FABSCO PRESSURE VESSEL CALCULATIONS PAGE 1

BOX HEADER - STAYED DESIGN REV 4

JOB#:	**A22-13312-4A-5A**	**0**	**DATE:**	**3/9/2023**	
CUSTOMER:	**Air Products Manufacturing LLC**		**ASME: SECT.VIII DIV.1 2021**		
TUBE BUNDLE QTY		**1**	**APPROVED** _____		

P=DESIGN PRESSURE	FV@350F		**550** PSIG	T=DESIGN TEMP		**555** DEGF
S_{Plate}=ALLOWABLE STRESS			**20000** PSI	St_{Plate}=ALLOW STRESS@T		**19670** PSIG
HP=HYDRO PRESSURE		1.3	727 PSIG	CA=CORROSION ALLOWANCE		**0.125** IN
NDE			**RT SPOT API 661**	MDMT (DEG F) / HT TREAT	**32**	**YES**
ROWS/PASS			**4** **4**	INPIPE QTY/DIA	**2**	**6**
TUBE L(FT)/QTY		**24**	**198**	PIPE SCH IN/OUT	**160**	**160**
PLATE/TUBE MATERIAL		**SA-516-70N**	**SA-179**	FLANGE/PIPE MATERIAL	**SA-350-LF2**	**SA-106-B**

TUBE WALL

S_{Tube}		13345	PSI
$T_{Available}$	Tavailable=0.12-.011	0.109	IN
$T_{Required}$	$T=(PR_O)/(SE+.4P)$=	0.025	IN

PIPE WALL 6 160

S_{Pipe}	SA-106-B	17100	PSI
OD PIPE		6.625	IN
T avail	T_{avail} = T-CA	0.593	IN
T reqd	$T=(((P(R_O)/(SE+.4P)))/.875=$	0.141	IN

NOTE VERIFY THKNS PER UG45

Current efficiency (E) (100% X-ray , 85% none) = 85%

NOZZLE INFO	QTY	SIZE	SCH
INLET	2	6	160
OUTLET	2	6	160

Flange Rating	600# RFWN	Max Pressure @ Temp	1174 PSI
Flange Grade	1.1		

INLET NOZZLE STRESS ANALYSIS

SO **A22-13312-4A-5A**

NOZZLE SIZE		**6**		**API NOZZLE LOAD MULTIPLIER**	**2.00**	
PIPE WALL		**160**				
P(DESIGN PRESSURE)		550	PSI	Fx (FORCE IN X DIR)*	1800	LBS
CA(CORROSION ALLOW.)		0.125	IN	Fy(FORCE IN Y DIR)*	2260	LBS
R1 (OUTER RAD. OF NOZZL)		3.3125	IN	Fz(FORCE IN Z DIR)	2260	LBS
R2 (INSIDE RAD. OF NOZZL)		2.809	IN	Mx(EXTRNL NOZ MOMENT)	37920	INLB
Tn(Tnoz*.875-CA)		0.50325	IN	My(EXTRNL NOZ MOMENT)	54000	INLB
Tw (LEG OF PERIM. WELD)		0.5	IN	Mz(EXTRNL NOZ MOMENT)	38400	INLB
Tc(CORR TKNS OF WRAP)		0.625	IN	Hx(MOMENT ARM FOR Fx)	8	IN
A1(NOZ. WELD AREA)		0.251625	IN^2	B(RATIO Tn/Rave)	0.151924528	
A2(PERIM WELD AREA)		0.125	IN^2	I1	2.35923368	IN4
A3(WRAPPER PL AREA)		0.62703125	IN^2	I2	1.514811198	IN4
X1(CENTROID A1)		3.060875	IN	I3	6.926042435	IN4
X2(CENTROID A2)		3.479	IN	ITOTAL	10.80008731	IN4
X3(CENTROID A3)		3.310875	IN	Seff = 2 * S	6.60725984	IN3
AX1		0.770192672	IN3	Mbending	94020.42331	INLB
AX2		0.434895833	IN3	SIG bending	14229.86618	PSI
AX3		2.07602209	IN3	SIG axial	233.5068148	PSI
X=SUM AX / SUM A		3.269157737	IN	SIG membrane	3412.440243	PSI
S=I/X (SECT MOD ONE SIDE)		3.30362992	IN3	SIG total	17644.22217	PSI
SIG1		0	PSI	SIG design	19670	PSI
SIG2		3367.825473	PSI	SIG allow	29505	PSI
SIG3		-550	PSI	**SIG allow>SIG total OK**		

OUTLET NOZZLE STRESS ANALYSIS						
SO	**A22-13312-4A-5A**					
NOZZLE SIZE		**6**		**API NOZZLE LOAD MULTIPLIER**	**2.00**	
PIPE WALL		**160**				
P(DESIGN PRESSURE)		550	PSI	Fx (FORCE IN X DIR)*	1800	LBS
CA(CORROSION ALLOW.)		0.125	IN	Fy(FORCE IN Y DIR)*	2260	LBS
R1 (OUTER RAD. OF NOZZL)		3.3125	IN	Fz(FORCE IN Z DIR)	2260	LBS
R2 (INSIDE RAD. OF NOZZL)		2.809	IN	Mx(EXTRNL NOZ MOMENT)	37920	INLB
Tn(Tnoz*.875-CA)		0.50325	IN	My(EXTRNL NOZ MOMENT)	54000	INLB
Tw (LEG OF PERIM. WELD)		0.5	IN	Mz(EXTRNL NOZ MOMENT)	38400	INLB
Tc(CORR TKNS OF WRAP)		0.750	IN	Hx(MOMENT ARM FOR Fx)	**8**	IN
A1(NOZ. WELD AREA)		0.251625	IN^2	B(RATIO Tn/Rave)	0.151924528	
A2(PERIM WELD AREA)		0.125	IN^2	I1	2.35923368	IN4
A3(WRAPPER PL AREA)		0.7524375	IN^2	I2	1.514811198	IN4
X1(CENTROID A1)		3.060875	IN	I3	8.311250922	IN4
X2(CENTROID A2)		3.479	IN	ITOTAL	12.1852958	IN4
X3(CENTROID A3)		3.310875	IN	Seff = 2 * S	7.444149371	IN3
AX1		0.770192672	IN3	Mbending	94020.42331	INLB
AX2		0.434895833	IN3	SIG bending	12630.10972	PSI
AX3		2.491226508	IN3	SIG axial	233.5068148	PSI
X=SUM AX / SUM A		3.273791321	IN	SIG membrane	3412.440243	PSI
S=I/X (SECT MOD ONE SIDE)		3.722074685	IN3	SIG total	16044.70833	PSI
SIG1		0	PSI	SIG design	19670	PSI
SIG2		3367.825473	PSI	SIG allow	29505	PSI
SIG3		-550	PSI	**SIG allow>SIG total OK**		

Input Echo, COMPONENT 1, Description: 13312-4/5 FRTop

Figure Number Analyzed A1

Design Internal Pressure	P	550.0000	psig
Design Temperature	Temp	555.0000	F

VESSEL MATERIAL DATA:

Material Specification		SA-516 70	
Shell Allowable Stress at Design Temp	S	19670.0000	psi
Shell Allowable Stress at Ambient	SA	20000.0000	psi
Shell Yield Stress at Design Temperature	Sy	29955.0000	psi

SHORT-SIDE VESSEL DATA:

Short-side Length Dimension	H	4.2500	in.
Minimum Thickness of Short-side Plates	t1	1.0000	in.
Mid-side Joint Efficiency on Short-side	E	0.8500	
Corner Joint Efficiency on Short-side	EC	0.8500	

LONG-SIDE VESSEL DATA:

Long-side Length Dimension	h	5.5000	in.
Minimum Thickness of Long-side Plates	t2	0.7500	in.
Mid-side Joint Efficiency on Long-side	E	0.8500	

ADDITIONAL VESSEL DATA:

Minimum Thickness of End Plate	t5	0.6250	in.
C-Factor for End Plate	Cf_Epl	0.2000	
Corrosion Allowance of Shell	CA	0.1250	in.

Short-Side Plate # 1,

Pitch Distance	p	2.7500	in.
Uniform Hole Diameter	d0	1.3750	in.
Depth of Holes	T0	1.0000	in.

Internal Pressure Results, Rect. Vessel # 1, Desc: 13312-4/5 FRTop

ASME Code, Section VIII, Division 1, 2021 App. 13

Ligament Efficiency Calculations (Section 13-6, Equations (1)-(6)):

Short-side 1 Calculations

Effective Diameter [De]: 1.375 in.

Membrane Ligament Efficiency [Em]:

= Pitch - De / Pitch

= 2.750 - 1.375 / 2.750

= 0.500

Bending Ligament Efficiency [Eb]:

As diameter holes are uniform Eb = Em

= 0.500

Dist from Neutral axis of c/s to inside surface of the vesssel [Ci]:

= t1 - CA / 2

= 1.000 - 0.125 / 2

= 0.438 in.

Dist from Neutral axis of c/s to extreme outside surface of the section [Co]:

= -(t1 - CA) / 2

= -(1.000 - 0.125) / 2

= -0.438 in.

Short-side 2 Calculations

Membrane Ligament Efficiency [Em]:

= 0.850

Bending Ligament Efficiency [Eb]:

= 0.850

Dist from Neutral axis of c/s to inside surface of the vesssel [Ci]:

= t1 - CA / 2

= 1.000 - 0.125 / 2

= 0.438 in.

Dist from Neutral axis of c/s to extreme outside surface of the section [Co]:

= -(t1 - CA) / 2

= -(1.000 - 0.125) / 2

= -0.438 in.

Long-side 1 Calculations

Membrane Ligament Efficiency [Em]:

= 0.850

Bending Ligament Efficiency [Eb]:

= 0.850

Dist from Neutral axis of c/s to inside surface of the vesssel [Ci]:

= t1 - CA / 2

= 0.750 - 0.125 / 2

= 0.312 in.

Dist from Neutral axis of c/s to extreme outside surface of the section [Co]:

= -(t1 - CA) / 2

= -(0.750 - 0.125) / 2

= -0.312 in.

Long-side 2 Calculations

Membrane Ligament Efficiency [Em]:

= 0.850

Bending Ligament Efficiency [Eb]:

= 0.850

Dist from Neutral axis of c/s to inside surface of the vesssel [Ci]:

= t1 - CA / 2

= 0.750 - 0.125 / 2

= 0.312 in.

Dist from Neutral axis of c/s to extreme outside surface of the section [Co]:

= -(t1 - CA) / 2

= -(0.750 - 0.125) / 2

= -0.312 in.

Ligament Efficiency Calculations (Section 13-6, Equations (1)-(6)):

		Em	Eb	Ci	Co
Short-side	1	0.500	0.500	0.438	-0.438
	2	0.850	0.850	0.438	-0.438
Long-side	1	0.850	0.850	0.312	-0.312
	2	0.850	0.850	0.312	-0.312

Moment of Inertia of a Strip of the Vessel Wall:

Thickness t1, I1 = 0.0558 in**4

Thickness t2, I2 = 0.0203 in**4

Rectangular Vessel Parameters:

Alpha = H / h = 0.7826

K = (I2/I1)*Alpha = 0.2852

Membrane Stress Calculations per Section 13-7

Membrane Stresses at Short-side 1

Membrane Stress at Short-side 1 [Sms]:

= P * H / (2 * t1)

= 550.0 * 5.75 / (2 * 0.875)

= 1807.14 psi

If Em(0.500) < E(0.850) and Eb(0.500) < E(0.850) then Sms = Sms / Em

= 1807.14 / 0.50

= 3614.29 psi

Membrane Stresses at Short-side 2

Membrane Stress at Short-side 2 [Sms]:

= P * H / (2 * t1)

= 550.0 * 5.75 / (2 * 0.875)

= 1807.14 psi

Membrane Stresses at Long-side 1

Membrane Stress at Long-side 1 at A [Sml]:

= p * h / (2 * t2)

= 550.0 * 4.50 / (2 * 0.625)

= 1980.00 psi

Membrane Stresses at Long-side 2

Membrane Stress at Long-side 2 at A [Sml]:

= p * h / (2 * t2)

= 550.0 * 4.50 / (2 * 0.625)

= 1980.00 psi

MEMBRANE STRESSES: Membrane Stress Calculations per Section 13-7,
Equations (1) and (2). (psi) :

STRESS LOCATIONS	Actual	Allowable
Short-side 1	3614.29	16719.50
Short-side 2	1807.14	16719.50
Short-side Corner	1807.14	16719.50
Long-side 1 at A	1980.00	16719.50
Long-side 2 at A	1980.00	16719.50
Long-side Corner	1980.00	16719.50

Bending Stress Calculations per Section 13-7

Bending Stresses at Short-side 1

Bending Stresses at short side 1 at N inner [Sbs_Ni]:

= (P * c) / (12 * I1) * ((-1.5 * H^(2)) +
(h^(2) * ((1 + alpha^(2) * K) / (1 + K))))

= (550.0 * 0.44) / (12 * 0.06) * ((-1.5 * 4.50^(2)) +
(5.75^(2) * ((1 + 0.78^(2) * 0.285) / (1 + 0.285))))

= -55.96 psi

If Em(0.500) < E(0.850) and Eb(0.500) < E(0.850) then
Sbs_Ni = Sbs_Ni / Eb

= -55.96 / 0.50

= -111.91 psi

Bending Stress at short side 1 at N outer [Sbs_No]:

= (P * c) / (12 * I1) * ((-1.5 * H^(2)) +
(h^(2) * ((1 + alpha^(2) * K) / (1 + K))))

= (550.0 * -0.44) / (12 * 0.06) * ((-1.5 * 4.50^(2)) +
(5.75^(2) * ((1 + 0.78^(2) * 0.285) / (1 + 0.285))))

= 55.96 psi

If Em(0.500) < E(0.850) and Eb(0.500) < E(0.850) then
Sbs_No = Sbs_No / Eb

= 55.96 / 0.50

= 111.91 psi

Bending Stress at short side 1 at Q inner [Sbs_Qi]:

= (P * h^(2) * c) / (12 * I1) * ((1 + alpha^(2) * K) / (1 + K))

= (550.0 * 5.75^(2) * 0.438) / (12 * 0.06) * ((1 + 0.78^(2) * 0.285) /
(1 + 0.285))

= 10854.25 psi

Bending Stress at short side 1 at Q outer [Sbs_Qo]:

= (P * h^(2) * c) / (12 * I1) * ((1 + alpha^(2) * K) / (1 + K))

= (550.0 * 5.75^(2) * -0.438) / (12 * 0.06) * ((1 + 0.78^(2) * 0.285) /
(1 + 0.285))

= -10854.25 psi

Bending Stresses at Short-side 2

Bending Stresses at short side 2 at N inner [Sbs_Ni]:

= (P * c) / (12 * I1) * ((-1.5 * H^(2)) +
(h^(2) * ((1 + alpha^(2) * K) / (1 + K))))

= (550.0 * 0.44) / (12 * 0.06) * ((-1.5 * 4.50^(2)) +
(5.75^(2) * ((1 + 0.78^(2) * 0.285) / (1 + 0.285))))

= -55.96 psi

Bending Stress at short side 2 at N outer [Sbs_No]:

= (P * c) / (12 * I1) * ((-1.5 * H^(2)) +
(h^(2) * ((1 + alpha^(2) * K) / (1 + K))))

= (550.0 * -0.44) / (12 * 0.06) * ((-1.5 * 4.50^(2)) +
(5.75^(2) * ((1 + 0.78^(2) * 0.285) / (1 + 0.285))))

= 55.96 psi

Bending Stress at short side 2 at Q inner [Sbs_Qi]:

= (P * h^(2) * c) / (12 * I1) * ((1 + alpha^(2) * K) / (1 + K))

= (550.0 * 5.75^(2) * 0.438) / (12 * 0.06) * ((1 + 0.78^(2) * 0.285) /
(1 + 0.285))

= 10854.25 psi

Bending Stress at short side 2 at Q outer [Sbs_Qo]:

= (P * h^(2) * c) / (12 * I1) * ((1 + alpha^(2) * K) / (1 + K))

= (550.0 * 5.75^(2) * -0.438) / (12 * 0.06) * ((1 + 0.78^(2) * 0.285) /
(1 + 0.285))

= -10854.25 psi

Bending Stress at Long-side 1

Bending Stress at long side 1 at M inner [Sbl_Mi]:

= (P * h^(2) * c) / (12 * I2) * (-1.5 + ((1 + alpha^(2) * K) / (1 + K)))

= (550.0 * 5.75^(2) * 0.3125) / (12 * 0.0203) * (-1.5 + ((1 + 0.7826^(2) * 0.2852)
/ (1 + 0.2852)))

= -13639.68 psi

Bending Stress at long side 1 at M outer [Sbl_Mo]:

= (P * h^(2) * c) / (12 * I2) * (-1.5 + (1 + alpha^(2) * K) / (1 + K))

= (550.0 * 5.75^(2) * -0.3125) / (12 * 0.0203) * (-1.5 + (1 + 0.7826^(2) * 0.2852)
/ (1 + 0.2852))

= 13639.68 psi

Bending Stress at long side 1 at Q inner [Sbl_Qi]:

= (P * h^(2) * c) / (12 * I2) * ((1 + alpha^(2) * K) / (1 + K))

= (550.0 * 5.75^(2) * 0.312) / (12 * 0.02) * ((1 + 0.78^(2) * 0.285) /
(1 + 0.285))

= 21274.32 psi

Bending Stress at long side 1 at Q outer [Sbl_Qo]:

= (P * h^(2) * c) / (12 * I2) * ((1 + alpha^(2) * K) / (1 + K))

= (550.0 * 5.75^(2) * -0.312) / (12 * 0.02) * ((1 + 0.78^(2) * 0.285)
/ (1 + 0.285))

= -21274.32 psi

Bending Stress at Long-side 2

Bending Stress at long side 2 at M inner [Sbl_Mi]:

= (P * h^(2) * c) / (12 * I2) * (-1.5 + ((1 + alpha^(2) * K) / (1 + K)))

= (550.0 * 5.75^(2) * 0.3125) / (12 * 0.0203) * (-1.5 + ((1 + 0.7826^(2) * 0.2852)

/ (1 + 0.2852)))

= -13639.68 psi

Bending Stress at long side 2 at M outer [Sbl_Mo]:

= (P * h^(2) * c) / (12 * I2) * (-1.5 + (1 + alpha^(2) * K) / (1 + K))

= (550.0 * 5.75^(2) * -0.3125) / (12 * 0.0203) * (-1.5 + (1 + 0.7826^(2) * 0.2852)

/ (1 + 0.2852))

= 13639.68 psi

Bending Stress at long side 2 at Q inner [Sbl_Qi]:

= (P * h^(2) * c) / (12 * I2) * ((1 + alpha^(2) * K) / (1 + K))

= (550.0 * 5.75^(2) * 0.312) / (12 * 0.02) * ((1 + 0.78^(2) * 0.285) /

(1 + 0.285))

= 21274.32 psi

Bending Stress at long side 2 at Q outer [Sbl_Qo]:

= (P * h^(2) * c) / (12 * I2) * ((1 + alpha^(2) * K) / (1 + K))

= (550.0 * 5.75^(2) * -0.312) / (12 * 0.02) * ((1 + 0.78^(2) * 0.285)

/ (1 + 0.285))

= -21274.32 psi

BENDING STRESSES: Bending Stress Calculations per Section 13-7,
Equations (3-6). (psi) :

STRESS LOCATIONS		Inner	Outer	Allowable
Short-side 1 at	N	-111.91	111.91	25079.25
	Q	10854.25	-10854.25	25079.25
Short-side 2 at	N	-55.96	55.96	25079.25
	Q	10854.25	-10854.25	25079.25
Long-side 1 at	M	-13639.68	13639.68	25079.25
	Q	21274.32	-21274.32	25079.25
Long-side 2 at	M	-13639.68	13639.68	25079.25
	Q	21274.32	-21274.32	25079.25

Total Stress Calculations per Section 13-7

Total Stresses at Short-side 1

Total Stress at short side 1 at N inner [STS_Ni]:

= Sms + Sbs_Ni

= 3614.29 + -111.91

= 3502.37 psi

Total Stress at short side 1 at N outer [STS_No]:

= Sms + Sbs_No

= 3614.29 + 111.91

= 3726.20 psi

Total Stress at short side 1 at Q inner [STS_Qi]:

= Sms + Sbs_Qi

= 3614.29 + 10854.25

= 14468.53 psi

Total Stress at short side 1 at Q outer [STS_Qo]:

= Sms + Sb_Qo

= 3614.29 + -10854.25

= -7239.96 psi

Total Stresses at Short-side 2

Total Stress at short side 2 at N inner [STS_Ni]:

= Sms + Sbs_Ni

= 1807.14 + -55.96

= 1751.19 psi

Total Stress at short side 2 at N outer [STS_No]:

= Sms + Sbs_No

= 1807.14 + 55.96

= 1863.10 psi

Total Stress at short side 2 at Q inner [STS_Qi]:

= Sms + Sbs_Qi

= 1807.14 + 10854.25

= 12661.39 psi

Total Stress at short side 2 at Q outer [STS_Qo]:

= Sms + Sb_Qo

= 1807.14 + -10854.25

= -9047.10 psi

Total Stresses at Long-side 1

Total Stress at long side 1 at M inner [STL_Mi]:

= Sml + Sbl_Mi

= 1980.00 + -13639.68

= -11659.68 psi

Total Stress at long side 1 at M outer [STL_Mo]:

= Sml + Sb_Mo

= 1980.00 + 13639.68

= 15619.68 psi

Total Stress at long side 1 at Q inner [STL_Qi]:

= Sml + Sbl_Qi

= 1980.00 + 21274.32

= 23254.32 psi

Total Stress at long side 1 at Q outer [STL_Qo]:

= Sml + Sb_Qo

= 1980.00 + -21274.32

= -19294.32 psi

Total Stresses at Long-side 2

Total Stress at long side 2 at M inner [STL_Mi]:

= Sml + Sbl_Mi

= 1980.00 + -13639.68

= -11659.68 psi

Total Stress at long side 2 at M outer [STL_Mo]:

= Sml + Sb_Mo

= 1980.00 + 13639.68

= 15619.68 psi

Total Stress at long side 2 at Q inner [STL_Qi]:

= Sml + Sbl_Qi

= 1980.00 + 21274.32

= 23254.32 psi

Total Stress at long side 2 at Q outer [STL_Qo]:

= Sml + Sb_Qo

= 1980.00 + -21274.32

= -19294.32 psi

TOTAL STRESSES: Total Stress Calculations per Section 13-7, Equations (7-10). (psi) :

STRESS LOCATIONS	Inner	Outer	Allowable
Short-side 1 at N	3502.37	3726.20	25079.25
at Q	14468.53	-7239.96	25079.25
Short-side 2 at N	1751.19	1863.10	25079.25
at Q	12661.39	-9047.10	25079.25

Long-side 1 at M	-11659.68	15619.68	25079.25	
at Q	23254.32	-19294.32	25079.25	
Long-side 2 at M	-11659.68	15619.68	25079.25	
at Q	23254.32	-19294.32	25079.25	

End Plate Stresses (psi):

	Actual	Allowable
End Plate	13558.70	16719.50 (0.85 EFF)

Required End Plate thickness due to Internal Pressure [trEP]:

= d * sqrt(Z * C * P / (SE)) + ca

= 4.500 * sqrt(1.522 * 0.200 * 550.000 / (19670.000)) + 0.125

= 0.540 in.

End Plate MAWP at given Thickness [MAWPEP]:

= ((T-ca)/d)^2 * ((SE)/(C*Z)) per UG-34 (c)(3)

= ((.6250-0.1250)/4.5000)^2*((19670)/(.20*1.52))

= 797.901 psig

where Z is:

= min(3.4 - 2.4(d/D), 2.5)

= min(3.4 - 2.4(4.500 / 5.750), 2.5)

= 1.522

SUMMARY OF RESULTS (INTERNAL PRESSURE):

MEMBRANE STRESS SUMMARY,

High Stress (Highest % of Allowable)	3614.29	psi
High Stress Percentage	18.37	%
M.A.W.P. for Membrane Stresses	2993.26	psig

BENDING STRESS SUMMARY,

High Stress (Highest % of Allowable)	-21274.32	psi
High Stress Percentage	84.83	%
M.A.W.P. for Bending Stresses	648.37	psig

TOTAL STRESS SUMMARY,

High Stress (Highest % of Allowable)	23254.32	psi
High Stress Percentage	92.72	%
M.A.W.P. for Total Stresses	593.16	psig

Input Echo, COMPONENT 2, Description: 13312-4/5 FRBTM

Figure Number Analyzed A7

Design Internal Pressure	P	550.0000	psig
Design Temperature	Temp	555.0000	F

VESSEL MATERIAL DATA:

Material Specification		SA-516 70	
Shell Allowable Stress at Design Temp	S	19670.0000	psi
Shell Allowable Stress at Ambient	SA	20000.0000	psi
Shell Yield Stress at Design Temperature	Sy	29955.0000	psi

SHORT-SIDE VESSEL DATA:

Short-side Length Dimension	H	5.5000	in.
Minimum Thickness of Short-side Plates	t1	0.8750	in.
Mid-side Joint Efficiency on Short-side	E	0.8500	
Corner Joint Efficiency on Short-side	EC	0.8500	

LONG-SIDE VESSEL DATA:

Long-side Length Dimension	h	4.9375	in.
Minimum Thickness of Long-side Plates	t2	1.0000	in.
Mid-side Joint Efficiency on Long-side	E	0.8500	

ADDITIONAL VESSEL DATA:

Minimum Thickness of End Plate	t5	0.6250	in.
C-Factor for End Plate	Cf_Epl	0.2000	
Corrosion Allowance of Shell	CA	0.1250	in.

Long-side Plate # 1,

Pitch Distance	p	2.7500	in.
Uniform Hole Diameter	d0	1.3750	in.
Depth of Holes	T0	1.0000	in.

STAY PLATE MATERIAL DATA:

Stay Material Specification		SA-516 70	
Stay Allowable Stress at Design Temp	Sr	19670.0000	psi
Stay Allowable Stress at Ambient	SA	20000.0000	psi
Stay Yield Stress at Design Temp	Sy	29955.0000	psi

STAY PLATE DATA:

Minimum Thickness of Stay	t3	0.5000	in.
The Stay(s) Are Welded to the End Plate	t3	0.5000	in.
Corrosion Allowance of Stay	CAS	0.1250	in.

Rectangular Vessel Results, Item number 2, Desc: 13312-4/5 FRBTM

ASME Code, Section VIII, Division 1, 2021 App. 13

Ligament Efficiency Calculations (Section 13-6, Equations (1)-(6)):

Short-side 1 Calculations

Membrane Ligament Efficiency [Em]:

= 0.850

Bending Ligament Efficiency [Eb]:

= 0.850

Dist from Neutral axis of c/s to inside surface of the vesssel [Ci]:

= t1 - CA / 2

= 0.875 - 0.125 / 2

= 0.375 in.

Dist from Neutral axis of c/s to extreme outside surface of the section [Co]:

= -(t1 - CA) / 2

= -(0.875 - 0.125) / 2

= -0.375 in.

Short-side 2 Calculations

Membrane Ligament Efficiency [Em]:

= 0.850

Bending Ligament Efficiency [Eb]:

= 0.850

Dist from Neutral axis of c/s to inside surface of the vesssel [Ci]:

= t1 - CA / 2

= 0.875 - 0.125 / 2

= 0.375 in.

Dist from Neutral axis of c/s to extreme outside surface of the section [Co]:

= -(t1 - CA) / 2

= -(0.875 - 0.125) / 2

= -0.375 in.

Long-side 1 Calculations

Effective Diameter [De]: 1.375 in.

Membrane Ligament Efficiency [Em]:

= Pitch - De / Pitch

= 2.750 - 1.375 / 2.750

= 0.500

Bending Ligament Efficiency [Eb]:

As diameter holes are uniform Eb = Em

= 0.500

Dist from Neutral axis of c/s to inside surface of the vesssel [Ci]:

= t1 - CA / 2

= 1.000 - 0.125 / 2

= 0.438 in.

Dist from Neutral axis of c/s to extreme outside surface of the section [Co]:

= -(t1 - CA) / 2

= -(1.000 - 0.125) / 2

= -0.438 in.

Long-side 2 Calculations

Membrane Ligament Efficiency [Em]:

= 0.850

Bending Ligament Efficiency [Eb]:

= 0.850

Dist from Neutral axis of c/s to inside surface of the vesssel [Ci]:

= t1 - CA / 2

= 1.000 - 0.125 / 2

= 0.438 in.

Dist from Neutral axis of c/s to extreme outside surface of the section [Co]:

= -(t1 - CA) / 2

= -(1.000 - 0.125) / 2

= -0.438 in.

Ligament Efficiency Calculations (Section 13-6, Equations (1)-(6)):

		Em	Eb	Ci	Co
Short-side	1	0.850	0.850	0.375	-0.375
	2	0.850	0.850	0.375	-0.375
Long-side	1	0.500	0.500	0.438	-0.438
	2	0.850	0.850	0.438	-0.438

Moment of Inertia of a Strip of the Vessel Wall:

Thickness t1, I1 = 0.0352 in**4

Thickness t2, I2 = 0.0558 in**4

Rectangular Vessel Parameters:

Alpha = H / h = 1.1084

K = (I2/I1)*Alpha = 1.7602

Membrane Stress Calculations per Section 13-9

Membrane Stresses at Short-side 1

Membrane Stress at Short-side 1 [Sms]:

= p * h / (4 * t1) * { 4 - [(2 + K *
(5 - alpha^(2)) / (1 + 2 * K)]}

= 550.00 * 5.19 / (4 * 0.75) * { 4 - [(2 + 1.76 *
(5 - 1.11^(2)) / (1 + 2 * 1.76)]}

= 1986.75 psi

Membrane Stresses at Short-side 2

Membrane Stress at Short-side 2 [Sms]:

= p * h / (4 * t1) * { 4 - [(2 + K *
(5 - alpha^(2)) / (1 + 2 * K)]}

= 550.00 * 5.19 / (4 * 0.75) * { 4 - [(2 + 1.76 *
(5 - 1.11^(2)) / (1 + 2 * 1.76)]}

= 1986.75 psi

Membrane Stresses at Long-side 1

Membrane Stress at Long-side 1 at A [Sml]:

= P * H / 2 * t2

= 550.00 * 5.75 / 2 * 0.88

= 1807.14 psi

If Em(0.500) < E(0.850) and Eb(0.500) < E(0.850) then

Sml = Sml / Em

= 1807.14 / 0.50

= 3614.29 psi

Membrane Stresses at Long-side 2

Membrane Stress at Long-side 2 at A [Sml]:

= P * H / 2 * t2

= 550.00 * 5.75 / 2 * 0.88

= 1807.14 psi

Membrane Stresses at Stay Plate

Membrane Stress at Stay Plate [Smsp]:

= P * h / (2 * t3) * [(2 + K * (5 -
alpha^(2)) / (1 + 2 * K)]

= 550.00 * 5.19 / (2 * 0.25) * [(2 + 1.76 * (5 -
1.11^(2)) / (1 + 2 * 1.76)]

= 10904.51 psi

MEMBRANE STRESSES: Membrane Stress Calculations per Section 13-9,
Equations (1-3). (psi) :

STRESS LOCATIONS	Actual	Allowable
Short-side 1	1986.75	16719.50
Short-side 2	1986.75	16719.50
Short-side Corner	1986.75	16719.50
Long-side 1 at A	3614.29	16719.50
Long-side 2 at A	1807.14	16719.50
Long-side Corner	1807.14	16719.50
Stay Plate (t3)	10904.51	11802.00 (0.6 EFF)

Bending Stress Calculations per Section 13-9

Bending Stresses at Short-side 1

Bending Stress at Short-side 1 at N Inner[SbsNi]:

= P * c / (24 * I1) * [-3 * H^(2) + 2 * h^(2) *
((1 + 2 * Alpha^(2) * K) / (1 + 2 * K))]

= 550.00 * 0.38 / (24 * 0.04) * [-3 * 5.75^(2) + 2 * 5.19^(2) *
((1 + 2 * 1.11^(2) * 1.76) / (1 + 2 * 1.76))]

= -8747.35 psi

Bending Stress at Short-side 1 at N Outer[SbsNo]:

= P * c / (24 * I1) * [-3 * H^(2) + 2 * h^(2) *
((1 + 2 * Alpha^(2) * K) / (1 + 2 * K))]

= 550.00 * -0.38 / (24 * 0.04) * [-3 * 5.75^(2) + 2 * 5.19^(2) *
((1 + 2 * 1.11^(2) * 1.76) / (1 + 2 * 1.76))]

= 8747.35 psi

Bending Stress at Short-side 1 at Q Inner[SbsQi]:

= P * h^(2) * c / (12 * I1) * ((1 + 2 *
Alpha^(2) * K) / (1 + 2 * K))

= 550.00 * 5.19^(2) * 0.38 / (12 * 0.04) * ((1 + 2 *
1.11^(2) * 1.76) / (1 + 2 * 1.76))

= 15498.49 psi

Bending Stress at Short-side 1 at Q Outer[SbsQo]:

= P * h^(2) * c / (12 * I1) * ((1 + 2 *
Alpha^(2) * K) / (1 + 2 * K))

= 550.00 * 5.19^(2) * -0.38 / (12 * 0.04) * ((1 + 2 *
1.11^(2) * 1.76) / (1 + 2 * 1.76))

= -15498.49 psi

Bending Stresses at Short-side 2

Bending Stress at Short-side 2 at N Inner[SbsNi]:

= P * c / (24 * I1) * [-3 * H^(2) + 2 * h^(2) *
((1 + 2 * Alpha^(2) * K) / (1 + 2 * K))]

= 550.00 * 0.38 / (24 * 0.04) * [-3 * 5.75^(2) + 2 * 5.19^(2) *
((1 + 2 * 1.11^(2) * 1.76) / (1 + 2 * 1.76))]

= -8747.35 psi

Bending Stress at Short-side 2 at N Outer[SbsNo]:

= P * c / (24 * I1) * [-3 * H^(2) + 2 * h^(2) *
((1 + 2 * Alpha^(2) * K) / (1 + 2 * K))]

= 550.00 * -0.38 / (24 * 0.04) * [-3 * 5.75^(2) + 2 * 5.19^(2) *
((1 + 2 * 1.11^(2) * 1.76) / (1 + 2 * 1.76))]

= 8747.35 psi

Bending Stress at Short-side 2 at Q Inner[SbsQi]:

= P * h^(2) * c / (12 * I1) * ((1 + 2 *
Alpha^(2) * K) / (1 + 2 * K))

= 550.00 * 5.19^(2) * 0.38 / (12 * 0.04) * ((1 + 2 *
1.11^(2) * 1.76) / (1 + 2 * 1.76))

= 15498.49 psi

Bending Stress at Short-side 2 at Q Outer[SbsQo]:

= P * h^(2) * c / (12 * I1) * ((1 + 2 *
Alpha^(2) * K) / (1 + 2 * K))

= 550.00 * 5.19^(2) * -0.38 / (12 * 0.04) * ((1 + 2 *
1.11^(2) * 1.76) / (1 + 2 * 1.76))

= -15498.49 psi

Bending Stresses at Long-side 1

Bending Stress at Long-side 1 at M Inner[SblMi]:

= P * h^(2) * c / (12 * I2) * [(1 + K *
(3 - Alpha^(2))) / (1 + 2 * K)]

= 550.00 * 5.19^(2) * 0.44 / (12 * 0.06) * [(1 + 1.76 *
(3 - 1.11^(2))) / (1 + 2 * 1.76)]

= 8805.21 psi

If Em(0.500) < E(0.850) and Eb(0.500) < E(0.850) then

SblMi = SblMi / Eb

= 8805.21 / 0.50

= 17610.42 psi

Bending Stress at Long-side 1 at M Outer[SblMo]:

= P * h^(2) * c / (12 * I2) * [(1 + K *
(3 - Alpha^(2))) / (1 + 2 * K)]

= 550.00 * 5.19^(2) * -0.44 / (12 * 0.06) * [(1 + 1.76 *
(3 - 1.11^(2))) / (1 + 2 * 1.76)]

= -8805.21 psi

If Em(0.500) < E(0.850) and Eb(0.500) < E(0.850) then

SblMo = SblMo / Eb

= -8805.21 / 0.50

= -17610.42 psi

Bending Stress at Long-side 1 at Q Inner[SblQi]:

= P * h^(2) * c / (12 * I2) * [(1 + 2 *
Alpha^(2) * K) / (1 + 2 * K)]

= 550.00 * 5.19^(2) * 0.44 / (12 * 0.06) * [(1 + 2 *
1.11^(2) * 1.76) / (1 + 2 * 1.76)]

= 11386.64 psi

Bending Stress at Long-side 1 at Q Outer[SblQo]:

= P * h^(2) * c / (12 * I2) * [(1 + 2 *
Alpha^(2) * K) / (1 + 2 * K)]

= 550.00 * 5.19^(2) * -0.44 / (12 * 0.06) * [(1 + 2 *
1.11^(2) * 1.76) / (1 + 2 * 1.76)]

= -11386.64 psi

Bending Stresses at Long-side 2

Bending Stress at Long-side 2 at M Inner[SblMi]:

= P * h^(2) * c / (12 * I2) * [(1 + K *
(3 - Alpha^(2))) / (1 + 2 * K)]

= 550.00 * 5.19^(2) * 0.44 / (12 * 0.06) * [(1 + 1.76 *
(3 - 1.11^(2))) / (1 + 2 * 1.76)]

= 8805.21 psi

Bending Stress at Long-side 2 at M Outer[SblMo]:

= P * h^(2) * c / (12 * I2) * [(1 + K *
(3 - Alpha^(2))) / (1 + 2 * K)]

= 550.00 * 5.19^(2) * -0.44 / (12 * 0.06) * [(1 + 1.76 *
(3 - 1.11^(2))) / (1 + 2 * 1.76)]

= -8805.21 psi

Bending Stress at Long-side 2 at Q Inner[SblQi]:

= P * h^(2) * c / (12 * I2) * [(1 + 2 *
Alpha^(2) * K) / (1 + 2 * K)]

= 550.00 * 5.19^(2) * 0.44 / (12 * 0.06) * [(1 + 2 *
1.11^(2) * 1.76) / (1 + 2 * 1.76)]

= 11386.64 psi

Bending Stress at Long-side 2 at Q Outer[SblQo]:

= P * h^(2) * c / (12 * I2) * [(1 + 2 *
Alpha^(2) * K) / (1 + 2 * K)]

= 550.00 * 5.19^(2) * -0.44 / (12 * 0.06) * [(1 + 2 *
1.11^(2) * 1.76) / (1 + 2 * 1.76)]

= -11386.64 psi

BENDING STRESSES: Bending Stress Calculations per Section 13-9,
Equations (4-7). (psi) :

STRESS LOCATIONS	Inner	Outer	Allowable
Short-side 1 at N	-8747.35	8747.35	25079.25
at Q	15498.49	-15498.49	25079.25

Short-side 2 at N		-8747.35	8747.35	25079.25
	at Q	15498.49	-15498.49	25079.25
Long-side 1 at M		17610.42	-17610.42	25079.25
	at Q	11386.64	-11386.64	25079.25
Long-side 2 at M		8805.21	-8805.21	25079.25
	at Q	11386.64	-11386.64	25079.25

Total Stress Calculations per Section 13-9

Total Stresses at Short-side 1

Total Stress at short side 1 at N inner [STS_Ni]:

= Sms + SbsNi

= 1986.75 + -8747.35

= -6760.60 psi

Total Stress at short side 1 at N outer [STS_No]:

= Sms + SbsNo

= 1986.75 + 8747.35

= 10734.10 psi

Total Stress at short side 1 at Q inner [STS_Qi]:

= Sms + SbsQi

= 1986.75 + 15498.49

= 17485.23 psi

Total Stress at short side 1 at Q outer [STS_Qo]:

= Sms + SbsQo

= 1986.75 + -15498.49

= -13511.74 psi

Total Stresses at Short-side 2

Total Stress at short side 2 at N inner [STS_Ni]:

= Sms + SbsNi

= 1986.75 + -8747.35

= -6760.60 psi

Total Stress at short side 2 at N outer [STS_No]:

= Sms + SbsNo

= 1986.75 + 8747.35

= 10734.10 psi

Total Stress at short side 2 at Q inner [STS_Qi]:

= Sms + SbsQi

= 1986.75 + 15498.49

= 17485.23 psi

Total Stress at short side 2 at Q outer [STS_Qo]:

= Sms + SbsQo

= 1986.75 + -15498.49

= -13511.74 psi

Total Stresses at Long-side 1

Total Stress at long side 1 at M inner [STL_Mi]:

= Sml + SblMi

= 3614.29 + 17610.42

= 21224.71 psi

Total Stress at long side 1 at M outer [STL_Mo]:

= Sml + SblMo

= 3614.29 + -17610.42

= -13996.14 psi

Total Stress at long side 1 at Q inner [STL_Qi]:

= Sml + SblQi

= 1807.14 + 11386.64

= 13193.79 psi

Total Stress at long side 1 at Q outer [STL_Qo]:

= Sml + SblQo

= 1807.14 + -11386.64

= -9579.50 psi

Total Stresses at Long-side 2

Total Stress at long side 2 at M inner [STL_Mi]:

= Sml + SblMi

= 1807.14 + 8805.21

= 10612.35 psi

Total Stress at long side 2 at M outer [STL_Mo]:

= Sml + SblMo

= 1807.14 + -8805.21

= -6998.07 psi

Total Stress at long side 2 at Q inner [STL_Qi]:

= Sml + SblQi

= 1807.14 + 11386.64

= 13193.79 psi

Total Stress at long side 2 at Q outer [STL_Qo]:

= Sml + SblQo

= 1807.14 + -11386.64

= -9579.50 psi

TOTAL STRESSES: Total Stress Calculations per Section 13-9, Equations (8-12). (psi) :

STRESS LOCATIONS	Inner	Outer	Allowable
Short-side 1 at N	-6760.60	10734.10	25079.25
at Q	17485.23	-13511.74	25079.25
Short-side 2 at N	-6760.60	10734.10	25079.25
at Q	17485.23	-13511.74	25079.25
Long-side 1 at M	21224.71	-13996.14	25079.25
at Q	13193.79	-9579.50	25079.25
Long-side 2 at M	10612.35	-6998.07	25079.25
at Q	13193.79	-9579.50	25079.25

End Plate Stresses (psi):

	Actual	Allowable
End Plate	14620.40	16719.50 (.85 EFF)

Required End Plate thickness due to Internal Pressure [trEP]:

= d * sqrt(Z * C * P / (SE)) + ca

= 5.188 * sqrt(1.235 * 0.200 * 550.000 / (19670.000)) + 0.125

= 0.556 in.

End Plate MAWP at given Thickness [MAWPEP]:

= ((T-ca)/d)^2 * ((SE)/(C*Z)) per UG-34 (c)(3)

= ((.6250-0.1250)/5.1875)^2*((19670)/(.20*1.23))

= 739.959 psig

where Z is:

= min(3.4 - 2.4(d/D), 2.5)

= min(3.4 - 2.4(5.188 / 5.750), 2.5)

= 1.235

SUMMARY OF RESULTS:

MEMBRANE STRESS SUMMARY,

High Stress (Highest % of Allowable)	10904.51	psi
High Stress Percentage	55.44	%
M.A.W.P. for Membrane Stresses	992.11	psig

BENDING STRESS SUMMARY,

High Stress (Highest % of Allowable)	-15498.49	psi
High Stress Percentage	61.80	%
M.A.W.P. for Bending Stresses	890.00	psig

TOTAL STRESS SUMMARY,

High Stress (Highest % of Allowable)	21224.71	psi
High Stress Percentage	71.94	%
M.A.W.P. for Total Stresses	764.57	psig

Input Echo, COMPONENT 3, Description: 13312-4/5 BACK

Figure Number Analyzed A7

Design Internal Pressure	P	550.0000	psig
Design Temperature	Temp	555.0000	F

VESSEL MATERIAL DATA:

Material Specification		SA-516 70	
Shell Allowable Stress at Design Temp	S	19670.0000	psi
Shell Allowable Stress at Ambient	SA	20000.0000	psi
Shell Yield Stress at Design Temperature	Sy	29955.0000	psi

SHORT-SIDE VESSEL DATA:

Short-side Length Dimension	H	5.5000	in.
Minimum Thickness of Short-side Plates	t1	0.7500	in.
Mid-side Joint Efficiency on Short-side	E	0.8500	
Corner Joint Efficiency on Short-side	EC	0.8500	

LONG-SIDE VESSEL DATA:

Long-side Length Dimension	h	4.9375	in.
Minimum Thickness of Long-side Plates	t2	1.0000	in.
Mid-side Joint Efficiency on Long-side	E	0.8500	

ADDITIONAL VESSEL DATA:

Minimum Thickness of End Plate	t5	0.6250	in.
C-Factor for End Plate	Cf_Epl	0.2000	
Corrosion Allowance of Shell	CA	0.1250	in.

Ligament Efficiency Data:

Long-side Plate # 1,

Pitch Distance	p	2.7500	in.
Uniform Hole Diameter	d0	1.3750	in.
Depth of Holes	T0	1.0000	in.

STAY PLATE MATERIAL DATA:

Stay Material Specification		SA-516 70	
Stay Allowable Stress at Design Temp	Sr	19670.0000	psi
Stay Allowable Stress at Ambient	SA	20000.0000	psi
Stay Yield Stress at Design Temp	Sy	29955.0000	psi

STAY PLATE DATA:

Minimum Thickness of Stay	t3	0.6250	in.
The Stay(s) Are Welded to the End Plate	t3	0.6250	in.
Corrosion Allowance of Stay	CAS	0.1250	in.

Rectangular Vessel Results, Item number 3, Desc: 13312-4/5 BACK

ASME Code, Section VIII, Division 1, 2021 App. 13

Ligament Efficiency Calculations (Section 13-6, Equations (1)-(6)):

Short-side 1 Calculations

Membrane Ligament Efficiency [Em]:

= 0.850

Bending Ligament Efficiency [Eb]:

= 0.850

Dist from Neutral axis of c/s to inside surface of the vesssel [Ci]:

= t1 - CA / 2

= 0.750 - 0.125 / 2

= 0.312 in.

Dist from Neutral axis of c/s to extreme outside surface of the section [Co]:

= -(t1 - CA) / 2

= -(0.750 - 0.125) / 2

= -0.312 in.

Short-side 2 Calculations

Membrane Ligament Efficiency [Em]:

= 0.850

Bending Ligament Efficiency [Eb]:

= 0.850

Dist from Neutral axis of c/s to inside surface of the vesssel [Ci]:

= t1 - CA / 2

= 0.750 - 0.125 / 2

= 0.312 in.

Dist from Neutral axis of c/s to extreme outside surface of the section [Co]:

= -(t1 - CA) / 2

= -(0.750 - 0.125) / 2

= -0.312 in.

Long-side 1 Calculations

Effective Diameter [De]: 1.375 in.

Membrane Ligament Efficiency [Em]:

= Pitch - De / Pitch

= 2.750 - 1.375 / 2.750

= 0.500

Bending Ligament Efficiency [Eb]:

As diameter holes are uniform Eb = Em

= 0.500

Dist from Neutral axis of c/s to inside surface of the vesssel [Ci]:

= t1 - CA / 2

= 1.000 - 0.125 / 2

= 0.438 in.

Dist from Neutral axis of c/s to extreme outside surface of the section [Co]:

= -(t1 - CA) / 2

= -(1.000 - 0.125) / 2

= -0.438 in.

Long-side 2 Calculations

Membrane Ligament Efficiency [Em]:

= 0.850

Bending Ligament Efficiency [Eb]:

= 0.850

Dist from Neutral axis of c/s to inside surface of the vesssel [Ci]:

= t1 - CA / 2

= 1.000 - 0.125 / 2

= 0.438 in.

Dist from Neutral axis of c/s to extreme outside surface of the section [Co]:

= -(t1 - CA) / 2

= -(1.000 - 0.125) / 2

= -0.438 in.

Ligament Efficiency Calculations (Section 13-6, Equations (1)-(6)):

		Em	Eb	Ci	Co
Short-side	1	0.850	0.850	0.312	-0.312
	2	0.850	0.850	0.312	-0.312
Long-side	1	0.500	0.500	0.438	-0.438
	2	0.850	0.850	0.438	-0.438

Moment of Inertia of a Strip of the Vessel Wall:

Thickness t1, I1 = 0.0203 in**4

Thickness t2, I2 = 0.0558 in**4

Rectangular Vessel Parameters:

Alpha = H / h = 1.1084

K = (I2/I1)*Alpha = 3.0415

Membrane Stress Calculations per Section 13-9

Membrane Stresses at Short-side 1

Membrane Stress at Short-side 1 [Sms]:

= p * h / (4 * t1) * { 4 - [(2 + K *
(5 - alpha^(2)) / (1 + 2 * K)]}

= 550.00 * 5.19 / (4 * 0.62) * { 4 - [(2 + 3.04 *
(5 - 1.11^(2)) / (1 + 2 * 3.04)]}

= 2394.54 psi

Membrane Stresses at Short-side 2

Membrane Stress at Short-side 2 [Sms]:

= p * h / (4 * t1) * { 4 - [(2 + K *
(5 - alpha^(2)) / (1 + 2 * K)]}

= 550.00 * 5.19 / (4 * 0.62) * { 4 - [(2 + 3.04 *
(5 - 1.11^(2)) / (1 + 2 * 3.04)]}

= 2394.54 psi

Membrane Stresses at Long-side 1

Membrane Stress at Long-side 1 at A [Sml]:

= P * H / 2 * t2

= 550.00 * 5.75 / 2 * 0.88

= 1807.14 psi

If Em(0.500) < E(0.850) and Eb(0.500) < E(0.850) then

Sml = Sml / Em

= 1807.14 / 0.50

= 3614.29 psi

Membrane Stresses at Long-side 2

Membrane Stress at Long-side 2 at A [Sml]:

= P * H / 2 * t2

= 550.00 * 5.75 / 2 * 0.88

= 1807.14 psi

Membrane Stresses at Stay Plate

Membrane Stress at Stay Plate [Smsp]:

= P * h / (2 * t3) * [(2 + K * (5 -
alpha^(2)) / (1 + 2 * K)]

= 550.00 * 5.19 / (2 * 0.38) * [(2 + 3.04 * (5 -
1.11^(2)) / (1 + 2 * 3.04)]

= 7234.86 psi

MEMBRANE STRESSES: Membrane Stress Calculations per Section 13-9,
Equations (1-3). (psi) :

STRESS LOCATIONS	Actual	Allowable
Short-side 1	2394.54	16719.50
Short-side 2	2394.54	16719.50
Short-side Corner	2394.54	16719.50
Long-side 1 at A	3614.29	16719.50
Long-side 2 at A	1807.14	16719.50
Long-side Corner	1807.14	16719.50
Stay Plate (t3)	7234.86	11802.00 (0.6 EFF)

Bending Stress Calculations per Section 13-9

Bending Stresses at Short-side 1

Bending Stress at Short-side 1 at N Inner[SbsNi]:

= P * c / (24 * I1) * [-3 * H^(2) + 2 * h^(2) *
((1 + 2 * Alpha^(2) * K) / (1 + 2 * K))]

= 550.00 * 0.31 / (24 * 0.02) * [-3 * 5.75^(2) + 2 * 5.19^(2) *
((1 + 2 * 1.11^(2) * 3.04) / (1 + 2 * 3.04))]

= -12249.49 psi

Bending Stress at Short-side 1 at N Outer[SbsNo]:

= P * c / (24 * I1) * [-3 * H^(2) + 2 * h^(2) *
((1 + 2 * Alpha^(2) * K) / (1 + 2 * K))]

= 550.00 * -0.31 / (24 * 0.02) * [-3 * 5.75^(2) + 2 * 5.19^(2) *
((1 + 2 * 1.11^(2) * 3.04) / (1 + 2 * 3.04))]

= 12249.49 psi

Bending Stress at Short-side 1 at Q Inner[SbsQi]:

= P * h^(2) * c / (12 * I1) * ((1 + 2 *
Alpha^(2) * K) / (1 + 2 * K))

= 550.00 * 5.19^(2) * 0.31 / (12 * 0.02) * ((1 + 2 *
1.11^(2) * 3.04) / (1 + 2 * 3.04))

= 22664.51 psi

Bending Stress at Short-side 1 at Q Outer[SbsQo]:

= P * h^(2) * c / (12 * I1) * ((1 + 2 *
Alpha^(2) * K) / (1 + 2 * K))

= 550.00 * 5.19^(2) * -0.31 / (12 * 0.02) * ((1 + 2 *
1.11^(2) * 3.04) / (1 + 2 * 3.04))

= -22664.51 psi

Bending Stresses at Short-side 2

Bending Stress at Short-side 2 at N Inner[SbsNi]:

= P * c / (24 * I1) * [-3 * H^(2) + 2 * h^(2) *
((1 + 2 * Alpha^(2) * K) / (1 + 2 * K))]

= 550.00 * 0.31 / (24 * 0.02) * [-3 * 5.75^(2) + 2 * 5.19^(2) *
((1 + 2 * 1.11^(2) * 3.04) / (1 + 2 * 3.04))]

= -12249.49 psi

Bending Stress at Short-side 2 at N Outer[SbsNo]:

= P * c / (24 * I1) * [-3 * H^(2) + 2 * h^(2) *
((1 + 2 * Alpha^(2) * K) / (1 + 2 * K))]

= 550.00 * -0.31 / (24 * 0.02) * [-3 * 5.75^(2) + 2 * 5.19^(2) *
((1 + 2 * 1.11^(2) * 3.04) / (1 + 2 * 3.04))]

= 12249.49 psi

Bending Stress at Short-side 2 at Q Inner[SbsQi]:

= P * h^(2) * c / (12 * I1) * ((1 + 2 *
Alpha^(2) * K) / (1 + 2 * K))

= 550.00 * 5.19^(2) * 0.31 / (12 * 0.02) * ((1 + 2 *
1.11^(2) * 3.04) / (1 + 2 * 3.04))

= 22664.51 psi

Bending Stress at Short-side 2 at Q Outer[SbsQo]:

= P * h^(2) * c / (12 * I1) * ((1 + 2 *
Alpha^(2) * K) / (1 + 2 * K))

= 550.00 * 5.19^(2) * -0.31 / (12 * 0.02) * ((1 + 2 *
1.11^(2) * 3.04) / (1 + 2 * 3.04))

= -22664.51 psi

Bending Stresses at Long-side 1

Bending Stress at Long-side 1 at M Inner[SblMi]:

= P * h^(2) * c / (12 * I2) * [(1 + K *
(3 - Alpha^(2))) / (1 + 2 * K)]

= 550.00 * 5.19^(2) * 0.44 / (12 * 0.06) * [(1 + 3.04 *
(3 - 1.11^(2))) / (1 + 2 * 3.04)]

= 8716.77 psi

If Em(0.500) < E(0.850) and Eb(0.500) < E(0.850) then

SblMi = SblMi / Eb

= 8716.77 / 0.50

= 17433.54 psi

Bending Stress at Long-side 1 at M Outer[SblMo]:

= P * h^(2) * c / (12 * I2) * [(1 + K *
(3 - Alpha^(2))) / (1 + 2 * K)]

= 550.00 * 5.19^(2) * -0.44 / (12 * 0.06) * [(1 + 3.04 *
(3 - 1.11^(2))) / (1 + 2 * 3.04)]

= -8716.77 psi

If Em(0.500) < E(0.850) and Eb(0.500) < E(0.850) then

SblMo = SblMo / Eb

= -8716.77 / 0.50

= -17433.54 psi

Bending Stress at Long-side 1 at Q Inner[SblQi]:

= P * h^(2) * c / (12 * I2) * [(1 + 2 *
Alpha^(2) * K) / (1 + 2 * K)]

= 550.00 * 5.19^(2) * 0.44 / (12 * 0.06) * [(1 + 2 *
1.11^(2) * 3.04) / (1 + 2 * 3.04)]

= 11563.52 psi

Bending Stress at Long-side 1 at Q Outer[SblQo]:

= P * h^(2) * c / (12 * I2) * [(1 + 2 *
Alpha^(2) * K) / (1 + 2 * K)]

= 550.00 * 5.19^(2) * -0.44 / (12 * 0.06) * [(1 + 2 *
1.11^(2) * 3.04) / (1 + 2 * 3.04)]

= -11563.52 psi

Bending Stresses at Long-side 2

Bending Stress at Long-side 2 at M Inner[SblMi]:

= P * h^(2) * c / (12 * I2) * [(1 + K *
(3 - Alpha^(2))) / (1 + 2 * K)]

= 550.00 * 5.19^(2) * 0.44 / (12 * 0.06) * [(1 + 3.04 *
(3 - 1.11^(2))) / (1 + 2 * 3.04)]

= 8716.77 psi

Bending Stress at Long-side 2 at M Outer[SblMo]:

= P * h^(2) * c / (12 * I2) * [(1 + K *
(3 - Alpha^(2))) / (1 + 2 * K)]

= 550.00 * 5.19^(2) * -0.44 / (12 * 0.06) * [(1 + 3.04 *
(3 - 1.11^(2))) / (1 + 2 * 3.04)]

= -8716.77 psi

Bending Stress at Long-side 2 at Q Inner[SblQi]:

= P * h^(2) * c / (12 * I2) * [(1 + 2 *
Alpha^(2) * K) / (1 + 2 * K)]

= 550.00 * 5.19^(2) * 0.44 / (12 * 0.06) * [(1 + 2 *
1.11^(2) * 3.04) / (1 + 2 * 3.04)]

= 11563.52 psi

Bending Stress at Long-side 2 at Q Outer[SblQo]:

= P * h^(2) * c / (12 * I2) * [(1 + 2 *
Alpha^(2) * K) / (1 + 2 * K)]

= 550.00 * 5.19^(2) * -0.44 / (12 * 0.06) * [(1 + 2 *
1.11^(2) * 3.04) / (1 + 2 * 3.04)]

= -11563.52 psi

BENDING STRESSES: Bending Stress Calculations per Section 13-9,
Equations (4-7). (psi) :

STRESS LOCATIONS	Inner	Outer	Allowable
Short-side 1 at N	-12249.49	12249.49	25079.25

	at Q	22664.51	-22664.51	25079.25
Short-side 2	at N	-12249.49	12249.49	25079.25
	at Q	22664.51	-22664.51	25079.25
Long-side 1	at M	17433.54	-17433.54	25079.25
	at Q	11563.52	-11563.52	25079.25
Long-side 2	at M	8716.77	-8716.77	25079.25
	at Q	11563.52	-11563.52	25079.25

Total Stress Calculations per Section 13-9

Total Stresses at Short-side 1

Total Stress at short side 1 at N inner [STS_Ni]:

= Sms + SbsNi

= 2394.54 + -12249.49

= -9854.95 psi

Total Stress at short side 1 at N outer [STS_No]:

= Sms + SbsNo

= 2394.54 + 12249.49

= 14644.03 psi

Total Stress at short side 1 at Q inner [STS_Qi]:

= Sms + SbsQi

= 2394.54 + 22664.51

= 25059.05 psi

Total Stress at short side 1 at Q outer [STS_Qo]:

= Sms + SbsQo

= 2394.54 + -22664.51

= -20269.97 psi

Total Stresses at Short-side 2

Total Stress at short side 2 at N inner [STS_Ni]:

= Sms + SbsNi

= 2394.54 + -12249.49

= -9854.95 psi

Total Stress at short side 2 at N outer [STS_No]:

= Sms + SbsNo

= 2394.54 + 12249.49

= 14644.03 psi

Total Stress at short side 2 at Q inner [STS_Qi]:

= Sms + SbsQi

= 2394.54 + 22664.51

= 25059.05 psi

Total Stress at short side 2 at Q outer [STS_Qo]:

= Sms + SbsQo

= 2394.54 + -22664.51

= -20269.97 psi

Total Stresses at Long-side 1

Total Stress at long side 1 at M inner [STL_Mi]:

= Sml + SblMi

= 3614.29 + 17433.54

= 21047.83 psi

Total Stress at long side 1 at M outer [STL_Mo]:

= Sml + SblMo

= 3614.29 + -17433.54

= -13819.26 psi

Total Stress at long side 1 at Q inner [STL_Qi]:

= Sml + SblQi

= 1807.14 + 11563.52

= 13370.67 psi

Total Stress at long side 1 at Q outer [STL_Qo]:

= Sml + SblQo

= 1807.14 + -11563.52

= -9756.38 psi

Total Stresses at Long-side 2

Total Stress at long side 2 at M inner [STL_Mi]:

= Sml + SblMi

= 1807.14 + 8716.77

= 10523.91 psi

Total Stress at long side 2 at M outer [STL_Mo]:

= Sml + SblMo

= 1807.14 + -8716.77

= -6909.63 psi

Total Stress at long side 2 at Q inner [STL_Qi]:

= Sml + SblQi

= 1807.14 + 11563.52

= 13370.67 psi

Total Stress at long side 2 at Q outer [STL_Qo]:

= Sml + SblQo

= 1807.14 + -11563.52

= -9756.38 psi

TOTAL STRESSES: Total Stress Calculations per Section 13-9, Equations (8-12). (psi) :

STRESS LOCATIONS	Inner	Outer	Allowable
Short-side 1 at N	-9854.95	14644.03	25079.25
at Q	25059.05	-20269.97	25079.25
Short-side 2 at N	-9854.95	14644.03	25079.25
at Q	25059.05	-20269.97	25079.25
Long-side 1 at M	21047.83	-13819.26	25079.25
at Q	13370.67	-9756.38	25079.25
Long-side 2 at M	10523.91	-6909.63	25079.25
at Q	13370.67	-9756.38	25079.25

End Plate Stresses (psi):

	Actual	Allowable
End Plate	14620.40	16719.50 (.85 EFF)

Required End Plate thickness due to Internal Pressure [trEP]:

= d * sqrt(Z * C * P / (SE)) + ca

= 5.188 * sqrt(1.235 * 0.200 * 550.000 / (19670.000)) + 0.125

= 0.556 in.

End Plate MAWP at given Thickness [MAWPEP]:

= ((T-ca)/d)^2 * ((SE)/(C*Z)) per UG-34 (c)(3)

= ((.6250-0.1250)/5.1875)^2*((19670)/(.20*1.23))

= 739.959 psig

where Z is:

= min(3.4 - 2.4(d/D), 2.5)

= min(3.4 - 2.4(5.188 / 5.750), 2.5)

= 1.235

SUMMARY OF RESULTS:

MEMBRANE STRESS SUMMARY,

High Stress (Highest % of Allowable)	7234.86	psi
High Stress Percentage	36.78	%
M.A.W.P. for Membrane Stresses	1495.33	psig

BENDING STRESS SUMMARY,

High Stress (Highest % of Allowable)	-22664.51	psi
High Stress Percentage	90.37	%
M.A.W.P. for Bending Stresses	608.60	psig

TOTAL STRESS SUMMARY,

High Stress (Highest % of Allowable)	25059.05	psi
High Stress Percentage	99.92	%
M.A.W.P. for Total Stresses	550.44	psig

Input Echo, COMPONENT 4, Description: -4/5 FRTOP FV

Figure Number Analyzed A1

Design External Pressure	Pext	15.0000	psig
Design Temperature	Temp	350.0000	F

VESSEL MATERIAL DATA:

Material Specification		SA-516 70	
Shell Allowable Stress at Design Temp	S	20000.0000	psi
Shell Allowable Stress at Ambient	SA	20000.0000	psi
Shell Yield Stress at Design Temperature	Sy	33050.0000	psi
Length of Vessel	Lv	138.0000	in.

SHORT-SIDE VESSEL DATA:

Short-side Length Dimension	H	4.2500	in.
Minimum Thickness of Short-side Plates	t1	1.0000	in.
Mid-side Joint Efficiency on Short-side	E	0.8500	
Corner Joint Efficiency on Short-side	EC	0.8500	

LONG-SIDE VESSEL DATA:

Long-side Length Dimension	h	5.5000	in.
Minimum Thickness of Long-side Plates	t2	0.7500	in.
Mid-side Joint Efficiency on Long-side	E	0.8500	

ADDITIONAL VESSEL DATA:

Minimum Thickness of End Plate	t5	0.6250	in.
C-Factor for End Plate	Cf_Epl	0.2000	
Corrosion Allowance of Shell	CA	0.1250	in.

Short-Side Plate # 1,

Pitch Distance	p	2.7500	in.
Uniform Hole Diameter	d0	1.3750	in.
Depth of Holes	T0	1.0000	in.

External Pressure Results, Rect. Vessel # 4, Desc: -4/5 FRTOP FV

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Ligament Efficiency Calculations (Section 13-6, Equations (1)-(6)):

Short-side 1 Calculations

Effective Diameter [De]: 1.375 in.

Membrane Ligament Efficiency [Em]:

= Pitch - De / Pitch

= 2.750 - 1.375 / 2.750

= 0.500

Bending Ligament Efficiency [Eb]:

As diameter holes are uniform Eb = Em

= 0.500

Dist from Neutral axis of c/s to inside surface of the vesssel [Ci]:

= t1 - CA / 2

= 1.000 - 0.125 / 2

= 0.438 in.

Dist from Neutral axis of c/s to extreme outside surface of the section [Co]:

= -(t1 - CA) / 2

= -(1.000 - 0.125) / 2

= -0.438 in.

Short-side 2 Calculations

Membrane Ligament Efficiency [Em]:

= 0.850

Bending Ligament Efficiency [Eb]:

= 0.850

Dist from Neutral axis of c/s to inside surface of the vesssel [Ci]:

= t1 - CA / 2

= 1.000 - 0.125 / 2

= 0.438 in.

Dist from Neutral axis of c/s to extreme outside surface of the section [Co]:

= -(t1 - CA) / 2

= -(1.000 - 0.125) / 2

= -0.438 in.

Long-side 1 Calculations

Membrane Ligament Efficiency [Em]:

= 0.850

Bending Ligament Efficiency [Eb]:

= 0.850

Dist from Neutral axis of c/s to inside surface of the vesssel [Ci]:

= t1 - CA / 2

= 0.750 - 0.125 / 2

= 0.312 in.

Dist from Neutral axis of c/s to extreme outside surface of the section [Co]:

= -(t1 - CA) / 2

= -(0.750 - 0.125) / 2

= -0.312 in.

Long-side 2 Calculations

Membrane Ligament Efficiency [Em]:

= 0.850

Bending Ligament Efficiency [Eb]:

= 0.850

Dist from Neutral axis of c/s to inside surface of the vesssel [Ci]:

= t1 - CA / 2

= 0.750 - 0.125 / 2

= 0.312 in.

Dist from Neutral axis of c/s to extreme outside surface of the section [Co]:

= -(t1 - CA) / 2

= -(0.750 - 0.125) / 2

= -0.312 in.

Ligament Efficiency Calculations (Section 13-6, Equations (1)-(6)):

		Em	Eb	Ci	Co
Short-side	1	0.500	0.500	0.438	-0.438
	2	0.850	0.850	0.438	-0.438
Long-side	1	0.850	0.850	0.312	-0.312
	2	0.850	0.850	0.312	-0.312

Moment of Inertia of a Strip of the Vessel Wall:

Thickness t1, I1 = 0.0558 in**4

Thickness t2, I2 = 0.0203 in**4

Rectangular Vessel Parameters:

Alpha = H / h = 0.7826

K = (I2/I1)*Alpha = 0.2852

Membrane Stress Calculations per Section 13-7

Membrane Stresses at Short-side 1

Membrane Stress at Short-side 1 [Sms]:

= P * H / (2 * t1)

= 15.0 * 5.75 / (2 * 0.875)

= 49.29 psi

If Em(0.500) < E(0.850) and Eb(0.500) < E(0.850) then Sms = Sms / Em

= 49.29 / 0.50

= 98.57 psi

Membrane Stresses at Short-side 2

Membrane Stress at Short-side 2 [Sms]:

= P * H / (2 * t1)

= 15.0 * 5.75 / (2 * 0.875)

= 49.29 psi

Membrane Stresses at Long-side 1

Membrane Stress at Long-side 1 at A [Sml]:

= p * h / (2 * t2)

= 15.0 * 4.50 / (2 * 0.625)

= 54.00 psi

Membrane Stresses at Long-side 2

Membrane Stress at Long-side 2 at A [Sml]:

= p * h / (2 * t2)

= 15.0 * 4.50 / (2 * 0.625)

= 54.00 psi

MEMBRANE STRESSES: Membrane Stress Calculations per Section 13-7,
Equations (1) and (2). (psi) :

STRESS LOCATIONS	Actual	Allowable
Short-side 1	98.57	17000.00
Short-side 2	49.29	17000.00
Short-side Corner	49.29	17000.00
Long-side 1 at A	54.00	17000.00
Long-side 2 at A	54.00	17000.00
Long-side Corner	54.00	17000.00

Bending Stress Calculations per Section 13-7

Bending Stresses at Short-side 1

Bending Stresses at short side 1 at N inner [Sbs_Ni]:

= (P * c) / (12 * I1) * ((-1.5 * H^(2)) +
(h^(2) * ((1 + alpha^(2) * K) / (1 + K))))

= (15.0 * 0.44) / (12 * 0.06) * ((-1.5 * 4.50^(2)) +
(5.75^(2) * ((1 + 0.78^(2) * 0.285) / (1 + 0.285))))

= -1.53 psi

If Em(0.500) < E(0.850) and Eb(0.500) < E(0.850) then
Sbs_Ni = Sbs_Ni / Eb

= -1.53 / 0.50

= -3.05 psi

Bending Stress at short side 1 at N outer [Sbs_No]:

= (P * c) / (12 * I1) * ((-1.5 * H^(2)) +
(h^(2) * ((1 + alpha^(2) * K) / (1 + K))))

= (15.0 * -0.44) / (12 * 0.06) * ((-1.5 * 4.50^(2)) +
(5.75^(2) * ((1 + 0.78^(2) * 0.285) / (1 + 0.285))))

= 1.53 psi

If Em(0.500) < E(0.850) and Eb(0.500) < E(0.850) then
Sbs_No = Sbs_No / Eb

= 1.53 / 0.50

= 3.05 psi

Bending Stress at short side 1 at Q inner [Sbs_Qi]:

= (P * h^(2) * c) / (12 * I1) * ((1 + alpha^(2) * K) / (1 + K))

= (15.0 * 5.75^(2) * 0.438) / (12 * 0.06) * ((1 + 0.78^(2) * 0.285) /
(1 + 0.285))

= 296.02 psi

Bending Stress at short side 1 at Q outer [Sbs_Qo]:

= (P * h^(2) * c) / (12 * I1) * ((1 + alpha^(2) * K) / (1 + K))

= (15.0 * 5.75^(2) * -0.438) / (12 * 0.06) * ((1 + 0.78^(2) * 0.285) /
(1 + 0.285))

= -296.02 psi

Bending Stresses at Short-side 2

Bending Stresses at short side 2 at N inner [Sbs_Ni]:

= (P * c) / (12 * I1) * ((-1.5 * H^(2)) +
(h^(2) * ((1 + alpha^(2) * K) / (1 + K))))

= (15.0 * 0.44) / (12 * 0.06) * ((-1.5 * 4.50^(2)) +
(5.75^(2) * ((1 + 0.78^(2) * 0.285) / (1 + 0.285))))

= -1.53 psi

Bending Stress at short side 2 at N outer [Sbs_No]:

= (P * c) / (12 * I1) * ((-1.5 * H^(2)) +
(h^(2) * ((1 + alpha^(2) * K) / (1 + K))))

= (15.0 * -0.44) / (12 * 0.06) * ((-1.5 * 4.50^(2)) +
(5.75^(2) * ((1 + 0.78^(2) * 0.285) / (1 + 0.285))))

= 1.53 psi

Bending Stress at short side 2 at Q inner [Sbs_Qi]:

= (P * h^(2) * c) / (12 * I1) * ((1 + alpha^(2) * K) / (1 + K))

= (15.0 * 5.75^(2) * 0.438) / (12 * 0.06) * ((1 + 0.78^(2) * 0.285) /
(1 + 0.285))

= 296.02 psi

Bending Stress at short side 2 at Q outer [Sbs_Qo]:

= (P * h^(2) * c) / (12 * I1) * ((1 + alpha^(2) * K) / (1 + K))

= (15.0 * 5.75^(2) * -0.438) / (12 * 0.06) * ((1 + 0.78^(2) * 0.285) /
(1 + 0.285))

= -296.02 psi

Bending Stress at Long-side 1

Bending Stress at long side 1 at M inner [Sbl_Mi]:

= (P * h^(2) * c) / (12 * I2) * (-1.5 + ((1 + alpha^(2) * K) / (1 + K)))

= (15.0 * 5.75^(2) * 0.3125) / (12 * 0.0203) * (-1.5 + ((1 + 0.7826^(2) * 0.2852)
/ (1 + 0.2852)))

= -371.99 psi

Bending Stress at long side 1 at M outer [Sbl_Mo]:

= (P * h^(2) * c) / (12 * I2) * (-1.5 + (1 + alpha^(2) * K) / (1 + K))

= (15.0 * 5.75^(2) * -0.3125) / (12 * 0.0203) * (-1.5 + (1 + 0.7826^(2) * 0.2852)
/ (1 + 0.2852))

= 371.99 psi

Bending Stress at long side 1 at Q inner [Sbl_Qi]:

= (P * h^(2) * c) / (12 * I2) * ((1 + alpha^(2) * K) / (1 + K))

= (15.0 * 5.75^(2) * 0.312) / (12 * 0.02) * ((1 + 0.78^(2) * 0.285) /
(1 + 0.285))

= 580.21 psi

Bending Stress at long side 1 at Q outer [Sbl_Qo]:

= (P * h^(2) * c) / (12 * I2) * ((1 + alpha^(2) * K) / (1 + K))

= (15.0 * 5.75^(2) * -0.312) / (12 * 0.02) * ((1 + 0.78^(2) * 0.285)
/ (1 + 0.285))

= -580.21 psi

Bending Stress at Long-side 2

Bending Stress at long side 2 at M inner [Sbl_Mi]:

= (P * h^(2) * c) / (12 * I2) * (-1.5 + ((1 + alpha^(2) * K) / (1 + K)))

= (15.0 * 5.75^(2) * 0.3125) / (12 * 0.0203) * (-1.5 + ((1 + 0.7826^(2) * 0.2852)
/ (1 + 0.2852)))

= -371.99 psi

Bending Stress at long side 2 at M outer [Sbl_Mo]:

= (P * h^(2) * c) / (12 * I2) * (-1.5 + (1 + alpha^(2) * K) / (1 + K))

= (15.0 * 5.75^(2) * -0.3125) / (12 * 0.0203) * (-1.5 + (1 + 0.7826^(2) * 0.2852)
/ (1 + 0.2852))

= 371.99 psi

Bending Stress at long side 2 at Q inner [Sbl_Qi]:

= (P * h^(2) * c) / (12 * I2) * ((1 + alpha^(2) * K) / (1 + K))

= (15.0 * 5.75^(2) * 0.312) / (12 * 0.02) * ((1 + 0.78^(2) * 0.285) /
(1 + 0.285))

= 580.21 psi

Bending Stress at long side 2 at Q outer [Sbl_Qo]:

= (P * h^(2) * c) / (12 * I2) * ((1 + alpha^(2) * K) / (1 + K))

= (15.0 * 5.75^(2) * -0.312) / (12 * 0.02) * ((1 + 0.78^(2) * 0.285)
/ (1 + 0.285))

= -580.21 psi

BENDING STRESSES: Bending Stress Calculations per Section 13-7,
Equations (3-6). (psi) :

STRESS LOCATIONS		Inner	Outer	Allowable
Short-side 1 at N		-3.05	3.05	25500.00
	at Q	296.02	-296.02	25500.00
Short-side 2 at N		-1.53	1.53	25500.00
	at Q	296.02	-296.02	25500.00
Long-side 1 at M		-371.99	371.99	25500.00
	at Q	580.21	-580.21	25500.00
Long-side 2 at M		-371.99	371.99	25500.00
	at Q	580.21	-580.21	25500.00

Total Stress Calculations per Section 13-7

Total Stresses at Short-side 1

Total Stress at short side 1 at N inner [STS_Ni]:

= Sms + Sbs_Ni

= 98.57 + -3.05

= 95.52 psi

Total Stress at short side 1 at N outer [STS_No]:

= Sms + Sbs_No

= 98.57 + 3.05

= 101.62 psi

Total Stress at short side 1 at Q inner [STS_Qi]:

= Sms + Sbs_Qi

= 98.57 + 296.02

= 394.60 psi

Total Stress at short side 1 at Q outer [STS_Qo]:

= Sms + Sb_Qo

= 98.57 + -296.02

= -197.45 psi

Total Stresses at Short-side 2

Total Stress at short side 2 at N inner [STS_Ni]:

= Sms + Sbs_Ni

= 49.29 + -1.53

= 47.76 psi

Total Stress at short side 2 at N outer [STS_No]:

= Sms + Sbs_No

= 49.29 + 1.53

= 50.81 psi

Total Stress at short side 2 at Q inner [STS_Qi]:

= Sms + Sbs_Qi

= 49.29 + 296.02

= 345.31 psi

Total Stress at short side 2 at Q outer [STS_Qo]:

= Sms + Sb_Qo

= 49.29 + -296.02

= -246.74 psi

Total Stresses at Long-side 1

Total Stress at long side 1 at M inner [STL_Mi]:

= Sml + Sbl_Mi

= 54.00 + -371.99

= -317.99 psi

Total Stress at long side 1 at M outer [STL_Mo]:

= Sml + Sb_Mo

= 54.00 + 371.99

= 425.99 psi

Total Stress at long side 1 at Q inner [STL_Qi]:

= Sml + Sbl_Qi

= 54.00 + 580.21

= 634.21 psi

Total Stress at long side 1 at Q outer [STL_Qo]:

= Sml + Sb_Qo

= 54.00 + -580.21

= -526.21 psi

Total Stresses at Long-side 2

Total Stress at long side 2 at M inner [STL_Mi]:

= Sml + Sbl_Mi

= 54.00 + -371.99

= -317.99 psi

Total Stress at long side 2 at M outer [STL_Mo]:

= Sml + Sb_Mo

= 54.00 + 371.99

= 425.99 psi

Total Stress at long side 2 at Q inner [STL_Qi]:

= Sml + Sbl_Qi

= 54.00 + 580.21

= 634.21 psi

Total Stress at long side 2 at Q outer [STL_Qo]:

= Sml + Sb_Qo

= 54.00 + -580.21

= -526.21 psi

TOTAL STRESSES: Total Stress Calculations per Section 13-7, Equations (7-10). (psi) :

STRESS LOCATIONS	Inner	Outer	Allowable
Short-side 1 at N	95.52	101.62	25500.00
at Q	394.60	-197.45	25500.00

Short-side 2 at N		47.76	50.81	25500.00
	at Q	345.31	-246.74	25500.00
Long-side 1 at M		-317.99	425.99	25500.00
	at Q	634.21	-526.21	25500.00
Long-side 2 at M		-317.99	425.99	25500.00
	at Q	634.21	-526.21	25500.00

End Plate Stresses (psi):

	Actual	Allowable
End Plate	369.78	17000.00 (.85 EFF)

Required End Plate thickness due to Internal Pressure [trEP]:

= d * sqrt(Z * C * P / (SE)) + ca

= 4.500 * sqrt(1.522 * 0.200 * 15.000 / (20000.000)) + 0.125

= 0.193 in.

End Plate MAWP at given Thickness [MAWPEP]:

= ((T-ca)/d)^2 * ((SE)/(C*Z)) per UG-34 (c)(3)

= ((.6250-0.1250)/4.5000)^2*((20000)/(.20*1.52))

= 811.287 psig

where Z is:

= min(3.4 - 2.4(d/D), 2.5)

= min(3.4 - 2.4(4.500 / 5.750), 2.5)

= 1.522

PLATE STABILITY CALCULATIONS PER SECTION 13-14(b) (psi) :

Plate Buckling Coefficients (Fig. 13-14(a)):

KA = 6.47

KB = 7.87

Stress Calculations per Section 13-15

Stresses at Short side plates

Membrane Stress at Short-side at A [SmsA]:

= Pe * h * H / (2 * (t1 * H + t2 * h))

= 15.00 * 5.75 * 4.50 / (2 * (0.44 * 4.50 + 0.62* 5.75))

= 34.89 psi

Membrane Stress at Short-side at B [SmsB]:

= Pe * h / (2 * t1)

= 15.00 * 5.75 / (2 * 0.44)

= 98.57 psi

Buckling Stress at Short-side at A [ScrsA]:

= (Pi^(2) * E2 / (12 * (1 - v^(2))) * (t1 / H)^(2) * KA

= (3.14^(2) * 28099998 / (12 * (1 - 0.3^(2))) * (0.88 / 4.50)^(2)) * 6.47

= 6214810.50 psi

Buckling Stress at Short-side at B [ScrsB]:

= Pi^(2) * E2 / (12 * (1 - v^(2)) * (t1 / Lv)^(2) * KB

= 3.14^(2) * 28099998 / (12 * (1 - 0.3^(2)) * (0.88 / 138.00)^(2) * 7.87

= 8035.11 psi

Stresses at Long side plates

Membrane Stress at Long-side at A [SmlA]:

= Pe * h * H / (2 * (t1 * H + t2 * H))

= 15.00 * 5.75 * 4.50 / (2 * (0.44 * 4.50 + 0.62* 4.50))

= 34.89 psi

Membrane Stress at Long-side at B [SmlB]:

= Pe * h / (2 * t2)

= 15.00 * 5.75 / (2 * 0.62)

= 54.00 psi

Buckling Stress at Long-side at A [ScrlA]:

= Pi^(2) * E2 / (12 * (1 - v^(2)) * (t2 / H)^(2) * KA

= 3.14^(2) * 28099998 / (12 * (1 - 0.3^(2)) * (0.62 / 4.50)^(2) * 6.47

= 1942053.25 psi

ScrlA(1942053) > 0.5 * Sy (33050.000)

= Sy - (Sy^(2) / (4 * ScrlA))

= 33050.00 - (33050.00^(2) / (4 * 1942053))

= 32909.39 psi

Buckling Stress at Long-side at B [ScrlB]:

= Pi^(2) * E2 / (12 * (1 - v^(2)) * (t2 / Lv)^(2) * KB

= 3.14^(2) * 28099998 / (12 * (1 - 0.3^(2)) * (0.62 / 138.00)^(2) * 7.87

= 4099.55 psi

Stresses at End plates

Membrane Stress at End plate at A [SmeA]:

= Pe * H * Lv / (2 * (t2 * Lv + t5 * H))

= 15.00 * 4.50 * 138.00 / (2 * (0.62 * 138.00 + 0.50* 4.50))

= 52.63 psi

Membrane Stress at End plate at B [SmeB]:

= Pe * h * Lv / (2 * (t1 * Lv + t5 * h))

= 15.00 * 5.75 * 138.00 / (2 * (0.44 * 138.00 + 0.50* 5.75))

= 94.09 psi

Buckling Stress at End plate at A [ScreA]:

= Pi^(2) * E2 / (12 * (1 - v^(2)) * (t5 / H)^(2) * KA

= 3.14^(2) * 28099998 / (12 * (1 - 0.3^(2)) * (0.50 / 4.50)^(2) * 6.47

= 2029326.12 psi

ScreA(2029326) > 0.5 * Sy (33050.000)

= Sy - (Sy^(2) / (4 * ScreA))

= 33050.00 - (33050.00^(2) / (4 * 2029326))

= 32915.43 psi

Buckling Stress at End plate at B [ScreB]:

= Pi^(2) * E2 / (12 * (1 - v^(2)) * (t5 / Lv)^(2) * KB

= 3.14^(2) * 28099998 / (12 * (1 - 0.3^(2)) * (0.50 / 5.75)^(2) * 7.87

= 1511257.50 psi

ScreB(1511257) > 0.5 * Sy (33050.000)

= Sy - (Sy^(2) / (4 * ScreB))

= 33050.00 - (33050.00^(2) / (4 * 1511257))

= 32869.30 psi

SUMMARY OF STRESSES PER SECTION 13-14

Plate(s)	SMA	SMB	SCRA	SCRB	EQN(1)	P/F
Short-sides	34.89	98.57	33006.06	8035.11	0.027	PASS
Long-sides	34.89	54.00	32909.39	4099.55	0.028	PASS
End Plates	52.63	94.09	32915.43	32869.30	0.009	PASS

CROSS-SECTION STABILITY CALCULATIONS PER SECTION 13-14(c)

Dist from Outside Surface of Long-side Plate to Vessel Centroid [Yc]:

= 2.88 in.

Dist from Geometric Center of End Plate to Vessel Centroid [Ybar]:

= 0.00 in.

Moment of Inertia of Cross Section about Axis Parallel to Long-side and

Passing through Vessel Centroid [Ie]:

= 75.15 in**4

Least Radius of Gyration of Cross Section [RG]:

= Min(0.289*Sqrt[Ho^(2) + H^(2)] , 0.289*Sqrt[ho^(2) + h^(2)])

= Min(0.289*Sqrt[5.75^(2) + 4.50^(2)] , 0.289*Sqrt[7.50^(2) + 5.75^(2)])

= Min(2.11 , 2.73)

= 2.11 in.

Bending Moment of Cross Section (Equation 19) [M]:

= Pe * Ho * ho * YBar

= 15.00 * 7.50 * 5.75 * 0.00

= 0.00 ft.lb.

Axial Stress (Eqn 15) [Sa]:

= Pe * ho * Ho / (2 * (t1 * Ho + t2 * ho))

= 15.00 * 7.50 * 5.75 / (2 * (0.88 * 7.50 + 0.62* 5.75))

= 33.28 psi

Bending Stress (Eqn 18) [Sb]:

= (M * c) / Ie

= (0.00 * 2.88) / 75.15

= 0.00 psi

Axial Allowed Compressive Stress (Eqn 16B) [Fa]:

= 12 * Pi^(2) * E2 / (23 * (2 * L1 / R1)^(2))

= 12 * 3.14^(2) * 28099998 / (23 * (2 * 138.00 / 2.11)^(2))

= 8457.97 psi

Euler Stress Divided by Factor of Safety (Eqn 20) [Fpe]:

= 12 * pi^(2) * E / (23 * (2 * L1 / R1)^(2))

= 12 * 3.14^(2) * 28099998 / (23 * (2 * 138.00 / 2.11)^(2))

= 8457.97 psi

Column Stability Check per Equation 14

= Sa / Fa + Sb / [(1 - Sa / Fpe) * S]

= 33.28 / 8457.97 + 0.00 / [(1 - 33.28 / 8457.97) * 20000.00]

= 0.004

  Check Passes [must be < 1.0]

SUMMARY OF RESULTS (EXTERNAL PRESSURE):

  MEMBRANE STRESS SUMMARY,

High Stress (Highest % of Allowable)	98.57	psi
High Stress Percentage	0.49	%
M.A.W.P. for Membrane Stresses	3043.48	psig

  BENDING STRESS SUMMARY,

High Stress (Highest % of Allowable)	-580.21	psi
High Stress Percentage	2.28	%
M.A.W.P. for Bending Stresses	659.25	psig

  TOTAL STRESS SUMMARY,

High Stress (Highest % of Allowable)	634.21	psi
High Stress Percentage	2.49	%
M.A.W.P. for Total Stresses	603.11	psig

SUMMARY OF COLUMN STABILITY CHECKS:

Plate Stability Checks	(Equation 1)	PASS
Cross Section Stability Check	(Equation 14)	PASS

Input Echo, COMPONENT 5, Description: 4/5 FR BTM FV

Figure Number Analyzed A1

Design External Pressure	Pext	15.0000	psig
Design Temperature	Temp	350.0000	F

VESSEL MATERIAL DATA:

Material Specification		SA-516 70	
Shell Allowable Stress at Design Temp	S	20000.0000	psi
Shell Allowable Stress at Ambient	SA	20000.0000	psi
Shell Yield Stress at Design Temperature	Sy	33050.0000	psi
Length of Vessel	Lv	138.0000	in.

SHORT-SIDE VESSEL DATA:

Short-side Length Dimension	H	5.5000	in.
Minimum Thickness of Short-side Plates	t1	0.8750	in.
Mid-side Joint Efficiency on Short-side	E	0.8500	
Corner Joint Efficiency on Short-side	EC	0.8500	

LONG-SIDE VESSEL DATA:

Long-side Length Dimension	h	9.6250	in.
Minimum Thickness of Long-side Plates	t2	1.0000	in.
Mid-side Joint Efficiency on Long-side	E	0.8500	

ADDITIONAL VESSEL DATA:

Minimum Thickness of End Plate	t5	0.6250	in.
C-Factor for End Plate	Cf_Epl	0.2000	
Corrosion Allowance of Shell	CA	0.1250	in.

Long-side Plate # 1,

Pitch Distance	p	2.7500	in.
Uniform Hole Diameter	d0	1.3750	in.
Depth of Holes	T0	1.0000	in.

External Pressure Results, Rect. Vessel # 5, Desc: 4/5 FR BTM FV

ASME Code, Section VIII, Division 1, 2021 App. 13

Ligament Efficiency Calculations (Section 13-6, Equations (1)-(6)):

Short-side 1 Calculations

Membrane Ligament Efficiency [Em]:

= 0.850

Bending Ligament Efficiency [Eb]:

= 0.850

Dist from Neutral axis of c/s to inside surface of the vesssel [Ci]:

= t1 - CA / 2

= 0.875 - 0.125 / 2

= 0.375 in.

Dist from Neutral axis of c/s to extreme outside surface of the section [Co]:

= -(t1 - CA) / 2

= -(0.875 - 0.125) / 2

= -0.375 in.

Short-side 2 Calculations

Membrane Ligament Efficiency [Em]:

= 0.850

Bending Ligament Efficiency [Eb]:

= 0.850

Dist from Neutral axis of c/s to inside surface of the vesssel [Ci]:

= t1 - CA / 2

= 0.875 - 0.125 / 2

= 0.375 in.

Dist from Neutral axis of c/s to extreme outside surface of the section [Co]:

= -(t1 - CA) / 2

= -(0.875 - 0.125) / 2

= -0.375 in.

Long-side 1 Calculations

Effective Diameter [De]: 1.375 in.

Membrane Ligament Efficiency [Em]:

= Pitch - De / Pitch

= 2.750 - 1.375 / 2.750

= 0.500

Bending Ligament Efficiency [Eb]:

As diameter holes are uniform Eb = Em

= 0.500

Dist from Neutral axis of c/s to inside surface of the vesssel [Ci]:

= t1 - CA / 2

= 1.000 - 0.125 / 2

= 0.438 in.

Dist from Neutral axis of c/s to extreme outside surface of the section [Co]:

= -(t1 - CA) / 2

= -(1.000 - 0.125) / 2

= -0.438 in.

Long-side 2 Calculations

Membrane Ligament Efficiency [Em]:

= 0.850

Bending Ligament Efficiency [Eb]:

= 0.850

Dist from Neutral axis of c/s to inside surface of the vesssel [Ci]:

= t1 - CA / 2

= 1.000 - 0.125 / 2

= 0.438 in.

Dist from Neutral axis of c/s to extreme outside surface of the section [Co]:

= -(t1 - CA) / 2

= -(1.000 - 0.125) / 2

= -0.438 in.

Ligament Efficiency Calculations (Section 13-6, Equations (1)-(6)):

		Em	Eb	Ci	Co
Short-side	1	0.850	0.850	0.375	-0.375
	2	0.850	0.850	0.375	-0.375
Long-side	1	0.500	0.500	0.438	-0.438
	2	0.850	0.850	0.438	-0.438

Moment of Inertia of a Strip of the Vessel Wall:

Thickness t1, I1 = 0.0352 in**4

Thickness t2, I2 = 0.0558 in**4

Rectangular Vessel Parameters:

Alpha = H / h = 0.5823

K = (I2/I1)*Alpha = 0.9246

Membrane Stress Calculations per Section 13-7

Membrane Stresses at Short-side 1

Membrane Stress at Short-side 1 [Sms]:

= P * H / (2 * t1)

= 15.0 * 9.88 / (2 * 0.750)

= 98.75 psi

Membrane Stresses at Short-side 2

Membrane Stress at Short-side 2 [Sms]:

= P * H / (2 * t1)

= 15.0 * 9.88 / (2 * 0.750)

= 98.75 psi

Membrane Stresses at Long-side 1

Membrane Stress at Long-side 1 at A [Sml]:

= p * h / (2 * t2)

= 15.0 * 5.75 / (2 * 0.875)

= 49.29 psi

If Em(0.500) < E(0.850) and Eb(0.500) < E(0.850) then Sml = Sml / Em

= 49.29 / 0.50

= 98.57 psi

Membrane Stresses at Long-side 2

Membrane Stress at Long-side 2 at A [Sml]:

= p * h / (2 * t2)

= 15.0 * 5.75 / (2 * 0.875)

= 49.29 psi

MEMBRANE STRESSES: Membrane Stress Calculations per Section 13-7,
Equations (1) and (2). (psi) :

STRESS LOCATIONS	Actual	Allowable
Short-side 1	98.75	17000.00
Short-side 2	98.75	17000.00
Short-side Corner	98.75	17000.00
Long-side 1 at A	98.57	17000.00
Long-side 2 at A	49.29	17000.00
Long-side Corner	49.29	17000.00

Bending Stress Calculations per Section 13-7

Bending Stresses at Short-side 1

Bending Stresses at short side 1 at N inner [Sbs_Ni]:

= (P * c) / (12 * I1) * ((-1.5 * H^(2)) +
(h^(2) * ((1 + alpha^(2) * K) / (1 + K))))

= (15.0 * 0.38) / (12 * 0.04) * ((-1.5 * 5.75^(2)) +
(9.88^(2) * ((1 + 0.58^(2) * 0.925) / (1 + 0.925))))

= 226.10 psi

Bending Stress at short side 1 at N outer [Sbs_No]:

= (P * c) / (12 * I1) * ((-1.5 * H^(2)) +
(h^(2) * ((1 + alpha^(2) * K) / (1 + K))))

= (15.0 * -0.38) / (12 * 0.04) * ((-1.5 * 5.75^(2)) +
(9.88^(2) * ((1 + 0.58^(2) * 0.925) / (1 + 0.925))))

= -226.10 psi

Bending Stress at short side 1 at Q inner [Sbs_Qi]:

= (P * h^(2) * c) / (12 * I1) * ((1 + alpha^(2) * K) / (1 + K))

= (15.0 * 9.88^(2) * 0.375) / (12 * 0.04) * ((1 + 0.58^(2) * 0.925) /
(1 + 0.925))

= 887.35 psi

Bending Stress at short side 1 at Q outer [Sbs_Qo]:

= (P * h^(2) * c) / (12 * I1) * ((1 + alpha^(2) * K) / (1 + K))

= (15.0 * 9.88^(2) * -0.375) / (12 * 0.04) * ((1 + 0.58^(2) * 0.925) /
(1 + 0.925))
= -887.35 psi

Bending Stresses at Short-side 2

Bending Stresses at short side 2 at N inner [Sbs_Ni]:
= (P * c) / (12 * I1) * ((-1.5 * H^(2)) +
(h^(2) * ((1 + alpha^(2) * K) / (1 + K))))
= (15.0 * 0.38) / (12 * 0.04) * ((-1.5 * 5.75^(2)) +
(9.88^(2) * ((1 + 0.58^(2) * 0.925) / (1 + 0.925))))
= 226.10 psi

Bending Stress at short side 2 at N outer [Sbs_No]:
= (P * c) / (12 * I1) * ((-1.5 * H^(2)) +
(h^(2) * ((1 + alpha^(2) * K) / (1 + K))))
= (15.0 * -0.38) / (12 * 0.04) * ((-1.5 * 5.75^(2)) +
(9.88^(2) * ((1 + 0.58^(2) * 0.925) / (1 + 0.925))))
= -226.10 psi

Bending Stress at short side 2 at Q inner [Sbs_Qi]:
= (P * h^(2) * c) / (12 * I1) * ((1 + alpha^(2) * K) / (1 + K))
= (15.0 * 9.88^(2) * 0.375) / (12 * 0.04) * ((1 + 0.58^(2) * 0.925) /
(1 + 0.925))
= 887.35 psi

Bending Stress at short side 2 at Q outer [Sbs_Qo]:
= (P * h^(2) * c) / (12 * I1) * ((1 + alpha^(2) * K) / (1 + K))
= (15.0 * 9.88^(2) * -0.375) / (12 * 0.04) * ((1 + 0.58^(2) * 0.925) /
(1 + 0.925))
= -887.35 psi

Bending Stress at Long-side 1

Bending Stress at long side 1 at M inner [Sbl_Mi]:
= (P * h^(2) * c) / (12 * I2) * (-1.5 + ((1 + alpha^(2) * K) / (1 + K)))
= (15.0 * 9.88^(2) * 0.4375) / (12 * 0.0558) * (-1.5 + ((1 + 0.5823^(2) * 0.9246)
/ (1 + 0.9246)))
= -780.95 psi

If Em(0.500) < E(0.850) and Eb(0.500) < E(0.850) then
Sbl_Mi = Sbl_Mi / Em
= -780.95 / 0.50
= -1561.91 psi

Bending Stress at long side 1 at M outer [Sbl_Mo]:
= (P * h^(2) * c) / (12 * I2) * (-1.5 + (1 + alpha^(2) * K) / (1 + K))
= (15.0 * 9.88^(2) * -0.4375) / (12 * 0.0558) * (-1.5 + (1 + 0.5823^(2) * 0.9246)
/ (1 + 0.9246))
= 780.95 psi

If Em(0.500) < E(0.850) and Eb(0.500) < E(0.850) then
Sbl_Mo = Sbl_Mo / Em
= 780.95 / 0.50
= 1561.91 psi

Bending Stress at long side 1 at Q inner [Sbl_Qi]:
= (P * h^(2) * c) / (12 * I2) * ((1 + alpha^(2) * K) / (1 + K))
= (15.0 * 9.88^(2) * 0.438) / (12 * 0.06) * ((1 + 0.58^(2) * 0.925) /
(1 + 0.925))
= 651.93 psi

Bending Stress at long side 1 at Q outer [Sbl_Qo]:
= (P * h^(2) * c) / (12 * I2) * ((1 + alpha^(2) * K) / (1 + K))
= (15.0 * 9.88^(2) * -0.438) / (12 * 0.06) * ((1 + 0.58^(2) * 0.925)
/ (1 + 0.925))
= -651.93 psi

Bending Stress at Long-side 2

Bending Stress at long side 2 at M inner [Sbl_Mi]:

= (P * h^(2) * c) / (12 * I2) * (-1.5 + ((1 + alpha^(2) * K) / (1 + K)))

= (15.0 * 9.88^(2) * 0.4375) / (12 * 0.0558) * (-1.5 + ((1 + 0.5823^(2) * 0.9246)
/ (1 + 0.9246)))

= -780.95 psi

Bending Stress at long side 2 at M outer [Sbl_Mo]:

= (P * h^(2) * c) / (12 * I2) * (-1.5 + (1 + alpha^(2) * K) / (1 + K))

= (15.0 * 9.88^(2) * -0.4375) / (12 * 0.0558) * (-1.5 + (1 + 0.5823^(2) * 0.9246)
/ (1 + 0.9246))

= 780.95 psi

Bending Stress at long side 2 at Q inner [Sbl_Qi]:

= (P * h^(2) * c) / (12 * I2) * ((1 + alpha^(2) * K) / (1 + K))

= (15.0 * 9.88^(2) * 0.438) / (12 * 0.06) * ((1 + 0.58^(2) * 0.925) /
(1 + 0.925))

= 651.93 psi

Bending Stress at long side 2 at Q outer [Sbl_Qo]:

= (P * h^(2) * c) / (12 * I2) * ((1 + alpha^(2) * K) / (1 + K))

= (15.0 * 9.88^(2) * -0.438) / (12 * 0.06) * ((1 + 0.58^(2) * 0.925)
/ (1 + 0.925))

= -651.93 psi

BENDING STRESSES: Bending Stress Calculations per Section 13-7,
Equations (3-6). (psi) :

STRESS LOCATIONS	Inner	Outer	Allowable
Short-side 1 at N	226.10	-226.10	25500.00
at Q	887.35	-887.35	25500.00
Short-side 2 at N	226.10	-226.10	25500.00
at Q	887.35	-887.35	25500.00
Long-side 1 at M	-1561.91	1561.91	25500.00
at Q	651.93	-651.93	25500.00
Long-side 2 at M	-780.95	780.95	25500.00
at Q	651.93	-651.93	25500.00

Total Stress Calculations per Section 13-7

Total Stresses at Short-side 1

Total Stress at short side 1 at N inner [STS_Ni]:

= Sms + Sbs_Ni

= 98.75 + 226.10

= 324.85 psi

Total Stress at short side 1 at N outer [STS_No]:

= Sms + Sbs_No

= 98.75 + -226.10

= -127.35 psi

Total Stress at short side 1 at Q inner [STS_Qi]:

= Sms + Sbs_Qi

= 98.75 + 887.35

= 986.10 psi

Total Stress at short side 1 at Q outer [STS_Qo]:

= Sms + Sb_Qo

= 98.75 + -887.35

= -788.60 psi

Total Stresses at Short-side 2

Total Stress at short side 2 at N inner [STS_Ni]:

= Sms + Sbs_Ni

= 98.75 + 226.10

= 324.85 psi

Total Stress at short side 2 at N outer [STS_No]:

= Sms + Sbs_No

= 98.75 + -226.10

= -127.35 psi

Total Stress at short side 2 at Q inner [STS_Qi]:

= Sms + Sbs_Qi

= 98.75 + 887.35

= 986.10 psi

Total Stress at short side 2 at Q outer [STS_Qo]:

= Sms + Sb_Qo

= 98.75 + -887.35

= -788.60 psi

Total Stresses at Long-side 1

Total Stress at long side 1 at M inner [STL_Mi]:

= Sml + Sbl_Mi

= 98.57 + -1561.91

= -1463.34 psi

Total Stress at long side 1 at M outer [STL_Mo]:

= Sml + Sb_Mo

= 98.57 + 1561.91

= 1660.48 psi

Total Stress at long side 1 at Q inner [STL_Qi]:

= Sml + Sbl_Qi

= 98.57 + 651.93

= 750.50 psi

Total Stress at long side 1 at Q outer [STL_Qo]:

= Sml + Sb_Qo

= 98.57 + -651.93

= -553.36 psi

Total Stresses at Long-side 2

Total Stress at long side 2 at M inner [STL_Mi]:

= Sml + Sbl_Mi

= 49.29 + -780.95

= -731.67 psi

Total Stress at long side 2 at M outer [STL_Mo]:

= Sml + Sb_Mo

= 49.29 + 780.95

= 830.24 psi

Total Stress at long side 2 at Q inner [STL_Qi]:

= Sml + Sbl_Qi

= 49.29 + 651.93

= 701.21 psi

Total Stress at long side 2 at Q outer [STL_Qo]:

= Sml + Sb_Qo

= 49.29 + -651.93

= -602.64 psi

TOTAL STRESSES: Total Stress Calculations per Section 13-7, Equations (7-10). (psi) :

STRESS LOCATIONS	Inner	Outer	Allowable
Short-side 1 at N	324.85	-127.35	25500.00
at Q	986.10	-788.60	25500.00

Short-side 2	at N	324.85	-127.35	25500.00
	at Q	986.10	-788.60	25500.00
Long-side 1	at M	-1463.34	1660.48	25500.00
	at Q	750.50	-553.36	25500.00
Long-side 2	at M	-731.67	830.24	25500.00
	at Q	701.21	-602.64	25500.00

End Plate Stresses (psi):

	Actual	Allowable
End Plate	794.50	17000.00 (.85 EFF)

Required End Plate thickness due to Internal Pressure [trEP]:

= d * sqrt(Z * C * P / (SE)) + ca

= 5.750 * sqrt(2.003 * 0.200 * 15.000 / (20000.000)) + 0.125

= 0.225 in.

End Plate MAWP at given Thickness [MAWPEP]:

= ((T-ca)/d)^2 * ((SE)/(C*Z)) per UG-34 (c)(3)

= ((.6250-0.1250)/5.7500)^2*((20000)/(.20*2.00))

= 377.594 psig

where Z is:

= min(3.4 - 2.4(d/D), 2.5)

= min(3.4 - 2.4(5.750 / 9.875), 2.5)

= 2.003

PLATE STABILITY CALCULATIONS PER SECTION 13-14(b) (psi) :

Plate Buckling Coefficients (Fig. 13-14(a)):

KA = 6.12

KB = 9.68

Stress Calculations per Section 13-15

Stresses at Short side plates

Membrane Stress at Short-side at A [SmsA]:

= Pe * h * H / (2 * (t1 * H + t2 * h))

= 15.00 * 9.88 * 5.75 / (2 * (0.75 * 5.75 + 0.44* 9.88))

= 49.33 psi

Membrane Stress at Short-side at B [SmsB]:

= Pe * h / (2 * t1)

= 15.00 * 9.88 / (2 * 0.75)

= 98.75 psi

Buckling Stress at Short-side at A [ScrsA]:

= (Pi^(2) * E2 / (12 * (1 - v^(2))) * (t1 / H)^(2) * KA

= (3.14^(2) * 28099998 / (12 * (1 - 0.3^(2))) * (0.75 / 5.75)^(2)) * 6.12

= 2644178.50 psi

Buckling Stress at Short-side at B [ScrsB]:

= Pi^(2) * E2 / (12 * (1 - v^(2)) * (t1 / Lv)^(2) * KB

= 3.14^(2) * 28099998 / (12 * (1 - 0.3^(2)) * (0.75 / 138.00)^(2) * 9.68

= 7259.36 psi

Stresses at Long side plates

Membrane Stress at Long-side at A [SmlA]:

= Pe * h * H / (2 * (t1 * H + t2 * H))

= 15.00 * 9.88 * 5.75 / (2 * (0.75 * 5.75 + 0.44* 5.75))

= 49.33 psi

Membrane Stress at Long-side at B [SmlB]:

= Pe * h / (2 * t2)

= 15.00 * 9.88 / (2 * 0.44)

= 98.57 psi

Buckling Stress at Long-side at A [ScrlA]:

= Pi^(2) * E2 / (12 * (1 - v^(2)) * (t2 / H)^(2) * KA

= 3.14^(2) * 28099998 / (12 * (1 - 0.3^(2)) * (0.44 / 5.75)^(2) * 6.12

= 1220241.62 psi

ScrlA(1220241) > 0.5 * Sy (33050.000)

= Sy - (Sy^(2) / (4 * ScrlA))

= 33050.00 - (33050.00^(2) / (4 * 1220241))

= 32826.21 psi

Buckling Stress at Long-side at B [ScrlB]:

= Pi^(2) * E2 / (12 * (1 - v^(2)) * (t2 / Lv)^(2) * KB

= 3.14^(2) * 28099998 / (12 * (1 - 0.3^(2)) * (0.88 / 138.00)^(2) * 9.68

= 9880.79 psi

Stresses at End plates

Membrane Stress at End plate at A [SmeA]:

= Pe * H * Lv / (2 * (t2 * Lv + t5 * H))

= 15.00 * 5.75 * 138.00 / (2 * (0.44 * 138.00 + 0.50* 5.75))

= 94.09 psi

Membrane Stress at End plate at B [SmeB]:

= Pe * h * Lv / (2 * (t1 * Lv + t5 * h))

= 15.00 * 9.88 * 138.00 / (2 * (0.75 * 138.00 + 0.50* 9.88))

= 94.25 psi

Buckling Stress at End plate at A [ScreA]:

= Pi^(2) * E2 / (12 * (1 - v^(2)) * (t5 / H)^(2) * KA

= 3.14^(2) * 28099998 / (12 * (1 - 0.3^(2)) * (0.50 / 5.75)^(2) * 6.12

= 1175190.62 psi

ScreA(1175190) > 0.5 * Sy (33050.000)

= Sy - (Sy^(2) / (4 * ScreA))

= 33050.00 - (33050.00^(2) / (4 * 1175190))

= 32817.63 psi

Buckling Stress at End plate at B [ScreB]:

= Pi^(2) * E2 / (12 * (1 - v^(2)) * (t5 / Lv)^(2) * KB

= 3.14^(2) * 28099998 / (12 * (1 - 0.3^(2)) * (0.50 / 9.88)^(2) * 9.68

= 630085.75 psi

ScreB(630085) > 0.5 * Sy (33050.000)

= Sy - (Sy^(2) / (4 * ScreB))

= 33050.00 - (33050.00^(2) / (4 * 630085))

= 32616.61 psi

SUMMARY OF STRESSES PER SECTION 13-14

Plate(s)	SMA	SMB	SCRA	SCRB	EQN(1)	P/F
Short-sides	49.33	98.75	32946.73	7259.36	0.030	PASS
Long-sides	49.33	98.57	32826.21	9880.79	0.023	PASS
End Plates	94.09	94.25	32817.63	32616.61	0.012	PASS

CROSS-SECTION STABILITY CALCULATIONS PER SECTION 13-14(c)

Dist from Outside Surface of Long-side Plate to Vessel Centroid [Yc]:

= 3.75 in.

Dist from Geometric Center of End Plate to Vessel Centroid [Ybar]:

= 0.00 in.

Moment of Inertia of Cross Section about Axis Parallel to Long-side and
Passing through Vessel Centroid [Ie]:

= 243.46 in**4

Least Radius of Gyration of Cross Section [RG]:

= Min(0.289*Sqrt[Ho^(2) + H^(2)] , 0.289*Sqrt[ho^(2) + h^(2)])

= Min(0.289*Sqrt[7.50^(2) + 5.75^(2)] , 0.289*Sqrt[11.38^(2) + 9.88^(2)])

= Min(2.73 , 4.35)

= 2.73 in.

Bending Moment of Cross Section (Equation 19) [M]:

= Pe * Ho * ho * YBar

= 15.00 * 11.38 * 7.50 * 0.00

= 0.00 ft.lb.

Axial Stress (Eqn 15) [Sa]:

= Pe * ho * Ho / (2 * (t1 * Ho + t2 * ho))

= 15.00 * 11.38 * 7.50 / (2 * (0.75 * 11.38 + 0.88* 7.50))

= 41.07 psi

Bending Stress (Eqn 18) [Sb]:

= (M * c) / Ie

= (0.00 * 3.75) / 243.46

= 0.00 psi

Axial Allowed Compressive Stress (Eqn 16A) [Fa]:

= [1 - ((2 * L1 * R1 / (2 * Cc^(2)))] * Sy / ((5 / 3) +
(3 * (2 * L1 / R1) / (8 * Cc)) - ((2 * L1 / R1)^(3) /
(8 * Cc^(3))))

= [1 - ((2 * 138.00 * 2.73 / (2 * 129.55^(2)))] * 33050.00 / ((5 / 3) +
(3 * (2 * 138.00 / 2.73) / (8 * 129.55)) - ((2 * 138.00 / 2.73)^(3) /
(8 * 129.55^(3))))

= 12103.49 psi

Euler Stress Divided by Factor of Safety (Eqn 20) [Fpe]:

= 12 * pi^(2) * E / (23 * (2 * L1 / R1)^(2))

= 12 * 3.14^(2) * 28099998 / (23 * (2 * 138.00 / 2.73)^(2))

= 14169.33 psi

Column Stability Check per Equation 14

= Sa / Fa + Sb / [(1 - Sa / Fpe) * S]

= 41.07 / 12103.49 + 0.00 / [(1 - 41.07 / 14169.33) * 20000.00]

= 0.003

Check Passes [must be < 1.0]

SUMMARY OF RESULTS (EXTERNAL PRESSURE):

MEMBRANE STRESS SUMMARY,		
High Stress (Highest % of Allowable)	98.75	psi
High Stress Percentage	0.58	%
M.A.W.P. for Membrane Stresses	2582.28	psig
BENDING STRESS SUMMARY,		
High Stress (Highest % of Allowable)	1561.91	psi
High Stress Percentage	5.21	%
M.A.W.P. for Bending Stresses	288.11	psig
TOTAL STRESS SUMMARY,		
High Stress (Highest % of Allowable)	1660.48	psi
High Stress Percentage	5.53	%
M.A.W.P. for Total Stresses	271.01	psig

SUMMARY OF COLUMN STABILITY CHECKS:

Plate Stability Checks	(Equation 1)	PASS
Cross Section Stability Check	(Equation 14)	PASS

Input Echo, COMPONENT 7, Description: 4/5 BACK FV

Figure Number Analyzed A1

Design External Pressure	Pext	15.0000	psig
Design Temperature	Temp	350.0000	F

VESSEL MATERIAL DATA:

Material Specification		SA-516 70	
Shell Allowable Stress at Design Temp	S	20000.0000	psi
Shell Allowable Stress at Ambient	SA	20000.0000	psi
Shell Yield Stress at Design Temperature	Sy	33050.0000	psi
Length of Vessel	Lv	138.0000	in.

SHORT-SIDE VESSEL DATA:

Short-side Length Dimension	H	5.5000	in.
Minimum Thickness of Short-side Plates	t1	0.7500	in.
Mid-side Joint Efficiency on Short-side	E	0.8500	
Corner Joint Efficiency on Short-side	EC	0.8500	

LONG-SIDE VESSEL DATA:

Long-side Length Dimension	h	10.5000	in.
Minimum Thickness of Long-side Plates	t2	1.0000	in.
Mid-side Joint Efficiency on Long-side	E	0.8500	

ADDITIONAL VESSEL DATA:

Minimum Thickness of End Plate	t5	0.6250	in.
C-Factor for End Plate	Cf_Epl	0.2000	
Corrosion Allowance of Shell	CA	0.1250	in.

Long-side Plate # 1,

Pitch Distance	p	2.7500	in.
Uniform Hole Diameter	d0	1.3750	in.
Depth of Holes	T0	1.0000	in.

External Pressure Results, Rect. Vessel # 7, Desc: 4/5 BACK FV

ASME Code, Section VIII, Division 1, 2021 App. 13

Ligament Efficiency Calculations (Section 13-6, Equations (1)-(6)):

Short-side 1 Calculations

Membrane Ligament Efficiency [Em]:

= 0.850

Bending Ligament Efficiency [Eb]:

= 0.850

Dist from Neutral axis of c/s to inside surface of the vesssel [Ci]:

= t1 - CA / 2

= 0.750 - 0.125 / 2

= 0.312 in.

Dist from Neutral axis of c/s to extreme outside surface of the section [Co]:

= -(t1 - CA) / 2

= -(0.750 - 0.125) / 2

= -0.312 in.

Short-side 2 Calculations

Membrane Ligament Efficiency [Em]:

= 0.850

Bending Ligament Efficiency [Eb]:

= 0.850

Dist from Neutral axis of c/s to inside surface of the vesssel [Ci]:

= t1 - CA / 2

= 0.750 - 0.125 / 2

= 0.312 in.

Dist from Neutral axis of c/s to extreme outside surface of the section [Co]:

= -(t1 - CA) / 2

= -(0.750 - 0.125) / 2

= -0.312 in.

Long-side 1 Calculations

Effective Diameter [De]: 1.375 in.

Membrane Ligament Efficiency [Em]:

= Pitch - De / Pitch

= 2.750 - 1.375 / 2.750

= 0.500

Bending Ligament Efficiency [Eb]:

As diameter holes are uniform Eb = Em

= 0.500

Dist from Neutral axis of c/s to inside surface of the vesssel [Ci]:

= t1 - CA / 2

= 1.000 - 0.125 / 2

= 0.438 in.

Dist from Neutral axis of c/s to extreme outside surface of the section [Co]:

= -(t1 - CA) / 2

= -(1.000 - 0.125) / 2

= -0.438 in.

Long-side 2 Calculations

Membrane Ligament Efficiency [Em]:

= 0.850

Bending Ligament Efficiency [Eb]:

= 0.850

Dist from Neutral axis of c/s to inside surface of the vesssel [Ci]:

= t1 - CA / 2

= 1.000 - 0.125 / 2

= 0.438 in.

Dist from Neutral axis of c/s to extreme outside surface of the section [Co]:

= -(t1 - CA) / 2

= -(1.000 - 0.125) / 2

= -0.438 in.

Ligament Efficiency Calculations (Section 13-6, Equations (1)-(6)):

		Em	Eb	Ci	Co
Short-side	1	0.850	0.850	0.312	-0.312
	2	0.850	0.850	0.312	-0.312
Long-side	1	0.500	0.500	0.438	-0.438
	2	0.850	0.850	0.438	-0.438

Moment of Inertia of a Strip of the Vessel Wall:

Thickness t1, I1 = 0.0203 in**4

Thickness t2, I2 = 0.0558 in**4

Rectangular Vessel Parameters:

Alpha = H / h = 0.5349

K = (I2/I1)*Alpha = 1.4677

Membrane Stress Calculations per Section 13-7

Membrane Stresses at Short-side 1

Membrane Stress at Short-side 1 [Sms]:

= P * H / (2 * t1)

= 15.0 * 10.75 / (2 * 0.625)

= 129.00 psi

Membrane Stresses at Short-side 2

Membrane Stress at Short-side 2 [Sms]:

= P * H / (2 * t1)

= 15.0 * 10.75 / (2 * 0.625)

= 129.00 psi

Membrane Stresses at Long-side 1

Membrane Stress at Long-side 1 at A [Sml]:

= p * h / (2 * t2)

= 15.0 * 5.75 / (2 * 0.875)

= 49.29 psi

If Em(0.500) < E(0.850) and Eb(0.500) < E(0.850) then Sml = Sml / Em

= 49.29 / 0.50

= 98.57 psi

Membrane Stresses at Long-side 2

Membrane Stress at Long-side 2 at A [Sml]:

= p * h / (2 * t2)

= 15.0 * 5.75 / (2 * 0.875)

= 49.29 psi

MEMBRANE STRESSES: Membrane Stress Calculations per Section 13-7,
Equations (1) and (2). (psi) :

STRESS LOCATIONS	Actual	Allowable
Short-side 1	129.00	17000.00
Short-side 2	129.00	17000.00
Short-side Corner	129.00	17000.00
Long-side 1 at A	98.57	17000.00
Long-side 2 at A	49.29	17000.00
Long-side Corner	49.29	17000.00

Bending Stress Calculations per Section 13-7

Bending Stresses at Short-side 1

Bending Stresses at short side 1 at N inner [Sbs_Ni]:

= (P * c) / (12 * I1) * ((-1.5 * H^(2)) +
(h^(2) * ((1 + alpha^(2) * K) / (1 + K))))

= (15.0 * 0.31) / (12 * 0.02) * ((-1.5 * 5.75^(2)) +
(10.75^(2) * ((1 + 0.53^(2) * 1.468) / (1 + 1.468))))

= 324.49 psi

Bending Stress at short side 1 at N outer [Sbs_No]:

= (P * c) / (12 * I1) * ((-1.5 * H^(2)) +
(h^(2) * ((1 + alpha^(2) * K) / (1 + K))))

= (15.0 * -0.31) / (12 * 0.02) * ((-1.5 * 5.75^(2)) +
(10.75^(2) * ((1 + 0.53^(2) * 1.468) / (1 + 1.468))))

= -324.49 psi

Bending Stress at short side 1 at Q inner [Sbs_Qi]:

= (P * h^(2) * c) / (12 * I1) * ((1 + alpha^(2) * K) / (1 + K))

= (15.0 * 10.75^(2) * 0.312) / (12 * 0.02) * ((1 + 0.53^(2) * 1.468) /
(1 + 1.468))

= 1276.69 psi

Bending Stress at short side 1 at Q outer [Sbs_Qo]:

= (P * h^(2) * c) / (12 * I1) * ((1 + alpha^(2) * K) / (1 + K))

= (15.0 * 10.75^(2) * -0.312) / (12 * 0.02) * ((1 + 0.53^(2) * 1.468) /
(1 + 1.468))
= -1276.69 psi

Bending Stresses at Short-side 2

Bending Stresses at short side 2 at N inner [Sbs_Ni]:
= (P * c) / (12 * I1) * ((-1.5 * H^(2)) +
(h^(2) * ((1 + alpha^(2) * K) / (1 + K))))
= (15.0 * 0.31) / (12 * 0.02) * ((-1.5 * 5.75^(2)) +
(10.75^(2) * ((1 + 0.53^(2) * 1.468) / (1 + 1.468))))
= 324.49 psi

Bending Stress at short side 2 at N outer [Sbs_No]:
= (P * c) / (12 * I1) * ((-1.5 * H^(2)) +
(h^(2) * ((1 + alpha^(2) * K) / (1 + K))))
= (15.0 * -0.31) / (12 * 0.02) * ((-1.5 * 5.75^(2)) +
(10.75^(2) * ((1 + 0.53^(2) * 1.468) / (1 + 1.468))))
= -324.49 psi

Bending Stress at short side 2 at Q inner [Sbs_Qi]:
= (P * h^(2) * c) / (12 * I1) * ((1 + alpha^(2) * K) / (1 + K))
= (15.0 * 10.75^(2) * 0.312) / (12 * 0.02) * ((1 + 0.53^(2) * 1.468) /
(1 + 1.468))
= 1276.69 psi

Bending Stress at short side 2 at Q outer [Sbs_Qo]:
= (P * h^(2) * c) / (12 * I1) * ((1 + alpha^(2) * K) / (1 + K))
= (15.0 * 10.75^(2) * -0.312) / (12 * 0.02) * ((1 + 0.53^(2) * 1.468) /
(1 + 1.468))
= -1276.69 psi

Bending Stress at Long-side 1

Bending Stress at long side 1 at M inner [Sbl_Mi]:
= (P * h^(2) * c) / (12 * I2) * (-1.5 + ((1 + alpha^(2) * K) / (1 + K)))
= (15.0 * 10.75^(2) * 0.4375) / (12 * 0.0558) * (-1.5 + ((1 + 0.5349^(2) * 1.4677)
/ (1 + 1.4677)))
= -1046.69 psi

If Em(0.500) < E(0.850) and Eb(0.500) < E(0.850) then
Sbl_Mi = Sbl_Mi / Em
= -1046.69 / 0.50
= -2093.38 psi

Bending Stress at long side 1 at M outer [Sbl_Mo]:
= (P * h^(2) * c) / (12 * I2) * (-1.5 + (1 + alpha^(2) * K) / (1 + K))
= (15.0 * 10.75^(2) * -0.4375) / (12 * 0.0558) * (-1.5 + (1 + 0.5349^(2) * 1.4677)
/ (1 + 1.4677))
= 1046.69 psi

If Em(0.500) < E(0.850) and Eb(0.500) < E(0.850) then
Sbl_Mo = Sbl_Mo / Em
= 1046.69 / 0.50
= 2093.38 psi

Bending Stress at long side 1 at Q inner [Sbl_Qi]:
= (P * h^(2) * c) / (12 * I2) * ((1 + alpha^(2) * K) / (1 + K))
= (15.0 * 10.75^(2) * 0.438) / (12 * 0.06) * ((1 + 0.53^(2) * 1.468) /
(1 + 1.468))
= 651.37 psi

Bending Stress at long side 1 at Q outer [Sbl_Qo]:
= (P * h^(2) * c) / (12 * I2) * ((1 + alpha^(2) * K) / (1 + K))
= (15.0 * 10.75^(2) * -0.438) / (12 * 0.06) * ((1 + 0.53^(2) * 1.468)
/ (1 + 1.468))
= -651.37 psi

Bending Stress at Long-side 2

Bending Stress at long side 2 at M inner [Sbl_Mi]:

= (P * h^(2) * c) / (12 * I2) * (-1.5 + ((1 + alpha^(2) * K) / (1 + K)))

= (15.0 * 10.75^(2) * 0.4375) / (12 * 0.0558) * (-1.5 + ((1 + 0.5349^(2) * 1.4677)
/ (1 + 1.4677)))

= -1046.69 psi

Bending Stress at long side 2 at M outer [Sbl_Mo]:

= (P * h^(2) * c) / (12 * I2) * (-1.5 + (1 + alpha^(2) * K) / (1 + K))

= (15.0 * 10.75^(2) * -0.4375) / (12 * 0.0558) * (-1.5 + (1 + 0.5349^(2) * 1.4677)
/ (1 + 1.4677))

= 1046.69 psi

Bending Stress at long side 2 at Q inner [Sbl_Qi]:

= (P * h^(2) * c) / (12 * I2) * ((1 + alpha^(2) * K) / (1 + K))

= (15.0 * 10.75^(2) * 0.438) / (12 * 0.06) * ((1 + 0.53^(2) * 1.468) /
(1 + 1.468))

= 651.37 psi

Bending Stress at long side 2 at Q outer [Sbl_Qo]:

= (P * h^(2) * c) / (12 * I2) * ((1 + alpha^(2) * K) / (1 + K))

= (15.0 * 10.75^(2) * -0.438) / (12 * 0.06) * ((1 + 0.53^(2) * 1.468)
/ (1 + 1.468))

= -651.37 psi

BENDING STRESSES: Bending Stress Calculations per Section 13-7,
Equations (3-6). (psi) :

STRESS LOCATIONS		Inner	Outer	Allowable
Short-side 1 at N		324.49	-324.49	25500.00
	at Q	1276.69	-1276.69	25500.00
Short-side 2 at N		324.49	-324.49	25500.00
	at Q	1276.69	-1276.69	25500.00
Long-side 1 at M		-2093.38	2093.38	25500.00
	at Q	651.37	-651.37	25500.00
Long-side 2 at M		-1046.69	1046.69	25500.00
	at Q	651.37	-651.37	25500.00

Total Stress Calculations per Section 13-7

Total Stresses at Short-side 1

Total Stress at short side 1 at N inner [STS_Ni]:

= Sms + Sbs_Ni

= 129.00 + 324.49

= 453.49 psi

Total Stress at short side 1 at N outer [STS_No]:

= Sms + Sbs_No

= 129.00 + -324.49

= -195.49 psi

Total Stress at short side 1 at Q inner [STS_Qi]:

= Sms + Sbs_Qi

= 129.00 + 1276.69

= 1405.69 psi

Total Stress at short side 1 at Q outer [STS_Qo]:

= Sms + Sb_Qo

= 129.00 + -1276.69

= -1147.69 psi

Total Stresses at Short-side 2

Total Stress at short side 2 at N inner [STS_Ni]:

= Sms + Sbs_Ni

= 129.00 + 324.49

= 453.49 psi

Total Stress at short side 2 at N outer [STS_No]:

= Sms + Sbs_No

= 129.00 + -324.49

= -195.49 psi

Total Stress at short side 2 at Q inner [STS_Qi]:

= Sms + Sbs_Qi

= 129.00 + 1276.69

= 1405.69 psi

Total Stress at short side 2 at Q outer [STS_Qo]:

= Sms + Sb_Qo

= 129.00 + -1276.69

= -1147.69 psi

Total Stresses at Long-side 1

Total Stress at long side 1 at M inner [STL_Mi]:

= Sml + Sbl_Mi

= 98.57 + -2093.38

= -1994.81 psi

Total Stress at long side 1 at M outer [STL_Mo]:

= Sml + Sb_Mo

= 98.57 + 2093.38

= 2191.95 psi

Total Stress at long side 1 at Q inner [STL_Qi]:

= Sml + Sbl_Qi

= 98.57 + 651.37

= 749.94 psi

Total Stress at long side 1 at Q outer [STL_Qo]:

= Sml + Sb_Qo

= 98.57 + -651.37

= -552.80 psi

Total Stresses at Long-side 2

Total Stress at long side 2 at M inner [STL_Mi]:

= Sml + Sbl_Mi

= 49.29 + -1046.69

= -997.40 psi

Total Stress at long side 2 at M outer [STL_Mo]:

= Sml + Sb_Mo

= 49.29 + 1046.69

= 1095.98 psi

Total Stress at long side 2 at Q inner [STL_Qi]:

= Sml + Sbl_Qi

= 49.29 + 651.37

= 700.66 psi

Total Stress at long side 2 at Q outer [STL_Qo]:

= Sml + Sb_Qo

= 49.29 + -651.37

= -602.09 psi

TOTAL STRESSES: Total Stress Calculations per Section 13-7, Equations (7-10). (psi) :

STRESS LOCATIONS	Inner	Outer	Allowable
Short-side 1 at N	453.49	-195.49	25500.00
at Q	1405.69	-1147.69	25500.00

Short-side 2 at N	453.49	-195.49	25500.00	
at Q	1405.69	-1147.69	25500.00	
Long-side 1 at M	-1994.81	2191.95	25500.00	
at Q	749.94	-552.80	25500.00	
Long-side 2 at M	-997.40	1095.98	25500.00	
at Q	700.66	-602.09	25500.00	

End Plate Stresses (psi):

	Actual	Allowable	
End Plate	839.63	17000.00	(.85 EFF)

Required End Plate thickness due to Internal Pressure [trEP]:

= d * sqrt(Z * C * P / (SE)) + ca

= 5.750 * sqrt(2.116 * 0.200 * 15.000 / (20000.000)) + 0.125

= 0.227 in.

End Plate MAWP at given Thickness [MAWPEP]:

= ((T-ca)/d)^2 * ((SE)/(C*Z)) per UG-34 (c)(3)

= ((.6250-0.1250)/5.7500)^2*((20000)/(.20*2.12))

= 357.299 psig

where Z is:

= min(3.4 - 2.4(d/D), 2.5)

= min(3.4 - 2.4(5.750 / 10.750), 2.5)

= 2.116

PLATE STABILITY CALCULATIONS PER SECTION 13-14(b) (psi) :

Plate Buckling Coefficients (Fig. 13-14(a)):

KA = 6.03

KB = 10.15

Stress Calculations per Section 13-15

Stresses at Short side plates

Membrane Stress at Short-side at A [SmsA]:

= Pe * h * H / (2 * (t1 * H + t2 * h))

= 15.00 * 10.75 * 5.75 / (2 * (0.62 * 5.75 + 0.44* 10.75))

= 55.88 psi

Membrane Stress at Short-side at B [SmsB]:

= Pe * h / (2 * t1)

= 15.00 * 10.75 / (2 * 0.62)

= 129.00 psi

Buckling Stress at Short-side at A [ScrsA]:

= (Pi^(2) * E2 / (12 * (1 - v^(2))) * (t1 / H)^(2) * KA

= (3.14^(2) * 28099998 / (12 * (1 - 0.3^(2))) * (0.62 / 5.75)^(2)) * 6.03

= 1808838.38 psi

Buckling Stress at Short-side at B [ScrsB]:

= Pi^(2) * E2 / (12 * (1 - v^(2)) * (t1 / Lv)^(2) * KB

= 3.14^(2) * 28099998 / (12 * (1 - 0.3^(2)) * (0.62 / 138.00)^(2) * 10.15

= 5288.12 psi

Stresses at Long side plates

Membrane Stress at Long-side at A [SmlA]:

= Pe * h * H / (2 * (t1 * H + t2 * H))

= 15.00 * 10.75 * 5.75 / (2 * (0.62 * 5.75 + 0.44* 5.75))

= 55.88 psi

Membrane Stress at Long-side at B [SmlB]:

= Pe * h / (2 * t2)

= 15.00 * 10.75 / (2 * 0.44)

= 98.57 psi

Buckling Stress at Long-side at A [ScrlA]:

= Pi^(2) * E2 / (12 * (1 - v^(2)) * (t2 / H)^(2) * KA

= 3.14^(2) * 28099998 / (12 * (1 - 0.3^(2)) * (0.44 / 5.75)^(2) * 6.03

= 1014319.12 psi

ScrlA(1014319) > 0.5 * Sy (33050.000)

= Sy - (Sy^(2) / (4 * ScrlA))

= 33050.00 - (33050.00^(2) / (4 * 1014319))

= 32780.78 psi

Buckling Stress at Long-side at B [ScrlB]:

= Pi^(2) * E2 / (12 * (1 - v^(2)) * (t2 / Lv)^(2) * KB

= 3.14^(2) * 28099998 / (12 * (1 - 0.3^(2)) * (0.88 / 138.00)^(2) * 10.15

= 10364.71 psi

Stresses at End plates

Membrane Stress at End plate at A [SmeA]:

= Pe * H * Lv / (2 * (t2 * Lv + t5 * H))

= 15.00 * 5.75 * 138.00 / (2 * (0.44 * 138.00 + 0.50* 5.75))

= 94.09 psi

Membrane Stress at End plate at B [SmeB]:

= Pe * h * Lv / (2 * (t1 * Lv + t5 * h))

= 15.00 * 10.75 * 138.00 / (2 * (0.62 * 138.00 + 0.50* 10.75))

= 121.43 psi

Buckling Stress at End plate at A [ScreA]:

= Pi^(2) * E2 / (12 * (1 - v^(2)) * (t5 / H)^(2) * KA

= 3.14^(2) * 28099998 / (12 * (1 - 0.3^(2)) * (0.50 / 5.75)^(2) * 6.03

= 1157656.62 psi

ScreA(1157656) > 0.5 * Sy (33050.000)

= Sy - (Sy^(2) / (4 * ScreA))

= 33050.00 - (33050.00^(2) / (4 * 1157656))

= 32814.11 psi

Buckling Stress at End plate at B [ScreB]:

= Pi^(2) * E2 / (12 * (1 - v^(2)) * (t5 / Lv)^(2) * KB

= 3.14^(2) * 28099998 / (12 * (1 - 0.3^(2)) * (0.50 / 10.75)^(2) * 10.15

= 557727.81 psi

ScreB(557727) > 0.5 * Sy (33050.000)

= Sy - (Sy^(2) / (4 * ScreB))

= 33050.00 - (33050.00^(2) / (4 * 557727))

= 32560.38 psi

SUMMARY OF STRESSES PER SECTION 13-14

Plate(s)	SMA	SMB	SCRA	SCRB	EQN(1)	P/F
Short-sides	55.88	129.00	32899.03	5288.12	0.052	PASS
Long-sides	55.88	98.57	32780.78	10364.71	0.022	PASS
End Plates	94.09	121.43	32814.11	32560.38	0.013	PASS

CROSS-SECTION STABILITY CALCULATIONS PER SECTION 13-14(c)

Dist from Outside Surface of Long-side Plate to Vessel Centroid [Yc]:

= 3.75 in.

Dist from Geometric Center of End Plate to Vessel Centroid [Ybar]:

= 0.00 in.

Moment of Inertia of Cross Section about Axis Parallel to Long-side and

Passing through Vessel Centroid [Ie]:

= 251.57 in**4

Least Radius of Gyration of Cross Section [RG]:

= Min(0.289*Sqrt[Ho^(2) + H^(2)] , 0.289*Sqrt[ho^(2) + h^(2)])

= Min(0.289*Sqrt[7.50^(2) + 5.75^(2)] , 0.289*Sqrt[12.00^(2) + 10.75^(2)])

= Min(2.73 , 4.66)

= 2.73 in.

Bending Moment of Cross Section (Equation 19) [M]:

= Pe * Ho * ho * YBar

= 15.00 * 12.00 * 7.50 * 0.00

= 0.00 ft.lb.

Axial Stress (Eqn 15) [Sa]:

= Pe * ho * Ho / (2 * (t1 * Ho + t2 * ho))

= 15.00 * 12.00 * 7.50 / (2 * (0.62 * 12.00 + 0.88* 7.50))

= 44.44 psi

Bending Stress (Eqn 18) [Sb]:

= (M * c) / Ie

= (0.00 * 3.75) / 251.57

= 0.00 psi

Axial Allowed Compressive Stress (Eqn 16A) [Fa]:

= [1 - ((2 * L1 * R1 / (2 * Cc^(2)))] * Sy / ((5 / 3) +
(3 * (2 * L1 / R1) / (8 * Cc)) - ((2 * L1 / R1)^(3) /
(8 * Cc^(3))))

= [1 - ((2 * 138.00 * 2.73 / (2 * 129.55^(2)))] * 33050.00 / ((5 / 3) +
(3 * (2 * 138.00 / 2.73) / (8 * 129.55)) - ((2 * 138.00 / 2.73)^(3) /
(8 * 129.55^(3))))

= 12103.49 psi

Euler Stress Divided by Factor of Safety (Eqn 20) [Fpe]:

= 12 * pi^(2) * E / (23 * (2 * L1 / R1)^(2))

= 12 * 3.14^(2) * 28099998 / (23 * (2 * 138.00 / 2.73)^(2))

= 14169.33 psi

Column Stability Check per Equation 14

= Sa / Fa + Sb / [(1 - Sa / Fpe) * S]

= 44.44 / 12103.49 + 0.00 / [(1 - 44.44 / 14169.33) * 20000.00]

= 0.004

Check Passes [must be < 1.0]

SUMMARY OF RESULTS (EXTERNAL PRESSURE):

MEMBRANE STRESS SUMMARY,		
High Stress (Highest % of Allowable)	129.00	psi
High Stress Percentage	0.76	%
M.A.W.P. for Membrane Stresses	1976.74	psig
BENDING STRESS SUMMARY,		
High Stress (Highest % of Allowable)	2093.38	psi
High Stress Percentage	6.98	%
M.A.W.P. for Bending Stresses	214.96	psig
TOTAL STRESS SUMMARY,		
High Stress (Highest % of Allowable)	2191.95	psi
High Stress Percentage	7.31	%
M.A.W.P. for Total Stresses	205.30	psig

SUMMARY OF COLUMN STABILITY CHECKS:

Plate Stability Checks	(Equation 1)	PASS
Cross Section Stability Check	(Equation 14)	PASS

Tube-to-Tubesheet Full Strength Weld Calculation

per UW-20, ASME Code Section VIII, Div. 1

sketch (d), af not equal to ag

Nomenclature:

actual fillet weld leg = af = **0.06250**

actual groove weld leg = ag = **0.09375**

tube outside diameter = do = **1.250**

nominal tube thickness = t = **0.120**

allowable stress of tube = Sa = **13300**

allowable stress of tubesheet = St = **19400**

allowable stress of weld = Sw = **13300**

tube strength = Ft = Pi t (do - t) Sa = **5665.8**

design strength, but not greater than Ft= Fd = **5665.8**

ratio of design weld strength to tube strength = fd = **1.000**

Fg1= 0.85 Pi ag (do + 0.67 ag) Sw = **4371.1**

groove weld strength = Fg = Smaller of Ft or Fg1 = **4371.1**

ratio of fillet weld strength to design strength = ff = 1 - [Fg / (fd * Ft)] = **0.2285**

weld strength factor = fw = Sa / Sw = **1.000**

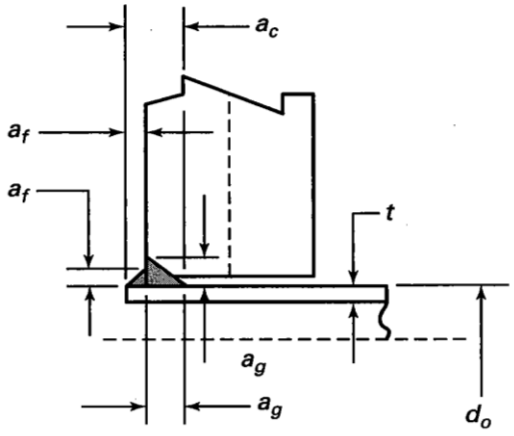
ar = minimum required length of fillet weld

ar = [(0.75 do)^2 + 2.73 t (do - t) fw fd ff]^1/2 - 0.75 do

ar = **0.044**

ac min = Larger of t or (ar + ag) = **0.138**

ac = actual total weld length parallel to tube axis = **0.156**



$a_c = a_f + a_g$

$a_f \neq a_g$

(d)

Item No: **18-XF-353A/B** P.O. No: **4505606036**

Job No.: **A22-13312-4A-5A** By: **BMH** Date: 22-Mar-22

Fabsco Fin Air, LLC
2410 Industrial Rd.
Sapulpa, OK 74066

3/9/2023

STANDARD ASME FLANGE EVALUATION PER UG-44

FABSCO FIN AIR:	A22-13312-4/5
CUSTOMER:	Air Products Manufacturing LLC
ENGINEER;	18-XF-353A/B
PO NO:	4505606036 / A8KM-4-406-PO-1
ITEM NO:	18-XF-353A/B
REV	3

Front Top Nozzle

Dn	6	in	NPS
Cl#	600		flange class
Std	B16.5		Applicable ASME/ANSI Standard - 2013
Material	**SA-350-LF2**		Table ii 2 1.1
P	**550**	psig	Design Pressure
T	**555**	def. F	Design Temperature
Pr	**1174**	psig	flange rating at Design Temp per ASME B16.5

Gasket

God	8.25	in	Gasket OD per B16. 20
Gid	6.875	in	Gasket ID per B16.20
N	0.688	in	Gasket Width
bo	0.344	in	Basic gasket seating width
b	0.293	in	Effective gasket seating width
G	7.664	in	Gasket Reaction Diam per ASME VIII, Div. 1, App 2

External Loads

Basis	API 661
Multiplier	2
Direction	All

Fy	2260	lb	
Mx	37920	in-lb	
Mz	38400	in-lb	
Me	53967	in-lb	External Moment
Fe	2260	lb	External Tensile Axial Force
Fm	0.5		Moment Factor per Table UG-44-1

UG-44(b) Eq. 1 Method

Pd	550	psi	Equipment Design Pressure (MAWP by Pr)
Pr	1174	psi	Flange Rating at Design Temp per ASME B16.5 II 2-1.1

16Me + 4FeG <= PI()G^3((Pr-Pd)+Fm*Pr)

16Me+4FeG=	932759.1	πG^3((Pr-Pd)+Fm*Pr)=	1711355.0

16Me + 4FeG<=PI()G^3((Pr-Pd)+Fm*Pr) ; OK, flange can accommodate nozzle loads