GIVE FEEDBACK

CONTINUE >

This section covers the analysis of the stresses in pressure vessels.

Pressure vessels exist when there is a difference between the pressure inside the vessel and the pressure surrounding it.

Pressure vessels are typically used for air compressor tanks, steam boilers and gas tanks.

< BACK GIVE FEEDBACK OK

Pressure vessels

Pressure vessels are cylindrical or, less frequently, spherical containers used to hold fluids, i.e. gases or liquids, under pressure.

GIVE FEEDBACK

OK

Type your answer in the box.

Pressure vessels are containers used to hold _____ under pressure.

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Which of the following is the best definition of a pressure vessel?

Click the correct answer.

- Pressure vessels are containers used to hold fluids under pressure.
- Pressure vessels are containers used to hold gases under pressure.
- Pressure vessels are containers used to hold liquids under pressure.
- Pressure vessels are containers that operate at atmospheric pressure.

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

The most common form of pressure vessel, as used in steam boilers and compressed-air receivers, is the cylinder of welded construction with curved, but not quite hemispherical, ends.

GIVE FEEDBACK

CONTINUE >

Spherical vessels are sometimes used, particularly for the containment of liquefied gases at high pressure and low temperature.

Type your answer in the box.

The most common shape used for pressure vessels is the _____ of welded construction with curved, but not quite hemispherical, ends.

A less commonly used shape for pressure vessels is the _____.

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Which of the following shapes are typically used for pressure vessels?

Check all that apply.

- [ ] Cylinder
- [ ] Sphere
- [ ] Tetrahedron
- [ ] Cube
- [ ] Triangular prism
- [ ] Cone

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Gauge pressure

A pressure vessel containing a gas is subject to uniform internal pressure normal to its walls.

The material of the wall, as well as the welded seams, must be sufficiently strong to resist stresses set up within the material due to the gas pressure.

The pressure responsible for stress in the walls of a vessel is the difference between internal pressure and atmospheric pressure outside the vessel.

It is in fact the pressure as measured directly by a pressure gauge fitted to a pressure vessel, and is known as **gauge pressure**.

What is the correct term for describing the difference between internal pressure and atmospheric pressure outside the vessel?

Click the correct answer.

- Gauge pressure
- Differential pressure
- Total pressure
- Pressure quotient
- Working pressure

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Which of the following is the best definition of gauge pressure?

Click the correct answer.

- The difference between internal pressure and atmospheric pressure outside the vessel
- The pressure indicated by a strain gauge
- The difference in pressure at the extremities of a pressure vessel
- The total pressure within a pressure vessel
- The sum of the internal pressures within a system of pressure vessels

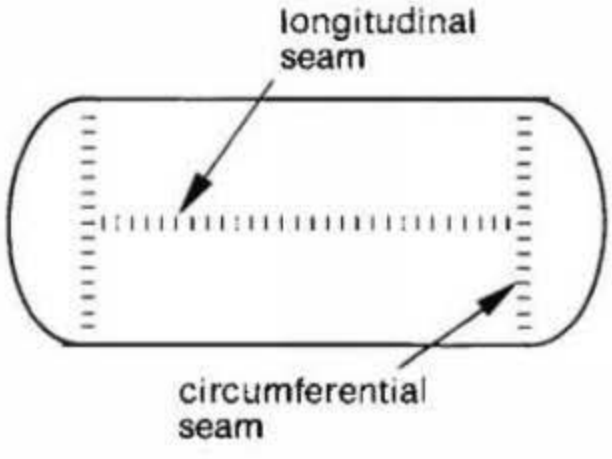
Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Seams that need to be considered for stress for a pressure vessel

In a cylindrical pressure vessel of welded construction, there are two types of seams that need to be considered for possible stress.

These are the **longitudinal seam** along the length of the cylinder, and the **circumferential seam**.



Seams in a cylindrical pressure vessel.

Cylindrical shell construction	Note

GIVE FEEDBACK

OK

Seams that need to be considered for stress for a pressure vessel

It should be noted at the outset that stresses induced in the material of the shell are found throughout the material of the shell, whether there is an actual welded joint at a particular point or not.

However, it is often useful to imagine two halves of the shell as if they were connected by some form of joint.

Cylindrical shell construction	Note

GIVE FEEDBACK

OK

Which of the following are the correct terms for the types of seams that need to be considered for possible stress in a cylindrical pressure vessel of welded construction?

Check all that apply.

- [ ] Longitudinal seam
- [ ] Circumferential seam
- [ ] Transverse seam
- [ ] Hoop seam
- [ ] Cylindrical seam

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Type your answer in the box.

In a cylindrical pressure vessel of welded construction, there are two types of seams that need to be considered for possible stress. These are the _____ seam along the length of the cylinder, and the _____ seam.

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

The pascal is the SI unit for pressure.

Units used to measure pressure in a fluid

For our purposes, pressure in a fluid can be regarded as similar to stress in a solid material, defined as force per unit area and measured in pascals or its derivatives, kilopascals and megapascals.

GIVE FEEDBACK

OK

Which of the following is the correct SI unit for pressure?

Click the correct answer.

- Pascal
- Joule
- Watt
- Newton
- Curie
- Ohm

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Type your answer in the box.

The SI unit for pressure is the _____ .

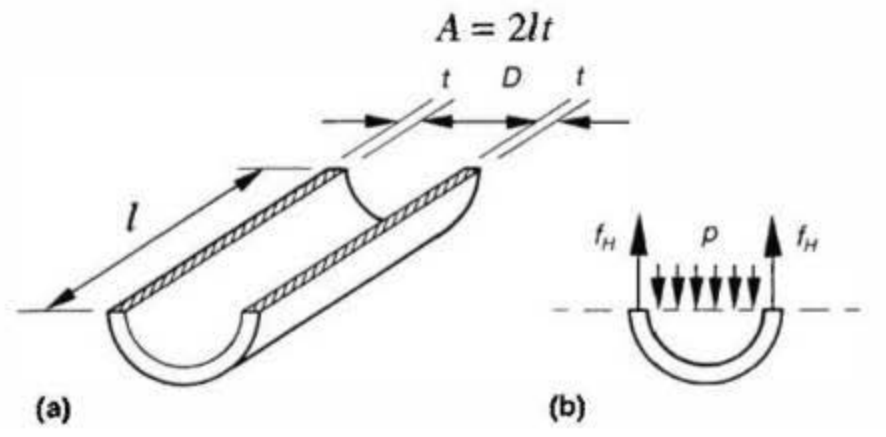
Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

The formula for calculating the total force due to pressure inside the shell

Let us consider one-half of a cylindrical shell separated from the other along its longitudinal seams, as shown in the figure.

For a given length l, and wall thickness t, the area subjected to stress is twice $l \times t$.



(a) Longitudinal section of cylindrical shell (b) Hoop stress perpendicular to the cross-section of the shell material

Stress on the longitudinal seam	Discussion	Equation

GIVE FEEDBACK

OK

The formula for calculating the total force due to pressure inside the shell

The pressure acts in the radial direction upon all elements of the exposed internal surface.

However, it can be shown that after summation of all components of pressure perpendicular to the plane of the section, the total force due to pressure is equal to the product of the pressure and the projected area.

Stress on the longitudinal seam | Discussion | Equation

The formula for calculating the total force due to pressure inside the shell

$$F = p\, l\, D$$

Where:

F is the total force acting on the shell due to pressure

p is the pressure on the shell

l is the length of the shell

D is the internal diameter of the shell

Stress on the longitudinal seam	Discussion	Equation

GIVE FEEDBACK

OK

Match each of the symbols from the equation $F = p\,l\,D$ with the correct description.

Drag statements on the right to match the left.

F	The total force acting on the shell due to pressure.
p	The pressure on the shell.
l	The length of the shell.
D	The internal diameter of the shell.

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Which of the following is the correct equation for calculating the force due to pressure for a cylindrical pressure vessel?

Click the correct answer.

$F = p\,l\,D$

$F = \frac{p\,l}{D}$

$F = \frac{p}{l\,D}$

$F = \frac{p + l}{D}$

$F = \frac{p\,D}{l}$

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Calculating the stress in the material of the shell of a cylindrical pressure vessel

The stress in the material of the shell can be found as force per unit area by considering the force acting on the shell and the area of the shell.

$$\sigma = \frac{F}{A} = \frac{p\,l\,D}{2\,l\,t} = \frac{p\,D}{2t}$$

Where:

σ is the stress in the shell material

F is the force acting on the shell

A is the area of the shell

p is the pressure acting on the shell

l is the length of the shell

D is the internal diameter of the shell

t is the thickness of the shell.

GIVE FEEDBACK

OK

Which of the following is the correct equation for calculating the stress in the longitudinal seam of a cylindrical pressure vessel?

Click the correct answer.

$$\sigma = \frac{p\,D}{2t}$$

$$\sigma = 2p\,D\,t$$

$$\sigma = \frac{2t}{p\,D}$$

$$\sigma = \frac{2p}{D\,t}$$

$$\sigma = \frac{D\,t}{2p}$$

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Match each of the symbols from the equation $\sigma = \frac{p\,D}{2t}$ with the correct description.

Drag statements on the right to match the left.

σ	The stress in the cylindrical shell due to pressure.
p	The pressure on the shell.
t	The thickness of the shell.
D	The internal diameter of the shell.

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

The term 'hoop stress' originates from a classic problem of stress analysis in a thin circular ring, or 'hoop', subjected to uniformly distributed radial forces, which produce uniform enlargement of the ring.

Hoop stress

Hoop stress is the tensile stress in the material of the shell set up in the tangential direction, all the way along length l of the longitudinal seam.

The direction of this stress is perpendicular to the cross-section of the shell material made by the imaginary plane of separation between the two halves.

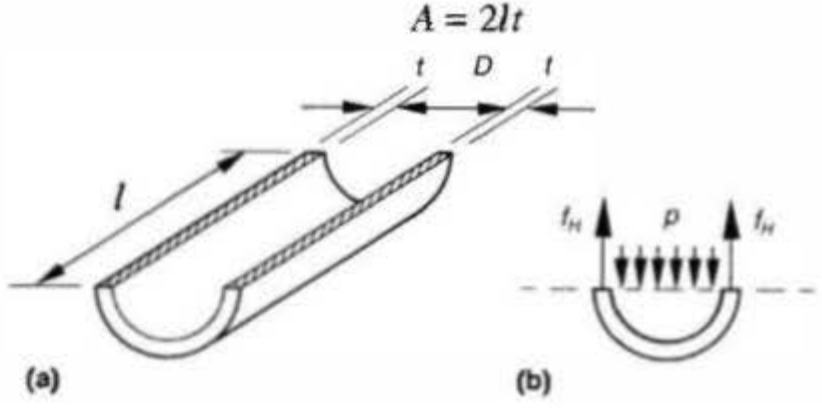


Figure: *(a) Longitudinal section of cylindrical shell (b) Hoop stress perpendicular to the cross-section of the shell material.*

GIVE FEEDBACK

OK

Type your answer in the box.

The tensile stress in the material of a shell set up in the tangential direction, all the way along the length of the longitudinal seam, is known as _____ stress.

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

What is the term used to describe the tensile stress in the material of a shell set up in the tangential direction, all the way along the length of the longitudinal seam?

Click the correct answer.

- Hoop stress
- Tangential stress
- Circular stress
- Axial stress
- Shell stress

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

The formula for calculating the hoop stress

$$\sigma_H = \frac{p\,D}{2t}$$

Where:

σ_H is the hoop stress

p is the pressure

D is the internal diameter of the shell

t is the thickness of the shell.

GIVE FEEDBACK

OK

Match each of the symbols from the equation $\sigma_H = \frac{p\,D}{2t}$ with the correct description.

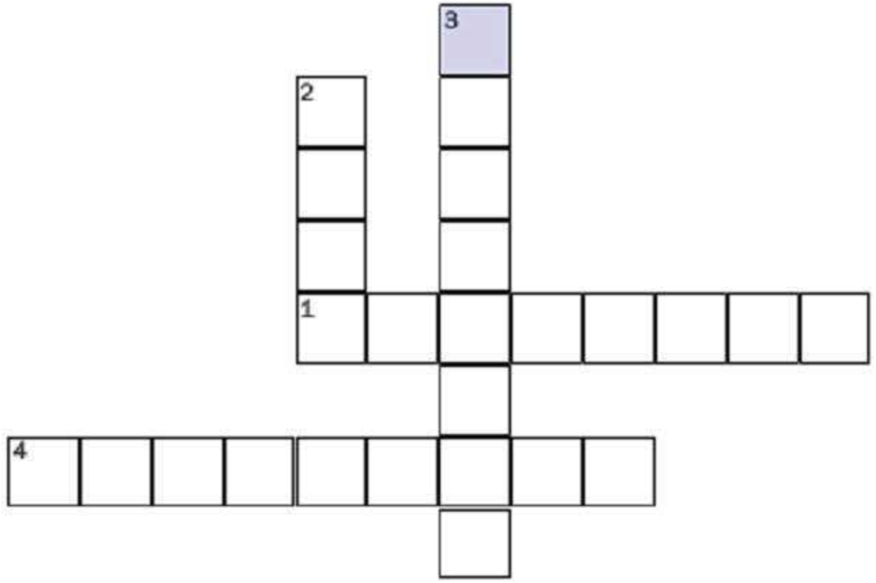
Drag statements on the right to match the left.

σ_H	The hoop stress.
p	The pressure on the shell.
t	The thickness of the shell.
D	The internal diameter of the shell.

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Hoop stress



Complete the crossword based on the equation $\sigma_H = \frac{p\,D}{2\,t}$.

1) p refers to the _____ .

2) σ_H refers to the _____ stress.

3) D refers to the internal _____ .

4) t refers to the shell _____ .

Done | Hint | Challenge

Calculate the hoop stress in the material

Determine the hoop stress in the material of a cylindrical air receiver 1.2 m long and 350 mm in diameter, with a wall thickness of 6 mm, subjected to a pressure of 1 MPa.

Example | Solution

GIVE FEEDBACK

OK

Calculate the hoop stress in the material

Keeping in mind that, in this context, pressure is similar to stress, we can use pressure in megapascals and dimensions in millimetres for convenience.

Hoop stress

$$\begin{aligned}\sigma_H &= \frac{p\ D}{2\,t} \\ &= \frac{1\ \text{MPa} \times 350\ \text{mm}}{2 \times 6\ \text{mm}} \\ &= 29.2\ \text{MPa}\end{aligned}$$

Example | Solution

GIVE FEEDBACK

OK

Determine the hoop stress in the material of a cylindrical air receiver 800 mm long and 270 mm in diameter, with a wall thickness of 4.5 mm, subjected to a pressure of 900 kPa.

Clear

Clear line

Undo

Click and type your answer here

CHALLENGE

SUBMIT

SHOW ANSWER

INSTRUCTIONS

- No intermediate steps are required
- If you choose to show steps, write one on each line.
- Write your final answer on the last line.
- The computer will check all your work in detail when you click "Submit".

Hint

Each hint will reduce the credit received for this question

Determine the hoop stress in the material of a cylindrical air receiver 1 m long and 300 mm in diameter, with a wall thickness of 5 mm, subjected to a pressure of 1.2 MPa.

Click and type your answer here

CHALLENGE SUBMIT SHOW ANSWER

INSTRUCTIONS

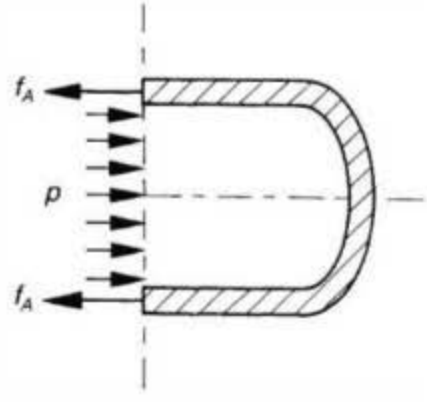
- No intermediate steps are required
- If you choose to show steps, write one on each line.
- Write your final answer on the last line.
- The computer will check all your work in detail when you click "Submit".

Hint

Each hint will reduce the credit received for this question

Axial stress

Axial stress in the shell of a pressure vessel is tensile stress in the direction of the principal axis of the cylinder.



Axial stress in the shell of a pressure vessel

GIVE FEEDBACK

OK

What is the term that is used to describe the tensile stress in the direction of the principal axis of the cylinder?

Click the correct answer.

- Axial stress
- Tangential stress
- Principal stress
- Hoop stress
- Shell stress

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Type your answer in the box.

Tensile stress in the direction of the principal axis of the cylinder of a pressure vessel is called _____ stress.

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Calculating the total axial force

To establish the magnitude of the axial stress, it is necessary to consider a section along the plane of a circumferential seam.

The pressure can be regarded as acting in the axial direction, i.e. perpendicular to the projected area of the cylinder end ($\frac{\pi D^2}{4}$).

$$F = p\frac{\pi D^2}{4}$$

Where:

F is the force in the axial direction

p is the pressure acting in the axial direction

D is the internal diameter.

GIVE FEEDBACK

OK

Match each of the symbols from the equation $F = p\frac{\pi D^2}{4}$ with the correct description.

Drag statements on the right to match the left.

F	The force acting on the shell due to axial pressure.
p	The pressure on the shell.
D	The internal diameter of the shell.

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Which of the following is the correct equation for calculating the axial force due to pressure for a cylindrical pressure vessel?

Click the correct answer.

$F = p \frac{\pi D^2}{4}$

$F = p\, l\, D$

$F = p\, l\, D^2$

$F = \frac{\pi l}{D^2}$

$F = \frac{4\pi D^2}{p}$

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Calculating the total area of shell material resisting axial force

The area of the shell material resisting the force due to pressure can be estimated approximately as the product of the circumference (based on the nominal diameter of the shell) and the wall thickness:

$$A = \pi D t$$

The accuracy of this approximation is quite acceptable provided that the cylinder is thin, i.e. its diameter is at least 10 times greater than the wall thickness, and the nominal diameter is somewhere between the inside and outside diameters of the shell.

GIVE FEEDBACK

OK

Match each of the symbols from the equation $A = \pi D t$ with the correct description.

Drag statements on the right to match the left.

A	The area of the shell material resisting the force due to pressure.
D	The nominal diameter of the shell.
t	The thickness of the shell.

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Which of the following is the correct equation for calculating the area of the shell material resisting the axial force due to pressure for a cylindrical pressure vessel?

Click the correct answer.

$A = \pi D t$

$A = \pi D^2 t$

$A = 4\pi D t$

$A = 4\pi D^2 t$

$A = \frac{\pi D^2}{4t}$

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Formula for calculating the axial stress

The stress resulting from the force acting on the cross-section of the circumferential seam can be found from:

$$\sigma = \frac{F}{A} = \frac{p\frac{\pi D^2}{4}}{\pi D\, t} = \frac{p\, D}{4t}$$

$$\sigma_A = \frac{p\, D}{4t}$$

Where:

σ_A is the axial stress

p is the pressure

D is the internal diameter

t is the shell thickness.

GIVE FEEDBACK

OK

Which of the following is the correct equation for calculating the axial stress for a cylindrical pressure vessel?

Click the correct answer.

$$\sigma_A = \frac{p\,D}{4t}$$

$$\sigma_A = \frac{p\,D}{2t}$$

$$\sigma_A = 4p\,D\,t$$

$$\sigma_A = \frac{p\,D^2}{4t}$$

$$\sigma_A = \frac{4t}{p\,D}$$

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Match each of the symbols from the equation $\sigma_A = \frac{p\,D}{4\,t}$ with the correct description.

Drag statements on the right to match the left.

σ_A	The axial stress.
p	The pressure on the shell.
t	The thickness of the shell.
D	The nominal diameter of the shell.

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Calculate the axial stress in the material

Calculate the axial stress in the material of a cylindrical air receiver 1.2 m long and 350 mm in diameter, with a wall thickness of 6 mm, subjected to a pressure of 1 MPa.

Example | Solution

GIVE FEEDBACK

OK

Calculate the axial stress in the material

$$\sigma_A = \frac{p\,D}{4\,t}$$

$$= \frac{1\ \text{MPa} \times 350\ \text{mm}}{4 \times 6\ \text{mm}}$$

$$= 14.6\ \text{MPa}$$

Example | Solution

GIVE FEEDBACK

OK

Determine the axial stress in the material of a cylindrical air receiver 1 m long and 300 mm in diameter, with a wall thickness of 5 mm, subjected to a pressure of 1.2 MPa.

Click and type your answer here

CHALLENGE SUBMIT SHOW ANSWER

INSTRUCTIONS

- No intermediate steps are required
- If you choose to show steps, write one on each line.
- Write your final answer on the last line.
- The computer will check all your work in detail when you click "Submit".

Hint

Each hint will reduce the credit received for this question

Determine the axial stress in the material of a cylindrical air receiver 800 mm long and 270 mm in diameter, with a wall thickness of 4.5 mm, subjected to a pressure of 900 kPa.

Clear

Clear line

Undo

Click and type your answer here

CHALLENGE

SUBMIT

SHOW ANSWER

INSTRUCTIONS

- No intermediate steps are required
- If you choose to show steps, write one on each line.
- Write your final answer on the last line.
- The computer will check all your work in detail when you click "Submit".

Hint

Each hint will reduce the credit received for this question

How the thickness of the plate required affacts the design of a pressure vessel

The first step in the design of a pressure vessel is to determine the thickness of plate required.

A simple comparison shows that a given pressure in a cylindrical pressure vessel causes hoop stress which is twice as high as the axial stress.

This means that a longitudinal seam is more vulnerable to rupture.

Therefore, if other conditions are equal, the strength of a longitudinal seam is the limiting factor in the design of cylindrical vessels, and the hoop stress formula should be used for calculating required plate thickness.

GIVE FEEDBACK

OK

Type your answer in the box.

If other conditions are equal, the strength of a [ ] seam is the limiting factor in the design of cylindrical vessels, and the [ ] stress formula should be used for calculating required plate thickness.

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

If other conditions are equal, which criteria should be used for calculating required plate thickness for a cylindrical pressure vessel?

Click the correct answer.

- Hoop stress
- Axial stress
- Combined stress
- Longitudinal stress

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Calculate the minimum plate thickness required for a pressure vessel

Determine the minimum plate thickness required for a steam boiler drum, with diameter 1.2 m, if the maximum allowable stress in the material is 75 MPa and the pressure is 1.5 MPa.

Example | Solution

GIVE FEEDBACK

OK

Calculate the minimum plate thickness required for a pressure vessel

Hoop stress $\sigma_H = \frac{p\ D}{2\,t}$ is the limiting factor, from which:

$$t = \frac{p\ D}{2\,\sigma_H}$$

Substitution gives:

$$t = \frac{1.5\ \text{MPa} \times 1{,}200\ \text{mm}}{2 \times 75\ \text{MPa}}$$
$$= 12\ \text{mm}$$

Example | Solution

GIVE FEEDBACK

OK

Determine the minimum plate thickness required for a steam boiler drum, with a diameter of 1 m, if the maximum allowable stress in the material is 60 MPa and the pressure is 1.2 MPa.

(Answer in millimetres).

Clear

Clear line

Undo

Click and type your answer here

CHALLENGE

SUBMIT

SHOW ANSWER

INSTRUCTIONS

- No intermediate steps are required
- If you choose to show steps, write one on each line.
- Write your final answer on the last line.
- The computer will check all your work in detail when you click "Submit".

Hint

Each hint will reduce the credit received for this question

Determine the minimum plate thickness required for a steam boiler drum, with a diameter of 2.16 m, if the maximum allowable stress in the material is 90 MPa and the pressure is 1 MPa.

(Answer in millimetres).

Clear

Clear line

Undo

Click and type your answer here

CHALLENGE

SUBMIT

SHOW ANSWER

INSTRUCTIONS

- No intermediate steps are required
- If you choose to show steps, write one on each line.
- Write your final answer on the last line.
- The computer will check all your work in detail when you click "Submit".

Hint

Each hint will reduce the credit received for this question

Various boiler and pressure vessel codes and specifications have been written to provide further information about the impact of joint efficiency. We will not consider these at this stage.

How joint efficiency affects the wall thickness required to withstand a specific pressure

For general purposes, it may be assumed that good-quality butt-welded joints in mild steel have the same strength as the plates being joined, i.e. a joint efficiency of 100 per cent is assumed.

However, under certain conditions of workmanship or service, it would be safer to assume an efficiency of the joint of 90 per cent or less.

If a joint has only a certain percentage of the strength that the solid plate has, then the thickness of the plate must be increased to allow for the weakness of the joint.

This in effect means that, to allow for joint efficiency, the required plate thickness must be equal to the calculated minimum thickness, t, divided by the joint efficiency.

GIVE FEEDBACK

OK

Type your answer in the box.

To allow for joint efficiency, the required plate thickness for a pressure vessel must be equal to the calculated minimum thickness, _____ by the joint efficiency.

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Type your answer in the box.

If a joint has only a certain percentage of the strength that the solid plate has, then the thickness of the plate, to allow for the weakness of the joint, must be _____ accordingly.

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Calculate the minimum plate thickness required for a pressure vessel with a given joint efficiency

Determine the minimum plate thickness required for a steam boiler drum, with diameter 1.2 m, if the maximum allowable stress in the material is 75 MPa, the pressure is 1.5 MPa and the joint efficiency is 80 per cent.

Example	Limiting stress	Effect of joint efficiency

GIVE FEEDBACK

OK

Calculate the minimum plate thickness required for a pressure vessel with a given joint efficiency

Hoop stress $\sigma_H = \frac{p\ D}{2t}$ is the limiting factor, from which:

$$t = \frac{p\ D}{2f_H}$$

Substitution gives:

$$t = \frac{1.5\ \text{MPa} \times 1{,}200\ \text{mm}}{2 \times 75\ \text{MPa}}$$
$$= 12\ \text{mm}$$

Example | Limiting stress | Effect of joint efficiency

The calculated thickness is $t = 12\ \text{mm}$.

The required thickness, to allow for joint efficiency of 80 per cent, is:

$$\frac{12\ \text{mm}}{0.8} = 15\ \text{mm}$$

Example | Limiting stress | Effect of joint efficiency

Determine the minimum plate thickness required for a steam boiler drum, with a diameter of 2.16 m, if the maximum allowable stress in the material is 90 MPa, the pressure is 1 MPa and the joint efficiency is 80%.

(Answer in millimetres).

Clear

Clear line

Undo

Click and type your answer here

CHALLENGE

SUBMIT

SHOW ANSWER

INSTRUCTIONS

- No intermediate steps are required
- If you choose to show steps, write one on each line.
- Write your final answer on the last line.
- The computer will check all your work in detail when you click "Submit".

Hint

Each hint will reduce the credit received for this question

Determine the minimum plate thickness required for a steam boiler drum, with a diameter of 1 m, if the maximum allowable stress in the material is 60 MPa, the pressure is 1.2 MPa and the joint efficiency is 80%.

(Answer in millimetres).

Clear

Clear line

Undo

Click and type your answer here

CHALLENGE

SUBMIT

SHOW ANSWER

INSTRUCTIONS

- No intermediate steps are required
- If you choose to show steps, write one on each line.
- Write your final answer on the last line.
- The computer will check all your work in detail when you click "Submit".

Hint

Each hint will reduce the credit received for this question

The stress of spherical containers compared to cylindrical containers

A pressure vessel of spherical shape is symmetrical in all directions, suggesting that stresses in the material of its wall induced by internal pressure are the same at all points and in all directions.

GIVE FEEDBACK

OK

Type your answer in the box.

A pressure vessel of _____ shape is symmetrical in all directions, suggesting that stresses in the material of its wall induced by internal pressure are the same at all points and in all directions.

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Which shape when used for a pressure vessel has the stresses in the material of its wall induced by internal pressure the same at all points and in all directions?

Click the correct answer.

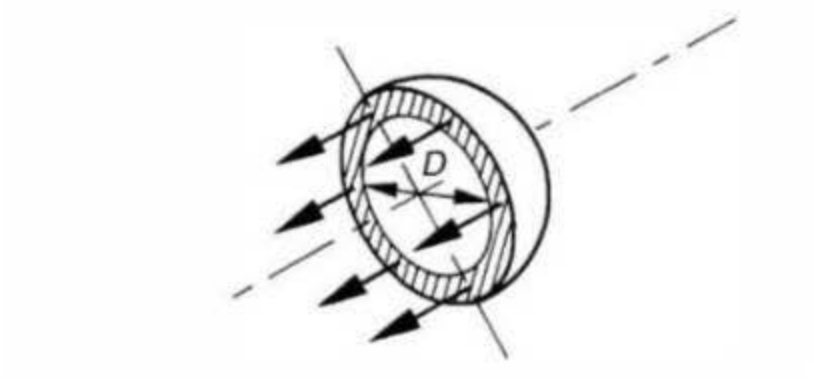
- Sphere
- Cylinder
- Tetrahedron
- Cube
- Cone

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

The formula for calculating the total force due to pressure inside the spherical shell

If we consider any diametral section of the sphere, as in the figure below, the similarity with stresses on circumferential seams can easily be seen.



Diametral section of spherical pressure vessel

The force due to pressure on a circular area $\pi D^2/4$ is equal to $p\ \pi D^2/4$.

GIVE FEEDBACK

OK

Which is the correct equation for the force due to pressure in a spherical pressure vessel?

Click the correct answer.

$$F = \frac{p\,\pi D^2}{4}$$

$$F = \frac{\pi D^2}{4} p$$

$$F = p\,\pi D^2$$

$$F = \frac{4\pi D}{p}$$

$$F = \frac{p\,\pi}{4D^2}$$

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Match each of the symbols from the equation $F = \frac{p\,\pi D^2}{4}$ with the correct description.

Drag statements on the right to match the left.

F	The force acting on the spherical pressure vessel due to pressure.	
p	The pressure acting on the spherical pressure vessel.	
D	The internal diameter of the spherical pressure vessel.	

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

The formula for calculating the stress in the material of a spherical shell

The force due to pressure is distributed over the cross-sectional area of the material, which is equal to $\pi D\, t$, assuming the 'thin-wall' approximation.

Therefore, stress in the wall material is:

$$\sigma = \frac{F}{A} = \frac{p\dfrac{\pi D^2}{4}}{\pi D\, t} = \frac{p\, D}{4t}$$

Where:

σ is the stress

F is the force due to pressure

A is the cross sectional area of the material

p is the pressure

D is the internal diameter of the spherical pressure vessel

t is the wall thickness.

GIVE FEEDBACK

OK

Which of the following is the correct equation for the stress in the wall material of a spherical pressure vessel?

Click the correct answer.

$\sigma = \frac{p\,D}{4t}$

$\sigma = 4p\,D\,t$

$\sigma = \frac{p\,\pi D}{4t}$

$\sigma = \frac{\pi D^2}{4t}$

$\sigma = \frac{p\,D}{4\pi}$

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Match each of the symbols from the equation $\sigma = \frac{p\,D}{4\,t}$ with the correct description.

Drag statements on the right to match the left.

σ	The stress in the shell of the spherical pressure vessel.	
p	The pressure acting on the spherical pressure vessel.	
D	The internal diameter of the spherical pressure vessel.	
t	The wall thickness of the shell of the spherical pressure vessel.	

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Formula for calculating the axial stress in the material of the spherical shell

For the same p , D and t , stress in a spherical shell is equivalent to axial stress on a circumferential seam in a cylindrical vessel, given by:

$$\sigma = \frac{p\ D}{4\,t}$$

Where:
σ is the stress
p is the pressure
D is the internal diameter
t is the wall thickness.

GIVE FEEDBACK

OK

Match each of the symbols from the equation $\sigma = \frac{p\,D}{4\,t}$ with the correct description.

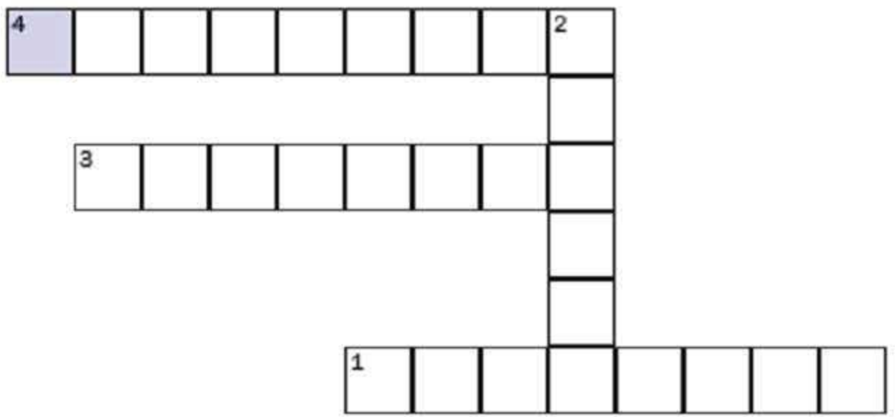
Drag statements on the right to match the left.

σ	The stress in the shell of the spherical pressure vessel.	
p	The pressure acting on the spherical pressure vessel.	
D	The internal diameter of the spherical pressure vessel.	
t	The wall thickness of the shell of the spherical pressure vessel.	

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Stress in spherical vessels



Complete the crossword based on the equation $\sigma = \frac{p\,D}{4t}$.

1) The symbol p refers to _____ .

2) The symbol σ refers to _____ .

3) The symbol D refers to _____ .

4) The symbol t refers to _____ .

Done Hint Challenge

The effects of hoop stress and axial stress in a spherical shell

A cylindrical shell of equal diameter and wall thickness to a spherical shell, subjected to the same pressure, will have hoop stress in its longitudinal seams of twice the magnitude of the axial stress.

It follows, therefore, that since a spherical shell does not have longitudinal seams, it is not subjected to hoop stress, and can be said to be twice as strong as a corresponding cylindrical container.

GIVE FEEDBACK

OK

Which of these statements about spherical pressure vessels are true?

Check all that apply.

- [ ] A spherical shell does not have longitudinal seams, therefore it is not subjected to hoop stress
- [ ] A spherical pressure vessel is twice as strong as a corresponding cylindrical container
- [ ] A spherical pressure vessel is half as strong as a corresponding cylindrical container
- [ ] A spherical shell does not have longitudinal seams, therefore it is not subjected to axial stress
- [ ] A spherical pressure vessel is equal in strength to a corresponding cylindrical container.

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Type your answer in the box.

Since a spherical shell does not have longitudinal seams, it is not subjected to _____ stress, and can be said to be _____ as strong as a corresponding cylindrical container.

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Calculate the maximum allowable (safe) pressure for a given container

Given the ultimate strength of steel plate of 380 MPa and using a factor of safety of 5, compare the maximum allowable pressure in (a) spherical and (b) cylindrical pressure vessels of diameter 1 m and wall thickness 10 mm, assuming 100 per cent joint efficiency in a fully welded construction.

Example	Allowable stress	Spherical pressure vessel	Cylindrical pressure vessel	Conclusion

GIVE FEEDBACK

OK

Calculate the maximum allowable (safe) pressure for a given container

Allowable stress:

$$\sigma = \frac{380\ \text{MPa}}{5}$$
$$= 76\ \text{MPa}$$

(a) *Spherical shell*

Stress in a spherical shell is given by $f = \frac{p\,D}{4t}$, from which maximum allowable pressure in a spherical pressure vessel is:

$$p = \frac{4tf}{D}$$
$$= \frac{4 \times 10\ \text{mm} \times 76\ \text{MPa}}{1{,}000\ \text{mm}}$$
$$= 3.04\ \text{MPa}$$

Example	Allowable stress	Spherical pressure vessel	Cylindrical pressure vessel	Conclusion

(b) *Cylindrical shell*

Critical stress in a cylindrical shell is hoop stress, $\sigma = \frac{p\ D}{2t}$, from which maximum allowable pressure in a cylindrical pressure vessel is:

$$\begin{aligned} p &= \frac{2t\,\sigma}{D} \\ &= \frac{2 \times 10\ \text{mm} \times 76\ \text{MPa}}{1{,}000\ \text{mm}} \\ &= 1.52\ \text{MPa} \end{aligned}$$

Example	Allowable stress	Spherical pressure vessel	Cylindrical pressure vessel	Conclusion

Calculate the maximum allowable (safe) pressure for a given container

The spherical pressure vessel can safely operate at a pressure that is twice that of the corresponding cylindrical pressure vessel.

Example	Allowable stress	Spherical pressure vessel	Cylindrical pressure vessel	Conclusion

GIVE FEEDBACK

OK

Calculate the maximum allowable pressure in the spherical pressure vessel.

Clear

Clear line

Undo

Click and type your answer here

CHALLENGE

SUBMIT

SHOW ANSWER

INSTRUCTIONS

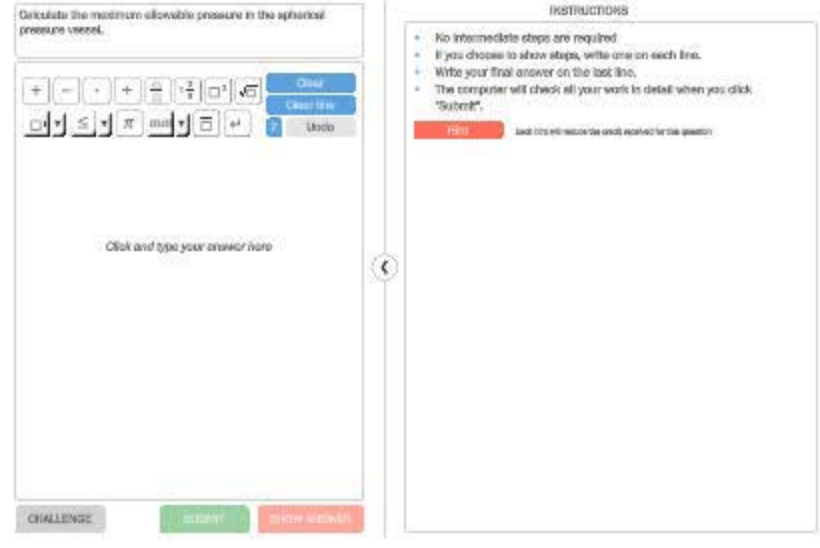
- No intermediate steps are required
- If you choose to show steps, write one on each line.
- Write your final answer on the last line.
- The computer will check all your work in detail when you click "Submit".

Hint

Each hint will reduce the credit received for this question

Given a material design strength of 70 MPa, compare the maximum allowable pressure in spherical and cylindrical pressure vessels of diameter 800 mm and wall thickness 10 mm, assuming 100 per cent joint efficiency in a fully welded construction.

SMALL MEDIUM LARGE



Given a material design strength of 70 MPa, compare the maximum allowable pressure in spherical and cylindrical pressure vessels of diameter 800 mm and wall thickness 10 mm, assuming 100 per cent joint efficiency in a fully welded construction.

SMALL | MEDIUM | LARGE

Calculate the maximum allowable pressure in the cylindrical pressure vessel.

Clear | Undo

Click and type your answer here

CHALLENGE | SUBMIT | SHOW ANSWER

Given a material design strength of 70 MPa, compare the maximum allowable pressure in spherical and cylindrical pressure vessels of diameter 800 mm and wall thickness 10 mm, assuming 100 per cent joint efficiency in a fully welded construction.

SMALL | MEDIUM | LARGE

Type your answer in the box.

The spherical pressure vessel can withstand [ ] the pressure compared to the cylindrical pressure vessel.

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Realistic considerations of producing a pressure vessel

It is apparent that within the specified parameters, the spherical vessel can withstand twice as large a pressure as would be allowed in the cylindrical vessel.

Although theoretically quite valid, this comparison should not be overemphasised.

Other comparisons on the basis of equal volume or equal cost may be more useful.

Practical considerations, such as ease of manufacture and resulting costs, may dictate a search for other alternatives.

For example, it could be easier and cheaper to manufacture a cylindrical vessel. The resultant saving may allow the use of heavier plate for extra strength.

GIVE FEEDBACK

OK

Type your answer in the box.

Although theoretically a spherical vessel can withstand twice as large a pressure as would be allowed in the corresponding cylindrical vessel, other comparisons on the basis of equal _____ or equal _____ may be more useful.

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA