PRESSURE VESSEL CALCULATIONS

FOR AN

APV PLATE HEAT EXCHANGER

IN ACCORDANCE WITH THE

ASME BOILER AND PRESSURE VESSEL CODE

SECTION VIII, DIVISION 1

2013 EDITION

HEAT EXCHANGER MODEL:	O034 M-10SP		
REFERENCE DRAWING NUMBER:	1500317		
DESIGN PRESSURE:	150.00	psi	[10.34 bar]
TEST PRESSURE:	195.00	psi	[13.42 bar]
MAXIMUM DESIGN TEMPERATURE:	320.00	F	[160.00 C]
MINIMUM DESIGN METAL TEMPERATURE:	-20.00	F	[-28.89 C]

P.O. NO:	4701066018
TAG NO.:	X-8230
CUSTOMER:	Evonik Corporation
LOCATION:	Theodore, AL

THE FOLLOWING PARAMETERS APPLY TO THIS HEAT EXCHANGER DESIGN:

P =	150.000	psi	DESIGN PRESSURE (UG-21, Appendix 3)
A =	527.000	sq in	PRESSURE AREA
d =	13.650	inches	SHORT SPAN (fig. UG-34 sketch j)
D =	38.608	inches	LONG SPAN (UG-34b)
G =	184.500	inches	GASKET PERIMETER (Appendix 2-3)
h_G =	1.206	inches	GASKET MOMENT ARM (Appendix 2-3, table 2.5.2)
L =	113.514	inches	TIE BAR PERIMETER (UG-34b, Appendix 2-10)
C =	0.300		UG-34 d sketch j
b =	0.055	inches	Appendix 2-3, Table 2-5.2, figure (1a) or (1b)
m =	1.000		ELASTOMER 75A SHORE (Table 2-5.1, Appendix 2-3)
y =	200.000	psi	ELASTOMER 75A SHORE (Table 2-5.1, Appendix 2-3)

BOLT (TIE BAR) DESIGN

REFERENCE: APPENDIX 2 - MANDATORY

MATERIAL:	SA-193 GR B7		
Sa =	25000	psi	@ ATMOSPHERIC TEMPERATURE
Sb =	25000	psi	@ DESIGN TEMPERATURE

BOLT LOAD:

DESIGN CONDITIONS:	Wm1 = A*P+2b*G*m*P	Appendix 2-5, formula 1
GASKET SEATING:	Wm2 = b*G*y	Appendix 2-3 & 2-5 (formula 2)

NOTE: THE FORMULAS HAVE BEEN MODIFIED FOR NONCIRCULAR GASKETS

Wm1 =	82094.25	lbf
Wm2 =	2029.50	lbf

TOTAL BOLT AREA REQUIRED IS THE GREATER OF THE FOLLOWING (Appendix 2-3 & 2-5d):

DESIGN CONDITIONS:	Am1 = Wm1/Sb =	3.284	sq in
GASKET SEATING:	Am2 = Wm2/Sa =	0.081	sq in

TOTAL BOLT AREA SUPPLIED:

SIZE 1	M20 x 2.5	QTY (n1)	10
SIZE 2		QTY (n2)	0

BOLT TENSILE AREA (As) = 0.7854 * (D - 0.9382 * P) ^ 2
Note: D is the bolt diameter, P is the bolt pitch

TOTAL AREA (Ab) = As1 * n1 + As2 * n2 3.794 sq in

TOTAL BOLT AREA SUPPLIED (3.794 sq in) IS GREATER THAN REQUIRED (3.284 sq in)

UNPORTED SLAB THICKNESS

The head and follower covers are designed as noncircular flat plates attached with bolts causing an edge moment. The thickness of the covers without openings is determined in accordance with UG-34 - UNSTAYED FLAT HEADS AND COVERS.

SLAB MATERIAL: SA-516 GR 70

Sop =	20000	psi	@	320	F
CA =	0.060	inches	Corrosion Allowance		
E =	1		Joint Efficiency (no welded joints)		

THICKNESS "T1" REQUIRED AT OPERATING CONDITIONS

$T1 = d*SQR[((Z*C*P/(Sop*E))+((6*W*h_G)/(Sop*E*L*d*d))]$ UG-34 Formula 5
Z = MINIMUM OF: 3.4-(2.4*d/D) OR 2.5 UG-34 Formula 4
W = Wm1 = A*P+2*b*G*m*P Appendix 2-5 Formula 3

Z =	2.500	
W =	82094.250	lbf

MINIMUM REQUIRED UNPORTED THICKNESS, INCLUDING CA T1 = 1.204 inches

THICKNESS "T2" REQUIRED DUE TO GASKET SEATING

$T2 = d*SQR[((Z*C*P/(Sgs*E))+((6*Wgs*h_G)/(Sgs*E*L*d*d))]$
P = 0 psig at gasket seating conditions
Wgs = ((Am+Ab)*Sa)/2 Appendix 2 - 5 Formula 4
Am = GREATER OF: Am1 = Wm1/Sb OR Am2 = Wm2/Sa (From page 2)

Am =	3.284	sq in
Sgs =	20000	psi
Wgs =	88476.164	lbf

MINIMUM REQUIRED UNPORTED THICKNESS, INCLUDING CA T2 = 0.591 inches

MINIMUM REQUIRED UNPORTED THICKNESS, INCLUDING CA, @ OPERATING OR GASKET SEATING CONDITIONS

T = GREATER OF: T1 OR T2

T =	1.204	inches

REINFORCEMENT REQUIRED FOR PORTED SLABS

A finite element analysis calculation (using ALGOR's Linear Stress Analysis package, version 9.20) in accordance with U-2(g) has been performed to calculate the required port reinforcement thickness. This analysis is summarized in APV Publication 3392. The following equation has been derived from the results of this analysis.

TBPA =	658.441	sq in	AREA ENCLOSED BY ALL TIE BARS
ATMIN =	385.132	sq in	MAXIMUM AREA ENCLOSED BY SIDE TIE BARS LOCATED INSIDE VERTICAL PORT CENTERS
VTC =	11.988	inches	MAXIMUM VERTICAL SPAN OF SIDE TIE BARS LOCATED INSIDE VERTICAL PORT CENTERS
TBMD =	12.441	inches	MAXIMUM VERTICAL SPAN FROM TOP / BOTTOM END TIE BARS TO TOP / BOTTOM SIDE TIE BAR LOCATED INSIDE VERTICAL PORT CENTERS
A =	0.9348		CONSTANT VALUE FOR US UNITS

THICKNESS "T3" REQUIRED FOR PORT REINFORCEMENT

T3 = A*(P/Sop)^0.5*d^1.0066*[(TBPA/ATMIN)*(VTC/TBMD)]^0.0201

MINIMUM REQUIRED REINFORCED THICKNESS, INCLUDING CA T3 = 1.196 inches

MINIMUM THICKNESS "Tport" REQUIRED FOR PORTED SLABS

Tport = GREATER OF: T OR T3

Tport = 1.204 inches

LOADINGS

The slab thickness for this heat exchanger is based on the loadings is section UG-22(a), taking into consideration both the internal and external (full vacuum) pressures. UG-21 states that the pressure vessel shall be designed for at least the most severe condition of coincident pressure and temperature expected in normal operation. The internal pressure is used in this calculation since it creates the maximum differential pressure between the inside and outside of the vessel. Loadings in sections UG-22 (b) through (i) have been considered with no additional thickness required.

HYDROSTATIC TEST PRESSURE

REFERENCE: UG-99 STANDARD HYDROSTATIC TEST

LOWEST STRESS RATIO (LSR):	1		UG-99(b)
MINIMUM TEST PRESSURE = 1.3*MAWP*LSR =	195.00	psi	

(PER NOTE 34, MAWP MAY BE ASSUMED TO BE THE SAME AS THE DESIGN PRESSURE)

IMPACT TESTING

The slab material, at 1.25 inches nominal thickness, is supplied in the as rolled condition. The slab material is thus classified by curve B in section UCS-66. The governing thickness for determining whether impact testing is required is 1.25 / 4 = 0.3125 inches [UCS-66(a)(3)]. Using 0.3125 inches as the minimum thickness, table UCS-66 indicates that impact testing is required for minimum temperatures less than -20.0 F. The tie bar material impact test exemption temperature is -55.0 F. Therefore, no impact testing is required for this frame since the minimum temperature is -20.0 F. (reference: UG-20, UG-84 & UCS-66)

DESIGN SUMMARY

DESIGN TEMPERATURE:	320.00	F
MINIMUM METAL DESIGN TEMPERATURE:	-20.00	F
MAXIMUM DESIGN PRESSURE:	150.00	psi
MINIMUM TEST PRESSURE:	195.00	psi
HEAD AND PORTED FOLLOWER:		
MINIMUM REQUIRED THICKNESS:	1.204	inches
UNPORTED FOLLOWER:		
MINIMUM REQUIRED THICKNESS:	1.204	inches
TIE BARS:		
REQUIRED TOTAL ROOT AREA:	3.284	sq in
SUPPLIED TOTAL ROOT AREA:	3.794	sq in

SPECIAL FRAME

The slab thickness is greater than the standard frame slab thickness.
Use a 1.25 inches slab thickness.