Thin Spherical Shell: Stress, Volume Change and Wall Thickness

Membrane stress, strain and volume increase of a thin spherical vessel under internal pressure, and the wall for an allowable stress and joint efficiency.

Method: Membrane theory of thin spherical shells

Input parameters

Unit system: SI

Parameter	Value	Unit
Internal pressure	1.5000	MPa
Inside diameter	2.0000	m
Wall thickness	10.000	mm
Young's modulus	200.00	GPa
Poisson's ratio	0.30000	
Joint efficiency	100.00	%
Allowable stress	100.00	MPa

Calculated results

Parameter	Value	Unit
Membrane stress	75.000	MPa
Increase in volume	3.2987	L
Volumetric strain	7.8750e-04	
Thickness for the allowable stress	7.5000	mm

Notes for this case

• A sphere carries pressure equally in all directions: σ = pd/(4tη), half the hoop stress of a cylinder of the same diameter and thickness. The strain in any direction is σ(1 − ν)/E and the volume grows by three times that, which also sets how much extra water a hydraulic test needs. Thin-shell theory applies while t is under about a tenth of d; for design to a code use that code's formulas.

Formula and method

$$\sigma = \frac{pd}{4t\eta}, \quad \frac{\Delta V}{V} = \frac{3\sigma(1-\nu)}{E}$$

Variables

p	Internal pressure	Pa
d	Inside diameter	m
t	Wall thickness	m
E	Young's modulus	Pa
ν	Poisson's ratio	-
η	Joint efficiency	-
σ_a	Allowable stress	Pa
σ	Membrane stress	Pa
ΔV	Increase in volume	m^3
$\Delta V/V$	Volumetric strain	-
t_{req}	Thickness for the allowable stress	m

Method and standards

Thin sphere.

Assumptions and limits

- Thin wall; elastic material.

References

Membrane theory of thin spherical shells

Report details

Report reference	FCC-SVNJ-53EP (the same inputs always give the same reference)
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Results are for engineering estimation. Verify critical designs against the referenced standards and your own data.

This calculator online

https://calc.firecad.com/mechanical/strength-of-materials/thin-spherical-shell

Open this case on calc.firecad.com →

Reopens the calculator with the inputs of this report.