TRADE OF

Pipefitting

PHASE 2

Module 3

Pipe Processes

UNIT: 1

Piping Materials

Produced by

SOLAS

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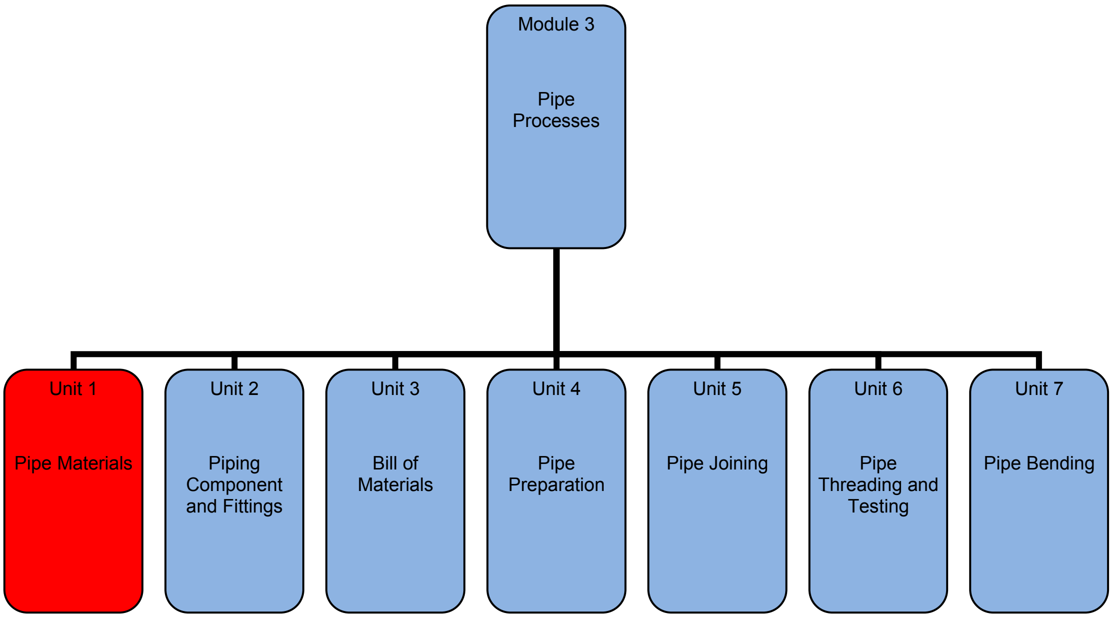
Unit Objective

There are seven Units in Module 3 for Pipe Processes. Unit 1 focuses on Piping Materials, Unit 2; Piping components and fittings, Unit 3; Bill of Materials, Unit 4; Pipe Preparation, Unit 5; Pipe Joining, Unit 6; Pipe threading and testing and Unit 7 Pipe bending.



In this unit you will be introduced to the different Piping materials available to the pipefitting industry, their properties, how they are classified and why they are selected for different applications and services.

Learning Outcome

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

- List and describe the different materials used in the pipe industry
- List and describe how pipes are classified in according with wall thickness, method of manufacture and grades of material.
- Describe pressure ratings of different pipe schedules and grades of material
- Differentiate between pipe and tube and how their diameters are specified:
- Recognise the most commonly used pipe sizes and the standard lengths supplied by manufacturers
- Define some of the physical properties in relation to piping materials
- Identify a selection of alloyed non-ferrous based pipes and explain why they are used for certain applications
- List and describe types and materials used for plastic pipe in the pipe industry and state their uses
- List and describe the types of tube and tubing used in the pipe trades and state the applications of each type of material.

1.0 Introduction to Pipe and Tube

Key Learning Points

- Introduction to pipe and tube
- Identify the differences between pipe and tube
- Identify the common markings for pipe and tube

1.1 Pipe and Tube

A pipe is round tubular section or hollow cylinder used mainly to convey media. It may also be used for structural applications; however in this instance we will concentrate on its use in the process industry. Pipe is generally manufactured to several long-standing and broadly applicable industrial standards. While similar standards exist for specific industry application tubing, tube is often made to custom sizes and a broader range of diameters and tolerances. Many industrial and government standards exist for the production of pipe and tubing. The term "tube" is also commonly applied to non-cylindrical sections (i.e. square or rectangular tubing).

1.2 Difference Between Pipe and Tube

In general terms the appellations pipe and tube are almost interchangeable, but in the pipe fitting industry and engineering discipline the terms are uniquely defined.

Pipe

Depending on the applicable standard to which it is manufactured, pipe is specified by the internal diameter (ID) and a wall thickness, the inside diameter called the nominal diameter may not exactly match the pipe size as it varies with the wall thickness. For example the ID of an 8” pipe varies from 213.54mm ID for Sch5 pipe to 193.68mm for Sch40 pipe.

Tube

Tube is most often defined by the outside diameter (OD) and a wall thickness. Therefore 8” tube would have an outside diameter of 203.2mm.

1.3 Markings on Pipe and Tube

As there are many different types of pipe and tube and different standards that are applicable for each, it is not possible to give a definitive list of the exact information required to be marked on pipe and tube; however the common requirements would be as follows and should be continuously marked down its whole length:

- Nominal Pipe Size (Nominal Bore)
- Schedule (Wall Thickness)
- Specification
- Grade
- Method of Manufacture (Seamless or Welded)
- Heat Number
- Manufacturer's Name or Symbol

2.0 Manufacture of Pipe and Tube

Key Learning Points

- Describe the basic methods of how pipe and tube are made
- Identify the finishing process that pipe and tube undergo
- Identify the type of non destructive testing that pipe and tube undergo

2.1 How Pipe and Tube are Made

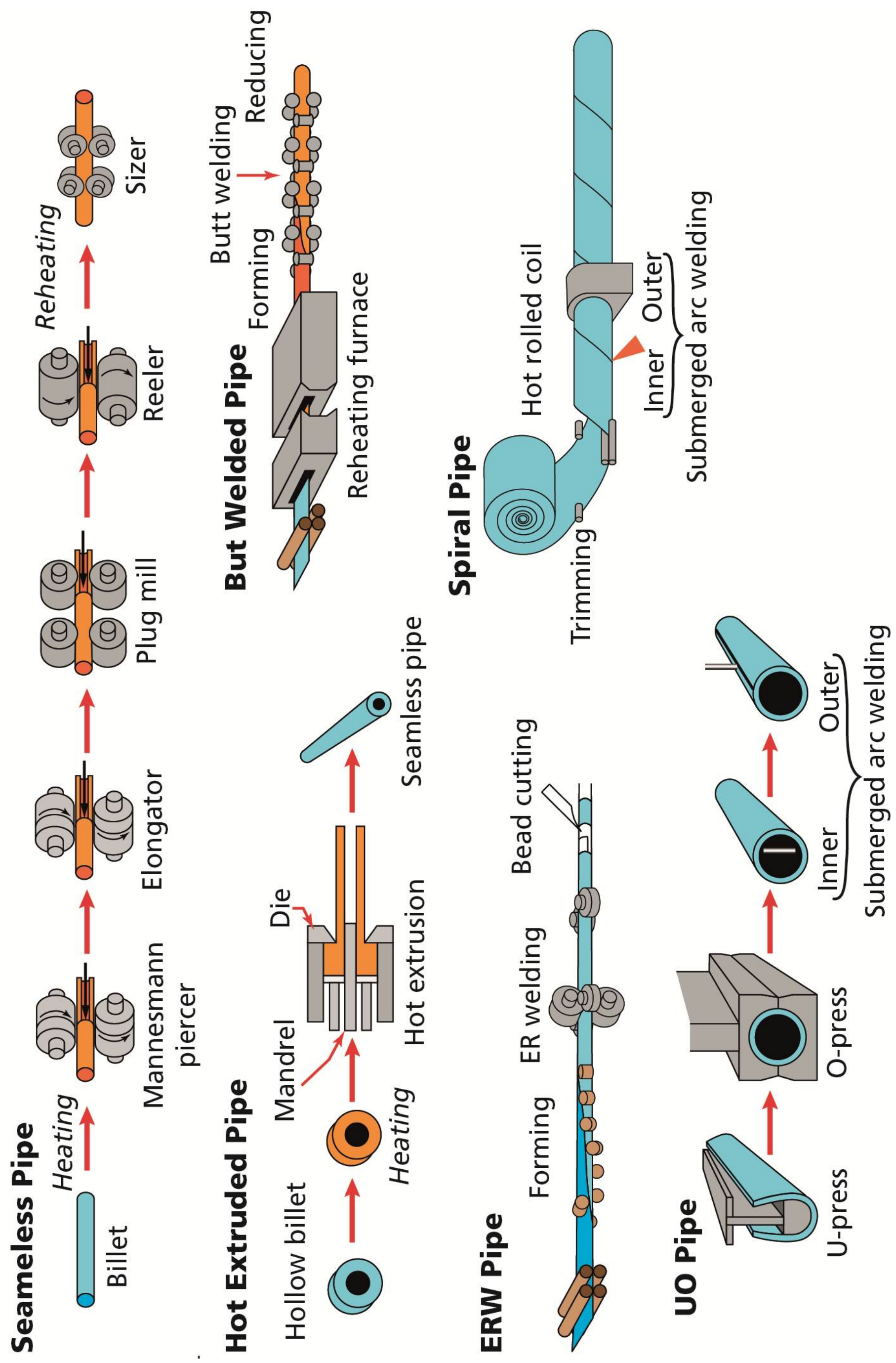
There are two main processes for metallic pipe manufacture. Seamless (SMLS) pipe is formed by drawing a solid billet over a piercing rod to create the hollow shell. Seamless pipe is generally more expensive to manufacture but provides higher pressure ratings. Welded pipe is formed by rolling plate and welding the seam. The weld seam is formed by Electric Resistance Welded (ERW) or Electric Fusion Welded (EFW) and is usually ground flush with the parent material as part of the manufacturing process. The weld zone can also be heat treated, so the seam is less visible. Welded pipe often has tighter dimensional tolerances than seamless, and can be cheaper if manufactured in large quantities. Large diameter pipe (about 10” or greater) may be ERW, or Submerged Arc Welded (SAW) pipe. Metal tubing due to the thinner wall thickness can be extruded but not always and many sanitary tubes such as hygienic stainless steel has a welded seam. Plastics are generally extruded due to the ease of handling the base materials. The illustration below shows the different ways that pipe are manufactured:

2.2 Finishing Processes for Pipe and Tube

There are limitations to the hot manufacturing processes for pipe and tube such as:

- Small diameters are impracticable
- Thin walls are difficult to obtain
- Tolerances are difficult to control
- Mechanical properties cannot be controlled adequately
- The surface finish on both the OD and the ID are rough
- Sophisticated shapes are not possible

For these reasons pipe and tube are cold worked after extrusion or seam welding.



Methods of forming Pipe and Tube

2.3 Non Destructive Tests for Pipe and Tube

Non-destructive tests do not damage the pipe or tube being tested and so they are frequently incorporated into the end of the production line. The following give a brief explanation of the common types of NDT available:

Ultrasonic Testing

This test involves ultrasonic sound waves being aimed, via a coupling medium, at the material to be tested. A proportion is bounced back at the interface but the remainder enter the material and bounce from the internal surface, to the external surface, where a transducer converts them into electrical energy. This is then monitored on a cathode ray tube where results are compared with those from a calibration standard. Any deviations from the standard are visible, thus indicating cracks or internal defects.

Eddy-Current Testing

This involves inducing eddy currents into the material by exciting a coil which surmounts two narrow search coils surrounding the material. Any discontinuities in material are found by comparing the electrical conditions that exist in the two search coils. The fault signals are amplified and can be shown on a cathode ray tube or as an audible signal.

Hydrostatic Testing

This is used to test the manufactured items under a pressure equivalent to or greater than pressure to be encountered in service. It involves filling the tube with water, which cannot be compressed, and increasing the pressure inside the tube to that specified.

Magnetic Particle Testing

This method of testing is used when trying to detect discontinuities in material of ferromagnetic structure. The method is based on the principle that an imperfection will cause a distortion in the magnetic field pattern of a magnetised component. The imperfection can be revealed by applying magnetic particles to the component during or after magnetisation.

Radiographic (X-Ray) Testing

This is usually used to determine whether a weld is sound. It involves subjecting a weld or weld area to an X-Ray source with an X-Ray sensitive film plate on the under side of the weld. The results are shown on the developed film (a photomicrograph) and interpreted according to specification.

Dye-Penetrant Test

This is used to detect cracks and involves spraying a dye on the area to be tested. After allowing time for penetration the surplus dye is removed and the area is then sprayed with a white developer. Any faults are revealed as coloured lines or spots caused by the developer absorbing the dye seeping from the cracks. If more sensitive results are required, a fluorescent dye is used and the same process is followed. When viewed under ultraviolet light any defects show as a highly fluorescent line or spot.

3.0 Materials Used for Pipe and Tube

Key Learning Points

- Identify common materials used for pipe and tube
- Identify why different materials are used
- Identify the different properties of materials used for pipe and tube
- Identify different uses for the different materials

3.1 Different Materials Used for Pipe and Tube

Pipe may be made from a variety of materials. In the past, materials have included wood and lead (Latin for lead is plumbum, from which we get the word plumbing). Nowadays the manufacturing of pipe uses many different materials including ceramics, fiberglass, concrete, plastics and metals.

- Concrete and ceramic
- Plastic
- Metals
- special piping materials such as glass or lined pipe

3.2 Concrete and Ceramic Pipes

Pipes may be made from concrete or ceramic materials. These pipes are usually used for low pressure applications such as gravity flow or drainage underground. Concrete pipes usually have a receiving bell or a stepped fitting, with various sealing methods applied at installation. Ceramic pipes are used for underground drainage which may be exposed to corrosive chemicals. These types of pipes are relatively inexpensive for the diameters in question and allow for ease of installation in rough site conditions.

3.3 Plastic Pipes

Plastic tubing is widely used for its light weight, chemical resistance, non-corrosive properties, and ease of making connections. Plastic materials include polyvinyl chloride (PVC), chlorinated polyvinyl chloride (CPVC), fibre reinforced plastic (FRP), reinforced polymer mortar (RPMP), polypropylene (PP), polyethylene (PE), cross-linked high-density polyethylene (PEX), polybutylene (PB), and acrylonitrile butadiene styrene (ABS), for example.

3.4 Metal Pipes and Tubes

Metallic pipes are commonly made from steel or iron; the metal chemistry and its finish are peculiar to the use fit and form. Typically metallic piping may be made of steel or iron, such as unfinished, black (lacquer) steel, carbon steel, stainless steel or galvanized steel, brass, and ductile iron. Aluminium pipe or tubing may be utilized where iron is incompatible with the service fluid or where weight is a concern; aluminium is also used for heat transfer tubing such as in refrigerant systems. Copper tubing is popular for domestic water (potable) plumbing systems; copper may be used where heat transfer is desirable (i.e. radiators or heat exchangers). Inconel, chrome moly, and titanium steel alloys are used for high temperature and pressure piping in process systems where corrosion resistance is important.

3.5 Stainless Steel Pipes and Tubes

Stainless steel pipe and tubing are used for a variety of reasons: to resist corrosion and oxidation, to resist high temperatures, for cleanliness and low maintenance costs, and to maintain the purity of materials which come In contact with stainless. There are more than 60 grades of stainless steel available. The ability of stainless steel to resist corrosion is achieved by the addition of a minimum of 12% chromium to the iron alloy. Additions of other elements affect other properties. The inherent characteristics of stainless steel permit the design of thin wall piping systems without fear of early failure due to corrosion. Because of the thinner wall thickness of stainless steel tube it is not possible to thread tube therefore this was overcome by fusion welding to join such pipe and tubing.

Type 304 stainless is the most widely used analysis for general corrosive resistant tubing and pipe applications, it is used in chemical plants, refineries, paper mills, and food processing industries. Type 304 has a maximum carbon content of .08%. It is not recommended for use in the temperature range between 400°C and 900°C due to carbide precipitation at the grain boundaries which can result in inter-granular corrosion and early failure under certain conditions.

Type 304L. Is the same as 304 except that a 0.03% maximum carbon content is maintained which precludes carbon precipitation and permits the use of this analysis in welded assemblies under more severe corrosive conditions. Type 318 is much more resistant to pitting than other chromium nickel alloys due to the addition of 2% to 3% molybdenum. it is particularly valuable wherever acids, brines, sulphur water, seawater or halogen salts are encountered. Type 316 is widely used in the sulphite paper industry and for manufacturing chemical plant apparatus, photographic equipment, and plastics. Type 316L, like 304L, is held to a maximum carbon content of .03%. This permits its use in welded assemblies without the need of final heat treatment. It is used extensively for pipe assemblies with welded fitting.

3.6 Material Traceability

Manufacturing standards for pipes commonly require a test of chemical composition and a series of mechanical strength tests for each heat of pipe. A heat of pipe is all forged from the same cast ingot, and therefore had the same chemical composition. Mechanical tests may be associated to a lot of pipe, which would be all from the same heat and have been through the same heat treatment processes. The manufacturer performs these tests and reports the composition in a mill traceability report and the mechanical tests in a material test report, both of which are referred to by the acronym MTR. Material with these associated test reports is called traceable. For critical applications, third party verification of these tests may be required; in this case an independent lab will produce a certified material test report (CMTR), and the material will be called certified. By etching the heat number on the components made from this batch of material, it ensures that there is full traceability from the component to the material certificate and therefore the chemical composition of the component is known.

Maintaining the traceability between the material and this paperwork is an important quality assurance issue. QA often requires the heat number to be written on the pipe. Precautions must also be taken to prevent the introduction of counterfeit materials. As a back up to etching/labelling of the material identification on the pipe, Positive Material Identification (PMI) is performed using a handheld device; the device scans the pipe material using an emitted electromagnetic wave (x-ray fluorescence/XRF) and receives a reply that is spectrographically analysed.

4.0 Classification of Pipes Sizes

Key Learning Points

- Identify different specifications
- Customer specifications

4.1 Introduction to Pipe Sizes

Pipe sizes can be confusing because the terminology may relate to historical dimensions. For example, a half-inch iron pipe doesn't have any dimension that is a half inch. Initially, a half inch pipe did have an internal dimension of 0.5" but it also had thick walls. As technology improved, the wall thickness got thinner (saving material costs), but the outside diameter stayed the same so it could mate with existing older pipe. The history of copper pipe is similar. In the 1930s, the pipe was designated by its internal diameter and a 1/16" wall thickness. Consequently, a 1" copper pipe would have a 1 1/8" outside diameter. The outside diameter was the important dimension for mating with fittings. The wall thickness on modern copper is usually thinner than 1/16", so the internal diameter is only "nominal" rather than a controlling dimension. Newer pipe technologies sometimes adopted a sizing system as it's own. PVC pipe uses the nominal pipe size.

4.2 Nominal Pipe Size and Nominal Diameter Pipe Size

Nominal Pipe Size (NPS) is a North American set of standard sizes for pipes used for high or low pressures and temperatures. Pipe size is specified with two non-dimensional numbers: a nominal pipe size (NPS) based on inches, and a schedule (Sch.) which specifies the wall thickness. The European designation equivalent to NPS is DN (Diamètre Nominal/nominal diameter), in which sizes are measured in millimetres. The term NB (nominal bore) is also frequently used interchangeably with NPS. Designating the outside diameter allows pipes of the same size to be fit together no matter what the wall thickness.

Pipe sizes are documented by many different international standards, including some of the following:

- DIN EN 10217-7 / DIN EN 10216-5
- BS EN 10255 in the United Kingdom and Europe.
- API Range Eg: API 5L Grade B
- ASME SA106 Grade B (Seamless carbon steel pipe for high temperature service)
- ASTM A312 (Seamless and welded austenitic stainless steel pipe)
- ASTM C76 (Concrete Pipe)
- ASTM D3033/3034 (PVC Pipe)
- ASTM D2239 (Polyethylene Pipe)

4.3 International Standards for Pipe Sizes

- **For pipe sizes less than DN 350 (NPS 14"),** both methods give a nominal value for the OD that is rounded off and is not the same as the actual OD. For example, NPS 2" and DN 50 are the same pipe, but the actual OD is 2.375", or 60.325mm. The only way to obtain the actual OD is to look it up in a reference table.
- **For pipe sizes of DN 350 (NPS 14") and greater** the NPS size is the actual diameter in inches and the DN size is equal to NPS times 25 rounded to a convenient multiple of 50. For example, NPS 14" has an OD of 14", or 355.6mm, and is equivalent to DN 350.

Since the outside diameter is fixed for a given pipe size, the inside diameter will vary depending on the wall thickness of the pipe. For example, 2" Schedule 80 (or Sch 80) pipe has thicker walls and therefore a smaller inside diameter than 2" Schedule 40 pipe. The table below lists the dimensions for 1/8" to 3" Pipe in both inches and millimetres and gives the different wall thicknesses for the different schedules.

NPS Inches	DN mm	OD Inches (millimetres)	Wall Thickness - inches (millimetres)			
			SCH 5	SCH 10	SCH 40	SCH 80
⅛	6	0.405 in (10.29 mm)	0.035 in (0.889 mm)	0.049 in (1.245 mm)	0.068 in (1.727 mm)	0.095 in (2.413 mm)
¼	8	0.540 in (13.72 mm)	0.049 in (1.245 mm)	0.065 in (1.651 mm)	0.088 in (2.235 mm)	0.119 in (3.023 mm)
⅜	10	0.675 in (17.15 mm)	0.049 in (1.245 mm)	0.065 in (1.651 mm)	0.091 in (2.311 mm)	0.126 in (3.200 mm)
½	15	0.840 in (21.34 mm)	0.065 in (1.651 mm)	0.083 in (2.108 mm)	0.109 in (2.769 mm)	0.147 in (3.734 mm)
¾	20	1.050 in (26.67 mm)	0.065 in (1.651 mm)	0.083 in (2.108 mm)	0.113 in (2.870 mm)	0.154 in (3.912 mm)
1	25	1.315 in (33.40 mm)	0.065 in (1.651 mm)	0.109 in (2.769 mm)	0.133 in (3.378 mm)	0.179 in (4.547 mm)
1¼	32	1.660 in (42.16 mm)	0.065 in (1.651 mm)	0.109 in (2.769 mm)	0.140 in (3.556 mm)	0.191 in (4.851 mm)
1½	40	1.900 in (48.26 mm)	0.065 in (1.651 mm)	0.109 in (2.769 mm)	0.145 in (3.683 mm)	0.200 in (5.080 mm)
2	50	2.375 in (60.33 mm)	0.065 in (1.651 mm)	0.109 in (2.769 mm)	0.154 in (3.912 mm)	0.218 in (5.537 mm)
2½	65	2.875 in (73.02 mm)	0.083 in (2.108 mm)	0.120 in (3.048 mm)	0.203 in (5.156 mm)	0.276 in (7.010 mm)
3	80	3.500 in (88.90 mm)	0.083 in (2.108 mm)	0.120 in (3.048 mm)	0.216 in (5.486 mm)	0.300 in (7.620 mm)

4.4 Pipe Sizes for Other Materials

While steel pipe has been produced for about 150 years, newer pipe materials such as PVC and galvanized pipe adopted the older steel pipe dimension conventions. Many different standards exist for pipe sizes, and their prevalence varies depending on industry and geographical area. The pipe size designation generally includes two numbers; one that indicates the outside (OD) or nominal diameter, and the other that indicates the wall thickness. In the early twentieth century, American pipe was sized by inside diameter. This practice was abandoned to improve compatibility with pipe fittings that must usually fit the OD of the pipe, but it has had a lasting impact on modern standards around the world.

4.5 Sizes for Copper Tube

Copper tubing was introduced in about 1900, but didn't become popular until approximately 1950, depending on local building code adoption. Copper plumbing tube for residential plumbing follows an entirely different size system, often called Copper Tube Size (CTS); see table below. It's nominal size is neither the inside nor outside diameter. Plastic tubing, such as PVC and CPVC, for plumbing applications also has different sizing standards. Common wall-thicknesses of copper tubing are "Type K", "Type L" and "Type M"

- Type K has the thickest wall section of the three types of pressure rated tubing and is commonly used for deep underground burial such as under sidewalks and streets, with a suitable corrosion protection coating or continuous polyethylene sleeve as required by code.
- Type L has a thinner pipe wall section, and is used in residential and commercial water supply and pressure applications.
- Type M has the thinnest wall section, and is generally suitable for condensate and other drains, but sometimes illegal for pressure applications, depending on local codes.

Nominal size	Outside diameter (OD) (inches)	Inside diameter (ID) (inches)		
		Type K	Type L	Type M
3/8	1/2	0.402	0.43	0.45
1/2	5/8	0.528	0.545	0.569
5/8	3/4	0.652	0.668	0.69
3/4	7/8	0.745	0.785	0.811
1	1 1/8	0.995	1.025	1.055
1 1/4	1 3/8	1.245	1.265	1.291
1 1/2	1 5/8	1.481	1.505	1.527
2	2 1/8	1.959	1.985	2.009
2 1/2	2 5/8	2.435	2.465	2.495
3	3 1/8	2.907	2.945	2.981

Sizes for copper tubes

Types K and L are generally available in both hard drawn "sticks" and in rolls of soft annealed tubing, whereas type M is usually only available in hard drawn "sticks". Thin-walled types used to be relatively inexpensive, but since 2002 copper prices have risen considerably due to rising global demand and a stagnant supply.

In the plumbing trade the size of copper tubing is measured by its nominal diameter (average inside diameter). Some trades, heating and cooling technicians for instance, use the outside diameter (OD) to designate copper tube sizes. The HVAC tradesman also use this different measurement to try and not confuse water pipe with copper pipe used for the HVAC trade, as pipe used in the Air-conditioning trade uses copper pipe that is made at the factory without processing oils that would be incompatible with the oils used to lubricate the compressors in the AC system. The OD of copper tube is always 1/8th inch larger than its nominal size. Therefore, 1" nominal copper tube and 1-1/8th" ACR tube are exactly the same tube with different size designations. The wall thickness of the tube, as mentioned above, never affects the sizing of the tube. Type K 1/2" nominal tube, is the same size as Type L 1/2" nominal tube (5/8" ACR).

4.6 Sizes for Stainless Steel Tube

Stainless steel pipes, which were coming into more common use in the mid 20th century, permitted the use of thinner pipe walls with much less risk of failure due to corrosion. This led to the development of stainless steel tubing, which due to it's thinner wall it could not be threaded together according to the ASME code, and therefore was fusion welded.

This led to the development of a range of hygienic stainless steel tube and fittings which could be used in applications requiring a clean and sanitary flow of liquids and where it is essential to avoid contamination of the products being carried. These applications cover the food processing, beverage, biotech and pharmaceutical industries including breweries and dairies.

- The applications are low pressure with a maximum of 10 Bar.
- The products are available in grades 304L and-316L.
- The size range is from ½"to 6 inch O/D.

The tube and fittings are of welded construction with the internal bead rolled and polished to eliminate crevices, thus preventing interruptions to the flow and eliminating the risk of contamination or bug traps as well as facilitate easy cleaning.

Hygienic tube and fittings are manufactured to the following standards including:

- ASTM A270
- ASME BPE for pharmaceutical tube applications
- DIN 11850
- ISO 2037
- BS 4825 Part 1

Hygienic fittings are manufactured to

- BS 4825 Parts 2 to 5.
- ASME BPE for pharmaceutical tube applications

O/D	Wall		Weight
In	swg	mm	kg/m
3/4	16	1.63	0.70
1	16	1.63	0.99
11/2	16	1.63	1.51
2	16	1.63	1.88
21/2	16	1.63	2.49
3	16	1.63	3.01
4	16	1.63	4.03
4	14	2.03	4.98

Sizes and weights for DN11850 Tube

O/D	Wall	Weight
in	mm	kg/m
1	1.5	0.90
11/2	1.5	1.38
2	1.5	1.85
21/2	1.5	2.34
3	1.5	2.81
4	2.0	5.02

Sizes and weights for ASTM 270 Tube

5.0 Pressure Ratings for Pipes and Tubes

Key Learning Points

- Identify why pipe and tube is classified as pressure rated
- Identify how to calculate the wall thickness required for a set pressure

5.1 Pressure Ratings for Pipe and Tube

The manufacture and installation of pressure piping is tightly regulated by the ASME "B31" code series such as B31.1 or B31.3 which have their basis in the ASME Boiler and Pressure Vessel Code. This code has the force of law in Canada and the USA. Europe has an equivalent system of codes. Pressure piping is generally classified as pipe that must carry pressures greater than 10 to 25 atmospheres, although definitions vary. To ensure safe operation of the system, the manufacture, storage, welding, testing, etc. of pressure piping must meet stringent quality standards.

In Europe, pressure piping uses the same pipe IDs and wall thicknesses as Nominal Pipe Size, but labels them with a metric Diameter Nominal (DN) instead of the imperial NPS. For NPS larger than 14, the DN is equal to the NPS multiplied by 25. (Not 25.4) This is documented by EN 10255 (formerly DIN 2448 and BS 1387) and ISO 65, and it is often called DIN or ISO pipe. In North America and the UK, pressure piping is usually specified by Nominal Pipe Size (NPS) and schedule (SCH). Pipe sizes are documented by a number of standards, including API 5L, ANSI/ASME B36.10M in the US, and BS 1600 and BS 1387 in the United Kingdom. Typically the pipe wall thickness is the controlled variable, and the Inside Diameter (I.D.) is allowed to vary. The pipe wall thickness has a variance of approximately 12.5 percent.

5.2 Wall Thickness Calculations for Straight Pipe Under Internal Pressure

The following equations and tables are based on those provided in the Process Piping Specification, ASME B31.3a-2008, ASME Code for Pressure Piping. There are four equations which may be used to calculate the 'pressure design wall thickness' (t) of a straight pipe subject to internal pressure, two of which are given as follows:

$$t = \frac{PD}{2(SE + PY)} \qquad t = \frac{PD}{2SE}$$

where:

- t = Pressure design thickness
- d = Inside diameter of pipe. For pressure design calculation, the inside diameter of the pipe is the maximum value allowable under the purchase specification.
- P = Internal design pressure.
- D = Outside diameter pipe as listed in tables of standards or specifications or as measured.
- Y = Coefficient from "Values of coefficient 'Y' for t<D/6" given in the table below.
- S = Stress value for material "Basic allowable stresses 'S' in tension for stainless steels" given in the table below.
- E = Quality factor, taken from the table below, "Basic quality factors 'E' for longitudinal weld joints in stainless steel pipes, tubes and fittings".
- The equations assume t<D/6 (for pipe with t >D/6 or P/SE >0.385 additional factors need to be considered).

Materials	**Temperature, °F (°C)**					
	≤900 (≤482)	950 (510)	1000 (538)	1050 (566)	1100 (593)	≥1150 (≥621)
	Y					
Ferritic Steels	0.4	0.5	0.7	0.7	0.7	0.7
Austenitic Steels	0.4	0.4	0.4	0.4	0.5	0.7
Cast Iron	0.0	-	-	-	-	-

Values of coefficient 'Y' for t<D/6

ASTM Spec No.	Grade	Min Temp °F (for °C see Notes)	Metal Temperature, °F (°C)										Notes
			Min Temp to 100 (37.8)	300 (149)	500 (260)	700 (371)	850 (454)	1000 (538)	1150 (621)	1300 (704)	1400 (760)	1500 (816)	
			Basic Allowable Stress, S ksi										
A312	TP321	-325	16.7	16.7	16.1	14.6	14.0	13.5	5.0	1.7	0.8	0.3	1, 2
A376	TP321	-325	16.7	16.7	16.1	14.6	14.0	13.5	5.0	1.7	0.8	0.3	1, 2
A269	TP304L	-425	16.7	16.7	14.8	13.5	12.8	7.8	4.0	2.1	1.1	0.9	2, 3
A312	TP304L	-425	16.7	16.7	14.8	13.5	12.8	7.8	4.0	2.1	1.1	0.9	-
A358	304L	-425	16.7	16.7	14.8	13.5	12.8	7.8	4.0	2.1	1.1	0.9	2
A269	TP316L	-325	16.7	16.7	14.4	12.9	12.1	11.2	8.8	3.5	1.8	1.0	2, 3
A312	TP316L	-325	16.7	16.7	14.4	12.9	12.1	11.2	8.8	3.5	1.8	1.0	-
A358	316L	-325	16.7	16.7	14.4	12.9	12.1	11.2	8.8	3.5	1.8	1.0	2
A312	TP321	-325	16.7	16.7	16.1	14.6	14.0	13.5	6.9	3.2	1.9	1.1	1, 2, 4
A376	TP321	-325	16.7	16.7	16.1	14.6	14.0	13.5	6.9	3.2	1.9	1.1	1, 2, 4
A312	TP321H	-325	16.7	16.7	16.1	14.6	14.0	13.5	6.9	3.2	1.9	1.1	1, 2
A376	TP321H	-325	16.7	16.7	16.1	14.6	14.0	13.5	6.9	3.2	1.9	1.1	-
A268	TP409	-20	20.0	-	-	-	-	-	-	-	-	-	6
A268	TP430Ti	-20	20.0	-	-	-	-	-	-	-	-	-	6, 7
A376	16-8-2H	-325	20.0	-	-	-	-	-	-	-	-	-	5, 6,8
A268	TP405	-20	20.0	17.7	17.2	16.2	10.4	4.0	-	-	-	-	6
A268	TP410	-20	20.0	17.7	17.2	16.2	10.4	6.4	1.8	-	-	-	6
A268	TP430	-20	20.0	19.6	19.0	17.6	10.4	6.5	2.4	-	-	-	6, 7
A312	TP317L	-325	20.0	20.0	17.7	16.2	15.2	-	-	-	-	-	-
A312	TP310	-325	20.0	20.0	20.0	18.3	14.6	11.0	3.6	0.8	0.4	0.2	4, 6, 10
A358	310S	-325	20.0	20.0	20.0	18.3	14.6	11.0	3.6	0.8	0.4	0.2	2, 4, 5, 6
A409	TP310	-325	20.0	20.0	20.0	18.3	14.6	11.0	3.6	0.8	0.4	0.2	2, 4, 5, 6, 10
A312	TP321	-325	20.0	20.0	19.3	17.5	16.7	16.2	5.0	1.7	0.8	0.3	1
A358	321	-325	20.0	20.0	19.3	17.5	16.7	16.2	5.0	1.7	0.8	0.3	1, 2
A376	TP321	-325	20.0	20.0	19.3	17.5	16.7	16.2	5.0	1.7	0.8	0.3	1, 2
A409	TP321	-325	20.0	20.0	19.3	17.5	16.7	16.2	5.0	1.7	0.8	0.3	1, 2
A312	TP309	-325	20.0	20.0	20.0	18.3	14.6	10.5	5.0	2.3	1.3	0.7	4, 6, 10
A358	309S	-325	20.0	20.0	20.0	18.3	14.6	10.5	5.0	2.3	1.3	0.7	4, 5, 6, 2
A409	TP309	-325	20.0	20.0	20.0	18.3	14.6	10.5	5.0	2.3	1.3	0.7	2, 4, 5, 6, 10
A312	TP347	-425	20.0	20.0	19.9	18.6	18.2	18.0	6.1	2.2	1.2	0.8	-
A358	347	-425	20.0	20.0	19.9	18.6	18.2	18.0	6.1	2.2	1.2	0.8	1, 2
A376	TP347	-425	20.0	20.0	19.9	18.6	18.2	18.0	6.1	2.2	1.2	0.8	1, 2
A409	TP347	-425	20.0	20.0	19.9	18.6	18.2	18.0	6.1	2.2	1.2	0.8	1, 2
A312	TP348	-325	20.0	20.0	19.9	18.6	18.2	18.0	6.1	2.2	1.2	0.8	-
A358	348	-325	20.0	20.0	19.9	18.6	18.2	18.0	6.1	2.2	1.2	0.8	1, 2
A376	TP348	-325	20.0	20.0	19.9	18.6	18.2	18.0	6.1	2.2	1.2	0.8	1, 2
A409	TP348	-325	20.0	20.0	19.9	18.6	18.2	18.0	6.1	2.2	1.2	0.8	1, 2
A312	TP310	-325	20.0	20.0	20.0	18.3	14.6	11.0	7.3	3.5	1.6	0.8	4, 6, 10, 11
A358	310S	-325	20.0	20.0	20.0	18.3	14.6	11.0	7.3	3.5	1.6	0.8	2, 4, 5, 6, 11
A430	FP321	-325	20.0	20.0	19.3	17.5	16.7	16.2	6.9	3.2	1.9	1.1	1, 2
A312	TP321	-325	20.0	20.0	19.3	17.5	16.7	16.2	6.9	3.2	1.9	1.1	1, 4
A358	321	-325	20.0	20.0	19.3	17.5	16.7	16.2	6.9	3.2	1.9	1.1	1, 2, 4
A376	TP321	-325	20.0	20.0	19.3	17.5	16.7	16.2	6.9	3.2	1.9	1.1	1, 2, 4
A409	TP321	-325	20.0	20.0	19.3	17.5	16.7	16.2	6.9	3.2	1.9	1.1	1, 2, 4
A430	FP321H	-325	20.0	20.0	19.3	17.5	16.7	16.2	6.9	3.2	1.9	1.1	1, 2
A376	TP321H	-325	20.0	20.0	19.3	17.5	16.7	16.2	6.9	3.2	1.9	1.1	1, 2
A312	TP321H	-325	20.0	20.0	19.3	17.5	16.7	16.2	6.9	3.2	1.9	1.1	-
A430	FP316	-425	20.0	20.0	17.9	16.3	15.7	15.3	9.8	4.1	2.3	1.3	2, 5, 8
A430	FP316H	-325	20.0	20.0	17.9	16.3	15.7	15.3	9.8	4.1	2.3	1.3	2, 5, 8

A269	TP316	-425	20.0	20.0	17.9	16.3	15.7	15.3	9.8	4.1	2.3	1.3	2, 3, 4, 5, 8
A312	TP316	-425	20.0	20.0	17.9	16.3	15.7	15.3	9.8	4.1	2.3	1.3	4, 8
A358	316	-425	20.0	20.0	17.9	16.3	15.7	15.3	9.8	4.1	2.3	1.3	2, 4, 5, 8
A376	TP316	-425	20.0	20.0	17.9	16.3	15.7	15.3	9.8	4.1	2.3	1.3	2, 4, 5, 8
A409	TP316	-425	20.0	20.0	17.9	16.3	15.7	15.3	9.8	4.1	2.3	1.3	2, 4, 5, 8
A312	TP317	-325	20.0	20.0	17.9	16.3	15.7	15.3	9.8	4.1	2.3	1.3	4, 8
A409	TP317	-325	20.0	20.0	17.9	16.3	15.7	15.3	9.8	4.1	2.3	1.3	2, 4, 5, 8

Basic allowable stresses 'S' in tension for stainless steels

Spec No.	Class (or Type)	Description	E	Notes
A182	-	Forgings and Fittings	1.00	-
A268	-	Seamless Tube	1.00	-
	-	Electric Fusion Welded Tube, Double Butt Seam	0.85	-
	-	Electric Fusion Welded Tube, Single Butt Seam	0.80	-
A269	-	Seamless Tube	1.00	-
	-	Electric Fusion Welded Tube, Double Butt Seam	0.85	-
	-	Electric Fusion Welded Tube, Single Butt Seam	0.80	-
A312	-	Seamless Pipe	1.00	-
	-	Electric Fusion Welded Pipe, Double Butt Seam	0.85	-
	-	Electric Fusion Welded Pipe, Single Butt Seam	0.80	-
A358	1, 3, 4	Electric Fusion Welded Pipe, 100% radiographed	1.00	-
	5	Electric Fusion Welded Pipe, Spot radiographed	0.90	-
	2	Electric Fusion Welded Pipe, Double Butt Seam	0.85	-
A376	-	Seamless Pipe	1.00	-
A403	-	Seamless Fittings	1.00	-
	-	Welded Fitting, 100% radiographed	1.00	1
	-	Welded Fitting, Double Butt Seam	0.85	-
	-	Welded Fitting, Single Butt Seam	0.80	-
A409	-	Electric Fusion Welded Pipe, Double Butt Seam	0.85	-
	-	Electric Fusion Welded Pipe, Single Butt Seam	0.80	-
A430	-	Seamless Pipe	1.00	-
A789	-	Seamless	1.00	-
	-	Electric Fusion Welded Pipe, 100% radiographed	1.00	-
	-	Electric Fusion Welded Tube, Double Butt Seam	0.85	-
	-	Electric Fusion Welded Tube, Single Butt Seam	0.80	-
A790	-	Seamless	1.00	-
	-	Electric Fusion Welded Pipe, 100% radiographed	1.00	-
	-	Electric Fusion Welded Pipe, Double Butt Seam	0.85	-
	-	Electric Fusion Welded Pipe, Single Butt Seam	0.80	-

Basic quality factors 'E' for longitudinal weld joints in stainless steel pipes, tubes and fittings

6.0 Physical Properties of Piping Materials

Key Learning Points

- Identify different physical properties of piping materials
- Define the physical properties
- Identify how these properties can effect the choice of pipe for different applications

6.1 Physical Properties of Piping Materials

The reasons pipe and tube are made from different materials is due the to physical properties of different materials. Properties such as:

- Malleability
- Ductility
- Brittleness
- Hardness
- Elasticity
- Conductivity
- Chemical resistance / resistance to corrosion

Malleability

Malleability can be defined as the property of a metal to be deformed by compression without cracking or rupturing. This property is very useful for copper tubing systems which allows the tube to be bent to follow the required route quickly without the need for expensive and time consuming fittings:

Ductility

Ductility is a mechanical property used to describe the extent to which materials can be deformed plastically without fracture. Ductile metals lend themselves to be formed into desired cross sectional shapes easier and therefore are cheaper to manufacture

Brittleness

The tendency for a metal to crack or break with deformation. Metals displaying this property are not readily used for pipe or tube as this is a disadvantage to a material.

Hardness

Is the property of being rigid and resistant to pressure; not easily scratched. It is measured on Mohs scale. It's presence in metals can be an advantage for high pressure systems but can be a disadvantage as it can increase machining, cutting and fabrication times.

Elasticity

The property by virtue of which a material deformed under the load can regain its original dimensions when unloaded. This property is utilized in piping system designs where pipes may expand or contract due to temperature differences. The elasticity of piping materials can help the designer cater for this.

Conductivity

The ability of a material to conduct electrical current or heat. Some piping systems high conductivity metals for high heat transfer while other piping systems use low conductivity plastic materials to prevent heat transfer.

Chemical resistance/ Resistance to Corrosion

The degree to which a material resists the corrosive action of industrial chemicals. This is probably the most significant property which affects the choice of piping material and is the biggest contributor to the price of material. Specialist alloys of stainless steel such as Hastelloy can be 10 to 20 times more expensive that standard stainless steel and can be slower to fit and weld which increase installation costs.

Exercises

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Additional Resources

- Nayyar, P.E., Mohinder L. (2000). "A1". in Mohinder L. Nayyar, P.E.. ***Piping Handbook*** (7th ed.). New York: McGraw-Hill. ISBN 0-07-047106-1.
- David L. Goetsch (2000). ***Technical Drawing*** (5th ed.). Thompson Delmar Learning ISBN: 1-4018-5760-4
- International standard ISO 7-1: Pipe threads where pressure-tight joints are made on the threads — Part 1: Dimensions, tolerances and designation. International Organization for Standardization, Geneva.
- BS EN 10226: Pipe threads where pressure tight joints are made on the threads. (The European version of ISO 7.)
- Part 1: Taper external threads and parallel internal threads — Dimensions, tolerances and designation.
- Part 2: Taper external threads and taper internal threads — Dimensions, tolerances and designation.
- BS 21: Pipe threads for tubes and fittings where pressure-tight joints are made on the threads (metric dimensions). British Standards Institution, 1985. (Superseded by BS EN 10226:2004).
- International standard ISO 228-1: Pipe threads where pressure-tight joints are not made on the threads — Part 1: Dimensions, tolerances and designation.
- BS 2779: Specification for pipe threads for tubes and fittings where pressure-tight joints are not made on the threads (metric dimensions), 1986.
- BS EN 10226-1:2004
- ASME B31.9 *Building Services Piping;* 937 – Leak Testing, 1996 Edition
- Elements of Plumbing by Samuel Edward Dibble, 2010

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