 'Std For Power Plant Hx', First Edition)
Vessel:  Shell Cylinder                     SA-240 S30400 Grd 304 Plate(G5)
Design pressure        Pr = 75 psi         Design temperature      T = 300 F
Joint efficiency        E = 1.00
Vessel design stress    S = 18900 psi      Vessel yield stress    Sy = 22400 psi
Inside corr. allow.   CAI = 0.0 in         Outside corr. all.    CAO = 0.0 in
Vessel outside dia.    OD = 36.0 in        Vessel mean radius     Rm = 17.875 in
Vessel thickness     tnom = 0.25 in
Nozzle:
Nozzle outside dia.   ODn = 6.625 in       Nozzle outside rad.    ro = 3.3125 in
Reinf. pad:
Pad thickness        Prtk = 0.0 in         Vessel + pad tks.       T = 0.25 in
Shape factors and Coefficients:
 Gamma = Rm/T = 71.5                      Beta = 0.875*ro/Rm = 0.1622
 Alpha =       = 2130.17     Sigma = 2477.62          Delta = 1262.12
Conversion factor                  Cf = 1
Maximum load & moment
S    = 2*pr*(Rm-T/2)/t              = 10650 psi
Sa   = shell allowable stress       = 18900 psi
Sig  = minimum of S & Sa            = 10650 psi
Frrf = Rm*Rm*(sy-sig)/alpha         = 1762 lbf
Mrcm = Rm*Rm*ro*sy*cf/sigma         = 9569 lbf*in
Mrlm = Rm*Rm*ro*(sy-sig)*cf/delta   = 9853 lbf*in
Frf  = maximum resultant force      = 1762 lbf
Mrm  = maximum resultant moment     = 9569 lbf*in
          |  Interaction diagram:
          |                             Applied loads:
          |                                 Radial load    P = 0 lbf
    FRF-+                                   Circ. moment  Mc = 0 lbf*in
   1762 |                                   Long. moment  Ml = 0 lbf*in
        |                               Maximum allowable loads:
        |                                   Radial Load P,Mc = 1762 lbf
        |                                   Radial Load P,Ml = 1762 lbf
        |                                   Mc or Ml (from P)= 9569 lbf*in
        +
        |                                   Note: Couples (P,Mc) & (P,Ml)
        |                                         must be located within
        |                                         the triangle limited by
        |                                         0, FRF, MRM.
        |
        ----------+---------+----
       0                   MRM
                           9569
```

Component: Nozzle Flange Details
Flange, Gasket and Bolting Details
Dimensional data in

Nozzle	Flg Type	Flg Dia.(*)	Flg Rating	Neck tks	Flg tks	Bolt Cir.	Gaskets O.D.	Gaskets Width	Bolts No	Bolts Dia.
A	ANSI SO	24.0	150	0.375	1.88	29.5	27.25	1.62	20	1.25
B	ANSI SO	2.375	150	0.154	0.75	4.75	3.62	0.62	4	0.625
C	ANSI SO	10.75	150	0.365	1.19	14.25	12.75	1.0	12	0.875
D	ANSI SO	10.75	150	0.365	1.19	14.25	12.75	1.0	12	0.875
G	ANSI SO	6.625	150	0.134	1.0	9.5	8.5	0.94	8	0.75

* Dia. = Nozzle O.D. if standard flange
= Flange O.D. if non-standard flange

```
Wind loads - ANSI/SEI/ASCE 7-02
Vessel outside diameter        OD                       OD = 36 in
Vessel effective length        EL                       EL = 257.0625 in
Vessel effective diameter      EOD                     EOD = 54 in
Effective wind area            Af            Af = EOD*EL = 96.4 ft2
Velocity pressure exposure     Kz                       Kz = 0.85
Topographic factor             Kzt                     Kzt = 1
Directionality factor          Kd                       Kd = 1
Importance factor              I                         I = 1
Wind speed, m/h                V                         V = 100
Velocity pressure, qz,   lbf/ft2 = 0.00256*Kz*Kzt*I*V**2 = 21.8
Gust response factor           G                         G = 0.85
Force coefficient              Cf                       Cf = 1
Wind force                     F           F = qz*G*Cf*Af = 1783 lbf
Moment arm                     L                         L = 10.71 ft
Overturning moment, OM,  ft-lbf                   OM = F*L = 19097
Earthquake Loads - ANSI/SEI/ASCE 7-02
Equipment occupancy category - wind/seismic design               = II
Equipment seismic site class                                     = B
Equipment seismic use group                                      = I
Response modification factor                                   R = 3
Seismic importance factor                                      I = 1
Mapped maximum spectral response acceleration at short periods Ss = 0.75
Mapped maximum spectral response acceleration at 1-sec period  S1 = 0.2
Site coefficient Fa - Table 9.4.1.2.4a                         Fa = 1
Site coefficient Fv - Table 9.4.1.2.4b                         Fv = 1
Maximum spectral response acceleration short periods  Sms = Fa*Ss = 0.75
Maximum spectral response acceleration at 1-sec per.  Sm1 = Fv*S1 = 0.2
Spectral response acceleration at short periods   Sds = (2/3)*Sms = 0.5
Spectral response acceleration at 1-sec period    Sd1 = (2/3)*Sm1 = 0.13
Seismic response coefficient, Cs = Sds/(R/I)                   Cs = 0.17
                              CsMin = 0.5*S1/(R/I)          CsMin = 0.03
Seismic zone coefficient, Cv                                   Cv = 0.24
Weight of vessel, full                                          W = 22005 lbf
Total shear at the base, V = Cs * W                             V = 3667.5 lbf
Maximum lateral force,    F = V                                 F = 3667.5 lbf
Overturning moment, OM,  ft-lbf                      OM = 0.5*F*L = 19641
```

Wind and Seismic Loads - Effect on Lugs

Distance center of vessel to supports		l = 0 ft
Distance center of gravity to supports		L = 0 ft
Distance between bolt holes (diametrical)		B = 0 ft
Projected area of vessel	Af = EOD*EL	Af = 0.02 ft2
Wind force	F = Af*Cf*G*qz	F = 20000 lbf
Wind load	Qw = F * l / B	Qw = 6 lbf
Horizontal seismic force	Fh = Cs*W	Fh = 15 lbf
Vertical seismic force	Fv = Cv*W	Fv = 300 lbf
Seismic load	Qs = Fv + Fh * L / B	Qs = 4627 lbf
Controlling load,Q = Qmax(Qw,Qs)		Q = 0 lbf

Weights, surface area, Insulation

		Shell side		Tube side
Volume	ft3	54.58		75.16
Avg. fluid density	lb/ft3	0		0
Fluid weight	lb	0		0
Surface area	ft2	150.7		51.2
Surface Area			201.9 ft2	
Insulation thickness			-	
Insulation type			-	
Insulation density			-	
Insulation weight			-	
Insulation seals and jackets			-	
Weight of Accessories			-	
Weight of piping attached SS nozzles			-	
Weight of piping attached TS nozzles			-	
Empty weight			13911 lb	
Operating weight			22005 lb	
Full weight			22005 lb	

```
Component:  Shell Lifting Lugs
Calculation of Plate-type Lifting Lugs
Lug material:  SA-36 K02600 Plate
Pad material:  SA-240 S30400 Grd 304 Plate
Basic data:
Thickness             tb = 1.5 in       Length                 L = 10.0 in
Outside radius        Rl = 2.0 in       Radius of hole        Rh = 1.0 in
Weld size              n = 0.25 in      Vessel outside radius  R = 18.0 in
Allowable stress      Sa = 16600 psi    Vessel thickness      ta = 0.25 in
Yield stress vessel   Sy = 22400 psi    Empty weight per lug   W = 9274 lbf
Distance vessel surface to lug hole                            d = 4.5 in
Factor f               f = 0.5 in       Number of lugs        nl = 3
Calculation of allowable lug load, P (minimum of P1 or P2):
   P1 = Sa*tb / ( 0.33/(Rl-Rh) + 0.76*(Rl+rh)/(Rl-Rh)**2)   = 9540 lbf
   P2 = 1.5*Sa*tb*L / ( (10.4*(d+f) /L) + 1 )               = 60242 lbf
                                          (P > W)       P = 9540 lbf
Component:  Shell Lifting Lugs
Calculation of the minimum required weld size, n
   n = 6.8 * W * d / l**2 * Sa = 0.171 in
Calculation of the required vessel thickness to resist lug loads, ts
   Equivalent radius of lug, RE = 0.644*(tb*l**2)**(1/3) = 3.4218 in
   ts = ( 0.415*SQRT(R)/Sy * ( (1.734*W*(d+f)/(RE**2))+0.75*W/RE ) )**2/3
   ts = 0.788 in
   Minimum reinforcing pad thickness, tp
   tp = ts - ta = 0.538 in
                                                 Actual        Entered
   Reinforcement pad thickness                   0.5625 in     0.625 in
   Pad dimension parallel to the lug:            15.0 in       0.0 in
   Pad dimension perpendicular to the lug:       7.5 in        0.0 in
```

Maximum Allowable Working Pressures
* = Shell Side MAWP + = Tube Side MAWP

Component	Side	--Design conditions-- Temp F	Stress psi	MAWP psi	---- New and cold --- Temp F	Stress psi	MAWP psi
Shell Cylinder	S	300	18900	184.8	70	20000	195.5
Front Head Cylinder	T	300	20000	244.8	70	20000	294.1
Rear Head Cylinder	T	300	20000	244.8	70	20000	294.1
Front Head Cover	T	300	20000	299.8	70	20000	360.9
Rear Head Cover	T	300	20000	299.8	70	20000	360.9
Front Tubesheet	S	300	15000	133.3	70	20000	133.3
Front Tubesheet	T	300	15000	244.4	70	20000	244.4
Rear Tubesheet	S	300	15000	133.3	70	20000	133.3
Rear Tubesheet	T	300	15000	244.4	70	20000	244.4
Front Head Flng At TS	T	300	20000	154.6	70	20000	154.6
Rear Head Flng At TS	T	300	20000	154.6	70	20000	154.6
Tubes	T	300	12700	1751	70	17000	2343.8
Nozzle A	S	300	15000	239.7	70	20000	253.7
Nozzle B	S	300	15000	141.9	70	20000	150.2
Nozzle C	T	300	14600	287.1	70	14600	357.4
Nozzle D	T	300	14600	287.1	70	14600	357.4
Nozzle G	S	300	15000	123.4	70	20000	130.6
Nozzle Flng A	S	300	15000	205	70	20000	275
Nozzle Flng B	S	300	15000	205	70	20000	275
Nozzle Flng C	T	300	20000	230	70	20000	285
Nozzle Flng D	T	300	20000	230	70	20000	285
Nozzle Flng G	S	300	15000	205	70	20000	275
Nozzle Reinforcement A	S	300	-	190	70	-	202
Nozzle Reinforcement B	S	-	-	N/C	-	-	N/C
Nozzle Reinforcement C	T	300	-	186	70	-	221
Nozzle Reinforcement D	T	300	-	186	70	-	221
Nozzle Reinforcement G	S	300	-	122*	70	-	130*
Front Hd Bolting At TS	T	300	25000	153+	70	25000	153+
Rear Hd Bolting At TS	T	300	25000	153+	70	25000	153+
Dist. Belt An.ring	S	-	-	N/C	-	-	N/C
Nozzle Flng Bolting A	S	300	25000	205	70	25000	275
Nozzle Flng Bolting B	S	300	25000	205	70	25000	275
Nozzle Flng Bolting C	T	300	25000	230	70	25000	285
Nozzle Flng Bolting D	T	300	25000	230	70	25000	285
Nozzle Flng Bolting G	S	300	25000	205	70	25000	275

Minimum Design Metal Temperature for Impact Test Exemption (UCS-66)

* Indicates the controlling components + Indicates compliance with UG-20(f)

Component	Curve	Temp F		******* UCS-66.1 ******* Ratio	Reduction	Temperature	
Front Head Cylinder	B	-20		0.49	58	-78	
Rear Head Cylinder	B	-20		0.49	58	-78	
Front Head Cover	B	-20		0.43	81	-101	
Rear Head Cover	B	-20		0.43	81	-101	
Front Head Flng At TS	D	-55		0.49	58	-113	
Rear Head Flng At TS	D	-55		0.49	58	-113	
Front Head Partitions	B	-7	+	-	-	-	*
Rear Head Partitions	B	-7	+	-	-	-	*
Nozzle C	B	-20		0.21	140	-160	
Nozzle D	B	-20		0.21	140	-160	
Nozzle Flng C	-	-20		-	-	-	
Nozzle Flng D	-	-20		-	-	-	
Front Hd Bolting At TS	A	-55		-	-	-	
Rear Hd Bolting At TS	A	-55		-	-	-	
Nozzle Flng Bolting A	A	-55		-	-	-	
Nozzle Flng Bolting B	A	-55		-	-	-	
Nozzle Flng Bolting C	A	-55		-	-	-	
Nozzle Flng Bolting D	A	-55		-	-	-	
Nozzle Flng Bolting G	A	-55		-	-	-	

Hydrostatic Test Pressure - ASME VIII-1 2004 A06 UG-99(b) Factor: 1.3
Shell Side: 97.5 psi Tube Side: 195 psi

Component	Material	Side	Design Temp F	Stress psi	Test Stress psi	Stress Ratio
Shell Cylinder	SA-240 S30400 Grd 304 Plat	S	300	18900	20000	1.0582
Front Head Cylinder	SA-516 K02700 Grd 70 Plate	T	300	20000	20000	1
Rear Head Cylinder	SA-516 K02700 Grd 70 Plate	T	300	20000	20000	1
Front Head Cover	SA-516 K02700 Grd 70 Plate	T	300	20000	20000	1
Rear Head Cover	SA-516 K02700 Grd 70 Plate	T	300	20000	20000	1
Front Tubesheet	SA-240 S30400 Grd 304 Plat	S	300	15000	20000	1.3333
Rear Tubesheet	SA-240 S30400 Grd 304 Plat	S	300	15000	20000	1.3333
Front Head Flng At TS	SA-516 K02700 Grd 70 Plate	T	300	20000	20000	1
Rear Head Flng At TS	SA-516 K02700 Grd 70 Plate	T	300	20000	20000	1
Tubes	SA-249 S30400 Grd TP304 Wl	T	300	12700	17000	1.3386
Nozzle A	SA-312 S30400 Grd TP304 Wl	S	300	15000	20000	1.3333
Nozzle B	SA-312 S30400 Grd TP304 Wl	S	300	15000	20000	1.3333
Nozzle C	SA-53 K03005 Grd E/B Wld.	T	300	14600	14600	1
Nozzle D	SA-53 K03005 Grd E/B Wld.	T	300	14600	14600	1
Nozzle G	SA-312 S30400 Grd TP304 Wl	S	300	15000	20000	1.3333
Nozzle Flng A	SA-182 S30400 Grd F304 For	S	300	15000	20000	1.3333
Nozzle Flng B	SA-182 S30400 Grd F304 For	S	300	15000	20000	1.3333
Nozzle Flng C	SA-105 K03504 Forgings	T	300	20000	20000	1
Nozzle Flng D	SA-105 K03504 Forgings	T	300	20000	20000	1
Nozzle Flng G	SA-182 S30400 Grd F304 For	S	300	15000	20000	1.3333
Front Hd Bolting At TS	SA-193 G41400 Grd B7 Bolt(	T	300	25000	25000	1
Rear Hd Bolting At TS	SA-193 G41400 Grd B7 Bolt(	T	300	25000	25000	1
Distributor Belt A	SA-240 S30400 Grd 304 Plat	S	300	18900	20000	1.0582
Nozzle Flng Bolting A	SA-193 G41400 Grd B7 Bolt(	S	300	25000	25000	1
Nozzle Flng Bolting B	SA-193 G41400 Grd B7 Bolt(	S	300	25000	25000	1
Nozzle Flng Bolting C	SA-193 G41400 Grd B7 Bolt(	T	300	25000	25000	1
Nozzle Flng Bolting D	SA-193 G41400 Grd B7 Bolt(	T	300	25000	25000	1
Nozzle Flng Bolting G	SA-193 G41400 Grd B7 Bolt(	S	300	25000	25000	1

HT/DcR Engineering, Inc.
2830 Parkway Street Lakeland, FL 33811

Date Printed: 9/14/2007

CUSTOMER

Delta-T
133 Waller Mill Road
Williamsburg, VA 23185

VESSEL LOCATION

BUNGE-ERGON

VICKSBURG, MISSISSIPPI

VESSEL DESCRIPTION

PRODUCT CONDENSER

Vessel designed per the ASME Boiler & Pressure Vessel Code,
Section VIII, Division 1,2004 Edition, 2006 Addenda
with Advanced Pressure Vessel, Version: 9.2.4
Vessel is ASME Code Stamped

Job No: 1494F
Vessel Number: 7793-E4401 Legs

NAMEPLATE INFORMATION

Vessel MAWP: 75.00 PSI and Full Vacuum at 300 °F
MDMT: -20 °F at 75.00 PSI
Serial Number(s): 4401-7793
National Board Number(s): ____________________
Year Built: 2007
Radiography: NONE
Postweld Heat Treated: NONE

HT/DcR Engineering, Inc.
2830 Parkway Street Lakeland, FL 33811

Date Printed: 9/14/2007

HT/DcR Engineering, Inc.
Leg 1

Customer: **Delta-T**
Job No: 1494F
Mark Number: LEG1

Vessel Number: 7793-E4401 Legs

Date Printed: 9/14/2007

Leg Information

Design Temperature:	300 °F	Factor B Chart:	CS-2
Material:	SA-36	Material Stress (Hot):	21600 PSI
Condition:		Material Stress (Cold):	21600 PSI
B.P. to Vessel Attachment Length (L):	73.8800 in.	Modulus of Elasticity:	28.3 10^6 PSI
Direction of Applied Force:	0 °	Yield Strength:	36000 PSI
Length of Supports:	83.8800 in.	Dist. From Reference Line:	24.0000 in.
Quantity:	4	Method of Attachment:	Leg In
Type:	Angle	Molded to Head Curvature:	No
Description:			
d_1:	6.0000 in.	t_1:	0.5000 in.
d_2:	6.0000 in.	t_2:	0.5000 in.
Weld Attachment Length Top (W_t):	0.0000 in.	Side (W_s):	10.0000 in.
Weld Leg Dimension (W_l):	0.3750 in.		

Repad Information

Design Temperature:	300 °F		
Material:	SA-240 304, High	Material Stress (Hot):	18900 PSI
Condition:		Material Stress (Cold):	20000 PSI
Height (L_{rh}):	10.0000 in.	Thickness:	0.5000 in.
Width (L_{rw}):	10.0000 in.	Weld Leg (W_r):	0.3750 in.

Base Plate Information

Design Temperature:	300 °F		
Material:	SA-36 Plate	Material Stress (Hot):	16600 PSI
Condition:		Material Stress (Cold):	16600 PSI
Length:	8.0000 in.	Yield Strength:	36000 PSI
Width:	8.0000 in.	Thickness:	0.5000 in.
Leg to B.P. Attachment Factor:	0.7500	Bending Coefficient (C_m):	1.0000
Effective Length Factor (K):	1.5000		

Anchor Bolt Information

Material:	F-1554 Gr. 105	Material Stress (Hot):	39000 PSI
Condition:		Material Stress (Cold):	39000 PSI
Diameter:	0.7500 in.	Root Area:	1.2940 sq. in.
Quantity:	1	Bolt Circle Diameter:	41.0000 in.
Ultimate 28 Day Concrete Strength:	3000 PSI		

Operating Pressurized Conditions - Ocassional Loads - Seismic Case 5

Support Leg Properties

Section Modulus, S_x $= \frac{I_x}{C_x} = \frac{31.7448}{4.2426}$ = 7.4824 in.³

Section Modulus, S_y $= \frac{I_y}{C_y} = \frac{8.0709}{2.3826}$ = 3.3874 in.³

Radius of gyration, r_x $= \sqrt{\frac{I_x}{A}} = \sqrt{\frac{31.7448}{5.7500}}$ = 2.3496 in.

Radius of gyration, r_y $= \sqrt{\frac{I_y}{A}} = \sqrt{\frac{8.0709}{5.7500}}$ = 1.1848 in.

Least radius of gyration, r_{min} $= \sqrt{\frac{I_{min}}{A}} = \sqrt{\frac{8.0709}{5.7500}}$ = 1.1848 in.

Slenderness ratio, SR_x $= \frac{K\,L}{r_x} = \frac{1.5000 * 73.8800}{2.3496}$ = 47.1655

Slenderness ratio, SR_y $= \frac{K\,L}{r_y} = \frac{1.5000 * 73.8800}{1.1848}$ = 93.5348

SR_{max} $= \frac{K\,L}{r_{min}} = \frac{1.5000 * 73.8800}{1.1848}$ = 93.5348

Critical slenderness ratio, C_c $= \sqrt{\frac{2\pi^2 E}{F_y}} = \sqrt{\frac{2 * \pi^2 * (28.3 * 10^6)}{36000}}$ = 124.57

F'_{ex} $= \frac{4}{3}\frac{12\pi^2 E}{23\,SR_x^2} = \frac{4}{3} * \frac{12 * \pi^2 * (28.3 * 10^6)}{23 * 47.1655^2}$ = 87343 PSI

F'_{ey} $= \frac{4}{3}\frac{12\pi^2 E}{23\,SR_y^2} = \frac{4}{3} * \frac{12 * \pi^2 * (28.3 * 10^6)}{23 * 93.5348^2}$ = 22209 PSI

For SR_{max} <= C_c, Allowable compressive stress:

$$F_a = \frac{4}{3}\frac{\left(1 - \frac{SR_{max}^2}{2\,C_c^2}\right)F_y}{\frac{5}{3} + \frac{3\,SR_{max}}{8\,C_c} - \frac{SR_{max}^3}{8\,C_c^3}} = \frac{4}{3} * \frac{\left(1 - \frac{93.5348^2}{2 * 124.57^2}\right) * 36000}{\frac{5}{3} + \frac{3 * 93.5348}{8 * 124.57} - \frac{93.5348^3}{8 * 124.57^3}}$$ = 18187 PSI

Allowable bending stress : S_b $= \frac{4}{3}\,0.6\,F_y = \frac{4}{3} * 0.6 * 36000$ = 28800 PSI

Allowable tension stress : S_t $= \frac{4}{3}\,0.6\,F_y = \frac{4}{3} * 0.6 * 36000$ = 28800 PSI

Leg to Vessel Weld Properties

Distance between welds along side of legs (b) = **= 7.7782** in.

$L_W = 2\,W_S = 2 * 10.0000$ **= 20.0000** in.

$$I_{wy} = \frac{W_S^3}{6} = \frac{10.0000^3}{6}$$ **= 166.6667** in.³

$$I_{wz} = \frac{W_S\, b^2}{2} = \frac{10.0000 * 7.7782^2}{2}$$ **= 302.5000** in.³

$J_{wx} = I_{wy} + I_{wz} = 166.6667 + 302.5000$ **= 469.1667** in.³

Distance from weld neutral axis to top/bottom of welds:

$$EF_{yt} = EF_{yb} = \frac{W_S}{2} = \frac{10.0000}{2}$$ **= 5.0000** in.

Distance from weld neutral axis to bottom of welds:

$$EF_Z = \frac{b}{2} = \frac{7.7782}{2}$$ **= 3.8891** in.

NO Wind Analysis Information

Wind Analysis Calculations

No Wind Load Calculations were performed

IBC 2003 Seismic Design Information

Spectral Resp. Accel. at short periods (S_S):	0.200	Response Modification Factor (R):	3.000
Spectral Resp. Accel. at a period of 1 s (S_1):	0.100	Site Class:	D
Seismic Use Group:	I		
Seismic Design Category:	C		

Seismic Analysis Calculations

Seismic Center of Gravity: **= 174.4404** in.

$$C_S = \frac{SD_S\, I}{R} = \frac{0.2133 * 1.00}{3.000}$$ **= 0.0711**

$V = W * C_S = 22668.57 * 0.03$ **= 1611.99** lb.

$F_S = V\, C_{eh} = 1611.99 * 0.70$ **= 1128** lb.

HT/DcR Engineering, Inc.
Leg 1

Job No: 1494F
Mark Number: LEG1

Vessel Number: 7793-E4401 Legs

Date Printed: 9/14/2007

Loadings and Stresses on Support Legs

Direction of Applied Force = **0 °**

Leg Orientation °	Moment of Inertia in.⁴	Lateral Force lb.	Axial Stress PSI	Bending Stresses (f_{bx}) PSI	Bending Stresses (f_{by}) PSI	Acceptance Ratio (Eqn_1)	Acceptance Ratio (Eqn_2)
0	8.0709	114	-280	0	1720	0.0751	
90	31.7448	450	-1015	3331	3973	0.3094	
180	8.0709	114	-1750	0	8720	0.3990	
270	31.7448	450	-1015	3331	3973	0.3094	

Direction of Worst case Force = **40 °**
Highest Stress Ratio = **0.4606**

Loadings and Stresses on Leg to Vessel attachment welds

Leg Orientation °	Load F_x lb.	Load F_y lb.	Load F_z lb.	Moment M_x in.-lb.	Moment M_y in.-lb.	Moment M_z in.-lb.	Total Stress PSI	Stress Ratio
0	114	0	-1611	0	-9246	0	785	0.0636
90	0	450	-5836	24925	-10539	813	1765	0.1429
180	-114	0	-10062	0	-11833	0	1633	0.1322
270	0	450	-5836	24925	-10539	813	1765	0.1429

Direction of Worst case Force = **1 °**
Highest Stress Ratio: **0.1878**

Repad to Shell Weld Properties

$L_w = 2\ (L_{rh} + L_{rw}) = 2 * (10.0000 + 10.0000)$ **= 40.0000** in.

$I_{wy} = \frac{L_{rw} L_{rh}^2}{2} + \frac{L_{rh}^3}{6} = \frac{10.0000 * 10.0000^2}{2} + \frac{10.0000^3}{6}$ **= 666.6667** in.³

$I_{wz} = \frac{L_{rh} L_{rw}^2}{2} + \frac{L_{rw}^3}{6} = \frac{10.0000 * 10.0000^2}{2} + \frac{10.0000^3}{6}$ **= 666.6667** in.³

$J_{wx} = I_{wy} + I_{wz} = 666.6667 + 666.6667$ **= 1333.3333** in.³

Distance from weld neutral axis to top of repad:

$EF_y = \frac{L_{rh}}{2} = \frac{10.0000}{2}$ **= 5.0000** in.

Distance from weld neutral axis to side of repad:

$EF_z = \frac{L_{rw}}{2} = \frac{10.0000}{2}$ **= 5.0000** in.

Loadings and Stresses on Repad-to-Shell Attachment Welds

Leg Orientation °	Load F_x lb.	Load F_y lb.	Load F_z lb.	Moment M_x in.-lb.	Moment M_y in.-lb.	Moment M_z in.-lb.	Total Stress PSI	Stress Ratio
0	114	0	-1611	0	-10052	0	235	0.0190
90	0	450	-5836	24925	-13457	1038	755	0.0611
180	-114	0	-10062	0	-16864	0	747	0.0605
270	0	450	-5836	24925	-13457	1038	755	0.0611

Direction of Worst case Force = **1 °**
Highest Stress Ratio = **0.0806**

Loadings and Pressure on Concrete Foundation

Direction of applied force: = **0 °**

Leg Orientation °	Bearing Pressure PSI	Moment M_x in.-lb.	Moment M_y in.-lb.	Maximum Pressure P_x PSI	Maximum Pressure P_y PSI	Max. Concrete Pressure PSI	Concrete Pressure Ratio
0	25	5614	5614	65.79	65.79	156.75	0.1306
90	91	21266	21266	249.21	249.21	589.61	0.4913
180	157	13419	13419	157.25	157.25	471.73	0.3931
270	91	21266	21266	249.21	249.21	589.61	0.4913

Direction of Worst case Force: = **1 °**
Highest Stress Ratio = **0.6320**

Loadings and Stresses on BasePlate and Anchor bolts

Leg Orientation °	Moment M_x in.-lb.	Moment M_y in.-lb.	Maximum Pressure P_x PSI	Maximum Pressure P_y PSI	Maximum B.P. Stress PSI	BasePlate Stress Ratio	Anchor Bolt Stress PSI	Anchor Bolt Stress Ratio
0	174	163	4183	3912	5727	0.1989	1064	0.0205
90	652	609	15640	14613	21405	0.7432	4114	0.0791
180	615	588	14750	14102	20407	0.7086	973	0.0187
270	652	609	15640	14613	21405	0.7432	4114	0.0791

Direction of Worst case Force: = **1 °**
Highest Stress Ratio = **0.9888**

Maximum General Longitudinal Stresses

$VE = (C_{de} + 0.2 * SDS * I * C_{ev}) = (1.00 + 0.2 * 0.21 * 1.00 * 0.70) =$ **1.03**

$$S_{L1} = \frac{M_a}{Z} - \frac{W\,VE}{A} + \left(\frac{P * D}{4 * t}\right) = \frac{113471}{256.2605} - \frac{22668.57 * 1.03}{28.47} + \left(\frac{76.96 * 36.5000}{4 * 0.2500}\right)$$ **= 2432** PSI

$$S_{L2} = -\frac{M_a}{Z} - \frac{W\,VE}{A} - \left(\frac{Pe * D}{4 * t}\right) = -\frac{113471}{256.2605} - \frac{22668.57 * 1.03}{28.47} - \left(\frac{14.70 * 36.5000}{4 * 0.2500}\right)$$ **= -1799** PSI

Allowable Tension Stress, S_{ta} $= 1.2\,S\,E = 1.2 * 18900 * 0.70$ **= 15876** PSI
Allowable Compressive Stress, S_{ca} $= -1.2\,B = -1.2 * 8963$ **= -10756** PSI

$$R_{SL1} = \frac{S_{L1}}{S_{ta}} = \frac{2432}{15876}$$ **= 0.1532**

$$R_{SL2} = \frac{S_{L2}}{S_{ca}} = \frac{-1799}{-10756}$$ **= 0.1673**

Summary

Governing external force	= Seismic load
Total Force	= 1128 lb.
Weight	= 22668.57 lb.
Base Moment	= 196837 in.-lb.
Tangent Moment	= 113471 in.-lb.

Leg Stresses

Maximum combined compressive and bending stress ratio	= 0.4606

Leg BasePlate

Concrete Stress Ratio	= 0.6320
Base Plate Stress Ratio	= 0.9888

Host Stresses

SI1 ratio	= 0.1532
SI2 ratio	= 0.1673

Weld Stresses

Leg to vessel weld stress ratio	= 0.1878
Repad to shell weld stress ratio	= 0.0806

Operating Pressurized Conditions - Ocassional Loads - Seismic Case 8

Support Leg Properties

Section Modulus, $S_x = \frac{I_x}{C_x} = \frac{31.7448}{4.2426}$ **= 7.4824 in.³**

Section Modulus, $S_y = \frac{I_y}{C_y} = \frac{8.0709}{2.3826}$ **= 3.3874 in.³**

Radius of gyration, $r_x = \sqrt{\frac{I_x}{A}} = \sqrt{\frac{31.7448}{5.7500}}$ **= 2.3496 in.**

Radius of gyration, $r_y = \sqrt{\frac{I_y}{A}} = \sqrt{\frac{8.0709}{5.7500}}$ **= 1.1848 in.**

Least radius of gyration, $r_{min} = \sqrt{\frac{I_{min}}{A}} = \sqrt{\frac{8.0709}{5.7500}}$ **= 1.1848 in.**

Slenderness ratio, $SR_x = \frac{K\,L}{r_x} = \frac{1.5000 * 73.8800}{2.3496}$ **= 47.1655**

Slenderness ratio, $SR_y = \frac{K\,L}{r_y} = \frac{1.5000 * 73.8800}{1.1848}$ **= 93.5348**

$SR_{max} = \frac{K\,L}{r_{min}} = \frac{1.5000 * 73.8800}{1.1848}$ **= 93.5348**

Critical slenderness ratio, $C_c = \sqrt{\frac{2\pi^2 E}{F_y}} = \sqrt{\frac{2 * \pi^2 * (28.3 * 10^6)}{36000}}$ **= 124.57**

$F'_{ex} = \frac{4}{3} \frac{12\pi^2 E}{23\,SR_x^2} = \frac{4}{3} * \frac{12 * \pi^2 * (28.3 * 10^6)}{23 * 47.1655^2}$ **= 87343 PSI**

$F'_{ey} = \frac{4}{3} \frac{12\pi^2 E}{23\,SR_y^2} = \frac{4}{3} * \frac{12 * \pi^2 * (28.3 * 10^6)}{23 * 93.5348^2}$ **= 22209 PSI**

For $SR_{max} <= C_c$, Allowable compressive stress:

$$F_a = \frac{4}{3}\frac{\left(1 - \frac{SR_{max}^2}{2\,C_c^2}\right) F_y}{\frac{5}{3} + \frac{3\,SR_{max}}{8\,C_c} - \frac{SR_{max}^3}{8\,C_c^3}} = \frac{4}{3} * \frac{\left(1 - \frac{93.5348^2}{2 * 124.57^2}\right) * 36000}{\frac{5}{3} + \frac{3 * 93.5348}{8 * 124.57} - \frac{93.5348^3}{8 * 124.57^3}}$$ **= 18187 PSI**

Allowable bending stress : $S_b = \frac{4}{3}\,0.6\,F_y = \frac{4}{3} * 0.6 * 36000$ **= 28800 PSI**

Allowable tension stress : $S_t = \frac{4}{3}\,0.6\,F_y = \frac{4}{3} * 0.6 * 36000$ **= 28800 PSI**

Leg to Vessel Weld Properties

Distance between welds along side of legs (b) = **= 7.7782** in.

$L_w = 2\, W_s = 2 * 10.0000$ **= 20.0000** in.

$I_{wy} = \dfrac{W_s^3}{6} = \dfrac{10.0000^3}{6}$ **= 166.6667** in.³

$I_{wz} = \dfrac{W_s\, b^2}{2} = \dfrac{10.0000 * 7.7782^2}{2}$ **= 302.5000** in.³

$J_{wx} = I_{wy} + I_{wz} = 166.6667 + 302.5000$ **= 469.1667** in.³

Distance from weld neutral axis to top/bottom of welds:

$EF_{yt} = EF_{yb} = \dfrac{W_s}{2} = \dfrac{10.0000}{2}$ **= 5.0000** in.

Distance from weld neutral axis to bottom of welds:

$EF_z = \dfrac{b}{2} = \dfrac{7.7782}{2}$ **= 3.8891** in.

NO Wind Analysis Information

Wind Analysis Calculations

No Wind Load Calculations were performed

IBC 2003 Seismic Design Information

Spectral Resp. Accel. at short periods (S_S):	0.200	Response Modification Factor (R):	3.000
Spectral Resp. Accel. at a period of 1 s (S_1):	0.100	Site Class:	D
Seismic Use Group:	I		
Seismic Design Category:	C		

Seismic Analysis Calculations

Seismic Center of Gravity: **= 174.4404** in.

$C_S = \dfrac{SD_S\, I}{R} = \dfrac{0.2133 * 1.00}{3.000}$ **= 0.0711**

$V = W * C_S = 22668.57 * 0.03$ **= 1611.99** lb.

$F_S = V\, C_{eh} = 1611.99 * 0.70$ **= 1128** lb.

Loadings and Stresses on Support Legs

Direction of Applied Force = **0 °**

Leg Orientation °	Moment of Inertia in.⁴	Lateral Force lb.	Axial Stress PSI	Bending Stresses (f_{bx}) PSI	Bending Stresses (f_{by}) PSI	Acceptance Ratio (Eqn_1)	Acceptance Ratio (Eqn_2)
0	8.0709	114	173	0	2548	0.0965	
90	31.7448	450	-562	3331	2199	0.2229	
180	8.0709	114	-1297	0	6947	0.3125	
270	31.7448	450	-562	3331	2199	0.2229	

Direction of Worst case Force = **40 °**
Highest Stress Ratio = **0.3741**

Loadings and Stresses on Leg to Vessel attachment welds

Leg Orientation °	Load F_x lb.	Load F_y lb.	Load F_z lb.	Moment M_x in.-lb.	Moment M_y in.-lb.	Moment M_z in.-lb.	Total Stress PSI	Stress Ratio
0	114	0	995	0	-4540	0	401	0.0325
90	0	450	-3231	24925	-5835	813	1341	0.1086
180	-114	0	-7457	0	-7129	0	1139	0.0922
270	0	450	-3231	24925	-5835	813	1341	0.1086

Direction of Worst case Force = **1 °**
Highest Stress Ratio: **0.1501**

Repad to Shell Weld Properties

$L_w = 2\ (L_{rh} + L_{rw}) = 2 * (10.0000 + 10.0000)$ **= 40.0000** in.

$I_{wy} = \frac{L_{rw} L_{rh}^2}{2} + \frac{L_{rh}^3}{6} = \frac{10.0000 * 10.0000^2}{2} + \frac{10.0000^3}{6}$ **= 666.6667** in.³

$I_{wz} = \frac{L_{rh} L_{rw}^2}{2} + \frac{L_{rw}^3}{6} = \frac{10.0000 * 10.0000^2}{2} + \frac{10.0000^3}{6}$ **= 666.6667** in.³

$J_{wx} = I_{wy} + I_{wz} = 666.6667 + 666.6667$ **= 1333.3333** in.³

Distance from weld neutral axis to top of repad:

$EF_y = \frac{L_{rh}}{2} = \frac{10.0000}{2}$ **= 5.0000** in.

Distance from weld neutral axis to side of repad:

$EF_z = \frac{L_{rw}}{2} = \frac{10.0000}{2}$ **= 5.0000** in.

Loadings and Stresses on Repad-to-Shell Attachment Welds

Leg Orientation °	Load F_x lb.	Load F_y lb.	Load F_z lb.	Moment M_x in.-lb.	Moment M_y in.-lb.	Moment M_z in.-lb.	Total Stress PSI	Stress Ratio
0	114	0	995	0	-4043	0	111	0.0090
90	0	450	-3231	24925	-7450	1038	568	0.0460
180	-114	0	-7457	0	-10858	0	539	0.0437
270	0	450	-3231	24925	-7450	1038	568	0.0460

Direction of Worst case Force = **1 °**
Highest Stress Ratio = **0.0645**

Loadings and Pressure on Concrete Foundation

Direction of applied force: = **0 °**

Leg Orientation °	Bearing Pressure PSI	Moment M_x in.-lb.	Moment M_y in.-lb.	Maximum Pressure P_x PSI	Maximum Pressure P_y PSI	Max. Concrete Pressure PSI	Concrete Pressure Ratio
0	-16	1365	1365	16.00	16.00	16.45	0.0137
90	50	17018	17018	199.43	199.43	449.34	0.3745
180	117	9171	9171	107.47	107.47	331.46	0.2762
270	50	17018	17018	199.43	199.43	449.34	0.3745

Direction of Worst case Force: = **1 °**
Highest Stress Ratio = **0.5151**

Loadings and Stresses on BasePlate and Anchor bolts

Leg Orientation °	Moment M_x in.-lb.	Moment M_y in.-lb.	Maximum Pressure P_x PSI	Maximum Pressure P_y PSI	Maximum B.P. Stress PSI	BasePlate Stress Ratio	Anchor Bolt Stress PSI	Anchor Bolt Stress Ratio
0	0	0	0	0	0	0.0000	873	0.0168
90	476	441	11415	10593	15573	0.5407	3762	0.0723
180	439	420	10525	10082	14574	0.5060	557	0.0107
270	476	441	11415	10593	15573	0.5407	3762	0.0723

Direction of Worst case Force: = **1 °**
Highest Stress Ratio = **0.7863**

Maximum General Longitudinal Stresses

$VE = (C_{de} + 0.2 * SDS * I * C_{ev}) = (0.60 + 0.2 * 0.21 * 1.00 * -0.70) =$ **0.57**

$$S_{L1} = \frac{M_a}{Z} - \frac{W\,VE}{A} + \left(\frac{P * D}{4 * t}\right) = \frac{113471}{256.2605} - \frac{22668.57 * 0.57}{28.47} + \left(\frac{76.08 * 36.5000}{4 * 0.2500}\right)$$ **= 2766** PSI

$$S_{L2} = -\frac{M_a}{Z} - \frac{W\,VE}{A} - \left(\frac{Pe * D}{4 * t}\right) = -\frac{113471}{256.2605} - \frac{22668.57 * 0.57}{28.47} - \left(\frac{14.70 * 36.5000}{4 * 0.2500}\right)$$ **= -1433** PSI

Allowable Tension Stress, S_{ta} = 1.2 S E = 1.2 * 18900 * 0.70 **= 15876** PSI
Allowable Compressive Stress, S_{ca} = -1.2 B = -1.2 * 8963 **= -10756** PSI

$$R_{SL1} = \frac{S_{L1}}{S_{ta}} = \frac{2766}{15876}$$ **= 0.1742**

$$R_{SL2} = \frac{S_{L2}}{S_{ca}} = \frac{-1433}{-10756}$$ **= 0.1332**

HT/DcR Engineering, Inc.
Leg 1

Job No: 1494F
Mark Number: LEG1

Vessel Number: 7793-E4401 Legs

Date Printed: 9/14/2007

Summary

Governing external force	**= Seismic load**
Total Force	**= 1128 lb.**
Weight	**= 22668.57 lb.**
Base Moment	**= 196837 in.-lb.**
Tangent Moment	**= 113471 in.-lb.**

Leg Stresses

Maximum combined compressive and bending stress ratio	**= 0.3741**

Leg BasePlate

Concrete Stress Ratio	**= 0.5151**
Base Plate Stress Ratio	**= 0.7863**

Host Stresses

SI1 ratio	**= 0.1742**
SI2 ratio	**= 0.1332**

Weld Stresses

Leg to vessel weld stress ratio	**= 0.1501**
Repad to shell weld stress ratio	**= 0.0645**

Operating Pressurized Conditions - Ocassional Loads - Wind Case 5

Support Leg Properties

Section Modulus, $S_x = \frac{I_x}{C_x} = \frac{31.7448}{4.2426}$ = 7.4824 in.³

Section Modulus, $S_y = \frac{I_y}{C_y} = \frac{8.0709}{2.3826}$ = 3.3874 in.³

Radius of gyration, $r_x = \sqrt{\frac{I_x}{A}} = \sqrt{\frac{31.7448}{5.7500}}$ = 2.3496 in.

Radius of gyration, $r_y = \sqrt{\frac{I_y}{A}} = \sqrt{\frac{8.0709}{5.7500}}$ = 1.1848 in.

Least radius of gyration, $r_{min} = \sqrt{\frac{I_{min}}{A}} = \sqrt{\frac{8.0709}{5.7500}}$ = 1.1848 in.

Slenderness ratio, $SR_x = \frac{K\,L}{r_x} = \frac{1.5000 * 73.8800}{2.3496}$ = 47.1655

Slenderness ratio, $SR_y = \frac{K\,L}{r_y} = \frac{1.5000 * 73.8800}{1.1848}$ = 93.5348

$SR_{max} = \frac{K\,L}{r_{min}} = \frac{1.5000 * 73.8800}{1.1848}$ = 93.5348

Critical slenderness ratio, $C_c = \sqrt{\frac{2\pi^2 E}{F_y}} = \sqrt{\frac{2 * \pi^2 * (28.3 * 10^6)}{36000}}$ = 124.57

$F'_{ex} = \frac{4}{3}\,\frac{12\pi^2 E}{23\,SR_x^2} = \frac{4}{3} * \frac{12 * \pi^2 * (28.3 * 10^6)}{23 * 47.1655^2}$ = 87343 PSI

$F'_{ey} = \frac{4}{3}\,\frac{12\pi^2 E}{23\,SR_y^2} = \frac{4}{3} * \frac{12 * \pi^2 * (28.3 * 10^6)}{23 * 93.5348^2}$ = 22209 PSI

For $SR_{max} <= C_c$, Allowable compressive stress:

$$F_a = \frac{4}{3}\,\frac{\left(1 - \frac{SR_{max}^2}{2\,C_c^2}\right) F_y}{\frac{5}{3} + \frac{3\,SR_{max}}{8\,C_c} - \frac{SR_{max}^3}{8\,C_c^3}} = \frac{4}{3} * \frac{\left(1 - \frac{93.5348^2}{2 * 124.57^2}\right) * 36000}{\frac{5}{3} + \frac{3 * 93.5348}{8 * 124.57} - \frac{93.5348^3}{8 * 124.57^3}}$$ = 18187 PSI

Allowable bending stress : $S_b = \frac{4}{3}\,0.6\,F_y = \frac{4}{3} * 0.6 * 36000$ = 28800 PSI

Allowable tension stress : $S_t = \frac{4}{3}\,0.6\,F_y = \frac{4}{3} * 0.6 * 36000$ = 28800 PSI

Leg to Vessel Weld Properties

Distance between welds along side of legs (b) = = 7.7782 in.

$L_w = 2\,W_s = 2 * 10.0000$ = 20.0000 in.

$I_{wy} = \frac{W_s^3}{6} = \frac{10.0000^3}{6}$ = 166.6667 in.³

$I_{wz} = \frac{W_s\,b^2}{2} = \frac{10.0000 * 7.7782^2}{2}$ = 302.5000 in.³

$J_{wx} = I_{wy} + I_{wz} = 166.6667 + 302.5000$ = 469.1667 in.³

Distance from weld neutral axis to top/bottom of welds:

$EF_{yt} = EF_{yb} = \frac{W_s}{2} = \frac{10.0000}{2}$ = 5.0000 in.

Distance from weld neutral axis to bottom of welds:

$EF_z = \frac{b}{2} = \frac{7.7782}{2}$ = 3.8891 in.

IBC 2003 Wind Analysis Information

Basic Wind Speed (V):	90	MPH	Wind Exposure type:	C
Importance factor (I):	1.0000		Force (shape) coefficient (C_f):	0.70
Topographic Factor (K_{zt}):	1.00		Directionality Factor (K_d):	1.00

Wind Analysis Calculations

Wind Center of Gravity = 178.6462 in.

$q_z = 0.00256\,K_z\,K_{zt}K_d\,V^2\,I = 0.00256 * 0.85 * 1.000 * 1.00 * 90^2 * 1.0000$ = 17.626

$P = q_z\,G\,C_f = 17.626 * 0.90 * 0.70$ = 11.10 lb./ft²

Wind Load, $F_w = P\,A\,C_{wi} = 11.10 * 74.7016 * 1.00$ = 829 lb.

NO Seismic Design Information

Seismic Analysis Calculations

No Seismic Analysis Calculations were performed.

Loadings and Stresses on Support Legs

Direction of Applied Force = **0 °**

Leg Orientation °	Moment of Inertia in.^{4}	Lateral Force lb.	Axial Stress PSI	Bending Stresses (f_{bx}) PSI	Bending Stresses (f_{by}) PSI	Acceptance Ratio (Eqn_1)	Acceptance Ratio (Eqn_2)
0	8.0709	84	-431	0	2145	0.0982	
90	31.7448	331	-986	2448	3858	0.2732	
180	8.0709	84	-1540	0	7403	0.3417	
270	31.7448	331	-986	2448	3858	0.2732	

Direction of Worst case Force = **40 °**
Highest Stress Ratio = **0.3860**

Loadings and Stresses on Leg to Vessel attachment welds

Leg Orientation °	Load F_x lb.	Load F_y lb.	Load F_z lb.	Moment M_x in.-lb.	Moment M_y in.-lb.	Moment M_z in.-lb.	Total Stress PSI	Stress Ratio
0	84	0	-2478	0	-9132	0	812	0.0658
90	0	331	-5667	18316	-10234	598	1539	0.1246
180	-84	0	-8856	0	-11336	0	1482	0.1200
270	0	331	-5667	18316	-10234	598	1539	0.1246

Direction of Worst case Force = **1 °**
Highest Stress Ratio: **0.1595**

Repad to Shell Weld Properties

$$L_w = 2\ (L_{rh} + L_{rw}) = 2 * (10.0000 + 10.0000) \quad = \mathbf{40.0000}\ \text{in.}$$

$$I_{wy} = \frac{L_{rw}\, L_{rh}^2}{2} + \frac{L_{rh}^3}{6} = \frac{10.0000 * 10.0000^2}{2} + \frac{10.0000^3}{6} \quad = \mathbf{666.6667}\ \text{in.}^3$$

$$I_{wz} = \frac{L_{rh}\, L_{rw}^2}{2} + \frac{L_{rw}^3}{6} = \frac{10.0000 * 10.0000^2}{2} + \frac{10.0000^3}{6} \quad = \mathbf{666.6667}\ \text{in.}^3$$

$$J_{wx} = I_{wy} + I_{wz} = 666.6667 + 666.6667 \quad = \mathbf{1333.3333}\ \text{in.}^3$$

Distance from weld neutral axis to top of repad:

$$EF_y = \frac{L_{rh}}{2} = \frac{10.0000}{2} \quad = \mathbf{5.0000}\ \text{in.}$$

Distance from weld neutral axis to side of repad:

$$EF_z = \frac{L_{rw}}{2} = \frac{10.0000}{2} \quad = \mathbf{5.0000}\ \text{in.}$$

HT/DcR Engineering, Inc.

Leg 1

Job No: 1494F

Mark Number: LEG1

Vessel Number: 7793-E4401 Legs

Date Printed: 9/14/2007

Loadings and Stresses on Repad-to-Shell Attachment Welds

Leg Orientation °	Load F_x lb.	Load F_y lb.	Load F_z lb.	Moment M_x in.-lb.	Moment M_y in.-lb.	Moment M_z in.-lb.	Total Stress PSI	Stress Ratio
0	84	0	-2478	0	-10371	0	270	0.0219
90	0	331	-5667	18316	-13067	763	658	0.0533
180	-84	0	-8856	0	-15764	0	667	0.0540
270	0	331	-5667	18316	-13067	763	658	0.0533

Direction of Worst case Force = **1 °**

Highest Stress Ratio = **0.0683**

Loadings and Pressure on Concrete Foundation

Direction of applied force: = **0 °**

Leg Orientation °	Bearing Pressure PSI	Moment M_x in.-lb.	Moment M_y in.-lb.	Maximum Pressure P_x PSI	Maximum Pressure P_y PSI	Max. Concrete Pressure PSI	Concrete Pressure Ratio
0	39	6235	6235	73.07	73.07	184.85	0.1540
90	89	17874	17874	209.46	209.46	507.47	0.4229
180	138	12244	12244	143.48	143.48	425.34	0.3545
270	89	17874	17874	209.46	209.46	507.47	0.4229

Direction of Worst case Force: = **1 °**

Highest Stress Ratio = **0.5292**

Loadings and Stresses on BasePlate and Anchor bolts

Leg Orientation °	Moment M_x in.-lb.	Moment M_y in.-lb.	Maximum Pressure P_x PSI	Maximum Pressure P_y PSI	Maximum B.P. Stress PSI	BasePlate Stress Ratio	Anchor Bolt Stress PSI	Anchor Bolt Stress Ratio
0	216	203	5172	4871	7105	0.2467	976	0.0188
90	572	536	13729	12865	18815	0.6533	3222	0.0620
180	550	526	13210	12619	18268	0.6343	951	0.0183
270	572	536	13729	12865	18815	0.6533	3222	0.0620

Direction of Worst case Force: = **1 °**

Highest Stress Ratio = **0.8388**

Maximum General Longitudinal Stresses

$VE = C_{de} = 1.00 =$ **1.00**

$$S_{L1} = \frac{M_a}{Z} - \frac{W\ VE}{A} + \left(\frac{P * D}{4 * t}\right) = \frac{86871}{256.2605} - \frac{22668.57 * 1.00}{28.47} + \left(\frac{76.90 * 36.5000}{4 * 0.2500}\right) = 2350 \text{ PSI}$$

$$S_{L2} = -\frac{M_a}{Z} - \frac{W\ VE}{A} - \left(\frac{Pe * D}{4 * t}\right) = -\frac{86871}{256.2605} - \frac{22668.57 * 1.00}{28.47} - \left(\frac{14.70 * 36.5000}{4 * 0.2500}\right) = -1672 \text{ PSI}$$

Allowable Tension Stress, S_{ta} = 1.2 S E = 1.2 * 18900 * 0.70 **= 15876** PSI

Allowable Compressive Stress, S_{ca} = -1.2 B = -1.2 * 8963 **= -10756** PSI

$$R_{SL1} = \frac{S_{L1}}{S_{ta}} = \frac{2350}{15876} = 0.1480$$

$$R_{SL2} = \frac{S_{L2}}{S_{ca}} = \frac{-1672}{-10756} = 0.1555$$

Summary

Governing external force	**= Wind load**
Total Force	**= 829 lb.**
Weight	**= 22668.57 lb.**
Base Moment	**= 148132 in.-lb.**
Tangent Moment	**= 86871 in.-lb.**

Leg Stresses

Maximum combined compressive and bending stress ratio	**= 0.3860**

Leg BasePlate

Concrete Stress Ratio	**= 0.5292**
Base Plate Stress Ratio	**= 0.8388**

Host Stresses

SI1 ratio	**= 0.1480**
SI2 ratio	**= 0.1555**

Weld Stresses

Leg to vessel weld stress ratio	**= 0.1595**
Repad to shell weld stress ratio	**= 0.0683**

Operating Pressurized Condition - Sustained Loads

Support Leg Properties

Section Modulus, $S_x = \frac{I_x}{C_x} = \frac{31.7448}{4.2426}$ **= 7.4824 in.³**

Section Modulus, $S_y = \frac{I_y}{C_y} = \frac{8.0709}{2.3826}$ **= 3.3874 in.³**

Radius of gyration, $r_x = \sqrt{\frac{I_x}{A}} = \sqrt{\frac{31.7448}{5.7500}}$ **= 2.3496 in.**

Radius of gyration, $r_y = \sqrt{\frac{I_y}{A}} = \sqrt{\frac{8.0709}{5.7500}}$ **= 1.1848 in.**

Least radius of gyration, $r_{min} = \sqrt{\frac{I_{min}}{A}} = \sqrt{\frac{8.0709}{5.7500}}$ **= 1.1848 in.**

Slenderness ratio, $SR_x = \frac{K\,L}{r_x} = \frac{1.5000 * 73.8800}{2.3496}$ **= 47.1655**

Slenderness ratio, $SR_y = \frac{K\,L}{r_y} = \frac{1.5000 * 73.8800}{1.1848}$ **= 93.5348**

$SR_{max} = \frac{K\,L}{r_{min}} = \frac{1.5000 * 73.8800}{1.1848}$ **= 93.5348**

Critical slenderness ratio, $C_c = \sqrt{\frac{2\,\pi^2\,E}{F_y}} = \sqrt{\frac{2 * \pi^2 * (28.3 * 10^6)}{36000}}$ **= 124.57**

$F'_{ex} = \frac{12\,\pi^2\,E}{23\,SR_x^2} = \frac{12 * \pi^2 * (28.3 * 10^6)}{23 * 47.1655^2}$ **= 65507 PSI**

$F'_{ey} = \frac{12\,\pi^2\,E}{23\,SR_y^2} = \frac{12 * \pi^2 * (28.3 * 10^6)}{23 * 93.5348^2}$ **= 16657 PSI**

For $SR_{max} \le C_c$, Allowable compressive stress:

$$F_a = \frac{\left(1 - \frac{SR_{max}^2}{2\,C_c^2}\right) F_y}{\frac{5}{3} + \frac{3\,SR_{max}}{8\,C_c} - \frac{SR_{max}^3}{8\,C_c^3}} = \frac{\left(1 - \frac{93.5348^2}{2 * 124.57^2}\right) * 36000}{\frac{5}{3} + \frac{3 * 93.5348}{8 * 124.57} - \frac{93.5348^3}{8 * 124.57^3}}$$ **= 13640 PSI**

Allowable bending stress : $S_b = 0.6\,F_y = 0.6 * 36000$ **= 21600 PSI**
Allowable tension stress : $S_t = 0.6\,F_y = 0.6 * 36000$ **= 21600 PSI**

Leg to Vessel Weld Properties

Distance between welds along side of legs (b) = **= 7.7782 in.**

$L_w = 2\,W_s = 2 * 10.0000$ **= 20.0000 in.**

$I_{wy} = \frac{W_s^3}{6} = \frac{10.0000^3}{6}$ **= 166.6667 in.³**

$I_{wz} = \frac{W_s\,b^2}{2} = \frac{10.0000 * 7.7782^2}{2}$ **= 302.5000 in.³**

$J_{wx} = I_{wy} + I_{wz} = 166.6667 + 302.5000$ **= 469.1667 in.³**

Distance from weld neutral axis to top/bottom of welds:

$EF_{yt} = EF_{yb} = \frac{W_s}{2} = \frac{10.0000}{2}$ **= 5.0000 in.**

Distance from weld neutral axis to bottom of welds:

$EF_z = \frac{b}{2} = \frac{7.7782}{2}$ **= 3.8891 in.**

NO Wind Analysis Information

Wind Analysis Calculations

No Wind Load Calculations were performed

NO Seismic Design Information

Seismic Analysis Calculations

No Seismic Analysis Calculations were performed.

Loadings and Stresses on Support Legs

Direction of Applied Force = 0 °

Leg Orientation °	Moment of Inertia in.⁴	Lateral Force lb.	Axial Stress PSI	Bending Stresses (f_{bx}) PSI	Bending Stresses (f_{by}) PSI	Acceptance Ratio (Eqn_1)	Acceptance Ratio (Eqn_2)
0	8.0709	0	-986	0	3858	0.2509	
90	31.7448	0	-986	0	3858	0.2509	
180	8.0709	0	-986	0	3858	0.2509	
270	31.7448	0	-986	0	3858	0.2509	

Direction of Worst case Force = 0 °
Highest Stress Ratio = 0.2509

HT/DcR Engineering, Inc.
Leg 1

Job No: 1494F
Mark Number: LEG1

Vessel Number: 7793-E4401 Legs

Date Printed: 9/14/2007

Loadings and Stresses on Leg to Vessel attachment welds

Leg Orientation °	Load F_x lb.	Load F_y lb.	Load F_z lb.	Moment M_x in.-lb.	Moment M_y in.-lb.	Moment M_z in.-lb.	Total Stress PSI	Stress Ratio
0	0	0	-5667	0	-10234	0	1114	0.1203
90	0	0	-5667	0	-10234	0	1114	0.1203
180	0	0	-5667	0	-10234	0	1114	0.1203
270	0	0	-5667	0	-10234	0	1114	0.1203

Direction of Worst case Force = **0 °**
Highest Stress Ratio: **0.1203**

Repad to Shell Weld Properties

$L_w = 2\ (L_{rh} + L_{rw}) = 2 * (10.0000 + 10.0000)$ **= 40.0000** in.

$I_{wy} = \frac{L_{rw} L_{rh}^2}{2} + \frac{L_{rh}^3}{6} = \frac{10.0000 * 10.0000^2}{2} + \frac{10.0000^3}{6}$ **= 666.6667** in.³

$I_{wz} = \frac{L_{rh} L_{rw}^2}{2} + \frac{L_{rw}^3}{6} = \frac{10.0000 * 10.0000^2}{2} + \frac{10.0000^3}{6}$ **= 666.6667** in.³

$J_{wx} = I_{wy} + I_{wz} = 666.6667 + 666.6667$ **= 1333.3333** in.³

Distance from weld neutral axis to top of repad:

$EF_y = \frac{L_{rh}}{2} = \frac{10.0000}{2}$ **= 5.0000** in.

Distance from weld neutral axis to side of repad:

$EF_z = \frac{L_{rw}}{2} = \frac{10.0000}{2}$ **= 5.0000** in.

Loadings and Stresses on Repad-to-Shell Attachment Welds

Leg Orientation °	Load F_x lb.	Load F_y lb.	Load F_z lb.	Moment M_x in.-lb.	Moment M_y in.-lb.	Moment M_z in.-lb.	Total Stress PSI	Stress Ratio
0	0	0	-5667	0	-13067	0	459	0.0496
90	0	0	-5667	0	-13067	0	459	0.0496
180	0	0	-5667	0	-13067	0	459	0.0496
270	0	0	-5667	0	-13067	0	459	0.0496

Direction of Worst case Force = **0 °**
Highest Stress Ratio = **0.0496**

HT/DcR Engineering, Inc.

Leg 1

Job No: 1494F

Mark Number: LEG1

Vessel Number: 7793-E4401 Legs

Date Printed: 9/14/2007

Loadings and Pressure on Concrete Foundation

Direction of applied force: = **0 °**

Leg Orientation °	Bearing Pressure PSI	Moment M_x in.-lb.	Moment M_y in.-lb.	Maximum Pressure P_x PSI	Maximum Pressure P_y PSI	Max. Concrete Pressure PSI	Concrete Pressure Ratio
0	89	9240	9240	108.28	108.28	305.11	0.3390
90	89	9240	9240	108.28	108.28	305.11	0.3390
180	89	9240	9240	108.28	108.28	305.11	0.3390
270	89	9240	9240	108.28	108.28	305.11	0.3390

Direction of Worst case Force: = **0 °**

Highest Stress Ratio = **0.3390**

Loadings and Stresses on BasePlate and Anchor bolts

Leg Orientation °	Moment M_x in.-lb.	Moment M_y in.-lb.	Maximum Pressure P_x PSI	Maximum Pressure P_y PSI	Maximum B.P. Stress PSI	BasePlate Stress Ratio	Anchor Bolt Stress PSI	Anchor Bolt Stress Ratio
0	383	364	9191	8745	12687	0.5874	936	0.0240
90	383	364	9191	8745	12687	0.5874	936	0.0240
180	383	364	9191	8745	12687	0.5874	936	0.0240
270	383	364	9191	8745	12687	0.5874	936	0.0240

Direction of Worst case Force: = **0 °**

Highest Stress Ratio = **0.5874**

Maximum General Longitudinal Stresses

VE = 1.00 **1.00**

$$S_{L1} = \frac{M_a}{Z} - \frac{W\,VE}{A} + \left(\frac{P * D}{4 * t}\right) = \frac{0}{256.2605} - \frac{22668.57 * 1.00}{28.47} + \left(\frac{76.90 * 36.5000}{4 * 0.2500}\right) \quad = \mathbf{2011}\ \text{PSI}$$

$$S_{L2} = -\frac{M_a}{Z} - \frac{W\,VE}{A} - \left(\frac{Pe * D}{4 * t}\right) = -\frac{0}{256.2605} - \frac{22668.57 * 1.00}{28.47} - \left(\frac{14.70 * 36.5000}{4 * 0.2500}\right) \quad = \mathbf{-1333}\ \text{PSI}$$

Allowable Tension Stress, S_{ta} = S E = 18900 * 0.70 **= 13230** PSI

Allowable Compressive Stress, S_{ca} = -B = -8963 **= -8963** PSI

$$R_{SL1} = \frac{S_{L1}}{S_{ta}} = \frac{2011}{13230} \quad = \mathbf{0.1520}$$

$$R_{SL2} = \frac{S_{L2}}{S_{ca}} = \frac{-1333}{-8963} \quad = \mathbf{0.1487}$$

Summary

Governing external force	= None
Total Force	= 0 lb.
Weight	= 22668.57 lb.
Base Moment	= 0 in.-lb.
Tangent Moment	= 0 in.-lb.

Leg Stresses

Maximum combined compressive and bending stress ratio	= 0.2509

Leg BasePlate

Concrete Stress Ratio	= 0.3390
Base Plate Stress Ratio	= 0.5874

Host Stresses

SI1 ratio	= 0.1520
SI2 ratio	= 0.1487

Weld Stresses

Leg to vessel weld stress ratio	= 0.1203
Repad to shell weld stress ratio	= 0.0496

Empty Pressurized Conditions - Ocassional Loads - Seismic Case 8

Support Leg Properties

Section Modulus, S_x $= \frac{I_x}{C_x} = \frac{31.7448}{4.2426}$ = 7.4824 in.³

Section Modulus, S_y $= \frac{I_y}{C_y} = \frac{8.0709}{2.3826}$ = 3.3874 in.³

Radius of gyration, r_x $= \sqrt{\frac{I_x}{A}} = \sqrt{\frac{31.7448}{5.7500}}$ = 2.3496 in.

Radius of gyration, r_y $= \sqrt{\frac{I_y}{A}} = \sqrt{\frac{8.0709}{5.7500}}$ = 1.1848 in.

Least radius of gyration, r_{min} $= \sqrt{\frac{I_{min}}{A}} = \sqrt{\frac{8.0709}{5.7500}}$ = 1.1848 in.

Slenderness ratio, SR_x $= \frac{K\,L}{r_x} = \frac{1.5000 * 73.8800}{2.3496}$ = 47.1655

Slenderness ratio, SR_y $= \frac{K\,L}{r_y} = \frac{1.5000 * 73.8800}{1.1848}$ = 93.5348

$SR_{max} = \frac{K\,L}{r_{min}} = \frac{1.5000 * 73.8800}{1.1848}$ = 93.5348

Critical slenderness ratio, C_c $= \sqrt{\frac{2 \pi^2 E}{F_y}} = \sqrt{\frac{2 * \pi^2 * (28.3 * 10^6)}{36000}}$ = 124.57

$$F'_{ex} = \frac{4}{3} \frac{12 \pi^2 E}{23 SR_x^2} = \frac{4}{3} * \frac{12 * \pi^2 * (28.3 * 10^6)}{23 * 47.1655^2}$$ = 87343 PSI

$$F'_{ey} = \frac{4}{3} \frac{12 \pi^2 E}{23 SR_y^2} = \frac{4}{3} * \frac{12 * \pi^2 * (28.3 * 10^6)}{23 * 93.5348^2}$$ = 22209 PSI

For SR_{max} <= C_c, Allowable compressive stress:

$$F_a = \frac{4}{3} \frac{\left(1 - \frac{SR_{max}^2}{2 C_c^2}\right) F_y}{\frac{5}{3} + \frac{3 SR_{max}}{8 C_c} - \frac{SR_{max}^3}{8 C_c^3}} = \frac{4}{3} * \frac{\left(1 - \frac{93.5348^2}{2 * 124.57^2}\right) * 36000}{\frac{5}{3} + \frac{3 * 93.5348}{8 * 124.57} - \frac{93.5348^3}{8 * 124.57^3}}$$ = 18187 PSI

Allowable bending stress : S_b $= \frac{4}{3}\ 0.6\ F_y = \frac{4}{3} * 0.6 * 36000$ = 28800 PSI

Allowable tension stress : S_t $= \frac{4}{3}\ 0.6\ F_y = \frac{4}{3} * 0.6 * 36000$ = 28800 PSI

Leg to Vessel Weld Properties

Distance between welds along side of legs (b) = **= 7.7782** in.

$L_W = 2 W_S = 2 * 10.0000$ **= 20.0000** in.

$I_{wy} = \frac{W_S^3}{6} = \frac{10.0000^3}{6}$ **= 166.6667** in.³

$I_{wz} = \frac{W_S b^2}{2} = \frac{10.0000 * 7.7782^2}{2}$ **= 302.5000** in.³

$J_{wx} = I_{wy} + I_{wz} = 166.6667 + 302.5000$ **= 469.1667** in.³

Distance from weld neutral axis to top/bottom of welds:

$EF_{yt} = EF_{yb} = \frac{W_S}{2} = \frac{10.0000}{2}$ **= 5.0000** in.

Distance from weld neutral axis to bottom of welds:

$EF_z = \frac{b}{2} = \frac{7.7782}{2}$ **= 3.8891** in.

NO Wind Analysis Information

Wind Analysis Calculations

No Wind Load Calculations were performed

IBC 2003 Seismic Design Information

Spectral Resp. Accel. at short periods (S_S):	0.200	Response Modification Factor (R):	3.000
Spectral Resp. Accel. at a period of 1 s (S_1):	0.100	Site Class:	D
Seismic Use Group:	I		
Seismic Design Category:	C		

Seismic Analysis Calculations

Seismic Center of Gravity: **= 179.4448** in.

$C_S = \frac{SD_S\, I}{R} = \frac{0.2133 * 1.00}{3.000}$ **= 0.0711**

$V = W * C_S = 14283.61 * 0.03$ **= 1015.72** lb.

$F_s = V\, C_{eh} = 1015.72 * 0.70$ **= 711** lb.

HT/DcR Engineering, Inc.
Leg 1

Job No: 1494F
Mark Number: LEG1

Vessel Number: 7793-E4401 Legs

Date Printed: 9/14/2007

Loadings and Stresses on Support Legs

Direction of Applied Force = **0 °**

Leg Orientation °	Moment of Inertia in.⁴	Lateral Force lb.	Axial Stress PSI	Bending Stresses (f_{bx}) PSI	Bending Stresses (f_{by}) PSI	Acceptance Ratio (Eqn_1)	Acceptance Ratio (Eqn_2)
0	8.0709	72	124	0	1663	0.0635	
90	31.7448	283	-354	2099	1386	0.1405	
180	8.0709	72	-832	0	4435	0.1997	
270	31.7448	283	-354	2099	1386	0.1405	

Direction of Worst case Force = **41 °**
Highest Stress Ratio = **0.2376**

Loadings and Stresses on Leg to Vessel attachment welds

Leg Orientation °	Load F_x lb.	Load F_y lb.	Load F_z lb.	Moment M_x in.-lb.	Moment M_y in.-lb.	Moment M_z in.-lb.	Total Stress PSI	Stress Ratio
0	72	0	712	0	-2707	0	245	0.0198
90	0	283	-2036	15705	-3677	511	845	0.0684
180	-72	0	-4784	0	-4646	0	733	0.0594
270	0	283	-2036	15705	-3677	511	845	0.0684

Direction of Worst case Force = **1 °**
Highest Stress Ratio: **0.0956**

Repad to Shell Weld Properties

$L_w = 2\ (L_{rh} + L_{rw}) = 2 * (10.0000 + 10.0000)$ **= 40.0000** in.

$I_{wy} = \frac{L_{rw} L_{rh}^2}{2} + \frac{L_{rh}^3}{6} = \frac{10.0000 * 10.0000^2}{2} + \frac{10.0000^3}{6}$ **= 666.6667** in.³

$I_{wz} = \frac{L_{rh} L_{rw}^2}{2} + \frac{L_{rw}^3}{6} = \frac{10.0000 * 10.0000^2}{2} + \frac{10.0000^3}{6}$ **= 666.6667** in.³

$J_{wx} = I_{wy} + I_{wz} = 666.6667 + 666.6667$ **= 1333.3333** in.³

Distance from weld neutral axis to top of repad:

$EF_y = \frac{L_{rh}}{2} = \frac{10.0000}{2}$ **= 5.0000** in.

Distance from weld neutral axis to side of repad:

$EF_z = \frac{L_{rw}}{2} = \frac{10.0000}{2}$ **= 5.0000** in.

Loadings and Stresses on Repad-to-Shell Attachment Welds

Leg Orientation °	Load F_x lb.	Load F_y lb.	Load F_z lb.	Moment M_x in.-lb.	Moment M_y in.-lb.	Moment M_z in.-lb.	Total Stress PSI	Stress Ratio
0	72	0	712	0	-2351	0	70	0.0057
90	0	283	-2036	15705	-4695	653	358	0.0290
180	-72	0	-4784	0	-7038	0	347	0.0281
270	0	283	-2036	15705	-4695	653	358	0.0290

Direction of Worst case Force = 1 °
Highest Stress Ratio = 0.0411

Loadings and Pressure on Concrete Foundation

Direction of applied force: = 0 °

Leg Orientation °	Bearing Pressure PSI	Moment M_x in.-lb.	Moment M_y in.-lb.	Maximum Pressure P_x PSI	Maximum Pressure P_y PSI	Max. Concrete Pressure PSI	Concrete Pressure Ratio
0	-11	721	721	8.45	8.45	5.77	0.0048
90	32	10723	10723	125.66	125.66	283.13	0.2359
180	75	5918	5918	69.35	69.35	213.45	0.1779
270	32	10723	10723	125.66	125.66	283.13	0.2359

Direction of Worst case Force: = 1 °
Highest Stress Ratio = 0.3275

Loadings and Stresses on BasePlate and Anchor bolts

Leg Orientation °	Moment M_x in.-lb.	Moment M_y in.-lb.	Maximum Pressure P_x PSI	Maximum Pressure P_y PSI	Maximum B.P. Stress PSI	BasePlate Stress Ratio	Anchor Bolt Stress PSI	Anchor Bolt Stress Ratio
0	0	0	0	0	0	0.0000	575	0.0111
90	300	278	7193	6675	9813	0.3407	2371	0.0456
180	282	270	6770	6484	9374	0.3255	365	0.0070
270	300	278	7193	6675	9813	0.3407	2371	0.0456

Direction of Worst case Force: = 1 °
Highest Stress Ratio = 0.5006

Maximum General Longitudinal Stresses

$VE = (C_{de} + 0.2 * SDS * I * C_{ev}) = (0.60 + 0.2 * 0.21 * 1.00 * -0.70) =$ **0.57**

$$S_{L1} = \frac{M_a}{Z} - \frac{W\,VE}{A} + \left(\frac{P * D}{4 * t}\right) = \frac{75057}{256.2605} - \frac{14283.61 * 0.57}{28.47} + \left(\frac{75.00 * 36.5000}{4 * 0.2500}\right)$$ **= 2744** PSI

$$S_{L2} = -\frac{M_a}{Z} - \frac{W\,VE}{A} - \left(\frac{Pe * D}{4 * t}\right) = -\frac{75057}{256.2605} - \frac{14283.61 * 0.57}{28.47} - \left(\frac{14.70 * 36.5000}{4 * 0.2500}\right)$$ **= -1115** PSI

Allowable Tension Stress, S_{ta} $= 1.2\ S\ E = 1.2 * 18900 * 0.70$ **= 15876** PSI

Allowable Compressive Stress, S_{ca} $= -1.2\ B = -1.2 * 8963$ **= -10756** PSI

$$R_{SL1} = \frac{S_{L1}}{S_{ta}} = \frac{2744}{15876}$$ **= 0.1728**

$$R_{SL2} = \frac{S_{L2}}{S_{ca}} = \frac{-1115}{-10756}$$ **= 0.1037**

Summary

Governing external force	= Seismic load
Total Force	= 711 lb.
Weight	= 14283.61 lb.
Base Moment	= 127586 in.-lb.
Tangent Moment	= 75057 in.-lb.

Leg Stresses

Maximum combined compressive and bending stress ratio	= 0.2376

Leg BasePlate

Concrete Stress Ratio	= 0.3275
Base Plate Stress Ratio	= 0.5006

Host Stresses

Sl1 ratio	= 0.1728
Sl2 ratio	= 0.1037

Weld Stresses

Leg to vessel weld stress ratio	= 0.0956
Repad to shell weld stress ratio	= 0.0411

Empty Pressurized Conditions - Ocassional Loads - Wind Case 7

Support Leg Properties

Section Modulus, $S_x = \frac{I_x}{C_x} = \frac{31.7448}{4.2426}$ = **7.4824** in.³

Section Modulus, $S_y = \frac{I_y}{C_y} = \frac{8.0709}{2.3826}$ = **3.3874** in.³

Radius of gyration, $r_x = \sqrt{\frac{I_x}{A}} = \sqrt{\frac{31.7448}{5.7500}}$ = **2.3496** in.

Radius of gyration, $r_y = \sqrt{\frac{I_y}{A}} = \sqrt{\frac{8.0709}{5.7500}}$ = **1.1848** in.

Least radius of gyration, $r_{min} = \sqrt{\frac{I_{min}}{A}} = \sqrt{\frac{8.0709}{5.7500}}$ = **1.1848** in.

Slenderness ratio, $SR_x = \frac{K\,L}{r_x} = \frac{1.5000 * 73.8800}{2.3496}$ = **47.1655**

Slenderness ratio, $SR_y = \frac{K\,L}{r_y} = \frac{1.5000 * 73.8800}{1.1848}$ = **93.5348**

$SR_{max} = \frac{K\,L}{r_{min}} = \frac{1.5000 * 73.8800}{1.1848}$ = **93.5348**

Critical slenderness ratio, $C_c = \sqrt{\frac{2\pi^2 E}{F_y}} = \sqrt{\frac{2 * \pi^2 * (28.3 * 10^6)}{36000}}$ = **124.57**

$F'_{ex} = \frac{4}{3}\,\frac{12\pi^2 E}{23\,SR_x^2} = \frac{4}{3} * \frac{12 * \pi^2 * (28.3 * 10^6)}{23 * 47.1655^2}$ = **87343** PSI

$F'_{ey} = \frac{4}{3}\,\frac{12\pi^2 E}{23\,SR_y^2} = \frac{4}{3} * \frac{12 * \pi^2 * (28.3 * 10^6)}{23 * 93.5348^2}$ = **22209** PSI

For $SR_{max} <= C_c$, Allowable compressive stress:

$$F_a = \frac{4}{3}\,\frac{\left(1 - \frac{SR_{max}^2}{2\,C_c^2}\right) F_y}{\frac{5}{3} + \frac{3\,SR_{max}}{8\,C_c} - \frac{SR_{max}^3}{8\,C_c^3}} = \frac{4}{3} * \frac{\left(1 - \frac{93.5348^2}{2 * 124.57^2}\right) * 36000}{\frac{5}{3} + \frac{3 * 93.5348}{8 * 124.57} - \frac{93.5348^3}{8 * 124.57^3}}$$ = **18187** PSI

Allowable bending stress : $S_b = \frac{4}{3}\,0.6\,F_y = \frac{4}{3} * 0.6 * 36000$ = **28800** PSI

Allowable tension stress : $S_t = \frac{4}{3}\,0.6\,F_y = \frac{4}{3} * 0.6 * 36000$ = **28800** PSI

Leg to Vessel Weld Properties

Distance between welds along side of legs (b) = = 7.7782 in.

$L_w = 2\,W_s = 2 * 10.0000$ = 20.0000 in.

$I_{wy} = \dfrac{W_s^3}{6} = \dfrac{10.0000^3}{6}$ = 166.6667 in.³

$I_{wz} = \dfrac{W_s\, b^2}{2} = \dfrac{10.0000 * 7.7782^2}{2}$ = 302.5000 in.³

$J_{wx} = I_{wy} + I_{wz} = 166.6667 + 302.5000$ = 469.1667 in.³

Distance from weld neutral axis to top/bottom of welds:

$EF_{yt} = EF_{yb} = \dfrac{W_s}{2} = \dfrac{10.0000}{2}$ = 5.0000 in.

Distance from weld neutral axis to bottom of welds:

$EF_z = \dfrac{b}{2} = \dfrac{7.7782}{2}$ = 3.8891 in.

IBC 2003 Wind Analysis Information

Basic Wind Speed (V):	90	MPH	Wind Exposure type:	C
Importance factor (I):	1.0000		Force (shape) coefficient (C_f):	0.70
Topographic Factor (K_{zt}):	1.00		Directionality Factor (K_d):	1.00

Wind Analysis Calculations

Wind Center of Gravity = 178.6462 in.

$q_z = 0.00256\, K_z\, K_{zt} K_d\, V^2\, I = 0.00256 * 0.85 * 1.000 * 1.00 * 90^2 * 1.0000$ = 17.626

$P = q_z\, G\, C_f = 17.626 * 0.90 * 0.70$ = 11.10 lb./ft²

Wind Load, $F_w = P\,A\,C_{wi} = 11.10 * 74.7016 * 1.00$ = 829 lb.

NO Seismic Design Information

Seismic Analysis Calculations

No Seismic Analysis Calculations were performed.

Loadings and Stresses on Support Legs

Direction of Applied Force = **0 °**

Leg Orientation °	Moment of Inertia in.⁴	Lateral Force lb.	Axial Stress PSI	Bending Stresses (f_{bx}) PSI	Bending Stresses (f_{by}) PSI	Acceptance Ratio (Eqn_1)	Acceptance Ratio (Eqn_2)
0	8.0709	84	182	0	2087	0.0809	
90	31.7448	331	-373	2448	1459	0.1562	
180	8.0709	84	-927	0	5004	0.2247	
270	31.7448	331	-373	2448	1459	0.1562	

Direction of Worst case Force = **40 °**
Highest Stress Ratio = **0.2690**

Loadings and Stresses on Leg to Vessel attachment welds

Leg Orientation °	Load F_x lb.	Load F_y lb.	Load F_z lb.	Moment M_x in.-lb.	Moment M_y in.-lb.	Moment M_z in.-lb.	Total Stress PSI	Stress Ratio
0	84	0	1047	0	-2766	0	271	0.0219
90	0	331	-2143	18316	-3870	598	951	0.0770
180	-84	0	-5332	0	-4972	0	809	0.0655
270	0	331	-2143	18316	-3870	598	951	0.0770

Direction of Worst case Force = **1 °**
Highest Stress Ratio: **0.1080**

Repad to Shell Weld Properties

$L_w = 2\ (L_{rh} + L_{rw}) = 2 * (10.0000 + 10.0000)$ **= 40.0000** in.

$I_{wy} = \frac{L_{rw}\, L_{rh}^2}{2} + \frac{L_{rh}^3}{6} = \frac{10.0000 * 10.0000^2}{2} + \frac{10.0000^3}{6}$ **= 666.6667** in.³

$I_{wz} = \frac{L_{rh}\, L_{rw}^2}{2} + \frac{L_{rw}^3}{6} = \frac{10.0000 * 10.0000^2}{2} + \frac{10.0000^3}{6}$ **= 666.6667** in.³

$J_{wx} = I_{wy} + I_{wz} = 666.6667 + 666.6667$ **= 1333.3333** in.³

Distance from weld neutral axis to top of repad:

$EF_y = \frac{L_{rh}}{2} = \frac{10.0000}{2}$ **= 5.0000** in.

Distance from weld neutral axis to side of repad:

$EF_z = \frac{L_{rw}}{2} = \frac{10.0000}{2}$ **= 5.0000** in.

HT/DcR Engineering, Inc.

Leg 1

Job No: 1494F

Mark Number: LEG1

Vessel Number: 7793-E4401 Legs

Date Printed: 9/14/2007

Loadings and Stresses on Repad-to-Shell Attachment Welds

Leg Orientation °	Load F_x lb.	Load F_y lb.	Load F_z lb.	Moment M_x in.-lb.	Moment M_y in.-lb.	Moment M_z in.-lb.	Total Stress PSI	Stress Ratio
0	84	0	1047	0	-2243	0	86	0.0070
90	0	331	-2143	18316	-4941	763	402	0.0326
180	-84	0	-5332	0	-7638	0	385	0.0312
270	0	331	-2143	18316	-4941	763	402	0.0326

Direction of Worst case Force = 1 °

Highest Stress Ratio = 0.0464

Loadings and Pressure on Concrete Foundation

Direction of applied force: = 0 °

Leg Orientation °	Bearing Pressure PSI	Moment M_x in.-lb.	Moment M_y in.-lb.	Maximum Pressure P_x PSI	Maximum Pressure P_y PSI	Max. Concrete Pressure PSI	Concrete Pressure Ratio
0	-16	488	488	5.72	5.72	0.00	0.0000
90	33	12128	12128	142.13	142.13	317.73	0.2648
180	83	6498	6498	76.15	76.15	235.61	0.1963
270	33	12128	12128	142.13	142.13	317.73	0.2648

Direction of Worst case Force: = 1 °

Highest Stress Ratio = 0.3710

Loadings and Stresses on BasePlate and Anchor bolts

Leg Orientation °	Moment M_x in.-lb.	Moment M_y in.-lb.	Maximum Pressure P_x PSI	Maximum Pressure P_y PSI	Maximum B.P. Stress PSI	BasePlate Stress Ratio	Anchor Bolt Stress PSI	Anchor Bolt Stress Ratio
0	0	0	0	0	0	0.0000	566	0.0109
90	334	309	8013	7427	10926	0.3794	2735	0.0526
180	312	299	7494	7180	10379	0.3604	386	0.0074
270	334	309	8013	7427	10926	0.3794	2735	0.0526

Direction of Worst case Force: = 1 °

Highest Stress Ratio = 0.5648

Maximum General Longitudinal Stresses

$VE = C_{de} = 0.60 =$ 0.60

$$S_{L1} = \frac{M_a}{Z} - \frac{W\,VE}{A} + \left(\frac{P * D}{4 * t}\right) = \frac{86871}{256.2605} - \frac{14283.61 * 0.60}{28.47} + \left(\frac{75.00 * 36.5000}{4 * 0.2500}\right) = 2775 \text{ PSI}$$

$$S_{L2} = -\frac{M_a}{Z} - \frac{W\,VE}{A} - \left(\frac{Pe * D}{4 * t}\right) = -\frac{86871}{256.2605} - \frac{14283.61 * 0.60}{28.47} - \left(\frac{14.70 * 36.5000}{4 * 0.2500}\right) = -1177 \text{ PSI}$$

Allowable Tension Stress, $S_{ta} = 1.2\,S\,E = 1.2 * 18900 * 0.70$ = 15876 PSI

Allowable Compressive Stress, $S_{ca} = -1.2\,B = -1.2 * 8963$ = -10756 PSI

$$R_{SL1} = \frac{S_{L1}}{S_{ta}} = \frac{2775}{15876} = 0.1748$$

$$R_{SL2} = \frac{S_{L2}}{S_{ca}} = \frac{-1177}{-10756} = 0.1094$$

Summary

Governing external force	= Wind load
Total Force	= 829 lb.
Weight	= 14283.61 lb.
Base Moment	= 148132 in.-lb.
Tangent Moment	= 86871 in.-lb.

Leg Stresses

Maximum combined compressive and bending stress ratio	= 0.2690

Leg BasePlate

Concrete Stress Ratio	= 0.3710
Base Plate Stress Ratio	= 0.5648

Host Stresses

SI1 ratio	= 0.1748
SI2 ratio	= 0.1094

Weld Stresses

Leg to vessel weld stress ratio	= 0.1080
Repad to shell weld stress ratio	= 0.0464

Empty Pressurized Condition - Sustained Loads

Support Leg Properties

Section Modulus, S_x $= \frac{I_x}{C_x} = \frac{31.7448}{4.2426}$ **= 7.4824 in.³**

Section Modulus, S_y $= \frac{I_y}{C_y} = \frac{8.0709}{2.3826}$ **= 3.3874 in.³**

Radius of gyration, r_x $= \sqrt{\frac{I_x}{A}} = \sqrt{\frac{31.7448}{5.7500}}$ **= 2.3496 in.**

Radius of gyration, r_y $= \sqrt{\frac{I_y}{A}} = \sqrt{\frac{8.0709}{5.7500}}$ **= 1.1848 in.**

Least radius of gyration, r_{min} $= \sqrt{\frac{I_{min}}{A}} = \sqrt{\frac{8.0709}{5.7500}}$ **= 1.1848 in.**

Slenderness ratio, SR_x $= \frac{K\,L}{r_x} = \frac{1.5000 * 73.8800}{2.3496}$ **= 47.1655**

Slenderness ratio, SR_y $= \frac{K\,L}{r_y} = \frac{1.5000 * 73.8800}{1.1848}$ **= 93.5348**

$SR_{max} = \frac{K\,L}{r_{min}} = \frac{1.5000 * 73.8800}{1.1848}$ **= 93.5348**

Critical slenderness ratio, C_c $= \sqrt{\frac{2\pi^2 E}{F_y}} = \sqrt{\frac{2 * \pi^2 * (28.3 * 10^6)}{36000}}$ **= 124.57**

$F'_{ex} = \frac{12\pi^2 E}{23\,SR_x^2} = \frac{12 * \pi^2 * (28.3 * 10^6)}{23 * 47.1655^2}$ **= 65507 PSI**

$F'_{ey} = \frac{12\pi^2 E}{23\,SR_y^2} = \frac{12 * \pi^2 * (28.3 * 10^6)}{23 * 93.5348^2}$ **= 16657 PSI**

For SR_{max} <= C_c, Allowable compressive stress:

$$F_a = \frac{\left(1 - \frac{SR_{max}^2}{2\,C_c^2}\right) F_y}{\frac{5}{3} + \frac{3\,SR_{max}}{8\,C_c} - \frac{SR_{max}^3}{8\,C_c^3}} = \frac{\left(1 - \frac{93.5348^2}{2 * 124.57^2}\right) * 36000}{\frac{5}{3} + \frac{3 * 93.5348}{8 * 124.57} - \frac{93.5348^3}{8 * 124.57^3}}$$ **= 13640 PSI**

Allowable bending stress : S_b $= 0.6\,F_y = 0.6 * 36000$ **= 21600 PSI**
Allowable tension stress : S_t $= 0.6\,F_y = 0.6 * 36000$ **= 21600 PSI**

Leg to Vessel Weld Properties

Distance between welds along side of legs (b) = = 7.7782 in.

$L_w = 2\,W_s = 2 * 10.0000$ = 20.0000 in.

$I_{wy} = \frac{W_s^3}{6} = \frac{10.0000^3}{6}$ = 166.6667 in.³

$I_{wz} = \frac{W_s\,b^2}{2} = \frac{10.0000 * 7.7782^2}{2}$ = 302.5000 in.³

$J_{wx} = I_{wy} + I_{wz} = 166.6667 + 302.5000$ = 469.1667 in.³

Distance from weld neutral axis to top/bottom of welds:

$EF_{yt} = EF_{yb} = \frac{W_s}{2} = \frac{10.0000}{2}$ = 5.0000 in.

Distance from weld neutral axis to bottom of welds:

$EF_z = \frac{b}{2} = \frac{7.7782}{2}$ = 3.8891 in.

NO Wind Analysis Information

Wind Analysis Calculations

No Wind Load Calculations were performed

NO Seismic Design Information

Seismic Analysis Calculations

No Seismic Analysis Calculations were performed.

Loadings and Stresses on Support Legs

Direction of Applied Force = 0 °

Leg Orientation °	Moment of Inertia in.⁴	Lateral Force lb.	Axial Stress PSI	Bending Stresses (f_{bx}) PSI	Bending Stresses (f_{by}) PSI	Acceptance Ratio (Eqn_1)	Acceptance Ratio (Eqn_2)
0	8.0709	0	-621	0	2431	0.1581	
90	31.7448	0	-621	0	2431	0.1581	
180	8.0709	0	-621	0	2431	0.1581	
270	31.7448	0	-621	0	2431	0.1581	

Direction of Worst case Force = 0 °

Highest Stress Ratio = 0.1581

HT/DcR Engineering, Inc.

Leg 1

Job No: 1494F

Mark Number: LEG1

Vessel Number: 7793-E4401 Legs

Date Printed: 9/14/2007

Loadings and Stresses on Leg to Vessel attachment welds

Leg Orientation °	Load F_x lb.	Load F_y lb.	Load F_z lb.	Moment M_x in.-lb.	Moment M_y in.-lb.	Moment M_z in.-lb.	Total Stress PSI	Stress Ratio
0	0	0	-3571	0	-6449	0	702	0.0758
90	0	0	-3571	0	-6449	0	702	0.0758
180	0	0	-3571	0	-6449	0	702	0.0758
270	0	0	-3571	0	-6449	0	702	0.0758

Direction of Worst case Force = **0 °**

Highest Stress Ratio: **0.0758**

Repad to Shell Weld Properties

$L_w = 2\ (L_{rh} + L_{rw}) = 2 * (10.0000 + 10.0000)$ **= 40.0000** in.

$I_{wy} = \frac{L_{rw} L_{rh}^2}{2} + \frac{L_{rh}^3}{6} = \frac{10.0000 * 10.0000^2}{2} + \frac{10.0000^3}{6}$ **= 666.6667** in.^{3}

$I_{wz} = \frac{L_{rh} L_{rw}^2}{2} + \frac{L_{rw}^3}{6} = \frac{10.0000 * 10.0000^2}{2} + \frac{10.0000^3}{6}$ **= 666.6667** in.^{3}

$J_{wx} = I_{wy} + I_{wz} = 666.6667 + 666.6667$ **= 1333.3333** in.^{3}

Distance from weld neutral axis to top of repad:

$EF_y = \frac{L_{rh}}{2} = \frac{10.0000}{2}$ **= 5.0000** in.

Distance from weld neutral axis to side of repad:

$EF_z = \frac{L_{rw}}{2} = \frac{10.0000}{2}$ **= 5.0000** in.

Loadings and Stresses on Repad-to-Shell Attachment Welds

Leg Orientation °	Load F_x lb.	Load F_y lb.	Load F_z lb.	Moment M_x in.-lb.	Moment M_y in.-lb.	Moment M_z in.-lb.	Total Stress PSI	Stress Ratio
0	0	0	-3571	0	-8234	0	289	0.0312
90	0	0	-3571	0	-8234	0	289	0.0312
180	0	0	-3571	0	-8234	0	289	0.0312
270	0	0	-3571	0	-8234	0	289	0.0312

Direction of Worst case Force = **0 °**

Highest Stress Ratio = **0.0312**

HT/DcR Engineering, Inc.
Leg 1

Job No: 1494F
Mark Number: LEG1

Vessel Number: 7793-E4401 Legs

Date Printed: 9/14/2007

Loadings and Pressure on Concrete Foundation

Direction of applied force: = **0 °**

Leg Orientation °	Bearing Pressure PSI	Moment M_x in.-lb.	Moment M_y in.-lb.	Maximum Pressure P_x PSI	Maximum Pressure P_y PSI	Max. Concrete Pressure PSI	Concrete Pressure Ratio
0	56	5822	5822	68.23	68.23	192.25	0.2136
90	56	5822	5822	68.23	68.23	192.25	0.2136
180	56	5822	5822	68.23	68.23	192.25	0.2136
270	56	5822	5822	68.23	68.23	192.25	0.2136

Direction of Worst case Force: = **0 °**
Highest Stress Ratio = **0.2136**

Loadings and Stresses on BasePlate and Anchor bolts

Leg Orientation °	Moment M_x in.-lb.	Moment M_y in.-lb.	Maximum Pressure P_x PSI	Maximum Pressure P_y PSI	Maximum B.P. Stress PSI	BasePlate Stress Ratio	Anchor Bolt Stress PSI	Anchor Bolt Stress Ratio
0	241	230	5792	5510	7994	0.3701	589	0.0151
90	241	230	5792	5510	7994	0.3701	589	0.0151
180	241	230	5792	5510	7994	0.3701	589	0.0151
270	241	230	5792	5510	7994	0.3701	589	0.0151

Direction of Worst case Force: = **0 °**
Highest Stress Ratio = **0.3701**

Maximum General Longitudinal Stresses

VE = 1.00 **1.00**

$$S_{L1} = \frac{M_a}{Z} - \frac{W\,VE}{A} + \left(\frac{P * D}{4 * t}\right) = \frac{0}{256.2605} - \frac{14283.61 * 1.00}{28.47} + \left(\frac{75.00 * 36.5000}{4 * 0.2500}\right)$$ **= 2236** PSI

$$S_{L2} = -\frac{M_a}{Z} - \frac{W\,VE}{A} - \left(\frac{Pe * D}{4 * t}\right) = -\frac{0}{256.2605} - \frac{14283.61 * 1.00}{28.47} - \left(\frac{14.70 * 36.5000}{4 * 0.2500}\right)$$ **= -1038** PSI

Allowable Tension Stress, S_{ta} = S E = 18900 * 0.70 **= 13230** PSI
Allowable Compressive Stress, S_{ca} = -B = -8963 **= -8963** PSI

$$R_{SL1} = \frac{S_{L1}}{S_{ta}} = \frac{2236}{13230}$$ **= 0.1690**

$$R_{SL2} = \frac{S_{L2}}{S_{ca}} = \frac{-1038}{-8963}$$ **= 0.1158**

Summary

Governing external force	= None
Total Force	= 0 lb.
Weight	= 14283.61 lb.
Base Moment	= 0 in.-lb.
Tangent Moment	= 0 in.-lb.

Leg Stresses

Maximum combined compressive and bending stress ratio	= 0.1581

Leg BasePlate

Concrete Stress Ratio	= 0.2136
Base Plate Stress Ratio	= 0.3701

Host Stresses

SI1 ratio	= 0.1690
SI2 ratio	= 0.1158

Weld Stresses

Leg to vessel weld stress ratio	= 0.0758
Repad to shell weld stress ratio	= 0.0312

HT/DcR Engineering, Inc.

Customer: **Delta-T**
Job No: 1494F

Vessel Number: 7793-E4401 Legs

Date Printed: 9/14/2007

Loading Summary

Type	Starting Elevation (in.)	Ending Elevation (in.)	Density (lb./Ft^3)	Thickness (in.)	Wind Diameter (in.)	Wind Pressure (lb./ft.^{2})
Liquid	32.0000	280.0000	62.4000	-	-	-
Insulation	0.0000	0.0000	-	-	-	-
Wind	32.0000	290.0000	-	-	42.0000	-

Attachment Summary

Attachment No.	Elevation (in.)	Description	Attachment Weight (lb.)	Horizontal Force (lb.)	Attachment Moment (in.-lb.)
1	180.0000	BUNDLE PLUS	12000.00	0	0

Summary Information

	Dry Weight	Flooded Weight
Shell	1981.56 lb.	10817.27 lb.
Head	302.05 lb.	890.11 lb.
Totals	2283.61 lb.	11707.38 lb.

	Volume
Shell	1057.65 Gal.
Head	70.51 Gal.
Totals	1128.16 Gal.

	Area
Shell	191.11 Sq. Ft.
Head	23.13 Sq. Ft.
Totals	214.24 Sq. Ft.

Hydrostatic Test Information (UG-99)

Gauge at Top

Component with controlling ratio is : Shell 1
Component with controlling pressure is : Shell 1

Calculated Test Pressure $= P * 1.3 * \frac{\text{Cold Stress}}{\text{Hot Stress}} = 75.00 * 1.3 * \frac{20000}{18900} =$ **103.17 PSI**

Table of Contents

HT/DcR Engineering, Inc.

Calculation Number:
1494F-7793-E4401-01

Client:	Project:	Discipline:
DcR Construction	1494F - 7793 - E4401	Structural
Subject/Title: E-4401 LIFTING LUGS & LEGS QUALIFICATIONS		**Job Number:** 1494F
Objective: QUALIFY LIFTING LUGS AND LEGS		
System or Equipment ID: 7793-E4401		

Contents

Topic	Page	Attachments (Computer Printouts, Technical Papers, Sketches, Correspondence)	# of Pages
Purpose	2	#1 - pg 120 Pressure Vessel Handbook 10th Ed.	1
Summary of Conclusions	2		
Methodology	2	#2 - BJAC OUTPUT FOR WTS.	2
Assumptions	2		
Criteria	2	#3 - APV OUTPUT FOR LEGS	41
Design Inputs/References	2		
Body of Calculations	3		

Last Page Number: 5

Version Record

Version No.	Description	Originator/Date Signature	Reviewer/Date Signature	Approver/Date Signature
A	FOR RECORD	[signature] 9-13-07		

HT/DcR Engineering, Inc.

Client: DcR Construction	Project: 1494F	Calculation Number: 1494F-7793-E4401-01

Title: LIFTING LUGS & LEGS QUALIFICATIONS	Sheet: 2

Purpose:

Qualify Lugs & Legs For E4401

Summary:

Lugs & Legs ok Per Drawings

Methodology

Lugs based on Conventional Methods & Ref. Material

Legs based on APV program.

Assumptions

Head Lugs Only For Lifting Head Assembly

Spreader bars used for vertical lifts

Criteria

Per Reference Material

Design Inputs / References

BJAC output for weights

Pressure Vessel Handbook by Eugene F. Megyesy, 10th Ed.

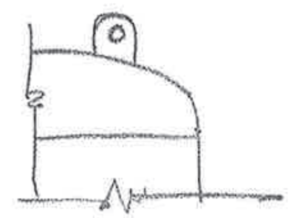
APV output For Leg Qualification

HT/DcR Engineering, Inc.

Client:	Project:	Calculation Number:
DcR Construction	1494F	1494F-7793-E4401-01

Title:	Sheet:
LIFTING LUGS & LEGS QUALIFICATIONS	3

SA-36
$F_y = 32,400$ psi



Qualify Head Lugs

Lug 1/2" thick
D = 1" ϕ
R = 1 1/8"

Pressure Vessel Handbook

$$t = \frac{P}{2S(R - D/2)}$$

Wt of Front Head
199# Shell
213# Head
110# Flng
522#

Design Load = 1.5(1/2(522)) = 392#

$$\text{Lug Stress} = \frac{392}{2(1/2'')(1.125 - 1/2)} = \underline{627 \text{ psi}}$$

Head Material 3/8" THICK

$$\text{Stress} = \frac{627}{3/8''} = \underline{1673 \text{ psi}}$$

Very Small Stress

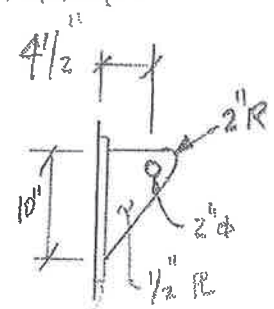
Head Lugs OK

HT/DcR Engineering, Inc.

Client:	Project:	Calculation Number:
DcR Construction	1494F	1494F-7793-E4401-01

Title:	Sheet:
LIFTING LUGS & LEGS QUALIFICATIONS	4

SA-36
$F_y = 32,400$ psi



PL 1/2 x 6" x 13 3/4"

Shell Lugs (3 TOTAL)

DEAD WT VESSEL ≅ 14,000#

$$LOAD/LUG = \frac{14,000}{3} \times 1.5 \text{ IMPACT} = 7,000^{\#}$$

$$LUG\ STRESS = \frac{7,000}{2(1/2")(2-1")} = 7,000 \text{ psi}$$

SHEAR ALLOW = $.4F_y$ = 12,960 psi > 7,000 psi

LUG STRESS OK

Stresses @ Face of Vessel

Vertical Shear = 7,000#

Moment = 7,000 (4 1/2") = 31,500 #-in

$$Stress\ f_b = \frac{7000}{1/2" \times 10"} + \frac{31,500}{1/6(1/2)(10^2)} = 1400 + 3780$$

$$= 5180 \text{ psi}$$

ok

Stresses @ Repad

6" × 13 3/4"

Area weld = 2(6 + 13 3/4") = 39 1/2"

$$S_{weld} = 6 \times 13^3/_4 + \frac{13^3/_4{}^2}{3} = 145 \text{ in}^3/\text{in}$$

$$f_w = \frac{7000}{39.5"} + \frac{31,500}{145} = 177 + 217 = 394^{\#}/\text{in} \Rightarrow \text{REPAD PL } f = \frac{394}{1/2"} = 800 \text{ psi}$$

REPAD OK

Stress @ Shell

f_{shell} = 394/0.25" ≅ 1600 psi SMALL SHELL OK

HT/DcR Engineering, Inc.

Client: DcR Construction	**Project:** 1494F	**Calculation Number:** 1494F-7793-E4401-01

Title: LIFTING LUGS & LEGS QUALIFICATIONS	**Sheet:** 5

SUPPORT LEGS

SEE APV ANALYSIS

SPLICE CONNECTION

WELD CAPACITY = 2×[3×4" × (9600×1/2")] = 115,200#/ANGLE

BOLT CAPACITY = 2×[3 × 10.6k] = 63,600#/ANGLE

OK BY INSPECTION

L 6×6×1/2 LEGS OK

LIFTING ATTACHMENTS (cont.)

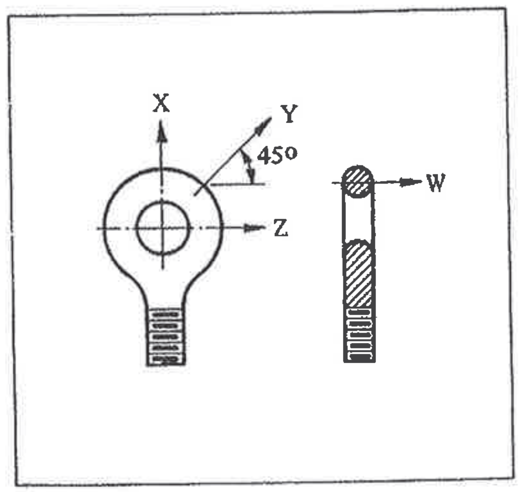
RECOMMENDED MATERIAL: A 515-70, A 302 or equivalent. The thickness, and length of the lifting lug shall be determined by calculation.*

WELD: When fillet welds are used, it is recommended that throat areas be at least 50 per cent greater than the cross sectional area of the lug.

To design the lugs the entire load should be assumed to act on one lug.

All possible directions of loading should be considered (during shipment, storage, erection, handling.) When two or more lugs are used for multileg sling, the angle between each leg of the sling and the horizontal should be assumed to be 30 degrees.

EYE - BOLT



Threaded fasteners smaller than 5/8" diameter should not be used for lifting because of the danger of overtorquing during assembly.

Commercial eyebolts are supplied with a rated breaking strength in the X direction.

For loadings other than along the axis of the eyebolt, the following ratings are recommended. These are expressed as percentage of the rating in the axial direction.

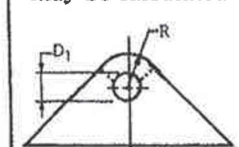
X = 100% Y = 33%
Z = 20% W = 10%

EXAMPLE:

An eyebolt of 1 in. diameter which is good for 4960 lb. load in tension (direction x) can carry only 4960 x 0.33 = 1637 lb. load if it acts in direction y.

The above dimensions and recommendations are taken from C. V. Moore: Designing Lifting Attachments, Machine Design, March 18, 1965.

*Assuming shear load only thru the minimum section, the required thickness may be calculated by the formula:



$$t = \frac{P}{2S\ (R - D_1/2)}$$

where t = required thickness of lug, in.
P = load, lbs.
S = allowable shear stress, psi.

See page 459 for design of weld and length of lug.

7793-4401 FINISHED DIMENSIONS ATTACHMENT #2 Pg.1/2

File: E-4401-7793.BJT Date: 8/24/2007 Time: 9:37:29 AM

Bill of Materials - Finished dimensions

Part				Dimensions						Cost	
Num	Name	Material	Qty	Dim1 in		Dim2 in		Thk. in	Weight lbf	Labor Dollar(US)	Total Dollar(US)
1	Shell Cylinder	SA-240 S30400 Grd Plate(G5	1	36	od	187.25	lg	0.25	1519	365	4230
2	Fr Hd Cylinder	SA-516 K02700 Grd Plate	1	36	od	16.625	lg	0.375	199	271	362
3	Re Hd Cylinder	SA-516 K02700 Grd Plate	1	36	od	26.1875	lg	0.375	314	288	429
5	Fr Hd Cover Ellip.	SA-516 K02700 Grd Plate	1	36	od	2	sf	0.375	213	0	788
6	Re Hd Cover Ellip.	SA-516 K02700 Grd Plate	1	36	od	2	sf	0.375	213	0	788
9	Shell Lift Lugs	SA-36 K02600 Plate	3	4	od	0		1.5	7	0	4
11	Front TubSh	SA-240 S30400 Grd Plate	1	39.5	od	0		2.5	514	3740	6305
12	Rear TubSh	SA-240 S30400 Grd Plate	1	39.5	od	0		2.5	514	3740	6305
17	Fr Hd Flng TubSh	SA-516 K02700 Grd Plate	1	39.5	od	36.125	id	2.0625	110	218	732
18	Re Hd Flng TubSh	SA-516 K02700 Grd Plate	1	39.5	od	36.125	id	2.0625	110	218	732
31	Fr Hd Gskt TubSh	Solid Teflon 1/8in Thickness	1	37.25	od	36.125	id	0.125	0	88	418
32	Re Hd Gskt TubSh	Solid Teflon 1/8in Thickness	1	37.25	od	36.125	id	0.125	0	88	418
38	Tubes (min wall)	SA-249 S30400 Grd Wld. t	1127	0.75	od	192	lg	0.049	7200	1429	61904
39	Baffles	SA-240 S30400 Grd Plate	9	35.3125	od	0		0.3125	260	7839	10520
40	Tie Rods	SA-479 S30400 Grd Bar	14	0.5	od	176	lg	0	139	122	418
41	Spacers	SA-249 S30400 Grd Wld. t	104	0.75	od	33.5	lg	0.109	279	68	532
41	Spacers	SA-249 S30400 Grd Wld. t	18	0.75	od	16.75	lg	0.109	0	0	0
44	FH Partitions	SA-516 K02700 Grd Plate	2	27.8125	lg	35.25	wi	0.5	278	190	321
45	RH Partitions	SA-516 K02700 Grd Plate	1	37.375	lg	35.25	wi	0.5	373	342	518
45	RH Partitions	SA-516 K02700 Grd Plate	2	37.375	od	17.625	lg	0.5	0	0	0
51	Coupling A	SA-182 S30400 Grd Forging	1	0.5	od	0		0	0	0	7
52	Coupling B	SA-182 S30400 Grd Forging	1	0.5	od	0		0	0	0	7
53	Coupling C	SA-182 S30400 Grd Forging	1	0.75	od	0		0	1	0	13
54	Coupling D	SA-182 S30400 Grd Forging	1	0.75	od	0		0	1	0	13
61	Nozzle A	SA-312 S30400 Grd Wld. p	1	24	od	6	lg	0.375	48	103	531
62	Nozzle B	SA-312 S30400 Grd Wld. p	1	2.375	od	6	lg	0.154	2	9	25
63	Nozzle C	SA-53 K03005 Grd Wld. pipe	1	10.75	od	6	lg	0.365	20	45	59
64	Nozzle D	SA-53 K03005 Grd Wld. pipe	1	10.75	od	6	lg	0.365	20	45	59

Attachment #2

File: E-4401-7793.BJT Date: 8/24/2007 Time: 9:37:30 AM

65	Nozzle G	SA-312 S30400 Grd Wld. p	1	6.625	od	6	lg	0.134	5	25	67
81	Nozzle Flng A Slip On	SA-182 S30400 Grd Forging	1	150	AN	24	di	0	185	0	1700
82	Nozzle Flng B Slip On	SA-182 S30400 Grd Forging	1	150	AN	2.375	di	0	5	0	47
83	Nozzle Flng C Slip On	SA-105 K03504 Forgings	1	150	AN	10.75	di	0	36	0	57
84	Nozzle Flng D Slip On	SA-105 K03504 Forgings	1	150	AN	10.75	di	0	36	0	57
85	Nozzle Flng G Slip On	SA-182 S30400 Grd Forging	1	150	AN	6.625	di	0	17	0	157
101	Fr Hd Blts TubSh	SA-193 G41400 Grd Bolt(<= 2	60	0.5	od	7	lg	0	23	0	58
102	Re Hd Blts TubSh	SA-193 G41400 Grd Bolt(<= 2	60	0.5	od	7	lg	0	23	0	58
115	Distrib. Belt A	SA-240 S30400 Grd Plate(G5	1	52	od	42	sf	0.5	1555	1682	7022
122	Dist.Belt An.Rng	SA-240 S30400 Grd Plate(G5	2	52		0		0.625	0	0	0

HT/DcR Engineering, Inc.
2830 Parkway Street Lakeland, FL 33811

Date Printed: 9/14/2007

CUSTOMER

Delta-T
133 Waller Mill Road
Williamsburg, VA 23185

VESSEL LOCATION

BUNGE-ERGON

VICKSBURG, MISSISSIPPI

VESSEL DESCRIPTION

PRODUCT CONDENSER

Vessel designed per the ASME Boiler & Pressure Vessel Code,
Section VIII, Division 1,2004 Edition, 2006 Addenda
with Advanced Pressure Vessel, Version: 9.2.4
Vessel is ASME Code Stamped

Job No: 1494F
Vessel Number: 7793-E4401 Legs

NAMEPLATE INFORMATION

Vessel MAWP: 75.00 PSI and Full Vacuum at 300 °F
MDMT: -20 °F at 75.00 PSI
Serial Number(s): 4401-7793
National Board Number(s): ______________________
Year Built: 2007
Radiography: NONE
Postweld Heat Treated: NONE

HT/DcR Engineering, Inc.
2830 Parkway Street Lakeland, FL 33811

Date Printed: 9/14/2007

HT/DcR Engineering, Inc.

Leg 1

Customer: **Delta-T**
Job No: 1494F
Mark Number: LEG1

Vessel Number: 7793-E4401 Legs

Date Printed: 9/14/2007

Leg Information

Design Temperature:	300 °F	Factor B Chart:	CS-2
Material:	SA-36	Material Stress (Hot):	21600 PSI
Condition:		Material Stress (Cold):	21600 PSI
B.P. to Vessel Attachment Length (L):	73.8800 in.	Modulus of Elasticity:	28.3 10^6 PSI
Direction of Applied Force:	0 °	Yield Strength:	36000 PSI
Length of Supports:	83.8800 in.	Dist. From Reference Line:	24.0000 in.
Quantity:	4	Method of Attachment:	Leg In
Type:	Angle	Molded to Head Curvature:	No
Description:			
d_1:	6.0000 in.	t_1:	0.5000 in.
d_2:	6.0000 in.	t_2:	0.5000 in.
Weld Attachment Length Top (W_t):	0.0000 in.	Side (W_s):	10.0000 in.
Weld Leg Dimension (W_l):	0.3750 in.		

Repad Information

Design Temperature:	300 °F		
Material:	SA-240 304, High	Material Stress (Hot):	18900 PSI
Condition:		Material Stress (Cold):	20000 PSI
Height (L_{rh}):	10.0000 in.	Thickness:	0.5000 in.
Width (L_{rw}):	10.0000 in.	Weld Leg (W_r):	0.3750 in.

Base Plate Information

Design Temperature:	300 °F		
Material:	SA-36 Plate	Material Stress (Hot):	16600 PSI
Condition:		Material Stress (Cold):	16600 PSI
Length:	8.0000 in.	Yield Strength:	36000 PSI
Width:	8.0000 in.	Thickness:	0.5000 in.
Leg to B.P. Attachment Factor:	0.7500	Bending Coefficient (C_m):	1.0000
Effective Length Factor (K):	1.5000		

Anchor Bolt Information

Material:	F-1554 Gr. 105	Material Stress (Hot):	39000 PSI
Condition:		Material Stress (Cold):	39000 PSI
Diameter:	0.7500 in.	Root Area:	1.2940 sq. in.
Quantity:	1	Bolt Circle Diameter:	41.0000 in.
Ultimate 28 Day Concrete Strength:	3000 PSI		

Operating Pressurized Conditions - Ocassional Loads - Seismic Case 5

Support Leg Properties

Section Modulus, $S_x = \frac{I_x}{C_x} = \frac{31.7448}{4.2426}$ **= 7.4824 in.³**

Section Modulus, $S_y = \frac{I_y}{C_y} = \frac{8.0709}{2.3826}$ **= 3.3874 in.³**

Radius of gyration, $r_x = \sqrt{\frac{I_x}{A}} = \sqrt{\frac{31.7448}{5.7500}}$ **= 2.3496 in.**

Radius of gyration, $r_y = \sqrt{\frac{I_y}{A}} = \sqrt{\frac{8.0709}{5.7500}}$ **= 1.1848 in.**

Least radius of gyration, $r_{min} = \sqrt{\frac{I_{min}}{A}} = \sqrt{\frac{8.0709}{5.7500}}$ **= 1.1848 in.**

Slenderness ratio, $SR_x = \frac{K\,L}{r_x} = \frac{1.5000 * 73.8800}{2.3496}$ **= 47.1655**

Slenderness ratio, $SR_y = \frac{K\,L}{r_y} = \frac{1.5000 * 73.8800}{1.1848}$ **= 93.5348**

$SR_{max} = \frac{K\,L}{r_{min}} = \frac{1.5000 * 73.8800}{1.1848}$ **= 93.5348**

Critical slenderness ratio, $C_c = \sqrt{\frac{2\,\pi^2\,E}{F_y}} = \sqrt{\frac{2 * \pi^2 * (28.3 * 10^6)}{36000}}$ **= 124.57**

$F'_{ex} = \frac{4}{3}\,\frac{12\,\pi^2\,E}{23\,SR_x^2} = \frac{4}{3} * \frac{12 * \pi^2 * (28.3 * 10^6)}{23 * 47.1655^2}$ **= 87343 PSI**

$F'_{ey} = \frac{4}{3}\,\frac{12\,\pi^2\,E}{23\,SR_y^2} = \frac{4}{3} * \frac{12 * \pi^2 * (28.3 * 10^6)}{23 * 93.5348^2}$ **= 22209 PSI**

For $SR_{max} <= C_c$, Allowable compressive stress:

$$F_a = \frac{4}{3}\,\frac{\left(1 - \frac{SR_{max}^2}{2\,C_c^2}\right) F_y}{\frac{5}{3} + \frac{3\,SR_{max}}{8\,C_c} - \frac{SR_{max}^3}{8\,C_c^3}} = \frac{4}{3} * \frac{\left(1 - \frac{93.5348^2}{2 * 124.57^2}\right) * 36000}{\frac{5}{3} + \frac{3 * 93.5348}{8 * 124.57} - \frac{93.5348^3}{8 * 124.57^3}}$$ **= 18187 PSI**

Allowable bending stress : $S_b = \frac{4}{3}\,0.6\,F_y = \frac{4}{3} * 0.6 * 36000$ **= 28800 PSI**

Allowable tension stress : $S_t = \frac{4}{3}\,0.6\,F_y = \frac{4}{3} * 0.6 * 36000$ **= 28800 PSI**

Leg to Vessel Weld Properties

Distance between welds along side of legs (b) = = 7.7782 in.

$L_W = 2\ W_S = 2 * 10.0000$ = 20.0000 in.

$$I_{wy} = \frac{W_S^3}{6} = \frac{10.0000^3}{6}$$ = 166.6667 in.³

$$I_{wz} = \frac{W_S\ b^2}{2} = \frac{10.0000 * 7.7782^2}{2}$$ = 302.5000 in.³

$J_{wx} = I_{wy} + I_{wz} = 166.6667 + 302.5000$ = 469.1667 in.³

Distance from weld neutral axis to top/bottom of welds:

$$EF_{yt} = EF_{yb} = \frac{W_S}{2} = \frac{10.0000}{2}$$ = 5.0000 in.

Distance from weld neutral axis to bottom of welds:

$$EF_Z = \frac{b}{2} = \frac{7.7782}{2}$$ = 3.8891 in.

NO Wind Analysis Information

Wind Analysis Calculations

No Wind Load Calculations were performed

IBC 2003 Seismic Design Information

Spectral Resp. Accel. at short periods (S_S):	0.200		
Spectral Resp. Accel. at a period of 1 s (S_1):	0.100	Response Modification Factor (R):	3.000
Seismic Use Group:	I	Site Class:	D
Seismic Design Category:	C		

Seismic Analysis Calculations

Seismic Center of Gravity: = 174.4404 in.

$$C_S = \frac{SD_S\ I}{R} = \frac{0.2133 * 1.00}{3.000}$$ = 0.0711

$V = W * C_S = 22668.57 * 0.03$ = 1611.99 lb.

$F_S = V\ C_{eh} = 1611.99 * 0.70$ = 1128 lb.

Loadings and Stresses on Support Legs

Direction of Applied Force = **0 °**

Leg Orientation °	Moment of Inertia in.⁴	Lateral Force lb.	Axial Stress PSI	Bending Stresses (f_{bx}) PSI	Bending Stresses (f_{by}) PSI	Acceptance Ratio (Eqn_1)	Acceptance Ratio (Eqn_2)
0	8.0709	114	-280	0	1720	0.0751	
90	31.7448	450	-1015	3331	3973	0.3094	
180	8.0709	114	-1750	0	8720	0.3990	
270	31.7448	450	-1015	3331	3973	0.3094	

Direction of Worst case Force = **40 °**
Highest Stress Ratio = **0.4606**

Loadings and Stresses on Leg to Vessel attachment welds

Leg Orientation °	Load F_x lb.	Load F_y lb.	Load F_z lb.	Moment M_x in.-lb.	Moment M_y in.-lb.	Moment M_z in.-lb.	Total Stress PSI	Stress Ratio
0	114	0	-1611	0	-9246	0	785	0.0636
90	0	450	-5836	24925	-10539	813	1765	0.1429
180	-114	0	-10062	0	-11833	0	1633	0.1322
270	0	450	-5836	24925	-10539	813	1765	0.1429

Direction of Worst case Force = **1 °**
Highest Stress Ratio: **0.1878**

Repad to Shell Weld Properties

$L_w = 2\ (L_{rh} + L_{rw}) = 2 * (10.0000 + 10.0000)$ **= 40.0000 in.**

$I_{wy} = \frac{L_{rw} L_{rh}^2}{2} + \frac{L_{rh}^3}{6} = \frac{10.0000 * 10.0000^2}{2} + \frac{10.0000^3}{6}$ **= 666.6667 in.³**

$I_{wz} = \frac{L_{rh} L_{rw}^2}{2} + \frac{L_{rw}^3}{6} = \frac{10.0000 * 10.0000^2}{2} + \frac{10.0000^3}{6}$ **= 666.6667 in.³**

$J_{wx} = I_{wy} + I_{wz} = 666.6667 + 666.6667$ **= 1333.3333 in.³**

Distance from weld neutral axis to top of repad:

$EF_y = \frac{L_{rh}}{2} = \frac{10.0000}{2}$ **= 5.0000 in.**

Distance from weld neutral axis to side of repad:

$EF_z = \frac{L_{rw}}{2} = \frac{10.0000}{2}$ **= 5.0000 in.**

Loadings and Stresses on Repad-to-Shell Attachment Welds

Leg Orientation °	Load F_x lb.	Load F_y lb.	Load F_z lb.	Moment M_x in.-lb.	Moment M_y in.-lb.	Moment M_z in.-lb.	Total Stress PSI	Stress Ratio
0	114	0	-1611	0	-10052	0	235	0.0190
90	0	450	-5836	24925	-13457	1038	755	0.0611
180	-114	0	-10062	0	-16864	0	747	0.0605
270	0	450	-5836	24925	-13457	1038	755	0.0611

Direction of Worst case Force = 1 °
Highest Stress Ratio = 0.0806

Loadings and Pressure on Concrete Foundation

Direction of applied force: = 0 °

Leg Orientation °	Bearing Pressure PSI	Moment M_x in.-lb.	Moment M_y in.-lb.	Maximum Pressure P_x PSI	Maximum Pressure P_y PSI	Max. Concrete Pressure PSI	Concrete Pressure Ratio
0	25	5614	5614	65.79	65.79	156.75	0.1306
90	91	21266	21266	249.21	249.21	589.61	0.4913
180	157	13419	13419	157.25	157.25	471.73	0.3931
270	91	21266	21266	249.21	249.21	589.61	0.4913

Direction of Worst case Force: = 1 °
Highest Stress Ratio = 0.6320

Loadings and Stresses on BasePlate and Anchor bolts

Leg Orientation °	Moment M_x in.-lb.	Moment M_y in.-lb.	Maximum Pressure P_x PSI	Maximum Pressure P_y PSI	Maximum B.P. Stress PSI	BasePlate Stress Ratio	Anchor Bolt Stress PSI	Anchor Bolt Stress Ratio
0	174	163	4183	3912	5727	0.1989	1064	0.0205
90	652	609	15640	14613	21405	0.7432	4114	0.0791
180	615	588	14750	14102	20407	0.7086	973	0.0187
270	652	609	15640	14613	21405	0.7432	4114	0.0791

Direction of Worst case Force: = 1 °
Highest Stress Ratio = 0.9888

Maximum General Longitudinal Stresses

$VE = (C_{de} + 0.2 * SDS * I * C_{ev}) = (1.00 + 0.2 * 0.21 * 1.00 * 0.70) =$ **1.03**

$$S_{L1} = \frac{M_a}{Z} - \frac{W\,VE}{A} + \left(\frac{P * D}{4 * t}\right) = \frac{113471}{256.2605} - \frac{22668.57 * 1.03}{28.47} + \left(\frac{76.96 * 36.5000}{4 * 0.2500}\right) = 2432 \text{ PSI}$$

$$S_{L2} = -\frac{M_a}{Z} - \frac{W\,VE}{A} - \left(\frac{Pe * D}{4 * t}\right) = -\frac{113471}{256.2605} - \frac{22668.57 * 1.03}{28.47} - \left(\frac{14.70 * 36.5000}{4 * 0.2500}\right) = -1799 \text{ PSI}$$

Allowable Tension Stress, S_{ta} $= 1.2\,S\,E = 1.2 * 18900 * 0.70$ **= 15876** PSI
Allowable Compressive Stress, S_{ca} $= -1.2\,B = -1.2 * 8963$ **= -10756** PSI

$$R_{SL1} = \frac{S_{L1}}{S_{ta}} = \frac{2432}{15876} = 0.1532$$

$$R_{SL2} = \frac{S_{L2}}{S_{ca}} = \frac{-1799}{-10756} = 0.1673$$

Summary

Governing external force	= Seismic load
Total Force	= 1128 lb.
Weight	= 22668.57 lb.
Base Moment	= 196837 in.-lb.
Tangent Moment	= 113471 in.-lb.

Leg Stresses

Maximum combined compressive and bending stress ratio	= 0.4606

Leg BasePlate

Concrete Stress Ratio	= 0.6320
Base Plate Stress Ratio	= 0.9888

Host Stresses

Sl1 ratio	= 0.1532
Sl2 ratio	= 0.1673

Weld Stresses

Leg to vessel weld stress ratio	= 0.1878
Repad to shell weld stress ratio	= 0.0806

Operating Pressurized Conditions - Ocassional Loads - Seismic Case 8

Support Leg Properties

Section Modulus, $S_x = \frac{I_x}{C_x} = \frac{31.7448}{4.2426}$ = **7.4824** in.³

Section Modulus, $S_y = \frac{I_y}{C_y} = \frac{8.0709}{2.3826}$ = **3.3874** in.³

Radius of gyration, $r_x = \sqrt{\frac{I_x}{A}} = \sqrt{\frac{31.7448}{5.7500}}$ = **2.3496** in.

Radius of gyration, $r_y = \sqrt{\frac{I_y}{A}} = \sqrt{\frac{8.0709}{5.7500}}$ = **1.1848** in.

Least radius of gyration, $r_{min} = \sqrt{\frac{I_{min}}{A}} = \sqrt{\frac{8.0709}{5.7500}}$ = **1.1848** in.

Slenderness ratio, $SR_x = \frac{K\,L}{r_x} = \frac{1.5000 * 73.8800}{2.3496}$ = **47.1655**

Slenderness ratio, $SR_y = \frac{K\,L}{r_y} = \frac{1.5000 * 73.8800}{1.1848}$ = **93.5348**

$SR_{max} = \frac{K\,L}{r_{min}} = \frac{1.5000 * 73.8800}{1.1848}$ = **93.5348**

Critical slenderness ratio, $C_c = \sqrt{\frac{2\pi^2 E}{F_y}} = \sqrt{\frac{2 * \pi^2 * (28.3 * 10^6)}{36000}}$ = **124.57**

$F'_{ex} = \frac{4}{3}\,\frac{12\pi^2 E}{23\,SR_x^2} = \frac{4}{3} * \frac{12 * \pi^2 * (28.3 * 10^6)}{23 * 47.1655^2}$ = **87343** PSI

$F'_{ey} = \frac{4}{3}\,\frac{12\pi^2 E}{23\,SR_y^2} = \frac{4}{3} * \frac{12 * \pi^2 * (28.3 * 10^6)}{23 * 93.5348^2}$ = **22209** PSI

For $SR_{max} <= C_c$, Allowable compressive stress:

$$F_a = \frac{4}{3}\,\frac{\left(1 - \frac{SR_{max}^2}{2\,C_c^2}\right) F_y}{\frac{5}{3} + \frac{3\,SR_{max}}{8\,C_c} - \frac{SR_{max}^3}{8\,C_c^3}} = \frac{4}{3} * \frac{\left(1 - \frac{93.5348^2}{2 * 124.57^2}\right) * 36000}{\frac{5}{3} + \frac{3 * 93.5348}{8 * 124.57} - \frac{93.5348^3}{8 * 124.57^3}}$$

= **18187** PSI

Allowable bending stress : $S_b = \frac{4}{3}\,0.6\,F_y = \frac{4}{3} * 0.6 * 36000$ = **28800** PSI

Allowable tension stress : $S_t = \frac{4}{3}\,0.6\,F_y = \frac{4}{3} * 0.6 * 36000$ = **28800** PSI

Leg to Vessel Weld Properties

Distance between welds along side of legs (b) =	= 7.7782 in.
$L_W = 2\, W_S = 2 * 10.0000$	= 20.0000 in.
$I_{wy} = \frac{W_S^3}{6} = \frac{10.0000^3}{6}$	= 166.6667 in.³
$I_{wz} = \frac{W_S\, b^2}{2} = \frac{10.0000 * 7.7782^2}{2}$	= 302.5000 in.³
$J_{wx} = I_{wy} + I_{wz} = 166.6667 + 302.5000$	= 469.1667 in.³

Distance from weld neutral axis to top/bottom of welds:

$EF_{yt} = EF_{yb} = \frac{W_S}{2} = \frac{10.0000}{2}$ = 5.0000 in.

Distance from weld neutral axis to bottom of welds:

$EF_Z = \frac{b}{2} = \frac{7.7782}{2}$ = 3.8891 in.

NO Wind Analysis Information

Wind Analysis Calculations

No Wind Load Calculations were performed

IBC 2003 Seismic Design Information

Spectral Resp. Accel. at short periods (S_S):	0.200	Response Modification Factor (R):	3.000
Spectral Resp. Accel. at a period of 1 s (S_1):	0.100	Site Class:	D
Seismic Use Group:	I		
Seismic Design Category:	C		

Seismic Analysis Calculations

Seismic Center of Gravity:	= 174.4404 in.
$C_S = \frac{SD_S\, I}{R} = \frac{0.2133 * 1.00}{3.000}$	= 0.0711
$V = W * C_S = 22668.57 * 0.03$	= 1611.99 lb.
$F_S = V\, C_{eh} = 1611.99 * 0.70$	= 1128 lb.

HT/DcR Engineering, Inc.

Leg 1

Job No: 1494F
Mark Number: LEG1

Vessel Number: 7793-E4401 Legs

Date Printed: 9/14/2007

Loadings and Stresses on Support Legs

Direction of Applied Force = **0 °**

Leg Orientation °	Moment of Inertia in.⁴	Lateral Force lb.	Axial Stress PSI	Bending Stresses (f_{bx}) PSI	Bending Stresses (f_{by}) PSI	Acceptance Ratio (Eqn_1)	Acceptance Ratio (Eqn_2)
0	8.0709	114	173	0	2548	0.0965	
90	31.7448	450	-562	3331	2199	0.2229	
180	8.0709	114	-1297	0	6947	0.3125	
270	31.7448	450	-562	3331	2199	0.2229	

Direction of Worst case Force = **40 °**
Highest Stress Ratio = **0.3741**

Loadings and Stresses on Leg to Vessel attachment welds

Leg Orientation °	Load F_x lb.	Load F_y lb.	Load F_z lb.	Moment M_x in.-lb.	Moment M_y in.-lb.	Moment M_z in.-lb.	Total Stress PSI	Stress Ratio
0	114	0	995	0	-4540	0	401	0.0325
90	0	450	-3231	24925	-5835	813	1341	0.1086
180	-114	0	-7457	0	-7129	0	1139	0.0922
270	0	450	-3231	24925	-5835	813	1341	0.1086

Direction of Worst case Force = **1 °**
Highest Stress Ratio: **0.1501**

Repad to Shell Weld Properties

$L_w = 2\ (L_{rh} + L_{rw}) = 2 * (10.0000 + 10.0000)$ **= 40.0000** in.

$I_{wy} = \frac{L_{rw}\, L_{rh}^2}{2} + \frac{L_{rh}^3}{6} = \frac{10.0000 * 10.0000^2}{2} + \frac{10.0000^3}{6}$ **= 666.6667** in.³

$I_{wz} = \frac{L_{rh}\, L_{rw}^2}{2} + \frac{L_{rw}^3}{6} = \frac{10.0000 * 10.0000^2}{2} + \frac{10.0000^3}{6}$ **= 666.6667** in.³

$J_{wx} = I_{wy} + I_{wz} = 666.6667 + 666.6667$ **= 1333.3333** in.³

Distance from weld neutral axis to top of repad:

$EF_y = \frac{L_{rh}}{2} = \frac{10.0000}{2}$ **= 5.0000** in.

Distance from weld neutral axis to side of repad:

$EF_z = \frac{L_{rw}}{2} = \frac{10.0000}{2}$ **= 5.0000** in.

Job No: 1494F
Mark Number: LEG1

Vessel Number: 7793-E4401 Legs

Date Printed: 9/14/2007

Loadings and Stresses on Repad-to-Shell Attachment Welds

Leg Orientation °	Load F_x lb.	Load F_y lb.	Load F_z lb.	Moment M_x in.-lb.	Moment M_y in.-lb.	Moment M_z in.-lb.	Total Stress PSI	Stress Ratio
0	114	0	995	0	-4043	0	111	0.0090
90	0	450	-3231	24925	-7450	1038	568	0.0460
180	-114	0	-7457	0	-10858	0	539	0.0437
270	0	450	-3231	24925	-7450	1038	568	0.0460

Direction of Worst case Force = **1 °**
Highest Stress Ratio = **0.0645**

Loadings and Pressure on Concrete Foundation

Direction of applied force: = **0 °**

Leg Orientation °	Bearing Pressure PSI	Moment M_x in.-lb.	Moment M_y in.-lb.	Maximum Pressure P_x PSI	Maximum Pressure P_y PSI	Max. Concrete Pressure PSI	Concrete Pressure Ratio
0	-16	1365	1365	16.00	16.00	16.45	0.0137
90	50	17018	17018	199.43	199.43	449.34	0.3745
180	117	9171	9171	107.47	107.47	331.46	0.2762
270	50	17018	17018	199.43	199.43	449.34	0.3745

Direction of Worst case Force: = **1 °**
Highest Stress Ratio = **0.5151**

Loadings and Stresses on BasePlate and Anchor bolts

Leg Orientation °	Moment M_x in.-lb.	Moment M_y in.-lb.	Maximum Pressure P_x PSI	Maximum Pressure P_y PSI	Maximum B.P. Stress PSI	BasePlate Stress Ratio	Anchor Bolt Stress PSI	Anchor Bolt Stress Ratio
0	0	0	0	0	0	0.0000	873	0.0168
90	476	441	11415	10593	15573	0.5407	3762	0.0723
180	439	420	10525	10082	14574	0.5060	557	0.0107
270	476	441	11415	10593	15573	0.5407	3762	0.0723

Direction of Worst case Force: = **1 °**
Highest Stress Ratio = **0.7863**

Maximum General Longitudinal Stresses

$VE = (C_{de} + 0.2 * SDS * I * C_{ev}) = (0.60 + 0.2 * 0.21 * 1.00 * -0.70) =$ **0.57**

$$S_{L1} = \frac{M_a}{Z} - \frac{W\,VE}{A} + \left(\frac{P * D}{4 * t}\right) = \frac{113471}{256.2605} - \frac{22668.57 * 0.57}{28.47} + \left(\frac{76.08 * 36.5000}{4 * 0.2500}\right)$$ **= 2766** PSI

$$S_{L2} = -\frac{M_a}{Z} - \frac{W\,VE}{A} - \left(\frac{Pe * D}{4 * t}\right) = -\frac{113471}{256.2605} - \frac{22668.57 * 0.57}{28.47} - \left(\frac{14.70 * 36.5000}{4 * 0.2500}\right)$$ **= -1433** PSI

Allowable Tension Stress, S_{ta} = 1.2 S E = 1.2 * 18900 * 0.70 **= 15876** PSI
Allowable Compressive Stress, S_{ca} = -1.2 B = -1.2 * 8963 **= -10756** PSI

$$R_{SL1} = \frac{S_{L1}}{S_{ta}} = \frac{2766}{15876}$$ **= 0.1742**

$$R_{SL2} = \frac{S_{L2}}{S_{ca}} = \frac{-1433}{-10756}$$ **= 0.1332**

Summary

Governing external force	= Seismic load
Total Force	= 1128 lb.
Weight	= 22668.57 lb.
Base Moment	= 196837 in.-lb.
Tangent Moment	= 113471 in.-lb.

Leg Stresses

Maximum combined compressive and bending stress ratio	= 0.3741

Leg BasePlate

Concrete Stress Ratio	= 0.5151
Base Plate Stress Ratio	= 0.7863

Host Stresses

SI1 ratio	= 0.1742
SI2 ratio	= 0.1332

Weld Stresses

Leg to vessel weld stress ratio	= 0.1501
Repad to shell weld stress ratio	= 0.0645

Operating Pressurized Conditions - Ocassional Loads - Wind Case 5

Support Leg Properties

Section Modulus, $S_x = \frac{I_x}{C_x} = \frac{31.7448}{4.2426}$ **= 7.4824 in.³**

Section Modulus, $S_y = \frac{I_y}{C_y} = \frac{8.0709}{2.3826}$ **= 3.3874 in.³**

Radius of gyration, $r_x = \sqrt{\frac{I_x}{A}} = \sqrt{\frac{31.7448}{5.7500}}$ **= 2.3496 in.**

Radius of gyration, $r_y = \sqrt{\frac{I_y}{A}} = \sqrt{\frac{8.0709}{5.7500}}$ **= 1.1848 in.**

Least radius of gyration, $r_{min} = \sqrt{\frac{I_{min}}{A}} = \sqrt{\frac{8.0709}{5.7500}}$ **= 1.1848 in.**

Slenderness ratio, $SR_x = \frac{K\,L}{r_x} = \frac{1.5000 * 73.8800}{2.3496}$ **= 47.1655**

Slenderness ratio, $SR_y = \frac{K\,L}{r_y} = \frac{1.5000 * 73.8800}{1.1848}$ **= 93.5348**

$SR_{max} = \frac{K\,L}{r_{min}} = \frac{1.5000 * 73.8800}{1.1848}$ **= 93.5348**

Critical slenderness ratio, $C_c = \sqrt{\frac{2\,\pi^2\,E}{F_y}} = \sqrt{\frac{2 * \pi^2 * (28.3 * 10^6)}{36000}}$ **= 124.57**

$F'_{ex} = \frac{4}{3}\,\frac{12\,\pi^2\,E}{23\,SR_x^2} = \frac{4}{3} * \frac{12 * \pi^2 * (28.3 * 10^6)}{23 * 47.1655^2}$ **= 87343 PSI**

$F'_{ey} = \frac{4}{3}\,\frac{12\,\pi^2\,E}{23\,SR_y^2} = \frac{4}{3} * \frac{12 * \pi^2 * (28.3 * 10^6)}{23 * 93.5348^2}$ **= 22209 PSI**

For SR_{max} <= C_c, Allowable compressive stress:

$$F_a = \frac{4}{3}\,\frac{\left(1 - \frac{SR_{max}^2}{2\,C_c^2}\right) F_y}{\frac{5}{3} + \frac{3\,SR_{max}}{8\,C_c} - \frac{SR_{max}^3}{8\,C_c^3}} = \frac{4}{3} * \frac{\left(1 - \frac{93.5348^2}{2 * 124.57^2}\right) * 36000}{\frac{5}{3} + \frac{3 * 93.5348}{8 * 124.57} - \frac{93.5348^3}{8 * 124.57^3}}$$ **= 18187 PSI**

Allowable bending stress : $S_b = \frac{4}{3}\,0.6\,F_y = \frac{4}{3} * 0.6 * 36000$ **= 28800 PSI**

Allowable tension stress : $S_t = \frac{4}{3}\,0.6\,F_y = \frac{4}{3} * 0.6 * 36000$ **= 28800 PSI**

Leg to Vessel Weld Properties

Distance between welds along side of legs (b) = **= 7.7782** in.

$L_w = 2\,W_s = 2 * 10.0000$ **= 20.0000** in.

$I_{wy} = \dfrac{W_s^3}{6} = \dfrac{10.0000^3}{6}$ **= 166.6667** in.³

$I_{wz} = \dfrac{W_s\,b^2}{2} = \dfrac{10.0000 * 7.7782^2}{2}$ **= 302.5000** in.³

$J_{wx} = I_{wy} + I_{wz} = 166.6667 + 302.5000$ **= 469.1667** in.³

Distance from weld neutral axis to top/bottom of welds:

$EF_{yt} = EF_{yb} = \dfrac{W_s}{2} = \dfrac{10.0000}{2}$ **= 5.0000** in.

Distance from weld neutral axis to bottom of welds:

$EF_z = \dfrac{b}{2} = \dfrac{7.7782}{2}$ **= 3.8891** in.

IBC 2003 Wind Analysis Information

Basic Wind Speed (V):	90	MPH	Wind Exposure type:	C
Importance factor (I):	1.0000		Force (shape) coefficient (C_f):	0.70
Topographic Factor (K_{zt}):	1.00		Directionality Factor (K_d):	1.00

Wind Analysis Calculations

Wind Center of Gravity **= 178.6462** in.

$q_z = 0.00256\,K_z\,K_{zt}K_d\,V^2\,I = 0.00256 * 0.85 * 1.000 * 1.00 * 90^2 * 1.0000$ **= 17.626**

$P = q_z\,G\,C_f = 17.626 * 0.90 * 0.70$ **= 11.10** lb./ft²

Wind Load, $F_w = P\,A\,C_{wi} = 11.10 * 74.7016 * 1.00$ **= 829** lb.

NO Seismic Design Information

Seismic Analysis Calculations

No Seismic Analysis Calculations were performed.

HT/DcR Engineering, Inc.

Leg 1

Job No: 1494F
Mark Number: LEG1

Vessel Number: 7793-E4401 Legs

Date Printed: 9/14/2007

Loadings and Stresses on Support Legs

Direction of Applied Force = **0 °**

Leg Orientation °	Moment of Inertia in.⁴	Lateral Force lb.	Axial Stress PSI	Bending Stresses (f_{bx}) PSI	Bending Stresses (f_{by}) PSI	Acceptance Ratio (Eqn_1)	Acceptance Ratio (Eqn_2)
0	8.0709	84	-431	0	2145	0.0982	
90	31.7448	331	-986	2448	3858	0.2732	
180	8.0709	84	-1540	0	7403	0.3417	
270	31.7448	331	-986	2448	3858	0.2732	

Direction of Worst case Force = **40 °**
Highest Stress Ratio = **0.3860**

Loadings and Stresses on Leg to Vessel attachment welds

Leg Orientation °	Load F_x lb.	Load F_y lb.	Load F_z lb.	Moment M_x in.-lb.	Moment M_y in.-lb.	Moment M_z in.-lb.	Total Stress PSI	Stress Ratio
0	84	0	-2478	0	-9132	0	812	0.0658
90	0	331	-5667	18316	-10234	598	1539	0.1246
180	-84	0	-8856	0	-11336	0	1482	0.1200
270	0	331	-5667	18316	-10234	598	1539	0.1246

Direction of Worst case Force = **1 °**
Highest Stress Ratio: **0.1595**

Repad to Shell Weld Properties

$L_w = 2\ (L_{rh} + L_{rw}) = 2 * (10.0000 + 10.0000)$ **= 40.0000** in.

$I_{wy} = \frac{L_{rw} L_{rh}^2}{2} + \frac{L_{rh}^3}{6} = \frac{10.0000 * 10.0000^2}{2} + \frac{10.0000^3}{6}$ **= 666.6667** in.³

$I_{wz} = \frac{L_{rh} L_{rw}^2}{2} + \frac{L_{rw}^3}{6} = \frac{10.0000 * 10.0000^2}{2} + \frac{10.0000^3}{6}$ **= 666.6667** in.³

$J_{wx} = I_{wy} + I_{wz} = 666.6667 + 666.6667$ **= 1333.3333** in.³

Distance from weld neutral axis to top of repad:

$EF_y = \frac{L_{rh}}{2} = \frac{10.0000}{2}$ **= 5.0000** in.

Distance from weld neutral axis to side of repad:

$EF_z = \frac{L_{rw}}{2} = \frac{10.0000}{2}$ **= 5.0000** in.

HT/DcR Engineering, Inc.

Leg 1

Job No: 1494F
Mark Number: LEG1

Vessel Number: 7793-E4401 Legs

Date Printed: 9/14/2007

Loadings and Stresses on Repad-to-Shell Attachment Welds

Leg Orientation °	Load F_x lb.	Load F_y lb.	Load F_z lb.	Moment M_x in.-lb.	Moment M_y in.-lb.	Moment M_z in.-lb.	Total Stress PSI	Stress Ratio
0	84	0	-2478	0	-10371	0	270	0.0219
90	0	331	-5667	18316	-13067	763	658	0.0533
180	-84	0	-8856	0	-15764	0	667	0.0540
270	0	331	-5667	18316	-13067	763	658	0.0533

Direction of Worst case Force = **1 °**
Highest Stress Ratio = **0.0683**

Loadings and Pressure on Concrete Foundation

Direction of applied force: = **0 °**

Leg Orientation °	Bearing Pressure PSI	Moment M_x in.-lb.	Moment M_y in.-lb.	Maximum Pressure P_x PSI	Maximum Pressure P_y PSI	Max. Concrete Pressure PSI	Concrete Pressure Ratio
0	39	6235	6235	73.07	73.07	184.85	0.1540
90	89	17874	17874	209.46	209.46	507.47	0.4229
180	138	12244	12244	143.48	143.48	425.34	0.3545
270	89	17874	17874	209.46	209.46	507.47	0.4229

Direction of Worst case Force: = **1 °**
Highest Stress Ratio = **0.5292**

Loadings and Stresses on BasePlate and Anchor bolts

Leg Orientation °	Moment M_x in.-lb.	Moment M_y in.-lb.	Maximum Pressure P_x PSI	Maximum Pressure P_y PSI	Maximum B.P. Stress PSI	BasePlate Stress Ratio	Anchor Bolt Stress PSI	Anchor Bolt Stress Ratio
0	216	203	5172	4871	7105	0.2467	976	0.0188
90	572	536	13729	12865	18815	0.6533	3222	0.0620
180	550	526	13210	12619	18268	0.6343	951	0.0183
270	572	536	13729	12865	18815	0.6533	3222	0.0620

Direction of Worst case Force: = **1 °**
Highest Stress Ratio = **0.8388**

Maximum General Longitudinal Stresses

$VE = C_{de} = 1.00 =$ **1.00**

$$S_{L1} = \frac{M_a}{Z} - \frac{W\,VE}{A} + \left(\frac{P * D}{4 * t}\right) = \frac{86871}{256.2605} - \frac{22668.57 * 1.00}{28.47} + \left(\frac{76.90 * 36.5000}{4 * 0.2500}\right) = \mathbf{2350}\ \text{PSI}$$

$$S_{L2} = -\frac{M_a}{Z} - \frac{W\,VE}{A} - \left(\frac{Pe * D}{4 * t}\right) = -\frac{86871}{256.2605} - \frac{22668.57 * 1.00}{28.47} - \left(\frac{14.70 * 36.5000}{4 * 0.2500}\right) = \mathbf{-1672}\ \text{PSI}$$

Allowable Tension Stress, S_{ta} = 1.2 S E = 1.2 * 18900 * 0.70 = **15876** PSI
Allowable Compressive Stress, S_{ca} = -1.2 B = -1.2 * 8963 = **-10756** PSI

$$R_{SL1} = \frac{S_{L1}}{S_{ta}} = \frac{2350}{15876} = \mathbf{0.1480}$$

$$R_{SL2} = \frac{S_{L2}}{S_{ca}} = \frac{-1672}{-10756} = \mathbf{0.1555}$$

Summary

Governing external force	= Wind load
Total Force	= 829 lb.
Weight	= 22668.57 lb.
Base Moment	= 148132 in.-lb.
Tangent Moment	= 86871 in.-lb.

Leg Stresses

Maximum combined compressive and bending stress ratio	= 0.3860

Leg BasePlate

Concrete Stress Ratio	= 0.5292
Base Plate Stress Ratio	= 0.8388

Host Stresses

Sl1 ratio	= 0.1480
Sl2 ratio	= 0.1555

Weld Stresses

Leg to vessel weld stress ratio	= 0.1595
Repad to shell weld stress ratio	= 0.0683

Operating Pressurized Condition - Sustained Loads

Support Leg Properties

Section Modulus, S_x $= \frac{I_x}{C_x} = \frac{31.7448}{4.2426}$ = **7.4824** in.³

Section Modulus, S_y $= \frac{I_y}{C_y} = \frac{8.0709}{2.3826}$ = **3.3874** in.³

Radius of gyration, r_x $= \sqrt{\frac{I_x}{A}} = \sqrt{\frac{31.7448}{5.7500}}$ = **2.3496** in.

Radius of gyration, r_y $= \sqrt{\frac{I_y}{A}} = \sqrt{\frac{8.0709}{5.7500}}$ = **1.1848** in.

Least radius of gyration, r_{min} $= \sqrt{\frac{I_{min}}{A}} = \sqrt{\frac{8.0709}{5.7500}}$ = **1.1848** in.

Slenderness ratio, SR_x $= \frac{K\,L}{r_x} = \frac{1.5000 * 73.8800}{2.3496}$ = **47.1655**

Slenderness ratio, SR_y $= \frac{K\,L}{r_y} = \frac{1.5000 * 73.8800}{1.1848}$ = **93.5348**

$SR_{max} = \frac{K\,L}{r_{min}} = \frac{1.5000 * 73.8800}{1.1848}$ = **93.5348**

Critical slenderness ratio, C_c $= \sqrt{\frac{2\pi^2 E}{F_y}} = \sqrt{\frac{2 * \pi^2 * (28.3 * 10^6)}{36000}}$ = **124.57**

$F'_{ex} = \frac{12\pi^2 E}{23\,SR_x^2} = \frac{12 * \pi^2 * (28.3 * 10^6)}{23 * 47.1655^2}$ = **65507** PSI

$F'_{ey} = \frac{12\pi^2 E}{23\,SR_y^2} = \frac{12 * \pi^2 * (28.3 * 10^6)}{23 * 93.5348^2}$ = **16657** PSI

For SR_{max} <= C_c, Allowable compressive stress:

$$F_a = \frac{\left(1 - \frac{SR_{max}^2}{2\,C_c^2}\right) F_y}{\frac{5}{3} + \frac{3\,SR_{max}}{8\,C_c} - \frac{SR_{max}^3}{8\,C_c^3}} = \frac{\left(1 - \frac{93.5348^2}{2 * 124.57^2}\right) * 36000}{\frac{5}{3} + \frac{3 * 93.5348}{8 * 124.57} - \frac{93.5348^3}{8 * 124.57^3}}$$ = **13640** PSI

Allowable bending stress : S_b $= 0.6\,F_y = 0.6 * 36000$ = **21600** PSI

Allowable tension stress : S_t $= 0.6\,F_y = 0.6 * 36000$ = **21600** PSI

Leg to Vessel Weld Properties

Distance between welds along side of legs (b) = = 7.7782 in.

$L_w = 2 W_S = 2 * 10.0000$ = 20.0000 in.

$I_{wy} = \frac{W_S^3}{6} = \frac{10.0000^3}{6}$ = 166.6667 in.³

$I_{wz} = \frac{W_S b^2}{2} = \frac{10.0000 * 7.7782^2}{2}$ = 302.5000 in.³

$J_{wx} = I_{wy} + I_{wz} = 166.6667 + 302.5000$ = 469.1667 in.³

Distance from weld neutral axis to top/bottom of welds:

$EF_{yt} = EF_{yb} = \frac{W_S}{2} = \frac{10.0000}{2}$ = 5.0000 in.

Distance from weld neutral axis to bottom of welds:

$EF_z = \frac{b}{2} = \frac{7.7782}{2}$ = 3.8891 in.

NO Wind Analysis Information

Wind Analysis Calculations

No Wind Load Calculations were performed

NO Seismic Design Information

Seismic Analysis Calculations

No Seismic Analysis Calculations were performed.

Loadings and Stresses on Support Legs

Direction of Applied Force = 0 °

Leg Orientation °	Moment of Inertia in.⁴	Lateral Force lb.	Axial Stress PSI	Bending Stresses (f_{bx}) PSI	Bending Stresses (f_{by}) PSI	Acceptance Ratio (Eqn_1)	Acceptance Ratio (Eqn_2)
0	8.0709	0	-986	0	3858	0.2509	
90	31.7448	0	-986	0	3858	0.2509	
180	8.0709	0	-986	0	3858	0.2509	
270	31.7448	0	-986	0	3858	0.2509	

Direction of Worst case Force = 0 °

Highest Stress Ratio = 0.2509

Loadings and Stresses on Leg to Vessel attachment welds

Leg Orientation °	Load F_x lb.	Load F_y lb.	Load F_z lb.	Moment M_x in.-lb.	Moment M_y in.-lb.	Moment M_z in.-lb.	Total Stress PSI	Stress Ratio
0	0	0	-5667	0	-10234	0	1114	0.1203
90	0	0	-5667	0	-10234	0	1114	0.1203
180	0	0	-5667	0	-10234	0	1114	0.1203
270	0	0	-5667	0	-10234	0	1114	0.1203

Direction of Worst case Force = **0 °**
Highest Stress Ratio: **0.1203**

Repad to Shell Weld Properties

$L_w = 2\ (L_{rh} + L_{rw}) = 2 * (10.0000 + 10.0000)$ **= 40.0000** in.

$I_{wy} = \frac{L_{rw} L_{rh}^2}{2} + \frac{L_{rh}^3}{6} = \frac{10.0000 * 10.0000^2}{2} + \frac{10.0000^3}{6}$ **= 666.6667** in.³

$I_{wz} = \frac{L_{rh} L_{rw}^2}{2} + \frac{L_{rw}^3}{6} = \frac{10.0000 * 10.0000^2}{2} + \frac{10.0000^3}{6}$ **= 666.6667** in.³

$J_{wx} = I_{wy} + I_{wz} = 666.6667 + 666.6667$ **= 1333.3333** in.³

Distance from weld neutral axis to top of repad:

$EF_y = \frac{L_{rh}}{2} = \frac{10.0000}{2}$ **= 5.0000** in.

Distance from weld neutral axis to side of repad:

$EF_z = \frac{L_{rw}}{2} = \frac{10.0000}{2}$ **= 5.0000** in.

Loadings and Stresses on Repad-to-Shell Attachment Welds

Leg Orientation °	Load F_x lb.	Load F_y lb.	Load F_z lb.	Moment M_x in.-lb.	Moment M_y in.-lb.	Moment M_z in.-lb.	Total Stress PSI	Stress Ratio
0	0	0	-5667	0	-13067	0	459	0.0496
90	0	0	-5667	0	-13067	0	459	0.0496
180	0	0	-5667	0	-13067	0	459	0.0496
270	0	0	-5667	0	-13067	0	459	0.0496

Direction of Worst case Force = **0 °**
Highest Stress Ratio = **0.0496**

Loadings and Pressure on Concrete Foundation

Direction of applied force: = 0 °

Leg Orientation °	Bearing Pressure PSI	Moment M_x in.-lb.	Moment M_y in.-lb.	Maximum Pressure P_x PSI	Maximum Pressure P_y PSI	Max. Concrete Pressure PSI	Concrete Pressure Ratio
0	89	9240	9240	108.28	108.28	305.11	0.3390
90	89	9240	9240	108.28	108.28	305.11	0.3390
180	89	9240	9240	108.28	108.28	305.11	0.3390
270	89	9240	9240	108.28	108.28	305.11	0.3390

Direction of Worst case Force: = 0 °
Highest Stress Ratio = 0.3390

Loadings and Stresses on BasePlate and Anchor bolts

Leg Orientation °	Moment M_x in.-lb.	Moment M_y in.-lb.	Maximum Pressure P_x PSI	Maximum Pressure P_y PSI	Maximum B.P. Stress PSI	BasePlate Stress Ratio	Anchor Bolt Stress PSI	Anchor Bolt Stress Ratio
0	383	364	9191	8745	12687	0.5874	936	0.0240
90	383	364	9191	8745	12687	0.5874	936	0.0240
180	383	364	9191	8745	12687	0.5874	936	0.0240
270	383	364	9191	8745	12687	0.5874	936	0.0240

Direction of Worst case Force: = 0 °
Highest Stress Ratio = 0.5874

Maximum General Longitudinal Stresses

VE = 1.00   1.00

$$S_{L1} = \frac{M_a}{Z} - \frac{W\,VE}{A} + \left(\frac{P * D}{4 * t}\right) = \frac{0}{256.2605} - \frac{22668.57 * 1.00}{28.47} + \left(\frac{76.90 * 36.5000}{4 * 0.2500}\right) = 2011 \text{ PSI}$$

$$S_{L2} = -\frac{M_a}{Z} - \frac{W\,VE}{A} - \left(\frac{Pe * D}{4 * t}\right) = -\frac{0}{256.2605} - \frac{22668.57 * 1.00}{28.47} - \left(\frac{14.70 * 36.5000}{4 * 0.2500}\right) = -1333 \text{ PSI}$$

Allowable Tension Stress, S_{ta} = S E = 18900 * 0.70 = 13230 PSI
Allowable Compressive Stress, S_{ca} = -B = -8963 = -8963 PSI

$$R_{SL1} = \frac{S_{L1}}{S_{ta}} = \frac{2011}{13230} = 0.1520$$

$$R_{SL2} = \frac{S_{L2}}{S_{ca}} = \frac{-1333}{-8963} = 0.1487$$

HT/DcR Engineering, Inc.
Leg 1

Job No: 1494F
Mark Number: LEG1

Vessel Number: 7793-E4401 Legs

Date Printed: 9/14/2007

Summary

Governing external force	= None
Total Force	= 0 lb.
Weight	= 22668.57 lb.
Base Moment	= 0 in.-lb.
Tangent Moment	= 0 in.-lb.

Leg Stresses

Maximum combined compressive and bending stress ratio	= 0.2509

Leg BasePlate

Concrete Stress Ratio	= 0.3390
Base Plate Stress Ratio	= 0.5874

Host Stresses

SI1 ratio	= 0.1520
SI2 ratio	= 0.1487

Weld Stresses

Leg to vessel weld stress ratio	= 0.1203
Repad to shell weld stress ratio	= 0.0496

Empty Pressurized Conditions - Ocassional Loads - Seismic Case 8

Support Leg Properties

Section Modulus, $S_x = \frac{I_x}{C_x} = \frac{31.7448}{4.2426}$ **= 7.4824** in.³

Section Modulus, $S_y = \frac{I_y}{C_y} = \frac{8.0709}{2.3826}$ **= 3.3874** in.³

Radius of gyration, $r_x = \sqrt{\frac{I_x}{A}} = \sqrt{\frac{31.7448}{5.7500}}$ **= 2.3496** in.

Radius of gyration, $r_y = \sqrt{\frac{I_y}{A}} = \sqrt{\frac{8.0709}{5.7500}}$ **= 1.1848** in.

Least radius of gyration, $r_{min} = \sqrt{\frac{I_{min}}{A}} = \sqrt{\frac{8.0709}{5.7500}}$ **= 1.1848** in.

Slenderness ratio, $SR_x = \frac{K\,L}{r_x} = \frac{1.5000 * 73.8800}{2.3496}$ **= 47.1655**

Slenderness ratio, $SR_y = \frac{K\,L}{r_y} = \frac{1.5000 * 73.8800}{1.1848}$ **= 93.5348**

$SR_{max} = \frac{K\,L}{r_{min}} = \frac{1.5000 * 73.8800}{1.1848}$ **= 93.5348**

Critical slenderness ratio, $C_c = \sqrt{\frac{2\pi^2 E}{F_y}} = \sqrt{\frac{2 * \pi^2 * (28.3 * 10^6)}{36000}}$ **= 124.57**

$F'_{ex} = \frac{4}{3}\,\frac{12\pi^2 E}{23\,SR_x^2} = \frac{4}{3} * \frac{12 * \pi^2 * (28.3 * 10^6)}{23 * 47.1655^2}$ **= 87343** PSI

$F'_{ey} = \frac{4}{3}\,\frac{12\pi^2 E}{23\,SR_y^2} = \frac{4}{3} * \frac{12 * \pi^2 * (28.3 * 10^6)}{23 * 93.5348^2}$ **= 22209** PSI

For $SR_{max} <= C_c$, Allowable compressive stress:

$$F_a = \frac{4}{3}\,\frac{\left(1 - \frac{SR_{max}^2}{2\,C_c^2}\right) F_y}{\frac{5}{3} + \frac{3\,SR_{max}}{8\,C_c} - \frac{SR_{max}^3}{8\,C_c^3}} = \frac{4}{3} * \frac{\left(1 - \frac{93.5348^2}{2 * 124.57^2}\right) * 36000}{\frac{5}{3} + \frac{3 * 93.5348}{8 * 124.57} - \frac{93.5348^3}{8 * 124.57^3}}$$ **= 18187** PSI

Allowable bending stress : $S_b = \frac{4}{3}\,0.6\,F_y = \frac{4}{3} * 0.6 * 36000$ **= 28800** PSI

Allowable tension stress : $S_t = \frac{4}{3}\,0.6\,F_y = \frac{4}{3} * 0.6 * 36000$ **= 28800** PSI

Leg to Vessel Weld Properties

Distance between welds along side of legs (b) = **= 7.7782** in.

$L_W = 2\,W_S = 2 * 10.0000$ **= 20.0000** in.

$I_{wy} = \frac{W_S^3}{6} = \frac{10.0000^3}{6}$ **= 166.6667** in.³

$I_{wz} = \frac{W_S\,b^2}{2} = \frac{10.0000 * 7.7782^2}{2}$ **= 302.5000** in.³

$J_{wx} = I_{wy} + I_{wz} = 166.6667 + 302.5000$ **= 469.1667** in.³

Distance from weld neutral axis to top/bottom of welds:

$EF_{yt} = EF_{yb} = \frac{W_S}{2} = \frac{10.0000}{2}$ **= 5.0000** in.

Distance from weld neutral axis to bottom of welds:

$EF_Z = \frac{b}{2} = \frac{7.7782}{2}$ **= 3.8891** in.

NO Wind Analysis Information

Wind Analysis Calculations

No Wind Load Calculations were performed

IBC 2003 Seismic Design Information

Spectral Resp. Accel. at short periods (S_S):	0.200		
Spectral Resp. Accel. at a period of 1 s (S_1):	0.100	Response Modification Factor (R):	3.000
Seismic Use Group:	I	Site Class:	D
Seismic Design Category:	C		

Seismic Analysis Calculations

Seismic Center of Gravity: **= 179.4448** in.

$C_S = \frac{SD_S\,I}{R} = \frac{0.2133 * 1.00}{3.000}$ **= 0.0711**

$V = W * C_S = 14283.61 * 0.03$ **= 1015.72** lb.

$F_S = V\,C_{eh} = 1015.72 * 0.70$ **= 711** lb.

Loadings and Stresses on Support Legs

Direction of Applied Force = **0 °**

Leg Orientation °	Moment of Inertia $in.^4$	Lateral Force lb.	Axial Stress PSI	Bending Stresses (f_{bx}) PSI	Bending Stresses (f_{by}) PSI	Acceptance Ratio (Eqn_1)	Acceptance Ratio (Eqn_2)
0	8.0709	72	124	0	1663	0.0635	
90	31.7448	283	-354	2099	1386	0.1405	
180	8.0709	72	-832	0	4435	0.1997	
270	31.7448	283	-354	2099	1386	0.1405	

Direction of Worst case Force = **41 °**
Highest Stress Ratio = **0.2376**

Loadings and Stresses on Leg to Vessel attachment welds

Leg Orientation °	Load F_x lb.	Load F_y lb.	Load F_z lb.	Moment M_x in.-lb.	Moment M_y in.-lb.	Moment M_z in.-lb.	Total Stress PSI	Stress Ratio
0	72	0	712	0	-2707	0	245	0.0198
90	0	283	-2036	15705	-3677	511	845	0.0684
180	-72	0	-4784	0	-4646	0	733	0.0594
270	0	283	-2036	15705	-3677	511	845	0.0684

Direction of Worst case Force = **1 °**
Highest Stress Ratio: **0.0956**

Repad to Shell Weld Properties

$L_w = 2\ (L_{rh} + L_{rw}) = 2 * (10.0000 + 10.0000)$ **= 40.0000** in.

$I_{wy} = \frac{L_{rw}\, L_{rh}^2}{2} + \frac{L_{rh}^3}{6} = \frac{10.0000 * 10.0000^2}{2} + \frac{10.0000^3}{6}$ **= 666.6667** $in.^3$

$I_{wz} = \frac{L_{rh}\, L_{rw}^2}{2} + \frac{L_{rw}^3}{6} = \frac{10.0000 * 10.0000^2}{2} + \frac{10.0000^3}{6}$ **= 666.6667** $in.^3$

$J_{wx} = I_{wy} + I_{wz} = 666.6667 + 666.6667$ **= 1333.3333** $in.^3$

Distance from weld neutral axis to top of repad:

$EF_y = \frac{L_{rh}}{2} = \frac{10.0000}{2}$ **= 5.0000** in.

Distance from weld neutral axis to side of repad:

$EF_z = \frac{L_{rw}}{2} = \frac{10.0000}{2}$ **= 5.0000** in.

Loadings and Stresses on Repad-to-Shell Attachment Welds

Leg Orientation °	Load F_x lb.	Load F_y lb.	Load F_z lb.	Moment M_x in.-lb.	Moment M_y in.-lb.	Moment M_z in.-lb.	Total Stress PSI	Stress Ratio
0	72	0	712	0	-2351	0	70	0.0057
90	0	283	-2036	15705	-4695	653	358	0.0290
180	-72	0	-4784	0	-7038	0	347	0.0281
270	0	283	-2036	15705	-4695	653	358	0.0290

Direction of Worst case Force = 1 °
Highest Stress Ratio = 0.0411

Loadings and Pressure on Concrete Foundation

Direction of applied force: = 0 °

Leg Orientation °	Bearing Pressure PSI	Moment M_x in.-lb.	Moment M_y in.-lb.	Maximum Pressure P_x PSI	Maximum Pressure P_y PSI	Max. Concrete Pressure PSI	Concrete Pressure Ratio
0	-11	721	721	8.45	8.45	5.77	0.0048
90	32	10723	10723	125.66	125.66	283.13	0.2359
180	75	5918	5918	69.35	69.35	213.45	0.1779
270	32	10723	10723	125.66	125.66	283.13	0.2359

Direction of Worst case Force: = 1 °
Highest Stress Ratio = 0.3275

Loadings and Stresses on BasePlate and Anchor bolts

Leg Orientation °	Moment M_x in.-lb.	Moment M_y in.-lb.	Maximum Pressure P_x PSI	Maximum Pressure P_y PSI	Maximum B.P. Stress PSI	BasePlate Stress Ratio	Anchor Bolt Stress PSI	Anchor Bolt Stress Ratio
0	0	0	0	0	0	0.0000	575	0.0111
90	300	278	7193	6675	9813	0.3407	2371	0.0456
180	282	270	6770	6484	9374	0.3255	365	0.0070
270	300	278	7193	6675	9813	0.3407	2371	0.0456

Direction of Worst case Force: = 1 °
Highest Stress Ratio = 0.5006

Maximum General Longitudinal Stresses

$VE = (C_{de} + 0.2 * SDS * I * C_{ev}) = (0.60 + 0.2 * 0.21 * 1.00 * -0.70) =$ 0.57

$$S_{L1} = \frac{M_a}{Z} - \frac{W\,VE}{A} + \left(\frac{P * D}{4 * t}\right) = \frac{75057}{256.2605} - \frac{14283.61 * 0.57}{28.47} + \left(\frac{75.00 * 36.5000}{4 * 0.2500}\right)$$ **= 2744** PSI

$$S_{L2} = -\frac{M_a}{Z} - \frac{W\,VE}{A} - \left(\frac{Pe * D}{4 * t}\right) = -\frac{75057}{256.2605} - \frac{14283.61 * 0.57}{28.47} - \left(\frac{14.70 * 36.5000}{4 * 0.2500}\right)$$ **= -1115** PSI

Allowable Tension Stress, S_{ta} = 1.2 S E = 1.2 * 18900 * 0.70 **= 15876** PSI
Allowable Compressive Stress, S_{ca} = -1.2 B = -1.2 * 8963 **= -10756** PSI

$$R_{SL1} = \frac{S_{L1}}{S_{ta}} = \frac{2744}{15876}$$ **= 0.1728**

$$R_{SL2} = \frac{S_{L2}}{S_{ca}} = \frac{-1115}{-10756}$$ **= 0.1037**

Summary

Governing external force	**= Seismic load**
Total Force	**= 711** lb.
Weight	**= 14283.61** lb.
Base Moment	**= 127586** in.-lb.
Tangent Moment	**= 75057** in.-lb.

Leg Stresses

Maximum combined compressive and bending stress ratio	**= 0.2376**

Leg BasePlate

Concrete Stress Ratio	**= 0.3275**
Base Plate Stress Ratio	**= 0.5006**

Host Stresses

SI1 ratio	**= 0.1728**
SI2 ratio	**= 0.1037**

Weld Stresses

Leg to vessel weld stress ratio	**= 0.0956**
Repad to shell weld stress ratio	**= 0.0411**

Empty Pressurized Conditions - Ocassional Loads - Wind Case 7

Support Leg Properties

Section Modulus, S_x $= \frac{I_x}{C_x} = \frac{31.7448}{4.2426}$ **= 7.4824 in.³**

Section Modulus, S_y $= \frac{I_y}{C_y} = \frac{8.0709}{2.3826}$ **= 3.3874 in.³**

Radius of gyration, r_x $= \sqrt{\frac{I_x}{A}} = \sqrt{\frac{31.7448}{5.7500}}$ **= 2.3496 in.**

Radius of gyration, r_y $= \sqrt{\frac{I_y}{A}} = \sqrt{\frac{8.0709}{5.7500}}$ **= 1.1848 in.**

Least radius of gyration, r_{min} $= \sqrt{\frac{I_{min}}{A}} = \sqrt{\frac{8.0709}{5.7500}}$ **= 1.1848 in.**

Slenderness ratio, SR_x $= \frac{K\,L}{r_x} = \frac{1.5000 * 73.8800}{2.3496}$ **= 47.1655**

Slenderness ratio, SR_y $= \frac{K\,L}{r_y} = \frac{1.5000 * 73.8800}{1.1848}$ **= 93.5348**

$SR_{max} = \frac{K\,L}{r_{min}} = \frac{1.5000 * 73.8800}{1.1848}$ **= 93.5348**

Critical slenderness ratio, C_c $= \sqrt{\frac{2\pi^2 E}{F_y}} = \sqrt{\frac{2 * \pi^2 * (28.3 * 10^6)}{36000}}$ **= 124.57**

$F'_{ex} = \frac{4}{3}\,\frac{12\pi^2 E}{23\,SR_x^2} = \frac{4}{3} * \frac{12 * \pi^2 * (28.3 * 10^6)}{23 * 47.1655^2}$ **= 87343 PSI**

$F'_{ey} = \frac{4}{3}\,\frac{12\pi^2 E}{23\,SR_y^2} = \frac{4}{3} * \frac{12 * \pi^2 * (28.3 * 10^6)}{23 * 93.5348^2}$ **= 22209 PSI**

For SR_{max} <= C_c, Allowable compressive stress:

$$F_a = \frac{4}{3}\,\frac{\left(1 - \frac{SR_{max}^2}{2\,C_c^2}\right) F_y}{\frac{5}{3} + \frac{3\,SR_{max}}{8\,C_c} - \frac{SR_{max}^3}{8\,C_c^3}} = \frac{4}{3} * \frac{\left(1 - \frac{93.5348^2}{2 * 124.57^2}\right) * 36000}{\frac{5}{3} + \frac{3 * 93.5348}{8 * 124.57} - \frac{93.5348^3}{8 * 124.57^3}}$$ **= 18187 PSI**

Allowable bending stress : S_b $= \frac{4}{3}\,0.6\,F_y = \frac{4}{3} * 0.6 * 36000$ **= 28800 PSI**

Allowable tension stress : S_t $= \frac{4}{3}\,0.6\,F_y = \frac{4}{3} * 0.6 * 36000$ **= 28800 PSI**

Leg to Vessel Weld Properties

Distance between welds along side of legs (b) = **= 7.7782** in.

$L_w = 2 W_s = 2 * 10.0000$ **= 20.0000** in.

$I_{wy} = \frac{W_s^3}{6} = \frac{10.0000^3}{6}$ **= 166.6667** in.³

$I_{wz} = \frac{W_s b^2}{2} = \frac{10.0000 * 7.7782^2}{2}$ **= 302.5000** in.³

$J_{wx} = I_{wy} + I_{wz} = 166.6667 + 302.5000$ **= 469.1667** in.³

Distance from weld neutral axis to top/bottom of welds:

$EF_{yt} = EF_{yb} = \frac{W_s}{2} = \frac{10.0000}{2}$ **= 5.0000** in.

Distance from weld neutral axis to bottom of welds:

$EF_z = \frac{b}{2} = \frac{7.7782}{2}$ **= 3.8891** in.

IBC 2003 Wind Analysis Information

Basic Wind Speed (V):	90	MPH	Wind Exposure type:	C
Importance factor (I):	1.0000		Force (shape) coefficient (C_f):	0.70
Topographic Factor (K_{zt}):	1.00		Directionality Factor (K_d):	1.00

Wind Analysis Calculations

Wind Center of Gravity **= 178.6462** in.

$q_z = 0.00256 K_z K_{zt} K_d V^2 I = 0.00256 * 0.85 * 1.000 * 1.00 * 90^2 * 1.0000$ **= 17.626**

$P = q_z G C_f = 17.626 * 0.90 * 0.70$ **= 11.10** lb./ft²

Wind Load, F_w $= P A C_{wi} = 11.10 * 74.7016 * 1.00$ **= 829** lb.

NO Seismic Design Information

Seismic Analysis Calculations

No Seismic Analysis Calculations were performed.

Loadings and Stresses on Support Legs

Direction of Applied Force = **0 °**

Leg Orientation °	Moment of Inertia in.⁴	Lateral Force lb.	Axial Stress PSI	Bending Stresses (f_{bx}) PSI	Bending Stresses (f_{by}) PSI	Acceptance Ratio (Eqn_1)	Acceptance Ratio (Eqn_2)
0	8.0709	84	182	0	2087	0.0809	
90	31.7448	331	-373	2448	1459	0.1562	
180	8.0709	84	-927	0	5004	0.2247	
270	31.7448	331	-373	2448	1459	0.1562	

Direction of Worst case Force = **40 °**
Highest Stress Ratio = **0.2690**

Loadings and Stresses on Leg to Vessel attachment welds

Leg Orientation °	Load F_x lb.	Load F_y lb.	Load F_z lb.	Moment M_x in.-lb.	Moment M_y in.-lb.	Moment M_z in.-lb.	Total Stress PSI	Stress Ratio
0	84	0	1047	0	-2766	0	271	0.0219
90	0	331	-2143	18316	-3870	598	951	0.0770
180	-84	0	-5332	0	-4972	0	809	0.0655
270	0	331	-2143	18316	-3870	598	951	0.0770

Direction of Worst case Force = **1 °**
Highest Stress Ratio: **0.1080**

Repad to Shell Weld Properties

$L_w = 2\ (L_{rh} + L_{rw}) = 2 * (10.0000 + 10.0000)$ **= 40.0000** in.

$I_{wy} = \frac{L_{rw} L_{rh}^2}{2} + \frac{L_{rh}^3}{6} = \frac{10.0000 * 10.0000^2}{2} + \frac{10.0000^3}{6}$ **= 666.6667** in.³

$I_{wz} = \frac{L_{rh} L_{rw}^2}{2} + \frac{L_{rw}^3}{6} = \frac{10.0000 * 10.0000^2}{2} + \frac{10.0000^3}{6}$ **= 666.6667** in.³

$J_{wx} = I_{wy} + I_{wz} = 666.6667 + 666.6667$ **= 1333.3333** in.³

Distance from weld neutral axis to top of repad:

$EF_y = \frac{L_{rh}}{2} = \frac{10.0000}{2}$ **= 5.0000** in.

Distance from weld neutral axis to side of repad:

$EF_z = \frac{L_{rw}}{2} = \frac{10.0000}{2}$ **= 5.0000** in.

HT/DcR Engineering, Inc.

Leg 1

Job No: 1494F
Mark Number: LEG1

Vessel Number: 7793-E4401 Legs

Date Printed: 9/14/2007

Loadings and Stresses on Repad-to-Shell Attachment Welds

Leg Orientation °	Load F_x lb.	Load F_y lb.	Load F_z lb.	Moment M_x in.-lb.	Moment M_y in.-lb.	Moment M_z in.-lb.	Total Stress PSI	Stress Ratio
0	84	0	1047	0	-2243	0	86	0.0070
90	0	331	-2143	18316	-4941	763	402	0.0326
180	-84	0	-5332	0	-7638	0	385	0.0312
270	0	331	-2143	18316	-4941	763	402	0.0326

Direction of Worst case Force = **1 °**
Highest Stress Ratio = **0.0464**

Loadings and Pressure on Concrete Foundation

Direction of applied force: = **0 °**

Leg Orientation °	Bearing Pressure PSI	Moment M_x in.-lb.	Moment M_y in.-lb.	Maximum Pressure P_x PSI	Maximum Pressure P_y PSI	Max. Concrete Pressure PSI	Concrete Pressure Ratio
0	-16	488	488	5.72	5.72	0.00	0.0000
90	33	12128	12128	142.13	142.13	317.73	0.2648
180	83	6498	6498	76.15	76.15	235.61	0.1963
270	33	12128	12128	142.13	142.13	317.73	0.2648

Direction of Worst case Force: = **1 °**
Highest Stress Ratio = **0.3710**

Loadings and Stresses on BasePlate and Anchor bolts

Leg Orientation °	Moment M_x in.-lb.	Moment M_y in.-lb.	Maximum Pressure P_x PSI	Maximum Pressure P_y PSI	Maximum B.P. Stress PSI	BasePlate Stress Ratio	Anchor Bolt Stress PSI	Anchor Bolt Stress Ratio
0	0	0	0	0	0	0.0000	566	0.0109
90	334	309	8013	7427	10926	0.3794	2735	0.0526
180	312	299	7494	7180	10379	0.3604	386	0.0074
270	334	309	8013	7427	10926	0.3794	2735	0.0526

Direction of Worst case Force: = **1 °**
Highest Stress Ratio = **0.5648**

Maximum General Longitudinal Stresses

$VE = C_{de} = 0.60 =$ **0.60**

$$S_{L1} = \frac{M_a}{Z} - \frac{W\,VE}{A} + \left(\frac{P * D}{4 * t}\right) = \frac{86871}{256.2605} - \frac{14283.61 * 0.60}{28.47} + \left(\frac{75.00 * 36.5000}{4 * 0.2500}\right) = \mathbf{2775}\ \text{PSI}$$

$$S_{L2} = -\frac{M_a}{Z} - \frac{W\,VE}{A} - \left(\frac{Pe * D}{4 * t}\right) = -\frac{86871}{256.2605} - \frac{14283.61 * 0.60}{28.47} - \left(\frac{14.70 * 36.5000}{4 * 0.2500}\right) = \mathbf{-1177}\ \text{PSI}$$

Allowable Tension Stress, S_{ta} = 1.2 S E = 1.2 * 18900 * 0.70 **= 15876** PSI
Allowable Compressive Stress, S_{ca} = -1.2 B = -1.2 * 8963 **= -10756** PSI

$$R_{SL1} = \frac{S_{L1}}{S_{ta}} = \frac{2775}{15876} = \mathbf{0.1748}$$

$$R_{SL2} = \frac{S_{L2}}{S_{ca}} = \frac{-1177}{-10756} = \mathbf{0.1094}$$

Summary

Governing external force	**= Wind load**
Total Force	**= 829** lb.
Weight	**= 14283.61** lb.
Base Moment	**= 148132** in.-lb.
Tangent Moment	**= 86871** in.-lb.

Leg Stresses

Maximum combined compressive and bending stress ratio	**= 0.2690**

Leg BasePlate

Concrete Stress Ratio	**= 0.3710**
Base Plate Stress Ratio	**= 0.5648**

Host Stresses

SI1 ratio	**= 0.1748**
SI2 ratio	**= 0.1094**

Weld Stresses

Leg to vessel weld stress ratio	**= 0.1080**
Repad to shell weld stress ratio	**= 0.0464**

Empty Pressurized Condition - Sustained Loads

Support Leg Properties

Section Modulus, $S_x = \frac{I_x}{C_x} = \frac{31.7448}{4.2426}$ **= 7.4824 in.³**

Section Modulus, $S_y = \frac{I_y}{C_y} = \frac{8.0709}{2.3826}$ **= 3.3874 in.³**

Radius of gyration, $r_x = \sqrt{\frac{I_x}{A}} = \sqrt{\frac{31.7448}{5.7500}}$ **= 2.3496 in.**

Radius of gyration, $r_y = \sqrt{\frac{I_y}{A}} = \sqrt{\frac{8.0709}{5.7500}}$ **= 1.1848 in.**

Least radius of gyration, $r_{min} = \sqrt{\frac{I_{min}}{A}} = \sqrt{\frac{8.0709}{5.7500}}$ **= 1.1848 in.**

Slenderness ratio, $SR_x = \frac{K\,L}{r_x} = \frac{1.5000 * 73.8800}{2.3496}$ **= 47.1655**

Slenderness ratio, $SR_y = \frac{K\,L}{r_y} = \frac{1.5000 * 73.8800}{1.1848}$ **= 93.5348**

$SR_{max} = \frac{K\,L}{r_{min}} = \frac{1.5000 * 73.8800}{1.1848}$ **= 93.5348**

Critical slenderness ratio, $C_c = \sqrt{\frac{2\pi^2 E}{F_y}} = \sqrt{\frac{2 * \pi^2 * (28.3 * 10^6)}{36000}}$ **= 124.57**

$F'_{ex} = \frac{12\pi^2 E}{23\,SR_x^2} = \frac{12 * \pi^2 * (28.3 * 10^6)}{23 * 47.1655^2}$ **= 65507 PSI**

$F'_{ey} = \frac{12\pi^2 E}{23\,SR_y^2} = \frac{12 * \pi^2 * (28.3 * 10^6)}{23 * 93.5348^2}$ **= 16657 PSI**

For $SR_{max} <= C_c$, Allowable compressive stress:

$$F_a = \frac{\left(1 - \frac{SR_{max}^2}{2\,C_c^2}\right) F_y}{\frac{5}{3} + \frac{3\,SR_{max}}{8\,C_c} - \frac{SR_{max}^3}{8\,C_c^3}} = \frac{\left(1 - \frac{93.5348^2}{2 * 124.57^2}\right) * 36000}{\frac{5}{3} + \frac{3 * 93.5348}{8 * 124.57} - \frac{93.5348^3}{8 * 124.57^3}}$$ **= 13640 PSI**

Allowable bending stress : $S_b = 0.6\,F_y = 0.6 * 36000$ **= 21600 PSI**
Allowable tension stress : $S_t = 0.6\,F_y = 0.6 * 36000$ **= 21600 PSI**

Leg to Vessel Weld Properties

Distance between welds along side of legs (b) = **= 7.7782** in.

$L_W = 2\,W_S = 2 * 10.0000$ **= 20.0000** in.

$I_{wy} = \frac{W_S^3}{6} = \frac{10.0000^3}{6}$ **= 166.6667** in.³

$I_{wz} = \frac{W_S\,b^2}{2} = \frac{10.0000 * 7.7782^2}{2}$ **= 302.5000** in.³

$J_{wx} = I_{wy} + I_{wz} = 166.6667 + 302.5000$ **= 469.1667** in.³

Distance from weld neutral axis to top/bottom of welds:

$EF_{yt} = EF_{yb} = \frac{W_S}{2} = \frac{10.0000}{2}$ **= 5.0000** in.

Distance from weld neutral axis to bottom of welds:

$EF_Z = \frac{b}{2} = \frac{7.7782}{2}$ **= 3.8891** in.

NO Wind Analysis Information

Wind Analysis Calculations

No Wind Load Calculations were performed

NO Seismic Design Information

Seismic Analysis Calculations

No Seismic Analysis Calculations were performed.

Loadings and Stresses on Support Legs

Direction of Applied Force = **0 °**

Leg Orientation °	Moment of Inertia in.⁴	Lateral Force lb.	Axial Stress PSI	Bending Stresses (f_{bx}) PSI	Bending Stresses (f_{by}) PSI	Acceptance Ratio (Eqn_1)	Acceptance Ratio (Eqn_2)
0	8.0709	0	-621	0	2431	0.1581	
90	31.7448	0	-621	0	2431	0.1581	
180	8.0709	0	-621	0	2431	0.1581	
270	31.7448	0	-621	0	2431	0.1581	

Direction of Worst case Force = **0 °**
Highest Stress Ratio = **0.1581**

Loadings and Stresses on Leg to Vessel attachment welds

Leg Orientation °	Load F_x lb.	Load F_y lb.	Load F_z lb.	Moment M_x in.-lb.	Moment M_y in.-lb.	Moment M_z in.-lb.	Total Stress PSI	Stress Ratio
0	0	0	-3571	0	-6449	0	702	0.0758
90	0	0	-3571	0	-6449	0	702	0.0758
180	0	0	-3571	0	-6449	0	702	0.0758
270	0	0	-3571	0	-6449	0	702	0.0758

Direction of Worst case Force = **0 °**
Highest Stress Ratio: **0.0758**

Repad to Shell Weld Properties

$L_w = 2\ (L_{rh} + L_{rw}) = 2 * (10.0000 + 10.0000)$ **= 40.0000** in.

$I_{wy} = \frac{L_{rw}\, L_{rh}^2}{2} + \frac{L_{rh}^3}{6} = \frac{10.0000 * 10.0000^2}{2} + \frac{10.0000^3}{6}$ **= 666.6667** in.³

$I_{wz} = \frac{L_{rh}\, L_{rw}^2}{2} + \frac{L_{rw}^3}{6} = \frac{10.0000 * 10.0000^2}{2} + \frac{10.0000^3}{6}$ **= 666.6667** in.³

$J_{wx} = I_{wy} + I_{wz} = 666.6667 + 666.6667$ **= 1333.3333** in.³

Distance from weld neutral axis to top of repad:

$EF_y = \frac{L_{rh}}{2} = \frac{10.0000}{2}$ **= 5.0000** in.

Distance from weld neutral axis to side of repad:

$EF_z = \frac{L_{rw}}{2} = \frac{10.0000}{2}$ **= 5.0000** in.

Loadings and Stresses on Repad-to-Shell Attachment Welds

Leg Orientation °	Load F_x lb.	Load F_y lb.	Load F_z lb.	Moment M_x in.-lb.	Moment M_y in.-lb.	Moment M_z in.-lb.	Total Stress PSI	Stress Ratio
0	0	0	-3571	0	-8234	0	289	0.0312
90	0	0	-3571	0	-8234	0	289	0.0312
180	0	0	-3571	0	-8234	0	289	0.0312
270	0	0	-3571	0	-8234	0	289	0.0312

Direction of Worst case Force = **0 °**
Highest Stress Ratio = **0.0312**

Loadings and Pressure on Concrete Foundation

Direction of applied force: = **0 °**

Leg Orientation °	Bearing Pressure PSI	Moment M_x in.-lb.	Moment M_y in.-lb.	Maximum Pressure P_x PSI	Maximum Pressure P_y PSI	Max. Concrete Pressure PSI	Concrete Pressure Ratio
0	56	5822	5822	68.23	68.23	192.25	0.2136
90	56	5822	5822	68.23	68.23	192.25	0.2136
180	56	5822	5822	68.23	68.23	192.25	0.2136
270	56	5822	5822	68.23	68.23	192.25	0.2136

Direction of Worst case Force: = **0 °**
Highest Stress Ratio = **0.2136**

Loadings and Stresses on BasePlate and Anchor bolts

Leg Orientation °	Moment M_x in.-lb.	Moment M_y in.-lb.	Maximum Pressure P_x PSI	Maximum Pressure P_y PSI	Maximum B.P. Stress PSI	BasePlate Stress Ratio	Anchor Bolt Stress PSI	Anchor Bolt Stress Ratio
0	241	230	5792	5510	7994	0.3701	589	0.0151
90	241	230	5792	5510	7994	0.3701	589	0.0151
180	241	230	5792	5510	7994	0.3701	589	0.0151
270	241	230	5792	5510	7994	0.3701	589	0.0151

Direction of Worst case Force: = **0 °**
Highest Stress Ratio = **0.3701**

Maximum General Longitudinal Stresses

VE = 1.00 **1.00**

$$S_{L1} = \frac{M_a}{Z} - \frac{W\,VE}{A} + \left(\frac{P * D}{4 * t}\right) = \frac{0}{256.2605} - \frac{14283.61 * 1.00}{28.47} + \left(\frac{75.00 * 36.5000}{4 * 0.2500}\right) = \mathbf{2236}\ \text{PSI}$$

$$S_{L2} = -\frac{M_a}{Z} - \frac{W\,VE}{A} - \left(\frac{Pe * D}{4 * t}\right) = -\frac{0}{256.2605} - \frac{14283.61 * 1.00}{28.47} - \left(\frac{14.70 * 36.5000}{4 * 0.2500}\right) = \mathbf{-1038}\ \text{PSI}$$

Allowable Tension Stress, S_{ta} = S E = 18900 * 0.70 **= 13230** PSI
Allowable Compressive Stress, S_{ca} = -B = -8963 **= -8963** PSI

$$R_{SL1} = \frac{S_{L1}}{S_{ta}} = \frac{2236}{13230} = \mathbf{0.1690}$$

$$R_{SL2} = \frac{S_{L2}}{S_{ca}} = \frac{-1038}{-8963} = \mathbf{0.1158}$$

Summary

Governing external force	**= None**
Total Force	**= 0 lb.**
Weight	**= 14283.61 lb.**
Base Moment	**= 0 in.-lb.**
Tangent Moment	**= 0 in.-lb.**

Leg Stresses

Maximum combined compressive and bending stress ratio	**= 0.1581**

Leg BasePlate

Concrete Stress Ratio	**= 0.2136**
Base Plate Stress Ratio	**= 0.3701**

Host Stresses

SI1 ratio	**= 0.1690**
SI2 ratio	**= 0.1158**

Weld Stresses

Leg to vessel weld stress ratio	**= 0.0758**
Repad to shell weld stress ratio	**= 0.0312**

HT/DcR Engineering, Inc.

Customer: **Delta-T**
Job No: 1494F

Vessel Number: 7793-E4401 Legs

Date Printed: 9/14/2007

Loading Summary						
Type	**Starting Elevation (in.)**	**Ending Elevation (in.)**	**Density (lb./Ft^3)**	**Thickness (in.)**	**Wind Diameter (in.)**	**Wind Pressure (lb./ft.^{2})**
Liquid	32.0000	280.0000	62.4000	-	-	-
Insulation	0.0000	0.0000	-	-	-	-
Wind	32.0000	290.0000	-	-	42.0000	-

Attachment Summary					
Attachment No.	**Elevation (in.)**	**Description**	**Attachment Weight (lb.)**	**Horizontal Force (lb.)**	**Attachment Moment (in.-lb.)**
1	180.0000	BUNDLE PLUS	12000.00	0	0

Summary Information

	Dry Weight	Flooded Weight
Shell	1981.56 lb.	10817.27 lb.
Head	302.05 lb.	890.11 lb.
Totals	2283.61 lb.	11707.38 lb.

	Volume
Shell	1057.65 Gal.
Head	70.51 Gal.
Totals	1128.16 Gal.

	Area
Shell	191.11 Sq. Ft.
Head	23.13 Sq. Ft.
Totals	214.24 Sq. Ft.

Hydrostatic Test Information (UG-99)

Gauge at Top

Component with controlling ratio is : Shell 1
Component with controlling pressure is : Shell 1

Calculated Test Pressure $= P * 1.3 * \frac{\text{Cold Stress}}{\text{Hot Stress}} = 75.00 * 1.3 * \frac{20000}{18900} =$ **103.17 PSI**

Table of Contents