PRESSURE VESSELS

Pressure Vessels: Vessels Contains fluids (G + L) under pressure.
Purpose of design: Identify the size parameters.

Pressure Vessels Types			
Thin Pressure Vessels ($D/t \geq 20$) **(GATE+ESE)**		Thick Pressure Vessels ($D/t < 20$) **(ESE)**	
Thin Cylinder	Thin Sphere	Thick Cylinder	Thick Sphere
Eg. Boiler PV, Gas Storage Tank		Eg. Gun Barrel, Normal Water Pipe	
Stress Distribution **constant** over thickness		Stress Distribution is **non uniform** and maximum at inner radius and zero at outer radius	

Due to Pressure(P) the Stresses in the cylinder is generated		
Circumferential/ Tangential / Hoop Stress (σ_h)	**Longitudinal Stress (σ_l)**	**Radial Stress (σ_r)**
Acts Along Circumference and perpendicular to longitudinal section plane	Acts perpendicular to Circumference plane and along longitudinal direction	Acts In radial Direction
Bursting force = Resisting force $Pdl = \sigma_h (2lt)$ $\boldsymbol{\sigma_h = Pd / 2t}$ **(for safety $\sigma_h \leq \sigma_{allowable}$)**	Bursting force = Resisting force $P (\pi/4) d^2 = \sigma_l (\pi dt)$ $\boldsymbol{\sigma_l = Pd / 4t}$ **(for safety $\sigma_l \leq \sigma_{allowable}$)**	Ignored for thin cylinder case $\boldsymbol{\sigma_r <<< \sigma_l , \sigma_h}$
$\boldsymbol{\sigma_h = 2 \sigma_l}$ (Valid only for Constant Pressure)	If ends are open $\boldsymbol{\sigma_l = 0}$	

Strain in Thin Cylinder:

$\varepsilon_1 = \delta d / d = (Pd / 4tE) (2 - \upsilon)$ (Because $\varepsilon_1 = (1/E) [\sigma_1 - \upsilon(\sigma_2 + \sigma_3)]$
$\varepsilon_2 = \delta l / l = (Pd / 4tE) (1 - 2\upsilon)$
$\varepsilon_v = \delta V / V = \varepsilon_2 + 2 \varepsilon_1 = (Pd / 4tE) (5 - 4\upsilon)$ (here $V = L (\pi/4) d^2$)

Special Case (Hydrostatic Pressure):

Always possible $\boldsymbol{\sigma_h > \sigma_l}$	
Yes, When Pressure distribution is constant	No, When Pressure is varying, we can't judge

Built Up Cylinder-Joint Efficiency:

Built Up Cylinder: Cylinder made of multiple metal sheets Joined by Riveted Joints.

Riveted Joints	
Longitudinal Riveted Joints	**Circumferential Riveted Joints**
Used in increase Diameter of cylinder	Used to increase Length of cylinder
$\eta_l \sigma_h = Pd / 2t$	$\eta_h \sigma_l = Pd / 4t$

Joint Efficiency (η) = Effective Area / Gross Area

Thin Spherical Pressure Vessels:

Bursting force = Resisting force
$P (\pi/4) d^2 = \sigma_h (\pi dt)$
$\boldsymbol{\sigma_h = Pd / 4t}$ **(for safety $\sigma_h \leq \sigma_{allowable}$)**
Here $\varepsilon_3 = \varepsilon_2 = \varepsilon_1 = \delta d / d = (Pd / 4tE) (1 - \upsilon)$ (Because $\varepsilon_1 = (1/E) [\sigma_1 - \upsilon(\sigma_2 + \sigma_3)]$
$\varepsilon_v = \delta V / V = \varepsilon_1 + \varepsilon_2 + \varepsilon_3 = (3Pd / 4tE) (1 - \upsilon)$ (here $V = (4/3) \pi r^3$)

Thin Cylindrical Pressure Vessels with Hemi-Spherical Ends):

To Avoid Deformation at junction, $\varepsilon_{hc} = [\delta d / d]_{Cylinder} = [\delta l / l]_{Sphere} = \varepsilon_{hs}$

$(Pd / 4t_cE) (2 - \upsilon) = (Pd / 4t_sE) (1 - \upsilon)$
$(t_s/t_c) = (1 - \upsilon) / (2 - \upsilon)$
$t_s \leq t_c$ (Condition to avoid Deformation at junction for same deformation)

To Avoid Deformation at junction, $[\sigma_{max}]_{Cylinder} = [\sigma_{max}]_{Sphere}$

$(t_s/t_c) = 0.5$ (Condition to avoid Deformation at junction for same maximum stress)

$\tau_{max} = \max \{ \mathrm{mod}[(\sigma_1 - \sigma_2)/2], \mathrm{mod} [(\sigma_2 - \sigma_3)/2], \mathrm{mod}[(\sigma_3 - \sigma_1)/2]\}$
$\tau_{max} = \max \{ 0, Pd/4t, Pd/8t \} = Pd/4t$ (For Sphere)
$\tau_{max} = \max \{ 0, Pd/8t, Pd/8t \} = Pd/8t$ (For Cylinder)