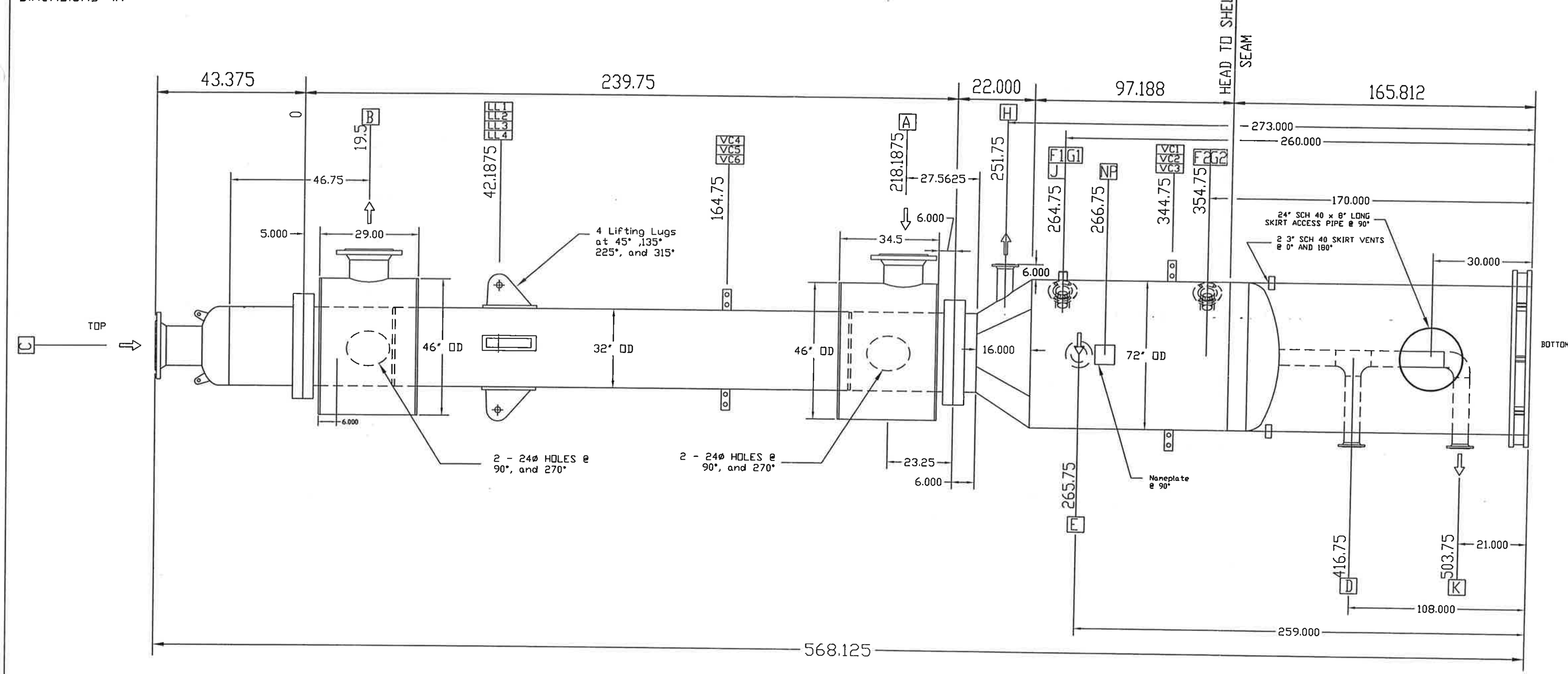
Dimensions: in



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Nozzles		(1)
Label	Size: Description	Proj. fm Ves. ℄
A	24" 150 # ANSI S.O.RF	29
B	20" 150 # ANSI S.O.RF	29
C	18" 150 # ANSI S.O.RF	6
D	6" 150 # ANSI S.O.RF	6
E	6" 150 # ANSI S.O.RF	42
F1	3" 150 # ANSI S.O.RF	42
F2	3" 150 # ANSI S.O.RF	42
H	2" 150 # ANSI S.O.RF	6
K	6" 150 # ANSI S.O.RF	6

Couplings / Supports (2)		
Label	Size: Description	Proj. fm Ves. ℄
G1	0.75 3000 # Half Length	37
G2	0.75 3000 # Half Length	37
J	0.5 3000 # Half Length	36.9375
LL1	Lifting Lug 1	30 to hole
LL2	Lifting Lug 2	30 to hole
LL3	Lifting Lug 3	30 to hole
LL4	Lifting Lug 4	30 to hole
VC1-3	Vessel Clips 1-3	44 to End
VC4-6	Vessel Clips 4-6	24 to End

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

Wt Empty: 21116 Full: 44452 Bundle: 7778 lb

Rev:	Date:	Description	Dwg	Ckd	Appd
4	12-10-07	Certified As-Built	RJT	DGB	PW

Company: DCR
Location: Bunge-Ergon
Reflux Condenser
Item No.: E-4201
Date: March 1, 2007 Job No.: 7793

DCR Construction, Inc.
Lakeland, Florida

ASME VIII-1 2004 A06
TEMA Type: BEM
Size: 31-240
TEMA Class: C

Setting Plan

Dwg No.: E-4201 01
Rev: 4

Component	O.D.	Thk.	Materials of Construction
Nozzle A Inlet	24.0	0.688	150 # ANSI S.O.RF Flg SA-105 on SA-53 K03005 Grd E/B Wld. pipe
Nozzle B Outlet	20.0	0.375	150 # ANSI S.O.RF Flg SA-105 on SA-53 K03005 Grd E/B Wld. pipe
Nozzle C Inlet	18.0	0.375	150 # ANSI S.O.RF Flg SA-182 on SA-312 S30400 Grd TP304 Wld. pipe
Nozzle D Outlet	6.625	0.28	150 # ANSI S.O.RF Flg SA-182 on SA-312 S30400 Grd TP304 Wld. pipe
Nozzle E Inlet	6.625	0.432	150 # ANSI S.O.RF Flg SA-182 on SA-312 S30400 Grd TP304 Wld. pipe
Nozzle F1	3.5	0.3	150 # ANSI S.O.RF Flg SA-182 on SA-312 S30400 Grd TP304 Wld. pipe
Nozzle F2	3.5	0.3	150 # ANSI S.O.RF Flg SA-182 on SA-312 S30400 Grd TP304 Wld. pipe
Nozzle H Outlet	2.375	0.218	150 # ANSI S.O.RF Flg SA-182 on SA-312 S30400 Grd TP304 Wld. pipe
Nozzle K Outlet	6.625	0.28	150 # ANSI S.O.RF Flg SA-182 on SA-312 S30400 Grd TP304 Wld. pipe
Coupling G1	0.75		3000 # Half Length SA-182 S30400 Grd. F304 Forging
Coupling G2	0.75		3000 # Half Length SA-182 S30400 Grd. F304 Forging
Coupling J	0.5		3000 # Half Length SA-182 S30400 Grd. F304 Forging
Shell Cylinder	32	0.375	SA-516 K02700 Grd 70 plate
Front Head Cylinder	32	0.25	SA-240 S30400 Grd 304 Plate
Front Head Cover	32	0.25	SA-240 S30400 Grd 304 Plate (Ellipsoidal Cover)
V.C. Rear Head Cylinder	72	0.3125	SA-240 S30400 Grd 304 Plate
V.C. Rear Head Cover	72	0.50	SA-240 S30400 Grd 304 Plate (Ellipsoidal Cover)
Front Tubesheet	35.25	1.75	SA-240 S30400 Grd 304 Plate
Front Head Flange at Tbsht	35.25	1.4375	SA-240 S30400 Grd 304 Plate (Ring Flange) (32.125 ID)
Front Head Gasket at Tbsht	33	0.125	Solid Teflon 1/8in Thickness (Periph. Width 0.5 in)
Front Head Bolting at Tbsht	0.5		SA-193 G41400 Grd B7 Bolt (24 Bolts on 34.00 in B.C.)
Tubes	0.75	0.049	SA-249 S30400 Grd TP304 Wld. tube (Plain Tubes)
Baffles	31.063	0.3125	SA-36 K02600 Plate
Distributor Belts	46	0.5	SA-516 K02700 Grd 70 Plate (Tube-Ts Joint:)
Distributor belt closure	47	0.750	SA-516 K02700 Grd 70 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-240 S30400 Grd 304 Plate
Shell Lift Lugs	-	1.000	SA-36 K02600 Plate
Shell Lift Lug Repads	-	0.625	SA-516 K02700 Grd 70 Plate
Skirt	72.000	0.375	SA-516 K02700 Grd 70 Plate
Anchor Chair - Top Ring	84.000	1.000	SA-516 K02700 Grd 70 Plate
Anchor Chair - Bottom Ring	84.000	1.000	SA-516 K02700 Grd 70 Plate
Anchor Chair - Gussets	-	0.500	SA-36 K02600 Plate
Skirt - Vent	3.500	0.216	SA-53 K03005 Grd E/B Wld. pipe
Transition	32-72	0.3125	SA-240 S30400 Grd 304 Plate
V.C. Rear Head Flng at Tbsht	35.50	1.750	SA-240 S30400 Grd 304 Plate
V.C. Flange Cylinder	32	0.3125	SA-240 S30400 Grd 304 Plate
Rear Tubesheet	35.50	1.75	SA-240 S30400 Grd 304 Plate
Rear Head Gasket at Tbsht	33.25	0.125	Solid Teflon 1/8" Thickness (Periph. Width 0.50 in.)
Tie Rods	0.5		SA-36 Bar
Spacers	0.75	0.109	SA-214 K01807 Wld. Tube
V.C. Head Bolting at Tbsht	0.50		SA-193 G41400 Grd B7 Bolt (24 Bolts on 34.25 in. B.C. Plate)
Vessel Clips 1-3		0.25	SA-240 S30400 Grd 304 Plate
Vessel Clips 4-6		0.25	SA-516 K02700 Grd 70 Plate
Skirt Nozzle Sleeve	10.75	0.25	SA-53 K03005 Grd E/B Wld. pipe

Dimensions: in

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Design Specifications

		Shell Side	Tube Side
Design Pressure	psig	150/15	75/15
Test Pressure	psig	195	98
Design Temperature	F	300	300
Number of Passes		1	1
Corrosion Allowance	in	0.0625	0.0
Radiographing		None	None

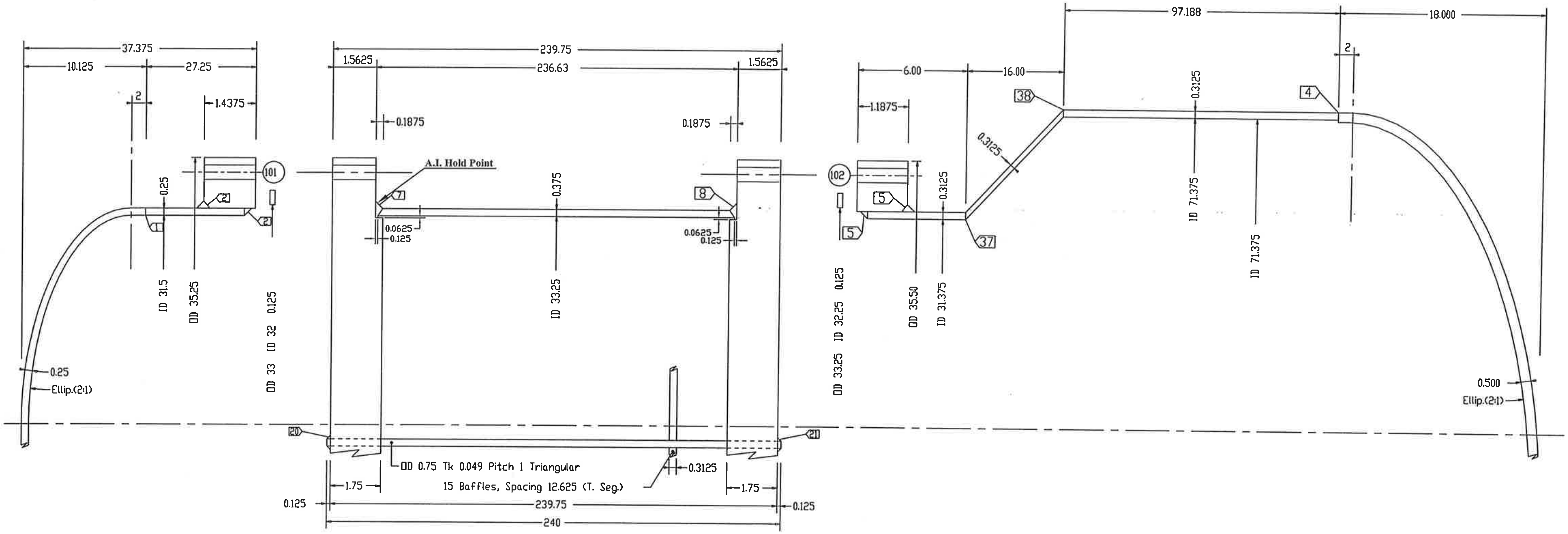
TEMA Type: BEM Size: 31-240 Area: 3224 ft2
Tube Type: Plain # Holes: 821 Length: 240 in
Layout: 1.0 in (30) Tube-Ts Joint: Exp/Str.Welded
Baffle Type: Triple Seg. Cut: 16% V No: 15
Baffle Spacing (C-C): 12.625 Inlet: 27.75 in
Impingement Protection: None
Code: ASME VIII-1 2004 A06 TEMA Class: C
Wt Empty: 21116 Full: 44452 Bundle: 7778 lb
Drawn By: BM Ckd By: Apvd By: PW
Dwg No.: Rev: 8 Date: 12-10-07

Company: DCR Construction, Inc.
Location: Bunge-Ergon
Reflux Condenser
Item No.: E-4201
Date: May 5, 2007 Job No.: 7793

DCR Construction, Inc.
Lakeland, Florida

REV 7 Revised Per DcR Request	Bill Of Material		
REV 8 Certified As-Built	Dwg No.: E-4201 02	Rev: 8	

All Dimensions
In Inches



102	24	0.5	5	34.25	0.625
101	24	0.5	5.5	34.00	0.625
Ref	No	Bolt Dia.	Bolt Length	Bolt Circle	Bolt Hole
Bolting					

Notes:

Scale: NTS

Rev:	Date:	Description	Dwg	Ckd	Appd
1	08-24-07	Issued for Construction	KFF	DGB	PW
2	10-09-07	Revised Per DcR Request	KFF	DGB	PW
3	12-10-07	CERTIFIED AS-BUILT	RJT	DGB	PW

HT/DcR Engineering, Inc.

Company: DCR
Location: Bunge-Ergon
Reflux Condenser
Item No.: E-4201
Date: March 1, 2007 Job No.: 7793

DCR Construction, Inc.
Lakeland, Florida

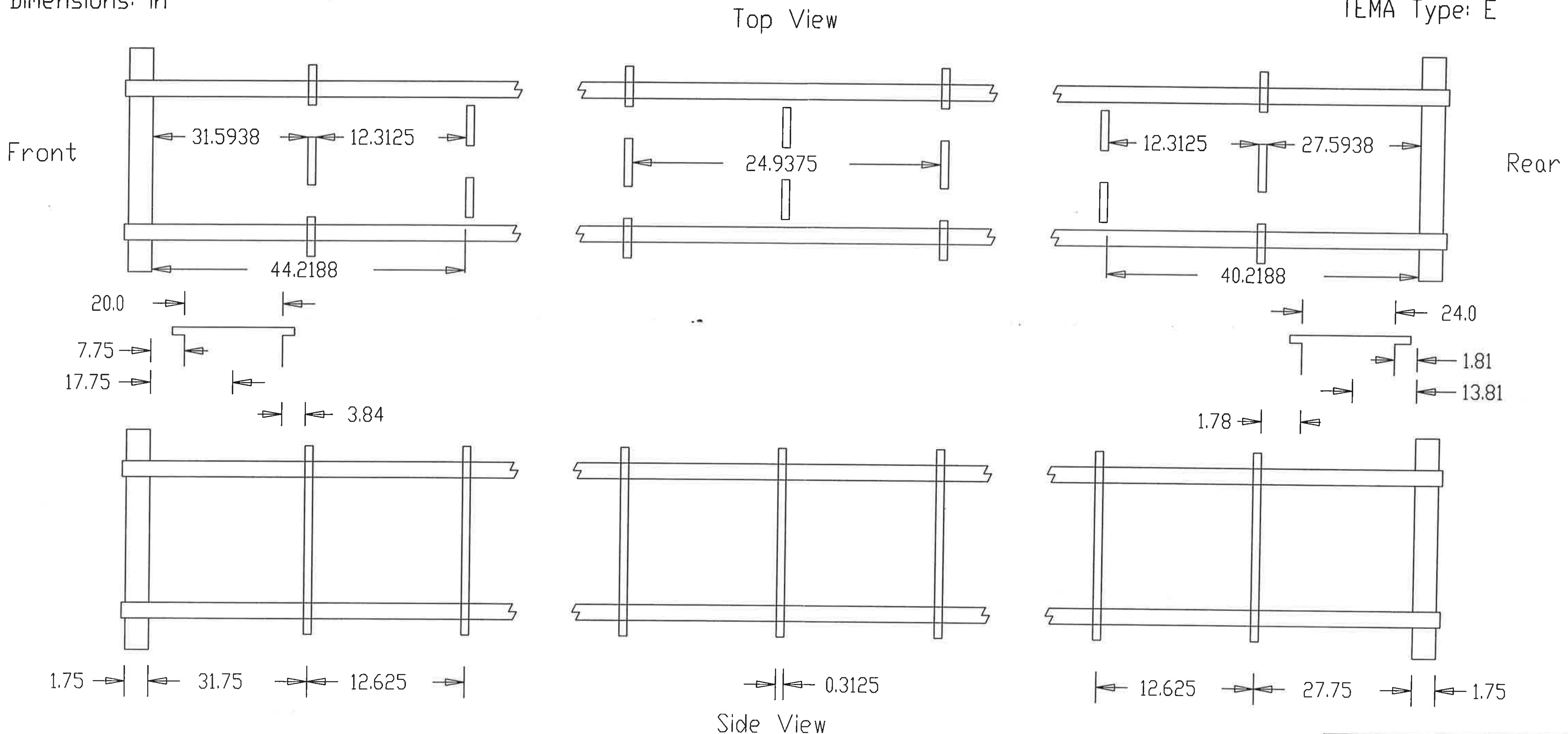
ASME VIII-1 2004 A06
TEMA Type: BEM
Size: 31-240
TEMA Class: C

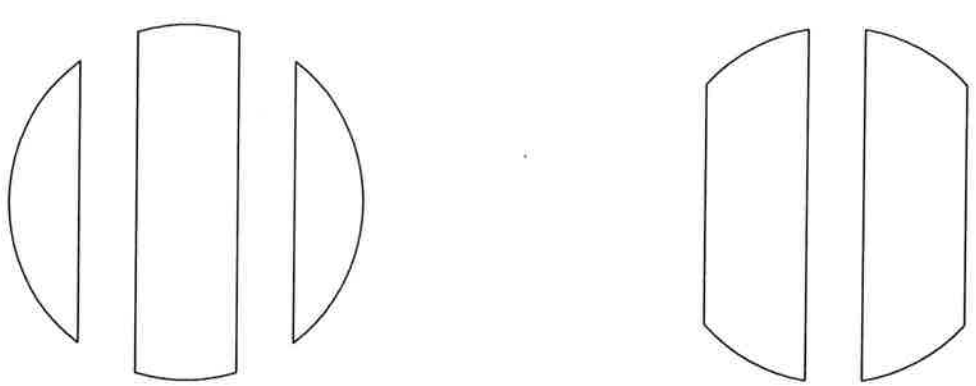
Sectional Plan

Dwg No.: E-4201 03
Rev: 3

Dimensions: in

TEMA Type: E





Baffles

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Notes:

Company: DCR Construction, Inc.
Location: Bunge-Ergon
Reflux Condenser
Item No.: E-4201
Date: May 5, 2007 Job No.: 7793

DCR Construction, Inc.
Lakeland, Florida

Scale: NTS

Rev:	Date:	Description	Dwg	Ckd	Appd
1	08-24-07	Issued for Construction	KFF	DGB	PW
2	12-10-07	CERTIFIED AS-BUILT	RJT	DGB	PW

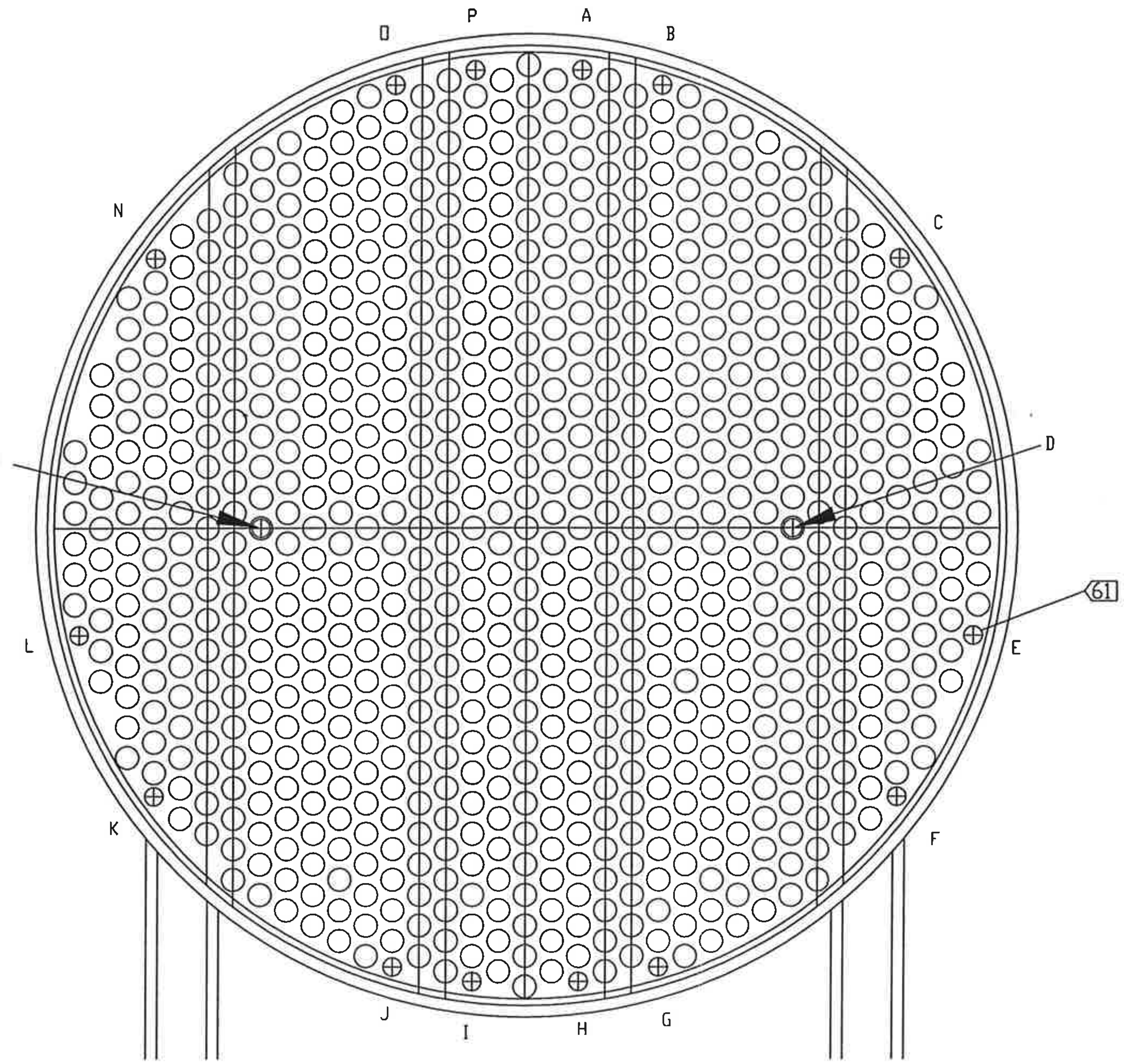
ASME VIII-1 2004 A06
TEMA Type: BEM
Size: 31-240
TEMA Class: C

Bundle Detail

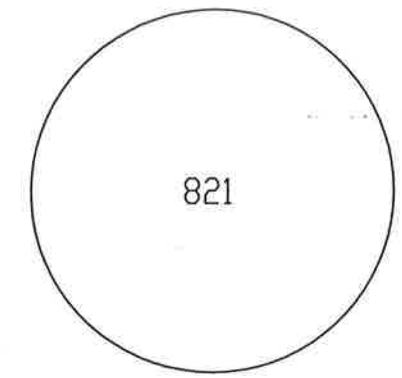
Dwg No.: E-4201 04

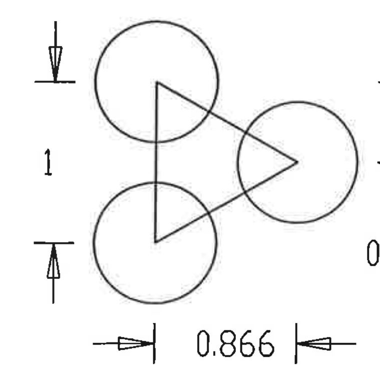
Rev: 2

Row	Holes
61	1
60	4
59	7
58	8
57	9
56	10
55	11
54	12
53	11
52	12
51	13
50	14
49	13
48	14
47	15
46	16
45	15
44	16
43	15
42	16
41	17
40	16
39	17
38	16
37	17
36	18
35	17
34	18
33	17
32	18
31	15
30	18
29	17
28	18
27	17
26	18
25	17
24	16
23	17
22	16
21	17
20	16
19	15
18	16
17	15
16	16
15	15
14	14
13	13
12	14
11	13
10	12
9	11
8	12
7	11
6	10
5	9
4	8
3	7
2	4
1	1
	821



Shell ID	31.25 in
O.T.L.	30.813 in
Baffle cut to C/L	2.598 in
	3.464 in
	9.526 in
	10.392 in





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Design Specifications

Number of Tube Holes	821
Tube Outside Diameter	0.75 in
Tube Pitch	1 in
Tube Pattern	Triangular
Tube Passes	1
Number of Tie Rods	16
Tie Rod Diameter	0.5 in
Baffle Diameter	31.0625 in
Baffle Type	Triple Segmental
Baffle Cut	17%
Tube Thickness	0.049 in

Tie Rod Locations

A	1.74604	14.8636
B	4.299	14.393
C	12.1000	8.900
D	8.6600	0.000
E	14.600	-3.500
F	12.1000	-8.900
G	4.299	-14.393
H	1.74604	-14.8636
I	-1.74604	-14.8636
J	-4.299	-14.393
K	-12.100	-8.900
L	-14.600	-3.500
M	-8.6600	0.000
N	-12.100	8.900
O	-4.299	14.393
P	-1.74604	14.8636

Notes:

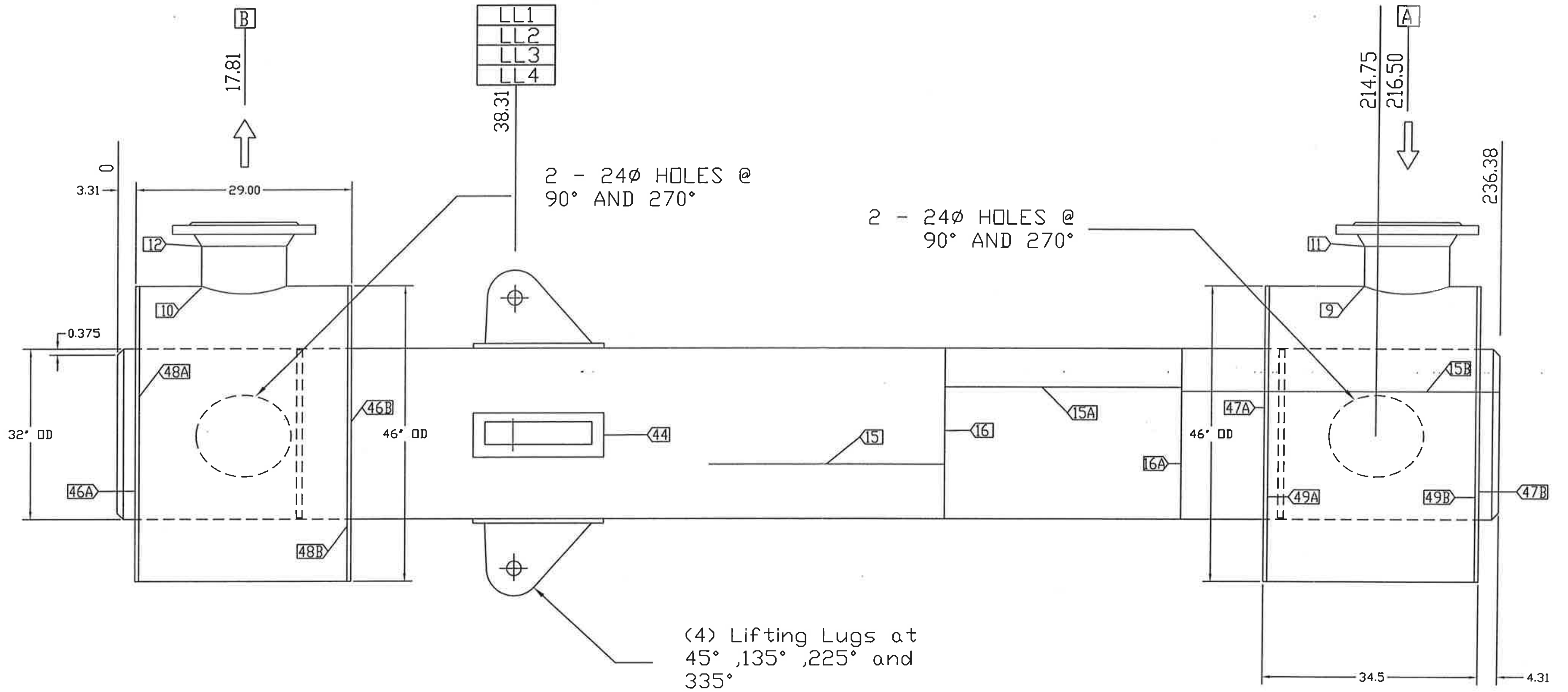
Scale: NTS

Rev:	Date:	Description	Dwg	Ckd	Appd
1	08-24-07	Issued for Construction	KFF	DGB	PW
2	12-10-07	CERTIFIED AS-BUILT	RJT	DGB	PW

Company: DCR Construction, Inc.
Location: Bunge-Ergon
Reflux Condenser
Item No.: E-4201
Date: May 5, 2007 Job No.: 7793

DCR Construction, Inc.
Lakeland, Florida

ASME VIII-1 2004 A06	Tube Layout		
TEMA Type: BEM			
Size: 31-240	Dwg No.:	E-4201 05	Rev: 2
TEMA Class: C			



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

Company: DCR
Location: Bunge-Ergon
Reflux Condenser
Item No.: E-4201
Date: March 2, 2007 Job No.: 7793

DCR Construction, Inc
Lakeland, FL

Scale: NTS

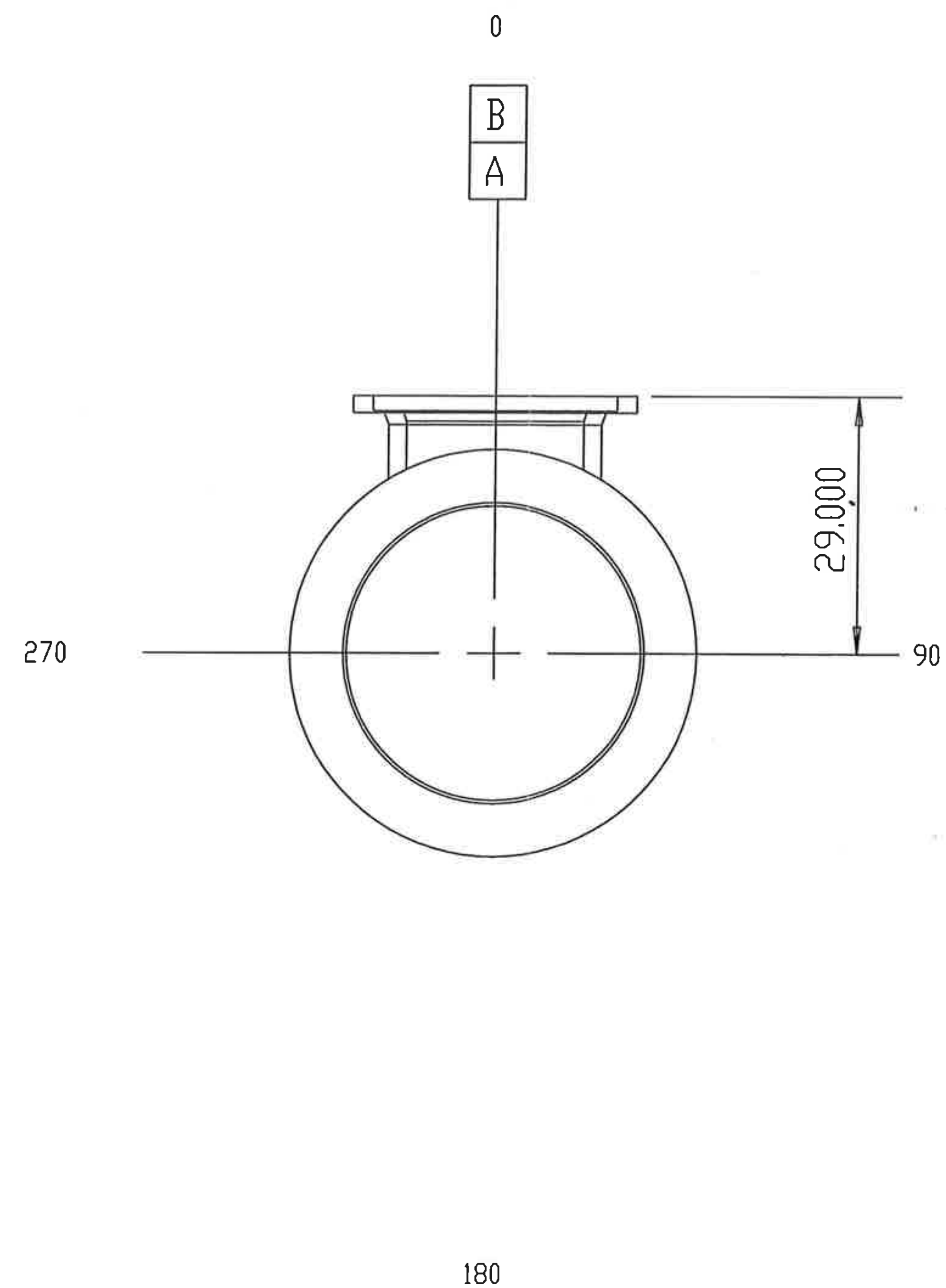
Rev:	Date:	Description	Dwg	Ckd	Appd
1	08-24-07	Issued for Construction	KFF	DGB	PW
2	12-07-07	Added Weld Seam	KFF	DGB	PW
3	12-10-07	CERTIFIED AS-BUILT	RJT	DGB	PW

ASME VIII-1 2004 A06
TEMA Type: BEM
Size: 31-240
TEMA Class: C

Shell Detail

Dwg No.: E-4201-06A

Rev: 3



Front End View

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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
Reflux Condenser
Item No.: E-4201
Date: March 2, 2007 Job No.: 7793

DCR Construction, Inc
Lakeland, FL

Scale: NTS

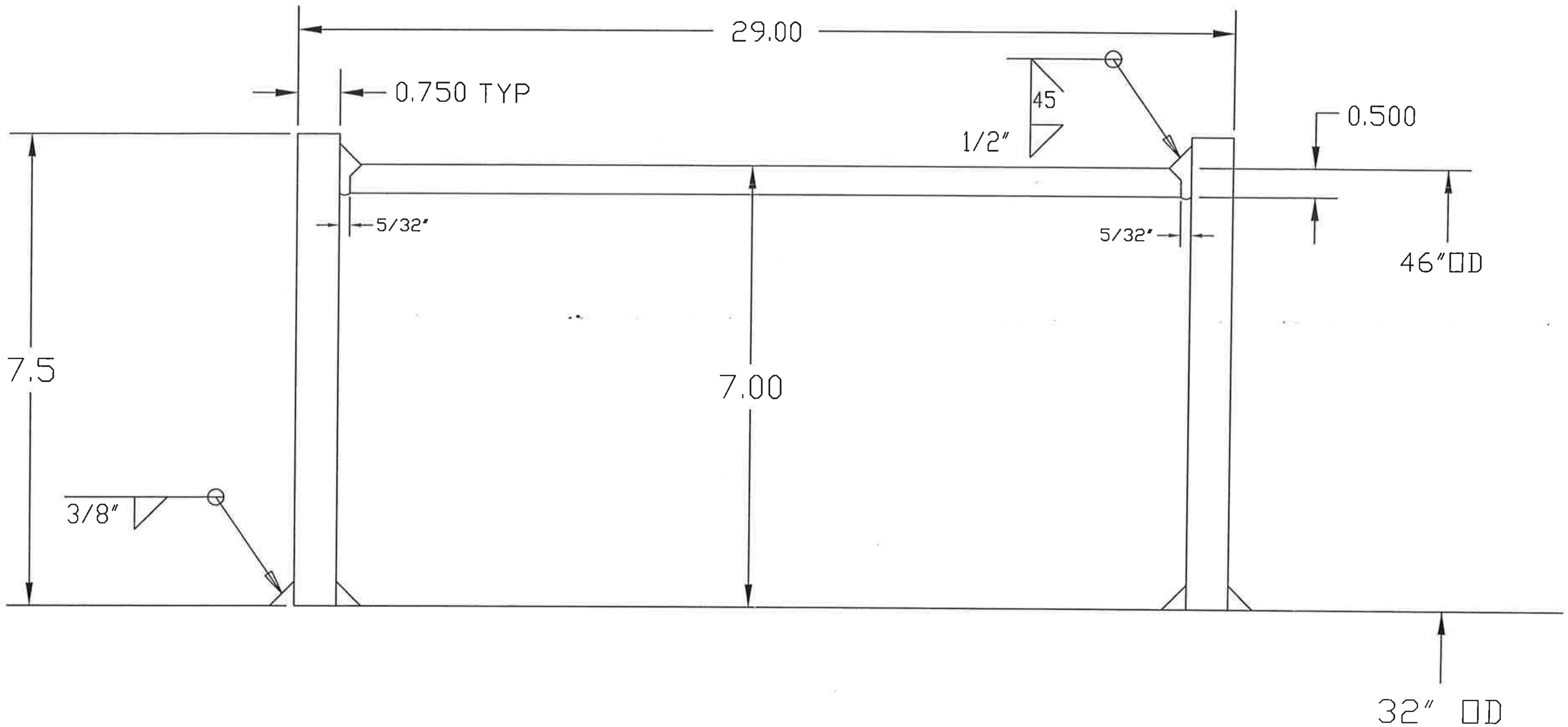
Rev:	Date:	Description	Dwg	Ckd	Appd
1	08-24-07	Issued for Construction	KFF	DGB	PW
2	12-10-07	CERTIFIED AS-BUILT	RJT	DGB	PW

ASME VIII-1 2004 A06
TEMA Type: BEM
Size: 31-240
TEMA Class: C

Shell Detail

Dwg No.: E-4201-06B

Rev: 2



Notes:
All Dimensions In Inches

Scale: NTS

Rev:	Date:	Description	Dwg	Ckd	Appd
1	08-24-07	Issued for Construction	KFF	DGB	PW
2	12-10-07	CERTIFIED AS-BUILT	RJT	DGB	PW

HT/DCR Engineering, Inc.

Company: DCR
Location: Bunge-Ergon
Reflux Condenser
Item No.: E-4201
Date: March 2, 2007 Job No.: 7793

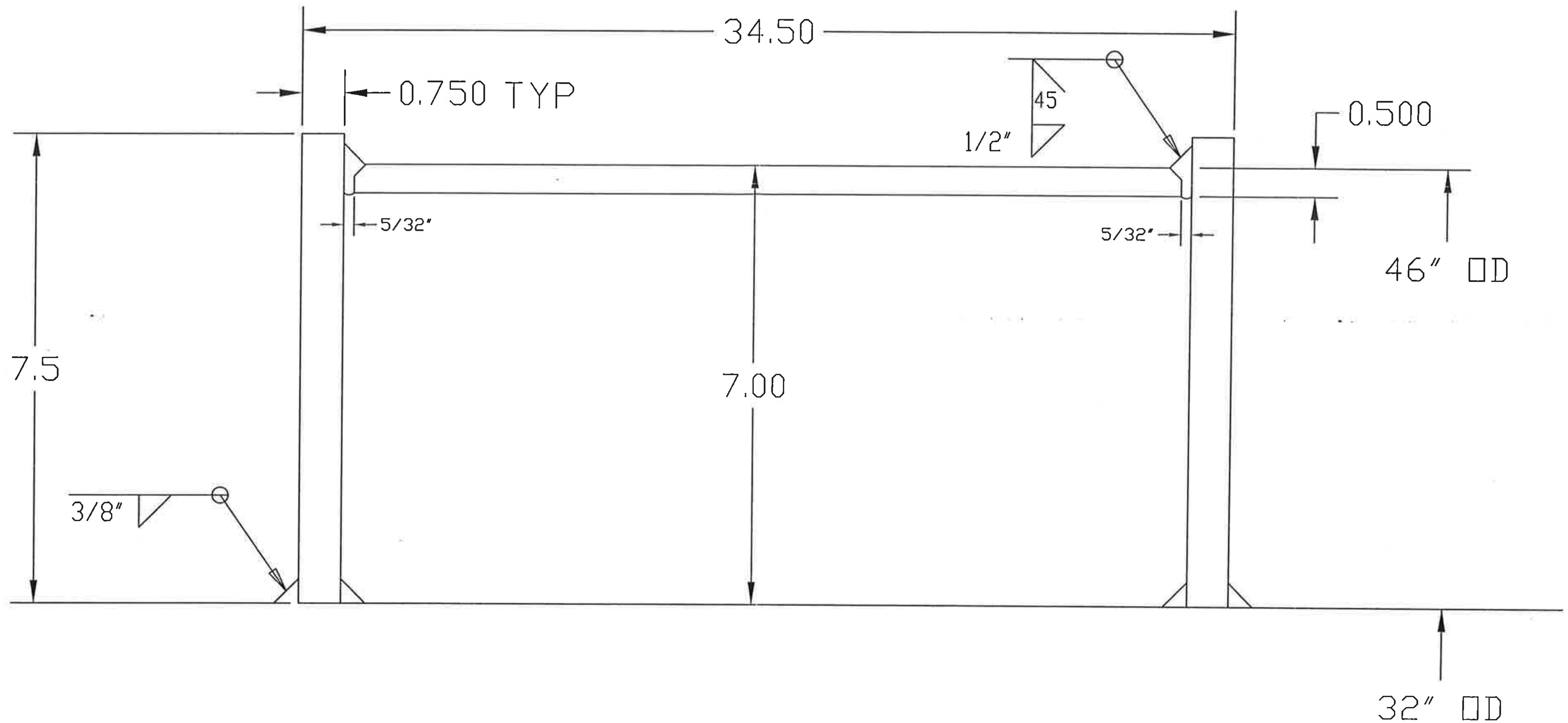
DCR Construction, Inc
Lakeland, FL

ASME VIII-1 2004 A06
TEMA Type: BEM
Size: 31-240
TEMA Class: C

Upper Vapor Belt Detail

Dwg No.: E-4201 07A

Rev: 2



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Notes:
All Dimensions In Inches

Company: DCR
Location: Bunge-Ergon
Reflux Condenser
Item No.: E-4201
Date: March 2, 2007 Job No.: 7793

DCR Construction, Inc
Lakeland, FL

Scale: NTS

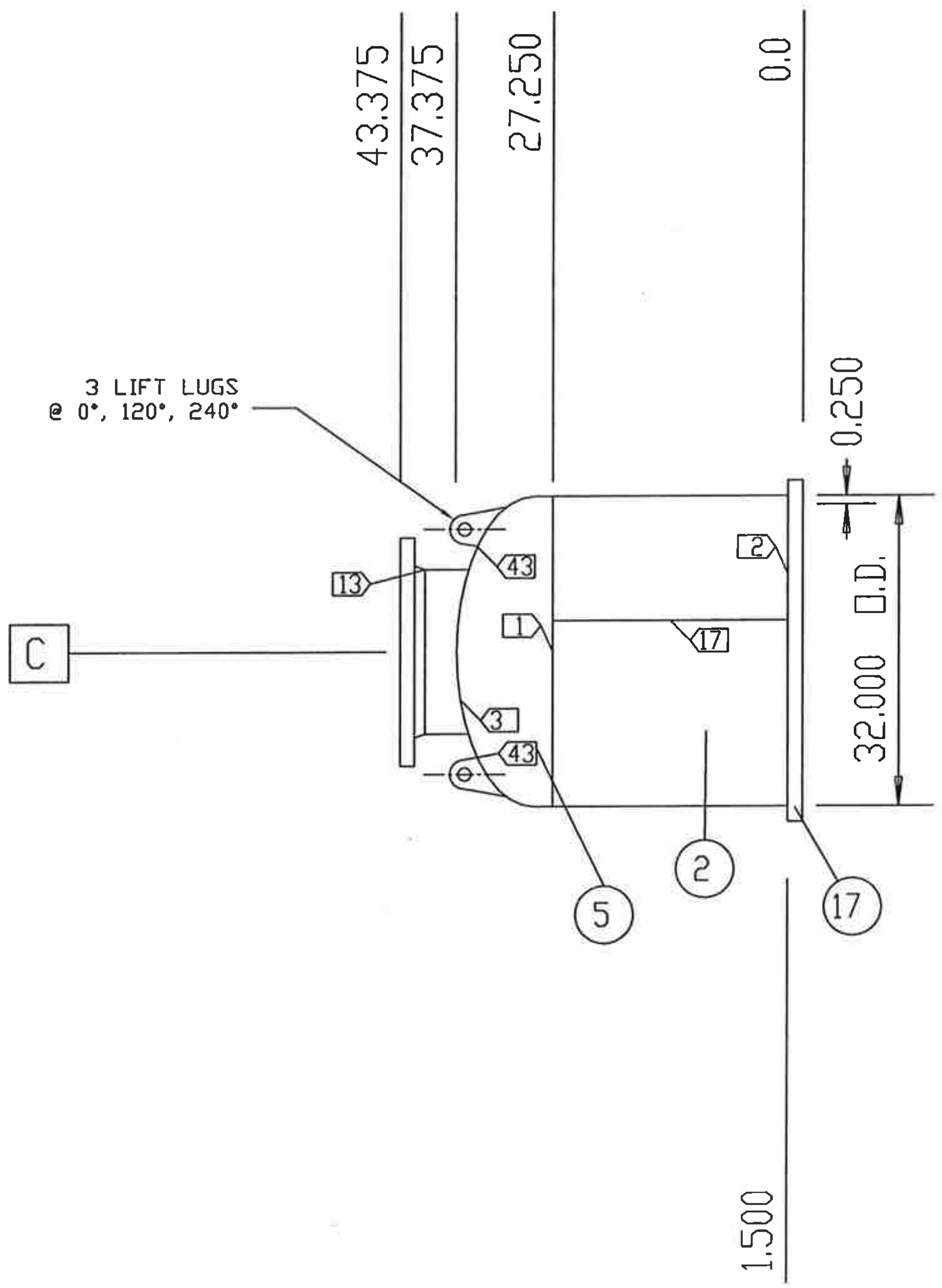
Rev:	Date:	Description	Dwg	Ckd	Appd
1	08-24-07	Issued For Construction	KFF	DGB	PW
2	12-10-07	CERTIFIED AS-BUILT	RJT	DGB	PW

ASME VIII-1 2004 A06
TEMA Type: BEM
Size: 31-240
TEMA Class: C

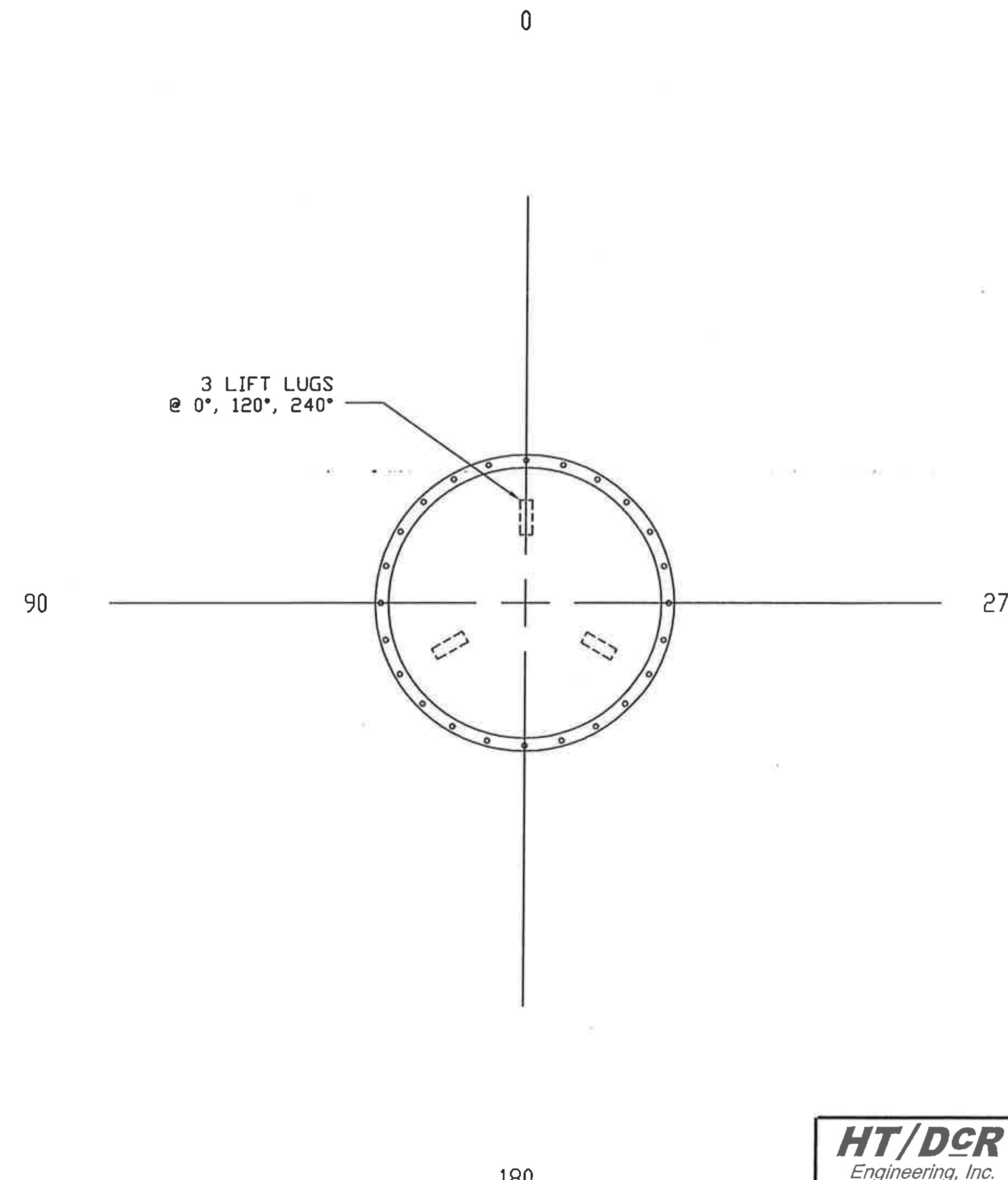
Lower Vapor Belt Detail

Dwg No.: E-4201 07B

Rev: 2



Side View



Rear End View

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

Company: DCR
Location: Bunge-Ergon
Reflux Condenser
Item No.: E-4201
Date: March 1, 2007 Job No.: 7793

DCR Construction, Inc.
Lakeland, Florida

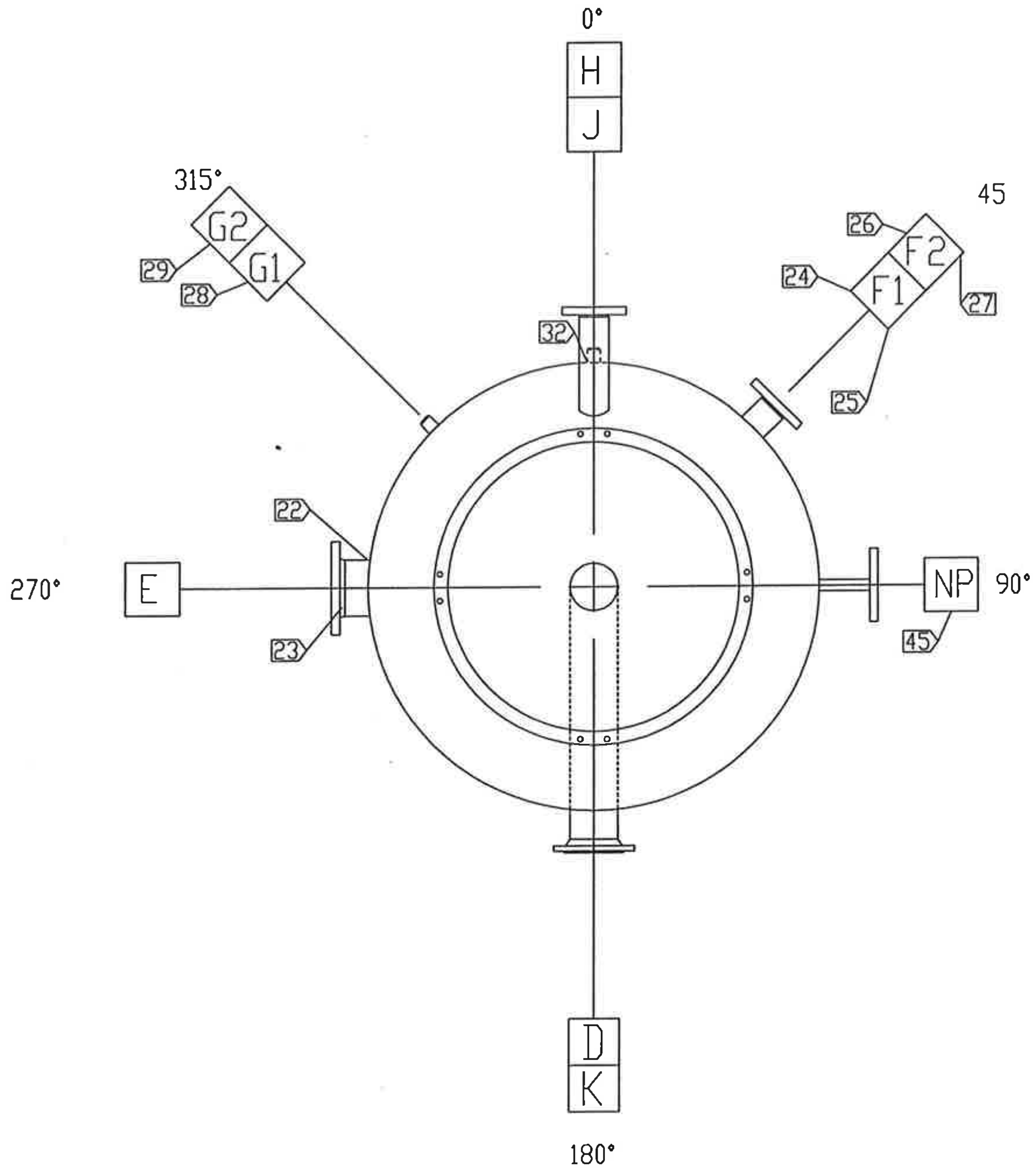
Scale: NTS

Rev:	Date:	Description	Dwg	Ckd	Appd
1	08-24-07	Issued for Construction	KFF	DGB	PW
2	12-10-07	CERTIFIED AS-BUILT	RJT	DGB	PW

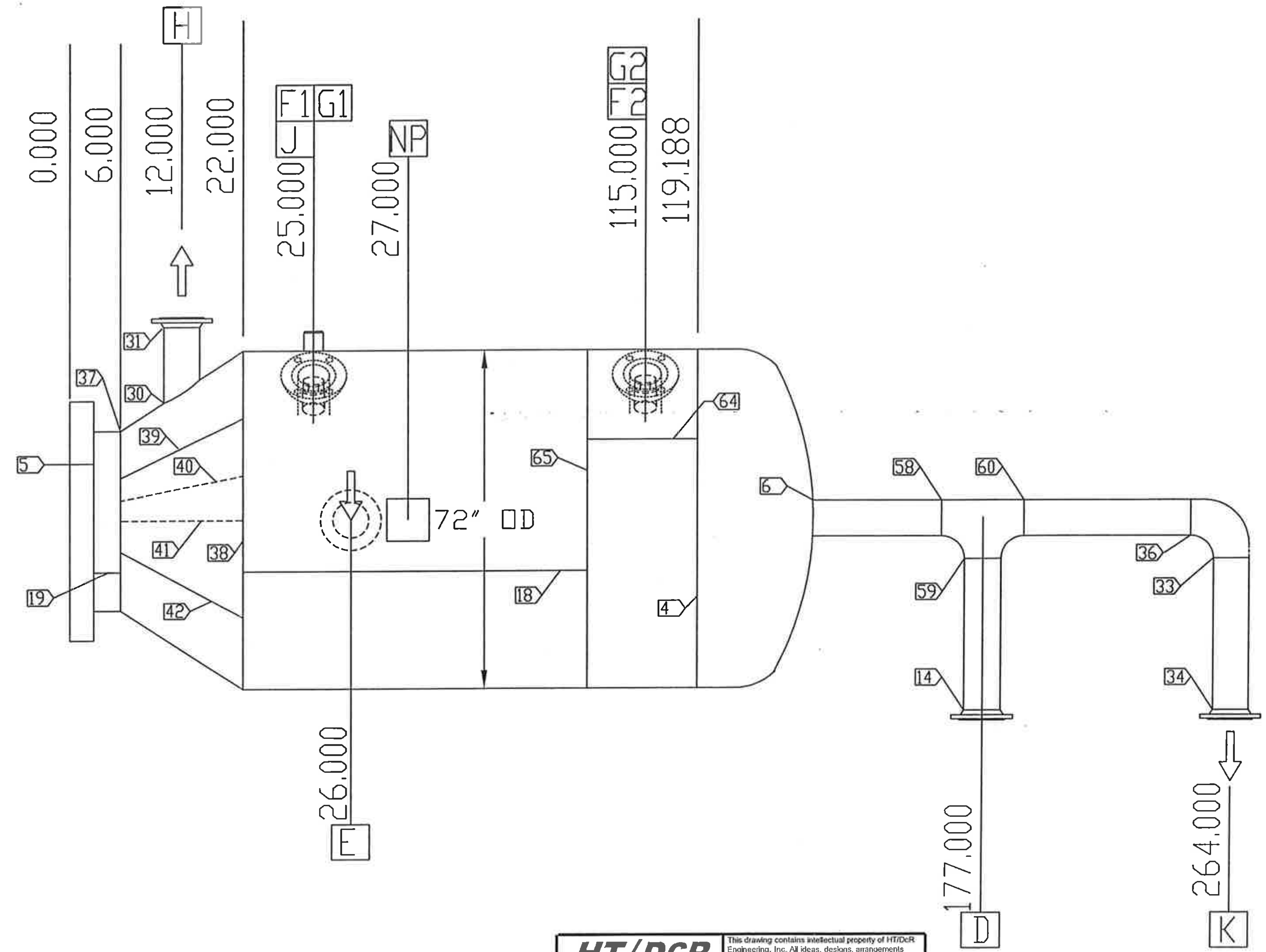
ASME VIII-1 2004 A06
TEMA Type: BEM
Size: 31-240
TEMA Class: C

Front Head Detail

Dwg No.: E-4201 08
Rev: 2



Front End View



Side View

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

Company: DCR
Location: Bunge-Ergon
Reflux Condenser
Item No.: E-4201
Date: March 1, 2007 Job No.: 7793

DCR Construction, Inc.
Lakeland, Florida

Scale: NTS

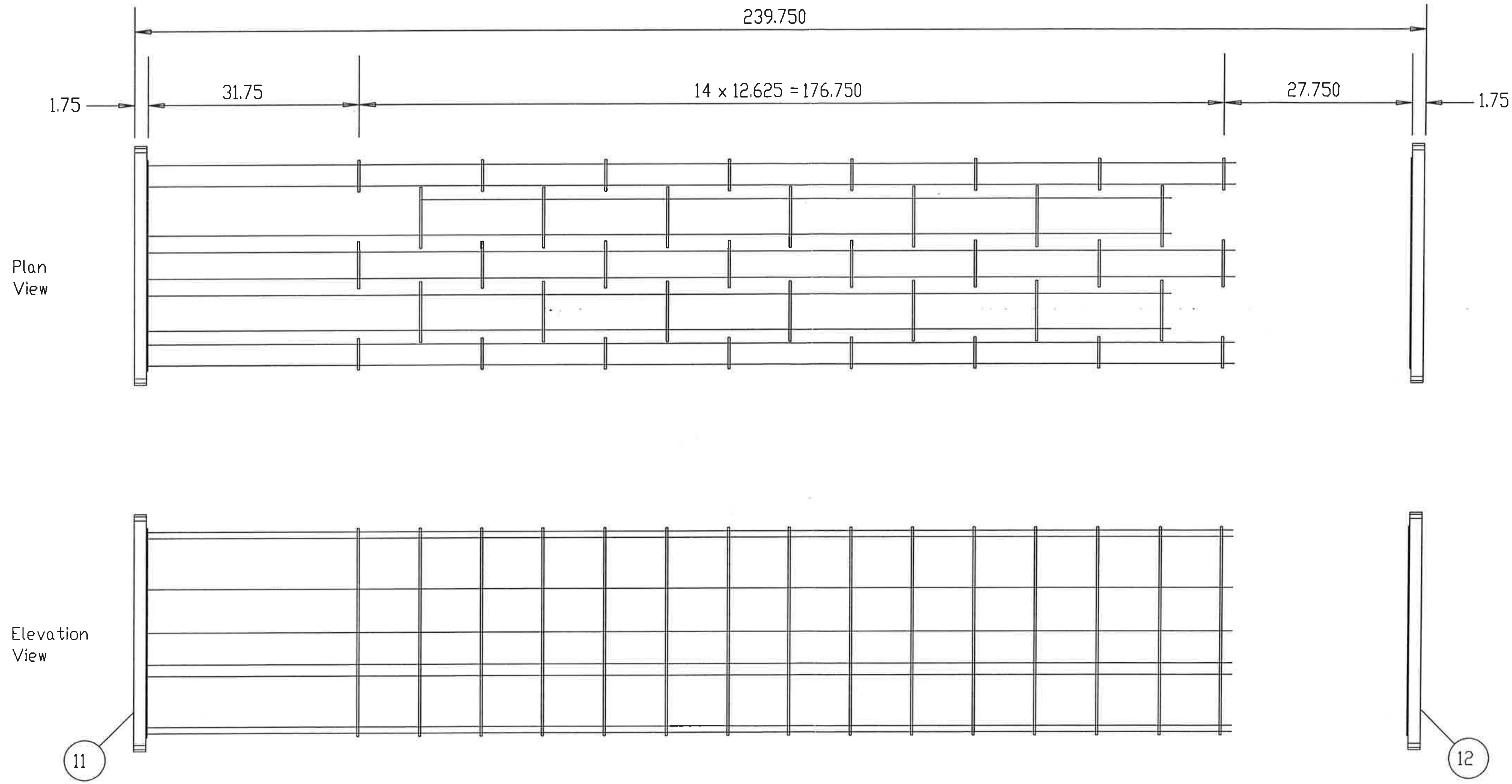
Rev:	Date:	Description	Dwg	Ckd	Appd
4	12-10-07	CERTIFIED AS-BUILT	RJT	DGB	PW
2	08-24-07	Issued For Construction	KFF	DGB	PW
3	10-09-07	Revised Per DcR Request	KFF	DGB	PW

ASME VIII-1 2004 A06
TEMA Type: BEM
Size: 31-240
TEMA Class: C

Rear Head Detail

Dwg No.: E-4201 09

Rev: 4



# of Spacers	Length
2	44.218
3	31.593
33	24.938

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

HT/DCR
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Scale: NTS

Rev:	Date:	Description	Dwg	Ckd	Appd
1	08-24-07	Issued for Construction	KFF	DGB	PW
2	12-10-07	CERTIFIED AS-BUILT	RJT	DGB	PW

Company: DCR Construction, Inc.
Location: Bunge-Ergon
Reflux Condenser
Item No.: E-4201
Date: May 5, 2007 Job No.: 7793

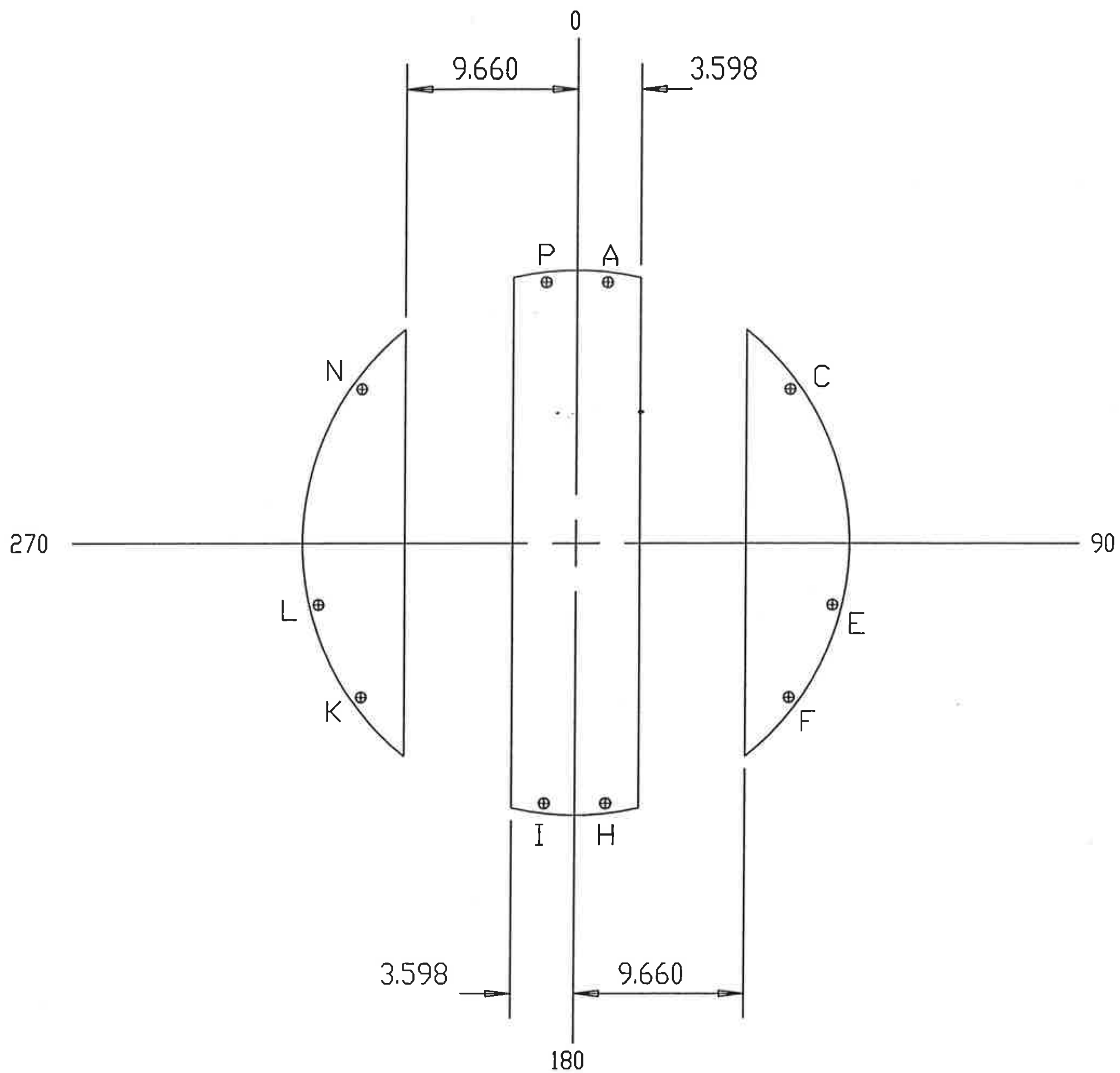
DCR Construction, Inc.
Lakeland, Florida

ASME VIII-1 2004 A06
TEMA Type: BEM
Size: 31-240
TEMA Class: C

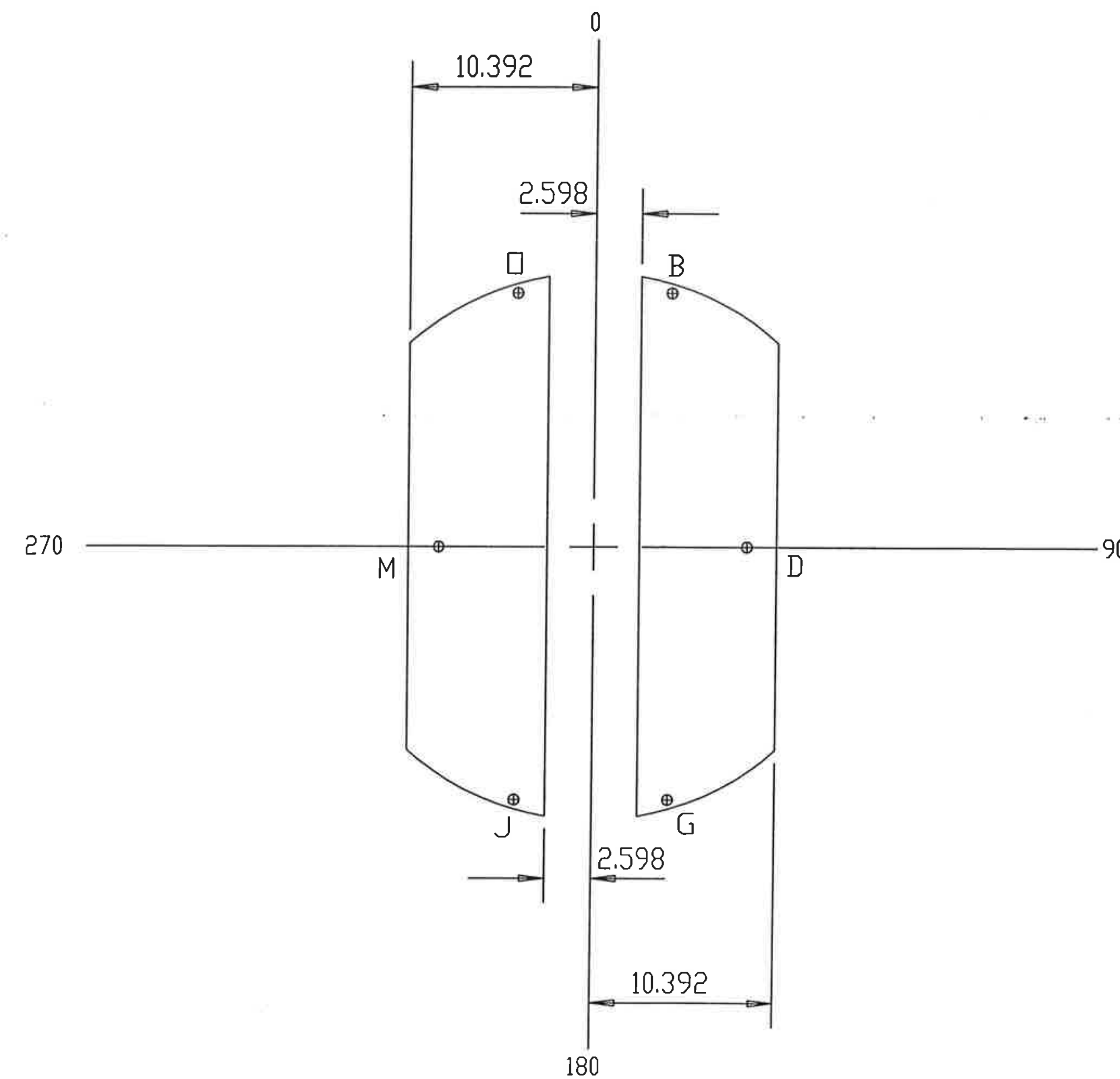
Bundle Detail

Dwg No.: E-4201 11

Rev: 2



(39 A) 8 Baffles 31.063 O.D. 0.313 Tk



(39 B) 7 Baffles 31.063 O.D. 0.313 Tk

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

Company: DCR Construction, Inc.
Location: Bunge-Ergon
Reflux Condenser
Item No.: E-4201
Date: May 5, 2007 Job No.: 7793

DCR Construction, Inc.
Lakeland, Florida

Scale: NTS

Rev:	Date:	Description	Dwg	Ckd	Appd
1	08-24-07	Issued for Construction	KFF	DGB	PW
2	12-10-07	CERTIFIED AS-BUILT	RJT	DGB	PW

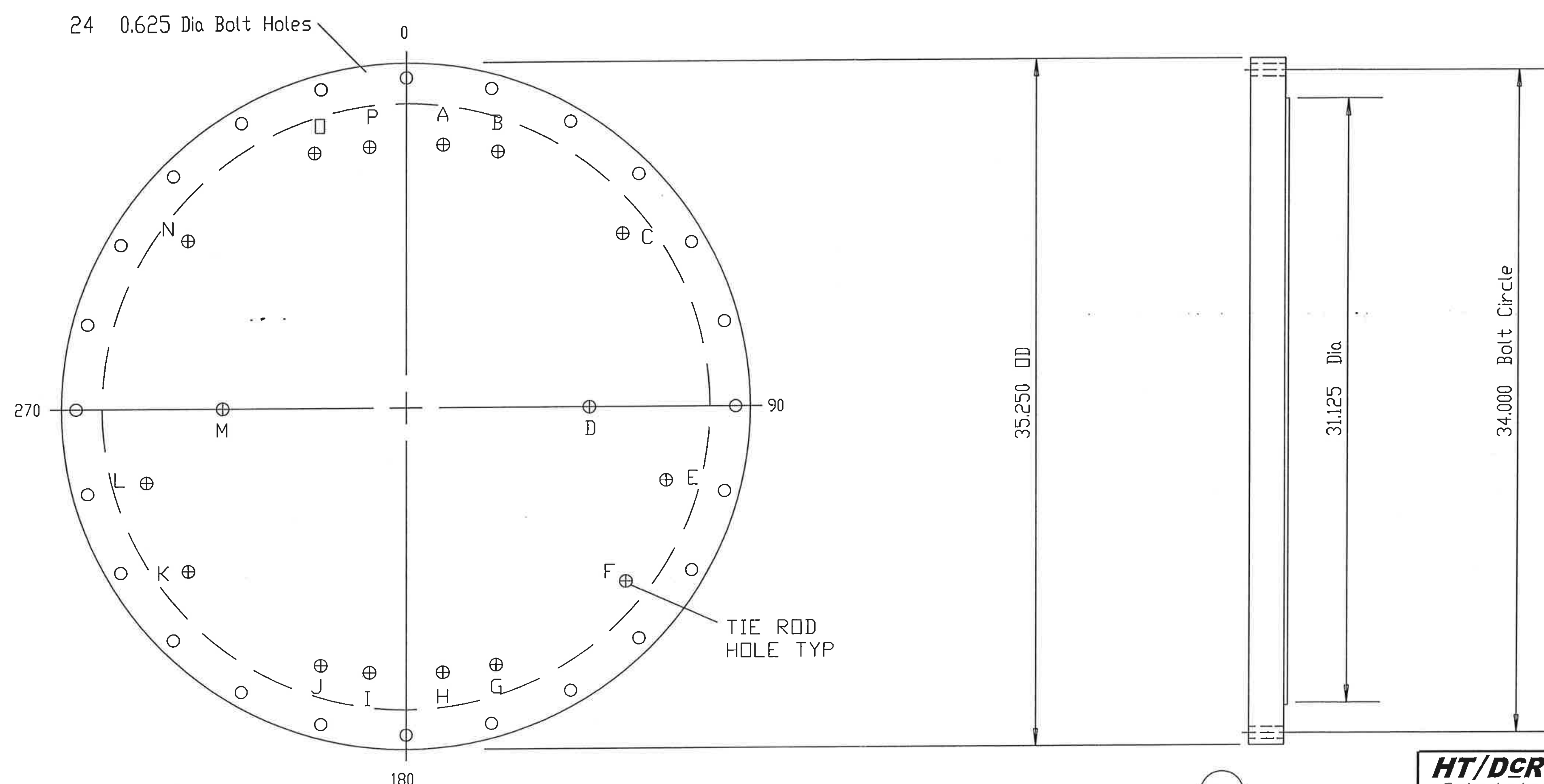
ASME VIII-1 2004 A06
TEMA Type: BEM
Size: 31-240
TEMA Class: C

Baffle Detail

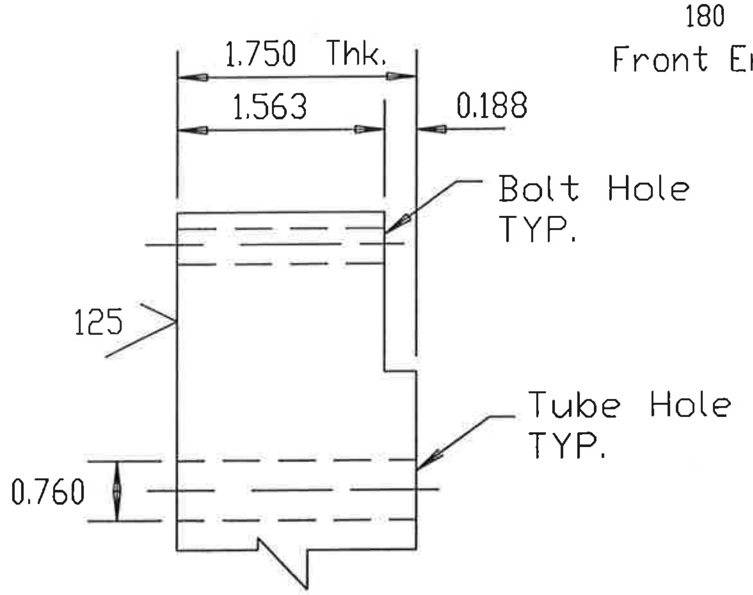
Dwg No.: E-4201 12

Rev: 2

HT/DCR Engineering, Inc.



Front End View



(11) Front TubSh

Notes:
All Dimensions In Inches
Bolt holes to straddle centerlines
Tube Hole Layout and Tie Rod Locations Shown in DWG E-4201 05

Company: DCR Construction, Inc.
Location: Bunge-Ergon
Reflux Condenser
Item No.: E-4201
Date: May 5, 2007 Job No.: 7793

DCR Construction, Inc.
Lakeland, Florida

Scale: NTS

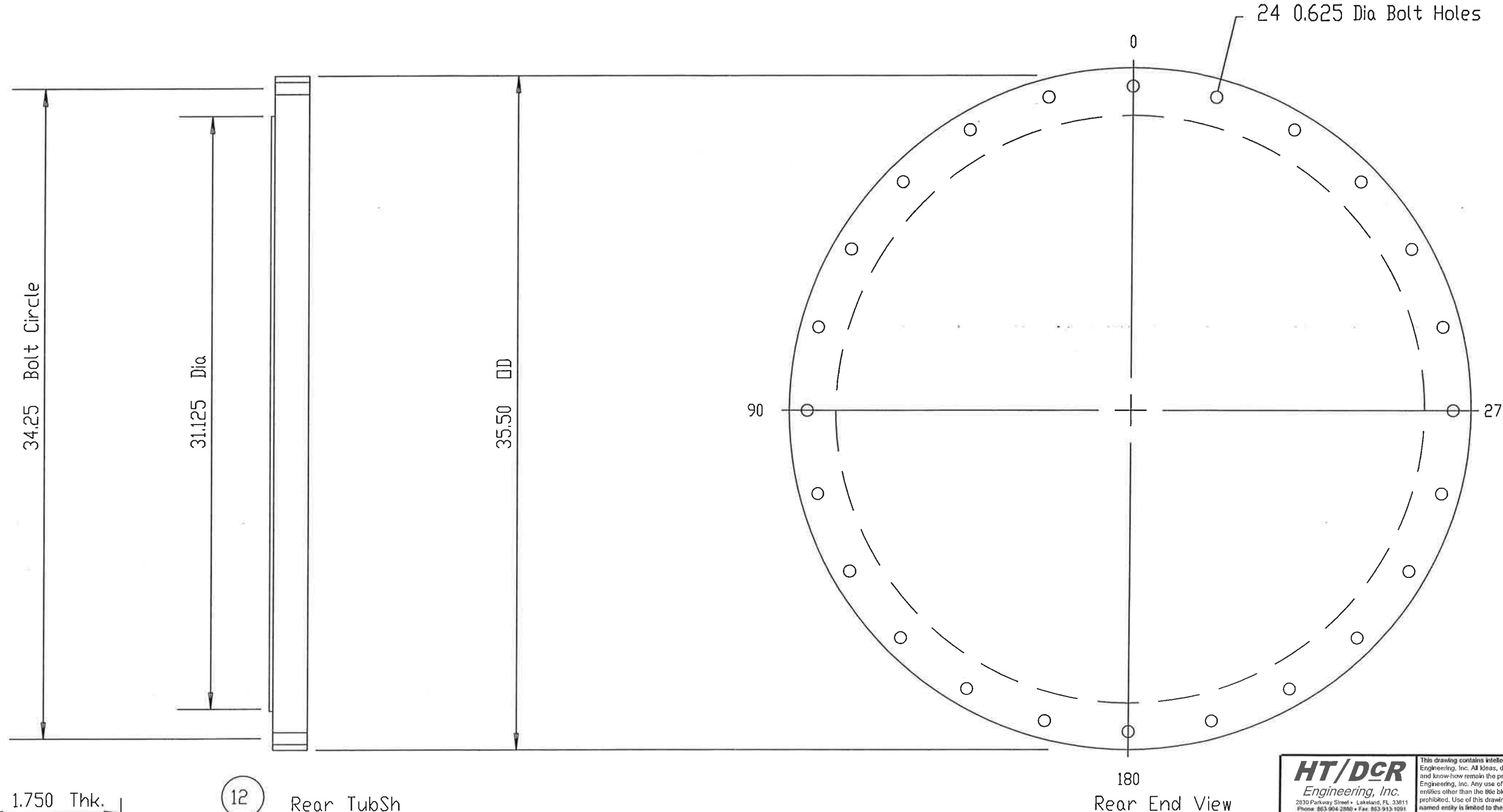
Rev:	Date:	Description	Dwg	Ckd	Appd
1	08-24-07	Issued for Construction	KFF	DGB	PW
2	12-10-07	CERTIFIED AS-BUILT	RJT	DGB	PW

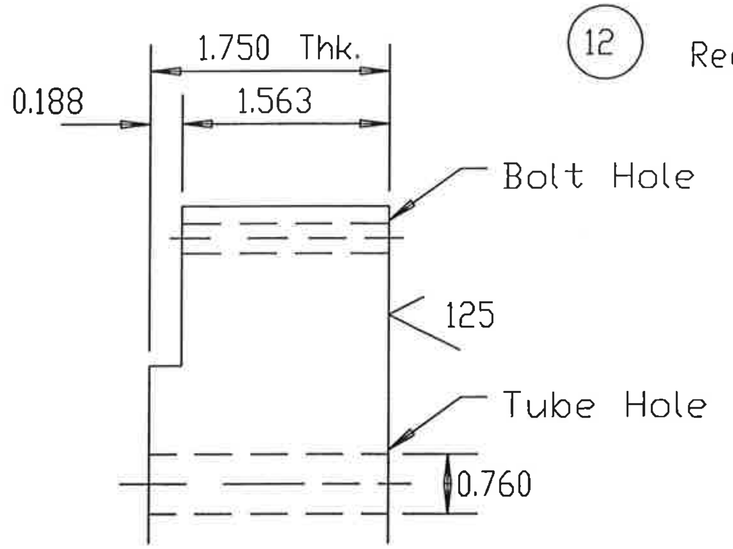
ASME VIII-1 2004 A06
TEMA Type: BEM
Size: 31-240
TEMA Class: C

Front Tubesheet Detail

Dwg No.: E-4201 14

Rev: 2





HT/DCR Engineering, Inc.

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Phone 863-904-2880 • Fax 863-913-1091
Florida Engineering Business License No 26522

Notes:
All Dimensions In Inches
Bolt holes to straddle centerlines
Tube Hole Layout Shown in DWG E-4201 05. 821 Tube Holes: No Tie Rods Required

Company: DCR Construction, Inc.
Location: Bunge-Ergon
Reflux Condenser
Item No.: E-4201
Date: May 5, 2007 Job No.: 7793

DCR Construction, Inc.

Lakeland, Florida

Scale: NTS

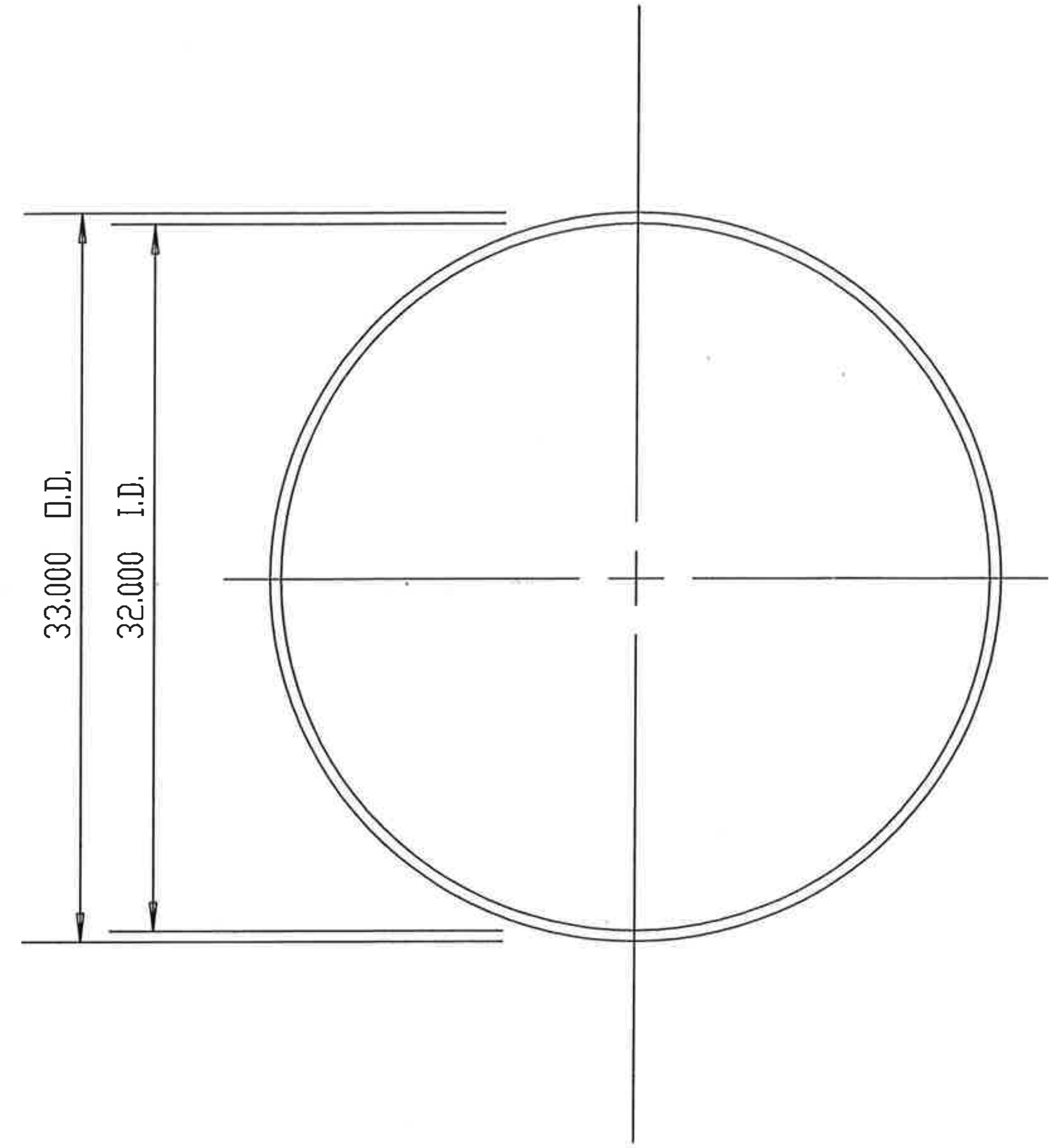
Rev:	Date:	Description	Dwg	Ckd	Appd
1	08-24-07	Issued For Construction	KFF	DGB	PW
2	12-10-07	CERTIFIED AS-BUILT	RJT	DGB	PW

ASME VIII-1 2004 A06
TEMA Type: BEM
Size: 31-240
TEMA Class: C

Rear Tubesheet Detail

Dwg No.: E-4201 15

Rev: 2



(31) Front Head Gaskets at Tbshts

0.125 Thk.

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Notes:
All Dimensions In Inches
Bolt holes to straddle centerlines

Company: DCR Construction, Inc.
Location: Bunge-Ergon
Reflux Condenser
Item No.: E-4201
Date: May 5, 2007 Job No.: 7793

DCR Construction, Inc.
Lakeland, Florida

Scale: NTS

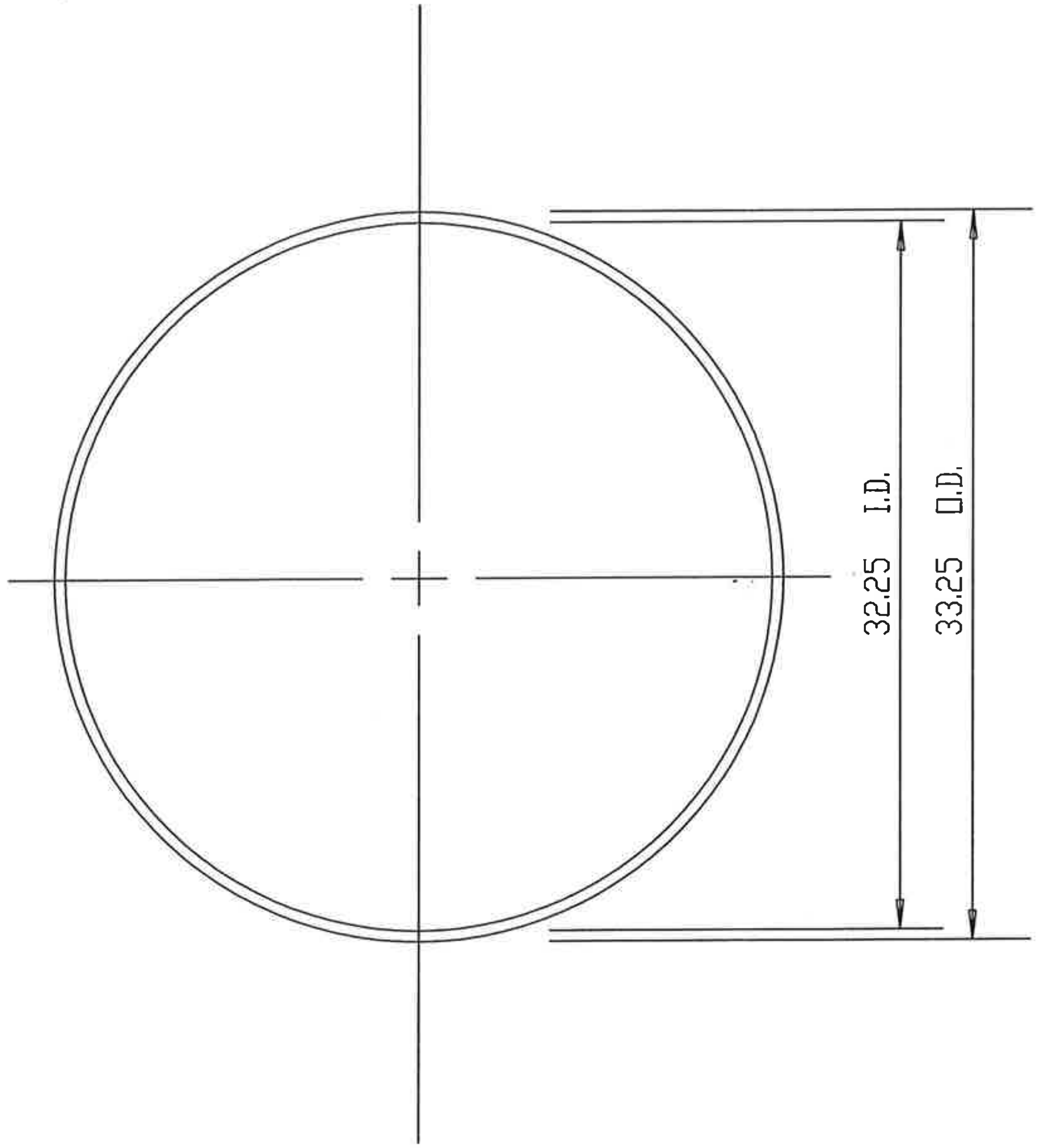
Rev:	Date:	Description	Dwg	Ckd	Appd
1	08-24-07	Issued for Construction	KFF	DGB	PW
2	12-10-07	CERTIFIED AS-BUILT	RJT	DGB	PW

ASME VIII-1 2004 A06
TEMA Type: BEM
Size: 31-240
TEMA Class: C

Front Gasket Detail

Dwg No.: E-4201 17A

Rev: 2



(32) Rear Head Gaskets at Tbshts

0.125 Thk.

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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 Construction, Inc.
Location: Bunge-Ergon
Reflux Condenser
Item No.: E-4201
Date: May 5, 2007 Job No.: 7793

DCR Construction, Inc.
Lakeland, Florida

Scale: NTS

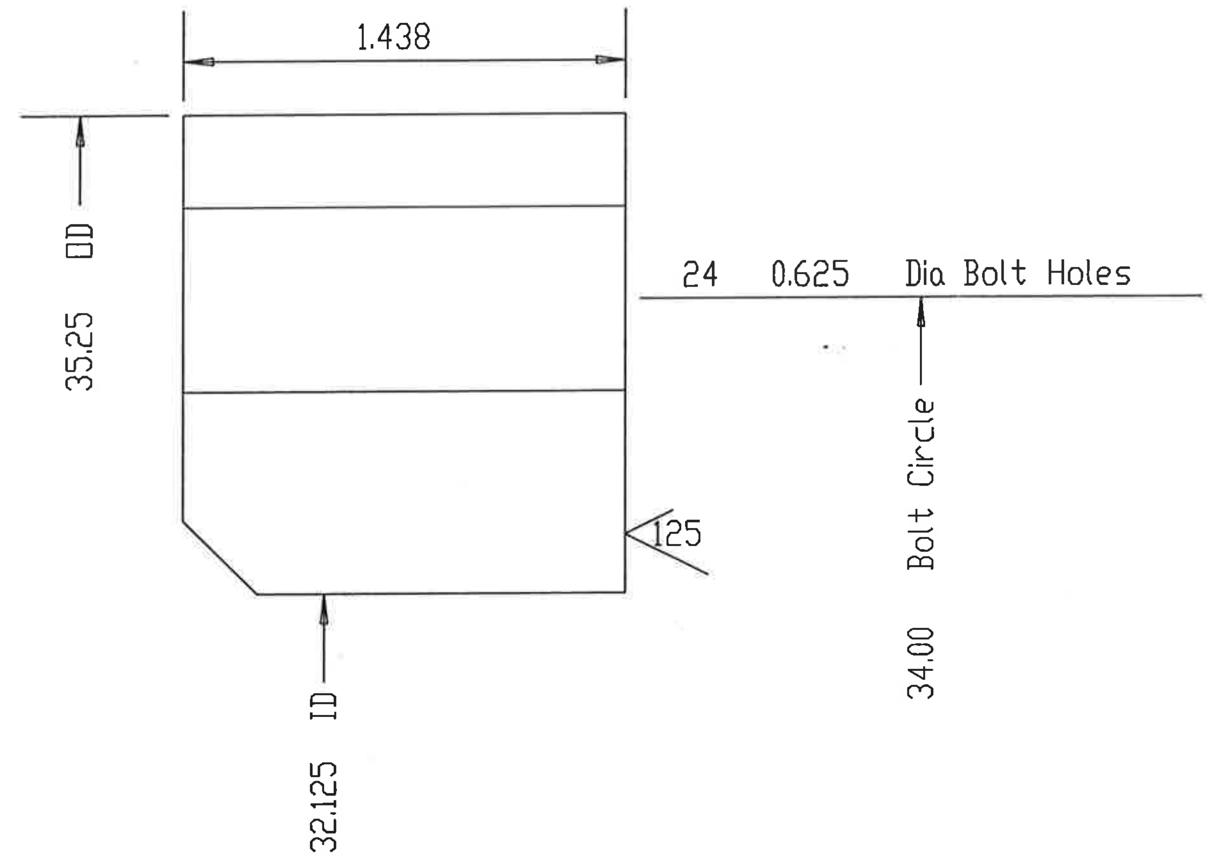
Rev:	Date:	Description	Dwg	Ckd	Appd
1	08-24-07	Issued for Construction	KFF	DGB	PW
2	12-10-07	CERTIFIED AS-BUILT	RJT	DGB	PW

ASME VIII-1 2004 A06
TEMA Type: BEM
Size: 31-240
TEMA Class: C

Rear Gasket Detail

Dwg No.: E-4201 17B

Rev: 2



(17) Fr 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 Construction, Inc.
Location: Bunge-Ergon
Reflux Condenser
Item No.: E-4201
Date: May 5, 2007 Job No.: 7793

DCR Construction, Inc.
Lakeland, Florida

Scale: NTS

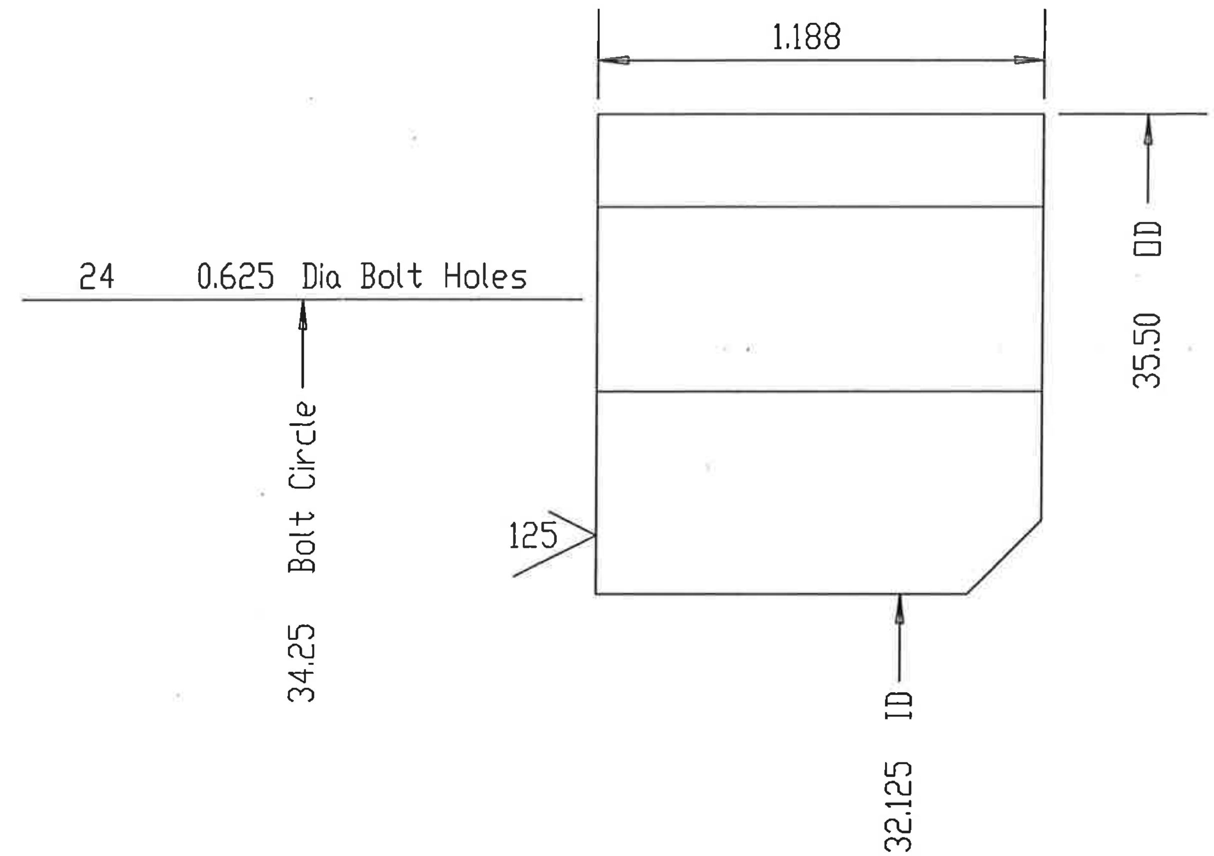
Rev:	Date:	Description	Dwg	Ckd	Appd
1	08-24-07	Issued for Construction	KFF	DGB	PW
2	12-10-07	CERTIFIED AS-BUILT	RJT	DGB	PW

ASME VIII-1 2004 A06
TEMA Type: BEM
Size: 31-240
TEMA Class: C

Flange Detail

Dwg No.: E-4201 18A

Rev: 2



(18) Re Hd Flng TubSh

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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 Construction, Inc.
Location: Bunge-Ergon
Reflux Condenser
Item No.: E-4201
Date: May 5, 2007 Job No.: 7793

DCR Construction, Inc.
Lakeland, Florida

Scale: NTS

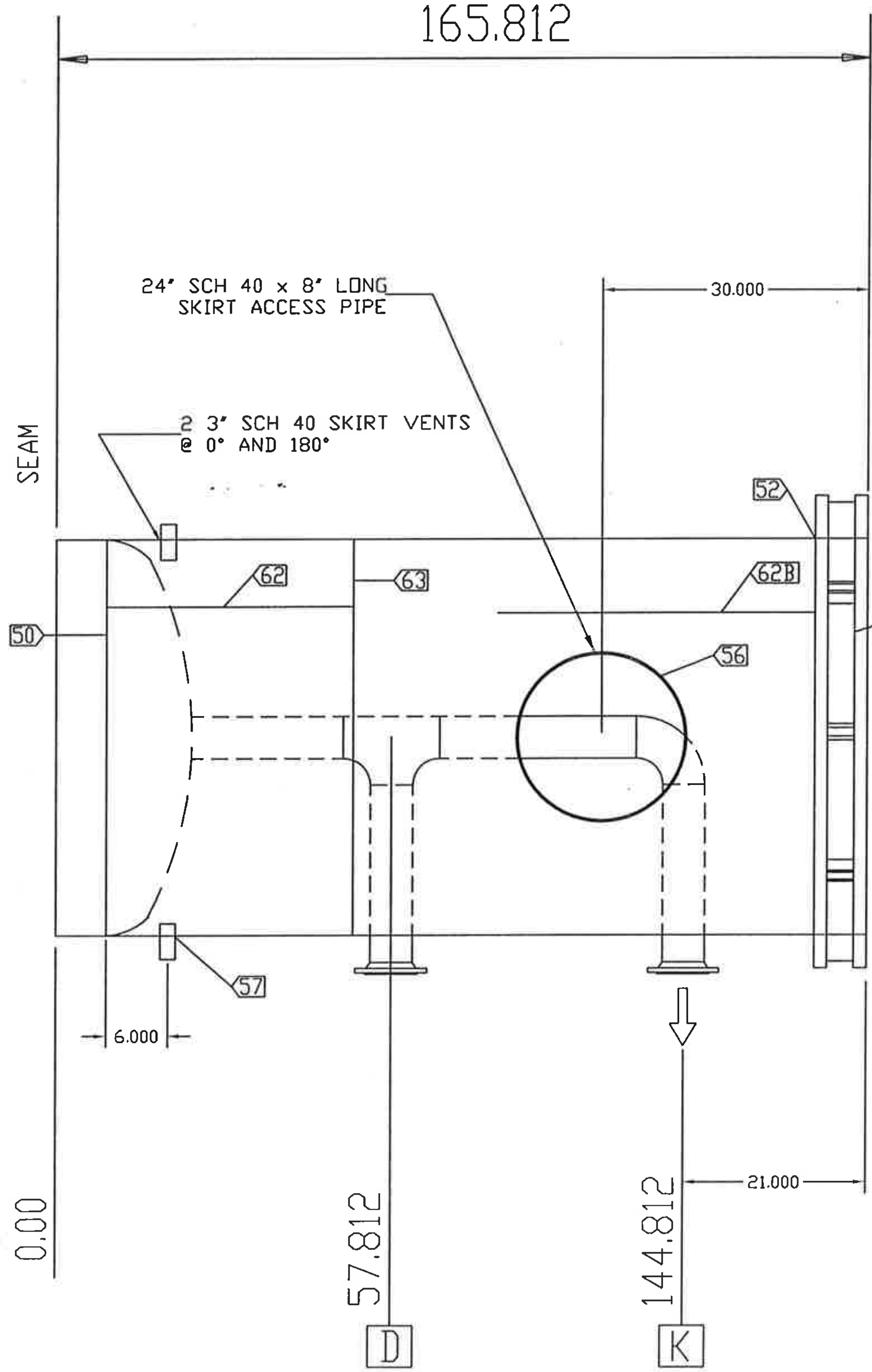
Rev:	Date:	Description	Dwg	Ckd	Appd
1	08-24-07	Issued for Construction	KFF	DGB	PW
2	12-10-07	CERTIFIED AS-BUILT	RJT	DGB	PW

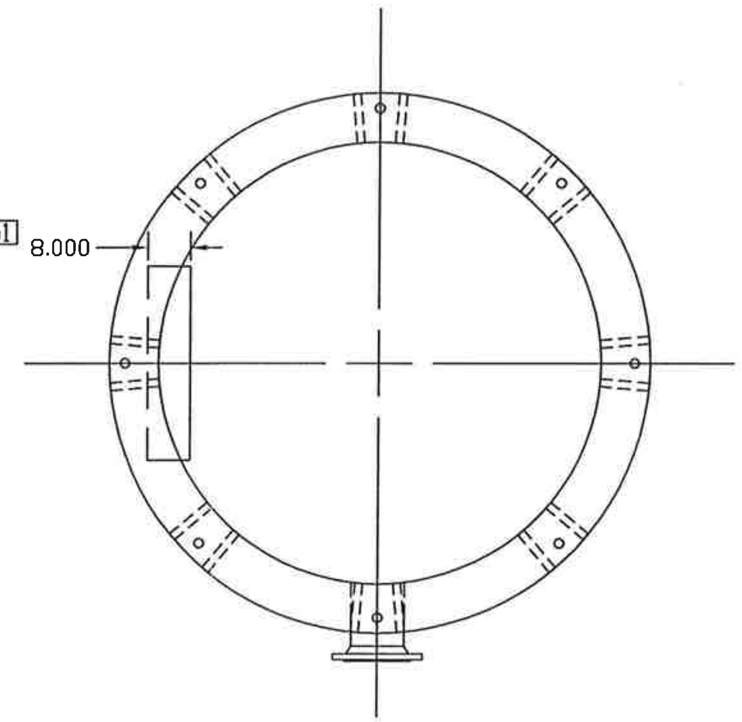
ASME VIII-1 2004 A06
TEMA Type: BEM
Size: 31-240
TEMA Class: C

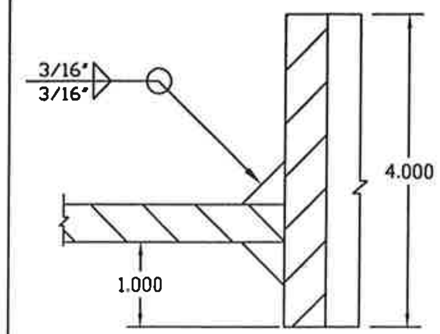
Flange Detail

Dwg No.: E-4201 18B

Rev: 2

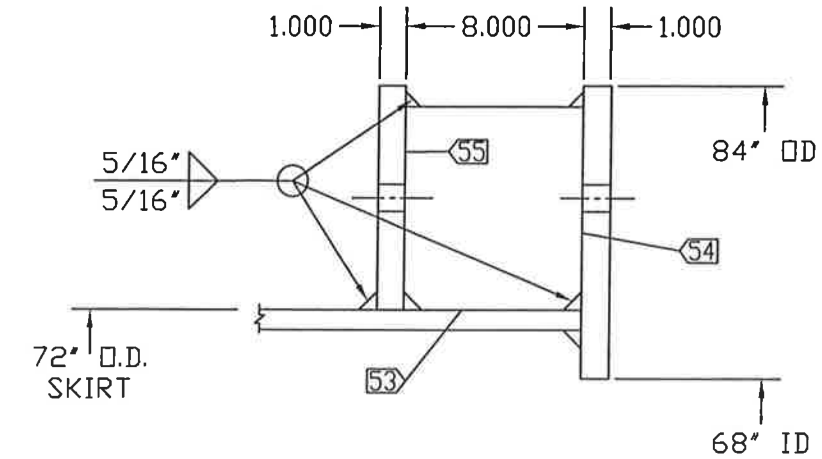




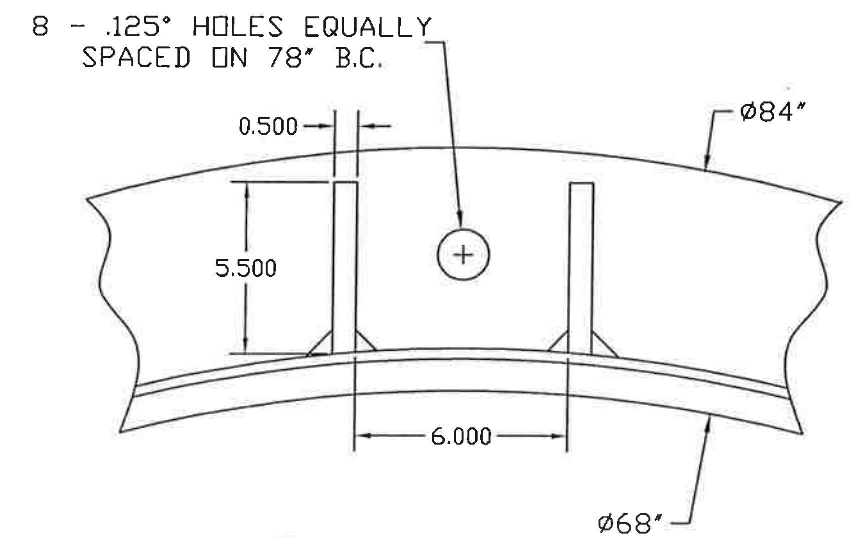


Skirt Vent Detail

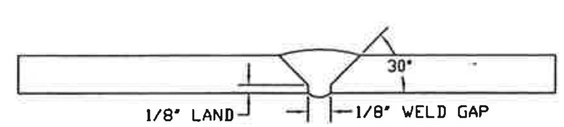
Archor Chair Detail
8 Required



Side View



Top View



Base Ring Weld Detail

Notes:
All Dimensions In Inches

HT/DCR Engineering, Inc.
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Phone: 863-904-2880 • Fax: 863-913-1091
Florida Engineering Business License No. 26522

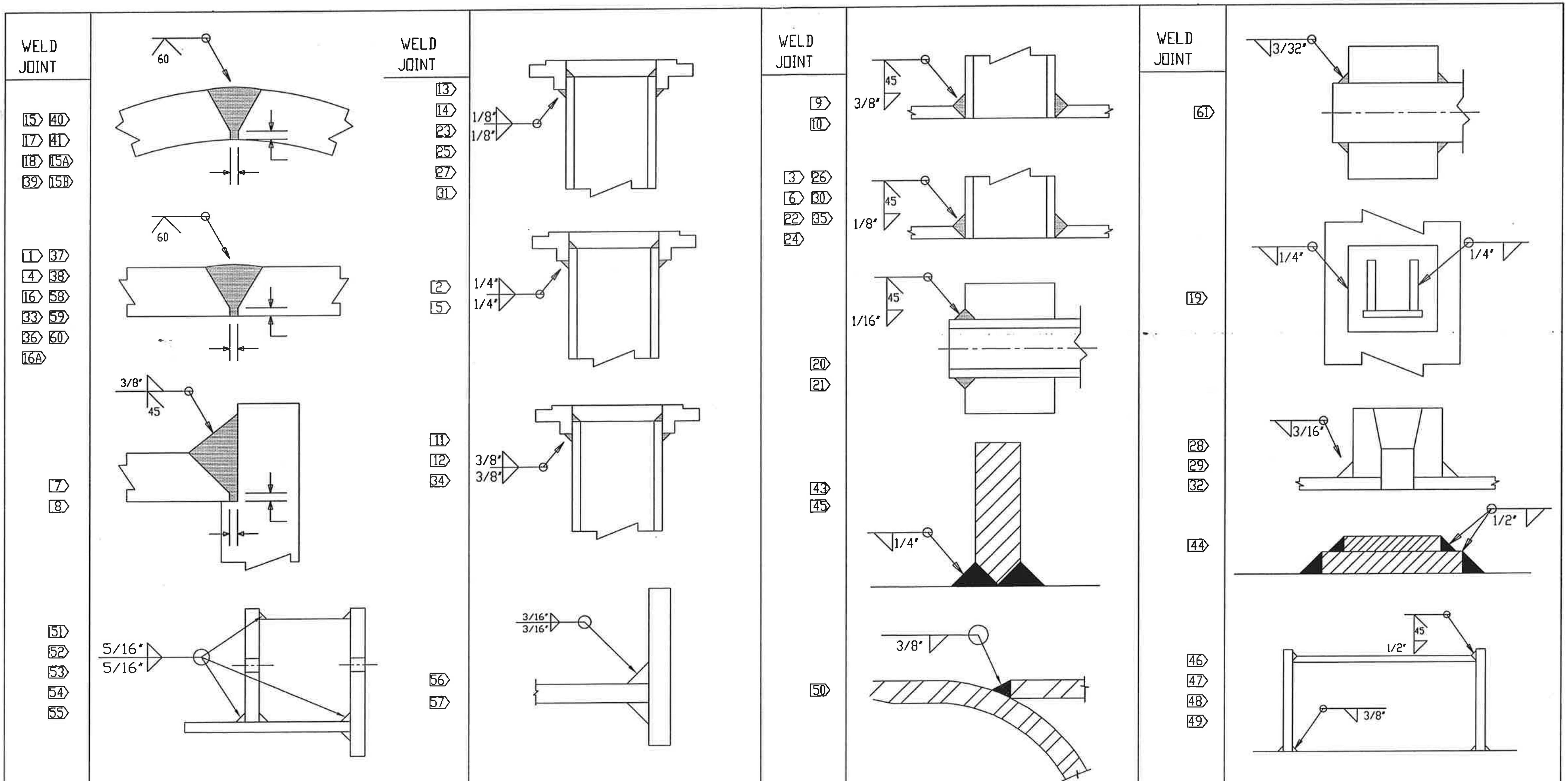
Company: DCR
Location: Bunge-Ergon
Reflux Condenser
Item No.: E-4201
Date: April 2, 2007 Job No.: 7793

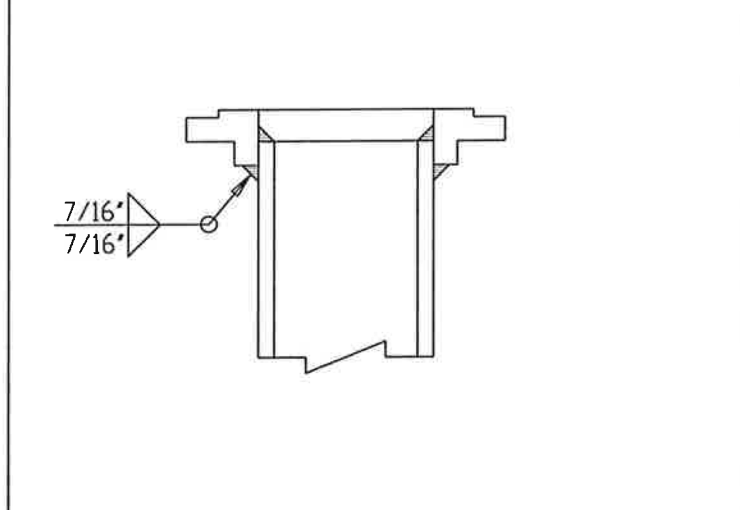
DCR Construction, Inc
Lakeland, FL

Scale: NTS

Rev:	Date:	Description	Dwg	Ckd	Appd
2	08-24-07	Issued For Construction	KFF	DGB	PW
3	10-09-07	Revised Per DcR Request	KFF	DGB	PW
4	12-10-07	CERTIFIED AS-BUILT	RJT	DGB	PW

ASME VIII-1 2004 A06	Skirt Details
TEMA Type: BEM	
Size: 31-240	Dwg No.: E-4201-19 — Rev: 4
TEMA Class: C	





Notes:
All Dimensions In Inches
Welding in accordance with Code

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Phone: 863-904-2880 • Fax: 863-913-1091
Florida Engineering Business License No. 26522

Company: DCR
Location: Bunge-Ergon
Reflux Condenser
Item No.: E-4201
Date: April 2, 2007 Job No.: 7793

DCR Construction, Inc
Lakeland, FL

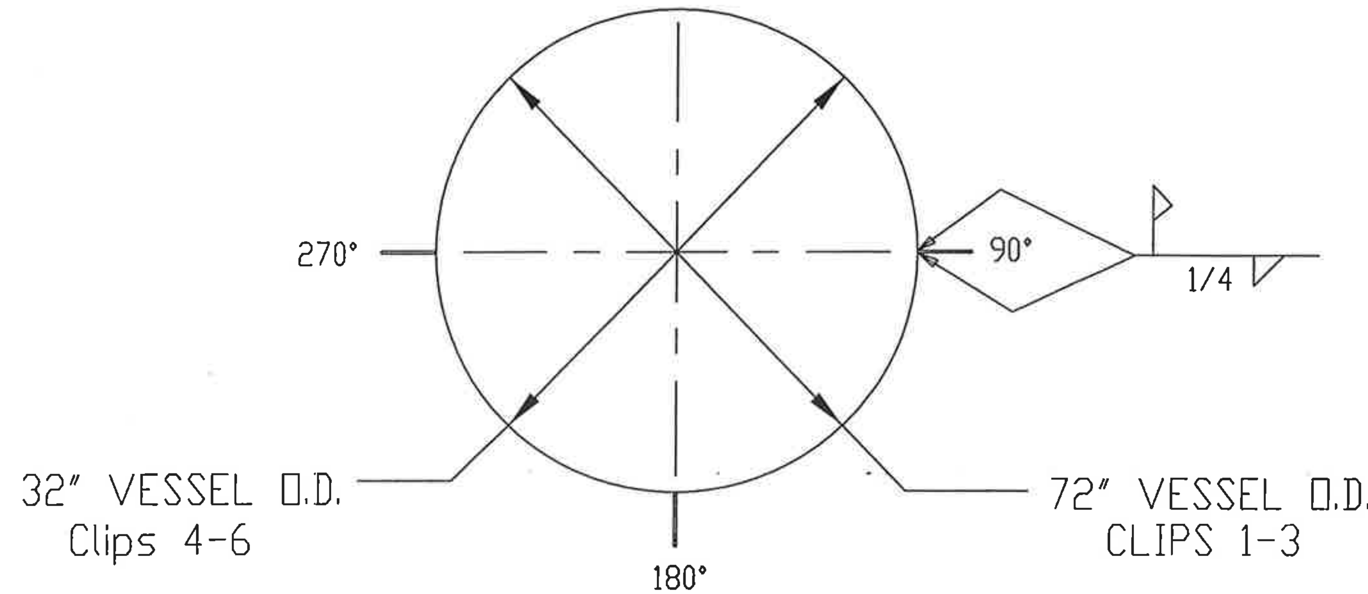
Scale: NTS

Rev:	Date:	Description	Dwg	Ckd	Appd
3	12-07-07	Issued for Construction	KFF	DGB	PW
4	12-10-07	CERTIFIED AS-BUILT	RJT	DGB	PW

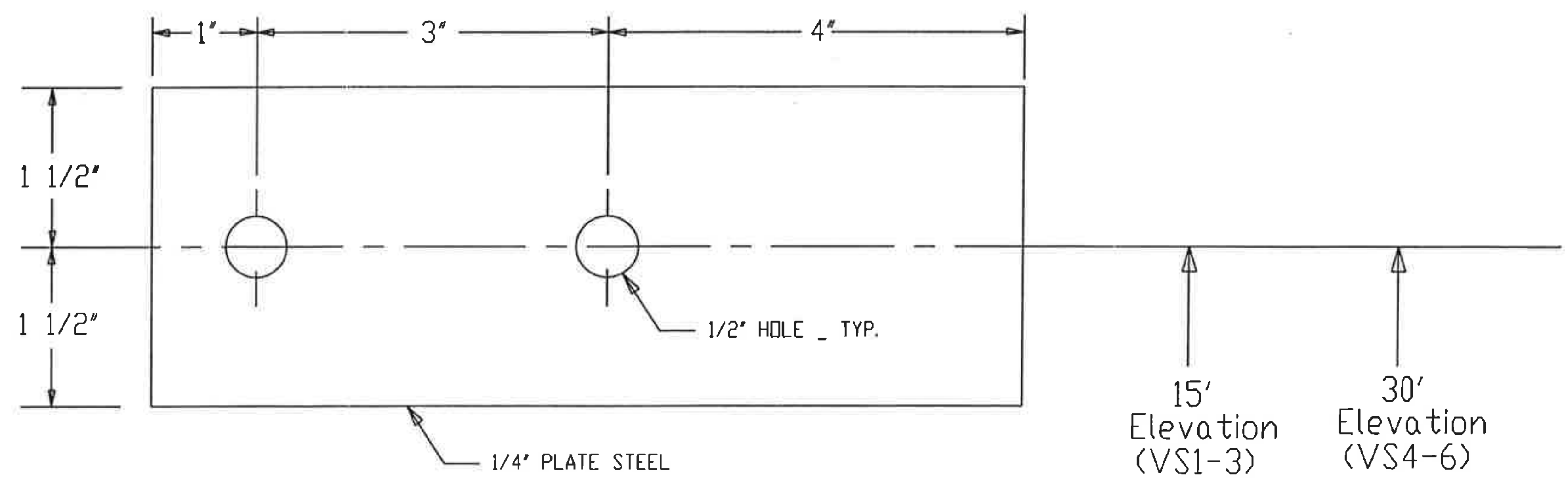
ASME VIII-1 2004 A06
TEMA Type: BEM
Size: 31-240
TEMA Class: C

Weld Joint Detail

Dwg No.: E-4201-20
Rev: 4



Orientation



Notes:
(1) All Dimensions In Inches
(2) Vessel Clips 1-3 are SA-240 304SS
(3) Vessel Clips 4-6 are SA-516 Grd70

Company: DCR Construction, Inc.
Location: Bunge-Ergon
Reflux Condenser
Item No.: E-4201
Date: September 12, 2007 Job No.: 7793

DCR Construction, Inc.
Lakeland, Florida

Scale: NTS

Rev:	Date:	Description	Dwg	Ckd	Appd
0	09-12-07	Issued for Construction	KFF	DGB	PW
1	12-10-07	CERTIFIED AS-BUILT	RJT	DGB	PW

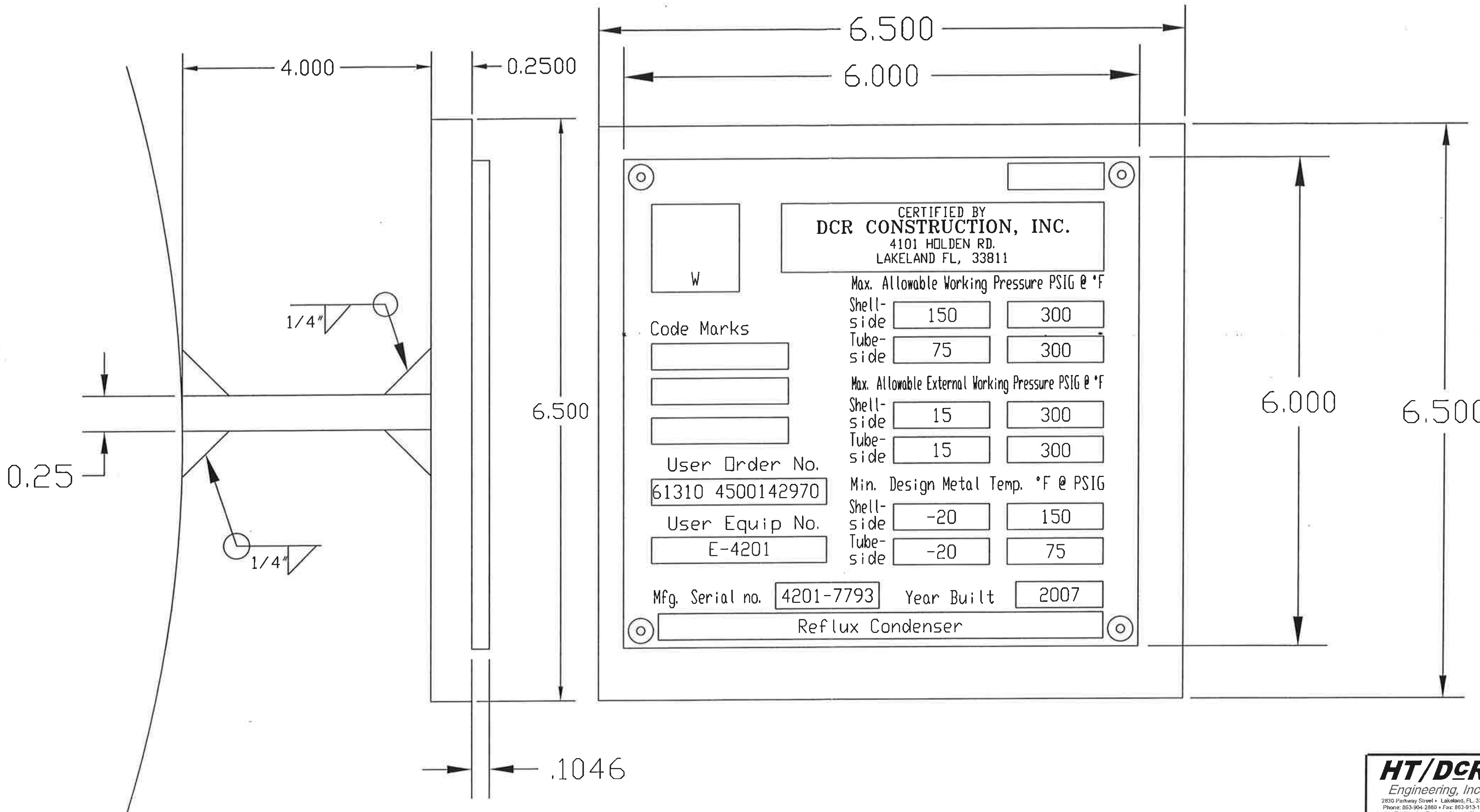
ASME VIII-1 2004 A06
TEMA Type: BEM
Size: 31-240
TEMA Class: C

Vessel Clips

Dwg No.: E-4201 21

Rev: 1

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



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Engineering, Inc.
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Phone: 863-904-2880 • Fax: 863-913-1091
Florida Engineering Business License No. 26522

Notes:
All Dimensions In Inches
Etching .004" Min. Depth

Company: DCR
Location: Bunge-Ergon
Reflux Condenser
Item No.: E-4201
Date: April 30, 2007 Job No.: 7793

DCR Construction, Inc
Lakeland, FL

Scale: NTS

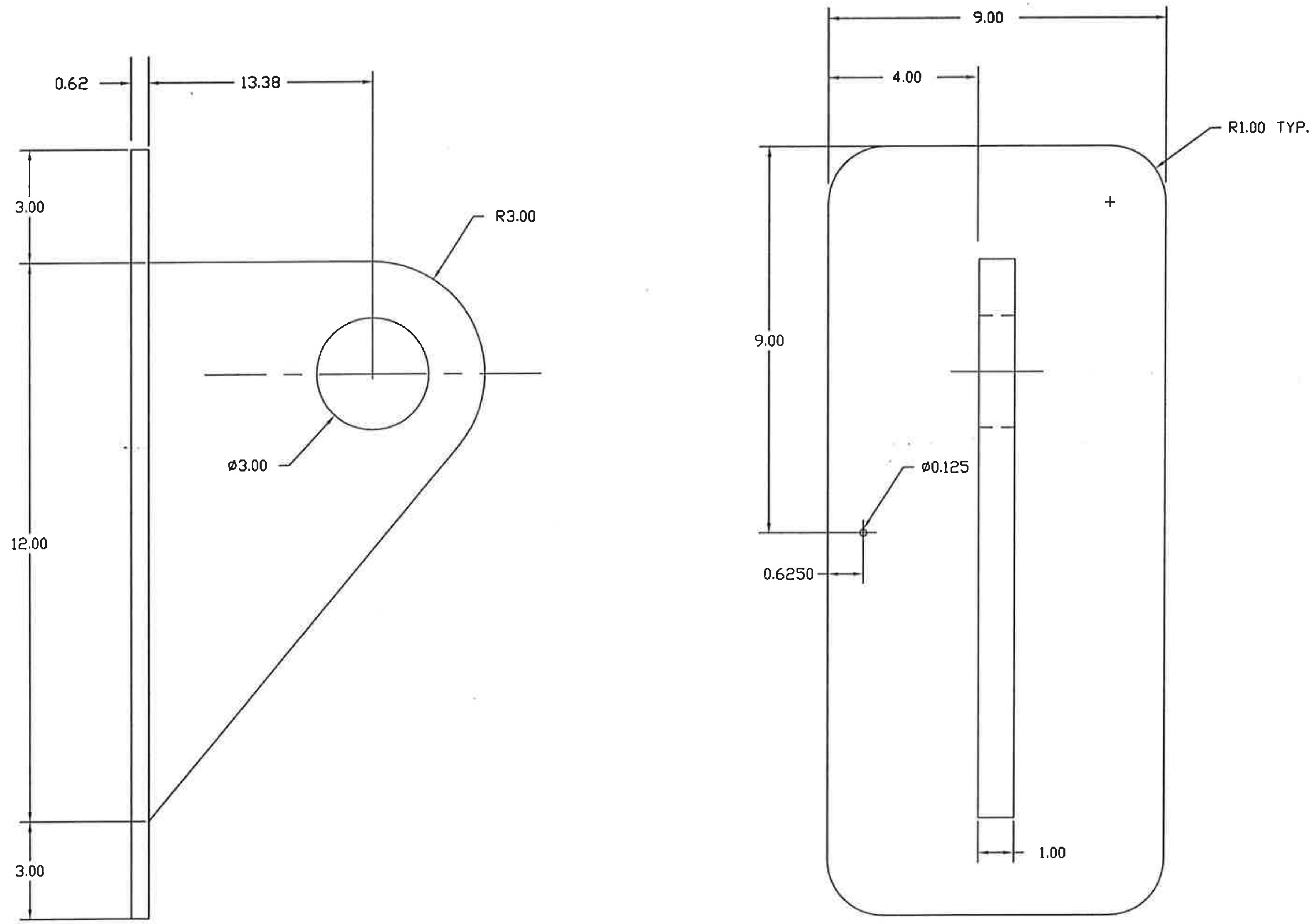
Rev:	Date:	Description	Dwg	Ckd	Appd
1	08-24-07	Issued for Construction	KFF	DGB	PW
2	12-10-07	CERTIFIED AS-BUILT	RJT	DGB	PW

ASME VIII-1 2004 A06
TEMA Type: BEM
Size: 31-240
TEMA Class: C

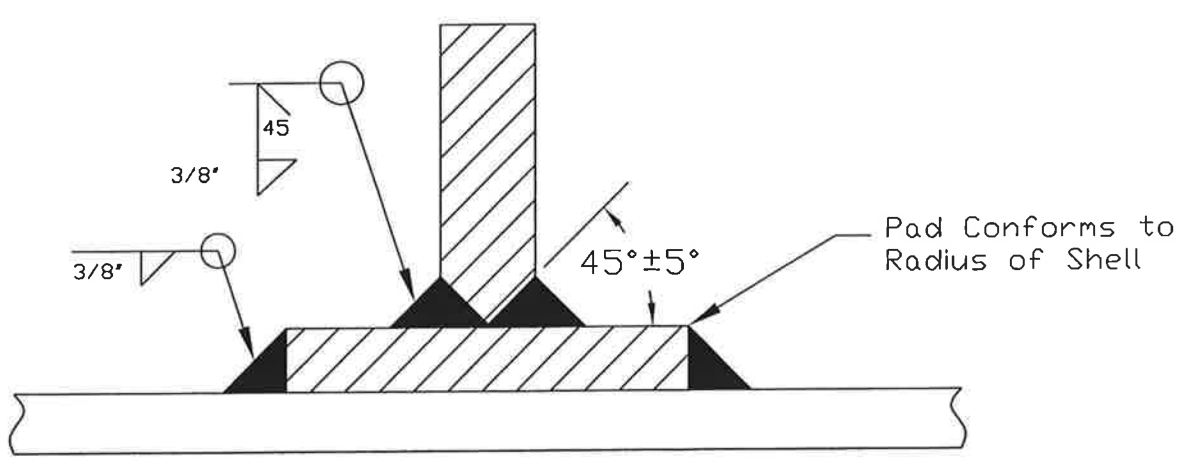
Code Data Plate

Dwg No.: E-4201 22

Rev: 2



LIFTING LUG
4 REQUIRED



HT/DCR
Engineering, Inc.
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Phone: 863-904-2880 • Fax: 863-913-1091
Florida Engineering Business License No. 26522

Notes:
All Dimensions In Inches

Company: DCR
Location: Bunge-Ergon
Reflux Condenser
Item No.: E-4201
Date: March 13, 2007 Job No.: 7793

DCR Construction, Inc
Lakeland, FL

Scale: NTS

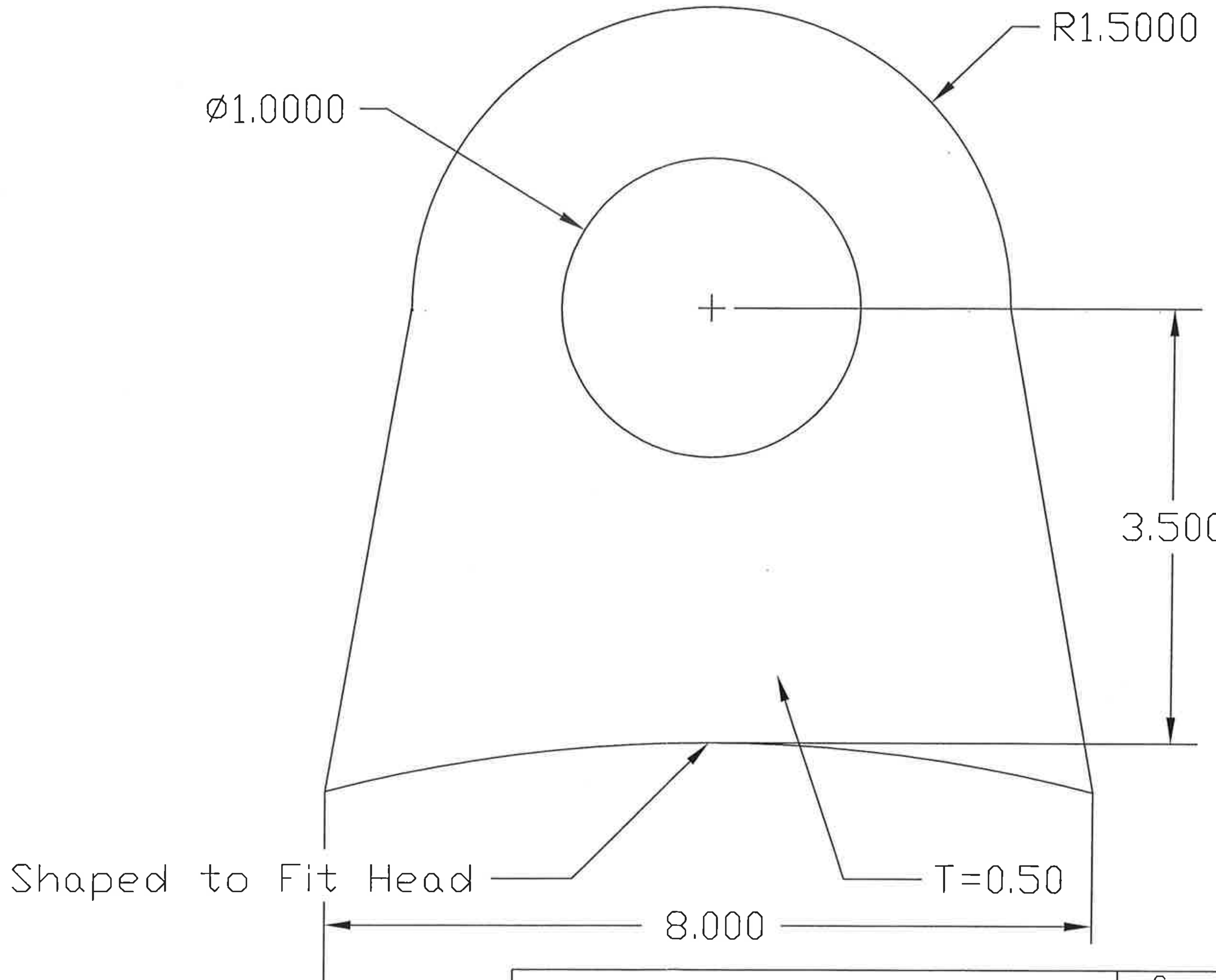
Rev:	Date:	Description	Dwg	Ckd	Appd
1	08-23-07	Issued for Construction	KFF	DGB	PW
2	12-10-07	CERTIFIED AS-BUILT	RJT	DGB	PW

ASME VIII-1 2004 A06
TEMA Type: BEM
Size: 31-240
TEMA Class: C

Lifting Lug Detail

Dwg No.: E-4201 23A

Rev: 2



FRONT HEAD
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
Reflux Condenser
Item No.: E-4201
Date: March 2, 2007 Job No.: 7793

DCR Construction, Inc
Lakeland, FL

Scale: NTS

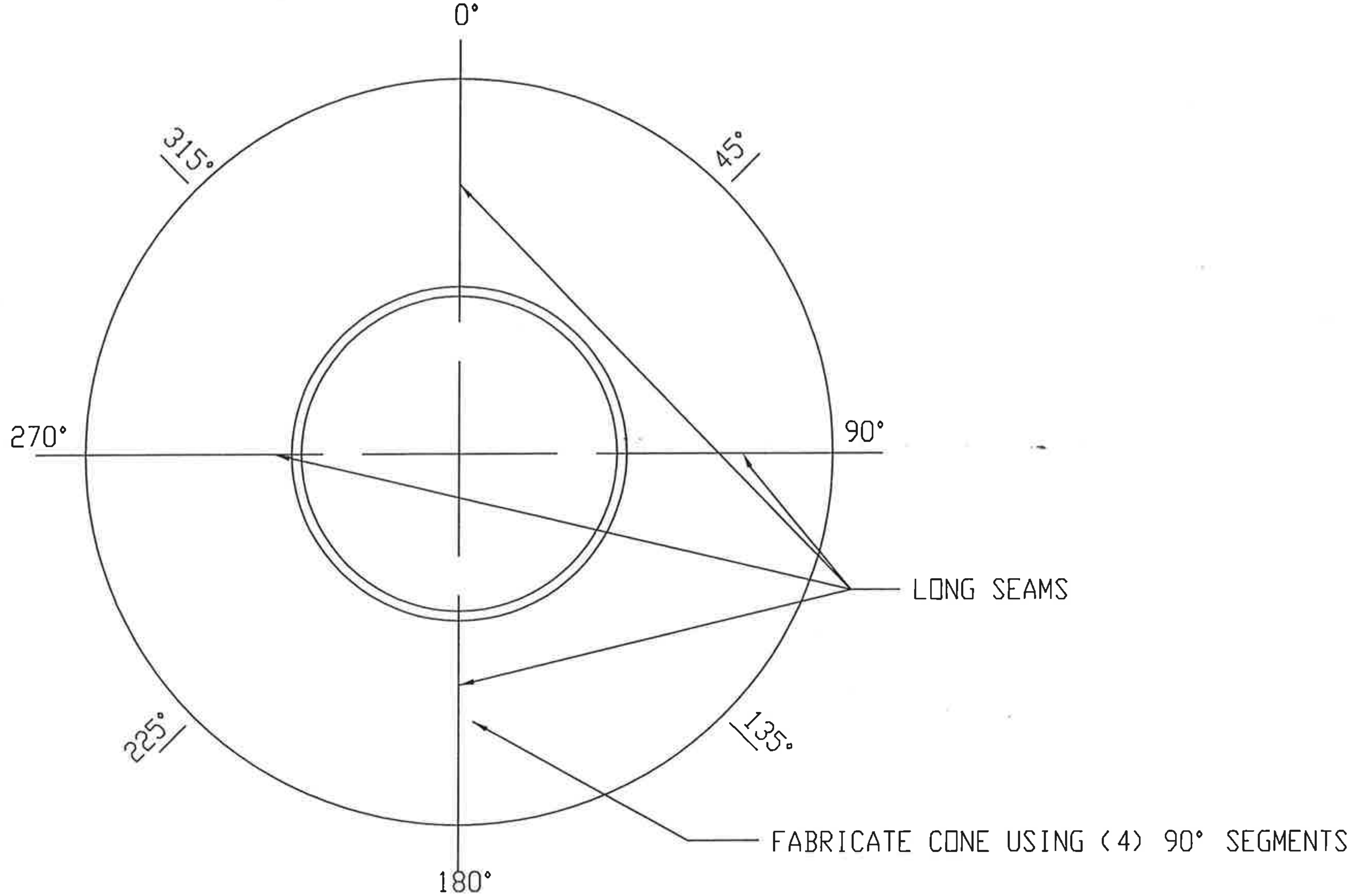
Rev:	Date:	Description	Dwg	Ckd	Appd
1	08-24-07	Issued for Construction	KFF	DGB	PW
2	12-10-07	CERTIFIED AS-BUILT	RJT	DGB	PW

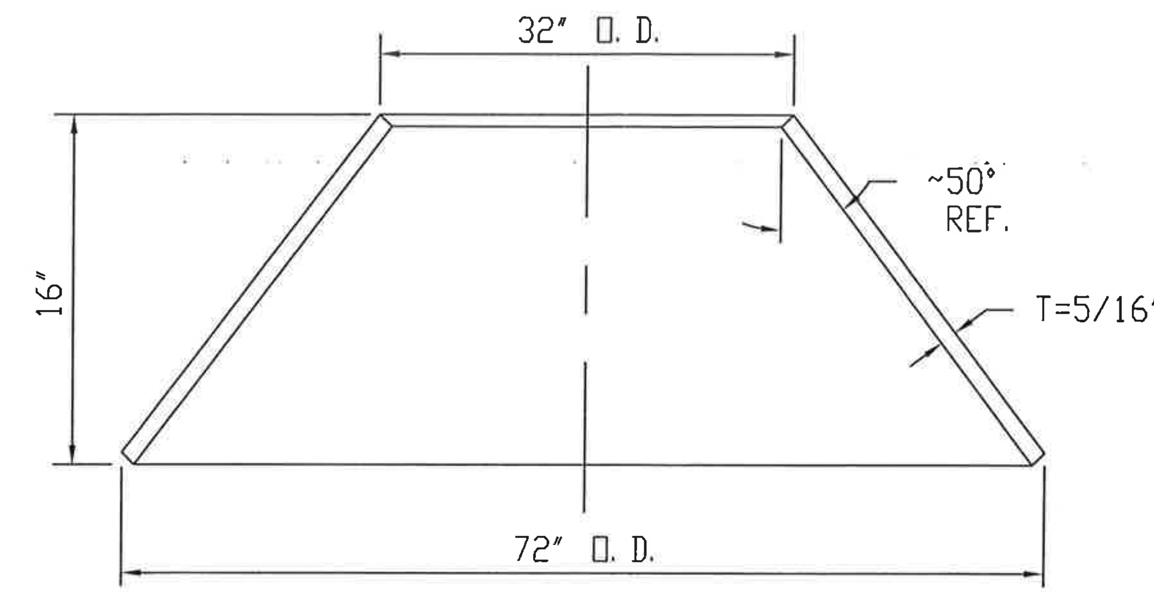
ASME VIII-1 2004 A06
TEMA Type: BEM
Size: 31-240
TEMA Class: C

Lifting Lug Detail

Dwg No.: E-4201 23B

Rev: 2





(4) REQ'D 5/16" THK
SA-240-304 S/S

Notes:
All Dimensions In Inches

HT/DCR Engineering, Inc.

Scale: NTS

Company: DCR
Location: Bunge-Ergon
Reflux Condenser
Item No.: E-4201
Date: March 2, 2007 Job No.: 7793

DCR Construction, Inc
Lakeland, FL

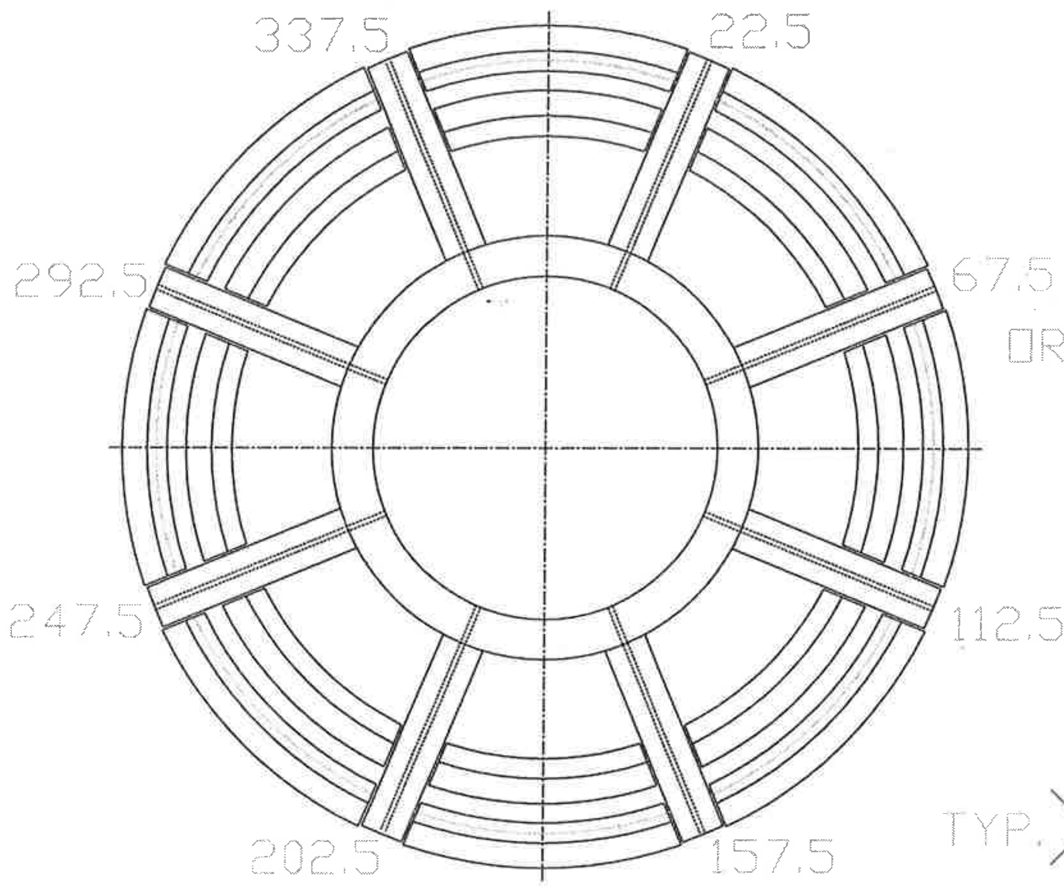
Rev:	Date:	Description	Dwg	Ckd	Appd
1	08-24-07	Issued for Construction	KFF	DGB	PW
2	12-10-07	CERTIFIED AS-BUILT	RJT	DGB	PW

ASME VIII-1 2004 A06
TEMA Type: BEM
Size: 31-240
TEMA Class: C

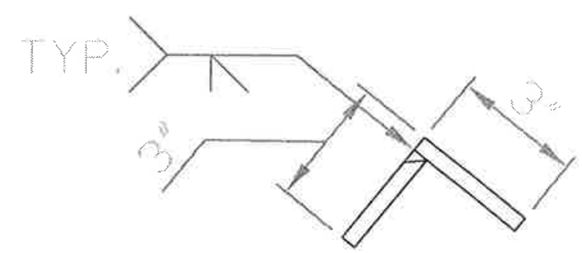
Transition Detail

Dwg No.: E-4201 24

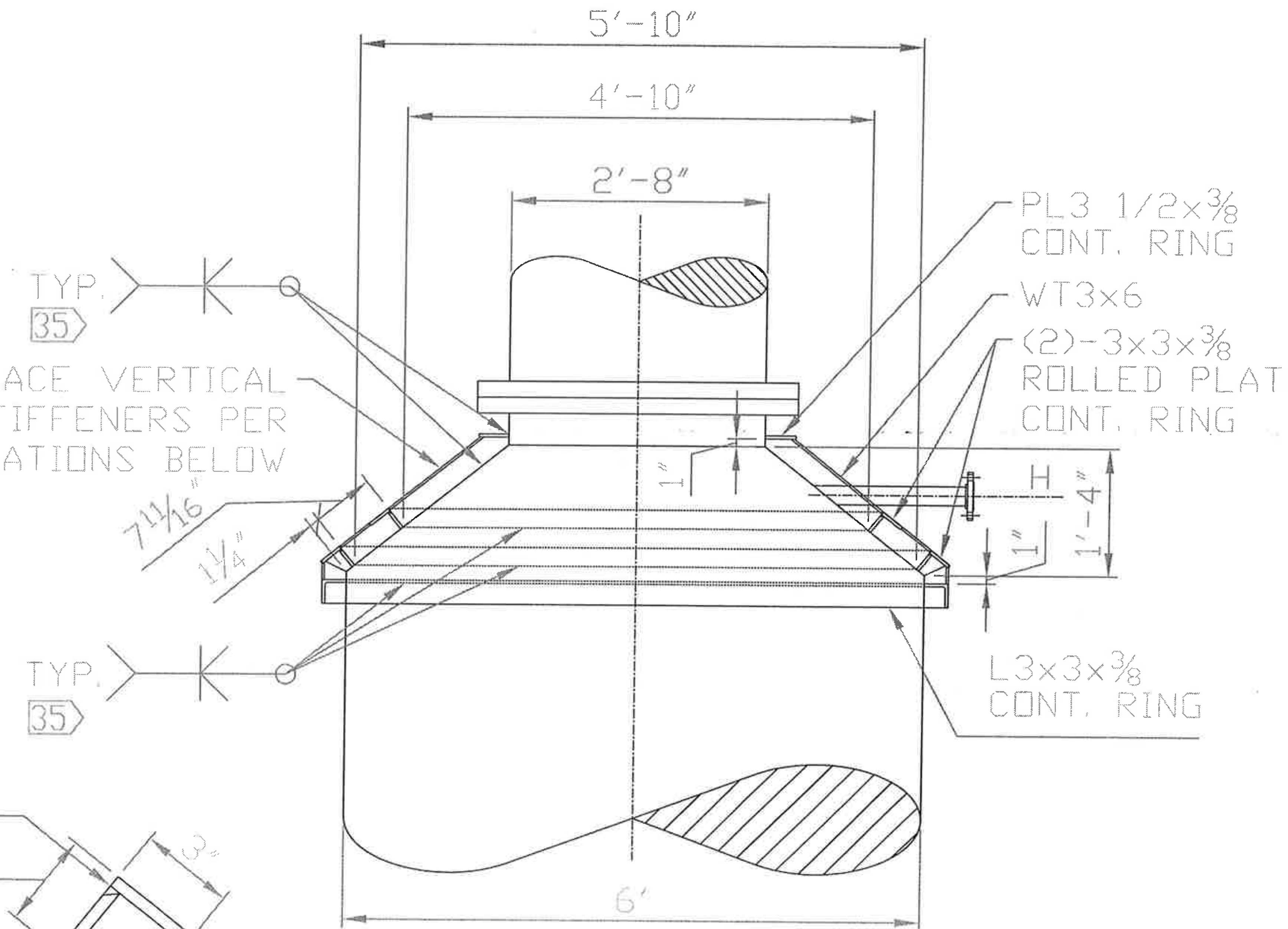
Rev: 2



PLAN - ORIENTATION
SPACE VERTICAL STIFFENERS
EVERY 45°
(8 TOTAL)



ROLLED
FLAT PLATE



E4201 - CONICAL SECTION
ELEVATION VIEW

Notes:
All Dimensions In Inches

Company: DCR
Location: Bunge-Ergon
Reflux Condenser
Item No.: E-4201
Date: March 2, 2007 Job No.: 7793

DCR Construction, Inc
Lakeland, FL

Scale: NTS

HT/DCR *Engineering, Inc.*
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Florida Engineering Business License No. 26522

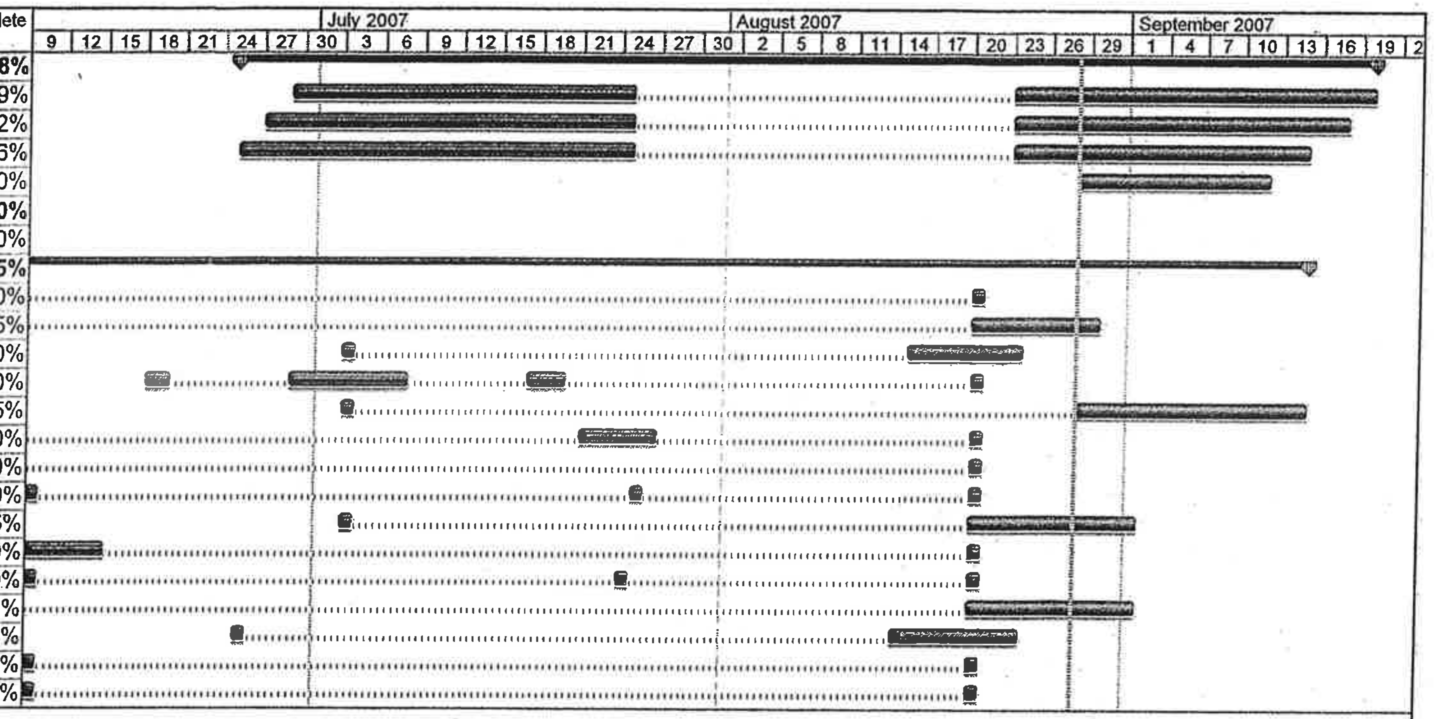
Rev:	Date:	Description	Dwg	Ckd	Appd
0	09-26-07	Issued for Construction	FJR	FTP	DC
1	10-04-07	Issued for Construction	FJR	FTP	DC
2	12-10-07	CERTIFIED AS-BUILT	RJT	DGB	PW

ASME VIII-1 2004 A06
TEMA Type: BEM
Size: 31-240
TEMA Class: C

Transition Reinforcement

Dwg No.: E-4201 25
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%

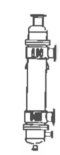


Heat Exchanger Specification Sheet

1	Company: DELTA-T CORPORATION	Phone: (757) 220-2955		
2	Location: WILLIAMSBURG, VIRGINIA	Fax: (757) 229-1705		
3	Service of Unit: REFLUX CONDENSER			L2357 REV C
4	Item No.: E4201-L	Your Reference: 50MM GPY	Job No.: 61310 Bunge-Ergon Vicksburg, LLC	
5	Date: 6 February 2007	Prepared by: RS	Checked by: AC	
6	Size 31 / 240 in	Type BEM vert	Connected in 1 parallel	1 series
7	Surf/unit(eff.) 3187.1 ft2	Shells/unit 1	Surf/shell (eff.) 3187.1	ft2

8	PERFORMANCE OF ONE UNIT					
9	Fluid allocation		Shell Side		Tube Side	
10	Fluid name		COOLING WATER		REFLUX	
11	Fluid quantity, Total	lb/h	2351168		113272	
12	Vapor (In/Out)	lb/h			113261	48
13	Liquid	lb/h	2351168	2351168		113212
14	Noncondensable	lb/h			11	
15						
16	Temperature (In/Out)	F	88	108	186.3	170
17	Dew / Bubble point	F			184.16	
18	Density	lb/ft3	62.241	62.03	0.107	46.541
19	Viscosity	cp	0.781	0.628	0.011	0.455
20	Molecular wt, Vap				41.3	41.93
21	Molecular wt, NC					44.01
22	Specific heat	BTU/(lb*F)	1.0007	1.0001	0.4285	0.7662
23	Thermal conductivity	BTU/(ft*h*F)	0.352	0.36	0.011	0.113
24	Latent heat	BTU/lb			402.6	404.3
25	Pressure	psi	60		18	
26	Velocity	ft/s	4.56		154.15	
27	Pressure drop, allow./calc.	psi	15	13.179	2	1.453
28	Fouling resist. (min)	ft2*h*F/BTU	0.001		0.0005	
29	Heat exchanged	47040270 BTU/h		MTD corrected	81.79	F
30	Transfer rate, Service	180.46	Dirty 197.19	Clean	286.03	BTU/(h*ft2*F)

31	CONSTRUCTION OF ONE SHELL				Sketch
32			Shell Side	Tube Side	
33	Design/Test pressure	psi	150 / Code	75 / Code	
34	Design temperature	F	300	300	
35	Number passes per shell		1	1	
36	Corrosion allowance	in	0.0625		
37	Connections	In	24 / 150 ANSI	18 / 150 ANSI	
38	Size/rating	Out	20 / 150 ANSI	3 / 150 ANSI	
39	in	Intermediate	/ 150 ANSI	/ 150 ANSI	



40	Tube No. 821	OD 0.75	0.049 in	Length 20 ft	Pitch 1	in	
41	Tube type Plain		Material	SS304	Tube pattern	30	
42	Shell CS	ID	OD 32 in	Shell cover			
43	Channel or bonnet	SS304		Channel cover			
44	Tubesheet-stationary	SS304		Tubesheet-floating			
45	Floating head cover			Impingement protection	None		
46	Baffle-crossing CS	Type triple seg	Cut(%d) 16 vert	Spacing: c/c	12.625	in	
47	Baffle-long	Seal type		Inlet	32.75	in	
48	Supports-tube	U-bend		Type			
49	Bypass seal	Tube-tubesheet joint		strength weld			
50	Expansion joint	Type					
51	RhoV2-Inlet nozzle 789	Bundle entrance	607	Bundle exit	1190	lb/(ft*s2)	
52	Gaskets - Shell side	Tube Side					
53	Floating head						
54	Code requirements	ASME Code Sec VIII Div 1		TEMA class	C		
55	Weight/Shell 12464.7	Filled with water	19818	Bundle	7736.3	lb	
56	Remarks	Shell inlet distributor belt to have 2-24 inch cutouts @ 180°,outlet distributor belt 2-20 inch cutouts @ 180°.					
57		Test run cooling water inlet temp at 88*F. Require 106.9% larger surface area than a standard unit.					
58							

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. Manufactured for: Delta-T Corporation 133 Waller Miller 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.) — 4201-7793 (Mfr's serial No.)

(CRN) — 4201-01 to 4201-25 (See Details) (Drawing No.) — 230 (Nat'l Bd No.) — 2007 (Year built)

5. ASME Code Section VIII Div 1 — Edition 2004, Addenda 2006 [Edition and Addenda (date)] — (Code Case No.) — [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.): 19' 8 5/8"

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	32" OD	4'	SA-516 GR70	0.375	0.0625	1	None	0.70	1	None	0.70		
1	32" OD	6' 10"	SA-516 GR70	0.375	0.0625	1	None	0.70	1	None	0.70		
1	32" OD	8' 10 ½"	SA-516 GR70	0.375	0.0625	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.)

If bolted, describe or sketch

, give dimensions ______

9. MAWP 150 psig (Internal) 15 (external) psig at max temp. 300 (internal) °F 300 (external) °F Min. design metal temp. -20 °F at 150 psig

10. Impact Test No Per UG-20(f) [Indicate yes or no and the component(s) impact tested] at test temperature of N/A °F

11. Hydro, Pneu., or comb. test press. 195 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.)] — 35.25" [Dia., In. (subject to press.)] — 1.75" (Nom. thk., in.) — 0 (Corr. Allow., in.) — Welded [Attachment (welded or bolted)]

SA-240 GR304 Floating (Mat'l Spec. No.)] — 35.50" (Dia., in.) — 1.188" (Nom. thk., in.) — 0 (Corr. Allow., in.) — Welded (Attachment)

13. Tubes SA-249 TP304 Wld Tube (Mat'l Spec. No., Grade or Type) — 0.75" (O.D., in.) — 0.049" (Nom. thk., in. or gauge) — 821 (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): 5 (b) Overall Length (ft & in.): 12' 2 7/16"

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	31.5 ID	27.25	SA-240 GR304	0.25	0	1	None	0.70	1	None	0.70		
1	31.375 ID	6	SA-240 GR304	0.3125	0	1	None	0.70	1	None	0.70		
1	71.375 ID	97.188	SA-240 GR304	0.3125	0	1	None	0.70	1	None	0.70		

15. Heads: (a) SA-240 GR304 (Matl. Spec. No., Grade or Type) (H.T. – Time & Temp) (b) SA-240 GR304 (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	0.0936"	0			2:1					X	1	None	0.70
	Bottom	0.2961"	0			2:1					X	1	None	0.70

If removable, bolts used (describe other fastenings) SA-193 GRB7 0.50" (48) (Mat'l Spec. No. Grade, size, No.)

FORM U-4 MANUFACTURER'S DATA REPORT SUPPLEMENTARY SHEET
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. 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 (Horiz., vert., or sphere) — Condenser (Tank, separator, heat exh., etc.) — 4201-7793 (Mfg's serial No.)

(CRN) — 4201-01 to 4201-25 (Drawing No.) — 230 (Nat'l Bd No.) — 2007 (Year built)

Data Report Item Number	Remarks
#14	(1) Shell section 71.375" 10 ½" SA-240 GR304 0.3125" 0 Type 1 None 0.70 Type 1 None 0.70
	(1) Conical Section 16" Length x 71.375" ID x 31.375" ID SA-240 GR304 0.3125 0 Type 1 None 0.70 Type 1 None 0.70
#19	Nozzle (J) 0.50" Half Cplg SA-182 F304 3000# 0 Inherent UW-16.1 Vapor Chamber
	Nozzle (E) Inlet 6" RFSO SA-312-304 SA-182 F304 0.432 0 Inherent UW-16.1 Welded Vapor Chamber
#6	(2) Vapor Belt sections Diameter 46" length 29" (Upper) 34.5" (Lower) Material SA-516 GR70 Thickness 0.500" Long. Joint Cat A Type 1 None 0.70 Circumference Joint A, B & C Type 1 & 2 None 0.70 Includes Closure Ring Material SA-516 GR70 Thickness 0.750" Joint UW 31.1C

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

Date 12/12/07 Name DCR Construction, Inc. (Manufacturer) Signed [signature] (Representative)

Date 12-12-07 Name [signature] (Authorized Inspector) Commission NB 10374 AB FL 420 (Nat'l Board incl. Endorsement, State, Province and No.)

DCR Construction, Inc.

EXHIBIT 11

PRESSURE TEST REPORT

Utility/Plant 7793-4201 Shell Side   Job No. 7793

Material Specification SA-240, Gr. 304

Pipe Size Range 32" Diameter (O.D.)   Wall Thickness Range 0.375"

Design Pressure 150 psig   PSI Test Pressure 195 psig

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 0-300 PSI ☆ Calibration Date 7/11/07

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 [signature] Date 12/11/07

Q.C. Inspector [signature] Date 12/6/07

Authorized Inspector [signature] for R. Snyder Date 12-6-07

Customer Inspector ______ Date ______

DCR Construction, Inc.

EXHIBIT 11

PRESSURE TEST REPORT

Utility/Plant 7793-4201 Tube Side Job No. 7793

Material Specification SA-249, Gr. 304

Pipe Size Range 0.75" Diameter Wall Thickness Range 0.049"

Design Pressure 75 psig PSI Test Pressure 91 psig

* Tubesheets = (Front)@ 35.25" x 1.4375", (Rear)@ 35.50" x 1.75", 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. 3901-15 Max. Range 0-200 PSI ☆ Calibration Date 11/26/07

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 [ ] Plant Water [ ] Condensate [ ] Treated Water

[ ] Demineralized Water [X] Other Air

Duration at Test Pressure ______ Hours 1 Minutes 15

Remarks ______

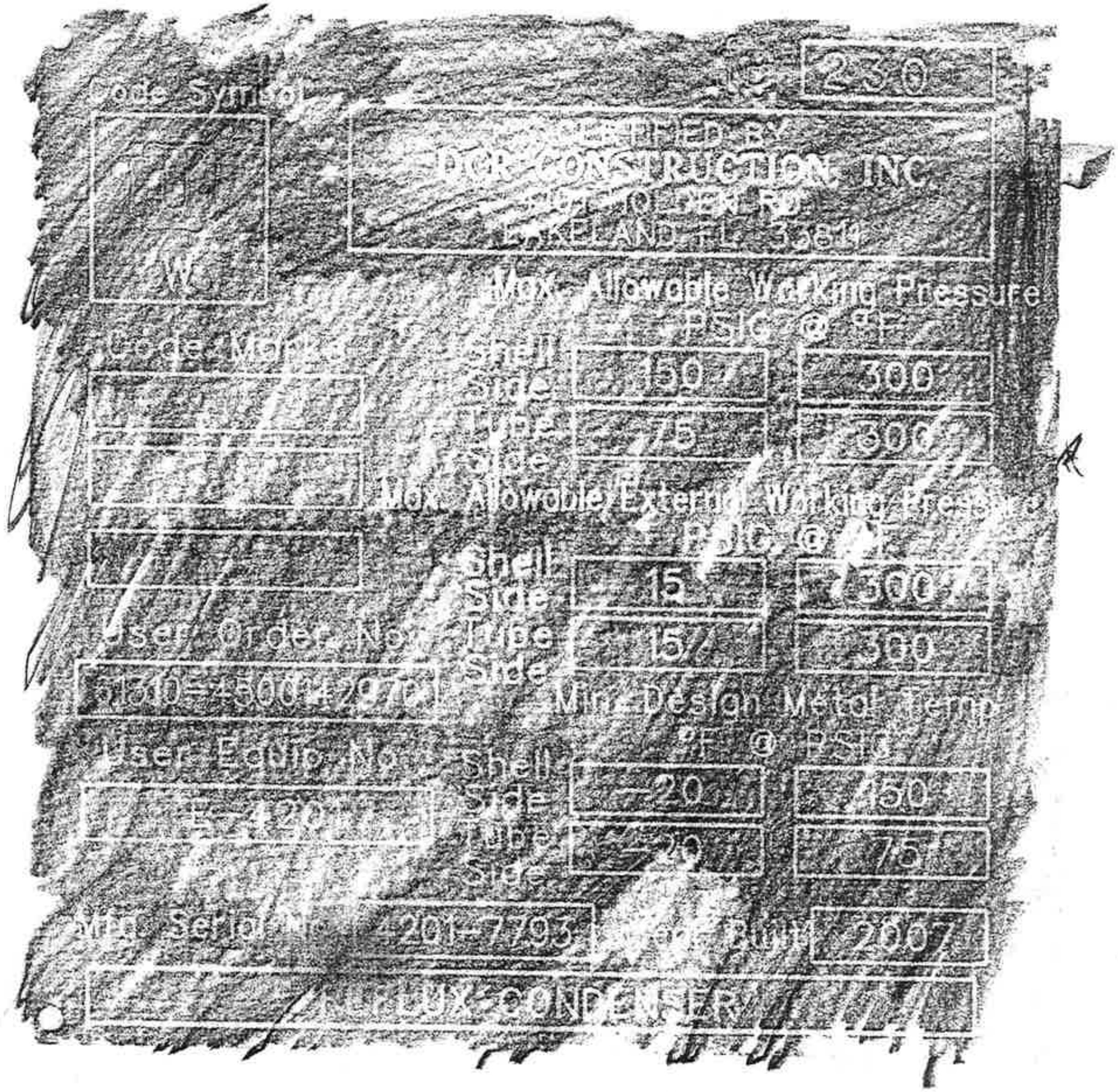
Test Results Acceptable

Project Manager/Superintendent [signature] Date 12/11/07

Q.C. Inspector [signature] Date 12/11/07

Authorized Inspector [signature] Date 12-11-07

Customer Inspector [signature] Date 12/11/07


Code Symbol
W
230
CERTIFIED BY
DCR CONSTRUCTION, INC.
LAKELAND, FL 3381
Max. Allowable Working Pressure
PSIG @ °F
Code Marks
Shell Side 150 300
Tube Side 75 300
Max. Allowable External Working Pressure
PSIG @ °F
Shell Side 15 300
Tube Side 15 300
User Order No.
Min. Design Metal Temp
°F @ PSIG
User Equip. No.
Shell Side 20 150
Tube Side 20 75
Serial No. 4201-7793
2007
CONDENSER

Design Specifications – Front Head to Rear flange

TEMA Class		Shell Side	Tube Side	Tubesheets
Design pressure	psi	150	75	
Vacuum design pressre	psi	15	15	
Test pressure	psi	195	97.5	
Design temperature	F	300	300	300
Average metal temperature	F	95	126	126
Corrosion allowance	in	0.0625		
Front tubesheet corrosion allow	in			
Rear tubesheet corrosion allow	in			
Radiographing		None	None	
Number of passes		1	1	
Nozzle flange rating		150	150	
Post weld heat treatment		No	No	
Code	ASME Section VIII Div.1 2004 A06		TEMA Eighth Edition 1999	
Front Head to Rear FLangeWeights	**Empty:** 12942	**Full:**19476	**Bundle:**7778	**lbf**
Weight Vessel / Vapor Chbr	**Empty:** 16116	**Full:**39452	**Bundle:**7778	**lbf**
Full Weight with Skirt	**Empty:** 21116	**Full:**44452	**Bundle:**7778	**lbf**

Cylinders/Covers

		Front Head		Shell	Rear Head		Shell Cover		Tubes
		Cover	Cyl.	Cyl.	Cyl.	Cover	Cyl.	Cover	
Head type		Ellipsoidal							
Outside diameter	in	32	32	32					0.75
Calculated thk.	in	0.0936	0.114	0.2332					0.0021
TEMA minimum thk.	in	0.25	0.25	0.375					
Actual thickness	in	0.25	0.25	0.375					0.049
X-ray		None	None	None					
Joint efficiency		None	None	None					
Corrosion allowance	in			0.0625					
External pressure	psi	15	15	15					165
Length Ext.Press.	in		27.25	198.75					240
Maximum Ext.Press.	psi	66.231	79.855	34.128					956.011
Minimum thk. Ext.Press.	in	0.087	0.099	0.286					0.016
Max.length Ext.Press.	in		235.5	1640					720

Nozzles

Nozzle designator		A	B	C
Vessel side		Shell	Shell	Tube
Outside diameter	in	24	20	18
Calculated thickness	in	0.3235	0.2553	0.111
Code minimum thk	in	0.3235	0.2739	0.1406
Actual thickness	in	0.6875	0.375	0.375
Reinf.pad OD	in			
Reinf.pad thickness	in			
Corrosion allowance	in	0.0625	0.0625	
External pressure	psi	15	15	15
Length ext. press.	in	6	6	6
Maximum ext. press.	psi	526.912	306.797	288.107

Nozzle Flanges

Nozzle designator		A	B	C
Flange type		Slip on	Slip on	Slip on
Flange rating		150	150	150
Flange OD	in	32	27.5	25
Bolt circle	in	29.5	25	22.75
Bolt diameter	in	1.25	1.125	1.125
Bolt number	in	20	20	16
Gasket OD	in	27.25	23	21
Gasket width	in	1.62	1.5	1.5
Gasket thickness	in	0.125	0.125	0.125
Flange calc. thk.	in			
Flange actual thk.	in	1.88	1.69	1.56
Lap jnt ring OD	in			
Hub length	in			
Hub slope	in			
Weld height	in			

Body Flanges

		Front Head Cover	Front Head at TbSh	Shell Front	Shell Rear	Rear Head at TbSh	Rear Head Cover	Shell Cover
Flange type			Ring			Ring		
Flange OD	in		35.25			35.5		
Bolt circle	in		34			34.25		
Bolt diameter	in		0.5			0.5		
Bolt number			24			24		
Gasket OD	in		33			33.25		
Gasket width	in		0.5			0.5		
Gasket thk.	in		0.125			0.125		
Flange calc. thk.	in		1.4375			1.1875		
Flange overlay	in							
Recess	in							
Flange act. thk.	in		1.4375			1.1875		
Lap jnt ring OD	in							
Hub length	in							
Hub slope	in							
Weld height	in		0.375			0.5		

Tubesheets

		Front	Rear
Tubesheet diameter	in	35.25	35.5
TEMA minimum thickness	in	0.5625	0.5625
TEMA bending thickness	in	1.2085	1.2085
TEMA shear thickness	in	0.1557	0.1557
TEMA flange extension thk	in	0.5063	0.5326
TEMA effective thickness	in	1.25	1.25
Code thickness	in	1.75	1.75
Corrosion allowance - shell	in		
Corrosion allowance - tube	in		
Recess	in		
Actual thickness	in	1.75	1.75

:ad thickness (not included above)	in	

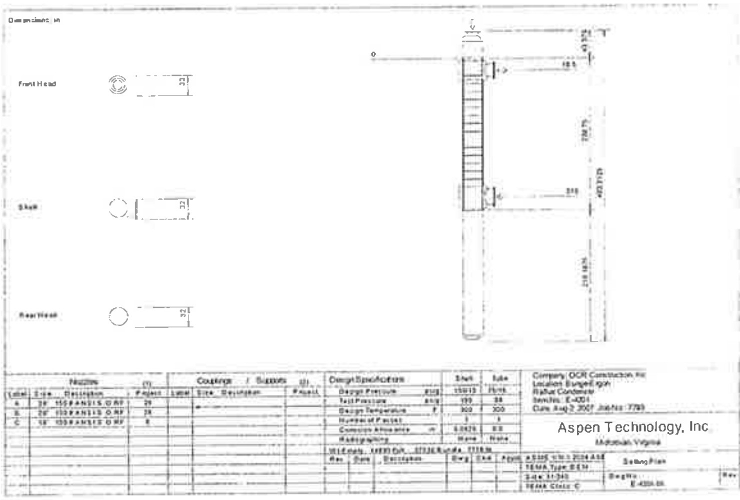
Tube Details

Tube type		Plain
Tube OD	in	0.75
Tube wall thickness	in	0.049
Number of tubes		821
Tube length	in	240
Tube pitch	in	1
Tube pattern		30
Outer tube limit diameter	in	30.8125

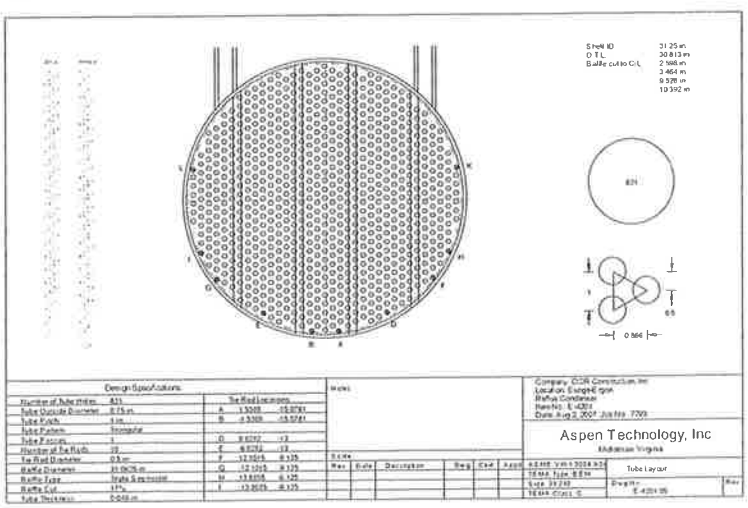
Materials of Construction

Component	Material
Shell Cylinder	SA-516 K02700 Grd 70 Plate
Front Head Cylinder	SA-240 S30400 Grd 304 Plate
Front Head Cover	SA-240 S30400 Grd 304 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-240 S30400 Grd 304 Plate
Rear Head Flng At TS	SA-240 S30400 Grd 304 Plate
›nt Head Gasket At TS	Solid Teflon 1/8in Thickness
،ear Head Gasket At TS	Solid Teflon 1/8in Thickness
Tubes	SA-249 S30400 Grd TP304 Wld. tube(G5)
Baffles	SA-36 K02600 Plate
Tie Rods	SA-36 Bar
Spacers	SA-214 K01807 Wld. tube
Nozzle A	SA-53 K03005 Grd E/B Wld. pipe
Nozzle B	SA-53 K03005 Grd E/B Wld. pipe
Nozzle C	SA-312 S30400 Grd TP304 Wld. pipe
Nozzle Flng A	SA-105 K03504 Forgings
Nozzle Flng B	SA-105 K03504 Forgings
Nozzle Flng C	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-516 K02700 Grd 70 Plate
Distributor Belt B	SA-516 K02700 Grd 70 Plate
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 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

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-516 K02700 Grd 70 Plate	1	99.5	ci	120	lg	0.375	2505	0.45	1124
1	Shell Cylinder	SA-516 K02700 Grd 70 Plate	1	99.5	ci	117	lg	0.375	0	0.45	0
2	Fr Hd Cylinder	SA-240 S30400 Grd 304 Plate	1	100	ci	27.5	lg	0.25	197	2.55	504
5	Fr Hd Cover Ellip.	SA-240 S30400 Grd 304 Plate	1	42.9375	lg	42.938	wi	0.3125	165	2.55	936
9	Shell Lift Lugs	SA-36 K02600 Plate	4	6	od	0		1	13	0.37	5
11	Front TubSh	SA-240 S30400 Grd 304 Plate	1	36	od	0		2	584	2.55	1492
12	Rear TubSh	SA-240 S30400 Grd 304 Plate	1	36.25	od	0		2	593	2.55	1513
17	Fr Hd Flng TubSh	SA-240 S30400 Grd 304 Plate	1	36	od	0		1.75	511	2.55	1306
18	Re Hd Flng TubSh	SA-240 S30400 Grd 304 Plate	1	36.25	od	0		1.5	444	2.55	1135
31	Fr Hd Gskt TubSh	Solid Teflon 1/8in Thickness	1	33.75	od	33.75	id	0.125	11	23	260
32	Re Hd Gskt TubSh	Solid Teflon 1/8in Thickness	1	34	od	34	id	0.125	11	23	264
38	Tubes (avg wall)	SA-249 S30400 Grd TP304 Wld. t	821	0.75	od	240	lg	0.049	6105	0.82	13403
39	Baffles	SA-36 K02600 Plate	15	31.8125	lg	31.813	wi	0.3125	1344	0.37	495
40	Tie Rods	SA-36 Bar	22	0.5	od	209.5	lg	0	256	0.37	94
41	Spacers	SA-214 K01807 Wld. tube	294	0.75	od	25.25	lg	0.109	568	0.67	379
	Spacers	SA-214 K01807 Wld. tube	30	0.75	od	12.625	lg	0.109	0	0.67	0
	Nozzle A	SA-53 K03005 Grd E/B Wld. pipe	1	24	od	6	lg	0.6875	86	0.7	60
62	Nozzle B	SA-53 K03005 Grd E/B Wld. pipe	1	20	od	6	lg	0.375	39	0.7	28
63	Nozzle C	SA-312 S30400 Grd TP304 Wld. p	1	18	od	6	lg	0.375	36	8.92	319
81	Nozzle Flng A Slip On	SA-105 K03504 Forgings	1	150	AN	24	di	0	182	1.58	287
82	Nozzle Flng B Slip On	SA-105 K03504 Forgings	1	150	AN	20	di	0	131	1.58	206
83	Nozzle Flng C Slip On	SA-182 S30400 Grd F304 Forging	1	150	AN	18	di	0	104	9.2	953
101	Fr Hd Blts TubSh	SA-193 G41400 Grd B7 Bolt(<= 2	24	0.5	od	5.5	lg	0	7	2.48	18
102	Re Hd Blts TubSh	SA-193 G41400 Grd B7 Bolt(<= 2	24	0.5	od	5	lg	0	7	2.48	17
115	Distrib. Belt A	SA-516 K02700 Grd 70 Plate	1	138.229	lg	29	wi	0.5	1329	0.45	596
116	Distrib. Belt B	SA-516 K02700 Grd 70 Plate	1	138.229	lg	34.5	wi	0.5	1464	0.45	656
122	Dist.Belt An.Rng	SA-516 K02700 Grd 70 Plate	4	44		0		0.625	0	0	0



besheet Layout



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Component:  Shell 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 = 32.0 in         Corroded radius      OR = 16.0 in
Required wall thickness of the cylinder , greater of:
  Circumferential stress
            t = (P*OR / (S*E+0.4*P))+cai+cao+tol = 0.2332 in   APP.1-1(A)
  Longitudinal stress
          t = (P*IR / (2*S*E+0.4*P))+cai+cao+tol = 0.1464 in   UG-27(c)(2)
Actual wall thickness of cylinder:            tnom = 0.375 in
  (Required wall tks. for nozzle attachments, E=1    ,  tri = 0.1196 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 = 32 in           Cylinder length EP   L = 198.75 in
Nominal thickness  tnom = 0.375 in        (tnom-CAI-CAO-Tol)   t = 0.3125 in
L/Do ratio          Ldo = 6.2109          Do/t               Dot = 102.4
(2*S) or (0.9*yield) SE = -               Mod. of elasticity ME = 28100000 psi
 Factor SII-D-FigG    A = 0.000183        B factor CS-2        B = 2621
  allowed external pressure: Pa = 4*B / (3*Dot)                  = 34.13 psi
Actual external design pressure:                              PE = 15 psi
  (Required cyl. tks. for nozzle attachments at PE, tre = 0.2235 in )
```

```
.mponent:  Front Head 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
Design pressure        P = 75 psi        Design temperature    T = 300 F
Radiography              = None          Joint eff.circ str.   E = 0.7
Design stress          S = 15000 psi     Joint eff.long str.   E = 0.7
Design stress, long    S = 15000 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 = 32.0 in       Corroded radius     OR = 16.0 in
Required wall thickness of the cylinder , greater of:
  Circumferential stress
            t = (P*OR / (S*E+0.4*P))+cai+cao+tol = 0.114 in    APP.1-1(A)
  Longitudinal stress
          t = (P*IR / (2*S*E+0.4*P))+cai+cao+tol = 0.0562 in   UG-27(c)(2)
Actual wall thickness of cylinder:             tnom = 0.25 in
  (Required wall tks. for nozzle attachments, E=1     ,  tri = 0.0798 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
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 = 32 in         Cylinder length EP   L = 27.25 in
Nominal thickness   tnom = 0.25 in       (tnom-CAI-CAO-Tol)   t = 0.25 in
L/Do ratio           Ldo = 0.8516        Do/t               Dot = 128.0
(2*S) or (0.9*yield) SE = -              Mod. of elasticity ME = 27000000 psi
r factor SII-D-FigG    A = 0.0011        B factor HA-1        B = 7666
  allowed external pressure: Pa = 4*B / (3*Dot)                = 79.85 psi
..ual external design pressure:                             PE = 15 psi
   (Required cyl. tks. for nozzle attachments at PE, tre = 0.099 in  )
```

```
·omponent:   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-240 S30400 Grd 304 Plate
Design pressure         P = 75 psi         Design temperature  T = 300 F
Radiography               = None           Joint efficiency    E = 0.85
Design stress           S = 15000 psi      TEMA min. thk      tm = 0.25 in
Inside corr.all.      CAI = 0.0 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 = 0.0797 in      Equiv.dish radius   L = 28.35 in
Ratio t/L                 = 0.00882        Material tol.     Tol = 0.0 in
Outside diameter       OD = 32.0 in        Corroded diameter  OD = 32.0 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 = 0.0936 in  App. 1-4(c)
Actual wall thickness of cover:                  ·tnom = 0.25 in
   (Required wall tks. for nozzle attachments, E=1    ,  tri = 0.0797 in )
   (If opening & reinf. are within 80% of head diameter, tri = 0.0719 in )
ASME Section VIII-1 2004 A06 UG-33 Formed Heads, Pressure on Convex Side
--- Calculations --- Ellipsoidal Cover External Pressure
Material:  SA-240 S30400 Grd 304 Plate
Design pressure        PE = 15 psi        Design temperature   T = 300 F
Inside corr. allow. CAI = 0 in            Outside corr. all. CAO = 0 in
Radiography               = None          Forming tolerance  Tol = 0 in
                                          Material tolerance Tol = 0 in
Cover outside dia.     Do = 32 in         Outside sph.radius  Ro = 28.8 in
Nominal thickness    tnom = 0.25 in       tnom-CAI-CAO-Tol     t = 0.25 in
Ko factor (UG-33.1)    Ko = 0.9           Ro/t ratio         Rot = 115.2
 33(a)     237.72/1.67 = 142.35 psi       Mod. of elasticity  ME = 27000000 psi
 factor = 0.125/Rot     = 0.001085        B factor HA-1        B = 7630
Maximum allowed external pressure:        Pa = B / Rot           = 66.23 psi
Actual external design pressure:                              PE = 15 psi
   (Required cov. tks. for nozzle attachments at PE, tre = 0.087 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 = 44.0 in       ID of dist. belt      ID = 43.0 in
Corroded jacket space  j = 5.5625 in     Min. fillet weld       Y = 0.28 in
Corrosion allowance    c = 0.0625 in     Min. thk.outer wall trj = 0.2972 in
Required minimum thickness of closure member, trc
Figure 9-5 type:  (d-1), (d-2), (e-1), (e-2)
trc = 0.707 * J * SQRT(P/S) + c          trc = 0.5944 in
Actual thickness, tc                     tc  = 0.625 in
```

```
 mponent:  Distributor Belt A
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 = 0.0 in
Outside diameter      OD = 44.0 in        Corroded radius     OR = 22.0 in
Required wall thickness of the cylinder , greater of:
  Circumferential stress
            t = (P*OR / (S*E+0.4*P))+cai+cao+tol = 0.2972 in   APP.1-1(A)
  Longitudinal stress
          t = (P*IR / (2*S*E+0.4*P))+cai+cao+tol = 0.1778 in   UG-27(c)(2)
Actual wall thickness of cylinder:            tnom = 0.5 in
  (Required wall tks. for nozzle attachments, E=1    ,  tri = 0.1645 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 = 44 in           Cylinder length EP  L = 29 in
Nominal thickness   tnom = 0.5 in          (tnom-CAI-CAO-Tol)  t = 0.4375 in
L/Do ratio           Ldo = 0.6591          Do/t              Dot = 100.5714
(2*S) or (0.9*yield) SE = -                Mod. of elasticity ME = 28100000 psi
A factor SII-D-FigG    A = 0.002084        B factor CS-2       B = 15117
  allowed external pressure: Pa = 4*B / (3*Dot)                  = 200.42 psi
Actual external design pressure:                                PE = 15 psi
   (Required cyl. tks. for nozzle attachments at PE, tre = 0.1195 in )
```

```
Component: Distributor Belt B
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 = 44.0 in       ID of dist. belt      ID = 43.0 in
Corroded jacket space  j = 5.5625 in      Min. fillet weld       Y = 0.28 in
Corrosion allowance    c = 0.0625 in      Min. thk.outer wall trj = 0.2972 in
Required minimum thickness of closure member, trc
Figure 9-5 type:  (d-1), (d-2), (e-1), (e-2)
trc = 0.707 * J * SQRT(P/S) + c           trc = 0.5944 in
Actual thickness, tc                      tc  = 0.625 in
```

```
Component:  Distributor Belt B
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 = 0.0 in
Outside diameter      OD = 44.0 in       Corroded radius     OR = 22.0 in
Required wall thickness of the cylinder , greater of:
  Circumferential stress
            t = (P*OR / (S*E+0.4*P))+cai+cao+tol = 0.2972 in   APP.1-1(A)
  Longitudinal stress
          t = (P*IR / (2*S*E+0.4*P))+cai+cao+tol = 0.1778 in   UG-27(c)(2)
Actual wall thickness of cylinder:           tnom = 0.5 in
  (Required wall tks. for nozzle attachments, E=1    ,  tri = 0.1645 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 = 44 in          Cylinder length EP  L = 34.5 in
Nominal thickness   tnom = 0.5 in         (tnom-CAI-CAO-Tol)  t = 0.4375 in
L/Do ratio           Ldo = 0.7841         Do/t              Dot = 100.5714
(2*S) or (0.9*yield) SE = -               Mod. of elasticity ME = 28100000 psi
A factor SII-D-FigG    A = 0.001726       B factor CS-2        B = 14380
  allowed external pressure: Pa = 4*B / (3*Dot)                = 190.65 psi
Actual external design pressure:                              PE = 15 psi
  (Required cyl. tks. for nozzle attachments at PE, tre = 0.1275 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(G5)
Design pressure        P = 90 psi        Design temperature   T = 300 F
Radiography              = -             Joint eff.circ str.  E = 1
Design stress          S = 16100 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 = 0.0021 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(G5)
Design pressure        PE = 165 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 = 240 in
Nominal thickness    tnom = 0.049 in       (tnom-CAI-CAO-Tol)   t = 0.049 in
L/Do ratio            Ldo = 320.0          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 = 165 psi
   (Required cyl. tks. for nozzle attachments at PE, tre = 0.016 in  )
```

```
 mponent: 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(G5)
Allowable stress TubS St = 15000 psi    All. stress tubes    Sa = 18941 psi
Allowable stress weld Sw = 15000 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 = 0.0938 in    Groove weld leg      ag = 0.0938 in
Minimum length ac  acmin = 0.0797 in    Total length ac = af+ag = 0.1875 in
Fillet weld strength = Ff = 0.55*Pi*af*(do+0.67*af)*Sw       Ff = 1975 lbf
Groove weld strength = Fg = 0.85*Pi*ag*(do+0.67*ag)*Sw       Fg = 4175 lbf
Tube strength          Ft = Pi * t * (do - t) * Sa           Ft = 2044 lbf
Design Strength        Fd                                    Fd = 2044 lbf
Fillet weld strength, Ff = min (Ff, Ft)                      Ff = 1975 lbf
Groove weld strength, Fg = min (Fg, Ft)                      Fg = 2044 lbf
Weld strength factor fw = Sa / Sw                            fw = 1.26
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 = 0.0797 in
UW-18(d) - Allowable load on fillet/groove welds       Weld Leg = 0.1875 in
               Allowable Load = PI * do * Weld Leg * Sw * 0.55 = 3645 lbf
Maximum Allowable Axial Loads, Lmax
  Pressure only = LmaxP = Ft                               LmaxP = 2044 lbf
  Other loads   = LmaxO = 2*Ft                             LmaxO = 4088 lbf
  Total weld throat dimension = 0.1327 in
```

```
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-240 S30400 Grd 304 Plate
Int. design pressure  PI = 75 psi       Design temperature     T = 300 F
Ext. design pressure  PE = 15 psi       B1 = B+g1 or B+go     B1 = -
Inside corr. allow   CAI = 0.0 in       Outside corr. all.   CAO = 0.0 in
Stress (operating)   SFO = 15000 psi    Stress (atmos.)      SFA = 20000 psi
Outside diameter       A = 35.25 in     Inside spherical rad.  L = -
Inside diameter        B = 31.5 in      Hub thickness         g1 = 0.625 in
Bolt circle diameter   C = 34.0 in      Hub tks. at attach.   go = 0.25 in
Mean gasket diameter   G = 32.5 in      Weld leg/hub length    h = 0.375 in
Hub to bolt circle     R = 0.625 in     Bolt circle to OD      E = 0.625 in
Flange thickness       t = 1.4375 in
Note: Optional Type Flanges use the smaller of integral or loose calculation.
Gasket material: Solid Teflon 1/8in Thickness
Gasket outside dia.  ODG = 33.0 in      Gasket width         Wth = 0.5 in
Gasket thickness     tks = 0.125 in     Gasket factor          m = 2.0
Gasket seating stress  y = 1600 psi     Gasket eff. width      b = 0.25 in
Gasket rib length    Rib = 0.0 in       Seating width         bo = 0.25 in
Gasket rib eff width  Br = 0.0 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. = 24
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 =    7658 lbf
Hydrostatic end force        H = 0.7854*G*G*PI                 =   62218 lbf
Hydrostatic end force        He= 0.7854*G*G*PE                 =   12444 lbf
Operating conditions:
Min. calc. bolt load       WM1 = HP+H                          =   69876 lbf
Min. used bolt load        WM1 = max of 2 mating flanges       =   69876 lbf
Bolting up conditions:
Minimum bolt load          WM2 = b*3.1416*G*Y+Br*Y*RIB         =   40841 lbf
Min. used bolt load        WM2 = max of 2 mating flanges       =   40841 lbf
Required bolt area          AM = WM2/SA or WM1/SB              =     2.8 in2
Available bolt area         AB = No.Bolt*Area                  =    3.02 in2
Design bolt load             W = 0.5*(AM+AB)*SA                =   72738 lbf
Minimum gasket width      NMIN = AB*SA/(6.283*y*G)             =  0.2314 in
Gasket compression stress Gcst = AB*SA/(Pi*G*Wth)              =    1481 psi
```

```
  ads:                        Integral Flange Calculations
Operating conditions:
Hydrostatic end load           HD = 0.785*B*B*PI      =  58448 lbf
Hydrostatic end load           HDe= 0.785*B*B*PE      =  11690 lbf
Gasket load                    HG = WM1-H             =   7658 lbf
Result. hydrostatic force      HT = H-HD              =   3770 lbf
Result. hydrostatic force      HTe= He-HDe            =    754 lbf
Bolting up conditions:
Gasket load                    HG = W                 =  72738 lbf
Operating conditions:
Hydrostatic lever arm          hd = R+0.5*g1          = 0.9375 in
Gasket load lever arm          hg = (C-G)/2           = 0.75 in
Result. hydro. lever arm       ht = (R+g1+hg)/2.0     = 1.0 in
Bolting up conditions:
Gasket load lever arm          hg = (C-G)/2           = 0.75 in
Operating conditions:
Hydrostatic moment             MD = HD*hd             =  54795 lbf*in
Gasket moment                  MG = HG*hg             =   5743 lbf*in
Result. hydro. moment          MT = HT*ht             =   3770 lbf*in
Total operating moment        MOP = MD+MG+MT          =  64309 lbf*in
Total operating mom. MOPe= HDe(hd-hg)+HTe(ht-hg)      =   2380 lbf*in
Bolting up conditions:
Bolt up moment                MATM = W*hg             =  54554 lbf*in
Effective bolt moment          MB = MATM*SFO/SFA      =  40915 lbf*in
Total moment                   MO = MOP  or MB        =  64309 lbf*in
Bolt spacing correction         M = MO*Cf             =  64313 lbf*in
 (TEMA 1999 RCB-11.23) Cf= 1
Flange shape constants:
        K = A/B              = 1.119         ho = SQ(B*G0)      = 2.8062
       TF = Fig.2-7.1        = 1.8703      h/ho = h/ho          = 0.1336
        Z = Fig.2-7.1        = 8.9281         F = Fig.2-7.2     = 0.9009
        Y = Fig.2-7.1        = 17.2597        V = Fig.2-7.3     = 0.3911
        U = Fig.2-7.1        = 18.9666        f = Fig.2-7.6     = 4.7818
    G1/G0 = G1/Go            = 2.5            e = F/ho          = 0.321
        t =                  = 1.4375 in
        D = U*ho*g0*g0/V     = 8.5063     Alpha = t*e+1.0       = 1.4615
     Beta = 1.333*t*e+1.0    = 1.6152     Gamma = Alpha/TF      = 0.7814
    Delta = t*t*t/D          = 0.3492    Lambda = Gamma+Delta   = 1.1306
Stress calculations:                                        Allowable stress:
Long. hub       SH = (f*M)/(Lambda*g1**2*B)   =   22106 psi 1.5*SFO =   22500 psi
Radial          SR = Beta*M/(Lambda*t**2*B)   =    1411 psi     SFO =   15000 psi
Tangential     ST1 = M*Y/(t**2*B)-(Z*SR)      =    4451 psi     SFO =   15000 psi
  (greater)    ST2 = (SH+SR)/2 or (SH+ST1)/2  =   13279 psi     SFO =   15000 psi
```

```
  ads:                          Loose Flange Calculations
Operating conditions:
Hydrostatic end load           HD = 0.785*B*B*PI      =  60791 lbf
Hydrostatic end load           HDe= 0.785*B*B*PE      =  12158 lbf
Gasket load                    HG = WM1-H             =   7658 lbf
Result. hydrostatic force      HT = H-HD              =   1428 lbf
Result. hydrostatic force      HTe= He-HDe            =    286 lbf
Bolting up conditions:
Gasket load                    HG = W                 =  72738 lbf
Operating conditions:
Hydrostatic lever arm          hd = (C-B)/2.0         = 0.9375 in
Gasket load lever arm          hg = (C-G)/2           = 0.75 in
Result. hydro. lever arm       ht = (hd+hg)/2.0       = 0.8438 in
Bolting up conditions:
Gasket load lever arm          hg = (C-G)/2           = 0.75 in
Operating conditions:
Hydrostatic moment             MD = HD*hd             =  56991 lbf*in
Gasket moment                  MG = HG*hg             =   5743 lbf*in
Result. hydro. moment          MT = HT*ht             =   1204 lbf*in
Total operating moment        MOP = MD+MG+MT          =  63939 lbf*in
Total operating mom. MOPe= HDe(hd-hg)+HTe(ht-hg)      =   2306 lbf*in
Bolting up conditions:
Bolt up moment               MATM = W*hg              =  54554 lbf*in
Effective bolt moment          MB = MATM*SFO/SFA      =  40915 lbf*in
Total moment                   MO = MOP  or MB        =  63939 lbf*in
Bolt spacing correction         M = MO*Cf             =  63939 lbf*in
 (TEMA 1999 RCB-11.23) Cf= 1
Flange shape constants:
       B =                 = 32.125 in
       K = A/B             = 1.0973
       Y = Fig.2-7.1       = 20.8547
Flange calculated thickness:      t = (M*Y/SFO*B)**0.5 = 1.6635 in
Flange nominal thickness:                       tnom = 1.4375 in
Stress calculations:                                Allowable stess:
Tangential, ST = MO*Cf*Y/(B*tnom**2) = 14576 psi      SFO = 15000 psi
```

```
Component:  Front Head Flng At TS
ASME Section VIII Div.1 2004 A06, Appendix 2, 2-14 Flange Rigidity
--- Calculations ---
Operating moment,     Mo = 64309 lbf*in  Gasket seat. moment Ma = 54554 lbf*in
Factor V               V = 0.391         Factor L                L = 1.1306
Mod. elast.design T   Ed = 27000000 psi  Mod.elast.atm. temp Ea = 28300000 psi
Thickness g0          g0 = 0.25 in       Factor h0             h0 = 2.8062 in
Factor KI             KI = 0.3           Factor KL             KL = 0.2
Corrosion allowance   ca = 0.0 in        Factor K               K = 1.119
Thickness, T           T = 1.4375 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) = 0.6607
Operating       J = 52.14 * Mo * V / (L * E * G0 ** 2 * ho * KI) = 0.8164
```

```
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-240 S30400 Grd 304 Plate
Int. design pressure   PI = 75 psi        Design temperature      T = 300 F
Ext. design pressure   PE = 15 psi        B1 = B+g1 or B+go      B1 = -
Inside corr. allow    CAI = 0.0 in        Outside corr. all.    CAO = 0.0 in
Stress (operating)    SFO = 15000 psi     Stress (atmos.)       SFA = 20000 psi
Outside diameter        A = 35.5 in       Inside spherical rad.   L = -
Inside diameter         B = 31.375 in     Hub thickness          g1 = 0.8125 in
Bolt circle diameter    C = 34.25 in      Hub tks. at attach.    go = 0.3125 in
Mean gasket diameter    G = 32.75 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 = 1.1875 in
Note: Optional Type Flanges use the smaller of integral or loose calculation.
Gasket material: Solid Teflon 1/8in Thickness
Gasket outside dia.  ODG = 33.25 in       Gasket width          Wth = 0.5 in
Gasket thickness     tks = 0.125 in       Gasket factor           m = 2.0
Gasket seating stress  y = 1600 psi       Gasket eff. width       b = 0.25 in
Gasket rib length    Rib = 0.0 in         Seating width          bo = 0.25 in
Gasket rib eff width  Br = 0.0 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. = 24
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 =     7717 lbf
Hydrostatic end force         H = 0.7854*G*G*PI                  =    63179 lbf
Hydrostatic end force        He= 0.7854*G*G*PE                  =    12636 lbf
Operating conditions:
 .. calc. bolt load         WM1 = HP+H                           =    70896 lbf
 ..n. used bolt load        WM1 = max of 2 mating flanges        =    70896 lbf
Bolting up conditions:
Minimum bolt load           WM2 = b*3.1416*G*Y+Br*Y*RIB          =    41155 lbf
Min. used bolt load         WM2 = max of 2 mating flanges        =    41155 lbf
Required bolt area           AM = WM2/SA or WM1/SB               =     2.84 in2
Available bolt area          AB = No.Bolt*Area                   =     3.02 in2
Design bolt load              W = 0.5*(AM+AB)*SA                 =    73248 lbf
Minimum gasket width       NMIN = AB*SA/(6.283*y*G)              =   0.2296 in
Gasket compression stress  Gcst = AB*SA/(Pi*G*Wth)               =     1470 psi
```

```
  ads:                        Integral Flange Calculations
Operating conditions:
Hydrostatic end load          HD = 0.785*B*B*PI      =  57986 lbf
Hydrostatic end load          HDe= 0.785*B*B*PE      =  11597 lbf
Gasket load                   HG = WM1-H             =   7717 lbf
Result. hydrostatic force     HT = H-HD              =   5194 lbf
Result. hydrostatic force     HTe= He-HDe            =   1039 lbf
Bolting up conditions:
Gasket load                   HG = W                 =  73248 lbf
Operating conditions:
Hydrostatic lever arm         hd = R+0.5*g1          = 1.0313 in
Gasket load lever arm         hg = (C-G)/2           = 0.75 in
Result. hydro. lever arm      ht = (R+g1+hg)/2.0     = 1.0938 in
Bolting up conditions:
Gasket load lever arm         hg = (C-G)/2           = 0.75 in
Operating conditions:
Hydrostatic moment            MD = HD*hd             =  59798 lbf*in
Gasket moment                 MG = HG*hg             =   5787 lbf*in
Result. hydro. moment         MT = HT*ht             =   5681 lbf*in
Total operating moment       MOP = MD+MG+MT          =  71266 lbf*in
Total operating mom. MOPe= HDe(hd-hg)+HTe(ht-hg)     =   3619 lbf*in
Bolting up conditions:
Bolt up moment              MATM = W*hg              =  54936 lbf*in
Effective bolt moment         MB = MATM*SFO/SFA      =  41202 lbf*in
Total moment                  MO = MOP  or MB        =  71266 lbf*in
Bolt spacing correction        M = MO*Cf             =  76904 lbf*in
 (TEMA 1999 RCB-11.23) Cf= 1.079
Flange shape constants:
       K = A/B           = 1.1315        ho = SQ(B*G0)      = 3.1312
      TF = Fig.2-7.1     = 1.8657      h/ho = h/ho          = 0.1597
       Z = Fig.2-7.1     = 8.1369         F = Fig.2-7.2     = 0.8977
       Y = Fig.2-7.1     = 15.7408        V = Fig.2-7.3     = 0.3637
       U = Fig.2-7.1     = 17.2975        f = Fig.2-7.6     = 4.8866
   G1/G0 = G1/Go         = 2.6            e = F/ho          = 0.2867
       t =               = 1.1875 in
       D = U*ho*g0*g0/V  = 14.5438    Alpha = t*e+1.0       = 1.3404
    Beta = 1.333*t*e+1.0 = 1.4538    Gamma = Alpha/TF      = 0.7185
   Delta = t*t*t/D       = 0.1151   Lambda = Gamma+Delta   = 0.8336
Stress calculations:                                    Allowable stress:
Long. hub      SH = (f*M)/(Lambda*g1**2*B)  =   21765 psi 1.5*SFO =   22500 psi
Radial         SR = Beta*M/(Lambda*t**2*B)  =    3031 psi     SFO =   15000 psi
Tangential    ST1 = M*Y/(t**2*B)-(Z*SR)     =    2694 psi     SFO =   15000 psi
  (greater)   ST2 = (SH+SR)/2 or (SH+ST1)/2 =   12398 psi     SFO =   15000 psi
```

Loose Flange Calculations

```
: ads:
Operating conditions:
Hydrostatic end load          HD = 0.785*B*B*PI      =  60791 lbf
Hydrostatic end load          HDe= 0.785*B*B*PE      =  12158 lbf
Gasket load                   HG = WM1-H             =   7717 lbf
Result. hydrostatic force     HT = H-HD              =   2388 lbf
Result. hydrostatic force     HTe= He-HDe            =    478 lbf
Bolting up conditions:
Gasket load                   HG = W                 =  73248 lbf
Operating conditions:
Hydrostatic lever arm         hd = (C-B)/2.0         = 1.0625 in
Gasket load lever arm         hg = (C-G)/2           = 0.75 in
Result. hydro. lever arm      ht = (hd+hg)/2.0       = 0.9063 in
Bolting up conditions:
Gasket load lever arm         hg = (C-G)/2           = 0.75 in
Operating conditions:
Hydrostatic moment -          MD = HD*hd             =  64590 lbf*in
Gasket moment                 MG = HG*hg             =   5787 lbf*in
Result. hydro. moment         MT = HT*ht             =   2165 lbf*in
Total operating moment       MOP = MD+MG+MT          =  72542 lbf*in
Total operating mom. MOPe= HDe(hd-hg)+HTe(ht-hg)     =   3874 lbf*in
Bolting up conditions:
Bolt up moment              MATM = W*hg              =  54936 lbf*in
Effective bolt moment         MB = MATM*SFO/SFA      =  41202 lbf*in
Total moment                  MO = MOP  or MB        =  72542 lbf*in
Bolt spacing correction        M = MO*Cf             =  72542 lbf*in
 (TEMA 1999 RCB-11.23) Cf= 1
Flange shape constants:
       B =                 = 32.125 in
       K = A/B             = 1.1051
       Y = Fig.2-7.1       = 19.3988
Flange calculated thickness:      t = (M*Y/SFO*B)**0.5 = 1.7089 in
Flange nominal thickness:                     tnom = 1.1875 in
Stress calculations:                              Allowable stess:
Tangential, ST = MO*Cf*Y/(B*tnom**2) = 14304 psi     SFO = 15000 psi
```

```
 mponent:  Rear Head Flng At TS
ASME Section VIII Div.1 2004 A06, Appendix 2, 2-14 Flange Rigidity
--- Calculations ---
Operating moment,     Mo = 71266 lbf*in  Gasket seat. moment Ma = 54936 lbf*in
Factor V               V = 0.364         Factor L               L = 0.8336
Mod. elast.design T   Ed = 27000000 psi  Mod.elast.atm. temp Ea = 28300000 psi
Thickness g0          g0 = 0.3125 in     Factor h0             h0 = 3.1312 in
Factor KI             KI = 0.3           Factor KL             KL = 0.2
Corrosion allowance   ca = 0.0 in        Factor K               K = 1.1315
Thickness, T           T = 1.1875 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) = 0.4814
Operating        J = 52.14 * Mo * V / (L * E * G0 ** 2 * ho * KI) = 0.6545
```

```
Component: Front Tubesheet
Tubesheet Details - TEMA 1999 Design
Materials of construction
  Shell:        SA-516 K02700 Grd 70 Plate
  Channel:      SA-240 S30400 Grd 304 Plate
  Tubesheet:    SA-240 S30400 Grd 304 Plate
  Tubes:        SA-249 S30400 Grd TP304 Wld. tube(G5)
Design conditions                   Shell     Channel    Tubesheet     Tubes
Design pressure        psi           165        90
Design temperature       F           300       300         300          300
Allowable stress       psi          20000                15000        18941
Mean metal temp.         F            95                   126          126
Mod.of elas/M.M.T.     psi        29165384              27998460     27998460
Coef.th.exp/M.M.T. in/in/F       0.0000064                           0.0000087
Corrosion allowance     in         0.0625       0.0
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 = 35.25 in     Reaction diameter     G = 31.375 in
Ratio A/G               r = 1.1235
Equivalent diameter    DL = 19.0459 in   Flange moment         M = 64309 lbf*in
                  (  M * (r**2 - 1 + 3.71 * r**2 * Ln(r)  )**1/2
Tr = 0.98 *       (-------------------------------------  )         = 0.5063 in
                  (    S * (A - G) * (1 + 1.86 * r**2)     )
Relative expansion between shell and tubes (TEMA T-4.5)
Shell metal temp. Thetas = 25 F          Tube metal temp. Thetat = 56 F
Tube length             L = 240.0 in
DeltaL = (Alphas*Thetas-Alphat*Thetat)*L = -0.0781 in
```

.mponent: Front Tubesheet

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 = 0.4898

Shear : T = 0.31*DL*(P/S)/(1-do/Pitch)

	-Without exp.joint-		-- With exp.joint --	
	Uncorroded	Corroded	Uncorroded	Corroded
User specified thickness	1.75	1.75	1.75	1.75
Effective thickness, T :	1.25	1.25	0.0	0.0
Req. tks. shell side (bending):	1.2085	1.1909	0.0	0.0
Req. tks. tube side (bending) :	0.8817	0.9084	0.0	0.0
Req. tks. shell side (shear) :	0.1557	0.15	0.0	0.0
Req. tks. tube side (shear) :	0.0849	0.0746	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 =	2616	3017	0	0
Shell compressive stress =	0	0	0	0
Tube longitudinal stress =	1164	1300	0	0
Tube compressive stress =	-7564	-7331	0	0
Tube-to-tubesheet load, lbf				
Tube-to-tubesheet load Wj =	147	162	0	0
Effective pressures P, psi				
Eff.pres.shell side (bend.)=	98.9	95.3	0	0
Eff.pres.tube side (bend.) =	52.6	55.4	0	0
.pres.shell side (shear)=	98.9	95.3	0	0
.f.pres.tube side (shear) =	53.9	47.4	0	0

```
 ..nponent: Front Tubesheet
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 = 821          Tube pitch         pitch = 1.0 in
Tube Length          Lt = 240.0 in     Mod.of Elasticity      E = 27998460 psi
Mod.of Elasticity    Es = 29165384 psi Mod.of Elasticity     Et = 27998460 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
```

	-Without exp.joint-		-- With exp.joint --	
	Uncorroded	Corroded	Uncorroded	Corroded
Units: in				
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 =	31.25	31.375	31.25	31.375
Dia. G tube side G = Gt =	31.25	31.375	31.25	31.375
Shell OD Do =	32.0	32.0	32.0	32.0
Shell thickness ts =	0.375	0.3125	0.375	0.3125
Spring rate, lbf/in Sj =	-	-	0	0
Stiffness multiplier K =	-	-	0	0
Effective tube length L =	237.5	237.5	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 =	0.4381	0.3658	0.4381	0.3658
Fq =	4.8572	4.8687	0.0	0.0
Pd =	-147.4	-137.3	0	0

Component: Front Tubesheet

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 =	13.1	12.9	13.1	12.9
Equiv. bolting pressure Pbs =	11.1	11	11.1	11

Operating moment M1 = 64309 lbf*in   Bolting-up moment M2 = 54554 lbf*in

$$\text{Operating - Pbt} = \frac{6.2 * M1}{F^{**}2 * Gs^{**}3} \qquad \text{Bolting up - Pbs} = \frac{6.2 * M2}{F^{**}2 * Gs^{**}3}$$

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

	-Without exp.joint-		-- With exp.joint --	
	Uncorroded	Corroded	Uncorroded	Corroded
P = (Ps'-Pd)/2	98.9	95.3	0	0
P = Ps'	50.4	53.2	0	0
P = PBs	11.1	11	0	0
P = (Ps'-Pd-PBs)/2	93.3	89.8	0	0
P = (PBs+Pd)/2	-68.2	-63.2	0	0
P = Ps'-PBs	39.3	42.3	0	0
G = Gs = Shell I.D., in	31.25	31.375	31.25	31.375
fs = 1-N*(do/G)**2	0.5271	0.5309	0.5271	0.5309
Dj = expansion joint ID, in	31.25	31.375	0.0	0.0
Ps' =	50.4	53.2	0	0

$$Ps' = Ps * \frac{0.4*J*(1.5+K*(1.5+fs))-((1-J)/2)*(Dj^{**}2/G^{**}2-1))}{1 + J * K * Fq}$$

Component: Front Tubesheet
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	-47.4	-40.9	0	0
P = Pt'+PBt	52.6	55.4	0	0
If Ps' is negative:				
P = (Pt'-Ps'+PBt+Pd)/2	-72.6	-67.6	0	0
P = Pt'-Ps'+PBt	2.3	2.2	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	31.25	31.375	31.25	31.375
ft = 1-N*((do-2*tt)/G)**2	0.6426	0.6455	0.6426	0.6455
Pt' =	39.6	42.5	0	0

```
                1 + 0.4 * J * K * (1.5 + ft)
   Pt' = Pt * -----------------------------
                     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	20000	20000	20000	20000
Tensile stress Ss =	2616	3017	0	0
Compressive stress (shell), psi				
Allowable stress	15579	16127	15579	16127
Compressive stress Ss =	0	0	0	0
Effective pressure, Ps*, psi				
Ps* = Pt-Pt'	50.4	47.5	0	0
Ps* = Ps'	50.4	53.2	0	0
Ps* = -Pd	147.4	137.3	0	0
Ps* = Pt-Pt'+Ps'	100.8	100.7	0	0
Ps* = Pt-Pt'-Pd	197.8	184.8	0	0
Ps* = Ps'-Pd	197.8	190.5	0	0
Ps* = Pt-Pt'+Ps'-Pd	248.2	238	0	0

Component: Front Tubesheet

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-		-- With exp.joint --	
	Uncorroded	Corroded	Uncorroded	Corroded
G = Gs = Shell I.D., in	31.25	31.375	31.25	31.375
Fs = 3.25-0.5*Fq	1.25	1.25	0	0
Tensile stress (tubes), psi				
Allowable stress	18941	18941	18941	18941
Tensile stress St =	1163.6	1299.8	0	0
Compressive stress (tubes), psi				
Allowable stress Sc =	9586	9586	0	0
Compressive stress St =	-7563.6	-7331.3	0	0
Intermediate pressures, P2 and P3, psi				
P2 = Pt'-(ft*Pt/Fq)	27.7	30.6	0	0
P3 = Ps'-(fs*Ps/Fq)	32.5	35.2	0	0

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

	-Without exp.joint-		-- With exp.joint --	
Effective pressure, Pt*, psi	Uncorroded	Corroded	Uncorroded	Corroded
Pt* = P2	27.7	30.6	0	0
Pt* = -P3	-32.5	-35.2	0	0
Pt* = Pd	-147.4	-137.3	0	0
Pt* = P2-P3	-4.8	-4.6	0	0
Pt* = P2+Pd	-119.7	-106.7	0	0
Pt* = -P3+Pd	-179.9	-172.5	0	0
Pt* = P2-P3+Pd	-152.2	-142	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 = 45.375 in
Cc = Sqrt(2*Pi**2*Et/Sy)          Cc = 157.1        kl/r = 146.11
r  = 0.25*Sqrt(do**2+(do-2*tt)**2) = 0.2484 in
```

```
 ponent: Front Tubesheet
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               31.25     31.375        31.25      31.375
Tube-to-tubesheet load, Wj            147.4      161.6            0           0
Effective pressure, Pt*, psi
  Pt* = P2                             27.7       30.6            0           0
  Pt* = -P3                           -32.5      -35.2            0           0
  Pt* = P2-P3                          -4.8       -4.6            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
                                               No Test              Test
Type      Joint description                 fr     Lmax        fr    Lmax
  a    Strength welded only                 0.8    1635         1    2044
  b    Seal welded only                    0.55    1124       0.7    1431
  e    Strength welded and expanded         0.8    1635         1    2044
  f    Seal welded and exp.with 2 grooves  0.75    1533      0.95    1942
  g    Seal welded and exp.with 1 groove   0.65    1329      0.85    1737
  h    Seal welded and exp.with no grooves  0.5    1022       0.7    1431
  i    Expanded with 2 grooves              0.7    1431       0.9    1840
  j    Expanded with 1 groove              0.65    1329       0.8    1635
  k    Expanded with no grooves             0.5    1022       0.6    1226
* = 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
  ss-sectional area  At = 0.1079 in2   Tube allowable stress Sa = 18941 psi
  ctor 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 = 126 F
Tubes Mod.Elasticity EtT = 27998460 psi TubSh Mod.Elast.     EsT = 27998460 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: Rear Tubesheet
Tubesheet Details - TEMA 1999 Design
Materials of construction
  Shell:        SA-516 K02700 Grd 70 Plate
  Channel:      SA-240 S30400 Grd 304 Plate
  Tubesheet:    SA-240 S30400 Grd 304 Plate
  Tubes:        SA-249 S30400 Grd TP304 Wld. tube(G5)
Design conditions                  Shell     Channel   Tubesheet    Tubes
Design pressure      psi            165        90
Design temperature    F             300        300       300         300
Allowable stress     psi           20000                15000       18941
Mean metal temp.      F              95                  126         126
Mod.of elas/M.M.T.   psi         29165384            27998460    27998460
Coef.th.exp/M.M.T. in/in/F       0.0000064                       0.0000087
Corrosion allowance   in          0.0625      0.0
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 = 35.5 in      Reaction diameter      G = 31.375 in
Ratio A/G              r = 1.1315
Equivalent diameter   DL = 19.0459 in   Flange moment          M = 71266 lbf*in
                (  M * (r**2 - 1 + 3.71 * r**2 * Ln(r)   )**1/2
Tr = 0.98 *     (-----------------------------------     )        = 0.5325 in
                (    S * (A - G) * (1 + 1.86 * r**2)     )
Relative expansion between shell and tubes (TEMA T-4.5)
Shell metal temp. Thetas = 25 F        Tube metal temp. Thetat = 56 F
Tube length              L = 240.0 in
DeltaL = (Alphas*Thetas-Alphat*Thetat)*L = -0.0781 in
```

Component: Rear Tubesheet

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 = 0.4898
Shear : T = 0.31*DL*(P/S)/(1-do/Pitch)

	-Without exp.joint-		-- With exp.joint --	
	Uncorroded	Corroded	Uncorroded	Corroded
User specified thickness	1.75	1.75	1.75	1.75
Effective thickness, T :	1.25	1.25	0.0	0.0
Req. tks. shell side (bending):	1.2085	1.1909	0.0	0.0
Req. tks. tube side (bending) :	0.8935	0.9198	0.0	0.0
Req. tks. shell side (shear) :	0.1557	0.15	0.0	0.0
Req. tks. tube side (shear) :	0.0849	0.0746	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 =	2616	3017	0	0
Shell compressive stress =	0	0	0	0
Tube longitudinal stress =	1164	1300	0	0
Tube compressive stress =	-7564	-7331	0	0
Tube-to-tubesheet load, lbf				
Tube-to-tubesheet load Wj =	147	162	0	0
Effective pressures P, psi				
Eff.pres.shell side (bend.)=	98.9	95.3	0	0
Eff.pres.tube side (bend.) =	54.1	56.8	0	0
Eff.pres.shell side (shear)=	98.9	95.3	0	0
Eff.pres.tube side (shear) =	53.9	47.4	0	0

```
Component: Rear Tubesheet
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 = 821           Tube pitch          pitch = 1.0 in
Tube Length            Lt = 240.0 in      Mod.of Elasticity       E = 27998460 psi
Mod.of Elasticity      Es = 29165384 psi Mod.of Elasticity       Et = 27998460 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
```

	-Without exp.joint-		-- With exp.joint --	
Units: in	Uncorroded	Corroded	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 =	31.25	31.375	31.25	31.375
Dia. G tube side G = Gt =	31.25	31.375	31.25	31.375
Shell OD Do =	32.0	32.0	32.0	32.0
Shell thickness ts =	0.375	0.3125	0.375	0.3125
Spring rate, lbf/in Sj =	-	-	0	0
Stiffness multiplier K =	-	-	0	0
Effective tube length L =	237.5	237.5	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 =	0.4381	0.3658	0.4381	0.3658
Fq =	4.8572	4.8687	0.0	0.0
Pd =	-147.4	-137.3	0	0

Component: Rear Tubesheet

Tubesheet Details - TEMA 1999 Design

RCB-7.162 Equivalent Bolting Pressure, Pb, psi

	-Without exp.joint- Uncorroded	Corroded	-- With exp.joint -- Uncorroded	Corroded
Equiv. bolting pressure Pbt =	14.5	14.3	14.5	14.3
Equiv. bolting pressure Pbs =	11.2	11	11.2	11

Operating moment M1 = 71266 lbf*in   Bolting-up moment M2 = 54936 lbf*in

$$\text{Operating - Pbt} = \frac{6.2 * M1}{F**2 * Gs**3} \qquad \text{Bolting up - Pbs} = \frac{6.2 * M2}{F**2 * Gs**3}$$

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

	-Without exp.joint- Uncorroded	Corroded	-- With exp.joint -- Uncorroded	Corroded
P = (Ps'-Pd)/2	98.9	95.3	0	0
P = Ps'	50.4	53.2	0	0
P = PBs	11.2	11	0	0
P = (Ps'-Pd-PBs)/2	93.3	89.8	0	0
P = (PBs+Pd)/2	-68.1	-63.1	0	0
P = Ps'-PBs	39.2	42.2	0	0
G = Gs = Shell I.D., in	31.25	31.375	31.25	31.375
fs = 1-N*(do/G)**2	0.5271	0.5309	0.5271	0.5309
Dj = expansion joint ID, in	31.25	31.375	0.0	0.0
Ps' =	50.4	53.2	0	0

$$Ps' = Ps * \frac{0.4*J*(1.5+K*(1.5+fs))-((1-J)/2)*(Dj**2/G**2-1))}{1 + J * K * Fq}$$

Component: Rear Tubesheet

Tubesheet Details - TEMA 1999 Design

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

	-Without exp.joint-		-- With exp.joint --	
	Uncorroded	Corroded	Uncorroded	Corroded
If Ps' is positive:				
P = (Pt'+PBt+Pd)/2	-46.7	-40.2	0	0
P = Pt'+PBt	54.1	56.8	0	0
If Ps' is negative:				
P = (Pt'-Ps'+PBt+Pd)/2	-71.9	-66.9	0	0
P = Pt'-Ps'+PBt	3.7	3.6	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	31.25	31.375	31.25	31.375
ft = 1-N*((do-2*tt)/G)**2	0.6426	0.6455	0.6426	0.6455
Pt' =	39.6	42.5	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-		-- With exp.joint --	
Tensile stress (shell), psi	Uncorroded	Corroded	Uncorroded	Corroded
Allowable stress	20000	20000	20000	20000
Tensile stress Ss =	2616	3017	0	0
Compressive stress (shell), psi				
Allowable stress	15579	16127	15579	16127
Compressive stress Ss =	0	0	0	0
Effective pressure, Ps*, psi				
Ps* = Pt-Pt'	50.4	47.5	0	0
Ps* = Ps'	50.4	53.2	0	0
Ps* = -Pd	147.4	137.3	0	0
Ps* = Pt-Pt'+Ps'	100.8	100.7	0	0
Ps* = Pt-Pt'-Pd	197.8	184.8	0	0
Ps* = Ps'-Pd	197.8	190.5	0	0
Ps* = Pt-Pt'+Ps'-Pd	248.2	238	0	0

Component: Rear Tubesheet

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	31.25	31.375	31.25	31.375
Fs = 3.25-0.5*Fq	1.25	1.25	0	0
Tensile stress (tubes), psi				
Allowable stress	18941	18941	18941	18941
Tensile stress St =	1163.6	1299.8	0	0
Compressive stress (tubes), psi				
Allowable stress Sc =	9586	9586	0	0
Compressive stress St =	-7563.6	-7331.3	0	0
Intermediate pressures, P2 and P3, psi				
P2 = Pt'-(ft*Pt/Fq)	27.7	30.6	0	0
P3 = Ps'-(fs*Ps/Fq)	32.5	35.2	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	27.7	30.6	0	0
Pt* = -P3	-32.5	-35.2	0	0
Pt* = Pd	-147.4	-137.3	0	0
Pt* = P2-P3	-4.8	-4.6	0	0
Pt* = P2+Pd	-119.7	-106.7	0	0
Pt* = -P3+Pd	-179.9	-172.5	0	0
Pt* = P2-P3+Pd	-152.2	-142	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 = 45.375 in
Cc = Sqrt(2*Pi**2*Et/Sy)   Cc = 157.1   kl/r = 146.11
r = 0.25*Sqrt(do**2+(do-2*tt)**2) = 0.2484 in

```
Component: Rear Tubesheet
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         31.25      31.375       31.25      31.375
Tube-to-tubesheet load, Wj      147.4      161.6          0           0
Effective pressure, Pt*, psi
  Pt* = P2                       27.7       30.6          0           0
  Pt* = -P3                     -32.5      -35.2          0           0
  Pt* = P2-P3                    -4.8       -4.6          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
                                                   No Test             Test
Type      Joint description                     fr    Lmax        fr    Lmax
  a    Strength welded only                     0.8   1635         1    2044
  b    Seal welded only                        0.55   1124        0.7   1431
  e    Strength welded and expanded             0.8   1635         1    2044
  f    Seal welded and exp.with 2 grooves      0.75   1533       0.95   1942
  g    Seal welded and exp.with 1 groove       0.65   1329       0.85   1737
  h    Seal welded and exp.with no grooves      0.5   1022        0.7   1431
  i    Expanded with 2 grooves                  0.7   1431        0.9   1840
  j    Expanded with 1 groove                  0.65   1329        0.8   1635
  k    Expanded with no grooves                 0.5   1022        0.6   1226
* = 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 = 18941 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 = 126 F
Tubes Mod.Elasticity EtT = 27998460 psi  TubSh Mod.Elast.        EsT = 27998460 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: Front Tubesheet  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)(3)
*** Tubesheet material:       SA-240 S30400 Grd 304 Plate
Design temp. tubesheet T = 300 F        TubSh metal tmp at rim T'= 126 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' = 8.704
Poisson's rat. tubSh   v = 0.3            *(th.exp.coef * 10**6)
*** Shell material:           SA-516 K02700 Grd 70 Plate
Design temp. shell    Ts = 300 F        Shell metal tmp/TubS T's = 95 F
Shell allowable str.  Ss = 20000 psi    *Shell th.ex.coe.alpha's = 6.4833
Shell mod.elasticity  Es = 28100000 psi Shell mean metal tmp Tsm = 95 F
Poisson's ratio shell vs = 0.3          *Shell th.ex.coe.alphasm = 6.4833
*** Tube material:            SA-249 S30400 Grd TP304 Wld. tube(G5)
Design temp. tubes    Tt = 300 F        Tubes mean metal tmp Ttm = 126 F
Tube allow.Str. at Tt St = 18941.2 psi  Tube allow.Str. at T Stt = 18941.2 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  = 8.704
Tube yield stress    Syt = 22400 psi      *(th.exp.coef * 10**6)
*** Channel material:         SA-240 S30400 Grd 304 Plate
Design temp. channel  Tc = 300 F        Channel metal tmp TS T'c = 126 F
Channel all. stress   Sc = 15000 psi    *Chan.th.ex.coe.alpha'c  = 8.704
Channel mod.elast.    Ec = 27000000 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 = 1.75 in     Actual tubesheet thk  ha = 1.75 in
Shell side corr allow   c = 0.0625 in   Tube side cor.allow.   c = 0.0 in
-- TubSh corr allow    cs = 0.0 in      TS TubSh corr allow   ct = 0.0 in
                                 Corroded case     Uncorroded case
Shell diameter, Ds                  31.375 in        31.25 in
Channel diameter, Dc                 31.5 in          31.5 in
Shell thickness, ts                 0.3125 in        0.375 in
Adjacent shell thk  ts,1             0.0 in           0.0 in
Channel thickness, tc                0.25 in          0.25 in
Minimum TubSh thk, hmin             0.9254 in        0.9428 in
Thickness h used                     1.75 in          1.75 in
Tubesheet OD            A = 35.25 in    Bolt circle diam.      C = 34.0 in
```

```
Shell gasket diam.       Gs = -              Channel gasket diam.   Gc = 32.5 in
Gasket reaction diam.  G = 32.5 in        Gasket reaction diam. G1 = 32.5 in
Number of tubes       Nt = 821            Flange load             W = 72738 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 = 1.0 in         Center-to-center dis   UL = 0.0 in
Tube projection      tpr = 0.125 in       Tube corrosion allow.   c = -
Tube length L         L  = 236.25 in      Tube length Lt         Lt = 239.75 in
Tube expanded depth  ltx = 1.625 in       Tube exp.depth ratio rho = 0.929
Tube buckling factor   k = 0.8            Unsupported tube span   l = 45.375 in
Outermost tube rad.   ro = 15.0313 in     Unsupp.length lt=k*l   lt = 36.3 in
Shell radius          as = 15.6875 in     Channel radius         ac = 16.25 in
Shell design pressure Ps = 165 psi        Tube design pressure Pt  = 90 psi
Exp.joint spring rate kj = -                     EJ diameter     Dj = -
Component: Front Tubesheet
           Fig.UHX-13.1(b)  Controlling Case: UHX-13.4(a)(3)
UHX-13.5.1 Step 1.  Determine Do, Mu, Mu* and h'g from UHX-11.5.1.
  Do = 2 * ro + dt                                              Do = 30.8125 in
  mu = (p - dt) / p                                             mu = 0.25
  d* = MAX(dt-2*tt*(Ett/E)*(Stt/S)*Rho),(dt-2*tt))              d* = 0.652 in
  Pass lane area limit                                      4*Do*p = 123.25 in2
  Actual pass lane area, AL                                     AL = 0 in2
  Effective pitch = p/SQRT(1-(4*MIN[AL,4*Do*p]/Pi*Do**2))       p* = 1.0 in
  mu* = (p* - d*) / p*                                         mu* = 0.348
  h'g = MAX[(hg-ct),(0)]                                       h'g = 0.0 in
  Calculate ao, rhos, rhoc, xs and xt
  ao = radius of the perforated region = Do / 2                 ao = 15.4063 in
  rhos = as/ao                                                rhos = 1.0183
  rhoc = ac/ao                                                rhoc = 1.0548
  xs = 1 - Nt(dt/(2*ao))**2                                     xs = 0.5136
  xt = 1 - Nt((dt-2*tt)/(2*ao))**2                              xt = 0.6324
```

```
X-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 = 3700176 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 = 12333 lbf/in
  Factor Ks,t = Ks/(Nt*Kt) or Ks*/(Nt*Kt)                Ks,t = 0.3654
  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 = 0.5777
  ks = betas*(Es*ts**3)/(6*(1-vs**2)                         ks = 90730
  lambdas=(6*Ds/h**3)*ks*(1+h*betas+(h**2*betas**2)/2) lambdas = 8037212
  deltas = (Ds**2/(4*Es*ts))*(1-vs/2)                    deltas = 0.0000238
  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: Front Tubesheet
           Fig.UHX-13.1(b)  Controlling Case: UHX-13.4(a)(3)
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 = 1.75 in
  From fig. UHX-11.2 or UHX-11.3 - E*/E = 0.3542             v* = 0.3201
                                  h/p = 1.75                mu* = 0.348

  Effective Tubsheet Mod.Elasticity  E* = 9563070 psi
  Parameter Xa = (24*(1-v*(**2))*Nt*(Et*tt*(dt-tt)*
             ao**2)/((E*)*L*h**3))**0.25                     Xa = 4.234
UHX-13.5.4 Step 4. Calculate diameter ratio K and coefficient F.
  K = A / Do                                                  K = 1.144
  F = ((1-v*)/E*)*(lambdas+lambdac+E*Ln(K))                   F = 0.830
```

```
Parameters Zd, Zv and Zm from Table UHX-13.1
  Psi1(Xa)=bei(Xa)+(1-v*)/Xa*ber'(Xa)                    Psi1(Xa) = 1.5484
  Psi2(Xa)=ber(Xa)-(1-v*)/Xa*bei'(Xa)                    Psi2(Xa) = -3.1558
  Za = bei'(Xa)*Psi2(Xa)-ber'(Xa)*Psi1(Xa)                     Za = 8.9504
  Zd = (ber(Xa)*Psi2(Xa)+ bei(Xa)*Psi1(Xa))/(Xa**3*Za)         Zd = 0.0203
  Zv = (ber'(Xa)*Psi2(Xa)+ bei'(Xa)*Psi1(Xa))/(Xa**2*Za)       Zv = 0.0572
  Zm = (ber'(Xa)**2+bei'(Xa)**2)/(Xa*Za)                       Zm = 0.3508
  Calculate Q1, Qz1, Qz2 and U
  Phi = (1+v*) * F                                            Phi = 1.0953
  Q1 = (rhos-1-Phi*Zv)/(1+Phi*Zm)                              Q1 = -0.032
  Qz1 = ((Zd+Q1*Zv)*Xa**4)/2                                  Qz1 = 2.9683
  Qz2 = ((Zv+Q1*Zm)*Xa**4)/2                                  Qz2 = 7.3834
  U = ((Zv+(rhos-1)*Zm)*Xa**4)/(1+Phi*Zm)                       U = 14.7668
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 = 2.5566
  omegas* = ao**2*((rhos**2-1)*(rhos-1))/4-omegas        omegas* = -2.5167
  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* = 4.6987
UHX-13.5.5(c) Calculate gammab
  gammab = (Gc-C)/Do                                     gammab = -0.0487
```

```
 mponent: Front Tubesheet
          Fig.UHX-13.1(b)  Controlling Case: UHX-13.4(a)(3)
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' = 397.14 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' = 323.04 psi
  Pgamma  = (Nt*Kt/(Pi*ao**2))*gamma                      Pgamma = 0 psi
  PW      = -(U/ao**2)(gammab/(2*Pi))*W                       PW = 35.06 psi
  Prim    = -(U/ao**2)*((omegas*)(Ps)-(omegac*)(Pt))        Prim = 52.14 psi
  Effective pressure, Pe
  Pe = (J*Kst/(1+J*Kst(Qz1+(rhos-1)Qz2))
       * (Ps'-Pt'+Pgamma+PW+Prim)                             Pe = 27.62 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 = -1012.5969
  Q3 = Q1 + 2*Q2 / Pe*ao**2                                   Q3 = -0.3409
  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 = 4.2345 in

Calculate functions Psi1 and Psi2 relative to x
  Psi1(x) = bei(x) + (1-v*)/x * ber'(x)                  Psi1(x) = 1.5484
  Psi2(x) = ber(x) - (1-v*)/x * bei'(x)                  Psi2(x) = -3.1557
Calculate functions Qm, Qv and Fm relative to x
  Qm(x) = (bei'(Xa)*Psi2(x)-ber'(Xa)*Psi1(x))/Za           Qm(x) = 1.0
  Qv(x) = (Psi1(Xa)*Psi2(x)-Psi2(Xa)*Psi1(x))/(Xa*Za)      Qv(x) = 0.0
```

```
Controlling Fm relative to x
  Fm(x) = (Qv(x) + Q3 * Qm(x)) / 2                         Fm(x) = -0.1705
  Fm = MAX|Fm(x)|                                             Fm = 0.1705
  For each loading case, calculate the bending stress in the tubesheet
  sigma = (1.5*Fm/mu*)*(2*ao/(h-h'g))**2 * Pe              sigma = 6292 psi
                                                         |sigma| <= 1.5*S
                                                        6292 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 = 653.85 in2
  Perimeter of the tube layout                                CL = 137.3205 in
  Shear diameter DL = 4*AL/CL or Do                           Do = 30.8125 in
  Ligament efficiency, mu                          mu = (p-dt)/p = 0.25
  Shear stress, tau = (1/(4*mu)*(Do/h)* Pe                   tau = 486 psi
                                                           |tau| <= 0.8*S
                                                         486 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     = 0.1294
            sigmato = ((Ps*xs-Ptxt)-Pe*Fq)/(xt-xs) = 204 psi
                                                         sigmato <= St
                                                         204 psi <= 18941 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 = 146.1084
  Fs = MAX((1.25,(3.25-0.5*Fq),2)                             Fs = 2.0
  For Ct <= Ft  Stb = MIN[(1/Fs)*(PI**2*Et/(Ft**2),St]       Stb = -
  or Ct >   Ft  Stb = MIN[(Syt/Fs)*(1-(Ft/2*Ct))   ,St]      Stb = -5896 psi
                                                         sigmato <= Stb
                                                               - <= -5896 psi
```

```
X-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 = 1.3648
  sigmati = ((Ps*xs-Ptxt)-Pe*Fi)/(xt-xs)                  sigmati = -83 psi
                                                         sigmati <= Stb
                                                         -83 psi <= -5896 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 = 2965 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 = 5497 psi
  sigmas = |sigmasm| + |sigmasb|                           sigmas = 8462 psi
                                                          sigmas <= 1.5*S
                                                        8462 psi <= 30000 psi
```

..SME 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	90	0	90	0	90	0	90
Shell-side press, Ps	0	165	165	0	0	165	165
Axial diff.Th.Exp	0.0	0.0	0.0	0.0769	0.0769	0.0769	0.0769
TubSh Bending stress	-5709	5660	6292	10913	7274	14595	10632
Max TubSh Bending st	22500	22500	22500	57426	57426	57426	57426
Min TubSh thk	0.8815	0.8778	0.9254	0.7629	0.6228	0.8823	0.753
TubSh Shear stress	-789	1381	486	3360	2470	4632	3742
Max TubSh Shear str	12000	12000	12000	15314	15314	15314	15314
Min TubSh thk	0.1151	0.2014	0.0709	0.384	0.2822	0.5294	0.4276
Tubesheet thickness	1.75	1.75	1.75	1.75	1.75	1.75	1.75

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

Load case:	1	2	3	4	5	6	7
Tubes stress	1105	-786	204	-4529	-3535	-5434	-4440
Max Tubes stress	18941	18941	18941	40000	40000	40000	40000
Max buckling stress	-	-5896	-	-6407	-6029	-6332	-6068
Total shell stress	15097	18467	8462	26753	16636	48184	38066
Max shell stress	30000	30000	30000	67200	67200	67200	67200
Max shell stress EP	67200	67200	67200				
Total channel stress	2903	0	2903	0	2903	0	2903
Max channel stress	22500	22500	22500	57426	57426	57426	57426
Max channel str. EP	45000	45000	45000				
EP factor - Facts(*)	1.0	1.0	1.0				
..P 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	-894	-786	-83	-4529	-3535	-5434	-4440
Max buckling stress	-9433	-5896	-5896	-6407	-6029	-6332	-6068

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	90	0	0	0
- 2 -	165	0	0	0	0
- 3 -	165	90	0	0	0
- 4 -	0	0	0.0769	0	0
- 5 -	0	90	0.0769	0	0
- 6 -	165	0	0.0769	0	0
- 7 -	165	90	0.0769	0	0

Load case	P's psi	P't psi	Pgamma psi	Pomega psi	Pw psi	Prim psi	Pe psi
- 1 -	0	323	0	0	35.1	26.3	-44.8
- 2 -	397.1	0	0	0	35.1	25.8	78.4
- 3 -	397.1	323	0	0	35.1	52.1	27.6
- 4 -	0	0	1082.3	0	35.5	0	190.9
- 5 -	0	322.8	1082.3	0	35.5	26.6	140.3
- 6 -	396.9	0	1082.3	0	35.5	26.1	263.1
- 7 -	396.9	322.8	1082.3	0	35.5	52.7	212.5

Load case	Q2	Q3	Fm	Sigma psi	Sigma All psi	Tau psi	Tau All psi
- 1 -	-712.6	0.102	0.0953	-5709	22500	-789	12000
- 2 -	-707.1	-0.108	0.054	5660	22500	1381	12000
- 3 -	-1012.6	-0.3409	0.1705	6292	22500	486	12000
- 4 -	-404	-0.0505	0.0414	10913	57426	3360	15314
- 5 -	-707.1	-0.0751	0.0376	7274	57426	2470	15314
- 6 -	-701.6	-0.0551	0.0402	14595	57426	4632	15314
- 7 -	-1004.7	-0.0725	0.0362	10632	57426	3742	15314

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

Load case	Fq	Fs	Sigto psi	Sigto All psi	Stb psi
- 1 -	4.1999	1.25	1105	18941	-9433
- 2 -	2.2702	2	-786	18941	-5896
- 3 -	0.1294	2	204	18941	-5896
- 4 -	2.8193	1.8403	-4529	40000	-6407
- 5 -	2.5888	1.9556	-3535	40000	-6029
- 6 -	2.7759	1.862	-5434	40000	-6332
- 7 -	2.6134	1.9433	-4440	40000	-6068

Load case	Sigsm psi	Sigsb psi	|Sigs| psi	Sigsall psi	Sigcm psi	Sigcb psi	|Sigc| psi	Sigcall psi
- 1 -	1083	-14013	15097	30000	2903	0	2903	22500
- 2 -	2026	16441	18467	30000	0	0	0	22500
- 3 -	2965	5497	8462	30000	2903	0	2903	22500
- 4 -	4575	22179	26753	67200	0	0	0	57426
- 5 -	5520	11116	16636	67200	2903	0	2903	57426
- 6 -	6452	41732	48184	67200	0	0	0	57426
- 7 -	7397	30670	38066	67200	2903	0	2903	57426

```
Type of tube-to-TS joint: expanded & strength welded
Load case:              1       2       3       4       5       6       7
Tube-to-TS Load, lbf   119      85      22     489     382     586     479
Allowable no-test     1635    1635    1635    3270    3270    3270    3270
Allowable test        2044    2044    2044    4088    4088    4088    4088
Allowable Loads per ASME Section VIII Div. 1 2004 A06 Appendix A
                                                  No Test            Test
Type      Joint description                      fr     Lmax        fr     Lmax
  a   Strength welded only                       0.8    1635         1     2044
  b   Seal welded only                          0.55    1124        0.7    1431
  e   Strength welded and expanded               0.8    1635         1     2044
  f   Seal welded and exp.with 2 grooves        0.75    1533       0.95    1942
  g   Seal welded and exp.with 1 groove         0.65    1329       0.85    1737
  h   Seal welded and exp.with no grooves        0.5    1022        0.7    1431
  i   Expanded with 2 grooves                    0.7    1431        0.9    1840
  j   Expanded with 1 groove                    0.65    1329        0.8    1635
  k   Expanded with no grooves                   0.5    1022        0.6    1226
* = 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 = 18941 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 = 126 F
Tubes Mod.Elasticity EtT = 27998460 psi TubSh Mod.Elast.       EsT = 27998460 psi
Tubes Coef.Th.Exp.    at = 0.0000087    TubSh Coef.Th.Exp.      as = 0.0000087
   = (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 = 32.5 in
hG = gasket moment arm                                  hG = 0.75 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 = 69876 lbf
Wg = flange design bolt load, gasket seating            Wg = 72738 lbf
Minimum required thickness of the tubesheet flanged extension
hro = SQRT(1.9 * Wo * hG) / (Sd * G)                   hro = 0.4519 in
hrg = SQRT(1.9 * Wg * hG) / (Sa * G)                   hro = 0.3993 in
hr = MAX[hro, hrg]                                      hr = 0.4519 in
```

```
..mponent: Rear Tubesheet   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)(3)
*** Tubesheet material:      SA-240 S30400 Grd 304 Plate
Design temp. tubesheet T = 300 F         TubSh metal tmp at rim T'= 126 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' = 8.704
Poisson's rat. tubSh   v = 0.3             *(th.exp.coef * 10**6)
*** Shell material:          SA-516 K02700 Grd 70 Plate
Design temp. shell    Ts = 300 F         Shell metal tmp/TubS T's = 95 F
Shell allowable str.  Ss = 20000 psi     *Shell th.ex.coe.alpha's = 6.4833
Shell mod.elasticity  Es = 28100000 psi Shell mean metal tmp Tsm = 95 F
Poisson's ratio shell vs = 0.3           *Shell th.ex.coe.alphasm = 6.4833
*** Tube material:           SA-249 S30400 Grd TP304 Wld. tube(G5)
Design temp. tubes    Tt = 300 F         Tubes mean metal tmp Ttm = 126 F
Tube allow.Str. at Tt St = 18941.2 psi  Tube allow.Str. at T Stt = 18941.2 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  =.8.704
Tube yield stress    Syt = 22400 psi       *(th.exp.coef * 10**6)
*** Channel material:        SA-240 S30400 Grd 304 Plate
Design temp. channel  Tc = 300 F         Channel metal tmp TS T'c = 126 F
Channel all. stress   Sc = 15000 psi     *Chan.th.ex.coe.alpha'c  = 8.704
Channel mod.elast.    Ec = 27000000 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 = 1.75 in       Actual tubesheet thk  ha = 1.75 in
Shell side corr allow  c = 0.0625 in     Tube side cor.allow.   c = 0.0 in
.. TubSh corr allow   cs = 0.0 in        TS TubSh corr allow   ct = 0.0 in
                                Corroded case     Uncorroded case
Shell diameter, Ds                 31.375 in         31.25 in
Channel diameter, Dc               31.375 in         31.375 in
Shell thickness, ts                0.3125 in         0.375 in
Adjacent shell thk  ts,1            0.0 in            0.0 in
Channel thickness, tc              0.3125 in         0.3125 in
Minimum TubSh thk, hmin            0.9557 in         0.9709 in
Thickness h used                    1.75 in           1.75 in
Tubesheet OD           A = 35.5 in       Bolt circle diam.      C = 34.25 in
```

```
Shell gasket diam.     Gs = -              Channel gasket diam.  Gc = 32.75 in
Gasket reaction diam.  G = 32.75 in     Gasket reaction diam. G1 = 32.75 in
Number of tubes       Nt = 821          Flange load             W = 73248 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 = 1.0 in       Center-to-center dis   UL = 0.0 in
Tube projection      tpr = 0.125 in     Tube corrosion allow.   c = -
Tube length L          L  = 236.25 in   Tube length Lt         Lt = 239.75 in
Tube expanded depth  ltx = 1.625 in     Tube exp.depth ratio rho = 0.929
Tube buckling factor   k = 0.8          Unsupported tube span   l = 45.375 in
Outermost tube rad.   ro = 15.0313 in   Unsupp.length lt=k*l   lt = 36.3 in
Shell radius          as = 15.6875 in   Channel radius         ac = 16.375 in
Shell design pressure Ps = 165 psi      Tube design pressure Pt  = 90 psi
Exp.joint spring rate kj = -                   EJ diameter     Dj = -
Component: Rear Tubesheet
          Fig.UHX-13.1(b)  Controlling Case: UHX-13.4(a)(3)
UHX-13.5.1 Step 1.  Determine Do, Mu, Mu* and h'g from UHX-11.5.1.
  Do = 2 * ro + dt                                          Do = 30.8125 in
  mu = (p - dt) / p                                         mu = 0.25
  d* = MAX(dt-2*tt*(Ett/E)*(Stt/S)*Rho),(dt-2*tt))          d* = 0.652 in
  Pass lane area limit                                  4*Do*p = 123.25 in2
  Actual pass lane area, AL                                 AL = 0 in2
  Effective pitch = p/SQRT(1-(4*MIN[AL,4*Do*p]/Pi*Do**2))   p* = 1.0 in
  mu* = (p* - d*) / p*                                     mu* = 0.348
  h'g = MAX[(hg-ct),(0)]                                   h'g = 0.0 in
  Calculate ao, rhos, rhoc, xs and xt
  ao = radius of the perforated region = Do / 2             ao = 15.4063 in
  rhos = as/ao                                            rhos = 1.0183
  rhoc = ac/ao                                            rhoc = 1.0629
  xs = 1 - Nt(dt/(2*ao))**2                                 xs = 0.5136
  xt = 1 - Nt((dt-2*tt)/(2*ao))**2                          xt = 0.6324
```

```
..X-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 = 3700176 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 = 12333 lbf/in
  Factor Ks,t = Ks/(Nt*Kt) or Ks*/(Nt*Kt)                  Ks,t = 0.3654
  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 = 0.5777
  ks = betas*(Es*ts**3)/(6*(1-vs**2)                          ks = 90730
  lambdas=(6*Ds/h**3)*ks*(1+h*betas+(h**2*betas**2)/2) lambdas = 8037212
  deltas = (Ds**2/(4*Es*ts))*(1-vs/2)                     deltas = 0.0000238
  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: Rear Tubesheet
           Fig.UHX-13.1(b)  Controlling Case: UHX-13.4(a)(3)
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 = 1.75 in
  From fig. UHX-11.2 or UHX-11.3 - E*/E = 0.3542             v* = 0.3201
                                 h/p = 1.75                 mu* = 0.348
  Effective Tubsheet Mod.Elasticity  E* = 9563070 psi
  Parameter Xa = (24*(1-v*(**2))*Nt*(Et*tt*(dt-tt)*
               ao**2)/((E*)*L*h**3))**0.25                    Xa = 4.234
..X-13.5.4 Step 4. Calculate diameter ratio K and coefficient F.
    = A / Do                                                   K = 1.152
  F = ((1-v*)/E*)*(lambdas+lambdac+E*Ln(K))                    F = 0.843
```

```
  Parameters Zd, Zv and Zm from Table UHX-13.1
  Psi1(Xa)=bei(Xa)+(1-v*)/Xa*ber'(Xa)                        Psi1(Xa) = 1.5484
  Psi2(Xa)=ber(Xa)-(1-v*)/Xa*bei'(Xa)                        Psi2(Xa) = -3.1558
  Za = bei'(Xa)*Psi2(Xa)-ber'(Xa)*Psi1(Xa)                         Za = 8.9504
  Zd = (ber(Xa)*Psi2(Xa)+ bei(Xa)*Psi1(Xa))/(Xa**3*Za)             Zd = 0.0203
  Zv = (ber'(Xa)*Psi2(Xa)+ bei'(Xa)*Psi1(Xa))/(Xa**2*Za)           Zv = 0.0572
  Zm = (ber'(Xa)**2+bei'(Xa)**2)/(Xa*Za)                           Zm = 0.3508
  Calculate Q1, Qz1, Qz2 and U
  Phi = (1+v*) * F                                                Phi = 1.1132
  Q1 = (rhos-1-Phi*Zv)/(1+Phi*Zm)                                  Q1 = -0.0326
  Qz1 = ((Zd+Q1*Zv)*Xa**4)/2                                      Qz1 = 2.9629
  Qz2 = ((Zv+Q1*Zm)*Xa**4)/2                                      Qz2 = 7.35
  U = ((Zv+(rhos-1)*Zm)*Xa**4)/(1+Phi*Zm)                           U = 14.7001
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 = 2.5566
  omegas* = ao**2*((rhos**2-1)*(rhos-1))/4-omegas          omegas* = -2.5167
  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* = 5.7799
UHX-13.5.5(c) Calculate gammab
  gammab = (Gc-C)/Do                                        gammab = -0.0487
```

```
Component: Rear Tubesheet
           Fig.UHX-13.1(b)  Controlling Case: UHX-13.4(a)(3)
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' = 397.14 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' = 323.04 psi
  Pgamma   = (Nt*Kt/(Pi*ao**2))*gamma                      Pgamma = 0 psi
  PW       = -(U/ao**2)(gammab/(2*Pi))*W                       PW = 35.15 psi
  Prim     = -(U/ao**2)*((omegas*)(Ps)-(omegac*)(Pt))        Prim = 57.94 psi
  Effective pressure, Pe
  Pe = (J*Kst/(1+J*Kst(Qz1+(rhos-1)Qz2))
       * (Ps'-Pt'+Pgamma+PW+Prim)                              Pe = 28.66 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 = -1080.8384
  Q3 = Q1 + 2*Q2 / Pe*ao**2                                    Q3 = -0.3504
  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 = 4.2345 in
Calculate functions Psi1 and Psi2 relative to x
  Psi1(x) = bei(x) + (1-v*)/x * ber'(x)                    Psi1(x) = 1.5484
  Psi2(x) = ber(x) - (1-v*)/x * bei'(x)                    Psi2(x) = -3.1557
Calculate functions Qm, Qv and Fm relative to x
  Qm(x) = (bei'(Xa)*Psi2(x)-ber'(Xa)*Psi1(x))/Za             Qm(x) = 1.0
  Qv(x) = (Psi1(Xa)*Psi2(x)-Psi2(Xa)*Psi1(x))/(Xa*Za)        Qv(x) = 0.0
```

```
Controlling Fm relative to x
Fm(x) = (Qv(x) + Q3 * Qm(x)) / 2                          Fm(x) = -0.1752
Fm = MAX|Fm(x)|                                              Fm = 0.1752
For each loading case, calculate the bending stress in the tubesheet
sigma = (1.5*Fm/mu*)*(2*ao/(h-h'g))**2 * Pe              sigma = 6710 psi
                                                        |sigma| <= 1.5*S
                                                       6710 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 = 653.85 in2
  Perimeter of the tube layout                                CL = 137.3205 in
  Shear diameter DL = 4*AL/CL or Do                           Do = 30.8125 in
  Ligament efficiency, mu                           mu = (p-dt)/p = 0.25
  Shear stress, tau = (1/(4*mu)*(Do/h)* Pe                   tau = 505 psi
                                                          |tau| <= 0.8*S
                                                        505 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    = 0.0422
                  sigmato = ((Ps*xs-Ptxt)-Pe*Fq)/(xt-xs) = 224 psi
                                                        sigmato <= St
                                                        224 psi <= 18941 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 = 146.1084
  Fs = MAX((1.25,(3.25-0.5*Fq),2)                             Fs = 2.0
  For Ct <= Ft  Stb = MIN[(1/Fs)*(PI**2*Et/(Ft**2),St]       Stb = -
  or Ct >  Ft  Stb = MIN[(Syt/Fs)*(1-(Ft/2*Ct))   ,St]       Stb = -5896 psi
                                                        sigmato <= Stb
                                                              - <= -5896 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 = 1.38
  sigmati = ((Ps*xs-Ptxt)-Pe*Fi)/(xt-xs)              sigmati = -99 psi
                                                     sigmati <= Stb
                                                     -99 psi <= -5896 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 = 2990 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 = 4967 psi
  sigmas = |sigmasm| + |sigmasb|                         sigmas = 7957 psi
                                                        sigmas <= 1.5*S
                                                    7957 psi <= 30000 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	90	0	90	0	90	0	90
Shell-side press, Ps	0	165	165	0	0	165	165
Axial diff.Th.Exp	0.0	0.0	0.0	0.0769	0.0769	0.0769	0.0769
TubSh Bending stress	-5967	5691	6710	10882	7759	14557	11141
Max TubSh Bending st	22500	22500	22500	57426	57426	57426	57426
Min TubSh thk	0.9012	0.8801	0.9557	0.7618	0.6433	0.8811	0.7708
TubSh Shear stress	-772	1382	505	3364	2491	4637	3763
Max TubSh Shear str	12000	12000	12000	15314	15314	15314	15314
Min TubSh thk	0.1125	0.2016	0.0736	0.3845	0.2846	0.5299	0.4301
Tubesheet thickness	1.75	1.75	1.75	1.75	1.75	1.75	1.75

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

Load case:	1	2	3	4	5	6	7
Tubes stress	1124	-784	224	-4525	-3513	-5428	-4416
Max Tubes stress	18941	18941	18941	40000	40000	40000	40000
Max buckling stress	-	-5896	-	-6397	-5967	-6324	-6024
Total shell stress	15622	18430	7957	26647	16052	48050	37455
Max shell stress	30000	30000	30000	67200	67200	67200	67200
Max shell stress EP	67200	67200	67200				
Total channel stress	2336	0	2336	0	2336	0	2336
Max channel stress	22500	22500	22500	57426	57426	57426	57426
Max channel str. EP	45000	45000	45000				
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	-905	-784	-99	-4525	-3513	-5428	-4416
Max buckling stress	-9433	-5896	-5896	-6397	-5967	-6324	-6024

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	90	0	0	0
- 2 -	165	0	0	0	0
- 3 -	165	90	0	0	0
- 4 -	0	0	0.0769	0	0
- 5 -	0	90	0.0769	0	0
- 6 -	165	0	0.0769	0	0
- 7 -	165	90	0.0769	0	0

Load case	P's psi	P't psi	Pgamma psi	Pomega psi	Pw psi	Prim psi	Pe psi
- 1 -	0	323	0	0	35.1	32.2	-43.8
- 2 -	397.1	0	0	0	35.1	25.7	78.5
- 3 -	397.1	323	0	0	35.1	57.9	28.7
- 4 -	0	0	1082.3	0	35.5	0	191.1
- 5 -	0	322.8	1082.3	0	35.5	32.6	141.5
- 6 -	396.9	0	1082.3	0	35.5	26	263.4
- 7 -	396.9	322.8	1082.3	0	35.5	58.6	213.7

Load case	Q2	Q3	Fm	Sigma	Sigma All	Tau	Tau All
				psi	psi	psi	psi
- 1 -	-782.2	0.1177	0.1019	-5967	22500	-772	12000
- 2 -	-706.7	-0.1085	0.0542	5691	22500	1382	12000
- 3 -	-1080.8	-0.3504	0.1752	6710	22500	505	12000
- 4 -	-404.9	-0.0511	0.0413	10882	57426	3364	15314
- 5 -	-776.1	-0.0795	0.0397	7759	57426	2491	15314
- 6 -	-701.2	-0.0557	0.04	14557	57426	4637	15314
- 7 -	-1072.4	-0.0755	0.0378	11141	57426	3763	15314

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

Load case	Fq	Fs	Sigto	Sigto All	Stb
			psi	psi	psi
- 1 -	4.345	1.25	1124	18941	-9433
- 2 -	2.2658	2	-784	18941	-5896
- 3 -	0.0422	2	224	18941	-5896
- 4 -	2.8136	1.8432	-4525	40000	-6397
- 5 -	2.5481	1.976	-3513	40000	-5967
- 6 -	2.7707	1.8646	-5428	40000	-6324
- 7 -	2.5851	1.9575	-4416	40000	-6024

Load case	Sigsm	Sigsb	|Sigs|	Sigsall	Sigcm	Sigcb	|Sigc|	Sigcall
	psi	psi	psi	psi	psi	psi	psi	psi
- 1 -	1107	-14515	15622	30000	2336	0	2336	22500
- 2 -	2028	16402	18430	30000	0	0	0	22500
- 3 -	2990	4967	7957	30000	2336	0	2336	22500
- 4 -	4580	22067	26647	67200	0	0	0	57426
- 5 -	5548	10504	16052	67200	2336	0	2336	57426
- 6 -	6458	41592	48050	67200	0	0	0	57426
- 7 -	7426	30029	37455	67200	2336	0	2336	57426

```
_ype of tube-to-TS joint: expanded & strength welded
Load case:                1      2      3      4      5      6      7
Tube-to-TS Load, lbf    121     85     24    488    379    586    477
Allowable no-test      1635   1635   1635   3270   3270   3270   3270
Allowable test         2044   2044   2044   4088   4088   4088   4088
Allowable Loads per ASME Section VIII Div. 1 2004 A06 Appendix A
                                              No Test              Test
Type       Joint description              fr     Lmax         fr    Lmax
  a    Strength welded only              0.8     1635          1    2044
  b    Seal welded only                 0.55     1124        0.7    1431
  e    Strength welded and expanded      0.8     1635          1    2044
  f    Seal welded and exp.with 2 grooves 0.75   1533       0.95    1942
  g    Seal welded and exp.with 1 groove  0.65   1329       0.85    1737
  h    Seal welded and exp.with no grooves 0.5   1022        0.7    1431
  i    Expanded with 2 grooves           0.7     1431        0.9    1840
  j    Expanded with 1 groove           0.65     1329        0.8    1635
  k    Expanded with no grooves          0.5     1022        0.6    1226
* = 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 = 18941 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 = 126 F
Tubes Mod.Elasticity EtT = 27998460 psi TubSh Mod.Elast.     EsT = 27998460 psi
Tubes Coef.Th.Exp.    at = 0.0000087    TubSh Coef.Th.Exp.    as = 0.0000087
   = (4*(do*t-t**2)*st)/do**2                                 Po = 7328 psi
 t = ((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 = 32.75 in
hG = gasket moment arm                                hG = 0.75 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 = 70896 lbf
Wg = flange design bolt load, gasket seating          Wg = 73248 lbf
Minimum required thickness of the tubesheet flanged extension
hro = SQRT(1.9 * Wo * hG) / (Sd * G)                  hro = 0.4535 in
hrg = SQRT(1.9 * Wg * hG) / (Sa * G)                  hro = 0.3992 in
hr = MAX[hro, hrg]                                     hr = 0.4535 in
```

```
Component:  Nozzle A
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 = 0.7
Design stress         S = 14600 psi
Inside corr.allow. cai = 0.0625 in        Outside corr. all. cao = 0.0 in
Material tolerance tol = 0.0859 in        Minimum thickness tmin = 0.3235 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 = 0.3235 in   APP.1-1(A)
  - UG-45(a) external pressure+cai+cao+tol       t = 0.192 in
  - UG-16(b) minimum thickness+cai+cao+tol       t = 0.2422 in
    UG-45(b) Smaller of:                         t = 0.3129 in
    UG-45(b)(4) std pipe*0.875+cai+cao+tol = 0.4766 in
      - UG-45(b) Greater of:                 t = 0.3129 in
        - UG-45(b)(1)+cai+cao+tol = 0.3129 in
        - UG-45(b)(2)+cai+cao+tol = 0 in
                        Minimum thickness:               tmin = 0.3235 in
                        Nominal thickness:               tnom = 0.6875 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 = 24 in           Cylinder length EP  L = 6 in
Nominal thickness   tnom = 0.6875 in       (tnom-CAI-CAO-Tol)  t = 0.5391 in
L/Do ratio           Ldo = 0.25            Do/t              Dot = 44.5217
(2*S) or (0.9*yield) SE = -                Mod. of elasticity ME = 28100000 psi
A factor SII-D-FigG    A = 0.024436        B factor CS-2       B = 17594
Max allowed external pressure: Pa = 4*B / (3*Dot)             = 526.91 psi
Actual external design pressure:                           PE = 15 psi
   (Required cyl. tks. for nozzle attachments at PE, tre = 0.0436 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 = 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 = 44.0 in       Corroded radius     OR = 22.0 in
Nominal thickness  tnom = 0.5 in        Reinforcement limit lp = 22.75 in
Req. tks. int.pres.  tr = 0.1645 in     Req. tks.ext.pres. tre = 0.1275 in
Corroded thickness    t = 0.4375 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 = 0.7
Nozzle outside dia. Don = 24.0 in       Corroded radius     OR = 12.0 in
Nominal thickness  tnom = 0.6875 in     Reinforcement limit ln = 1.0938 in
Req.tks. int.pres.  trn = 0.1751 in     Req.tks.ext.pres. trne = 0.0436 in
Corroded thickness   tn = 0.625 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  = 0.4375 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)    = 0.3063 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                = 0.73
 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
```

```
..rroded inside diameter                                         d = 22.75 in
Vessel wall length available for reinforcement     2*Lp-d = 22.75 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)| = 6.1185 in2
 |2*(t+tn)*(E1*t-F*tr)-2*tn*(E1*t-F*tr)*(1-fr1)| = 0.488 in2
                                                                A1 = 6.1185 in2
A2 = Nozzle wall outward   | 5*(tn-trn)*fr2*t    | = 0.7184 in2
     Smaller of:           | 5*(tn-trn)*fr2*tn   | = 1.0263 in2
                                                                A2 = 0.7184 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 = 0.0931 in2
A42 = Outer element weld  = (L2**2)*fr4 = 0.0 in2
A43 = Inward nozzle weld  = (L3**2)*fr2 = 0.0 in2
                                                                A4 = 0.0931 in2
A5 = Reinforcement pad Area = (Dp-d-2*tn)*te*fr4                A5 = 0.0 in2
Aa = Area Available = A1+A2+A3+A4+A5                            Aa = 6.93 in2
A = Area required   = (d*tr*F)+2*tn*tr*F*(1-f1)                  A = 3.798 in2
For large nozzles per 1-7:
  Reinforcement limit Dp2 = MIN(Dp, 1-7(a)(1))                 Dp2 = 34.125 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)| = 3.0132 in
    |2*(t+tn)*(E1*t-F*tr)-2*tn*(E1*t-F*tr)*(1-fr1)|  = 0.488 in
   a2= Area Available    = A12+A2+A3+A4+A52                    Aa2 = 3.8247 in2
  A = (2/3)Area required = (2/3)*((d*tr*F)+2*tn*tr*F*(1-f1)) A = 2.532 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)| = 6.9479 in2
 |2*(t+tn)*(E1*t-F*tre)-2*tn*(E1*t-F*tre)*(1-fr1)| = 0.5541 in2
                                                                A1 = 6.9479 in2
A2 = Nozzle wall outward   | 5*(tn-trne)*fr2*t   | = 0.9285 in2
     Smaller of:           | 5*(tn-trne)*fr2*tn  | = 1.3264 in2
                                                                A2 = 0.9285 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 = 0.0931 in2
A42 = Outer element weld  =    (L2**2)*fr4 = 0.0 in2
A43 = Inward nozzle weld  =    (L3**2)*fr2 = 0.0 in2
                                                                A4 = 0.0931 in2
A5 = Reinforcement pad Area = (Dp-d-2*tn)*te*fr4                A5 = 0.0 in2
Aa = Area Available = A1+A2+A3+A4+A5                            Aa = 7.9695 in2
A = Area required   = 0.5*(d*tre*F+2*tn*tre*F*(1-fr1))           A = 1.4718 in2
```

```
.ozzle 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) = 16231 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) = 24215 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                =   96273 lbf
    Nozzle wall shear                      =   234414 lbf
    Groove weld tension                    =   145391 lbf
    Outer fillet weld shear                =   -
 Possible paths of failure
    1-1       234414 + 96273               =   330687 lbf
    2-2        96273 + 145391              =   241664 lbf
    3-3            - + -                   =   -
 Welds strong enough if path greater than the smaller of W or W(path)
                           Path 1-1 > W or W11
                         330687 lbf > 16231 lbf               OK
                           Path 2-2 > W or W22
                         241664 lbf > 24215 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-53 K03005 Grd E/B Wld. pipe
Design pressure        P = 150 psi        Design temperature    T = 300 F
Radiography              = None           Joint efficiency      E = 0.7
Design stress          S = 14600 psi
Inside corr.allow. cai = 0.0625 in        Outside corr. all. cao = 0.0 in
Material tolerance tol = 0.0469 in        Minimum thickness tmin = 0.2739 in
Outside diameter      OD = 20.0 in        Corroded radius      OR = 10.0 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 = 0.2553 in   APP.1-1(A)
  - UG-45(a) external pressure+cai+cao+tol        t = 0.149 in
  - UG-16(b) minimum thickness+cai+cao+tol        t = 0.2031 in
    UG-45(b) Smaller of:                          t = 0.2739 in
    UG-45(b)(4) std pipe*0.875+cai+cao+tol = 0.4375 in
      - UG-45(b) Greater of:              t = 0.2739 in
        - UG-45(b)(1)+cai+cao+tol = 0.2739 in
        - UG-45(b)(2)+cai+cao+tol = 0 in
                        Minimum thickness:                tmin = 0.2739 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-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 = 20 in           Cylinder length EP  L = 6 in
Nominal thickness   tnom = 0.375 in        (tnom-CAI-CAO-Tol)  t = 0.2656 in
L/Do ratio           Ldo = 0.3             Do/t              Dot = 75.2941
(2*S) or (0.9*yield) SE = -                Mod. of elasticity ME = 28100000 psi
A factor SII-D-FigG   A = 0.008301         B factor CS-2       B = 17325
Max allowed external pressure: Pa = 4*B / (3*Dot)              = 306.8 psi
Actual external design pressure:                             PE = 15 psi
   (Required cyl. tks. for nozzle attachments at PE, tre = 0.0396 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 = 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 = 44.0 in        Corroded radius     OR = 22.0 in
Nominal thickness  tnom = 0.5 in         Reinforcement limit lp = 19.375 in
Req. tks. int.pres.  tr = 0.1645 in      Req. tks.ext.pres. tre = 0.1195 in
Corroded thickness    t = 0.4375 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 = 0.7
Nozzle outside dia. Don = 20.0 in        Corroded radius     OR = 10.0 in
Nominal thickness  tnom = 0.375 in       Reinforcement limit ln = 0.7813 in
Req.tks. int.pres.  trn = 0.1459 in      Req.tks.ext.pres. trne = 0.0396 in
Corroded thickness   tn = 0.3125 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  = 0.3125 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)    = 0.2188 in      Weld tw     (actual)   = 0.0 in
Weld  tc   (minimum)    = 0.2188 in      Weld tc     (actual)   = 0.2188 in
    smaller |0.25 in    |                Leg size tw (actual)   = 0.0 in
      of    |0.7 * tmin|                 Leg size tc (actual)   = 0.3125 in
Outward nozzle weld   L1 = 0.3125 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
```

```
                                                          d = 19.375 in
Corroded inside diameter
Vessel wall length available for reinforcement     2*Lp-d = 19.375 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)| = 5.2432 in2
 |2*(t+tn)*(E1*t-F*tr)-2*tn*(E1*t-F*tr)*(1-fr1)| = 0.3634 in2
                                                          A1 = 5.2432 in2

A2 = Nozzle wall outward    | 5*(tn-trn)*fr2*t   | = 0.266 in2
     Smaller of:            | 5*(tn-trn)*fr2*tn  | = 0.19 in2
                                                          A2 = 0.19 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 = 0.0713 in2
A42 = Outer element weld  = (L2**2)*fr4 = 0.0 in2
A43 = Inward nozzle weld  = (L3**2)*fr2 = 0.0 in2
                                                          A4 = 0.0713 in2
                                                          A5 = 0.0 in2
A5 = Reinforcement pad Area = (Dp-d-2*tn)*te*fr4
Aa = Area Available = A1+A2+A3+A4+A5                      Aa = 5.5045 in2
A = Area required   = (d*tr*F)+2*tn*tr*F*(1-f1)            A = 3.2151 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)| = 6.1076 in2
 |2*(t+tn)*(E1*t-F*tre)-2*tn*(E1*t-F*tre)*(1-fr1)| = 0.4233 in2
                                                          A1 = 6.1076 in2

A2 = Nozzle wall outward    | 5*(tn-trne)*fr2*t   | = 0.4357 in2
     Smaller of:            | 5*(tn-trne)*fr2*tn  | = 0.3112 in2
                                                          A2 = 0.3112 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 = 0.0713 in2
A42 = Outer element weld  =   (L2**2)*fr4 = 0.0 in2
A43 = Inward nozzle weld  =   (L3**2)*fr2 = 0.0 in2
                                                          A4 = 0.0713 in2
                                                          A5 = 0.0 in2
A5 = Reinforcement pad Area = (Dp-d-2*tn)*te*fr4
Aa = Area Available = A1+A2+A3+A4+A5                      Aa = 6.4901 in2
A = Area required   = 0.5*(d*tre*F+2*tn*tre*F*(1-fr1))     A = 1.1677 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) = 5226 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) = 9218 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             =   70199 lbf
    Nozzle wall shear                   =   98717 lbf
    Groove weld tension                 =   106015 lbf
    Outer fillet weld shear             =   -
 Possible paths of failure
    1-1        98717 + 70199            =   168916 lbf
    2-2        70199 + 106015           =   176214 lbf
    3-3            - + -                =   -
 Welds strong enough if path greater than the smaller of W or W(path)
                          Path 1-1 > W or W11
                        168916 lbf > 5226 lbf             OK
                          Path 2-2 > W or W22
                        176214 lbf > 9218 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-312 S30400 Grd TP304 Wld. pipe
Design pressure       P = 75 psi          Design temperature    T = 300 F
Radiography             = None            Joint efficiency      E = 0.7
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 = 0.1406 in
Outside diameter    OD = 18.0 in          Corroded radius     OR = 9.0 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 = 0.111 in    APP.1-1(A)
  - UG-45(a) external pressure+cai+cao+tol        t = 0.085 in
  - UG-16(b) minimum thickness+cai+cao+tol        t = 0.1406 in
    UG-45(b) Smaller of:                          t = 0.1265 in
    UG-45(b)(4) std pipe*0.875+cai+cao+tol = 0.375 in
      - UG-45(b) Greater of:               t = 0.1265 in
        - UG-45(b)(1)+cai+cao+tol = 0.1265 in
        - UG-45(b)(2)+cai+cao+tol = 0.0629 in
                      Minimum thickness:               tmin = 0.1406 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
 '. outside dia.     Do = 18 in           Cylinder length EP  L = 6 in
 .inal thickness   tnom = 0.375 in        (tnom-CAI-CAO-Tol)  t = 0.3281 in
L/Do ratio          Ldo = 0.3333          Do/t              Dot = 54.8571
(2*S) or (0.9*yield) SE = -               Mod. of elasticity ME = 27000000 psi
A factor SII-D-FigG   A = 0.011908        B factor HA-1       B = 11854
Max allowed external pressure: Pa = 4*B / (3*Dot)              = 288.11 psi
Actual external design pressure:                            PE = 15 psi
   (Required cyl. tks. for nozzle attachments at PE, tre = 0.0381 in )
```

```
..mponent: 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 = 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
Inside corr. allow. CAI = 0.0 in          Outside corr.allow.CAO = 0.0 in
Vessel design stress Sv = 15000 psi       Joint efficiency      E = 1
Vessel outside dia   Do = 32.0 in         Corroded radius      OR = 16.0 in
Nominal thickness  tnom = 0.25 in         Reinforcement limit lp = 17.25 in
Req. tks. int.pres.  tr = 0.0797 in       Req. tks.ext.pres. tre = 0.087 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 = 0.7
Nozzle outside dia. Don = 18.0 in         Corroded radius      OR = 9.0 in
Nominal thickness  tnom = 0.375 in        Reinforcement limit ln = 0.625 in
Req.tks. int.pres.  trn = 0.0641 in       Req.tks.ext.pres. trne = 0.0381 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  = 0.25 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)    = 0.175 in        Weld tw     (actual)   = 0.0 in
Weld  tc   (minimum)    = 0.175 in        Weld tc     (actual)   = 0.175 in
     smaller |0.25 in   |                 Leg size tw (actual)   = 0.0 in
  :   of     |0.7 * tmin|                 Leg size tc (actual)   = 0.25 in
   ward nozzle weld   L1 = 0.25 in        fr1 = Sn/Sv                = 1.0
..uter element weld   L2 = 0.0 in         fr2 = Sn/Sv                = 1.0
Inward nozzle weld    L3 = 0.0 in         fr3 = Sn/Sv or Se/Sv       = 1.0
Inward nozzel weld new   = 0.0 in         fr4 = Se/Sv                = 1.0
Corroded int.proj.thk ti = 0.0 in
```

```
Corroded inside diameter                                          d = 17.25 in
Vessel wall length available for reinforcement          2*Lp-d = 17.25 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)| = 2.9384 in2
 |2*(t+tn)*(E1*t-F*tr)-2*tn*(E1*t-F*tr)*(1-fr1)| = 0.2129 in2
                                                              A1 = 2.9384 in2

A2 = Nozzle wall outward   | 5*(tn-trn)*fr2*t    | = 0.3886 in2
     Smaller of:           | 5*(tn-trn)*fr2*tn   | = 0.5829 in2
                                                              A2 = 0.3886 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 = 0.0625 in2
A42 = Outer element weld  = (L2**2)*fr4 = 0.0 in2
A43 = Inward nozzle weld  = (L3**2)*fr2 = 0.0 in2
                                                              A4 = 0.0625 in2
A5 = Reinforcement pad Area = (Dp-d-2*tn)*te*fr4              A5 = 0.0 in2
Aa = Area Available = A1+A2+A3+A4+A5                          Aa = 3.3895 in2
A = Area required   = (d*tr*F)+2*tn*tr*F*(1-f1)                A = 1.3741 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)| = 2.8117 in2
 |2*(t+tn)*(E1*t-F*tre)-2*tn*(E1*t-F*tre)*(1-fr1)| = 0.2037 in2
                                                              A1 = 2.8117 in2

A2 = Nozzle wall outward   | 5*(tn-trne)*fr2*t   | = 0.4211 in2
     Smaller of:           | 5*(tn-trne)*fr2*tn  | = 0.6316 in2
                                                              A2 = 0.4211 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 = 0.0625 in2
A42 = Outer element weld  =   (L2**2)*fr4 = 0.0 in2
A43 = Inward nozzle weld  =   (L3**2)*fr2 = 0.0 in2
                                                              A4 = 0.0625 in2
A5 = Reinforcement pad Area = (Dp-d-2*tn)*te*fr4              A5 = 0.0 in2
Aa = Area Available = A1+A2+A3+A4+A5                          Aa = 3.2953 in2
A = Area required   = 0.5*(d*tre*F+2*tn*tre*F*(1-fr1))         A = 0.7504 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) = 6767 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) = 9579 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                 =   51928 lbf
    Nozzle wall shear                       =   108956 lbf
    Groove weld tension                     =   78422 lbf
    Outer fillet weld shear                 =   -
 Possible paths of failure
    1-1       108956 + 51928                =   160884 lbf
    2-2        51928 + 78422                =   130350 lbf
    3-3              - + -                  =   -
 Welds strong enough if path greater than the smaller of W or W(path)
                                Path 1-1 > W or W11
                              160884 lbf > 6767 lbf                 OK
                                Path 2-2 > W or W22
                              130350 lbf > 9579 lbf                 OK
                                Path 3-3 > W or W33
                                       - > -
```

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	0.6875	1.88	29.5	27.25	1.62	20	1.25
B	ANSI SO	20.0	150	0.375	1.69	25.0	23.0	1.5	20	1.125
C	ANSI SO	18.0	150	0.375	1.56	22.75	21.0	1.5	16	1.125

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

```
 d loads - ANSI/SEI/ASCE 7-02
Vessel outside diameter        OD                            OD = 32 in
Vessel effective length        EL                            EL = 487.3125 in
Vessel effective diameter      EOD                          EOD = 48 in
Effective wind area            Af                   Af = EOD*EL = 162.44 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 = 3004.4 lbf
Moment arm                     L                              L = 20.3 ft
Overturning moment, OM,   ft-lbf                     OM = F*L = 61004
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
   ctral response acceleration at 1-sec period    Sd1 = (2/3)*Sm1 = 0.13
  smic 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 = 19476 lbf
Total shear at the base, V = Cs * W                               V = 4587.8 lbf
Maximum lateral force,    F = V                                   F = 4587.8 lbf
Overturning moment, OM,   ft-lbf                    OM = 0.5*F*L = 46577
```

nd 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 = 0.04 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	56.04		146.53
Avg. fluid density	lb/ft3	0		0
Fluid weight	lb	0		0
Surface area	ft2	167.4		172.8
Surface Area			340.2 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			12942 lb	
Operating weight			19476 lb	
Full weight			19476 lb	

```
Component:  Shell Lifting Lugs
Calculation of Plate-type Lifting Lugs
Lug material:  SA-36 K02600 Plate
Pad material:  SA-516 K02700 Grd 70 Plate
Basic data:
Thickness                tb = 1.0 in       Length                      L = 12.0 in
Outside radius           Rl = 3.0 in       Radius of hole             Rh = 1.5 in
Weld size                 n = 0.375 in     Vessel outside radius       R = 16.0 in
Allowable stress         Sa = 16600 psi    Vessel thickness           ta = 0.375 in
Yield stress vessel      Sy = 33600 psi    Empty weight per lug        W = 8115 lbf
Distance vessel surface to lug hole                                    d = 14.0 in
Factor f                  f = 0.5 in       Number of lugs             nl = 4
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 )               = 22025 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 = 0.3232 in
Calculation of the required vessel thickness to resist lug loads, ts
   Equivalent radius of lug, RE = 0.644*(tb*l**2)**(1/3) = 3.3755 in
   ts = ( 0.415*SQRT(R)/Sy * ( (1.734*W*(d+f)/(RE**2))+0.75*W/RE ) )**2/3
   ts = 0.9825 in
   Minimum reinforcing pad thickness, tp
   tp = ts - ta = 0.6075 in
                                                 Actual        Entered
   Reinforcement pad thickness                  0.625 in      0.625 in
   Pad dimension parallel to the lug:           18.0 in        0.0 in
   Pad dimension perpendicular to the lug:       9.0 in        0.0 in
```

..ximum 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	20000	275.6	70	20000	331.2
Front Head Cylinder	T	300	15000	165.1	70	20000	220.1
Front Head Cover	T	300	15000	202	70	20000	269.4
Front Tubesheet	S	300	15000	231	70	20000	231*
Front Tubesheet	T	300	15000	126	70	20000	126
Rear Tubesheet	S	300	15000	231	70	20000	231*
Rear Tubesheet	T	300	15000	126	70	20000	126
Front Head Flng At TS	T	300	15000	88.7	70	20000	88.7
Rear Head Flng At TS	T	300	15000	100.8	70	20000	100.8
Tubes	T	300	16100	2219.8	70	17000	2343.8
Nozzle A	S	300	14600	467.5	70	14600	522.8
Nozzle B	S	300	14600	242.6	70	14600	300.1
Nozzle C	T	300	15000	313.3	70	20000	417.8
Nozzle Flng A	S	300	20000	230	70	20000	285
Nozzle Flng B	S	300	20000	230	70	20000	285
Nozzle Flng C	T	300	15000	205	70	20000	275
Nozzle Reinforcement A	S	300	-	213	70	-	242
Nozzle Reinforcement B	S	300	-	203*	70	-	232
Nozzle Reinforcement C	T	300	-	129	70	-	172
Front Hd Bolting At TS	T	300	25000	81.1	70	25000	81.1
Rear Hd Bolting At TS	T	300	25000	80+	70	25000	80+
Dist. Belt An.ring	S	-	-	N/C	-	-	N/C
Dist. Belt An.ring	S	-	-	N/C	-	-	N/C
Nozzle Flng Bolting A	S	300	25000	230	70	25000	285
zle Flng Bolting B	S	300	25000	230	70	25000	285
Nozzle Flng Bolting C	T	300	25000	205	70	25000	275

..nimum 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	
Shell Cylinder	B	-20		0.57	43	-63	
Nozzle A	B	10	+	0.26	140	-130	
Nozzle B	B	-20		0.44	76	-96	
Nozzle Flng A	-	-20		-	-	-	
Nozzle Flng B	-	-20		-	-	-	
Front Hd Bolting At TS	A	-55		-	-	-	
Rear Hd Bolting At TS	A	-55		-	-	-	
Distributor Belt A	B	-7	+	-	-	-	*
Distributor Belt B	B	-7	+	-	-	-	*
Nozzle Flng Bolting A	A	-55		-	-	-	
Nozzle Flng Bolting B	A	-55		-	-	-	
Nozzle Flng Bolting C	A	-55		-	-	-	

ɪrostatic Test Pressure - ASME VIII-1 2004 A06 UG-99(b) Factor: 1.3

Shell Side: 195 psi Tube Side: 97.5 psi

Component	Material	Side	Design Temp F	Design Stress psi	Test Stress psi	Stress Ratio
Shell Cylinder	SA-516 K02700 Grd 70 Plate	S	300	20000	20000	1
Front Head Cylinder	SA-240 S30400 Grd 304 Plat	T	300	15000	20000	1.3333
Front Head Cover	SA-240 S30400 Grd 304 Plat	T	300	15000	20000	1.3333
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-240 S30400 Grd 304 Plat	T	300	15000	20000	1.3333
Rear Head Flng At TS	SA-240 S30400 Grd 304 Plat	T	300	15000	20000	1.3333
Tubes	SA-249 S30400 Grd TP304 Wl	T	300	16100	17000	1.0559
Nozzle A	SA-53 K03005 Grd E/B Wld.	S	300	14600	14600	1
Nozzle B	SA-53 K03005 Grd E/B Wld.	S	300	14600	14600	1
Nozzle C	SA-312 S30400 Grd TP304 Wl	T	300	15000	20000	1.3333
Nozzle Flng A	SA-105 K03504 Forgings	S	300	20000	20000	1
Nozzle Flng B	SA-105 K03504 Forgings	S	300	20000	20000	1
Nozzle Flng C	SA-182 S30400 Grd F304 For	T	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-516 K02700 Grd 70 Plate	S	300	20000	20000	1
Distributor Belt B	SA-516 K02700 Grd 70 Plate	S	300	20000	20000	1
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

Design Specifications – Vapor Chamber

TEMA Class		Shell Side	Tube Side	Tubesheets
Design pressure	psi	75		
Vacuum design pressre	psi	15		
Test pressure	psi	97.5		
Design temperature	F	300		
Average metal temperature	F			
Corrosion allowance	in			
Front tubesheet corrosion allow	in			
Rear tubesheet corrosion allow	in			
Radiographing		None		
Number of passes		1		
Nozzle flange rating		150		
Post weld heat treatment		No	Program	
Code	ASME Section VIII Div.1 2004 A06			
Weights	Empty:3174	Full:19976	Bundle:	lbf

Cylinders/Covers

		Front Head Cover	Front Head Cyl.	Shell Cyl.	Rear Head Cyl.	Rear Head Cover	Shell Cover Cyl.	Shell Cover Cover	Tubes
Head type		Cone				Ellipsoidal			
·utside diameter	in	72		72		72			
alculated thk.	in	0.2961		0.2564		0.2107			
TEMA minimum thk.	in								
Actual thickness	in	0.3125		0.3125		0.5			
X-ray		None		None		None			
Joint efficiency		None		None		None			
Corrosion allowance	in								
External pressure	psi	15		15		15			
Length Ext.Press.	in	34.125		95					
Maximum Ext.Press.	psi	36.716		22.16		56.504			
Minimum thk. Ext.Press.	in	0.178		0.269		0.196			
Max.length Ext.Press.	in	70		137.5					

Nozzles

Nozzle designator		E	F1	F2	H	Front	D	K
Vessel side		Shell	Shell	Shell	Shell	Shell	Shell	Shell
Outside diameter	in	6.625	3.5	3.5	2.375	32	6.625	6.625
Calculated thickness	in	0.0721	0.0471	0.0471	0.0337	0.153	0.0531	0.0531
Code minimum thk	in	0.2336	0.2171	0.2171	0.162	0.2465	0.2142	0.2142
Actual thickness	in	0.432	0.3	0.3	0.218	0.3125	0.28	0.28
Reinf.pad OD	in							
Reinf.pad thickness	in							
Corrosion allowance	in							
External pressure	psi	15	15	15	15	15	15	15
·ngth ext. press.	in	6	6	6	6	6	6	6
Maximum ext. press.	psi	935.834	1209.205	1209.205	1271.187	129.813	582.329	582.329

Nozzle Flanges

Nozzle designator		E	F1	F2	H	TC	D	K
Flange type		Slip on	Slip on	Slip on	Slip on	Slip on	Slip on	Slip on
Flange rating		150	150	150	150	150	150	150
Flange OD	in	11	7.5	7.5	6	41.75	11	11
Bolt circle	in	9.5	6	6	4.75	38.5	9.5	9.5
Bolt diameter	in	0.75	0.625	0.625	0.625	1.5	0.75	0.75
Bolt number	in	8	4	4	4	28	8	8
Gasket OD	in	8.5	5	5	3.62	36	8.5	8.5
Gasket width	in	0.94	0.75	0.75	0.62		0.94	0.94
Gasket thickness	in	0.125	0.125	0.125	0.125	0.125	0.125	0.125
Flange calc. thk.	in							
Flange actual thk.	in	1	0.94	0.94	0.75	2.25	1	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								
Flange OD	in							
Bolt circle	in							
Bolt diameter	in							
Bolt number								
Gasket OD	in							
Gasket width	in							
Gasket thk.	in							
Flange calc. thk.	in							
Flange overlay	in							
Recess	in							
Flange act. thk.	in							
Lap jnt ring OD	in							
Hub length	in							
Hub slope	in							
Weld height	in							

Tubesheets

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

Tube Details

Tube type	
Tube OD	in
Tube wall thickness	in
Number of tubes	
Tube length	in
Tube pitch	in
Tube pattern	
Outer tube limit diameter	in

Materials of Construction

Component	Material
Shell Cylinder	SA-240 S30400 Grd 304 Plate
Front Head Cover	SA-240 S30400 Grd 304 Plate
Rear Head Cover	SA-240 S30400 Grd 304 Plate
Coupling	SA-182 S30400 Grd F304 Forgings(<= 5)
Coupling	SA-182 S30400 Grd F304 Forgings(<= 5)
Coupling	SA-182 S30400 Grd F304 Forgings(<= 5)
Nozzle E	SA-312 S30400 Grd TP304 Wld. pipe(G5)
Nozzle F1	SA-312 S30400 Grd TP304 Wld. pipe(G5)
Nozzle F2	SA-312 S30400 Grd TP304 Wld. pipe(G5)
Nozzle H	SA-312 S30400 Grd TP304 Wld. pipe(G5)
Nozzle TC	SA-312 S30400 Grd TP304 Wld. pipe
Nozzle D	SA-312 S30400 Grd TP304 Wld. pipe(G5)
Nozzle K	SA-312 S30400 Grd TP304 Wld. pipe(G5)
Nozzle Flng F1	SA-182 S30400 Grd F304 Forgings(<= 5)
Nozzle Flng F2	SA-182 S30400 Grd F304 Forgings(<= 5)
Nozzle Flng H	SA-182 S30400 Grd F304 Forgings(<= 5)
Nozzle Flng Front	SA-240 S30400 Grd 304 Plate
Nozzle Flng D	SA-182 S30400 Grd F304 Forgings(> 5)
Nozzle Flng Bolting E	SA-193 G41400 Grd B7 Bolt(<= 2 1/2)
Nozzle Flng Bolting F1	SA-193 G41400 Grd B7 Bolt(<= 2 1/2)
Nozzle Flng Bolting F2	SA-193 G41400 Grd B7 Bolt(<= 2 1/2)
Nozzle Flng Bolting H	SA-193 G41400 Grd B7 Bolt(<= 2 1/2)
Nozzle Flng BoltingFront	SA-193 G41400 Grd B7 Bolt(<= 2 1/2)
Nozzle Flng Bolting D	SA-193 G41400 Grd B7 Bolt(<= 2 1/2)
Nozzle Flg Gasket E	Solid Teflon 1/8in Thickness
Nozzle Flg Gasket F1	Solid Teflon 1/8in Thickness
Nozzle Flg Gasket F2	Solid Teflon 1/8in Thickness
Nozzle Flg Gasket H	Solid Teflon 1/8in Thickness
Nozzle Flg Gasket Front	Solid Teflon 1/8in Thickness
Nozzle Flg Gasket D	Solid Teflon 1/8in Thickness
Shell Side Nozzle Cplgs	SA-182 S30400 Grd F304 Forgings(<= 5)
Tube Side Nozzle Cplgs	SA-182 S30400 Grd F304 Forgings(<= 5)

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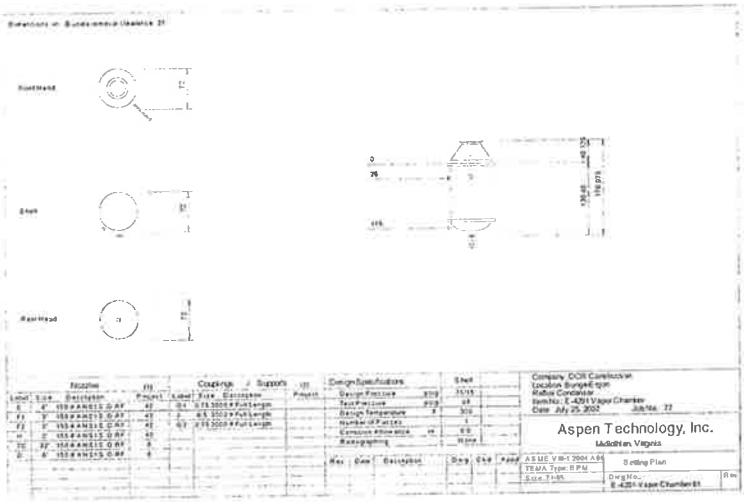
Part #	Component Name	Material	Qnty	Dim1		Dim2		Thks	Wght	Cost/Unit	Mat Cost
				in		in		in	lbf	Dollar(US)	Dollar(US)
1	Shell Cylinder	SA-240 S30400 Grd 304 Plate	1	225.5	ci	95	lg	0.3125	1922	2.55	4907
5	Fr Hd Cover Conical	SA-240 S30400 Grd 304 Plate	1	197		50		0.3125	884	2.55	2256
6	Re Hd Cover Ellip.	SA-240 S30400 Grd 304 Plate	1	90.6875	lg	90.688	wi	0.5625	1328	2.55	5236
51	Coupling E	SA-182 S30400 Grd F304 Forging	1	0.75	od	0		0	1	9.2	6
52	Coupling F1	SA-182 S30400 Grd F304 Forging	1	0.5	od	0		0	0	9.2	3
53	Coupling F2	SA-182 S30400 Grd F304 Forging	1	0.75	od	0		0	1	9.2	6
61	Nozzle E	SA-312 S30400 Grd TP304 Wld. p	1	6.625	od	6	lg	0.432	14	4	58
62	Nozzle F1	SA-312 S30400 Grd TP304 Wld. p	1	3.5	od	6	lg	0.3	5	4	21
63	Nozzle F2	SA-312 S30400 Grd TP304 Wld. p	1	3.5	od	6	lg	0.3	5	4	21
64	Nozzle H	SA-312 S30400 Grd TP304 Wld. p	1	2.375	od	6	lg	0.218	3	4	10
65	Nozzle TC	SA-312 S30400 Grd TP304 Wld. p	1	32	od	6	lg	0.3125	54	8.92	478
66	Nozzle D	SA-312 S30400 Grd TP304 Wld. p	1	6.625	od	6	lg	0.28	10	4	38
81	Nozzle Flng E Slip On	SA-182 S30400 Grd F304 Forging	1	150	AN	6.625	di	0	17	9.2	157
82	Nozzle Flng F1 Slip On	SA-182 S30400 Grd F304 Forging	1	150	AN	3.5	di	0	9	9.2	85
83	Nozzle Flng F2 Slip On	SA-182 S30400 Grd F304 Forging	1	150	AN	3.5	di	0	9	9.2	85
84	Nozzle Flng H Slip On	SA-182 S30400 Grd F304 Forging	1	150	AN	2.375	di	0	5	9.2	47
	Nozzle Flng D Slip On	SA-182 S30400 Grd F304 Forging	1	150	AN	6.625	di	0	17	9.2	157
86	Nozzle Flng K Slip On	SA-182 S30400 Grd F304 Forging	1	150	AN	6.625	di	0	17	9.2	157



⁻ ·besheet 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
Design pressure        P = 75 psi         Design temperature   T = 300 F
Radiography              = None           Joint eff.circ str.  E = 0.7
Design stress          S = 15000 psi      Joint eff.long str.  E = 0.7
Design stress, long    S = 15000 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 = 72.0 in        Corroded radius     OR = 36.0 in
Required wall thickness of the cylinder , greater of:
  Circumferential stress
             t = (P*OR / (S*E+0.4*P))+cai+cao+tol = 0.2564 in   APP.1-1(A)
  Longitudinal stress
           t = (P*IR / (2*S*E+0.4*P))+cai+cao+tol = 0.1273 in   UG-27(c)(2)
Actual wall thickness of cylinder:             tnom = 0.3125 in
  (Required wall tks. for nozzle attachments, E=1    ,  tri = 0.1796 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
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 = 72 in           Cylinder length EP   L = 95 in
Nominal thickness   tnom = 0.3125 in       (tnom-CAI-CAO-Tol)   t = 0.3125 in
L/Do ratio           Ldo = 1.3194          Do/t               Dot = 230.4
(2*S) or (0.9*yield) SE = -                Mod. of elasticity ME = 27000000 psi
  factor SII-D-FigG    A = 0.00029         B factor HA-1        B = 3829
   allowed external pressure: Pa = 4*B / (3*Dot)                  = 22.16 psi
Actual external design pressure:                               PE = 15 psi
  (Required cyl. tks. for nozzle attachments at PE, tre = 0.269 in  )
```

```
.nponent:  Front Head Cover
ASME Section VIII-1 2004 A06 UG-32 Formed Heads, and Sections,
                                Pressure on Concave Side
--- Calculations --- Conical Cover Internal Pressure
Material:  SA-240 S30400 Grd 304 Plate
Design pressure        P = 75 psi         Design temperature    T = 300 F
Radiography              = None           Joint efficiency      E = 0.7
Design stress          S = 15000 psi      TEMA min. thickness tm = 0.0 in
Inside corr.allow.   CAI = 0.0 in         Outside corr. all. CAO = 0.0 in
                                          Material tolerance Tol = 0 in
Large outside dia.    Do = 72.0 in        Large inside dia.   ID = 71.375 in
Cone length            L = 34.125 in      Conical angle    Alpha = 30.0 Deg
   Required wall thickness of the conical cover:
        t = (P*Do/(2*COS(Alpha)*(S*E+0.4*P))+cai+cao+tol = 0.2961 in App.1-4(e)
   Actual wall thickness of cover:                      ta = 0.3125 in
ASME Section VIII-1 2004 A06 UG-33(f) Formed Heads,
                                   Pressure on Convex Side
--- Calculations --- Conical Cover External Pressure
Material:  SA-240 S30400 Grd 304 Plate
Design pressure       PE = 15 psi         Design temperature    T = 300 F
Inside corr.allow.   CAI = 0 in           Outside corr. all. CAO = 0 in
Radiography              = None           Material tolerance Tol = 0 in
Larger outside dia.   DL = 72 in          Small outside dia.  Ds = 32 in
Larger outside dia.  DLs = -              Small outside dia. Dss = -
Cone length            L = 34.125 in      Stress  UG-33(f)    ST = 0 psi
Nominal thickness   tnom = 0.3125 in      tnom-CAI-CAO-Tol     t = 0.3125 in
t*Cos Alpha           te = 0.2706 in      Length Lc           Lc = -
Le = (L/2)*(1+Ds/DL)                                          Le = 24.6458 in
R~dius r1             r1 = -              Radius r2           r2 = -
   te                Dot = 266.0429 psi   Mod. of elasticity  ME = 27000000 psi
.. factor SII-D-FigG   A = 0.000966       B factor HA-1        B = 7326
Max. allowed ext. design pressure:        Pa = 4*B / (3*Dot)     = 36.72 psi
                        Actual external design pressure       PE = 15 psi
```

```
.nponent: Front Head Cover
ASME Section VIII-1 2004 A06 App.1-5 Rules for Conical Reducer Sect. and
                                    Conical Heads Under Internal Pressure

--- Design conditions
Design pressure      P = 75 psi          Design temperature T = 300 F
Inside cor.allow. CAI = 0.0 in           Outside corr.all.CAO = 0.0 in
Large cylinder:                          Small cylinder:
SA-240 S30400 Grd 304 Plate              SA-312 S30400 Grd TP304 Wld. pipe
Design stress       Ss = 15000 psi       Design stress      Ss = 15000 psi
Joint efficiency    E1 = 0.7             Joint efficiency   E1 = 0.7
Mod. of elasticity Es = 27000000 psi     Mod. of elast.     Es = 27000000 psi
Min cyl len SQRT(R*t) = 3.3395 in        Min cyl len SQRT(R*t)= 2.2141 in
Cone material: SA-240 S30400 Grd 304 Plate
Design stress       Sc = 15000 psi       Mod. of elast.     Ec = 27000000 psi
Joint efficiency    E2 = 0.7             Halfapex angle Alpha = 30
Reinforcement ring material: SA-240 S30400 Grd 304 Plate
Design stress   Sr = 15000 psi      Mod. of elasticity    Er = 27000000 psi
--- Calculations:                        Large cyl.            Small cyl.
Axial load (wind+dead loads)        f1 = 0 lbf/in         f2 = 0 lbf/in
Cylinder inside radius              RL = 35.6875 in       RS = 15.6875 in
Cylinder corroded thickness         ts = 0.3125 in        ts = 0.3125 in
Minimum required thk. of cylinder    t = 0.2564 in         t = 0.153 in
Nominal thicknes of cone            tc = 0.3125 in        tc = 0.3125 in
Minimum required thk. of cone       tr = 0.2961 in        tr = 0.1316 in
(P*RL /2.)+f1 & (P*RS/2.)+f2        QL = 1338.3 lbf/in    QS = 588.3 lbf/in
Pressure/stress ratio         P/Ss*E1 = 0.0071      P/Ss*E1 = 0.0071
Angle for reinforcement (deg)  DeltaL = 27.21        DeltaS = 7.29
Reinforcement required when Delta is less than Alpha
```

```
.mponent:  Front Head Cover
Cross sectional area requirement cone to large cylinder junction:
Cone to cyl. factor (reinf. ring on cyl.) yL = Sl*El          yL =  0.4050E+12
Reinforcement factor (minimum=1) kL = yL/Sr*Er      Calculated kL = 1
                                                       Minimum kL = 1

Area required for reinforcement element:
    ArL = (kL*QL*RL/(Sl*El))*(1-DeltaL/Alpha)*tan(Alpha)      ArL = 0.2439 in2
Excess area available in large cylinder:
    AeL = (ts-t)*(RL*ts)**0.5+(tc-tr)*(RL*tc/Cos Alpha)**0.5  AeL = 0.2462 in2
        *** Enough area available - reinforcing not required per area rules ***
Reinforcing element width:     w = -
Reinforcing element thickness: t = -
Reinforcing element area required = ArL - AeL = -
Reinforcing element area: Ar = w * t       Ar = -
Reinforcing element within this dist.from junction SQRT(RL*ts)    = -
Centroid reinf. elem. within this dist. junction 0.25*SQRT(RL*ts) = -
Cross sectional area requirement cone to small cylinder junction:
Cone to cyl. factor (reinf. ring on cyl.) yS = Ss*Es          yS =  0.4050E+12
Reinforcement factor (minimum=1) kS = yS/Sr*Er      Calculated kS = 1
                                                       Minimum kS = 1

Area required for reinforcement element:
   ArS = (kS*QS*RS/(Ss*El)) * (1-DeltaS/Alpha) * tan(Alpha)   ArS = 0.3842 in2
Excess area available in small cylinder:
   AeS = 0.78*(RS*ts)**0.5 * ( (ts-t)+(tc-tr)/Cos Alpha )     AeS = 0.6362 in2
        *** Enough area available - reinforcing not required per area rules ***
Reinforcing element width:     w = -
Reinforcing element thickness: t = -
Reinforcing element area required = ArS - AeS = -
Reinforcing element area: Ar = w * t       Ar = -
 nforcing element within this dist.from junction SQRT(Rs*ts)    = -
..ntroid reinf. elem. within this dist. junction 0.25*SQRT(Rs*ts) = -
```

```
 mponent: Front Head Cover
ASME Section VIII-1 2004 A06 App.1-8 Rules for Reinforcement of
                         Cone-to-cylinder junction under External Pressure
Design pressure     P = 15 psi         Design temperature T = 300 F
Cone length Lc = SQRT(L**2 + (RL - Rs)**2)                Lc = 39.554 in
Equivalent area of cylinder, cone and stiffening ring, AT
ATL = (LL*ts)/2 + (Lc*tc)/2 + As
ATS = (Ls*ts)/2 + (Lc*tc)/2 + As
                                    Large cyl.            Small cyl.
Design length                  LL = 129.125 in        Ls = 129.125 in
Equivalante area              ATL = 26.3561 in2      ATS = 26.3561 in2
Design stress                  Ss = 15000 psi         Ss = -
Joint efficiency               E1 = 0.7               E1 = -
Ratio P/SsE1               P/SsE1 = 0.00143       P/SsE1 = -
Delta, degress              delta = 3.6            delta = -
Stiffening ring area           As = 0.0 in2           As = 0.0 in2
Required area of reinforcement at the large end, QL in compression:
ArL = (k*QL*RL*tan(alpha))/(Ss*E1)*[1-0.25*((P*RL-QL)/QL)*(delta/alpha)
                                             ArL = 0.5186 in2        (1)

Effective area of reinforcement:
AeL = 0.55*SQRT(DL*ts)*(ts+tc/cos(alpha))    AeL = 1.7567 in2        (2)
        *** Enough area available - reinforcing not required per area rules ***
Reinforcing element area required = ArL - AeL = -
Reinforcing element area: Ar = w * t       Ar = -
Reinforcing element width:      w = -
Reinforcing element thickness: t = -
Reinforcing element within this dist.from junction SQRT(RL*ts)    = -
Centroid reinf. elem. within this dist. junction 0.25*SQRT(RL*ts) = -
               *** The cone-to-cylinder junctions are not a line of support ***
  uired area of reinforcement at the small end, Qs in compression:
Ars = (k*Qs*Rs*tan(alpha))/(Ss*E1)           Ars = 0.1056 in2        (3)
Effective area of reinforcement:
Aes = 0.55*SQRT(Ds*ts)*[(ts-t)+(tc-tr)/cos(alpha))  Aes = 0.6449 in2  (4)
        *** Enough area available - reinforcing not required per area rules ***
Reinforcing element area required = ArL - AeL = -
Reinforcing element area: Ar = w * t       Ar = -
Reinforcing element width:      w = -
Reinforcing element thickness: t = -
Reinforcing element within this dist.from junction SQRT(RL*ts)    = -
Centroid reinf. elem. within this dist. junction 0.25*SQRT(RL*ts) = -
```

```
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-240 S30400 Grd 304 Plate
Design pressure        P = 75 psi          Design temperature  T = 300 F
Radiography              = None            Joint efficiency    E = 0.85
Design stress          S = 15000 psi       TEMA min. thk      tm = 0.0 in
Inside corr.all.     CAI = 0.0 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 = 0.1792 in       Equiv.dish radius   L = 63.9 in
Ratio t/L                = 0.00782         Material tol.     Tol = 0.0 in
Outside diameter      OD = 72.0 in         Corroded diameter  OD = 72.0 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 = 0.2107 in  App. 1-4(c)
Actual wall thickness of cover:                  tnom = 0.5 in
   (Required wall tks. for nozzle attachments, E=1    ,  tri = 0.1792 in )
   (If opening & reinf. are within 80% of head diameter, tri = 0.1617 in )
ASME Section VIII-1 2004 A06 UG-33 Formed Heads, Pressure on Convex Side
--- Calculations --- Ellipsoidal Cover External Pressure
Material:  SA-240 S30400 Grd 304 Plate
Design pressure      PE = 15 psi         Design temperature   T = 300 F
Inside corr. allow. CAI = 0 in           Outside corr. all. CAO = 0 in
Radiography             = None           Forming tolerance  Tol = 0 in
                                         Material tolerance Tol = 0 in
Cover outside dia.    Do = 72 in         Outside sph.radius  Ro = 64.8 in
Nominal thickness   tnom = 0.5 in        tnom-CAI-CAO-Tol     t = 0.5 in
   factor (UG-33.1)   Ko = 0.9           Ro/t ratio         Rot = 129.6
   33(a)     210.97/1.67 = 126.33 psi    Mod. of elasticity  ME = 27000000 psi
A factor = 0.125/Rot     = 0.000965      B factor HA-1        B = 7323
Maximum allowed external pressure:       Pa = B / Rot           = 56.5 psi
Actual external design pressure:                             PE = 15 psi
   (Required cov. tks. for nozzle attachments at PE, tre = 0.196 in  )
```

```
..nponent:  Nozzle E
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(G5)
Design pressure       P = 75 psi          Design temperature   T = 300 F
Radiography             = None            Joint efficiency     E = 0.85
Design stress         S = 16100 psi
Inside corr.allow. cai = 0.0 in           Outside corr. all. cao = 0.0 in
Material tolerance tol = 0.054 in         Minimum thickness tmin = 0.2336 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 = 0.0721 in   APP.1-1(A)
  - UG-45(a) external pressure+cai+cao+tol       t = 0.076 in
  - UG-16(b) minimum thickness+cai+cao+tol       t = 0.1478 in
    UG-45(b) Smaller of:                         t = 0.2336 in
    UG-45(b)(4) std pipe*0.875+cai+cao+tol = 0.299 in
      - UG-45(b) Greater of:           t = 0.2336 in
        - UG-45(b)(1)+cai+cao+tol = 0.2336 in
        - UG-45(b)(2)+cai+cao+tol = 0.09 in
                     Minimum thickness:                 tmin = 0.2336 in
                     Nominal thickness:                 tnom = 0.432 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(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
C..l. outside dia.    Do = 6.625 in        Cylinder length EP  L = 6 in
  inal thickness   tnom = 0.432 in         (tnom-CAI-CAO-Tol)  t = 0.378 in
_.Do ratio           Ldo = 0.9057          Do/t              Dot = 17.5265
(2*S) or (0.9*yield) SE = -                Mod. of elasticity ME = 27000000 psi
A factor SII-D-FigG   A = 0.022471         B factor HA-1       B = 12301
Max allowed external pressure: Pa = 4*B / (3*Dot)                = 935.83 psi
Actual external design pressure:                                PE = 15 psi
  (Required cyl. tks. for nozzle attachments at PE, tre = 0.022 in  )
```

```
.mponent: Reinforcement Nozzle E
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
Inside corr. allow. CAI = 0.0 in        Outside corr.allow.CAO = 0.0 in
Vessel design stress Sv = 15000 psi     Joint efficiency     E = 1
Vessel outside dia   Do = 72.0 in       Corroded radius     OR = 36.0 in
Nominal thickness  tnom = 0.3125 in     Reinforcement limit lp = 5.761 in
Req. tks. int.pres.  tr = 0.1796 in     Req. tks.ext.pres. tre = 0.269 in
Corroded thickness    t = 0.3125 in     Reinf. efficiency   E1 = 1.0
Attachment Material: SA-312 S30400 Grd TP304 Wld. pipe(G5)
Inside corr. allow. CAI = 0.0 in        Outside corr.allow.CAO = 0.0 in
Nozzle design stress Sn = 16100 psi     Joint efficiency     E = 0.85
Nozzle outside dia. Don = 6.625 in      Corroded radius     OR = 3.3125 in
Nominal thickness  tnom = 0.432 in      Reinforcement limit ln = 0.7813 in
Req.tks. int.pres.  trn = 0.0181 in     Req.tks.ext.pres. trne = 0.022 in
Corroded thickness   tn = 0.432 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  = 0.3125 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)    = 0.2188 in     Weld tw     (actual)   = 0.0 in
Weld  tc   (minimum)    = 0.2188 in     Weld tc     (actual)   = 0.2188 in
    smaller |0.25 in   |                Leg size tw (actual)   = 0.0 in
 +c   of    |0.7 * tmin|                Leg size tc (actual)   = 0.3125 in
  ward nozzle weld    L1 = 0.3125 in    fr1 = Sn/Sv                = 1.0
 ..cer element weld   L2 = 0.0 in       fr2 = Sn/Sv                = 1.0
Inward nozzle weld    L3 = 0.0 in       fr3 = Sn/Sv or Se/Sv       = 1.0
Inward nozzel weld new   = 0.0 in       fr4 = Se/Sv                = 1.0
Corroded int.proj.thk ti = 0.0 in
```

```
 rroded inside diameter                                   d = 5.761 in
Vessel wall length available for reinforcement    2*Lp-d = 5.761 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)| = 0.7654 in2
 |2*(t+tn)*(E1*t-F*tr)-2*tn*(E1*t-F*tr)*(1-fr1)| = 0.1978 in2
                                                          A1 = 0.7654 in2

A2 = Nozzle wall outward   | 5*(tn-trn)*fr2*t    | = 0.6467 in2
     Smaller of:           | 5*(tn-trn)*fr2*tn   | = 0.894 in2
                                                          A2 = 0.6467 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 = 0.0977 in2
A42 = Outer element weld  = (L2**2)*fr4 = 0.0 in2
A43 = Inward nozzle weld  = (L3**2)*fr2 = 0.0 in2
                                                          A4 = 0.0977 in2
A5 = Reinforcement pad Area = (Dp-d-2*tn)*te*fr4          A5 = 0.0 in2
Aa = Area Available = A1+A2+A3+A4+A5                      Aa = 1.5098 in2
A = Area required   = (d*tr*F)+2*tn*tr*F*(1-f1)            A = 1.0349 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)| = 0.2506 in2
 |2*(t+tn)*(E1*t-F*tre)-2*tn*(E1*t-F*tre)*(1-fr1)| = 0.0648 in2
                                                          A1 = 0.2506 in2

A2 = Nozzle wall outward   | 5*(tn-trne)*fr2*t   | = 0.6406 in2
     Smaller of:           | 5*(tn-trne)*fr2*tn  | = 0.8856 in2
                                                          A2 = 0.6406 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 = 0.0977 in2
A42 = Outer element weld  =   (L2**2)*fr4 = 0.0 in2
A43 = Inward nozzle weld  =   (L3**2)*fr2 = 0.0 in2
                                                          A4 = 0.0977 in2
A5 = Reinforcement pad Area = (Dp-d-2*tn)*te*fr4          A5 = 0.0 in2
Aa = Area Available = A1+A2+A3+A4+A5                      Aa = 0.9889 in2
A = Area required   = 0.5*(d*tre*F+2*tn*tre*F*(1-fr1))     A = 0.7749 in2
```

```
 zzle 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 = 5764 lbf
Weld load for strength path 1-1 (UG-41(b)(1)
  W(1-1) = (A2+A5+A41+A42)*Sv                           W(1-1) = 11165 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) = 15215 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                        =   11270 psi
 Strength of connection elements
    Inner fillet weld shear                  =   23891 lbf
    Nozzle wall shear                        =   47338 lbf
    Groove weld tension                      =   36080 lbf
    Outer fillet weld shear                  =   -
 Possible paths of failure
    1-1         47338 + 23891                =   71229 lbf
    2-2         23891 + 36080                =   59971 lbf
    3-3             - + -                    =   -
 Welds strong enough if path greater than the smaller of W or W(path)
                                Path 1-1 > W or W11
                               71229 lbf > 5764 lbf                 OK
                                Path 2-2 > W or W22
                               59971 lbf > 5764 lbf                 OK
                                Path 3-3 > W or W33
                                       - > -
```

```
Component:  Nozzle F1
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(G5)
Design pressure       P = 75 psi          Design temperature    T = 300 F
Radiography             = None            Joint efficiency      E = 0.85
Design stress         S = 16100 psi
Inside corr.allow. cai = 0.0 in           Outside corr. all. cao = 0.0 in
Material tolerance tol = 0.0375 in        Minimum thickness tmin = 0.2171 in
Outside diameter     OD = 3.5 in          Corroded radius      OR = 1.75 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 = 0.0471 in   APP.1-1(A)
  - UG-45(a) external pressure+cai+cao+tol      t = 0.053 in
  - UG-16(b) minimum thickness+cai+cao+tol      t = 0.1312 in
    UG-45(b) Smaller of:                        t = 0.2171 in
    UG-45(b)(4) std pipe*0.875+cai+cao+tol = 0.2265 in
      - UG-45(b) Greater of:           t = 0.2171 in
        - UG-45(b)(1)+cai+cao+tol = 0.2171 in
        - UG-45(b)(2)+cai+cao+tol = 0.0735 in
                    Minimum thickness:               tmin = 0.2171 in
                    Nominal thickness:               tnom = 0.3 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(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 = 3.5 in          Cylinder length EP  L = 6 in
Nominal thickness   tnom = 0.3 in          (tnom-CAI-CAO-Tol)  t = 0.2625 in
L/Do ratio           Ldo = 1.7143          Do/t              Dot = 13.3333
(2*S) or (0.9*yield) SE = -                Mod. of elasticity ME = 27000000 psi
A factor SII-D-FigG    A = 0.016749        B factor HA-1       B = 12092
Max allowed external pressure: Pa = 4*B / (3*Dot)               = 1209.21 psi
Actual external design pressure:                               PE = 15 psi
   (Required cyl. tks. for nozzle attachments at PE, tre = 0.0155 in )
```

```
.mponent: Reinforcement Nozzle F1
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
Inside corr. allow. CAI = 0.0 in          Outside corr.allow.CAO = 0.0 in
Vessel design stress Sv = 15000 psi       Joint efficiency      E = 1
Vessel outside dia   Do = 72.0 in         Corroded radius      OR = 36.0 in
Nominal thickness  tnom = 0.3125 in       Reinforcement limit lp = 2.9 in
Req. tks. int.pres.  tr = 0.1796 in       Req. tks.ext.pres. tre = 0.269 in
Corroded thickness    t = 0.3125 in       Reinf. efficiency    E1 = 1.0
Attachment Material: SA-312 S30400 Grd TP304 Wld. pipe(G5)
Inside corr. allow. CAI = 0.0 in          Outside corr.allow.CAO = 0.0 in
Nozzle design stress Sn = 16100 psi       Joint efficiency      E = 0.85
Nozzle outside dia. Don = 3.5 in          Corroded radius      OR = 1.75 in
Nominal thickness  tnom = 0.3 in          Reinforcement limit ln = 0.75 in
Req.tks. int.pres.  trn = 0.0096 in       Req.tks.ext.pres. trne = 0.0155 in
Corroded thickness   tn = 0.3 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  = 0.3 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)    = 0.21 in         Weld tw     (actual)   = 0.0 in
Weld  tc   (minimum)    = 0.21 in         Weld tc     (actual)   = 0.21 in
     smaller |0.25 in    |                Leg size tw (actual)   = 0.0 in
  tc   of    |0.7 * tmin|                 Leg size tc (actual)   = 0.3 in
  ward nozzle weld    L1 = 0.3 in         fr1 = Sn/Sv                = 1.0
Outer element weld    L2 = 0.0 in         fr2 = Sn/Sv                = 1.0
Inward nozzle weld    L3 = 0.0 in         fr3 = Sn/Sv or Se/Sv       = 1.0
Inward nozzel weld new   = 0.0 in         fr4 = Se/Sv                = 1.0
Corroded int.proj.thk ti = 0.0 in
```

```
 eroded inside diameter                                    d = 2.9 in
Vessel wall length available for reinforcement    2*Lp-d = 2.9 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)| = 0.3853 in2
 |2*(t+tn)*(E1*t-F*tr)-2*tn*(E1*t-F*tr)*(1-fr1)| = 0.1628 in2
                                                          A1 = 0.3853 in2
A2 = Nozzle wall outward   | 5*(tn-trn)*fr2*t    | = 0.4538 in2
     Smaller of:           | 5*(tn-trn)*fr2*tn   | = 0.4356 in2
                                                          A2 = 0.4356 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 = 0.09 in2
A42 = Outer element weld  = (L2**2)*fr4 = 0.0 in2
A43 = Inward nozzle weld  = (L3**2)*fr2 = 0.0 in2
                                                          A4 = 0.09 in2
A5 = Reinforcement pad Area = (Dp-d-2*tn)*te*fr4          A5 = 0.0 in2
Aa = Area Available = A1+A2+A3+A4+A5                      Aa = 0.9109 in2
A = Area required   = (d*tr*F)+2*tn*tr*F*(1-f1)            A = 0.521 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)| = 0.1261 in2
 |2*(t+tn)*(E1*t-F*tre)-2*tn*(E1*t-F*tre)*(1-fr1)| = 0.0533 in2
                                                          A1 = 0.1261 in2
   = Nozzle wall outward   | 5*(tn-trne)*fr2*t   | = 0.4445 in2
     Smaller of:           | 5*(tn-trne)*fr2*tn  | = 0.4268 in2
                                                          A2 = 0.4268 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 = 0.09 in2
A42 = Outer element weld  =  (L2**2)*fr4 = 0.0 in2
A43 = Inward nozzle weld  =  (L3**2)*fr2 = 0.0 in2
                                                          A4 = 0.09 in2
A5 = Reinforcement pad Area = (Dp-d-2*tn)*te*fr4          A5 = 0.0 in2
Aa = Area Available = A1+A2+A3+A4+A5                      Aa = 0.6429 in2
A = Area required   = 0.5*(d*tre*F+2*tn*tre*F*(1-fr1))     A = 0.3901 in2
```

```
.zle 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 = 3231 lbf
Weld load for strength path 1-1 (UG-41(b)(1)
 W(1-1) = (A2+A5+A41+A42)*Sv                     W(1-1) = 7885 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) = 10697 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                    =   11270 psi
 Strength of connection elements
    Inner fillet weld shear              =   12117 lbf
    Nozzle wall shear                    =   16987 lbf
    Groove weld tension                  =   18299 lbf
    Outer fillet weld shear              =   -
 Possible paths of failure
    1-1        16987 + 12117             =   29104 lbf
    2-2        12117 + 18299             =   30416 lbf
    3-3            - + -                 =   -
 Welds strong enough if path greater than the smaller of W or W(path)
                          Path 1-1 > W or W11
                        29104 lbf > 3231 lbf                OK
                          Path 2-2 > W or W22
                        30416 lbf > 3231 lbf                OK
                          Path 3-3 > W or W33
                                 - > -
```

```
 mponent:  Nozzle F2
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(G5)
Design pressure        P = 75 psi          Design temperature    T = 300 F
Radiography              = None            Joint efficiency      E = 0.85
Design stress          S = 16100 psi
Inside corr.allow. cai = 0.0 in            Outside corr. all. cao = 0.0 in
Material tolerance tol = 0.0375 in         Minimum thickness tmin = 0.2171 in
Outside diameter     OD = 3.5 in           Corroded radius      OR = 1.75 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 = 0.0471 in   APP.1-1(A)
  - UG-45(a) external pressure+cai+cao+tol        t = 0.053 in
  - UG-16(b) minimum thickness+cai+cao+tol        t = 0.1312 in
    UG-45(b) Smaller of:                          t = 0.2171 in
    UG-45(b)(4) std pipe*0.875+cai+cao+tol = 0.2265 in
      - UG-45(b) Greater of:              t = 0.2171 in
        - UG-45(b)(1)+cai+cao+tol = 0.2171 in
        - UG-45(b)(2)+cai+cao+tol = 0.0735 in
                       Minimum thickness:              tmin = 0.2171 in
                       Nominal thickness:              tnom = 0.3 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(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
C'l. outside dia.     Do = 3.5 in          Cylinder length EP   L = 6 in
  inal thickness    tnom = 0.3 in          (tnom-CAI-CAO-Tol)   t = 0.2625 in
_,Do ratio           Ldo = 1.7143          Do/t               Dot = 13.3333
(2*S) or (0.9*yield) SE = -                Mod. of elasticity ME = 27000000 psi
A factor SII-D-FigG   A = 0.016749         B factor HA-1        B = 12092
Max allowed external pressure: Pa = 4*B / (3*Dot)                 = 1209.21 psi
Actual external design pressure:                               PE = 15 psi
   (Required cyl. tks. for nozzle attachments at PE, tre = 0.0155 in )
```

```
mponent: Reinforcement Nozzle F2
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
Inside corr. allow. CAI = 0.0 in        Outside corr.allow.CAO = 0.0 in
Vessel design stress Sv = 15000 psi     Joint efficiency     E = 1
Vessel outside dia   Do = 72.0 in       Corroded radius     OR = 36.0 in
Nominal thickness  tnom = 0.3125 in     Reinforcement limit lp = 2.9 in
Req. tks. int.pres.  tr = 0.1796 in     Req. tks.ext.pres. tre = 0.269 in
Corroded thickness    t = 0.3125 in     Reinf. efficiency   E1 = 1.0
Attachment Material: SA-312 S30400 Grd TP304 Wld. pipe(G5)
Inside corr. allow. CAI = 0.0 in        Outside corr.allow.CAO = 0.0 in
Nozzle design stress Sn = 16100 psi     Joint efficiency     E = 0.85
Nozzle outside dia. Don = 3.5 in        Corroded radius     OR = 1.75 in
Nominal thickness  tnom = 0.3 in        Reinforcement limit ln = 0.75 in
Req.tks. int.pres.  trn = 0.0096 in     Req.tks.ext.pres. trne = 0.0155 in
Corroded thickness   tn = 0.3 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  = 0.3 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)    = 0.21 in       Weld tw     (actual)   = 0.0 in
Weld  tc   (minimum)    = 0.21 in       Weld tc     (actual)   = 0.21 in
     smaller |0.25 in    |              Leg size tw (actual)   = 0.0 in
  tc    of   |0.7 * tmin|               Leg size tc (actual)   = 0.3 in
   ward nozzle weld    L1 = 0.3 in      fr1 = Sn/Sv               = 1.0
 ..ter element weld    L2 = 0.0 in      fr2 = Sn/Sv               = 1.0
Inward nozzle weld     L3 = 0.0 in      fr3 = Sn/Sv or Se/Sv      = 1.0
Inward nozzel weld new    = 0.0 in      fr4 = Se/Sv               = 1.0
Corroded int.proj.thk ti  = 0.0 in
```

```
 .roded inside diameter                                        d = 2.9 in
Vessel wall length available for reinforcement    2*Lp-d = 2.9 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)| = 0.3853 in2
 |2*(t+tn)*(E1*t-F*tr)-2*tn*(E1*t-F*tr)*(1-fr1)| = 0.1628 in2
                                                               A1 = 0.3853 in2
A2 = Nozzle wall outward   | 5*(tn-trn)*fr2*t   | = 0.4538 in2
     Smaller of:           | 5*(tn-trn)*fr2*tn  | = 0.4356 in2
                                                               A2 = 0.4356 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 = 0.09 in2
A42 = Outer element weld  = (L2**2)*fr4 = 0.0 in2
A43 = Inward nozzle weld  = (L3**2)*fr2 = 0.0 in2
                                                               A4 = 0.09 in2
A5 = Reinforcement pad Area = (Dp-d-2*tn)*te*fr4               A5 = 0.0 in2
Aa = Area Available = A1+A2+A3+A4+A5                           Aa = 0.9109 in2
A = Area required   = (d*tr*F)+2*tn*tr*F*(1-f1)                 A = 0.521 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)| = 0.1261 in2
 |2*(t+tn)*(E1*t-F*tre)-2*tn*(E1*t-F*tre)*(1-fr1)| = 0.0533 in2
                                                               A1 = 0.1261 in2
   = Nozzle wall outward   | 5*(tn-trne)*fr2*t  | = 0.4445 in2
     Smaller of:           | 5*(tn-trne)*fr2*tn | = 0.4268 in2
                                                               A2 = 0.4268 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 = 0.09 in2
A42 = Outer element weld  =   (L2**2)*fr4 = 0.0 in2
A43 = Inward nozzle weld  =   (L3**2)*fr2 = 0.0 in2
                                                               A4 = 0.09 in2
A5 = Reinforcement pad Area = (Dp-d-2*tn)*te*fr4               A5 = 0.0 in2
Aa = Area Available = A1+A2+A3+A4+A5                           Aa = 0.6429 in2
A = Area required   = 0.5*(d*tre*F+2*tn*tre*F*(1-fr1))          A = 0.3901 in2
```

```
 zzle 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 = 3231 lbf
Weld load for strength path 1-1 (UG-41(b)(1)
  W(1-1) = (A2+A5+A41+A42)*Sv                           W(1-1) = 7885 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) = 10697 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                       =    11270 psi
 Strength of connection elements
    Inner fillet weld shear                 =    12117 lbf
    Nozzle wall shear                       =    16987 lbf
    Groove weld tension                     =    18299 lbf
    Outer fillet weld shear                 =    -
 Possible paths of failure
    1-1        16987 + 12117                =    29104 lbf
    2-2        12117 + 18299                =    30416 lbf
    3-3            - + -                    =    -
 Welds strong enough if path greater than the smaller of W or W(path)
                              Path 1-1 > W or W11
                             29104 lbf > 3231 lbf                 OK
                              Path 2-2 > W or W22
                             30416 lbf > 3231 lbf                 OK
                              Path 3-3 > W or W33
                                     - > -
```

```
..mponent:  Nozzle H
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(G5)
Design pressure        P = 75 psi          Design temperature    T = 300 F
Radiography              = None            Joint efficiency      E = 0.85
Design stress          S = 16100 psi
Inside corr.allow. cai = 0.0 in            Outside corr. all. cao = 0.0 in
Material tolerance tol = 0.0272 in         Minimum thickness tmin = 0.162 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 = 0.0337 in    APP.1-1(A)
  - UG-45(a) external pressure+cai+cao+tol         t = 0.039 in
  - UG-16(b) minimum thickness+cai+cao+tol         t = 0.121 in
    UG-45(b) Smaller of:                           t = 0.162 in
    UG-45(b)(4) std pipe*0.875+cai+cao+tol = 0.162 in
      - UG-45(b) Greater of:              t = 0.2069 in
        - UG-45(b)(1)+cai+cao+tol = 0.2069 in
        - UG-45(b)(2)+cai+cao+tol = 0.0632 in
                    Minimum thickness:                tmin = 0.162 in
                    Nominal thickness:                tnom = 0.218 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(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 = 2.375 in        Cylinder length EP  L = 6 in
  inal thickness   tnom = 0.218 in         (tnom-CAI-CAO-Tol)  t = 0.1908 in
_,Do ratio           Ldo = 2.5263          Do/t              Dot = 12.4509
(2*S) or (0.9*yield) SE = -                Mod. of elasticity ME = 27000000 psi
A factor SII-D-FigG   A = 0.012203         B factor HA-1       B = 11871
Max allowed external pressure: Pa = 4*B / (3*Dot)                = 1271.19 psi
Actual external design pressure:                              PE = 15 psi
   (Required cyl. tks. for nozzle attachments at PE, tre = 0.0118 in )
```

```
.-mponent: Reinforcement Nozzle H
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
Inside corr. allow. CAI = 0.0 in         Outside corr.allow.CAO = 0.0 in
Vessel design stress Sv = 15000 psi      Joint efficiency     E = 1
Vessel outside dia   Do = 72.0 in        Corroded radius     OR = 36.0 in
Nominal thickness  tnom = 0.3125 in      Reinforcement limit lp = 1.939 in
Req. tks. int.pres.  tr = 0.1796 in      Req. tks.ext.pres. tre = 0.269 in
Corroded thickness    t = 0.3125 in      Reinf. efficiency   E1 = 1.0
Attachment Material: SA-312 S30400 Grd TP304 Wld. pipe(G5)
Inside corr. allow. CAI = 0.0 in         Outside corr.allow.CAO = 0.0 in
Nozzle design stress Sn = 16100 psi      Joint efficiency     E = 0.85
Nozzle outside dia. Don = 2.375 in       Corroded radius    OR- = 1.1875 in
Nominal thickness  tnom = 0.218 in       Reinforcement limit ln = 0.545 in
Req.tks. int.pres.  trn = 0.0065 in      Req.tks.ext.pres. trne = 0.0118 in
Corroded thickness   tn = 0.218 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  = 0.218 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)   = 0.1526 in      Weld tw     (actual)   = 0.0 in
Weld  tc    (minimum)   = 0.1526 in      Weld tc     (actual)   = 0.1526 in
    smaller |0.25 in    |                Leg size tw (actual)   = 0.0 in
 tc   of    |0.7 * tmin|                 Leg size tc (actual)   = 0.218 in
  ward nozzle weld    L1 = 0.218 in      fr1 = Sn/Sv               = 1.0
outer element weld    L2 = 0.0 in        fr2 = Sn/Sv               = 1.0
Inward nozzle weld    L3 = 0.0 in        fr3 = Sn/Sv or Se/Sv      = 1.0
Inward nozzel weld new   = 0.0 in        fr4 = Se/Sv               = 1.0
Corroded int.proj.thk ti = 0.0 in
```

```
 rroded inside diameter                                 d = 1.939 in
Vessel wall length available for reinforcement   2*Lp-d = 1.939 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)| = 0.2576 in2
 |2*(t+tn)*(E1*t-F*tr)-2*tn*(E1*t-F*tr)*(1-fr1)| = 0.141 in2
                                                         A1 = 0.2576 in2

A2 = Nozzle wall outward  | 5*(tn-trn)*fr2*t    | = 0.3305 in2
     Smaller of:          | 5*(tn-trn)*fr2*tn   | = 0.2305 in2
                                                         A2 = 0.2305 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 = 0.0475 in2
A42 = Outer element weld  = (L2**2)*fr4 = 0.0 in2
A43 = Inward nozzle weld  = (L3**2)*fr2 = 0.0 in2
                                                         A4 = 0.0475 in2
A5 = Reinforcement pad Area = (Dp-d-2*tn)*te*fr4         A5 = 0.0 in2
Aa = Area Available = A1+A2+A3+A4+A5                     Aa = 0.5357 in2
A = Area required   = (d*tr*F)+2*tn*tr*F*(1-f1)           A = 0.3483 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)| = 0.0843 in2
 |2*(t+tn)*(E1*t-F*tre)-2*tn*(E1*t-F*tre)*(1-fr1)| = 0.0462 in2
                                                         A1 = 0.0843 in2
.. = Nozzle wall outward  | 5*(tn-trne)*fr2*t   | = 0.3223 in2
     Smaller of:          | 5*(tn-trne)*fr2*tn  | = 0.2248 in2
                                                         A2 = 0.2248 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 = 0.0475 in2
A42 = Outer element weld  =  (L2**2)*fr4 = 0.0 in2
A43 = Inward nozzle weld  =  (L3**2)*fr2 = 0.0 in2
                                                         A4 = 0.0475 in2
A5 = Reinforcement pad Area = (Dp-d-2*tn)*te*fr4         A5 = 0.0 in2
Aa = Area Available = A1+A2+A3+A4+A5                     Aa = 0.3567 in2
A = Area required   = 0.5*(d*tre*F+2*tn*tre*F*(1-fr1))    A = 0.2608 in2
```

```
.zzle 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 = 2230 lbf
Weld load for strength path 1-1 (UG-41(b)(1)
  W(1-1) = (A2+A5+A41+A42)*Sv                          W(1-1) = 4171 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) = 6215 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                    =   11270 psi
 Strength of connection elements
    Inner fillet weld shear              =   5975 lbf
    Nozzle wall shear                    =   8321 lbf
    Groove weld tension                  =   9023 lbf
    Outer fillet weld shear              =   -
 Possible paths of failure
    1-1        8321 + 5975               =   14296 lbf
    2-2        5975 + 9023               =   14998 lbf
    3-3           - + -                  =   -
 Welds strong enough if path greater than the smaller of W or W(path)
                          Path 1-1 > W or W11
                         14296 lbf > 2230 lbf              OK
                          Path 2-2 > W or W22
                         14998 lbf > 2230 lbf              OK
                          Path 3-3 > W or W33
                                 - > -
```

```
.ponent:  Nozzle Front
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 = 0.7
Design stress         S = 15000 psi
Inside corr.allow. cai = 0.0 in           Outside corr. all. cao = 0.0 in
Material tolerance tol = 0.0391 in        Minimum thickness tmin = 0.2465 in
Outside diameter    OD = 32.0 in          Corroded radius     OR = 16.0 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 = 0.153 in     APP.1-1(A)
  - UG-45(a) external pressure+cai+cao+tol       t = 0.097 in
  - UG-16(b) minimum thickness+cai+cao+tol       t = 0.1016 in
    UG-45(b) Smaller of:                         t = 0.2465 in
    UG-45(b)(4) std pipe*0.875+cai+cao+tol = 0.3672 in
      - UG-45(b) Greater of:             t = 0.2465 in
        - UG-45(b)(1)+cai+cao+tol = 0.2465 in
        - UG-45(b)(2)+cai+cao+tol = 0.0806 in
                      Minimum thickness:                tmin = 0.2465 in
                      Nominal thickness:                tnom = 0.3125 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 = 32 in           Cylinder length EP  L = 6 in
  inal thickness    tnom = 0.3125 in       (tnom-CAI-CAO-Tol)  t = 0.2734 in
 .o ratio            Ldo = 0.1875          Do/t              Dot = 117.0286
(2*S) or (0.9*yield) SE = -                Mod. of elasticity ME = 27000000 psi
A factor SII-D-FigG   A = 0.007165         B factor HA-1       B = 11394
Max allowed external pressure: Pa = 4*B / (3*Dot)                = 129.81 psi
Actual external design pressure:                                PE = 15 psi
   (Required cyl. tks. for nozzle attachments at PE, tre = 0.0579 in )
```

```
 mponent:  Nozzle D
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(G5)
Design pressure       P = 75 psi          Design temperature    T = 300 F
Radiography             = None            Joint efficiency      E = 0.85
Design stress         S = 16100 psi
Inside corr.allow. cai = 0.0 in          Outside corr. all. cao = 0.0 in
Material tolerance tol = 0.035 in        Minimum thickness tmin = 0.2142 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 = 0.0531 in   APP.1-1(A)
  - UG-45(a) external pressure+cai+cao+tol        t = 0.057 in
  - UG-16(b) minimum thickness+cai+cao+tol        t = 0.0975 in
    UG-45(b) Smaller of:                          t = 0.2142 in
    UG-45(b)(4) std pipe*0.875+cai+cao+tol = 0.28 in
      - UG-45(b) Greater of:               t = 0.2142 in
        - UG-45(b)(1)+cai+cao+tol = 0.2142 in
        - UG-45(b)(2)+cai+cao+tol = 0.071 in
                     Minimum thickness:               tmin = 0.2142 in
                     Nominal thickness:               tnom = 0.28 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(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 = 6.625 in        Cylinder length EP   L = 6 in
  inal thickness   tnom = 0.28 in         (tnom-CAI-CAO-Tol)   t = 0.245 in
 Do ratio           Ldo = 0.9057          Do/t               Dot = 27.0408
(2*S) or (0.9*yield) SE = -               Mod. of elasticity ME = 27000000 psi
A factor SII-D-FigG   A = 0.01118         B factor HA-1        B = 11810
Max allowed external pressure: Pa = 4*B / (3*Dot)               = 582.33 psi
Actual external design pressure:                              PE = 15 psi
  (Required cyl. tks. for nozzle attachments at PE, tre = 0.022 in  )
```

```
 .mponent: 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 = 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
Inside corr. allow. CAI = 0.0 in        Outside corr.allow.CAO = 0.0 in
Vessel design stress Sv = 15000 psi     Joint efficiency     E = 1
Vessel outside dia   Do = 72.0 in       Corroded radius     OR = 36.0 in
Nominal thickness  tnom = 0.5 in        Reinforcement limit lp = 6.065 in
Req. tks. int.pres.  tr = 0.1617 in     Req. tks.ext.pres. tre = 0.196 in
Corroded thickness    t = 0.5 in        Reinf. efficiency   E1 = 1.0
Attachment Material: SA-312 S30400 Grd TP304 Wld. pipe(G5)
Inside corr. allow. CAI = 0.0 in        Outside corr.allow.CAO = 0.0 in
Nozzle design stress Sn = 16100 psi     Joint efficiency     E = 0.85
Nozzle outside dia. Don = 6.625 in      Corroded radius     OR = 3.3125 in
Nominal thickness  tnom = 0.28 in       Reinforcement limit ln = 0.7 in
Req.tks. int.pres.  trn = 0.0181 in     Req.tks.ext.pres. trne = 0.022 in
Corroded thickness   tn = 0.28 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  = 0.28 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)    = 0.196 in      Weld tw     (actual)   = 0.0 in
Weld  tc   (minimum)    = 0.196 in      Weld tc     (actual)   = 0.196 in
    smaller |0.25 in    |               Leg size tw (actual)   = 0.0 in
 +c    of   |0.7 * tmin|                Leg size tc (actual)   = 0.28 in
  ward nozzle weld    L1 = 0.28 in      fr1 = Sn/Sv               = 1.0
 ..cer element weld   L2 = 0.0 in       fr2 = Sn/Sv               = 1.0
Inward nozzle weld    L3 = 0.0 in       fr3 = Sn/Sv or Se/Sv      = 1.0
Inward nozzel weld new   = 0.0 in       fr4 = Se/Sv               = 1.0
Corroded int.proj.thk ti = 0.0 in
```

```
 Eroded inside diameter                                          d = 6.065 in
Vessel wall length available for reinforcement    2*Lp-d = 6.065 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)| = 2.0519 in2
 |2*(t+tn)*(E1*t-F*tr)-2*tn*(E1*t-F*tr)*(1-fr1)| = 0.5278 in2
                                                                A1 = 2.0519 in2
A2 = Nozzle wall outward    | 5*(tn-trn)*fr2*t    | = 0.6547 in2
     Smaller of:            | 5*(tn-trn)*fr2*tn   | = 0.3666 in2
                                                                A2 = 0.3666 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 = 0.0784 in2
A42 = Outer element weld  = (L2**2)*fr4 = 0.0 in2
A43 = Inward nozzle weld  = (L3**2)*fr2 = 0.0 in2
                                                                A4 = 0.0784 in2
A5 = Reinforcement pad Area = (Dp-d-2*tn)*te*fr4                A5 = 0.0 in2
Aa = Area Available = A1+A2+A3+A4+A5                            Aa = 2.497 in2
A = Area required    = (d*tr*F)+2*tn*tr*F*(1-f1)                 A = 0.9806 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)| = 1.8438 in2
 |2*(t+tn)*(E1*t-F*tre)-2*tn*(E1*t-F*tre)*(1-fr1)| = 0.4742 in2
                                                                A1 = 1.8438 in2
A2 = Nozzle wall outward    | 5*(tn-trne)*fr2*t   | = 0.645 in2
     Smaller of:            | 5*(tn-trne)*fr2*tn  | = 0.3612 in2
                                                                A2 = 0.3612 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 = 0.0784 in2
A42 = Outer element weld  =    (L2**2)*fr4 = 0.0 in2
A43 = Inward nozzle weld  =    (L3**2)*fr2 = 0.0 in2
                                                                A4 = 0.0784 in2
A5 = Reinforcement pad Area = (Dp-d-2*tn)*te*fr4                A5 = 0.0 in2
Aa = Area Available = A1+A2+A3+A4+A5                            Aa = 2.2834 in2
A = Area required    = 0.5*(d*tre*F+2*tn*tre*F*(1-fr1))          A = 0.5944 in2
```

```
 ..zzle 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) = 6676 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) = 10876 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                   =    11270 psi
 Strength of connection elements
    Inner fillet weld shear             =    21406 lbf
    Nozzle wall shear                   =    31435 lbf
    Groove weld tension                 =    32328 lbf
    Outer fillet weld shear             =    -
 Possible paths of failure
    1-1         31435 + 21406           =    52841 lbf
    2-2         21406 + 32328           =    53734 lbf
    3-3              - + -              =    -
 Welds strong enough if path greater than the smaller of W or W(path)
                              Path 1-1 > W or W11
                             52841 lbf > 6676 lbf                OK
                              Path 2-2 > W or W22
                             53734 lbf > 10876 lbf               OK
                              Path 3-3 > W or W33
                                     - > -
```

```
 mponent:  Nozzle E
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
Design pressure       Pr = 75 psi          Design temperature    T = 300 F
Joint efficiency       E = 1.00
Vessel design stress   S = 15000 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 = 72.0 in         Vessel mean radius   Rm = 35.8438 in
Vessel thickness    tnom = 0.3125 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 = 0.3125 in
Shape factors and Coefficients:
 Gamma = Rm/T = 114.7                    Beta = 0.875*ro/Rm = 0.0809
 Alpha =      = 8546.78     Sigma = 7376.00        Delta = 4368.71
Conversion factor              Cf = 1
Maximum load & moment
S     = 2*pr*(Rm-T/2)/t             = 17130 psi
Sa    = shell allowable stress      = 15000 psi
Sig   = minimum of S & Sa           = 15000 psi
Frrf  = Rm*Rm*(sy-sig)/alpha        = 1112 lbf
Mrcm  = Rm*Rm*ro*sy*cf/sigma        = 12924 lbf*in
Mrlm  = Rm*Rm*ro*(sy-sig)*cf/delta  = 7209 lbf*in
Frf   = maximum resultant force     = 1112 lbf
Mrm   = maximum resultant moment    = 7209 lbf*in
           |  Interaction diagram:
           |                         Applied loads:
           |                             Radial load    P = 0 lbf
       FRF-+                             Circ. moment  Mc = 0 lbf*in
      1112 |                             Long. moment  Ml = 0 lbf*in
           |                         Maximum allowable loads:
           |                             Radial Load P,Mc = 1112 lbf
           |                             Radial Load P,Ml = 1112 lbf
           |                             Mc or Ml (from P)= 7209 lbf*in
           +
           |                             Note: Couples (P,Mc) & (P,Ml)
           |                                   must be located within
           |                                   the triangle limited by
           |                                   0, FRF, MRM.
           |
           ----------+---------+----
          0                   MRM
                              7209
```

```
.mponent:  Nozzle F1
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
Design pressure        Pr = 75 psi        Design temperature    T = 300 F
Joint efficiency        E = 1.00
Vessel design stress    S = 15000 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 = 72.0 in       Vessel mean radius   Rm = 35.8438 in
Vessel thickness     tnom = 0.3125 in
Nozzle:
Nozzle outside dia.   ODn = 3.5 in        Nozzle outside rad.  ro = 1.75 in
Reinf. pad:
Pad thickness        Prtk = 0.0 in        Vessel + pad tks.     T = 0.3125 in
Shape factors and Coefficients:
 Gamma = Rm/T = 114.7                   Beta = 0.875*ro/Rm = 0.0427
 Alpha =       = 13911.63    Sigma = 8457.67         Delta = 5626.43
Conversion factor                Cf = 1
Maximum load & moment
S     = 2*pr*(Rm-T/2)/t             = 17130 psi
Sa    = shell allowable stress      = 15000 psi
Sig   = minimum of S & Sa           = 15000 psi
Frrf  = Rm*Rm*(sy-sig)/alpha        = 683 lbf
Mrcm  = Rm*Rm*ro*sy*cf/sigma        = 5955 lbf*in
Mrlm  = Rm*Rm*ro*(sy-sig)*cf/delta  = 2957 lbf*in
Frf   = maximum resultant force     = 683 lbf
Mrm   = maximum resultant moment    = 2957 lbf*in
          |  Interaction diagram:
          |                            Applied loads:
          |                                Radial load     P = 0 lbf
      FRF-+                                Circ. moment   Mc = 0 lbf*in
      683 |                                Long. moment   Ml = 0 lbf*in
          |                            Maximum allowable loads:
          |                                Radial Load P,Mc = 683 lbf
          |                                Radial Load P,Ml = 683 lbf
          |                                Mc or Ml (from P)= 2957 lbf*in
          +
          |                                Note: Couples (P,Mc) & (P,Ml)
          |                                      must be located within
          |                                      the triangle limited by
          |                                      0, FRF, MRM.
          |
          ----------+---------+----
         0                   MRM
                            2957
```

```
.aponent:  Nozzle F2
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
Design pressure       Pr = 75 psi        Design temperature    T = 300 F
Joint efficiency       E = 1.00
Vessel design stress   S = 15000 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 = 72.0 in       Vessel mean radius   Rm = 35.8438 in
Vessel thickness    tnom = 0.3125 in
Nozzle:
Nozzle outside dia.  ODn = 3.5 in        Nozzle outside rad.  ro = 1.75 in
Reinf. pad:
Pad thickness       Prtk = 0.0 in        Vessel + pad tks.     T = 0.3125 in
Shape factors and Coefficients:
 Gamma = Rm/T = 114.7                  Beta = 0.875*ro/Rm = 0.0427
 Alpha =      = 13911.63    Sigma = 8457.67        Delta = 5626.43
Conversion factor              Cf = 1
Maximum load & moment
S    = 2*pr*(Rm-T/2)/t            = 17130 psi
Sa   = shell allowable stress     = 15000 psi
Sig  = minimum of S & Sa          = 15000 psi
Frrf = Rm*Rm*(sy-sig)/alpha       = 683 lbf
Mrcm = Rm*Rm*ro*sy*cf/sigma       = 5955 lbf*in
Mrlm = Rm*Rm*ro*(sy-sig)*cf/delta = 2957 lbf*in
Frf  = maximum resultant force    = 683 lbf
Mrm  = maximum resultant moment   = 2957 lbf*in
         |  Interaction diagram:
         |                            Applied loads:
         |                                Radial load    P = 0 lbf
    FRF-+                                 Circ. moment  Mc = 0 lbf*in
    683  |                                Long. moment  Ml = 0 lbf*in
         |                            Maximum allowable loads:
         |                                Radial Load P,Mc = 683 lbf
         |                                Radial Load P,Ml = 683 lbf
         |                                Mc or Ml (from P)= 2957 lbf*in
         +
         |                                Note: Couples (P,Mc) & (P,Ml)
         |                                      must be located within
         |                                      the triangle limited by
         |                                      0, FRF, MRM.
         |
         ----------+---------+----
        0                  MRM
                          2957
```

```
 mponent:  Nozzle H
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
Design pressure        Pr = 75 psi      Design temperature    T = 300 F
Joint efficiency        E = 1.00
Vessel design stress    S = 15000 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 = 72.0 in     Vessel mean radius   Rm = 35.8438 in
Vessel thickness     tnom = 0.3125 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 = 0.3125 in
Shape factors and Coefficients:
 Gamma = Rm/T = 114.7                  Beta = 0.875*ro/Rm = 0.029
 Alpha =      = 18704.78    Sigma = 9191.07         Delta = 6561.56
Conversion factor              Cf = 1
Maximum load & moment
S     = 2*pr*(Rm-T/2)/t           = 17130 psi
Sa    = shell allowable stress    = 15000 psi
Sig   = minimum of S & Sa         = 15000 psi
Frrf  = Rm*Rm*(sy-sig)/alpha      = 508 lbf
Mrcm  = Rm*Rm*ro*sy*cf/sigma      = 3718 lbf*in
Mrlm  = Rm*Rm*ro*(sy-sig)*cf/delta = 1721 lbf*in
Frf   = maximum resultant force   = 508 lbf
Mrm   = maximum resultant moment  = 1721 lbf*in
          |  Interaction diagram:
          |                         Applied loads:
          |                             Radial load    P = 0 lbf
      FRF-+                             Circ. moment  Mc = 0 lbf*in
      508 |                             Long. moment  Ml = 0 lbf*in
          |                         Maximum allowable loads:
          |                             Radial Load P,Mc = 508 lbf
          |                             Radial Load P,Ml = 508 lbf
          |                             Mc or Ml (from P)= 1721 lbf*in
          +
          |                             Note: Couples (P,Mc) & (P,Ml)
          |                                   must be located within
          |                                   the triangle limited by
          |                                   0, FRF, MRM.
          |
          ----------+---------+----
         0                   MRM
                             1721
```

ponent: 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.
E	ANSI SO	6.625	150	0.432	1.0	9.5	8.5	0.94	8	0.75
F1	ANSI SO	3.5	150	0.3	0.94	6.0	5.0	0.75	4	0.625
F2	ANSI SO	3.5	150	0.3	0.94	6.0	5.0	0.75	4	0.625
H	ANSI SO	2.375	150	0.218	0.75	4.75	3.62	0.62	4	0.625
TC	ANSI SO	32.0	150	0.3125	2.25	38.5	36.0	0.0	28	1.5
D	ANSI SO	6.625	150	0.28	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

```
Component:  Nozzle K
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(G5)
Design pressure      P = 75 psi          Design temperature   T = 300 F
Radiography            = None            Joint efficiency     E = 0.85
Design stress        S = 16100 psi
Inside corr.allow. cai = 0.0 in          Outside corr. all. cao = 0.0 in
Material tolerance tol = 0.035 in        Minimum thickness tmin = 0.2142 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 = 0.0531 in   APP.1-1(A)
  - UG-45(a) external pressure+cai+cao+tol       t = 0.057 in
  - UG-16(b) minimum thickness+cai+cao+tol       t = 0.0975 in
    UG-45(b) Smaller of:                         t = 0.2142 in
    UG-45(b)(4) std pipe*0.875+cai+cao+tol = 0.28 in
      - UG-45(b) Greater of:             t = 0.2142 in
        - UG-45(b)(1)+cai+cao+tol = 0.2142 in
        - UG-45(b)(2)+cai+cao+tol = 0.071 in
                    Minimum thickness:                tmin = 0.2142 in
                    Nominal thickness:                tnom = 0.28 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(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 = 6.625 in       Cylinder length EP  L = 6 in
Nominal thickness  tnom = 0.28 in        (tnom-CAI-CAO-Tol)  t = 0.245 in
L/Do ratio          Ldo = 0.9057         Do/t              Dot = 27.0408
(2*S) or (0.9*yield) SE = -              Mod. of elasticity ME = 27000000 psi
A factor SII-D-FigG   A = 0.01118        B factor HA-1       B = 11810
Max allowed external pressure: Pa = 4*B / (3*Dot)              = 582.33 psi
Actual external design pressure:                            PE = 15 psi
   (Required cyl. tks. for nozzle attachments at PE, tre = 0.022 in  )
```

```
Component: Reinforcement Nozzle K
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
Inside corr. allow. CAI = 0.0 in        Outside corr.allow.CAO = 0.0 in
Vessel design stress Sv = 15000 psi     Joint efficiency     E = 1
Vessel outside dia   Do = 72.0 in       Corroded radius     OR = 36.0 in
Nominal thickness  tnom = 0.5 in        Reinforcement limit lp = 6.065 in
Req. tks. int.pres.  tr = 0.1617 in     Req. tks.ext.pres. tre = 0.196 in
Corroded thickness    t = 0.5 in        Reinf. efficiency   E1 = 1.0
Attachment Material: SA-312 S30400 Grd TP304 Wld. pipe(G5)
Inside corr. allow. CAI = 0.0 in        Outside corr.allow.CAO = 0.0 in
Nozzle design stress Sn = 16100 psi     Joint efficiency     E = 0.85
Nozzle outside dia. Don = 6.625 in      Corroded radius     OR = 3.3125 in
Nominal thickness  tnom = 0.28 in       Reinforcement limit ln = 0.7 in
Req.tks. int.pres.  trn = 0.0181 in     Req.tks.ext.pres. trne = 0.022 in
Corroded thickness   tn = 0.28 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  = 0.28 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)   = 0.196 in      Weld tw     (actual)   = 0.0 in
Weld  tc    (minimum)   = 0.196 in      Weld tc     (actual)   = 0.196 in
    smaller |0.25 in    |               Leg size tw (actual)   = 0.0 in
 tc    of   |0.7 * tmin|                Leg size tc (actual)   = 0.28 in
Outward nozzle weld    L1 = 0.28 in     fr1 = Sn/Sv                = 1.0
Outer element weld     L2 = 0.0 in      fr2 = Sn/Sv                = 1.0
Inward nozzle weld     L3 = 0.0 in      fr3 = Sn/Sv or Se/Sv       = 1.0
Inward nozzel weld new    = 0.0 in      fr4 = Se/Sv                = 1.0
Corroded int.proj.thk ti  = 0.0 in
```

```
 croded inside diameter                                      d = 6.065 in
Vessel wall length available for reinforcement       2*Lp-d = 6.065 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)| = 2.0519 in2
 |2*(t+tn)*(E1*t-F*tr)-2*tn*(E1*t-F*tr)*(1-fr1)| = 0.5278 in2
                                                               A1 = 2.0519 in2
A2 = Nozzle wall outward   | 5*(tn-trn)*fr2*t    | = 0.6547 in2
     Smaller of:           | 5*(tn-trn)*fr2*tn   | = 0.3666 in2
                                                               A2 = 0.3666 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 = 0.0784 in2
A42 = Outer element weld  = (L2**2)*fr4 = 0.0 in2
A43 = Inward nozzle weld  = (L3**2)*fr2 = 0.0 in2
                                                               A4 = 0.0784 in2
A5 = Reinforcement pad Area = (Dp-d-2*tn)*te*fr4               A5 = 0.0 in2
Aa = Area Available = A1+A2+A3+A4+A5                           Aa = 2.497 in2
A = Area required   = (d*tr*F)+2*tn*tr*F*(1-f1)                 A = 0.9806 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)| = 1.8438 in2
 |2*(t+tn)*(E1*t-F*tre)-2*tn*(E1*t-F*tre)*(1-fr1)| = 0.4742 in2
                                                               A1 = 1.8438 in2
A2 = Nozzle wall outward   | 5*(tn-trne)*fr2*t   | = 0.645 in2
     Smaller of:           | 5*(tn-trne)*fr2*tn  | = 0.3612 in2
                                                               A2 = 0.3612 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 = 0.0784 in2
A42 = Outer element weld  =   (L2**2)*fr4 = 0.0 in2
A43 = Inward nozzle weld  =   (L3**2)*fr2 = 0.0 in2
                                                               A4 = 0.0784 in2
A5 = Reinforcement pad Area = (Dp-d-2*tn)*te*fr4               A5 = 0.0 in2
Aa = Area Available = A1+A2+A3+A4+A5                           Aa = 2.2834 in2
A = Area required   = 0.5*(d*tre*F+2*tn*tre*F*(1-fr1))          A = 0.5944 in2
```

```
 zzle 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) = 6676 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) = 10876 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                    =   11270 psi
 Strength of connection elements
    Inner fillet weld shear              =   21406 lbf
    Nozzle wall shear                    =   31435 lbf
    Groove weld tension                  =   32328 lbf
    Outer fillet weld shear              =   -
 Possible paths of failure
    1-1        31435 + 21406             =   52841 lbf
    2-2        21406 + 32328             =   53734 lbf
    3-3            - + -                 =   -
 Welds strong enough if path greater than the smaller of W or W(path)
                           Path 1-1 > W or W11
                          52841 lbf > 6676 lbf               OK
                           Path 2-2 > W or W22
                          53734 lbf > 10876 lbf              OK
                           Path 3-3 > W or W33
                                  - > -
```

d loads - ANSI/SEI/ASCE 7-02		
sel outside diameter	OD	OD = 72 in
Vessel effective length	EL	EL = 149.375 in
Vessel effective diameter	EOD	EOD = 92.16 in
Effective wind area	Af	Af = EOD*EL = 95.6 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 = 1768.2 lbf
Moment arm	L	L = 6.22 ft
Overturning moment, OM, ft-lbf		OM = F*L = 11005
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
smic 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 = 21859 lbf
Total shear at the base, V = Cs * W		V = 3643.1 lbf
Maximum lateral force, F = V		F = 3643.1 lbf
Overturning moment, OM, ft-lbf		OM = 0.5*F*L = 11337

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 = 17000 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 = 1181 lbf
Controlling load,Q = Qmax(Qw,Qs)		Q = 0 lbf

.ights, surface area, Insulation

		Shell side		Tube side
Volume	ft3	219.97		68.81
Avg. fluid density	lb/ft3	0		0
Fluid weight	lb	0		0
Surface area	ft2	149.2		82.3
Surface Area			231.5 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			3844 lb	
Operating weight			21859 lb	
Full weight			21859 lb	

.ximum 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		300	15000	91.5	70	20000	122
Front Head Cover		300	15000	79.2*	70	20000	105.6*
Rear Head Cover		300	15000	179.3	70	20000	239.1
Nozzle E		300	16100	158.2	70	17000	210.9
Nozzle F1		300	16100	109.7	70	17000	146.3
Nozzle F2		300	16100	109.7	70	17000	146.3
Nozzle H		300	16100	2349.2	70	17000	2480.5
Nozzle Front		300	15000	180.7	70	20000	240.9
Nozzle D		300	16100	102.7	70	17000	136.9
Nozzle K		300	16100	102.7	70	17000	136.9
Nozzle Flng E		300	15000	205	70	20000	275
Nozzle Flng F1		300	15000	205	70	20000	275
Nozzle Flng F2		300	15000	205	70	20000	275
Nozzle Flng H		300	15000	205	70	20000	275
Nozzle Flng Front		300	15000	205	70	20000	275
Nozzle Flng D		300	15000	205	70	20000	275
Nozzle Flng K		300	15000	205	70	20000	275
Nozzle Reinforcement E		300	-	90	70	-	120
Nozzle Reinforcement F1		-	-	N/C	-	-	N/C
Nozzle Reinforcement F2		-	-	N/C	-	-	N/C
Nozzle Reinforcement H		-	-	N/C	-	-	N/C
Nozzle Reinforcement Front		-	-	N/C	-	-	N/C
Nozzle Reinforcement D		300	-	118	70	-	157
Nozzle Reinforcement K		300	-	118	70	-	157
.zzle Flng Bolting E		300	25000	205	70	25000	275
.zzle Flng Bolting F1		300	25000	205	70	25000	275
Nozzle Flng Bolting F2		300	25000	205	70	25000	275
Nozzle Flng Bolting H		300	25000	205	70	25000	275
Nozzle Flng Bolting Front		300	25000	205	70	25000	275
Nozzle Flng Bolting D		300	25000	205	70	25000	275
Nozzle Flng Bolting K		300	25000	205	70	25000	275

.nimum 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	
Nozzle Flng Bolting E	A	-55	-	-	-	*
Nozzle Flng Bolting F1	A	-55	-	-	-	*
Nozzle Flng Bolting F2	A	-55	-	-	-	*
Nozzle Flng Bolting H	A	-55	-	-	-	*
Nozzle Flng Bolting Front	A	-55	-	-	-	*
Nozzle Flng Bolting D	A	-55	-	-	-	*
Nozzle Flng Bolting K	A	-55	-	-	-	*

drostatic Test Pressure - ASME VIII-1 2004 A06 UG-99(b) Factor: 1.3

Shell Side: 97.5 psi Tube Side: -

Component	Material	Side	Temp F	Design Stress psi	Test Stress psi	Stress Ratio
Shell Cylinder	SA-240 S30400 Grd 304 Plat	S	300	15000	20000	1.3333
Front Head Cover	SA-240 S30400 Grd 304 Plat	S	300	15000	20000	1.3333
Rear Head Cover	SA-240 S30400 Grd 304 Plat	S	300	15000	20000	1.3333
Nozzle E	SA-312 S30400 Grd TP304 Wl	S	300	16100	17000	1.0559
Nozzle F1	SA-312 S30400 Grd TP304 Wl	S	300	16100	17000	1.0559
Nozzle F2	SA-312 S30400 Grd TP304 Wl	S	300	16100	17000	1.0559
Nozzle H	SA-312 S30400 Grd TP304 Wl	S	300	16100	17000	1.0559
Nozzle Front	SA-312 S30400 Grd TP304 Wl	S	300	15000	20000	1.3333
Nozzle D	SA-312 S30400 Grd TP304 Wl	S	300	16100	17000	1.0559
Nozzle K	SA-312 S30400 Grd TP304 Wl	S	300	16100	17000	1.0559
Nozzle Flng E	SA-182 S30400 Grd F304 For	S	300	15000	20000	1.3333
Nozzle Flng F1	SA-182 S30400 Grd F304 For	S	300	15000	20000	1.3333
Nozzle Flng F2	SA-182 S30400 Grd F304 For	S	300	15000	20000	1.3333
Nozzle Flng H	SA-182 S30400 Grd F304 For	S	300	15000	20000	1.3333
Nozzle Flng Front	SA-240 S30400 Grd 304 Plat	S	300	15000	20000	1.3333
Nozzle Flng D	SA-182 S30400 Grd F304 For	S	300	15000	20000	1.3333
Nozzle Flng K	SA-182 S30400 Grd F304 For	S	300	15000	20000	1.3333
Nozzle Flng Bolting E	SA-193 G41400 Grd B7 Bolt(	S	300	25000	25000	1
Nozzle Flng Bolting F1	SA-193 G41400 Grd B7 Bolt(	S	300	25000	25000	1
Nozzle Flng Bolting F2	SA-193 G41400 Grd B7 Bolt(	S	300	25000	25000	1
Nozzle Flng Bolting H	SA-193 G41400 Grd B7 Bolt(	S	300	25000	25000	1
Nozzle Flng Bolting Frt	SA-193 G41400 Grd B7 Bolt(	S	300	25000	25000	1
Nozzle Flng Bolting D	SA-193 G41400 Grd B7 Bolt(	S	300	25000	25000	1
Nozzle Flng Bolting K	SA-193 G41400 Grd B7 Bolt(	S	300	25000	25000	1

HT/DcR Engineering, Inc.

2830 Parkway Street Lakeland, FL 33811

Date Printed: 9/6/2007

CUSTOMER

DELTA-T CORPORATION
133 WALLER MILL ROAD
WILLILAMSBURG, VA 23185

VESSEL LOCATION

BUNGE-ERGON

VICKSBURG, MISSISSIPPI

VESSEL DESCRIPTION

REFLUX 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-E4201 SKIRT

NAMEPLATE INFORMATION

Vessel MAWP:	150.00 PSI and Full Vacuum at 300 °F
MDMT:	-20 °F at 150.00 PSI
Serial Number(s):	7793-4201 SKIRT
National Board Number(s):	______________________
Year Built:	2007
Radiography:	NONE
Postweld Heat Treated:	NONE
Construction Type:	W

HT/DcR Engineering, Inc.

2830 Parkway Street   Lakeland, FL 33811

Date Printed: 9/6/2007

HT/DcR Engineering, Inc.

Skirt 1

Customer: **DELTA-T CORPORATION**
Job No: 1494F
Number: 1

Vessel Number: 7793-E4201 SKIRT
Mark Number: SK1

Date Printed: 9/6/2007

Cylindrical Skirt Design Information

Design Temperature:	300 °F		Joint Efficiency:	45	%
Skirt Material:	SA-516 Gr 70		Factor B Chart:	CS-2	
			Material Stress(hot):	20000	PSI
Skirt Length:	84.0000	in.	Material Stress(cold):	20000	PSI
Corrosion Allowance:	0.0000	in.	Yield Strength:	33600	PSI
Outside Diameter:	72.0000	in.	Modulus of Elasticity:	28.3	10^6 PSI
			Density:	0.2830	lb/in.^3
Surface Area:	131.9469	Sq. Ft.	Weight:	2005.91	lb.
Long. Factor A:	0.0013021		Long. Factor B:	13405	PSI

Nominal Skirt Thickness Selected = **0.3750** in.

Cylindrical Skirt Design Information

Design Temperature:	300 °F		Joint Efficiency:	45	%
Skirt Material:	SA-516 Gr 70		Factor B Chart:	CS-2	
			Material Stress(hot):	20000	PSI
Skirt Length:	84.0000	in.	Material Stress(cold):	20000	PSI
Corrosion Allowance:	0.0000	in.	Yield Strength:	33600	PSI
Outside Diameter:	72.0000	in.	Modulus of Elasticity:	28.3	10^6 PSI
			Density:	0.2830	lb/in.^3
Surface Area:	131.9469	Sq. Ft.	Weight:	2005.91	lb.
Long. Factor A:	0.0013021		Long. Factor B:	13405	PSI

Nominal Skirt Thickness Selected = **0.3750** in.

HT/DcR Engineering, Inc.
Base Plate 1

Customer: **DELTA-T CORPORATION**
Job No: 1494F
Mark Number: BP1

Vessel Number: 7793-E4201 SKIRT

Date Printed: 9/6/2007

Base Ring with gussets and complete top ring Design Information

Design Temperature:	300 °F		Yield Strength:	33600	PSI
Base Ring Material:	SA-516 Gr 70		Density:	0.2830	lb/in.^3
Base Plate Thickness (T_b):	1.0000	in.	Skirt OD at Bottom (D_{sk}):	72.0000	in.
Base Plate OD (OD_b):	84.0000	in.	Base Plate ID (ID_b):	68.0000	in.
Base Plate Width (W_b):	8.0000	in.	Width Outside of Skirt (W_{bo}):	6.0000	in.

Anchor Bolt Information

Anchor Bolt Material:	SA-36		Material Stress(hot):	16600	PSI
			Material Stress(cold):	16600	PSI
Bolt Size:	1"	in.	Density:	0.2830	lb/in.^3
Bolt Circle (BC):	78.0000	in.	Number of Bolts (N_b):	8	
Nominal Diameter (D_b):	1.0000	in.	Bolt Hole Diameter (D_{bh}):	1.1250	in.
Root Area (A_b):	0.5510	sq. in.	Distance across Flats of Bolting Nut:	1.6250	in.
Threads Per Inch (thd):	8.00		Ultimate 28 Day Concrete Strength:	3000	PSI

Gusset Information

Gusset Thickness (T_g):	0.5000	in.	Max.Distance between Gussets (C_m):	24.0000	in.
Gusset Depth (W_g):	5.5000	in.	Max. Dist. between Gussets Straddling Bolts (C_b):	6.0000	in.
Gusset Height (H_g):	8.0000	in.	Number of Gussets (N_g):	16	

Compression Plate Information

Top Ring OD, (OD_t):	84.0000	in.	Top Ring thickness, (T_t):	1.0000	in.

Base Support Analysis - Operating Pressurized Condition - Ocassional Loads - Seismic Case 5

Total Weight of Tower as adjusted by load case combinations **W = 38089 lb.**

Maximum total moment at base of tower **M = 573379 in.-lb.**

Base Ring Calculations - Operating Pressurized Condition - Ocassional Loads - Seismic Case 5

Base ring area, $A_c = \left(\frac{\pi}{4}\right) * (OD_b^2 - ID_b^2) = \left(\frac{\pi}{4}\right) * (84.0000^2 - 68.0000^2)$ $A_c = 1910.09$ in.²

Base ring modulus, $Z_c = \left(\frac{\pi}{32}\right) * \left(\frac{OD_b^4 - ID_b^4}{OD_b}\right) = \left(\frac{\pi}{32}\right) * \left(\frac{84.0000^4 - 68.0000^4}{84.0000}\right)$ $Z_c = 33199$ in.³

Base ring-gusset geometry coefficient, k_y $k_y = 0.4460$

Base ring bearing pressure, $P = \left(\frac{W}{A_c}\right) + \left(\frac{M}{Z_c}\right) = \left(\frac{38089}{1910.09}\right) + \left(\frac{573379}{33199}\right)$ $P = 37$ PSI

$M_b = k_y * P * W_{bo}^2 = 0.4460 * 37 * 6.0000^2$ $M_b = 597$ lb.

Base ring stress, $S_b = \frac{6 * M_b}{T_b^2} = \frac{6 * 597}{1.0000^2}$ $S_b = 3585$ PSI

Anchor Bolt and Concrete Stresses - Operating Pressurized Condition - Ocassional Loads - Seismic Case 5

Recommended min. preload, $F_i = \left(\frac{M * A_c}{N_b * Z_c}\right) - \left(\frac{W}{N_b}\right) = \left(\frac{573379 * 1910.09}{8 * 33199}\right) - \left(\frac{38089}{8}\right)$ — $F_i = 0$ lb.

Torque required, $T_i = \frac{F_i * (1 + (thd * D_b))}{2 * \pi * thd} = \frac{0 * (1 + (8.00 * 1.0000))}{2 * \pi * 8.00}$ — $T_i = 0$ in.-lb.

Maximum bolt force, $M_{bf} = 1.25 * F_i = 1.25 * 0$ — $M_{bf} = 0$ lb.

Anchor bolt stress, $S_{bolt} = \frac{M_{bf}}{A_b} = \frac{0}{0.5510}$ — $S_{bolt} = 0$ PSI

Concrete stress, $S_c = \left(\frac{N_b * F_i}{A_c}\right) + \left(\frac{W}{A_c}\right) + \left(\frac{M}{Z_c}\right) = \left(\frac{8 * 0}{1910.09}\right) + \left(\frac{38089}{1910.09}\right) + \left(\frac{573379}{33199}\right)$ — $S_c = 37$ PSI

Gusset Calculations - Operating Pressurized Condition - Ocassional Loads - Seismic Case 5

Gusset buckling stress, $S_{gb} = \frac{M_{bf}}{2 * W_g * T_g} = \frac{0}{2 * 5.5000 * 0.5000}$ — $S_{gb} = 0$ PSI

Top Ring Calculations - Operating Pressurized Condition - Ocassional Loads - Seismic Case 5

Top Ring-gusset geometry coefficient, k_t — $k_t = 0.3500$

$$M_{max} = \left[\frac{M_{bf}}{4 * \pi}\right] * \left[\left(1.3 * Ln\left(\frac{2 * W_t * \sin\left(\frac{\pi * (BC - ID_t)}{2 * W_t}\right)}{\pi * e}\right)\right) + (1 - k_t)\right] =$$

$$\left[\frac{0}{4 * \pi}\right] * \left[\left(1.3 * Ln\left(\frac{2 * 6.0000 * \sin\left(\frac{\pi * (78.0000 - 72.0000)}{2 * 6.0000}\right)}{\pi * 0.8125}\right)\right) + (1 - 0.3500)\right]$$

$M_{max} = 0$ lb.

Top Ring stress, $S_t = \frac{6 * M_{max}}{Tt^2} = \frac{6 * 0}{1.0000^2}$ — $S_t = 0$ PSI

Base Support Allowable Stresses - Operating Pressurized Condition - Ocassional Loads - Seismic Case 5

Base support material yield strength, S_y — $S_y = 33600$ PSI

Base ring allowable stress, $S_{ba} = 1.0 * 0.6 * Sy = 1.0 * 0.6 * 33600$ — $S_{ba} = 20160$ PSI

Anchor bolt allowable stress, S_{bolta} — $S_{bolta} = 16600$ PSI

Concrete safe bearing load, $S_{ca} = 0.3 * 28$ day concrete strength $= 0.3 * 3000.00$ — $S_{ca} = 900$ PSI

Gusset buckling allowable stress, $S_{gba} = \frac{1.0 * 18000}{1 + \left(\frac{Hg^2}{1500 * Tg^2}\right)} = \frac{1.0 * 18000}{1 + \left(\frac{8.0000^2}{1500 * 0.5000^2}\right)}$ — $S_{gba} = 15376$ PSI

Top Ring allowable stress, $S_{ta} = 1.0 * 0.6 * S_y = 1.0 * 0.6 * 33600$ — $S_{ta} = 20160$ PSI

Base Support Stress Ratios - Operating Pressurized Condition - Ocassional Loads - Seismic Case 5

Base Ring, R_b — $R_b = 0.178$

Bolting, R_{bolt} — $R_{bolt} = 0.000$

Concrete, R_c — $R_c = 0.041$

Gusset-buckling, R_{gb} — $R_{gb} = 0.000$

Top Plate, R_t — $R_t = 0.000$

* NOTE: Stress ratios greater than 1.0 represent overstressed conditions.

Base Support Analysis - Operating Pressurized Condition - Ocassional Loads - Seismic Case 8

Total Weight of Tower as adjusted by load case combinations — **W = 21086 lb.**

Maximum total moment at base of tower — **M = 573379 in.-lb.**

Base Ring Calculations - Operating Pressurized Condition - Ocassional Loads - Seismic Case 8

Base ring area, $A_c = \left(\frac{\pi}{4}\right) * (OD_b^2 - ID_b^2) = \left(\frac{\pi}{4}\right) * (84.0000^2 - 68.0000^2)$ — $A_c = 1910.09$ in.²

Base ring modulus, $Z_c = \left(\frac{\pi}{32}\right) * \left(\frac{OD_b^4 - ID_b^4}{OD_b}\right) = \left(\frac{\pi}{32}\right) * \left(\frac{84.0000^4 - 68.0000^4}{84.0000}\right)$ — $Z_c = 33199$ in.³

Base ring-gusset geometry coefficient, k_y — $k_y = 0.4460$

Base ring bearing pressure, $P = \left(\frac{W}{A_c}\right) + \left(\frac{M}{Z_c}\right) = \left(\frac{21086}{1910.09}\right) + \left(\frac{573379}{33199}\right)$ — $P = 28$ PSI

$M_b = k_y * P * W_{bo}^2 = 0.4460 * 28 * 6.0000^2$ — $M_b = 455$ lb.

Base ring stress, $S_b = \frac{6 * M_b}{T_b^2} = \frac{6 * 455}{1.0000^2}$ — $S_b = 2727$ PSI

Anchor Bolt and Concrete Stresses - Operating Pressurized Condition - Ocassional Loads - Seismic Case 8

Recommended min. preload, $F_i = \left(\frac{M * A_c}{N_b * Z_c}\right) - \left(\frac{W}{N_b}\right) = \left(\frac{573379 * 1910.09}{8 * 33199}\right) - \left(\frac{21086}{8}\right)$ — $F_i = 1488$ lb.

Torque required, $T_i = \frac{F_i * (1 + (thd * D_b))}{2 * \pi * thd} = \frac{1488 * (1 + (8.00 * 1.0000))}{2 * \pi * 8.00}$ — $T_i = 266$ in.-lb.

Maximum bolt force, $M_{bf} = 1.25 * F_i = 1.25 * 1488$ — $M_{bf} = 1860$ lb.

Anchor bolt stress, $S_{bolt} = \frac{M_{bf}}{A_b} = \frac{1860}{0.5510}$ — $S_{bolt} = 3375$ PSI

Concrete stress, $S_c = \left(\frac{N_b * F_i}{A_c}\right) + \left(\frac{W}{A_c}\right) + \left(\frac{M}{Z_c}\right) = \left(\frac{8 * 1488}{1910.09}\right) + \left(\frac{21086}{1910.09}\right) + \left(\frac{573379}{33199}\right)$ — $S_c = 35$ PSI

Gusset Calculations - Operating Pressurized Condition - Ocassional Loads - Seismic Case 8

Gusset buckling stress, $S_{gb} = \dfrac{M_{bf}}{2 * W_g * T_g} = \dfrac{1860}{2 * 5.5000 * 0.5000}$ — $S_{gb} = 338$ PSI

Top Ring Calculations - Operating Pressurized Condition - Ocassional Loads - Seismic Case 8

Top Ring-gusset geometry coefficient, k_t — $k_t = 0.3500$

$$M_{max} = \left[\frac{M_{bf}}{4 * \pi} \right] * \left[\left(1.3 * Ln\left(\frac{2 * W_t * \sin\left(\frac{\pi * (BC - ID_t)}{2 * W_t} \right)}{\pi * e} \right) \right) + (1 - k_t) \right] =$$

$$\left[\frac{1860}{4 * \pi} \right] * \left[\left(1.3 * Ln\left(\frac{2 * 6.0000 * \sin\left(\frac{\pi * (78.0000 - 72.0000)}{2 * 6.0000} \right)}{\pi * 0.8125} \right) \right) + (1 - 0.3500) \right]$$

$M_{max} = 394$ lb.

Top Ring stress, $S_t = \dfrac{6 * M_{max}}{Tt^2} = \dfrac{6 * 394}{1.0000^2}$ — $S_t = 2364$ PSI

Base Support Allowable Stresses - Operating Pressurized Condition - Ocassional Loads - Seismic Case 8

Base support material yield strength, S_y — $S_y = 33600$ PSI

Base ring allowable stress, $S_{ba} = 1.0 * 0.6 * Sy = 1.0 * 0.6 * 33600$ — $S_{ba} = 20160$ PSI

Anchor bolt allowable stress, S_{bolta} — $S_{bolta} = 16600$ PSI

Concrete safe bearing load, $S_{ca} = 0.3 * 28$ day concrete strength $= 0.3 * 3000.00$ — $S_{ca} = 900$ PSI

Gusset buckling allowable stress, $S_{gba} = \dfrac{1.0 * 18000}{1 + \left(\dfrac{Hg^2}{1500 * Tg^2} \right)} = \dfrac{1.0 * 18000}{1 + \left(\dfrac{8.0000^2}{1500 * 0.5000^2} \right)}$ — $S_{gba} = 15376$ PSI

Top Ring allowable stress, $S_{ta} = 1.0 * 0.6 * S_y = 1.0 * 0.6 * 33600$ — $S_{ta} = 20160$ PSI

Base Support Stress Ratios - Operating Pressurized Condition - Ocassional Loads - Seismic Case 8

Base Ring, R_b — $R_b = 0.135$

Bolting, R_{bolt} — $R_{bolt} = 0.203$

Concrete, R_c — $R_c = 0.038$

Gusset-buckling, R_{gb} — $R_{gb} = 0.022$

Top Plate, R_t — $R_t = 0.117$

* NOTE: Stress ratios greater than 1.0 represent overstressed conditions.

Base Support Analysis - Operating Pressurized Condition - Ocassional Loads - Wind Case 5

Total Weight of Tower as adjusted by load case combinations — **W = 36985 lb.**

Maximum total moment at base of tower — **M = 747867 in.-lb.**

Base Ring Calculations - Operating Pressurized Condition - Ocassional Loads - Wind Case 5

Base ring area, $A_c = \left(\frac{\pi}{4}\right) * (OD_b^2 - ID_b^2) = \left(\frac{\pi}{4}\right) * (84.0000^2 - 68.0000^2)$ — $A_c = 1910.09$ in.²

Base ring modulus, $Z_c = \left(\frac{\pi}{32}\right) * \left(\frac{OD_b^4 - ID_b^4}{OD_b}\right) = \left(\frac{\pi}{32}\right) * \left(\frac{84.0000^4 - 68.0000^4}{84.0000}\right)$ — $Z_c = 33199$ in.³

Base ring-gusset geometry coefficient, k_y — $k_y = 0.4460$

Base ring bearing pressure, $P = \left(\frac{W}{A_c}\right) + \left(\frac{M}{Z_c}\right) = \left(\frac{36985}{1910.09}\right) + \left(\frac{747867}{33199}\right)$ — P = 42 PSI

$M_b = k_y * P * W_{bo}^2 = 0.4460 * 42 * 6.0000^2$ — $M_b = 673$ lb.

Base ring stress, $S_b = \frac{6 * M_b}{T_b^2} = \frac{6 * 673}{1.0000^2}$ — $S_b = 4035$ PSI

Anchor Bolt and Concrete Stresses - Operating Pressurized Condition - Ocassional Loads - Wind Case 5

Recommended min. preload, $F_i = \left(\frac{M * A_c}{N_b * Z_c}\right) - \left(\frac{W}{N_b}\right) = \left(\frac{747867 * 1910.09}{8 * 33199}\right) - \left(\frac{36985}{8}\right)$ — $F_i = 755$ lb.

Torque required, $T_i = \frac{F_i * (1 + (thd * D_b))}{2 * \pi * thd} = \frac{755 * (1 + (8.00 * 1.0000))}{2 * \pi * 8.00}$ — $T_i = 135$ in.-lb.

Maximum bolt force, $M_{bf} = 1.25 * F_i = 1.25 * 755$ — $M_{bf} = 944$ lb.

Anchor bolt stress, $S_{bolt} = \frac{M_{bf}}{A_b} = \frac{944}{0.5510}$ — $S_{bolt} = 1714$ PSI

Concrete stress, $S_c = \left(\frac{N_b * F_i}{A_c}\right) + \left(\frac{W}{A_c}\right) + \left(\frac{M}{Z_c}\right) = \left(\frac{8 * 755}{1910.09}\right) + \left(\frac{36985}{1910.09}\right) + \left(\frac{747867}{33199}\right)$ — $S_c = 45$ PSI

Gusset Calculations - Operating Pressurized Condition - Ocassional Loads - Wind Case 5

Gusset buckling stress, $S_{gb} = \frac{M_{bf}}{2 * W_g * T_g} = \frac{944}{2 * 5.5000 * 0.5000}$ — $S_{gb} = 172$ PSI

Top Ring Calculations - Operating Pressurized Condition - Ocassional Loads - Wind Case 5

Top Ring-gusset geometry coefficient, k_t — $k_t = 0.3500$

$$M_{max} = \left[\frac{M_{bf}}{4 * \pi} \right] * \left[\left(1.3 * Ln\left(\frac{2 * W_t * \sin\left(\frac{\pi * (BC - ID_t)}{2 * W_t} \right)}{\pi * e} \right) \right) + (1 - k_t) \right] =$$

$$\left[\frac{944}{4 * \pi} \right] * \left[\left(1.3 * Ln\left(\frac{2 * 6.0000 * \sin\left(\frac{\pi * (78.0000 - 72.0000)}{2 * 6.0000} \right)}{\pi * 0.8125} \right) \right) + (1 - 0.3500) \right]$$

$M_{max} = 200$ lb.

Top Ring stress, $S_t = \frac{6 * M_{max}}{Tt^2} = \frac{6 * 200}{1.0000^2}$ — $S_t = 1200$ PSI

Base Support Allowable Stresses - Operating Pressurized Condition - Ocassional Loads - Wind Case 5

Base support material yield strength, S_y — $S_y = 33600$ PSI

Base ring allowable stress, $S_{ba} = 1.2 * 0.6 * Sy = 1.2 * 0.6 * 33600$ — $S_{ba} = 24192$ PSI

Anchor bolt allowable stress, S_{bolta} — $S_{bolta} = 16600$ PSI

Concrete safe bearing load, $S_{ca} = 0.4 * 28$ day concrete strength $= 0.4 * 3000.00$ — $S_{ca} = 1200$ PSI

Gusset buckling allowable stress, $S_{gba} = \frac{1.2 * 18000}{1 + \left(\frac{Hg^2}{1500 * Tg^2} \right)} = \frac{1.2 * 18000}{1 + \left(\frac{8.0000^2}{1500 * 0.5000^2} \right)}$ — $S_{gba} = 18451$ PSI

Top Ring allowable stress, $S_{ta} = 1.2 * 0.6 * S_y = 1.2 * 0.6 * 33600$ — $S_{ta} = 24192$ PSI

Base Support Stress Ratios - Operating Pressurized Condition - Ocassional Loads - Wind Case 5

Base Ring, R_b — $R_b = 0.167$

Bolting, R_{bolt} — $R_{bolt} = 0.103$

Concrete, R_c — $R_c = 0.038$

Gusset-buckling, R_{gb} — $R_{gb} = 0.009$

Top Plate, R_t — $R_t = 0.050$

* NOTE: Stress ratios greater than 1.0 represent overstressed conditions.

Base Support Analysis - Operating Pressurized Condition - Sustained Loads

Total Weight of Tower as adjusted by load case combinations — **W = 36985 lb.**

Maximum total moment at base of tower — **M = 0 in.-lb.**

Base Ring Calculations - Operating Pressurized Condition - Sustained Loads

Base ring area, $A_c = \left(\frac{\pi}{4}\right) * (OD_b^2 - ID_b^2) = \left(\frac{\pi}{4}\right) * (84.0000^2 - 68.0000^2)$ — $A_c = 1910.09$ in.²

Base ring modulus, $Z_c = \left(\frac{\pi}{32}\right) * \left(\frac{OD_b^4 - ID_b^4}{OD_b}\right) = \left(\frac{\pi}{32}\right) * \left(\frac{84.0000^4 - 68.0000^4}{84.0000}\right)$ — $Z_c = 33199$ in.³

Base ring-gusset geometry coefficient, k_y — $k_y = 0.4460$

Base ring bearing pressure, $P = \left(\frac{W}{A_c}\right) + \left(\frac{M}{Z_c}\right) = \left(\frac{36985}{1910.09}\right) + \left(\frac{0}{33199}\right)$ — **P = 19 PSI**

$M_b = k_y * P * W_{bo}^2 = 0.4460 * 19 * 6.0000^2$ — $M_b = 311$ lb.

Base ring stress, $S_b = \frac{6 * M_b}{T_b^2} = \frac{6 * 311}{1.0000^2}$ — $S_b = 1865$ PSI

Anchor Bolt and Concrete Stresses - Operating Pressurized Condition - Sustained Loads

Recommended min. preload, $F_i = \left(\frac{M * A_c}{N_b * Z_c}\right) - \left(\frac{W}{N_b}\right) = \left(\frac{0 * 1910.09}{8 * 33199}\right) - \left(\frac{36985}{8}\right)$ — $F_i = 0$ lb.

Torque required, $T_i = \frac{F_i * (1 + (thd * D_b))}{2 * \pi * thd} = \frac{0 * (1 + (8.00 * 1.0000))}{2 * \pi * 8.00}$ — $T_i = 0$ in.-lb.

Maximum bolt force, $M_{bf} = 1.25 * F_i = 1.25 * 0$ — $M_{bf} = 0$ lb.

Anchor bolt stress, $S_{bolt} = \frac{M_{bf}}{A_b} = \frac{0}{0.5510}$ — $S_{bolt} = 0$ PSI

Concrete stress, $S_c = \left(\frac{N_b * F_i}{A_c}\right) + \left(\frac{W}{A_c}\right) + \left(\frac{M}{Z_c}\right) = \left(\frac{8 * 0}{1910.09}\right) + \left(\frac{36985}{1910.09}\right) + \left(\frac{0}{33199}\right)$ — $S_c = 19$ PSI

Gusset Calculations - Operating Pressurized Condition - Sustained Loads

Gusset buckling stress, $S_{gb} = \frac{M_{bf}}{2 * W_g * T_g} = \frac{0}{2 * 5.5000 * 0.5000}$ — $S_{gb} = 0$ PSI

Top Ring Calculations - Operating Pressurized Condition - Sustained Loads

Top Ring-gusset geometry coefficient, k_t — $k_t = 0.3500$

$$M_{max} = \left[\frac{M_{bf}}{4 * \pi}\right] * \left[\left(1.3 * Ln\left(\frac{2 * W_t * \sin\left(\frac{\pi * (BC - ID_t)}{2 * W_t}\right)}{\pi * e}\right)\right) + (1 - k_t)\right] =$$

$$\left[\frac{0}{4 * \pi}\right] * \left[\left(1.3 * Ln\left(\frac{2 * 6.0000 * \sin\left(\frac{\pi * (78.0000 - 72.0000)}{2 * 6.0000}\right)}{\pi * 0.8125}\right)\right) + (1 - 0.3500)\right]$$

$M_{max} = 0$ lb.

Top Ring stress, $S_t = \frac{6 * M_{max}}{Tt^2} = \frac{6 * 0}{1.0000^2}$ — $S_t = 0$ PSI

Base Support Allowable Stresses - Operating Pressurized Condition - Sustained Loads

Base support material yield strength, S_y — $S_y = 33600$ PSI

Base ring allowable stress, $S_{ba} = 1.0 * 0.6 * Sy = 1.0 * 0.6 * 33600$ — $S_{ba} = 20160$ PSI

Anchor bolt allowable stress, S_{bolta} — $S_{bolta} = 16600$ PSI

Concrete safe bearing load, $S_{ca} = 0.3 * 28$ day concrete strength $= 0.3 * 3000.00$ — $S_{ca} = 900$ PSI

Gusset buckling allowable stress, $S_{gba} = \frac{1.0 * 18000}{1 + \left(\frac{Hg^2}{1500 * Tg^2}\right)} = \frac{1.0 * 18000}{1 + \left(\frac{8.0000^2}{1500 * 0.5000^2}\right)}$ — $S_{gba} = 15376$ PSI

Top Ring allowable stress, $S_{ta} = 1.0 * 0.6 * S_y = 1.0 * 0.6 * 33600$ — $S_{ta} = 20160$ PSI

Base Support Stress Ratios - Operating Pressurized Condition - Sustained Loads

Base Ring, R_b — $R_b = 0.093$

Bolting, R_{bolt} — $R_{bolt} = 0.000$

Concrete, R_c — $R_c = 0.022$

Gusset-buckling, R_{gb} — $R_{gb} = 0.000$

Top Plate, R_t — $R_t = 0.000$

* NOTE: Stress ratios greater than 1.0 represent overstressed conditions.

Base Support Analysis - Empty Pressurized Condition - Ocassional Loads - Seismic Case 8

Total Weight of Tower as adjusted by load case combinations **W = 11413 lb.**

Maximum total moment at base of tower **M = 366856 in.-lb.**

Base Ring Calculations - Empty Pressurized Condition - Ocassional Loads - Seismic Case 8

Base ring area, $A_c = \left(\frac{\pi}{4}\right) * (OD_b^2 - ID_b^2) = \left(\frac{\pi}{4}\right) * (84.0000^2 - 68.0000^2)$ $A_c = 1910.09$ in.²

Base ring modulus, $Z_c = \left(\frac{\pi}{32}\right) * \left(\frac{OD_b^4 - ID_b^4}{OD_b}\right) = \left(\frac{\pi}{32}\right) * \left(\frac{84.0000^4 - 68.0000^4}{84.0000}\right)$ $Z_c = 33199$ in.³

Base ring-gusset geometry coefficient, k_y $k_y = 0.4460$

Base ring bearing pressure, $P = \left(\frac{W}{A_c}\right) + \left(\frac{M}{Z_c}\right) = \left(\frac{11413}{1910.09}\right) + \left(\frac{366856}{33199}\right)$ $P = 17$ PSI

$M_b = k_y * P * W_{bo}^2 = 0.4460 * 17 * 6.0000^2$ $M_b = 273$ lb.

Base ring stress, $S_b = \frac{6 * M_b}{T_b^2} = \frac{6 * 273}{1.0000^2}$ $S_b = 1640$ PSI

Anchor Bolt and Concrete Stresses - Empty Pressurized Condition - Ocassional Loads - Seismic Case 8

Recommended min. preload, $F_i = \left(\frac{M * A_c}{N_b * Z_c}\right) - \left(\frac{W}{N_b}\right) = \left(\frac{366856 * 1910.09}{8 * 33199}\right) - \left(\frac{11413}{8}\right)$ $F_i = 1212$ lb.

Torque required, $T_i = \frac{F_i * (1 + (thd * D_b))}{2 * \pi * thd} = \frac{1212 * (1 + (8.00 * 1.0000))}{2 * \pi * 8.00}$ $T_i = 217$ in.-lb.

Maximum bolt force, $M_{bf} = 1.25 * F_i = 1.25 * 1212$ $M_{bf} = 1515$ lb.

Anchor bolt stress, $S_{bolt} = \frac{M_{bf}}{A_b} = \frac{1515}{0.5510}$ $S_{bolt} = 2749$ PSI

Concrete stress, $S_c = \left(\frac{N_b * F_i}{A_c}\right) + \left(\frac{W}{A_c}\right) + \left(\frac{M}{Z_c}\right) = \left(\frac{8 * 1212}{1910.09}\right) + \left(\frac{11413}{1910.09}\right) + \left(\frac{366856}{33199}\right)$ $S_c = 22$ PSI

Gusset Calculations - Empty Pressurized Condition - Ocassional Loads - Seismic Case 8

Gusset buckling stress, $S_{gb} = \frac{M_{bf}}{2 * W_g * T_g} = \frac{1515}{2 * 5.5000 * 0.5000}$ $S_{gb} = 275$ PSI

Top Ring Calculations - Empty Pressurized Condition - Ocassional Loads - Seismic Case 8

Top Ring-gusset geometry coefficient, k_t, $k_t = 0.3500$

$$M_{max} = \left[\frac{M_{bf}}{4 * \pi} \right] * \left[\left(1.3 * Ln\left(\frac{2 * W_t * \sin\left(\frac{\pi * (BC - ID_t)}{2 * W_t} \right)}{\pi * e} \right) \right) + (1 - k_t) \right] =$$

$$\left[\frac{1515}{4 * \pi} \right] * \left[\left(1.3 * Ln\left(\frac{2 * 6.0000 * \sin\left(\frac{\pi * (78.0000 - 72.0000)}{2 * 6.0000} \right)}{\pi * 0.8125} \right) \right) + (1 - 0.3500) \right]$$

$M_{max} = 321$ lb.

Top Ring stress, $S_t = \frac{6 * M_{max}}{Tt^2} = \frac{6 * 321}{1.0000^2}$ $S_t = 1925$ PSI

Base Support Allowable Stresses - Empty Pressurized Condition - Ocassional Loads - Seismic Case 8

Base support material yield strength, S_y — $S_y = 33600$ PSI

Base ring allowable stress, $S_{ba} = 1.0 * 0.6 * Sy = 1.0 * 0.6 * 33600$ — $S_{ba} = 20160$ PSI

Anchor bolt allowable stress, S_{bolta} — $S_{bolta} = 16600$ PSI

Concrete safe bearing load, $S_{ca} = 0.3 * 28$ day concrete strength $= 0.3 * 3000.00$ — $S_{ca} = 900$ PSI

Gusset buckling allowable stress, $S_{gba} = \frac{1.0 * 18000}{1 + \left(\frac{Hg^2}{1500 * Tg^2} \right)} = \frac{1.0 * 18000}{1 + \left(\frac{8.0000^2}{1500 * 0.5000^2} \right)}$ — $S_{gba} = 15376$ PSI

Top Ring allowable stress, $S_{ta} = 1.0 * 0.6 * S_y = 1.0 * 0.6 * 33600$ — $S_{ta} = 20160$ PSI

Base Support Stress Ratios - Empty Pressurized Condition - Ocassional Loads - Seismic Case 8

Base Ring, R_b — $R_b = 0.081$

Bolting, R_{bolt} — $R_{bolt} = 0.166$

Concrete, R_c — $R_c = 0.025$

Gusset-buckling, R_{gb} — $R_{gb} = 0.018$

Top Plate, R_t — $R_t = 0.095$

* NOTE: Stress ratios greater than 1.0 represent overstressed conditions.

Base Support Analysis - Empty Pressurized Condition - Ocassional Loads - Wind Case 7

Total Weight of Tower as adjusted by load case combinations — **W = 12011 lb.**

Maximum total moment at base of tower — **M = 747867 in.-lb.**

Base Ring Calculations - Empty Pressurized Condition - Ocassional Loads - Wind Case 7

Base ring area, $A_c = \left(\frac{\pi}{4}\right) * (OD_b^2 - ID_b^2) = \left(\frac{\pi}{4}\right) * (84.0000^2 - 68.0000^2)$ — $A_c = 1910.09$ in.²

Base ring modulus, $Z_c = \left(\frac{\pi}{32}\right) * \left(\frac{OD_b^4 - ID_b^4}{OD_b}\right) = \left(\frac{\pi}{32}\right) * \left(\frac{84.0000^4 - 68.0000^4}{84.0000}\right)$ — $Z_c = 33199$ in.³

Base ring-gusset geometry coefficient, k_y — $k_y = 0.4460$

Base ring bearing pressure, $P = \left(\frac{W}{A_c}\right) + \left(\frac{M}{Z_c}\right) = \left(\frac{12011}{1910.09}\right) + \left(\frac{747867}{33199}\right)$ — $P = 29$ PSI

$M_b = k_y * P * W_{bo}^2 = 0.4460 * 29 * 6.0000^2$ — $M_b = 463$ lb.

Base ring stress, $S_b = \frac{6 * M_b}{T_b^2} = \frac{6 * 463}{1.0000^2}$ — $S_b = 2776$ PSI

Anchor Bolt and Concrete Stresses - Empty Pressurized Condition - Ocassional Loads - Wind Case 7

Recommended min. preload, $F_i = \left(\frac{M * A_c}{N_b * Z_c}\right) - \left(\frac{W}{N_b}\right) = \left(\frac{747867 * 1910.09}{8 * 33199}\right) - \left(\frac{12011}{8}\right)$ — $F_i = 3877$ lb.

Torque required, $T_i = \frac{F_i * (1 + (thd * D_b))}{2 * \pi * thd} = \frac{3877 * (1 + (8.00 * 1.0000))}{2 * \pi * 8.00}$ — $T_i = 694$ in.-lb.

Maximum bolt force, $M_{bf} = 1.25 * F_i = 1.25 * 3877$ — $M_{bf} = 4846$ lb.

Anchor bolt stress, $S_{bolt} = \frac{M_{bf}}{A_b} = \frac{4846}{0.5510}$ — $S_{bolt} = 8796$ PSI

Concrete stress, $S_c = \left(\frac{N_b * F_i}{A_c}\right) + \left(\frac{W}{A_c}\right) + \left(\frac{M}{Z_c}\right) = \left(\frac{8 * 3877}{1910.09}\right) + \left(\frac{12011}{1910.09}\right) + \left(\frac{747867}{33199}\right)$ — $S_c = 45$ PSI

Gusset Calculations - Empty Pressurized Condition - Ocassional Loads - Wind Case 7

Gusset buckling stress, $S_{gb} = \frac{M_{bf}}{2 * W_g * T_g} = \frac{4846}{2 * 5.5000 * 0.5000}$ — $S_{gb} = 881$ PSI

Top Ring Calculations - Empty Pressurized Condition - Ocassional Loads - Wind Case 7

Top Ring-gusset geometry coefficient, k_t — $k_t = 0.3500$

$$M_{max} = \left[\frac{M_{bf}}{4 * \pi} \right] * \left[\left(1.3 * Ln\left(\frac{2 * W_t * \sin\left(\frac{\pi * (BC - ID_t)}{2 * W_t} \right)}{\pi * e} \right) \right) + (1 - k_t) \right] =$$

$$\left[\frac{4846}{4 * \pi} \right] * \left[\left(1.3 * Ln\left(\frac{2 * 6.0000 * \sin\left(\frac{\pi * (78.0000 - 72.0000)}{2 * 6.0000} \right)}{\pi * 0.8125} \right) \right) + (1 - 0.3500) \right]$$

$M_{max} = 1027$ lb.

Top Ring stress, $S_t = \frac{6 * M_{max}}{Tt^2} = \frac{6 * 1027}{1.0000^2}$ — $S_t = 6160$ PSI

Base Support Allowable Stresses - Empty Pressurized Condition - Ocassional Loads - Wind Case 7

Base support material yield strength, S_y — $S_y = 33600$ PSI

Base ring allowable stress, $S_{ba} = 1.2 * 0.6 * Sy = 1.2 * 0.6 * 33600$ — $S_{ba} = 24192$ PSI

Anchor bolt allowable stress, S_{bolta} — $S_{bolta} = 16600$ PSI

Concrete safe bearing load, $S_{ca} = 0.4 * 28$ day concrete strength $= 0.4 * 3000.00$ — $S_{ca} = 1200$ PSI

Gusset buckling allowable stress, $S_{gba} = \frac{1.2 * 18000}{1 + \left(\frac{Hg^2}{1500 * Tg^2} \right)} = \frac{1.2 * 18000}{1 + \left(\frac{8.0000^2}{1500 * 0.5000^2} \right)}$ — $S_{gba} = 18451$ PSI

Top Ring allowable stress, $S_{ta} = 1.2 * 0.6 * S_y = 1.2 * 0.6 * 33600$ — $S_{ta} = 24192$ PSI

Base Support Stress Ratios - Empty Pressurized Condition - Ocassional Loads - Wind Case 7

Base Ring, R_b — $R_b = 0.115$

Bolting, R_{bolt} — $R_{bolt} = 0.530$

Concrete, R_c — $R_c = 0.038$

Gusset-buckling, R_{gb} — $R_{gb} = 0.048$

Top Plate, R_t — $R_t = 0.255$

* NOTE: Stress ratios greater than 1.0 represent overstressed conditions.

Base Support Analysis - Empty Pressurized Condition - Sustained Loads

Total Weight of Tower as adjusted by load case combinations **W = 12011 lb.**

Maximum total moment at base of tower **M = 0 in.-lb.**

Base Ring Calculations - Empty Pressurized Condition - Sustained Loads

Base ring area, $A_c = \left(\frac{\pi}{4}\right) * (OD_b^2 - ID_b^2) = \left(\frac{\pi}{4}\right) * (84.0000^2 - 68.0000^2)$ — $A_c = 1910.09$ in.²

Base ring modulus, $Z_c = \left(\frac{\pi}{32}\right) * \left(\frac{OD_b^4 - ID_b^4}{OD_b}\right) = \left(\frac{\pi}{32}\right) * \left(\frac{84.0000^4 - 68.0000^4}{84.0000}\right)$ — $Z_c = 33199$ in.³

Base ring-gusset geometry coefficient, k_y — $k_y = 0.4460$

Base ring bearing pressure, $P = \left(\frac{W}{A_c}\right) + \left(\frac{M}{Z_c}\right) = \left(\frac{12011}{1910.09}\right) + \left(\frac{0}{33199}\right)$ — $P = 6$ PSI

$M_b = k_y * P * W_{bo}^2 = 0.4460 * 6 * 6.0000^2$ — $M_b = 101$ lb.

Base ring stress, $S_b = \frac{6 * M_b}{T_b^2} = \frac{6 * 101}{1.0000^2}$ — $S_b = 606$ PSI

Anchor Bolt and Concrete Stresses - Empty Pressurized Condition - Sustained Loads

Recommended min. preload, $F_i = \left(\frac{M * A_c}{N_b * Z_c}\right) - \left(\frac{W}{N_b}\right) = \left(\frac{0 * 1910.09}{8 * 33199}\right) - \left(\frac{12011}{8}\right)$ — $F_i = 0$ lb.

Torque required, $T_i = \frac{F_i * (1 + (thd * D_b))}{2 * \pi * thd} = \frac{0 * (1 + (8.00 * 1.0000))}{2 * \pi * 8.00}$ — $T_i = 0$ in.-lb.

Maximum bolt force, $M_{bf} = 1.25 * F_i = 1.25 * 0$ — $M_{bf} = 0$ lb.

Anchor bolt stress, $S_{bolt} = \frac{M_{bf}}{A_b} = \frac{0}{0.5510}$ — $S_{bolt} = 0$ PSI

Concrete stress, $S_c = \left(\frac{N_b * F_i}{A_c}\right) + \left(\frac{W}{A_c}\right) + \left(\frac{M}{Z_c}\right) = \left(\frac{8 * 0}{1910.09}\right) + \left(\frac{12011}{1910.09}\right) + \left(\frac{0}{33199}\right)$ — $S_c = 6$ PSI

Gusset Calculations - Empty Pressurized Condition - Sustained Loads

Gusset buckling stress, $S_{gb} = \frac{M_{bf}}{2 * W_g * T_g} = \frac{0}{2 * 5.5000 * 0.5000}$ — $S_{gb} = 0$ PSI

Top Ring Calculations - Empty Pressurized Condition - Sustained Loads

Top Ring-gusset geometry coefficient, k_t — $k_t = 0.3500$

$$M_{max} = \left[\frac{M_{bf}}{4 * \pi} \right] * \left[\left(1.3 * Ln\left(\frac{2 * W_t * \sin\left(\frac{\pi * (BC - ID_t)}{2 * W_t} \right)}{\pi * e} \right) \right) + (1 - k_t) \right] =$$

$$\left[\frac{0}{4 * \pi} \right] * \left[\left(1.3 * Ln\left(\frac{2 * 6.0000 * \sin\left(\frac{\pi * (78.0000 - 72.0000)}{2 * 6.0000} \right)}{\pi * 0.8125} \right) \right) + (1 - 0.3500) \right]$$

$M_{max} = 0$ lb.

Top Ring stress, $S_t = \frac{6 * M_{max}}{Tt^2} = \frac{6 * 0}{1.0000^2}$ — $S_t = 0$ PSI

Base Support Allowable Stresses - Empty Pressurized Condition - Sustained Loads

Base support material yield strength, S_y — $S_y = 33600$ PSI

Base ring allowable stress, $S_{ba} = 1.0 * 0.6 * Sy = 1.0 * 0.6 * 33600$ — $S_{ba} = 20160$ PSI

Anchor bolt allowable stress, S_{bolta} — $S_{bolta} = 16600$ PSI

Concrete safe bearing load, $S_{ca} = 0.3 * 28$ day concrete strength $= 0.3 * 3000.00$ — $S_{ca} = 900$ PSI

Gusset buckling allowable stress, $S_{gba} = \frac{1.0 * 18000}{1 + \left(\frac{Hg^2}{1500 * Tg^2} \right)} = \frac{1.0 * 18000}{1 + \left(\frac{8.0000^2}{1500 * 0.5000^2} \right)}$ — $S_{gba} = 15376$ PSI

Top Ring allowable stress, $S_{ta} = 1.0 * 0.6 * S_y = 1.0 * 0.6 * 33600$ — $S_{ta} = 20160$ PSI

Base Support Stress Ratios - Empty Pressurized Condition - Sustained Loads

Base Ring, R_b — $R_b = 0.030$

Bolting, R_{bolt} — $R_{bolt} = 0.000$

Concrete, R_c — $R_c = 0.007$

Gusset-buckling, R_{gb} — $R_{gb} = 0.000$

Top Plate, R_t — $R_t = 0.000$

* NOTE: Stress ratios greater than 1.0 represent overstressed conditions.

Loading Summary

Type	Starting Elevation (in.)	Ending Elevation (in.)	Density (lb./Ft^3)	Thickness (in.)	Wind Diameter (in.)	Wind Pressure (lb./ft.^{2})
Liquid	160.0000	285.0000	62.4300	-	-	-
Insulation	160.0000	570.0000	12.0000	3.0000	-	-
Wind	488.0000	570.0000	-	-	52.0000	-
Wind	327.0000	488.0000	-	-	38.0000	-
Wind	279.0000	327.0000	-	-	52.0000	-
Wind	0.0000	279.0000	-	-	78.0000	-

Attachment Summary

Attachment No.	Elevation (in.)	Description	Attachment Weight (lb.)	Horizontal Force (lb.)	Attachment Moment (in.-lb.)
1	405.0000	TUBE BUNDLE	7800.00	0	0

Tower Analysis

Operating Pressurized Condition - Ocassional Loads - Seismic Case 5

First Period of Natural Vibration for Operating conditions: 0.2208 seconds/cycle

IBC 2003 Seismic Design Information

0.2 s Spectral Response Accel (S_S):	0.200		
1 s Spectral Response Accel. (S_1):	0.100	Response Modification Factor (R):	3.000
Seismic Use Group:	I	Site Class:	D
Total seismic shear force at the base (V):	2630 lb.		

IBC 2003 Seismic Analysis

Segment Type	Segment No.	Wi Weight (lb.)	Hi Mid-Elevation (in.)	Wi * Hi (Ft.-lb.)	Segment Seismic Force (lb.)	Shear @ Top (lb.)	Moment @ Bottom (Ft.-lb.)	Seismic Stress (PSI)
Head	1	116.52	563.0626	5467	12	0	4	0
Shell	2	929.77	523.5001	40561	92	12	351	14
Shell	3	117.86	483.5001	4749	11	105	434	18
Shell	4	969.06	442.0001	35694	81	116	1398	58
Attach	5t	7800.00	405.0000	263250	600			
Shell	5	340.48	392.0001	11122	25	796	3151	130
Shell	6	680.96	353.0001	20032	46	822	6810	281
Shell	7	550.01	306.0000	14025	32	867	9902	408
Shell	8	244.83	282.0001	5753	13	899	10355	427
Cone	9	0.01	279.0001	0	0	912	10355	324
Cone	10	1906.32	271.0000	43051	98	912	11637	70
Shell	11	16718.43	215.5000	300235	684	1010	22343	160
Head	12t	2598.66	168.0000	36381	83			
Skirt	12	2005.91	126.0000	21062	48	1777	34950	279
Skirt	13	2005.91	42.0000	7021	16	1825	47782	381
Total		**36984.72**		**808404**				

Stress Summary

Segment Type	Segment No.	Sm Attachments With Wind or Seismic (PSI)	Sp Internal Pressure Stress (PSI)	Sp External Pressure Stress (PSI)	Sw Weight Stress (PSI)	Maximum Tensile Stress (PSI)	Maximum Compressive Stress (PSI)
Head	1	0	4763	476	5	4758	-481
Shell	2	14	3163	316	29	3148	-360
Shell	3	18	3163	316	32	3148	-366
Shell	4	58	3163	316	59	3161	-433
Shell	5	130	3163	316	284	3008	-730
Shell	6	281	3163	316	303	3140	-900
Shell	7	408	3163	316	318	3253	-1042
Shell	8	427	3163	316	320	3269	-1063
Cone	9	324	3746	375	390	3680	-1088
Cone	10	70	8548	855	181	8437	-1106
Shell	11	160	6463	639	167	6455	-966
Skirt	12	279	0	0	427	-148	-706
Skirt	13	381	0	0	451	-70	-833

Positive values represent tensile stress, and negative values represent compressive.
Stress ratios greater than 1.0 represent overstressed conditions.

Stress Comparisons

Segment Type	Segment No.	Maximum Tensile Stress (PSI)	Allowable Stress (PSI)	Maximum Tensile Stress Ratio	Maximum Compressive Stress (PSI)	Allowable Stress (PSI)	Maximum Compressive Stress Ratio	Critical Buckling Stress (PSI)	Critical Buckling Ratio
Head	1	4758	15876	0.2997	-481	-11098	0.0434	-11200	0.0430
Shell	2	3148	15876	0.1983	-360	-12215	0.0294	-11200	0.0321
Shell	3	3148	15876	0.1983	-366	-12215	0.0300	-11200	0.0327
Shell	4	3161	15876	0.1991	-433	-12215	0.0354	-11200	0.0386
Shell	5	3008	15876	0.1895	-730	-12215	0.0598	-11200	0.0652
Shell	6	3140	15876	0.1978	-900	-12215	0.0737	-11200	0.0803
Shell	7	3253	15876	0.2049	-1042	-12215	0.0853	-11200	0.0931
Shell	8	3269	15876	0.2059	-1063	-12215	0.0870	-11200	0.0949
Cone	9	3680	15876	0.2318	-1088	-10792	0.1008	-11200	0.0972
Cone	10	8437	15876	0.5314	-1106	-10792	0.1025	-11200	0.0987
Shell	11	6455	15876	0.4066	-966	-10340	0.0934	-11200	0.0862
Skirt	12	-148	-16086	0.0092	-706	-16086	0.0439	-16800	0.0420
Skirt	13	-70	-16086	0.0043	-833	-16086	0.0518	-16800	0.0496

Operating Pressurized Condition - Ocassional Loads - Seismic Case 8

First Period of Natural Vibration for Operating conditions: 0.2208 seconds/cycle

IBC 2003 Seismic Design Information

0.2 s Spectral Response Accel (S_S):	0.200		
1 s Spectral Response Accel. (S_1):	0.100	Response Modification Factor (R):	3.000
Seismic Use Group:	I	Site Class:	D
Total seismic shear force at the base (V):	2630 lb.		

IBC 2003 Seismic Analysis

Segment Type	Segment No.	Wi Weight (lb.)	Hi Mid-Elevation (in.)	Wi * Hi (Ft.-lb.)	Segment Seismic Force (lb.)	Shear @ Top (lb.)	Moment @ Bottom (Ft.-lb.)	Seismic Stress (PSI)
Head	1	116.52	563.0626	5467	12	0	4	0
Shell	2	929.77	523.5001	40561	92	12	351	14
Shell	3	117.86	483.5001	4749	11	105	434	18
Shell	4	969.06	442.0001	35694	81	116	1398	58
Attach	5t	7800.00	405.0000	263250	600			
Shell	5	340.48	392.0001	11122	25	796	3151	130
Shell	6	680.96	353.0001	20032	46	822	6810	281
Shell	7	550.01	306.0000	14025	32	867	9902	408
Shell	8	244.83	282.0001	5753	13	899	10355	427
Cone	9	0.01	279.0001	0	0	912	10355	324
Cone	10	1906.32	271.0000	43051	98	912	11637	70
Shell	11	16718.43	215.5000	300235	684	1010	22343	160
Head	12t	2598.66	168.0000	36381	83			
Skirt	12	2005.91	126.0000	21062	48	1777	34950	279
Skirt	13	2005.91	42.0000	7021	16	1825	47782	381
Total		**36984.72**		**808404**				

Stress Summary

Segment Type	Segment No.	Sm Attachments With Wind or Seismic (PSI)	Sp Internal Pressure Stress (PSI)	Sp External Pressure Stress (PSI)	Sw Weight Stress (PSI)	Maximum Tensile Stress (PSI)	Maximum Compressive Stress (PSI)
Head	1	0	4763	476	3	4760	-479
Shell	2	14	3163	316	16	3161	-347
Shell	3	18	3163	316	18	3163	-352
Shell	4	58	3163	316	33	3187	-406
Shell	5	130	3163	316	157	3135	-603
Shell	6	281	3163	316	168	3276	-765
Shell	7	408	3163	316	176	3395	-900
Shell	8	427	3163	316	177	3412	-920
Cone	9	324	3746	375	216	3854	-914
Cone	10	70	8548	855	100	8518	-1025
Shell	11	160	6431	639	93	6498	-891
Skirt	12	279	0	0	236	43	-515
Skirt	13	381	0	0	250	132	-631

Positive values represent tensile stress, and negative values represent compressive.
Stress ratios greater than 1.0 represent overstressed conditions.

Stress Comparisons

Segment Type	Segment No.	Maximum Tensile Stress (PSI)	Allowable Stress (PSI)	Maximum Tensile Stress Ratio	Maximum Compressive Stress (PSI)	Allowable Stress (PSI)	Maximum Compressive Stress Ratio	Critical Buckling Stress (PSI)	Critical Buckling Ratio
Head	1	4760	15876	0.2998	-479	-11098	0.0432	-11200	0.0428
Shell	2	3161	15876	0.1991	-347	-12215	0.0284	-11200	0.0310
Shell	3	3163	15876	0.1992	-352	-12215	0.0288	-11200	0.0314
Shell	4	3187	15876	0.2008	-406	-12215	0.0333	-11200	0.0363
Shell	5	3135	15876	0.1975	-603	-12215	0.0494	-11200	0.0539
Shell	6	3276	15876	0.2063	-765	-12215	0.0626	-11200	0.0683
Shell	7	3395	15876	0.2138	-900	-12215	0.0737	-11200	0.0804
Shell	8	3412	15876	0.2149	-920	-12215	0.0753	-11200	0.0822
Cone	9	3854	15876	0.2428	-914	-10792	0.0847	-11200	0.0816
Cone	10	8518	15876	0.5365	-1025	-10792	0.0950	-11200	0.0915
Shell	11	6498	15876	0.4093	-891	-10340	0.0862	-11200	0.0796
Skirt	12	43	10800	0.0040	-515	-16086	0.0320	-16800	0.0307
Skirt	13	132	10800	0.0122	-631	-16086	0.0392	-16800	0.0376

Operating Pressurized Condition - Ocassional Loads - Wind Case 5

IBC 2003 Wind Design Information

Basic Wind Speed (V):	90 MPH	Wind Exposure type:	C
Importance factor (I):	1	Force (shape) coefficient (C_f):	0.7
Gust response Factor (G_f):	0.89	Directionality Factor (K_d):	1.00
Total deflection of top of tower is :	0.0658 in.		
Total deflection dist. per 100 ft height is :	0.1393 in.		

First Period of Natural Vibration for Operating conditions: 0.2208 seconds/cycle

IBC 2003 Wind Analysis

Segment Type	Segment No.	Segment Height (in.)	Wind Load Diameter (in.)	Projection Area (Sq. Ft.)	(Kz) Exposure Factor	Wind Pressure (lb./ft.^{2})	Wind Force (lb.)	Shear @ Top (lb.)	Moment @ Bottom (Ft.-lb.)	Wind Stress (PSI)
Head	1	8.1250	52.0000	2.9340	1.08	14.0	41	0	14	1
Shell	2	71.0001	52.0000	25.6389	1.08	14.0	358	41	1314	54
Shell	3	8.9999	38.0000	2.3750	1.05	13.6	32	399	1625	67
Shell	4	74.0001	38.0000	19.5278	1.04	13.4	262	431	5091	210
Shell	5	25.9999	38.0000	6.8611	1.01	13.1	90	693	6690	276
Shell	6	52.0001	38.0000	13.7222	0.99	12.8	176	783	10462	431
Shell	7	42.0000	52.0000	15.1667	0.96	12.4	188	958	14145	583
Shell	8	5.9999	52.0000	2.1666	0.94	12.1	26	1146	14725	607
Cone	9	0.0001	52.0000	0.0000	0.93	12.0	0	1173	14725	461
Cone	10	16.0000	78.0000	8.6667	0.93	12.0	104	1173	16358	98
Shell	11	95.0000	78.0000	51.4583	0.92	11.9	612	1277	28888	206
Skirt	12	84.0000	78.0000	45.5000	0.85	11.0	500	1889	43856	350
Skirt	13	84.0000	78.0000	45.5000	0.85	11.0	500	2388	62322	498

Stress Summary

Segment Type	Segment No.	Sm Attachments With Wind or Seismic (PSI)	Sp Internal Pressure Stress (PSI)	Sp External Pressure Stress (PSI)	Sw Weight Stress (PSI)	Maximum Tensile Stress (PSI)	Maximum Compressive Stress (PSI)
Head	1	1	4763	476	5	4759	-482
Shell	2	54	3163	316	28	3189	-398
Shell	3	67	3163	316	31	3198	-414
Shell	4	210	3163	316	57	3315	-583
Shell	5	276	3163	316	276	3162	-868
Shell	6	431	3163	316	294	3300	-1041
Shell	7	583	3163	316	309	3437	-1208
Shell	8	607	3163	316	311	3459	-1234
Cone	9	461	3746	375	378	3828	-1213
Cone	10	98	8548	855	176	8471	-1129
Shell	11	206	6461	639	162	6504	-1008
Skirt	12	350	0	0	415	-64	-765
Skirt	13	498	0	0	438	59	-936

Positive values represent tensile stress, and negative values represent compressive.
Stress ratios greater than 1.0 represent overstressed conditions.

Stress Comparisons

Segment Type	Segment No.	Maximum Tensile Stress (PSI)	Allowable Stress (PSI)	Maximum Tensile Stress Ratio	Maximum Compressive Stress (PSI)	Allowable Stress (PSI)	Maximum Compressive Stress Ratio	Critical Buckling Stress (PSI)	Critical Buckling Ratio
Head	1	4759	15876	0.2997	-482	-11098	0.0434	-11200	0.0430
Shell	2	3189	15876	0.2008	-398	-12215	0.0326	-11200	0.0356
Shell	3	3198	15876	0.2015	-414	-12215	0.0339	-11200	0.0370
Shell	4	3315	15876	0.2088	-583	-12215	0.0478	-11200	0.0521
Shell	5	3162	15876	0.1992	-868	-12215	0.0710	-11200	0.0775
Shell	6	3300	15876	0.2078	-1041	-12215	0.0853	-11200	0.0930
Shell	7	3437	15876	0.2165	-1208	-12215	0.0989	-11200	0.1079
Shell	8	3459	15876	0.2178	-1234	-12215	0.1010	-11200	0.1102
Cone	9	3828	15876	0.2411	-1213	-10792	0.1124	-11200	0.1083
Cone	10	8471	15876	0.5336	-1129	-10792	0.1046	-11200	0.1008
Shell	11	6504	15876	0.4097	-1008	-10340	0.0975	-11200	0.0900
Skirt	12	-64	-16086	0.0040	-765	-16086	0.0475	-16800	0.0455
Skirt	13	59	10800	0.0055	-936	-16086	0.0582	-16800	0.0557

Operating Pressurized Condition - Sustained Loads

First Period of Natural Vibration for Operating conditions: 0.2208 seconds/cycle

Moment Analysis							
Segment Type	**Segment No.**	**Weight (lb.)**	**Elevation (in.)**	**Segment Force (lb.)**	**Shear @ Top (lb.)**	**Moment @ Bottom (Ft.-lb.)**	**Stress (PSI)**
Head	1	116.52	563.0626	0	0	0	0
Shell	2	929.77	523.5001	0	0	0	0
Shell	3	117.86	483.5001	0	0	0	0
Shell	4	969.06	442.0001	0	0	0	0
Attach	5t	7800.00	405.0000	0			
Shell	5	340.48	392.0001	0	0	0	0
Shell	6	680.96	353.0001	0	0	0	0
Shell	7	550.01	306.0000	0	0	0	0
Shell	8	244.83	282.0001	0	0	0	0
Cone	9	0.01	279.0001	0	0	0	0
Cone	10	1906.32	271.0000	0	0	0	0
Shell	11	16718.43	215.5000	0	0	0	0
Head	12t	2598.66	168.0000	0			
Skirt	12	2005.91	126.0000	0	0	0	0
Skirt	13	2005.91	42.0000	0	0	0	0
Total		**36984.72**					

Stress Summary							
Segment Type	**Segment No.**	**Sm Attachments With Wind or Seismic (PSI)**	**Sp Internal Pressure Stress (PSI)**	**Sp External Pressure Stress (PSI)**	**Sw Weight Stress (PSI)**	**Maximum Tensile Stress (PSI)**	**Maximum Compressive Stress (PSI)**
Head	1	0	4763	476	5	4758	-481
Shell	2	0	3163	316	28	3134	-344
Shell	3	0	3163	316	31	3131	-347
Shell	4	0	3163	316	57	3105	-374
Shell	5	0	3163	316	276	2887	-592
Shell	6	0	3163	316	294	2868	-610
Shell	7	0	3163	316	309	2854	-625
Shell	8	0	3163	316	311	2852	-627
Cone	9	0	3746	375	378	3367	-753
Cone	10	0	8548	855	176	8372	-1031
Shell	11	0	6461	639	162	6298	-802
Skirt	12	0	0	0	415	-415	-415
Skirt	13	0	0	0	438	-438	-438

Positive values represent tensile stress, and negative values represent compressive.
Stress ratios greater than 1.0 represent overstressed conditions.

Stress Comparisons

Segment Type	Segment No.	Maximum Tensile Stress (PSI)	Allowable Stress (PSI)	Maximum Tensile Stress Ratio	Maximum Compressive Stress (PSI)	Allowable Stress (PSI)	Maximum Compressive Stress Ratio	Critical Buckling Stress (PSI)	Critical Buckling Ratio
Head	1	4758	13230	0.3596	-481	-9248	0.0520	-11200	0.0429
Shell	2	3134	13230	0.2369	-344	-10179	0.0338	-11200	0.0307
Shell	3	3131	13230	0.2367	-347	-10179	0.0341	-11200	0.0310
Shell	4	3105	13230	0.2347	-374	-10179	0.0367	-11200	0.0333
Shell	5	2887	13230	0.2182	-592	-10179	0.0582	-11200	0.0529
Shell	6	2868	13230	0.2168	-610	-10179	0.0600	-11200	0.0545
Shell	7	2854	13230	0.2157	-625	-10179	0.0614	-11200	0.0558
Shell	8	2852	13230	0.2155	-627	-10179	0.0616	-11200	0.0560
Cone	9	3367	13230	0.2545	-753	-8993	0.0837	-11200	0.0672
Cone	10	8372	13230	0.6328	-1031	-8993	0.1146	-11200	0.0920
Shell	11	6298	13230	0.4760	-802	-8617	0.0930	-11200	0.0716
Skirt	12	-415	-13405	0.0309	-415	-13405	0.0309	-16800	0.0247
Skirt	13	-438	-13405	0.0327	-438	-13405	0.0327	-16800	0.0261

Empty Pressurized Condition - Ocassional Loads - Seismic Case 8

First Period of Natural Vibration for Empty Pressurized conditions: 0.1913 seconds/cycle

IBC 2003 Seismic Design Information

0.2 s Spectral Response Accel (S_S):	0.200		
1 s Spectral Response Accel. (S_1):	0.100	Response Modification Factor (R):	3.000
Seismic Use Group:	I	Site Class:	D
Total seismic shear force at the base (V):	1424 lb.		

IBC 2003 Seismic Analysis

Segment Type	Segment No.	Wi Weight (lb.)	Hi Mid-Elevation (in.)	Wi * Hi (Ft.-lb.)	Segment Seismic Force (lb.)	Shear @ Top (lb.)	Moment @ Bottom (Ft.-lb.)	Seismic Stress (PSI)
Head	1	116.52	563.0626	5467	11	0	4	0
Shell	2	929.77	523.5001	40561	80	11	304	13
Shell	3	117.86	483.5001	4749	9	91	376	15
Shell	4	969.06	442.0001	35694	70	100	1211	50
Attach	5t	7800.00	405.0000	263250	520			
Shell	5	340.48	392.0001	11122	22	690	2731	113
Shell	6	680.96	353.0001	20032	40	712	5903	243
Shell	7	550.01	306.0000	14025	28	752	8582	354
Shell	8	78.57	282.0001	1846	4	779	8973	370
Cone	9	0.00	279.0001	0	0	783	8973	281
Cone	10	692.58	271.0000	15641	31	783	10038	60
Shell	11	3068.36	215.5000	55103	109	814	16912	121
Head	12t	662.00	168.0000	9268	18			
Skirt	12	2005.91	126.0000	21062	42	941	23645	189
Skirt	13	2005.91	42.0000	7021	14	983	30571	244
Total		**20017.98**		**504841**				

Stress Summary

Segment Type	Segment No.	Sm Attachments With Wind or Seismic (PSI)	Sp Internal Pressure Stress (PSI)	Sp External Pressure Stress (PSI)	Sw Weight Stress (PSI)	Maximum Tensile Stress (PSI)	Maximum Compressive Stress (PSI)
Head	1	0	4763	476	3	4760	-479
Shell	2	13	3163	316	16	3159	-345
Shell	3	15	3163	316	18	3160	-350
Shell	4	50	3163	316	33	3180	-399
Shell	5	113	3163	316	157	3118	-586
Shell	6	243	3163	316	168	3238	-727
Shell	7	354	3163	316	176	3340	-846
Shell	8	370	3163	316	177	3355	-863
Cone	9	281	3746	375	216	3811	-871
Cone	10	60	8548	855	100	8508	-1015
Shell	11	121	6391	639	93	6419	-853
Skirt	12	189	0	0	122	67	-310
Skirt	13	244	0	0	135	109	-379

Positive values represent tensile stress, and negative values represent compressive.
Stress ratios greater than 1.0 represent overstressed conditions.

Stress Comparisons

Segment Type	Segment No.	Maximum Tensile Stress (PSI)	Allowable Stress (PSI)	Maximum Tensile Stress Ratio	Maximum Compressive Stress (PSI)	Allowable Stress (PSI)	Maximum Compressive Stress Ratio	Critical Buckling Stress (PSI)	Critical Buckling Ratio
Head	1	4760	15876	0.2998	-479	-11098	0.0432	-11200	0.0428
Shell	2	3159	15876	0.1990	-345	-12215	0.0282	-11200	0.0308
Shell	3	3160	15876	0.1991	-350	-12215	0.0286	-11200	0.0312
Shell	4	3180	15876	0.2003	-399	-12215	0.0327	-11200	0.0356
Shell	5	3118	15876	0.1964	-586	-12215	0.0480	-11200	0.0523
Shell	6	3238	15876	0.2040	-727	-12215	0.0595	-11200	0.0649
Shell	7	3340	15876	0.2104	-846	-12215	0.0693	-11200	0.0755
Shell	8	3355	15876	0.2113	-863	-12215	0.0707	-11200	0.0771
Cone	9	3811	15876	0.2400	-871	-10792	0.0807	-11200	0.0778
Cone	10	8508	15876	0.5359	-1015	-10792	0.0941	-11200	0.0907
Shell	11	6419	15876	0.4043	-853	-10340	0.0824	-11200	0.0761
Skirt	12	67	10800	0.0062	-310	-16086	0.0193	-16800	0.0185
Skirt	13	109	10800	0.0101	-379	-16086	0.0236	-16800	0.0226

Empty Pressurized Condition - Ocassional Loads - Wind Case 7

IBC 2003 Wind Design Information

Basic Wind Speed (V):	90 MPH		Wind Exposure type:	C
Importance factor (I):	1		Force (shape) coefficient (C_f):	0.7
Gust response Factor (G_f):	0.89		Directionality Factor (K_d):	1.00
Total deflection of top of tower is :	0.0658 in.			
Total deflection dist. per 100 ft height is :	0.1393 in.			

First Period of Natural Vibration for Empty Pressurized conditions: 0.1913 seconds/cycle

IBC 2003 Wind Analysis

Segment Type	Segment No.	Segment Height (in.)	Wind Load Diameter (in.)	Projection Area (Sq. Ft.)	(Kz) Exposure Factor	Wind Pressure (lb./ft.^{2})	Wind Force (lb.)	Shear @ Top (lb.)	Moment @ Bottom (Ft.-lb.)	Wind Stress (PSI)
Head	1	8.1250	52.0000	2.9340	1.08	14.0	41	0	14	1
Shell	2	71.0001	52.0000	25.6389	1.08	14.0	358	41	1314	54
Shell	3	8.9999	38.0000	2.3750	1.05	13.6	32	399	1625	67
Shell	4	74.0001	38.0000	19.5278	1.04	13.4	262	431	5091	210
Shell	5	25.9999	38.0000	6.8611	1.01	13.1	90	693	6690	276
Shell	6	52.0001	38.0000	13.7222	0.99	12.8	176	783	10462	431
Shell	7	42.0000	52.0000	15.1667	0.96	12.4	188	958	14145	583
Shell	8	5.9999	52.0000	2.1666	0.94	12.1	26	1146	14725	607
Cone	9	0.0001	52.0000	0.0000	0.93	12.0	0	1173	14725	461
Cone	10	16.0000	78.0000	8.6667	0.93	12.0	104	1173	16358	98
Shell	11	95.0000	78.0000	51.4583	0.92	11.9	612	1277	28888	206
Skirt	12	84.0000	78.0000	45.5000	0.85	11.0	500	1889	43856	350
Skirt	13	84.0000	78.0000	45.5000	0.85	11.0	500	2388	62322	498

Stress Summary

Segment Type	Segment No.	Sm Attachments With Wind or Seismic (PSI)	Sp Internal Pressure Stress (PSI)	Sp External Pressure Stress (PSI)	Sw Weight Stress (PSI)	Maximum Tensile Stress (PSI)	Maximum Compressive Stress (PSI)
Head	1	1	4763	476	3	4761	-480
Shell	2	54	3163	316	17	3200	-387
Shell	3	67	3163	316	19	3211	-402
Shell	4	210	3163	316	34	3338	-560
Shell	5	276	3163	316	165	3273	-757
Shell	6	431	3163	316	176	3417	-924
Shell	7	583	3163	316	185	3560	-1085
Shell	8	607	3163	316	187	3583	-1110
Cone	9	461	3746	375	227	3979	-1062
Cone	10	98	8548	855	105	8541	-1059
Shell	11	206	6391	639	97	6500	-943
Skirt	12	350	0	0	128	222	-478
Skirt	13	498	0	0	142	355	-640

Positive values represent tensile stress, and negative values represent compressive.
Stress ratios greater than 1.0 represent overstressed conditions.

Stress Comparisons									
Segment Type	**Segment No.**	**Maximum Tensile Stress (PSI)**	**Allowable Stress (PSI)**	**Maximum Tensile Stress Ratio**	**Maximum Compressive Stress (PSI)**	**Allowable Stress (PSI)**	**Maximum Compressive Stress Ratio**	**Critical Buckling Stress (PSI)**	**Critical Buckling Ratio**
Head	1	4761	15876	0.2999	-480	-11098	0.0432	-11200	0.0428
Shell	2	3200	15876	0.2016	-387	-12215	0.0317	-11200	0.0346
Shell	3	3211	15876	0.2022	-402	-12215	0.0329	-11200	0.0359
Shell	4	3338	15876	0.2103	-560	-12215	0.0459	-11200	0.0500
Shell	5	3273	15876	0.2061	-757	-12215	0.0620	-11200	0.0676
Shell	6	3417	15876	0.2152	-924	-12215	0.0756	-11200	0.0825
Shell	7	3560	15876	0.2243	-1085	-12215	0.0888	-11200	0.0968
Shell	8	3583	15876	0.2257	-1110	-12215	0.0908	-11200	0.0991
Cone	9	3979	15876	0.2507	-1062	-10792	0.0984	-11200	0.0948
Cone	10	8541	15876	0.5380	-1059	-10792	0.0981	-11200	0.0945
Shell	11	6500	15876	0.4094	-943	-10340	0.0912	-11200	0.0842
Skirt	12	222	10800	0.0206	-478	-16086	0.0297	-16800	0.0285
Skirt	13	355	10800	0.0329	-640	-16086	0.0398	-16800	0.0381

Empty Pressurized Condition - Sustained Loads

First Period of Natural Vibration for Empty Pressurized conditions: 0.1913 seconds/cycle

Moment Analysis							
Segment Type	Segment No.	Weight (lb.)	Elevation (in.)	Segment Force (lb.)	Shear @ Top (lb.)	Moment @ Bottom (Ft.-lb.)	Stress (PSI)
Head	1	116.52	563.0626	0	0	0	0
Shell	2	929.77	523.5001	0	0	0	0
Shell	3	117.86	483.5001	0	0	0	0
Shell	4	969.06	442.0001	0	0	0	0
Attach	5t	7800.00	405.0000	0			
Shell	5	340.48	392.0001	0	0	0	0
Shell	6	680.96	353.0001	0	0	0	0
Shell	7	550.01	306.0000	0	0	0	0
Shell	8	78.57	282.0001	0	0	0	0
Cone	9	0.00	279.0001	0	0	0	0
Cone	10	692.58	271.0000	0	0	0	0
Shell	11	3068.36	215.5000	0	0	0	0
Head	12t	662.00	168.0000	0			
Skirt	12	2005.91	126.0000	0	0	0	0
Skirt	13	2005.91	42.0000	0	0	0	0
Total		**20017.98**					

Stress Summary							
Segment Type	Segment No.	Sm Attachments With Wind or Seismic (PSI)	Sp Internal Pressure Stress (PSI)	Sp External Pressure Stress (PSI)	Sw Weight Stress (PSI)	Maximum Tensile Stress (PSI)	Maximum Compressive Stress (PSI)
Head	1	0	4763	476	3	4760	-479
Shell	2	0	3163	316	17	3146	-333
Shell	3	0	3163	316	19	3144	-335
Shell	4	0	3163	316	34	3128	-351
Shell	5	0	3163	316	165	2997	-482
Shell	6	0	3163	316	176	2986	-493
Shell	7	0	3163	316	185	2977	-502
Shell	8	0	3163	316	187	2976	-503
Cone	9	0	3746	375	227	3519	-602
Cone	10	0	8548	855	105	8443	-960
Shell	11	0	6391	639	97	6294	-737
Skirt	12	0	0	0	128	-128	-128
Skirt	13	0	0	0	142	-142	-142

Positive values represent tensile stress, and negative values represent compressive.
Stress ratios greater than 1.0 represent overstressed conditions.

Stress Comparisons

Segment Type	Segment No.	Maximum Tensile Stress (PSI)	Allowable Stress (PSI)	Maximum Tensile Stress Ratio	Maximum Compressive Stress (PSI)	Allowable Stress (PSI)	Maximum Compressive Stress Ratio	Critical Buckling Stress (PSI)	Critical Buckling Ratio
Head	1	4760	13230	0.3598	-479	-9248	0.0518	-11200	0.0428
Shell	2	3146	13230	0.2378	-333	-10179	0.0327	-11200	0.0297
Shell	3	3144	13230	0.2376	-335	-10179	0.0329	-11200	0.0299
Shell	4	3128	13230	0.2364	-351	-10179	0.0344	-11200	0.0313
Shell	5	2997	13230	0.2265	-482	-10179	0.0473	-11200	0.0430
Shell	6	2986	13230	0.2257	-493	-10179	0.0484	-11200	0.0440
Shell	7	2977	13230	0.2250	-502	-10179	0.0493	-11200	0.0448
Shell	8	2976	13230	0.2249	-503	-10179	0.0494	-11200	0.0449
Cone	9	3519	13230	0.2660	-602	-8993	0.0669	-11200	0.0537
Cone	10	8443	13230	0.6381	-960	-8993	0.1068	-11200	0.0857
Shell	11	6294	13230	0.4757	-737	-8617	0.0855	-11200	0.0658
Skirt	12	-128	-13405	0.0096	-128	-13405	0.0096	-16800	0.0076
Skirt	13	-142	-13405	0.0106	-142	-13405	0.0106	-16800	0.0085

HT/DcR Engineering, Inc.

Customer: **DELTA-T CORPORATION**
Job No: 1494F

Vessel Number: 7793-E4201 SKIRT

Date Printed: 9/6/2007

Summary Information

	Dry Weight	Flooded Weight
Shell	5627.33 lb.	27060.21 lb.
Head	628.77 lb.	2754.05 lb.
Conical Reducer	597.36 lb.	1810.42 lb.
Skirt	4011.82 lb.	4011.82 lb.
Totals	10865.28 lb.	35636.50 lb.

	Volume
Shell	2565.57 Gal.
Head	254.83 Gal.
Conical Reducer	145.45 Gal.
Totals	2965.85 Gal.

	Area
Shell	344.70 Sq. Ft.
Head	49.92 Sq. Ft.
Conical Reducer	29.06 Sq. Ft.
Skirt	263.89 Sq. Ft.
Totals	687.57 Sq. Ft.

Hydrostatic Test Information (UG-99)

Gauge at Top

Component with controlling ratio is : VAPOR BODY SHELL
Component with controlling pressure is : VAPOR BODY SHELL

$$\text{Calculated Test Pressure} = P * 1.3 * \frac{\text{Cold Stress}}{\text{Hot Stress}} = 150.00 * 1.3 * \frac{20000}{18900} =$$ **206.35 PSI**

Table of Contents

HT/DcR Engineering, Inc.

Calculation Number:
1494F-7793-E4201-01

Client:	Project:	Discipline:
DcR Construction	1494F - 7793 - E4201	Structural
Subject/Title: E-4201 TOP HEAD LIFTING LUGS QUALIFICATION		**Job Number:** 1494F
Objective: QUALIFY LIFTING LUGS AT TOP HEAD		
System or Equipment ID: 7793-E4201		

Contents

Version Record

Version No.	Description	Originator/Date Signature	Reviewer/Date Signature	Approver/Date Signature
A	LUG QUALIFICATION	[signature] 9/4/07		

HT/DcR Engineering, Inc.

Client: DcR Construction	Project: 1494F	Calculation Number: 1494F-7793-E4201-01

Title: TOP HEAD LIFTING LUGS QUALIFICATIONS	Sheet: 2

Purpose:

QUALIFY LUGS @ TOP HEAD

Summary of Conclusions:

LUGS are compared to Pressure Vessel Handbook by Eugene F. Megyesy

Methodology:

As given per "Pressure Vessel Handbook"

Assumptions

Top head lugs only used for lifting front head assembly, NOT entire vessel.

Criteria

Per reference

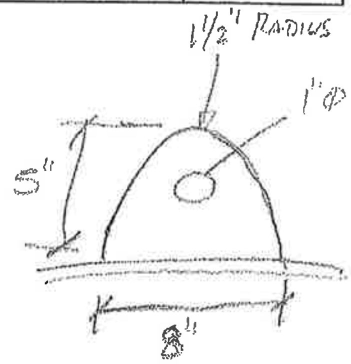
Design Input/References:

BJAC Weights

HT/DcR Engineering, Inc.

Client:	Project:	Calculation Number:
DcR Construction	1494F	1494F-7793-E4201-01

Title:	Sheet:
TOP HEAD LIFTING LUGS QUALIFICATIONS	3



TOP HEAD LIFTING LUGS

ACTUAL WT FROM BJAC OUTPUT (ATTACHMENT "A")

Fr. Hd. Cylinder = 196#

Fr. Hd Cover = 125#

Fr. Hd Flng. Tub Sh = 66#

Nozzle C w/Flng = 36# + 104 = 140#

ACTUAL TOTAL WT = 527#

Pressure Vessel Handbook, PG 118 (SEE ATTACHMENT "B")

D = 1", T = 1/2" R = 1 1/2" H = 5", L = 10" — Reduce to 8"

$$\frac{8^2}{10^2}(12{,}000\#) = 7700\# \gg 527\#$$

Lug OK Compared to Pressure Vessel Handbook

ATTACHMENT "A"

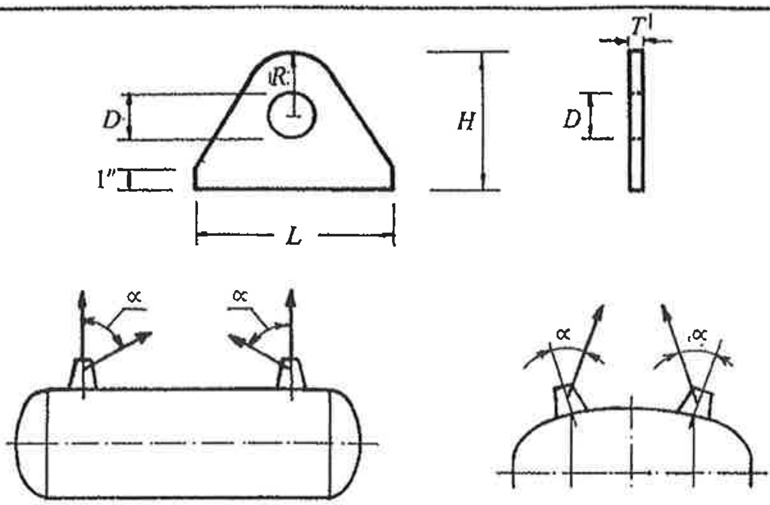
File: E-4201 FINAL small flange.BJT Date: 9/5/2007 Time: 5:24:38 PM

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-516 K02700 Grd Plate	1	32	od	236.625	lg	0.375	2526	869	1992
2	Fr Hd Cylinder	SA-240 S30400 Grd Plate	1	32	od	27.25	lg	0.25	196	107	611
3	Re Hd Cylinder	SA-240 S30400 Grd Plate	1	32	od	350	lg	0.3125	3149	999	9016
5	Fr Hd Cover Ellip.	SA-240 S30400 Grd Plate	1	32	od	2	sf	0.25	125	0	936
6	Re Hd Cover Ellip.	SA-240 S30400 Grd Plate	1	32	od	2	sf	0.3125	150	0	1052
9	Shell Lift Lugs	SA-285 K02801 Grd C Plate	3	6.375	od	0		0.75	9	0	4
11	Front TubSh	SA-240 S30400 Grd Plate	1	35.25	od	0		1.75	306	2293	3785
12	Rear TubSh	SA-240 S30400 Grd Plate	1	35.5	od	0		1.75	313	2298	3811
17	Fr Hd Flng TubSh	SA-240 S30400 Grd Plate	1	35.25	od	32.125	id	1.4375	66	172	1478
18	Re Hd Flng TubSh	SA-240 S30400 Grd Plate	1	35.5	od	32.125	id	1.1875	59	164	1299
31	Fr Hd Gskt TubSh	Solid Teflon 1/8in Thickness	1	33	od	32	id	0.125	0	60	320
32	Re Hd Gskt TubSh	Solid Teflon 1/8in Thickness	1	33.25	od	32.25	id	0.125	0	60	324
38	Tubes (avg wall)	SA-249 S30400 Grd Wld. t	821	0.75	od	240	lg	0.049	6105	1100	14503
39	Baffles	SA-36 K02600 Plate	15	31.0625	od	0		0.3125	309	6829	7324
40	Tie Rods	SA-36 Bar	22	0.5	od	209.5	lg	0	256	192	287
41	Spacers	SA-214 K01807 Wld. tube	294	0.75	od	25.25	lg	0.109	568	181	560
41	Spacers	SA-214 K01807 Wld. tube	30	0.75	od	12.625	lg	0.109	0	0	0
61	Nozzle A	SA-53 K03005 Grd Wld. pipe	1	24	od	6	lg	0.6875	86	115	175
62	Nozzle B	SA-53 K03005 Grd Wld. pipe	1	20	od	6	lg	0.375	39	85	113
63	Nozzle C	SA-312 S30400 Grd Wld. p	1	18	od	6	lg	0.375	36	77	396
81	Nozzle Flng A Slip On	SA-105 K03504 Forgings	1	150	AN	24	di	0	182	0	287
82	Nozzle Flng B Slip On	SA-105 K03504 Forgings	1	150	AN	20	di	0	131	0	206
83	Nozzle Flng C Slip On	SA-182 S30400 Grd Forging	1	150	AN	18	di	0	104	0	953
101	Fr Hd Blts TubSh	SA-193 G41400 Grd Bolt(<= 2	24	0.5	od	5.5	lg	0	7	0	18
102	Re Hd Blts TubSh	SA-193 G41400 Grd Bolt(<= 2	24	0.5	od	5	lg	0	7	0	17
115	Distrib. Belt A	SA-516 K02700 Grd Plate	1	44	od	29	sf	0.5	920	1411	2007
116	Distrib. Belt B	SA-516 K02700 Grd Plate	1	44	od	34.5	sf	0.5	1053	1411	2067
122	Dist.Belt An.Rng	SA-516 K02700 Grd Plate	4	44		0		0.625	0	0	0

ATTACHMENT "B"

LIFTING LUG



VESSEL WEIGHT (LBS)	D (IN)	T (IN)	R (IN)	H (IN)	L (IN)	WELD (Min)
12,000	1	½	1½	5	10	Full Penetration with ½ Fillet
20,000	1⅛	¾	2	6	10	Full Penetration with ½ Fillet
30,000	1⅜	1	2⅛	6	10	Full Penetration with ½ Fillet
50,000	1⅝	1¼	2½	7	12	Full Penetration with ½ Fillet
70,000	2⅛	1¼	3½	8	12	Full Penetration with ¾ Fillet
100,000	2½	1½	4½	9	16	Full Penetration with ¾ Fillet
150,000	3	1¾	5	10	16	Full Penetration with ¾ Fillet
200,000	4	2	6	12	18	Full Penetration with ¾ Fillet
250,000	4¼	2	6½	13	18	Full Penetration with ¾ Fillet
300,000	4½	2½	7	14	20	Full Penetration with ¾ Fillet

Notes:

1. All dimensions are in inches
2. The design is based on conditions:
   a. $\propto = 45°$ minimum
   b. Minimum tensile strength of lug material 70,000 psi.
   c. Direction of force is in the plane of lugs.
3. Use wear plate if necessary to eliminate buckling due to normal or sudden loading.