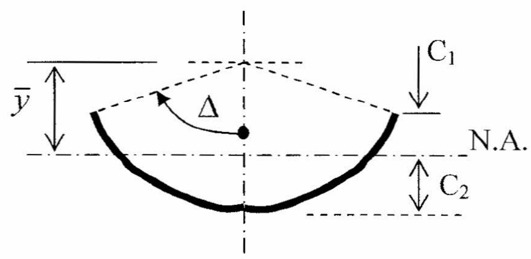
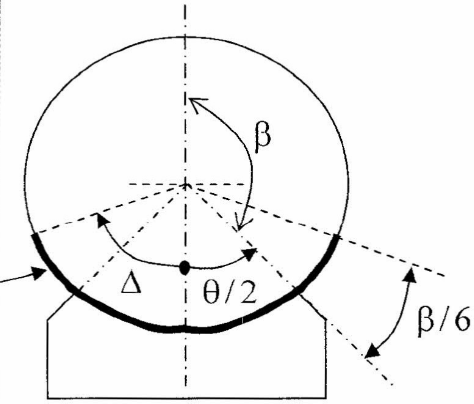
$$K_8 = \frac{\Delta + SIN(\Delta)COS(\Delta) - \frac{2\,SIN^2(\Delta)}{\Delta}}{1 - \frac{SIN(\Delta)}{\Delta}}$$

The top portion of shell above the saddle support would deform under load and is deemed ineffective in resisting longitudinal moment. So the moment of inertia at this cross section is reduced to that of a ring with its top portion removed.

The effective arc is assumed to be: $2\Delta = 2(\theta/2 + \beta/6)$





The position of the neutral axis, N.A. and the second moment of area I about this axis can be found.

$$\bar{y} = \frac{r\sin\Delta}{\Delta}, \qquad C_1 = r\left(\frac{\sin\Delta}{\Delta} - \cos\Delta\right), \qquad C_2 = r\left(1 - \frac{\sin\Delta}{\Delta}\right)$$

$$I = r^3 t\left[\Delta + \sin\Delta\cos\Delta - 2\frac{\sin^2\Delta}{\Delta}\right]$$

Longitudinal bending stresses at the highest and lowest point of the effective cross section are:

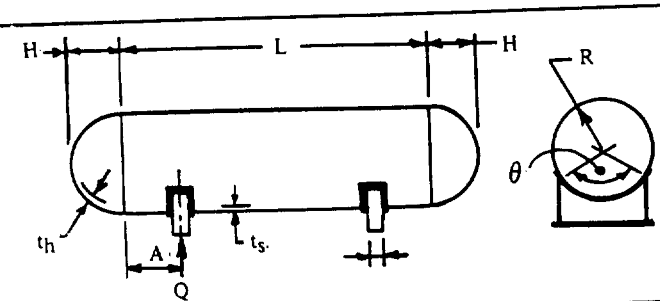
$$S_1' = \frac{M_2}{I}\cdot C_1 \qquad \text{(Highest point – tension)}$$

$$S_1' = -\frac{M_2}{I}\cdot C_2 \qquad \text{(Lowest point – compression)}$$

Allowable stress limits

The tensile stress combined with the pressure stress (pr/2t) should not exceed the allowable tensile stress for the shell material.

STRESSES IN VESSELS ON TWO SADDLES



NOTATION:
All dimensions in inches
Q = Load on one saddle lbs.
R = Radius of shell
S = Stress pound per sq. inch
t_s = Wall thickness of shell
th = Wall thickness of head
(Excluding corrosion allow.)
K = Constant, see page 90
θ = Contact angle of saddle degree

Stress	Conditions	Max. Stress Occurs	FORMULAS	Max. Allow. Stress
LONGITUDINAL BENDING	SHELL STIFFENED BY HEADS OR RINGS OR SHELL UNSTIFFENED	AT THE SADDLES (Tension at the Top. Compression at the Bottom)	$S_1 = \pm \frac{QA\left(1-\frac{1-\frac{A}{L}+\frac{R^2-H^2}{2AL}}{1+\frac{4H}{3L}}\right)}{*KR^2 t_s}$ *See note on facing page	In tension S_1 plus the stress due to internal pressure ($PR/2t_s$) shall not exceed the allowable stress value of shell material times the efficiency of girth seam. In compression the stress due to internal pressure minus S_1 shall not exceed one half of the compression yield point of the material or the value given by: $S_1 \leq \left(\frac{E}{29}\right)(t/R)[2-(2/3)(100)(t/R)]$
		AT MIDSPAN (Tension at the Bottom Compression at the Top)	$S_1 = \pm \frac{\frac{QL}{4}\left(\frac{1+2\frac{R^2-H^2}{L^2}}{1+\frac{4H}{3L}}-\frac{4A}{L}\right)}{\pi R^2 t_s}$	
TANGENTIAL SHEAR	Saddles Away From Head A > R/2 See Note	IN SHELL	$S_2 = \frac{K_2 Q}{Rt_s}\left(\frac{L-2A}{L+4/3\ H}\right)$	S_2 shall not exceed 0.8 times the allowable stress value of vessel material. S_3 plus stress due to internal pressure shall not exceed 1.25 times the allowable tensile stress value of head material. NOTE: Use formula with factor K_2 if ring not used or rings are adjacent to the saddle. Use formula with factor K_3 if ring used in plane of saddle.
		IN SHELL	$S_2 = \frac{K_3 Q}{Rt_s}\left(\frac{L-2A}{L+4/3\ H}\right)$	
	SADDLES CLOSE TO HEAD A ≤ R/2	IN SHELL	$S_2 = \frac{K_4 Q}{Rt_s}$	
		IN HEAD	$S_2 = \frac{K_4 Q}{Rt_h}$	
		ADDITIONAL STRESS IN HEAD	$S_3 = \frac{K_5 Q}{Rt_h}$	
CIRCUMFERENTIAL	L ≥ 8R UNSTIFFENED	AT HORN OF SADDLE	$S_4 = -\frac{Q}{4t_s(b+1.56\sqrt{Rt_s})}-\frac{3K_6 Q}{2t_s^2}$	S_4 shall not exceed 1.50 times the allowable tensile stress value of shell material. S_5 shall not exceed 0.5 times the compression yield point of shell material.
	L < 8R UNSTIFFENED		$S_4 = -\frac{Q}{4t_s(b+1.56\sqrt{Rt_s})}-\frac{12K_6 QR}{Lt_s^2}$	
	Stiffened or Unstiffened	AT BOTTOM OF SHELL	$S_5 = -\frac{K_7 Q}{t_s(b+1.56\sqrt{Rt_s})}$	

STRESSES IN VESSELS ON TWO SADDLES

STRESS

NOTES:

Positive values denote tensile stresses and negative values denote compression.

E = Modulus of elasticity of shell or stiffener ring material, pound per square inch.

LONGITUDINAL BENDING

The maximum bending stress S_1 may be either tension or compression.

Computing the tension stress in the formula for S_1, for factor K the values of K_1 shall be used.

Computing the compression stress in the formula for S_1, for factor K the values of K_8 shall be used.

When the shell is stiffened, the value of factor K = 3.14 in the formula for S_1.

The compression stress is not factor in a steel vessel where $t/R \geqq 0.005$ and the vessel is designed to be fully stressed under internal pressure.

Use stiffener ring if stress S_1 exceeds the maximum allowable stress.

TANGENTIAL SHEAR

If wear plate is used, in formulas for S_2 for the thickness t_s may be taken the sum of the shell and wear plate thickness, provided the wear plate extends R/10 inches above the horn of the saddle near the head and extends between the saddle and an adjacent stiffener ring.

In unstiffened shell the maximum shear occurs at the horn of the saddle. When the head stiffness is utilized by locating the saddle close to the heads, the tangential shear stress can cause an additional stress (S3) in the heads. This stress shall be added to the stress in the heads due to internal pressure.

When stiffener rings are used, the maximum shear occurs at the equator.

CIRCUMFERENTIAL

If wear plate is used, in formulas for S_4 for the thickness t_s may be taken the sum of the shell and wear plate thickness and for t_s^2 may be taken the shell thickness squared plus the wear plate thickness squared, provided the wear plate extends R/10 inches above the horn of the saddle, and $A \leqslant R/2$. The combined circumferential stress at the top edge of the wear plate should also be checked. When checking at this point: t_s = shell thickness,
b = width of saddle
θ = central angle of the wear plate but not more than the included angle of the saddle plus 12°

If wear plate is used, in formulas for S_5 for the thickness t_s may be taken the sum of the shell and wear plate thickness, provided the width of the wear plate equals at least $b + 1.56\sqrt{Rt_s}$.

If the shell is not stiffened, the maximum stress occurs at the horn of the saddle. This stress is not be to added to the internal pressure-stress.

In a stiffened shell the maximum ring-compression is at the bottom of shell.

Use stiffener ring if the circumferential bending stress exceeds the maximum allowable stress.

STRESSES IN LARGE HORIZONTAL VESSELS SUPPORTED BY TWO SADDLES

VALUES OF CONSTANT K
(Interpolate for Intermediate Values)

*K_1 = 3.14 if the shell is stiffened by ring or head (A < R/2)

CONTACT ANGLE θ	K_1*	K_2	K_3	K_4	K_5	K_6	K_7	K_8
120	0.335	1.171	0.319 For Any Con-Tact Angles θ	0.880	0.401	See chart on facing page	0.760	0.603
122	0.345	1.139		0.846	0.393		0.753	0.618
124	0.355	1.108		0.813	0.385		0.746	0.634
126	0.366	1.078		0.781	0.377		0.739	0.651
128	0.376	1.050		0.751	0.369		0.732	0.669
130	0.387	1.022		0.722	0.362		0.726	0.689
132	0.398	0.996		0.694	0.355		0.720	0.705
134	0.409	0.971		0.667	0.347		0.714	0.722
136	0.420	0.946		0.641	0.340		0.708	0.740
138	0.432	0.923		0.616	0.334		0.702	0.759
140	0.443	0.900		0.592	0.327		0.697	0.780
142	0.455	0.879		0.569	0.320		0.692	0.796
144	0.467	0.858		0.547	0.314		0.687	0.813
146	0.480	0.837		0.526	0.308		0.682	0.831
148	0.492	0.818		0.505	0.301		0.678	0.853
150	0.505	0.799		0.485	0.295		0.673	0.876
152	0.518	0.781		0.466	0.289		0.669	0.894
154	0.531	0.763		0.448	0.283		0.665	0.913
156	0.544	0.746		0.430	0.278		0.661	0.933
158	0.557	0.729		0.413	0.272		0.657	0.954
160	0.571	0.713		0.396	0.266		0.654	0.976
162	0.585	0.698		0.380	0.261		0.650	0.994
164	0.599	0.683		0.365	0.256		0.647	1.013
166	0.613	0.668		0.350	0.250		0.643	1.033
168	0.627	0.654		0.336	0.245		0.640	1.054
170	0.642	0.640		0.322	0.240		0.637	1.079
172	0.657	0.627		0.309	0.235		0.635	1.097
174	0.672	0.614		0.296	0.230		0.632	1.116
176	0.687	0.601		0.283	0.225		0.629	1.137
178	0.702	0.589		0.271	0.220		0.627	1.158
180	0.718	0.577		0.260	0.216		0.624	1.183