Saddle

Developer: Meca Enterprises
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Description: Perform analysis of a horizontal vessel supported on two saddles. The program performs a complete analysis of teh vessels based upon L. P. Zick's analysis procedure. The program allows the user to specify the wind load, thermal loads, liquid load, and seismic loads on the vessel. A complete analysis is also performed on the saddle, calculating stresses on bolts, base plate, web, stiffeners, and wear plate.

Platform: Saddle is a Microsoft Excel spreadsheet. It requires MS Excel 2000 or later to run.

Units: English or Metric
(Click of the button automatically toggles all inputs and results)

Sample Output: The following pages are the output from the Saddle spreadsheet. As an example, we have simulated an example of the Zick analysis performed in the "Pressure Vessel Handbook" by Megyesy. The example in Megyesy does not address the design of the saddle itself, so there is only a comparison of the vessel stresses.

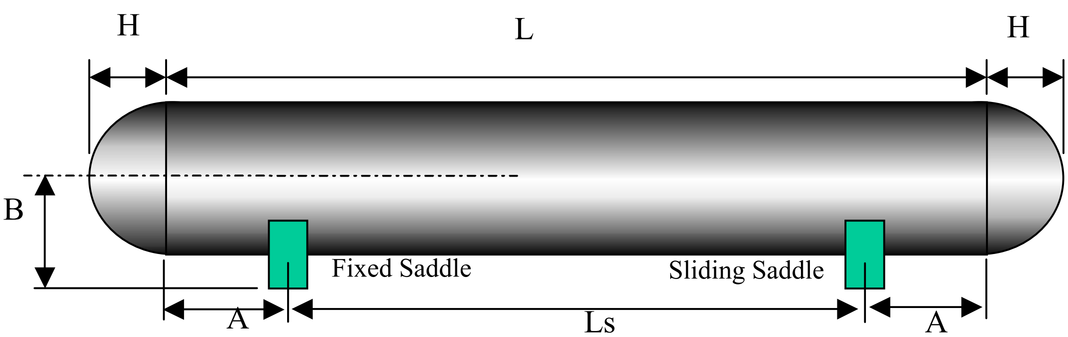
In the output you will see a note symbol that looks like this →

If you double click this note, you will receive further explanation of the output.

Saddle v1-1

per "Pressure Vessel Design Manual" by Dennis R. Moss

Customer: Meca **Project:** Pg 93
Desc: Example from Pressure Vessel Handbook **by:** CR

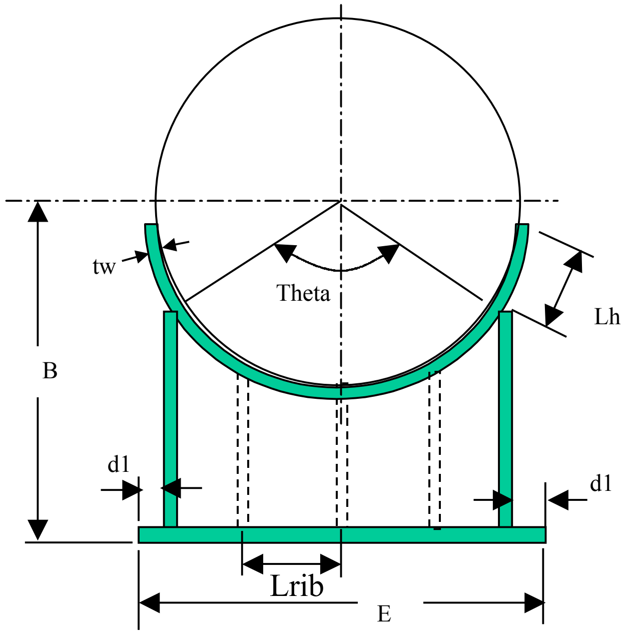


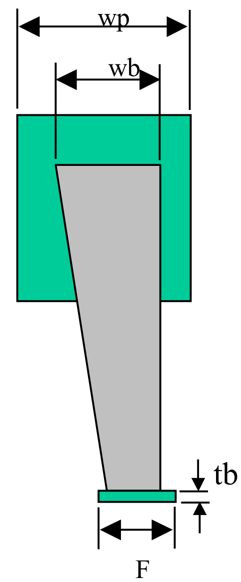
Vessel Information			
OD	Outside Diameter of Vessel	120.0000	in
ts	Corroded Thickness of Shell	1.0000	in
P	Internal Design Pressure	250.00	psig
Pe	External Design Pressure	0.00	psig
L	Tangent to Tangent Length of Vessel	960.00	in
H	Depth of Head	21	in
A	Distance from Head Tangent to Saddle Center Line	48.00	in
B	Height from vessel centerline to bottom of saddle	69.00	in
HType	Head Type	Hemis	
th	Corroded Thickness of Head	1	in
Wind Design (ASCE 7-98)			
V	Design Wind Speed	0	mph
I	Importance Factor	1	
Exp	Exposure	C	
Seismic Design (UBC 1997)			
Z	UBC 1997 Seismic Zone	0	
I	Importance Factor	1	
Sc	Soil Coefficient (SA, SB, SC, SD, or SE)	SC	
Temperature			
Tinst	Installation Temperature of Vessel	70.00	Deg. F
Tmin	Minimum Temperature of Vessel	70.00	Deg. F
Tmax	Maximum Temperture of Vessel	70.00	Deg. F
u	Coefficient of Friction between Saddle and Concrete	0.45	
fc	Allowable bearing pressure on concrete	750	psi
Material Properties			
S	Allowable Stress: Vessel Shell	17,500	psi
Fys	Yield Stress of Shell at Design Temperature	38,000	psi
Fy	Yield Stress of Saddle	36,000	psi
Emod	Modulus of Elasticity of Saddle	2.900E+07	psi
Fbolt	Allowable Tensile Stress on Bolts	20,000	psi
Fvbolt	Allowable Shear Stress on Bolts	10,000	psi
Av	Coefficient of Thermal Expansion of Vessel	7.00E-06	in/in/F
JE	Joint Efficiency	0.85	
Weight			
W	Total Weight (If zero, program will estimate)	600,000	lbs

Saddle v1-1

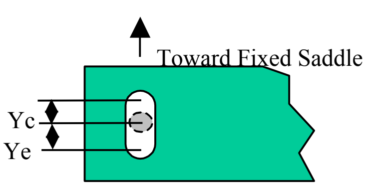
per "Pressure Vessel Design Manual" by Dennis R. Moss

Customer: Meca **Project:** Pg 93
Desc: Example from Pressure Vessel Handbook **by:** CR

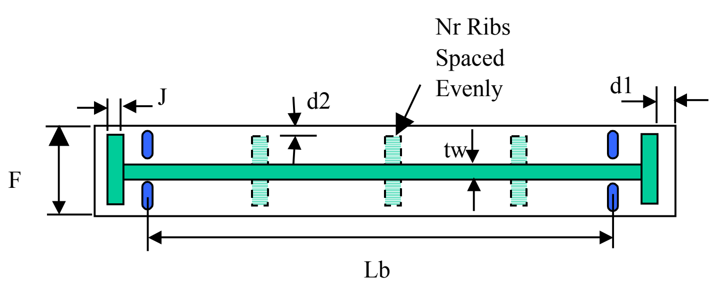




Saddle Information (Note Click "Std Dims" button to get a standard saddle)					
E	Width of Saddle perpendicular to Longitudinal Axis	Theta =	120.15	104.000	in
F	Width of Saddle at Bottom (along Longitudinal Vessel Axis)			9.000	in
wb	Width of Saddle at Top of Saddle (along longitudinal Vessel axis)			24.000	in
d1	Distance from Outside of Baseplate to First Rib			0.000	in
tb	Thickness of Base Plate			1.000	in
wp	Width of wear plate			24.000	in
Lh	Wear Plt ext. above Horn			1.000	in
tw	Thickness of Wear Plate			0.750	in



Sliding Saddle
Bolt shown in cold as-installed Position



Saddle Information			
d2	Distance from Outside of Baseplate to First Rib	0.000	in
Lb	Center to Center bolt spacing in transverse direction	80.000	in
tweb	Thickness of Web	0.75	in
J	Thickness of Ribs	0.75	in
Nr	Number of Ribs	2	
Nb	Number of Anchor Bolts per Saddle	2	
Dbolt	Nominal Diameter of Bolt	1.250	in
Ww	Fillet Leg Size (Web to Baseplate)	0.750	in

Saddle v1-1

per "Pressure Vessel Design Manual" by Dennis R. Moss

Customer: Meca **Project:** Pg 93
Desc: Example from Pressure Vessel Handbook **by:** CR

Calculated Parameters			
Rm	Mean Radius of Shell	59.500	in
Rs	Radius of Shell	60.000	in
Ls	Saddle Spacing: L-2*A	864.000	in
Theta	Saddle Angle: 2*Atan((E-2*d1)/OD)	120.1	Deg
ThetaW	Angle of Wear Plate	122.1	Deg
Calculate Weights			
Wtot	User Entered Total Weight	600,000	lbs
Wind Loading: (Based upon ASCE 7-98)			
De	Effective Diameter based upon Table 3-24	141.6000	in
zg	Constant from table 6-4	900.0000	
Alpha	Constant from table 6-4	9.5000	
Kz	2.01*((B+OD/2)/zg)^(2/Alpha)	1.3353	
Cf	Shape Factor	0.8	
Gq	Gust Factor (Rigid Structure)	0.85	
qz	Wind Pressure: 0.00256*Kz*V^2*I	0.00	psf
Afl	PI()*(De/12)^2/4	109	ft^2
Flw	Af*Cf*Gq*qz	-	lbs
Aft	De*(L+2*H)/144	985	ft^2
Ftw	(Aft*Cf*Gq*qz)*0.5	-	lbs
Seismic Loading: (Based upon UBC)			
Ca	Seismic Coefficient based upon Soil and Zone	0.0000	
V	2.5*Ca*I*W / R	-	lbs
Fls	V / 1.4	-	lbs
Fts	V / (2 * 1.4)	-	lbs
Thermal Expansion			
Ye	Maximum Expansion of Vessel	-	in
Yc	Maximum Contraction of Vessel	-	in
Flt	Frictional Force due to Expansion/Contraction (u*Wtot/2)	-	lbs
Saddle Reactions			
Fl	Maximum Longitudinal Force: Max(Flw, Fls, Flt, Flp)	-	lbs
Ft	Maximum Transverse Force: Max(Ftw, Fts)	-	lbs
Qo	Operating Load on Saddles: (Wtot)/2	300,000	lbs
Q1	Reaction due to Long Force: Wo/2+Fl*B/Ls	300,000	lbs
Q2	Reaction due to Tran Force: Wo/2+3*Ft*B/E	300,000	lbs
Q	Maximum of Q1 or Q2	300,000	lbs

Saddle v1-1

per "Pressure Vessel Design Manual" by Dennis R. Moss

Customer: Meca **Project:** Pg 93

Desc: Example from Pressure Vessel Handbook **by:** CR

"K" Constants from Figure 3-46

A./Rs	=	0.8000	K5	=	0.7595
K1	=	0.3357	K6	=	0.0369
K2	=	1.1686	K7	=	0.6041
K3	=	0.8775	K8	=	0.3399
K4	=	0.4004	K9	=	0.0529

Longitudinal Bending

M1	6*Q*(8*A*H+6*A^2-3*Rm^2+3*H^2)/(3*L+4*H)	6.372E+05	in-lbs
M2	3*Q*((3*L^2+6*Rm^2-6*H^2-12*A*L-16*A*H)/(3*L+4*H))	5.603E+07	in-lbs
S1	Long. Bending @ Saddles w/o Stiffeners - Tension: M1/(K1*Rm^2*ts)	536	psi
S2	Long. Bending @ Saddle w/o Stiffeners - Compression: -M1/(K7*Rm^2*ts)	-298	psi
S4	Long. Bending @ Midspan: +/- M2/(pi()*Rm^2*ts)	5,038	psi

Tangential Shear

S6	Tang. Shear - shell not stiffened A>0.5R: (K2*Q/(Rm*ts))*((L-2*A)/(L+4*H/3))	5,153	psi

Circumferential Bending

Check # 1	Lh >= Rm/10:	1.00	<=	5.95	FALSE	
Check # 2	Is A <= 0.5*Rm:	48.00	>=	29.75	FALSE	
Check # 3	Wp >= wb+1.56*(Rm*ts)^0.5	24.00	<=	36.03	FALSE	
tes	Check # 1 & # 2 did not both pass: ts				1.0000	in
tes1	Check # 3 did not both pass: ts				1.0000	in
tes2	Check # 1 & # 2 did not both pass: ts^2				1.0000	in
S9	Bend @ horn L>=8R: -Q/(4*ts*(wb+1.56*(Rm*ts)^0.5))-3*KK6*Q/(2*tes2)				-18,694	psi
S10	Bend @ horn L<8R: -Q/(4*ts*(wb+1.56*(Rs*ts)^0.5))-12*KK6*Q*Rs/(L*ts^2)				-10,385	psi
S11	Since A>0.5*Rs --> Add'l Tension in Head = 0				0	psi
S12	Circ Compression: -KK5*Q/(tes1*(wb+1.56*(Rm*tes1)^0.5))				-6,323	psi

Pressure Stresses

fx	Longitudinal Pressure Stress	P*Rm/(2*ts)	7,438	psi
fp	Circumferential Pressure Stress	P*Rm/ts	14,875	psi

Saddle Design - Web

Element	b	h	Area	I	d	A*d	A*d^2	Itot
	in	in	in^2	in^4	in	in^3	in^4	in^4
Shell	48.167	1.000	48.2	4.01.E+00	0.50	2.408E+01	1.204E+01	1.606E+01
Wear Plt	36.084	0.750	27.1	1.27.E+00	1.38	3.721E+01	5.117E+01	5.243E+01
Web	0.750	37.250	27.9	3.23.E+03	20.38	5.692E+02	1.160E+04	1.483E+04
Baseplt	9.000	1.000	9.0	7.50.E-01	39.50	3.555E+02	1.404E+04	1.404E+04
		Area =	112.2		A*Y =	9.860E+02	I =	2.894E+04

c1	Dist from Id of Shell to Center of Gravity for Saddle (A*Y/Area)	8.79	in
c2	Dist from Center of Gravity to Base Plate	0.21	in
Is	Moment of Inertia of Saddle	2.894E+04	in^4
As	Area of Saddle	112.2	in^2
Beta	Pi() - Theta/2	2.093	rads
K1	(1+COS(Beta)-0.5*(SIN(Beta))^2)/(PI()-Beta+(SIN(Beta))*(COS(Beta)))	0.2038	
fh	Saddle Splitting Force: K1*Q	61,137	lbs
ft	Tensile Stress in Saddle: fh/As	545	psi
d	B-Rs*Sin(Theta)/Theta	49	in
M	fh * d	3.005E+06	in-lbs
fb	Bending Stress in Saddle: M*C1/I	913	psi

Saddle Design - Wear Plate

fb	Bending Stress in Wear Plate: 6*Q*K5*wb/(8*tw^2*Rs)	17,624	psi

Saddle Design - Baseplate

Ab	Bearing Area: E * F	936	in^2
Bp	Bearing Pressure: Q/Ab	321	psi
fbplt	(3*Q*F)/(4*E*tb^2)	19,471	psi

Saddle v1-1

per "Pressure Vessel Design Manual" by Dennis R. Moss

Customer: Meca **Project:** Pg 93
Desc: Example from Pressure Vessel Handbook **by:** CR

Saddle Design - Anchor Bolts						
Longitudinal Load						
Tension?	Is Qo > Q1?	300,000	<	300,000	FALSE	
Pb	Since Q0>Q1 then Tensile Load will exist Each Bolt: ((Q1-Q0)/(Nb))				-	lbs
Abolt	(Pi()/4) * Dbolt^2				1.23	in^2
fal	Bolt Tensile Stress: Pb/Abolt				-	psi
Shear Load (Assume Fixed Saddle takes entire load)						
fv	Shear Stress: Fl / Abolt				-	psi
Transverse Load						
M	Transverse Moment: Ft * B				-	in-lbs
e	M / Q0				-	in
E/6	E / 6				17.333	in
Since e < E / 6 --> There is No Uplift						

Saddle v1-1

per "Pressure Vessel Design Manual" by Dennis R. Moss

Customer: Meca **Project:** Pg 93
Desc: Example from Pressure Vessel Handbook **by:** CR

Saddle Design - Ribs			
Outside Ribs			
Lrib	Rib Spacing: (E-2*d1)/(Nr-1)	104.0000	in
Lotrib	Tributary Length: Min (e , 0.5*Lrib)	52.0000	in
Pr	Axial Load on Ribs: Bp * F * Lotrib	150,000	lbs
Ar	Area of Web and Rib: J*(F-2*d2-tweb) + tweb*(Lotrib-d1)	45.19	in^2
fa	Compressive Stress: Pr / Ar	3,320	psi
I1	(J/12) * ((wb + F) / 2)^3	2.808E+02	in^4
C1	(wb + F) / 4	8.250	in
r	Radius of Gyration: (I1 / Ar)^0.5	2.493	in
L1	Height of Saddle: B - Rs * Cos(Theta/2)	39.067	in
Lr	Slenderness Ratio: L1 / r	15.7	
Cc	(2*PI()^2*Emod/Fy)^0.5	126.1	
Fa	(1-Lr^2/(2*Cc^2))*Fy/(5/3+3*Lr/(8*Cc)-Lr^3/(8*Cc^3))	20,853	psi
fu	Unit Force: Fl / (2 * E)	-	lb/ft
M	Bending Moment: 0.5 * fu * e * L1	0.000E+00	in-lbs
fb	Bending Stress: M * C1 / I1	-	psi
SR	Stress Ratio: fa/Fa+fb/Fb	0.16	
Inside Ribs			
Litrib	Tributary Length: Min (e , Lrib)	104.000	in
Pr	Axial Load on Ribs: Bp * F * Litrib	3.000E+05	lbs
Ar	Area of Web and Rib: J*(F-2*d2-tweb) + tweb*Litrib	84.19	in^2
fa	Compressive Stress: Pr / Ar	3,563	psi
I2	(J/12) * ((wb + F) / 2)^3	8.640E+02	in^4
C2	0.5 * Wb	12.000	in
r	Radius of Gyration: (I2 / Ar)^0.5	3.204	in
L2	Height of Saddle: B - (Rs^2-(E/2-d1-Lrib)^2)^0.5	39.1	in
Lr	Slenderness Ratio: L1 / r	12.2	
Cc	(2*PI()^2*Emod/Fy)^0.5	126.1	
Fa	(1-Lr^2/(2*Cc^2))*Fy/(5/3+3*Lr/(8*Cc)-Lr^3/(8*Cc^3))	21,043	psi
fu	Unit Force: Fl / (2 * E)	-	lb/ft
M	Bending Moment: 0.5 * fu * e * L2	0.000E+00	in-lbs
fb	Bending Stress: M * C2 / I2	-	psi
SR	Stress Ratio: fa/Fa+fb/Fb	0.17	

Saddle v1-1

per "Pressure Vessel Design Manual" by Dennis R. Moss

Customer: Meca
Desc: Example from Pressure Vessel Handbook

Project: Pg 93
by: CR

Description	Equation	SR	Result	Actual	Allowable	
Stress Summary						
Tangential Shear						
Shell not stiffened	S6	0.37	PASS	5,153	14,000	psi
Circumferential Bending						
Horn of Saddle - Shell Not Stiffened	S9	0.71	PASS	(18,694)	26,250	psi
Horn of Saddle - Shell not Stiffened	S10	0.40	PASS	(10,385)	26,250	psi
Circumferential Compressive Stress	S12	0.33	PASS	(6,323)	19,000	psi
Combined Stress - Tension						
Longitudinal Tension at Saddles	S1+fx	0.54	PASS	7,974	14,875	psi
Longitudinal Bending @ Midspan	S4+fx	0.84	PASS	12,475	14,875	psi
Tension in Head	S11+fp	0.80	PASS	14,875	18,594	psi
Saddle Web						
Tensile Stress in Web	ft	0.03	PASS	545	21,600	psi
Bending Stress in Saddle	fb	0.04	PASS	913	23,760	psi
Saddle Wear Plate						
Bending Stress in Wear Plate	fb	0.74	PASS	17,624	23,760	psi
Saddle Base Plate						
Bending stress in Baseplate	fbplt	0.82	PASS	19,471	23,760	psi
Bearing pressure on Concrete	Bp	0.43	PASS	321	750	psi
Saddle - Outside Ribs						
Bending Stress	fb	0.00	PASS	-	23,760	psi
Axial Stress	fa	0.16	PASS	3,320	20,853	psi
S.R. for Bending + Axial	ftot	0.16	PASS	0.16	1.00	
Saddle - Inside Ribs						
Bending Stress	fb	0.00	PASS	-	23,760	psi
Axial Stress	fa	0.17	PASS	3,563	21,043	psi
S.R. for Bending + Axial	ftot	0.17	PASS	0.17	1.00	
Saddle - Inside Ribs						
Tensile Stress	fa	0.00	PASS	-	20,000	psi
Shear Stress	fv	0.00	PASS	-	10,000	psi