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Unfired pressure vessels - Part 3: Design

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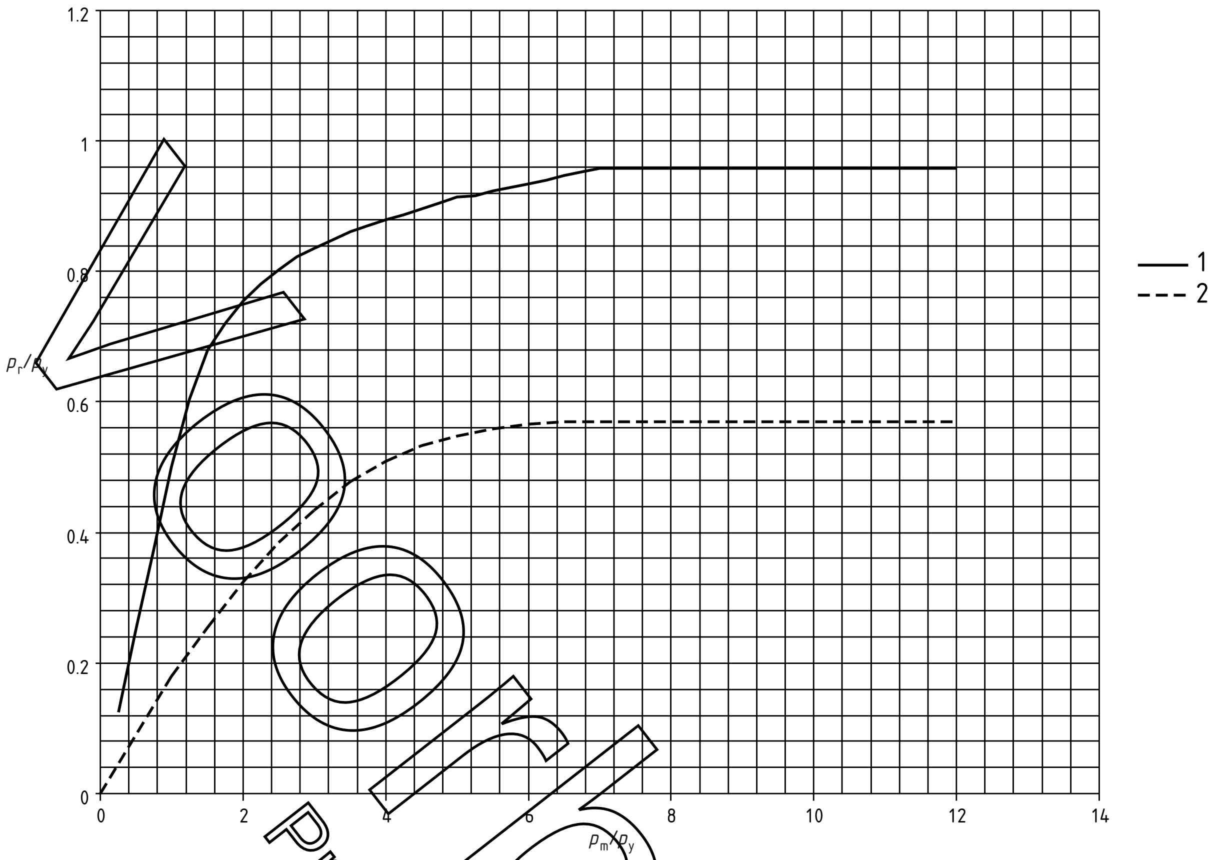


KEY

1 - Cylinders and cones

P_m/P_y	0	0,25	0,5	0,75	1,0	1,25	1,5	1,75	2,0	2,25	2,5	2,75	3	3,25	3,5
P_r/P_y	0	0,125	0,251	0,375	0,5	0,605	0,68	0,72	0,755	0,78	0,803	0,822	0,836	0,849	0,861
P_m/P_y		3,75	4,0	4,25	4,5	4,75	5,0	5,25	5,5	5,75	6,0	6,25	6,5	6,75	$\geq$ 7,0
P_r/P_y		0,87	0,879	0,887	0,896	0,905	0,914	0,917	0,923	0,929	0,935	0,941	0,947	0,953	0,959

2 - Spheres and dished ends

P_m / P_y	0	0,5	1	1,5	2	2,5	3,0	3,5	4	4,5	5,0	5,5	6	$\geq$ 6,5
P_r / P_y	0	0,09	0,18	0,255	0,324	0,386	0,435	0,479	0,51	0,533	0,548	0,565	0,56	0,57

Figure 8.5-5 — Values of P_r/P_y versus P_m/P_y

8.5.3 Stiffened cylinders

8.5.3.1 Introduction

8.5.3 provides a procedure to determine whether a cylinder with specified stiffeners can support the design external pressure. All stiffeners shall be designated as either 'heavy' or 'light'. It is permissible not to consider small circumferential rings as stiffeners.

NOTE A 'heavy' stiffener is usually a girth flange or other major component, but it may be a particularly large conventional stiffener. A light stiffener is usually a ring (flat bar), tee, angle or I-section. In most practical cases there will be a number of similar stiffeners uniformly distributed along the cylinder. It is then most economical to designate all stiffeners as 'light' since the calculation of overall collapse pressure takes account of the resistance of the shell to that mode of failure, but to designate them all as 'heavy' leads to a much simpler calculation.

8.5.3.2 Unsupported length

The unsupported lengths of a cylinder with stiffeners shall be in accordance with Table 8.5-1. The dimensions are shown in Figures 8.5-6, 8.5-7 and 8.5-8.

Table 8.5-1 — Definition of cylinder length

Cylinder with light stiffeners	Cylinder with light and heavy stiffeners
For each bay separately $L = \left(L_s' - w_1''\right) + 0{,}4h'$ (8.5.3-1) or $L = L_s'' - w_1' - w_2''$ (8.5.3-2)	For each bay separately $L = \left(L_s' - w_1'''\right) + 0{,}4h'$ (8.5.3-3) or $L = L_s'' - w_1' - w_2''$ (8.5.3-4) or $L = L_s''' - w_2' - w_3''$ (8.5.3-5)
For each light stiffener separately $L_s = \left(L_s' + 0{,}4h' + L_s''\right)/2$ (8.5.3-6) or $L_s = \left(L_s'' + L_s'''\right)/2$ (8.5.3-7)	For each light stiffener separately $L_s = \left(L_s' + 0{,}4h' + L_s''\right)/2$ (8.5.3-8) or $L_s = \left(L_s'' + L_s'''\right)/2$ (8.5.3-9)
For purpose of evaluating β $L_H = L_{cyl} + 0{,}4h' + 0{,}4h''$ (8.5.3-10)	For purpose of evaluating β $L_H = L_H' + 0{,}4h'$ (8.5.3-11) or $L_H = L_H''$ (8.5.3-12) For each heavy stiffener $L_{sH} = \left(L_H' + 0{,}4h' + L_H''\right)/2$ (8.5.3-13) or $L_{sH} = \left(L_H'' + L_H'''\right)/2$ (8.5.3-14)

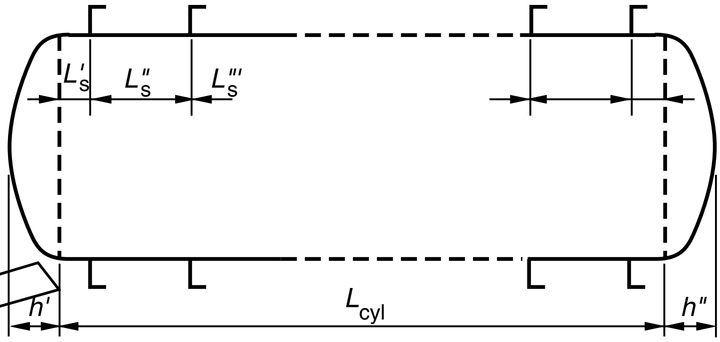


Figure 8.5-6 — Cylinder with light stiffeners

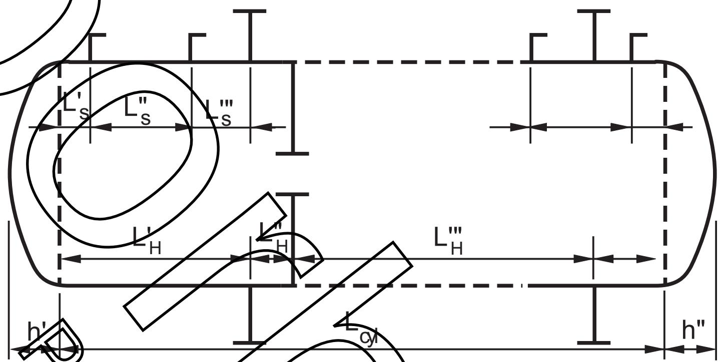


Figure 8.5-7 — Cylinder with light and heavy stiffeners

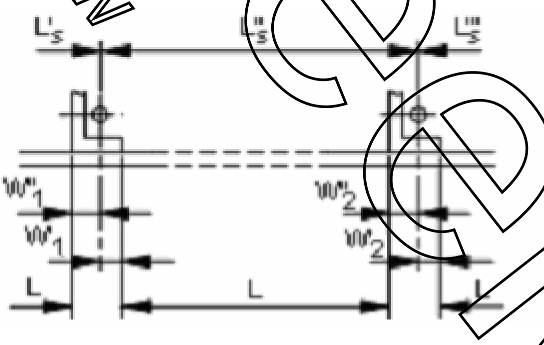
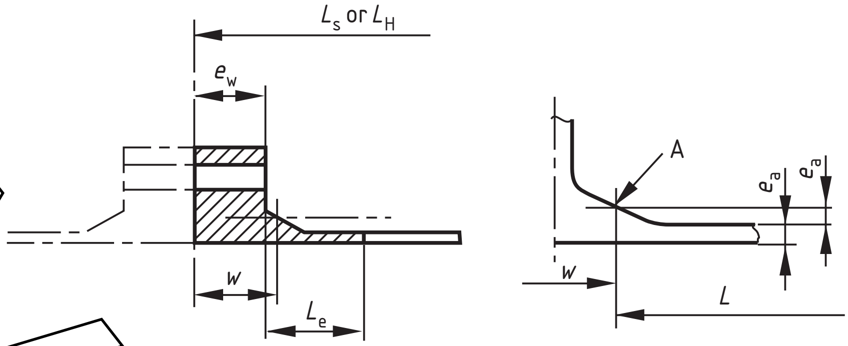


Figure 8.5-8 — Dimensional details

Where flanges act as heavy stiffeners, the shaded area shall be determined as shown in Figure 8.5-9 a). Point 'A' shall be positioned as shown in Figure 8.5-9 b) and w determined.

A_s of one flange shall be calculated from the shaded area minus $e_a\left(e_w + L_e\right)$.

The combined A_s and L_e of both flanges shall be taken when evaluating their adequacy as stiffeners.



a) Definition of shaded area b) Location of A

Figure 8.5-9 — Flanges as heavy stiffeners

8.5.3.3 Design of stiffeners

When stiffeners take the form of purpose-built rings encompassing the shell, such rings may be located internally, externally or partly internally and partly externally to the vessel. Rings may also combine process duties, such as tray support in fractionating columns, with resisting external pressure. They shall meet the requirements of 8.5.3 and be adequate for the process loading.

Where the stiffening ring has a space between it and the shell, the length of the unsupported shell shall not exceed:

$$\frac{\text{vessel circumference}}{4\, n_{\text{cyl}}}$$

See Figure 8.5-10.

Where crevice corrosion can occur, intermittent welds shall not be used for the attachment of such rings to the shell.

NOTE An initial approximate size for a ring stiffener may be obtained using 10 % of the area of the shell between the stiffeners.

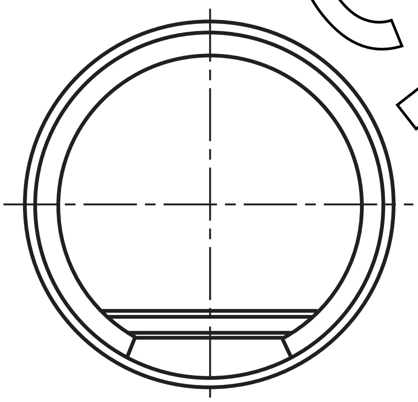


Figure 8.5-10 — Internal stiffening ring where this is not in complete contact with the shell

Table 16.5-1 — Coefficients for C_1

e_b / e_c	a_0	a_1	a_2	a_3	a_4
All	0,60072181	0,95196257	0,0051957881	-0,001406381	0

Table 16.5-2 — Coefficients for C_2

e_b / e_c	a_0	a_1	a_2	a_3	a_4
All	4,526315	0,064021889	0,15887638	-0,021419298	0,0010350407

Table 16.5-3 — Coefficients for C_3

e_b / e_c	a_0	a_1	a_2	a_3	a_4
≤ 0,2	4,8517511	0,0251012	0,7428624	- 0,0153153	0
≥ 0,5	4,8588639	2,1870887	1,4567053	- 0,3316430	0,0253850

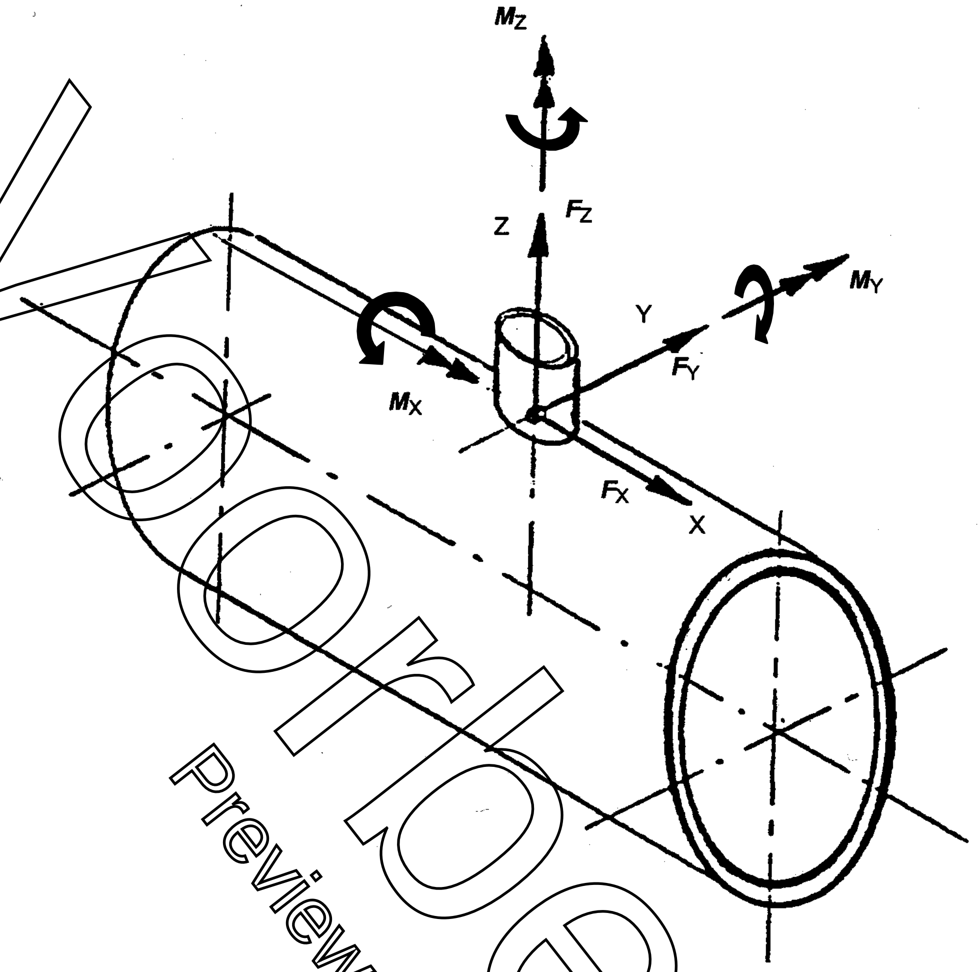


Figure 16.5-1 — Moment and Force Vectors

Table 17-1 — Stress factors η and associated maximum permissible pressures

Detail description			Detail No.	Maximum permissible pressure P_{max}	Conditions		η	Relevant details in Table 17-4
Cylindrical or conical shells	Longitudinal butt weld	without shape imperfection	**S1.1**	cylindrical shell: equation (7.4-3) 4)	$e_1 = e_2$ $(= e)$		$1{,}0z$ 1)	1.1 to 1.3, 1.5
		with offset δ 2), without ovality and peaking or flat	**S1.2**				$(1+\eta_1)z$ 1), $\eta_1 = 3\delta/e$	
		with ovality u 3), without offset and peaking or flat	**S1.3**			all u	$(1+\eta_2)z$ 1), $\eta_2 = 1{,}5u{\cdot}D/e$	
						upper bound for $u \le 2\%$	$1{,}5z$ 1)	
		with peaking or flat δ 2), without offset and ovality	**S1.4**			all δ	$(1+\eta_4)z$ 1), $\eta_4 = 6\delta/e$	
						for $\delta = e/3$	$3{,}0z$ 1)	
		General case (combined offset, ovality and peaking or flat)	**S1.5**				$(1+\eta_1+\eta_2+\eta_4)z$ 1)	
	Circumferential butt weld	with equal wall thicknesses, without offset	**S2.1**	conical shell: equation (7.6-4) 4)	$D_1 = D_2$ and $e_1 = e_2$		$1{,}0z$ 1)	1.1 and 1.2, 1.5 and 1.6
		with unequal wall thicknesses, without offset	**S2.2**		$D_1 = D_2$		$(1+\eta_0)z$ 1), $\eta_0 = 0{,}1$	1.2
		with offset δ 2) and with equal wall thicknesses	**S2.3**		$e_1 = e_2$ $(= e)$		$(1+\eta_1)z$ 1), $\eta_1 = \delta/2e$	1.3, 1.5 and 1.6
		General case (combined offset and unequal thicknesses)	**S2.4**		$e_1 \le e_2$		$(1+\eta_0+\eta_1)z$ 1), $\eta_1 = \delta/2e_2$	1.1 to 1.3, 1.5 and 1.6
	Circumferential joggle joint		**S3**		$e_1 = e_2$		$1{,}8z$ 5)	1.7
	Stiffening ring (with inter-stiffener distance b)		**S4**		$b \le \sqrt{D.e}$		$1{,}0z$ 5)	5.3
					$b > \sqrt{D.e}$		$1{,}8z$ 5)	