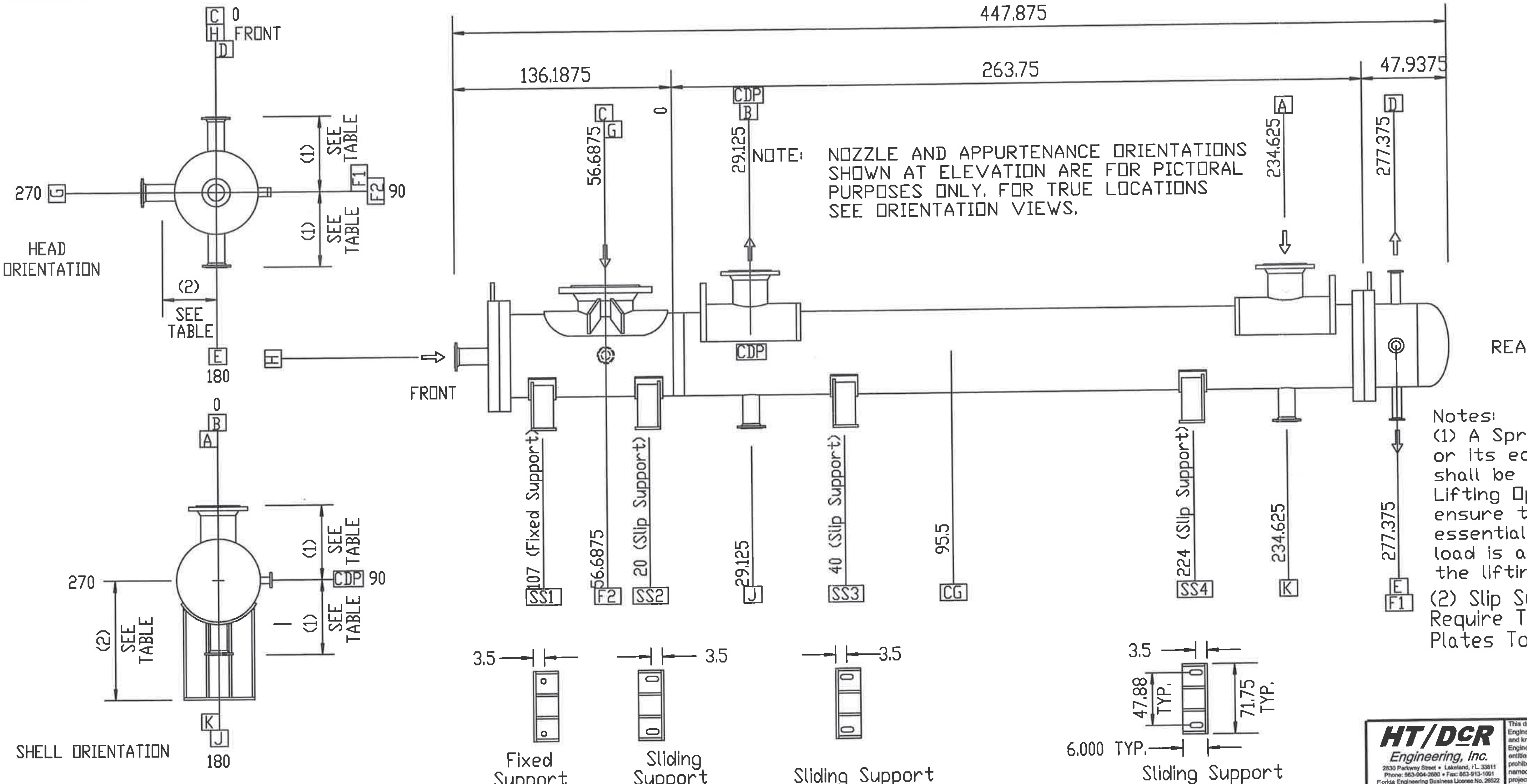
Dimensions: in



Notes:
(1) A Spreader Bar or its equivalent shall be used during Lifting Operations to ensure that essentially a vertical load is applied to the lifting lugs.
(2) Slip Supports Require Teflon Sliding Plates To Be Installed

HT/DCR Engineering, Inc.

Nozzles			(1)
Label	Size:	Description	Project.
A	30"	150 # ANSI S.O.RF	53.00
B	30"	150 # ANSI S.O.RF	53.00
C	54"	150 # ANSI S.O.RF	54.75
D	6"	150 # ANSI S.O.RF	42
E	6"	150 # ANSI S.O.RF	42
G	4"	150 # ANSI S.O.RF	42
H	3"	150 # ANSI S.O.RF	6
J	2"	150 # ANSI S.O.RF	42
K	2"	150 # ANSI S.O.RF	42

Couplings / Supports(2)		
Label	Size: Description	Project.
F1	0.5 3000 # Half Length	36.9375
F2	0.5 3000 # Half Length	36.9375
SS1	SADDLE1 W/2 1.25 HOLES	60
SS2	SADDLE2 W/2 1.25X2.5 SLOTS	60
SS3	SADDLE3 W/2 1.25X2.5 SLOTS	60
SS4	SADDLE4 W/2 1.25X2.5 SLOTS	60
CDP	CODE DATA PLATE	

Design Specifications		Shell	Tube
Design Pressure	psig	150/15	50/15
Test Pressure	psig	195	65
Min. Design Temperature	F	200	300
Max. Design Temperature	F	200	300
Number of Passes		1	1
Corrosion Allowance	in	0.0625	0.0
Radiographing		None	None
Post-Weld Heat Treatment		None	None

Wt Empty: 63056 Full: 121779 Bundle: 30902 lb

Rev:	Date:	Description	Dwg	Ckd	Appd
4	1-09-08	CERTIFIED AS-BUILT	AGB	DGB	PW

Company: DCR Construction, Inc.
Location: Bunge-Ergon
Evaporator Condenser
Item No: E-4504
Date: May 5, 2007 Job No: 7793

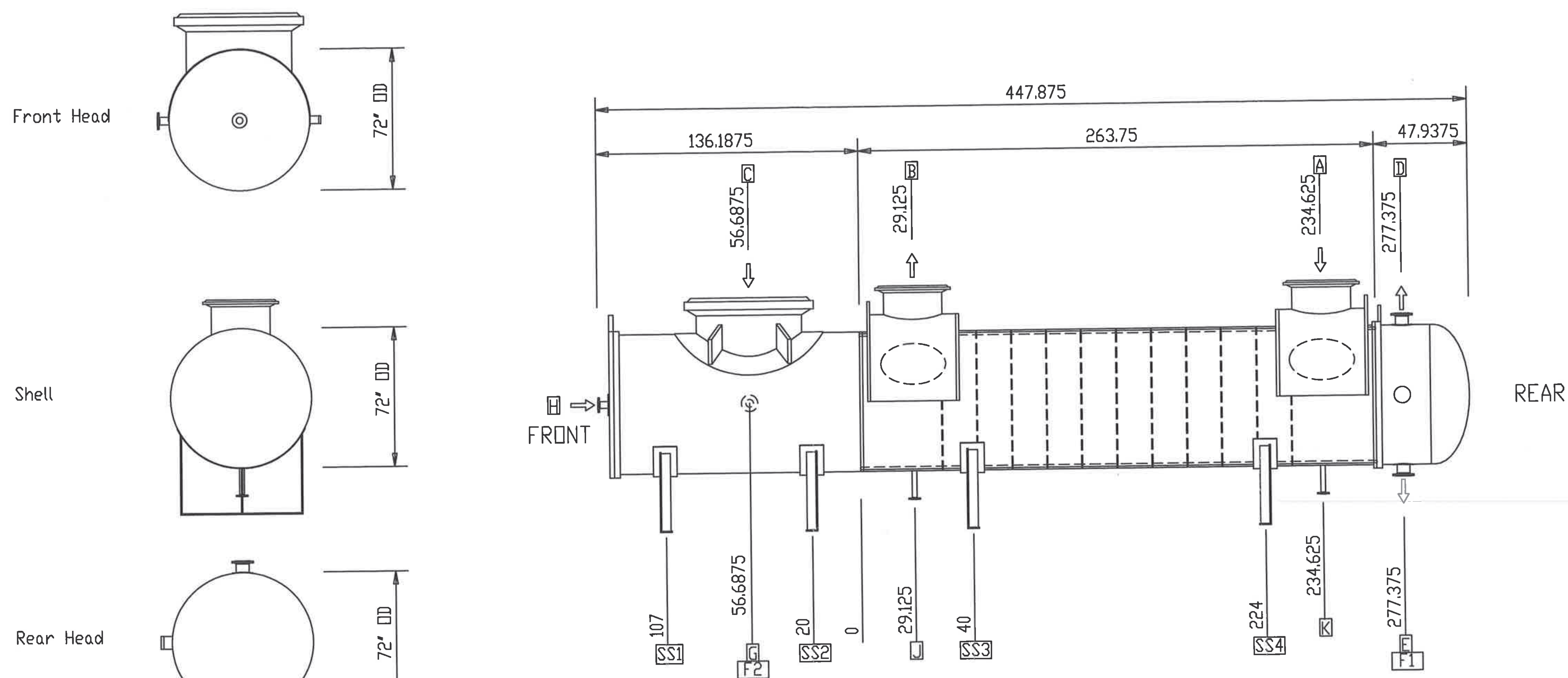
DCR Construction, Inc.
Lakeland, Florida

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

Setting Plan

Dwg No.: E-4504 01A
Rev: 4

Dimensions: in



NOTE: NOZZLE AND APPURTENANCE ORIENTATIONS SHOWN IN ABOVE VIEW ARE FOR PICTORAL PURPOSES ONLY. FOR TRUE LOCATIONS SEE ORIENTATIONS ON DRG E-4504-01A

HT/DCR Engineering, Inc.

Nozzles		(1)
Label	Size: Description	Project.
A	30" 150 # ANSI S.O.RF	53.00
B	30" 150 # ANSI S.O.RF	53.00
C	54" 150 # ANSI S.O.RF	54.75
D	6" 150 # ANSI S.O.RF	42
E	6" 150 # ANSI S.O.RF	42
G	4" 150 # ANSI S.O.RF	42
H	3" 150 # ANSI S.O.RF	6
J	2" 150 # ANSI S.O.RF	42
K	2" 150 # ANSI S.O.RF	42

Couplings / Supports(2)		
Label	Size: Description	Project.
F1	0.5 3000 # Half Length	36.9375
F2	0.5 3000 # Half Length	36.9375
SS1	SADDLE1 W/2 HOLES	60
SS2	SADDLE2 W/2 1.25X2.5 SLOTS	60
SS3	SADDLE3 W/2 1.25X2.5 SLOTS	60
SS4	SADDLE4 W/2 1.25X2.5 SLOTS	60
CDP	CODE DATA PLATE	

Design Specifications		Shell	Tube
Design Pressure	psig	150/15	50/15
Test Pressure	psig	195	65
Design Temperature	F	200	300
Number of Passes		1	1
Corrosion Allowance	in	0.0625	0.0
Radiographing		None	None

Wt Empty: 63056 Full: 121779 Bundle: 30902 lb

Rev:	Date:	Description	Dwg	Ckd	Appd
4	01-09-08	CERTIFIED AS-BUILT	AGB	DGB	PW
2	08-30-07	REVISED PER CLIENT	KFF	DGB	PW
3	09-18-07	REVISED AS NOTED	KFF	DGB	PW

Company: DCR Construction, Inc.
Location: Bunge-Ergon
Evaporator Condenser
Item No: E-4504
Date: May 5, 2007 Job No: 7793

DCR Construction, Inc.
Lakeland, Florida

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

Setting Plan

Dwg No.: E-4504 01B

Rev: 4

Component	O.D.	Thk.	Materials of Construction
Nozzle A Cooling Wtr.Inlet	30.0	0.500	150# Series B 30" SORF B16.47 SA-105 Forged Flange
Nozzle B Cooling Wtr.Outlet	30.0	0.500	150# Series B 30" SORF B16.47 Forged Flange SA-105
Nozzle C Vapor Inlet	54.0	0.625	150# Series B 54" FFWN B16.47 Forged Flange on SA-240 S30400 Grd 304 Plate
Nozzle D Vapor Outlet	6.625	0.28	150 # ANSI S.O.RF Flg SA-182 on SA-312 S30400 Grd TP304 Wld. pipe
Nozzle E Non. Cond Outlet	6.625	0.28	150 # ANSI S.O.RF Flg SA-182 on SA-312 S30400 Grd TP304 Wld. pipe
Nozzle G Tube Side Inlet	4.5	0.337	150 # ANSI S.O.RF Flg SA-182 on SA-312 S30400 Grd TP304 Wld. pipe
Nozzle H Tube Side Inlet	3.5	0.300	150 # ANSI S.O.RF Flg SA-182 on SA-312 S30400 Grd TP304 Wld. pipe
Nozzle J Spare Port	2.375	0.344	150 # ANSI S.O.RF Flg SA-105 on SA-53 K03005 Grd. E/B Wld. Pipe
Nozzle K Spare Port	2.375	0.344	150 # ANSI S.O.RF Flg SA-105 on SA-53 K03005 Grd. E/B Wld. Pipe
Coupling F1	0.5		3000 # Half Length SA-182 S30400 Grd F304 Forgings
Coupling F2	0.5		3000 # Half Length SA-182 S30400 Grd F304 Forgings
Shell Cylinder	72	0.5	SA-516 K02700 Grd 70 Plate
Front Head Cylinder	72	0.375	SA-240 S30400 Grd 304 Plate
Rear Head Cylinder	72	0.3125	SA-240 S30400 Grd 304 Plate
Fr Hd Cover	75.625	2.8125	SA-516 K02700 Grd 70 Plate (Flat Cover) (Alloy Overlayed)
Re Hd Cover	72	0.3125	SA-240 S30400 Grd 304 Plate (Ellipsoidal Cover)
Front TubSh	72	1.5	SA-240 S30400 Grd 304 Plate
Rear TubSh	75.5	1.5	SA-240 S30400 Grd 304 Plate
Re Hd Flng	75.5	2.9375	SA-516 K02700 Grd 70 Plate (Ring Flange) (Alloy Overlayed)
Fr Hd Flng	75.625	2.125	SA-240 S30400 Grd 304 Plate
Re Hd Gskt TubSh	73.25	0.125	Solid Teflon 1/8in Thickness (Periph. Width 0.5 in)
Fr Hd Gskt Cover	73.375	0.125	Solid Teflon 1/8in Thickness (Periph. Width 0.5 in)
Re Hd Blts TubSh	0.5		SA-193 G41400 Grd B7 Bolt (72 Bolts on 74.25 in B.C.)
Fr Hd Blts Cover	0.5		SA-193 G41400 Grd B7 Bolt (72 Bolts on 74.375 in B.C.)
Tubes	1.25	0.049	SA-249 S30400 Grd TP304 Wld. tube (Plain Tubes)
Baffles	70.625	0.5	A-36 K02600 Plate
Distributor Belts	89.5	0.75	SA-516 K02700 Grd 70 Plate (Tube-Ts Joint:)
Shell Supports		0.625	SA-516 K02700 Grd 70 Plate
Distributor belt closure		1.0	SA-516 K02700 Grd 70 Plate
CDP Bracket		0.25	SA-36 K02600 Plate
CODE DATA PLATE		0.1046	SA-240 S30400 Grd 304 Plate
Nozzle C Repad	103	0.625	SA-240 S30400 Grd 304 Plate
Head Lift Lugs		0.500	SA-240 S30400 Grd 304 Plate
Nozzle C Facing	56.75	0.375	SA-240 S30400 Grd 304 FLAT BAR 1 3/4" X 3/8" ROLLED HARD WAY
Shell Support Repad		0.50	SA-240 S30400 Grd 304 Plate (SS1,SS2)
Shell Support Repad		0.50	SA-516 K02700 Grd 70 Plate (SS3,SS4)
Nozzle C Gussets		0.750	SA-240 S30400 Grd 304 Plate
Nozzle H Repad	11.00	0.750	SA-516 K02700 Grd 70 Plate

Dimensions: in

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Design Specifications

		Shell Side	Tube Side
Design Pressure	psig	150/15	50/15
Test Pressure	psig	195	65
Design Temperature	F	200	300
Number of Passes		1	1
Corrosion Allowance	in	0.0625	0.0
Radiographing		None	None

TEMA Type: NEM Size: 71-264 Area: 12863 ft2
Tube Type: Plain # Holes: 1785 Length: 264.25 in
Layout: 1.5625 in (30) Tube-Ts Joint: Exp/Str.Welded
Baffle Type: Double Seg. Cut: 30% V No: 11
Baffle Spacing (C-C): 17.875 Inlet: 40.0 in
Impingement Protection: None
Code: ASME VIII-1 2004 A06 TEMA Class: C
Wt Empty: 63056 Full: 121779 Bundle: 30902 lb
Drawn By: RM Ckd By: Apvd By:
Dwg No.: Rev: 4 Date: 01-09-08

Company: DCR Construction, Inc.
Location: Bunge-Ergon
Evaporator Condenser
Item No: E-4504
Date: May 5, 2007 Job No: 7793

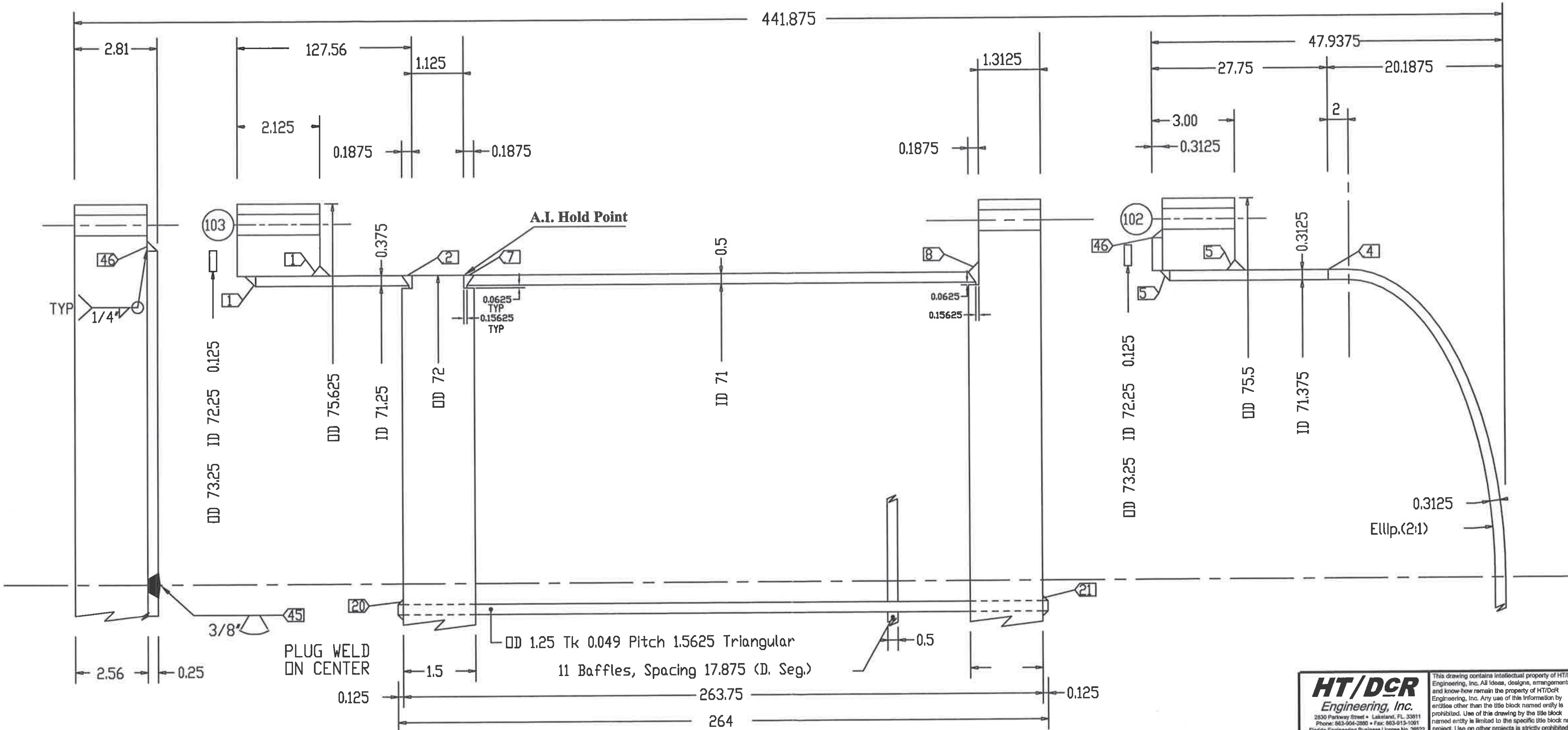
DCR Construction, Inc.
Lakeland, Florida

Rev 4 CERTIFIED AS-BUILT
Rev 3 Revised Nozzle "C"

Bill Of Material

Dwg No.: E-4504 02 Rev: 4

All Dimensions In Inches



Ref	No	Bolt Dia.	Bolt Length	Bolt Circle	Bolt Hole
103	72	0.5	7.5	74.375	0.625
102	72	0.5	6.5	74.25	0.625

Bolting

Notes:

Scale: NTS

Rev:	Date:	Description	Dwg	Ckd	Appd
4	01-09-08	CERTIFIED AS-BUILT	AGB	DGB	PW
2	08-30-07	REVISIONS PER CLIENT	KFF	DGB	PW
3	09-25-07	CHANGED ALLOY FACING	KFF	DGB	PW

Company: DCR Construction, Inc.
Location: Bunge-Ergon
Evaporator Condenser
Item No: E-4504
Date: May 5, 2007 Job No: 7793

DCR Construction, Inc.
Lakeland, Florida

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

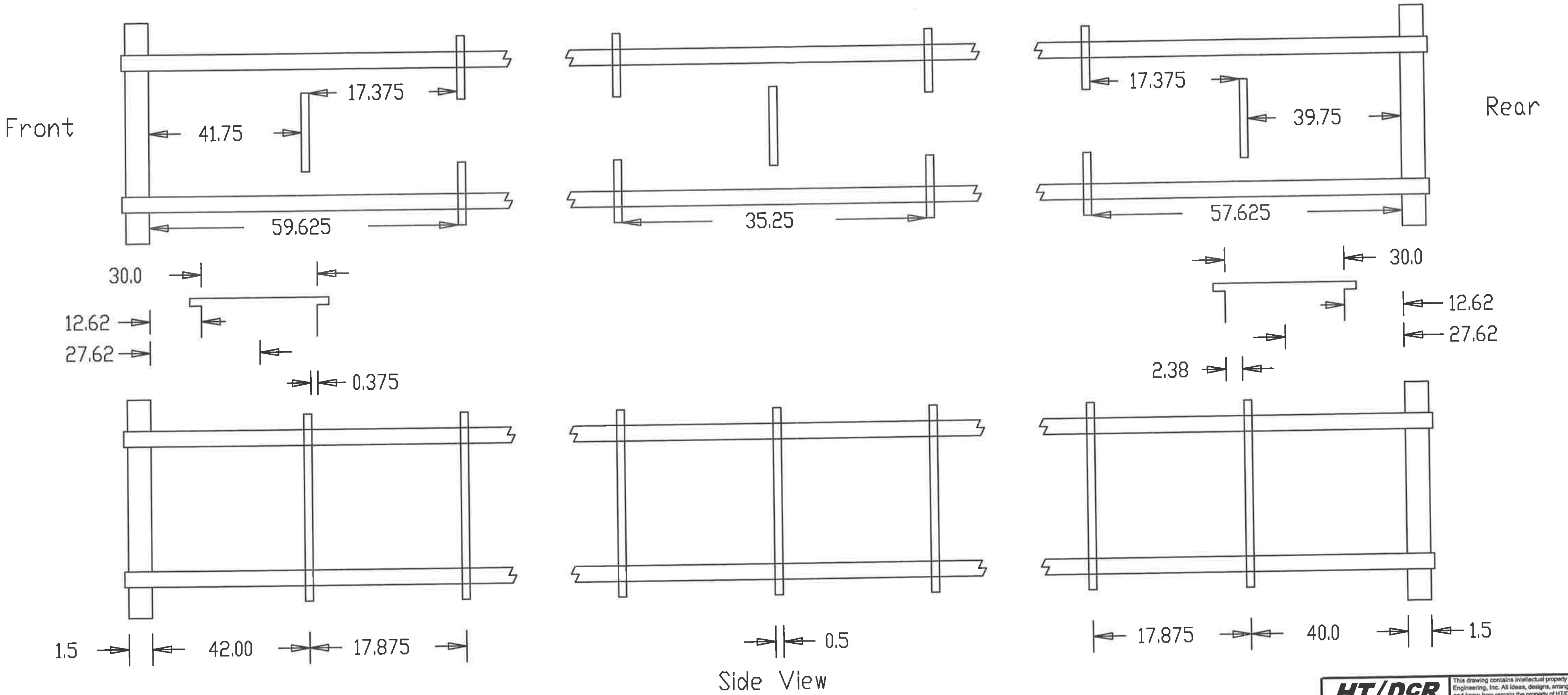
Sectional Plan

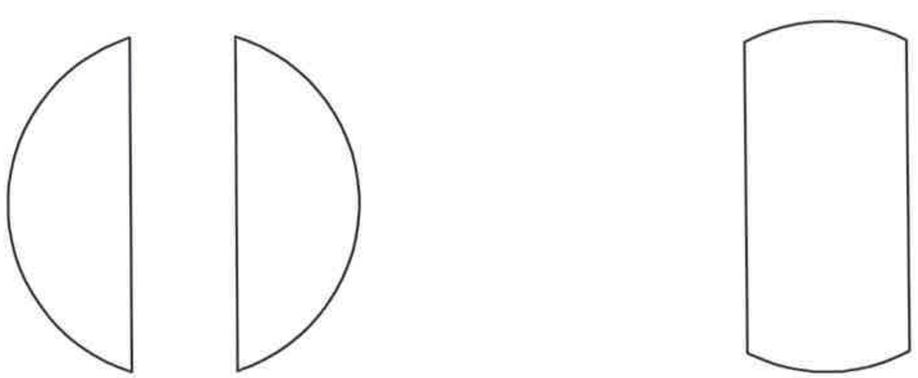
Dwg No.: E-4504 03

Rev: 4

Dimensions: in

TEMA Type: E





Baffles

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Notes:

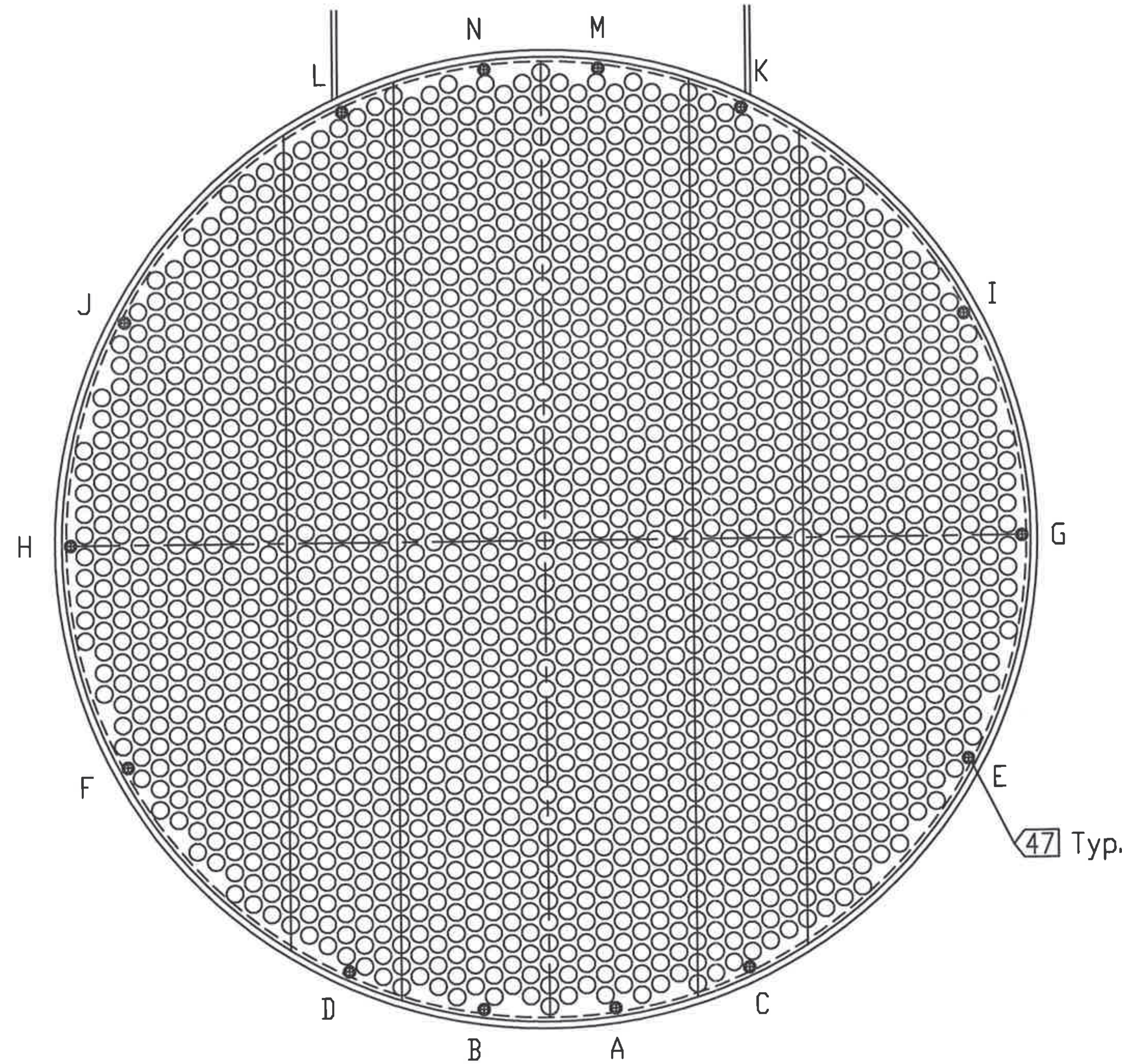
Company: DCR Construction, Inc.
Location: Bunge-Ergon
Evaporator Condenser
Item No: E-4504
Date: May 5, 2007 Job No: 7793

DCR Construction, Inc.
Lakeland, Florida

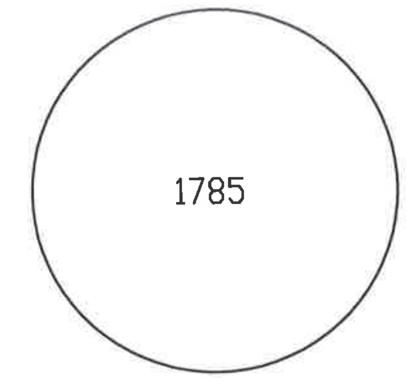
Scale: NTS

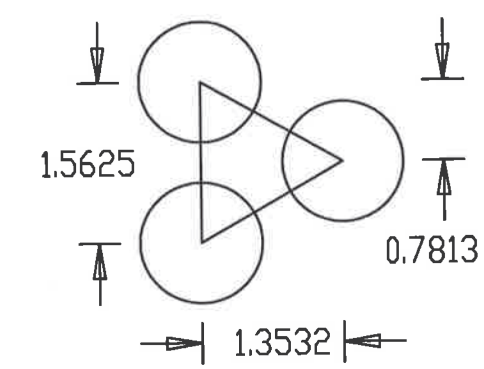
Rev:	Date:	Description	Dwg	Ckd	Appd
1	08-22-07	ISSUED FOR CONSTRUCTION	KFF	DGB	PW
2	08-22-07	REVISED PER CLIENT	KFF	DGB	PW
3	01-09-08	CERTIFIED AS-BUILT	AGB	DGB	PW

ASME VIII-1 2004 A06	Bundle Detail
TEMA Type: NEM	Dwg No.: E-4504 04 — Rev: 3
Size: 71-264	
TEMA Class: C	



Shell ID 71 in
O.T.L. 70.375 in
Baffle cut to C/L 10.825 in
18.944 in





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Design Specifications

Number of Tube Holes	1785
Tube Outside Diameter	1.25 in
Tube Pitch	1.5625 in
Tube Pattern	Triangular
Tube Passes	1
Number of Tie Rods	14
Tie Rod Diameter	0.625 in
Baffle Diameter	70.625 in
Baffle Type	Double Segmental
Baffle Cut	30%
Tube Thickness	0.049 in

Tie Rod Locations

A	4.8103	-34.5417
B	-4.8103	-34.5417
C	14.6675	-31.6406
D	-14.6675	-31.6406
E	30.775	-16.4063
F	-30.775	-16.4063
G	34.875	0
H	-34.875	0
I	30.775	16.4063
J	-30.775	16.4063

Tie Rod Locations (CONT.)

K	14.6675	31.6406
L	-14.6675	31.6406
M	4.8103	34.5417
N	-4.8103	34.5417

Scale: NTS

Rev:	Date:	Description	Dwg	Ckd	Appd
1	08-22-07	ISSUED FOR CONSTRUCTION	KFF	DGB	PW
2	01-09-08	CERTIFIED AS-BUILT	AGB	DGB	PW

Company: DCR Construction, Inc.
Location: Bunge-Ergon
Evaporator Condenser
Item No: E-4504
Date: May 5, 2007 Job No: 7793

DCR Construction, Inc.

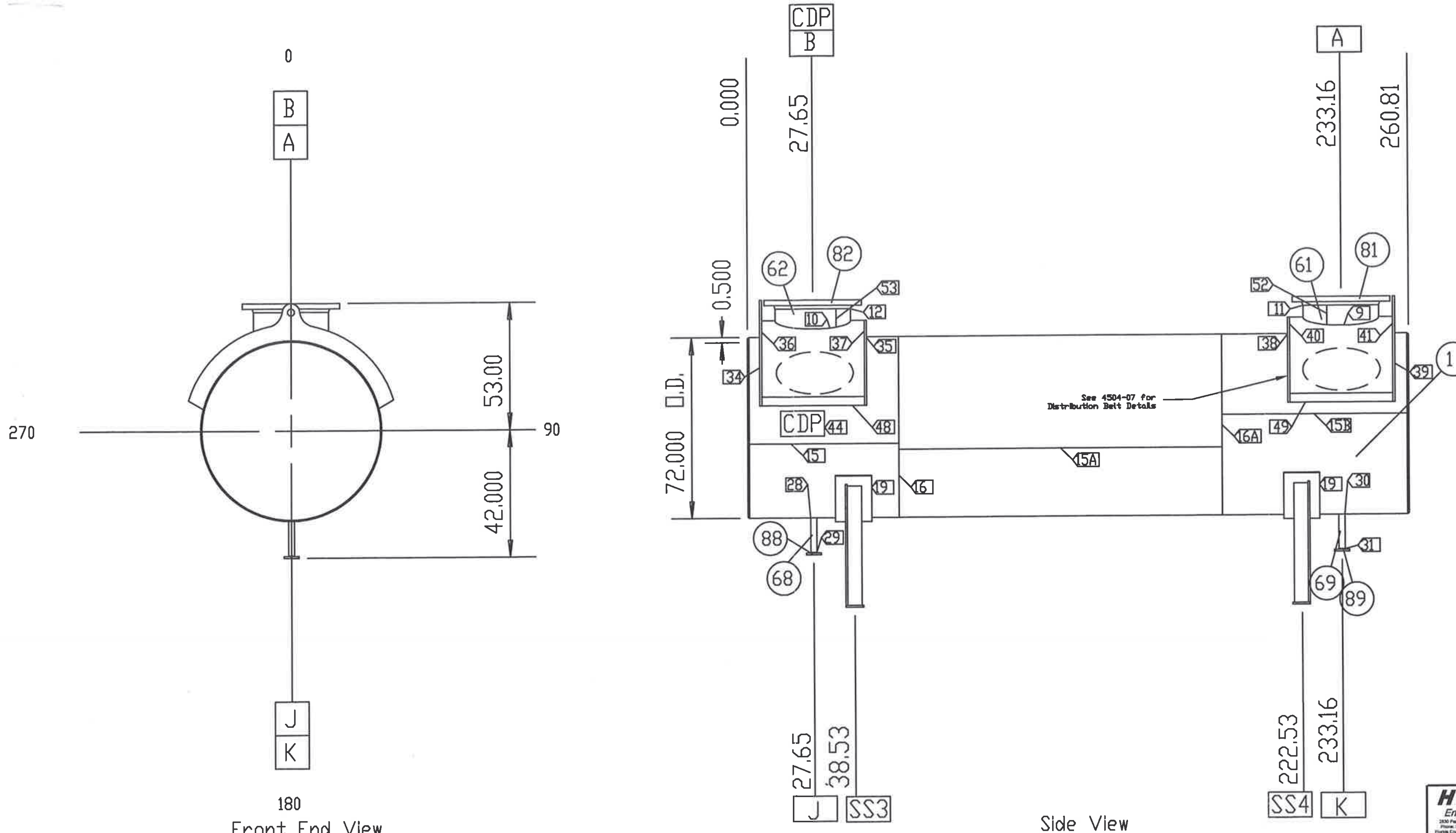
Lakeland, Florida

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

Tube Layout

Dwg No.: E-4504 05

Rev: 2



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

Scale: NTS

Rev:	Date:	Description	Dwg	Ckd	Appd
5	01-09-08	CERTIFIED AS-BUILT	AGB	DGB	PW
2	08-30-07	REVISED PER CLIENT	KFF	DGB	PW
3	09-27-07	REVISED AS NOTED	KFF	DGB	PW
4	10-04-07	ADDED WELD SEAM	KFF	DGB	PW

HT/DCR Engineering, Inc.

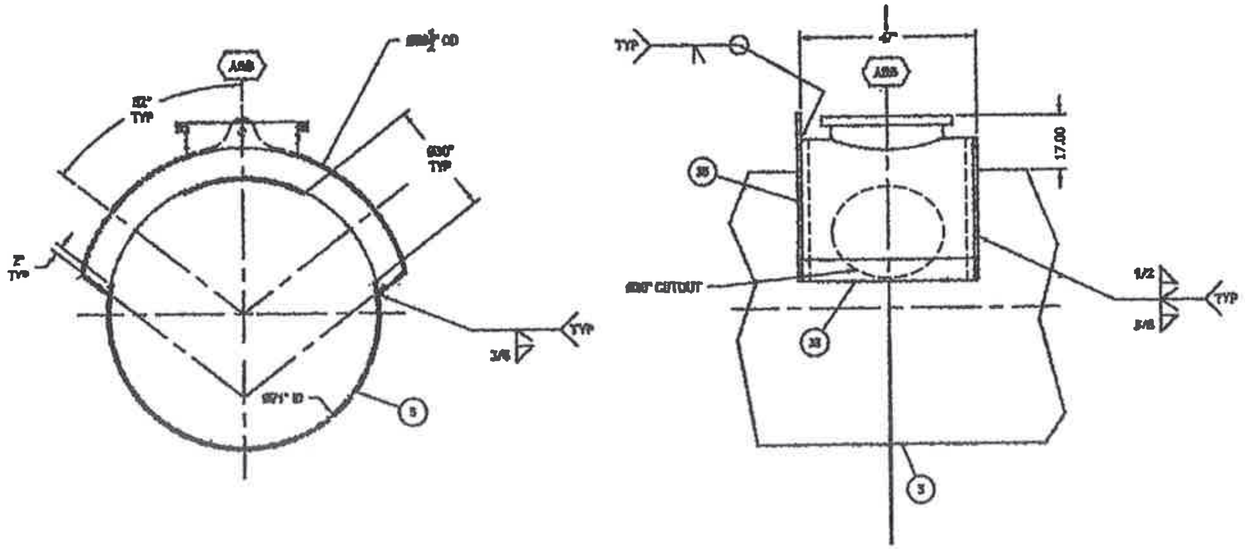
Company: DCR Construction, Inc.
Location: Bunge-Ergon
Evaporator Condenser
Item No: E-4504
Date: May 5, 2007 Job No: 7793

DCR Construction, Inc.
Lakeland, Florida

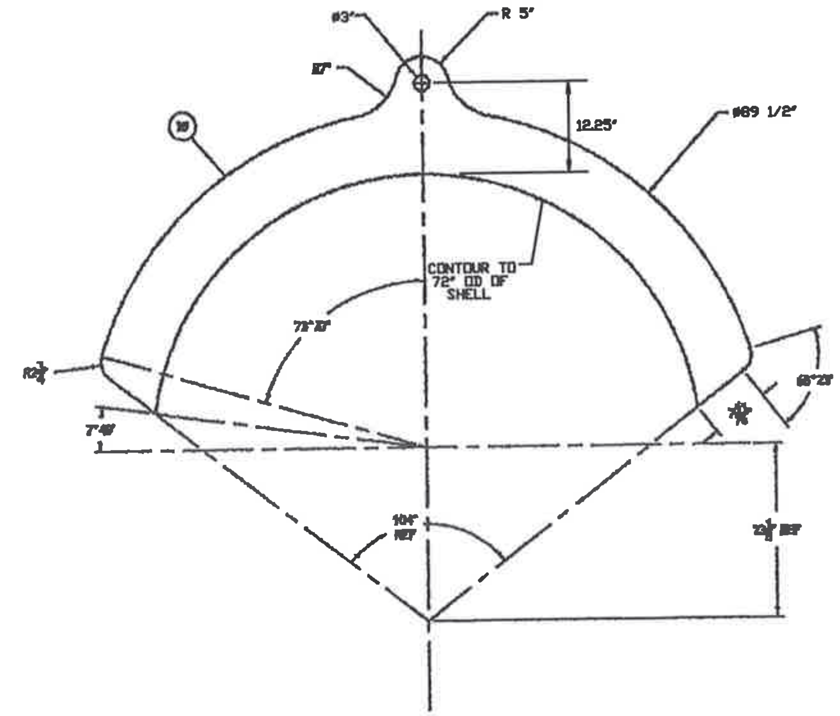
ASME VIII-1 2004 A06
TEMA Type: NEM
Size: 71-264
TEMA Class: C

Shell Detail

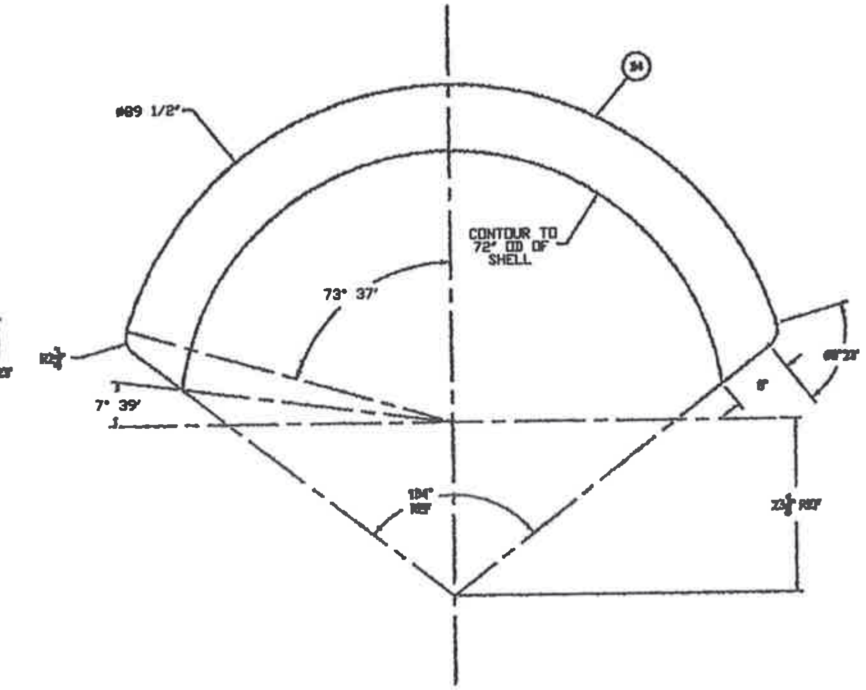
Dwg No.: E-4504 06
Rev: 5



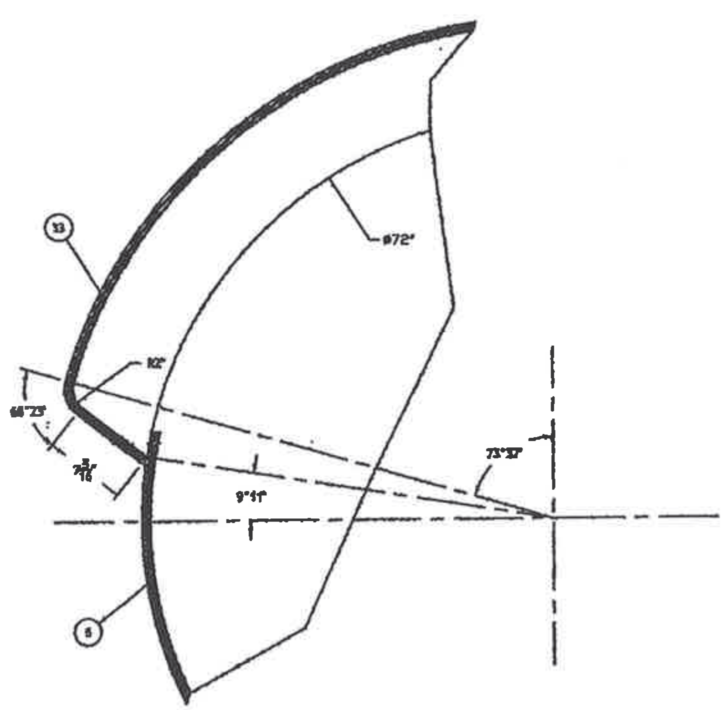
DISTRIBUTION BELT ASSY DETAIL
SCALE: 1/2" = 1'



DISTRIBUTION BELT CLOSURE W/LUG DETAIL
SCALE: 1" = 1'



DISTRIBUTION BELT CLOSURE DETAIL
SCALE: 1" = 1'



DISTRIBUTION BELT DETAIL
SCALE: 1 1/2" = 1'

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Notes:
All Dimensions In Inches
Welding in accordance with Code

Company: DCR Construction, Inc.
Location: Bunge-Ergon
Evaporator Condenser
Item No: E-4504
Date: May 5, 2007 Job No: 7793

DCR Construction, Inc.
Lakeland, Florida

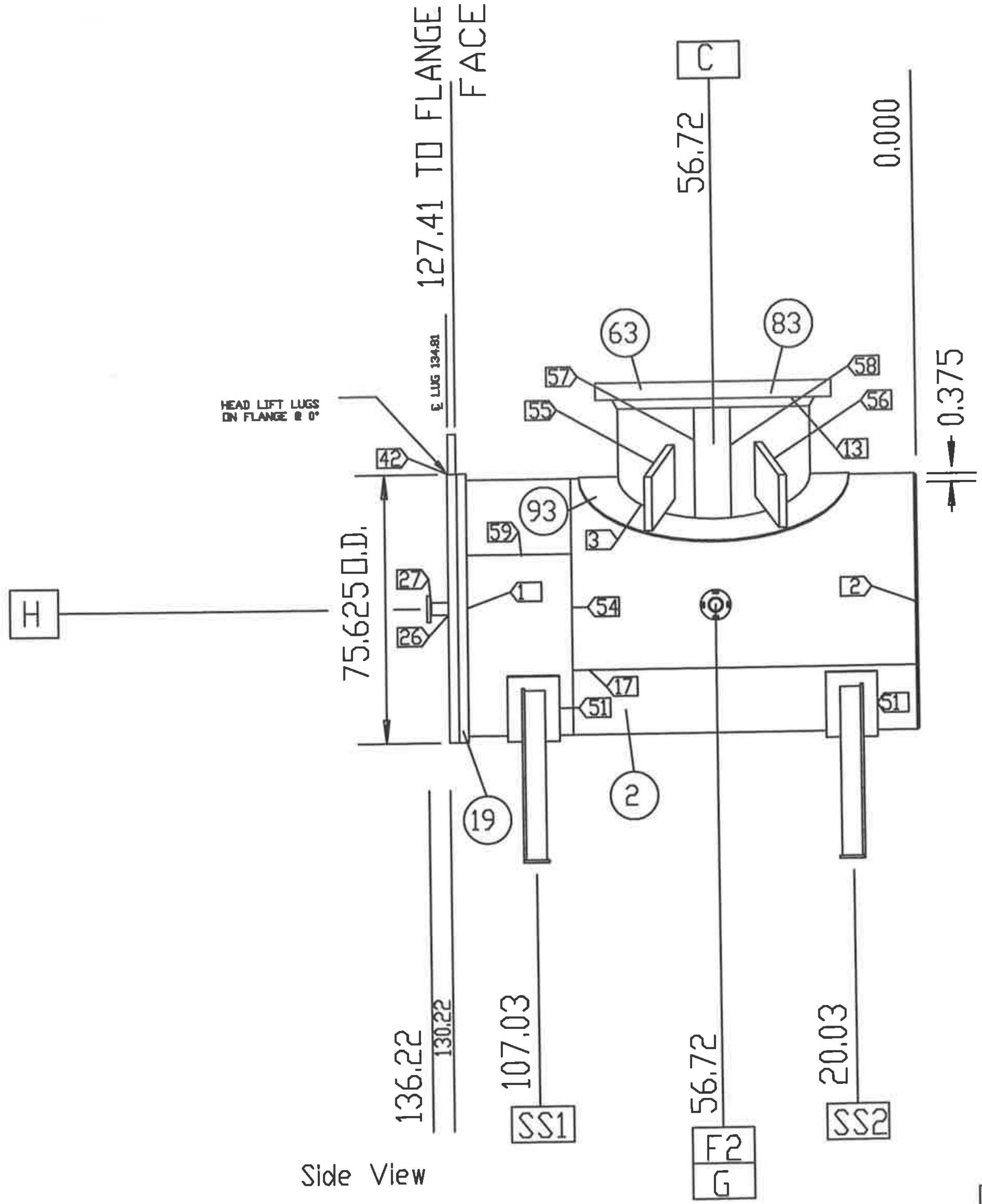
Scale: NTS

Rev:	Date:	Description	Dwg	Ckd	Appd
4	01-09-08	CERTIFIED AS-BUILT	AGB	DGB	PW
2	08-30-07	REVISED PER CLIENT	KFF	DGB	PW
3	09-27-07	REVISED AS NOTED	KFF	DGB	PW

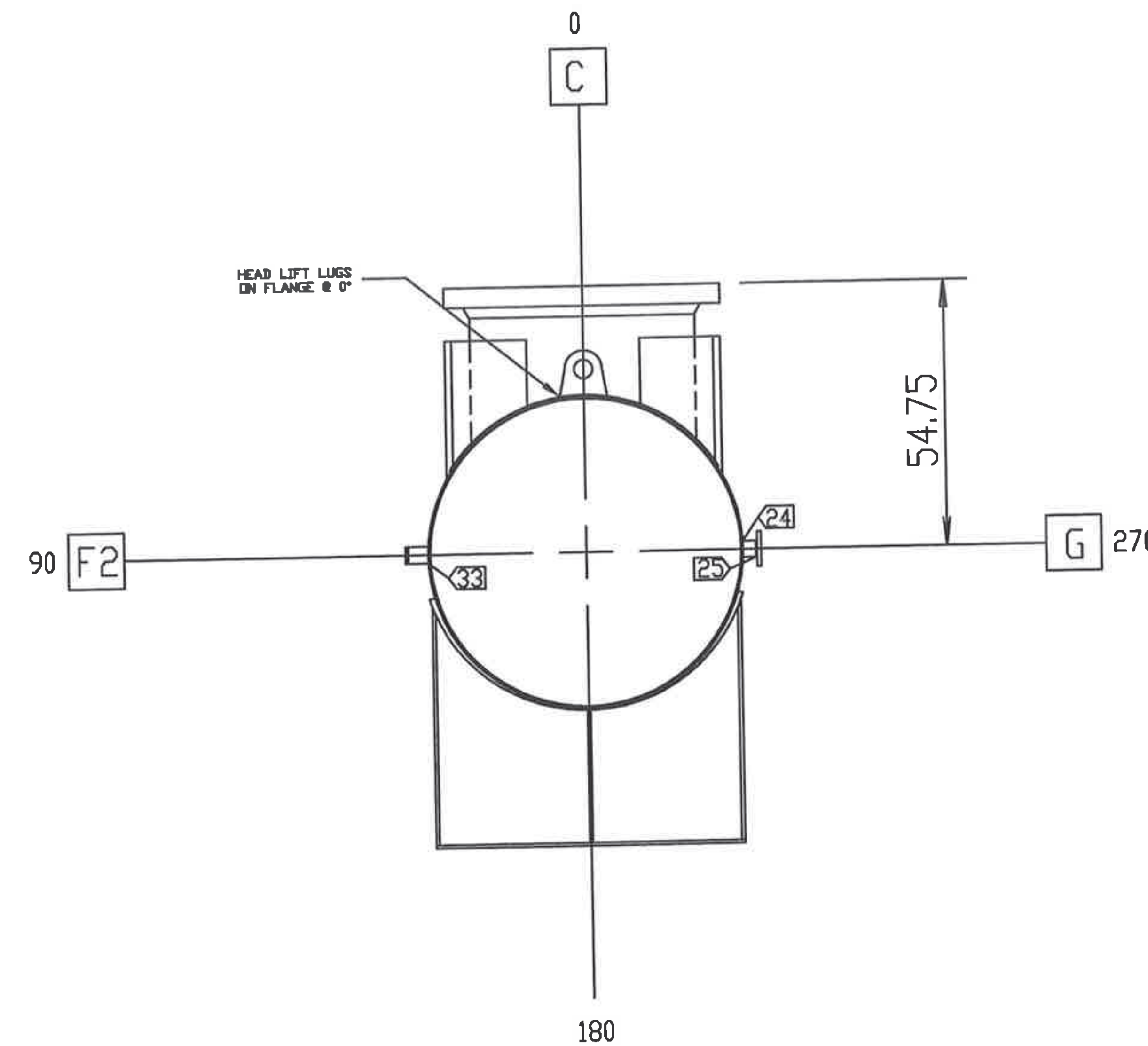
ASME VIII-1 2004 A06
TEMA Type: NEM
Size: 71-264
TEMA Class: C

Distribution Belt Detail

Dwg No.: E-4504 07
Rev: 4



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 Construction, Inc.
Location: Bunge-Ergon
Evaporator Condenser
Item No: E-4504
Date: May 5, 2007 Job No: 7793

DCR Construction, Inc.
Lakeland, Florida

Scale: NTS

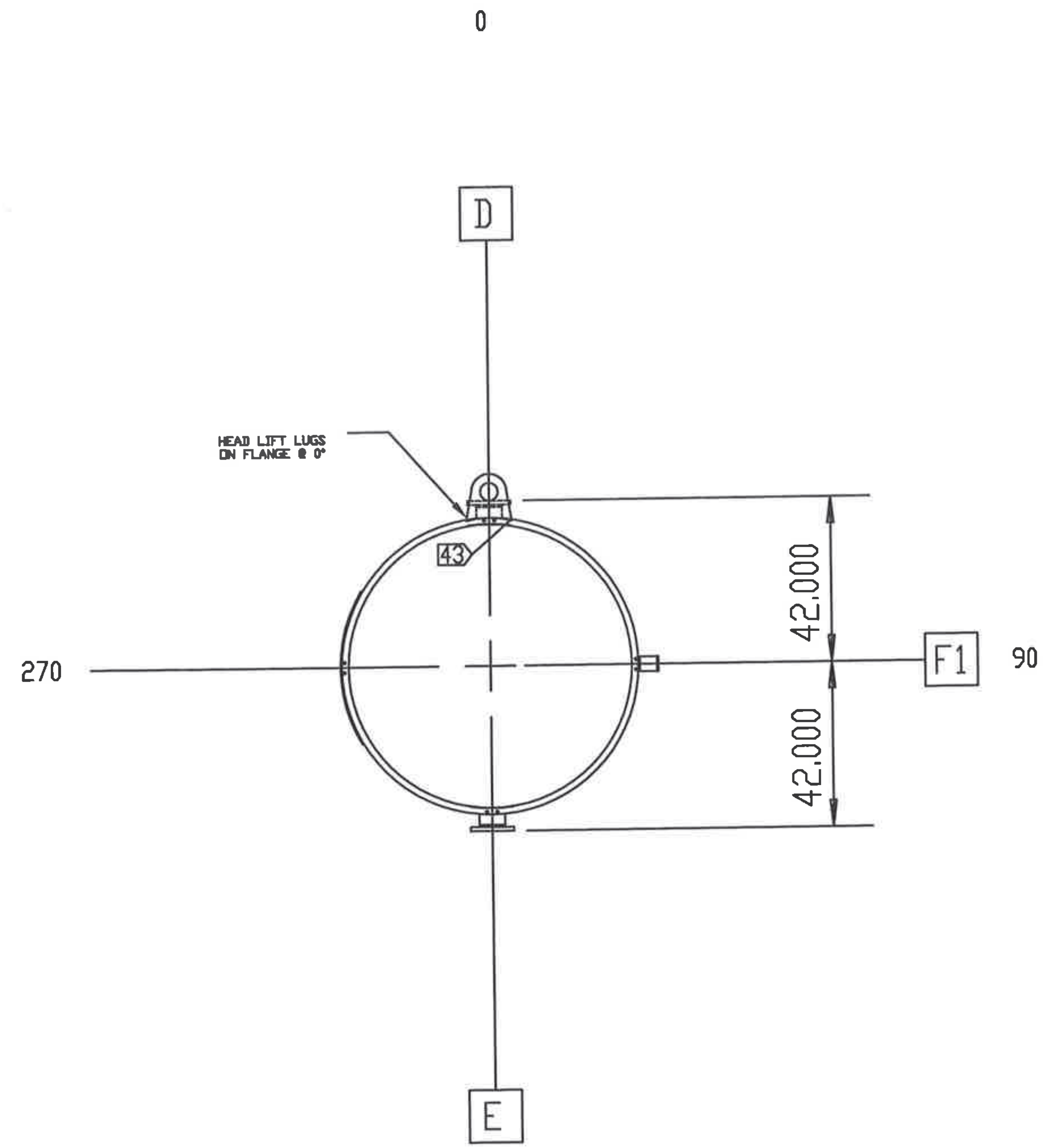
Rev:	Date:	Description	Dwg	Ckd	Appd
5	01-09-08	CERTIFIED AS-BUILT	AGB	DGB	PW
2	08-30-07	REVISED PER CLIENT CHANGES	KFF	DGB	PW
3	09-18-07	REVISED AS NOTED	KFF	DGB	PW
4	10-04-07	ADDED WELD SEAM	KFF	DGB	PW

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

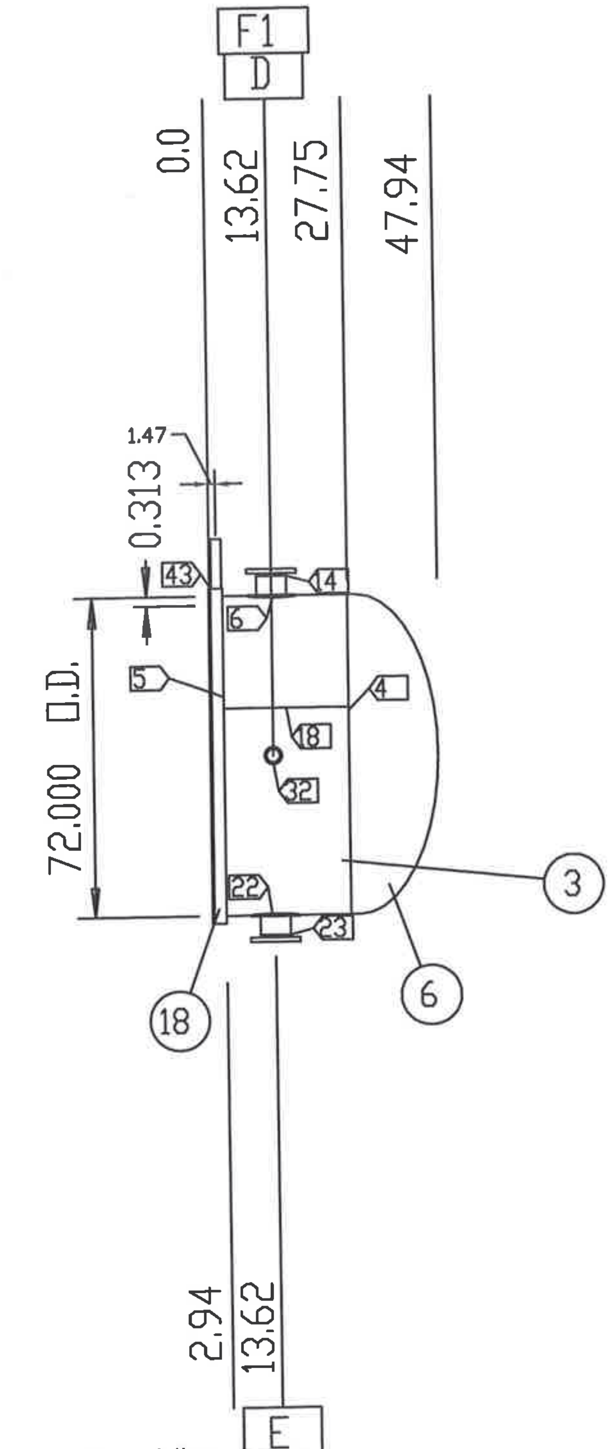
Front Head Detail

Dwg No.: E-4504 08

Rev: 5



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 Construction, Inc.
Location: Bunge-Ergon
Evaporator Condenser
Item No: E-4504
Date: May 5, 2007 Job No: 7793

DCR Construction, Inc.
Lakeland, Florida

Scale: NTS

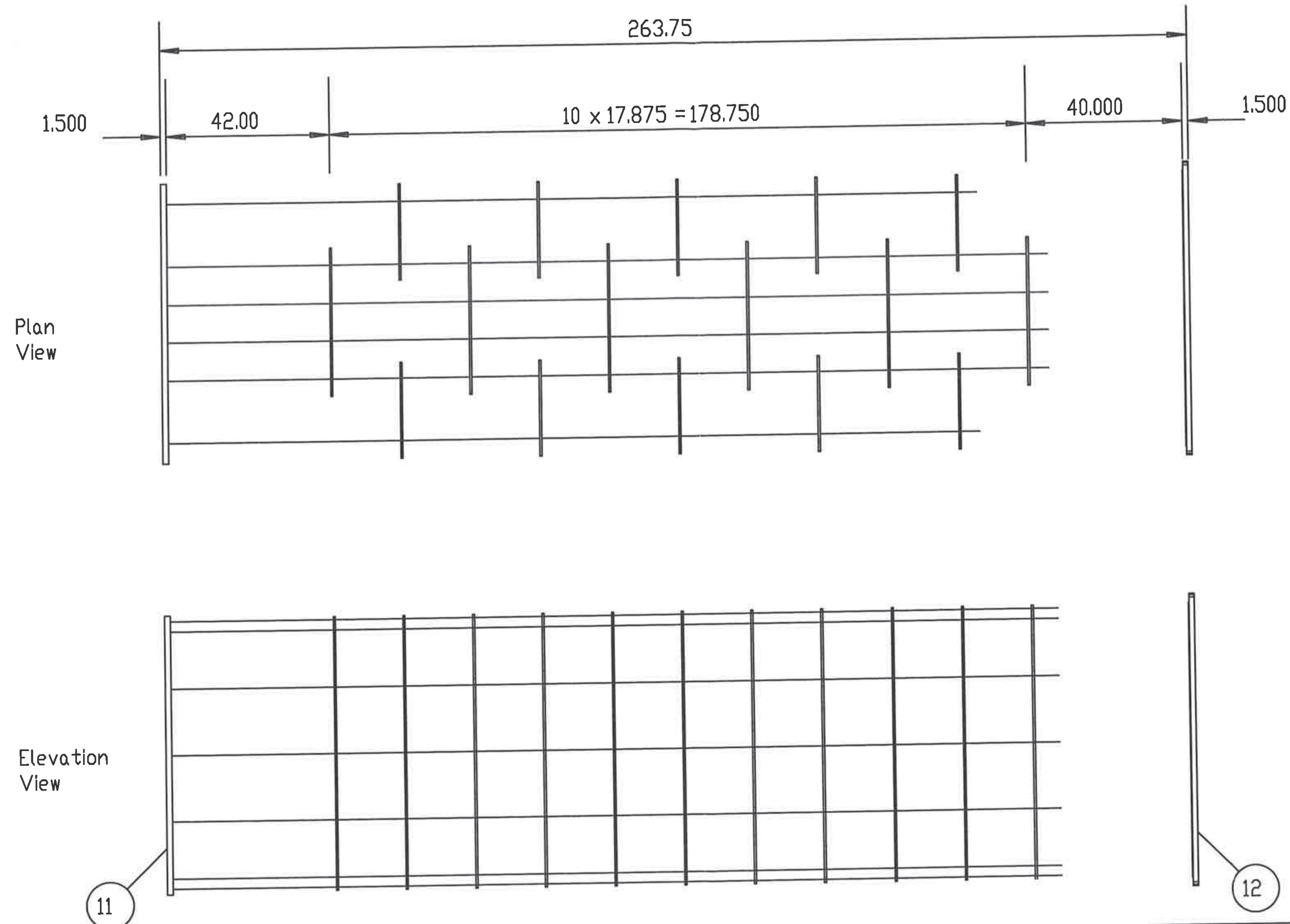
Rev:	Date:	Description	Dwg	Ckd	Appd
1	08-22-07	ISSUED FOR CONSTRUCTION	KFF	DGB	PW
2	08-30-07	REVISED PER CLIENT	KFF	DGB	PW
3	01-09-08	CERTIFIED AS-BUILT	AGB	DGB	PW

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

Rear Head Detail

Dwg No.: E-4504 09

Rev: 3



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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 Construction, Inc.
Location: Bunge-Ergon
Evaporator Condenser
Item No: E-4504
Date: May 5, 2007 Job No: 7793

DCR Construction, Inc.
Lakeland, Florida

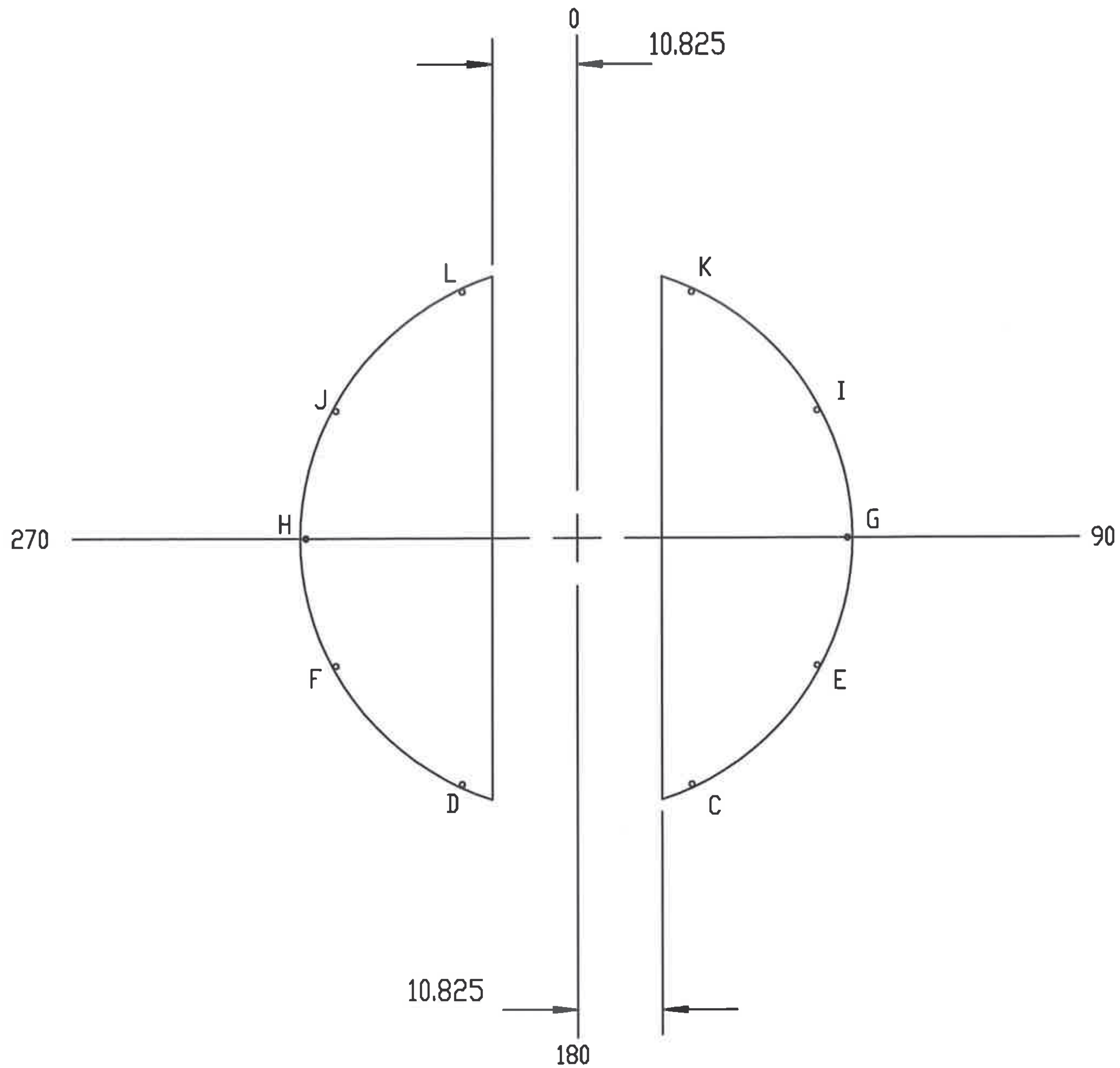
Scale: NTS

Rev:	Date:	Description	Dwg	Ckd	Appd
1	08-22-07	ISSUED FOR CONSTRUCTION	KFF	DGB	PW
2	08-30-07	REVISED PER CLIENT	KFF	DGB	PW
3	01-09-08	CERTIFIED AS-BUILT	AGB	DGB	PW

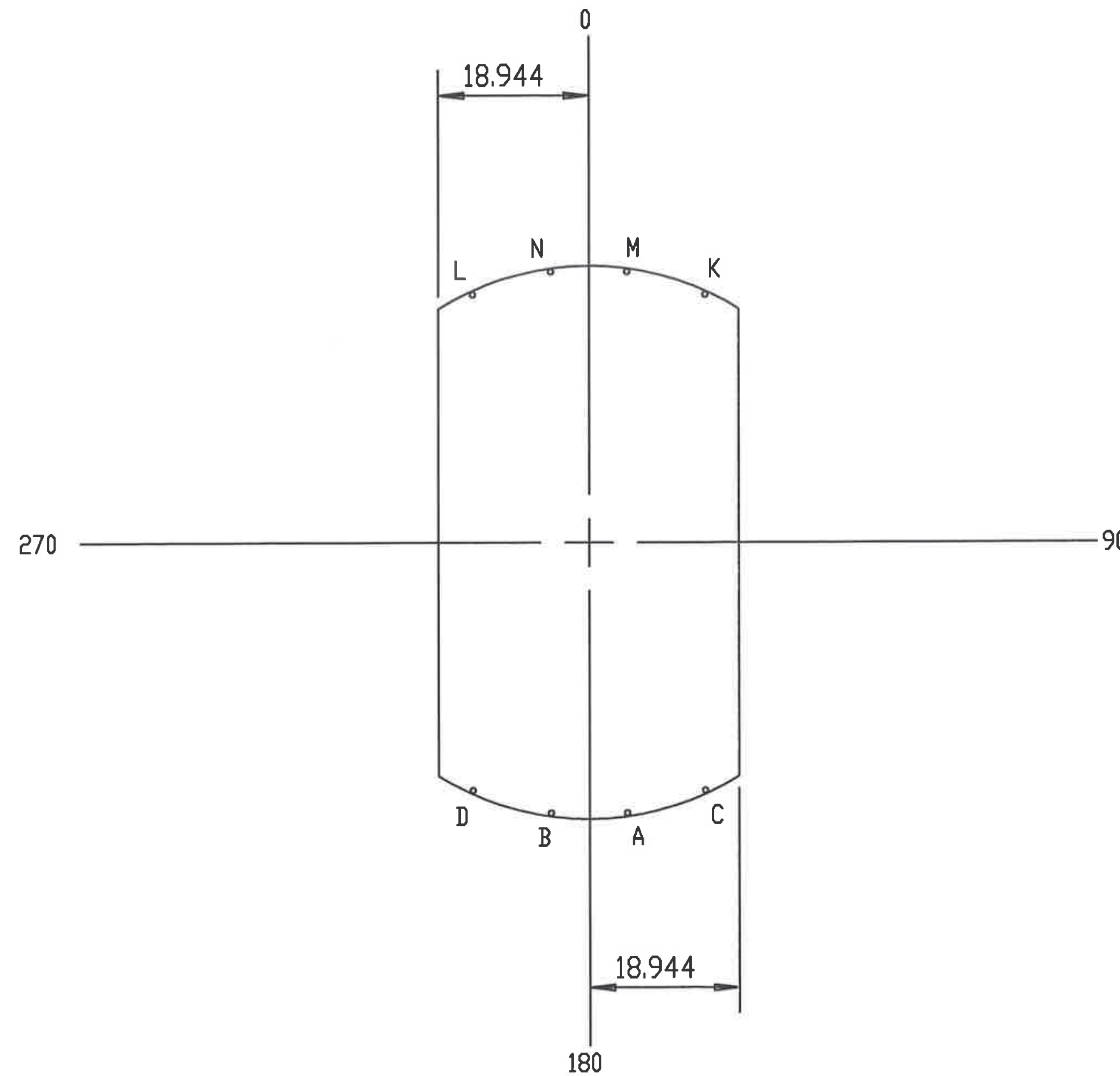
ASME VIII-1 2004 A06
TEMA Type: NEM
Size: 71-264
TEMA Class: C

Bundle Detail

Dwg No.: E-4504 11
Rev: 3



(39 A) 5 Baffles 70.625 O.D. 0.500 Tk



(39 B) 6 Baffles 70.625 O.D. 0.500 Tk

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

HT/DCR Engineering, Inc.
2630 Parkway Street • Lakeland, FL 33811
Phone: 863-904-2580 • Fax: 863-913-1091
Florida Engineering Business License No. 26522

Company: DCR Construction, Inc.
Location: Bunge-Ergon
Evaporator Condenser
Item No: E-4504
Date: May 5, 2007 Job No: 7793

DCR Construction, Inc.
Lakeland, Florida

Scale: NTS

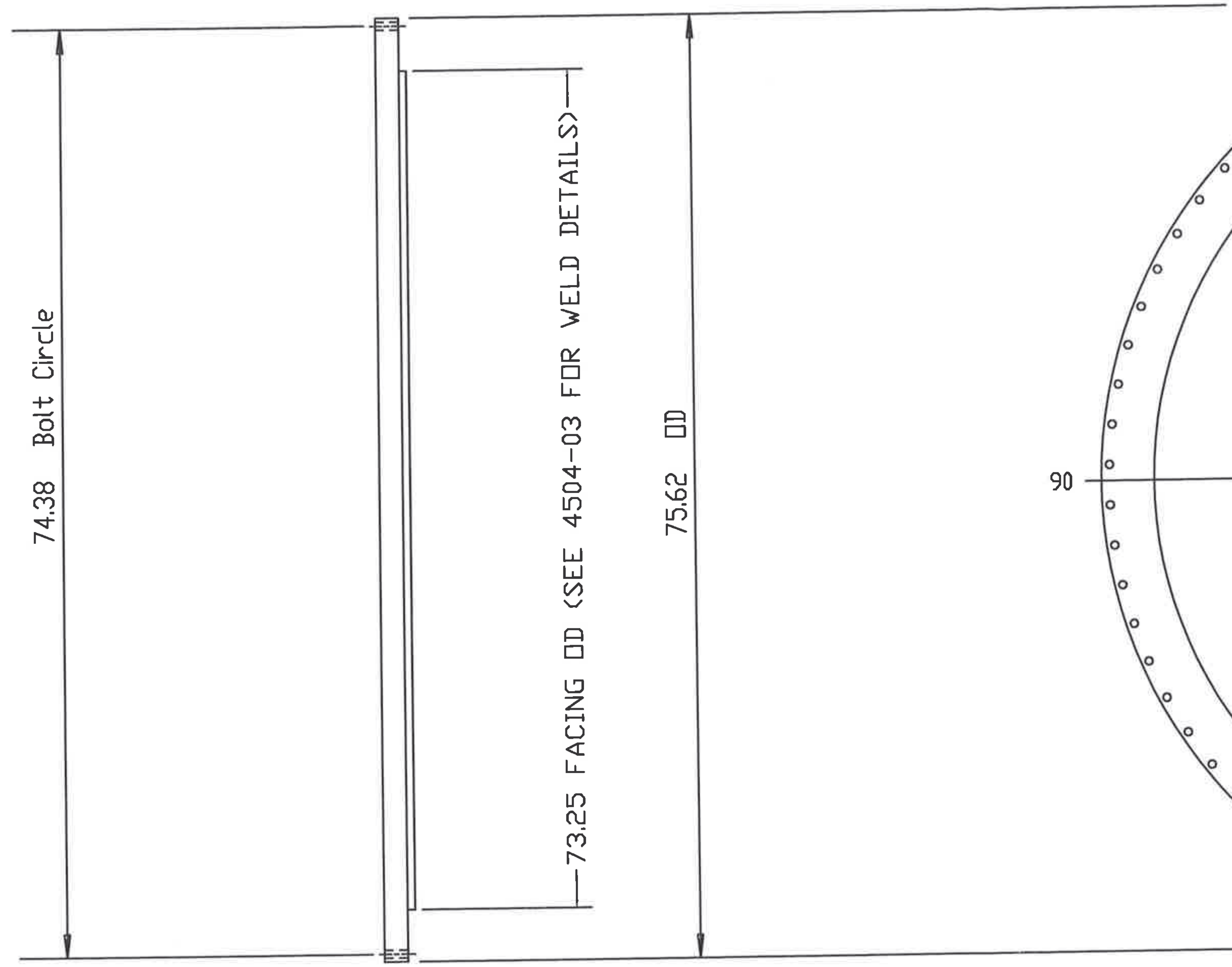
Rev:	Date:	Description	Dwg	Ckd	Appd
1	08-22-07	ISSUED FOR CONSTRUCTION	KFF	DGB	PW
2	01-09-08	CERTIFIED AS-BUILT	AGB	DGB	PW

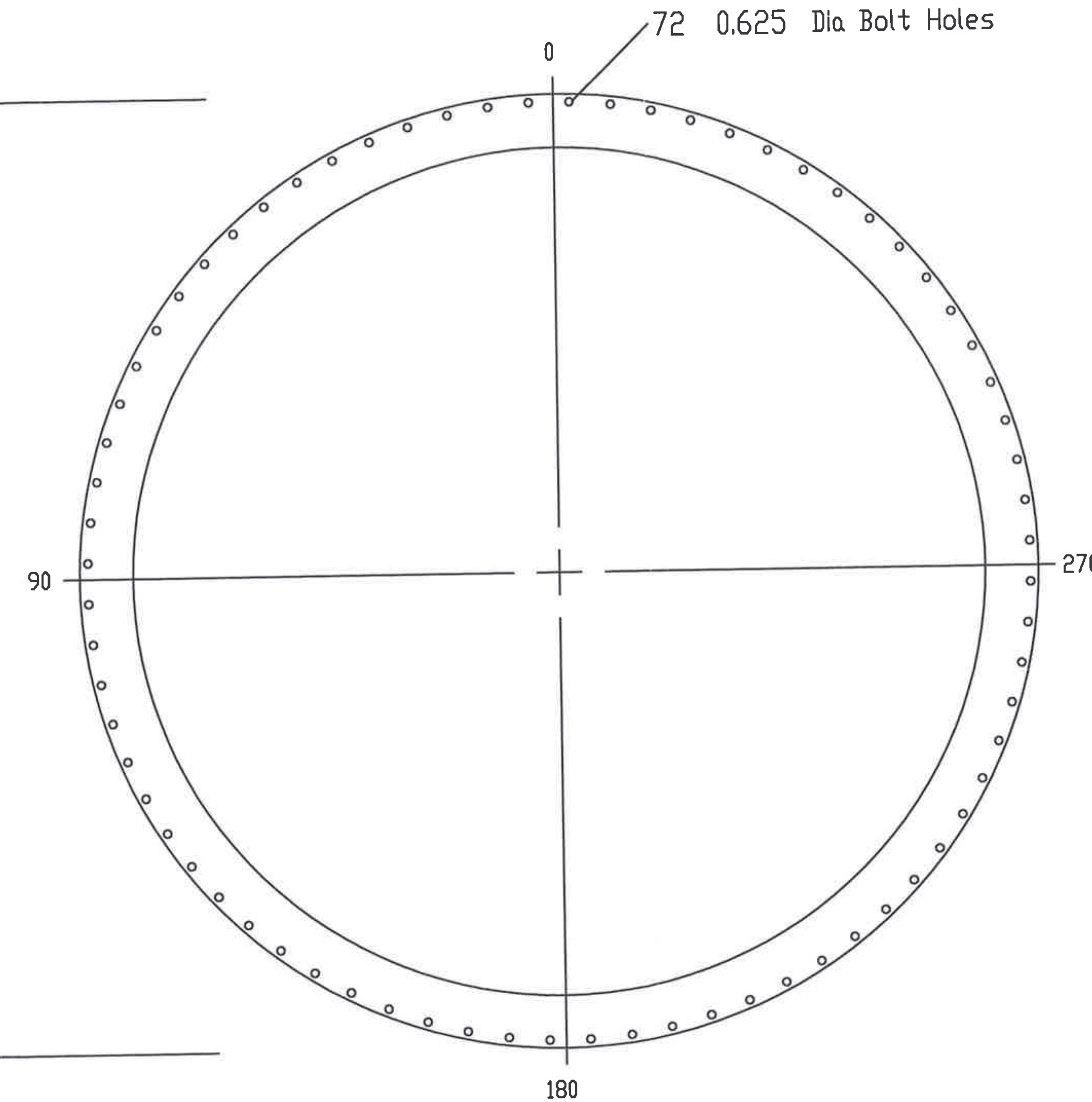
ASME VIII-1 2004 A06
TEMA Type: NEM
Size: 71-264
TEMA Class: C

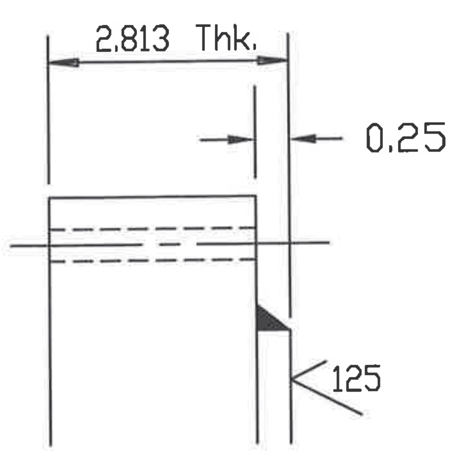
Baffle Detail

Dwg No.: E-4504 12

Rev: 2







(5) Front Head Cover

Notes:
All Dimensions In Inches
Bolt holes to straddle centerlines

HT/DCR Engineering, Inc.
2830 Parkway Street • Lakeland, FL 33811
Phone: 863-904-2800 • Fax: 863-913-1091
Florida Engineering Business License No. 26522

Company: DCR Construction, Inc.
Location: Bunge-Ergon
Evaporator Condenser
Item No: E-4504
Date: May 5, 2007 Job No: 7793

DCR Construction, Inc.
Lakeland, Florida

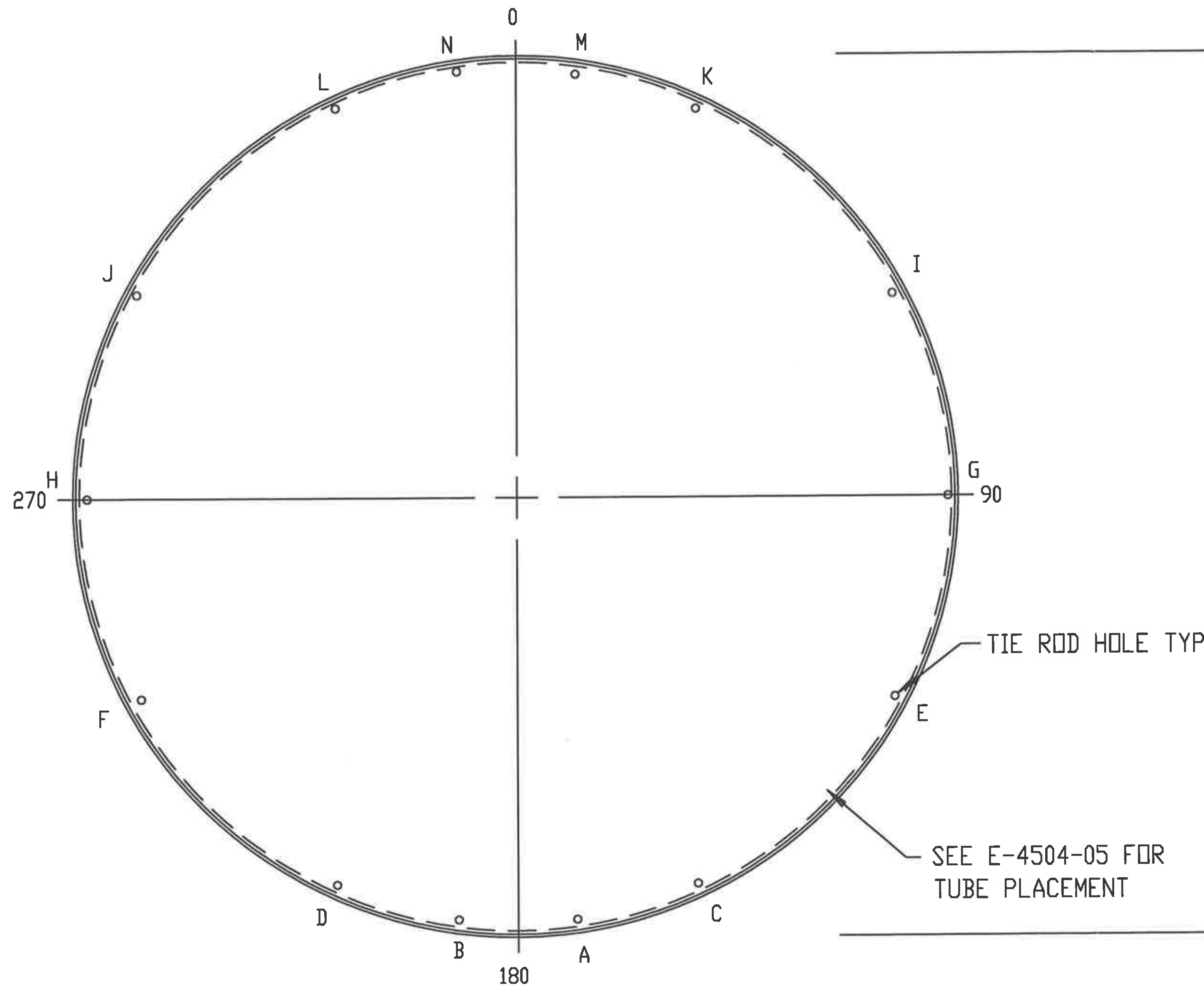
Scale: NTS

Rev:	Date:	Description	Dwg	Ckd	Appd
1	08-22-07	ISSUED FOR CONSTRUCTION	KFF	DGB	PW
2	09-25-07	CHANGED ALLOY FACING	KFF	DGB	PW
3	01-09-08	CERTIFIED AS-BUILT	AGB	DGB	PW

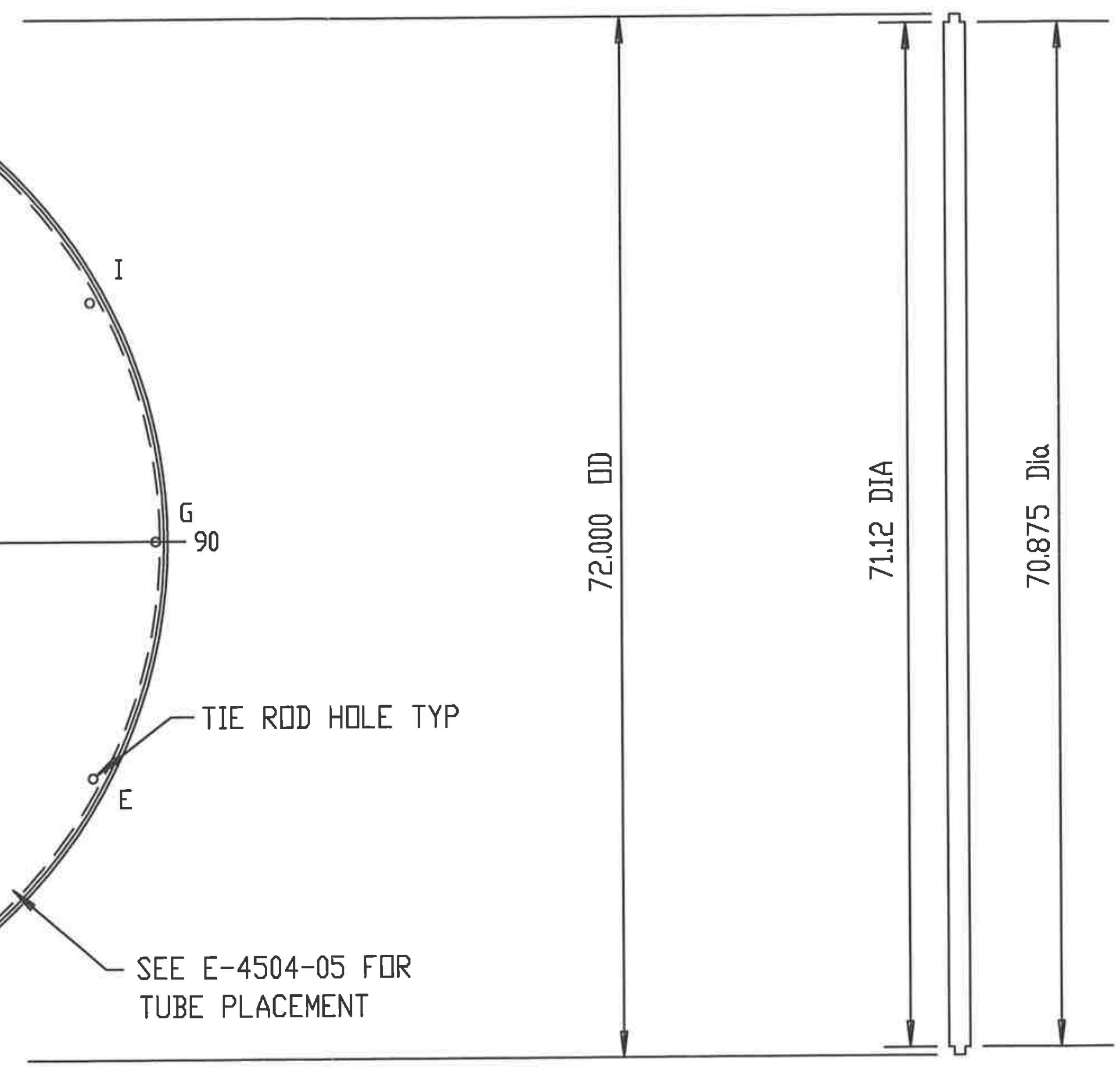
ASME VIII-1 2004 A06
TEMA Type: NEM
Size: 71-264
TEMA Class: C

Flat Cover Detail

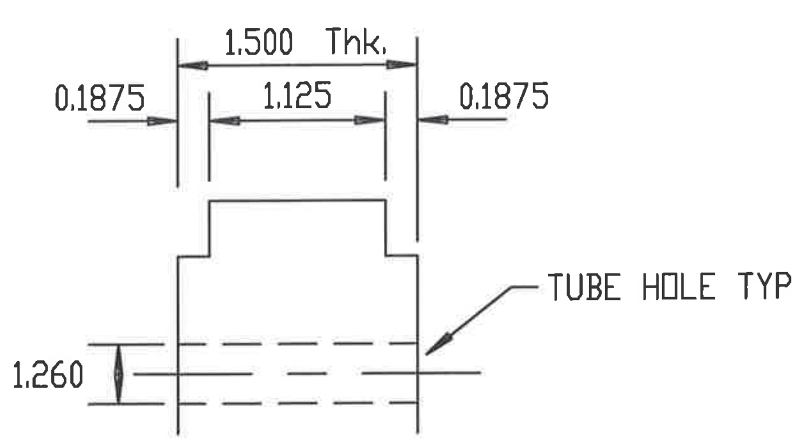
Dwg No.: E-4504 13
Rev: 3



Front End View



(13) Front TubSh



Notes:
All Dimensions In Inches
Bolt holes to straddle centerlines

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

Company: DCR Construction, Inc.
Location: Bunge-Ergon
Evaporator Condenser
Item No: E-4504
Date: May 5, 2007 Job No: 7793

DCR Construction, Inc.
Lakeland, Florida

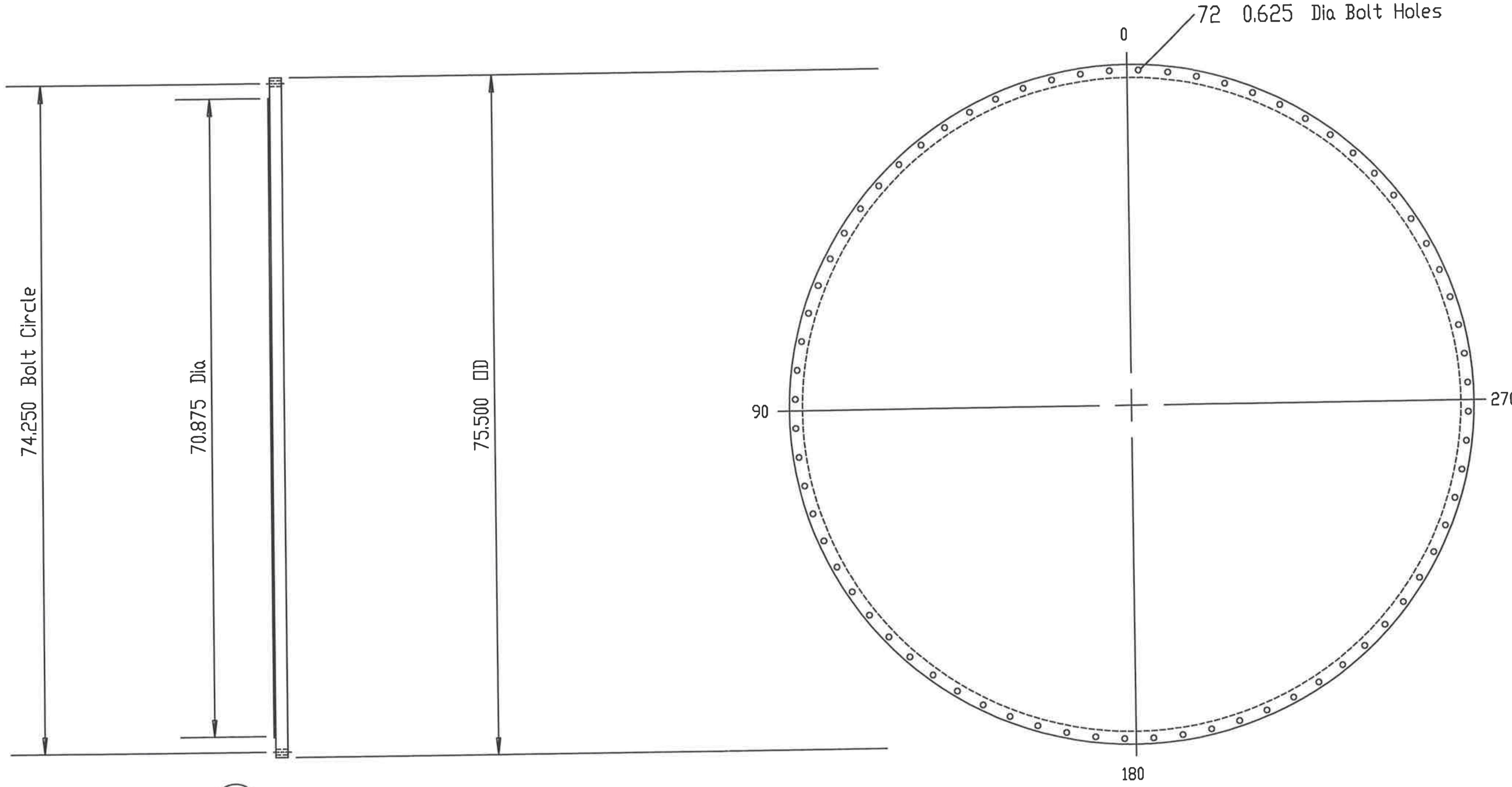
Scale: NTS

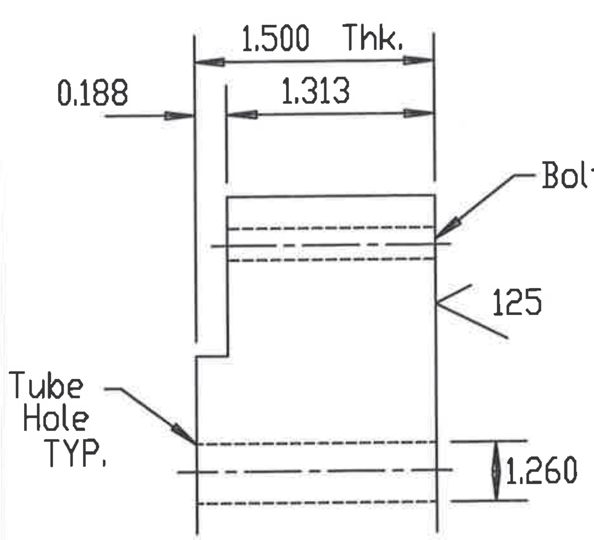
Rev:	Date:	Description	Dwg	Ckd	Appd
1	08-22-07	ISSUED FOR CONSTRUCTION	KFF	DGB	PW
2	01-09-08	CERTIFIED AS-BUILT	AGB	DGB	PW

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

Front Tubesheet Detail

Dwg No.: E-4504 14
Rev: 2





Notes:
All Dimensions In Inches
Bolt holes to straddle centerlines

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

Company: DCR Construction, Inc.
Location: Bunge-Ergon
Evaporator Condenser
Item No: E-4504
Date: May 5, 2007 Job No: 7793

DCR Construction, Inc.
Lakeland, Florida

Scale: NTS

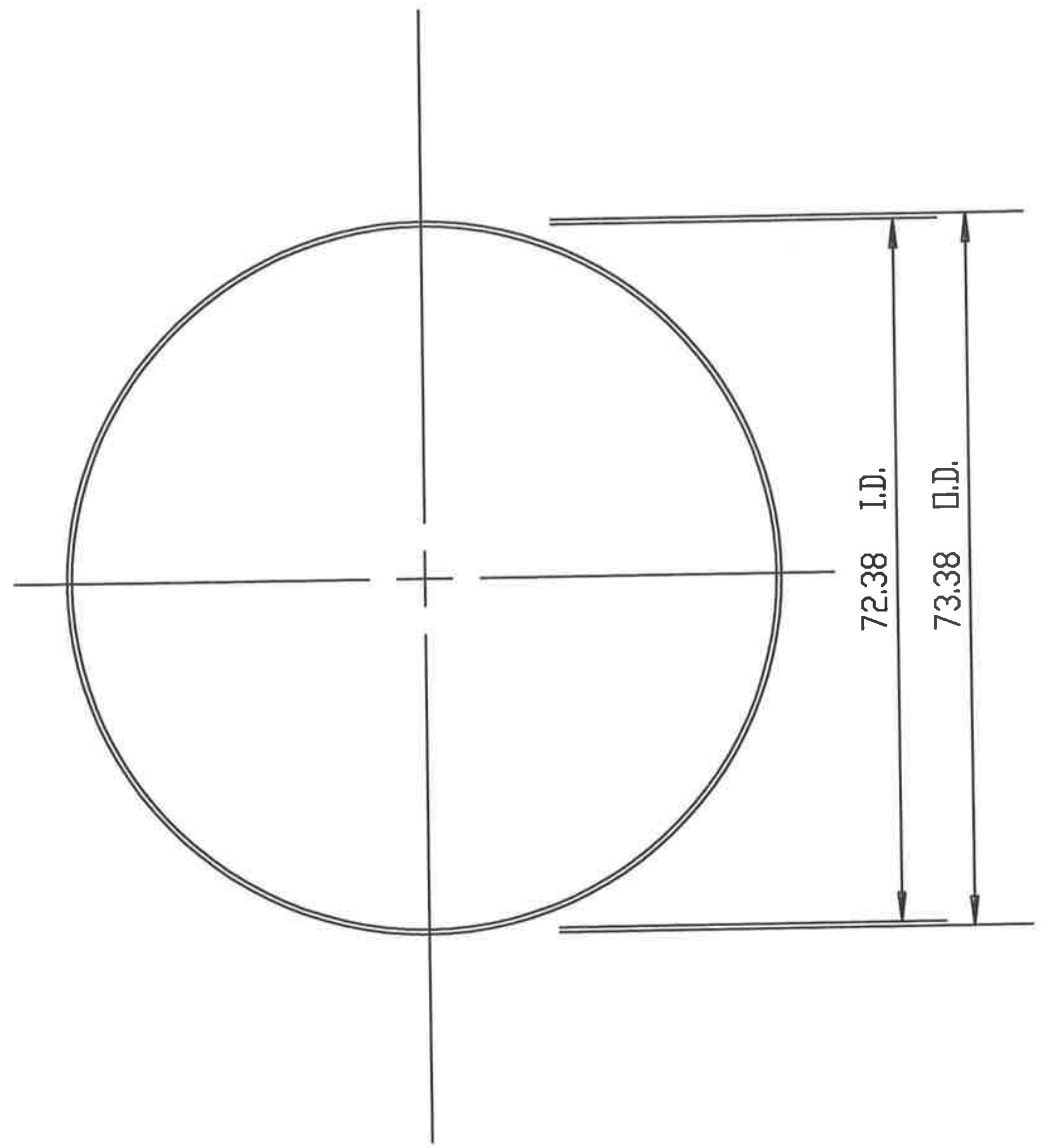
Rev:	Date:	Description	Dwg	Ckd	Appd
1	08-22-07	ISSUED FOR CONSTRUCTION	KFF	DGB	PW
2	01-09-08	CERTIFIED AS-BUILT	AGB	DGB	PW

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

Rear Tubesheet Detail

Dwg No.: E-4504 15

Rev: 2



(33) Front Head Gasket at Cover

0.125 Thk.

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

Notes:
All Dimensions In Inches
Bolt holes to straddle centerlines

Company: DCR Construction, Inc.
Location: Bunge-Ergon
Evaporator Condenser
Item No: E-4504
Date: May 5, 2007 Job No: 7793

DCR Construction, Inc.
Lakeland, Florida

Scale: NTS

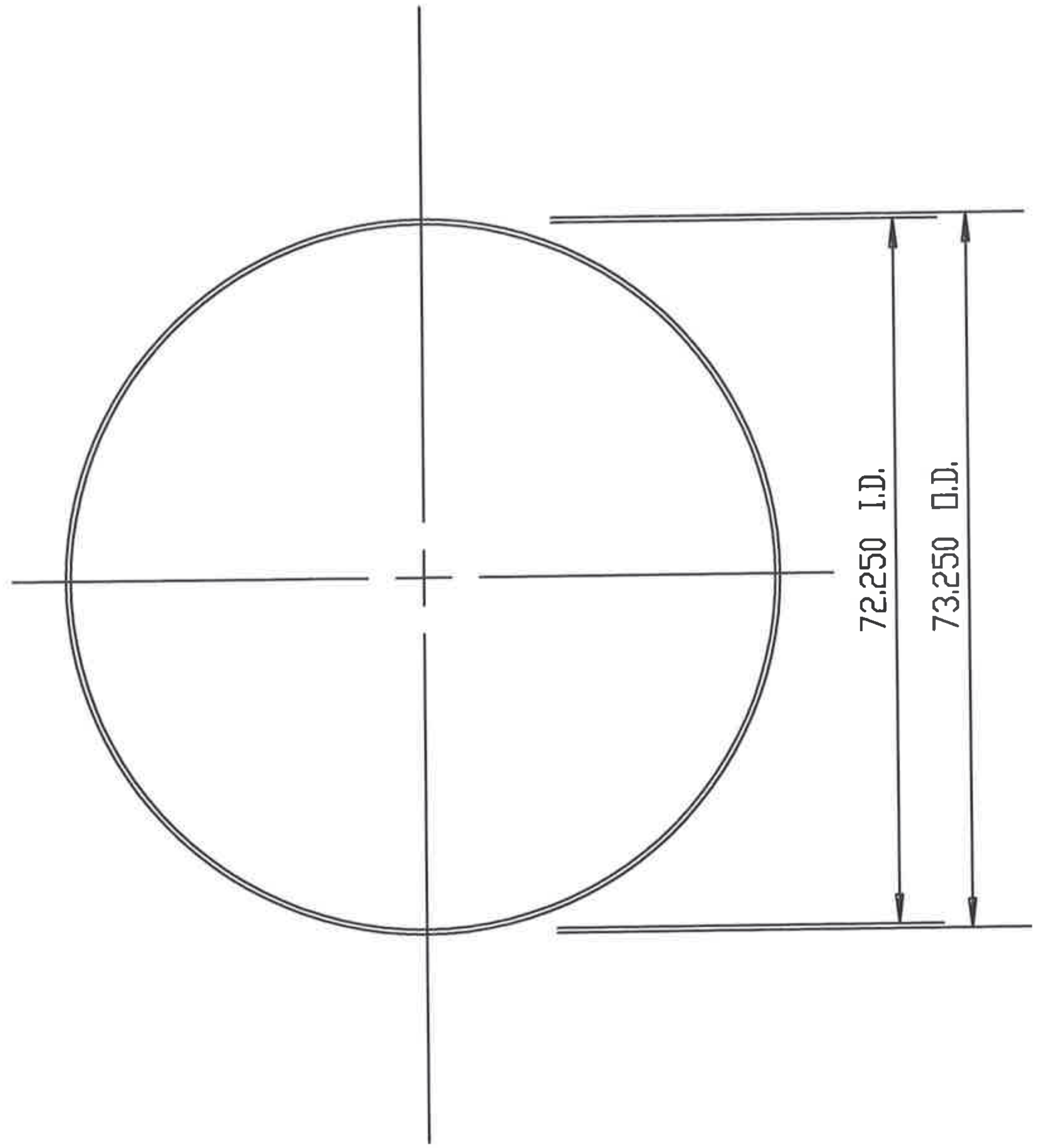
Rev:	Date:	Description	Dwg	Ckd	Appd
1	08-22-07	ISSUED FOR CONSTRUCTION	KFF	DGB	PW
2	01-09-08	CERTIFIED AS-BUILT	AGB	DGB	PW

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

Front Head Gasket Detail

Dwg No.: E-4504 17A

Rev: 2



(32) Rear Head Gasket at Tbsht

0.125 Thk.

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

Notes:
All Dimensions In Inches
Bolt holes to straddle centerlines

Company: DCR Construction, Inc.
Location: Bunge-Ergon
Evaporator Condenser
Item No: E-4504
Date: May 5, 2007 Job No: 7793

DCR Construction, Inc.
Lakeland, Florida

Scale: NTS

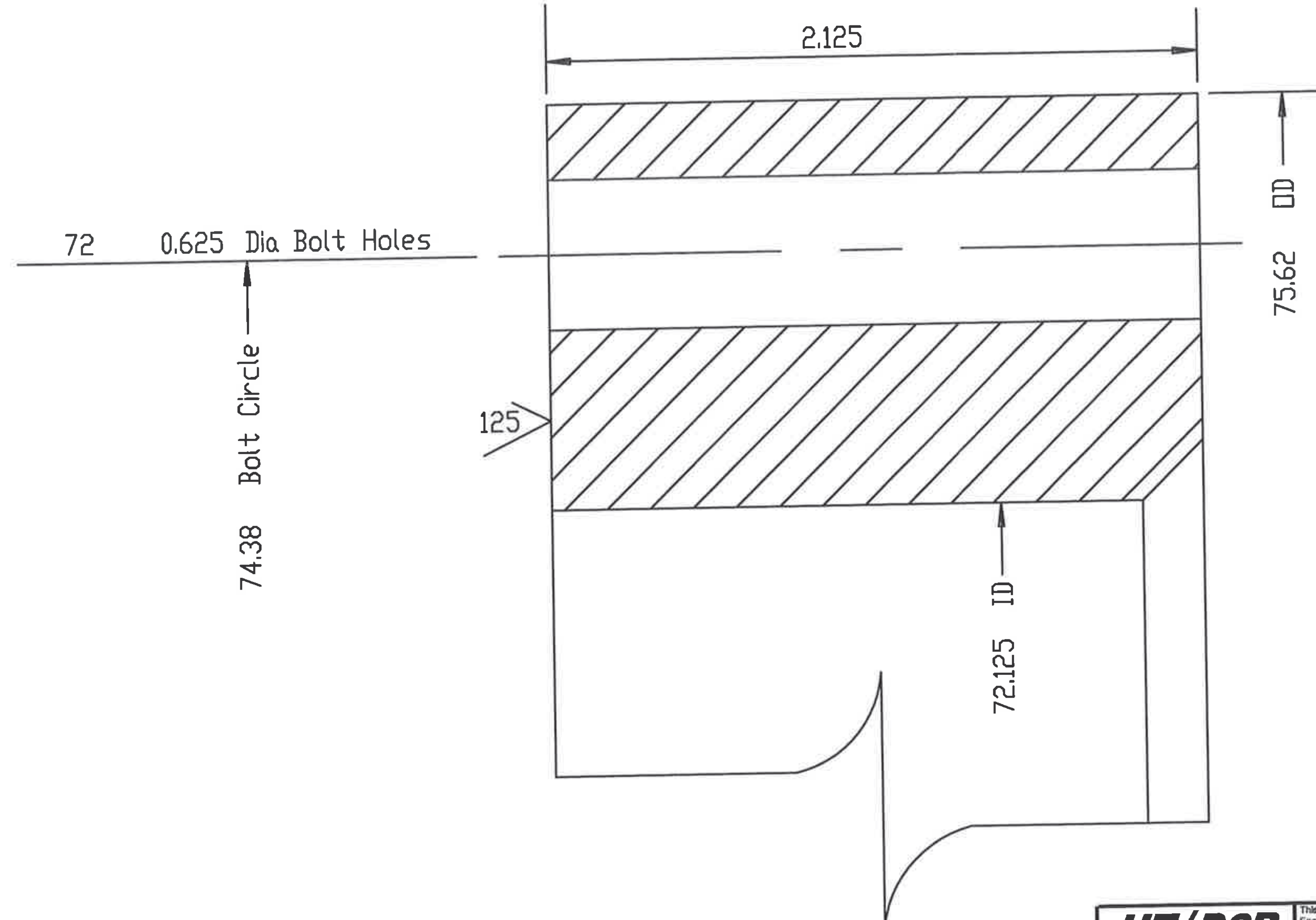
Rev:	Date:	Description	Dwg	Ckd	Appd
1	08-22-07	ISSUED FOR CONSTRUCTION	KFF	DGB	PW
2	01-09-08	CERTIFIED AS-BUILT	AGB	DGB	PW

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

Rear Head Gasket Detail

Dwg No.: E-4504 17B

Rev: 2



(19) Fr Hd Flng

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
Evaporator Condenser
Item No: E-4504
Date: May 5, 2007 Job No: 7793

DCR Construction, Inc.
Lakeland, Florida

Scale: NTS

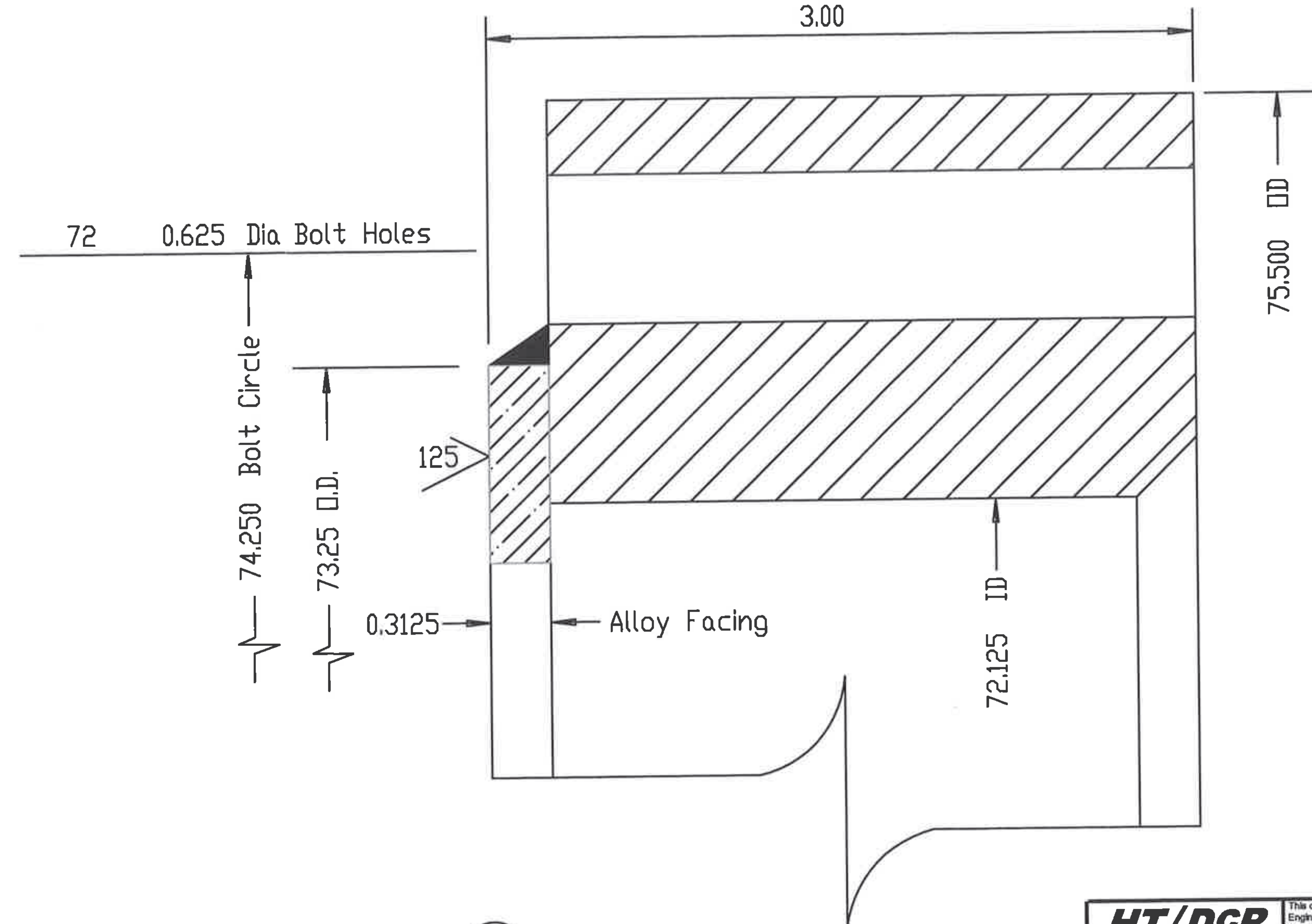
Rev:	Date:	Description	Dwg	Ckd	Appd
1	08-22-07	ISSUED FOR CONSTRUCTION	KFF	DGB	PW
2	01-09-08	CERTIFIED AS-BUILT	AGB	DGB	PW

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

Flange Detail

Dwg No.: E-4504 18A

Rev: 2



(18) Re Hd Flng

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
Evaporator Condenser
Item No: E-4504
Date: May 5, 2007 Job No: 7793

DCR Construction, Inc.
Lakeland, Florida

Scale: NTS

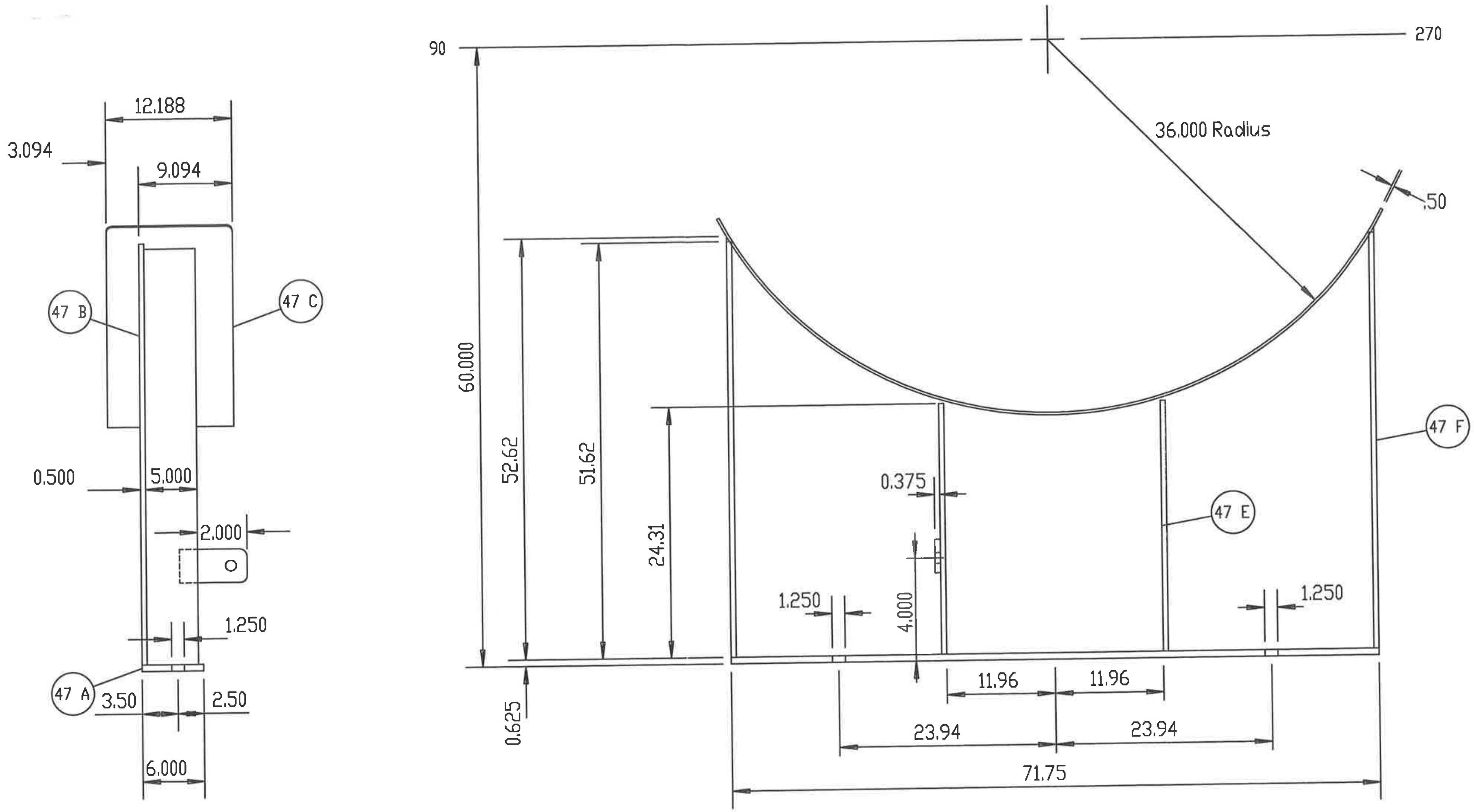
Rev:	Date:	Description	Dwg	Ckd	Appd
1	08-22-07	ISSUED FOR CONSTRUCTION	KFF	DGB	PW
2	09-25-07	CHANGED ALLOW FACING	KFF	DGB	PW
3	01-09-08	CERTIFIED AS-BUILT	AGB	DGB	PW

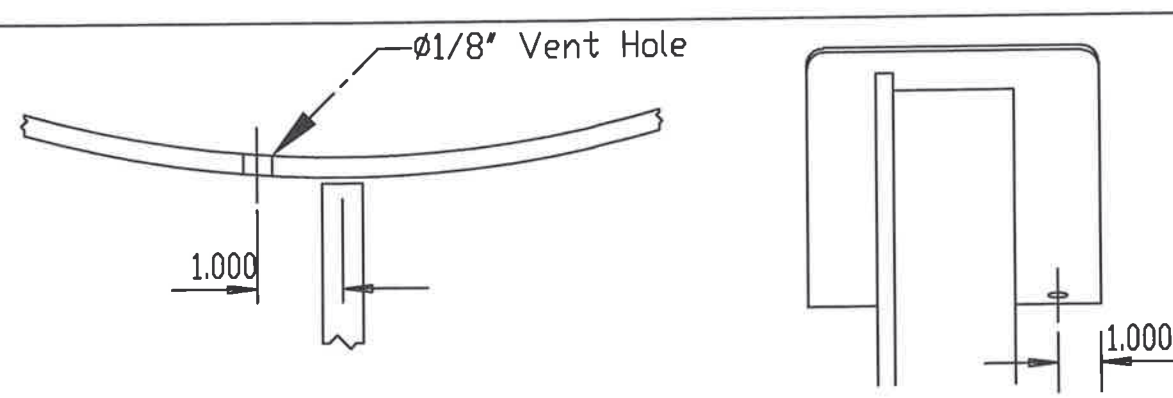
ASME VIII-1 2004 A06
TEMA Type: NEM
Size: 71-264
TEMA Class: C

Flange Detail

Dwg No.: E-4504 18B

Rev: 3





Front View

Side View

Vent Hole Detail (Not to Scale)

Notes:
All Dimensions In Inches

HT/DCR Engineering, Inc.
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Phone: 863-904-2880 • Fax: 863-913-1001
Florida Engineering Business License No. 26522

Company: DCR Construction, Inc.
Location: Bunge-Ergon
Evaporator Condenser
Item No: E-4504
Date: May 5, 2007 Job No: 7793

DCR Construction, Inc.
Lakeland, Florida

Scale: NTS

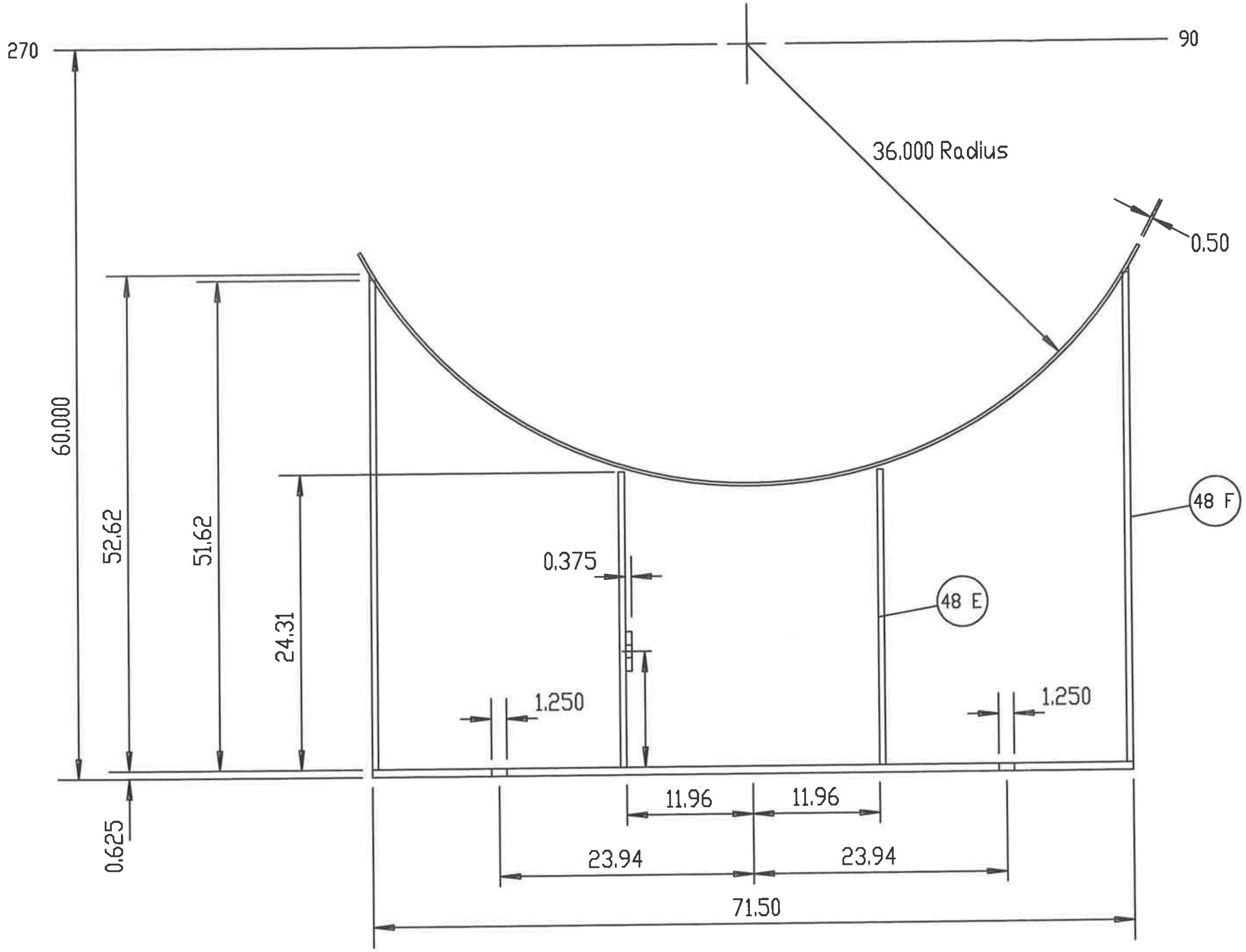
Rev:	Date:	Description	Dwg	Ckd	Appd
1	08-22-07	ISSUED FOR CONSTRUCTION	KFF	DGB	PW
2	01-09-08	CERTIFIED AS-BUILT	AGB	DGB	PW

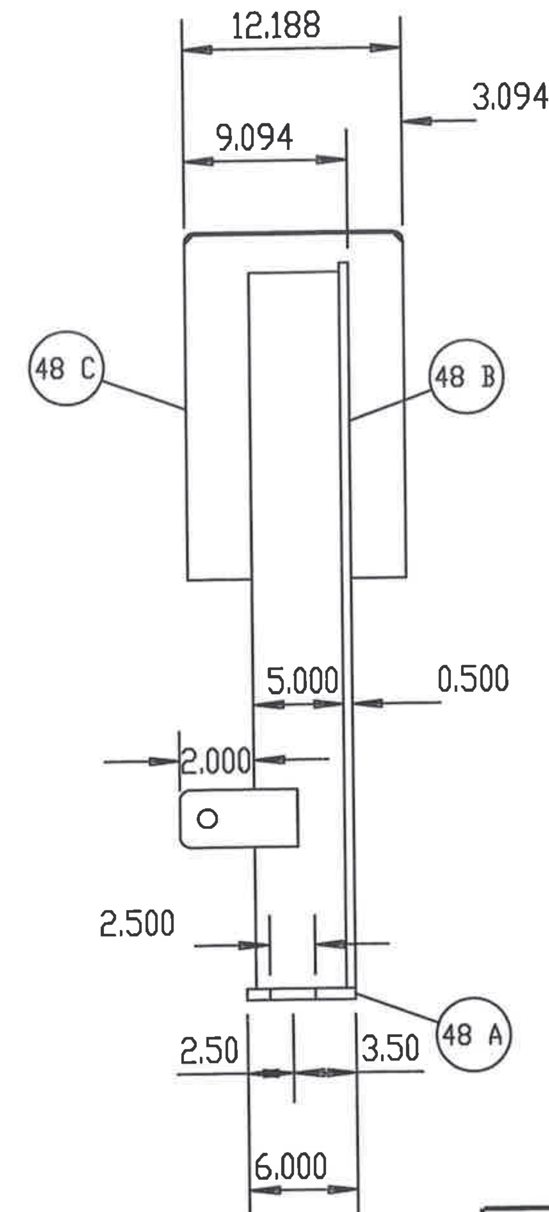
ASME VIII-1 2004 A06
TEMA Type: NEM
Size: 71-264
TEMA Class: C

SS1 Fixed Support Detail

Dwg No.: E-4504 19A

Rev: 2





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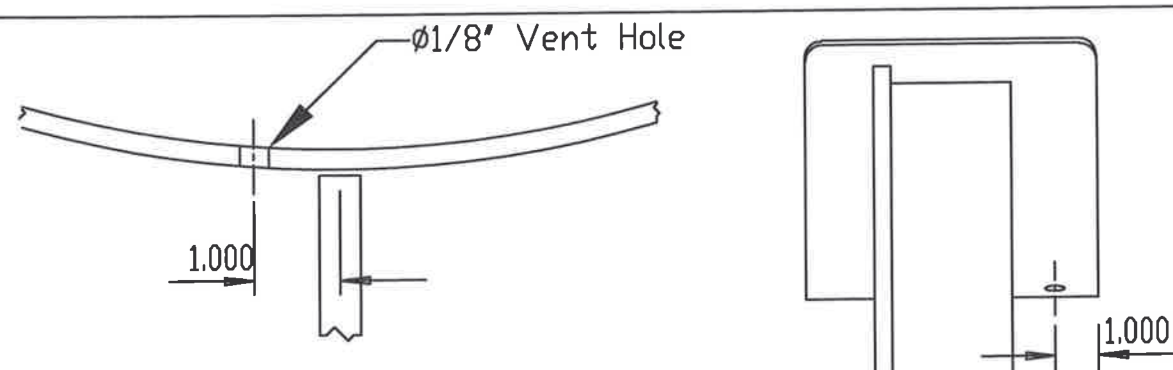
2830 Parkway Street • Lakeland, FL. 33811
Phone: 863-904-2880 • Fax: 863-913-1091
Florida Engineering Business License No. 26522



Front View   Side View

Vent Hole Detail (Not to Scale)

Notes:
All Dimensions In Inches

Company: DCR Construction, Inc.
Location: Bunge-Ergon
Evaporator Condenser
Item No: E-4504
Date: May 5, 2007 Job No: 7793

DCR Construction, Inc.
Lakeland, Florida

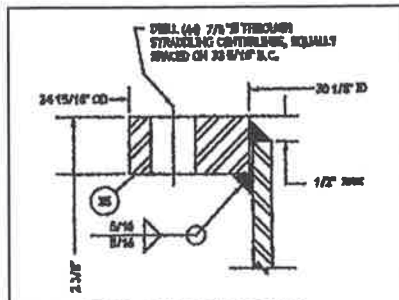
Scale: NTS

Rev:	Date:	Description	Dwg	Ckd	Appd
1	08-22-07	ISSUED FOR CONSTRUCTION	KFF	DGB	PW
2	01-09-08	CERTIFED AS-BUILT	AGB	DGB	PW

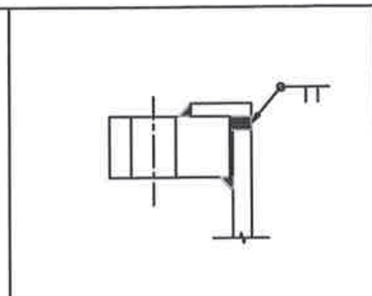
ASME VIII-1 2004 A06
TEMA Type: NEM
Size: 71-264
TEMA Class: C

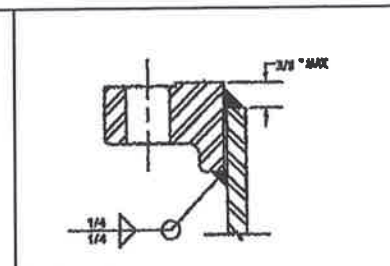
SS2,SS3,SS4 Slip Support Det.

Dwg No.: E-4504 19B
Rev: 2

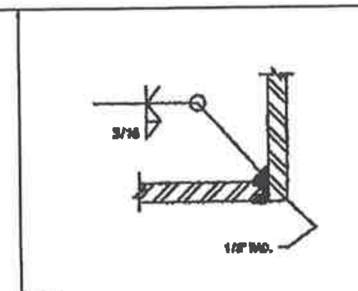


UW2.4 (3) WELD DETAIL

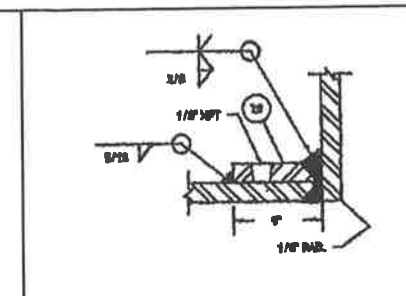




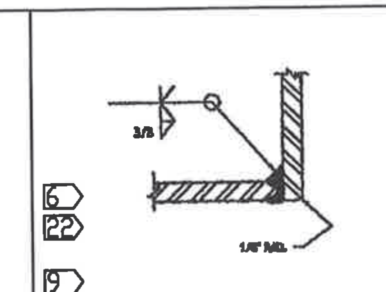
UG-40 (n)



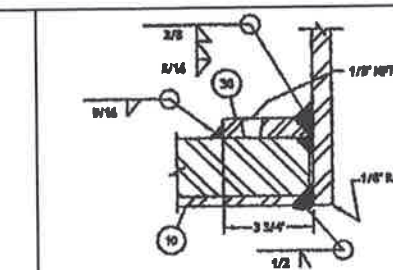
UW-16.1e WELD DETAIL



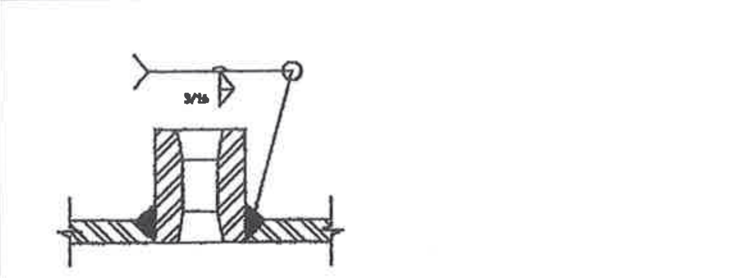
UW 16.1 (a) NOZZLE WELD DETAIL



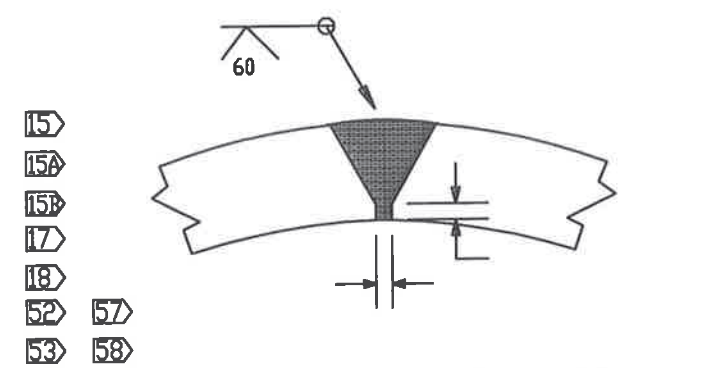
UW-16.1e WELD DETAIL



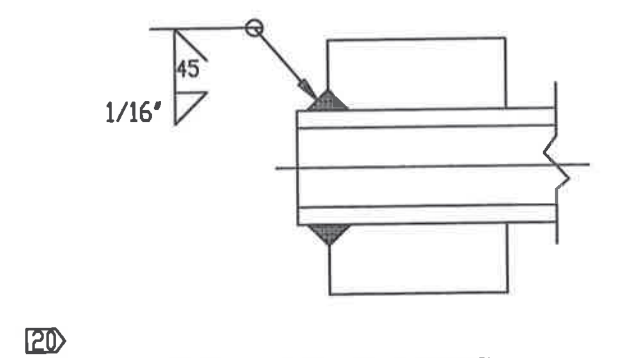
TYPICAL NOZZLE WELD DETAIL



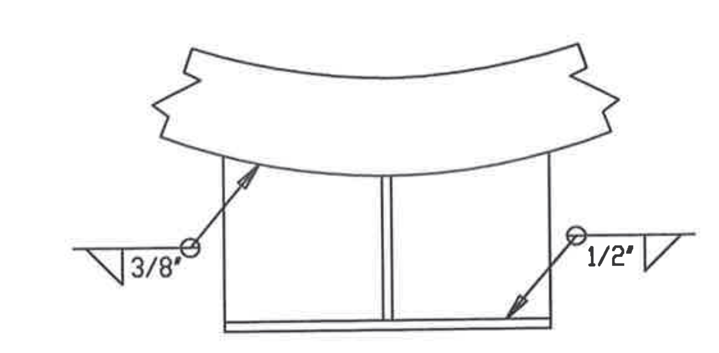
UW 16.1 (Z-1) WELD DETAIL



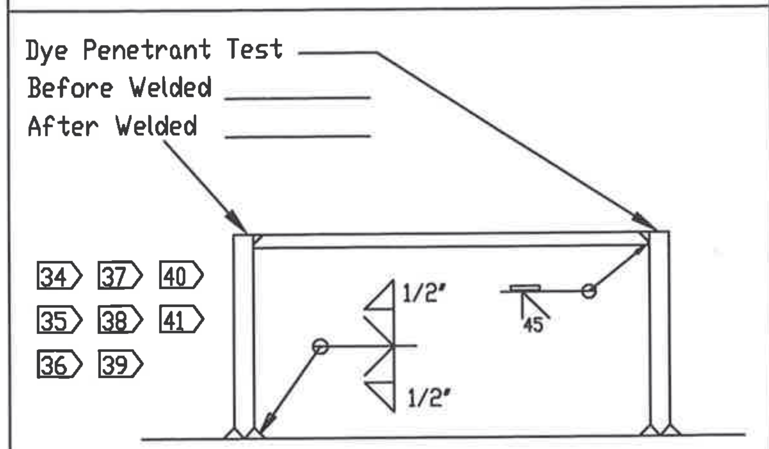
TYPICAL LONGITUDE SEAM WELD DETAIL



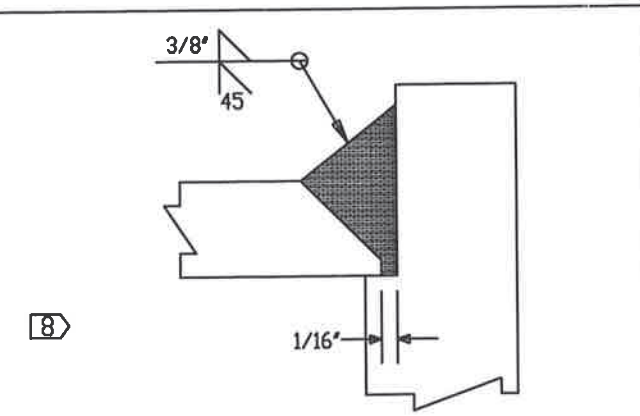
TYPICAL TUBE WELD DETAIL



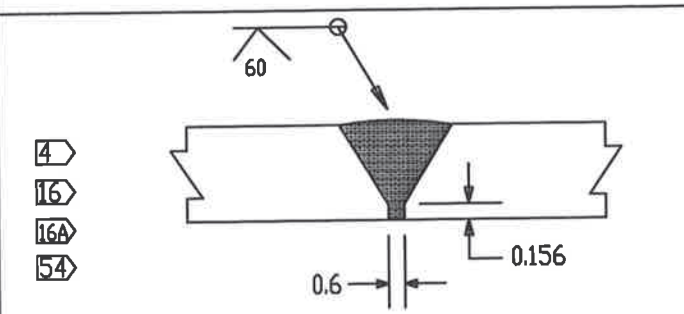
TYPICAL SUPPORT WELD DETAIL



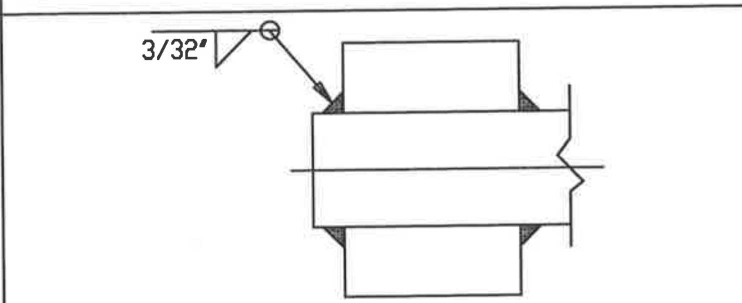
DISTRIBUTION BELT WELD DETAIL



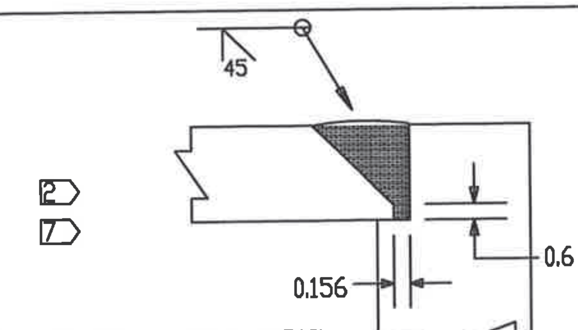
TUBESHEET/SHELL WELD DETAIL



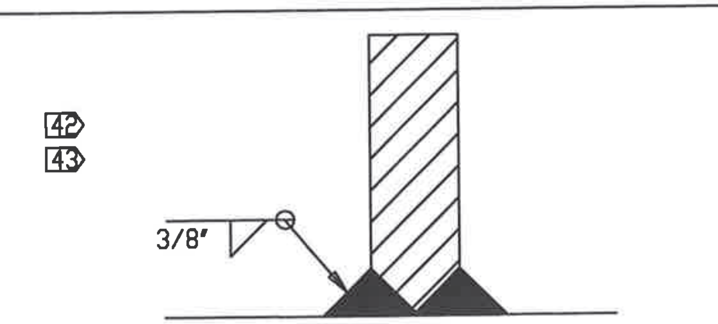
TYPICAL GIRTH WELD DETAIL



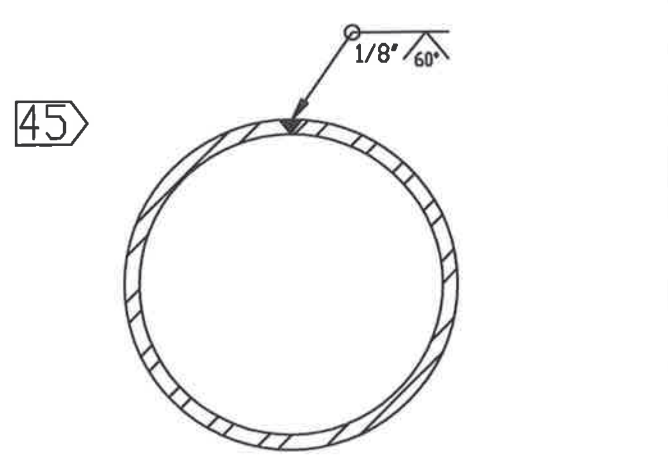
TYPICAL TIE ROD WELD DETAIL



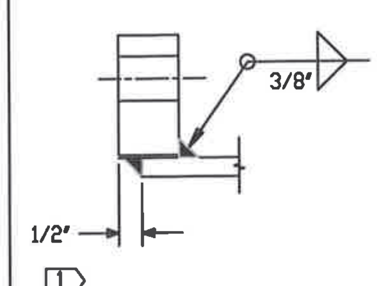
TUBESHEET/CHANNEL WELD DETAIL



TYPICAL HEAD LIFT LUG WELD DETAIL



Nozzle C Sleeve



Notes:
All Dimensions In Inches
Welding in accordance with Code

Company: DCR Construction, Inc.
Location: Bunge-Ergon
Evaporator Condenser
Item No: E-4504
Date: May 5, 2007 Job No: 7793

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

DCR Construction, Inc.
Lakeland, Florida

Scale: NTS

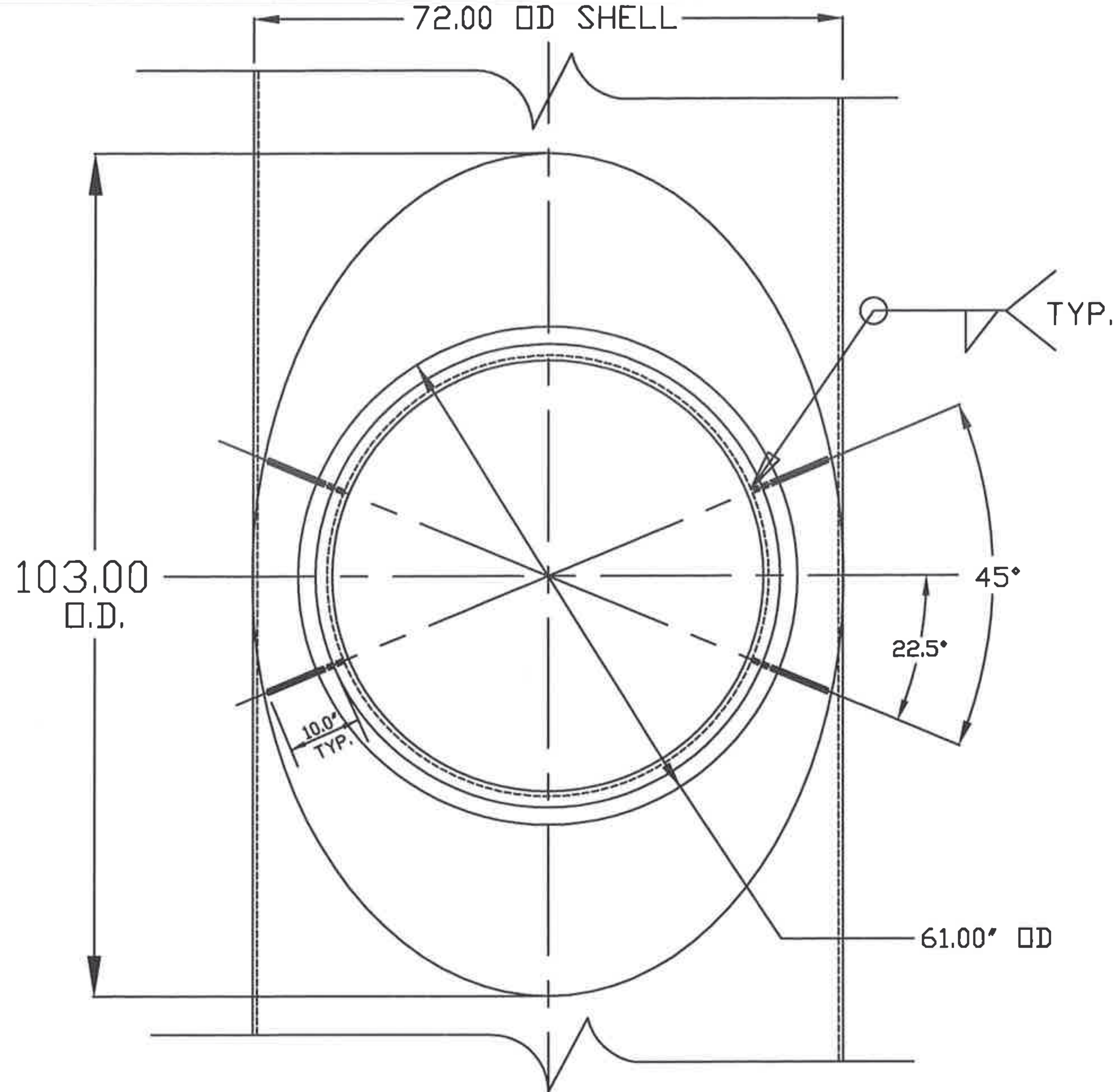
Rev:	Date:	Description	Dwg	Ckd	Appd
1	08-22-07	ISSUED FOR CONSTRUCTION	KFF	DGB	PW
2	09-18-07	Added Weld #45&Weld #s	KFF	DGB	PW
3	01-09-08	CERTIFIED AS-BUILT	AGB	DGB	PW

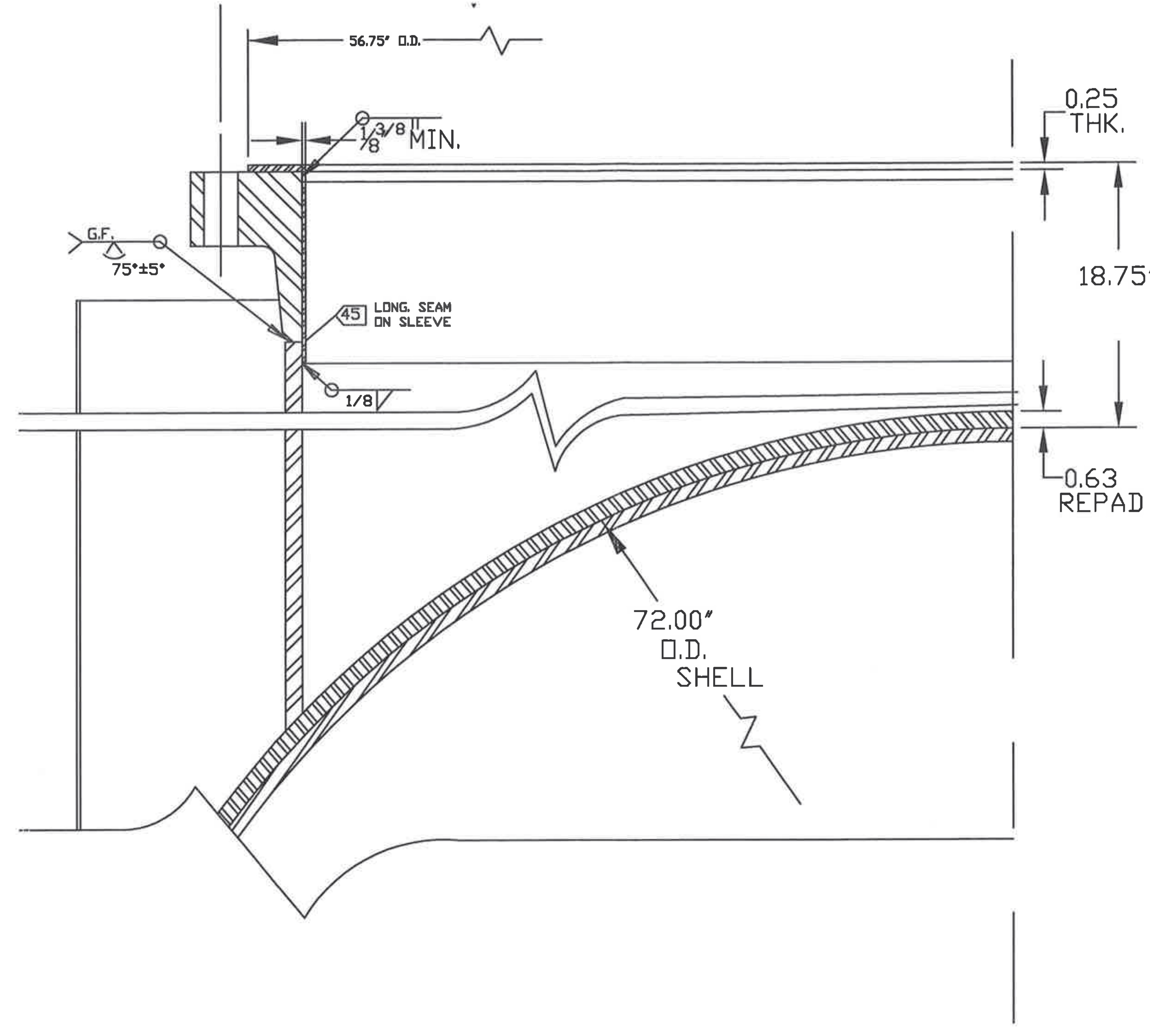
ASME VIII-1 2004 A06
TEMA Type: NEM
Size: 71-264
TEMA Class: C

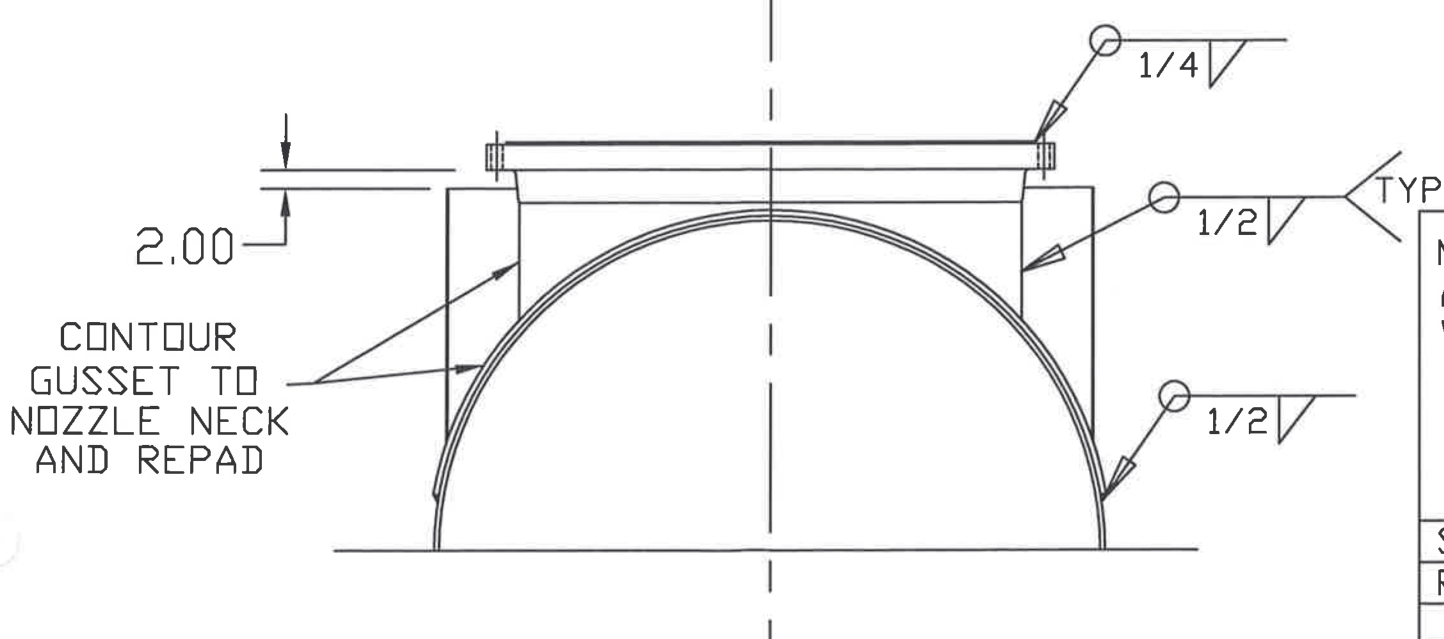
Weld Joint Detail

Dwg No.: E-4504 20

Rev: 3







Notes:
All Dimensions In Inches
Welding in accordance with Code

HT/DCR Engineering, Inc.
2830 Parkway Street • Lakeland, FL 33811
Phone: 863-904-2880 • Fax: 863-613-1091
Florida Engineering Business License No. 26522

Company: DCR Construction, Inc.
Location: Bunge-Ergon
Evaporator Condenser
Item No: E-4504
Date: May 5, 2007 Job No: 7793

DCR Construction, Inc.
Lakeland, Florida

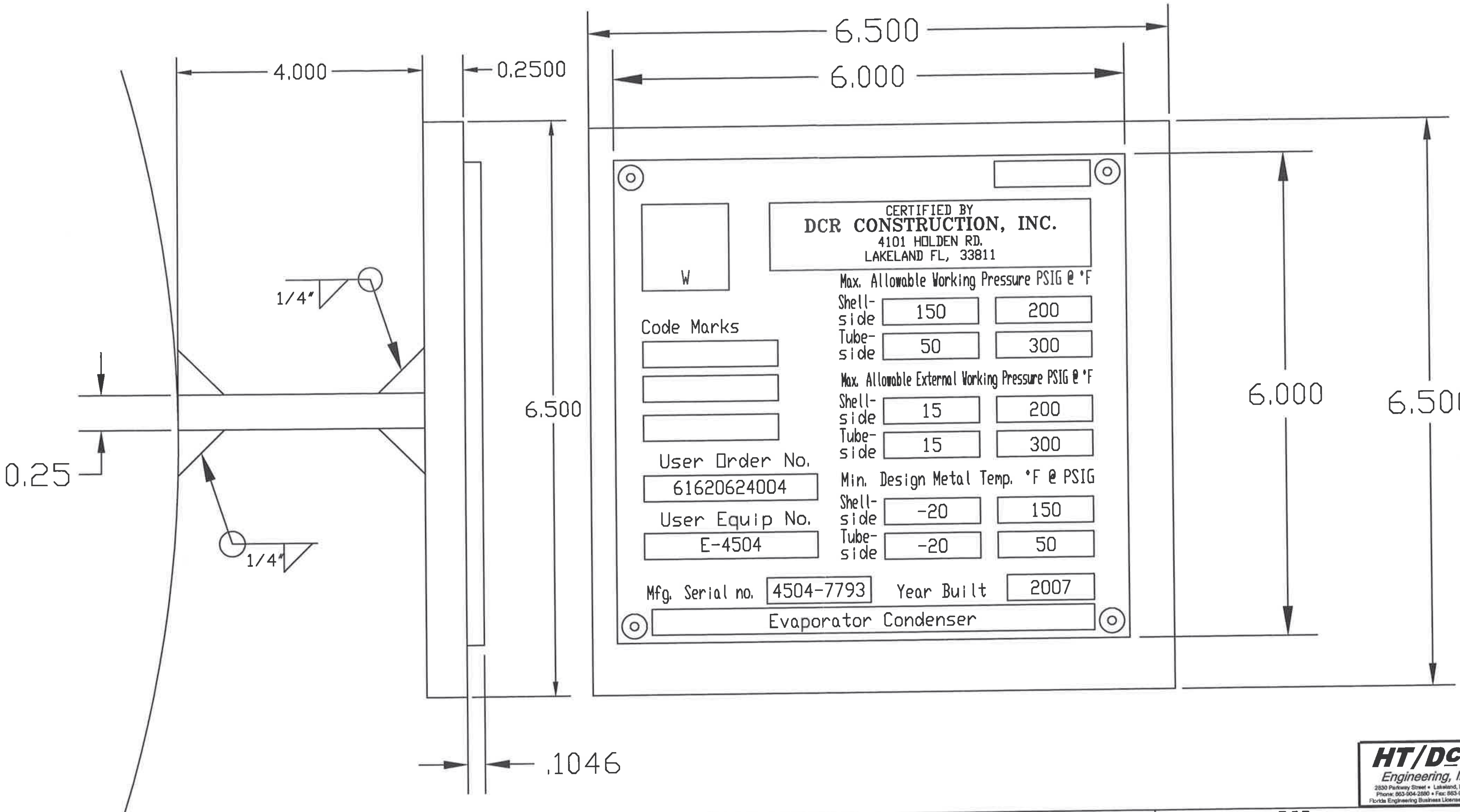
Scale: NTS

Rev:	Date:	Description	Dwg	Ckd	Appd
0	09-18-07	ISSUED FOR CONSTRUCTION	KFF	DGB	PW
1	01-09-08	CERTIFIED AS-BUILT	AGB	DGB	PW

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

NOZZLE "C" WELD DETAIL

Dwg No.: E-4504 20A
Rev: 1



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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
Evaporator Condenser
Item No.: E-4504
Date: February 17, 2007 Job No.: 7793

DCR Construction, Inc
Lakeland, FL

Scale: NTS

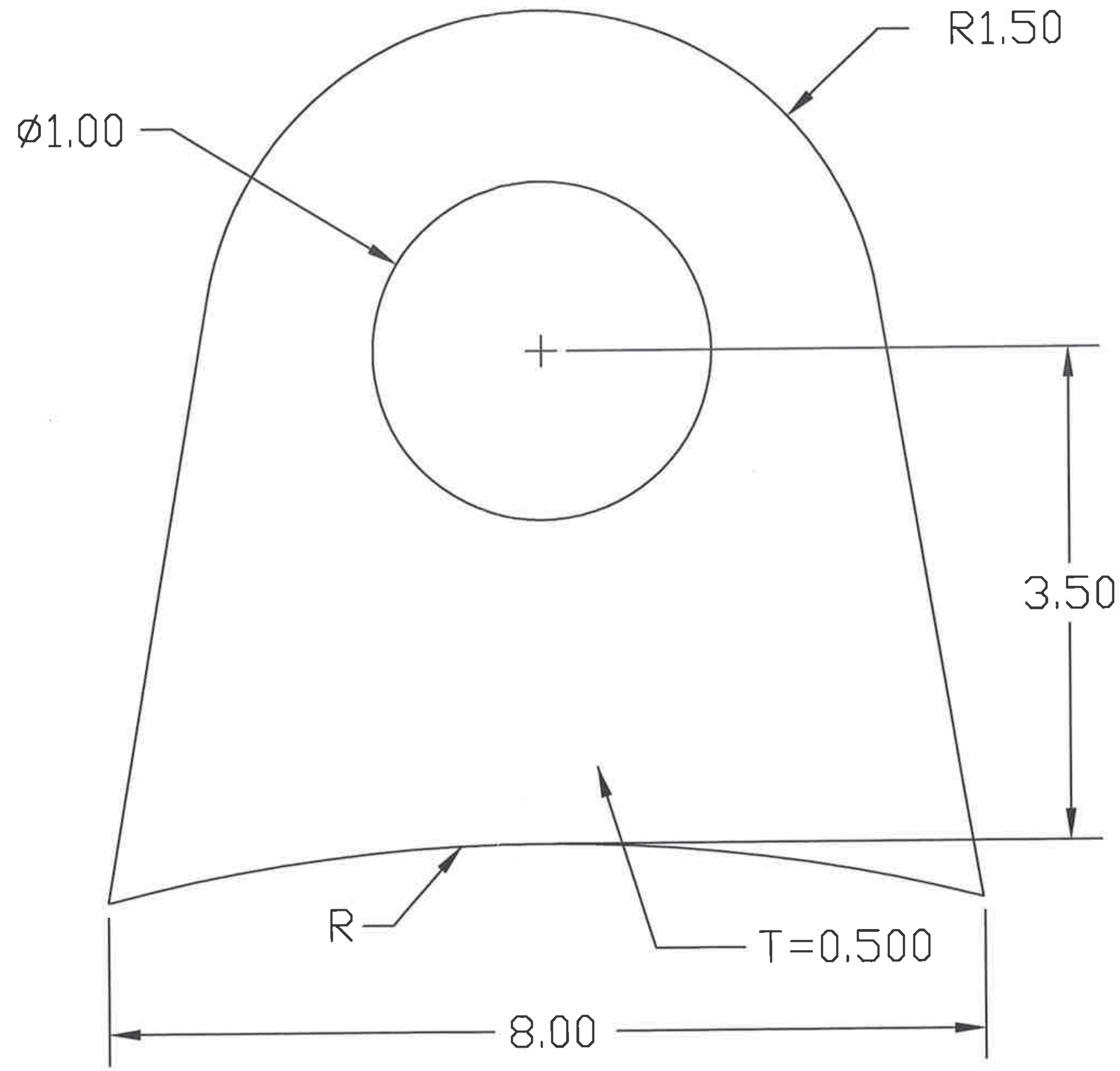
Rev:	Date:	Description	Dwg	Ckd	Appd
1	08-22-07	ISSUED FOR CONSTRUCTION	KFF	DGB	PW
2	01-09-08	CERTIFIED AS-BUILT	AGB	DGB	PW

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

Code Data Plate

Dwg No.: E-4504 22

Rev: 2



LUG	R
FLAT COVER	37.81″
REAR HEAD	37.75″

FLAT COVER AND HEAD
LIFTING LUG
2 REQUIRED-(1) FLAT COVER
(1) REAR HEAD

Notes:
All Dimensions In Inches

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

Company: DCR
Location: Bunge-Ergon
Evaporator Condenser
Item No.: E-4504
Date: March 24, 2007 Job No.: 7793

DCR Construction, Inc
Lakeland, FL

Scale: NTS

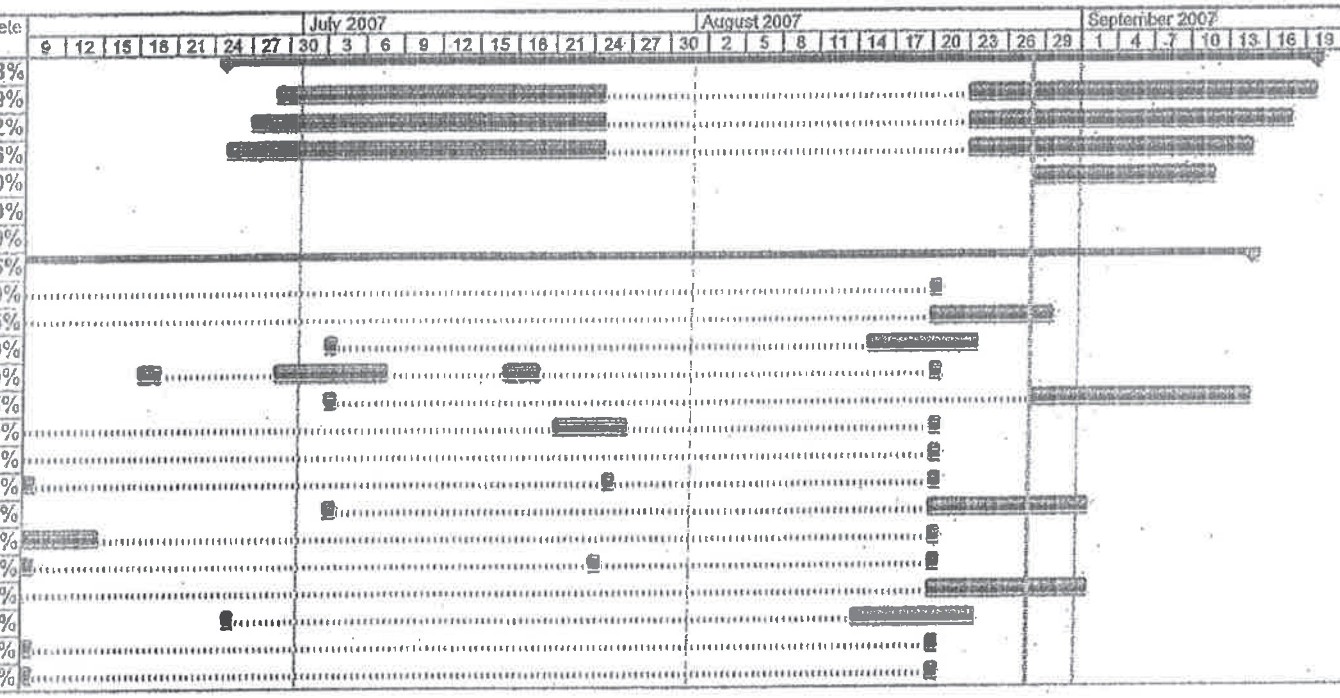
Rev:	Date:	Description	Dwg	Ckd	Appd
1	08-22-07	ISSUED FOR CONSTRUCTION	KFF	DGB	PW
2	01-09-08	CERTIFIED AS-BUILT	AGB	DGB	PW

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

Lifting Lug Detail

Dwg No.: E-4504 23
Rev: 2

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



Heat Exchanger Specification Sheet

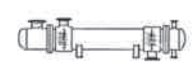
Company: DELTA-T CORPORATION	Phone: (757) 220-2955		
Location: WILLIAMSBURG, VIRGINIA	Fax: (757) 229-1705		
Service of Unit: EVAPORATOR CONDENSER			L2357 REV C
Item No.: E4504-L	Your Reference: 50MM GPY		Job No.: 61310 Bunge-Ergon Vicksburg, LLC
Date: 6 February 2007	Prepared by: RS	Checked by: AC	
Size 71 / 264 in	Type NEM hor	Connected in 1 parallel	1 series
Surf/unit(eff.) 12595.5 ft2	Shells/unit 1	Surf/shell (eff.) 12595.5	ft2

PERFORMANCE OF ONE UNIT

		Shell Side		Tube Side	
Fluid allocation		Shell Side		Tube Side	
Fluid name		COOLING WATER		EVAPORATOR COND.	
Fluid quantity, Total	lb/h	3532100		67574	
Vapor (In/Out)	lb/h			67481	104
Liquid	lb/h	3532100	3532100		67377
Noncondensable	lb/h			93	
Temperature (In/Out)	F	88	108	130.7	105
Dew / Bubble point	F			124.63	
Density	lb/ft3	62.241	62.031	0.005	62.021
Viscosity	cp	0.781	0.628	0.011	0.655
Molecular wt, Vap				18.02	21.95
Molecular wt, NC					28.96
Specific heat	BTU/(lb*F)	1.0007	1.0001	0.4596	1.0003
Thermal conductivity	BTU/(ft*h*F)	0.352	0.36	0.012	0.358
Latent heat	BTU/lb			1025.5	1034.9
Pressure	psi	60		1.9	
Velocity	ft/s	3.93		268.82	
Pressure drop, allow./calc.	psi	15	10.196	0.2	0.163
Fouling resist. (min)	ft2*h*F/BTU	0.001		0.0005	
Heat exchanged	70667330 BTU/h			MTD corrected 20.62	F
Transfer rate, Service	272.1	Dirty 278.18		Clean 487.27	BTU/(h*ft2*F)

CONSTRUCTION OF ONE SHELL | **Sketch**

			Shell Side	Tube Side
Design/Test pressure		psi	150 / Code	50 / Code
Design temperature		F	200	300
Number passes per shell			1	1
Corrosion allowance		in	0.0625	
Connections	In		30 / 150 ANSI	54 / 150 ANSI
Size/rating	Out		30 / 150 ANSI	6 / 150 ANSI
in	Intermediate		/ 150 ANSI	/ 150 ANSI



Tube No. 1785	OD 1.25	0.049 in	Length 22 ft
Pitch 1.5625 in			
Tube type Plain	Material SS304	Tube pattern 30	
Shell CS	ID OD 72 in	Shell cover	
Channel or bonnet SS304		Channel cover	
Tubesheet-stationary SS304		Tubesheet-floating	
Floating head cover		Impingement protection	None
Baffle-crossing CS	Type double seg Cut(%d) 30 vert	Spacing: c/c 17.875	in
Baffle-long	Seal type	Inlet 40	in
Supports-tube	U-bend	Type	
Bypass seal	Tube-tubesheet joint	strength weld	
Expansion joint	Type		
RhoV2-Inlet nozzle 711	Bundle entrance 861	Bundle exit 864	lb/(ft*s2)
Gaskets - Shell side	Tube Side		
Floating head			
Code requirements	ASME Code Sec VIII Div 1	TEMA class	C
Weight/Shell 54108.1	Filled with water 109888.7	Bundle 36768.9	lb
Remarks	Design basis is 120% of nominal capacity.		
	Test run cooling water inlet temp at 88°F. Require 122.8% larger surface area than the standard unit.		

FORM U-1 MANUFACTURER'S DATA REPORT FOR PRESSURE VESSELS
As Required by the Provisions of the ASME Code Rules, Section VIII, Division 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: Horizontal (Horiz, vert., or sphere) — Condenser (Tank, separator, jkt. vessel, heat exh, etc.) — 4504-7793 (Mfr's serial No.)

_____ (CRN) — 4504-01 to 4504-23 (See Details) (Drawing No.) — 238 (Nat'l Bd No.) — 2008 (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.): 21' 9 5/16"

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
2	72" OD	5' 9 ½"	SA-516 GR70	0.500"	0.0625"	1	None	0.70	1	None	0.70		
1	72" OD	10' 2 5/16"	SA-516 GR70	0.500"	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 bar, give dimensions _____ If bolted, describe or sketch

9. MAWP 150 psig (internal) 15 (external) psig at max temp. 200 (internal) °F 200 (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.)] — 72" [Dia., In. (subject to press.)] — 1.5" (Nom. thk., in.) — 0 (Corr. Allow., in.) — Welded [Attachment (welded or bolted)]

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

13. Tubes SA-249 TP304 Wld Tube (Mat'l Spec. No., Grade or Type) — 1.25" (O.D., in.) — 0.049" (Nom. thk., in. or gauge) — 1785 (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): 3 (b) Overall Length (ft & in.): 12' 8 1/2"

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	72" OD	8' 5"	SA-240 GR304	0.500"	0	1	None	0.70	1	None	0.70		
1	72" OD	2'	SA-240 GR304	0.500"	0	1	None	0.70	1	None	0.70		
1	72" OD	27 ½"	SA-240 GR304	0.500"	0	1	None	0.70	1	None	0.70		

15. Heads: (a) SA-516 GR 70 SA-240-304 Clad (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)	Front	2.1049	0						75 5/8"		Flat			
	Rear	0.1358	0			80:10					X			0.85

If removable, bolts used (describe other fastenings) SA-193 GRB7 7/8" (228)
(Mat'l Spec. No. Grade, size, No.)

Form U-1 (Back)

16. MAWP 50 psig (internal) 15 (external) psig at max temp. 300 (internal) °F 300 (external) °F Min. design metal temp. -20 °F at 50 psig

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

18. Hydro., pneu., or comb. test press. 65 psig Proof Test N/A

19. Nozzles, inspection, and safety valve openings:

Purpose (Inlet, Outlet, Drain, etc)	No.	Diameter or Size	Flange Type	Material		Nozzle Thickness		Reinforcement Material	How Attached		Location (Insp. Open.)
				Nozzle	Flange	Nom.	Corr.		Nozzle	Flange	
CW Inlet/Outlet	2	30"	RFSO	SA-516 GR70	SA-105	0.500"	0.0625"	Inherent	UW-16.1	Welded	Vapor Belt
Vapor Inlet	1	54"	FFWN	SA-240 304	SA-105	0.0625"	0.0625"	SA-240 GR304 0.375	UW-16.1	Welded	Front Channel
Vapor Outlet	1	6"	RFSO	SA-312 304	SA-182 304	0.280"	0	Inherent	UW-16.1	Welded	Rear Channel
Non. Cond. Outlet	1	6"	RFSO	SA-312 304	SA-182 304	0.280"	0	Inherent	UW-16.1	Welded	Rear Channel
Tubeside Inlet	1	4"	RFSO	SA-312 304	SA-182 304	0.337"	0	Inherent	UW-16.1	Welded	Rear Channel
Tubeside Inlet	1	3"	RFSO	SA-312 304	SA-182 304	0.300"	0	SA-516 GR70 0.750	UW-16.1	Welded	Front Cover
Spare Port	2	2"	RFSO	SA-53B	SA-105	0.344"	0.0625"	Inherent	UW-16.1	Welded	Shell
Coupling	2	0.5" NPT	CPLG	SA-182	N/A	3000#	0	Inherent	UW-16.1	Welded	Channels

20. Supports: Skirt ______ (Yes or No) Lugs ______ (No.) Legs 4 (No.) Others ______ (Describe) Attached Welded, Bottom (Where and How)

21. Manufacturer's Partial Data Reports properly identified and signed by Commissioned Inspectors have been furnished for the following items of the report: (List the name of part, item number, mfr's name and identifying number)

22. Remarks 4504-01A Rev 4 4504-01B Rev 4 4504-02 Rev 4 4504-03 Rev 4 4504-04 Rev 3 4504-05 Rev 2 4504-06 Rev 5 4504-07 Rev 4 4504-08 Rev 5 4504- 09 Rev 3 4504-11 Rev 3 4504-12 Rev 2 4504-13 Rev 3 4504-14 Rev 2 4504-15 Rev 2 4504-17A Rev 2 4504-17B Rev 2 4504-18A Rev 2 4504-18B Rev 3 4504-19A Rev 2 4504-19B Rev 2 4504-20 Rev 3 4504-20A Rev 1 4504-22 Rev 2 4504-23 Rev 2

CERTIFICATE OF SHOP COMPLIANCE

We certify that the statements in this report are correct and that all details of design, material, construction and workmanship of this vessel conform to the ASME Code for Pressure Vessels, Section VIII, Division 1.

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

Date 1/11/08 Name DCR Construction, Inc. (Manufacturer) Signed D. O Cel (Representative)

CERTIFICATE OF SHOP INSPECTION

I, the undersigned, holding a valid commission issued by the National Board of Boiler and Pressure Vessel Inspectors and/or the State or Province of Florida and employed by ARISE, Inc of Brecksville, OH have inspected the pressure vessel described in this Manufacturer's Data Report on 1-11-2008 and state that, to the best of my knowledge and belief, the Manufacturer has constructed this pressure vessel in accordance with ASME Code, Section VIII, Division 1. By signing this certificate neither the Inspector nor his employer makes any warranty, expressed or implied, concerning the pressure vessel described in this Manufacturer's Data Report. Furthermore, neither the inspector nor his employer shall be liable in any manner for any personal injury or property damage or a loss of any kind arising from or connected with this inspection.

Date 1-11-2008 Signed Raymond Anglen (Authorized Inspector) Commissions 5489 A+B FL 442 (Nat'l Board incl endorsements State, Province and No)

CERTIFICATE OF FIELD ASSEMBLY COMPLIANCE

We certify that the statements on this report are correct and that the field assembly construction of all parts of this vessel conforms with the requirements of ASME Code Section VIII, Division 1. U Certificate of Authorization No. ______ Expires ______

Date ______ Name ______ (Assembler) Signed ______ (Representative)

CERTIFICATE OF FIELD ASSEMBLY INSPECTION

I, the undersigned, holding a valid commission issued by the National Board of Boiler and Pressure Vessel Inspectors and/or the State or Province of ______ and employed by ______ of ______, have compared the statements in this Manufacturer's Data Report with the described pressure vessel and state that parts referred to as data items ______, not included in the certificate of shop inspection, have been inspected by me and to the best of my knowledge and belief, the Manufacturer has constructed this pressure vessel in accordance with ASME Code, Section VIII, Division 1. The described vessel was inspected and subjected to a hydrostatic test of ______ psi By signing this certificate neither the inspector nor his employer makes any warranty, expressed or implied, concerning the pressure vessel described in this Manufacturer's Data Report. Furthermore, neither the inspector nor his employer shall be liable in any manner for any personal injury or property damage or a loss of any kind arising from or connected with this inspection.

Date ______ Signed ______ (Authorized Inspector) Commissions ______ (Nat'l Board incl endorsements State, Province and 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 Horizontal (Horiz., vert., or sphere) Condenser (Tank, separator, heat exh., etc.) 4504-7793 (Mfg's serial No.)
N/A (CRN) 4504-01 to 4504-23 (Drawing No.) 238 (Nat'l Bd No.) 2008 (Year built)

Data Report Item Number	Remarks
#6	(2) Partial Vapor Belt sections diameter 89.5", length 47", material SA-516 GR70 Thickness .750"
	Long. Joint Cat. A Type 1, none, 0.70 circumference joint Cat. A, B, & C, type 1 & 2*, none, 0.70
	Includes closing ring material SA 516 GR70 Thickness 1.00" Joint UW 31.1C located at top of shell, each end.
#12	Tubesheet SA-240 GR304 75.5" 1.5" 0 Welded

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

Date 1/11/08 Name DCR Construction, Inc. (Manufacturer) Signed [signature] (Representative)

Date 1-11-2008 Name [signature] (Authorized Inspector) Commission 5789 IAB FL 11/4/12 (Nat'l Board incl. Endorsement, State, Province and No.)

DCR Construction, Inc.

EXHIBIT 11

PRESSURE TEST REPORT

Utility/Plant 7793-4504 Tube Side Job No. 7793

Material Specification SA-249, Gr. 304

Pipe Size Range 1.25" Diameter Wall Thickness Range 0.049"

Design Pressure 50 psig PSI Test Pressure 65 psig

* Tubesheets = (Front)@ 72" x 1.5",(Rear)@ 75.5" x 1.5", SA-240, Gr. 304

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

Pressure Gauges Serial No. 3701-14 Max. Range 0-200 PSI ☆ Calibration Date 11/26/07

Pressure Gauges Serial No. ______ Max. Range ______ PSI ☆ Calibration Date ______

☆ 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 Position Horizontal

Project Manager/Superintendent Daniel Parker Date 1-11-08

Q.C. Inspector [signature] Date 1/11/08

Authorized Inspector Raymond Snyder Date 1-11-08

Customer Inspector ______ Date ______

DCR Construction, Inc.

EXHIBIT 11

PRESSURE TEST REPORT

Utility/Plant 7793-4504 Shell Side Job No. 7793

Material Specification SA-516 Grd. 70

Pipe Size Range 72" Diameter (O.D.) Wall Thickness Range .500"

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. ______ Max. Range ______ PSI ☆ Calibration Date ______

☆ 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 ______ Minutes 15

Remarks ______

Test Results Acceptable

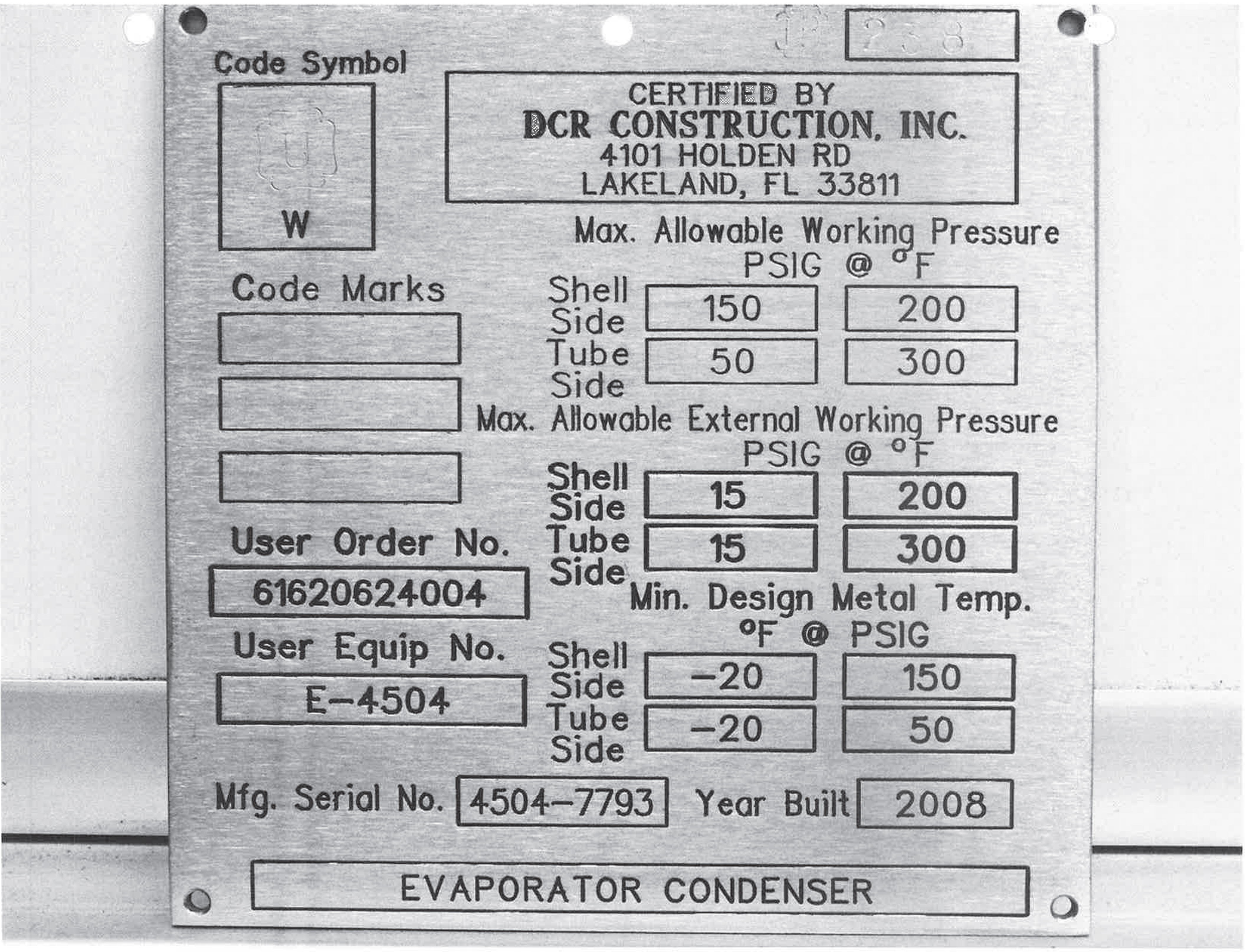
Position Horizontal

Project Manager/Superintendent Daniel [signature] Date 1-11-08

Q.C. Inspector [signature] Date 1/11/08

Authorized Inspector [signature] Date 1-11-08

Customer Inspector ______ Date ______


Code Symbol
W
CERTIFIED BY
DCR CONSTRUCTION, INC.
4101 HOLDEN RD
LAKELAND, FL 33811
Max. Allowable Working Pressure
PSIG @ °F
Shell Side 150 200
Tube Side 50 300
Code Marks
Max. Allowable External Working Pressure
PSIG @ °F
Shell Side 15 200
Tube Side 15 300
User Order No.
61620624004
Min. Design Metal Temp.
°F @ PSIG
User Equip No.
E-4504
Shell Side -20 150
Tube Side -20 50
Mfg. Serial No. 4504-7793
Year Built 2008
EVAPORATOR CONDENSER

Design Specifications

TEMA Class		Shell Side	Tube Side	Tubesheets
Design pressure	psi	150	50	
Vacuum design pressre	psi	15	15	
Test pressure	psi	195	65	
Design temperature	F	200	300	300
Average metal temperature	F	94	105	105
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	
Weights	**Empty:**63547	**Full:**122848	**Bundle:**30877	**lbf**

Cylinders/Covers

		Front Head		Shell	Rear Head		Shell Cover		Tubes
		Cover	Cyl.	Cyl.	Cyl.	Cover	Cyl.	Cover	
Head type		Flat bolted				Ellipsoidal			
Outside diameter	in	75.625	72	72	72	72			1.25
Calculated thk.	in	2.4301	0.1358	0.4466	0.1358	0.1118			0.0032
TEMA minimum thk.	in		0.3125	0.5	0.3125	0.3125			
Actual thickness	in	2.8125	0.375	0.5	0.3125	0.3125			0.049
X-ray			None	None	None	None			
Joint efficiency			None	None	None	None			
Corrosion allowance	in			0.0625					
External pressure	psi		15	15	15	15			165
Length Ext.Press.	in		127.3125	215.1	27.75				264
Maximum Ext.Press.	psi		25.7	23.887	43.903	29.99			463.726
Minimum thk. Ext.Press.	in		0.303	0.429	0.161	0.196			0.027
Max.length Ext.Press.	in		212.5	332	137.5				800

Nozzles

Nozzle designator		A	B	C	D	E	G	H
Vessel side		Shell	Shell	Tube	Tube	Tube	Tube	Tube
Outside diameter	in	30	30	54	6.625	6.625	4	3.5
Calculated thickness	in	0.2225	0.2225	0.114	0.0471	0.0471	0.0494	0.0439
Code minimum thk	in	0.3906	0.3906	0.114	0.1301	0.1301	0.1373	0.2265
Actual thickness	in	0.5	0.5	0.375	0.28	0.28	0.337	0.3
Reinf.pad OD	in			76				8
Reinf.pad thickness	in			0.375				0.1875
Corrosion allowance	in	0.0625	0.0625					
External pressure	psi	15	15	15	15	15	15	15
Length ext. press.	in	10	10	17.75	6	6	6	6
Maximum ext. press.	psi	337.032	337.032	91.809	582.329	582.329	1197.307	1209.205

Nozzle Flanges

Nozzle designator		A	B	C	D	E	G	H
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	38.75	38.75	66.25	11	11	8.5	7.5
Bolt circle	in	36	36	62.75	9.5	9.5	7	6
Bolt diameter	in	1.25	1.25	1.75	0.75	0.75	0.625	0.625
Bolt number	in	28	28	44	8	8	8	4
Gasket OD	in	33.75	33.75	59.5	8.5	8.5	5.5	5
Gasket width	in				0.94	0.94	0.75	0.75
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	2.12	2.12	4.75	1	1	0.94	0.94
Lap jnt ring OD	in							
Hub length	in							
Hub slope	in							
Weld height	in							

Body Flanges

		Front Head		Shell		Rear Head		Shell
		Cover	at TbSh	Front	Rear	at TbSh	Cover	Cover
Flange type		Ring				Ring with overlay		
Flange OD	in	75.625				75.5		
Bolt circle	in	74.375				74.25		
Bolt diameter	in	0.5				0.5		
Bolt number		72				72		
Gasket OD	in	73.375				73.25		
Gasket width	in	0.5				0.5		
Gasket thk.	in	0.125				0.125		
Flange calc. thk.	in	2.125				2.6875		
Flange overlay	in					0.25		
Recess	in							
Flange act. thk.	in	2.125				2.9375		
Lap jnt ring OD	in							
Hub length	in							
Hub slope	in							
Weld height	in	0.5625				0.5		

Tubesheets

		Front	Rear
Tubesheet diameter	in	72	75.5
TEMA minimum thickness	in	0.875	0.875
TEMA bending thickness	in	1.9892	1.9892
TEMA shear thickness	in	0.2128	0.2128
TEMA flange extension thk	in		0.6304
TEMA effective thickness	in	2	2
Code thickness	in	1.5	1.5
Corrosion allowance - shell	in		
Corrosion allowance - tube	in		
Recess	in		
Actual thickness	in	1.5	1.5
Clad thickness (not included above)	in		

Tube Details

Tube type		Plain
Tube OD	in	1.25
Tube wall thickness	in	0.049
Number of tubes		1785
Tube length	in	264
Tube pitch	in	1.5625
Tube pattern		30
Outer tube limit diameter	in	70.375

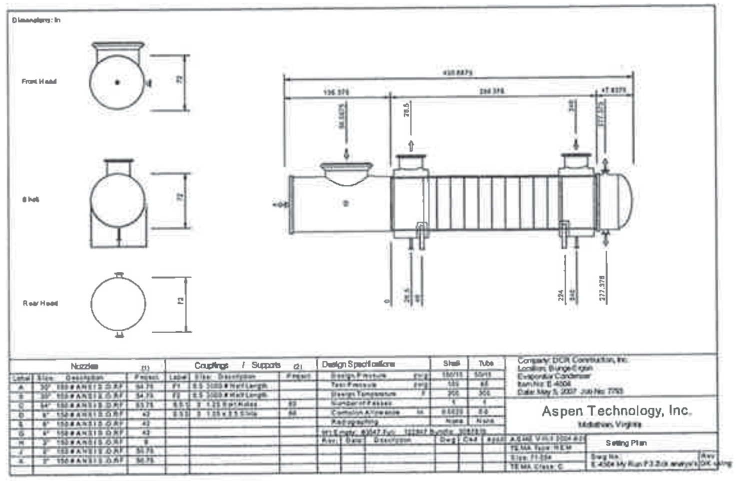
Materials of Construction

Component	Material
Shell Cylinder	SA-516 K02700 Grd 70 Plate
Front Head Cylinder	SA-240 S30400 Grd 304 Plate(G5)
Rear Head Cylinder	SA-240 S30400 Grd 304 Plate(G5)
Front Head Cover	SA-516 K02700 Grd 70 Plate
Rear Head Cover	SA-240 S30400 Grd 304 Plate(G5)
Front Head Lifting Lugs	SA-285 K02801 Grd C Plate
Shell Lifting Lugs	SA-285 K02801 Grd C Plate
Front Tubesheet	SA-240 S30400 Grd 304 Plate
Rear Tubesheet	SA-240 S30400 Grd 304 Plate
Rear Head Flng At TS	SA-516 K02700 Grd 70 Plate
Front Head Flng At Cov	SA-516 K02700 Grd 70 Plate
Rear Head Gasket At TS	Solid Teflon 1/8in Thickness
Front Head Gasket At Cov	Solid Teflon 1/8in Thickness
Tubes	SA-249 S30400 Grd TP304 Wld. tube
Baffles	SA-36 K02600 Plate
Tie Rods	SA-36 Bar
Spacers	SA-214 K01807 Wld. tube
Shell Support A	SA-516 K02700 Grd 70 Plate
Shell Support B	SA-516 K02700 Grd 70 Plate
Coupling	SA-182 S30403 Grd F304L Forgings(<= 5)
Coupling	SA-182 S30403 Grd F304L Forgings(<= 5)
Nozzle A	SA-516 K02700 Grd 70 Plate
Nozzle B	SA-516 K02700 Grd 70 Plate
Nozzle C	SA-240 S30400 Grd 304 Plate(G5)
Nozzle D	SA-312 S30400 Grd TP304 Wld. pipe(G5)
Nozzle E	SA-312 S30400 Grd TP304 Wld. pipe(G5)
Nozzle G	SA-312 S30400 Grd TP304 Wld. pipe(G5)
Nozzle H	SA-312 S30400 Grd TP304 Wld. pipe(G5)
Nozzle J	SA-53 K03005 Grd E/B Wld. pipe
Nozzle K	SA-53 K03005 Grd E/B Wld. pipe
Nozzle Flng A	SA-105 K03504 Forgings
Nozzle Flng B	SA-105 K03504 Forgings
Nozzle Flng C	SA-105 K03504 Forgings
Nozzle Flng D	SA-182 S30403 Grd F304L Forgings(<= 5)
Nozzle Flng E	SA-182 S30403 Grd F304L Forgings(<= 5)
Nozzle Flng G	SA-182 S30403 Grd F304L Forgings(<= 5)
Nozzle Flng H	SA-182 S30403 Grd F304L Forgings(<= 5)
Nozzle Flng J	SA-105 K03504 Forgings
Nozzle Flng K	SA-105 K03504 Forgings
Nozzle Reinforcement C	SA-240 S30400 Grd 304 Plate(G5)
Nozzle Reinforcement H	SA-516 K02700 Grd 70 Plate
Rear Hd Bolting At TS	SA-193 G41400 Grd B7 Bolt(<= 2 1/2)
Front Hd Bolting At Cov	SA-193 G41400 Grd B7 Bolt(<= 2 1/2)
Distributor Belt A	SA-516 K02700 Grd 70 Plate

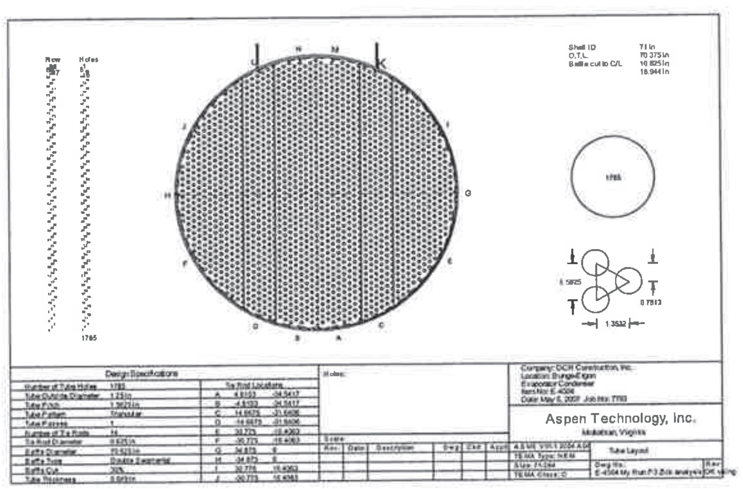
Distributor Belt B	SA-516 K02700 Grd 70 Plate
Front Head Cover Liner	SA-240 S30400 Grd 304 Plate(G5)
Nozzle Flng Bolting A	SA-193 G41400 Grd B7 Bolt(<= 2 1/2)
Nozzle Flng Bolting B	SA-193 G41400 Grd B7 Bolt(<= 2 1/2)
Nozzle Flng Bolting C	SA-193 G41400 Grd B7 Bolt(<= 2 1/2)

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	2	225	ci	120	lg	0.5	8414	0.45	3774
1	Shell Cylinder	SA-516 K02700 Grd 70 Plate	1	225	ci	24	lg	0.5	0	0.45	0
2	Fr Hd Cylinder	SA-240 S30400 Grd 304 Plate(G5	1	225.5	ci	120	lg	0.375	3095	2.55	7903
2	Fr Hd Cylinder	SA-240 S30400 Grd 304 Plate(G5	1	225.5	ci	7.5	lg	0.375	0	2.55	0
3	Re Hd Cylinder	SA-240 S30400 Grd 304 Plate(G5	1	225.5	ci	28	lg	0.3125	566	2.55	1446
5	Fr Hd Cover Bolted	SA-516 K02700 Grd 70 Plate	1	76.375	lg	76.375	wi	3.25	5371	0.45	2409
6	Re Hd Cover Ellip.	SA-240 S30400 Grd 304 Plate(G5	1	90.875	lg	90.875	wi	0.375	889	2.55	3783
8	Fr Hd Lift Lugs	SA-285 K02801 Grd C Plate	1	6.375	od	0		1.4375	21	0.4	8
9	Shell Lift Lugs	SA-285 K02801 Grd C Plate	2	6.375	od	0		3.5625	51	0.4	21
11	Front TubSh	SA-240 S30400 Grd 304 Plate	1	72.75	od	0		1.75	2088	2.55	5332
12	Rear TubSh	SA-240 S30400 Grd 304 Plate	1	76.25	od	0		1.75	2294	2.55	5857
18	Re Hd Flng TubSh	SA-516 K02700 Grd 70 Plate	1	76.25	lg	76.25	wi	3.25	5353	0.45	2401
19	Fr Hd Flng Cover	SA-516 K02700 Grd 70 Plate	1	76.375	lg	76.375	wi	2.5	4131	0.45	1853
32	Re Hd Gskt TubSh	Solid Teflon 1/8in Thickness	1	74	od	74	id	0.125	54	23	1252
33	Fr Hd Gskt Cover	Solid Teflon 1/8in Thickness	1	74.125	od	74.125	id	0.125	55	23	1256
38	Tubes (min wall)	SA-249 S30400 Grd TP304 Wld. t	1785	1.25	od	264	lg	0.049	26926	5.75	225639
39	Baffles	SA-36 K02600 Plate	11	71.375	lg	71.375	wi	0.5	7938	0.37	2921
40	Tie Rods	SA-36 Bar	7	0.625	od	218.75	lg	0	220	0.37	81
40	Tie Rods	SA-36 Bar	5	0.625	od	200.88	lg	0	0	0.37	0
41	Spacers	SA-214 K01807 Wld. tube	85	0.875	od	35.75	lg	0.109	291	0.8	232
41	Spacers	SA-214 K01807 Wld. tube	22	0.875	od	17.875	lg	0.109	0	0.8	0
47	Shell Support A	SA-516 K02700 Grd 70 Plate	1	0		0		0	1240	0.45	556
48	Shell Support B	SA-516 K02700 Grd 70 Plate	1	0		0		0	1240	0.45	556
51	Coupling A	SA-182 S30403 Grd F304L Forgin	1	0.5	od	0		0	0	11.47	4
52	Coupling B	SA-182 S30403 Grd F304L Forgin	1	0.5	od	0		0	0	11.47	4
182	TS Nozzle Cplgs	SA-182 S30403 Grd F304L Forgin	1	0		0		0	0	11.47	0
61	Nozzle A	SA-516 K02700 Grd 70 Plate	1	92.6742	ci	10	lg	0.5	131	0.45	59
62	Nozzle B	SA-516 K02700 Grd 70 Plate	1	92.6742	ci	10	lg	0.5	131	0.45	59
63	Nozzle C	SA-240 S30400 Grd 304 Plate(G5	1	168.463	ci	17.75	lg	0.375	322	2.55	822
64	Nozzle D	SA-312 S30400 Grd TP304 Wld. p	1	6.625	od	6	lg	0.28	10	4	38
65	Nozzle E	SA-312 S30400 Grd TP304 Wld. p	1	6.625	od	6	lg	0.28	10	4	38
66	Nozzle G	SA-312 S30400 Grd TP304 Wld. p	1	4	od	6	lg	0.337	7	4	27
67	Nozzle H	SA-312 S30400 Grd TP304 Wld. p	1	3.5	od	6	lg	0.3	5	4	21
68	Nozzle J	SA-53 K03005 Grd E/B Wld. pipe	1	2.375	od	6	lg	0.344	4	0.7	3
69	Nozzle K	SA-53 K03005 Grd E/B Wld. pipe	1	2.375	od	6	lg	0.344	4	0.7	3
93	Nozzle Reinf. C	SA-240 S30400 Grd 304 Plate(G5	1	76.875	lg	76.875	wi	0.375	636	2.55	1624
97	Nozzle Reinf. H	SA-516 K02700 Grd 70 Plate	1	8.75	lg	8.75	wi	0.1875	4	0.45	2
81	Nozzle Flng A Slip On	SA-105 K03504 Forgings	1	150	AN	30	di	0	277	1.58	436
82	Nozzle Flng B Slip On	SA-105 K03504 Forgings	1	150	AN	30	di	0	277	1.58	436
83	Nozzle Flng C Slip On	SA-105 K03504 Forgings	1	150	AN	54	di	0	4639	1.58	7308
84	Nozzle Flng D Slip On	SA-182 S30403 Grd F304L Forgin	1	150	AN	6.625	di	0	17	11.47	196
85	Nozzle Flng E Slip On	SA-182 S30403 Grd F304L Forgin	1	150	AN	6.625	di	0	17	11.47	196
86	Nozzle Flng G Slip On	SA-182 S30403 Grd F304L Forgin	1	150	AN	4	di	0	12	11.47	135
87	Nozzle Flng H Slip On	SA-182 S30403 Grd F304L Forgin	1	150	AN	3.5	di	0	9	11.47	106
88	Nozzle Flng J Slip On	SA-105 K03504 Forgings	1	150	AN	2.375	di	0	5	1.58	8
89	Nozzle Flng K Slip On	SA-105 K03504 Forgings	1	150	AN	2.375	di	0	5	1.58	8
102	Re Hd Blts TubSh	SA-193 G41400 Grd B7 Bolt(<= 2	72	0.5	od	6.5	lg	0	26	2.48	65

103	Fr Hd Blts Cover	SA-193 G41400 Grd B7 Bolt(<= 2	72	0.5od	7.5	lg	0	30	2.48	75
115	Distrib. Belt A	SA-516 K02700 Grd 70 Plate	1	281.17lg	45	wi	0.75	7240	0.45	3247
116	Distrib. Belt B	SA-516 K02700 Grd 70 Plate	1	281.17lg	45	wi	0.75	7240	0.45	3247
118	Fr Hd Cover Liner	SA-240 S30400 Grd 304 Plate(G5	1	76.375od	0		0.5	658	2.55	1679
122	Dist.Belt An.Rng	SA-516 K02700 Grd 70 Plate	4	89.5	0		1	0	0	0
184	Small Cyl Reinf	SA-516 K02700 Grd 70 Plate	1	1.25lg	1.25	wi	0.0625	0	0.45	0



Tubesheet Layout



Component: Shell Cylinder

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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 = 200 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 = 0.5 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 = 0.4466 in    APP.1-1(A)
  Longitudinal stress
         t = (P*IR / (2*S*E+0.4*P))+cai+cao+tol = 0.2526 in    UG-27(c)(2)
Actual wall thickness of cylinder:            tnom = 0.5 in
  (Required wall tks. for nozzle attachments, E=1    ,  tri = 0.2692 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 = 200 F
Inside corr. allow. CAI = 0.0625 in       Corrosion allow.   CAO = 0 in
Radiography             = None            Material tol.      Tol = 0 in
Cyl. outside dia.     Do = 72 in          Cylinder length EP   L = 215.1 in
Nominal thickness   tnom = 0.5 in         (tnom-CAI-CAO-Tol)   t = 0.4375 in
L/Do ratio           Ldo = 2.9875         Do/t               Dot = 164.5714
(2*S) or (0.9*yield) SE = -               Mod. of elasticity ME = 28600000 psi
A factor SII-D-FigG   A = 0.000205        B factor CS-2        B = 2948
Max allowed external pressure: Pa = 4*B / (3*Dot)             = 23.89 psi
Actual external design pressure:                            PE = 15 psi
   (Required cyl. tks. for nozzle attachments at PE, tre = 0.3665 in )
```

```
Component:  Front Head Cylinder
ASME Section VIII-1 2004 A06 UG-27 Thickness of Shells under Int. Pressure
--- Calculations --- Cylinder Internal Pressure
Material:  SA-240 S30400 Grd 304 Plate(G5)
Design pressure        P = 50 psi         Design temperature    T = 300 F
Radiography              = None           Joint eff.circ str.   E = 0.7
Design stress          S = 18900 psi      Joint eff.long str.   E = 0.7
Design stress, long    S = 18900 psi      (circum. butt welds)
Inside corr.allow.   CAI = 0.0 in         Outside corr. all. CAO = 0.0 in
Material tolerance   Tol = 0.0 in         TEMA min. thickness tm = 0.3125 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 = 0.1358 in    APP.1-1(A)
  Longitudinal stress
           t = (P*IR / (2*S*E+0.4*P))+cai+cao+tol = 0.0673 in    UG-27(c)(2)
Actual wall thickness of cylinder:            tnom = 0.375 in
  (Required wall tks. for nozzle attachments, E=1     ,  tri = 0.0951 in )
ASME Section VIII-1 2004 A06 UG-28 Thickness of Shells under Ext. Pressure
--- Calculations --- Cylinder External Pressure
Material:  SA-240 S30400 Grd 304 Plate(G5)
Design pressure      PE = 15 psi          Design temperature  T = 300 F
Inside corr. allow. CAI = 0 in            Corrosion allow.  CAO = 0 in
Radiography             = None            Material tol.     Tol = 0 in
Cyl. outside dia.    Do = 72 in           Cylinder length EP  L = 127.3125 in
Nominal thickness  tnom = 0.375 in        (tnom-CAI-CAO-Tol)  t = 0.375 in
L/Do ratio          Ldo = 1.7682          Do/t              Dot = 192.0
(2*S) or (0.9*yield) SE = -               Mod. of elasticity ME = 27000000 psi
A factor SII-D-FigG   A = 0.000281        B factor HA-1       B = 3701
Max allowed external pressure: Pa = 4*B / (3*Dot)               = 25.7 psi
Actual external design pressure:                             PE = 15 psi
   (Required cyl. tks. for nozzle attachments at PE, tre = 0.303 in  )
```

```
Component:  Rear Head Cylinder
ASME Section VIII-1 2004 A06 UG-27 Thickness of Shells under Int. Pressure
--- Calculations --- Cylinder Internal Pressure
Material:  SA-240 S30400 Grd 304 Plate(G5)
Design pressure       P = 50 psi        Design temperature   T = 300 F
Radiography             = None          Joint eff.circ str.  E = 0.7
Design stress         S = 18900 psi     Joint eff.long str.  E = 0.7
Design stress, long   S = 18900 psi     (circum. butt welds)
Inside corr.allow.  CAI = 0.0 in        Outside corr. all. CAO = 0.0 in
Material tolerance  Tol = 0.0 in        TEMA min. thickness tm = 0.3125 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 = 0.1358 in   APP.1-1(A)
  Longitudinal stress
          t = (P*IR / (2*S*E+0.4*P))+cai+cao+tol = 0.0674 in   UG-27(c)(2)
Actual wall thickness of cylinder:            tnom = 0.3125 in
  (Required wall tks. for nozzle attachments, E=1    ,  tri = 0.0951 in )
ASME Section VIII-1 2004 A06 UG-28 Thickness of Shells under Ext. Pressure
--- Calculations --- Cylinder External Pressure
Material:  SA-240 S30400 Grd 304 Plate(G5)
Design pressure      PE = 15 psi          Design temperature  T = 300 F
Inside corr. allow. CAI = 0 in            Corrosion allow.  CAO = 0 in
Radiography             = None            Material tol.     Tol = 0 in
Cyl. outside dia.    Do = 72 in           Cylinder length EP  L = 27.75 in
Nominal thickness  tnom = 0.3125 in       (tnom-CAI-CAO-Tol)  t = 0.3125 in
L/Do ratio          Ldo = 0.3854          Do/t              Dot = 230.4
(2*S) or (0.9*yield) SE = -               Mod. of elasticity ME = 27000000 psi
A factor SII-D-FigG   A = 0.001067        B factor HA-1       B = 7586
Max allowed external pressure: Pa = 4*B / (3*Dot)              = 43.9 psi
Actual external design pressure:                          PE = 15 psi
   (Required cyl. tks. for nozzle attachments at PE, tre = 0.161 in  )
```

```
Component:  Rear Head Cover
ASME Section VIII-1 2004 A06 UG-32 Formed Heads, and Sections,
                                Pressure on Concave Side
--- Calculations --- Ellipsoidal Cover Internal Pressure with t/L >= 0.002
Material:  SA-240 S30400 Grd 304 Plate(G5)
Design pressure       P = 50 psi          Design temperature  T = 300 F
Radiography             = None            Joint efficiency    E = 0.85
Design stress         S = 18900 psi       TEMA min. thk      tm = 0.3125 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 = 0.095 in        Equiv.dish radius   L = 64.2375 in
Ratio t/L               = 0.00486         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 = 0.1118 in  App. 1-4(c)
Actual wall thickness of cover:                  tnom = 0.3125 in
   (Required wall tks. for nozzle attachments, E=1    ,  tri = 0.095 in  )
   (If opening & reinf. are within 80% of head diameter, tri = 0.0856 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(G5)
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 = 0.3125 in      tnom-CAI-CAO-Tol     t = 0.3125 in
Ko factor (UG-33.1)  Ko = 0.9            Ro/t ratio         Rot = 207.36
UG-33(a)    165.35/1.67 = 99.01 psi      Mod. of elasticity  ME = 27000000 psi
A factor = 0.125/Rot    = 0.000603       B factor HA-1        B = 6219
Maximum allowed external pressure:       Pa = B / Rot           = 29.99 psi
Actual external design pressure:                             PE = 15 psi
   (Required cov. tks. for nozzle attachments at PE, tre = 0.196 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 = 89.5 in      ID of dist. belt     ID = 88.0 in
Corroded jacket space  j = 8.0625 in    Min. fillet weld      Y = 0.52 in
Corrosion allowance    c = 0.0625 in    Min. thk.outer wall trj = 0.0 in
Required minimum thickness of closure member, trc
Figure 9-5 type:  (b-2)
trc = <= trj                            trc = 0.5399 in
Actual thickness, tc                    tc  = 1.0 in
```

```
Component:  Distributor Belt A
ASME Section VIII-1 2004 A06 UG-27 Thickness of Shells under Int. Pressure
--- Calculations --- Cylinder Internal Pressure
Material:  SA-516 K02700 Grd 70 Plate
Design pressure        P = 150 psi        Design temperature    T = 200 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 = 89.5 in        Corroded radius      OR = 44.75 in
Required wall thickness of the cylinder , greater of:
  Circumferential stress
            t = (P*OR / (S*E+0.4*P))+cai+cao+tol = 0.5399 in    APP.1-1(A)
  Longitudinal stress
           t = (P*IR / (2*S*E+0.4*P))+cai+cao+tol = 0.298 in    UG-27(c)(2)
Actual wall thickness of cylinder:             tnom = 0.75 in
  (Required wall tks. for nozzle attachments, E=1    ,  tri = 0.3346 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 = 200 F
Inside corr. allow. CAI = 0.0625 in       Corrosion allow.   CAO = 0 in
Radiography             = None            Material tol.      Tol = 0 in
Cyl. outside dia.    Do = 89.5 in         Cylinder length EP   L = 45 in
Nominal thickness  tnom = 0.75 in         (tnom-CAI-CAO-Tol)   t = 0.6875 in
L/Do ratio          Ldo = 0.5028          Do/t               Dot = 130.1818
(2*S) or (0.9*yield) SE = -               Mod. of elasticity ME = 28600000 psi
A factor SII-D-FigG   A = 0.001901        B factor CS-2        B = 14783
Max allowed external pressure: Pa = 4*B / (3*Dot)                = 151.4 psi
Actual external design pressure:                              PE = 15 psi
   (Required cyl. tks. for nozzle attachments at PE, tre = 0.2185 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 = 89.5 in       ID of dist. belt     ID = 88.0 in
Corroded jacket space  j = 8.0625 in    Min. fillet weld      Y = 0.52 in
Corrosion allowance    c = 0.0625 in    Min. thk.outer wall trj = 0.0 in
Required minimum thickness of closure member, trc
Figure 9-5 type:  (b-2)
trc = <= trj                            trc = 0.5399 in
Actual thickness, tc                    tc  = 1.0 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 = 200 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 = 89.5 in       Corroded radius     OR = 44.75 in
Required wall thickness of the cylinder , greater of:
  Circumferential stress
            t = (P*OR / (S*E+0.4*P))+cai+cao+tol = 0.5399 in    APP.1-1(A)
  Longitudinal stress
          t = (P*IR / (2*S*E+0.4*P))+cai+cao+tol = 0.298 in     UG-27(c)(2)
Actual wall thickness of cylinder:             tnom = 0.75 in
  (Required wall tks. for nozzle attachments, E=1    ,  tri = 0.3346 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 = 200 F
Inside corr. allow. CAI = 0.0625 in      Corrosion allow.  CAO = 0 in
Radiography             = None           Material tol.     Tol = 0 in
Cyl. outside dia.    Do = 89.5 in        Cylinder length EP  L = 45 in
Nominal thickness  tnom = 0.75 in        (tnom-CAI-CAO-Tol)  t = 0.6875 in
L/Do ratio          Ldo = 0.5028         Do/t              Dot = 130.1818
(2*S) or (0.9*yield) SE = -              Mod. of elasticity ME = 28600000 psi
A factor SII-D-FigG   A = 0.001901       B factor CS-2       B = 14783
Max allowed external pressure: Pa = 4*B / (3*Dot)              = 151.4 psi
Actual external design pressure:                            PE = 15 psi
   (Required cyl. tks. for nozzle attachments at PE, tre = 0.2185 in )
```

```
Component:  Tubes
ASME Section VIII-1 2004 A06 UG-27 Thickness of Shells under Int. Pressure
--- Calculations --- Cylinder Internal Pressure
Material:  SA-249 S30400 Grd TP304 Wld. tube
Design pressure        P = 65 psi         Design temperature   T = 300 F
Radiography              = -              Joint eff.circ str.  E = 1
Design stress          S = 12700 psi      Joint eff.long str.  E = -
Design stress, long    S = -              (circum. butt welds)
Inside corr.allow.   CAI = 0.0 in         Outside corr. all. CAO = 0.0 in
Material tolerance   Tol = 0.0 in         TEMA min. thickness tm = 0.0 in
Outside diameter      OD = 1.25 in        Corroded radius     OR = 0.625 in
Required wall thickness of the cylinder , greater of:
  Circumferential stress
            t = (P*OR / (S*E+0.4*P))+cai+cao+tol = 0.0032 in    APP.1-1(A)
  Longitudinal stress
          t = (P*IR / (2*S*E+0.4*P))+cai+cao+tol = -            UG-27(c)(2)
Actual wall thickness of cylinder:             tnom = 0.049 in
  (Required wall tks. for nozzle attachments, E=-    ,  tri = -          )
ASME Section VIII-1 2004 A06 UG-28 Thickness of Shells under Ext. Pressure
--- Calculations --- Cylinder External Pressure
Material:  SA-249 S30400 Grd TP304 Wld. tube
Design pressure      PE = 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 = 1.25 in        Cylinder length EP  L = 264 in
Nominal thickness  tnom = 0.049 in       (tnom-CAI-CAO-Tol)  t = 0.049 in
L/Do ratio          Ldo = 211.2          Do/t              Dot = 25.5102
(2*S) or (0.9*yield) SE = -              Mod. of elasticity ME = 27000000 psi
A factor SII-D-FigG   A = 0.001705       B factor HA-1       B = 8872
Max allowed external pressure: Pa = 4*B / (3*Dot)              = 463.73 psi
Actual external design pressure:                            PE = 165 psi
  (Required cyl. tks. for nozzle attachments at PE, tre = 0.027 in  )
```

Component: Tube-to-Tubesheet Welds

```
ASME Section VIII Div.1 2004 A06  UW-20 Tube-To-Tubesheet Welds
--- Calculations ---        Fig UW-20.1 Sketch (a) Full Strength
Tubesheet material:  SA-240 S30400 Grd 304 Plate
Tubesheet clad mtl:  -
Tubes material:      SA-249 S30400 Grd TP304 Wld. tube
Allowable stress TubS St = 15000 psi    All. stress tubes     Sa = 14941 psi
Allowable stress weld Sw = 14941 psi    Tube OD               do = 1.25 in
                                        Tube thickness         t = 0.049 in
Design temperature TubSh = 300 F        Design temp. tubes       = 300 F
Fille weld leg        af = 0.0833 in    Groove weld leg       ag = 0.0 in
Minimum length ac  acmin = 0.0821 in    Total length ac = af+ag = 0.0833 in
Fillet weld strength = Ff = 0.55*Pi*af*(do+0.67*af)*Sw       Ff = 2808 lbf
Groove weld strength = Fg = 0.85*Pi*ag*(do+0.67*ag)*Sw       Fg = 0 lbf
Tube strength           Ft = Pi * t * (do - t) * Sa          Ft = 2762 lbf
Design Strength         Fd                                   Fd = 2762 lbf
Fillet weld strength, Ff = min (Ff, Ft)                      Ff = 2762 lbf
Groove weld strength, Fg = min (Fg, Ft)                      Fg = 0 lbf
Weld strength factor fw = Sa / Sw                            fw = 1
Ratio fd = Fd / Ft                                           fd = 1
Ratio ff = 1 - Fg / (fd * Ft)                                ff = 1
Minimum required length of the weld leg(s), ar
ar = SQRT((0.75*do)**2 + 2.73*t(do-t)*fw*fd) - 0.75*do       ar = 0.0821 in
UW-18(d) - Allowable load on fillet/groove welds       Weld Leg = 0.0833 in
                Allowable Load = PI * do * Weld Leg * Sw * 0.55 = 2688 lbf
Maximum Allowable Axial Loads, Lmax
  Pressure only = LmaxP = Ft                              LmaxP = 2762 lbf
  Other loads   = LmaxO = 2*Ft                            LmaxO = 5525 lbf
  Total weld throat dimension = 0.059 in
```

```
Component:  Front Head Flng At Cov
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 = 50 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 = 75.625 in     Inside spherical rad.  L = -
Inside diameter        B = 71.25 in      Hub thickness         g1 = 0.9375 in
Bolt circle diameter   C = 74.375 in     Hub tks. at attach.   go = 0.375 in
Mean gasket diameter   G = 72.875 in     Weld leg/hub length    h = 0.5625 in
Hub to bolt circle     R = 0.625 in      Bolt circle to OD      E = 0.625 in
Flange thickness       t = 2.125 in
Note: Optional Type Flanges use the smaller of integral or loose calculation.
Gasket material: Solid Teflon 1/8in Thickness
Gasket outside dia.  ODG = 73.375 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. = 72
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 =    11447 lbf
Hydrostatic end force         H = 0.7854*G*G*PI                 =   208554 lbf
Hydrostatic end force        He= 0.7854*G*G*PE                  =    62566 lbf
Operating conditions:
Min. calc. bolt load        WM1 = HP+H                          =   220001 lbf
Min. used bolt load         WM1 = max of 2 mating flanges       =   220001 lbf
Bolting up conditions:
Minimum bolt load           WM2 = b*3.1416*G*Y+Br*Y*RIB         =    91577 lbf
Min. used bolt load         WM2 = max of 2 mating flanges       =    91577 lbf
Required bolt area           AM = WM2/SA or WM1/SB              =      8.8 in2
Available bolt area          AB = No.Bolt*Area                  =     9.07 in2
Design bolt load              W = 0.5*(AM+AB)*SA                =   223400 lbf
Minimum gasket width       NMIN = AB*SA/(6.283*y*G)             =   0.3096 in
Gasket compression stress  Gcst = AB*SA/(Pi*G*Wth)              =     1981 psi
```

```
Loads:                     Integral Flange Calculations
Operating conditions:
Hydrostatic end load        HD = 0.785*B*B*PI      = 199357 lbf
Hydrostatic end load        HDe= 0.785*B*B*PE      =  59807 lbf
Gasket load                 HG = WM1-H             =  11447 lbf
Result. hydrostatic force   HT = H-HD              =   9197 lbf
Result. hydrostatic force   HTe= He-HDe            =   2759 lbf
Bolting up conditions:
Gasket load                 HG = W                 = 223400 lbf
Operating conditions:
Hydrostatic lever arm       hd = R+0.5*g1          = 1.0938 in
Gasket load lever arm       hg = (C-G)/2           = 0.75 in
Result. hydro. lever arm    ht = (R+g1+hg)/2.0     = 1.1563 in
Bolting up conditions:
Gasket load lever arm       hg = (C-G)/2           = 0.75 in
Operating conditions:
Hydrostatic moment          MD = HD*hd             = 218046 lbf*in
Gasket moment               MG = HG*hg             =   8585 lbf*in
Result. hydro. moment       MT = HT*ht             =  10634 lbf*in
Total operating moment     MOP = MD+MG+MT          = 237266 lbf*in
Total operating mom. MOPe= HDe(hd-hg)+HTe(ht-hg)   =  21680 lbf*in
Bolting up conditions:
Bolt up moment            MATM = W*hg              = 167550 lbf*in
Effective bolt moment       MB = MATM*SFO/SFA      = 125663 lbf*in
Total moment                MO = MOP  or MB        = 237266 lbf*in
Bolt spacing correction      M = MO*Cf             = 237266 lbf*in
 (TEMA 1999 RCB-11.23) Cf= 1
Flange shape constants:
          K = A/B         = 1.0614       ho = SQ(B*G0)     = 5.169
         TF = Fig.2-7.1   = 1.8907     h/ho = h/ho         = 0.1088
          Z = Fig.2-7.1   = 16.8006       F = Fig.2-7.2    = 0.9037
          Y = Fig.2-7.1   = 32.3321       V = Fig.2-7.3    = 0.4157
          U = Fig.2-7.1   = 35.5297       f = Fig.2-7.6    = 5.0418
    G1/G0 = G1/Go         = 2.5           e = F/ho         = 0.1748
          t =             = 2.125 in
          D = U*ho*g0*g0/V = 62.1218  Alpha = t*e+1.0      = 1.3715
     Beta = 1.333*t*e+1.0 = 1.4952    Gamma = Alpha/TF     = 0.7254
    Delta = t*t*t/D       = 0.1545   Lambda = Gamma+Delta  = 0.8799
Stress calculations:                                  Allowable stress:
Long. hub     SH = (f*M)/(Lambda*g1**2*B)  =  21711 psi 1.5*SFO =  22500 psi
Radial        SR = Beta*M/(Lambda*t**2*B)  =   1253 psi     SFO =  15000 psi
Tangential   ST1 = M*Y/(t**2*B)-(Z*SR)     =   2789 psi     SFO =  15000 psi
  (greater)  ST2 = (SH+SR)/2 or (SH+ST1)/2 =  12250 psi     SFO =  15000 psi
```

```
Loads:                       Loose Flange Calculations
Operating conditions:
Hydrostatic end load        HD = 0.785*B*B*PI      = 204283 lbf
Hydrostatic end load        HDe= 0.785*B*B*PE      =  61285 lbf
Gasket load                 HG = WM1-H             =  11447 lbf
Result. hydrostatic force   HT = H-HD              =   4271 lbf
Result. hydrostatic force   HTe= He-HDe            =   1281 lbf
Bolting up conditions:
Gasket load                 HG = W                 = 223400 lbf
Operating conditions:
Hydrostatic lever arm       hd = (C-B)/2.0         = 1.125 in
Gasket load lever arm       hg = (C-G)/2           = 0.75 in
Result. hydro. lever arm    ht = (hd+hg)/2.0       = 0.9375 in
Bolting up conditions:
Gasket load lever arm       hg = (C-G)/2           = 0.75 in
Operating conditions:
Hydrostatic moment          MD = HD*hd             = 229819 lbf*in
Gasket moment               MG = HG*hg             =   8585 lbf*in
Result. hydro. moment       MT = HT*ht             =   4004 lbf*in
Total operating moment     MOP = MD+MG+MT          = 242408 lbf*in
Total operating mom. MOPe= HDe(hd-hg)+HTe(ht-hg)   =  23222 lbf*in
Bolting up conditions:
Bolt up moment            MATM = W*hg              = 167550 lbf*in
Effective bolt moment       MB = MATM*SFO/SFA      = 125663 lbf*in
Total moment                MO = MOP  or MB        = 242408 lbf*in
Bolt spacing correction      M = MO*Cf             = 242408 lbf*in
 (TEMA 1999 RCB-11.23) Cf= 1
Flange shape constants:
      B =               = 72.125 in
      K = A/B           = 1.0485
      Y = Fig.2-7.1     = 40.5881
Flange calculated thickness:     t = (M*Y/SFO*B)**0.5 = 3.0157 in
Flange nominal thickness:                  tnom = 2.125 in
Stress calculations:                            Allowable stess:
Tangential, ST = MO*Cf*Y/(B*tnom**2) = 14545 psi     SFO = 15000 psi
```

```
Component:  Channel Cover
ASME Section VIII-1 2004 A06 UG-34 Unstayed Flat Heads and Covers
--- Calculations --- Channel Cover Internal Pressure
Material:  SA-516 K02700 Grd 70 Plate
Design pressure          P = 50 psi       Design temperature     T = 300 F
Stress (operating)      SO = 20000 psi    Stress (atmos.)       SA = 20000 psi
Corr. allowance        CAI = 0.0 in
Outside diameter        OD = 75.625 in
Bolt circle diameter     C = 74.375 in
Mean gasket diameter     G = 72.875 in
Mod. of elasticity      ME = -
Required thickness       t = 2.4301 in    Nominal thickness     tn = 2.8125 in
Gasket load lever arm         hg = (C-G)/2         = 0.75 in
ASME Section VIII-1 2004 A06 UG-34 Unstayed Flat Heads and Covers
--- Calculations --- Channel Cover Internal Pressure
Operating bolt load     Wo = 220001 lbf   Factor 'C'             C = 0.3
Gasket seating load     Wb = 223400 lbf   Joint efficiency       E = 0.7
Available bolt area     Ab = 9.072 in2    Factor x per UG-39(d)(2) = 1
Bolt stress (oper.)     Sb = 25000 psi    Nominal diameter      ND = 71 in
Code required cover thickness:
     Operating:  t = G*sqrt(x*(C*P/SO*E+1.9*Wo*hg/(SO*G**3)))     = 2.4301 in
     Bolting:    t = G*sqrt(x*(1.9*Wb*hg/(SA*E*G**3)))            = 0.5586 in
TEMA 1999 RCB-9.21 (cover deflection)
         Y = G*(0.0435*G**3*P+0.5*Sb*Ab*hg)/(ME*t**3)             = -
     Ymax = 0.03 in. (0.076 mm) or ND/800 or User specified       = -
         t = (G*(0.0435*G**3*P+0.5*Sb*Ab*hg)/(ME*Ymax))**.333     = -
Thicknesses do NOT include corrosion or recesses.
```

Component: Front Head Flng At Cov

```
ASME Section VIII Div.1 2004 A06, Appendix 2, 2-14 Flange Rigidity
--- Calculations ---
Operating moment,     Mo = 237266 lbf*in Gasket seat. moment Ma = 167550 lbf*in
Factor V               V = 0.416         Factor L               L = 0.8799
Mod. elast.design T   Ed = 27000000 psi  Mod.elast.atm. temp Ea = 28300000 psi
Thickness g0          g0 = 0.375 in      Factor h0             h0 = 5.169 in
Factor KI             KI = 0.3           Factor KL             KL = 0.2
Corrosion allowance   ca = 0.0 in        Factor K               K = 1.0614
Thickness, T           T = 2.125 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) = 0.6689
Operating         J = 52.14 * Mo * V / (L * E * G0 ** 2 * ho * KI) = 0.9928
```

Component: Rear Head Flng At TS

```
ASME Section VIII-1 2004 A06 App. 2 Bolted Flange With Ring Type Gaskets
Flange type: Ring
Flange material: SA-516 K02700 Grd 70 Plate
Int. design pressure  PI = 50 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 = 20000 psi    Stress (atmos.)      SFA = 20000 psi
Outside diameter       A = 75.5 in      Inside spherical rad.  L = -
Inside diameter        B = 71.375 in    Hub thickness         g1 = 0.8125 in
Bolt circle diameter   C = 74.25 in     Hub tks. at attach.   go = 0.3125 in
Mean gasket diameter   G = 72.75 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 = 2.6875 in
Note: Optional Type Flanges use the smaller of integral or loose calculation.
Gasket material: Solid Teflon 1/8in Thickness
Gasket outside dia.  ODG = 73.25 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. = 72
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 =   11428 lbf
Hydrostatic end force         H = 0.7854*G*G*PI                 =  207839 lbf
Hydrostatic end force        He= 0.7854*G*G*PE                  =   62352 lbf
Operating conditions:
Min. calc. bolt load        WM1 = HP+H                          =  219266 lbf
Min. used bolt load         WM1 = max of 2 mating flanges       =  219266 lbf
Bolting up conditions:
Minimum bolt load           WM2 = b*3.1416*G*Y+Br*Y*RIB         =   91420 lbf
Min. used bolt load         WM2 = max of 2 mating flanges       =   91420 lbf
Required bolt area           AM = WM2/SA or WM1/SB              =    8.77 in2
Available bolt area          AB = No.Bolt*Area                  =    9.07 in2
Design bolt load              W = 0.5*(AM+AB)*SA                =  223033 lbf
Minimum gasket width       NMIN = AB*SA/(6.283*y*G)             =  0.3101 in
Gasket compression stress  Gcst = AB*SA/(Pi*G*Wth)              =    1985 psi
```

```
Loads:                        Integral Flange Calculations
Operating conditions:
Hydrostatic end load            HD = 0.785*B*B*PI       = 200057 lbf
Hydrostatic end load            HDe= 0.785*B*B*PE       =  60017 lbf
Gasket load                     HG = WM1-H              =  11428 lbf
Result. hydrostatic force       HT = H-HD               =   7782 lbf
Result. hydrostatic force       HTe= He-HDe             =   2335 lbf
Bolting up conditions:
Gasket load                     HG = W                  = 223033 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              = 206308 lbf*in
Gasket moment                   MG = HG*hg              =   8571 lbf*in
Result. hydro. moment           MT = HT*ht              =   8512 lbf*in
Total operating moment         MOP = MD+MG+MT           = 223391 lbf*in
Total operating mom. MOPe= HDe(hd-hg)+HTe(ht-hg)        =  17682 lbf*in
Bolting up conditions:
Bolt up moment                MATM = W*hg               = 167275 lbf*in
Effective bolt moment           MB = MATM*SFO/SFA       = 167275 lbf*in
Total moment                    MO = MOP  or MB         = 223391 lbf*in
Bolt spacing correction          M = MO*Cf              = 223391 lbf*in
 (TEMA 1999 RCB-11.23) Cf= 1
Flange shape constants:
         K = A/B            = 1.0578        ho = SQ(B*G0)      = 4.7228
        TF = Fig.2-7.1      = 1.8919      h/ho = h/ho          = 0.1059
         Z = Fig.2-7.1      = 17.8171        F = Fig.2-7.2     = 0.9043
         Y = Fig.2-7.1      = 34.2758        V = Fig.2-7.3     = 0.4162
         U = Fig.2-7.1      = 37.6656        f = Fig.2-7.6     = 5.4874
     G1/G0 = G1/Go          = 2.6            e = F/ho          = 0.1915
         t =                = 2.6875 in
         D = U*ho*g0*g0/V   = 41.7374    Alpha = t*e+1.0       = 1.5146
      Beta = 1.333*t*e+1.0  = 1.6859     Gamma = Alpha/TF      = 0.8006
     Delta = t*t*t/D        = 0.4651    Lambda = Gamma+Delta   = 1.2656
Stress calculations:                                  Allowable stress:
Long. hub     SH = (f*M)/(Lambda*g1**2*B)  =   20556 psi 1.5*SFO =   28350 psi
Radial        SR = Beta*M/(Lambda*t**2*B)  =     577 psi     SFO =   20000 psi
Tangential   ST1 = M*Y/(t**2*B)-(Z*SR)     =    4568 psi     SFO =   20000 psi
  (greater)  ST2 = (SH+SR)/2 or (SH+ST1)/2 =   12562 psi     SFO =   20000 psi
```

Loads: **Loose Flange Calculations**

```
Operating conditions:
Hydrostatic end load          HD = 0.785*B*B*PI      = 204283 lbf
Hydrostatic end load          HDe= 0.785*B*B*PE      =  61285 lbf
Gasket load                   HG = WM1-H             =  11428 lbf
Result. hydrostatic force     HT = H-HD              =   3556 lbf
Result. hydrostatic force     HTe= He-HDe            =   1067 lbf
Bolting up conditions:
Gasket load                   HG = W                 = 223033 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             = 217051 lbf*in
Gasket moment                 MG = HG*hg             =   8571 lbf*in
Result. hydro. moment         MT = HT*ht             =   3222 lbf*in
Total operating moment       MOP = MD+MG+MT          = 228844 lbf*in
Total operating mom. MOPe= HDe(hd-hg)+HTe(ht-hg)     =  19318 lbf*in
Bolting up conditions:
Bolt up moment              MATM = W*hg              = 167275 lbf*in
Effective bolt moment         MB = MATM*SFO/SFA      = 167275 lbf*in
Total moment                  MO = MOP  or MB        = 228844 lbf*in
Bolt spacing correction        M = MO*Cf             = 228844 lbf*in
 (TEMA 1999 RCB-11.23) Cf= 1
Flange shape constants:
       B =               = 72.125 in
       K = A/B           = 1.0468
       Y = Fig.2-7.1     = 42.0461
Flange calculated thickness:     t = (M*Y/SFO*B)**0.5 = 2.5827 in
Flange nominal thickness:                      tnom = 2.6875 in
Stress calculations:                              Allowable stess:
Tangential, ST = MO*Cf*Y/(B*tnom**2) = 18471 psi      SFO = 20000 psi
```

Component: Rear Head Flng At TS

```
ASME Section VIII Div.1 2004 A06, Appendix 2, 2-14 Flange Rigidity
--- Calculations ---
Operating moment,    Mo = 223391 lbf*in Gasket seat. moment Ma = 167275 lbf*in
Factor V              V = 0.416         Factor L              L = 1.2656
Mod. elast.design T  Ed = 28100000 psi  Mod.elast.atm. temp Ea = 29300000 psi
Thickness g0         g0 = 0.3125 in     Factor h0            h0 = 4.7228 in
Factor KI            KI = 0.3           Factor KL            KL = 0.2
Corrosion allowance  ca = 0.0 in        Factor K              K = 1.0578
Thickness, T          T = 2.6875 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) = 0.7075
Operating        J = 52.14 * Mo * V / (L * E * G0 ** 2 * ho * KI) = 0.9852
```

```
Component: Front Tubesheet  Rules for the Design of Fixed Tubesheets
ASME VIII-1 2004 A06 UHX-13 Fig.UHX-13.1(a)  Controlling Case: UHX-13.4(a)(2)
*** Tubesheet material:     SA-240 S30400 Grd 304 Plate
Design temp. tubesheet T = 300 F        TubSh metal tmp at rim T'= 105 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' = 8.62
Poisson's rat. tubSh   v = 0.3            *(th.exp.coef * 10**6)
*** Shell material:         SA-516 K02700 Grd 70 Plate
Design temp. shell    Ts = 200 F        Shell metal tmp/TubS T's = 94 F
Shell allowable str.  Ss = 20000 psi    *Shell th.ex.coe.alpha's = 6.48
Shell mod.elasticity  Es = 28600000 psi Shell mean metal tmp Tsm = 94 F
Poisson's ratio shell vs = 0.3          *Shell th.ex.coe.alphasm = 6.48
*** Tube material:          SA-249 S30400 Grd TP304 Wld. tube
Design temp. tubes    Tt = 300 F        Tubes mean metal tmp Ttm = 105 F
Tube allow.Str. at Tt St = 14941.2 psi  Tube allow.Str. at T Stt = 14941.2 psi
Tube mod.elas. at Tt  Et = 27000000 psi Tube mod.elas. at T  Ett = 27000000 psi
Poisson's rat. tubes  vt = 0.3          *Tube th.ex.coe.alphatm  = 8.62
Tube yield stress    Syt = 22400 psi      *(th.exp.coef * 10**6)
*** Channel material:       SA-240 S30400 Grd 304 Plate(G5)
Design temp. channel  Tc = 300 F        Channel metal tmp TS T'c = 105 F
Channel all. stress   Sc = 18900 psi    *Chan.th.ex.coe.alpha'c  = 8.62
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 = 1.5 in       Actual tubesheet thk  ha = 1.5 in
Shell side corr allow  c = 0.0625 in    Tube side cor.allow.   c = 0.0 in
SS TubSh corr allow   cs = 0.0 in       TS TubSh corr allow   ct = 0.0 in
                                   Corroded case     Uncorroded case
Shell diameter, Ds                    71.125 in          71.0 in
Channel diameter, Dc                  71.25 in          71.25 in
Shell thickness, ts                   0.4375 in          0.5 in
Adjacent shell thk  ts,1               0.0 in            0.0 in
Channel thickness, tc                 0.375 in          0.375 in
Minimum TubSh thk, hmin               1.1614 in         1.2271 in
Thickness h used                       1.5 in            1.5 in
Tubesheet OD            A = 72.0 in      Bolt circle diam.      C = -
```

```
Shell gasket diam.     Gs = -           Channel gasket diam.  Gc = -
Gasket reaction diam.  G = -           Gasket reaction diam. G1 = -
Number of tubes       Nt = 1785        Flange load            W = 0 lbf
Pass partition groove hg = 0.0 in      Eff.tube side groove h'g = 0.0 in
Tube outside diam.    dt = 1.25 in     Tube thickness        tt = 0.049 in
Tube pitch             p = 1.5625 in   Center-to-center dis  UL = 0.0 in
Tube projection      tpr = 0.125 in    Tube corrosion allow.  c = -
Tube length L          L  = 260.75 in  Tube length Lt        Lt = 263.75 in
Tube expanded depth  ltx = 1.375 in    Tube exp.depth ratio rho = 0.917
Tube buckling factor   k = 0.8         Unsupported tube span  l = 59.875 in
Outermost tube rad.   ro = 34.5625 in  Unsupp.length lt=k*l  lt = 47.9 in
Shell radius          as = 35.5625 in  Channel radius        ac = 35.625 in
Shell design pressure Ps = 165 psi     Tube design pressure Pt  = 0 psi
Exp.joint spring rate kj = -              EJ diameter    Dj = -
Component: Front Tubesheet
           Fig.UHX-13.1(a)  Controlling Case: UHX-13.4(a)(2)
UHX-13.5.1 Step 1.  Determine Do, Mu, Mu* and h'g from UHX-11.5.1.
  Do = 2 * ro + dt                                         Do = 70.375 in
  mu = (p - dt) / p                                        mu = 0.2
  d* = MAX(dt-2*tt*(Ett/E)*(Stt/S)*Rho),(dt-2*tt))         d* = 1.1605 in
  Pass lane area limit                                 4*Do*p = 439.84 in2
  Actual pass lane area, AL                                AL = 0 in2
  Effective pitch = p/SQRT(1-(4*MIN[AL,4*Do*p]/Pi*Do**2))  p* = 1.5625 in
  mu* = (p* - d*) / p*                                    mu* = 0.2573
  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 = 35.1875 in
  rhos = as/ao                                           rhos = 1.0107
  rhoc = ac/ao                                           rhoc = 1.0124
  xs = 1 - Nt(dt/(2*ao))**2                                xs = 0.4369
  xt = 1 - Nt((dt-2*tt)/(2*ao))**2                         xt = 0.5217
```

```
UHX-13.5.2 Step 2.  Calculate the shell axial stiffness Ks, tube axial
  stiffness Kt, and stiffness factors Ks,t and J
  Shell axial stiffness, Ks = PI*ts(Ds+ts)*Es/L          Ks = 10788353 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 = 19144 lbf/in
  Factor Ks,t = Ks/(Nt*Kt) or Ks*/(Nt*Kt)              Ks,t = 0.3157
  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 = 0.3249
  ks = betas*(Es*ts**3)/(6*(1-vs**2)                        ks = 142505
  lambdas=(6*Ds/h**3)*ks*(1+h*betas+(h**2*betas**2)/2) lambdas = 28939662
  deltas = (Ds**2/(4*Es*ts))*(1-vs/2)                  deltas = 0.0000859
  Calculate channel coefficients betac, kc, lambdac and deltac
  betac = (12*(1-vc**2))**0.25 / ((Dc+tc)*tc)**0.5       betac = 0.3508
  kc = betac*(Ec*tc**3)/(6*(1-vc**2)                        kc = 91469
  lambdac=(6*Dc/h**3)*kc*(1+h*betac+(h**2*betac**2)/2) lambdac = 19285510
  deltac = (Dc**2/(4*Ec*tc))*(1-vc/2)                  deltac = 0.0001065
  NOTE: If the effect of plasticity used, Es or Ec will be Es* or Ec*
Component: Front Tubesheet
           Fig.UHX-13.1(a)  Controlling Case: UHX-13.4(a)(2)
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 = 1.5 in
  From fig. UHX-11.2 or UHX-11.3 - E*/E = 0.2613             v* = 0.3418
                                  h/p = 0.96               mu* = 0.2573
  Effective Tubsheet Mod.Elasticity  E* = 7055350 psi
  Parameter Xa = (24*(1-v*(**2))*Nt*(Et*tt*(dt-tt)*
              ao**2)/((E*)*L*h**3))**0.25                   Xa = 10.464
UHX-13.5.4 Step 4. Calculate diameter ratio K and coefficient F.
  K = A / Do                                                 K = 1.023
  F = ((1-v*)/E*)*(lambdas+lambdac+E*Ln(K))                  F = 4.556
```

```
  Parameters Zd, Zv and Zm from Table UHX-13.1
  Psi1(Xa)=bei(Xa)+(1-v*)/Xa*ber'(Xa)                  Psi1(Xa) = 133.5542
  Psi2(Xa)=ber(Xa)-(1-v*)/Xa*bei'(Xa)                  Psi2(Xa) = 141.2525
  Za = bei'(Xa)*Psi2(Xa)-ber'(Xa)*Psi1(Xa)                   Za = 26823.4707
  Zd = (ber(Xa)*Psi2(Xa)+ bei(Xa)*Psi1(Xa))/(Xa**3*Za)       Zd = 0.0013
  Zv = (ber'(Xa)*Psi2(Xa)+ bei'(Xa)*Psi1(Xa))/(Xa**2*Za)     Zv = 0.0093
  Zm = (ber'(Xa)**2+bei'(Xa)**2)/(Xa*Za)                     Zm = 0.1376
  Calculate Q1, Qz1, Qz2 and U
  Phi = (1+v*) * F                                          Phi = 6.1138
  Q1 = (rhos-1-Phi*Zv)/(1+Phi*Zm)                            Q1 = -0.025
  Qz1 = ((Zd+Q1*Zv)*Xa**4)/2                                Qz1 = 6.3132
  Qz2 = ((Zv+Q1*Zm)*Xa**4)/2                                Qz2 = 34.9301
  U = ((Zv+(rhos-1)*Zm)*Xa**4)/(1+Phi*Zm)                     U = 69.8602
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 = 5.9789
  omegas* = ao**2*((rhos**2-1)*(rhos-1))/4-omegas      omegas* = -5.9082
  omegac = rhoc*kc*betac*deltac*(1+h*betac)             omegac = 5.2817
  omegac* = ao**2*((rhoc**2+1)*(rhoc-1))/4-
                (rhos-1)/2-omegac                      omegac* = -4.0858
UHX-13.5.5(c) Calculate gammab
  gammab = 0                                           gammab = 0.0
```

```
Component: Front Tubesheet
              Fig.UHX-13.1(a)  Controlling Case: UHX-13.4(a)(2)
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' = 436.93 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' = 0 psi
  Pgamma  = (Nt*Kt/(Pi*ao**2))*gamma                    Pgamma = 0 psi
  PW      = -(U/ao**2)(gammab/(2*Pi))*W                     PW = 0 psi
  Prim    = -(U/ao**2)*((omegas*)(Ps)-(omegac*)(Pt))      Prim = 55 psi
  Effective pressure, Pe
  Pe = (J*Kst/(1+J*Kst(Qz1+(rhos-1)Qz2))
       * (Ps'-Pt'+Pgamma+PW+Prim)                           Pe = 49.93 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 = -529.3972
  Q3 = Q1 + 2*Q2 / Pe*ao**2                                 Q3 = -0.0421
  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 = 10.4638 in
Calculate functions Psi1 and Psi2 relative to x
  Psi1(x) = bei(x) + (1-v*)/x * ber'(x)                 Psi1(x) = 133.5543
  Psi2(x) = ber(x) - (1-v*)/x * bei'(x)                 Psi2(x) = 141.2525
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) = -0.021
  Fm = MAX|Fm(x)|                                            Fm = 0.021
  For each loading case, calculate the bending stress in the tubesheet
  sigma = (1.5*Fm/mu*)*(2*ao/(h-h'g))**2 * Pe            sigma = 13488 psi
                                                         |sigma| <= 1.5*S
                                                      13488 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 = 3573.2 in2
  Perimeter of the tube layout                                CL = 307.476 in
  Shear diameter DL = 4*AL/CL or Do                           Do = 70.375 in
  Ligament efficiency, mu                          mu = (p-dt)/p = 0.2
  Shear stress, tau = (1/(4*mu)*(Do/h)* Pe                   tau = 2928 psi
                                                           |tau| <= 0.8*S
                                                        2928 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     = 5.3621
               sigmato = ((Ps*xs-Ptxt)-Pe*Fq)/(xt-xs)  = -2306 psi
                                                   sigmato <= St
                                                  2306 psi <= 14941 psi

  UHX-13.5.9(b) Check the tubes for buckling.
  Ct = SQRT(2*PI**2*(Et/Syt)                                  Ct = 154.2491
  rt = SQRT(dt**2+(dt-2*tt)**2)/4                             rt = 0.425 in
  Ft = lt/rt                                                  Ft = 112.7136
  Fs = MAX((1.25,(3.25-0.5*Fq),2)                             Fs = 1.25
  For Ct <= Ft  Stb = MIN[(1/Fs)*(PI**2*Et/(Ft**2),St]       Stb = -
  For Ct >  Ft  Stb = MIN[(Syt/Fs)*(1-(Ft/2*Ct))   ,St]      Stb = -11373 psi
                                                   sigmato <= Stb
                                                 -2306 psi <= -11373 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 = 5.3621
  sigmati = ((Ps*xs-Ptxt)-Pe*Fi)/(xt-xs)              sigmati = -2306 psi
                                                     sigmati <= Stb
                                                  -2306 psi <= -11373 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 = 2114 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 = 28760 psi
  sigmas = |sigmasm| + |sigmasb|                        sigmas = 30875 psi
                                                      sigmas <= 2*Sy
                                                  30875 psi <= 69600 psi
```

Calculate the axial membrane stress sigmacm, axial bending stress sigmacb

```
and total axial stress sigmac in the channel at its junction to the tubesheet
sigmacm = (ac**2/(tc*(2*ac+tc)))*Pt                     sigmacm = 0 psi
sigmacb = (6/tc**2)*kc*[betac*deltac*Pt
          -6*(1-(v*)**2)/(E*)*
          (ao**3/h**3)*(1+h*betac/2)*
          [Pe*(Zv+Zm*Q1)+2/ao**2*Zm*Q2}]                 sigmacb = -8280 psi
sigmac = |sigmacm| + |sigmacb|                            sigmac = 8280 psi
                                                         sigmac <= 1.5*S
                                                       8280 psi <= 30000 psi
```

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

Load case:	1	2	3	4	5	6	7
Tube-side press, Pt	65	0	65	0	65	0	65
Shell-side press, Ps	0	165	165	0	0	165	165
Axial diff.Th.Exp	0.0	0.0	0.0	0.0381	0.0381	0.0381	0.0381
TubSh Bending stress	-5942	13488	7546	7128	2397	20340	13990
Max TubSh Bending st	22500	22500	22500	59505	59505	59505	59505
Min TubSh thk	0.7708	1.1614	0.8687	0.5192	0.301	0.877	0.7273
TubSh Shear stress	-1628	2928	1301	2046	415	4977	3345
Max TubSh Shear str	12000	12000	12000	15868	15868	15868	15868
Min TubSh thk	0.2034	0.366	0.1626	0.1934	0.0392	0.4705	0.3162
Tubesheet thickness	1.5	1.5	1.5	1.5	1.5	1.5	1.5

Elastic-Plastic analysis results:

Load case:	1	2	3
TubSh Bending stress	-5942	13488	7546
Max TubSh Bending st	22500	22500	22500

Component: Front Tubesheet

ASME Fig.UHX-13.1(a) All Load Cases

Controlling case:

Load case:	1	2	3	4	5	6	7
Tubes stress	1513	-2306	-793	-2624	-1086	-4964	-3426
Max Tubes stress	14941	14941	14941	39671	39671	39671	39671
Max buckling stress	-	-11373	-11373	-11373	-11373	-11373	-11373
Total shell stress	9254	30875	24567	11556	5270	42324	36038
Max shell stress	30000	30000	30000	69600	69600	69600	69600
Max shell stress EP	69600	69600	69600				
Total channel stress	18748	8280	10468	9893	8962	18249	5535
Max channel stress	28350	28350	28350	60000	60000	60000	60000
Max channel str. EP	56700	56700	56700				
EP factor - Facts(*)	1.0	1.0694	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	-527	-2306	-793	-2624	-1086	-4964	-3426
Max buckling stress	-11373	-11373	-11373	-11373	-11373	-11373	-11373

ASME VIII-1 2004 A06 UHX-13 - Rules for the Design of Fixed Tubesheets

ASME UHX-13.7 Design Formulas and Calculation Procedure for Effect of Plasticity at Tubesheet/Channel or Shell Joint

The elastic-plastic procedure is only used for pressure loading cases (cases 1, 2 and 3) when sigmas <= Sps,s and/or sigmac <= Sps,c UG-23(e)

```
Shell yield strength Sy,s= 34800 psi     Channel yield str. Sy,c = 22400 psi
Shell allowable stress Ss= 20000 psi     Channel all. stress  Sc = 18900 psi
Shell allow. str.  Sps,s = 69600 psi     Channel all. str. Sps,c = 56700 psi
Ss*=MIN((Sy,s)(Sps,s/2)) = 34800 psi     Sc*=MIN((Sy,c)(Sps,c/2))= 22400 psi
facts = MIN[1.4-0.4|sigmas,b|/Ss* , 1] = MIN[1.0694 , 1]  facts = 1.0
factc = MIN[1.4-0.4|sigmac,b|/Sc* , 1] = MIN[  1.0  , 1]  factc = 1.0
Reduced Modulus of Elasticity
Es = Es(facts)                                            Es = 28600000 psi
Ec = Ec(factc)                                            Ec = 27000000 psi
```

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	65	0	0	0
- 2 -	165	0	0	0	0
- 3 -	165	65	0	0	0
- 4 -	0	0	0.0381	0	0
- 5 -	0	65	0.0381	0	0
- 6 -	165	0	0.0381	0	0
- 7 -	165	65	0.0381	0	0

Load case	P's psi	P't psi	Pgamma psi	Pomega psi	Pw psi	Prim psi	Pe psi
- 1 -	0	258.4	0	0	0	-15	-27.8
- 2 -	436.9	0	0	0	0	55	49.9
- 3 -	436.9	258.4	0	0	0	40	22.2
- 4 -	0	0	348.6	0	0	0	34.9
- 5 -	0	262.7	348.6	0	0	-15.3	7.1
- 6 -	443.4	0	348.6	0	0	56	84.9
- 7 -	443.4	262.7	348.6	0	0	40.7	57

Load case	Q2	Q3	Fm	Sigma psi	Sigma All psi	Tau psi	Tau All psi
- 1 -	144.2	-0.0334	0.0167	-5942	22500	-1628	12000
- 2 -	-529.4	-0.0421	0.021	13488	22500	2928	12000
- 3 -	-385.2	-0.053	0.0265	7546	22500	1301	12000
- 4 -	0	-0.0252	0.015	7128	59505	2046	15868
- 5 -	141.6	0.0072	0.0248	2397	59505	415	15868
- 6 -	-519.9	-0.0351	0.0175	20340	59505	4977	15868
- 7 -	-378.2	-0.0359	0.0179	13990	59505	3345	15868

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

Load case	Fq	Fs	Sigto psi	Sigto All psi	Stb psi
- 1 -	5.847	1.25	1513	14941	-11373
- 2 -	5.3621	1.25	-2306	14941	-11373
- 3 -	4.7552	1.25	-793	14941	-11373
- 4 -	6.3804	1.25	-2624	39671	-11373
- 5 -	8.2389	1.25	-1086	39671	-11373
- 6 -	5.8121	1.25	-4964	39671	-11373
- 7 -	5.7652	1.25	-3426	39671	-11373

Load case	Sigsm psi	Sigsb psi	|Sigs| psi	Sigsall psi	Sigcm psi	Sigcb psi	|Sigc| psi	Sigcall psi
- 1 -	1473	-7781	9254	30000	3071	15677	18748	28350
- 2 -	2114	28760	30875	69600	0	-8280	8280	28350
- 3 -	3587	20979	24567	30000	3071	7396	10468	28350
- 4 -	1380	10176	11556	69600	0	-9893	9893	60000
- 5 -	2850	2420	5270	69600	3071	5891	8962	60000
- 6 -	3496	38828	42324	69600	0	-18249	18249	60000
- 7 -	4966	31072	36038	69600	3071	-2464	5535	60000

Elastic-Pl. Load case	facts	factc	Es,ep psi	Ec,ep psi	ks,ep	kc,ep	lambs,ep
- 1 -	1	1	28600000	27000000	142505	91469	28939662
- 2 -	1.07	1	28600000	27000000	142505	91469	28939662
- 3 -	1	1	28600000	27000000	142505	91469	28939662

Elastic-Pl. Load case	lambc,ep	F,ep	Phi,ep	Q1,ep	Qz1,ep	Qz2,ep	U,ep
- 1 -	19285510	4.5564	6.1138	-0.025	6.3132	34.9301	69.8602
- 2 -	19285510	4.5564	6.1138	-0.025	6.3132	34.9301	69.8602
- 3 -	19285510	4.5564	6.1138	-0.025	6.3132	34.9301	69.8602

Elastic-Pl. Load case	Pw,ep psi	Prim,ep psi	Pe,ep psi	Q2,ep	Q3,ep	Fm,ep	sig,ep psi
- 1 -	0	-15	-27.8	144	-0.0334	0.0167	-5942
- 2 -	0	55	49.9	-529	-0.0421	0.021	13488
- 3 -	0	40	22.2	-385	-0.053	0.0265	7546

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

Load case:	1	2	3	4	5	6	7
Tube-to-TS Load, lbf	280	426	147	485	201	918	633
Allowable no-test	2210	2210	2210	4420	4420	4420	4420
Allowable test	2762	2762	2762	5525	5525	5525	5525

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

Type	Joint description	No Test fr	No Test Lmax	Test fr	Test Lmax
a	Strength welded only	0.8	2210	1	2762
b	Seal welded only	0.55	1519	0.7	1934
e	Strength welded and expanded	0.8	2210	1	2762
f	Seal welded and exp.with 2 grooves	0.75	2072	0.95	2624
g	Seal welded and exp.with 1 groove	0.65	1796	0.85	2348
h	Seal welded and exp.with no grooves	0.5	1381	0.7	1934
i	Expanded with 2 grooves	0.7	1934	0.9	2486
j	Expanded with 1 groove	0.65	1796	0.8	2210
k	Expanded with no grooves	0.5	1381	0.6	1657

* = 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 = 0.1849 in2   Tube allowable stress Sa = 14941 psi
Factor fe (1/do or 1) fe = 1            Ratio fy                fy = 1
ft = (Po+Pt)/Po       ft = 1            Min Yield Str       SigmaM = 30000 psi
 (ft = 1 if max exceeded)
Tube OD               do = 1.25 in      Tube thickness          tt = 0.049 in
Tubes yield str(min)  st = 30000 psi    TubSh mean metal tmp     T = 105 F
Tubes Mod.Elasticity EtT = 28111538 psi TubSh Mod.Elast.       EsT = 28111538 psi
Tubes Coef.Th.Exp.    at = 0.0000086    TubSh Coef.Th.Exp.      as = 0.0000086
Po = (4*(do*t-t**2)*st)/do**2                                   Po = 4520 psi
Pt = ((T-Tamb)*(at-as)*(EtT*EsT)/(EtT+EsT)                      Pt = -
         For joint types i, j, k:                       Po + Pt <= 0.58*SigmaM
                                                      4520 psi <= 17400 psi
```

```
Component: 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'= 105 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' = 8.62
Poisson's rat. tubSh   v = 0.3             *(th.exp.coef * 10**6)
*** Shell material:          SA-516 K02700 Grd 70 Plate
Design temp. shell    Ts = 200 F          Shell metal tmp/TubS T's = 94 F
Shell allowable str.  Ss = 20000 psi     *Shell th.ex.coe.alpha's = 6.48
Shell mod.elasticity  Es = 28600000 psi Shell mean metal tmp Tsm = 94 F
Poisson's ratio shell vs = 0.3           *Shell th.ex.coe.alphasm = 6.48
*** Tube material:           SA-249 S30400 Grd TP304 Wld. tube
Design temp. tubes    Tt = 300 F          Tubes mean metal tmp Ttm = 105 F
Tube allow.Str. at Tt St = 14941.2 psi  Tube allow.Str. at T Stt = 14941.2 psi
Tube mod.elas. at Tt  Et = 27000000 psi Tube mod.elas. at T  Ett = 27000000 psi
Poisson's rat. tubes  vt = 0.3           *Tube th.ex.coe.alphatm  = 8.62
Tube yield stress    Syt = 22400 psi       *(th.exp.coef * 10**6)
*** Channel material:        SA-240 S30400 Grd 304 Plate(G5)
Design temp. channel  Tc = 300 F          Channel metal tmp TS T'c = 105 F
Channel all. stress   Sc = 18900 psi     *Chan.th.ex.coe.alpha'c  = 8.62
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 = 1.5 in         Actual tubesheet thk  ha = 1.5 in
Shell side corr allow  c = 0.0625 in      Tube side cor.allow.   c = 0.0 in
SS TubSh corr allow   cs = 0.0 in         TS TubSh corr allow   ct = 0.0 in
                                    Corroded case      Uncorroded case
Shell diameter, Ds                    71.125 in          71.0 in
Channel diameter, Dc                  71.375 in          71.375 in
Shell thickness, ts                   0.4375 in          0.5 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               1.4828 in          1.5231 in
Thickness h used                       1.5 in            1.5 in
Tubesheet OD            A = 75.5 in       Bolt circle diam.      C = 74.25 in
```

```
Shell gasket diam.      Gs = -              Channel gasket diam.  Gc = 72.75 in
Gasket reaction diam.  G = 72.75 in      Gasket reaction diam. G1 = 72.75 in
Number of tubes       Nt = 1785          Flange load            W = 223033 lbf
Pass partition groove hg = 0.0 in        Eff.tube side groove h'g = 0.0 in
Tube outside diam.    dt = 1.25 in       Tube thickness        tt = 0.049 in
Tube pitch             p = 1.5625 in     Center-to-center dis  UL = 0.0 in
Tube projection      tpr = 0.125 in      Tube corrosion allow.  c = -
Tube length L          L = 260.75 in     Tube length Lt        Lt = 263.75 in
Tube expanded depth  ltx = 1.375 in      Tube exp.depth ratio rho = 0.917
Tube buckling factor   k = 0.8           Unsupported tube span  l = 59.875 in
Outermost tube rad.   ro = 34.5625 in    Unsupp.length lt=k*l  lt = 47.9 in
Shell radius          as = 35.5625 in    Channel radius        ac = 36.375 in
Shell design pressure Ps = 165 psi       Tube design pressure Pt  = 65 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 = 70.375 in
  mu = (p - dt) / p                                         mu = 0.2
  d* = MAX(dt-2*tt*(Ett/E)*(Stt/S)*Rho),(dt-2*tt))          d* = 1.1605 in
  Pass lane area limit                                  4*Do*p = 439.84 in2
  Actual pass lane area, AL                                 AL = 0 in2
  Effective pitch = p/SQRT(1-(4*MIN[AL,4*Do*p]/Pi*Do**2))   p* = 1.5625 in
  mu* = (p* - d*) / p*                                     mu* = 0.2573
  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 = 35.1875 in
  rhos = as/ao                                            rhos = 1.0107
  rhoc = ac/ao                                            rhoc = 1.0337
  xs = 1 - Nt(dt/(2*ao))**2                                 xs = 0.4369
  xt = 1 - Nt((dt-2*tt)/(2*ao))**2                          xt = 0.5217
```

```
UHX-13.5.2 Step 2.  Calculate the shell axial stiffness Ks, tube axial
  stiffness Kt, and stiffness factors Ks,t and J
  Shell axial stiffness, Ks = PI*ts(Ds+ts)*Es/L          Ks = 10788353 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 = 19144 lbf/in
  Factor Ks,t = Ks/(Nt*Kt) or Ks*/(Nt*Kt)              Ks,t = 0.3157
  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 = 0.3249
  ks = betas*(Es*ts**3)/(6*(1-vs**2)                       ks = 142505
  lambdas=(6*Ds/h**3)*ks*(1+h*betas+(h**2*betas**2)/2) lambdas = 28939662
  deltas = (Ds**2/(4*Es*ts))*(1-vs/2)                  deltas = 0.0000859
  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 = 1.5 in
  From fig. UHX-11.2 or UHX-11.3 - E*/E = 0.2613            v* = 0.3418
                                    h/p = 0.96             mu* = 0.2573
  Effective Tubsheet Mod.Elasticity  E* = 7055350 psi
  Parameter Xa = (24*(1-v*(**2))*Nt*(Et*tt*(dt-tt)*
                  ao**2)/((E*)*L*h**3))**0.25              Xa = 10.464
UHX-13.5.4 Step 4. Calculate diameter ratio K and coefficient F.
  K = A / Do                                                K = 1.073
  F = ((1-v*)/E*)*(lambdas+lambdac+E*Ln(K))                 F = 2.877
```

Parameters Zd, Zv and Zm from Table UHX-13.1

```
  Psi1(Xa)=bei(Xa)+(1-v*)/Xa*ber'(Xa)                    Psi1(Xa) = 133.5542
  Psi2(Xa)=ber(Xa)-(1-v*)/Xa*bei'(Xa)                    Psi2(Xa) = 141.2525
  Za = bei'(Xa)*Psi2(Xa)-ber'(Xa)*Psi1(Xa)                     Za = 26823.4707
  Zd = (ber(Xa)*Psi2(Xa)+ bei(Xa)*Psi1(Xa))/(Xa**3*Za)         Zd = 0.0013
  Zv = (ber'(Xa)*Psi2(Xa)+ bei'(Xa)*Psi1(Xa))/(Xa**2*Za)       Zv = 0.0093
  Zm = (ber'(Xa)**2+bei'(Xa)**2)/(Xa*Za)                       Zm = 0.1376
  Calculate Q1, Qz1, Qz2 and U
  Phi = (1+v*) * F                                            Phi = 3.8601
  Q1 = (rhos-1-Phi*Zv)/(1+Phi*Zm)                              Q1 = -0.0164
  Qz1 = ((Zd+Q1*Zv)*Xa**4)/2                                  Qz1 = 6.7894
  Qz2 = ((Zv+Q1*Zm)*Xa**4)/2                                  Qz2 = 42.0055
  U = ((Zv+(rhos-1)*Zm)*Xa**4)/(1+Phi*Zm)                       U = 84.011
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 = 5.9789
  omegas* = ao**2*((rhos**2-1)*(rhos-1))/4-omegas         omegas* = -5.9082
  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* = 15.0119
UHX-13.5.5(c) Calculate gammab
  gammab = (Gc-C)/Do                                       gammab = -0.0213
```

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' = 436.93 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' = 258.45 psi
  Pgamma  = (Nt*Kt/(Pi*ao**2))*gamma                      Pgamma = 0 psi
  PW      = -(U/ao**2)(gammab/(2*Pi))*W                       PW = 51.34 psi
  Prim    = -(U/ao**2)*((omegas*)(Ps)-(omegac*)(Pt))        Prim = 132.35 psi
  Effective pressure, Pe
  Pe = (J*Kst/(1+J*Kst(Qz1+(rhos-1)Qz2))
       * (Ps'-Pt'+Pgamma+PW+Prim)                             Pe = 34.81 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 = -1767.954
  Q3 = Q1 + 2*Q2 / Pe*ao**2                                   Q3 = -0.0984
  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 = 10.4638 in
Calculate functions Psi1 and Psi2 relative to x
  Psi1(x) = bei(x) + (1-v*)/x * ber'(x)                  Psi1(x) = 133.5543
  Psi2(x) = ber(x) - (1-v*)/x * bei'(x)                  Psi2(x) = 141.2525
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) = -0.0492
  Fm = MAX|Fm(x)|                                              Fm = 0.0492
  For each loading case, calculate the bending stress in the tubesheet
  sigma = (1.5*Fm/mu*)*(2*ao/(h-h'g))**2 * Pe              sigma = 21987 psi
                                                          |sigma| <= 1.5*S
                                                       21987 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 = 3573.2 in2
  Perimeter of the tube layout                                CL = 307.476 in
  Shear diameter DL = 4*AL/CL or Do                           Do = 70.375 in
  Ligament efficiency, mu                            mu = (p-dt)/p = 0.2
  Shear stress, tau = (1/(4*mu)*(Do/h)* Pe                   tau = 2041 psi
                                                          |tau| <= 0.8*S
                                                        2041 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     = 2.2337
                  sigmato = ((Ps*xs-Ptxt)-Pe*Fq)/(xt-xs)   = -467 psi
                                                    sigmato <= St
                                                    467 psi <= 14941 psi

  UHX-13.5.9(b) Check the tubes for buckling.
  Ct = SQRT(2*PI**2*(Et/Syt)                                   Ct = 154.2491
  rt = SQRT(dt**2+(dt-2*tt)**2)/4                              rt = 0.425 in
  Ft = lt/rt                                                   Ft = 112.7136
  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 = -
  For Ct >  Ft  Stb = MIN[(Syt/Fs)*(1-(Ft/2*Ct))   ,St]       Stb = -7108 psi
                                                    sigmato <= Stb
                                                   -467 psi <= -7108 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 = 2.9132
  sigmati = ((Ps*xs-Ptxt)-Pe*Fi)/(xt-xs)         sigmati = -745 psi
                                                sigmati <= Stb
                                               -745 psi <= -7108 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 = 4087 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 = 10329 psi
  sigmas = |sigmasm| + |sigmasb|                       sigmas = 14416 psi
                                                      sigmas <= 1.5*S
                                                 14416 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	65	0	65	0	65	0	65
Shell-side press, Ps	0	165	165	0	0	165	165
Axial diff.Th.Exp	0.0	0.0	0.0	0.0381	0.0381	0.0381	0.0381
TubSh Bending stress	-12400	17326	21987	9685	14555	22102	26972
Max TubSh Bending st	22500	22500	22500	59505	59505	59505	59505
Min TubSh thk	1.1135	1.3163	1.4828	0.6052	0.7419	0.9142	1.0099
TubSh Shear stress	-794	3125	2041	2227	1145	5063	3982
Max TubSh Shear str	12000	12000	12000	15868	15868	15868	15868
Min TubSh thk	0.0993	0.3906	0.2552	0.2105	0.1083	0.4786	0.3764
Tubesheet thickness	1.5	1.5	1.5	1.5	1.5	1.5	1.5

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	1880	-2219	-467	-2543	-759	-4925	-3142
Max Tubes stress	14941	14941	14941	39671	39671	39671	39671
Max buckling stress	-	-11373	-7108	-11373	-7108	-11373	-11373
Total shell stress	21796	28177	14416	9048	11564	41124	27197
Max shell stress	30000	30000	30000	69600	69600	69600	69600
Max shell stress EP	69600	69600	69600				
Total channel stress	3767	0	3767	0	3767	0	3767
Max channel stress	28350	28350	28350	60000	60000	60000	60000
Max channel str. EP	56700	56700	56700				
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	-724	-2219	-745	-2543	-1046	-4925	-3142
Max buckling stress	-11373	-11373	-7108	-11373	-7108	-11373	-11373

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	65	0	0	0
- 2 -	165	0	0	0	0
- 3 -	165	65	0	0	0
- 4 -	0	0	0.0381	0	0
- 5 -	0	65	0.0381	0	0
- 6 -	165	0	0.0381	0	0
- 7 -	165	65	0.0381	0	0

Load case	P's psi	P't psi	Pgamma psi	Pomega psi	Pw psi	Prim psi	Pe psi
- 1 -	0	258.4	0	0	51.3	66.2	-13.5
- 2 -	436.9	0	0	0	51.3	66.1	53.3
- 3 -	436.9	258.4	0	0	51.3	132.4	34.8
- 4 -	0	0	348.6	0	52.6	0	38
- 5 -	0	262.7	348.6	0	52.6	67.9	19.5
- 6 -	443.4	0	348.6	0	52.6	67.8	86.3
- 7 -	443.4	262.7	348.6	0	52.6	135.7	67.9

Load case	Q2	Q3	Fm	Sigma psi	Sigma All psi	Tau psi	Tau All psi
- 1 -	-1131.3	0.1185	0.0713	-12400	22500	-794	12000
- 2 -	-1130.7	-0.0507	0.0253	17326	22500	3125	12000
- 3 -	-1768	-0.0984	0.0492	21987	22500	2041	12000
- 4 -	-488.5	-0.0373	0.0187	9685	59505	2227	15868
- 5 -	-1118.6	-0.1091	0.0545	14555	59505	1145	15868
- 6 -	-1118	-0.0375	0.0187	22102	59505	5063	15868
- 7 -	-1748.1	-0.0581	0.0291	26972	59505	3982	15868

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

Load case	Fq	Fs	Sigto psi	Sigto All psi	Stb psi
- 1 -	14.2826	1.25	1880	14941	-11373
- 2 -	4.886	1.25	-2219	14941	-11373
- 3 -	2.2337	2	-467	14941	-7108
- 4 -	5.6825	1.25	-2543	39671	-11373
- 5 -	1.5626	2	-759	39671	-7108
- 6 -	5.6749	1.25	-4925	39671	-11373
- 7 -	4.4877	1.25	-3142	39671	-11373

Load case	Sigsm psi	Sigsb psi	|Sigs| psi	Sigsall psi	Sigcm psi	Sigcb psi	|Sigc| psi	Sigcall psi
- 1 -	2035	-19761	21796	30000	3767	0	3767	28350
- 2 -	2247	25930	28177	30000	0	0	0	28350
- 3 -	4087	10329	14416	30000	3767	0	3767	28350
- 4 -	1502	7547	9048	69600	0	0	0	60000
- 5 -	3343	-8221	11564	69600	3767	0	3767	60000
- 6 -	3554	37570	41124	69600	0	0	0	60000
- 7 -	5396	21802	27197	69600	3767	0	3767	60000

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

Load case:	1	2	3	4	5	6	7
Tube-to-TS Load, lbf	348	410	86	470	140	911	581
Allowable no-test	2210	2210	2210	4420	4420	4420	4420
Allowable test	2762	2762	2762	5525	5525	5525	5525

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

Type	Joint description	No Test fr	No Test Lmax	Test fr	Test Lmax
a	Strength welded only	0.8	2210	1	2762
b	Seal welded only	0.55	1519	0.7	1934
e	Strength welded and expanded	0.8	2210	1	2762
f	Seal welded and exp.with 2 grooves	0.75	2072	0.95	2624
g	Seal welded and exp.with 1 groove	0.65	1796	0.85	2348
h	Seal welded and exp.with no grooves	0.5	1381	0.7	1934
i	Expanded with 2 grooves	0.7	1934	0.9	2486
j	Expanded with 1 groove	0.65	1796	0.8	2210
k	Expanded with no grooves	0.5	1381	0.6	1657

```
* = 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 = 0.1849 in2   Tube allowable stress Sa = 14941 psi
Factor fe (1/do or 1) fe = 1            Ratio fy                fy = 1
ft = (Po+Pt)/Po       ft = 1            Min Yield Str      SigmaM = 30000 psi
 (ft = 1 if max exceeded)
Tube OD               do = 1.25 in      Tube thickness          tt = 0.049 in
Tubes yield str(min)  st = 30000 psi    TubSh mean metal tmp     T = 105 F
Tubes Mod.Elasticity EtT = 28111538 psi TubSh Mod.Elast.       EsT = 28111538 psi
Tubes Coef.Th.Exp.    at = 0.0000086    TubSh Coef.Th.Exp.      as = 0.0000086
Po = (4*(do*t-t**2)*st)/do**2                                   Po = 4520 psi
Pt = ((T-Tamb)*(at-as)*(EtT*EsT)/(EtT+EsT)                      Pt = -
         For joint types i, j, k:                      Po + Pt <= 0.58*SigmaM
                                                      4520 psi <= 17400 psi

UHX-9 Tubesheet Flanged Extension
G  = diameter of gasket load reaction                   G = 72.75 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 = 219266 lbf
Wg = flange design bolt load, gasket seating           Wg = 223033 lbf
Minimum required thickness of the tubesheet flanged extension
hro = SQRT(1.9 * Wo * hG) / (Sd * G)                  hro = 0.5351 in
hrg = SQRT(1.9 * Wg * hG) / (Sa * G)                  hro = 0.4674 in
hr = MAX[hro, hrg]                                     hr = 0.5351 in
```

```
Component:  Nozzle A
ASME VIII-1 2004 A06 UG-27 Thickness of Cylinders under Internal Pressure
--- Calculations --- Cylinder Internal Pressure
Material:  SA-516 K02700 Grd 70 Plate
Design pressure       P = 150 psi          Design temperature   T = 200 F
Radiography             = None             Joint efficiency     E = 0.7
Design stress         S = 20000 psi
Inside corr.allow. cai = 0.0625 in         Outside corr. all. cao = 0.0 in
Material tolerance tol = 0.0 in            Minimum thickness tmin = 0.3906 in
Outside diameter    OD = 30.0 in           Corroded radius     OR = 15.0 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 = 0.2225 in   APP.1-1(A)
  - UG-45(a) external pressure+cai+cao+tol       t = 0.124 in
  - UG-16(b) minimum thickness+cai+cao+tol       t = 0.1563 in
    UG-45(b) Smaller of:                         t = 0.3906 in
    UG-45(b)(4) std pipe*0.875+cai+cao+tol = 0.3906 in
      - UG-45(b) Greater of:               t = 0.3971 in
        - UG-45(b)(1)+cai+cao+tol = 0.3971 in
        - UG-45(b)(2)+cai+cao+tol = 0 in
                       Minimum thickness:                tmin = 0.3906 in
                       Nominal thickness:                tnom = 0.5 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 = 200 F
Inside corr. allow. CAI = 0.0625 in       Corrosion allow.  CAO = 0 in
Radiography             = None            Material tol.     Tol = 0 in
Cyl. outside dia.    Do = 30 in           Cylinder length EP  L = 10 in
Nominal thickness  tnom = 0.5 in          (tnom-CAI-CAO-Tol)  t = 0.4375 in
L/Do ratio          Ldo = 0.3333          Do/t              Dot = 68.5714
(2*S) or (0.9*yield) SE = -               Mod. of elasticity ME = 28600000 psi
A factor SII-D-FigG   A = 0.008576        B factor CS-2       B = 17333
Max allowed external pressure: Pa = 4*B / (3*Dot)               = 337.03 psi
Actual external design pressure:                             PE = 15 psi
   (Required cyl. tks. for nozzle attachments at PE, tre = 0.0615 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 = 200 F         Fig.UW-16.1 Sketch (q)
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 = 89.5 in       Corroded radius     OR = 44.75 in
Nominal thickness  tnom = 0.75 in       Reinforcement limit lp = 29.125 in
Req. tks. int.pres.  tr = 0.3346 in     Req. tks.ext.pres. tre = 0.2185 in
Corroded thickness    t = 0.6875 in     Reinf. efficiency   E1 = 1.0
Attachment Material: SA-516 K02700 Grd 70 Plate
Inside corr. allow. CAI = 0.0625 in     Outside corr.allow.CAO = 0.0 in
Nozzle design stress Sn = 20000 psi     Joint efficiency     E = 0.7
Nozzle outside dia. Don = 30.0 in       Corroded radius     OR = 15.0 in
Nominal thickness  tnom = 0.5 in        Reinforcement limit ln = 1.0938 in
Req.tks. int.pres.  trn = 0.16 in       Req.tks.ext.pres. trne = 0.0615 in
Corroded thickness   tn = 0.4375 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)    = 0.0 in        Weld tw     (actual)   = 0.0 in
Weld  tc   (minimum)    = 0.0 in        Weld tc     (actual)   = 0.0 in
    smaller |0.25 in   |                Leg size tw (actual)   = 0.0 in
 tc    of   |0.7 * tmin|                Leg size tc (actual)   = 0.0 in
Outward nozzle weld   L1 = 0.0 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
```

```
Corroded inside diameter                                      d = 29.125 in
Vessel wall length available for reinforcement     2*Lp-d = 29.125 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)| = 10.2776 in2
 |2*(t+tn)*(E1*t-F*tr)-2*tn*(E1*t-F*tr)*(1-fr1)| = 0.794 in2
                                                         A1 = 10.2776 in2
A2 = Nozzle wall outward  | 5*(tn-trn)*fr2*t   | = 0.9538 in2
     Smaller of:          | 5*(tn-trn)*fr2*tn  | = 0.607 in2
                                                         A2 = 0.607 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 = 0.0 in2
A42 = Outer element weld  = (L2**2)*fr4 = 0.0 in2
A43 = Inward nozzle weld  = (L3**2)*fr2 = 0.0 in2
                                                         A4 = 0.0 in2
A5 = Reinforcement pad Area = (Dp-d-2*tn)*te*fr4         A5 = 0.0 in2
Aa = Area Available = A1+A2+A3+A4+A5                     Aa = 10.8846 in2
A = Area required    = (d*tr*F)+2*tn*tr*F*(1-f1)          A = 9.7458 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)| = 13.6596 in2
 |2*(t+tn)*(E1*t-F*tre)-2*tn*(E1*t-F*tre)*(1-fr1)| = 1.0552 in2
                                                         A1 = 13.6596 in2
A2 = Nozzle wall outward  | 5*(tn-trne)*fr2*t  | = 1.2925 in2
     Smaller of:          | 5*(tn-trne)*fr2*tn | = 0.8225 in2
                                                         A2 = 0.8225 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 = 0.0 in2
A42 = Outer element weld  =   (L2**2)*fr4 = 0.0 in2
A43 = Inward nozzle weld  =   (L3**2)*fr2 = 0.0 in2
                                                         A4 = 0.0 in2
A5 = Reinforcement pad Area = (Dp-d-2*tn)*te*fr4         A5 = 0.0 in2
Aa = Area Available = A1+A2+A3+A4+A5                     Aa = 14.4821 in2
A = Area required    = 0.5*(d*tre*F+2*tn*tre*F*(1-fr1))   A = 3.1819 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) = 12139 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) = 24171 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              =   9800 psi
    Outer fillet weld shear              =   -
    Groove weld tension                  =   14800 psi
    Groove weld shear                    =   -
    Nozzle wall shear                    =   14000 psi
 Strength of connection elements
    Inner fillet weld shear              =   0 lbf
    Nozzle wall shear                    =   284281 lbf
    Groove weld tension                  =   -
    Outer fillet weld shear              =   -
 Possible paths of failure
    1-1       284281 + 0                 =   284281 lbf
    2-2            0 + 0                 =   -0 lbf
    3-3            - + -                 =   -
 Welds strong enough if path greater than the smaller of W or W(path)
                            Path 1-1 > W or W11
                          284281 lbf > 12139 lbf               OK
                            Path 2-2 > W or W22
                              -0 lbf > 24171 lbf
                            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-516 K02700 Grd 70 Plate
Design pressure       P = 150 psi           Design temperature   T = 200 F
Radiography             = None              Joint efficiency     E = 0.7
Design stress         S = 20000 psi
Inside corr.allow. cai = 0.0625 in          Outside corr. all. cao = 0.0 in
Material tolerance tol = 0.0 in             Minimum thickness tmin = 0.3906 in
Outside diameter    OD = 30.0 in            Corroded radius     OR = 15.0 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 = 0.2225 in    APP.1-1(A)
  - UG-45(a) external pressure+cai+cao+tol       t = 0.124 in
  - UG-16(b) minimum thickness+cai+cao+tol       t = 0.1563 in
    UG-45(b) Smaller of:                         t = 0.3906 in
    UG-45(b)(4) std pipe*0.875+cai+cao+tol = 0.3906 in
      - UG-45(b) Greater of:             t = 0.3971 in
        - UG-45(b)(1)+cai+cao+tol = 0.3971 in
        - UG-45(b)(2)+cai+cao+tol = 0 in
                    Minimum thickness:                tmin = 0.3906 in
                    Nominal thickness:                tnom = 0.5 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 = 200 F
Inside corr. allow. CAI = 0.0625 in         Corrosion allow.  CAO = 0 in
Radiography             = None              Material tol.     Tol = 0 in
Cyl. outside dia.    Do = 30 in             Cylinder length EP  L = 10 in
Nominal thickness  tnom = 0.5 in            (tnom-CAI-CAO-Tol)  t = 0.4375 in
L/Do ratio          Ldo = 0.3333            Do/t              Dot = 68.5714
(2*S) or (0.9*yield) SE = -                 Mod. of elasticity ME = 28600000 psi
A factor SII-D-FigG   A = 0.008576          B factor CS-2       B = 17333
Max allowed external pressure: Pa = 4*B / (3*Dot)                 = 337.03 psi
Actual external design pressure:                               PE = 15 psi
   (Required cyl. tks. for nozzle attachments at PE, tre = 0.0615 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 = 200 F         Fig.UW-16.1 Sketch (q)
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 = 89.5 in       Corroded radius     OR = 44.75 in
Nominal thickness  tnom = 0.75 in       Reinforcement limit lp = 29.125 in
Req. tks. int.pres.  tr = 0.3346 in     Req. tks.ext.pres. tre = 0.2185 in
Corroded thickness    t = 0.6875 in     Reinf. efficiency   E1 = 1.0
Attachment Material: SA-516 K02700 Grd 70 Plate
Inside corr. allow. CAI = 0.0625 in     Outside corr.allow.CAO = 0.0 in
Nozzle design stress Sn = 20000 psi     Joint efficiency     E = 0.7
Nozzle outside dia. Don = 30.0 in       Corroded radius     OR = 15.0 in
Nominal thickness  tnom = 0.5 in        Reinforcement limit ln = 1.0938 in
Req.tks. int.pres.  trn = 0.16 in       Req.tks.ext.pres. trne = 0.0615 in
Corroded thickness   tn = 0.4375 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)    = 0.0 in        Weld tw     (actual)   = 0.0 in
Weld  tc   (minimum)    = 0.0 in        Weld tc     (actual)   = 0.0 in
    smaller |0.25 in   |                Leg size tw (actual)   = 0.0 in
 tc    of   |0.7 * tmin|                Leg size tc (actual)   = 0.0 in
Outward nozzle weld   L1 = 0.0 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
```

```
Corroded inside diameter                                   d = 29.125 in
Vessel wall length available for reinforcement    2*Lp-d = 29.125 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)| = 10.2776 in2
  |2*(t+tn)*(E1*t-F*tr)-2*tn*(E1*t-F*tr)*(1-fr1)| = 0.794 in2
                                                        A1 = 10.2776 in2
A2 = Nozzle wall outward   | 5*(tn-trn)*fr2*t    | = 0.9538 in2
     Smaller of:           | 5*(tn-trn)*fr2*tn   | = 0.607 in2
                                                        A2 = 0.607 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 = 0.0 in2
A42 = Outer element weld  = (L2**2)*fr4 = 0.0 in2
A43 = Inward nozzle weld  = (L3**2)*fr2 = 0.0 in2
                                                        A4 = 0.0 in2
A5 = Reinforcement pad Area = (Dp-d-2*tn)*te*fr4        A5 = 0.0 in2
Aa = Area Available = A1+A2+A3+A4+A5                    Aa = 10.8846 in2
A = Area required    = (d*tr*F)+2*tn*tr*F*(1-f1)         A = 9.7458 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)| = 13.6596 in2
  |2*(t+tn)*(E1*t-F*tre)-2*tn*(E1*t-F*tre)*(1-fr1)| = 1.0552 in2
                                                        A1 = 13.6596 in2
A2 = Nozzle wall outward   | 5*(tn-trne)*fr2*t   | = 1.2925 in2
     Smaller of:           | 5*(tn-trne)*fr2*tn  | = 0.8225 in2
                                                        A2 = 0.8225 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 = 0.0 in2
A42 = Outer element weld  =   (L2**2)*fr4 = 0.0 in2
A43 = Inward nozzle weld  =   (L3**2)*fr2 = 0.0 in2
                                                        A4 = 0.0 in2
A5 = Reinforcement pad Area = (Dp-d-2*tn)*te*fr4        A5 = 0.0 in2
Aa = Area Available = A1+A2+A3+A4+A5                    Aa = 14.4821 in2
A = Area required    = 0.5*(d*tre*F+2*tn*tre*F*(1-fr1))  A = 3.1819 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) = 12139 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) = 24171 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              =   9800 psi
    Outer fillet weld shear              =   -
    Groove weld tension                  =   14800 psi
    Groove weld shear                    =   -
    Nozzle wall shear                    =   14000 psi
 Strength of connection elements
    Inner fillet weld shear              =   0 lbf
    Nozzle wall shear                    =   284281 lbf
    Groove weld tension                  =   -
    Outer fillet weld shear              =   -
 Possible paths of failure
    1-1       284281 + 0                 =   284281 lbf
    2-2            0 + 0                 =   -0 lbf
    3-3            - + -                 =   -
 Welds strong enough if path greater than the smaller of W or W(path)
                           Path 1-1 > W or W11
                         284281 lbf > 12139 lbf                 OK
                           Path 2-2 > W or W22
                             -0 lbf > 24171 lbf
                           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-240 S30400 Grd 304 Plate(G5)
Design pressure       P = 50 psi         Design temperature    T = 300 F
Radiography             = None           Joint efficiency      E = 0.7
Design stress         S = 18900 psi
Inside corr.allow. cai = 0.0 in          Outside corr. all. cao = 0.0 in
Material tolerance tol = 0.0 in          Minimum thickness tmin = 0.114 in
Outside diameter    OD = 54.0 in         Corroded radius     OR = 27.0 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 = 0.1019 in   APP.1-1(A)
  - UG-45(a) external pressure+cai+cao+tol      t = 0.114 in
  - UG-16(b) minimum thickness+cai+cao+tol      t = 0.0938 in
    UG-45(b) Smaller of:                        t = 0.0951 in
    UG-45(b)(4) std pipe*0.875+cai+cao+tol = 0.3281 in
      - UG-45(b) Greater of:            t = 0.0951 in
        - UG-45(b)(1)+cai+cao+tol = 0.0951 in
        - UG-45(b)(2)+cai+cao+tol = 0.0286 in
                        Minimum thickness:                tmin = 0.114 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-240 S30400 Grd 304 Plate(G5)
Design pressure      PE = 15 psi          Design temperature  T = 300 F
Inside corr. allow. CAI = 0 in            Corrosion allow.  CAO = 0 in
Radiography             = None            Material tol.     Tol = 0 in
Cyl. outside dia.    Do = 54 in           Cylinder length EP  L = 17.75 in
Nominal thickness  tnom = 0.375 in        (tnom-CAI-CAO-Tol)  t = 0.375 in
L/Do ratio          Ldo = 0.3287          Do/t              Dot = 144.0
(2*S) or (0.9*yield) SE = -               Mod. of elasticity ME = 27000000 psi
A factor SII-D-FigG   A = 0.002624        B factor HA-1       B = 9915
Max allowed external pressure: Pa = 4*B / (3*Dot)               = 91.81 psi
Actual external design pressure:                             PE = 15 psi
   (Required cyl. tks. for nozzle attachments at PE, tre = 0.114 in  )
```

Component: Reinforcement Nozzle C

```
ASME Section VIII-1 2004 A06 UG-37  Reinforcement Required for Openings in
                                    Shells and Formed Heads
--- Design Conditions:
Int. design pressure PI = 50 psi        Ext. design press.  PE = 15 psi
Design temperature    T = 300 F         Fig.UW-16.1 Sketch (q)
Vessel material: SA-240 S30400 Grd 304 Plate(G5)
Inside corr. allow. CAI = 0.0 in        Outside corr.allow.CAO = 0.0 in
Vessel design stress Sv = 18900 psi     Joint efficiency     E = 1
Vessel outside dia   Do = 72.0 in       Corroded radius     OR = 36.0 in
Nominal thickness  tnom = 0.375 in      Reinforcement limit lp = 53.25 in
Req. tks. int.pres.  tr = 0.0951 in     Req. tks.ext.pres. tre = 0.303 in
Corroded thickness    t = 0.375 in      Reinf. efficiency   E1 = 1.0
Attachment Material: SA-240 S30400 Grd 304 Plate(G5)
Inside corr. allow. CAI = 0.0 in        Outside corr.allow.CAO = 0.0 in
Nozzle design stress Sn = 18900 psi     Joint efficiency     E = 0.7
Nozzle outside dia. Don = 54.0 in       Corroded radius     OR = 27.0 in
Nominal thickness  tnom = 0.375 in      Reinforcement limit ln = 0.9375 in
Req.tks. int.pres.  trn = 0.1019 in     Req.tks.ext.pres. trne = 0.114 in
Corroded thickness   tn = 0.375 in      Nozzle Projection    h = 0.0 in
Reinforcement element material: SA-240 S30400 Grd 304 Plate(G5)
Limit of reinf.      Dp = 76.0 in       Nominal thickness   te = 0.375 in
Outside diameter        = 76.0 in       Design stress       Se = 18900 psi
Minimum weld size tmin  = 0.375 in      Leg size(1/2*tmin)(Act)= 0.2679 in
1/2 * tmin (minimum)    = 0.1875 in     1/2 * tmin  (actual)   = 0.1875 in
Weld  tw   (minimum)    = 0.2625 in     Weld tw     (actual)   = 0.3571 in
Weld  tc   (minimum)    = 0.25 in       Weld tc     (actual)   = 0.25 in
    smaller |0.25 in   |                Leg size tw (actual)   = 0.3571 in
 tc    of   |0.7 * tmin|                Leg size tc (actual)   = 0.3571 in
Outward nozzle weld   L1 = 0.3571 in    fr1 = Sn/Sv              = 1.0
Outer element weld    L2 = 0.2679 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 = 53.25 in
Vessel wall length available for reinforcement     2*Lp-d = 53.25 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)| = 14.9027 in2
 |2*(t+tn)*(E1*t-F*tr)-2*tn*(E1*t-F*tr)*(1-fr1)| = 0.4198 in2
                                                         A1 = 14.9027 in2
A2 = Nozzle wall outward  | 5*(tn-trn)*fr2*t    | = 0.5121 in2
     Smaller of:  | 2*(tn-trn)*(2.5*tn+te)*fr2 | = 0.7169 in2
                                                         A2 = 0.5121 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 = 0.1276 in2
A42 = Outer element weld  = (L2**2)*fr4 = 0.0717 in2
A43 = Inward nozzle weld  = (L3**2)*fr2 = 0.0 in2
                                                         A4 = 0.1993 in2
A5 = Reinforcement pad Area = (Dp-d-2*tn)*te*fr4         A5 = 8.25 in2
Aa = Area Available = A1+A2+A3+A4+A5                     Aa = 23.8641 in2
A = Area required    = (d*tr*F)+2*tn*tr*F*(1-f1)          A = 5.0661 in2
For large nozzles per 1-7:
  Reinforcement limit Dp2 = MIN(Dp, 1-7(a)(1))          Dp2 = 76.0 in
  A52 = Reinforcement pad Area = (Dp2-d-2*tn)*te*fr4    A52 = 8.25 in2
  A12 = Vessel wall.  Larger of:
     |(1.5Lp-d)*(E1*t-F*tr)-2*tn*(E1*t-F*tr)*(1-fr1)| = 7.4513 in
     |2*(t+tn)*(E1*t-F*tr)-2*tn*(E1*t-F*tr)*(1-fr1)|  = 0.4198 in
  Aa2= Area Available    = A12+A2+A3+A4+A52             Aa2 = 16.4127 in2
  A = (2/3)Area required = (2/3)*((d*tr*F)+2*tn*tr*F*(1-f1)) A = 3.3774 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)| = 3.834 in2
 |2*(t+tn)*(E1*t-F*tre)-2*tn*(E1*t-F*tre)*(1-fr1)| = 0.108 in2
                                                         A1 = 3.834 in2
A2 = Nozzle wall outward  | 5*(tn-trne)*fr2*t  | = 0.4894 in2
     Smaller of:  | 2*(tn-trne)*(2.5*tn+te)*fr2| = 0.6851 in2
                                                         A2 = 0.4894 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 = 0.1276 in2
A42 = Outer element weld  =   (L2**2)*fr4 = 0.0717 in2
A43 = Inward nozzle weld  =   (L3**2)*fr2 = 0.0 in2
                                                         A4 = 0.1993 in2
A5 = Reinforcement pad Area = (Dp-d-2*tn)*te*fr4         A5 = 8.25 in2
Aa = Area Available = A1+A2+A3+A4+A5                     Aa = 12.7727 in2
A = Area required   = 0.5*(d*tre*F+2*tn*tre*F*(1-fr1))    A = 8.0674 in2
```

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

```
 -
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) = 169370 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) = 17405 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) = 174686 lbf
Reinforcing element strength = A5 * Se                         = 155925 lbf
Nozzle attachment weld loads - ASME 2004 UG-41 - Strength of reinforcement
 Unit stresses - UW15(c)and UG-45(c)
    Inner fillet weld shear           =   9261 psi
    Outer fillet weld shear           =   9261 psi
    Groove weld tension               =   13986 psi
    Groove weld shear                 =   11340 psi
    Nozzle wall shear                 =   13230 psi
 Strength of connection elements
    Inner fillet weld shear           =   280410 lbf
    Nozzle wall shear                 =   417694 lbf
    Groove weld tension               =   423477 lbf
    Outer fillet weld shear           =   295989 lbf
 Possible paths of failure
    1-1       417694 + 295989         =   713683 lbf
    2-2       280410 + 846954         =   1127364 lbf
    3-3       423477 + 295989         =   719466 lbf
 Welds strong enough if path greater than the smaller of W or W(path)
                            Path 1-1 > W or W11
                          713683 lbf > 169370 lbf              OK
                            Path 2-2 > W or W22
                         1127364 lbf > 17405 lbf               OK
                            Path 3-3 > W or W33
                          719466 lbf > 0 lbf
```

Component: Reinforcement Nozzle C

```
Appendix 1-7 - Large Openings in Cylindrical Shells
Paragraph 1-7(b) - All dimensions in their corroded state
Radius R                R = 35.625 in     Radius Rn            Rn = 26.625 in
Ratio Rn / R       Rn /R = 0.7474         Method applicable for Rn / R <= 0.7
Mean cylinder radius Rm = 35.8125 in      Mean nozzle radius Rnm = 26.8125 in
Cylinder thickness    t = 0.375 in        Nozzle thickness    tn = 0.375 in
Pad thickness        te = 0.375 in
Nozzle ID          2*Rn = 53.25 in        Factor 3.4*Sqrt(R*t)    = 12.4272 in
Shell area available  A = 1.37 in2        Nozzle area avail.  An = 2.53 in2
Pad area available   Ap = 2.25 in2        Total area As=A+An+Ap  = 6.16 in2
Limit       (Rm*t)**0.5 = 3.6647 in       Limit te+(Rnm*tn)**0.5 = 3.5459 in
Limit              16*t = 6.0 in          Limit te+16*tn         = 6.375 in
(Larger limit used)
Dimension a           a = 1.6353 in       Dimension e            e = 1.4478 in
Component: Reinforcement Nozzle C
Appendix 1-7 - Large Openings in Cylindrical Shells
Paragraph 1-7(b) - All dimensions in their corroded state
M = ((Rn**3/6)+R*Rn*e)*P = 225950 lbf/in  Moment of Inertia   I = 22.7947
Membrane stress, Sm and Bending stress, Sb
Sm = P * (R*(Rn+tn+(Rm*t)**.5)+Rn(t+te+(Rnm*tn)**.5)) / As  Sm = 9722 psi
Sb = M * a / I                                              Sb = 16210 psi
Acceptance criteria:  Sm <= S                         Sm + SB <= 1.5 * S
                9722 psi <= 18900 psi              25932 psi <= 28350 psi
```

Component: 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 = 50 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 = 0.1301 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 = 0.0471 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 = 0.1287 in
    UG-45(b) Smaller of:                          t = 0.1301 in
    UG-45(b)(4) std pipe*0.875+cai+cao+tol = 0.28 in
      - UG-45(b) Greater of:              t = 0.1301 in
        - UG-45(b)(1)+cai+cao+tol = 0.1301 in
        - UG-45(b)(2)+cai+cao+tol = 0.0636 in
                        Minimum thickness:                tmin = 0.1301 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 D

```
ASME Section VIII-1 2004 A06 UG-37  Reinforcement Required for Openings in
                                Shells and Formed Heads
--- Design Conditions:
Int. design pressure PI = 50 psi        Ext. design press.  PE = 15 psi
Design temperature    T = 300 F         Fig.UW-16.1 Sketch (q)
Vessel material: SA-240 S30400 Grd 304 Plate(G5)
Inside corr. allow. CAI = 0.0 in        Outside corr.allow.CAO = 0.0 in
Vessel design stress Sv = 18900 psi     Joint efficiency     E = 1
Vessel outside dia   Do = 72.0 in       Corroded radius     OR = 36.0 in
Nominal thickness  tnom = 0.3125 in     Reinforcement limit lp = 6.065 in
Req. tks. int.pres.  tr = 0.0951 in     Req. tks.ext.pres. tre = 0.161 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 = 0.28 in       Reinforcement limit ln = 0.7 in
Req.tks. int.pres.  trn = 0.0121 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              = 0.8519
Outer element weld    L2 = 0.0 in       fr2 = Sn/Sv              = 0.8519
Inward nozzle weld    L3 = 0.0 in       fr3 = Sn/Sv or Se/Sv     = 0.8519
Inward nozzel weld new   = 0.0 in       fr4 = Se/Sv              = 1.0
Corroded int.proj.thk ti = 0.0 in
```

```
Corroded inside diameter                                 d = 6.065 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)| = 1.3003 in2
 |2*(t+tn)*(E1*t-F*tr)-2*tn*(E1*t-F*tr)*(1-fr1)| = 0.2395 in2
                                                        A1 = 1.3003 in2
A2 = Nozzle wall outward  | 5*(tn-trn)*fr2*t    | = 0.3566 in2
     Smaller of:          | 5*(tn-trn)*fr2*tn   | = 0.3195 in2
                                                        A2 = 0.3195 in2
A3 = Nozzle wall inward   | 5*t*ti*fr2  | = 0.0 in2
     Smallest of:         | 5*ti*ti*fr2 | = 0.0 in2
                          | 2*h*ti*fr2  | = 0.0 in2
                                                        A3 = 0.0 in2
A41 = Outward nozzle weld = (L1**2)*fr3 = 0.0668 in2
A42 = Outer element weld  = (L2**2)*fr4 = 0.0 in2
A43 = Inward nozzle weld  = (L3**2)*fr2 = 0.0 in2
                                                        A4 = 0.0668 in2
A5 = Reinforcement pad Area = (Dp-d-2*tn)*te*fr4        A5 = 0.0 in2
Aa = Area Available = A1+A2+A3+A4+A5                    Aa = 1.6866 in2
A = Area required   = (d*tr*F)+2*tn*tr*F*(1-f1)          A = 0.5849 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)| = 0.9063 in2
 |2*(t+tn)*(E1*t-F*tre)-2*tn*(E1*t-F*tre)*(1-fr1)| = 0.167 in2
                                                        A1 = 0.9063 in2
A2 = Nozzle wall outward  | 5*(tn-trne)*fr2*t  | = 0.3434 in2
     Smaller of:          | 5*(tn-trne)*fr2*tn | = 0.3077 in2
                                                        A2 = 0.3077 in2
A3 = Nozzle wall inward   | 5*t*ti*fr2  | = 0.0 in2
     Smallest of:         | 5*ti*ti*fr2 | = 0.0 in2
                          | 2*h*ti*fr2  | = 0.0 in2
                                                        A3 = 0.0 in2
A41 = Outward nozzle weld =   (L1**2)*fr3 = 0.0668 in2
A42 = Outer element weld  =   (L2**2)*fr4 = 0.0 in2
A43 = Inward nozzle weld  =   (L3**2)*fr2 = 0.0 in2
                                                        A4 = 0.0668 in2
A5 = Reinforcement pad Area = (Dp-d-2*tn)*te*fr4        A5 = 0.0 in2
Aa = Area Available = A1+A2+A3+A4+A5                    Aa = 1.2808 in2
A = Area required   = 0.5*(d*tre*F+2*tn*tre*F*(1-fr1))   A = 0.4949 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) = 7301 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) = 10119 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              =   7889 psi
    Outer fillet weld shear              =   -
    Groove weld tension                  =   11914 psi
    Groove weld shear                    =   11340 psi
    Nozzle wall shear                    =   11270 psi
 Strength of connection elements
    Inner fillet weld shear              =   22976 lbf
    Nozzle wall shear                    =   31435 lbf
    Groove weld tension                  =   34698 lbf
    Outer fillet weld shear              =   -
 Possible paths of failure
    1-1        31435 + 22976             =   54411 lbf
    2-2        22976 + 69396             =   57674 lbf
    3-3            - + -                 =   -
 Welds strong enough if path greater than the smaller of W or W(path)
                            Path 1-1 > W or W11
                           54411 lbf > 7301 lbf                  OK
                            Path 2-2 > W or W22
                           57674 lbf > 10119 lbf                 OK
                            Path 3-3 > W or W33
                                   - > -
```

```
Component:  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 = 50 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 = 0.1301 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 = 0.0471 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 = 0.1287 in
    UG-45(b) Smaller of:                          t = 0.1301 in
    UG-45(b)(4) std pipe*0.875+cai+cao+tol = 0.28 in
      - UG-45(b) Greater of:              t = 0.1301 in
        - UG-45(b)(1)+cai+cao+tol = 0.1301 in
        - UG-45(b)(2)+cai+cao+tol = 0.0636 in
                        Minimum thickness:                 tmin = 0.1301 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 E
ASME Section VIII-1 2004 A06 UG-37  Reinforcement Required for Openings in
                                Shells and Formed Heads
--- Design Conditions:
Int. design pressure PI = 50 psi        Ext. design press.  PE = 15 psi
Design temperature    T = 300 F         Fig.UW-16.1 Sketch (q)
Vessel material: SA-240 S30400 Grd 304 Plate(G5)
Inside corr. allow. CAI = 0.0 in        Outside corr.allow.CAO = 0.0 in
Vessel design stress Sv = 18900 psi     Joint efficiency     E = 1
Vessel outside dia   Do = 72.0 in       Corroded radius     OR = 36.0 in
Nominal thickness  tnom = 0.3125 in     Reinforcement limit lp = 6.065 in
Req. tks. int.pres.  tr = 0.0951 in     Req. tks.ext.pres. tre = 0.161 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 = 0.28 in       Reinforcement limit ln = 0.7 in
Req.tks. int.pres.  trn = 0.0121 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              = 0.8519
Outer element weld    L2 = 0.0 in       fr2 = Sn/Sv              = 0.8519
Inward nozzle weld    L3 = 0.0 in       fr3 = Sn/Sv or Se/Sv     = 0.8519
Inward nozzel weld new   = 0.0 in       fr4 = Se/Sv              = 1.0
Corroded int.proj.thk ti = 0.0 in
```

```
Corroded inside diameter                                     d = 6.065 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)| = 1.3003 in2
 |2*(t+tn)*(E1*t-F*tr)-2*tn*(E1*t-F*tr)*(1-fr1)| = 0.2395 in2
                                                            A1 = 1.3003 in2
A2 = Nozzle wall outward  | 5*(tn-trn)*fr2*t   | = 0.3566 in2
     Smaller of:          | 5*(tn-trn)*fr2*tn  | = 0.3195 in2
                                                            A2 = 0.3195 in2
A3 = Nozzle wall inward   | 5*t*ti*fr2  | = 0.0 in2
     Smallest of:         | 5*ti*ti*fr2 | = 0.0 in2
                          | 2*h*ti*fr2  | = 0.0 in2
                                                            A3 = 0.0 in2
A41 = Outward nozzle weld = (L1**2)*fr3 = 0.0668 in2
A42 = Outer element weld  = (L2**2)*fr4 = 0.0 in2
A43 = Inward nozzle weld  = (L3**2)*fr2 = 0.0 in2
                                                            A4 = 0.0668 in2
A5 = Reinforcement pad Area = (Dp-d-2*tn)*te*fr4            A5 = 0.0 in2
Aa = Area Available = A1+A2+A3+A4+A5                        Aa = 1.6866 in2
A = Area required   = (d*tr*F)+2*tn*tr*F*(1-f1)              A = 0.5849 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)| = 0.9063 in2
 |2*(t+tn)*(E1*t-F*tre)-2*tn*(E1*t-F*tre)*(1-fr1)| = 0.167 in2
                                                            A1 = 0.9063 in2
A2 = Nozzle wall outward  | 5*(tn-trne)*fr2*t  | = 0.3434 in2
     Smaller of:          | 5*(tn-trne)*fr2*tn | = 0.3077 in2
                                                            A2 = 0.3077 in2
A3 = Nozzle wall inward   | 5*t*ti*fr2  | = 0.0 in2
     Smallest of:         | 5*ti*ti*fr2 | = 0.0 in2
                          | 2*h*ti*fr2  | = 0.0 in2
                                                            A3 = 0.0 in2
A41 = Outward nozzle weld =   (L1**2)*fr3 = 0.0668 in2
A42 = Outer element weld  =   (L2**2)*fr4 = 0.0 in2
A43 = Inward nozzle weld  =   (L3**2)*fr2 = 0.0 in2
                                                            A4 = 0.0668 in2
A5 = Reinforcement pad Area = (Dp-d-2*tn)*te*fr4            A5 = 0.0 in2
Aa = Area Available = A1+A2+A3+A4+A5                        Aa = 1.2808 in2
A = Area required   = 0.5*(d*tre*F+2*tn*tre*F*(1-fr1))       A = 0.4949 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) = 7301 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) = 10119 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              =   7889 psi
    Outer fillet weld shear              =   -
    Groove weld tension                  =   11914 psi
    Groove weld shear                    =   11340 psi
    Nozzle wall shear                    =   11270 psi
 Strength of connection elements
    Inner fillet weld shear              =   22976 lbf
    Nozzle wall shear                    =   31435 lbf
    Groove weld tension                  =   34698 lbf
    Outer fillet weld shear              =   -
 Possible paths of failure
    1-1        31435 + 22976             =   54411 lbf
    2-2        22976 + 69396             =   57674 lbf
    3-3            - + -                 =   -
 Welds strong enough if path greater than the smaller of W or W(path)
                          Path 1-1 > W or W11
                         54411 lbf > 7301 lbf                OK
                          Path 2-2 > W or W22
                         57674 lbf > 10119 lbf               OK
                          Path 3-3 > W or W33
                                 - > -
```

```
Component:  Nozzle G
ASME VIII-1 2004 A06 UG-27 Thickness of Cylinders under Internal Pressure
--- Calculations --- Cylinder Internal Pressure
Material:  SA-312 S30400 Grd TP304 Wld. pipe(G5)
Design pressure       P = 50 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 = 0.0421 in        Minimum thickness tmin = 0.1373 in
Outside diameter    OD = 4.0 in           Corroded radius      OR = 2.0 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 = 0.0494 in    APP.1-1(A)
  - UG-45(a) external pressure+cai+cao+tol       t = 0.058 in
  - UG-16(b) minimum thickness+cai+cao+tol       t = 0.1359 in
    UG-45(b) Smaller of:                         t = 0.1373 in
    UG-45(b)(4) std pipe*0.875+cai+cao+tol = 0.2399 in
      - UG-45(b) Greater of:               t = 0.1373 in
        - UG-45(b)(1)+cai+cao+tol = 0.1373 in
        - UG-45(b)(2)+cai+cao+tol = 0.0707 in
                        Minimum thickness:                tmin = 0.1373 in
                        Nominal thickness:                tnom = 0.337 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 = 4 in            Cylinder length EP   L = 6 in
Nominal thickness  tnom = 0.337 in        (tnom-CAI-CAO-Tol)   t = 0.2949 in
L/Do ratio          Ldo = 1.5             Do/t               Dot = 13.5651
(2*S) or (0.9*yield) SE = -               Mod. of elasticity ME = 27000000 psi
A factor SII-D-FigG   A = 0.018993        B factor HA-1        B = 12181
Max allowed external pressure: Pa = 4*B / (3*Dot)               = 1197.31 psi
Actual external design pressure:                              PE = 15 psi
   (Required cyl. tks. for nozzle attachments at PE, tre = 0.0159 in )
```

Component: Reinforcement Nozzle G

```
ASME Section VIII-1 2004 A06 UG-37  Reinforcement Required for Openings in
                                Shells and Formed Heads
--- Design Conditions:
Int. design pressure PI = 50 psi         Ext. design press.  PE = 15 psi
Design temperature    T = 300 F          Fig.UW-16.1 Sketch (e)
Vessel material: SA-240 S30400 Grd 304 Plate(G5)
Inside corr. allow. CAI = 0.0 in         Outside corr.allow.CAO = 0.0 in
Vessel design stress Sv = 18900 psi      Joint efficiency     E = 1
Vessel outside dia   Do = 72.0 in        Corroded radius     OR = 36.0 in
Nominal thickness  tnom = 0.375 in       Reinforcement limit lp = 3.326 in
Req. tks. int.pres.  tr = 0.0951 in      Req. tks.ext.pres. tre = 0.303 in
Corroded thickness    t = 0.375 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 = 4.0 in         Corroded radius     OR = 2.0 in
Nominal thickness  tnom = 0.337 in       Reinforcement limit ln = 0.8425 in
Req.tks. int.pres.  trn = 0.0073 in      Req.tks.ext.pres. trne = 0.0159 in
Corroded thickness   tn = 0.337 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  = 0.337 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)    = 0.2359 in      Weld tw     (actual)   = 0.0 in
Weld  tc   (minimum)    = 0.2359 in      Weld tc     (actual)   = 0.2359 in
    smaller |0.25 in   |                 Leg size tw (actual)   = 0.0 in
  tc   of   |0.7 * tmin|                 Leg size tc (actual)   = 0.337 in
Outward nozzle weld   L1 = 0.337 in      fr1 = Sn/Sv              = 0.8519
Outer element weld    L2 = 0.0 in        fr2 = Sn/Sv              = 0.8519
Inward nozzle weld    L3 = 0.0 in        fr3 = Sn/Sv or Se/Sv     = 0.8519
Inward nozzel weld new   = 0.0 in        fr4 = Se/Sv              = 1.0
Corroded int.proj.thk ti = 0.0 in
```

```
Corroded inside diameter                                d = 3.326 in
Vessel wall length available for reinforcement    2*Lp-d = 3.326 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)| = 0.9029 in2
 |2*(t+tn)*(E1*t-F*tr)-2*tn*(E1*t-F*tr)*(1-fr1)| = 0.3706 in2
                                                        A1 = 0.9029 in2
A2 = Nozzle wall outward  | 5*(tn-trn)*fr2*t   | = 0.5266 in2
     Smaller of:          | 5*(tn-trn)*fr2*tn  | = 0.4732 in2
                                                        A2 = 0.4732 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 = 0.0967 in2
A42 = Outer element weld  = (L2**2)*fr4 = 0.0 in2
A43 = Inward nozzle weld  = (L3**2)*fr2 = 0.0 in2
                                                        A4 = 0.0967 in2
A5 = Reinforcement pad Area = (Dp-d-2*tn)*te*fr4        A5 = 0.0 in2
Aa = Area Available = A1+A2+A3+A4+A5                    Aa = 1.4729 in2
A = Area required    = (d*tr*F)+2*tn*tr*F*(1-f1)         A = 0.3259 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)| = 0.2323 in2
 |2*(t+tn)*(E1*t-F*tre)-2*tn*(E1*t-F*tre)*(1-fr1)| = 0.0953 in2
                                                        A1 = 0.2323 in2
A2 = Nozzle wall outward  | 5*(tn-trne)*fr2*t  | = 0.5129 in2
     Smaller of:          | 5*(tn-trne)*fr2*tn | = 0.4609 in2
                                                        A2 = 0.4609 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 = 0.0967 in2
A42 = Outer element weld  =   (L2**2)*fr4 = 0.0 in2
A43 = Inward nozzle weld  =   (L3**2)*fr2 = 0.0 in2
                                                        A4 = 0.0967 in2
A5 = Reinforcement pad Area = (Dp-d-2*tn)*te*fr4        A5 = 0.0 in2
Aa = Area Available = A1+A2+A3+A4+A5                    Aa = 0.79 in2
A = Area required   = 0.5*(d*tre*F+2*tn*tre*F*(1-fr1))   A = 0.519 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) = 10773 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) = 14842 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               =   7889 psi
    Outer fillet weld shear               =   -
    Groove weld tension                   =   11914 psi
    Groove weld shear                     =   11340 psi
    Nozzle wall shear                     =   11270 psi
 Strength of connection elements
    Inner fillet weld shear               =   16696 lbf
    Nozzle wall shear                     =   21842 lbf
    Groove weld tension                   =   25215 lbf
    Outer fillet weld shear               =   -
 Possible paths of failure
    1-1        21842 + 16696              =   38538 lbf
    2-2        16696 + 25215              =   41911 lbf
    3-3            - + -                  =   -
 Welds strong enough if path greater than the smaller of W or W(path)
                           Path 1-1 > W or W11
                          38538 lbf > 10773 lbf               OK
                           Path 2-2 > W or W22
                          41911 lbf > 14842 lbf               OK
                           Path 3-3 > W or W33
                                  - > -
```

Component: 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 = 50 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 = 0.2265 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 = 0.0439 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 = 0.2265 in
    UG-45(b)(4) std pipe*0.875+cai+cao+tol = 0.2265 in
      - UG-45(b) Greater of:             t = 2.4676 in
        - UG-45(b)(1)+cai+cao+tol = 2.4676 in
        - UG-45(b)(2)+cai+cao+tol = 1.0375 in
                        Minimum thickness:                 tmin = 0.2265 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 )
```

Component: 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 = 50 psi         Ext. design press.  PE = 0 psi
Design temperature    T = 300 F          Fig.UW-16.1 Sketch (q)
Vessel material: SA-516 K02700 Grd 70 Plate
Inside corr. allow. CAI = 0.0 in         Outside corr.allow.CAO = 0.0 in
Vessel design stress Sv = 20000 psi      Joint efficiency     E = 1
Vessel outside dia   Do = 75.625 in      Corroded radius     IR = 35.625 in
Nominal thickness  tnom = 2.8125 in      Reinforcement limit lp = 4.5625 in
Req. tks. int.pres.  tr = 2.4301 in      Req. tks.ext.pres. tre = 0.0 in
Corroded thickness    t = 2.8125 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 = 0.9375 in
Req.tks. int.pres.  trn = 0.0064 in      Req.tks.ext.pres. trne = 0.0155 in
Corroded thickness   tn = 0.3 in         Nozzle Projection    h = 0.0 in
Reinforcement element material: SA-516 K02700 Grd 70 Plate
Limit of reinf.      Dp = 8.0 in         Nominal thickness   te = 0.1875 in
Outside diameter        = 8.0 in         Design stress       Se = 20000 psi
Minimum weld size tmin  = 0.1875 in      Leg size(1/2*tmin)(Act)= 0.1464 in
1/2 * tmin (minimum)    = 0.0938 in      1/2 * tmin  (actual)   = 0.1024 in
Weld  tw   (minimum)    = 0.1312 in      Weld tw     (actual)   = 0.1875 in
Weld  tc   (minimum)    = 0.21 in        Weld tc     (actual)   = 0.21 in
    smaller |0.25 in    |                Leg size tw (actual)   = 0.1875 in
 tc    of   |0.7 * tmin|                 Leg size tc (actual)   = 0.3 in
Outward nozzle weld   L1 = 0.1875 in     fr1 = Sn/Sv               = 0.805
Outer element weld    L2 = 0.1464 in     fr2 = Sn/Sv               = 0.805
Inward nozzle weld    L3 = 0.0 in        fr3 = Sn/Sv or Se/Sv      = 0.805
Inward nozzel weld new   = 0.0 in        fr4 = Se/Sv               = 1.0
Corroded int.proj.thk ti = 0.0 in
```

```
Corroded inside diameter                              d = 2.9 in
Vessel wall length available for reinforcement    2*Lp-d = 4.5625 in
Plane correction factor (Fig.UG-37)                    F = 1.0
Offset distance from centerline                     doff = 0.0 in
Reinforcement areas (internal pressure condition) ASME 2004 UG-37
A1 = Vessel wall.  Larger of:
 |(2*Lp-d)*(E1*t-F*tr)-2*tn*(E1*t-F*tr)*(1-fr1)| = 1.7001 in2
 |2*(t+tn)*(E1*t-F*tr)-2*tn*(E1*t-F*tr)*(1-fr1)| = 2.3359 in2
                                                        A1 = 2.3359 in2
A2 = Nozzle wall outward  | 5*(tn-trn)*fr2*t    | = 3.3238 in2
     Smaller of:  | 2*(tn-trn)*(2.5*tn+te)*fr2 | = 0.4432 in2
                                                        A2 = 0.4432 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 = 0.0283 in2
A42 = Outer element weld  = (L2**2)*fr4 = 0.0214 in2
A43 = Inward nozzle weld  = (L3**2)*fr2 = 0.0 in2
                                                        A4 = 0.0497 in2
A5 = Reinforcement pad Area = (Dp-d-2*tn)*te*fr4        A5 = 0.8438 in2
Aa = Area Available = A1+A2+A3+A4+A5                    Aa = 3.6726 in2
A = Area required   = 0.5*d*t + t*tn*(1-f1)              A = 3.6657 in2
```

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

```
-
Total weld load (UG-41(b)(2))
  W = (A-A1+2*tn*fr1(E1*t-F*tr))*Sv                       W = 30291 lbf
Weld load for strength path 1-1 (UG-41(b)(1)
  W(1-1) = (A2+A5+A41+A42)*Sv                         W(1-1) = 26733 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) = 36598 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) = 53902 lbf
Reinforcing element strength = A5 * Se                       = 16875 lbf
Nozzle attachment weld loads - ASME 2004 UG-41 - Strength of reinforcement
 Unit stresses - UW15(c)and UG-45(c)
    Inner fillet weld shear             =   7889 psi
    Outer fillet weld shear             =   9800 psi
    Groove weld tension                 =   11914 psi
    Groove weld shear                   =   9660 psi
    Nozzle wall shear                   =   11270 psi
 Strength of connection elements
    Inner fillet weld shear             =   8129 lbf
    Nozzle wall shear                   =   16987 lbf
    Groove weld tension                 =   12276 lbf
    Outer fillet weld shear             =   18015 lbf
 Possible paths of failure
    1-1        16987 + 18015            =   35002 lbf
    2-2         8129 + 24552            =   32681 lbf
    3-3        12276 + 18015            =   30291 lbf
 Welds strong enough if path greater than the smaller of W or W(path)
                          Path 1-1 > W or W11
                         35002 lbf > 26733 lbf              OK
                          Path 2-2 > W or W22
                         32681 lbf > 30291 lbf              OK
                          Path 3-3 > W or W33
                         30291 lbf > 30291 lbf              OK
```

Component: Nozzle J

```
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 = 200 F
Radiography             = None            Joint efficiency      E = 0.85
Design stress         S = 14600 psi
Inside corr.allow. cai = 0.0625 in        Outside corr. all. cao = 0.0 in
Material tolerance tol = 0.043 in         Minimum thickness tmin = 0.2403 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 = 0.1198 in    APP.1-1(A)
  - UG-45(a) external pressure+cai+cao+tol       t = 0.117 in
  - UG-16(b) minimum thickness+cai+cao+tol       t = 0.1992 in
    UG-45(b) Smaller of:                         t = 0.2403 in
    UG-45(b)(4) std pipe*0.875+cai+cao+tol = 0.2403 in
      - UG-45(b) Greater of:             t = 1.043 in
        - UG-45(b)(1)+cai+cao+tol = 0.4401 in
        - UG-45(b)(2)+cai+cao+tol = 1.043 in
                        Minimum thickness:               tmin = 0.2403 in
                        Nominal thickness:               tnom = 0.344 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 = 200 F
Inside corr. allow. CAI = 0.0625 in       Corrosion allow.  CAO = 0 in
Radiography             = None            Material tol.     Tol = 0 in
Cyl. outside dia.    Do = 2.375 in        Cylinder length EP  L = 6 in
Nominal thickness  tnom = 0.344 in        (tnom-CAI-CAO-Tol)  t = 0.2385 in
L/Do ratio          Ldo = 2.5263          Do/t              Dot = 9.9581
(2*S) or (0.9*yield) SE = 31680 psi       Mod. of elasticity ME = 28600000 psi
A factor SII-D-FigG   A = 0.016022        B factor CS-2       B = 17489
Max allowed external pressure: Pa = B*((2.167/Dot)-0.0833)     = 2348.92 psi
Actual external design pressure:                            PE = 15 psi
   (Required cyl. tks. for nozzle attachments at PE, tre = 0.0115 in )
```

Component: Reinforcement Nozzle J

```
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 = 200 F         Fig.UW-16.1 Sketch (e)
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 = 89.5 in       Corroded radius     OR = 44.75 in
Nominal thickness  tnom = 0.75 in       Reinforcement limit lp = 1.875 in
Req. tks. int.pres.  tr = 0.3346 in     Req. tks.ext.pres. tre = 0.2185 in
Corroded thickness    t = 0.6875 in     Reinf. efficiency   E1 = 1.0
Attachment Material: SA-53 K03005 Grd E/B Wld. pipe
Inside corr. allow. CAI = 0.0625 in     Outside corr.allow.CAO = 0.0 in
Nozzle design stress Sn = 14600 psi     Joint efficiency     E = 0.85
Nozzle outside dia. Don = 2.375 in      Corroded radius     OR = 1.1875 in
Nominal thickness  tnom = 0.344 in      Reinforcement limit ln = 0.7038 in
Req.tks. int.pres.  trn = 0.0143 in     Req.tks.ext.pres. trne = 0.0115 in
Corroded thickness   tn = 0.2815 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  = 0.2815 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)    = 0.1971 in     Weld tw     (actual)   = 0.0 in
Weld  tc   (minimum)    = 0.1971 in     Weld tc     (actual)   = 0.1971 in
    smaller |0.25 in   |                Leg size tw (actual)   = 0.0 in
 tc   of    |0.7 * tmin|                Leg size tc (actual)   = 0.2815 in
Outward nozzle weld   L1 = 0.2815 in    fr1 = Sn/Sv               = 0.73
Outer element weld    L2 = 0.0 in       fr2 = Sn/Sv               = 0.73
Inward nozzle weld    L3 = 0.0 in       fr3 = Sn/Sv or Se/Sv      = 0.73
Inward nozzel weld new   = 0.0 in       fr4 = Se/Sv               = 1.0
Corroded int.proj.thk ti = 0.0 in
```

```
Corroded inside diameter                               d = 1.812 in
Vessel wall length available for reinforcement    2*Lp-d = 1.875 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)| = 0.608 in2
 |2*(t+tn)*(E1*t-F*tr)-2*tn*(E1*t-F*tr)*(1-fr1)| = 0.6302 in2
                                                    A1 = 0.6302 in2
A2 = Nozzle wall outward  | 5*(tn-trn)*fr2*t   | = 0.6705 in2
     Smaller of:          | 5*(tn-trn)*fr2*tn  | = 0.2746 in2
                                                    A2 = 0.2746 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 = 0.0578 in2
A42 = Outer element weld  = (L2**2)*fr4 = 0.0 in2
A43 = Inward nozzle weld  = (L3**2)*fr2 = 0.0 in2
                                                    A4 = 0.0578 in2
A5 = Reinforcement pad Area = (Dp-d-2*tn)*te*fr4    A5 = 0.0 in2
Aa = Area Available = A1+A2+A3+A4+A5                Aa = 0.9626 in2
A = Area required   = (d*tr*F)+2*tn*tr*F*(1-f1)      A = 0.6572 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)| = 0.8081 in2
 |2*(t+tn)*(E1*t-F*tre)-2*tn*(E1*t-F*tre)*(1-fr1)| = 0.8376 in2
                                                    A1 = 0.8376 in2
A2 = Nozzle wall outward  | 5*(tn-trne)*fr2*t   | = 0.6775 in2
     Smaller of:          | 5*(tn-trne)*fr2*tn  | = 0.2774 in2
                                                    A2 = 0.2774 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 = 0.0578 in2
A42 = Outer element weld  =   (L2**2)*fr4 = 0.0 in2
A43 = Inward nozzle weld  =   (L3**2)*fr2 = 0.0 in2
                                                    A4 = 0.0578 in2
A5 = Reinforcement pad Area = (Dp-d-2*tn)*te*fr4    A5 = 0.0 in2
Aa = Area Available = A1+A2+A3+A4+A5                Aa = 1.1729 in2
A = Area required   = 0.5*(d*tre*F+2*tn*tre*F*(1-fr1))  A = 0.2146 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 = 3440 lbf
Weld load for strength path 1-1 (UG-41(b)(1)
  W(1-1) = (A2+A5+A41+A42)*Sv                           W(1-1) = 6648 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) = 12299 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                    =   9660 psi
    Nozzle wall shear                    =   10220 psi
 Strength of connection elements
    Inner fillet weld shear              =   7510 lbf
    Nozzle wall shear                    =   9456 lbf
    Groove weld tension                  =   11341 lbf
    Outer fillet weld shear              =   -
 Possible paths of failure
    1-1         9456 + 7510              =   16966 lbf
    2-2         7510 + 11341             =   18851 lbf
    3-3            - + -                 =   -
 Welds strong enough if path greater than the smaller of W or W(path)
                           Path 1-1 > W or W11
                          16966 lbf > 3440 lbf                 OK
                           Path 2-2 > W or W22
                          18851 lbf > 3440 lbf                 OK
                           Path 3-3 > W or W33
                                  - > -
```

```
Component:  Nozzle K
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 = 200 F
Radiography             = None           Joint efficiency     E = 0.85
Design stress         S = 14600 psi
Inside corr.allow. cai = 0.0625 in       Outside corr. all. cao = 0.0 in
Material tolerance tol = 0.043 in        Minimum thickness tmin = 0.2403 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 = 0.1198 in   APP.1-1(A)
  - UG-45(a) external pressure+cai+cao+tol       t = 0.117 in
  - UG-16(b) minimum thickness+cai+cao+tol       t = 0.1992 in
    UG-45(b) Smaller of:                         t = 0.2403 in
    UG-45(b)(4) std pipe*0.875+cai+cao+tol = 0.2403 in
      - UG-45(b) Greater of:             t = 1.043 in
        - UG-45(b)(1)+cai+cao+tol = 0.4401 in
        - UG-45(b)(2)+cai+cao+tol = 1.043 in
                        Minimum thickness:                 tmin = 0.2403 in
                        Nominal thickness:                 tnom = 0.344 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 = 200 F
Inside corr. allow. CAI = 0.0625 in       Corrosion allow.  CAO = 0 in
Radiography             = None            Material tol.     Tol = 0 in
Cyl. outside dia.    Do = 2.375 in        Cylinder length EP  L = 6 in
Nominal thickness  tnom = 0.344 in        (tnom-CAI-CAO-Tol)  t = 0.2385 in
L/Do ratio          Ldo = 2.5263          Do/t              Dot = 9.9581
(2*S) or (0.9*yield) SE = 31680 psi       Mod. of elasticity ME = 28600000 psi
A factor SII-D-FigG   A = 0.016022        B factor CS-2       B = 17489
Max allowed external pressure: Pa = B*((2.167/Dot)-0.0833)      = 2348.92 psi
Actual external design pressure:                             PE = 15 psi
   (Required cyl. tks. for nozzle attachments at PE, tre = 0.0115 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 = 150 psi       Ext. design press.  PE = 15 psi
Design temperature    T = 200 F         Fig.UW-16.1 Sketch (e)
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 = 89.5 in       Corroded radius     OR = 44.75 in
Nominal thickness  tnom = 0.75 in       Reinforcement limit lp = 1.875 in
Req. tks. int.pres.  tr = 0.3346 in     Req. tks.ext.pres. tre = 0.2185 in
Corroded thickness    t = 0.6875 in     Reinf. efficiency   E1 = 1.0
Attachment Material: SA-53 K03005 Grd E/B Wld. pipe
Inside corr. allow. CAI = 0.0625 in     Outside corr.allow.CAO = 0.0 in
Nozzle design stress Sn = 14600 psi     Joint efficiency     E = 0.85
Nozzle outside dia. Don = 2.375 in      Corroded radius     OR = 1.1875 in
Nominal thickness  tnom = 0.344 in      Reinforcement limit ln = 0.7038 in
Req.tks. int.pres.  trn = 0.0143 in     Req.tks.ext.pres. trne = 0.0115 in
Corroded thickness   tn = 0.2815 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  = 0.2815 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)    = 0.1971 in     Weld tw     (actual)   = 0.0 in
Weld  tc   (minimum)    = 0.1971 in     Weld tc     (actual)   = 0.1971 in
     smaller |0.25 in   |               Leg size tw (actual)   = 0.0 in
 tc   of    |0.7 * tmin|                Leg size tc (actual)   = 0.2815 in
Outward nozzle weld   L1 = 0.2815 in    fr1 = Sn/Sv               = 0.73
Outer element weld    L2 = 0.0 in       fr2 = Sn/Sv               = 0.73
Inward nozzle weld    L3 = 0.0 in       fr3 = Sn/Sv or Se/Sv      = 0.73
Inward nozzel weld new   = 0.0 in       fr4 = Se/Sv               = 1.0
Corroded int.proj.thk ti = 0.0 in
```

```
Corroded inside diameter                                    d = 1.812 in
Vessel wall length available for reinforcement    2*Lp-d = 1.875 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)| = 0.608 in2
 |2*(t+tn)*(E1*t-F*tr)-2*tn*(E1*t-F*tr)*(1-fr1)| = 0.6302 in2
                                                          A1 = 0.6302 in2
A2 = Nozzle wall outward  | 5*(tn-trn)*fr2*t    | = 0.6705 in2
     Smaller of:          | 5*(tn-trn)*fr2*tn   | = 0.2746 in2
                                                          A2 = 0.2746 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 = 0.0578 in2
A42 = Outer element weld  = (L2**2)*fr4 = 0.0 in2
A43 = Inward nozzle weld  = (L3**2)*fr2 = 0.0 in2
                                                          A4 = 0.0578 in2
A5 = Reinforcement pad Area = (Dp-d-2*tn)*te*fr4          A5 = 0.0 in2
Aa = Area Available = A1+A2+A3+A4+A5                      Aa = 0.9626 in2
A = Area required   = (d*tr*F)+2*tn*tr*F*(1-f1)            A = 0.6572 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)| = 0.8081 in2
 |2*(t+tn)*(E1*t-F*tre)-2*tn*(E1*t-F*tre)*(1-fr1)| = 0.8376 in2
                                                          A1 = 0.8376 in2
A2 = Nozzle wall outward  | 5*(tn-trne)*fr2*t  | = 0.6775 in2
     Smaller of:          | 5*(tn-trne)*fr2*tn | = 0.2774 in2
                                                          A2 = 0.2774 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 = 0.0578 in2
A42 = Outer element weld  =   (L2**2)*fr4 = 0.0 in2
A43 = Inward nozzle weld  =   (L3**2)*fr2 = 0.0 in2
                                                          A4 = 0.0578 in2
A5 = Reinforcement pad Area = (Dp-d-2*tn)*te*fr4          A5 = 0.0 in2
Aa = Area Available = A1+A2+A3+A4+A5                      Aa = 1.1729 in2
A = Area required   = 0.5*(d*tre*F+2*tn*tre*F*(1-fr1))     A = 0.2146 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 = 3440 lbf
Weld load for strength path 1-1 (UG-41(b)(1)
  W(1-1) = (A2+A5+A41+A42)*Sv                          W(1-1) = 6648 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) = 12299 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                   =   9660 psi
    Nozzle wall shear                   =   10220 psi
 Strength of connection elements
    Inner fillet weld shear             =   7510 lbf
    Nozzle wall shear                   =   9456 lbf
    Groove weld tension                 =   11341 lbf
    Outer fillet weld shear             =   -
 Possible paths of failure
    1-1         9456 + 7510             =   16966 lbf
    2-2         7510 + 11341            =   18851 lbf
    3-3            - + -                =   -
 Welds strong enough if path greater than the smaller of W or W(path)
                           Path 1-1 > W or W11
                          16966 lbf > 3440 lbf                OK
                           Path 2-2 > W or W22
                          18851 lbf > 3440 lbf                OK
                           Path 3-3 > W or W33
                                  - > -
```

```
Component:  Nozzle C
Method: Local Stresses in Cylindrical Shell Due to External Loadings per
        Heat Exchange Institute (HEI 'Std For Power Plant Hx', First Edition)
Vessel:  Front Head Cylinder             SA-240 S30400 Grd 304 Plate(G5)
Design pressure        Pr = 50 psi       Design temperature     T = 300 F
Joint efficiency        E = 1.00
Vessel design stress    S = 18900 psi    Vessel yield stress  Sy = 22400 psi
Inside corr. allow.   CAI = 0.0 in       Outside corr. all.   CAO = 0.0 in
Vessel outside dia.    OD = 72.0 in      Vessel mean radius    Rm = 35.8125 in
Vessel thickness     tnom = 0.375 in
Nozzle:
Nozzle outside dia.   ODn = 54.0 in      Nozzle outside rad.   ro = 27.0 in
Reinf. pad:
Pad thickness        Prtk = 0.375 in     Vessel + pad tks.      T = 0.75 in
Shape factors and Coefficients:
 Gamma = Rm/T = 47.75                  Beta = 0.875*ro/Rm = 0.6597
 Alpha =      = 114.25      Sigma = 868.48         Delta = 129.84
Conversion factor               Cf = 1
Maximum load & moment
S    = 2*pr*(Rm-T/2)/t             = 4725 psi
Sa   = shell allowable stress      = 18900 psi
Sig  = minimum of S & Sa           = 4725 psi
Frrf = Rm*Rm*(sy-sig)/alpha        = 198408 lbf
Mrcm = Rm*Rm*ro*sy*cf/sigma        = 893139 lbf*in
Mrlm = Rm*Rm*ro*(sy-sig)*cf/delta  = 4713804 lbf*in
Frf  = maximum resultant force     = 198408 lbf
Mrm  = maximum resultant moment    = 893139 lbf*in
          |  Interaction diagram:
          |                               Applied loads:
          |                                   Radial load    P = 0 lbf
      FRF-+                                   Circ. moment  Mc = 0 lbf*in
   198408 |                                   Long. moment  Ml = 0 lbf*in
          |                               Maximum allowable loads:
          |                                   Radial Load P,Mc = 198408 lbf
          |                                   Radial Load P,Ml = 198408 lbf
          |                                   Mc or Ml (from P)= 893139 lbf*in
          +
          |                                   Note: Couples (P,Mc) & (P,Ml)
          |                                         must be located within
          |                                         the triangle limited by
          |                                         0, FRF, MRM.
          |
          ----------+---------+----
         0                   MRM
                           893139
```

```
Component:  Nozzle D
Method: Local Stresses in Cylindrical Shell Due to External Loadings per
        Heat Exchange Institute (HEI 'Std For Power Plant Hx', First Edition)
Vessel:  Rear Head Cylinder                SA-240 S30400 Grd 304 Plate(G5)
Design pressure       Pr = 50 psi          Design temperature    T = 300 F
Joint efficiency       E = 1.00
Vessel design stress   S = 18900 psi       Vessel yield stress  Sy = 22400 psi
Inside corr. allow.  CAI = 0.0 in          Outside corr. all.  CAO = 0.0 in
Vessel outside dia.   OD = 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            = 11420 psi
Sa    = shell allowable stress     = 18900 psi
Sig   = minimum of S & Sa          = 11420 psi
Frrf  = Rm*Rm*(sy-sig)/alpha       = 1651 lbf
Mrcm  = Rm*Rm*ro*sy*cf/sigma       = 12924 lbf*in
Mrlm  = Rm*Rm*ro*(sy-sig)*cf/delta = 10696 lbf*in
Frf   = maximum resultant force    = 1651 lbf
Mrm   = maximum resultant moment   = 10696 lbf*in
          |  Interaction diagram:
          |                             Applied loads:
          |                                 Radial load    P = 0 lbf
      FRF-+                                 Circ. moment  Mc = 0 lbf*in
     1651 |                                 Long. moment  Ml = 0 lbf*in
          |                             Maximum allowable loads:
          |                                 Radial Load P,Mc = 1651 lbf
          |                                 Radial Load P,Ml = 1651 lbf
          |                                 Mc or Ml (from P)= 10696 lbf*in
          +
          |                                 Note: Couples (P,Mc) & (P,Ml)
          |                                       must be located within
          |                                       the triangle limited by
          |                                       0, FRF, MRM.
          |
          ----------+---------+----
         0                  MRM
                           10696
```

```
Component:  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:  Rear Head Cylinder              SA-240 S30400 Grd 304 Plate(G5)
Design pressure       Pr = 50 psi        Design temperature     T = 300 F
Joint efficiency       E = 1.00
Vessel design stress   S = 18900 psi     Vessel yield stress  Sy = 22400 psi
Inside corr. allow.  CAI = 0.0 in        Outside corr. all.  CAO = 0.0 in
Vessel outside dia.   OD = 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             = 11420 psi
Sa   = shell allowable stress      = 18900 psi
Sig  = minimum of S & Sa           = 11420 psi
Frrf = Rm*Rm*(sy-sig)/alpha        = 1651 lbf
Mrcm = Rm*Rm*ro*sy*cf/sigma        = 12924 lbf*in
Mrlm = Rm*Rm*ro*(sy-sig)*cf/delta  = 10696 lbf*in
Frf  = maximum resultant force     = 1651 lbf
Mrm  = maximum resultant moment    = 10696 lbf*in
          |  Interaction diagram:
          |                            Applied loads:
          |                                Radial load    P = 0 lbf
     FRF-+                                 Circ. moment  Mc = 0 lbf*in
    1651 |                                 Long. moment  Ml = 0 lbf*in
          |                            Maximum allowable loads:
          |                                Radial Load P,Mc = 1651 lbf
          |                                Radial Load P,Ml = 1651 lbf
          |                                Mc or Ml (from P)= 10696 lbf*in
          +
          |                                Note: Couples (P,Mc) & (P,Ml)
          |                                      must be located within
          |                                      the triangle limited by
          |                                      0, FRF, MRM.
          |
          ----------+---------+----
         0                  MRM
                           10696
```

```
Component:  Nozzle G
Method: Local Stresses in Cylindrical Shell Due to External Loadings per
        Heat Exchange Institute (HEI 'Std For Power Plant Hx', First Edition)
Vessel:  Front Head Cylinder               SA-240 S30400 Grd 304 Plate(G5)
Design pressure        Pr = 50 psi         Design temperature    T = 300 F
Joint efficiency        E = 1.00
Vessel design stress    S = 18900 psi      Vessel yield stress  Sy = 22400 psi
Inside corr. allow.  CAI = 0.0 in          Outside corr. all.  CAO = 0.0 in
Vessel outside dia.   OD = 72.0 in         Vessel mean radius   Rm = 35.8125 in
Vessel thickness    tnom = 0.375 in
Nozzle:
Nozzle outside dia.  ODn = 4.0 in          Nozzle outside rad.  ro = 2.0 in
Reinf. pad:
Pad thickness       Prtk = 0.0 in          Vessel + pad tks.     T = 0.375 in
Shape factors and Coefficients:
 Gamma = Rm/T = 95.5                     Beta = 0.875*ro/Rm = 0.0489
 Alpha =      = 9845.13     Sigma = 6237.27        Delta = 4057.68
Conversion factor                Cf = 1
Maximum load & moment
S     = 2*pr*(Rm-T/2)/t             = 9500 psi
Sa    = shell allowable stress      = 18900 psi
Sig   = minimum of S & Sa           = 9500 psi
Frrf  = Rm*Rm*(sy-sig)/alpha        = 1680 lbf
Mrcm  = Rm*Rm*ro*sy*cf/sigma        = 9212 lbf*in
Mrlm  = Rm*Rm*ro*(sy-sig)*cf/delta  = 8155 lbf*in
Frf   = maximum resultant force     = 1680 lbf
Mrm   = maximum resultant moment    = 8155 lbf*in
          |  Interaction diagram:
          |                              Applied loads:
          |                                  Radial load    P = 0 lbf
      FRF-+                                  Circ. moment  Mc = 0 lbf*in
     1680 |                                  Long. moment  Ml = 0 lbf*in
          |                              Maximum allowable loads:
          |                                  Radial Load P,Mc = 1680 lbf
          |                                  Radial Load P,Ml = 1680 lbf
          |                                  Mc or Ml (from P)= 8155 lbf*in
          +
          |                                  Note: Couples (P,Mc) & (P,Ml)
          |                                        must be located within
          |                                        the triangle limited by
          |                                        0, FRF, MRM.
          |
          ----------+---------+----
         0                  MRM
                           8155
```

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	30.0	150	0.5	2.12	36.0	33.75	0.0	28	1.25
B	ANSI SO	30.0	150	0.5	2.12	36.0	33.75	0.0	28	1.25
C	ANSI SO	54.0	150	0.375	4.75	62.75	59.5	0.0	44	1.75
D	ANSI SO	6.625	150	0.28	1.0	9.5	8.5	0.94	8	0.75
E	ANSI SO	6.625	150	0.28	1.0	9.5	8.5	0.94	8	0.75
G	ANSI SO	4.0	150	0.337	0.94	7.0	5.5	0.75	8	0.625
H	ANSI SO	3.5	150	0.3	0.94	6.0	5.0	0.75	4	0.625
J	ANSI SO	2.375	150	0.344	0.75	4.75	3.62	0.62	4	0.625
K	ANSI SO	2.375	150	0.344	0.75	4.75	3.62	0.62	4	0.625

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

```
Horizontal Vessels on Saddles
Saddle material: SA-516 K02700 Grd 70 Plate
Wear plate mtl:  SA-516 K02700 Grd 70 Plate
Shell radius             R = 35.5625 in   Total force           Q = 122848 lbf
Shell length             L = 263.75 in    Angle alpha       Alpha = 1.5752    rad
Angle beta            Beta = 95    deg.   Angle delta       Delta = 1.7599    rad
Vessel thickness        TS = 0.5 in       Wear plate tks.       w = 0.5 in
Vessel corr.allowance   CA = 0.0625 in    Angle theta       Theta = 170        deg
Wear plate width         b = 12.1875 in  *Vessel thk TS+w-CA  tsw = 0.4375 in
Pressure                 P = 150 psi      Inside diameter      ID = 71.125 in
Joint efficiency        JE = 0.7          Head joint eff.     JEH = 0.85
Front head thickness    TH = 2.8125 in    Rear head thickness  TH = 0.3125 in
Head diameter            D = ---          Head corr.allowance CAH = 0.0 in
Saddles                                                Saddle A      Saddle B
Loads on saddles              Q =                       86127         36721   lbf
Distance from ref. point      A =                       38.5          41.25    in
Head length                   H =                       ---           ---      in
Ratio A/R                                              1.0826        1.1599
Bending moment factor        K7 =                      0.0208        0.0208
  * w included in tsw only if A / R < 0.5
Shell pressure stress             PS = P*ID/(4*JE*(TS-CA)) = 8709 psi
Fr. head press. stress P*D+0.2*P*(TH-CAH)/(2*JEH*(TH-CAH)) = ---
Re. head press. stress P*D+0.2*P*(TH-CAH)/(2*JEH*(TH-CAH)) = ---
Alpha = Pi-(Pi/180)*(Theta/2+Beta/20)    Delta = (Pi/180)*(5*Theta/12+30)
S11 = (3*Q*L/(Pi*(TS-CA)*R**2))    S12 = 1-(1-A/L+(R**2-H**2)/2*A*L)/(1+4*H/3*L)
S13 = Pi*(Sin(Delta)/Delta-Cos(Delta)
S14 = Delta+Sin(Delta*Cos(Delta)-2*Sin(Delta)**2/Delta)
Stresses in psi                                     ** Saddles **
Bending stress at saddle + pressure                 A          B       Allowable
  S1 = S11*(4*A/L)*S12*S13/S14 + PS               9490       9128       14000
Bending stress at midspan + pressure
  S21 = (1+2*(R**2-H**2)/L**2)/(1+4*H/3*L)
  S2  = S11*(S21-4*A/L) + PS                      10187       9281       14000
Tangential shear in shell (unstiffened)
  S41 = Sin(Alpha)/
       (Pi-Alpha+Sin(Alpha)*Cos(Alpha))
  S42 = L-H-2*A/(L+H)
  S4  = (Q/R*(TS-CA))*S42*S41                     2509       1038       16000
```

```
Component:  Shell Cylinder
Horizontal vessels on saddles
Tangential shear stress in shell (stiffened), psi
                                                  ** Saddles **
                                                   A         B      Allowable
S61 = Sin(Alpha)*Cos(Alpha)
S62 = Sin(Alpha)/(Pi-Alpha+S61)
S6  = (Q/R*(TS-CA))*(L-H-2*A/(L+H))*S62)          ---       ---       ---
Circumferential stress at horn, psi
  S71 = 12 * Q * K7 * R/(L *tsw**2)
  S72 = 4*tsw*(b+1.56*(R*tsw)**0.5)
  S7  = -Q/S72 - S71                            -23165     -9876    -25000
Ring compression in shell over saddle, psi
  S91 = 1+Cos(Alpha)/
        (Pi-Alpha+Sin(Alpha)*Cos(Alpha))
  S92 = (TS-CA)*(B+1.56*(R*(TS-CA))**0.5)
  S9  = (Q/S92) * S91                             2707      1154     17400
Tangential shear stresses in head, psi
  S51 = Sin(Alpha) * Cos(Alpha)
  S52 = (Sin(Alpha)/Pi)*(Alpha-S51)/
            (Pi-Alpha+S51)
  S5  = (Q/(12*R*(TH-CAH)))*S52                    ---       ---       ---
Head stresses, psi
  S81 = 3*Q/(8*12*R*(TH-CAH))
  S82 = (Sin(Alpha))**2
  S83 = Pi-Alpha+Sin(Alpha)*Cos(Alpha)
  S8  = S81*(S82/S83)                              ---       ---
Head stresses + pressure, psi
  S8 + PH                                          ---       ---       ---
```

```
Saddle Geometry Verification
Saddle width          A = 71.75 in        Saddle depth        F = 6.0 in
Rib thickness         J = 0.5 in          Web thickness      tw = 0.5 in
Base plate thk       tb = 0.625 in        Wear plate thk    tra = 0.5 in
Min saddle height     h = 24.0 in         Corr.Shell thk     ts = 0.4375 in
Number of ribs        n = 4               Vessel CL to base  B = 60.0 in
Angle alpha,rad alpha = 1.5752            Angle beta, rad beta = 1.6581
Angle theta,rad theta = 2.9671            Rib depth           G = 6.0 in
Yield saddle mtl     fy = 34800 psi       Inside radius       R = 35.5625 in
Max. load/saddle     Qm = 86127 lbf       Friction factor    mu = 0.1
     Saddle to foundation surface type: Teflon to Teflon
Expansion load      mu*Qm = FL1 = 8613 lbf
Max wind or seismic load = Fws = 0 lbf
Bundle pull load         = Fbl = -
Maximum horizontal load = FL = MAX[FL1,Fws,Fbl]          FL = 8613 lbf
Saddle coefficient K1 = (1+Cos(beta)-0.5*(Sin(beta))**2/
                        (Pi-Beta+Sin(Beta)*Cos(Beta))     K1 = 0.2983
Saddle splitting force, fh = K1*Qm                        fh = 25692 lbf
Cross sectional area of saddle, As                        As = 21.06 in2
Web tension stress, sigmaT = fh/As                    sigmaT = 1220 psi
Max web tension stress, sigmaTmax = 0.6*fy         sigmaTmax = 20880 psi
Distance centroid of saddle to base plate, d
  d = B - R*Sin(Theta)/Theta                               d = 57.9187 in
Web moment M = fh*d                                        M = 1488043 lbf*in
Distance saddle centroid to vessel ID, C1                 C1 = 15.9325 in
Saddle moment of inertia, I                                I = 2429.5
Web bending stress, fbweb = M*C1/I                     fbweb = 9758 psi
                fbweb <= fbMax = 0.66*fy            fbwebMax = 23200 psi
Base plate with center web
  Base plate area,  Ab = A*F                              Ab = 430.5 in2
  Bearing pressure, Bp = Q/Ab                             Bp = 200 psi
  Base plate moment, M = Q*F/8                             M = 64595 lbf*in
  Section modulus, Z = A*tb**2/6                           Z = 4.67
  Base plate bending stress, fbc = M/Z                   fbc = 13828 psi
                  fbc <= fbcMax = 0.66*fy             fbcMax = 23200 psi
Base plate with offset web
  Distance edge base plate to web, d2                     d2 = 0.5 in
  Weld leg size, base to web, ww                          ww = 0.5 in
  Web length, Lw = A - 2*j                                Lw = 70.75 in
  Ribs length, Lr = n*(G-tw)                              Lr = 22.0 in
  Overall length, L = Lw + Lr                              L = 92.75 in
  Unit load, fu = Q/L  lbf/in                             fu = 928.59
  Distance l1 = d2+tw+ww+tb                               l1 = 2.125 in
  Distance l2 = F - l1                                    l2 = 3.875 in
  Linear load, Omega = Fu/(l1+0.5*l2)                  Omega = 228.58 psi
  Base plate linear moment, M = (omega*l2**2)/6            M = 572 lbf
  Base plate bending stress, fbo = 6*M/tb**2             fbo = 8786 psi
                  fbo <= fboMax = 0.66*fy             fboMax = 23200 psi
  fb = MAX(fbweb,fbc.fbo)                                 fb = 13828 psi
  Minimum depth of saddle at top, Gtm
  Gtm=SQRT((5.012*FL/(J*(n-1)*Fb)*(h+(A/1.96)*(1-Sin(Alpha)))= 5.4562 in
  Actual depth of saddle at top, Gt                       Gt = 6.0 in
Minimum wear plate width, H = Gt + 1.56*SQRT(R*ts)         H = 12.1533 in
Actual wear plate width, Ha                               Ha = 12.1875 in
Minimum wear plate thickness, tr = (Ha-Gt)**2/(2.43*R)    tr = 0.443 in
Actual wear plate thickness, tra                         tra = 0.5 in
Anchor bolts
  Bolt material: SA-325 Carbon steel Bolt
  Maximum longitudinal load, QL                           QL = 20475 lbf
  Maximum load, Qm                                        Qm = 86127 lbf
  Bolt diameter, d                                         d = 1.125 in
  Number of bolts per saddle, N                            N = 2
  If Qm>QL, no uplift occurs.  Uplift load per bolt: QL-Qm/N = -
  Shear load per bolt
```

```
  ShearB = mu * FL / N                                  Shearb = 431 lbf
  Allowable bolt force, bf                                  bf = 20079 lbf
  Bolt transverse load
  Maximum transverse load (seismic or wind), Ftr           Ftr = 10237 lbf
  Bolt transverse moment, MtransB = Ftr * B            MtransB = 614238 lbf*in
  Critical bolt distance, e = MtransB / Q                    e = 7.1318 in
  If e < A/6, no uplift occurs                             A/6 = 11.9583 in
                                   Uplift bolt tension force = -
Inside ribs/web design
  Saddle rib width   Gb = 6.0 in        Base length         e = 23.9167 in
  Pressure area F*e  Ap = 143.5 in2     Axial load Bp*Ap    P = 28709 lbf
  Area rib and web   Ar = 14.96 in2     Comp. str P/Ar     fa = 1919 psi
  Mom.iner.J*Gb**3/12 I = 9             Rad gyr SQRT(I/Ar) r = 0.7757 in
  Compression dist.  l2 = 25.8834 in    Slender ratio K*l2/r = 66.7
  Unit force Fl/2*A  fu = 60.02         Moment fu*l2*e      M = 37154 lbf*in
  Moment arm C2      C2 = 3.0 in        Bend.str. M*C2/I   fb = 12385 psi
  Max. comp.stress   Fa = 16740 psi     Max.bending str.   Fb = 23200 psi
  K end connection coeff= 2
  Combined stress (must be less than one)       fa/Fa + fb/Fb = 0.65
Outside ribs/web design
  Press.area 0.5F*e  Ap = 71.75 in2     Axial load Bp*Ap    P = 14354 lbf
  Area rib and web   Ar = 8.98 in2      Comp. str P/Ar     fa = 1599 psi
  Compression dist.  l1 = 59.375 in     Slender ratio K*l1/r = 153.1
  Unit force Fl/2*A  fu = 60.02         Moment 0.5*fu*l1*e M = 42615 lbf*in
  Moment arm C1      C1 = 3.0 in        Bend.str. M*C1/I   fb = 14205 psi
  Max. comp.stress   Fa = 10280 psi     Max.bending str.   Fb = 23200 psi
  Combined stress (must be less than one)       fa/Fa + fb/Fb = 0.77
```

```
Wind loads - ANSI/SEI/ASCE 7-02
Vessel outside diameter         OD                       OD = 72 in
Vessel effective length         EL                       EL = 444.5 in
Vessel effective diameter       EOD                     EOD = 92.16 in
Effective wind area             Af              Af = EOD*EL = 284.48 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 = 5261.7 lbf
Moment arm                      L                         L = 5 ft
Overturning moment, OM,  ft-lbf                    OM = F*L = 26309
Earthquake Loads - ANSI/SEI/ASCE 7-02
Equipment occupancy category - wind/seismic design              = II
Equipment seismic site class                                    = B
Equipment seismic use group                                     = I
Response modification factor                                  R = 3
Seismic importance factor                                     I = 1
Mapped maximum spectral response acceleration at short periods Ss = 0.75
Mapped maximum spectral response acceleration at 1-sec period  S1 = 0.2
Site coefficient Fa - Table 9.4.1.2.4a                         Fa = 1
Site coefficient Fv - Table 9.4.1.2.4b                         Fv = 1
Maximum spectral response acceleration short periods  Sms = Fa*Ss = 0.75
Maximum spectral response acceleration at 1-sec per.  Sm1 = Fv*S1 = 0.2
Spectral response acceleration at short periods   Sds = (2/3)*Sms = 0.5
Spectral response acceleration at 1-sec period    Sd1 = (2/3)*Sm1 = 0.13
Seismic response coefficient, Cs = Sds/(R/I)                   Cs = 0.17
                              CsMin = 0.5*S1/(R/I)          CsMin = 0.03
Seismic zone coefficient, Cv                                   Cv = 0.24
Weight of vessel, full                                          W = 122848 lbf
Total shear at the base, V = Cs * W                             V = 20474.6 lbf
Maximum lateral force,   F = V                                  F = 20474.6 lbf
Overturning moment, OM,  ft-lbf                      OM = 0.5*F*L = 51186
```

Wind and Seismic Loads - Effect on Saddles

Dist.between saddles		Ls = 15.3333 ft
Saddle width		E = 5.9792 ft
Longitudinal seismic force	Fl=Cs*W	Fl = 20474.6 lbf
Projected area of vessel	Af=PI*EOD**2/4	Af = 46.32 ft2
Longitudinal wind force	Fl=Af*Cf*G*qz	Fl = 856.8 lbf
Longitudinal seismic load/saddle	Ql=Fl*L/Ls	Ql = 6676.5 lbf
Longitudinal wind load/saddle	Ql=Fl*L/Ls	Ql = 279.4 lbf
Transverse seismic force	Ft=0.5*Cs*W	Ft = 10237.3 lbf
Projected area of vessel	Af=EOD*EL	Af = 284.48 ft2
Transversal wind force	Ft=0.5*Af*Cf*G*qz	Ft = 2630.9 lbf
Transverse seismic load/saddle	Qt=1.5*Ft*L/E	Qt = 12841.2 lbf
Transverse wind load per saddle	Qt=1.5*Ft*L/E	Qt = 3300 lbf
Maximum (seismic/wind) load per saddle	Q = max(Ql, Qt)	Q = 12841.2 lbf

Seismic and wind loads have NOT been applied to supports design.

Weights, surface area, Insulation

		Shell side	Tube side
Volume	ft3	275.65	674.96
Avg. fluid density	lb/ft3	0	0
Fluid weight	lb	0	0
Surface area	ft2	418.4	275.3
Surface Area		693.7 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		63547 lb	
Operating weight		122848 lb	
Full weight		122848 lb	

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

Component	Side	--Design conditions-- Temp F	Stress psi	MAWP psi	---- New and cold --- Temp F	Stress psi	MAWP psi
Shell Cylinder	S	200	20000	171	70	20000	195.5
Front Head Cylinder	T	300	18900	138.4	70	20000	146.4
Rear Head Cylinder	T	300	18900	115.2	70	20000	122
Front Head Cover	T	300	20000	94.2	70	20000	94.2
Rear Head Cover	T	300	18900	140.5	70	20000	148.7
Front Tubesheet	S	300	15000	195	70	20000	202.3
Front Tubesheet	T	300	15000	76.8	70	20000	79.7
Rear Tubesheet	S	300	15000	162.5	70	20000	166.9*
Rear Tubesheet	T	300	15000	64	70	20000	65.7
Rear Head Flng At TS	T	300	20000	50.6	70	20000	50.6
Front Head Flng At Cov	T	300	15000	50.3+	70	20000	50.3+
Tubes	T	300	12700	1027.9	70	17000	1375.9
Nozzle A	S	200	20000	196.3	70	20000	224.5
Nozzle B	S	200	20000	196.3	70	20000	224.5
Nozzle C	T	300	18900	184.8	70	20000	195.5
Nozzle D	T	300	16100	129	70	17000	136.5
Nozzle E	T	300	16100	129	70	17000	136.5
Nozzle G	T	300	16100	155.3	70	17000	164.4
Nozzle H	T	300	16100	2183.8	70	17000	2305.9
Nozzle J	S	200	14600	2710.2	70	14600	3500.5
Nozzle K	S	200	14600	2710.2	70	14600	3500.5
Nozzle Flng A	S	200	20000	260	70	20000	285
Nozzle Flng B	S	200	20000	260	70	20000	285
Nozzle Flng C	T	300	20000	230	70	20000	285
Nozzle Flng D	T	300	12800	175	70	16700	230
Nozzle Flng E	T	300	12800	175	70	16700	230
Nozzle Flng G	T	300	12800	175	70	16700	230
Nozzle Flng H	T	300	12800	175	70	16700	230
Nozzle Flng J	S	200	20000	260	70	20000	285
Nozzle Flng K	S	200	20000	260	70	20000	285
Nozzle Reinforcement A	S	200	-	158*	70	-	172
Nozzle Reinforcement B	S	200	-	158*	70	-	172
Nozzle Reinforcement C	T	300	18900	111	70	20000	116
Nozzle Reinforcement D	T	300	-	95	70	-	101
Nozzle Reinforcement E	T	300	-	95	70	-	101
Nozzle Reinforcement G	T	-	-	N/C	-	-	N/C
Nozzle Reinforcement H	T	-	-	N/C	-	-	N/C
Nozzle Reinforcement J	S	-	-	N/C	-	-	N/C
Nozzle Reinforcement K	S	-	-	N/C	-	-	N/C
Rear Hd Bolting At TS	T	300	25000	51.7	70	25000	51.7
Front Hd Bolting At Cov	T	300	25000	51.5	70	25000	51.5
Dist. Belt An.ring	S	-	-	N/C	-	-	N/C

Maximum Allowable Working Pressures

* = Shell Side MAWP + = Tube Side MAWP

Component	Side	--Design conditions-- Temp F	Stress psi	MAWP psi	---- New and cold --- Temp F	Stress psi	MAWP psi
Dist. Belt An.ring	S	-	-	N/C	-	-	N/C
Nozzle Flng Bolting A	S	200	25000	260	70	25000	285
Nozzle Flng Bolting B	S	200	25000	260	70	25000	285
Nozzle Flng Bolting C	T	300	25000	230	70	25000	285
Nozzle Flng Bolting D	T	300	25000	175	70	25000	230
Nozzle Flng Bolting E	T	300	25000	175	70	25000	230
Nozzle Flng Bolting G	T	300	25000	175	70	25000	230
Nozzle Flng Bolting H	T	300	25000	175	70	25000	230
Nozzle Flng Bolting J	S	200	25000	260	70	25000	285
Nozzle Flng Bolting K	S	200	25000	260	70	25000	285

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

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

Component	Curve	Temp F		******* UCS-66.1 Ratio	Reduction	******* Temperature	
Shell Cylinder	B	-7	+	0.70	29	-36	
Front Head Cover	D	-44		0.69	30	-74	
Rear Head Flng At TS	D	-55		0.91	8	-63	
Nozzle A	B	-7	+	0.29	140	-147	
Nozzle B	B	-7	+	0.29	140	-147	
Nozzle J	B	-20		0.05	140	-160	
Nozzle K	B	-20		0.05	140	-160	
Nozzle Flng A	-	-20		-	-	-	
Nozzle Flng B	-	-20		-	-	-	
Nozzle Flng C	-	-20		-	-	-	
Nozzle Flng J	-	-20		-	-	-	
Nozzle Flng K	-	-20		-	-	-	
Nozzle Reinforcement H	B	-20		-	-	-	
Rear Hd Bolting At TS	A	-55		-	-	-	
Front Hd Bolting At Cov	A	-55		-	-	-	
Distributor Belt A	B	15	+	-	-	-	*
Distributor Belt B	B	15	+	-	-	-	*
Nozzle Flng Bolting A	A	-55		-	-	-	
Nozzle Flng Bolting B	A	-55		-	-	-	
Nozzle Flng Bolting C	A	-55		-	-	-	
Nozzle Flng Bolting D	A	-55		-	-	-	
Nozzle Flng Bolting E	A	-55		-	-	-	
Nozzle Flng Bolting G	A	-55		-	-	-	
Nozzle Flng Bolting H	A	-55		-	-	-	
Nozzle Flng Bolting J	A	-55		-	-	-	
Nozzle Flng Bolting K	A	-55		-	-	-	

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

Shell Side: 195 psi Tube Side: 65 psi

Component	Material	Side	Design Temp F	Stress psi	Test Stress psi	Stress Ratio
Shell Cylinder	SA-516 K02700 Grd 70 Plate	S	200	20000	20000	1
Front Head Cylinder	SA-240 S30400 Grd 304 Plat	T	300	18900	20000	1.0582
Rear Head Cylinder	SA-240 S30400 Grd 304 Plat	T	300	18900	20000	1.0582
Front Head Cover	SA-516 K02700 Grd 70 Plate	T	300	20000	20000	1
Rear Head Cover	SA-240 S30400 Grd 304 Plat	T	300	18900	20000	1.0582
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
Rear Head Flng At TS	SA-516 K02700 Grd 70 Plate	T	300	20000	20000	1
Front Head Flng At Cov	SA-240 S30400 Grd 304 Plat	T	300	15000	20000	1.3333
Tubes	SA-249 S30400 Grd TP304 Wl	T	300	12700	17000	1.3386
Nozzle A	SA-516 K02700 Grd 70 Plate	S	200	20000	20000	1
Nozzle B	SA-516 K02700 Grd 70 Plate	S	200	20000	20000	1
Nozzle C	SA-240 S30400 Grd 304 Plat	T	300	18900	20000	1.0582
Nozzle D	SA-312 S30400 Grd TP304 Wl	T	300	16100	17000	1.0559
Nozzle E	SA-312 S30400 Grd TP304 Wl	T	300	16100	17000	1.0559
Nozzle G	SA-312 S30400 Grd TP304 Wl	T	300	16100	17000	1.0559
Nozzle H	SA-312 S30400 Grd TP304 Wl	T	300	16100	17000	1.0559
Nozzle J	SA-53 K03005 Grd E/B Wld.	S	200	14600	14600	1
Nozzle K	SA-53 K03005 Grd E/B Wld.	S	200	14600	14600	1
Nozzle Flng A	SA-105 K03504 Forgings	S	200	20000	20000	1
Nozzle Flng B	SA-105 K03504 Forgings	S	200	20000	20000	1
Nozzle Flng C	SA-105 K03504 Forgings	T	300	20000	20000	1
Nozzle Flng D	SA-182 S30403 Grd F304L Fo	T	300	12800	16700	1.3047
Nozzle Flng E	SA-182 S30403 Grd F304L Fo	T	300	12800	16700	1.3047
Nozzle Flng G	SA-182 S30403 Grd F304L Fo	T	300	12800	16700	1.3047
Nozzle Flng H	SA-182 S30403 Grd F304L Fo	T	300	12800	16700	1.3047
Nozzle Flng J	SA-105 K03504 Forgings	S	200	20000	20000	1
Nozzle Flng K	SA-105 K03504 Forgings	S	200	20000	20000	1
Nozzle Reinforcement C	SA-240 S30400 Grd 304 Plat	T	300	18900	20000	1.0582
Rear Hd Bolting At TS	SA-193 G41400 Grd B7 Bolt(	T	300	25000	25000	1
Front Hd Bolting At Cov	SA-193 G41400 Grd B7 Bolt(	T	300	25000	25000	1
Distributor Belt A	SA-516 K02700 Grd 70 Plate	S	200	20000	20000	1
Distributor Belt B	SA-516 K02700 Grd 70 Plate	S	200	20000	20000	1
Nozzle Flng Bolting A	SA-193 G41400 Grd B7 Bolt(	S	200	25000	25000	1
Nozzle Flng Bolting B	SA-193 G41400 Grd B7 Bolt(	S	200	25000	25000	1
Nozzle Flng Bolting C	SA-193 G41400 Grd B7 Bolt(	T	300	25000	25000	1
Nozzle Flng Bolting D	SA-193 G41400 Grd B7 Bolt(	T	300	25000	25000	1
Nozzle Flng Bolting E	SA-193 G41400 Grd B7 Bolt(	T	300	25000	25000	1
Nozzle Flng Bolting G	SA-193 G41400 Grd B7 Bolt(	T	300	25000	25000	1
Nozzle Flng Bolting H	SA-193 G41400 Grd B7 Bolt(	T	300	25000	25000	1
Nozzle Flng Bolting J	SA-193 G41400 Grd B7 Bolt(	S	200	25000	25000	1
Nozzle Flng Bolting K	SA-193 G41400 Grd B7 Bolt(	S	200	25000	25000	1