

Unit 203: Scientific principles for domestic, industrial and commercial plumbing

Outcome 1

Properties of common plumbing materials

Properties of plumbing materials



Steel
Iron

Ferrous metals
Non-ferrous metals
Plastic
Alloys



Properties of plumbing materials

Metals are some of the main materials used in plumbing: pipes, fittings, boilers, radiators.

Pure metals

Gained straight from ore, such as iron (ferrous), copper, aluminium, lead, zinc.

Ferrous

These are metals that contain iron. They are magnetic and will corrode easily if not treated (ferrous oxide or rust).

Properties of plumbing materials

Alloys

A mixture of two or more metals, these are commonly used in the plumbing industry.

- Brass – copper and zinc
- Bronze – copper and tin
- Gunmetal – copper, tin and zinc
- Steel – iron and carbon.

Non-ferrous metals

Any metal that does not contain iron (copper, lead, zinc, aluminium etc).

Properties of plumbing materials

Plastics

There are many different plastics that plumbers use on a daily basis. They can be used for cold water, hot water, central heating, guttering, above ground drainage and below ground drainage.

Thermoplastic

Made from polymer resin; can be heated and re-shaped but become brittle when frozen, (guttering). These plastics are recyclable.

There are many types of thermoplastics, which are suitable for different situations.

Properties of plumbing materials

Thermoplastics

PVCu	Unplasticised polyvinyl chloride Cold water Soil pipes Waste and overflow pipes Guttering and downpipe	Not suitable for hot water Solvent weld Push fit
MDPE	Medium density polyethylene Underground mains (blue) CWSC	Degrades in sunlight Fusion welded Push fit Compression
HDPE	High density polyethylene Underground mains (black)	Degrades in sunlight Fusion welded Push fit Compression

Properties of plumbing materials

Thermoplastics

Polypropylene	Waste pipes Overflow CWSC	Degrades in direct sunlight Feels slightly greasy to the touch Not solvent welded
Polybutylene	Cold water Hot water Central heating	Push fit Compression Not solvent welded
ABS Acrylonitrile Butadiene Styrene	Commercial water Waste Overflow	Solvent welded Degrades in sunlight

Properties of plumbing materials

Thermosetting

These are rigid plastics that can cope with high temperatures, but are not recyclable.

Formica and bakelite are examples.



Properties of plumbing materials

Mass is an amount of substance. It is measured in kilograms. (We do not use this term correctly, as we buy our food by weight.)

Weight is the force of gravity pulling on a mass:
 $1 \text{ kg} = 10\text{N} \text{ (} 9.81\text{N)}$

Weight is a force, it is measured in newtons, not kilograms.

$$\text{weight} = \text{mass} \times \text{gravity}$$

Our weight alters if we go to the moon – as gravity is much less on the moon – but our mass stays the same.

Properties of plumbing materials

Gravity is a force of attraction between masses.

Gravity is a property of mass; the bigger the mass, the bigger the gravity.

On earth, gravity is 9.81N; on the moon, which is a smaller planet, it is only 1.6N.

Video links:

<http://www.youtube.com/watch?v=RnCQjSRG8Ps>

<http://www.youtube.com/watch?v=ig6Bth7Zu0o>

Properties of plumbing materials

Density

Solid materials of the same size and shape can have a completely different weight because their molecules are more tightly packed together.

To find the density of an object, use the following formula:

$$\text{density} = \frac{\text{mass}}{\text{volume}}$$

Properties of plumbing materials

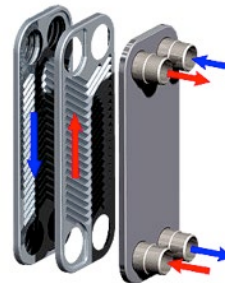
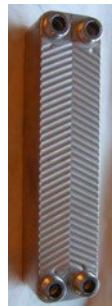
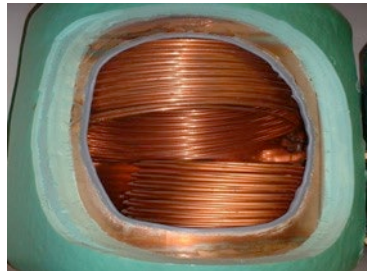
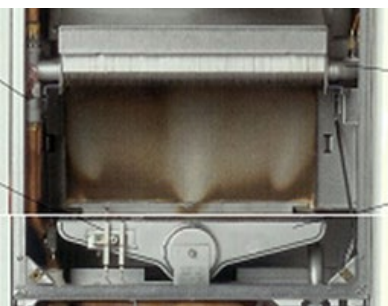
Heat transfer through differing materials can vary according to their density, like a heat exchanger.



Dry to wet	Boiler
Dry to dry	Warm air unit
Wet to dry	Radiator
Wet to wet	DHWC



Heated molecules pass on heat to the adjoining material, which in turn heats up. Some materials are better at conducting heat than others. Eg metal (copper) is a good conductor of heat but wood is not.



Properties of plumbing materials

Relative density is when we compare the mass of material.

We say: **water has a density of 1**

This means that any solid or liquid with a density of more than 1 will sink, and any solid or liquid with a density of less than 1 will float.

We say: **air has a density of 1**

This means that any gas with a density of more than 1 will sink, and any gas with a density of less than 1 will rise.

Properties of plumbing materials

Relative density

Polythene	0.90	Float
Water	1.00	
uPVC	1.28	Sink
Aluminium	2.70	Sink
Cast Iron	7.90	Sink
Copper	8.90	Sink

Natural gas	0.6	Rise
Air	1.0	Mix
Propane	1.5	Sink
Butane	2.0	Sink

Properties of plumbing materials

Solid materials are made up of many molecules. How these molecules are arranged, and how they behave under certain conditions, will determine the properties of that material:

- Strength
- Hardness
- Malleability
- Ductility
- Elasticity
- Durability
- Thermal expansion
- Conductivity (thermal and electrical).

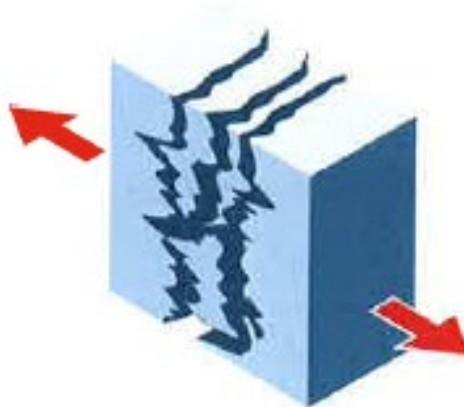
Properties of plumbing materials

Strength

Tensile strength: how strong is it when stretched or pulled?
Some will stretch and some will break – plastic, metal, concrete. Like all forces, it is measured in N/m^2 or pascals.

Video link:

http://www.youtube.com/watch?v=CILowisIpPQ&feature=bf_prev&list=PLB20A0B2C099BF231



Properties of plumbing materials

Strength

Compressive strength: how strong is a material when it is crushed? Some will shatter, others distort.

Video link:

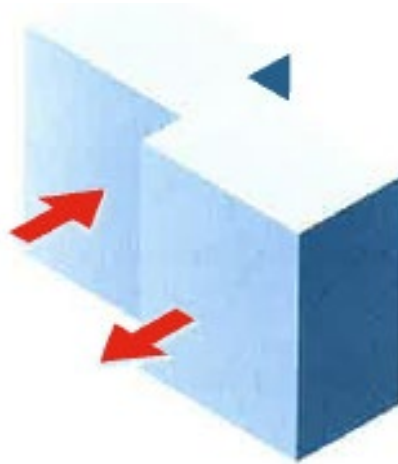
http://www.youtube.com/watch?v=5_6KydWxyqE



Properties of plumbing materials

Strength

Shear strength: how strong is a material when forces are opposing? Scissors, and ripping apart, are examples.



Properties of plumbing materials

Ductile

Sometimes known as toughness. How much can a material be pulled, pushed or stretched without breaking?

Copper is very ductile, as we bend copper tube into shape.



Properties of plumbing materials

Malleability

How much can a material be compressed without fracturing?

If we hammer or roll a material, will it change shape without cracking?

Lead is very malleable, as it can be bossed into shape.



Properties of plumbing materials

Hardness

This is the resistance of a material to bending, scratching, abrasion or cutting.

Try to cut: Wood
 Copper
 LCS
 Diamond



Properties of plumbing materials

Specific heat capacity

How much energy is required to heat something up?

It is the amount of heat required to raise 1kg of a substance through 1°C.

Specific heat values change as the temperature increases. For plumbers, it may be important to work out how much heat is needed to heat a volume of water from one temperature to another.

Properties of plumbing materials

Specific heat capacity

Specific heat value x kg x temperature rise

1kg of water to rise 5°C

$$4.186 \times 1 \times 5 = 20.93 \text{ KJ/kg/}^{\circ}\text{C}$$

Kilojoules/kilogram/degrees centigrade



Properties of plumbing materials

Specific heat capacity

Water	4.186KJ/kg
Aluminium	0.887KJ/kg
Cast iron	0.554KJ/kg
Zinc	0.397KJ/kg
Copper	0.385KJ/kg
Lead	0.125KJ/kg
Mercury	0.125KJ/kg

Note: water requires a high energy input to heat. How much energy is required to raise 150 litres of water from 10⁰C to 50⁰C?

Properties of plumbing materials

Coefficient of linear expansion

How much does a piece of material expand by when heated?

In every installation, plumbers need to take into consideration the expansion of materials: when hot water flows through pipes; when the material is in the sun or in the shade.

Plastic guttering expands the most out of all installations. Creaking pipework under floors is due to expansion and contraction.

Properties of plumbing materials

Coefficient of linear expansion

Length of material x the temperature rise x the coefficient of expansion for that material.

Plastic uPVC	0.00018
Lead	0.000029
Copper	0.000016
Steel	0.000011

How much will a 6 metre length of plastic guttering expand by, if the temperature rises by 10°C?

$$6000\text{mm} \times 10 \times 0.00018 = 10.8\text{mm}$$

Properties of plumbing materials

Corrosion

All materials will corrode over time. The amount and speed of the corrosion will depend on the material's resistance and environment.

Wet conditions

Gases

Dissimilar metals

Acids (chemicals)

Heat

UV

Properties of plumbing materials

Corrosion

The most common form of corrosion is rust (ferrous oxide). Rust occurs when water, iron and oxygen are together.

LCS pipework – only for central heating, is unprotected where inhibitor is used.

Cast iron central heating pump – only used with inhibitor.



Properties of plumbing materials

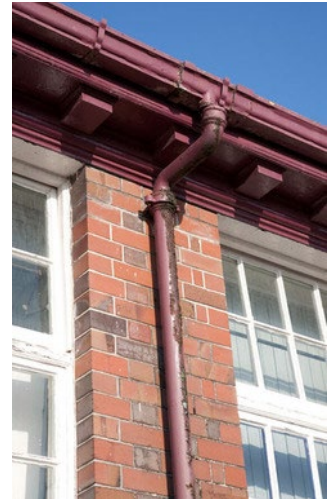
Preventing corrosion

Inhibitor protects iron in central heating systems (annual check).

Galvanised coating protects LCS from environment and oxygen in the water (life, if coating is not damaged).

Painting cast iron guttering, downpipes and central heating pipes protects the metal from atmospheric corrosion (regular maintenance).

Denso tape protects LCS pipes from external environment and underground (20 years).



Properties of plumbing materials

Corrosion

Enamelling: pressed steel baths, cast iron baths and appliance casings.



Properties of plumbing materials

Corrosion

Dezincification is another form of corrosion that can occur within a plumbing and heating system.

Brass (copper and zinc) components can have zinc leached out, as fresh water passes through them. It leaves the brass fitting weak and brittle, quite often covered in white powder (zinc oxide).

Modern brass components are dezincification resistant and have **DZR** or **DZ** stamped on them.



Properties of plumbing materials

Corrosion

Electrolytic corrosion happens where dissimilar metals are in contact with each other – through the presence of an electrolyte.

In a plumbing system, there are many different metals in contact, ie you may have copper and LCS pipework, a cast iron pump, brass compression fittings, an aluminium heat exchanger etc.

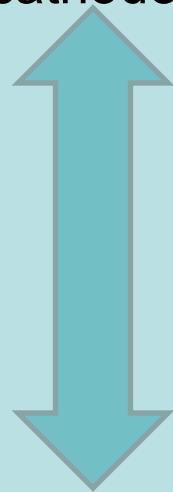
Because the pipes are filled with water (electrolyte), they are all in contact. So, as the water flows, it creates an electric current which dissolves the weakest metal.

Properties of plumbing materials

Corrosion

Electrolytic corrosion: the further away metals are in the electromotive series, the quicker the electrolytic corrosion takes place.

In a hot water cylinder, we install a **sacrificial anode** made of magnesium. For a central heating system, they can go in the boiler.

Electromotive series	
Copper	<div>cathode</div>  <div>anode</div>
Tin	
Lead	
Cadmium	
Iron	
Chromium	
Zinc	
Aluminium	
Magnesium	

Cathode attacks the anode

Properties of plumbing materials

Corrosion

Pitting: after a solder joint is made, if flux is not cleaned off the outside of the tube and **flushed** out of the inside of the copper tube at the commissioning stage, the copper could be affected by:

Type 1 pitting corrosion on the inside of the tube.



Properties of plumbing materials

Corrosion

Erosion: is the wearing away of pipes and fittings due to the flow of water or gas?

Turbulence (over 3m/s flow rate) can increase erosion (hot and cold water pipework). Burrs are left on tube ends.



Properties of plumbing materials

Corrosion

Blue water corrosion can occur in a new system, which is allowed to stand dormant for a period while it is filled with water.



Properties of plumbing materials

Corrosion

Plastics: Can be effected by:

Heat: Thermal movement and distortion

UV: Sunlight degrading

Oxygen: Degrading

Light: Yellowing of plastic

Chemicals: Degrading