

TRADE OF
Industrial Insulation

PHASE 2

Module 5

Ductwork & Vessels

UNIT: 7

Vessels: Storage & High Pressure

Produced by

SOLAS

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Further Education and Training Authority

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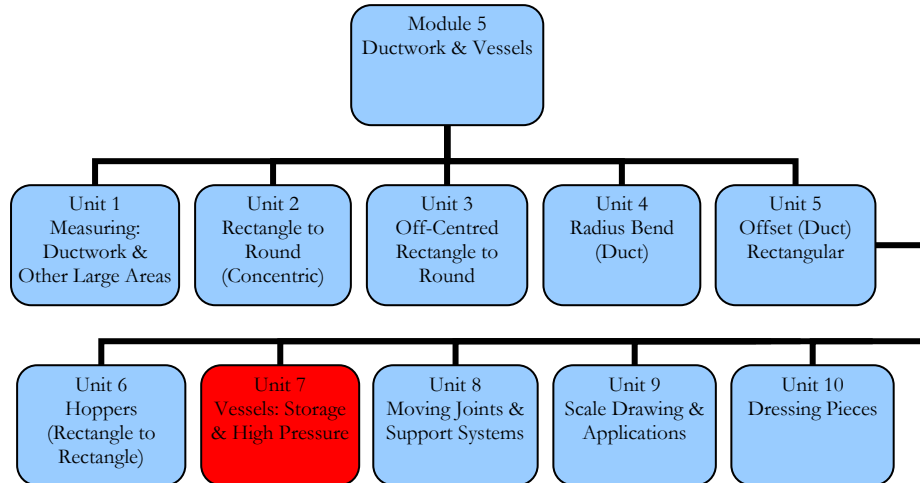
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Introduction

Pressure vessels most often contain fluids, vapours or gases at pressure levels greater than that of atmospheric pressure. Storage vessels/tanks are simple vessels used for storing liquids, solutions or pharmaceutical raw material and other chemicals.



Unit Objective

By the end of this unit *each apprentice* will be able to:

- Differentiate between storage and high pressure vessels.
- Sketch and measure any vessel.
- Measure a raised vessel head and a dished vessel head.
- Calculate areas and volumes of vessels.
- Fabricate a raised vessel head (small scale).
- Fabricate a dished vessel head (small scale).
- Insulate and clad a small vessel including the vessel head.

1.0 Vessels

Key Learning Points

- Difference between storage vessel and pressure vessels
- Standard units of pressure
- Hazards associated with storage and pressure vessels
- Determination of size through accurate measurement and calculations

1.1 Differentiate Between Storage Vessels and Pressure Vessels

Pressure Vessel

Pressure vessels most often contain fluids, vapours or gases at pressure levels greater than that of atmospheric pressure. Pressure vessels contain a wide variety of substances used for various industrial applications including the chemical, pharmaceutical, food and beverage, oil, fuel and plastic industries. The substance contained and the industrial application of the pressure vessels determines such design components as vessel material, size, shape, temperature and pressure level. Vessel creation and maintenance consist of structured steps in which the above factors are determined. When a substance is stored under pressure, the potential for rupture and leakage exists. This risk increases when the substance is toxic or gaseous. Engineers take precautions when creating a pressure vessel to limit the occurrence of vessel failure. The division of vessel creation into steps, which include design, construction, testing and inspection, keeps safety hazards to a minimum.



Steel Pressure Vessel

Storage Vessel

Storage vessels/tanks are simple vessels used for storing liquids, solutions or pharmaceutical raw material and other chemicals. These general purpose vessels made of stainless steel, fibre glass, titanium, galvanised steel etc. and are used by a number of industries to store various substances and solutions. Storage vessels/tanks can either be horizontal or vertical in their orientation. Horizontal storage vessels are generally mounted on stands or saddles and have a access hatch either on the bottom or on the top. Vertical storage vessels are

erected vertically and usually have access ports on the bottom. These specialised vessels can either be placed above or below ground, depending on the construction of the storage facility. The wall thickness of the vessel determines the application and the use of the vessel, while single wall storage vessels can be used for general applications, double walls vessels are generally used for high pressure considerations.

1.2 Standard Units of Pressure

The SI derived unit of pressure is the Pascal (PA). Also used is the pound per square inch (PSI).

1.3 Hazards Associated with Storage and Pressure Vessels

Improperly operated or maintained pressure vessels can fail catastrophically, kill and injure workers and others and cause extensive damage even if the contents are benign. One of the hazards associated with pressure vessels is operating the vessels above their design limits which can lead to catastrophic weld failure, loss of life and major structural damage to plant and buildings. Another possible hazard is the improper operation of relief devices due to faulty maintenance and failure to test regularly. Other possible hazards include:

- Failure of the vessel due to fatigue from repeated pressurization.
- General thinning of the vessel wall due to corrosion or erosion.
- Stress corrosion cracking embrittlement, holes and leaks.
- Failure to inspect on a regular basis.
- Improper repair of a leak or other defect involving welding and annealing that embrittles and further weakens the vessel.

Pressure vessels and storage vessels should be inspected regularly to survey the vessel, review any important history or data on the vessel to identify hazards, and prevent vessel rupture or catastrophic failure.

1.4 Vessel Head Shapes

The end caps on a cylindrically shaped pressure vessel are known as heads. The shape of the heads used can vary. The most common head shapes are:

Hemispherical Head

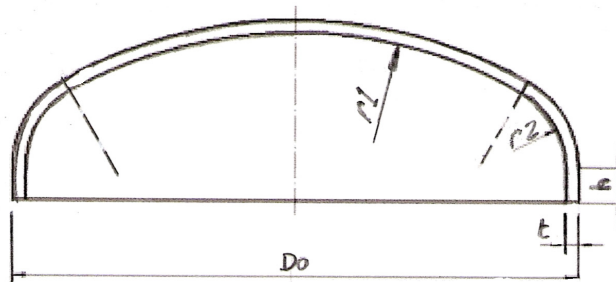
A sphere is an ideal shape for a head, because the pressure in the vessel is divided equally across the surface of the head. The radius (R) of the head equals the radius of the cylindrical part of the vessel.

Ellipsoidal Head

This is also called a 2:1 elliptical head. The shape of this head is more economical, because the height of the head is just a quarter of the diameter. Its radius varies between the major and minor axis.

Torispherical Head

These heads have a dish with a fixed radius (r_1), the size of which depends on the type of torispherical head. The transition between the cylinder and the dish is called the knuckle. The knuckle has a toroidal shape. The most common types of torispherical head is the klopfer head. This is a torispherical head. The dish has a radius that equals the diameter of the cylinder it is attached to ($r_1 = D_0$). The knuckle has a radius that equals a tenth of the diameter of the cylinder ($r_2 = 0.1 D_0$).



Schematic of a torispherical head

1.5 Determination of Size Through Accurate Measurement and Calculations

The tank or vessel is carefully measured to avoid costly errors and mistakes leading to waste of time and materials, financial penalties and or loss of productivity to the contractor.

It is very important to study the tanks or vessels when measuring so as to study their location; where they are situated and their proximity to other obstacles such as walls, ceilings, pipe work and other equipment which may be nearby.

When measuring a tank or vessel, a number of things should be taken into consideration:

- Is there a manufacturer's drawing available that can be used to verify the diameter, size of tank, height of tank, measurements or head details? Is there a drawing available showing the position of vents, connecting pipe work, temperature gauges etc.
- If a drawing is not available the following measurements should be taken in the case of a square or rectangular vessel or tank: (1) length, breadth, height of the vessel, (2) Roof details including the angle of the roof, (3) Position of pipe work connections, (4) Position of walkways around the vessel. In the case of a cylindrical vessel the following measurements should be taken: (1) Circumference of the vessel to determine its diameter, (2) Overall height of the vessel including the head, (3) Detailed measurements of the head and base of the vessel, (4) Position and measurements for connecting pipe work and temperature connections.

It is always a good idea to make a detailed sketch or scaled drawing of the vessel and its features as this will save time when manufacturing and installing the cladding for the vessel. Detailed drawings force you, to a certain extent, to consider different aspects of the job which might otherwise go unnoticed such as;

- Are all the measurements correct and adding up?
- The positions of insulation supports.
- Joint positions in the cladding and their relationship to possible pipe work connections.
- Will sheets have to be joined to fit the measurements of the tank or vessel.

2.0 Drawing, Sketching and Calculating

Key Learning Points

- Sketching of vessels
- Orthographic projection: construction of views
- Calculation of radius from circumference
- Manipulation of formulae
- Tangent lines

2.1 3D Sketching - Isometric Projection, First and Third Angle Projection

Refer to Module 2 – Unit 2 – Orthographic Projections.

2.2 Calculating the Radius from the Circumference

Diameter = Radius x 2 or $D = 2r$.

$\pi = 3.14$

Circumference $\div \pi =$ Diameter Radius = Diameter $\div 2$.

Example: The circumference of a vessel = 9420mm – Find the diameter and the radius of the vessel.

Diameter = Circumference $\div \pi = 9420 \div 3.14 = 3000\text{mm}$

Radius = Diameter $\div 2 = 3000\text{mm} \div 2 = 1500\text{mm}$

2.3 Tangent Line

The tangent line refers to the point of contact (tangency) between the cylinder and the knuckle portion of the vessel head. The distance from the tangent line on one head to the tangent line on the opposite head is known as tangent to tangent or T/T.

2.4 Area and Volume of a Vessel

Example: A vessel is 1.5 metres in diameter and 4 metres long. Find the total surface area of the vessel and the volume of the vessel.

Solution

Surface Area

$\pi = 3.14$ $r =$ radius $d =$ diameter $l =$ length

Area of a circle = πr^2 .

Area of one end of tank = $3.14 \times 0.75^2 = 1.77\text{m}^2$

Area of 2 ends = $1.77\text{m}^2 \times 2 = 3.54\text{m}^2$

Area of cylindrical section of tank = $\pi \times d \times l = 3.14 \times 1.5 \times 4 = 18.84\text{m}^2$.

Total surface area of tank = $3.54 \text{ m}^2 + 18.84 \text{ m}^2 = 22.38\text{m}^2$.

Volume

Volume of tank = $\pi r^2 l = 3.14 \times 0.75^2 \times 4 = 7.06\text{m}^3$



2.5 DIN Vessel Standards

An array of differing national regulations, standards, and codes for pressure vessels has been replaced by a single European directive. The European Union has adopted more than 40 European standards for boilers, pipes and flanges, as well as supporting standards for materials, welding and testing. The latest addition to the approved standards is DIN EN 13445, which covers the design and fabrication of unfired pressure vessels and their parts. The standards cover such areas as:

- Shells under internal pressure.
- Shells under external pressure.
- Alternative methods for the design of flanges and flanged connections.
- Horizontal vessels on saddles.
- Vertical vessels on support brackets.

3.0 Marking Out, Fabrication and Fitting of Insulation to a Small Vessel

Key Learning Points

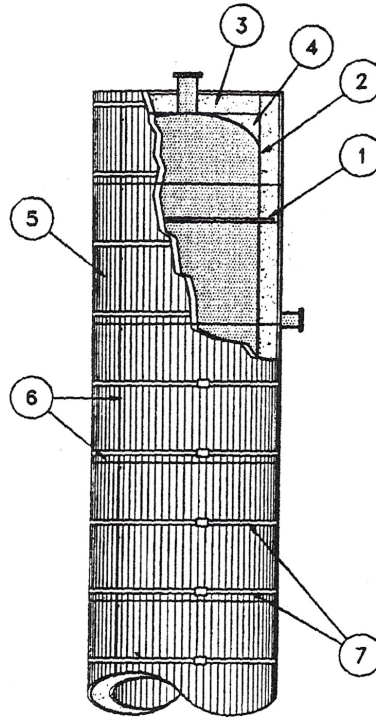
- Pattern Development
- Shearing and swaging
- Flush jointing and crimping
- DIN vessel standards
- Fabrication of dished and raised head vessels
- Sources of data and standards
- Dished and raised head assembly
- Support systems

3.1 Pattern Development – Parallel Line Development

Refer to module 2 – Geometry and pattern development.

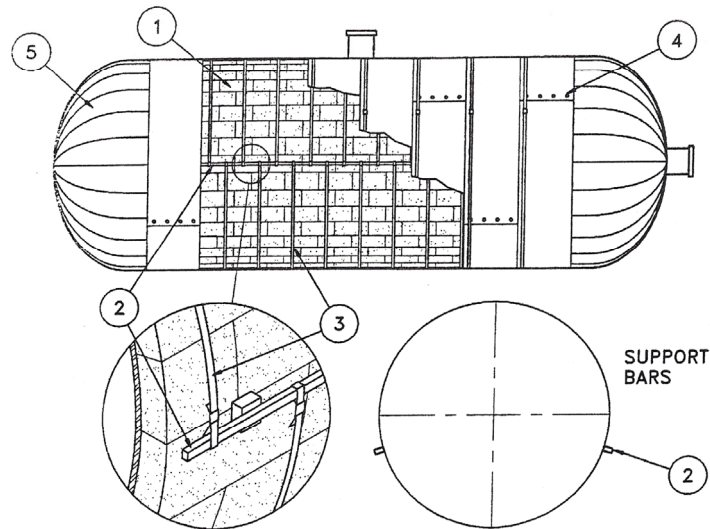
3.2 Accurate Cutting, Forming, Swaging and Assembly of Cladding

After the patterns/sheets have been marked out, they are ready for cutting on the guillotine or power hand shears. Use a hand snips for any notching of the pattern. Once the patterns have been cut out they are now ready to be punched using a hand punch or a multi-linear punching machine. The patterns are then folded, rolled and swaged to suit the piece required. The figure below shows the assembly details of insulation and profiled cladding to a small vessel.



- 1 INSULATION SUPPORT RING (BY OTHERS)
- 2 PIPE INSULATION SECURED WITH BANDS OR WIRE
- 3 RIGID INSULATION CUT TO FIT
- 4 FLEXIBLE INSULATION FILLER
- 5 FINISH JACKET (METAL SHOWN)
- 6 SHEET METAL SCREWS OR POP RIVETS
- 7 BANDING AS REQUIRED

LARGE DIAMETER HORIZONTAL VESSELS INSULATION SUPPORT AND SECUREMENT



- 1 RIGID INSULATION
- 2 BANDING SUPPORT BARS
- 3 BANDING
- 4 FINISH JACKET SECURED WITH BANDING OR SCREWS
- 5 HEAD COVER

All joints in the cladding should be suitably overlapped and arranged to shed water and if the vessel is located outdoors, all joints should be sealed with waterproof mastic.

3.3 Cutting and Fitting of Insulation to a Vessel Using Appropriate Fixings

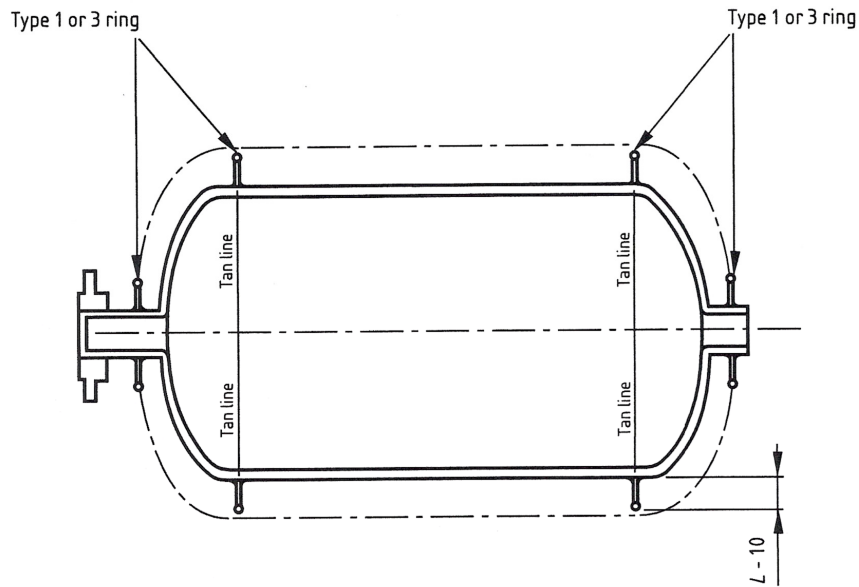
The insulation vessel can be a small or large rectangular or cylindrical tank or vessel, erected in a vertical or horizontal position. The specified insulation of suitable thickness and density is selected and cut to size. It is firmly secured to the vessel with metal bands, adhesive or a combination of both. Alternatively the insulation may be impaled over pins fixed to the surface of the vessel at recommended centres. Location of the pins should be arranged so that there is a pin no more than 50mm from each corner of the insulation. Another method of supporting the insulation on vertical surfaces on larger circular tanks or vessels is to fit circumferential support rings, spaced at distances which will provide adequate support according to the weight of the insulation. The support rings shall protrude from the vessel slightly less than the thickness of the insulation.

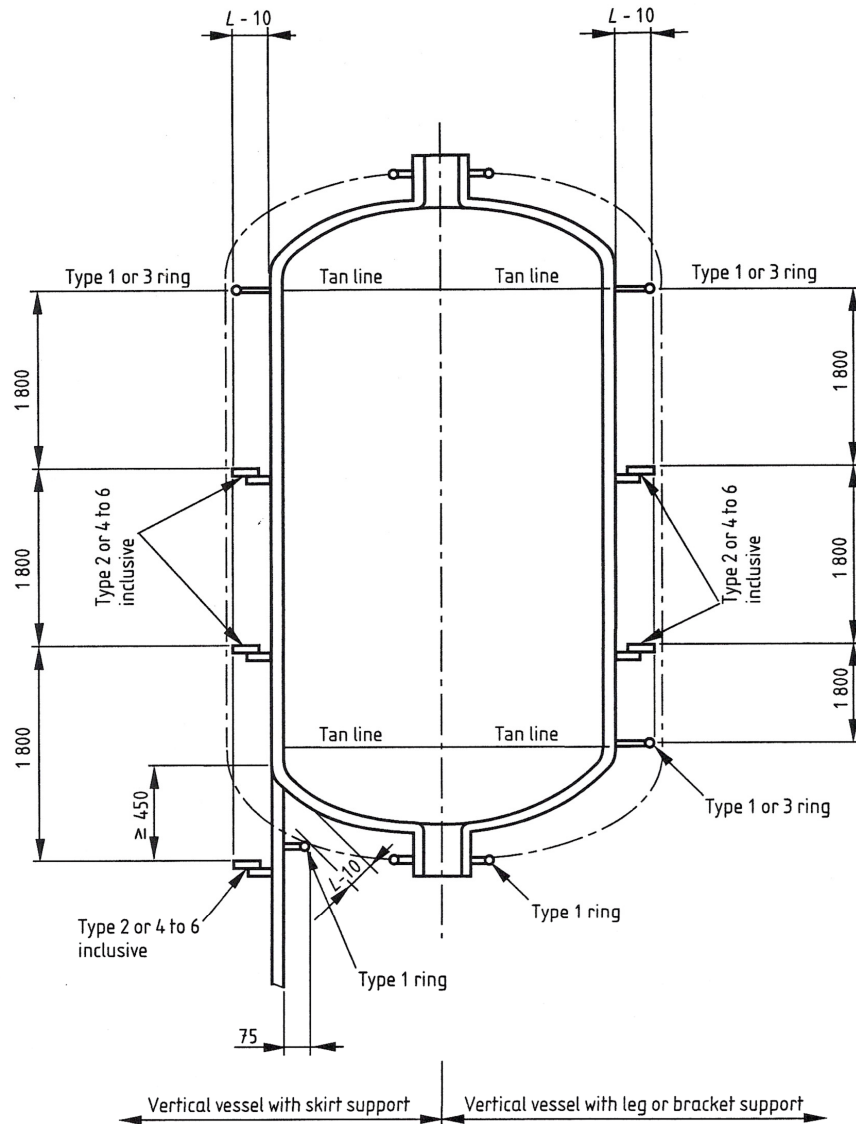
All joints should be closely butted together. Vertical joints (and in multi-layer applications all joints) must be staggered. The corners on rectangular tanks should be overlapped by adjacent slabs to the thickness of the insulation. When using pins with spring clip washers, the length of the pin should be 10mm less than the thickness of the insulation to avoid hot spots on the cladding.

3.4 Support System for Securing Insulation and Cladding

As part of the support system for both the insulation and the cladding on vertical piping, or vertical/downward facing vessels and equipment, attachments such as angle iron and flat bar can be welded to the vessel (usually carried out by the manufacturers' of the vessel or equipment). These attachments provide a secure base for secondary angle rings and other secondary supports. The spacing is determined by the maximum permitted span under wind loading conditions for the cladding used.

L = thickness of insulation.





L = thickness of insulation.

Typical insulation supports for vessels.

3.5 Sources of Data and Standards

There are a number of different sources of information which can be used for general information and specifications such as;

- British Standard BS 5970:2001 – Code of practice for thermal insulation of pipe-work and equipment in the temperature range from -100°C to $+870^{\circ}\text{C}$.
- British Standard BS 5422:2001 – Method of specifying thermal insulating materials for pipes, tanks, vessels, ductwork and equipment operating within a temperature range from -40°C to 700°C .
- Manufacturers Catalogues.
- World Wide Web.

Summary

Pressure vessels contain a wide variety of substances used for various industrial applications including the chemical, pharmaceutical, food and beverage, oil, fuel and plastic industries. When a substance is stored under pressure, the potential for rupture and leakage exists. This risk increases when the substance is toxic or gaseous. Engineers take precautions when creating a pressure vessel to limit the occurrence of vessel failure.

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S O L A S

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