







SUMMARY OF CALCULATIONS

Design Pressure (given by client)	$P_d = 150 \text{ psi}$
Design Temperature (given by client)	$T_d = 350 \text{ }^\circ\text{F}$
Service (given by client)	<i>Steam</i>

THE MAXIMUM PRESSURE THIS DEVICE WILL SUSTAIN IS $Max_{pressure} = 249 \text{ psi}$

The assembly is made from SA-516 Gr 70 plates and held together by studs of SA-193 Gr B7 & SA-194 Gr 2H nuts.

The injection pressure, $P_i = 165 \text{ psi}$, is derived from the design pressure. It is the differential pressure required at the gauge to overcome the design pressure. This pressure is assumed to be in the device after attachment, so it is used throughout the calculation package.

All the formulas are from ASME Sect. VIII Div. I, Mark's Mechanical Engineers Handbook, Roark's Formulas for Stress and Strain or otherwise cited.

The shell walls are stressed at $\sigma_{sw} = 594 \text{ psi}$ vs the allowed $\sigma_{APlate} = 20000 \text{ psi}$

The endplate blank is stressed at $\sigma_{bl} = 1361 \text{ psi}$ vs the allowed $\sigma_{APlate} = 20000 \text{ psi}$

The studs are stressed at $\sigma_s = 7817 \text{ psi}$ vs the allowed $\sigma_{AStud} = 25000 \text{ psi}$
(worst case)

The strongbacks are stressed at $\sigma_{sb} = 13271 \text{ psi}$ vs the allowed $\sigma_{APlate} = 20000 \text{ psi}$
(worst case)

The installed unit will weigh about 74 *lbs*.

CALCULATION OF STRESSES

The stress in the shell walls of the enclosure is:

Where Injection pressure = $P_i = 165 \text{ psi}$

W.C. Inner Radius = $r = 1.875 \text{ in}$

Shell Thickness = $t_{sw} = 0.625 \text{ in}$

Corrosion Allowance = $ca = 0 \text{ in}$

$t_{sc} := t_{sw} - ca$ $t_{sc} = 0.625 \text{ in}$

$$\sigma_{sw} := \frac{P_i \cdot (r + .6 \cdot t_{sc})}{t_{sc}} = 594 \text{ psi}$$

vs the allowed

$\sigma_{APlate} = 20000 \text{ psi}$

The stress in the blank endplate is:

Where Table Factor = $c_1 = 0.33$

Endplate Thickness = $t_b = 0.75 \text{ in}$

$t_{bc} := t_b - ca$ $t_{bc} = 0.75 \text{ in}$

$$\sigma_{bl} := \frac{c_1 \cdot P_i \cdot r^2 \cdot 4}{t_{bc}^2} = 1361 \text{ psi}$$

vs the allowed

$\sigma_{APlate} = 20000 \text{ psi}$

The stress in the retaining studs due to pressure is:

Where Pressure Area = $A_{pr1} = 19.141 \text{ in}^2$
(4.375 x 4.375)

Number of Studs = $N_{sr1} = 4$

Area of Each Stud = $A_{sr1} = 0.202 \text{ in}^2$

$F_{r1} := P_i \cdot A_{pr1}$ $F_{r1} = 3158 \text{ lbf}$

$\sigma_{sr1} := \frac{F_{r1}}{N_{sr1} \cdot A_{sr1}} = 3909 \text{ psi}$ vs the allowed $\sigma_{AStud} = 25000 \text{ psi}$

The stress in the strongbacking studs due to pressure is:
(The strongbacking studs are hand tightened plus
an 1/8 to 1/4 turn.)

Where Pressure Area = $A_{psb} = 19.141 \text{ in}^2$
(4.375 x 4.375)

Number of Studs = $N_{ssb} = 2$

Area of Each Stud = $A_{ssb} = 0.202 \text{ in}^2$

$F_{sb} := P_i \cdot A_{psb}$ $F_{sb} = 3158 \text{ lbf}$

$\sigma_{ssb} := \frac{F_{sb}}{N_{ssb} \cdot A_{ssb}} = 7817 \text{ psi}$ vs the allowed $\sigma_{AStud} = 25000 \text{ psi}$

The stress in the strongback is:
(SB1)

Where	Effective length=	$L_{sb}=7.375 \text{ in}$
	Reaction location A =	$A=5.375 \text{ in}$
	Reaction location B =	$B=2 \text{ in}$
	Width = (1.5" - 0.625")	$b_{sb}=0.875 \text{ in}$
	Thickness =	$d_{sb}=2 \text{ in}$
	$Z_{sb}:=\frac{b_{sb} \cdot d_{sb}^2}{6}$	$Z_{sb}=0.583 \text{ in}^3$
	Max Moment =	$M_{max}:=\frac{(F_{sb}+F_{ssb}) \cdot A \cdot B}{L_{sb}}=7374 \text{ lbf} \cdot \text{in}$
	Bending Stress =	$\sigma_{sbb}:=\frac{M_{max}}{Z_{sb}}=12641.433 \text{ psi}$
	Shear Stress =	$\sigma_{ssb}:=\frac{F_{sb}+F_{ssb}}{b_{sb} \cdot d_{sb}}=2890.87 \text{ psi}$

Combined Stress = $\sigma_{sb1}:=\frac{\sigma_{sbb}}{2}+\sqrt{\left(\frac{\sigma_{sbb}}{2}\right)^2+\sigma_{ssb}^2}=13271 \text{ psi}$ vs the allowed $\sigma_{APlate}=20000 \text{ psi}$

CALCULATION OF TORQUE

Torque Analysis of Retaining Studs: (5/8" studs)

Formula from *Machinery's Handbook*, 27th. Edition, Industrial Press Inc, New York, NY, 2004. pg.1495.

where	Yield Stress of Stud = (Section 2 part D @ design temp)	$\sigma_{YStud}=94100 \text{ psi}$
	Load Per Stud =	$F_{sr}:=\sigma_{YStud} \cdot A_{sr1} \cdot 15\%=2851 \text{ lbf}$
	Torque Coefficient =	$k=0.2$
	Nominal Stud Diameter =	$d_{sr1}=0.625 \text{ in}$
	Target Torque =	$T_{sr}:=k \cdot F_{sr} \cdot d_{sr1}=30 \text{ ft} \cdot \text{lbf}$

MAXIMUM ALLOWABLE PRESSURE

For the Shell Wall:

$$Max_{sw} := \frac{\sigma_{APlate} \cdot P_i}{\sigma_{sw}} = 5556 \text{ } \mathbf{psi}$$

For the Blank:

$$Max_{bl} := \frac{\sigma_{APlate} \cdot P_i}{\sigma_{bl}} = 2424 \text{ } \mathbf{psi}$$

For the Studs:
(worst case)

$$Max_s := \frac{\sigma_{AStud} \cdot P_i}{\sigma_s} = 528 \text{ } \mathbf{psi}$$

For the Strongbacks:
(worst case)

$$Max_{sbl} := \frac{\sigma_{APlate} \cdot P_i}{\sigma_{sbl}} = 249 \text{ } \mathbf{psi}$$

For this device (STRONGBACK LIMIT): $Max_{pressure} = 249 \text{ } \mathbf{psi}$

BILL OF MATERIALS

ITEM	QTY	DESCRIPTION	MATERIAL
<u>ENCLOSURE</u>			
1	1	PLATE 4 1/2" THK X 5 1/2" X 9 1/4" LONG	SA-516 Gr 70
2	4	JACKING BOLTS 5/8 - 11 X 4" LONG	SA-193 Gr B7
3	1	1" NPT COUPLING	SA-105
4	4	STANDARD INJECTORS	STAINLESS
5	1 /b	SEALANT (PERIMETER)	CS 200
6	AS REQ'D	PACKING ROPE (1/4")	GRAPHOIL
<u>STRONGBACK</u>			
7	1	PLATE 1 1/4" THK X 16 1/4" X 16 11/16" LONG	SA-516 Gr 70
8	1	PLATE 1 1/4" THK X 2 13/16" X 10" LONG	SA-516 Gr 70
9	2	BARS 1 1/4" THK X 2" X 9" LONG	SA-516 Gr 70
10	4	STUDS 5/8 - 11 X 5" LONG	SA-193 Gr B7
11	2	STUDS 5/8 - 11 X 9" LONG	SA-193 Gr B7
12	12	NUTS 5/8 - 11 HEX	SA-194 Gr 2H