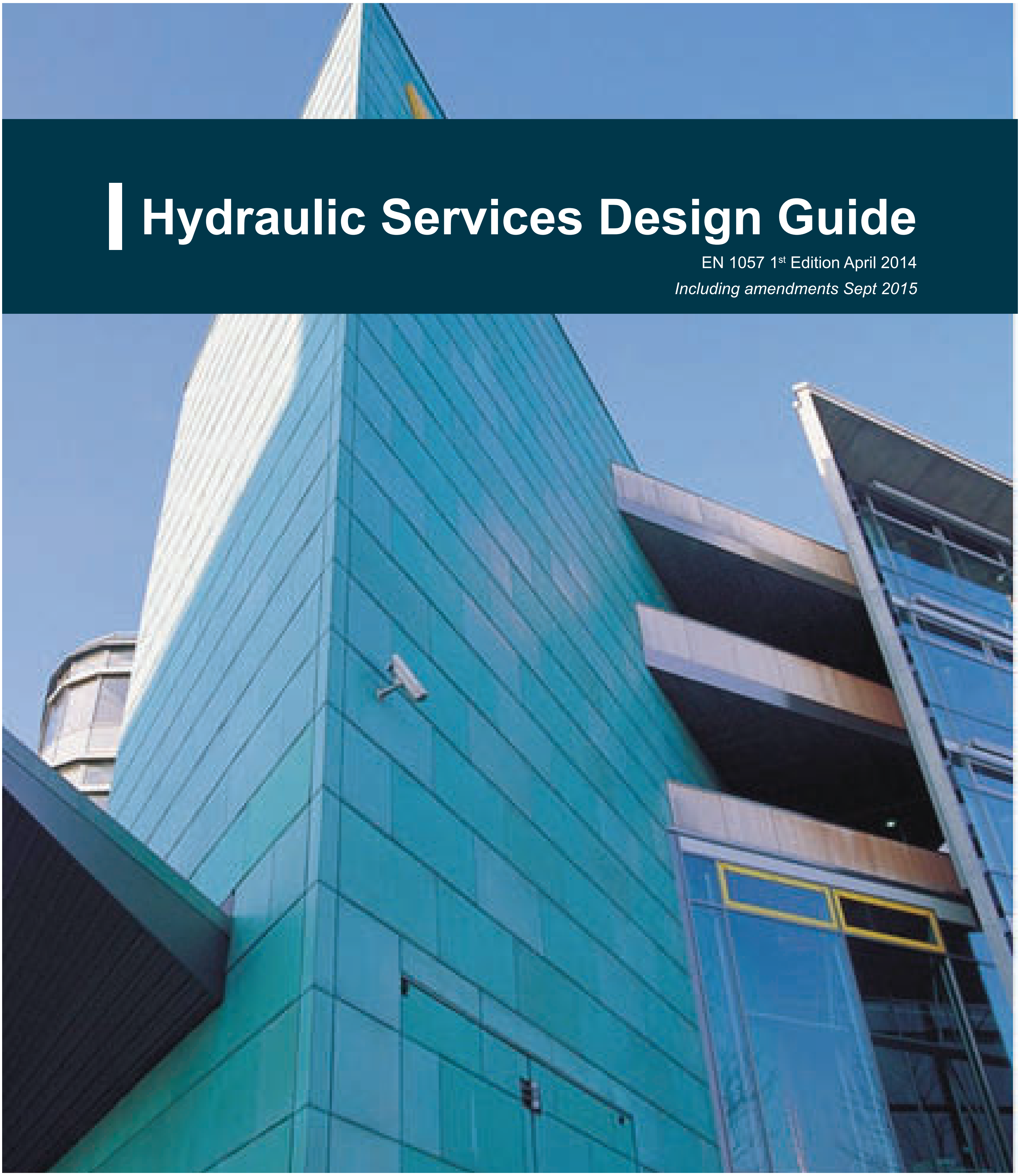
Hydraulic Services Design Guide

EN 1057 1st Edition April 2014

Including amendments Sept 2015



International Copper Association Australia

Copper Alliance

Hydraulic Services Design Guide – EN 1057 1st Edition April 2014 *Changes September 2015*
Chapter 7 – Modified wording concerning Soft Solder
Chapter 12 – Changes to Table 12.4 regarding velocities
Chapter 13 – Changes to example of insulation calculations
Chapter 15 – Added reference to AS/NZS 3666.1 and AS/NZS 3666.2
Chapter 17 – Changes to Table 17.1 regarding velocities
Chapter 18 – Update flushing requirements during installation

Table A
Changes to Hydraulic Services Design Guide 1st Edition April 2014

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1

Chapter One

Chapter 1 – Introduction

EN 1057 version

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Introduction

A New and Exciting Contemporary E-Design Guide on the Fundamentals for Plumbing Services.

This Hydraulic Services Design Guide has been developed for the Australian and New Zealand Hydraulic design engineers and plumbing contractors responsible for designing plumbing systems for commercial high rise and industrial buildings.

This on-line resource is supported by a Smartphone App and is available to designers and contractors as an on the job reference and as an education resource for lectures and students.

This Hydraulic Services Design Guide has been developed by the International Copper Association Australia with the support of MM Kembla and Crane Copper Tube and the Association of Hydraulic Services Consultants Australia.

The Hydraulic Services Design Guide will be reviewed and updated annually to ensure that designers, contractors and students have the latest and most up to date reference material into the future.

It takes into account resource material previously available in various technical references (including Barrie Smith's *"Selection and Sizing of Copper Tubes for Water Piping Systems"* and Paul Funnell's *"Pipe Sizing for Building Services"*) and will help to improve the skill level of designers, plumbers and students alike.

About Us

The International Copper Association Australia (ICAA) is part of the global Copper Alliance™, which has a history spanning more than 80 years.

The Global ICA evolved out of the International Copper Research Association (INCRA), which was formed in 1927. In 1989 ICA was formed by 24 of the world's leading Copper producers who recognized the need to coordinate and integrate efforts in Copper promotion worldwide.

Globalization and an increased demand for Copper product technologies have driven the Copper industry to expand its vision for Copper.

Not only does this unique element propel technological advancements, but it fulfills broad societal needs to protect the environment and improve human health. Copper advances the delivery of basic services (e.g., electricity and drinking water) to developing countries, adds convenience to the developed world, and provides both with improved energy efficiency, reduced greenhouse gases and increased disease prevention.

Copper Alliance™
Global ICA

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Copper Alliance

Within the Copper Alliance™, ICA maintains its global-level role in support of the world's copper industry, and its governance structure remains intact.

As global issues such as energy, climate change and health become more urgent, Copper plays an important role in almost every industry. The ICAA and its members defend and grow markets for Copper based on its superior technical performance and its contribution to a higher quality of life.

The ICAA, MM Kembla, Crane Copper Tube and its members and partners are pleased to bring you this excellent resource to improve your skills and design of hydraulic plumbing systems in high-rise buildings.

It is intended that this e-design manual is read in-conjunction with appropriate plumbing and fire installation standards.

We would also like to recognize the contribution of Neil McPherson, Phil Nichols and those acknowledged in the development of this Hydraulic Services Design Guide.

This EN1057 version of the Guide has been developed in Australia due to the strong market leadership of Australian manufacturers in Asia where this copper tube standard is so widely specified.

The ICAA are proud to support the training of professional designers and installers throughout Asia and the Middle East and we commend this Hydraulic Services Design Guide to you.

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Contents

2

Chapter Two

Chapter 2 – The History of Copper

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The History of Copper

Copper has been an essential material to man since prehistoric times.

Introduction

In fact, one of the major 'ages' or stages of human history is named after a copper alloy: bronze.

Copper was the first metal used by man in any quantity. The earliest workers in copper soon found that it could be easily hammered into sheets and the sheets in turn worked into shapes, which became more complex as their skill increased.

After the introduction of bronze, a wide range of castings also became possible. Many of the illustrations in the timeline (Figure 2.1) serve to show man's progress as a metalworker, culminating in the priceless inheritance of the Renaissance craftsmen.

But copper and its principal alloys, bronze and brass, have always been more than a means of decorative embellishment.

Although iron became the basic metal of every Western civilisation from Rome onwards, it was the copper metals, which were used when a combination of strength and durability was required.

The ability to resist corrosion ensured that copper, bronze and brass remained as both functional and decorative materials during the Middle Ages and the successive centuries through the Industrial Revolution and on to the present day.

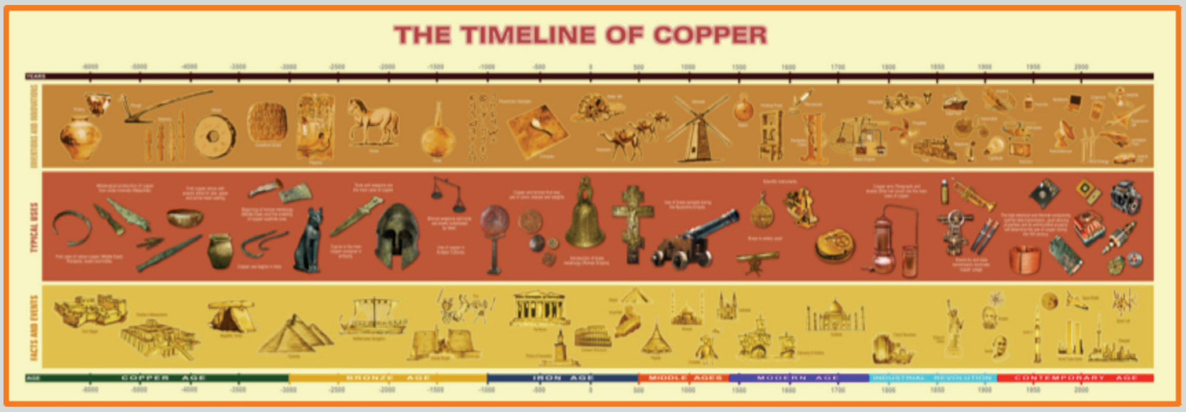

Figure 2.1
Timeline of Copper Production

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Copper Ores

An ore is a rock (Figure 2.2) containing enough valuable minerals to make it worth extracting. In the case of copper, it is worth extracting when there is about 2 kg of copper per 1,000 kg of ore (0.2%).

Copper minerals are found in over one hundred varieties, although only a few have been worked for copper on a large scale.

The most abundant ores are chalcopyrite and bornite, which contain both copper and iron sulphides. These account for about 80% of the world's known ores.

Figure 2.2
Natural Ore Rock

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Processes

Copper is found in natural ore deposits around the world. Figure 2.3 explains the production route taken from ore-containing rock to a final product. This is the highest-purity commercial metal in existence and used in a wide variety of applications essential to modern living.

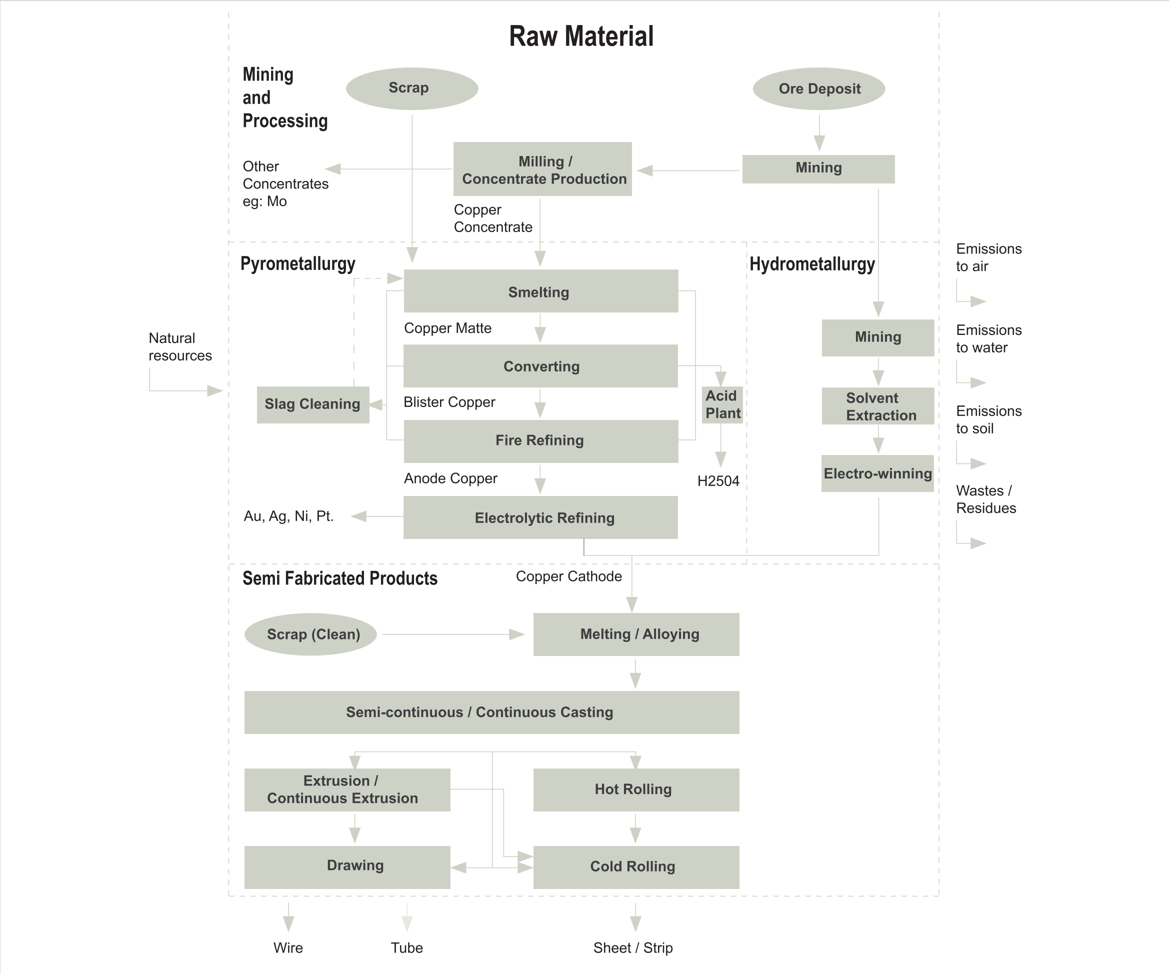

Figure 2.3
Production Route of Copper

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Copper Minerals

Copper minerals are found throughout the earth's crust. They occur in both sedimentary and igneous rocks. The outer 10 kilometres of the crust contains 33 grams of copper for every tonne of rock and in some places volcanic activity, millions of years ago, deposited molten copper in one location.It is these areas, which are mined today as they contain enough copper to make mining profitable. As well as the valuable copper there is large amounts of waste rock (called gangue), which has to be removed.

Copper Mining

The following gives an overview of how copper is extracted from its ore and converted into pure metal.

Mining

The ore is removed from the ground in either open pit or underground mines.

Underground: Sinking a vertical shaft into the earth to reach the copper ore and driving horizontal tunnels into the ore.
Open-pit: 90% of ore is mined using the open pit method. Ores near the surface can be quarried after removal of the surface layers.

The Ore

An ore is a rock that contains enough metal to make it worthwhile extracting.

Grinding

The ore is crushed and then ground into powder.

Concentrating

The ore is enriched using a process called froth flotation. Unwanted material (called gangue) sinks to the bottom and is removed.

Roasting

This is where the chemical reactions start. The powdered, enriched ore is heated in air between 500°C and 700°C to remove some sulphur and dry the ore, which is still a solid called calcine.

Smelting with Fluxes

A flux is a substance, which is added to the ore to make it melt more easily. The solid calcine is heated to 1200°C and liquefies. Some impurities are removed forming a matte (a mixture of liquid copper and iron sulphide).

Conversion of Matte

Air is blown into the liquid matte forming blister copper, so called because the gas bubbles trapped in the solid form blisters on the surface.

Anode Casting

The blister is cast into anodes for electrolysis.

Electrolytic Refining

The copper is purified to 99.99% by electrolysis. The production route described in Figure 2.3 shows the progression from a rock containing about 0.2% copper to a copper cathode of 99.99% purity.

Leaching

Leaching offers an alternative to copper mining. First, the ore is treated with dilute sulphuric acid. This trickles slowly down through the ore, over a period of months, dissolving copper to form a weak solution of copper sulphate.
The copper is then recovered by electrolysis. This process is known as SX-EW (solvent extraction / electrowinning).

Advantages of these processes are:

- Much less energy is used than in traditional mining
- No waste gases are given off
- Low capital investment
- Ability to be operated economically on a small scale.

It can be used on ore with as little as 0.1% copper - for this reason leaching extraction is growing in importance.

It is estimated that in 2011 SX-EW represented 17% of total copper refined production.

Recycling

Another important source of copper is recycled scrap, (Figure 2.4) described as secondary copper production, which in 2011 accounted for 64% of total refined copper production.

The use of scrap is one example illustrating the sustainable nature of copper. The World's demand for copper is increasingly met by recycling.

According to the International Copper Study Group (ICSG), 41.5% of the copper used in Europe comes from recycling. This reveals our copper requirements are increasingly being met by recycling. This win-win situation is helping to supply our ever-increasing demand for the metal (+250% since the 1960s) while, at the same time, lessening the environmental impact of its production and ensuring its availability for generations to come.

A computer contains around 1.5 kg of copper, a typical home about 100 kg and a wind turbine 5 tons.

Considering copper can be fully recycled and reused again and again, without any loss of performance, we have every incentive to ensure our products and copper waste are correctly processed when they reach the end of their useful lives. After all, the copper from one's smartphone could end up as part of the water system in one's home!

Recycling has become an important part of the supply chain, keeping resources local, creating local jobs, saving on landfill and incentivising the recycling of other materials.

This increased recycling of copper is being driven by the growth demand of the metal across the planet. Copper is omnipresent in the equipment modern life depends upon more and more, namely high-tech products, electrical installations, engines, solar systems and smart buildings.

Since the mid-1960s, global demand for refined copper has increased by over 250% (from 5 million to 20 million tons). Mine production remains vital in order to meet this growing demand.

Ensuring that sufficient copper will be available to meet society's future needs will require increased levels of recovery and recycling, as well as substantial investments in mining.

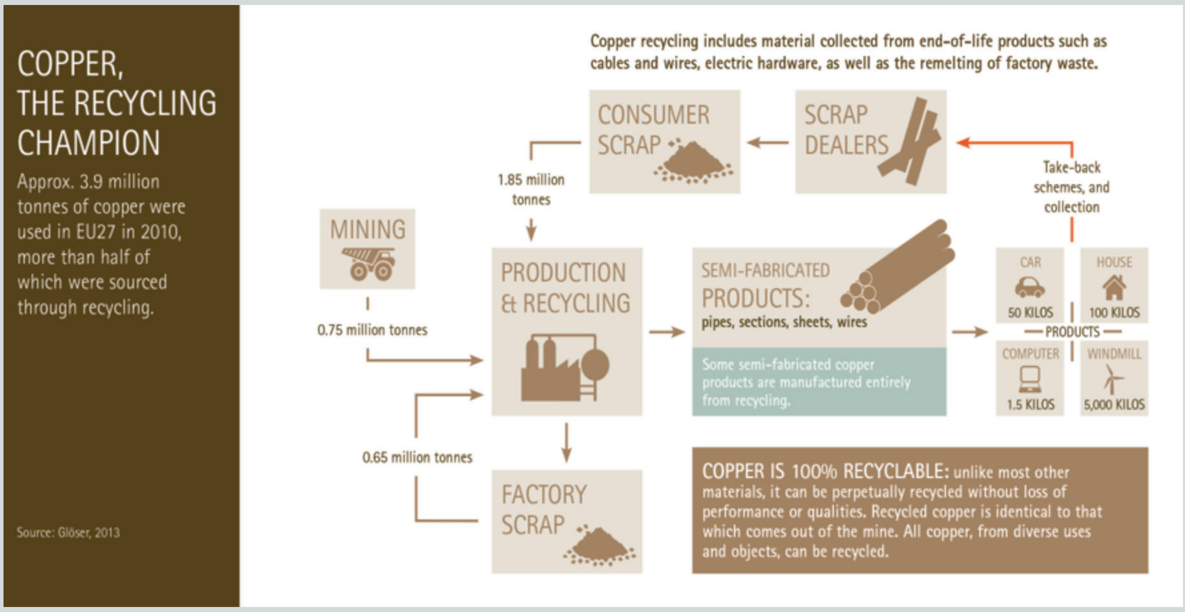

Figure 2.4
Copper Recycling Process

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Pipe Systems

Copper is the ideal pipework material for plumbing, heating, gas and fire sprinkler pipework. (Figure 2.5) **Copper is probably the most used material for plumbing in the World.**

Benefits Of Copper Tube

Reliable and time proven: Copper has been conveying water for thousands of years. The first known installation was laid in an ancient Egyptian temple, almost 5,000 years ago.

High resistance: It can withstand extreme high and low temperatures and pressures and can be exposed to the UV rays, temperature and oxygen of outside environments.

Versatile: Copper tube is used in many services: drinking water, heating (domestic and radiant), gas, medical gases, solar energy systems, fire sprinklers, air conditioning systems. It meets the requirements of safety in a unmatched, wide range of temperatures and pressures.

Energy saving: Thanks to its excellent thermal conductivity, copper is the best material to exchange heat (or cold fluids). That's why the most efficient radiant hydronic heating have circuits in copper tube.

Hygenic: Copper is an excellent tube material for installations to combat build up of germs and bacteria, like legionella.

Recyclable: In cases of demolition or renovation, copper tube can be 100% recycled without loss of performance; so, the volume of waste at landfill is not increased and the mine resources are not further exploited.

Healthy: The tube is made of 99,90% copper, and the composition will not change in time; no additives, volatile organic compounds or pigments are inside it. Beyond that, it is the material of choice for transport of medical gases - like pure oxygen - in hospitals.

Beautiful: Copper tube can be fitted on the outside of a wall and, thanks to its attractive look, can even be exploited to make beautiful wall radiators.

Drinking water

Copper has a unique feature among the materials used for the transport of drinking water: its hygienic properties can fight and inhibit the proliferation of bacteria coming in contact with its inner surface, like legionella pneumophila.

Several research papers have proved the benefit of copper tube, and some hospitals have decided to again install copper tube for their water piping system to protect the health of their patients. In addition, copper tube can release only copper ions into water, which are necessary for the metabolism of our body: the water we drink and use transported by copper tubes will not contain additives, pigments, VOCs or other synthetic compounds.

Figure 2.5
Copper Tubes

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Hydronic Heating

Copper is the material of choice for heating installations, thanks to its reliability and safety. It melts at 1083°C: therefore, hot water or steam do not soften or alter the shape of the tube; high temperature does not shorten the life of the tube, and consequently the life of the installation.
In addition, copper has excellent thermal conductivity and, for that reason, is the most efficient material for systems that have to exchange heat. This is the case, for example, with underfloor or wall radiant heating: systems made with copper have shorter piping paths compared to plastic systems, which means less head loss and less energy consumption for the circulation pumps.

Gas Pipelines

Copper tube for gas can be placed almost everywhere: indoor and outdoor, embedded, in the ground or in dedicated structures, because it is able to meet the safety requirements for this kind of installation. The red metal is not permeable to gases and air, so no leakage or contamination from outside is possible; oxygen, UV rays and temperature do not lower its mechanical properties. All over the World copper tube is approved for use by international and local standards; designers and installers rely on it, knowing that it doesn't burn or propagate fire and it provides gas-tight joints.

3

Chapter Three

Chapter 3 – Copper Tube Production

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Copper Tube Production

Industry-wide, about 64% of the copper in plumbing tube is derived from recycled scrap.

Raw Materials for Tube Production

The production of copper plumbing tube begins with raw material: copper, which in this case may be either copper from scrap, newly refined copper cathode copper or copper ingots.

The choice of raw material depends on economic factors such as cost and availability, and the technical capabilities of the plant's melting furnaces.

Copper scrap for tube-making is most often in the form of recycled copper wire (Figure 3.1), that has been stripped of its insulation and/or baled copper tube that has been removed from demolished buildings.

Another common form of scrap is the so-called "home" or "runaround" scrap generated within the tube mill itself. Only the highest quality grades of scrap are used to make copper tube.

These materials are relatively clean, considering that they're recycled scrap, but they do contain some impurities, mainly the sort of metals, such as zinc, tin and nickel, found in copper alloys, plus a bit of iron.

Figure 3.1
Copper Scrap

Industry-wide, about 64% of the copper in plumbing tube is derived from recycled scrap, although the percentage varies from zero to 100% among different tube mills.

The type of high-quality scrap the mills buy to make tube costs around 90% of the value of newly refined cathode, but its use can be justified because very little refining is needed to return the metal to the purity required for plumbing tube.

Cathode copper gets its name from the way it is made. Cathode copper is produced in large (football field-sized) electrolytic cells that refine the relatively impure (99+%Cu) blister copper taken from smelting and refining furnaces.

In the cells, cast copper anodes (the positively charged pole) approximately 1m square and weighing 180kg are dissolved in a copper sulphuric acid solution under the action of a DC electric current.

The copper is immediately re-deposited onto negatively charged cathodes by a simple electroplating process. Cathodes (Figure 3.2), are removed from the cells when they have grown to about 80 kg Cathode copper contains at least 99.95% Cu, making it one of the purest metals in common usage.

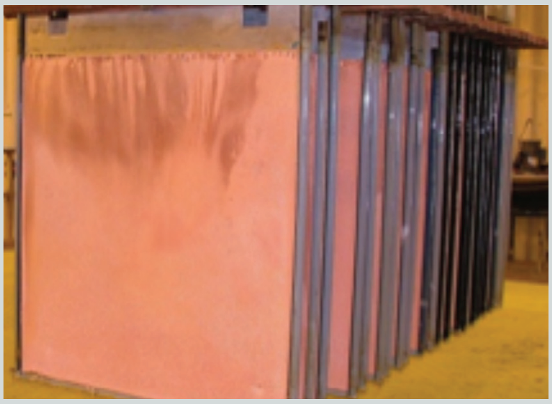

Figure 3.2
Copper Cathode

Melting

The charge of raw materials is melted in a furnace (Figure 3.3), which, in a large tube mill, may hold up to 20 tonnes of metal.

The furnace's primary function is to melt the copper charge, and if the raw materials are only in the form of cathode, refined ingot or home scrap, a simple shaft furnace or induction-melting furnace will suffice.

This type of furnace cannot be used to refine metal.

Small samples are taken from the molten copper periodically to check the progress of the operation. Samples are transferred to a fast-reading spectrograph that monitors the metal's impurity content.

When analysis reaches the level required by the specification the metal is nearly ready to be cast.

At the end of the refining operation, the copper's oxygen content is too high, and the resulting metal, if cast, would have inferior properties.

The molten copper is therefore deoxidized in the furnace by adding controlled amounts of phosphorus.

Phosphorus has a greater affinity for oxygen than copper and therefore reduces whatever copper oxide was present in the melt.

The final product is called phosphorus-deoxidized, high residual phosphorus copper.

It bears the designation DHP copper or C12200 under the Unified Numbering System (UNS) used to identify metals and alloys.

Figure 3.3
Copper Shaft Furnace

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Casting

In most mills, molten metal is transferred from the melting/refining furnace into a holding furnace or into a tundish, either of which acts as a reservoir for the casting process thereby allowing the melting/refining furnace to begin processing the next charge.

The holding furnace/tundish is heated just enough to maintain the molten metal at a constant temperature.

To protect the copper from oxidation, the liquid metal surface may be covered with a blanket of graphite powder.

From the holding furnace/tundish copper is cast into large “logs” by continuous casting (Figure 3.4), where metal is poured into horizontally or vertically oriented, cylindrical graphite moulds, which are water-cooled to force the copper to freeze quickly.

As the copper in the chilled moulds solidifies, gripping devices withdraw it in short (approximately 6-12mm) steps. At the same time, more molten copper flows into the mould from behind.

Slowly, a solid log of pure copper is formed. These logs can vary in diameter up to approximately 300mm, depending of the requirements of each mill.

A moving flying saw cuts the log into various lengths as it emerges from the casting machine. These sections are known as billets.

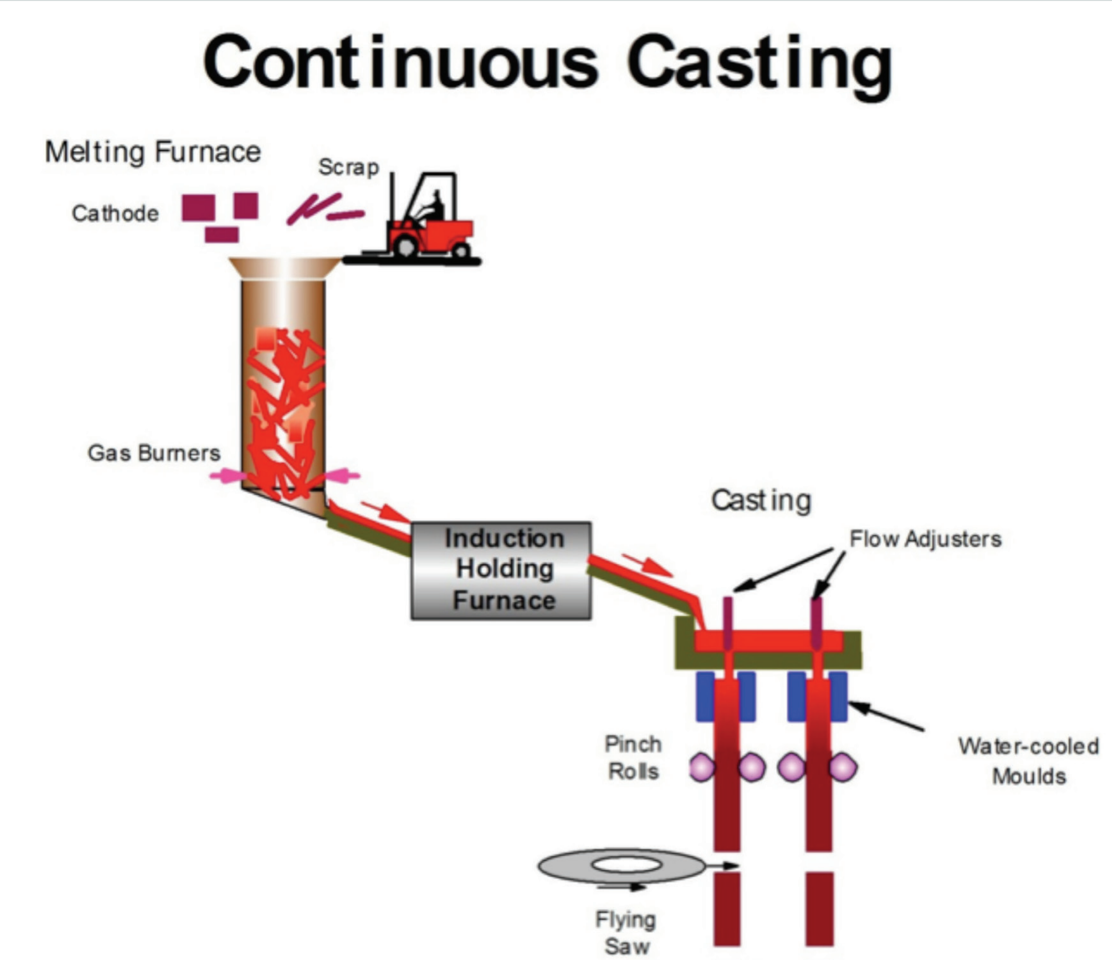

Figure 3.4
Continuous Casting

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Extrusion

Extrusion is often quite accurately compared with squeezing toothpaste from a tube. During extrusion, the billet, heated to the proper hot-working temperature, is placed in the chamber of an extrusion press (Figure 3.5.).

The horizontally mounted chamber contains a die at one end and a hydraulically driven ram at the other. The face of the ram is fitted with a dummy block that is slightly smaller in diameter than the billet.

The ram may also be fitted with a piercing mandrel and as the ram moves forward, the copper is forced over the mandrel and through the hole in the die, causing a long hollow tube, between about 70 mm and 110mm in diameter and up to 50 m long to squirt out of the extrusion press (the length can vary depending of the capabilities of each mill).

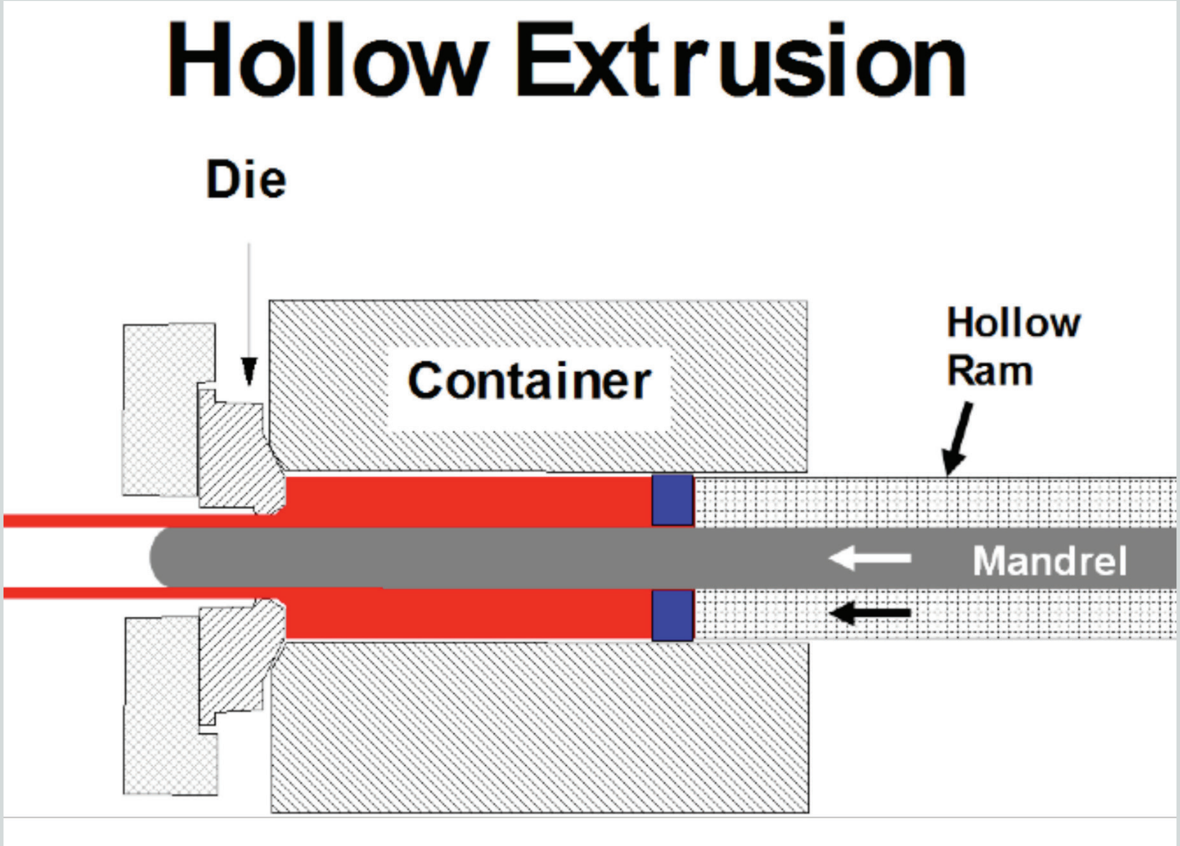

Figure 3.5
Hollow Extrusion

International Copper Association Australia

Drawing

Drawing simply involves pulling the hollow tube through a series of hardened steel dies to reduce its diameter (Figure 3.6).

Large diameter tubes (>25mm) are generally straight drawn on a drawbench whereas smaller diameter tubes are drawn using the Rotary Drawing Process using Bull Blocks or Spinner Blocks which have a diameter of up to 2.1 metres.

Before each step of the drawing process, the tube is pointed at one end to fit through the next die.

A tapered plug, which may be either fixed to a rod or floating, depending on the process used, is placed inside the tube. (Floating plugs are used with the Rotary Drawing Process).

As the tube is drawn, the mandrel and die act together to reduce both the tube's outside diameter and its wall thickness.

The mandrel also imparts a smooth surface to the tube's inside surface. The tube is drawn in several stages until the desired diameter and wall thickness is attained.

Drawing work-hardens the copper, and the tube is now quite stiff.

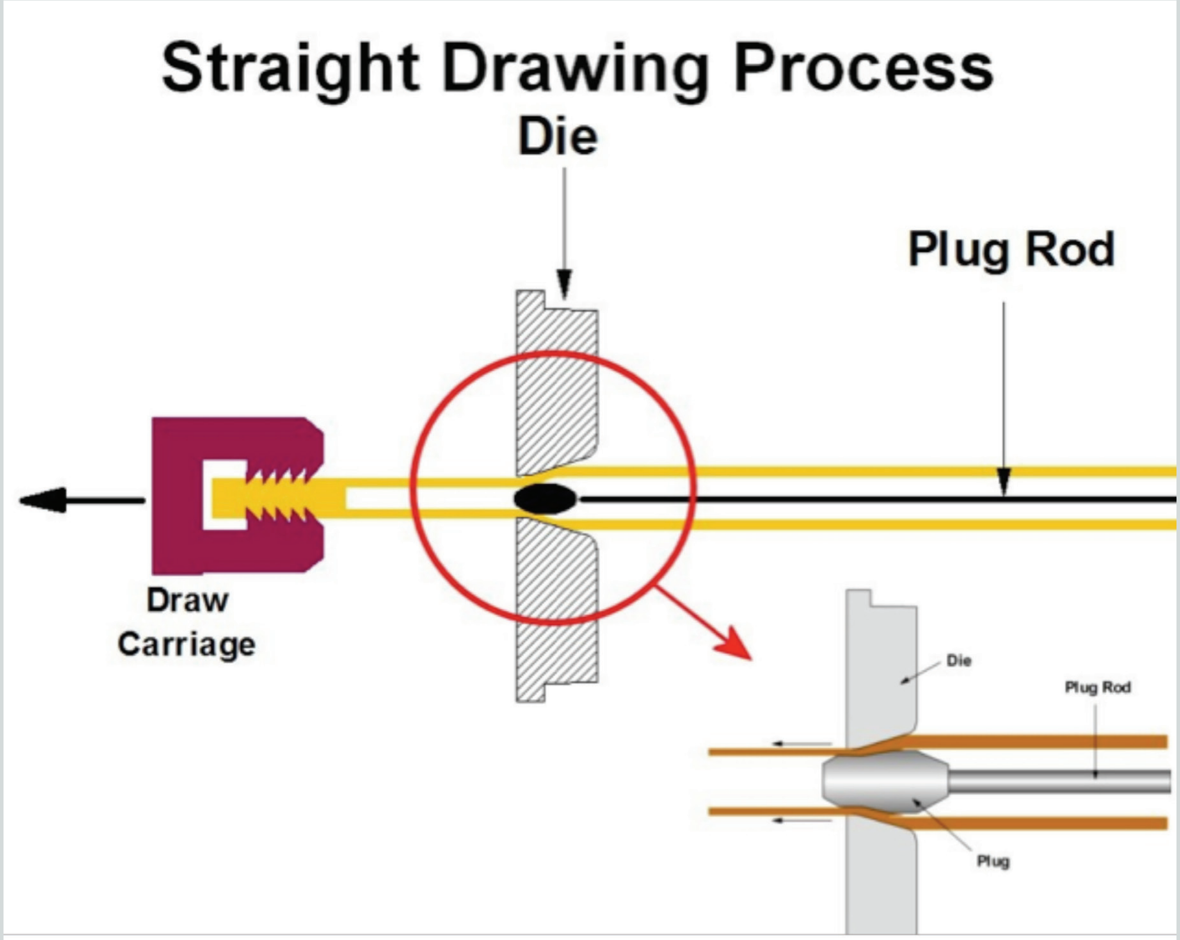

Figure 3.6
Straight Drawing Process

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Copper plumbing tube is sold in either the hard, i.e., as drawn, condition, bendable i.e. half-hard or in a soft, annealed state.

Both hard-drawn and bendable tube is sold in straight lengths whereas annealed tubes are generally sold in coils (Figure 3.7).

The next steps in the tube-making process therefore depend on the type of product to be produced. Tube that is to be sold in straight lengths is passed through a series of straightening rolls that are arranged in a slight zigzag pattern.

The rolls' positions are set such that the tube is bent slightly less at each step in the series. Tube emerges straight and ready to be cut to length.

Tube that is to be sold in coils is treated very similarly, the only difference being the position of the rolls.

For coils, they are set so as to impart a bend of appropriate radius to the tube as it emerges.

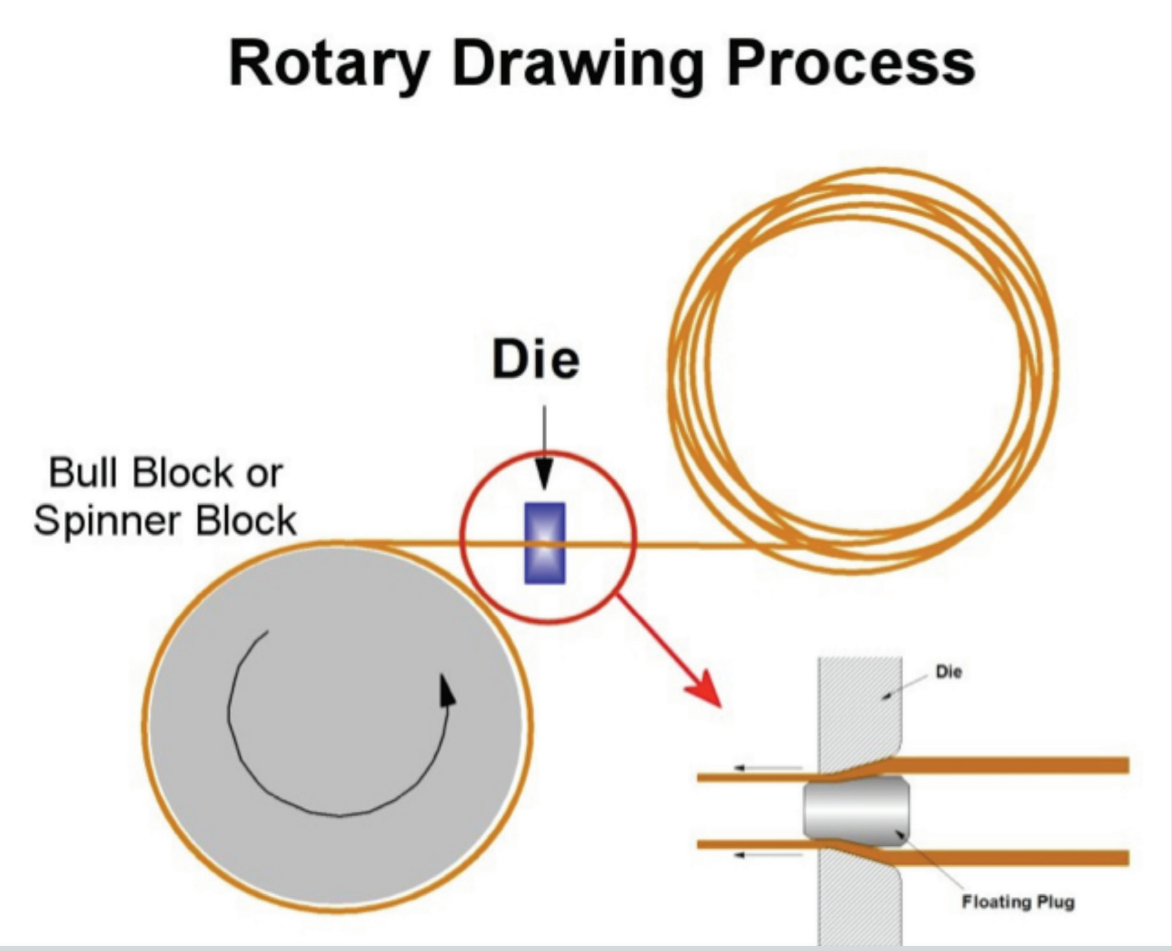

Figure 3.7
Rotary Drawing Process

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Annealing

Tube that is to be sold in the soft condition, generally as coils (Figure 3.8), is next passed through a continuous annealing furnace operating at about 600°C.

The furnace is essentially a long heated box filled with a protective atmosphere to prevent the copper from oxidizing.

In plants that are not equipped with continuous annealing furnaces, annealing is done in batches in what are aptly called bell furnaces.

These furnaces look similar to large cylindrical church bells, the open bottoms of which can be sealed to keep air out. Coils of tube to be annealed are stacked under the bells and heated in a protective atmosphere.

Annealed tube can be visually distinguished from hard-drawn tube by its matte surface finish. Aside from their appearance and stiffness, however, annealed and hard-drawn tubes have the same qualities and, in general, act identically when in contact with properly treated drinking water.

Figure 3.8
Finished Tube

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Final steps

The tube is now almost ready for shipping. It may be cleaned to remove any traces of drawing lubricants or other contaminants. This is particularly important for special-use products; such as tube that is intended to carry medical gases and refrigerants for cooling applications.

In all cases, however, samples of the finished tube are taken at regular intervals to ensure that it meets all requirements of size, wall thickness and quality as required by the applicable standards (Figure 3.9).

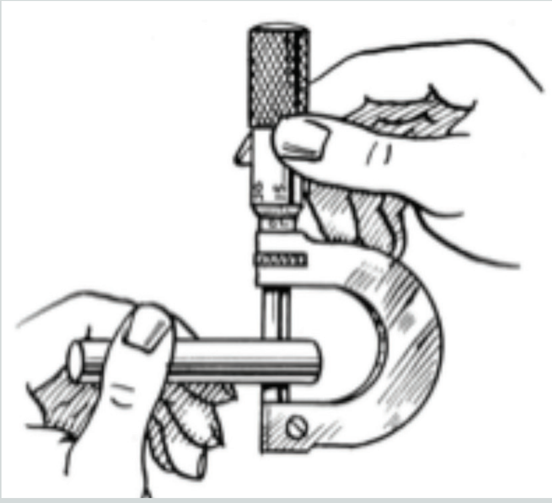

Figure 3.9
Sample of Finished Tube

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Copper tube is identified with continuous identification on the outer surface that nominates the type of tube, size and standard of manufacture.

Distribution

Australian copper tube and plumbing products are sold throughout Asia and the Middle East retail outlets in many countries and many major cities.

A large variety of product is available at short notice from local stockists and larger project lots can be delivered from the Australian manufacturers at short notice.

4

Chapter Four

Chapter 4 – Copper Tube Specification

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Copper Tube Specification

Cu

Copper tubes are impervious to oxygen, insecticide, solvents and toxins.

Introduction

Copper tube is manufactured to EN 1057 European Standard using high grade material and modern extruding and drawing technology to provide excellent products for water, gas and sanitary waste in domestic, commercial and industrial application.

In many countries Copper tubes are Quality Certified by independent organisations to comply with EN 1057 depending on the local regulations. It is important that the supplier has the correct certification for the location. Where regulation does not stipulate a certifying body, independent third party accreditation will provide assurance that the manufacturer meets the requirements of the EN 1057 standard.

Copper tube manufactured for plumbing, gasfitting and drainage applications enhance the internal surface of the tube to provide superior internal bore characteristic that offer improved corrosion resistance. The inherent strength of copper tube provides protection to external damage; puncture, abrasion and vibration whilst offering a wide operating range for internal pressure and vacuum.

Copper tubes are impervious to oxygen, insecticide, solvents and toxins. Copper tubes are considered non-flammable and does not emit toxic fumes during a fire.

The advantage of copper tubes in plumbing services has been proven whilst offering the design engineer and plumber a product that incorporates full flow fittings, very little resistance to the flow of water and gas as the fitting does not reduce the internal bore of the tube. This unique design provides for higher flow rates with minimum resistance compared to non-metallic piping systems.

Copper tubes are UV resistance and does not degrade or become brittle from being installed in direct sunlight.

Copper tubes are free from rodent attack, this is very important given that many remote locations where plumbing services systems are installed.

A prominent feature of copper tube when used in heated water systems is that material does not creep with age and has 7-15 times less lineal expansion than other materials. Copper tubes continue to perform at elevated temperature making it ideal where uncontrolled heat sources are encountered.

Copper tube has a proven track record for plumbing services systems when installed correctly in accordance with this design manual.

Note:
The terminology applying to the specification of copper tube is derived from the European designation – dimension, as opposed to using American standards terminology being pipe.

Copper Tube Properties

Copper tubes are made from high residual phosphorus deoxidised copper and is classified as C12200 Alloy. Refer Table 4.1.

A general description of C12200 phosphorus deoxidised copper has been made weldable and brazeable by deoxidising with phosphorus. It is widely used as flat products and tubing, especially where brazing and welding is required.

Phosphorous significantly reduces the conductivity, which may go low as 75% IACS, but raises the softening temperatures when work hardened and promotes fine grain size. It has excellent drawing characteristics and resistance to pitting corrosion when exposed to severe weather and water environments.

Chemical Composition			
Copper: 99.90% minimum			
Phosphorus: 0.015% - 0.040%			
Tube Specifications			
Recommended: EN 1057 Related: AS/NZS 1571, AS 1432, ASTM B88, JISH 3300, NZS 3501			
Physical Properties			
Melting Point: 1083°C			
Density: 8.94 x 10^3 kg/m^3 at 20°C			
Thermal Expansion Coefficient: 17.7 x 10^{-6} per °K			
Thermal Conductivity: 305-355 W/(m.K)			
Specific Heat Capacity: 0.385 kJ (kg.K)			
Electrical Conductivity (annealed): 75-90% I.A.C.S.			
Electrical Resistivity (annealed): 0.0192-0.0230 micro-ohms m at 20°C			
Modulus of Elasticity: 17GPa			
Modulus of Rigidity: 44 GPa			

Jointing Properties	Fabrication Properties
Soldering: Excellent	Cold Work: Excellent
Brazing: Excellent	Hot Work: Excellent
Welding: Oxy-acetylene: Good Carbon arc: Good using alloy filler rods gas Shield arc: Good Coated metal arc: Good using alloy filler rods Resistance spot: Not recommended resistance Butt: Not recommended	Hot Work Temp: 750°C – 875°C Annealing Range: 450°C – 600°C

Suitability For Surface Finishing By
Polishing: Excellent
Plating: Excellent
Machining: Machinability rating (20)

Typical Mechanical Properties			
Tube temper:	Annealed	Half Hard	Hard Drawn
Hardness(HV/5)	70max	75-100	100min
Yield 0.2% proof (MPa)	70	220	350
Ultimate tensile (MPa)	220	280	380
Elongation (% on 50mm)	55	20	5

Table 4.1
Copper Tube Properties

EN 1057 Standard Specifications for Copper Tubes - Plumbing Services

EN 1057 Copper tubing for plumbing, gasfitting and drainage application (Table 4.2).

This European Standard provides for round seamless copper tubes intended for use in pressure and non-pressure plumbing, gasfitting and drainage applications.

MM Kembla and **Crane** copper tube's are manufactured as hard drawn, half hard quality, annealed and pre-lagged coils and straight lengths.

Features and benefits of copper tubes are well documented, being manufactured to the highest quality.

All tubes are permanently marked to provide product traceability for the life of the installation. Copper tubes meet the requirements for premium applications in accordance with BS 1306 and further meets the stringent requirement for AS 4020 Materials in contact with drinking water.

EN 1057 has many allowable diameter and wall thickness combinations and the sizes listed in Table 4.2 are the most common. The naming of the two size ranges, Table X and Table Y are a carryover of a previous standard and are the common method of nominating this product.

Table X is generally used for above ground applications including drinking water, hot and cold water systems, sanitation, central heating, and other general purpose applications.

Table Y is generally used for underground works and heavy duty requirements including hot and cold water supply, gas reticulation, sanitary plumbing, heating and general engineering.

COPPER TUBE - TABLE X

DIAMETER (mm)	THICKNESS (mm)	MAXIMUM WORKING PRESSURES† (kPa)			MASS/ LENGTH* (kg/5.8m)	LENGTH/ BUNDLE	LAGGED SIZES	
		ANNEALED	HALF HARD	HARD			KEMLINE (mm)	KEMLAG (mm)
15 #	0.7	4 500	5 800	7 100	1.63	100	15	15
22 #	0.9	3 900	5 100	6 200	3.09	50	22	22
28 #	0.9	3 100	4 000	4 800	3.98	50	28	28
35	1.2	3 300	4 200	5 100	6.61	50	35	35
42	1.2	2 700	3 500	4 300	7.98	50	42	42
54	1.2	2 100	2 700	3 300	10.33	30	54	54
66.7	1.2	1 700	2 000	2 700	12.81	25	66.7	
76.1	1.5	1 800	2 400	2 900	18.24	25	76.1	
108	1.5	1 300	1 700	2 000	26.04	10	108	
133	1.5	1 000	1 400	1 700	32.15	10		
159	2.0	1 200	1 500	1 800	51.18	5		

Table 4.2
EN1057 Standard for Copper Tubes

† Based on individual tempers for temperatures up to 65⁰c. Annealed values apply when tubes are softened during joining or fabrication.
• Based on nominal diameter and thickness.
¨ Based on 5.0mm length as manufactured
Manufactured in half-hard temper, all other sizes are hard drawn.

COPPER TUBE - TABLE Y								
DIAMETER (mm)	THICKNESS (mm)	MAXIMUM WORKING PRESSURES† (kPa)			MASS/ LENGTH* (kg/5.8m)	LENGTH/ BUNDLE	LAGGED SIZES	
		ANNEALED	HALF HARD	HARD			KEMLINE (mm)	KEMLAG (mm)
15 #	1.0	6 700	8 700	10 400	2.28	100	15	15
22 #	1.2	5 300	6 900	8 400	4.07	50	22	22
28 #	1.2	4 200	5 500	6 500	5.24	50	28	28
35	1.5	4 100	5 400	6 500	8.19	50	35	35
42	1.5	3 400	4 500	5 400	9.90	50	42	42
54	2.0	3 600	4 700	5 600	16.95	30	54	54
66.7	2.0	2 800	3 700	4 500	21.09	25	66.7	
76.1	2.0	2 500	3 300	3 900	24.15	25	76.1	
108	2.5	2 200	2 900	3 400	42.99	10	108	
133	2.0	1 400	1 800	2 200	42.70	10		
159	3.0	1 800	2 400	2 800	65.76¨	5		

Table 4.2 – Continued
EN1057 Standard for Copper Tubes

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Copper Alliance

† Based on individual tempers for temperatures up to 65⁰c. Annealed values apply when tubes are softened during joining or fabrication.
• Based on nominal diameter and thickness.
¨ Based on 5.0mm length as manufactured
Manufactured in half-hard temper, all other sizes are hard drawn.

Copper Tube – Safe Working Pressures

The safe working pressures for copper tubes are shown in Table 4.2. These values are applicable for temperatures up to 65⁰C and are based on annealed temper tube.

Values for elevated temperatures shall be calculated by multiplying the safe working pressure figures for up to 65⁰C by the appropriate temperature factor (T). Refer Table 4.3.

Pressures for intermediate temperatures may be calculated by interpolation.

Temperature Range ⁰C	Rating Factor (T)
Up to 65	1
Over 65-100	0.97
Over 100-150	0.83
Over 150-175	0.63
Over 175-200	0.44

Table 4.3
De-rating Factors for Copper Tube at Elevated Temperatures

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Copper Tube – Safe Working Pressures

(Continued)

The Safe Working Pressure (SWP) for EN 1057 products, as well as other copper tubes, is derived from BS 1306 Pressure Piping. BS 1306 stipulates the method for calculating the SWP and the maximum Design Tensile Strength for the material.

The Safe Working Pressure of a particular size copper tube is the pressure at which the tube is capable of being continually operated at and includes a significant safety margin.

The Test Pressure as specified by the various Standards, on some larger size tubes, is considerably higher than the Safe Working Pressure and in some cases requires pressures 1.5 times the maximum working pressure.

All copper tubes are capable of withstanding the Test Pressures for the required testing period.

When testing tube installations, and in particular when applying the test pressure, due care must be taken to ensure the system is completely bled of air and that pressure changes are done smoothly to avoid hydraulic shock (water hammer).

Water hammer is known to momentarily produce pressure spike up to 3 times the operating pressure which can cause damage and blow outs.

At temperatures up to 650C the Design Tensile Strength for copper is 41 MPa but for temperatures greater than 650C, a lower Design Tensile Strength must be used as the strength of the material is lower.

The calculation and the maximum allowable design tensile strengths at various temperatures as specified by BS 1306. Refer Table 4.4.

Safe Working Pressure Calculations for Copper Tubes:
For sizes outside EN 1057, may be calculated by the following formula.

Calculations are base on annealed tube to allow for softening at brazed joints.

$$P_{sw} = \frac{2000 \times S_d \times t_{min}}{D - t_{min}}$$

Where:

- P_{sw} safe working pressure (kPa)
- t_{min} minimum wall thickness (mm) as per relevant standard.
- D outside diameter (mm)
- S_D maximum allowable design tensile stress for annealed tube. Refer Table 4.4

Temperature Range (⁰C)	Maximum Allowable Design Tensile Stress (S_D)(MPa)
Up to 50	41
Over 50 - 100	40
Over 100 – 150	34
Over 150 - 175	26
Over 175 – 200	18

Table 4.4
Maximum Allowable Design Tensile Strength

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Copper Tube – Safe Working Pressures
(Continued)

Where the Design Tensile Strength for copper tube, at temperatures up to 65°C, is 41 MPa, the Ultimate Tensile Strength (UTS) for annealed copper is 200 MPa.

The UTS is the minimum stress at which the copper will fail or in the case of tube, burst. This equates to a safety factor of 5:1 over the burst pressure.

That is, the burst pressure of any tube (when manufactured) is no less than 5 times the SWP for any given temperature.

However copper tube should not be used anywhere near the burst pressure as the safety factor is designed to account for installation damage, corrosion, pressure spikes and water hammer.

If a tube is exposed to pressures well in excess of the SWP there will be some noticeable change in shape, called ballooning, primarily around the annealed areas near the brazed joint (Figure 4.1a and Figure 4.1b).

This starts to be noticeable at 2 to 3 times the safe working pressure and is the metal yielding. As it balloons the copper ‘work hardens’ but the ballooning will continue if the pressure is increased up until the tube bursts.

Below is an example were a section of 101.6mm OD x 1.63mm Wt copper tube when subjected to increasing pressure up until is burst.

The ballooning is readily noticeable and occurs primarily around the sections that have been softened by brazing to join the end caps to the sample.

This sample did not burst until a pressure of 7,500 kPa which is in excess of 6 times the SWP.

DN 100B Pressure Test

Figure 4.1a
Sample prior to pressure test

Figure 4.1b
Sample after exposure to 7,500 kPa (6 times SWP)

Copper tubes balloons under pressure when greater than the safe working limits

Tube Identification

All EN 1057 copper tube supplied must be identified and can contain two types of identification being incise (metal stamping) and an ink mark as per Table 4.5.

All markings must be applied before the tubes leave the manufacturer's works and be continuous along the length of the tubes.

The marking on the tube shall also be marked throughout its length, repeated at intervals not exceeding 600mm (Figure 4.2).

Some countries require third party accreditation of the manufacturer and it may also be necessary to include some designation in the marking.

Many suppliers also use a colour mark to help identify the different wall thickness types and these will be as the colour of the ink mark and/or a stripe down the length of the tube.

Incise	Ink Mark Legend
The number of the standard - EN 1057	**Diameter and Thickness**
Manufacturer's Identification Mark	**'HH' if Half Hard Temper**
Date of Production (quarter & year)	

Table 4.5

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Other information may be provided at the discretion of the manufacturer.

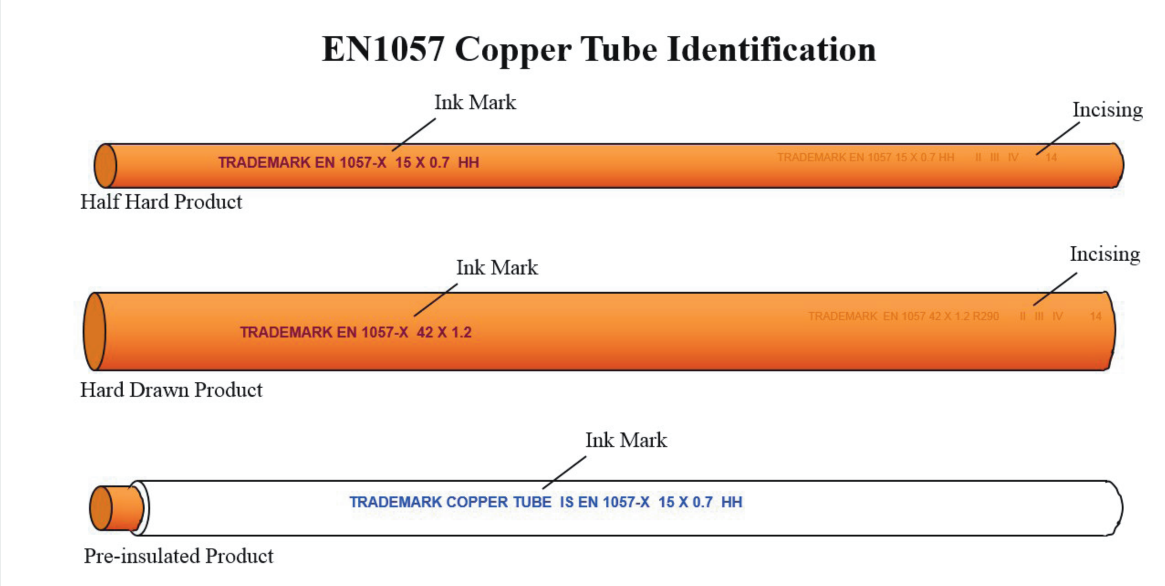

Figure 4.2
Examples of acceptable markings

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Types of Copper Tubes

Pre-Insulated Copper Tubing

A comprehensive range of pre-insulated tubes are available with a moisture resistant and chemically inert white plastic sheathing for use in a variety of end use applications e.g. short run domestic hot water lines, burying in corrosive soils, laying under floors embedded in concrete walls and pipework exposed to aggressive environments.

When devices are to be exposed to aggressive and moist environments or buried, all joints must be wrapped or otherwise protected to ensure that the entire pipeline covering is water tight. Each end must also be made water tight.

Plastic insulation will soften at elevated temperatures and the product should not be used for installations operating continuously at temperatures above 75^{0}C.

Under no circumstances should pre insulated tubing be used on solar hot water flow and return systems.Where tubes are to be used in sizes for the conveyance of hot water, it may be necessary to provide other forms of insulation to achieve acceptable heat losses.

Purpose designed insulation should be used where heat loss is critical. Most factory supplied pre-insulated copper tube will not meet the hot water energy efficiency requirements of AS/NZS 3500.4 as this requires at least 13mm insulation thickness of an efficient thermal insulation.

In localities subject to freezing conditions, additional insulation may be required to prevent water freezing in exposed pipelines. On its own, the plastic, on pre-insulated tubes, will not prevent water freezing.

Steam Lines

Lightweight, ductility, ease of installation and corrosion resistance are some of the attributes, which make copper worthy of consideration for steam lines. Care needs to be taken when choosing the correct size pipes and attention paid to the SWP de-rating factors when operating at elevated temperatures.

Copper tube is not suitable for use at temperatures in excess of 200^{0}C such as with super-heated steam. When designing steam lines it is necessary to:

- Refer to the requirements of BS 1306.
- Select tubes, which will withstand the maximum operating pressures and temperatures of the system. Safe working pressures and temperatures for tubes are addressed earlier in this chapter.
- Avoid steam hammer, which could produce undesirable pressure surges.
- Ensure provision is made to accommodate thermal expansion.
- Take precautions to eliminate vibration from the piping.
- Tubes should be of the thicker gauge as an
- added safety margin.
- Copper tube may not be suitable when steam is contaminated with chemicals and where high velocities could be involved.

Gas Piping

EN 1057 copper tube is also used for fuel gas applications. Local regulations will specify appropriate installation procedures for fuel gas piping subject to internal pressure.

Sanitary Piping

Sanitary piping shall be in accordance with AS/NZS 3500.2, which includes the requirements for the following:

- Clearances required for buried pipework.
- Pipework support and fixing requirements.
- Location.
- Materials and methods of joining.
- Expansion and contraction of pipework.
- Pipe access.
- Pipe gradients.

Copper is not suitable for use with undiluted urines and strong chemical waste lines.

Fire Services Piping

Copper is suitable for use as fire service piping and shall be installed, tested and commissioned in accordance with the relevant Standard.

Installation and materials shall also comply with other relevant regulations and codes.

Air-conditioning and Refrigeration Piping

An extensive range of copper tube is manufactured specifically to cater for the special requirements of refrigeration gas lines.

These tubes comply with the required internal cleanliness limits specified in:

- EN 12735.1: Seamless Round Copper Tubes for air Conditioning and Refrigeration
- AS/NZS 1571 Copper - Seamless tubes for air conditioning and refrigeration and
- ASTM B280 Standard Specification for Seamless Copper Tube for Air Conditioning and Refrigeration Field Service.

Tubes are factory cleaned and supplied sealed to maintain the internal cleanness of the bore under normal conditions of handling and storage.

Medical Gas Piping

Copper tubes are widely used for medical gas installations. Only appropriately qualified personnel are to be involved in the design and installation of medical gas systems.

Many builders specify that the installation of Medical Gas pipe work is in accordance with the UK, Health Technical Memorandum 02-01: Medical gas pipeline systems. It addresses safety, construction, testing, operation and maintenance of non-flammable medical gas pipeline systems using common gases but not those with special mixtures.

The internal cleanness of piping and components is critical to the effective performance of medical gas lines.

Factory sealed EN 13348 copper pipe are usually specified but it is important to check local regulations.

Special precautions are required when making joints in medical gas piping. During all heating and brazing operations, to prevent formation of oxide and scale, piping is to be purged with protective gas in accordance with specified procedures. A15% silver-copper-phosphorus filler metal should to be used for all brazing.

5

Chapter Five

Chapter 5 – Water Supplies

EN 1057 version

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Water Supplies

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Australia's cities face significant water challenges into the future.

This chapter broadly describes the water supplies and provides the designer with some basic information that will assist in making their buildings more water efficient.

It is not intended to cover all aspects of different water supplies available.

There are many types of water supplies, which include traditional and alternative sources in particular to those services for residential, commercial and industrial type of buildings.

Australia's cities face significant water challenges into the future due to the combination of rapidly growing populations, increasingly unreliable rainfall patterns and our ability to adjust to climatic uncertainty.

From these challenges government and industry have developed programs and systems to conserve water used within buildings

The most common water supplies that feed plumbing systems may include:

- Towns Mains Supply – water utility supply.
- Towns Mains Recycled Supply – water utility supply.
- Desalinated / blended supply.
- Black and grey water treated reuse.
- Rainwater harvesting.
- Raw water - lakes, rivers and bore water.

The designers and installers when using alternate water supplies must assess the risks that are present.

These risks may include cross connection of non-drinking water with drinking water resulting in health risks, failure of supply and water quality.

Water Quality

The quality of drinking water supplies is outlined in the Water Services Association Australia – Drinking Water Guideline. Regional water agencies provide detailed information on their water supply quality.

The following extract and link will assist designers to appreciate those elements of a fit for purpose water supply.

"The ADWG are not mandatory standards; however, they provide a basis for determining the quality of water to be supplied to consumers in all parts of Australia.

These determinations need to consider the diverse array of regional or local factors, and take into account economic, political and cultural issues, including customer expectations and willingness and ability to pay.

The ADWG are intended for use by the Australian community and all agencies with responsibilities associated with the supply of drinking water, including catchment and water resource managers, drinking water suppliers, water regulators and health authorities".

www.nhmrc.gov.au/guidelines/publications/subject/Water Quality

Water Conservation

We all recognise the importance of water conservation, growing populations and water wastage, as designers we have a responsibility to consider and contribute to water conservation within the design process and the construction.

Generally it would be fair to say Australian governments focus on those water efficiencies related directly to the housing markets. Programs like "Every Drop Counts" and "Water Efficiency Tapware" have been very effective in reducing water usage in homes.

There are a number of governments and industries who are leading water conservation initiatives many of which have been accepted by the industry and consumers to reduce the water consumption.

The following list outlines the initiatives that currently related to plumbing services – water supply;

- Building Sustainable Index (BASIX).
- National Australian Built Environment Rating System (NABERS).
- Green Star.
- Leadership in Energy & Design (Leed) – USA.
- State government water conservation policies.
- Local council water conservation policies.
- Water utility water conservation initiatives.

As all new buildings will have some form of water conservation, the designers are required to be aware of each building needs and how to apply these requirements to the plumbing systems.

The following list will outline the questions that may be posed when developing a plumbing system that incorporates water conservation:

- What regulatory water conservation requirements apply to this development?
- What are the building owner's water conservation targets?
- What sources of water are available to the site?
- What alternate water supplies can be generated on site?
- What combination of water supplies can be used to meet the water reduction target?
- What water conservation devices are available?
- What alternate equipment can be investigated to reduce water conservation?
- Are there any government assistance/funding to implement water conservation initiatives?

Designers need to embrace these water conservation measures and adapt plumbing system to either commercial or industrial designs; rarely do we consider the net benefit in hydraulic engineering and return on capital investment over longer time periods (life of the building). What is our role in education within design that reflects those government policies?

Forms Of Water Supply

Towns Mains Supply – Water Agency Supply

Towns water supply systems obtain water from a variety of locations, including ground water (aquifers), surface water (lakes & rivers), recycled and sea water through desalination.

Water is in most cases treated and disinfected through chlorination and sometimes with fluorides to a level suitable for drinking.

Towns drinking water is distributed through a network of catchment, reservoirs, pump stations and pipelines. Water agencies prefer to utilise gravity to distribute the water through their network to minimize the reliance on electrical pumping systems (Figure 5.1).

Mains supply is now defined as drinking water (as opposed to potable water) in accordance with AS/NZS 3500. However other forms of water supply may also be called drinking water depending on the location, region and the water quality being supplied.

Water supply distributed from reservoirs is by a network of piping called Trunk and Reticulated Mains having materials and pipe sizing as;

- Trunk mains – sizes from DN 300 and above made from steel, ductile iron, glass reinforced plastic, polyvinyl chloride and medium density polyethylene.
- Reticulation mains – sizes from DN100 – DN300 made from polyvinyl chloride and medium density polyethylene and ductile iron.

An excellent description and specification for the construction and materials used with water supplies networks can be seen on the Gold Coast - Planning Scheme Policy – Land Development Guidelines. The water utility engineer or an accredited designer usually carries out the design of the water supply network. An accredited designer must hold qualifications recognized by the utility or be formally accredited by the utility who's water network that they intend to alter or extend.

www.goldcoast.qld.gov.au/gcplanningscheme_0509/attachments/policies/policy11/SS2_water_supply_mains_and_associated_works.pdf

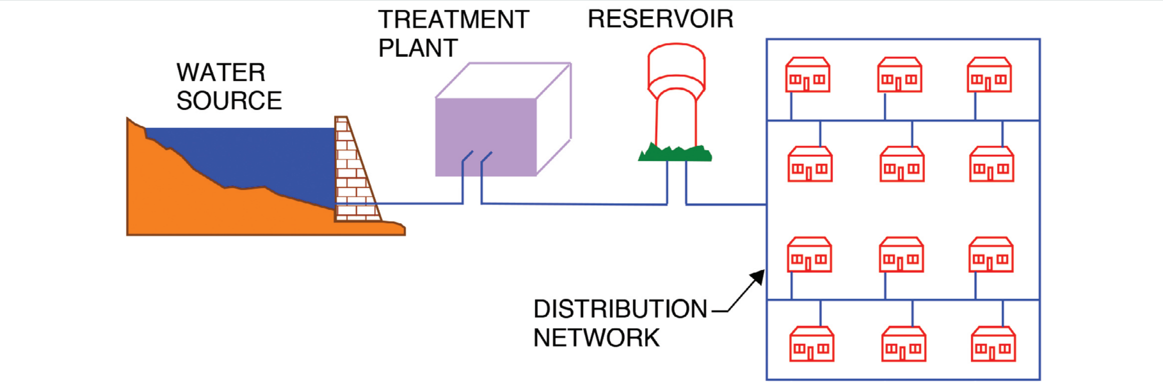

Figure 5.1
Towns Mains Supply Distribution Network

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Towns Mains Recycled Supply – Water Utility Supply

Water utilities that operate sewage networks have developed large recycled water supplies. Water utilities capture the sewage wastewater within the sewage network and treat the water to a level fit for the intended use. The wastewater is usually treated through the following process:

- Primary Treatment - Primary treatment includes screens, sedimentation and grit removal.
- Secondary Treatment – remove nutrients.
- Tertiary Treatment – Filtering, disinfecting and preparing for recycling.

Tertiary treated wastewater then goes through several processes that may include:

- Passing through a mechanical strainer.
- Ultrafiltration to remove any particles of organic matter that may still be present.
- Reverse osmosis that extract water and leave behind a wastewater concentrate.
- De-carbonators that reduce carbon dioxide in the water.

The treated water may be used in such applications as:

- Households non-drinking use such as toilets, irrigation, wash down etc.
- Cooling water – cooling towers.
- Fire services water (with approval from fire brigade).
- Industrial process water.
- Agriculture irrigation & Golf course irrigation.

The designer and installers before commencing a design or installation for buildings must be aware of the requirements and allowable uses of recycled water.

Desalination / Blended Water Supply

Desalination is a technology that separates dissolved salts and other minerals from seawater or other salty water to provide clean drinking water.

Governments and Water Utilities adopted this technology to supplement the water supply available from dam, rivers and aquifers. Australia is one of many countries that rely on desalination for example; Perth has a low rainfall and relies on desalination for a considerable portion of their water.

Another example of a countries/cities reliance on desalination is Dubai, which is located by the sea and has little rainfall to provide a reliable water supply.

Climate change has also played a significant role in the need for alternate water supplies. With the impact of climate change and the threat of un-reliable water supplies counties have built desalination plants as part of their water network to ensure supply.

Water can be produced through a variety of desalination processes, but the most common method of desalination in Australia is reverse osmosis. Reverse osmosis, consists of the following stages (Figure 5.2);

Stage 1 - Seawater Pre-Treatment
Seawater is drawn in from the ocean through a large pipe. It then goes through a screen to remove things like sand or weeds. It sinks down through filter beds to remove smaller particles.

Stage 2 - Desalination
Seawater is desalinated using reverse osmosis. The seawater is pumped at high pressure through thousands of reverse osmosis membranes. They extract fresh water, leaving behind a salty liquid called the seawater concentrate.

Stage 3 - Producing Drinking Water
The fresh water produced by desalination plant is treated to meet the Australian Drinking Water Guidelines. This may also include additives such as fluoride depending on which water utility operates the plant.

Stage 4 - Seawater Concentrate
The salty liquid that is left over has about twice the content of salt and is two degrees warmer than the ocean in which it was sourced. The seawater concentrate is discharged back into the ocean in a method that reduces the impact on the environment.

Desalinated water is either directly supplied to the consumer or blended with other water sources within the utility water network.

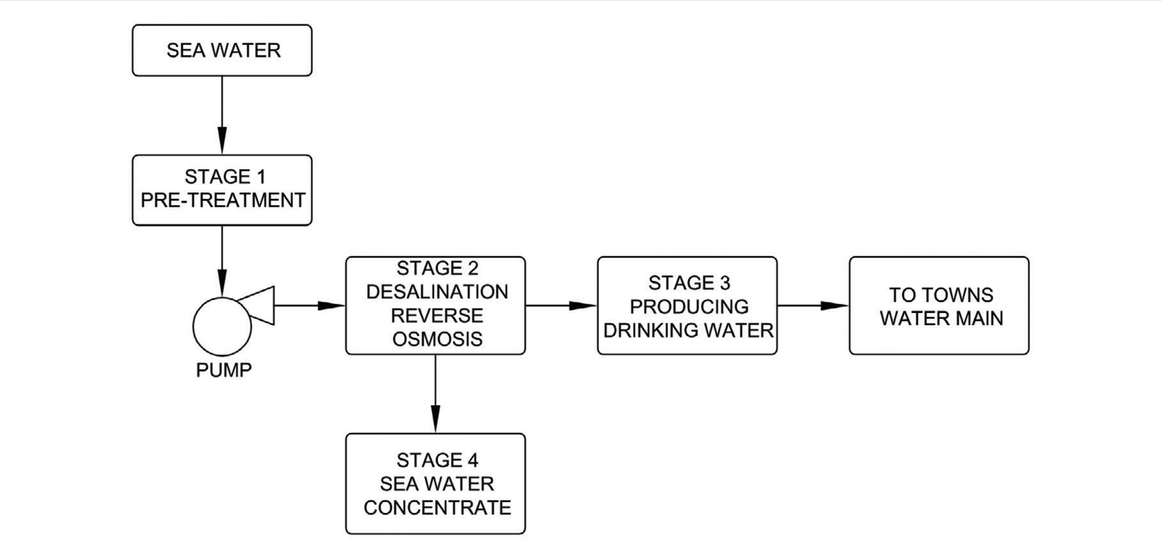

Figure 5.2
Typical Desalination / Blended Water Supply

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Desalination plants operating throughout every state in Australia

Areas that are supplemented by desalinated water include:

- Sydney, NSW
- Melbourne, Vic
- Adelaide, SA
- Perth, WA
- Coober Pedy, WA
- Penneshaw, SA
- Marion Bay, SA
- Gold Coast, Qld

Private Black And Grey Water Treatment Systems

Black and grey water reuse is similar to towns mains recycled supply as described previously in this section. Black and grey water reuse is generally associated with private small scale waste water treatment systems in residential and commercial buildings.

The reason a building owner installs a black and grey water treatment system is to reduce the reliance on the town's main water supply and to increase the environmental sustainability of the building.

Black and grey water systems must be designed and installed correctly. There is a risk to the public and building occupants if a treatment system fails. The design of a black and grey water system must be designed by a suitably qualified person and before installation commences be approved by the relevant regulatory authority.

The designer, installer and building owner must also be aware of the federal, state and local government approvals process when installing a treatment system.

The designer, installer and building owner shall be aware of the operational and maintenance responsibilities associated with operating a wastewater treatment plant.

Black And Grey Water Sources Within A Building

Generally there are three sources of wastewater within a building. These sources of wastewater are:

Black Water

Black water is a portion of the wastewater stream that originates from toilet fixtures.

Grey Water

Grey water is captured from non-food preparation sinks, showers, baths, spa baths, clothes washing machines, and laundry tubs.

Reject Waste Water

Reject waste water is wastewater that cannot be treated for reuse within the building. Reject waste water includes cooling water bleed off water, fire sprinkler system drain down water, trade waste water and grease water etc.

Rejected wastewater can be treated for reuse but generally isn't, due to the excessive cost associated additional pretreatment systems.

Black and Grey Waste Water Treatment Systems

Black water (Figure 5.3) and Grey water (Figure 5.4) reuse has been identified as an alternate water source to supplement the drinking water supply similar to rainwater harvesting.

When deciding on a waste water system the designer and building owner must select a system that achieves the required water reduction targets from the town's water main.

The wastewater treatment system is limited to the amount of black and grey water that is generated within the building.

The following information forms part of the assessment required to evaluate the size and type of wastewater treatment system that will be required for the building.

- Create a profile of the waste water generated within the building, this includes:
  - » Type of building.
  - » Population.
  - » Hours, days, weeks and annual operation of the building.
  - » Types of fixtures fittings and equipment that generate waste water.
  - » Volume of source water generated within the building.
- Create a profile of potable water that can be supplemented by reuse water within the building, this includes:
  - » Irrigation demand.
  - » Toilet flushing demand.
  - » Wash down.
  - » Cooling tower make up water demand etc.
- Amount of wastewater discharged from the wastewater treatment system during operation as a byproduct of the process.
- Discharge point for wastewater discharged from the system e.g. utility sewer main, absorption trenches etc.
- Location of the wastewater treatment system.
- Budget for installing the system (capital expenditure).
- Budget for operating the system including maintenance, consumables, equipment replacement and upgrades (operating expenses).
- Expected building design life of the building and wastewater treatment system.
- Cost of the system and expected payback.

There are many ways to reuse black and grey water that would otherwise be discharged into sewer, these are listed below;

- Greywater Diversion Devices.
- On-site Single Domestic Wastewater Management.
- Constructed Wetland Treatment
- Systems (CWTS).
- Aerobic Sand & Textile Filter Systems.
- Biological Filter Systems.
- Aerated Wastewater Treatment Systems (AWTS).
- Membrane Bio-Reactor (MBR).

When selecting a wastewater treatment system there are many options that are available, which include proprietary systems and site-specific engineered system.

The designer and building owner must investigate all options that will best suit the application in which it will be installed.

There are a number of proprietary systems available to treat and reuse black and grey wastewater for smaller wastewater treatment systems.

There are also medium to large modular waste water systems, which are pre-engineered to expedite the time it would take to design and construct the unit.

Check with the state or local health departments for pre-approved waste water systems. An example of pre-approved waste water systems can be found at the NSW Health website;

www.health.nsw.gov.au/environment/domesticwastewater/Pages/default.aspx

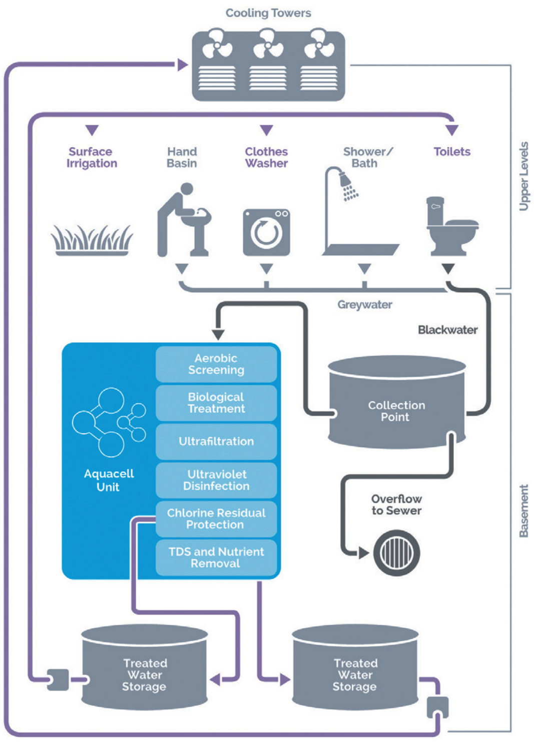

Image source, Aquacell Pty Ltd

Figure 5.3
Black Waste Water Treatment Systems

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Copper Alliance

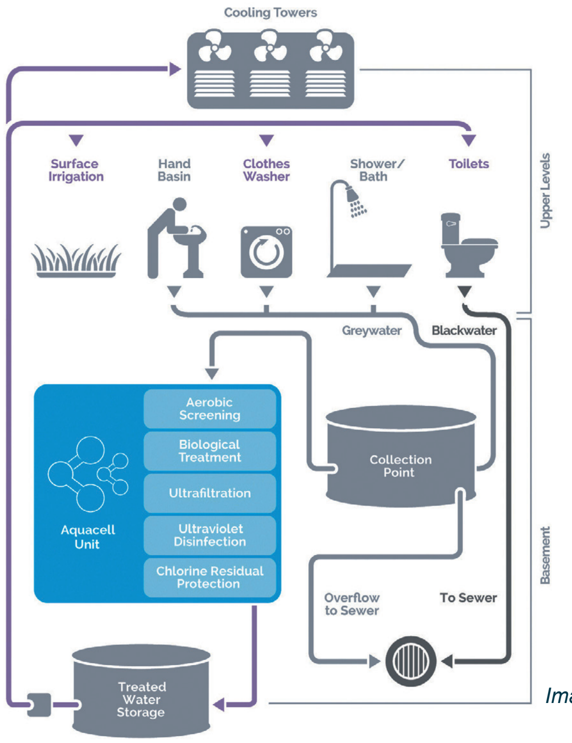


Image source, Aquacell Pty Ltd

Figure 5.4
Grey Waste Water Treatment Systems

International Copper Association Australia
Copper Alliance

Rainwater

Rainwater collection is the most common alternate source of water. Rainwater has been used as a primary water supply to many rural areas where town's main water is not available. Within cities rainwater has been used as alternate sources of water to supplement the town's main water for non-potable use e.g. irrigation; wash down, cooling towers etc.

Rainwater has become an essential part of reducing the reliance on town's main water supply due to the relatively inexpensive cost to treat, store and distribute throughout a development or building.

Green building rating tools have been created with rainwater harvesting calculators to estimate the reduction of water drawn from the town's water main to supply the building (Figure 5.5). These tools allow the designers to estimate the most efficient size of water storage while considering the cost to install the system.

While there is increasing Government support for using rainwater tanks in Australia, there are states and territory requirements relating to design and installation.

The government and health departments recommend that where a property can be supplied by town's main water that the property be connected and town's main water shall be used for drinking and personal ablution purposes.

There is a vast amount of information to help the designers and building owners to assist them to design, build and operate a rainwater harvesting system and it is recommended that the designer use these available resources.

It is the designer and installer's responsibility to understand the relevant regulations when designing a rainwater harvesting system and to obtain all required approvals.

The following links are provided to help designers to build and operate a rainwater harvesting system as outlined in the regulatory requirements.

www.health.nsw.gov.au/environment/water/Pages/rainwater.aspx

www.sydneywater.com.au/sw/plumbing-building-developing/plumbing/rainwater-tanks/index.htm

www.health.qld.gov.au/ph/documents/ehu/32922.pdf

Rainwater harvesting can vary in size from a single dwelling to a multi-use high-rise development. Generally a rainwater harvesting system comprises of the following components (Figure 5.6):

- Rainwater catchment area (roof or surface water).
- Gutter leaf guard.
- Downpipe or drainage system.
- First flush device.
- Rainwater storage vessel (tank or dam).
- Tank overflow to stormwater drainage.
- Pump system.
- Primary and secondary filtration system.
- Ultra violet or chlorine disinfection.
- Town's water main back up.
- Pipe distribution network.

There are generally requirements in place including mandatory use of backflow prevention devices to prevent the possibility of water from tanks entering mains water supplies. Refer AS/NZS 3500.

Discharge of rainwater or disposal of accumulated sludge may also be subject to local or state regulations environment protection acts.

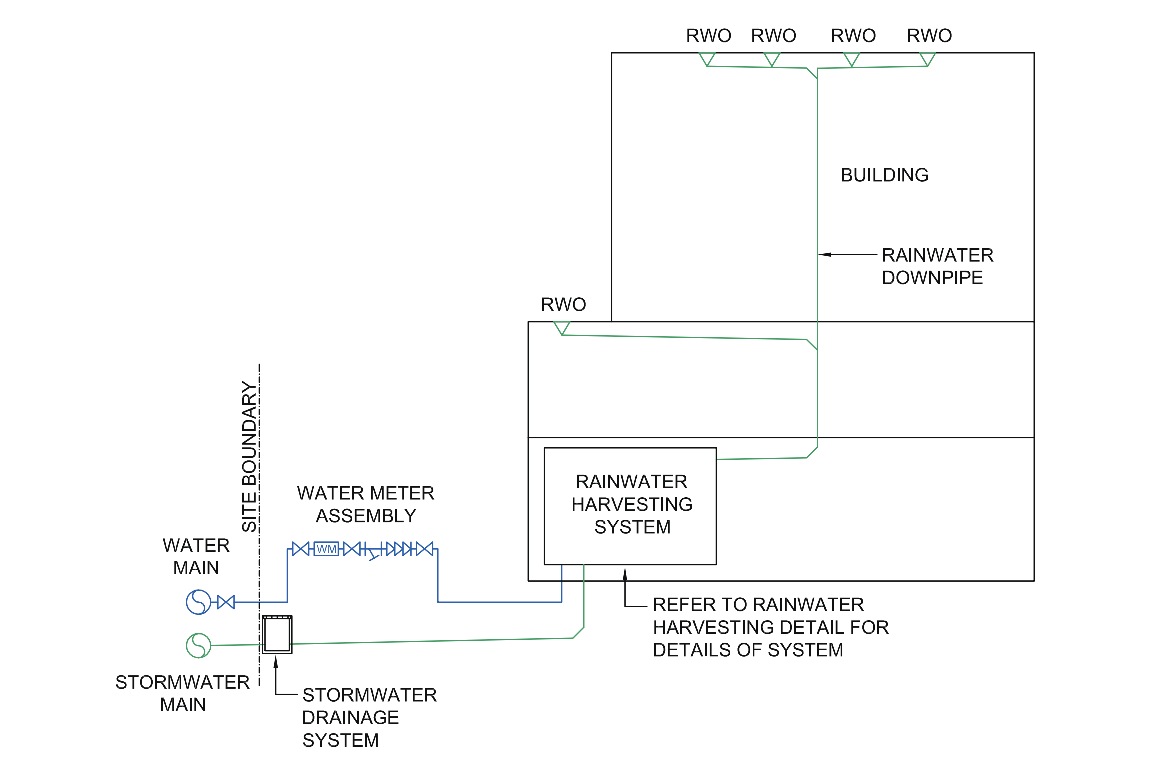
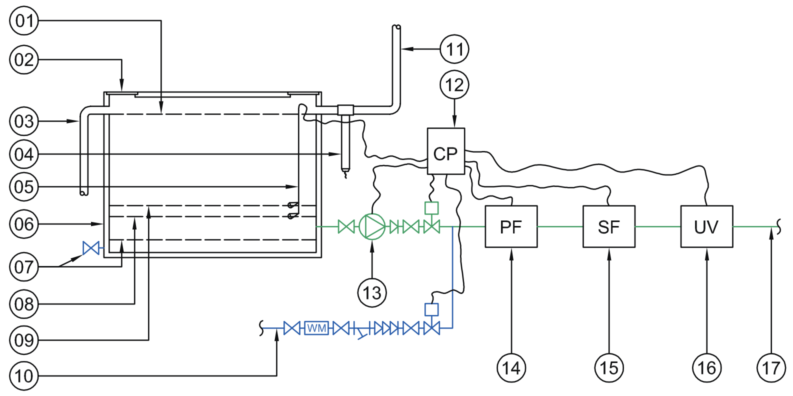


Figure 5.5
Rainwater Building – Concept Design Diagram



- (01) TANK TOP WATER LEVEL
- (02) TANK ACCESS
- (03) TANK OVERFLOW PIPE
- (04) FIRST FLUSH DEVICE
- (05) FLOAT / LEVEL SWITCHES
- (06) RAINWATER TANK
- (07) SLUDGE LEVEL / SLUDGE VALVE
- (08) LOW LEVEL ALARM - TANK WATER LEVEL
- (09) TANK LOW LEVEL, SWITCH TO MAINS WATER BYPASS WATER SUPPLY
- (10) MAINS WATER SUPPLY FEED, WATER METER AND BACK FLOW DEVICE
- (11) RAINWATER DOWNPIPE
- (12) RAINWATER HARVESTING SYSTEM CONTROL PANEL
- (13) PRESSURE BOOSTER PUMP
- (14) PRIMARY FILTRATION
- (15) SECONDARY FILTRATION
- (16) ULTRA VIOLET DISINFECTION
- (17) TREATED RAINWATER SUPPLY FEED

Figure 5.6
Rainwater Harvesting System – Concept Design Diagram

6 Chapter Six

Chapter 6 – Limitations of Copper Tubes – Corrosion

EN 1057 version

International Copper Association Australia
Copper Alliance

Limitations of Copper Tubes – Corrosion

Cu

Balanced water chemistry is important to the corrosion resistance of copper piping.

History Of Copper Plumbing Systems

Copper tube is recognised as a reliable material for plumbing water supply and sanitary systems due to its successful & widespread international usage. Copper has been used in plumbing systems worldwide for over 100 years. There have been a small number of cases where copper plumbing has suffered premature failure from pitting or discolouration of water due to the presence of copper species from corrosion or effects from the external environment.

Research undertaken over recent years has demonstrated that water chemistry is the primary factor influencing these failure processes. The other significant contributing factor is design and installation issues such as pipe sizing, flow rates or contact with incompatible materials such as aggressive soils.

Balanced water chemistry is important to the corrosion resistance of copper piping. Transient conditions may either prevent the formation of uniform, protective, internal films, or cause irreparable damage.

Copper water piping achieves its longevity through the development of a stable protective internal surface film. Corrosion may occur if either an unstable film forms, or a protective film is interfered with during the installed life of the water pipe.

Water composition, systems design, commissioning, and on-going compatible operating conditions are all critical to the development and retention of protective films, and long term satisfactory performance of copper.

Types of Copper Corrosion

Microbiologically Influenced Corrosion (MIC)

The MIC mechanism involves the presence of a biofilm which has the capability of adhering itself to a metal surface.

When biological material lodges on the metal surface, it forms concentration cells due to the development of micro colonies of bacteria (Figure 6.1). A pH gradient is established within the region, with a lower pH produced at the film layer close to the metal, which corrodes.

It is important to note that:

- The formation of biofilms is related to water chemistry not the metal.
- International investigations have shown copper to have superior resistance to the impact of bacteria compared to alternative piping materials.

MIC generally affects only cold water (Figure 6.1), and is more likely in untreated water supplies. Hot water systems where the water is maintained above 60^{0}C and treated water where a disinfectant level is maintained (residual free chlorine) do not suffer from MIC.

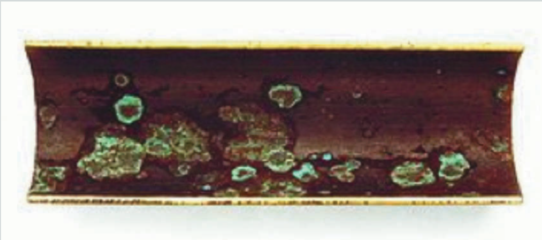


Figure 6.1
MIC Corrosion – Cold Water

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There are many case studies where MIC corrosion symptoms have occurred and have been resolved by the installation of re-chlorination stations closer to the affected area.

Chlorine used as a disinfectant does not have an indefinite life and will lose it effectiveness after several days.

This means that areas remote from the treatment plants may not have any residual chlorination and may need to be re-chlorinated.

Blue Water

Blue water is characterised by a blue-green colour in the water when first drawn from a tap. It is more frequently observed in pipes with low patterns of use.

Often it will be visible when a tap is left unused for a short period of time.

The colour of the water can vary from a milky colour through to green/blue colour and particles will settle on the bottom if the container is left to stand overnight (Figure 6.2).

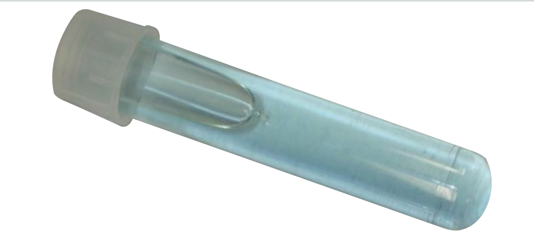

Figure 6.2
Blue Water

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It's Occurrence

Information gathered about this phenomenon, also known as by-product release, revealed that it has been associated with cold water in:

- Water which had no or very little residual chlorine.
- Occurs in cold soft alkaline (pH>7.5) waters.
- Dead end piping and rarely used sections of a system.
- New developments where pipes were left filled with stagnant water for prolonged periods.
- Systems where cold water was warmed.

Preventative Measures

It is important that water is adequately disinfected, with as little as 0.2ppm residual chlorine desirable throughout piping systems.

At the design stage, special care should be taken to avoid undesirable low velocities, dead ends and long runs of piping which is likely to be infrequently used. During construction, only non-contaminated water should be used for testing pipes. Procedures must be instituted and monitored to ensure piping is flushed on a routine basis until the building is commissioned.

AS 4809 Copper Pipes and Fitting - Installation and Commissioning describes methods for achieving this requirement. Cold and hot pipes should be installed with appropriate separation to ensure there is no transfer of heat to cold pipes.

Remedial Action

On occasions, some 'blue water' cases have been resolved by flushing water through affected piping and systematic, routine operation of the end of line taps. Flushing should be the first action taken. Where possible, the affected line could be connected to a more regularly used pipe to create flow through conditions.

In cases, which did not respond to flushing, traditional chemical cleaning has proved successful. In the main, 'blue water' reappeared after a short period of time. Investigations by the Materials Performance Technologies New Zealand have shown heat treatment to be successful in killing and permitting subsequent removal of biofilms.

It was recommended that pipes should be exposed to 70°C water for at least 10 minutes with taps opened. Clean cold water should be run through treated pipes on a regular basis for the next two weeks. Residual chlorine must be present in the water for effective control.

Cuprosolvency

Cuprosolvency is typified by general corrosion of copper pipe releasing slightly elevated levels of colourless soluble copper into the drinking water.

There is no noticeable change in the colour or clarity of the water and whilst the integrity of the copper pipe is unaffected, staining of sanitary ware (Figure 6.3) and clothing can occur.

It is typically associated with dripping water taps or a particular soap that reacts with the low levels of copper and can readily be removed using ammonia-based cleaning agent.

It's Occurrence

Information gathered about this phenomenon indicate that it has been associated with untreated cold water typically in rain water tanks systems and is associated with:

- Water, which have no residual chlorine or disinfection system.
- Soft waters with low pH<6.5 (acid waters).
- Generally can occur where the system is not regular cleaned and maintained.
- Contain high levels of carbon dioxide CO2.
- More common with copper pipe less than 3 years old.

Figure 6.3
Cuprosolvency staining of sanitary ware

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Preventative Measures

All water supplies used for drinking need to be maintained to ensure that the risk of contamination is minimised. For tank water supplies, regular cleaning of the tank and ensuring roofs and gutters are clean.

It is important that water is suitable for human consumption and annual checking the level of microbiological contamination will determine if this is an issue.

Adding a filtration and disinfection system, such as ultraviolet or chlorination, will ensure long term suitability of the system.

At the design stage, special care should be taken to avoid undesirable low velocities, dead ends and long runs of piping which is likely to be infrequently used.

During construction, only non-contaminated water should be used for testing pipes. Procedures must be instituted and monitored to ensure piping is flushed on a routine basis until the building is commissioned.

AS 4809 Copper Pipes and Fitting - Installation and Commissioning describes methods for achieving this requirement.

Remedial Action

Modification of the water chemistry may be required to eliminate the problem.

For example, the addition of marble chips or limestone to the water storage tank will increase water hardness and provide buffering capacity to enable the risk of copper corrosion to be reduced.

Regular flushing of the water system and the occasional high temperature water flush have provided some relief. The long term solution is to install pH correction filters and a disinfection system.

Pitting corrosion

Pitting (non-uniform) corrosion in both warm and cold water systems is usually associated with water composition issues, particularly but not exclusively with low pH and low alkalinity parameters.

Pitting corrosion in warm water systems is generally in recirculating systems where there is no disinfection, or chlorine levels have dissipated to very low levels.

These conditions are typified by rain (roof collected) water as well as some Australian surface and bore waters. Where pitting corrosion is observed (Figure 6.4), it should be addressed by replacement of the affected section of pipe.

It's Occurrence

More prevalent with untreated water supplies and occasionally some tempered water system. Non-uniform pitting corrosion failures have occurred in a small number of institutional buildings in different regions of the world.

It was reported that while water provided from the mains to facilities was initially potable, subsequent storage at some of the installations might have resulted in changes in water quality prior to distribution throughout the building.

Microbial activity (Figure 6.5), was found to be associated with pitting. The occurrence of biofilms contributed to the pitting process. Contributing factors include: Little or no disinfection control pH levels in the range 7-8.2, low levels of organic matter.

Preventive Measures

The areas identified for 'blue water' action also need to be addressed to avoid MIC pitting corrosion. Other areas of attention are proper covering and periodic cleaning of water storage tanks.

Piping systems should be designed to avoid the formation of air pockets and uniform flow rates maintained.

Routine chlorine disinfection of water piping should be considered and in the case of hot water systems, the operating water temperature should be above 60°C in order to inhibit bacterial growth.

Remedial Action

When it become evident that there is an issue with pitting corrosion, pinhole leaks have occurred in the wall of the tubes and replacement may be the only course of action.

Pitting corrosion is more prevalent in horizontal runs of infrequently used sections of piping. Pitting may be restricted to certain sections of pipe work but this can only be confirmed by removal and inspection.

When repairing leaks it is recommended that the full section of pipe work around the leak be replaced and not just replacing a short section around the leak.

Figure 6.4
Pitting Corrosion
– Warm Water Systems

International Copper Association Australia

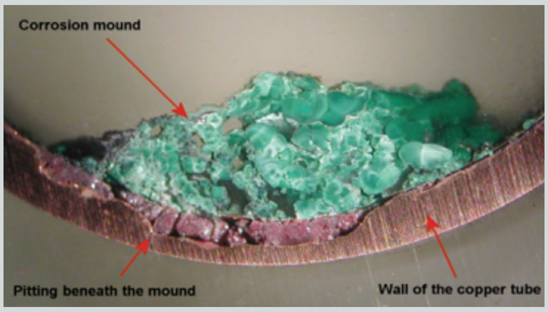

Figure 6.5
Cross Section of a Corrosion Pit

International Copper Association Australia

External Corrosion Of Copper Pipe

Copper pipe has generally good corrosion resistance in most environments and when buried in natural soils, and failures are relatively rare.

There have been issues were there is chemical attack of exposed pipe work and aggressive soils attacking buried pipe work (Figure 6.6). Buried pipe work should be placed in clean bedding sand or the natural excavated material provided it is free from rocks and rubble.

Reference should be made to AS/NZS 3500.1 Water Supply concerning bedding and backfill.

Causes of External Corrosion of Buried Copper Pipe

Corrosive soils and fills; Unprotected Copper pipe should **NOT** be used in the following soil and fill types:

- Very low resistivity soils (<5 Ω-m), which usually indicates a high salt content.
- Soils with large quantities of organic matter.
- Moist cinders, due to the possible presence of sulphides or galvanic action from carbon particles.
- Acid sulphate soils that contain anaerobic sulphur reducing bacteria (SRB), which can produce sulphides.
- Acidic soil (pH <4.5) due to organic or inorganic acids.
- Soils and fills containing high levels of ammonia compounds (e.g., some fertilizers, animal urine).
- Soils containing elevated levels of sulphate and/or chloride together with poor drainage, retained moisture, and high annual rainfall (>750 mm/yr.).

Causes of External Corrosion of Exposed Copper Pipe

Acid Attack

Cases have been recorded where copper piping has corroded due to excess brick cleaning acid being used to wash down brick wall where the copper piping is placed. The acid has not been thoroughly diluted and washed away allowing it to attack the copper. Animal excreta and decomposed undiluted urine is also acidic and can lead to corrosion of copper piping.

Chemical Attack

In heavy industry and waste disposal business, strong chemical are occasionally used. These can produce gases and vapours that can settle on exposed pipe work allowing the chemicals to attack the copper. Ammonia and sulphides are not conducive to copper and will cause problems.

Thermogalvanic Corrosion

Thermogalvanic corrosion can occur where a hot water pipe is connected to a cold water pipe (e.g., via a hot water cylinder) when both pipes are buried together in conductive ground.

This situation should be avoided by running the hot water pipe above ground or isolating both pipes by separately wrapping them with an impermeable material.

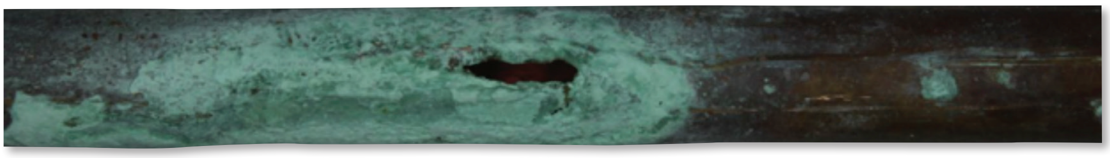

Figure 6.6
External Corrosion

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Copper Alliance

Interface Corrosion

Corrosion can be induced in damp, conductive soils by partial encasement in concrete where the pipe may corrode at the soil/concrete interface, as well as where the pipe is in contact with moist cinders. Wrapping or sleeving the pipe with an impermeable material where it passes through the concrete will prevent interface corrosion.

Oxygen Differential Cells

Oxygen differential cells are created by non-homogenous backfill material or by pipe laying on undisturbed soil being backfilled with aerated material.

Wrapping or sleeving the pipe with an impermeable material or otherwise isolating the pipe from the surrounding soil will prevent this form of corrosion.

Methods of External Corrosion Control

Use of pre-insulated copper pipes will avoid most incidences of external copper corrosion. It is imperative that all joints are wrapped with a waterproof tape to ensue the entire length if pipe is fully sealed.

Alternative, isolating buried uninsulated copper pipe from corrosive situations by wrapping the pipe in petrolatum tape or other approved methods will protect pipes from corrosive attack.

Other Causes of Corrosion

Erosion-Corrosion

Erosion-corrosion is a form of failure that can occur in both hot and cold copper water pipes but is more prevalent in hot water recirculating systems. Erosion-corrosion can be identified by the presence of smooth grooves (Figure 6.7), troughs, waves or rounded holes on the inside of the pipe that usually exhibit a directional pattern.

Factors that can Contribute to Erosion Corrosion

Piping Design

Water velocity exceeding **3 m/s** for a significant time may cause erosion-corrosion and increased water temperature contributes to the problem. Attack mostly occurs in the heated water circulating supply systems but rarely in the heated water reticulated (dead-leg) supply systems.

Installation Issues

Sharp changes in direction, burrs inside joints and dents in the wall can contribute to this type of corrosion by generating turbulences that cause very high-localised water velocities (Figure 6.8). Extensions to building without consideration for the increased hot water draw off, resulting in higher water velocities, have regularly contributed to this problem. Erosion is more common near the suction points of circulating pumps, due to lower pressure, rather than the outlet side of the pump.

Figure 6.7
Erosion Corrosion

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Figure 6.8
Erosion Corrosion from turbulence caused by burr left inside of tube

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Copper Alliance

Dissolved Gases

Entrained air and high levels of carbon dioxide in the water can cause erosion-corrosion as they continually break down the normal protective films formed inside copper pipes.

Dissolved gases cause localised boiling and cavitation bubbles to form where turbulence exists and bubbles subsequently implode on the nearby surfaces contributing to the impingement of the water on the wall of the tube (Figure 6.9).

Particulate Matter

Sand, grit or other debris carried in copper pipe can also break down protective films and wearing the tube away.

Preventive Measures

Design Water Velocities

It is generally recommended that the design velocities for cold water do not exceed **2.4 m/s.** and for hot water no more than **1.6 m/s**. Recirculating hot water systems need to ensure that the recirculating pumps are set so that the return water velocity is no more than **1.0 m/s**. It is better to design with conservative velocities to compensate for other contributing factors.

Installation Issues

During installation, good plumbing practices need to be carried out in accordance with AS 4809 Copper Pipes and Fitting - Installation and Commissioning. Designed pipe sizes should be adhered to and substituting small diameter pipes prohibited.

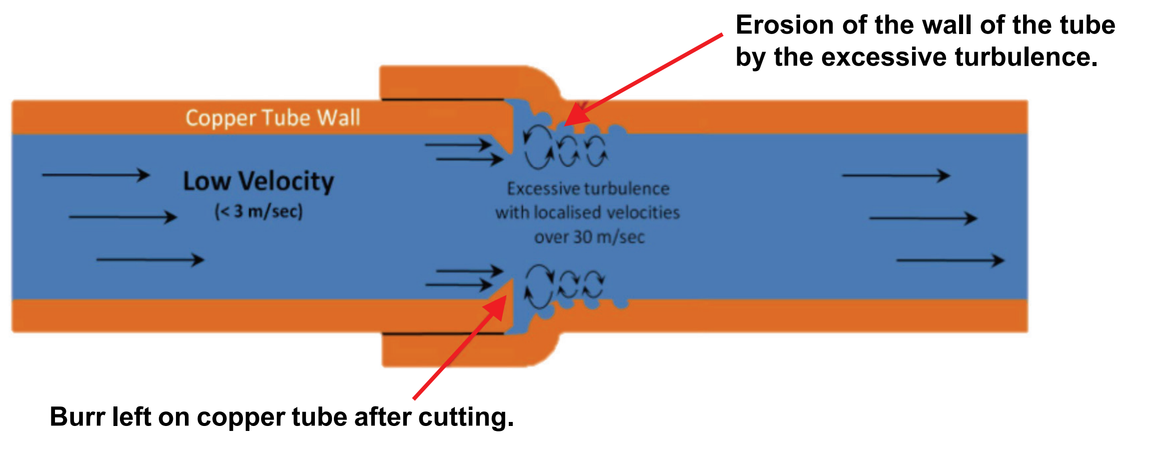

Figure 6.9
Explanation of how turbulence causes Erosion Corrosion

International Copper Association Australia

Stray current corrosion

Where DC. electricity (e.g., from a welding unit, or diode switched AC. supply) is 'earthed' to a pipe, severe corrosion will occur at the point where the current leaves the pipe.

It can also be induced from proximity to cathodic protection system anode beds or stray current from electric train or tram systems.

Power systems should not be earthed via a copper water reticulation system for this reason.

Note:
Stray current corrosion only affects external corrosion. It has no effect on internal pitting or 'blue water'.

Flux Induced Corrosion

Flux induced corrosion was relatively common when soft solder was the predominant joining methods for pipe work.

It relates to excessive flux remaining inside the pipe work that has been identified as the cause for localised pitting corrosion.

As fluxless silver brazing or mechanical joining is now the most common methods of joining, this cause of corrosion is very rare and easily identifiable.

Corrosion fatigue

Corrosion fatigue can occur in hot water pipes where thermal expansion and contraction of the pipe has not been allowed for. Corrosion fatigue may also occur at points where the pipe has been damaged or distorted (Figure 6.10).

Provision has to be made to allow the pipe to expand and contract as specified in this manual and AS/NZS 3500.4. Care has to be taken to prevent mechanical damage to pipe during installation and throughout its service life.

Figure 6.10
Edge Cracking due to Fatigue Corrosion of an Elbow

Table 6.1 provides a Summary of Corrosion Types, Systems and Remedies that can be employed to mitigate the occurrence of corrosion within copper tubes – water supply services.

Name	Symptoms	Type of Installation Affected	Remedial Actions
Blue Water	White or light blue colouration of the cold water by fine particulate matter that generally precipitates with time. Very high copper levels. (2-8 mg/l)	High pH levels (>7.2), soft water with no residual free chorine levels – no disinfection.	Increase bicarbonate levels and/or add disinfection.
Cuprosolvency	Staining of hand basins and showers from cold water outlets. Water remains clean. Moderate copper levels. (1-2 mg/l)	Low pH (<7.0) without disinfection. Typified by tank water installations.	Neutralize pH and/or add disinfection. Hot water flushing. Sterilisation.
Cold and Warm Water Pitting Corrosion	Perforation of the wall of the cold water copper tube after varying years of life. (4-20 years). Usually low levels of copper detected. (<1 mg/l)	High pH levels (7-7.8), soft water supply with no residual chlorination. Warm Water Pitting usually only affects tempered water recirculating systems with no residual free chorine levels.	Increase hardness of water and increase disinfection. (chlorine dosing) Increase temperature warm water system to <60°C.
Hot Water Pitting Corrosion (Type II corrosion)	Perforation of the wall of the hot water copper tube after varying years of life. (4-20 years). Usually low levels of copper detected. (<1 mg/l)	Typically very hot water, recirculating systems with high chorine levels.	Lower temperature, increase pH
Erosion Corrosion	Erosion of the wall of the tube by high water velocity, turbulence or particular mater.	Recirculation hot water systems.	Reduce water velocity.
External Pitting Corrosion	Perforation of the wall of the copper tube from corrosion initiated from the outside	Generally buried tubes or tube exposed to corrosive liquids or gases.	Replace with lagged or sleeved tubes.
Corrosion Fatigue	Cracking of the pipe at elbows, changes in direction or at branches	Hot water installation or installations subject to repetitive cyclic movement.	Ensure that there is allowance for the pipe to move and that the pipe is not constrained close to changes in direction.

Table 6.1
Summaries of Corrosion and Remedies

International Copper Association Australia
Copper Alliance

Reference:

Guidance on the use of Rainwater Tanks

www.health.gov.au/internet/main/publishing.nsf/Content/ohp-enhealth-raintank-cnt.htm

7

Chapter Seven

Chapter 7 – Joining of Copper Tubes

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Copper Alliance

Joining of Copper Tubes

Cu

There is a variety of ways to assemble copper tubes for plumbing and heating services systems.

Introduction to Joining Copper Tubes

All fittings listed in the Australian Standards are related to Australian Copper Tubes sizes manufactured in accordance with AS 1432. The choice of jointing method used is generally made by the installer, however the skill level of workers and the availability of the correct tools usually determine the preferred system.

The pressure rating of an assembled copper fitting is directly related to Type B tubes, where heat is applied. Copper fittings are traditionally made from copper and copper alloy, although in roll grooved couplings these may be of cast iron metal.
When installing copper tubes and fittings care and consideration of the following best practice installation methods;

- The removal of any tube burrs.
- Ensure the tubes and fittings are not damaged by the application of heat or force.
- When making a change in tube sizing the use of an appropriate fitting must be used.
- There shall be no crimping of tubes to join different diameter tubes.
- Where fabricated sockets and tees are made from tubes, the use of recommended tools shall be used.
- All excessive brazing and soldering flux shall be removed from the made joint assembly.

Types of Joints used for Copper Tube Assembly

Whilst soldering or brazing is usually the accepted method of joining copper tube, there are times when a mechanical joint may be required or preferred. The different types of joint assemblies are described in this chapter, explaining their function and benefits.

Compression End - Flared Joints

Flared fittings (Figure 7.1a and Figure 7.1b), are an alternative when the use of an open flame is either not desired or is impractical. Water and gas service applications generally use a flare to threaded pipe end-connection, when connecting the copper tube to the gas main and/or the meter the flare jointing method is preferred. Threaded pipe threads are specified to AS 1722.2 Series G or GB.

Copper tube used for Fuel Gas (Liquefied Petroleum (LP), Propane Gas or Natural Gas may be joined utilizing a flared brass fitting having a single 60º flare face, according to AS 3688 and AS 5601 Gasfitting Installation standard. AS/NZS 3500 Installation Codes permit the use of flare joints, but it is important to check with the local authority having jurisdiction to determine acceptance for a specific application.

Figure 7.1a
Assembling Copper Flare Pipe Adaptor and Nut

Compression End –

Olive and Croxed Joints

This joint is created using a special tool, which is placed into the tube to form a ring on the external surface of the tube. The ring allows either a brass or nylon olive including the compression nut to pull the raised copper tube surface against the surface of the brass male fittings having an internal flare face of 60^0.

AS/NZS 3500 Installation Codes permit the use of flare joints, but it is important to check with the local plumbing authority having jurisdiction to determine acceptance for a specific application.

AS 5601 Gasfitting does not permit the use of compression croxed joints (Figure 7.2), using a sleeve or olive.

Figure 7.2
Compression Joint with Brass or Nylon Olive

Figure 7.1b
Assembled Copper Flare Compression Joint

Threaded End Joint

Threaded end connectors used with copper tubes comply with AS 3688 and are nominated as BSPT (British Standard Pipe Thread). Australian pipe threads are divided into two distinct groups, sealing pipe threads and fastening pipe threads (Figure 7.3a and Figure 7.3b).

Sealing Pipe Threads

Designated "R" to AS 1722 Part 1 (Formerly BSPT) are based on ISO 7/1 where pressure tight joints are made on the mating threads. These threads are intended for pipe suitable for screwing and for valves and other fittings to be connected to screwed pipes and tubes.

If necessary an appropriate jointing medium may be used on the threads to ensure pressure tight joints. The male thread "R" is always tapered. The internal thread may be parallel "RP" or tapered "RC".

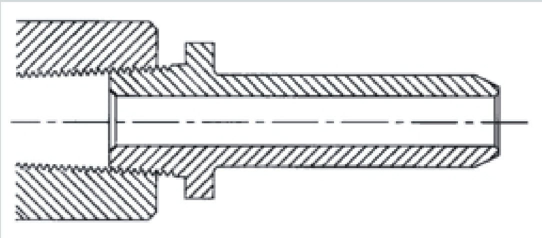

Figure 7.3a
Fastening Pipe Threads

Designated "G" to AS 1722 Part 2 (Formerly BSPF) is based on ISO 228/1, where pressure type joints are not made on the threads. These threads are intended for the mechanical assembly of the component parts of fittings, cocks, valves, accessories etc.

If these assemblies are required to be pressure tight this will be achieved by compressing two surfaces other than the thread and the use of jointing medium if necessary e.g. gaskets on flanges or O rings. G series threads, both male and female threads are always parallel.

For internal threads one class of tolerance is provided "G". For external threads, two classes of tolerance on the pitch diameter are provided, class "GB" is used for general applications where no tolerance class is stated.

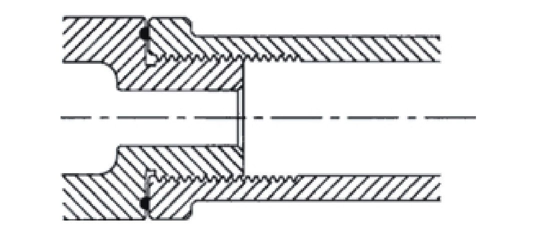

Figure 7.3b
Sealing Pipe Thread

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Roll Groove Joints

Grooved-end piping joints have been familiar to pipe fitters and sprinkler system contractors for many years. Since 1925, this method of joining pipe has been used reliably on steel and iron pipe in HVAC, fire protection, process piping and related applications.

This method of mechanical joining is also available in a system for copper tubes in sizes ranging from 50mm through 200mm (Figure 7.4). Included are couplings, gaskets and a myriad of fitting configurations. The system offers a practical alternative to soldering and brazing larger-diameter copper tube. And most importantly it requires no heat or open flame Copper roll groove joining takes advantage of copper's excellent malleability and its increased strength when cold worked. The joints rely on the sealing capability of a special clamping system that contains an EPDM or Nitrile gasket and a specially designed clamp. Several manufacturers offer roll groove tools, gaskets, clamps and fittings.

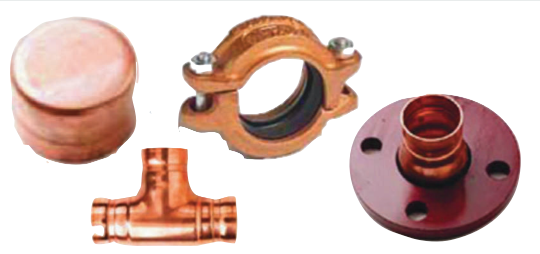

Figure 7.4
Roll Grooved Copper Fittings

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Press-connect Joints

Press-connect joining of copper and copper alloy tube is fast, economical, and most importantly it requires no heat or open flame (Figure 7.5). The press-connect joining method (sometimes called press-fit) was patented in Europe in the late 1950s and continues to be used successfully. The method and associated fittings and tools were introduced in the United States in the late 1990s. Since then, there has been growing acceptance, and those using the method experience excellent results.

Press-connect joining takes advantage of copper's excellent malleability and its proven increased strength when cold worked. The joints rely on the sealing capability of a special fitting that contains an elastomeric gasket or seal (such as EPDM) and the proper use of an approved pressing tool and jaws. Typical ranges of pressure-temperature ratings for these no-flame joints are found in AS 3688.

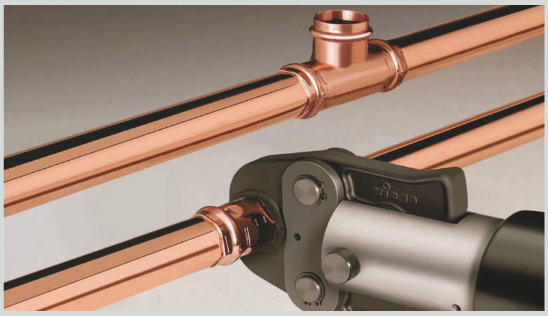

Figure 7.5
Pressfit Copper Fittings

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Soldered Joints

Solder is a joining process using a filler metal (solder) that melts at about 180^{0}C to 320^{0}C. Historically plumbing solder had been a lead-tin alloy but this is now banned due to health reasons.

There are solders that are better but these also have some issues. It is necessary to check local regulations and your regional authority to ensure soft solder can be used.

Figure 7.6
Copper Capillary Fitting – Pre Solder

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Brazed Joints

Strong, leak-tight brazed connections for copper tube may be made by brazing with filler metals which melt at temperatures in the range between 600^{0}C and 820^{0}C. Brazing filler metals are sometimes referred to as "hard solder" or "silver solder." These confusing terms should be avoided (Figure 7.7).

The temperature at which the filler metal starts to melt on heating is the *solidus* temperature; the *liquidus* temperature is the higher temperature at which the filler metal is completely melted. The *liquidus* temperature is the minimum temperature at which brazing will take place.

The difference between *solidus* and *liquidus* is the melting range and may be of importance when selecting a filler metal. It indicates the width of the working range for the filler metal and the speed with which the filler metal will become fully solid after brazing.

Figure 7.7
Copper Capillary Fitting – Silver Brazed

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Push-Fit Connection Joints

The push- fit connection joining method of copper and copper alloy tube is fast, economical and requires no heat or open flame (Figure 7.8).

However, unlike most other joining methods, no additional tools, special fuel gases or electrical power are required for installation.

Push-fit connection utilises an integral elastomeric gasket or seal (such as EPDM) and stainless steel grab ring to produce a strong, leak-free joint. Typical ranges of pressure-temperature ratings for these no-flame joints are found in AS 3688.

There are two common types of push-connect fittings. Both create strong, permanent joints however one allows for easy removal after installation to allow for equipment service, while the second type cannot be easily removed once the fitting is installed.

Figure 7.8
Push-Fit Fittings

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Mechanically Formed Fabricated Outlets

Another joining technology that has been used effectively for many years involves a hand tool designed to quickly pull tee connections and outlets from the run of the tube, thus reducing the number of tee fittings and soldered or brazed joints. It allows branches to be formed faster and usually results in a lower installed system cost (Figure 7.9).

This method may be used for general plumbing, HVAC, refrigeration, fire sprinkler and service projects.

Portable hand tool kits and power operated equipment are available that produce lap joints for brazing. The system can be used with Types A, B and C copper tube to form DN15mm to DN150mm outlets from DN15mm to DN200mm tubes, depending on tool selection.

It is essential that the manufacturer's instructions and guidelines be followed exactly to ensure proper installation and safe performance.

Note:
Mechanically formed fabricated outlets should only be performed on annealed supplied copper tube or where tube is supplied in hard drawn finish, the tube will require onsite annealing.

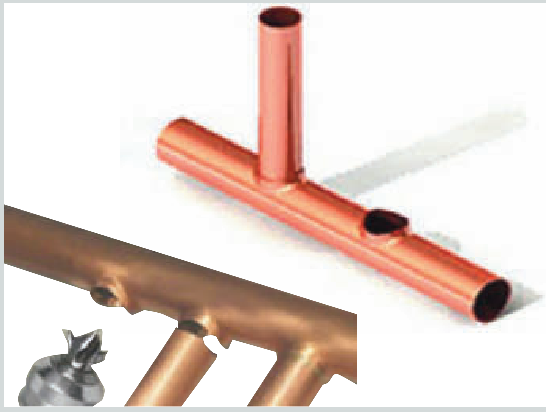

Figure 7.9
Copper Formed Tees – Silver Brazed

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Flange Connection

Flange connections can be made of brass (copper alloy) complying to AS 4807 Metallic Flanges for Waterworks Purposes, the copper tube is silver brazed into the flange, this allows the pipe work to be connected and disconnected to valves, pumps and tanks usually in larger sized pipework.

Two flanges are bolted together with a rubber gasket between them to create a seal.They are available in different types and sizes in accordance with AS 2129 Flanges for pipes, Valves & Fittings, supplied as Table A, D, E, F or H.

The advantages of flange connections joints are easy and simple to install, be assembled in water charged pipes and once made no further heat is required.

Flanges generally come into use when dismantling of the pipework, or removing a flange valve may be necessary.

Flanges Specification to AS2129 Nominal sizes range DN65 - DN200 (Figure 7.10a, Figure 7.10b and Table 7.1).

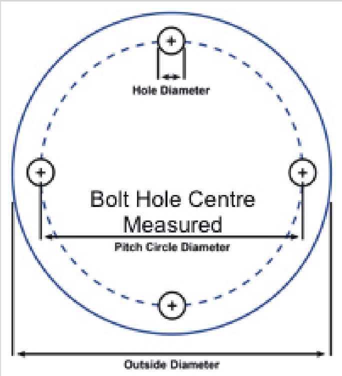

Figure 7.10a
Plan View of Flange

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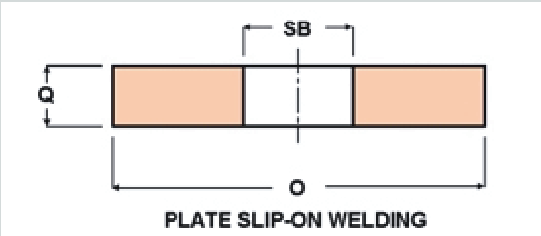

Figure 7.10b
Side View of Flange

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DN50

Class/Table	Outside Diameter	Pitch Circle Diameter	No. Holes	Hole Diameter	Bolt Diameter	Minimum Flange Thickness
Table A	150	114	4	18	M16	10
Table D	150	114	4	18	M16	10
Table E	150	114	4	18	M16	10
Table F	165	127	4	18	M16	11
Table H	165	127	4	18	M16	13

DN65

Class/Table	Outside Diameter	Pitch Circle Diameter	No. Holes	Hole Diameter	Bolt Diameter	Minimum Flange Thickness
Table A	165	127	4	18	M16	11
Table D	165	127	4	18	M16	11
Table E	165	127	4	18	M16	11
Table F	185	146	8	18	M16	13
Table H	185	146	8	18	M16	14

DN80

Class/Table	Outside Diameter	Pitch Circle Diameter	No. Holes	Hole Diameter	Bolt Diameter	Minimum Flange Thickness
Table A	185	146	4	18	M16	13
Table D	185	146	4	18	M16	13
Table E	185	146	4	18	M16	13
Table F	205	165	8	18	M16	14
Table H	205	165	8	18	M16	16

DN100

Class/Table	Outside Diameter	Pitch Circle Diameter	No. Holes	Hole Diameter	Bolt Diameter	Minimum Flange Thickness
Table A	215	178	4	18	M16	16
Table D	215	178	4	18	M16	16
Table E	215	178	8	18	M16	16
Table F	230	191	8	18	M16	17
Table H	230	191	8	18	M16	19

DN125

Class/Table	Outside Diameter	Pitch Circle Diameter	No. Holes	Hole Diameter	Bolt Diameter	Minimum Flange Thickness
Table A	255	210	4	18	M16	17
Table D	255	210	8	18	M16	17
Table E	255	210	8	18	M16	17
Table F	280	235	8	22	M20	19
Table H	280	235	8	22	M20	22

Table 7.1
Typical Flange Specification – Copper Alloy

Cu

DN150

Class/Table	Outside Diameter	Pitch Circle Diameter	No. Holes	Hole Diameter	Bolt Diameter	Minimum Flange Thickness
Table A	280	235	4	18	M16	17
Table D	280	235	8	18	M16	17
Table E	280	235	8	22	M20	17
Table F	305	260	12	22	M20	22
Table H	305	260	12	22	M20	25

DN200

Class/Table	Outside Diameter	Pitch Circle Diameter	No. Holes	Hole Diameter	Bolt Diameter	Minimum Flange Thickness
Table A	335	292	8	18	M16	19
Table D	335	292	8	18	M16	19
Table E	335	292	8	22	M20	19
Table F	370	324	12	22	M20	25
Table H	370	324	12	22	M20	32

Table 7.1
Typical Flange Specification – Copper Alloy – (Continued)

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8

Chapter Eight

Chapter 8 – Pipework Installation

EN 1057 version

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Pipework Installation

Copper tubes have a significantly lower thermal expansion rate compared to those experienced in thermostatic piping system.

Thermal Expansion and Contraction

All materials used in plumbing services pipework experience change in dimension due to the change in temperature. This chapter addresses the requirement of expansion for above ground copper tubes and the means for accommodating thermal expansion in the design and installation of cold and heated pipework systems.

Thermal effects on piping materials can be quite dramatic and for this reason the design and installation of pipework material must take into consideration each material type, the method of installation and the change in temperature either by median heat being transferred or the ambient temperature surrounding the pipe.

Different design provisions and supporting methods may be applicable for specific project requirements, larger diameter tubes and temperature differential.
For larger diameter tube installation the tubes can be supported on rollers if the expansion movement is constant.

Thermal Expansion of Copper Tubes

Copper tubes have a significantly lower thermal expansion rate compared to those experienced in thermoplastic piping systems (Refer Table 8.1). As a general rule for copper tube expansion rates in heated water services a general allowance rule of 1mm per metre of pipework expansion for temperatures up to 80^{0}C or where the change in temperature does not exceed 60^{0}C.

To calculate the stress related forces placed on plumbing services materials and the likely effect on the piping systems, the following mathematical formula is used for a range of temperature differentials;

Formula: $X = L \times (T_1 - T_2) \times C$

Where;
X = Expansion and Contraction (m)
L = Length of pipework (m)
T_1 = Starting Temperature (^{0}C)
T_2 = Final temperature (^{0}C)
C = Coefficient of linear expansion

Coefficients of Thermal Expansion for Common Pipe Materials			
Metals		Plastic	
Materials	Coefficient	Materials	Coefficient
Copper	17.7×10^{-6}	ABS	100×10^{-6}
Carbon Steel	12.2×10^{-6}	PVCU	$90 - 180 \times 10^{-6}$
Stainless Steel (austenitic)	15.9×10^{-6}	PVCC	$90 - 180 \times 10^{-6}$
Stainless Steel (ferritic)	10.9×10^{-6}	PE	$200 - 400 \times {}^{-6}$
Cast iron	11.0×10^{-6}	PP	$146 – 180^{-6}$

Table 8.1
Coefficients of Common Pipe Materials

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Rates of Thermal Expansion for Common Pipe Materials (mm/m)									
⁰C	Copper	Carbon Steel	Stainless steel	Cast Iron	ABS	PVCU	PVCC	PE	PP
10	0.16	0.12	0.16	0.11	1.00	0.80	0.70	2.00	1.50
20	0.33	0.24	0.33	0.22	2.00	1.60	1.40	4.00	3.00
30	0.49	0.37	0.49	0.33	3.00	2.40	2.10	6.00	4.50
40	0.66	0.49	0.65	0.44	4.00	3.20	2.80	8.00	6.00
50	0.82	0.61	0.82	0.55	5.00	4.00	3.50	10.00	7.50
60	0.98	0.73	0.98	0.66	6.00	4.80	4.20	12.00	9.00
70	1.15	0.85	1.14	0.77			4.90		10.50
80	1.31	0.98	1.30	0.88			5.60		12.00
90	1.48	1.10	1.47	0.99					
100	1.64	1.22	1.63	1.10					

Table 8.2
Expansion Rates of Common Materials at Various Temperature Changes

Note:
For specific material types refer to each manufacturer's data or piping material standard.

Calculation Examples

Example 1

Calculate the thermal expansion using the co-efficient as shown in Table 8.1, for a 40mm copper tube, heated water circulating system up to 30m in length, having a temperature change between 15⁰C to 65⁰C

Formula:
$E = L \times (T_1 - T_2) \times C/1000$
$E = 30 \times 50 \times (17.7^{-6}/1000)$
$E = 26.55mm$

Example 2

Calculate the expansion using the rate of thermal expansion as shown in Table 8.2, for a copper tube heated water system 30 metres in length, incurring a change in temperature from start up 15⁰C and up to 65⁰C operation.

Temperature rise from 15⁰C - 65⁰C
Length of pipework = 30m
Expansion per metre of copper pipework = 0.82mm
Total expansion = 30 x 0.82 = 24.60mm

Another method of calculation the thermal expansion is by using a web base calculator for thermal expansion.
www.calculatoredge.com/cal/exp.htm

Effects of Expansion and Contraction

With any increase in temperature of a piping system will cause the pipe to expand. If the pipework is locked into position and does not allow movement, related stress in the material and system will eventuate. If the stress exceeds the allowable stresses catered in the installation the system will fail. This stress on the material is known as fatigue stress, refer Chapter 6. Ongoing deformation may occur upon by repeated thermal cycling or prolonged exposure to elevated temperatures in restrained pipework systems. Copper tube systems like all other material systems require sufficient design allowances for flexibility or thermal expansion devices to prevent expansion and contraction from causing stress fracturing. The following problems can occur;

- Failure of the piping from over straining in particular at fabricated junctions or branches.
- Leakage at location where the material has reached its stress point.
- Distortion in the piping or connected equipment.

Copper tube having a low expansion rate is idea for both heated and cold water plumbing services pipework, however in some location fixed anchors and expansion allowances should be provided.

Thermal Expansion Design

The design of above ground pipelines, the supports and guides for the copper tubes, becomes an important consideration because of the related thermal expansion in some piping systems. In addition to consideration for pressure resistance and the material life limitations, the effects of thermal expansion and contraction, the designer/installer is required to ensure that the pipework remains;

- Flexible with due allowance for expansion.
- Reduce or limit any forces being placed on plant and equipment.

The designer must also consider the movement of any branch pipeline in particular where the pipe passes through a wall.

Flexible System Design

A flexible pipe design is where there is control of the planned expansion and contraction within the pipework system. To control the planned movement and provide for stress relief, some of the following may need to be employed;

- Expansion loops.
- Expansion offsets.
- Change in direction.
- Mechanical expansion joints/fittings.
- Flexible bellows or flexible hose connectors.

Acceptable methods of catering for the thermal expansion and contraction in copper tubes is using pipe guides, expansion loops and mechanical expansion joints, which are installed in the straight pipework and are anchored at each end. Thermal expansion will then occur between all fixed points in the piping system. The expansion loops (Figure 8.1), should be located in the center of the pipe length between two anchors. The width of the expansion loop can be up to 2/3 of the height of the calculated loop.

Expansion Loop Calculations

The height of a common loop for copper tubes provides common pipe sizes, and the calculated height of the expansion loop (Figure 8.1) in metres is derived from the following formula.

Formula: Loop Height = $\frac{0.06\sqrt{(DX)}}{2}$

Example: As per our calculation a 40mm copper pipe 30metres in length having a temperature change of 50⁰C will expand 24.60mm.

Using the formula $H = \frac{0.06\sqrt{(DX)}}{2}$

Where H = Height of the expansion loop in m
D = Diameter nominal of the copper tube in mm
X = Expansion length in mm

Where $H = \frac{0.06\sqrt{(40 \times 24.6)}}{2}$

Where $H = \frac{0.06\sqrt{984}}{2}$

Where $H = 0.06\sqrt{492}$

Where H = 0.06 X 22.18

Where H = 1.33m and the width

Where W = 0.88m (being 2/3 of 1.33m height)

Alternately a 20mm expansion with a corresponding pipe diameter of 40mm the height of the loop is estimated at 1.23m.

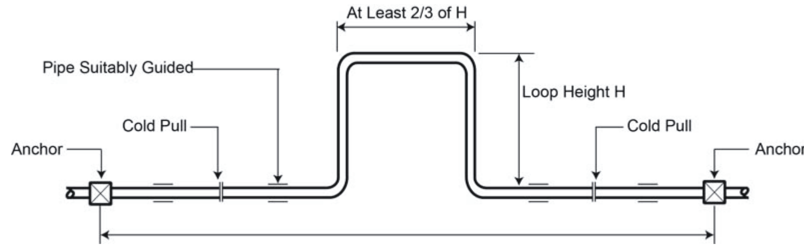

Figure 8.1
Expansion Loop Illustration

Height of Expansion Loop

As a guide Table 8.3 provides an estimate height of an expansion loop for the prescribed expansion rate in mm.

Once the height is determined use ⅔ of the listed height to calculate the length of the actual loop.

Height of Loop (H) for Copper Tubes in Metres									
Expansion in mm	Pipe Nominal Size								
	15	20	32	40	50	65	80	100	150
10	0.52	0.63	0.80	0.82	0.99	1.10	1.17	1.40	1.69
15	0.64	0.77	0.97	1.07	1.21	1.35	1.43	1.71	2.07
20	0.74	0.89	1.12	1.23	1.40	1.56	1.66	1.97	2.39
30	0.90	1.09	1.38	1.51	1.71	1.90	2.03	2.42	2.93
40	1.04	1.26	1.59	1.74	1.97	2.20	2.34	2.79	3.39
60	1.27	1.54	1.95	2.13	2.42	2.69	2.87	3.42	4.15
80	1.47	1.78	2.25	2.46	2.79	3.11	3.31	3.95	4.79
100	1.65	1.99	2.51	2.75	3.12	3.47	3.70	4.41	5.35

Table 8.3
Height of Expansion Loop

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Offset Allowance for Controlling Expansion

Provisions for expansion must be considered when designing tube runs and fixing points, by allowing freedom of movement at bends, branches and tees. Figures 8.2, 8.3, 8.4 and 8.5 describe methods for fixing and expansion.

Table 8.4 provides the required measurements for the free length of tubing around the bend or along the branch to prevent over stressing the tube.

An offset can be used to accommodate the thermal expansion or contraction using change in direction (elbows).

By allowing the pipe to flex at the elbows, stress can be relieved without installing an expansion loop or device (Figure 8.2).

Length of Pipe	Offset L	Expansion X (for 60ºC temp rise)
	Min.	Min.
m	mm	mm
Up to 4.5	600	5
Over 4.5 to 9	900	10
Over 9 to 18	1200	20

Table 8.4
Provisions For Expansion – Free Movement

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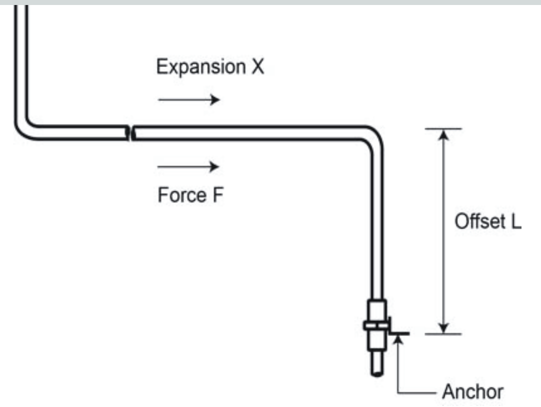

Figure 8.2
Pipe - Offset

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The offset distance ' L' is the amount of distance required prior to placing an anchor/ fixed bracket on the pipe from the elbow.

This distance 'L' is left free floating allowing the pipe to expand and or contract, eliminating stress on the piping system (Figure 8.3).

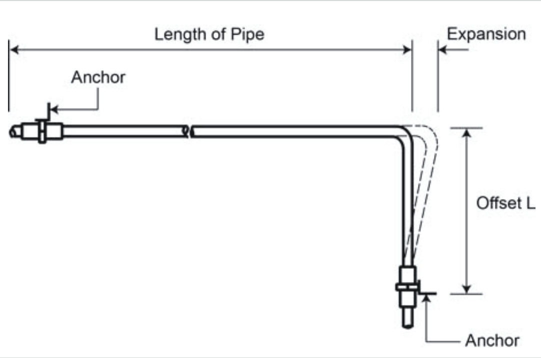

Figure 8.3
Pipe - Change in Direction

Vertical Expansion Control

Expansion allowance in vertical pipework is calculated from the cold pre-commissioned and commissioned state. Pipes in the cold state have very little movement until such time the water temperature is increased.

During the heating, the pipes are subjected to thermal expansion potentially causing stress at the pipe joint (tees) at each floor interval take-off. Approximate 3mm of thermal expansion/contraction can occur.

To compensate for this movement an expansion device and fixed anchors are employed (Figure 8.4). Anchors are installed at approximately 36m intervals and flexible bellows or expansion loops are installed at 18m maximum distances between the anchors.

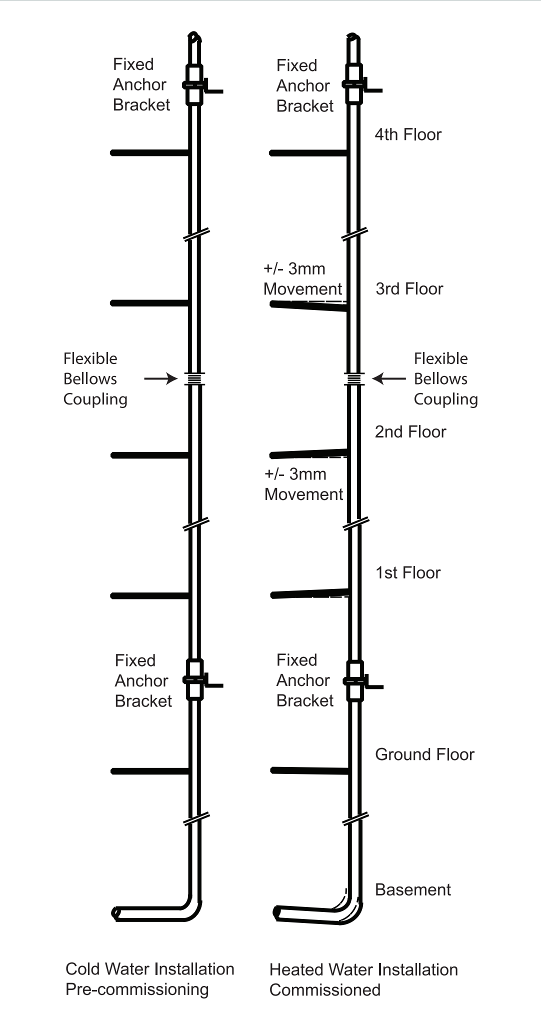

Figure 8.4
Pipe – Vertical Expansion Control

Expansion Allowance at Tees

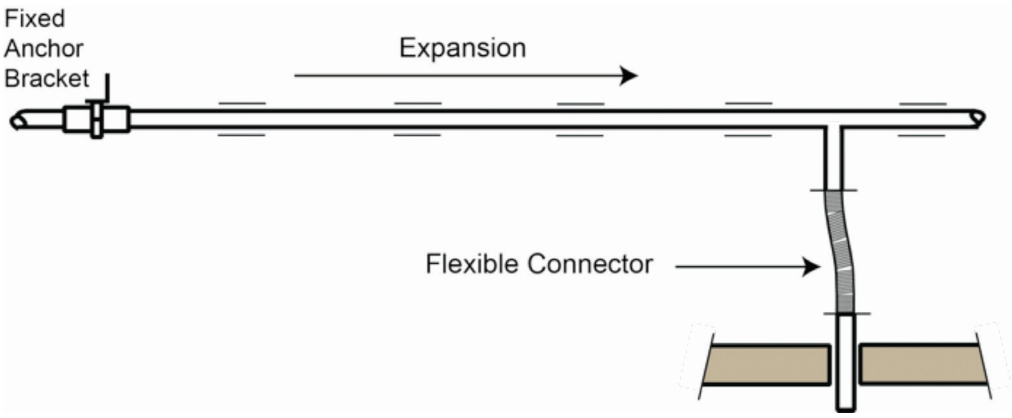

Figure 8.5
Pipe – Flexible Connection

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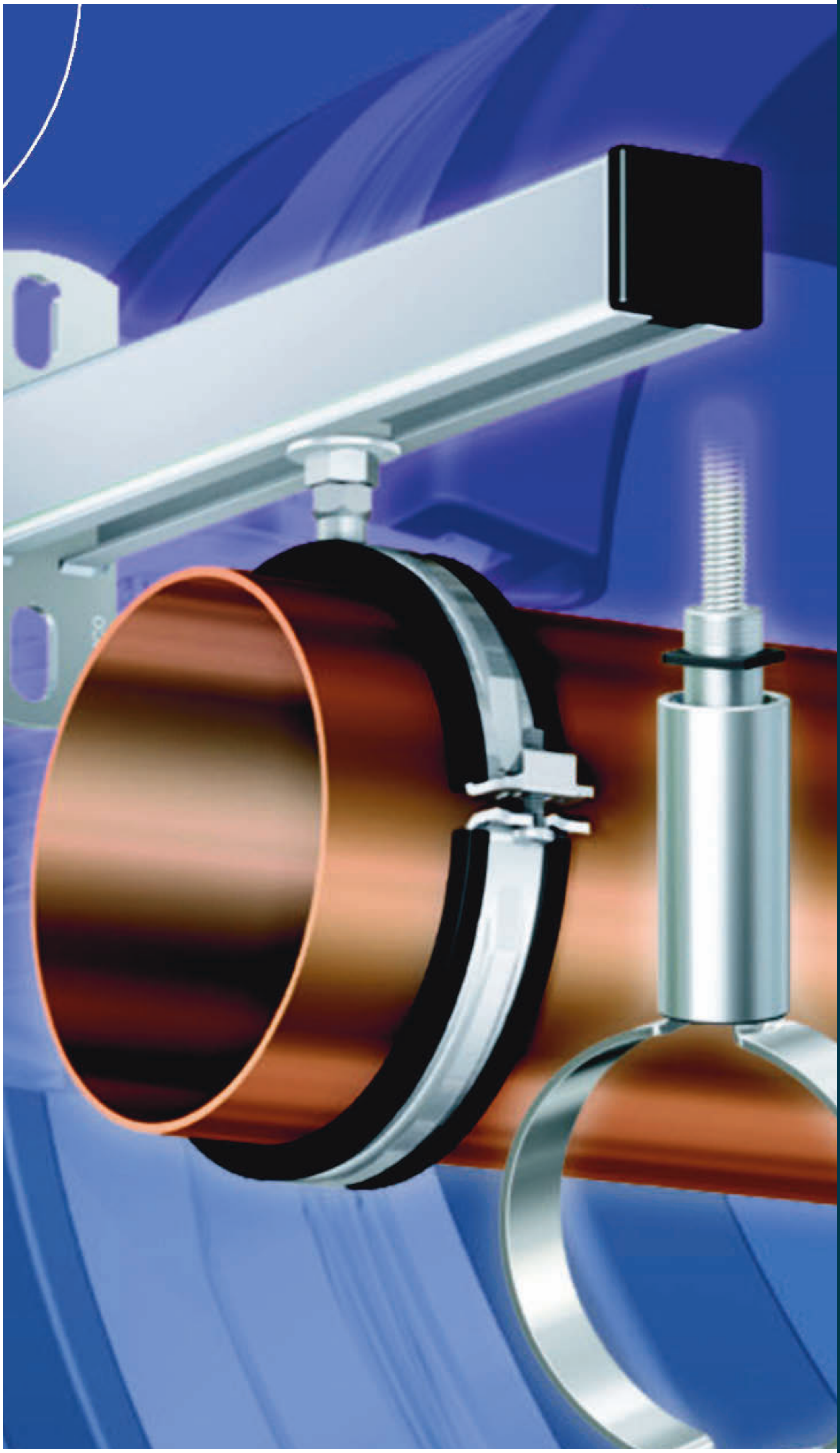
Flexible connector can be used to absorb thermal movement when a branch pipe passes through a wall, ceiling or connected to a fixed pipe off-take.



9

Chapter Nine

Chapter 9 – Pipe Supports, Anchors and Guides

EN 1057 version

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Pipe Supports, Anchors and Guides

Above ground piping systems may be designed as restrained or unrestrained.

General

Pipes are supported in a variety of ways, depending on the type of building materials, pipe size, type of service and cost. Smaller diameter pipes and tubes installed within a building for plumbing services may be supported by adjustable hangers or by brackets, which are attached to the building structure.

When subjected to temperature change causing expansion/lateral movement, larger diameter copper tubes are frequently set on pipe support frames to cater for the calculated expansion.

Above ground piping systems may be designed as restrained or unrestrained. Selection of design method is dependent on variables such as operating temperatures, flow rates, pressure and piping layout.

Design consideration of pipe supports and anchors should be referred to the manufacturer where engineering assessment is necessary. This is important where building materials are of light structure and weight, where the bracket anchor cannot be set into that building structure material.

Australian Standards for Plumbing Systems provides a “deem to satisfy” method for general plumbing, but seldom considers specific applications for large diameter pipes, in particular for fire and heated water systems.

This chapter provides a selection and guidelines for plumbing services systems.

Unrestrained System Design

The unrestrained system is often referred to as a “simple supported design”. It makes use of the inherent flexibility of the pipe or tube material to safely absorb deflections and bending stresses. Simple pipe hangers, clips and clamps are use to provide vertical support to the pipe.

These simple supports incorporating a sleeve, allow the piping to expand and contract freely, resulting in very small axial stress in the piping system. Long straight runs of piping often employ changes in direction to safely absorb the movement due to thermal expansion, contraction, flow rate changes and internal pressure.

Restrained System Design

The restrained system is often referred to as an “anchored and guided design”. The low thermal expansion coefficient of copper tube translates to significantly less thermal forces when compared with plastic materials. Anchors used to restrain thermal expansion create compressive forces in the copper pipeline. Incorporating pipe guides to prevent fatigue stress failure of the copper tubes usually controls these forces.

Supports

Pipe supports hold the pipe in a fixed position and when properly spaced will prevent excessive deflection due to the weight of the pipe, fluid, external insulation and other loads (Table 9.1).

Anchors

Pipe anchors prevent axial movement and applied forces. These forces may result from thermal loads, water hammer, vibration equipment, or externally applied mechanical loads when used to direct expansion.

Guides

Pipe guides prevent lateral (side to side) movement of the pipe. Guides are required to prevent the pipe from buckling under compressive loading. For example; when anchors are used to control thermal expansion, guides are always required to be used to maintain pipe straightness and pipe direction.

Quality Assurance

Hangers and support for use in plumbing and fire services shall be selected as a minimum from those specified in;

- AS/NZS 3500 Plumbing and Drainage Parts 1 Water services, Part 4 Heated Water Services and Part 5 Housing Installation.
- AS 2419.1 Fire Hydrant Installations.
- AS 2118 Automatic Fire Sprinkler Systems.
- AS 2441 Installation of Fire Hose Reels.
- AS 4118.2.1 Fire Sprinkler Systems - Piping – General.

Whilst these standards specify a minimum design requirement, each project will need to be considered individually based on the materials, environment, internal pressures, the type of service and expected thermal expansion and weight of the tube containing liquid. When considering the type of hanger or support system a qualified structural engineer and or proprietary systems technical expert should be engaged to approve the support system assessing the building structure, the weight of the piping system and any necessary drilling into concrete.

Positioning of Pipework Hangers and Clamps

Pipes installed in the horizontal location are recommended to be located no further than 1 metre from any change of direction or branch take off in the pipework network. The distance from the last support to the end of any horizontal pipework network is ideally placed no further than 1 metre.

Pipes Installed in Vertical Location

It is recommended that clips at each floor level to support the vertical pipe risers or droppers. The distance between the supports should not exceed those specified in the relevant standard AS/NZS 3500, AS 2149 and AS 2441 for the nominated pipe size. Where the vertical rising pipe varies from the vertical plane by more than 10^0 for the purpose of the pipe support, it should be considered as a change of direction or offset to the vertical. Where a vertical pipe is rising or dropping it is also recommended to be supported no more than 300mm from any mechanical jointed fitting.

Selection of Pipe Hanger and Supports

When deciding on a hanging system the first and foremost criterion is to assess the environment and the material type to be used, these include;

- The potential for corrosion, the environment and material compatibility.
- Dry or exposure to long term moisture applications.
- Exposure to chemical.
- Expected life of the service and hanging systems.
- Weight of the pipe filled with water.

Materials used for Hangers and Brackets

There is a variety of materials and finishes available for pipe supports, these include;

- Pre-galvanized. Use in dry environments, not recommended for external or industrial.
- Hot-dip galvanized. Ideal for outdoor application, where a cut is made apply a zinc rich primer.
- Stainless steel in both 304 and 316 grade. Use for marine and chemical applications.
- Coated, painted. Usually is a primer/ finished containing rust inhibitive additive.
- Plastic coating. Some commercially available products are plastic coated for prevention of galvanic corrosion between the bracket and the pipe material and or for noise reduction.

Where required hangers and brackets may be required to be approved for fire systems pipework. Approvals can be obtained from Underwriters Laboratories (UL), Factory Mutual (FM) or other recognised listing bodies.

Types of Pipe Supports, Clamps and Hangers;

- Two piece channel clip – Generally used in conjunction with trapeze and channel supports for DN 20 to 200mm pipes where pipes suspended from a floor or ceiling (Figure 9.1).
- Two-piece channel clip and timber ferrule – Used where heated water services are to be insulated and provides for thermal expansion (Figure 9.2).
- Shank clip – Small diameter tubes suspended from timber floor or ceiling (Figure 9.3).
- Standard saddle clamp – Used as a fixed point clamp for smaller diameters against walls (Figure 9.4).
- Standard pear clamp – Used for hanging of tubes, suspended from under slab (Figure 9.5).
- Nut clamp and timber ferrule - Used where heated water services are to be insulated and provides for thermal expansion, hanging from timber structures (Figure 9.6).
- Two piece nut clip (Figure 9.7).
- Light duty Yoke clamp (Figure 9.8).
- Acoustic pipe clip (Figure 9.9).
- Two piece clip and flexi barrier (Figure 9.10).
- Wall mounted anchor (Figure 9.11).
- Slider clamp (Figure 9.12).
- Horizontal floor mount nut clamp and vibration spring (Figure 9.13).
- Wall mounted channel and two piece clip (Figure 9.14).
- Wall mounted anchor (Figure 9.15).

Typical Pipe Supports, Clamps and Hangers

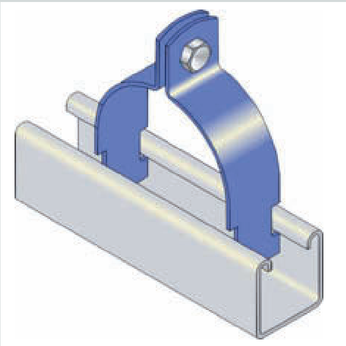

Figure 9.1 Two-piece Channel Clip

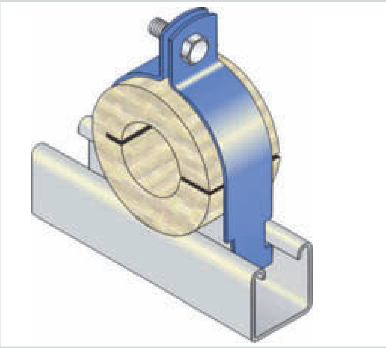

Figure 9.2 Two-piece Channel Clip and Timber Ferrule

Figure 9.3 Shank Clip

Image Source, Flexistrut.

Figure 9.4
Standard Saddle Clamp

Figure 9.5
Standard Pear Clip

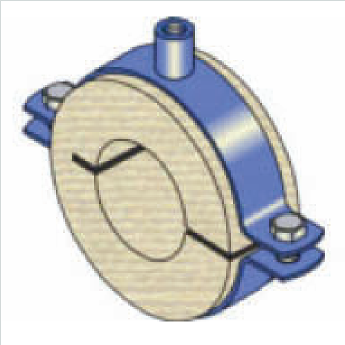

Figure 9.6
Nut Clamp and Timber Ferrule

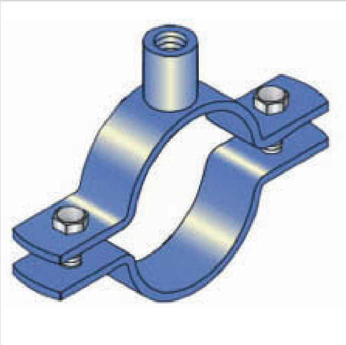

Figure 9.7
Two-piece Nut Clip

Figure 9.8
Light Duty Yoke Clamp

Figure 9.9
Acoustic Pipe Clip

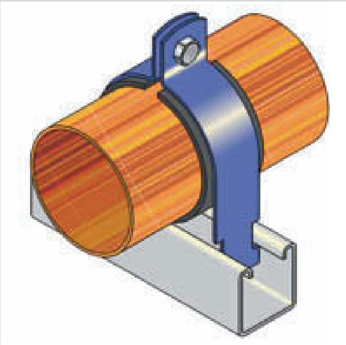

Figure 9.10
Two Piece Clip and Flexi Barrier

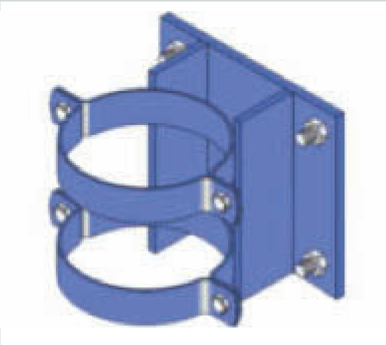

Figure 9.11
Wall Mounted Anchor

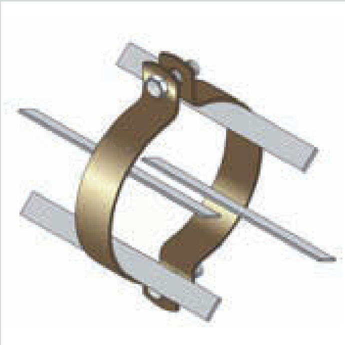

Figure 9.12
Slider Clamp

Image Source, Flexistrut.

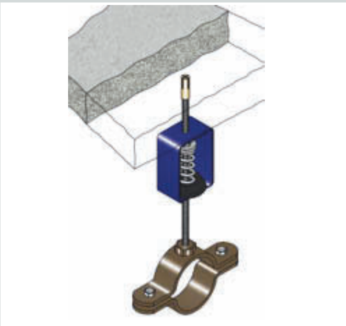

Figure 9.13
Horizontal Floor
Mount Nut
Clamp Anchor

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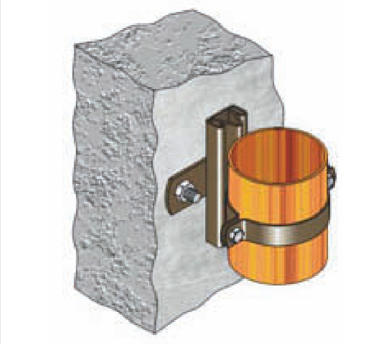

Figure 9.14
Wall Mounted Channel
and Vibration Spring

International Copper Association Australia Copper Alliance

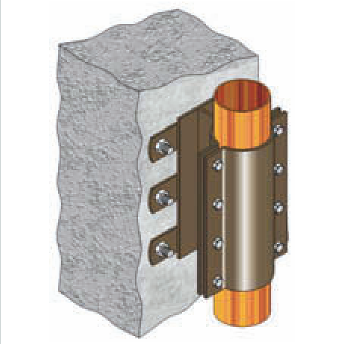

Figure 9.15
Wall Mounted

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Image Source, Flexistrut.

Pipe diameter nominal DN	Actual pipe size in mm	Mass tube kg/m	Mass pipe filled with water kg/m
15	12.70	0.30	0.39
18	15.88	0.43	0.58
20	19.05	0.52	0.75
25	25.40	0.83	1.25
32	31.75	1.05	1.72
40	38.10	1.27	2.27
50	50.80	1.70	3.57
65	63.50	2.14	5.07
80	76.20	3.42	7.595
100	101.60	4.58	12.18
125	127.00	5.74	17.77
150	152.40	8.58	25.86
200	203.20	11.48	42.63

Table 9.1
Type B Copper Tubes Mass Weights and Mass filled with Water

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Piping Support Design

AS/NZS 3500 Water Services specifies the minimum requirement for the spacing of pipe clips and brackets, whilst these figures are mandatory as a means of compliance the figures being nominal do not take into account the potential for end loads and stress placed onto the piping system.

The designer, installer most take into account the specific temperature range, effects of water pressures, the type of pipe support or bracket used in each application. Copper tubes as shown in Table 9.2 are self-supportive of over a greater span than other thin wall metallic and non-metallic pipe materials.

Nominal Pipe Size DN	Maximum Spacing of Brackets and Clips in Metres			
	Copper, Copper Alloy and Stainless Steel	Galvanised Steel and Ductile Iron Pipes	PVC-U, Polyethylene, Cross-linked Polyethylene, Polybutylene	
			Horizontal or Graded Pipes	Vertical Pipes
10	-	-	0.50	1.00
15	1.5	2.0	0.60	1.20
16	-	-	0.60	1.20
18	1.5	-	0.60	1.20
20	1.5	2.0	0.70	1.40
22	-	-	0.70	1.40
25	2.0	2.0	0.75	1.50
32	2.5	2.5	0.85	1.70
40	2.5	2.5	0.90	1.80
50	3.0	3.0	1.05	2.10
63	-	-	1.10	2.20
65	3.0	3.0	1.20	2.40
75	-	-	1.30	2.60
80	3.0	4.0	1.35	2.70
90	-	4.0	1.40	2.80
100	3.0	4.0	1.50	3.00
110	-	-	1.50	3.00
125	3.0	4.0	1.70	3.40
140	-	-	1.70	3.40
150	3.00	4.0	2.00	4.00
160	-	-	2.00	4.00
200	3.00	-	-	-

Table 9.2
Pipe Supports and Spacing – AS/NZS 3500

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Hanging Rods and Anchor Sizes

Selecting hanging rod sizes and anchor sizes is an engineered solution. However when installing copper tubes for water supply services a range of copper pipe sizes, hanging rod and anchors are available, refer Table 9.3.

Pipe Diameter Nominal DN	Actual Pipe Size in mm	Hanging Rod Size in mm	Anchor Size in mm
15	12.70	M10.00	1 x M10 x 40
18	15.88	M10.00	1 x M10 x 40
20	19.05	M10.00	1 x M10 x 40
25	25.40	M10.00	1 x M10 x 40
32	31.75	M10.00	1 x M10 x 40
40	38.10	M10.00	2 x M10 x 50
50	50.80	M10.00	2 x M10 x 75
65	63.50	M12.00	2 x M10 x 75
80	76.20	M12.00	2 x M10 x 75
100	101.60	M12.00	2 x M12 x 100
125	127.00	M16.00	2 x M12 x 100
150	152.40	M16.00	2 x M12 x 120
200	203.20	M16.00	2 x M12 x 120

Table 9.3
Hanging Rod and Anchor Sizes

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Side Bracing

Where large diameter pipes are subjected to constant and or infrequent change in internal pressure forces it is recommended that the piping system incorporate the placement of side bracing or fixed point bracketing to reduce the shock or uncontrolled thrusts caused by the sudden change in pressure and flow.

The following figure 9.16 shows a typical method of providing for restraints for trapeze and hanging pipe supports.

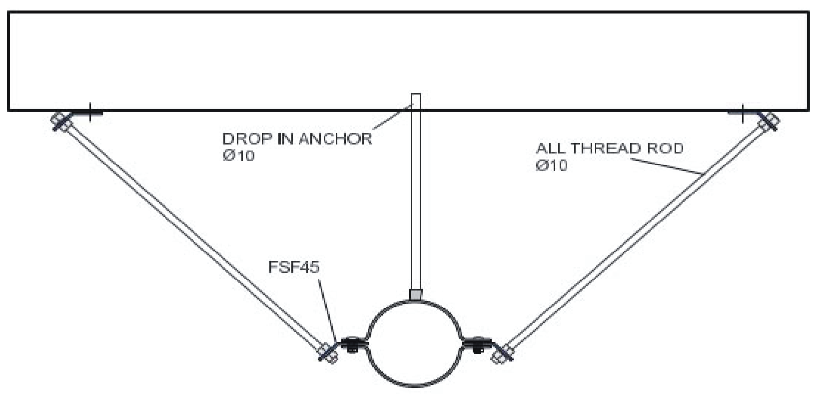

Figure 9.16
Hanging Bracket with Side Bracing Rods

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Cantilever Brackets

Cantilever bracing and supports for pipe clamps are used for horizontal wall mounted pipework. Cantilever support systems provide strength and bracing for both light and heavy weight pipes or in most cases where multiple size pipes are installed. Cantilever channel systems interface with either a one piece or two-piece channel clips.

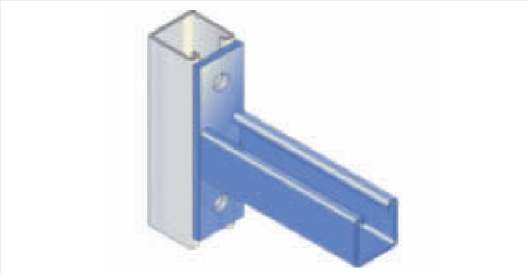

Figure 9.17
Cantilever Bracket

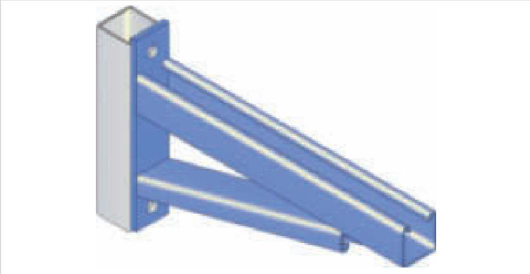

Figure 9.18
Cantilever with Support

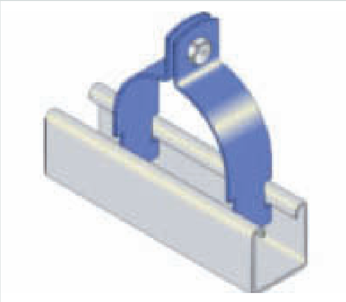

Figure 9.19
Two-piece Channel Clip

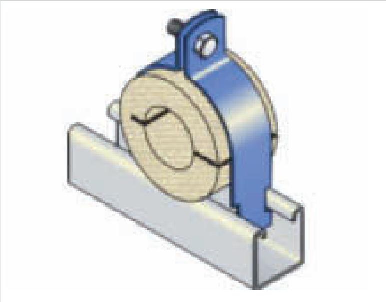

Figure 9.20
Two-piece Channel Clip and Timber Ferrule

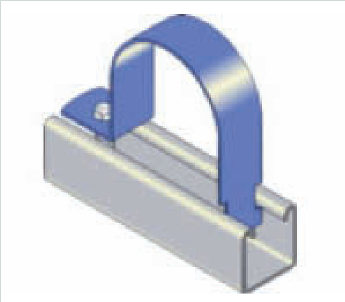

Figure 9.21
One-piece Channel Clip

Image Source, Flexistrut.

Selecting the Correct Clamp for Hydraulic Services Pipework

There are a number of key elements for making a decision on the type of pipe clamp for cold and heated water supply services.

1. Determine the pipe material and calculate the total weight per metre.
2. What is the medium (fluid) to be carried within the pipe material?
3. What applied forces are applicable to the services?
   These include thrust loads of bends and pump pressure including startup pressure, any vibration likely to occur during pump startup and expected expansion and contraction.
4. 1,2 and 3 = the combined total weight per metre.
5. Calculate the total weight per metre by the number of pipe metres between the pipe brackets/clamps to determine the total weight being applied to each clamp.
6. Consult the relevant installation requirements AS/NZS 3500, AS 2419 and AS 2441 Plumbing and Fire Codes.
7. Select a pipe clamp with adequate load rating to support the weight calculated in Point 5.

Note:
Refer to manufacturers specification for load rating for clamps. Choose a clamp with sufficient yield load rating to support the total weight calculated.

Example;

DN 200mm – Type B copper tube is to be installed for a cold water supply service.

- Total weight of pipe and content 42.63kg/metre.
- The total distance between pipe clips is 3 metres. Based on AS/NZS 3500.1 Water Supply.
- 42.63 x 3 = 127.89kg yield weight.

Using the total yield weight, select from manufacturers, a clamp that suits not only the yield weight but aligns with the specific pipe diameter.

Fixing of Pipes Supports and Clamps

Water Supply and Fire Services pipework may be supported from a building where the structure is capable of supporting the loads calculated. Services pipework should not be supported from ceiling sheathing or any other associated suspension system.

Fixing to Concrete, Masonry and/or Steel

Explosive-powered fasteners, common wooden plugs, or plugs made from plastic material should be used for fixing services pipe supports to concrete or masonry. Fixings used in supporting pipework brackets must be designed to cater for the design loads as calculated. Where services pipework may be required to be fixed to timber, an acceptable method for fixing is by using coach screws or coach bolts.

Note:
Nails are not recommended for fixing pipe supports to timber.

Thrust Blocks and Anchors

Thrust blocks and anchors shall be installed in any water supply or fire services systems where unrestraint is used. They should be designed to provide adequate action to the forces imposed by the maximum pressures generated, including systems water pressure, water hammer, ground pressures and soil conditions.

Penetration of Pipework through Structures, Walls and Floors.

Where pipes penetrate a concrete or brick wall and/or concrete slabs, the core hole shall have a minimum clearance of 10mm all around the pipe. The core hole shall accommodate the pipe and any settlement after commissioning of the pipework system (Refer Figure 9.22 and 9.23). There are specific requirements under both the Building Code of Australia (ABCB) and National Construction Code (PCC) for penetrating walls and floors.

Pipe Penetrations and Pipe Fire Collars

Pipe penetrations incorporating fire stop are collars manufactured using a fire resistance/retardant like intumescent materials. The fire collars are designed to maintain the integrity of the fire resistant element through which non-flow resistant pipe material such as copper tube or plastic pipe. In the event of a fire the pipe will deform. Once the pipe commences to deform, the intumescent material in fire collar expands, closing off pipe or material forming on insulating barrier. There are many brands of fire stop/collars available for both wall and floor applications. Designers should engage a fire specialist to select the appropriate fire collar for the specific building design, performance and fire rating.

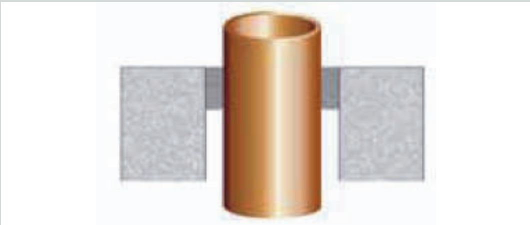

Figure 9.22
Up to 1 Hour Fire Rating
Metal Pipe Floor Penetrations

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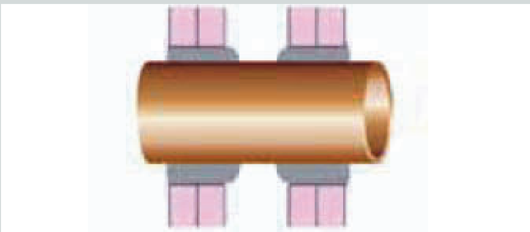

Figure 9.23
Up to 4 Hour Fire Rating
Metal Pipe Wall Penetration

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10

Chapter Ten

Chapter 10 – Valves

EN 1057 version

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Valves

Cu

The most common types of valve used to date are control, gate, plug, bell, butterfly, check, pressure relief and globe (balancing).

Introduction

Valves used for plumbing and fire services are classified as ancillary products to piping systems. By definition valves are mechanical devices designed to isolate or control water supplies, their selection is based on design, function, and application. Valves are available in a wide variety of styles, sizes, pressure class and temperature rating.

In water services such as cold water, heated warm water, recycled water and fire system valves may be electronically monitored, operated and regulated to suit the demand and the type of services system. The most common types used to date are control, gate, plug, bell, butterfly, check, pressure relief and globe (balancing).

These valves are manufactured from a variety of materials including steel, stainless steel, ductile and cast iron, polyvinyl chloride (PVC), brass, bronze and composite materials incorporating special alloys and rubber.

This chapter describes the most frequently used valves in plumbing services, suitable for connecting to copper tubes. The valve design, function and applications are presented to assist hydraulic engineers and plumbers in understanding the valve purpose and selection.

Valves General

Valves are devices that regulate, direct or control the flow of a fluid (gases, liquids, fluidized solids, or slurries) by opening, closing, or partially obstructing various passageways.

In an open valve, fluid flows in a direction from higher pressure to lower pressure.

Valves may be operated manually, either by a handle, lever or wheel. Valves may also be automatic, driven by changes in pressure, temperature, or flow.

More complex control systems using valves requiring automatic control based on an external input (i.e., regulating flow through a pipe to a changing set point) require an actuator.

An actuator will stroke the valve depending on its input and set-up, allowing the valve to be positioned accurately, and allowing control over a variety of requirements.

The basic types of valves are:

- Isolation valves, typically operated as fully open or fully closed and designed to have a tight reliable seal during shut-off and minimal flow restriction when open.
- Control valves, used to modulate the flow by opening or closing by a certain percentage.
- Switching valves, used to converge or divert the flow in a piping system.

Gate Valves

The gate valve (also known as a sluice valve or knife valve) is a valve that opens by lifting a round or rectangular gate/wedge out of the path of the fluid.

The distinct feature of a gate valve is the sealing surfaces between the gate and seats are planar, so gate valves are often used when a straight-line flow of fluid and minimum restriction is desired.

Gate valves are primarily used as isolation valves (designed to be fully opened or closed) to permit or prevent the flow of liquids, but typical gate valves shouldn't be used for regulating flow, unless they are specifically designed for that purpose.

On opening the gate valve, the flow path is enlarged in a highly nonlinear manner with respect to percentage of opening.

This means that:

- Flow rate does not change evenly with stem travel.
- Most of the flow change occurs near shutoff with a relatively high fluid velocity causing disk and seat wear and eventual leakage if used to regulate flow. A partially open gate disk tends to vibrate from the fluid flow.
- When fully open, the typical gate valve has no obstruction in the flow path, resulting in very low head loss.

Gate valves may have threaded connections or flanged ends, which are drilled according to pipeline compatible flange dimensional standards.

Gate valves are typically constructed from bronze, corrosion resistant brass, cast iron, ductile iron, stainless steel, alloy steel and forged steel (Figure 10.1).

Figure 10.1
Gate Valve

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Size Range	Materials	Temperature Range	Max Pressure
15mm to 50mm	DZR Brass	-10°C to 99°C	2500kPa
65mm to 100mm	DZR Brass	-10°C to 99°C	2000kPa
15mm to 50mm	Stainless Steel 316	-50°C to 200°C	1600kPa

Table 10.1
Pressure and Temperature Ratings for Gate Valves

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Isolating/Stop Valves

The flow from any water service main to any water service must be controlled by an isolating/stop valve (loose jumper) or a ball valve combined with a non return valve.

Their components are made from a wide range of materials including brass, plastic, cast iron, steel, stainless steel. The principal operation can be covered by gate, ball, spring and butterfly.

The most common type of valve used in water service is a screw down type, however, other types are now starting to become more acceptable.

The design of a isolating/stop valve incorporates a disc, which is raised and lowered onto the body seat by a stem with its axis perpendicular to the face of the body seat (Figure 10.2 and Figure 10.3).

Screwed down/loose jumper valve type valves are used as a stop tap for controlling, isolating both cold water and heated water to outlets including water heaters, recessed taps, pillar taps, bib taps, hose taps, meter taps, cistern taps, washing machine taps.

AS 3500 Part 1 Water supply covers isolating valves on cold and fire services.

Figure 10.2
Right Angle Isolating Valve

Figure 10.3
Straight Through Isolating Valve

Ball Valves – Screwed and Compression End Connection

A ball valve is a valve with a spherical disc with a hole (port) through the middle so that when the port is in line with both ends of the valve the flow will occur. When the valve is closed, the hole is perpendicular to the ends of the valve, and flow is blocked (Figure 10.4 and Figure 10.6).The handle or lever is usually in line with the port position letting you understand the valve's position.

The ball valve is part of the family of quarter turn valves, along with the butterfly valve and plug valve. This means that to operate the valve from the open to the close position, the handle shall be moved by an angle of 90 degree.

Ball valves are primarily used as isolation valves (designed to be fully opened or closed) to permit or prevent the flow of liquids, and **should not be used for regulating flow, unless they are specifically designed for that purpose.**

Depending on the size of the hole in the ball the valve can be:

- Full port or more commonly known full bore when the hole in the ball is the same size as the pipeline resulting in lower friction loss. Flow is unrestricted but the valve is larger and more expensive so this is only used where free flow is required.
- Reduced port or more commonly known reduced bore ball valves, flow through the valve is one pipe size smaller than the valve's pipe size resulting in flow area being smaller than pipe.
- The flow rate remains constant but the velocity increases.

Ball Valve – Flanged

Bronzed body and flanged ball valve with stainless steel ball and stem size range DN 50-100 are manufactured to comply with Australian Standards for drinking water applications (Figure 10.5). The valve being full bore with blow out proof stem with flanges drilled to AS 2129.

Figure 10.4
Screwed End Connection

Figure 10.5
Compression End Connection

Figure 10.6
Flanged End Connection

Size Range	Materials	Temperature Range	Max Pressure
8mm to 100mm	DZR Brass	-20ºC to 120ºC	2500kPa
10mm to 50mm	DZR Brass	-20ºC to 99ºC	2500kPa
50mm to 100mm	Bronze	-20ºC to 120ºC	1600kPa

Table 10.2
Pressure and Temperature Ratings for Ball Valves

Check Valves

A spring check valve (Figure 10.7), is a check valve in which the jumper (the movable part used to block the flow) is spring-loaded and moves longitudinally to:

- Block the reverse flow, when pulled onto the seat.
- Allow forward flow, when drawn off the seat with enough pressure to open the spring resistance (cracking pressure).

Spring check valves are primarily used as backflow preventer and the spring made the valve suitable to:

- Be installed in vertical or horizontal position.
- Reduce the width of pressure spikes and water hammer dangerous effects.
- Limit the leakage rate during the reverse flow (table 4 of ISO 5208).

On opening the spring check valve, the flow path is enlarged in a nonlinear manner with respect to percentage of opening of the jumper.

This means that:

- Flow rate does change proportionally with jumper travel.
- When fully open, the typical spring check valve has significant obstruction in the flow path, resulting in considerable head loss.

Spring check valves may have threaded connections or flanged ends, which are drilled according to pipeline compatible flange dimensional standards.

Spring check valves are typically constructed from bronze, corrosion resistant brass, cast iron, ductile iron, stainless steel, alloy steels, and forged steels.

Pressure and Temperature Ratings for Check Valves refer Table 10.3

Figure 10.7
Spring Check Valve

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Size Range	Materials	Temperature Range	Pressure (kPa)	
			Cracking	Max
15mm to 100mm	DZR Brass	-20°C to 120°C	2.5	4000 (DN15) 3000 (DN25) 2500 (DN50) 1600 (DN100)
6mm to 100mm	Brass	-20°C to 135°C	2.5	

Table 10.3
Pressure and Temperature Ratings for Check Valves

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Temperature & Pressure Relief Valves

A Temperature & Pressure Relief Valve (Figure10.8), is a safety control which ensures that when the normal thermostatic controls (e.g. thermostat and energy cut out devices) fail, the temperature of the water in a pressurised, unvented water heater cannot exceed 99^{0}C.
This prevents the hazardous condition whereby pressurised water above 99^{0}C would instantaneously turn to steam in the event of the water heater pressure vessel rupturing.
The temperature relief function of the valve is to open and discharge water to drain when the thermal element is exposed to water between 93^{0}C-99^{0}C. Across this temperature range the thermal element expands and lifts the valve mechanism off the valve seat, relieving hot water from the system which is replaced by cold water from the mains supply, which in turn causes the thermal element to contract and allows the valve mechanism to close.
The pressure relief function of the valve is to open and discharge heated water to drain when the water heater system pressure exceeds the set pressure of the valve. This event may occur during a normal heating sequence as the system pressure rises as a result of the volume expansion of water as it is heated.

Expansion Control Valve

An Expansion Control Valve (Figure10.9), is a pressure activated valve which opens in response to an increase in pressure caused by expansion of water during the normal heating cycle of a water heater and which is designed to be installed on the cold water supply line to the water heater. The pressure relief function of the valve is to open and discharge cold water to drain when the water heater system pressure exceeds the set pressure of the valve.
The Expansion Control Valve is designed to open preferentially at a lower set pressure than the Temperature & Pressure Relief Valve fitted to the same water heater, to ensure that cold water is discharged, minimising temperature/energy loss from the water heater.

Pressure Reducing Valve

Pressure Reducing Valves (Figure10.10), are the modern solution to pressure control and can be fitted at the boundary of a domestic installation to control supply pressure to a set maximum pressure across the whole installation. This can prolong the life of downstream valves and appliances and help conserve water. By design, Pressure Reducing Valves are typically serviceable and able to be adjusted on-site to meet water delivery requirements.

Note:
Some designs are non-adjustable with a fixed set pressure.

When tested to the manufacturer's specified maximum inlet pressure, the reduced outlet pressure must operate within ±10% of the set pressure.

Pressure Limiting Valve

Pressure Limiting Valves (Figure10.11), are a legacy product ideal for retrofitting or maintenance purposes. Pressure Limiting valves can be fitted to the inlet side of a water heater installation and control the supply to a water heater to a pre-set maximum pressure is smaller than a Pressure Reducing Valve and is both non-adjustable and non-serviceable, the Pressure Limiting Valve is best suited to limit pressure on high pressure water heaters (1000 - 1400 kPa). When tested to the manufacturer's specified maximum inlet pressure, the limited outlet pressure must operate within +35%, -10% of the set pressure.

Figure 10.8
Temperature & Pressure Relief Valve

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Figure 10.9
Expansion Control Valve

International Copper Association Australia
Copper Alliance

Figure 10.10
Pressure Reducing Valve

International Copper Association Australia Copper Alliance

Figure 10.11
Pressure Limiting Valve

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Valve Application Guide

The following Table 10.4 highlights the set pressure combinations for Temperature & Pressure Relief Valves, Expansion Control Valves and Pressure Limiting/Reducing Valves required for water heaters, where mandated in AS/NS 3500.

Pressure I.D. Colour	Temperature & Pressure Relief Valve Set Pressure	Expansion Control Valve Set Pressure	Pressure Limiting/ Reducing Valve Set Pressure
Black	700 kPa	550 kPa	350 kPa
Blue	850 kPa	700 kPa	500 kPa
Green	1000 kPa	850 kPa	500 kPa
Red	1400 kPa	1200 kPa	600 kPa

Table 10.4
Valve Application Guide

International Copper Association Australia Copper Alliance

Combination Isolating, Line Strainer and Non-Return Valves

Isolating Non-return Valves combine the mandatory valves specified in AS/NZS 3500.4 (isolating valve and non-return valve) into a single, compact unit.

Often referred to as “Duo” valves, due to the dual functions of the device, various types of inlet and outlet connections are available to suit local usage across Australia (Figure 10.12)

Isolating, (Figure 10.13) Line Strainer, Non-return Valves are specifically designed for use in the installation of pressurised storage water heaters, where the combined “trio” of functions eliminate the need for additional fittings. The line strainer is positioned after the isolating mechanism to allow for servicing of the filter and protects the non-return mechanism and any other valves downstream.

In some locations, the provision of a line strainer to protect the water heater and associated valves is mandated by regulation, making the “Trio” valve a viable alternative to the inclusion of a separate line strainer.

Figure 10.12
Combination
– Strainer and Non Return

International Copper Association Australia
Copper Alliance

Figure 10.13
Isolating Valve

International Copper Association Australia
Copper Alliance

Globe Valves

Globe valves (Figure 10.14), are named for their spherical body shape with the two halves of the body being separated by an internal baffle with an opening that forms a seat.

The movable disc is connected to a stem, which is operated using a hand wheel by screw action to close (or shut) the valve.

Globe valves are used for applications requiring throttling and frequent operation. Since the baffle restricts the flow, they’re not recommended where full, unobstructed flow is required.

On opening the globe valve, the flow path is enlarged in a manner that is strictly related to the shape of the disc. Globe valves can be installed in heating and cooling systems to obtain the design flow rates through each circuit in the building (balancing valves).

Using the mechanical engineer's design drawings, the balancing contractor carefully adjusts each balancing valve throughout the system to ensure the engineer's design intent is met, and that the correct flow rate is achieved in each circuit (Figure 10.15 and Table10.5).

Each valve has a performance curve that correlates the head loss of the primary measuring element to the flow rate through the valve. Using this curve, the design flow is achieved by adjusting the hand wheel until the target head loss, and thus flow rate, is reached.

To measure and reach the target head loss, globe valves may have:

- graduated scale on the stem.
- pressure plugs on the inlet and outlet.

Figure 10.14
Globe Valve

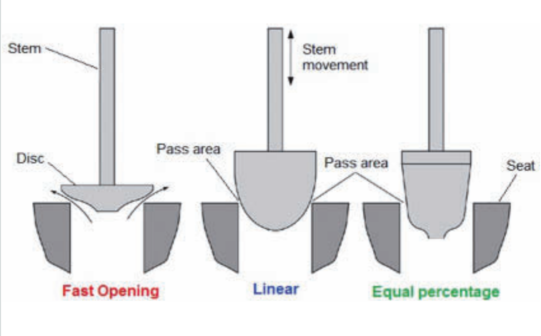

Figure 10.15
Globe Valve – Throttling Adjustment

Size Range	Materials	Temperature Range	Max Pressure
8mm to 80mm	Bronze	-10^{0}C to 120^{0}C	4000kPa

Table 10.5
Pressure and Temperature Rating for Globe Valves

Butterfly Valve

The Butterfly valves is a quarter turn rotary motion valve that uses a round disc as the closure element. When in the fully opened position, the disc is parallel to the piping. The disc when used in drinking water application is coated with an approved EPDM rubber. The disc may be fully encapsulated or depending on the metallic component the rubber may be positioned around the outer edge of the disc (Figure 10.16a and Figure 10.16b).

Butterfly valves are available in flanged, lugged end or roll grooved to meet the specification of copper tubes. Valves manufactured in ductile iron are fully coated in epoxy resin suitable to meet those requirements of AS 4020.

When compared to ball and valves, butterfly valve bodies have a very narrow face-to-face measurement. The inside diameter of the butterfly valve permits higher flow rates as well as straight flow through flow.

The butterfly valve is suitable for connecting to copper tubes in sizes greater than DN75mm up to DN200mm.

When installed in fire or mechanical services system butterfly valves can be coupled with a motor to provide automatic control to modulate and or shut off.

Knife Edge Gate Valves

Knife Edge Gate Valves are designed for isolation, On-off and Throttling services in Paper and Pulp Industries, Power Plants, Steel Plants, Cement Plants, Sugar Industries, Chemical and Textile Processing Industries, Mining, Water and Sewage Plants to handle Slurries, Slag, Plug, and Fibrous Materials, Fly ash, Powders, Clean or Corrosive gases.

The body of a knife-edge valve is made from corrosive resistant steels or cast iron. The end connection are usually flanged or wafer design lugged. Supplied in sizes DN50mm to up to DN3.0M (Figure 10.17).

Knife-edge valves are not usually generally incorporated into a water supply services system for building services drinking water.

Figure 10.16a
Butterfly Valve

International Copper Association Australia
Copper Alliance

Figure 10.16b
Butterfly Valve

International Copper Association Australia
Copper Alliance

Figure 10.17
Knife Edge Gate Valve

International Copper Association Australia
Copper Alliance

Strainers

A Y strainer is a component for the mechanical removal of unwanted solids from liquid by means of a perforated or wire mesh straining element (usually made of high quality stainless steel) (Figure 10.18).

They are used in pipelines to protect pumps, meters, control valves, steam traps, regulators and other process equipment.

Y strainers are typically used in applications where the amount of solids to be removed is small, and where frequent clean-out is not required.

The compact, cylindrical shape of the Y-strainer is very strong and can readily accommodate high pressures (Table 10.6).

A Y strainer has the advantage of being able to be installed in either a horizontal or vertical position but the screening element or 'leg' must be on the 'downside' of the strainer body so the entrapped solids can be properly collected and held for disposal (Figure 10.19).

The flow path is limited by the presence of the wire mesh straining element, this means that:

- Flow rate decrease proportionally with the mesh size of the straining element.
- Flow rate can be affected by the quality of the liquid and the cleaning frequency.

Figure 10.18
Brass Y Strainer

Cu International Copper Association Australia Copper Alliance

Figure 10.19
Bronzed Flanged Y Strainer

Cu International Copper Association Australia Copper Alliance

Size Range	Materials	Temperature Range	Max Pressure
8mm to 50mm	DZR Brass	0ºC to 99ºC	2000kPa
65mm to 100mm	Brass	-10ºC to 180ºC	2500kPa
65mm to 100mm	Brass	-10ºC to 170ºC	1600kPa

Table 10.6
Pressure and Temperature Rating for Strainers

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Balancing Valves

Highly quality STAD balancing valves enable an unparalleled level of accuracy when adjusting flow rates whilst delivering precise hydronic performance in an impressive range of application (Figure 10.20a).

It is ideally suited for use on the secondary side in heating and cooling systems, and heated water systems. Equipped with calibrated hand-wheels, STAD type balancing valves enable the flow resistance to be adjusted in different parts of a hydronic system in order to obtain the desired flow distribution (Table 10.7). The standard setting STAD has an easy to read 2-digit indicator with calibrations that ensure certainty when setting a pressure drop.

Features of Balancing Valves

- Self-sealing measuring points.
- Well-adapted Kv range.
- DN 10-50. (STAF DN 65 - 400).
- Functions: balancing, pre-setting, measuring, shut-off & draining (optional).
- STAD-C has been specially developed for use in applications where there are special temperature constraints such as cold storage rooms and solar systems.

Easy-grip Ergonomic Hand-Wheel

The new STAD hand-wheel has a more ergonomic shape for effortless adjustment and control. It has a positive shut-off function for easy draining and maintenance (Figure 10.20b).

Self-sealing Measuring Points

Measuring and balancing instruments can be connected to the valve via self-sealing measuring points. Carefully positioned for ease of access, these points enable quick measurement of vital parameters (Figure 10.20c).

Figure 10.20a Balancing Valve

Figure 10.20b Balancing Valve – Handle and Setting

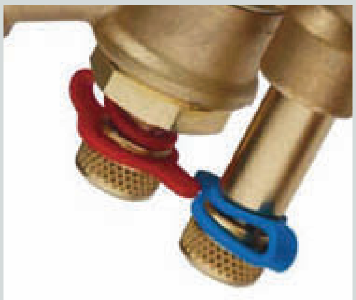

Figure 10.20c Balancing Valve – Temperature Measurement Points

Turns	DN 10/09	DN 15/14	DN20	DN25	DN32	DN40	DN50
0.5		0.127	0.511	0.60	1.14	1.75	2.56
1	0.090	0.212	0.757	1.03	1.90	3.30	4.20
1.5	0.137	0.314	1.19	2.10	3.10	4.60	7.20
2	0.260	0.571	1.90	3.62	4.66	6.10	11.7
2.5	0.480	0.877	2.80	5.30	7.10	8.80	16.2
3	0.826	1.38	3.87	6.90	9.50	12.6	21.5
3.5	1.26	1.98	4.75	8.00	11.8	16.0	26.5
4	1.47	2.52	5.70	8.70	14.2	19.2	33.0

Table 10.7 Balancing Valve Flow Resistance

Tempering Valves

Tempering Valves are designed to minimise the risk of scalding from heated water delivered to outlets for ablution purposes (e.g. baths, showers and basins).

This is achieved through a regulating mechanism that allows the proportional delivery of heated and cold water through the tempering valve (Figure 10.21).

The design of the tempering valve allows for variations in pressure and temperature (within stated limits) of both the heated and cold water supplies to the valve in the delivery of “tempered” water.

The use of tempering valves to deliver water at or below 50^{0}C permits heated water to be stored at higher temperatures that minimise the growth of Legionella bacteria.

These elevated temperatures would otherwise present a significant scalding risk to the end user if a tempering valve were not installed.

Tempering Valves deliver tempered water (up to a 50^{0}C maximum limit) by using a sealed thermal element that reacts to changes in temperature of the hot and cold supplies, adjusting the proportional flow through the valve.

A temperature differential must be maintained between the heated water supply and the tempered water at the outlet of the tempering valve, to ensure that the outlet flow will be shut off in the event of cold supply failure (the scald protection function).

Manufacturers’ product instructions must specify the temperature differential between the hot water supply to the tempering valve and the mixed water discharge temperature of the tempering valve.

Thermostatic Mixing Valves (TMV)

Thermostatic Mixing Valves when designed and manufactured to meet AS 4032 are approved for use in application such as hospitals, aged health, childcare and other locations where the water temperature is to be controlled.

The purpose of TMV’S is to ensure the risk of scalding associated with heated water is removed (Figure 10.22).

Thermostatic mixing valves blend heated water above 60^{0}C with cold water to ensure safe use in with sanitary fixtures such as; showers, basins and baths.

Most TMV’s use a wax thermostatic element for regulating the temperatures of the delivered water. They automatically shut off (rapidly) in the event of heated or cold water supply failure.

TMV’S can be installed for warm water delivery in either a;

- Control groups – heated water distribution system.
- Point of use – single outlet TMV’s, often referred to as Tap outlet or thermostatic taps.

Figure 10.21
Tempering Valve

International Copper Association Australia
Copper Alliance

Figure 10.22
Thermostatic Mixing Valve

International Copper Association Australia
Copper Alliance

Swing Check Valves

A swing check valve or tilting disc check valve is a check valve in which the disc (the movable part to block the flow) swings on a hinge to:

- Block the reverse flow, when pulled onto the seat.
- Allow forward flow, when drawn off the seat.

The seat opening cross-section may be perpendicular to the centerline between the two ports or at an angle.

Swing check valves can come in various sizes and are widely used when large check valves are required (Figure 10.23 and Figure 10.24).

Swing check valves are primarily used as backflow preventer against flooding caused by return flow of sewage waters.

Such risk occurs most often in sanitary drainage systems connected to combine sewerage systems and in rainwater drainage systems and may be caused by intense rainfall, thaw or flood.

The swing check valve can be:

- Metal seated when both the disc and the body seat are metallic and a leakage rate is allowed.
- Rubber seated, when the disc or the body seat is provided with a rubber gasket to limit the leakage rate during the reverse flow.

On opening the swing check valve, the flow path is enlarged in a linear manner with respect to percentage of opening. This means that:

- flow rate does change proportionally with disc travel.
- when fully open, the typical swing check valve has minimal obstruction in the flow path, resulting in very low head loss.

Pressure and Temperature Ratings for Swing Check Valves are shown in Table 10.8.

Figure 10.23
Screwed End - Swing Check Valve

International Copper Association Australia Copper Alliance

Figure 10.24
Flanged End - Swing Check Valve

International Copper Association Australia Copper Alliance

Size Range	Materials	Temperature Range	Max Pressure
15mm to 100mm	DZR Brass	0°C to 99°C	1600kPa
15mm to 100mm	Bronze	-10°C to 99°C	2500kPa
50mm to 100mm	Bronze	-10°C to 99°C	1600kPa

Table 10.8
Pressure and Temperature Ratings for Swing Check Valves

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11

Chapter Eleven

Chapter 11 – Design Principles Cold Water & Heated Water Service Systems EN 1057 version

International Copper Association Australia
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Design Principles Cold Water & Heated Water Service Systems

Water demand is dependent on building type, occupancy and water usage.

Introduction

Designing and installing cold-water services supply systems for buildings can be complex or simplistic depending on the building function, design criteria, materials and the fixtures outlets associated with the type of the building and use.

Design requirements for a cold water supply service will continually change over time with innovation and purpose, meeting these changes is the basis of a sound design.

The design considerations covered in this chapter are those essential elements that bring together the customers or end users expectations and the requirements of the plumbing system.

These elements range from the type of materials, tap-ware, fixture operation, pipe access, flow, water temperature, water quality, installation methods, maintenance and repairs.

The Plumbing Codes (PCA), (Figure 11.1), and Plumbing Standards AS 3500 (Figure 11.2), provisions for the cold and heated water systems are integral to the overall design and functionality.

Figure 11.1
Codes of Australia – Part 3 Plumbing

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Copper Alliance

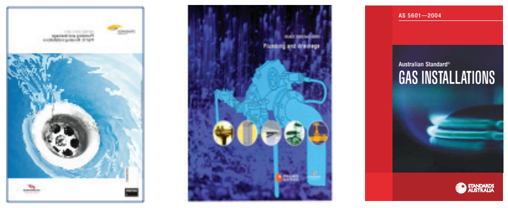

Figure 11.2
Australian Standards AS/NZ 3500 Installation, AS 5601 Gasfitting

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Building Function

A client or property owner's intent to develop a project is derived from a need, a purpose or mission, and a desired result.

When the design and installation of a water service satisfies that desire including the health & safety, emotion, cognitive and cultural needs of the people who use it, the project and services are most likely to be functionally successful. The building type also characterises its functionality.

A building services function, as it is intended is integral of a "whole" building, the qualities of a building service may not even be initially noticed or recognized, but a poorly designed and installed building service can be costly to correct, if the opportunity to correct ever becomes available.

When a water services falls short of the intended design and installation parameters the cost can be modest to extreme, failures are generally more cost significant to change or repair than the original install cost.

Design Principles

Water quality

The quality of water that is deemed suitable for drinking purposes has been covered in more detailed in previous chapters. For plumbing systems the water shall be suitable for drinking, flushing, ablution and general purpose. It is important to consider the water quality when selection materials for water services systems pipework.

In many regional locations within Australia the quality of water can differ from those in major cities, towns and remote communities and will in many cases influence the performance and longevity of the water services pipes and fittings. The temperature of cold water can influence the type of pipe material and how the material will perform. We know that warmer water, say greater than say 25^{0}C will support bacteria and that same bacteria have an impact on the both metallic and plastic piping materials.

Biofilms

A biofilm is the accumulation of organic and inorganic materials deposited on a pipe internal surface. It may be a complete film or, more commonly in water systems, appearing as small deposits on pipe internal surfaces.

Biofilms in drinking water pipeworks can be responsible for a wide range of water quality and operational problems. Biofilms can be responsible for loss of flow in the distribution system, increasing bacterial levels, reduction of dissolved oxygen, taste and odor changes of the water.

Types of Cold Water Supplies

Drinking water (potable water)

Potable water is generally defined as 'water which is suitable for human consumption' (AS/NZS 3500) and is now referred to as drinking water.

Acceptable characteristics of potable water are specifically defined in the Australian Drinking Water Quality Guidelines and in the international World Health Organization (WHO) guidelines for drinking-water quality.

A national guideline for drinking water standards, the Australian Drinking Water Quality Guidelines, was initially published in 1996 and regularly updated.

Greywater

Greywater is the term given to domestic wastewater from bathroom fixtures (such as basins, showers and baths), laundry fixtures (such as clothes washing machines and laundry troughs) and kitchen facilities (such as sinks and dishwashing machines).

Depending on the level of wastewater treatment, greywater can be recovered and used for applications such as toilet flushing and irrigation. Greywater should not contain human waste or industrial waste, when reused.

Although untreated wastewater can be used for sub-surface irrigation, it is generally recommended that some level of treatment be provided for most end uses, particularly for commercial and/or public applications.

Greywater from kitchens is not suitable for re-use, as it contains higher levels of fats and oils that require removal with a grease trap, as well as caustic chemicals from dishwasher detergents that may damage soils. Refer to Chapter 5 for more information.

Blackwater

Blackwater refers to waste discharges from the human body, which are collected through fixtures such as toilets, urinals and bidets. This wastewater can be used for non-drinking purposes once treated and disinfected.

The wastewater can be obtained directly from sewers and treated on site, or can be obtained from a large treatment plant that collects and treats the wastewater from a sewage system and then pipes it to the re-use location once treated.

Re-use of wastewater is heavily dependent on a reliable treatment system, from a safe source, and generally the ideal locations for such re-use projects are close to wastewater treatment plants. Recycled water can be used for irrigation and toilet flushing through the provision of an independent pipe network. Refer to Chapter 5 for more information.

Stormwater

Stormwater refers to run-off due to rainfall collected from roofs, impervious surfaces and drainage systems.

Stormwater collected from roofs (also referred to as rainwater) can be used untreated for applications such as wash- down, irrigation and toilet flushing. Stormwater from surfaces and drainage systems is likely to require treatment due to potential contaminants from the surrounding catchment.

Stormwater from surfaces and drainage systems lends itself to treatment using wetlands. Water sensitive urban design (WSUD) refers to treating stormwater run-off from impervious surfaces to improve its quality before re-use or release into the environment.

Groundwater

Groundwater is water that lies beneath the surface of the ground. On a small scale, it can be extracted by drilling a borehole, while on a larger scale it can be extracted by constructing and operating extraction wells.

Groundwater can be used for various applications, such as agricultural, municipal and industrial uses, depending on its quality.

Groundwater quality varies widely, with the limiting factors for usage being volumes available, recharge rates, flow rates and salt content and contaminants. In many areas, groundwater is highly saline, limiting its beneficial uses.

Embodied Water

Embodied water is the amount of water required to manufacture products, including the extraction of raw materials, transporting those materials, and processing them into the final product. Virtually all products we use will have consumed water during their manufacturing process. Determining how much water a particular product has consumed is a complex process that is only now beginning to be understood.

Pipe Materials

Listed in AS/NZS 3500 series documents are materials related to standards for manufacturing and installation that satisfy the requirement of the Plumbing Code of Australia.

The materials stated in the AS/NZS 3500 standards cover both metallic and polymer piping systems.

Pipes and fittings-

1. Up to and including DN100, shall have a maximum allowable operating pressure (MAOP) of at least 1.2 MPa at 20^{0}C; and
2. Where larger than DN100, shall be selected to satisfy design criteria for the system.

All materials have limitation and those limiting factors must be assess before any pipe selection. It is imperative that designers and installers have comprehensive knowledge and experience of those selected products and limitations for their application.

Copper tubes manufactured to AS 1432 have proven over time to be a reliable material for cold water services. Copper tubes and fittings provides a service life in excess of 50 years when installed correctly.

The higher safe working and test pressures ensure that copper when compared to non metallic material can be used in most applications for building services. AS/NZS 3500 describes the installed conditions that ensures copper tube suitability and performance under the" deem to satisfy" provision.

The installation advantages of copper tubes and fittings include;

- Resistance to corrosion.
- Mechanical strength.
- Ease of fabrication and assembly.
- Minimal flow resistance.
- Bactericidal properties.
- Service life cost effectiveness.

Care should be taken when selecting copper tube for some treated/purified water systems. The level of purification will determine the pipe material that needs to be selected.

Water Demand for Building

Water demand for buildings is highly dependent on the type of building, the occupancy and the water usage profile. There are various building types that influence the actual demand which are;

- Residential – both private and institutional.
- Community.
- Warehousing/storage.
- Public entertainment.
- Retail/Shops.
- Food Services – Restaurants, take away and fast food outlets.
- Educational – primary, secondary & tertiary.
- Commercial offices.
- Hotels.
- Caravan/tourist parks.
- Hospitals and aged care facilities.
- Motels.
- Sports facilities and stadiums
- Religion/cultural.
- Research and laboratory facilities.
- Factories and industrial facilities.

As designers we must be clear on the type of premises, the available water quality and the water usage pattern requirement to meet the daily demand.

Note:
Refer Plumbing Code of Australia (BCA Vol.3) for the requirements for different building classes

Fixture Outlet Flow Requirement

Flow requirements for plumbing fixtures may be acquired from many sources including Australian Standards, Plumbing Design Standards and from those manufacturing companies distributing products for cold and heated water supply systems.

Water Conservation

In Australia we have a mandatory scheme that regulates the type of tap-ware and those nominated flow rates. This scheme is called the Water Efficiency Labelling and Standards (WELS) scheme.

With the use of WELS rated products the designer is able to choose the fixtures and fittings that will achieve a water usage reduction target set for the project.

These water reductions also allow the probable simultaneous peak flows of the water systems to be reduced, in turn reduces the pipe sizes within the project.

WELS is Australia's water efficiency labelling scheme that requires certain products to be registered and labelled with their water efficiency in accordance with the standard set under the national Water Efficiency Labelling and Standards Act 2005.

The objectives of WELS Scheme are to encourage the development and marketing of water efficient products and enable consumers to clearly identify and purchase water efficient products.

The fixtures covered under the scheme are:

- Showers.
- Tapware.
- Flow controllers.
- Toilets (lavatory equipment).
- Urinal equipment.
- Washing machine.
- Dishwashers.

www.waterrating.gov.au

To understand water conservation the comparison is required between the Australian Standard and Industry Standards.

Before WELS the fixtures and fittings were designed at a much higher flow rate.

Since water conservation fixture and fittings flow rates have been measured and rated against the WELS rating criteria.

The following Tables 11.1, 11.2 and 11.3 provide an understanding of fixtures and fittings flow rates and the comparison with WELS flow rate criteria.

Cu

Taps or Sanitary Fixtures	Institute of Plumbing Australia Selection and Sizing of Copper Tubes For Water Piping Systems	Australian Standards AS 3500.1.2003 + Amend 1&2
	Cold Water Flow In Litres Per Second	Cold Water Flow In Litres Per Second
Toilet Cistern	0.11	0.10
Basin (Spray Tap)	0.04	0.03
Basin (Standard Outlet)	0.12	0.10
Kitchen Sink	0.22	0.12
Shower	0.22	0.10
Bath	0.30	0.30
Kitchen Sink	0.22	0.12
Laundry Tubs	0.23	0.12
Dishwashing Machine	0.10	0.20
Clothes Washing Machine	0.10	0.20

Table 11.1
Sanitary Fixtures - Flow Rates

Taps & Equipment	WELS Star Ratings Criteria Litres Per Second						
	0	1	2	3	4	5	6
Tap Equipment – Basin, sink, abutilon trough, kitchen sink, laundry trough	>0.266	<0.266 to >0.20	<0.20 to >0.15	<0.15 to >0.125	<0.125 to >0.10	<0.10 to >0.075	<0.066
Shower	>0.266	<0.266 to >0.20	<0.20 to >0.15	<0.15	-	-	-
Flow Controller	>0.266	<0.266 to >0.20	<0.20 to >0.15	<0.15 to >0.125	<0.125 to >0.10	<0.10 to >0.075	<0.066

Table 11.2
Water Efficient Tapware - Flow Rates

Note: WELS rating does not apply to a tap that is used solely over a bath.

Sanitary Fixtures	WELS Star Ratings Criteria Litres Per Average Flush						
	0	1	2	3	4	5	6
Toilet	-	<5.5 to >4.5	<4.5 to >4.0	<4.5 to >4.0	<4.0 to >3.5	-	-
Urinal Equipment	>2.5/ 1x stall or >4.0/ 2x stall	<4.0/ 2x stall	<2.5	<2.0	<1.5	<1.0	<1.0 Waterless + Other

Table 11.3
Sanitary Ware Water Efficient Flush Requirements

Definition of Water Pressures

Static Pressures

Static pressure is the pressure that is exerted by a liquid, such as cold and heated water. Specifically, it is the pressure measured when the liquid is stationary (no flow).

In plumbing and fire systems the pressure associated with hydrostatic testing is simply static pressure. The pressure exerted by a static fluid depends only upon the depth of the fluid, the density of the fluid, and the acceleration of gravity.

Dynamic Pressures

Dynamic pressure is a form of kinetic energy pressure that is applied by moving water on its surroundings.

Water flowing through a pipe exerts more pressure on the pipe than the static pressure, which would be exerted if the water in the pipes were stationary. Water in different parts of the pipe system will have different pressures. This difference in pressure can be measured by using a differential pressure gauge.

By reading the pressure at two points in a pipe and taking into account the resistance of the pipes, the flow rate of the water can be determined.

Basically dynamic pressure is the pressure in the piping system when at flow.

Design Pressures

Australian standards prescribe the requirement for minimum design pressures within buildings, at fixture discharge outlets and where specific appliances are.

Many designers formulate the parameter to which they design a water supply system. In most cases the design pressures for tap outlets other than thermostatic mixing valves are preferred as 250kPa.

Where thermostatic valves or other inline equipment is used and a higher design pressure is required to overcome the pressure loss within the valve itself.

Noise or Water Hammer

What causes the pipework noise associated with a cold and heated pipework system? Is it the type of material or is it something more concerning?

Poor plumbing installation practices, including the choice of tapware, high water velocity and other factors are often never considered the principle cause. We hear so often that plastic pipes are better than metallic pipes because the noise is reduced. What can designers do to eliminate unwanted noise and or limit the impact of noise within the design?

Water hammer is the main factor and generally occurs in a high-pressure system when the flow of water is suddenly stopped. A sudden fluctuation in flow velocity sets up shockwaves through the pipework, causing the pipe to vibrate making a ‘hammering’ noise sound. Water hammer mostly occurs in metal pipes, although it also present in plastic pipe systems.

Fast-acting taps such as lever taps with ceramic disc washers, solenoid valves such as those used with washing machines, spring-closing valves and pumps are often a cause of water hammer.

It is related directly to the water velocity – the faster the water travels, the greater likelihood of water hammer. It is recommended to prevent the noise associated with water supplies than trying to fix the problem once a building is complete.

To reduce the likelihood of noise within a water supply system consider;

- Avoiding direct contact of pipes with the structure.
- Clipping pipes with rubber insulated clips or clip over the pipe insulation.
- Fixing pipework to prevent uncontrolled movement used.
- Providing long radius bends or flexible sections of pipe to absorb shock.
- Fitting grommets where pipes pass through structural elements.
- Sizing the pipework to avoid excessive water velocity (below 2.4 m/s) for cold water.

- Limiting the system pressure – recommended is 350 kPa, maximum 500 kPa within a building. (Install pressure reducing, pressure limiting devices where high pressure is evident).
- Limiting pump speed.

Air Locks in Water Supply Pipework

If air enters a water supply system, it will accumulate at high points and can restrict the flow of water. If there is not enough pressure to push the air bubble through the pipe, the air lock will remain until the pipeline is manually purged.

Air may enter the system from:

- A cylinder vent.
- The tank if it runs low.
- Water as it is heated.
- Initial pipework charging and bleeding off the air during commissioning.

Low pressure pipes should be graded to allow air to exit from predetermined high points and to prevent air locks from occurring.

Temperature

The desired cold water temperature is between 12 - 20^{0}C. The water temperature supplied by the water agencies can vary and shall be confirmed before the commencement of the design.

It is designers and or plumbers' responsibility to ensure the cold water temperature does not increase before discharging at any tap outlet.

The temperature of the supplied water, plus the environmental influences and piping material conveying the water can determine the temperature of tap water discharge. If it is cold out side, the temperature of your tap water could be as low as 10^{0}C. If it is hot outside, the temperature of your tap water may reach as high as 26^{0}C and in some remote location 40^{0}C.

In those regional locations where the environment raises the cold water above that temperature that is safe to drink, insulation the pipework may be necessary for cold water piping networks. The temperature of heated water is regulated in AS/NZS 3500. Heated water shall be stored and delivered to avoid the likelihood of the growth of legionella bacteria. Stored water should not be held at temperatures less than 60^{0}C.

For personal hygiene 50^{0}C water is mandated for all building unless the building and sanitary fixtures is design for aged care, children, people with disabilities and or health care institutions the temperature shall not exceed 45^{0}C.

Access to Pipework

Providing access to installed pipework should be considered a priority for designers and plumbers. Often we rely on the plumbing codes to instruct on the minimum requirement for accessing.

However, in practice access to pipework is being ignored, our standards are never clear on their intent.

When designing cold and heated pipework a designer must consider the likelihood of pipe and fitting failure, location of control valves and the opportunity for replacement and or servicing.

At all time installing pipework into structure (concrete) should be avoided. Where pipes are installed in pipe ducts, an access panel or door shall be provided to accommodate a person to access the pipework or valves. The location of the access panel shall be located to ensure safe entry.

Valves

Valves are a mechanical devices designed to direct, stop, mix or regulate the flow, pressure, or temperature of the fluid being conveyed. Valves incorporated with plumbing systems shall be certified for their intended purpose.

Valves listed in AS/NZS 3500, AS 2419 and AS 2441 are covered in more detail in Chapter 10 describing the purpose, material and operation.

The inclusion of valves in plumbing services systems provides the ability for the service to be maintained in sections or within specific locations throughout a building without the need to close the entire water supply.

For this reason isolation valves such as gate and ball valves are essential as those pipes and fitting material type and size selection.

Pipework Protection

Wherever possible the location of installed cold and heated pipework should be considered as part of the design process. Pipes should be installed to avoid those areas of a building or site that may impact on the longevity of the material.

Pipes located in ground must have at least 300mm of cover and surrounded with material that is unlikely to cause damage. Pipes located in ceiling/roof spaces shall be installed in a manner that prevents heat gain from the surrounding environment.

Where pipes are fixed to metal roof or wall cladding they should be insulated.

Protection Against Freezing

Freezing of water within the tube can result in bursting and precautions should be taken to prevent direct exposure of piping to these conditions (Figure 11.3).

When the ambient air temperature regularly falls below freezing, all piping located outside buildings should be buried to a minimum depth of 300mm.

Any exposed sections should be covered with a continuous waterproof insulation. In very cold climates, it will be necessary to provide additional insulation over the normal pre-insulated tubes.

Piping within the building may also freeze up if it is located in positions, which are difficult to keep warm.

These areas would include: on the outside of roof or wall insulation bats, unheated roof spaces, unheated cellars, locations near windows, ventilators or external doors where cold drafts occur, and any location in direct contact with cold surfaces such as metal roofs, metal framework or external metal cladding. Tubes installed in any of these locations should be insulated to minimise the possibility of water freezing.

AS/NZS 3500 - Part 1 Water Supplies provides minimum requirement for insulating materials for the protection of pipework against freezing.

Figure 11.3
Picture Showing Pipe Burst At Subzero Temperature

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Identification of Pipework

In location other than domestic situations pipes should be clearly marked identifying the type of service in accordance with AS 1345. Lilac pipe shall be provided for recycled water.

Marking should be placed along the pipe at interval not exceeding 8 metres and adjacent to any valve, junction, tee or floor or wall penetration. All non potable taps and outlets shall be labelled.

Backflow Prevention – Cross Connection

Backflow occurs when water from a customer's property flows backwards into the utility pipes. This may carry contaminants that can harm people's/community health.

Backflow is more likely to occur if:

- There's a drop in pressure in the main, eg during a main break.
- Water pressure at the property is higher than at the main, eg if a pump is operating on the site.

Backflow prevention devices ensure the community water supply isn't contaminated from hazards on a customer's property. They stop water in a customer's water pipe flowing back into the community water main.

AS/NZS 3500 specifies the minimum requirement for addressing the need for prevention devices, the type of back flow device and the situation (hazard) where each device type shall be installed.

There are three classifications for cross connect hazard:

- **High hazard**
  Any condition, device or practice that, in connection with the water supply system, has the potential to cause death.

- **Medium hazard**
  Any condition, device or practice that, in connection with the water supply system, having the potential to endanger health.

- **Low hazard**
  Any condition, device or practice that, in connection with the water supply system, constitutes a nuisance but does not endanger health or cause injury.

Listed in AS/NZS 3500 Water Supplies are requirements that describe the type of devices, the cross connection hazard, whether protection is required against back-flow and protection against back-siphonage.

In addition to AS/NZS 3500 local authorities may have their own requirements for testing and certifying Backflow Prevention Devices.

12
Chapter
Twelve

Chapter 12 – Cold Water System Design

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Cold Water System Design

Cu

AS/NZS 3500 provisions for the cold and heated water systems are integral to the overall design and functionality.

Introduction

This chapter has been developed to assist designers in understanding the key elements of water service system design, fixtures outlet performances and the copper tube sizing selection for building cold-water services applications.

In previous chapters we have explained the function of a building, their purpose and the clients expectation. In this chapter we look at the specific engineering requirements of cold-water services systems whilst meeting those building requirements to ensure functional operation and satisfaction is achieved.

The Plumbing Codes (PCA) and Plumbing Standards AS/NZS 3500 provisions for the cold and heated water systems are integral to the overall design and functionality.

Functions of a Cold Water Services System.

The function of a cold water supply system is to provide the required volume of water for the use by the occupants of the building. Having a desired temperature of not more than 20^{0}C temperature, having suitable bacteriological, chemical and physical characteristics that are described in the Australian Drinking Water Guidelines.

The cold water supply system shall have adequate pressure for the satisfactory operation of the fixtures and fittings to which it serves.

System Design and Engineering

Designing and installing water services pipes and fittings of correct size to meet the functional requirements of the system, the following engineering criteria;

- Achieving the design flow pressure at all outlets.
- Limiting the velocity within pipework.
- Available pressure (head loss) shall not be exceeded.

Head loss occurs when water flows through a pipe or tube and is calculated so that the design flow pressure at the outlets can be achieved. Head loss is the calculation derived from the factors such as;

- Design flow rate.
- Selected tube material.
- Internal diameters of the tubes.
- Length of the water services reticulated pipework.
- Frictional loss accumulated by the number of valves, tees and bends in the pipework length.
- Density of water being conveyed.
- Velocity of the water flow.
- Vertical head loss or gain.

The design flow rate of water flow through the pipework system is determined by calculating the probable simultaneous flow rate (PSD), which is the diversified flow of the maximum flow rate.

The maximum flow rates can occur in a water supply system where the following situations are encountered;

- Simultaneous flushing of water closets.
- Simultaneous usage of groups of showers are experienced in sporting facilities.
- Industrial or production environments.
- Mains pressure flushing of water closets and urinals.
- Landscape irrigation.
- Water supply filling of storage tanks.
- Pumping of water to open outlets.
- Pumping in a closed pipework loop/circuit.
- Fire Services (hydrants and hose reels).

Probable Simultaneous Flow Rate

Estimating the simultaneous flow is theoretical on the basis that all plumbing systems pipework should be sized for a maximum flow rate that is capable of serving the sanitary fixtures and appliances simultaneously (at the same time).

In practice the chances of their simultaneous operation or use are remote and the plumbing design criteria may be relaxed to some degree.

Plumbing water distribution systems are recommended to be designed on the basis and the idea of the most probable peak demand loading reflects the worst-case scenario for the water supply system.

Probable simultaneous flow rate through a section of pipework can be determined by applying "Loading Units" to the fixture outlets, accumulating those totals and converting them to litres per second flow.

A schedule of loading units for residential applications - in Flow Rates and Loading units in accordance with AS/NZS 3500 or Table 47 and 48 of '*Selection and Sizing of Copper Tubes for Water Piping Systems'* by Barrie Smith.

As an example, one residential house or apartment has an allocation of 0.48 litres per second as a probable simultaneous flow for non - efficient tapware. The flow in litres is derived from the total loading unit of around 20-30.

Water flow requirements and loading units applied to sanitary fixtures in residential type buildings may also reflect those units described in Table 12.1 below and compares the WELS (Water Efficient Labeling) for fixture outlets.

Taps or Sanitary Fixtures	Non WELS Rated		WELS Rated (5 Star)	
	Cold Water Flow in Litres Per Second	Cold Water Fixture Loading Units	Water Efficient - Cold Water Flow in Litres Per Second	Water Efficient – Cold Water Fixture Loading Units
Toilet Cistern	0.11	2	0.10	2
Basin	0.12	1	0.10	1
Shower	0.22	4	0.15	3
Bath	0.30	8	0.30	8
Kitchen Sink	0.22	3	0.10	1
Laundry Taps	0.23	3	0.10	1
Total	**1.20**	**21**	**0.85**	**16**
40% of full flow	**0.48**		**0.34**	

Table 12.1
Comparison of Sanitary Fixtures Flow Rates

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For Example;

Non Water efficient tapware for apartments

For cold water supply, the probable simultaneous flow to one dwelling would be 40 per cent of the full flow total, which is 40% of 1.20 = 0.48l/s

WELS Rated (Water Efficient Tapware)

For cold water the probable simultaneous demand when using water efficient tap-ware the flow to one dwelling or apartment may be 40 percent of the water efficient flow total, which is 40% of 0.85 = 0.34l/s.

The total demand on the cold water system when using water efficient tap-ware reducing the flow when pipe sizing, which can significantly reduce the pipe/tube size and the initial cost of the installed copper piping system.

When comparing copper tube sizes to polyolefin pipe it should be a consideration of the designer/plumber to assess the internal diameter of the pipe and any further pipe reduction, frictional pressure loss through the fittings (Table 12.2).

The actual pipe size reduction of the internal diameter of polyolefin pipes means a larger diameter size may be required in comparison to Type B Copper.

Remember that loading units are non-dimensional factors that take into account the flow rate, length of time in use and the frequency of use of each fixture, appliance or tap within the house or apartment and building.

Full Flow Rate

In many water services applications it is very difficult to apply a diversify flow rate for a particular supply system.

Application such as industrial, commercial and sporting facilities the non-diversified flow used to determined the pipe size should not be applied. Where a non-diversified flow is required the designer may need to apply a full load flow rate or make an engineering assessment of the building function and fixture usage pattern before applying and such diversity.

DN	Copper Tube (AUS) mm			Copper Pipe (NZ) mm
	Type A	Type B	Type C	
10	7.5	7.7	8.1	9.5
15	10.7	10.9	11.3	12.7
18	13.4	13.8	14.1	-
20	16.2	17.0	17.2	19.0
25	22.1	23.0	23.6	25.4
32	28.5	29.3	-	31.8
40	34.8	35.7	-	38.1
50	47.5	48.4	-	50.8

Table 12.2
Internal Diameters for Copper Tubes and Pipes

Water Pressure Requirements

Water pressure is a measure of the forces required to move the water within the water services pipework to the fixture outlet and in addition to retain a residual force after the water discharges the outlet.

Water pressure within a commercial or residential building should be in accordance with AS/NZS 3500.1 being not less than 50kPa and not more than 500kPa within a building. Ideally pressure at outlets should not be less than 150kPa.

When water pressure falls below 150kPa it is likely that plumbing fixtures and appliances fail to operate or function correctly. Where the water pressure is deemed inadequate, a means for increasing the pressure shall be provided, re: pumping.

If water pressure is excessive and beyond those specified in AS/NZS 3500 the associated installation risk are potentially;

- Water wastage.
- Noisy piping system.
- Water hammer.
- Potential for leakage.
- Failure of pipe joints and assemblies.

The installation of pressure limiting or reducing valves is then considered when the residual pressure at outlets exceeds those specified or required. Incidentally, the warranties of some appliances or fixture outlet devices may be voided if excessive pressure is evident.

Flow Pressure

Flow pressure is the pressure that exists at any point in the system when water is flowing at that point. Once water starts to flow, the water moving through the pipe uses some of its energy to push past the pipe surface, bends, tees and valves no matter how smooth the internal piping system is.

This consumes energy and reduces the pressure available to push the water out the end of the pipe or outlet. This pressure loss is due to friction that occurs at every point along the pipe. When water starts to flow through a pipe, the pressure is highest at the source and decreases every metre along that pipe. The pressure would be lowest at the furthest tap or outlet.

For example, if we wanted to move 1litre of water per second (l/s) at 2.4 metres per second (m/s) velocity through DN25mm copper tube, say 25 metres in length, we might expect to lose about 70kPa of pressure.

If the pressure at the beginning of the pipe is 350kPa, less 70kPa, the pressure at the end would be 280kPa. Flows (or flow rates) are measurements of the volume of water that comes out of the tap every second/minute. To summarize, as water is flowing through a pipe, the flow pressure drops as it moves along the pipe but the flow remains constant.

Static Pressure

Static pressure is the pressure exerted by the water on the walls of the pipe, fittings or valves when there is no water flowing. There will be no flow, as long as the taps are closed. Assuming that the pipe is horizontal, no matter where you measure the static pressure along that pipe, you would have the same pressure reading.

If that pressure were 350kPa where the pipe first came into the house, it would also be 350kPa at the rear tap of the house.

Example;
To convert 250kilopascals (kPa) to metres head

$$\text{m head} = \frac{250}{9.81}$$

$$= 25 \text{ metres head pressure}$$

This simple conversion is generally applied and accepted for practical purposes by industry, plumbers and engineers. Conversion of pressure measured in kilopascal (kPa) to metres head can be determined from the formula;

kPa	= m head x 9.81
Where kPa	= Pressure in kilopascals
9.81	= Gravitational acceleration

Example:
Convert 50 metres head pressure to kilopascals pressure

kPa = 50 x 9.81
= 490.5 kilopascals pressure (kPa)

The rule of thumb conversion is generally acceptable to supplement 9.81 to 10 to make it easier to convert in the field.

Creation of Water Pressure

Water pressure is created in two ways, these being;

- Gravity pressure, generated at water outlets, which are lower than a water storage tank or vessel.
- Pumped (boost) pressure created by the force of a pump, which draws water at a lower pressure into the suction connection and discharges at a higher water pressure of the outlet of the pump.

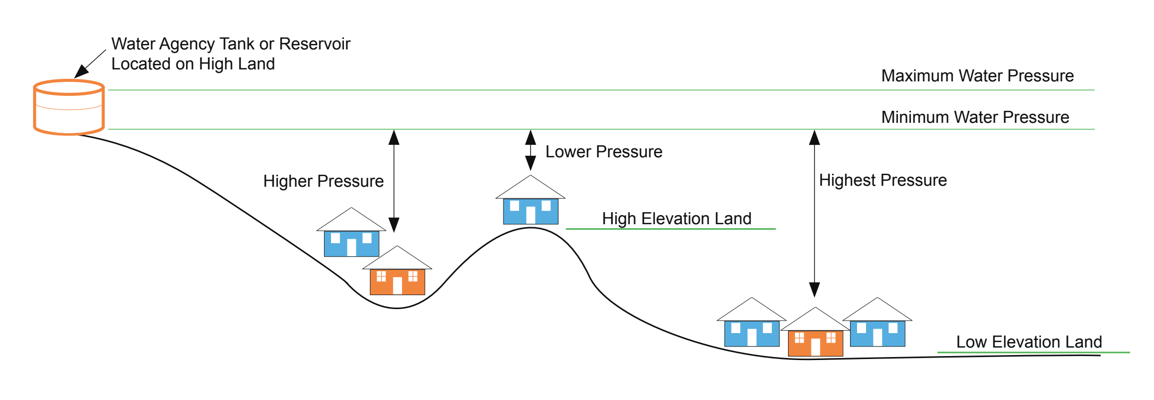

Figure 12.1
Illustration of Gravity Water Pressure

Gravity Water Pressure

Where water agencies have constructed storage vessels or reservoirs at elevated locations. Water is distributed from these tanks through a network of piping known as a gravity water mains system.

Water pressure varies at different locations along the distribution water main depending on the distance from the reservoir and the properties elevation from that reservoir (Figure 12.1).

Properties located at the low elevation areas receive higher water pressure. Alternately properties located at the highest elevation receive lower water pressure.

The horizontal distance of a high or low location property from the agency reservoir or tank has considerable influence on the gravity water supply pressure at the property itself.

Properties located at a greater distance from the reservoir will have lower water supply pressure due to frictional loss of pressure within the pipework as compared to property sited closer to the agencies storage vessel.

The Agencies Water Distribution explains the relation of the available water supply gravity water pressure.

Agency Water Pressure Statement

Water Services Association around Australia generally provides the designer or installer with a water pressure statement upon application. These agencies provide a statement (Table 12.3), with detailed information that is critical to the location of the building site, distance and direction from nearest cross street, the size of the water main with the maximum and minimum water pressure most likely for the time of application (Figure 12.2).These pressures may change over time given the agencies continuing strategy to lower the available pressure of the water mains, reducing the risk of water mains bursting.

The pressure statement provided by agencies will detail;

- Expected water mains pressures at the property connection point under normal flow conditions.
- Flow and pressure under fire prevention systems (two hose reels simultaneously).
- Fire hydrant & fire sprinkler installations. Combined flows with peak demand in the water main.
- Maximum permissible from flow in litres per second from the main.

A sample ‘Statement of Available Pressure and Flow” (Table 12.3), illustrates the type of information provided by the water agencies in most Australian cities and regional locations.

Assumed Connection Details	
Street Name: Smith Street	Side of Street: North
Distance & Direction from Nearest Cross Street	0 metres West from Jones Road
Approximate Ground Level (AHD)	6 metres
Nominal Size of Water Main (DN)	150 mm

Expected Water Main Pressures at Connection Point	
Normal Supply Conditions	
Maximum Pressure Minimum Pressure	69 metre head 29 metre head

With Property Fire Prevention System Demands	Flow l/s	Pressure head m
Fire Hose Reel Installations (Two hose reels simultaneously)	0.66	29
Fire Hydrant / Sprinkler Installations (Pressure expected to be maintained for 95% of the time	5 10 15 20	26 23 19 15
Maximum Permissible Flow	26	9

Table 12.3
Statement of Available Pressure and Flow

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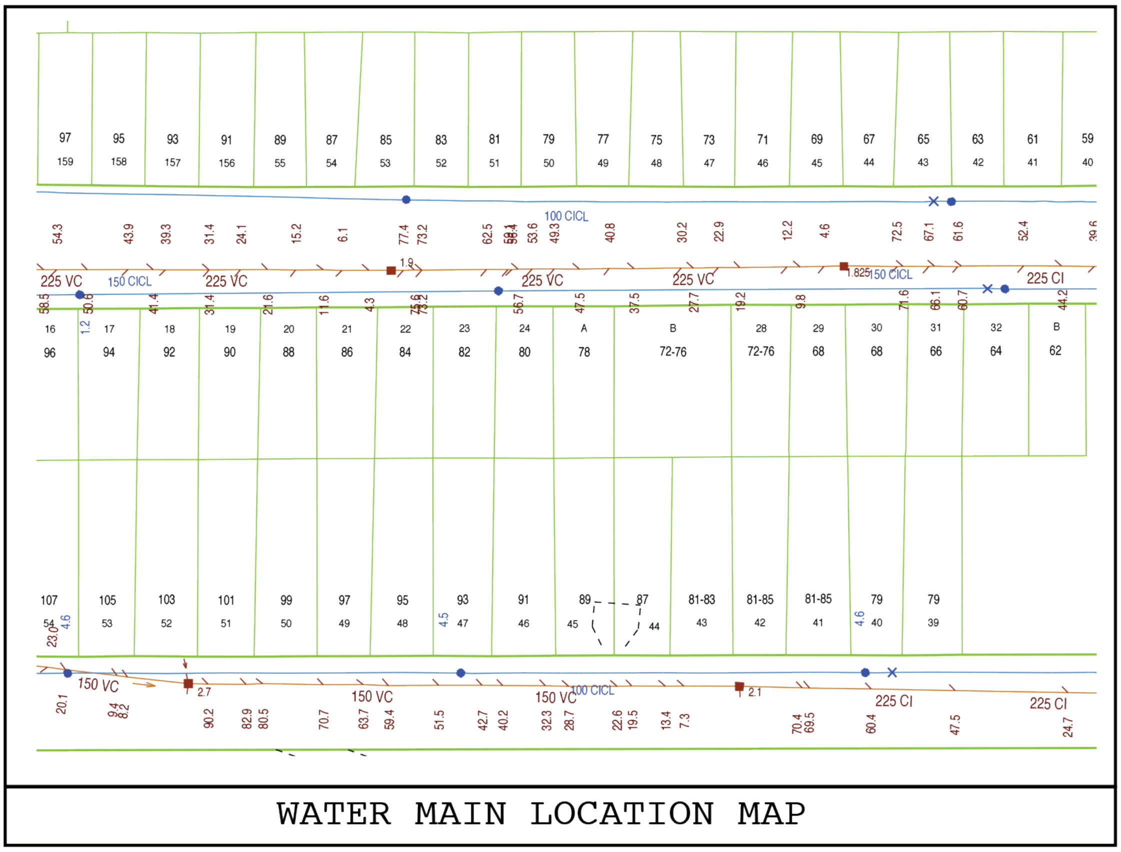

Figure 12.2
Statement of Available Pressure and Flow

International Copper Association Australia
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Creation of Pumped Water Pressure

When water supply pressure is considered inadequate for the water service functions required by that property or building, a pressure pump (boost) set would need to be provided.

Pressure pumps sets have the low pressure gravity water supply service pipe connected to the pump suction (inlet).

Pump pressure head is added to the available gravity pressure to create a desired head to overcome and compensate the vertical height of the building and any water flow frictional resistance within the pipes, fittings or valves and the residual water pressure at the fixture outlet.

Pressure limiting may be required at each branch take off.

The following Figures 12.3, 12.4, 12.5 and 12.6 illustrate the typical arrangement of pumped water pressure sets to buildings.

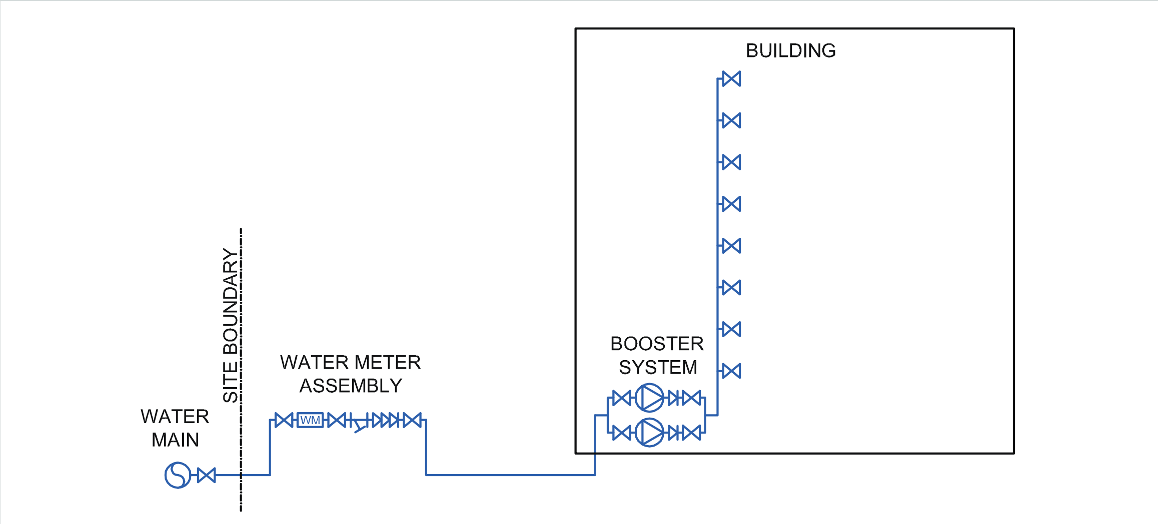

Figure 12.3
Typical Direct Boosting

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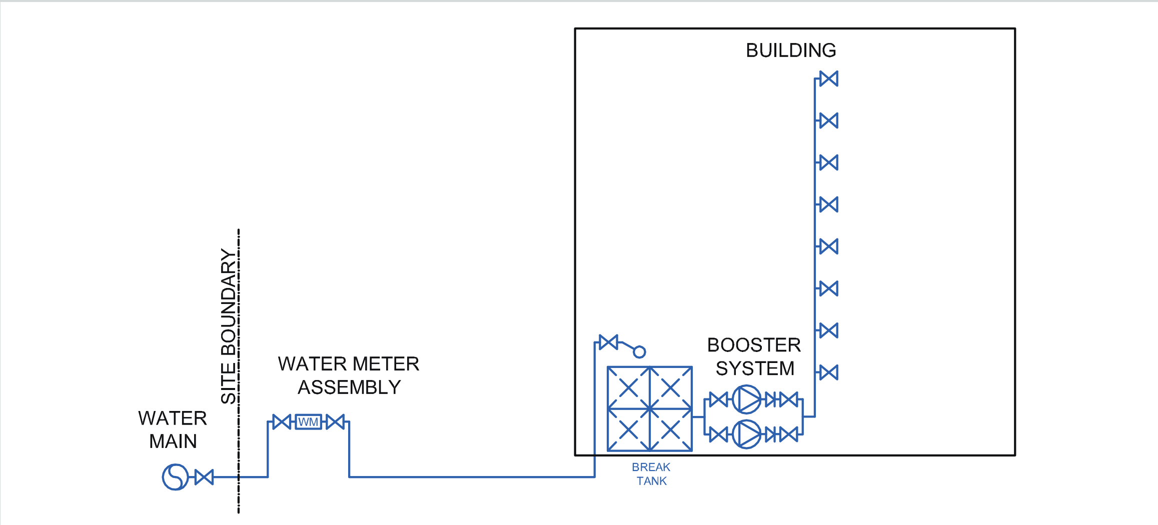

Figure 12.4
Typical Break Tank and Boosting

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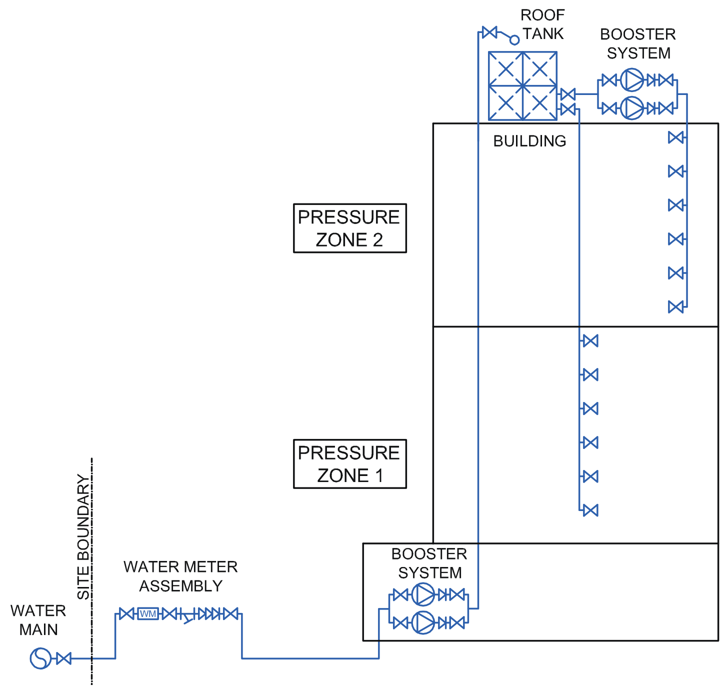

Figure 12.5
Typical Direct Water Boost to Roof Storage Tank

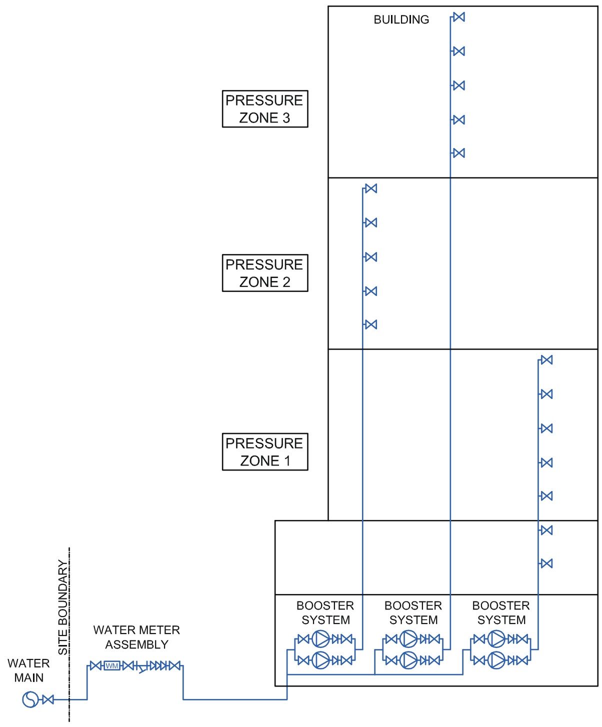

Figure 12.6
Typical Direct Water Boost to Zone

Water Pressure Requirements At Taps And Outlets

The designer, installer must provide the client or building owner with water flow and water pressure at the taps and outlets to satisfy the function and operation of the fixture and or appliances.

The Plumbing Code of Australia - Australian Standards AS/NZS 3500 requirements prescribe the minimum and maximum water pressure requirement at taps and outlets. These requirements can be very different to those desired by the building owners/occupiers.

In an ideal environment designers would hope to achieve at least 250 to 400kpa pressure at those selected tap outlets. These pressures may not be met without the aid of boost pressure pumps. In some location throughout Australia the water supply may be a low as 50kpa.

For this reason the designer must take into consideration the Plumbing Codes and Standards, best practice plumbing and the manufacturer's requirements for specific fixtures and appliances.

As designers we consider those factors like water flow and pressure together, having an aim to meet the building owners requirements while also employing water efficiently principles. Achieving the correct water pressure is crucial.

If the pressure is too low, this will inconvenience the user, for example washing down, gardening, bath filling and showers are all impacted if the available water pressure is too low. If the pressure is too high, this will lead to water wastage, water hammer and excessive wear and tear on the plumbing piping system.

Some examples of water pressure requirements are;

- Water pressure requirements for fire-fighting purposes are generally 250 kPa when the flow is equal to 10 litres per second.
- Minimum pressure at fire hose reel outlets is 220kPa.
- Maximum pressure at thermostatic mixing valves should not exceed 500kPa.
- Garden tap outlets is preferred to have a pressure of 350-400kPa.

When using water pressure controls, limiting and reducing valves or combinations, it is recommended that the designer research the technical information made available from the tap, fixture or appliance manufacturers.

Available Head Loss

For the purpose of selecting and sizing copper water services tubes and fittings head loss or pressure loss available to the designer are equally important as the supply pressure.

Excessive pressure losses in the system can be caused by selecting incorrect pipe sizes, valves with high frictional loss, this may cause greater overall frictional head loss within the water supply services system. This of course is provided that velocity of the flow is not excessive.

Designers must take into account the selected pipe diameters, which will enable the design flows to be achieved, without losing significant pressure due to frictional resistance.

To apply this principle, cold water flow velocities are ideally within the range of 1.2 to a maximum of 2.4 metres per second (m/s)

There is a point that may be reached in the pipe sizing process where the realization indicates the losses are excessive and a pressure pump set must be adopted within the design.

Velocity of Water Services Systems

Velocity is a word that describes the motion or speed of water flow as it travels through a network of piping, fittings and valves, generally referred to as a network of water service pipework.

Many designers and plumbers under estimate the relationship between pressure, flow and velocity and how the velocity influences the pipe material type and selection, pipe size, fittings and fixtures.

Velocity may have a negative influence on material depending on temperature and pipe design configuration.

Velocity when associated with water services describes the time rate of position. Water flows within the pipes and tubes per second are the velocity of flow and to which the term metres per second (m/s) is applied.

As water travels through the pipes etc: at a velocity, which is considered too high for building services, the frequency of use and for the type of pipe materials the more likelihood of noise, turbulence, water hammer and erosion corrosion is increased.

With excessive velocity the greater frictional loss is created by the generated turbulence, which in turn increases friction on pipe inner wall, fittings and valves.

In practical terms it is assumed that all particles of water have the same velocity and the mean of all velocities in the cross section is taken as velocity flow. Frictional resistance of water flow in pipes has been given the term, friction pressure loss and is expressed as metres head (m/h), or kilopascals (kpa).

The formula for calculating the velocity of water flowing in a pipe is;

$$V = \frac{Q}{A}$$

Where
V = Velocity of flow in metres per second, m/s
Q = Cubic metres of water per second, m^3/s
A = Internal cross sectional area in square metres, m^2

An example of this formula is as follows;

The volume of water within a pipe will transmit or convey in a given time depending on;

- It's cross sectional area, and
- The speed at which the water is passing through it, ie. Velocity of flow.

The velocity or rate of flow is expressed in metres per second, m/s.

The formula for calculating the quantity of water passing through a pipe is;

$$Q = A \times V$$

Where
Q = Cubic metres of water per second, m/s.
A = Internal cross sectional area in square metres, $m^{2.}$
V = Velocity of flow in metres per second, m/s.

Example;

What is the flow in a Type B copper tube, 50mm nominal size having an internal diameter of 48.36mm, when the velocity is 1.5metres per seconds?

$$Q = A \times V$$
$$= D^2 \times \frac{Pi}{4} \times V$$
$$= 0.04836^2 \times 0.7854 \times 1.5$$
$$= 0.002339 \times 0.7854 \times 1.5$$
$$Q = 0.00276 \text{ cubic metres of water per second}$$

To convert cubic metres of water to litres multiply by 1000.

$$= 0.00276 \times 1000$$
$$= 2.76 \text{ litres per second}$$

Viscosity of Water

Viscosity is that property which determines the amount of water resistance to a shearing force. Viscosity is due primarily to interaction between water molecules.

Viscosity of water will decrease with temperature increase but is not affected appreciably by pressure changes.

Cold water is more viscous than heated water; therefore with cold water a greater pressure drop results when comparing flows of equal velocity through pipes of the same diameter. It may be worth to point out that viscosity only makes a little difference when sizing cold and water heated copper tube for building services.

Generally designers do not consider the viscosity in pipe sizing copper tubes.

Incompressibility of Water

When contained in and conveyed by water supply pipework system water is an incompressible fluid.

This is essentially due to the strong polarity of water molecules, which are extremely resistant to compression.

Pressure Surges and Water Hammer

Pressure surges may occur in a water pipework system when the velocity in a pipe increases from one steady state condition to another.

Starting and stopping a pump and opening and closing a valve or taps in the pipeline can trigger pressure surges and water hammer noises.

Design solutions are to minimize velocity of water flows by selecting pipe diameter to convey flows but with low velocities in the pipes.

Friction Pressure Loss and Flow Velocity

There is direct relationship between flow velocity and frictional loss. The loss of energy or “head” that occurs in pipe flow due to viscous effects generated by the surface of the pipe. Friction loss is considered as a “major loss” and it is not to be confused with “minor loss” which includes energy lost due to obstructions, changes of direction and fittings in a pipeline.

This energy (pressure) drop is dependent on the wall shear stress between the fluid and pipe surface.

The shear stress of a flow is also dependent on whether the flow is turbulent or laminar.

For turbulent flow, the pressure drop is dependent on the roughness of the surface, while in laminar flow; the roughness effects of the wall are negligible.

Given the same internal diameter of a copper tube and increase in flow (l/s) will have a direct increase in lost pressure due to frictional resistance.

Refer:
“Selection and Sizing Copper Tubes for Water Piping Systems.” Barrie Smith

Effects On Water Supply Systems Where High Velocities Flows Are Experienced

Water supply piping systems through which there is high velocity flows are very likely to have the following outcomes.

- Erosion corrosion of the tube internal wall surface.
- Noise generated and emitted through pipe walls.
- Creation of water hammer and associated noises caused by pipe movement against building components.
- Noise, pressure surges at taps and outlets.
- High-pressure loss in the water supply system due to frictional loss.
- Higher than necessary pump pressure to compensate for high-pressure loss in water.
- Supply system losses due to frictional loss. This will lead to inefficiencies in the operating cost.
- Increase frequency and securing of pipe brackets along the pipeline.
- Influence the performance of electronic taps, their operations and safety.

Water Velocity Recommended For Building Services Systems

The plumbing installation standard AS/NZS 3500 series documents list the maximums velocity (3.0 m/s) for water supply systems (Table 12.4).

The standard deals with only the maximum and fails to address best practice velocities for differing water services, differing materials and specific requirements of sensitive tapware associated with either cold and or heated water supplies for specific application.

The plumbing services design must consider all elements of the water supply systems before choosing a design layout, pipe materials, tapware, plant and equipment.

Only then can the designer consider the design velocity applicable to the building type and its function.

Recommended Water Velocities				
Service	Velocity Range m/s.			
	Recommended Design Velocity m/s	Institute of Plumbing Australia Selection and Sizing of Copper Tubes for Water Piping Systems	Australian Standards AS 3500.4 2015	British Standard BS 6700:2006 +A1:2009
Cold Water - Mains pressure water services pipelines	Up to 2.4 Up to 1.6 within Dwelling / Apartment	1.0 to 2.1	Max. 3.0	Max. 3.0
Cold Water - Gravity flow pipelines from upper level storage tanks – Top two floors only	0.1 to 0.4	0.1 to 0.4	Max. 3.0	Max. 3.0
Cold Water - Gravity flow pipelines from upper level storage tanks – below top two floors	1.0 to 2.1	1.0 to 2.1	Max. 3.0	Max. 3.0
Cold Water - Pump suction pipelines	1.2 to 2.1	1.2 to 2.1	Max. 3.0	Max. 3.0
Cold Water - Pump delivery pipelines	1.5 to 2.1	1.5 to 2.1	Max. 3.0	Max. 3.0
Heated water - Flow and return – circulating system	1.0	Not Specified	Max. 1.2	Max. 3.0
Heated water - Non-circulatory systems	2.0	1.0 to 2.1	Max. 3.0	Max. 3.0

Table 12.4
Statement of Available Pressure and Flow

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Water Supply Flow Requirements

The water consumption and flow rate of a building depends on the application (type of building), the location of the building and the amount of water saving devices used.

Factors that may influence water demand; **Source** *WSAA, White and Turner.*

In Australia there are statuary requirements to reduce the amount of water consumed at appliances and outlets within buildings.

Many designers and installers usually ignore these requirements for the purpose of water storage, flow demand and pipe sizing. www.waterrating.gov.au

First and foremost the building services designer must appreciate the users requirements and the type of plumbing fixtures.

These requirements are generally classified into the building types, which include;

- Residential buildings (houses, retirement group homes and apartments).
- Office buildings.
- Shopping centers.
- Hotels.
- Hospitals.
- Schools.
- Warehouses.
- Clubs and Restaurants.
- University Buildings.
- Gymnasiums.
- Supermarkets.

With each building classification there are peak water demands placed on the water supply system.

Generally with apartments and hospitals the peak demand for water is around 6.00am to 9.00am in the morning and around 6.00pm - 7.00pm at evenings.

In hotels the water demand consumptions will fluctuate during the day. In the morning, where most of the guest are taking a shower and all of the service facilities, such as cleaning, cooking and washing commences the highest flow demand is most likely to occur.

Note:
Issues with poor plumbing design are often created where extensions are added to an existing building or a build type is changed. Care needs to be exercised to ensure the existing plumbing system is capable of servicing the new requirements.

13

Chapter Thirteen

Chapter 13 – Heated Water Systems Design

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Heated Water Systems Design

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Heated water consumption is the biggest single factor that effects the energy consumption of buildings and facilities.

Introduction

The heated water consumption is the biggest single factor that effects the energy consumption of buildings and facilities.

Many engineers struggle to appreciate the concept of heated water systems design and their performance. Engineers generally accept the recommendation for the heated water plant capacity, efficiency, make up and pump duty based on the manufacturers specification.

This chapter provides information that will assist designers to challenge those design processes and those manufacturer specifications to achieve the best solutions for a building and their occupants.

Functions And Design Of Heated Water Services System

When designing a heated water services system the role of the engineer is to consider and appreciate the type of building, it functions, energy efficiency, water conservations, water temperature and the occupant's requirements.

As with cold water systems the heated water system is designed to meet the expectations of those who occupy and or use the building. An engineer needs to be aware of the building classification or type and those building objectives, including whether the facility is used for health, age care, disability or education.

Prior to heating plant selection, pipe design and pipe sizing, the following information should be obtained and considered, including *AS/NZS 3500 " Pipes and fittings shall have a maximum allowable operating pressure of at least 1.0 MPa at 60⁰C."* and the following design elements;

- Identify the building class in accordance with the Australian Building Code.
- Consider the function and usage pattern for the heated water demand.
- Ensure that comprehensive details are gathered on the occupancy intended for the building.
- Consider the type of energy available and the potential energy savings.
- The supply temperature range of the heated water supply.
- Understand the proposed heating plant capability.
- Have knowledge of the fixtures and outlets being used and their water efficiencies.
- Examine the building layout and the availability to access pipework.
- Determine the type of material intended to be used for heated water pipework.
- Assess the pipework heat loss and thermal insulation requirements and apply to the region or location of the intended building.

When designing heated water systems the design engineers should never assume there is a typical usage profile or pattern to cover the heated water demand and or services system.

Australian Standards AS/NZS 3500 – Heated Water does not provide designers with details for the selection of the heating plant, pipe material or design, it simply provides the performance requirements meeting the deemed to satisfy provision of those systems being installed.

Design Principles For Heated Water Systems

At the commencement of the design proposal the designer identifies whether there is a specific need to use a particular type of energy, this may be gas or electric incorporating either or both solar and or co-generation boost. Once the energy source is known, the design process is planned linking the cost involved with the energy source and the initial install cost of the plant and equipment to be used. Energy savings and pay back periods are also key elements of the design process.

Heat Source

Heated water systems categories are based on;

- Type of Operation – storage or instantaneous (continuous flow).
- Energy Source – may be solar, gas, air (heat pump) and electricity.

Type of Operation (storage versus instantaneous)

- Storage systems operate by heating and storing water in storage vessels. Some of the energy used by these systems is lost as the heat dissipates from the storage vessel and connecting pipework.
- Instantaneous (continuous flow) systems heat water as it is required and may use or not use a storage vessel. The systems sense when the tap is turned on and it commences to heat the water passing through the heater.
- Typically 1-2 litres of water passes through an instantaneous hot water system as it heats up, creating a short delay in hot water delivery. In larger heated water systems a bank of instantaneous heated are coupled together to provide adequate flow meeting the services demand.

Energy Sources

- Solar water heaters use solar collectors to heat the water in a storage vessel. A solar system with a high STC rating (refer to definition on page 118), will meet the best BASIX (refer to definition on the right) requirements score.
- It may be necessary to ensure adequate storage by providing additional heating "boost" by gas or electric.
- Gas water heaters can be either storage type or instantaneous. High efficiency gas heated water systems with a high star rating will score best in BASIX.
- Air source water heaters are typically referred to as heat pumps, which transfers the heat from the air to the water. This type of system is most appropriate in warmer climate regions. An electric heat pump with high STC rating will also score well with BASIX.
- Electric water heaters can be either storage or instantaneous type directly supplied with electricity to heat the water. Although these are very common in housing applications and are most green-house gas intensive attracting the lower BASIX score.

About BASIX

The Building Sustainability Index (BASIX) aims to deliver equitable, effective water and greenhouse gas reductions across the state. BASIX is one of the strongest sustainable planning measures to be undertaken in Australia.

BASIX and the planning system

An integrated part of the planning system, BASIX is implemented under the Environmental Planning and Assessment Act. BASIX applies to all residential dwelling types and is part of the development application process in NSW.

BASIX assessment

BASIX is assessed online using the BASIX assessment tool. The tool checks elements of a proposed design against sustainability targets.

Outcomes

BASIX reduces water and energy consumption in homes across NSW. These environmental outcomes also provide a long term financial saving for the homeowner – and a valuable contribution to the sustainable future of our communities.

What is an STC?

Small-scale technology certificates, or STCs, are a tradeable commodity attached to eligible installations of renewable energy systems (including solar panels, solar water heaters and heat pumps).

Under the Federal Government's Small-scale Renewable Energy Scheme (SRES), when you install an eligible system, you may claim a set number of these STCs.

This number is based on the amount of electricity in megawatt hours (MWh):

- **Generated** by your small-scale solar panel, wind or hydro system over the course of its lifetime of up to 15 years; or
- **Displaced** by your solar water heater or heat pump over the course of its lifetime of up to 10 years, where one STC equals one megawatt hour (MWh) of electricity generated or displaced.

The number of certificates you can claim may vary depending on your geographic location, what you're installing, whether your installation is eligible for Solar Credits, and/or the size and capacity of the installed system. For example, a 1.5kW solar panel system in Melbourne might be eligible for a minimum 21 STCs, while a solar water heater in Hobart might be eligible for a minimum of 20 STCs.

Solar Credits is a mechanism which increases the number of STCs that can be created for eligible installations of small-scale solar panel (photovoltaic – PV), wind, and hydro systems.

You can calculate the number of STCs claimable by a system by using the calculators on the Clean Energy Regulator website:

- Solar Water Heater STC Calculator.
- Small-scale Generation Unit (small-scale solar panel, wind, and hydro) STC Calculator.

STCs are created in the online REC Registry for correctly installed eligible solar water heaters, heat pumps, and small-scale solar panels, wind, and hydro systems.

Pipework Layout or Design

The pipework design and layout generally follows the building design, pipework access, service ducts based around the use of a central water heating plant or localized heating systems being placed throughout the building. In any case a designer will consider;

- The heated water fixture usage pattern. The diversity or Probable Simultaneous Demand (PSD).
- The storage requirements, what is the size of the heating plant and recovery rate.
- The location of the water heating plant.
- The total length of pipework and associated energy loss in the pipework system.
- The time taken, when the heated water reaches the tap outlet. The water wastage and any stagnation of heated water, minimizing dead legs.
- Requirements for tempering or thermostatic control valve if required.
- Pipe sizes, the flow requirement of the fixture or fixture groups, available pressure and velocity. Consider water efficient tap-ware and pressure losses throughout the pipework system.
- Consider alternative energy, either solar or co-generation.
- Overall energy cost, design cost and system installed cost.
- The piping material choice, flow capacity, frictional loss and energy loss.
- Required temperature.
- Highest temperature within the system and its effect on pipes, fittings and equipment.

Water Temperature

The requirements of the Plumbing Codes AS 3500 Part 4 – Heated Water Services specifies the controlling of water temperatures to plumbing services fixtures and outlets.

The minimum water temperature shall not be less than 60^0C, so as to inhibit the growth of legionella bacteria.

The maximum delivery temperature to sanitary fixtures used for personal hygiene purpose must deliver heated water at a temperature not exceeding,

- 43.5^0C for early childhood centres, primary and secondary schools and nursing homes and similar facilities for the young, aged, sick, or disabled.
- 50^0C in all other buildings, including new houses.
- Other fixtures such as the laundry tub or kitchen sink are not required to have the temperature limited.

Fundamental Of Heated Water Systems

Consumers are often frustrated waiting for heated water to arrive at the tap outlets. Many will turn on the tap and leave the bathroom knowing it may take up to 3-5 minutes for the heated water to reach the tap outlet.

This time delay associated water wastage accounts for thousand of litres of heated water and energy loss that cannot be recovered.

Australian Standard AS/NZS 3500 Part 4 Heated Water Services at this time does not specify the maximum length of dead leg of a heated water piping system.

However it clearly states that the design and installation shall;

- Reduce to a minimum the amount of dead (cold) water drawn off before hot water commences to flow from any tap.
- Be sufficient to give the required flow at all outlets, including branches from non-circulating services.
- Be the shortest practicable route for the main flow heated water pipes and branches to the heated water outlets.
- Be the minimum necessary diameter of the heated water pipes requires to supply the outlet draw off.

To estimate the heated water wasted in a typical home each year you can calculate the litres lost by;

Time delay (min)

$$= \frac{\text{Litres/metres of pipework x Length of pipework}}{\text{Fixture flow rate in litres per min}}$$

As stated whilst there is no requirement on the amount of heated water lost is a system most designers will incorporate a circulating pipework system where the length of dead leg exceeds 6- 8 metres or configure the piping system to limit the time waiting for the heated water to arrive at the outlet to 10-30 seconds.

This may be derived from calculating the contained water in the pipework material, which equates to approximately 0.22 litre in a metre of DN 20mm copper tube x 8 metres = 1.76 total litres.

When comparing to DN15 copper tube the maximum draw off would be 0.093 litres x 8 metres = 0.774 litres.

Note: The amount of water contained in one metre of copper tube as shown in Table 13.1.

Types of Heated Water Pipework Distribution Systems

There are many types and or interpretations of heated water systems pipework layouts, but these are generally a variation/modification or a combination of three distribution arrangements as shown in the following sketches, which may be described as;

- Low-rise building heated water system with the heating plant installed at the bottom of the pipework system.
- Mid to high-rise building heated water system with the heating plant installed at the bottom of the pipework system.
- Mid to high-rise down feed heated water system with the heating plant installed at the top of the pipework system.

Hydraulic engineers may describe the types of heated water circuits as pipework systems being either a;

- One Pipe Reticulated System – Dead Leg (Figure 13.1).
- One Pipe Circulating System – Up Feed (Figure 13.2).
- Primary Flow and Return (Figure 13.3).
- Hot Water Flow and Return System (Figure 13.4).
- Hot Water Flow and Return System (Figure 13.5).
- Two Pipe – Direct Return System (Figure 13.6).
- Two Pipe – Reverse Return System (Figure 13.7).

Tube Diameter Nominal DN	Actual Tube Size in mm	Litres Contained per Metre of Tube
15	12.70	0.093
18	15.88	0.150
20	19.05	0.227
25	25.40	0.414
32	31.75	0.675
40	38.10	0.999
50	50.80	1.837
65	63.50	2.928
80	76.20	4.179
100	101.60	7.595
125	127.00	12.026
150	152.40	17.283
200	203.20	31.146

Table 13.1
Litres of Water in one (1) metre of Copper Tube Length – Type B – AS 1432

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One Pipe Reticulated System – Dead Leg

In this system a single pipe distributes the heated water to the fixtures or tap outlets without any return pipework back to the heating plant. This system is commonly known as the dead-leg or reticulating pipework and is used where the calculated water wastage is limited. The pipe size of the heated water pipework should be of a smaller diameter to reduce heated water becoming cold (Figure 13.1).

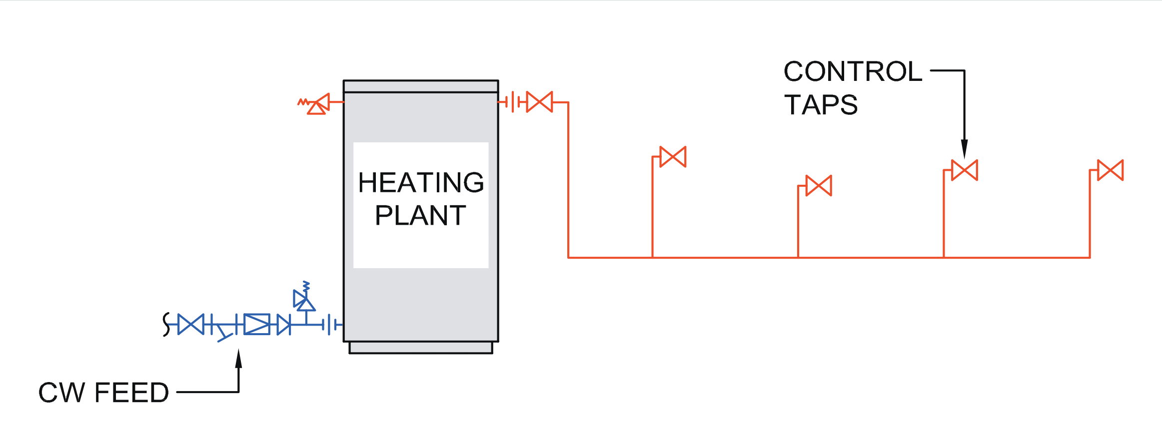

Figure 13.1
One Pipe Reticulated System – Dead Leg

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One Pipe Flow And Return System (Circulating System)

This system of heated water distribution incorporates a pump or pumps set to circulate the heated water throughout the pipework circuit.

The pipework circuit can be sized to minimise temperature loss and limits the amount of water wasted in typical dead-leg systems.

A typical pipework heating circuit with insulation should only loose 3 degrees (maximum 5) around the system circuit.

The flow and return pipework system is mostly used in commercial buildings, high rise apartments where a centralised heating plant is used.

Take-offs to each branch or say apartment can be placed on either the flow and or return pipework.

The circulating pump may be installed on either the flow or return pipework adjacent the heating plant or in some cases at the lower end of the heating pipework circuit (Figure 13.2, Figure 13.3, Figure 13.4, Figure 13.5).

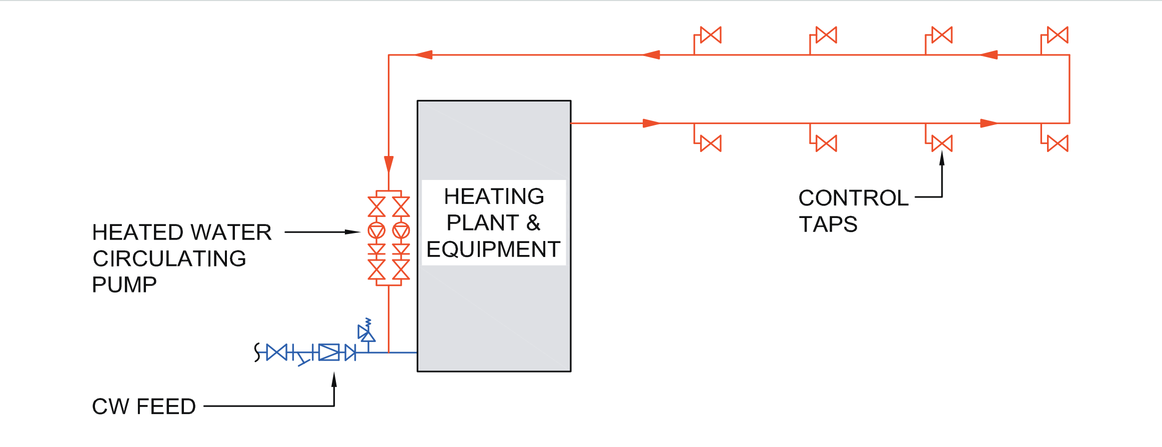

Figure 13.2
One Pipe Circulating System – Up Feed

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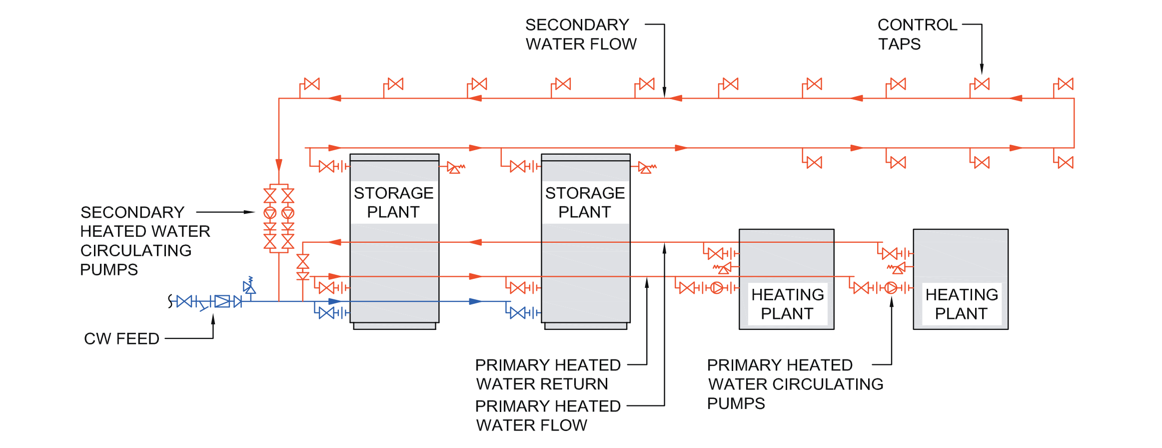

Figure 13.3
Primary Flow and Return

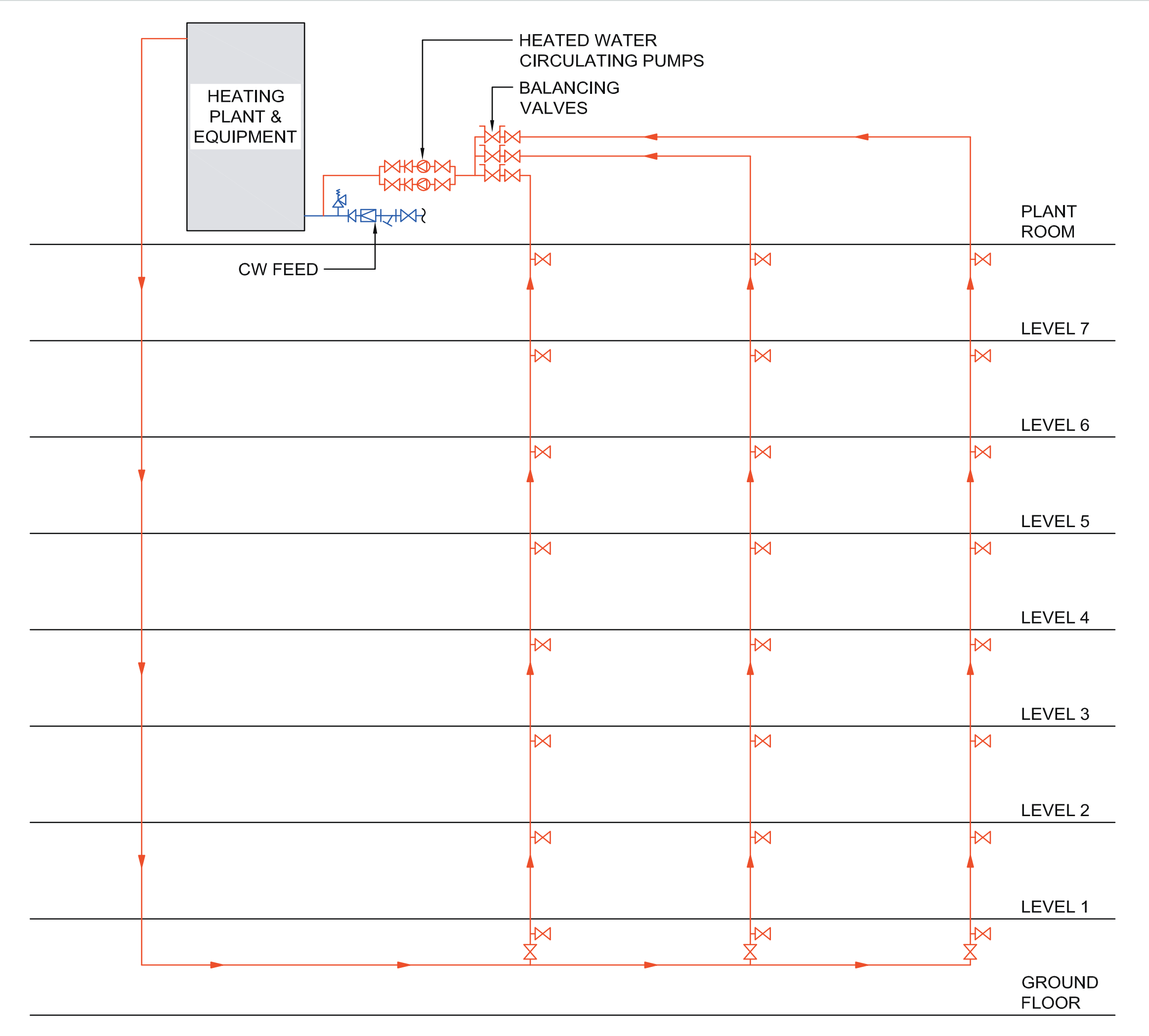

Figure 13.4
Hot Water Flow and Return System

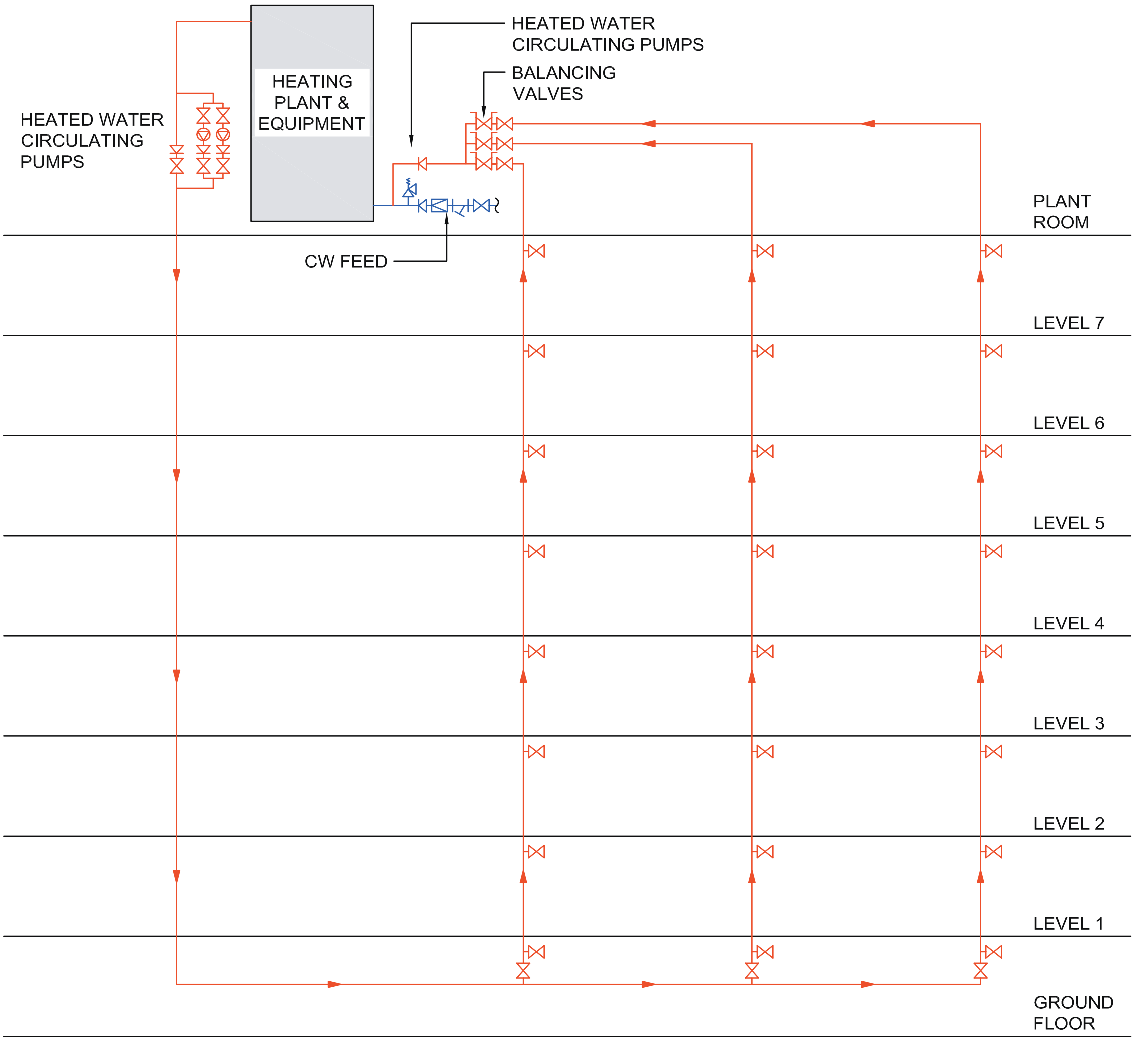

Figure 13.5
Hot Water Flow and Return System

Two Pipe - Direct Return System

A two-pipe water heating system is focused on two main (ring) pipes; one delivers water (the heated supply) and one returns the heated water back to the heating plant (the heated water return).

Additionally to the two mains, each section or extended branch of pipework longer than say 8-10 metres in length, connected to the main (ring/circuit) will also have a supply and return pipework system.

The direct return system runs with branches so that their position on the supply and return pipes correspond, that being the first branch on the supply service is the first on the return, and the last on the supply service is the last branch on the return service pipe (Figure 13.6).

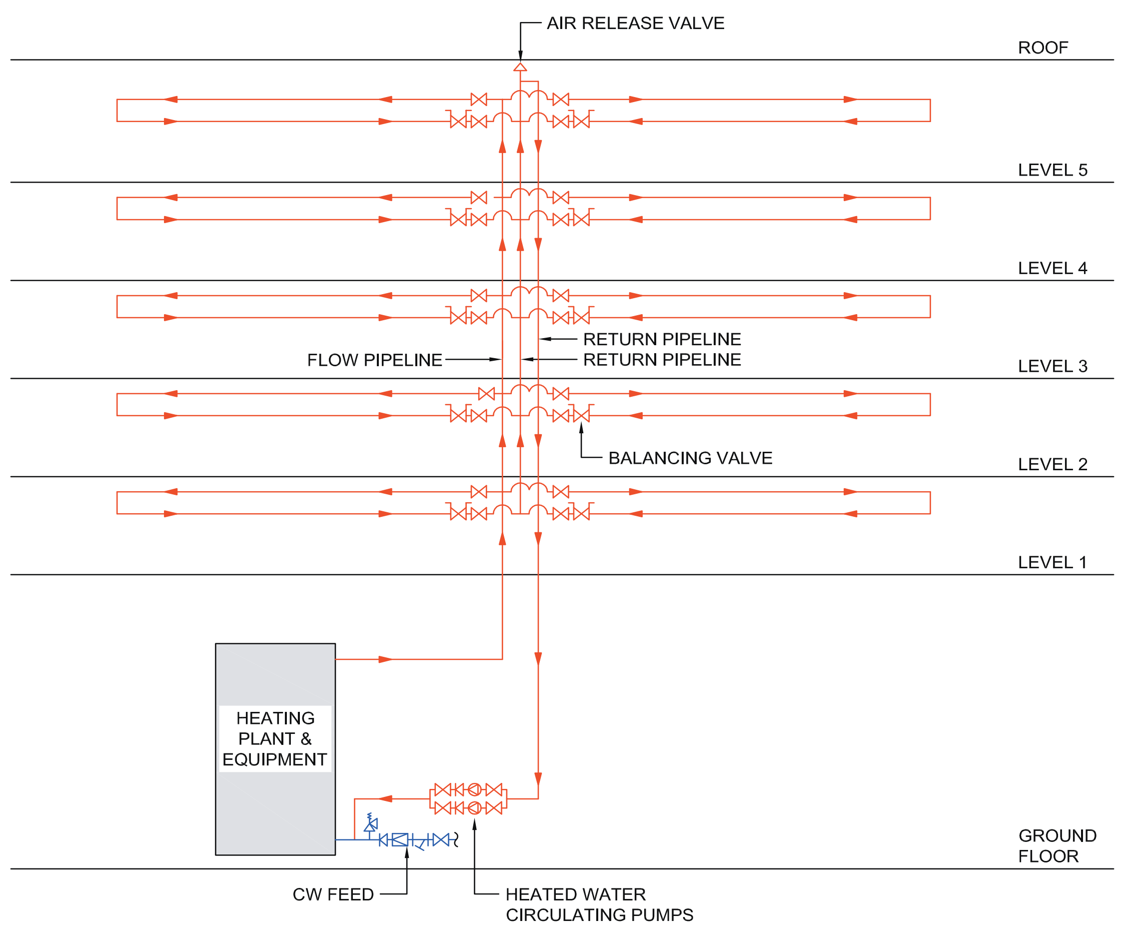

Figure 13.6
Two Pipe - Direct Return System

Two pipe - Reverse Return System

The reverse return piping system is designed to be opposite of the direct return system. Its principle design being the first branch in the supply is installed is the last branch on the main (ring/circuit) and vice-versa.

This is achieved by the layout of the return pipework being set up to be the same length as the supply pipework layout and runs in a circle around the building.

A reverse return system having the supply pipework and the return pipework are the same length throughout the heated water system, creating a more even water flow to all branches (Figure 13.7).

However, unless the system is designed to be self-balancing, balancing valves will still be required to ensure consistent water flow.

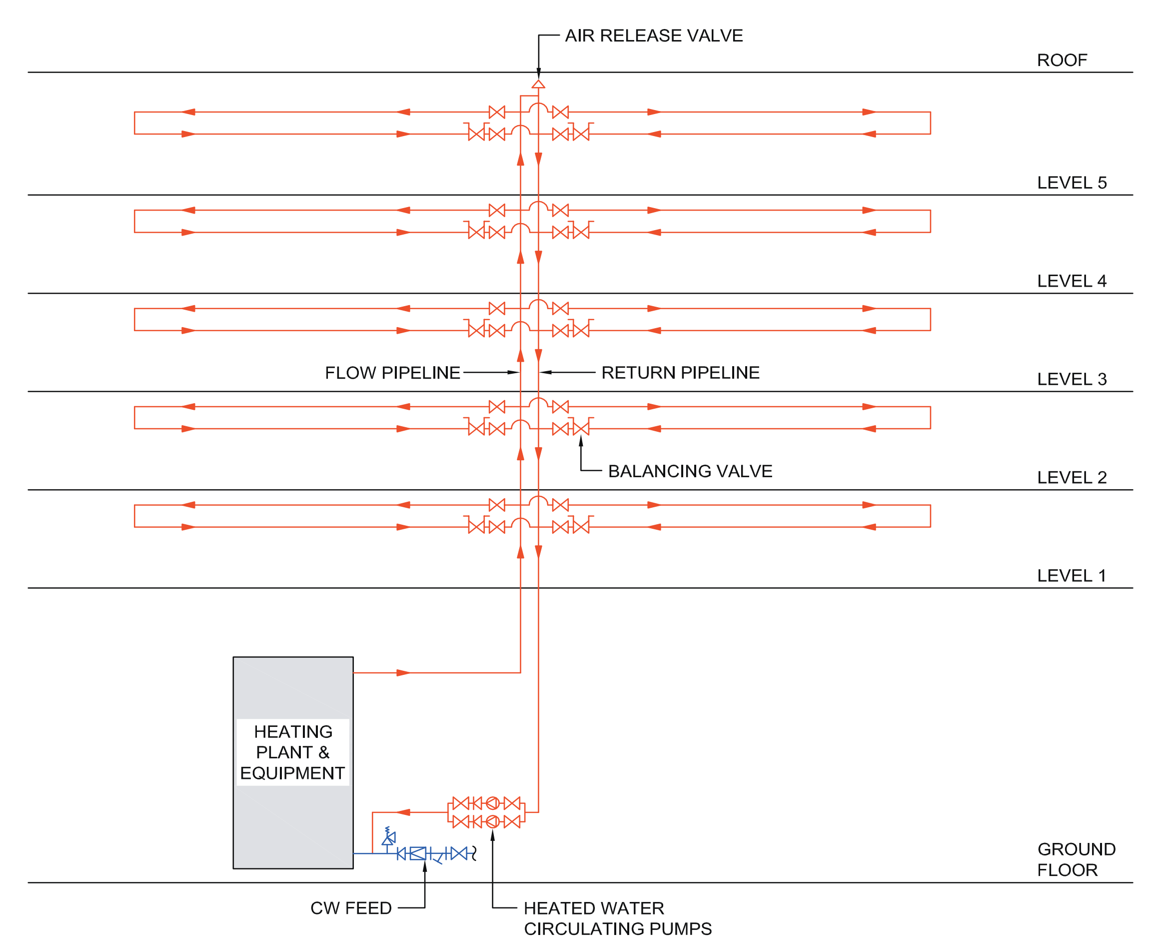

Figure 13.7
Two Pipe - Reverse Return System

Heated Water Circulation

Heated water circulation may be achieved by convection to move the water throughout the pipework, however in modern buildings of complex design it difficult to circulate heated water without the use of circulating pump.

Heated water circulation is moved throughout the pipework by pumps either installed on the return line or as preferred by some designers they may be installed on the flow.

The principle of circulation in both domestic and commercial applications is to draw the cooler temperature water of the piping system and return it to the heating plant for re-heating.

The purpose of circulation is the reduced the time of waiting for desired temperature heated water at the tap outlet.

A circulator pump or pumps must be selected with sufficient design pressure and flow rate for the total system resistance when operational.

If the pump is undersized or is set too low, the flow may be inadequate to meet the design minimum requirement. Incorrectly selected circulating pumps will result in the water heating plant operating with a much higher and fluctuating temperatures than the intended design.

On the other hand, a pump that is larger than required will result in excessive water velocity causing erosion corrosion of the metallic piping, excessive noise as well as unnecessary electricity/energy consumption.

Circulating pumps that are built into the secondary piping system may be placed into the flow and or the return pipework shall be sized in litres per second at a head pressure and after considering the;

- Heat loss measured in m^2 /W/m per metre length derived from the insulation material specifications.
- Differential water temperatures between the flow temperature 65^{0}C and a return temperature of 60^{0}C.
- Ambient winter conditions of say 10 - 15^{0}C. This depends on the climate region in accordance with AS 3500 Part 4
- Calculate the total head loss or pressure drop associated with that friction of water against the pipe internal surface and through the fittings.

Formula:

$$\text{litres (l)} = \frac{\text{kw}}{\text{specific heat in kJ/kg} \times (f1 - f2)}$$

Where:

l = Flow in litres per second circulating pump duty

kW = Thermal rating of the insulation in kw/per metre length

kJ/kg = Specific heat of water being the heat required to raise 1kg 1^{0}C at sea level 4.189kJ/kg (say 4.2)

f1 = The temperature of the heated water flow

f2 = The temperature of the heated water return

Example:

Calculate the circulating pump duty of a DN25 copper tube heated water piping system using insulation material for internal circulating pipe work that must have an R – value of 0.3 (as listed in AS/NZS 3500.4)

- Closed cell polymer insulation at 0.30 R-value is 13mm material thickness, which is estimated at 17.4W/m length
- The different in flow and return ($f_1 - f_2$) heated water temperature is 5^{0}C.
- Specific heat of water is 4.2kJ/kg.

Therefore:

$$\text{Circulating pump duty (l/s)} = \frac{17.4}{4.2 \times 5}$$

Circulating pump duty flow = 0.8 l/s

Balancing Heated Water Systems

Balancing heated water systems have developed over the past few years. Today there are more choices when it comes to balancing flow and return piping systems.

Some of the reasons for selecting and ensuring balancing valves are considered are;

- Increase cost of generating domestic heated water.
- The actual increase of water.
- The reliability of heated water supply temperatures and pressures.
- Control of legionella bacteria.

Advantages of a properly balanced circulation heated water system are;

- A reduction in heated water production cost.
- A reduction in water consumption. Reducing the waiting time for heated water to reach the tap outlet.
- Provide equal temperature throughout the pipework and to outlets.
- Thermal disinfection is provided throughout the total pipework system.
- Reduces the risk of scalding.
- Monitoring and control the heated water temperatures to specific outlets.

Traditional balancing heated water systems used pipe sizing methods in the sixties to eighties which relied on calculation that ensured individual pipe risers were proportional to nominal water consumption to the branch takeoffs.

Today we use sizing methods that compensates for heat losses through the pipes.

Heat losses are calculated, taking into consideration thermal insulation efficiencies of the pipe and the difference in between the ambient temperature and the heated supply water temperature.

The amount of heat losses is based on an assumed range that is acceptable, usually 5^0C-10^0C, depending on the water temperature being transported.

14 Chapter Fourteen

Chapter 14 – Design Guidelines for Selecting Heated Water Plant EN 1057 version

International Copper Association Australia
Copper Alliance

Design Guidelines for Selecting Heated Water Plant

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An appreciation of the building function is critical for a designer before selecting the heating plant.

Introduction

Designing, selecting and sizing the water heating plant for a modern building is as equally complex and misunderstood as the design for the cold water services systems.

Today there are many choices of heating plant available to the designer. The selection will depend on several factors such as:

- The type and layout of the building (e.g. industrial, aged care, residential, office, or health applications).
- The usage pattern.
- The source of energy.
- The location of the plant (indoor or outdoor).
- The initial plant cost budget and the related operating and payback costs.

All of these factors form part of the design decision making process. Energy rebates can also lead to further confusion.

This chapter is intended to provide the designer and installers with those design and operational factors that will assist in the selection process. Before selecting the heating plant system careful consideration of the building function, energy source and cost is required.

The location of the building whether it is situated in either a major city or town, regional and/or remote communities, often makes this choice a little easier.

In many locations around Australia the availability of a network gas supply, solar efficiency and/or off peak electricity are the first and foremost reasons for selecting a particular type of water heating plant.

Regional variations in weather extremes will dictate aspects of plant performance, such as the heat rise required if the incoming water supply temperatures are low in winter. Frost and/or solar conditions will need to be considered for plant location and choice of equipment.

Building function

An appreciation of the building function is critical for a designer before selecting the heating plant. Peak flow rates, the duration of those peak periods and the heated water usage patterns need to be considered before sizing the plant.

A building used for residential housing, a hospital, nursing home or industry premises all have distinctly different water usage patterns, including design flows (demand) and peak usage periods. Those patterns are further discussed in pipe sizing of this manual.

Only when the flows and peak usage patterns are defined can a type of heating plant and energy source be determined.

Typical Heating Equipment

There are multiple types of water heating plant available in the market today, many of which are used in both domestic and commercial applications. The major technology types are:

- Gas fired continuous flow (also referred to as 'instantaneous').
- Gas fired storage.
- Large gas fired boiler products (water heating or modulating product – typically large residential or commercial applications only).
- Electric continuous flow (or 'instantaneous').
- Electric storage.
- Heat pumps.
- Solar water heaters.

There are also combinations of the above technologies, such as continuous flow coupled with storage water vessels to buffer peak demand flow periods.

Products such as heat pumps can be used as either the primary heating source or as a pre-heater for gas or electric products, depending on the location of the project, the demand, and the peak flows. As previously mentioned each project needs to be designed on a case by case basis to ensure the building demand is satisfied. Manufacturers and Australian Standards describe water-heating systems and energy sources as follows:

Types Of Energy - General

There are a variety of energy sources suitable for water heating – some of which are mentioned above. These include electricity, fuels such as Liquefied Petroleum Gas (LPG, often also referred to as propane), Natural Gas, and renewable forms of energy such as solar radiation used for thermal heating (referred to as 'solar thermal' as opposed to solar electric or photovoltaic electricity producing cells).

Electric storage heaters are described under the Minimum Energy Performance Scheme (MEPS) in accordance with the labelling to AS 1056.1 for energy rating as managed by the Australian Green House Office.

Under this scheme electric water heaters are required to demonstrate that they meet the energy efficiency requirements of the standard before being sold within Australia.

Refer www.energyrating.gov.au

As water heating is the biggest energy user in Australian residential buildings (single stand alone dwellings) an electric hot water system typically accounts for more than a third of the energy used in those applications. Because most electricity in Australia is generated from coal-fired power stations, electric hot water systems emit the most greenhouse gas emissions.

That being said, they are still one of the most energy efficient water heating systems available, converting >95% of the energy (electricity) into heat. Gas fired hot water systems, are energy star rated under an Australian Gas Association Scheme (AGA) having performances and methods before labeling in accordance with AG103 MOT.

Refer www.gas.asn.au (star ratings apply for storage water heater products less than 50MJ/hr, and for continuous flow water heater products less than 250MJ/hr.)

Both storage and continuous flow systems are available. Consider the energy rating with the highest number of stars - choose one with a 5 or 6 star rating. Heating energy sources for heating water can be categorised into the following:

Mains Electricity

Standard mains electricity systems are available.

Standard Tariff Electricity

Standard or 'continuous' tariff electricity is the most widely available water heating energy source, in particular within the housing industry. Coal fired electricity as mentioned has a number of disadvantages in that it generates the highest greenhouse gases of all the fuels available in Australia and consequently can be the most expensive form of energy in particular for domestic water heating with resistive element water heaters, with exception to bottled LPG.

Commercial tariff rates for electricity can however be contrastingly low cost as the privatization of generators has introduced significant competition between energy sources.

The advantages of standard or 'continuous' tariff electricity is that it is readily available and the capital outlay for the initial supply, plant and heating equipment is relatively low when compared to other forms of energy and equipment.

When used for electric continuous flow units or storage water heaters, these systems can be expensive to run, and should only be used when the client's electricity tariff has been confirmed and other options such as a gas supply are not suitable. Alternatively, if electricity is the only available energy source, consider using pre-heater options such as solar or heat pump water heating.

Electric heat pumps can also be utilized as the primary source of hot water supply, particularly in climates where the minimum ambient temperatures in winter are >5^{0}C. The cost benefits to the client can be considerable vs. resistive element water heaters or bottled LPG gas water heaters.

Off Peak Electricity

Off peak electricity offers many advantages over standard tariff in that electricity is offered at cheaper tariff rates.

However, one must remember that these cheaper tariffs are only offered at specific times of the day for limited periods.

There are generally two off peak periods in Australia:

- Off peak 1: generally 22:00hrs to 07:00hrs.
- Off peak 2: available up to 16 hours per day in the off peak and shoulder periods such as 09:00hrs to 14:00hrs, and at times overnight.

Having a running cost similar to that of natural gas an off peak tariff can only be used in storage heated water systems, usually having a capacity greater than 160 litres. Water is heated overnight or during shoulder periods to provide adequate hot water during the day. Twin element units can operate with a 24-hour continuous tariff boost (if hot water runs out, water is reheated automatically on the standard tariff).

Solar

A solar hot water system, which requires an additional capital investment of $3000 - $5500 for a house depending on the number of solar collectors and the tank capacity, will significantly reduce the running costs versus a conventional electric or gas hot water system.

The payback for these domestic and commercial systems can be further enhanced with Small Scale Technology Certificate rebates or STCs (formerly Renewable Energy Certicates or RECs) which are traded by energy providers in exchange for the greenhouse gas emissions saved in producing that electricity that otherwise would have been required.

The energy costs for a commercial building vary widely depending on the application, the hot water load, the booster energy source, and the availability of roof area for the solar thermal collectors.

State schemes such as NSW BASIX require apartment buildings for example to be energy efficient and the use of solar thermal is a significant contributor to those targets. The ideal payback period for the additional capitol cost in energy savings is approximately 5-10 years. Depending on the solar region, approximately 65-80% of your hot water will be heated relatively free of charge.

All solar systems come with gas, off-peak electric or solid fuel booster to supply hot water during periods of low solar radiation. Collector panels are located on the roof, with a storage tank either on the roof or at ground level. Solar hot water systems have a low impact on the environment.

All piping used for the conveyance of heated water to or from the collector to the container shall be of a type, under the likely maximum temperature and pressure conditions of use, not inferior to copper pipe.

Heat Pump

Highly efficient form of water heating which uses around 70% less electricity than other electric forms of heating. When used in conjunction with a timer and the off-peak tariff, running costs are even lower.
Heat is extracted from the atmosphere using a refrigerant gas and a compressor (much the same way as heat is extracted from your refrigerator) and used to heat water stored in a tank.
Domestic style heat pump systems have very few limitations; heat pumps are suitable for operation in most weather conditions. The common type of heat pump is capable of maintaining a water temperature at 60°C or greater.

There are two main types of heat pump systems. The first works as an air source unit, which is integral to the water storage vessel incorporating a fan to force air over the evaporator to collect the ambient energy from the surrounding air before transferring it to the refrigerant.

A heat exchanger in the form of either a plate heat exchanger or a coil in the storage vessel then passes that refrigerant past the water and the heat is rejected to the water.
The second type is a solar boosted heat pump, in which the air warms an evaporator through which a refrigerant is piped. The heat rejected from the refrigeration cycle is again discharged via a coil in the storage vessel to the water.

Types Of Domestic Commercially Available Heated Water Systems.

There are a variety of domestic and commercial water heating systems on the market within Australia. Generally these systems use the energy sources outlined in this chapter, however there are many combinations of such systems and energy sources available to designers and installers. Project designers evaluate the building, its function and available energy source before committing to a specific type of heated water system, plant and equipment.

In most cases the designer will consult the manufacturers and distributors before making a final decision on the heating plant configurations and piping layout.

It is recommended that those manufacturers form part of the hydraulic/plumbing design team. The heated water demand, design and calculations for the building type and function are covered in Chapter 13.

Types Of Domestic And Commercial Heated Water Systems (Typical)

Domestic Heating

Electric storage, capacities of 25 litres up 80 litres (Figure 14.1)

- Mains pressure, continuous delivery or multiple outlets.
- Ideal for 1-2 persons.
- No off-peak tariff available.
- Limited demand, where space is not available, one-bedroom apartment, remote kitchen sinks, commercial applications such as cafes and utilities.
- Commercial 50 litre models with multiple elements and larger fittings are available for larger hot water loads.
- Small and compact.

Electric storage, capacities of 125 litres up to 400 litres (Figure 14.1)

- Mains pressure, ideal for simultaneous flow within a building.
- Off peak tariff for domestic applications only.
- Available in both single and twin elements for domestic applications, and up to 6 elements in 300 litre capacities for commercial applications.
- Indoor and outdoor application.
- Ideal for large houses and apartments or commercial applications where gas is not feasible

Figure 14.1
Electrical storage heated water systems - domestic

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Electric continuous flow – instantaneous (Figure 14.2)

Electric mains pressure instantaneous hot water systems are available for applications where small flow heated water is required. The units are low flow demand usually installed at point of use or close by the group fixtures. The instantaneous units are mostly 3 phase with 415V electric.

The instantaneous water heaters today are available in a number of sizes up to 27litres per minute to suit an apartment with two bathrooms.

Instantaneous Water Heaters incl:

- Maximum hot water output temperature 50^{0}C.
- No Tempering Valve Needed (approved to AS 3498).
- Electronically controlled.
- The three phase water heater saves power due to the fact that no water is stored.
- Point of use installation.

Figure 14.2
Electric continuous flow – instantaneous – domestic

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Gas storage, capacities 90 litres up to 170 litres, delivery up to 360 litres per hour (Figure 14.3)

- Mains pressure, ideal for simultaneous flow within a building, typically domestic applications only for these capacities.
- 25 – 40MJ/hr pilot light and electronic ignition.
- Indoor and outdoor locations.
- Ideal for large houses and apartments.

Figure 14.3
Gas storage heated water systems – domestic and commercial

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Large gas fired boiler products (water heating or modulating product) (Figure 14.4)

- Typically used in commercial water heating applications, and large residential/ commercial space heating applications.
- Products as Raypak provide efficiencies of >80%.
- Available for both natural and LPG energy sources.
- Coupled with storage vessels these units provide large volumes of hot water for peak period buffer.
- Indoor or outdoor.

Figure 14.4
Large gas fired boiler – commercial

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Gas continuous flow – (also referred to as Instantaneous) (Figure 14.5)

- Flow demand for 12 -27 litres for individual units, and up to 28,000 litres per hour for commercial applications when manifolded together.
- Excellent energy rating of greater than 6 stars for individual heaters less than 250MJ/h.
- Up to 82^{0}C for commercial applications such as restaurants and kitchens.
- Also available with factory preset temperatures limited to 50^{0}C to the outlet.
- Solar connection available.
- Suitable for storage tank connection to buffer peak demands.
- Energy source LPG or Natural Gas.
- Indoor and outdoor locations.

Figure 14.5
Gas continuous flow – commercial

Solar (Figure 14.6)

- Tank capacities from 160 – 400 litres for domestic applications, and up to 5,000 litre tanks for commercial applications.
- In tank electric boosted or inline gas boosted.
- Collectors range from 1 – 4 collectors for domestic applications and unlimited collector array sizes for commercial applications.
- Ground mounted tank ‘pumped systems’.
- Roof mounted tank ‘thermosiphon systems’ (no pump required).
- Collector types range in efficiency based on installation location climate and hot water demand.

Figure 14.6
Solar panel installation
– domestic and commercial

Heat pump (Figure 14.7)

- Off peak or continuous tariff options for domestic applications.
- Energy efficient with commercial models having a Coefficient of Performance up to 4:1.
- Eligible for rebates for domestic applications only.
- Use the same electrical and plumbing connections.
- Install outdoor either on ground or on concrete roofs.

Figure 14.7
Heat pump
– domestic and commercial

Speak to the manufacturers to discuss your specific project, and always consider a range of heating technologies before selecting a particular system.

15

Chapter Fifteen

Chapter 15 – Warm Water Systems

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Warm Water Systems

The temperatures set to minimize the risk of scalding are outlined in the Australian Standards.

Introduction

This chapter outlines the general requirements for warm water systems and provides helpful information to designers and installers in understanding different types of warm water systems and their functions.

Designing a warm water system to all relevant standards and regulatory requirements for each type of system requires assistance from the manufacture to understand the limitations and maintenance requirements.

Warm water systems have been developed to address the potential for risk associated with scalding when using sanitary fixtures.

The sanitary fixtures generally associated with the warm water include showers, baths, basins and bidets.

Temperature limits have been set by regulatory authorities and are described in AS/NZS 3500 to provide an industry standard. The temperatures may vary depending on the usage and building classification. At greatest risk from scalding are children, the aged, the sick and people with disabilities, particularly those in institutional care.

The temperatures settings are set to minimize the risk of scalding are outlined in the Australian Standards. The following extract from AS/NZS 3500.4, *"sanitary fixtures delivering temperatures and minimum requirements"*.

All new heated water installations shall deliver heated water not exceeding –

a 45⁰C at the outlet of sanitary fixtures used primarily for personal hygiene purposes for the aged, the sick, children or people with disabilities in healthcare and aged care buildings, early childhood centers, primary and secondary schools and nursing homes or similar facilities for the aged, the sick, children or people with disabilities; and

b 50⁰C at the outlet of sanitary fixtures used primarily for personal hygiene purposes for all other situations.

Delivery temperatures are also regulated but not limited to the states and territories health departments and user requirements (Table 15.1).

The designer shall confirm the required temperatures with the all regulatory authorities and facility managers to ensure that the correct temperatures are provided to required fixtures.

As an example state health department NSW Health have issued policies directives, which set out their required set temperatures for range of building/facility types. Policy Directive, *Water – Requirements for the Provision of Cold and Heated water* list the following set temperatures:

Warm Water Temperatures for Patient Use		
Patient Classification	**Allowable Range at Outlet**	**Safety Cut Off Temperature Whenever The Cold Water Fails**
Adult	**40.5⁰C to 43.5⁰C**	**46⁰C**
Children & neonates	**38.0⁰C to 40.5⁰C**	**43.5⁰C**

Table 15.1
Warm Water Temperatures for Patient Use

The designer must be aware that, not all warm water systems are approved for use in all applications. The designer must confirm that the warm water system that is intended has been approved for the application.

For example, a tempering valve cannot be used for supplying water temperature at 45^{0}C in healthcare, aged care buildings, early childhood centers, primary and secondary schools and nursing homes or similar facilities for the aged, the sick, children or people with disabilities in substitute for thermostatic mixing valves (TMV's).

Example: A shopping centre with a disabled access utility room will be required to provide warm water at a maximum of 45^{0}C incorporating a thermostatic mixing valve.

There are four main warm water systems that are approved for use in warm water services. These systems control the water temperature in a number of different ways. The four warm water systems are:

Tempering Valve

Tempering valves operate when hot and cold water is mixed as it passes through the valve and is discharged at the required temperature.

Tempering valves incorporate a temperature sensitive element, which expands, and contracts depending on the temperature of the water flowing across it to maintain a set temperature.

Tempering valves have a thermal shut-off in case of any disruptions to the cold water supply. This safety feature prevents scalding and/or thermal shock.

Figure 15.1
Tempering Valves in Cabinet

Tempering valves shall be manufactured to AS/NZS 4032.2 and installed in accordance with AS 3500.4. Tempering valves have an accuracy of +/- 3^{0}C from the set temperature. Tempering valves are usually installed in single occupancy buildings, apartments or houses (Figure15.1 and Figure 15.3).

Thermostatic Mixing Valve

Thermostatic mixing valves are similar to tempering valves. Hot and cold water is mixed as it passes through the valve and is discharged at the required temperature. Unlike tempering valves, thermostatic mixing valves are much more reliable and accurate providing fail safe in case of any disruptions in either the cold or hot water supply. This safety feature prevents scalding and/or thermal shock.

Thermostatic mixing valves shall be manufactured to AS 4032.1 and installed in accordance with AS/NZS 3500.4. Thermostatic mixing valves have an accuracy of +/- 2^{0}C from the set temperature. There are also centralised warm water systems incorporating thermostatic mixing valves with the addition of an ultra violet sterilizer to maintain disinfection of the circulating warm water and piping system (Figure 15.2 and Figure 15.3).

Figure 15.2
Thermostatic Mixing Valve in Cabinet

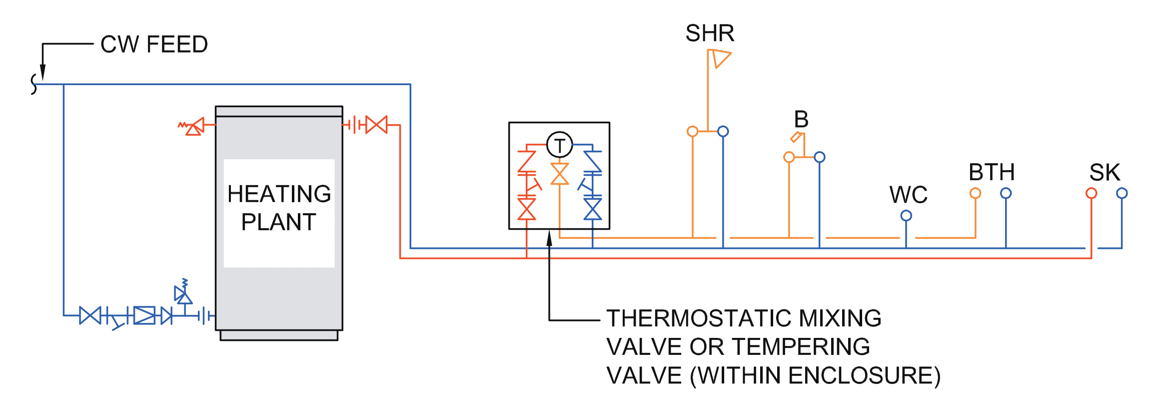

Figure 15.3
Thermostatic Mixing Valve or Tempering Valve (within enclosure)

Centralised Warm Water System

A centralised warm water system generally operates as a boiler or bank of storage water heaters, providing a primary heated water circulation system (Figure 15.4).

The primary heated water is blended; a temperature sensor monitors the warm water temperature and the valve arrangement allowing the cold water to be diverted into the system to lower the water temperature. The warm water is sterilsed by an ultraviolet sterilser located within the warm water circulation system.

The designer should confirm that the proposed centralised warm water system has all relevant approvals for the purpose that it is being installed.

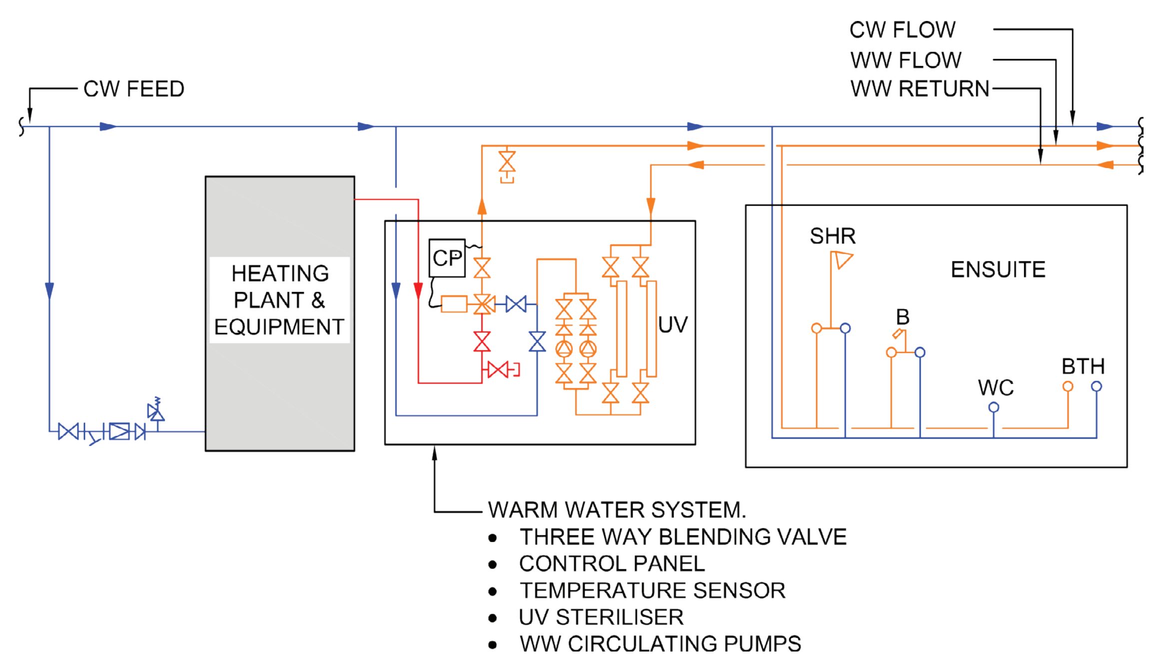

Figure 15.4
Centralised Warm Water System Incorporating a TMV and UV System

Digital Monitored System

A digitally monitored warm water system is generally associated with continuous flow hot water heaters.

The continuous flow hot water heaters monitor by an in-built sensor limits the outlet temperature flow. The temperature of the warm water is controlled by, the management of the gas burner heating in the heat exchanger.

There are also centralised warm water systems based on digital monitored systems with the addition of an ultra violet steriliser to maintain disinfection of the circulating warm water.

Warm Water System Risks

There are a number of risks associated with warm water systems where the range in temperatures is between 20⁰C and 55⁰C. The designer must be aware of all the risks associated with warm water systems before choosing a warm water system design.

The risks associated with warm water systems include but not limited to the following:

- Legionella bacteria.
- System failure.

These risks are managed through design and routine maintenance.

Legionella bacteria that is likely within a warm water system can be managed by a number of methods which may include the following:

- Routine chlorination or thermal disinfection.
- Ultra violet sterilization.
- Routine water sampling and testing for legionella bacteria.
- Routine temperature monitoring and recording of plant, equipment, fittings, fixtures and pipelines.
- Reducing the length of pipelines (dead legs) from the heat source or main circulating pipeline.
- Routine flushing of the dead legs supplying fixtures with minimal use.
- Removing any redundant branch pipelines that are not returned back to the main pipeline. This includes the branch tee.
- Routine flushing and disinfection of fittings as legionella bacteria can be found in shower roses, taps and spouts etc.
- Removal of biofilms, sediments, sludge, solids, scale, corrosion and microorganisms that provide a favorable environment for legionella growth.

System failures are managed by a number of methods, which may include the following:

- Routine monitoring and recording of plant, equipment, fittings, fixtures and pipelines.
- Routine temperature monitoring and recording of plant, equipment, fittings, fixtures and pipelines.
- Routine maintenance of plant, equipment, fittings, fixtures and pipelines.
- Replacement of end of life plant, equipment, fittings, fixtures and pipelines.

Warm Water Installation And Maintenance

This chapter also provides some practical advice and information for use by designers and installers to ensure that manufactured warm water systems are constructed, operated and maintained to minimise the risk of legionella outbreaks. Please refer to AS/NZS 3666.1 and AS/NZS 3666.2 for the full requirements.

In general, the key points of reducing the risk associated with warm water supplies may include:

- Manufactured water systems should be manufactured, installed, maintained and operated in a manner that prevents the transmission of disease organisms to persons.
- Selected materials of the system may have different limitations and the design/installer must know these to be able to tailor the routine maintenance to suit the limitation of the system.
- Regular maintenance.
- High risk manufactured warm water systems must be inspected as part of routine maintenance.
- The temperature of stored hot water within heaters must be maintained at above 60⁰C.

16

Chapter Sixteen

Chapter 16 – Pumps

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Pumps

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Pumps can be classified into two main classes – centrifugal pumps or positive-displacement pumps.

Introduction To Pump Boosting

The requirements for cold water boosting is increasing today given the water supply agencies are reducing the available pressure to buildings to manage water losses and increase pipe life. Buildings are being constructed much taller and are spreading over a larger footprint than ever before.

The designer/engineer in determining the appropriate pump sets and ancillary devices must consider the total design criteria, and the type of buildings e.g. residential, commercial and industrial developments primarily determines the water system requirements.

These water systems include drinking water, domestic heated water, rainwater, fire protection and mechanical services.

Pumps have a very important role and function within buildings:

- In-line pressure booster stations used whenever the city water pressure is not sufficient for supplying a building.
- Domestic heated water circulation pumps ensuring flow of heat water is always available at each tap or outlet.
- Mechanical services heating water circulating pumps to provide hot water to radiators and fan-coil units for building heating systems.
- Wastewater lifting pumps are required when wastewater or sewage comes from below the level of the connecting sewer or drain.
- Pumps in pools, fountains or aquariums.
- Pumps for fire-fighting applications.
- Rainwater reuse systems for toilet flushing, cleaning and irrigation.

In broad terms, pumps can be classified into two main classes – centrifugal pumps or positive-displacement pumps. Since the vast majority of pumps used in building services are centrifugal pumps, we will focus our explanations on the design and selection of centrifugal pumps to suit these systems.

Pump Terminology

The following terminology is commonly used in relation to pumps used for cold water supply (Figure 16.1):

- **NPSH** – *Nett positive suction head* – total head at pump suction branch over and above the vapour pressure of the liquid being pumped.

- **NPSHr** – *NPSH required* – is a function of the pump design and is the lowest value of NPSH at which the pump can be guaranteed to operate without significant cavitation.

  There is no absolute criterion for determining what this minimum allowable NPSH should be, but pump manufacturers normally select an arbitrary drop in total dynamic head (differential head) of 3% as the normal value for determining NPSHr.

- **NPSHa** – *NPSH available* – is a function of the system in which the pump operates and is equal to the absolute pressure head on the liquid surface plus the static liquid level above the pump centreline (negative for a suction lift) minus the absolute liquid vapour pressure head at pumping temperature minus the suction friction head losses.

Cavitation – Process in which small bubbles are formed and implode violently; occurs when NPSHa < NPSHr.

Density (specific weight of a fluid) – Weight per unit volume, often expressed as pounds per cubic foot or grams per cubic centimeter.

Flooded Suction – Liquid flows to pump inlet from an elevated source by means of gravity.

Flow – A measure of the liquid volume capacity of a pump. Given in gallons per minute (gpm), litres per second (l/s), and cubic metres per hour (m^2/h).

Head – A measure of pressure, expressed in metres for centrifugal pumps. Indicates the height of a column of water being moved by the pump (without friction losses).

Pressure – The force exerted on the walls of a tank, pipe, etc. by a liquid. Normally measured in pounds per square inch (psi) or kilopascals (kpa).

Prime – Charge of liquid required to begin pumping action when liquid source is lower than pump. Held in pump by a foot valve on the intake line or by a valve or chamber within the pump.

Self/Dry Priming – Pumps that draw liquid up from below pump inlet (suction lift), as opposed to pumps requiring flooded suction.

Specific Gravity – The ratio of the weight of a given volume of liquid to pure water. Pumping heavy liquids (specific gravity greater than 1.0) will require more drive kilowatts.

Static Discharge Head – Maximum vertical distance (in metres) from pump to point of discharge with no flow.

Total Head – Sum of discharge head, suction lift, and friction loss.

Viscosity – The "thickness" of a liquid or its ability to flow. Most liquids decrease in viscosity and flow more easily as they get warmer.

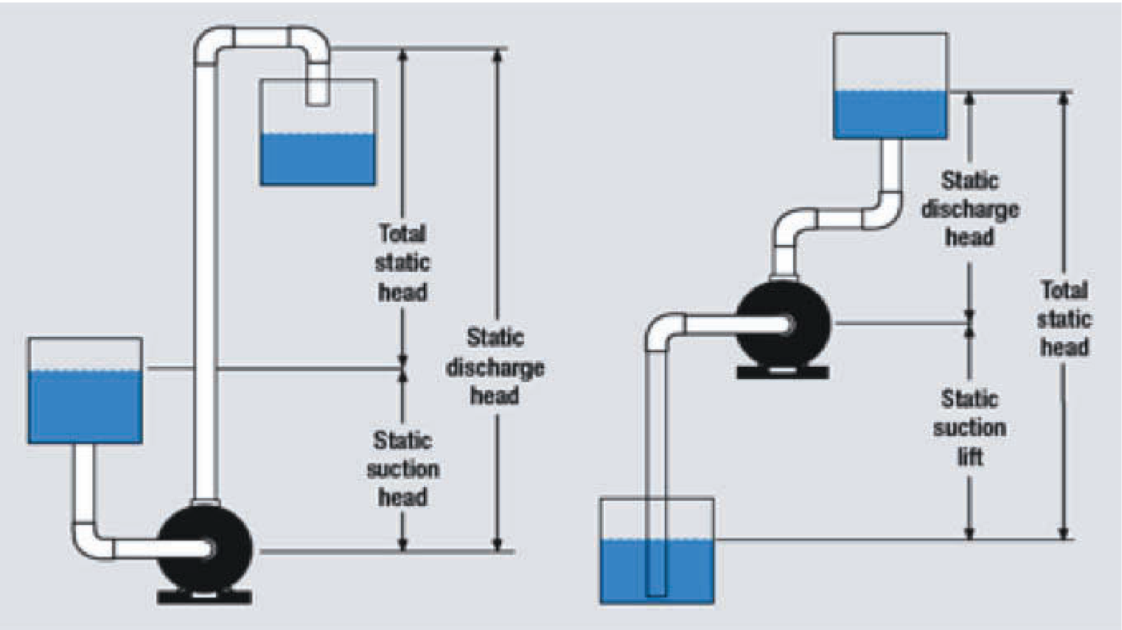

Figure 16.1
Typical Cold Water Pumping

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Centrifugal Pumps – Principle Of Operation

Centrifugal pumps are built on a simple principle. Liquid is led to the impeller hub and by means of the centrifugal force, it is flung towards the periphery of the impellers.

The construction is fairly inexpensive, robust and simple and its high speed makes it possible to connect the pump directly to an electric motor. The centrifugal pump provides a steady liquid flow, and it can easily be throttled without causing any damage to the pump. If a pressure difference occurs in the system while the centrifugal pump is not running, liquid can still pass through it due to its open design.

Types Of Centrifugal Pumps

Centrifugal pumps can be classified in various ways as follows (Figure 16.2, Figure 16.3, Figure 16.4, Figure 16.5, Figure 16.6):

- The relative position of the inlet and the outlet pipework – pumps may be end-suction, with inlet and outlet pipes at right angles to each other, or they may be inline.
- The number of stages - depending on the number of impellers in the pump, a centrifugal pump can be either a single-stage pump or a multistage pump.
- The position of the pump shaft - single-stage and multistage pumps come with horizontal or vertical pump shafts. These pumps are normally designated horizontal or vertical pumps.
- The way the motor is coupled to the pump – pumps may be long-coupled with pump and motor mounted on a baseplate with a flexible coupling joining the shafts, or the motor may be bolted onto the pump to form a close-coupled unit.

Figure 16.3
Horizontal Multistage Centrifugal Pump

Figure 16.4
Single Stage End Suction Centrifugal Pump (Horizontal Mounted)

Figure 16.5
Typical Vertical In-Line Pump

Figure 16.2
Vertical Multistage Centrifugal Pump

Figure 16.6
Typical Heating Water Circulating Pump

Pump Specifications and Technical Data

The information provided with this copper Hydraulic Services Design Guide and pumps is for general purpose use and explanation only.

To obtain a comprehensive user guide for the specifically selected/designed systems pumps, refer to the manufacturers handbooks.

Pump Performance

We will now look briefly at the basic characteristics of pump performance curves.

The performance curves for a centrifugal pump are shown in Figure 16.7 indicating the head (delivery head), power consumption, efficiency and NPSH are shown as a function of the flow.

In general, pump curves are designed according to ISO 9906, which specifies the tolerances of the curves:

• Flow	Q +/- 9%
• Head	H +/-7%
• Power consumption	P +9%
• Efficiency	η -7%

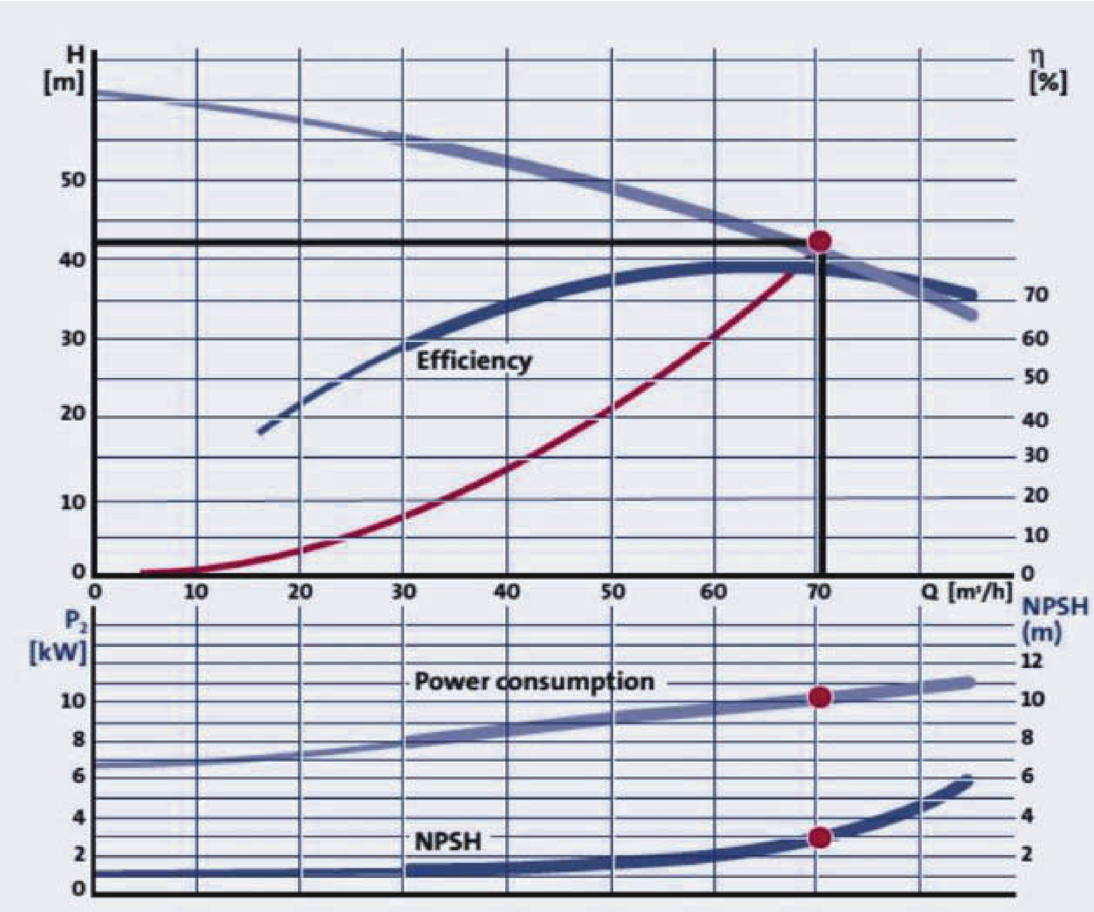

Figure 16.7
Typical Performance Curve for a Centrifugal Pump Head, Power Consumption, Efficiency and NPSH

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Head - the QH-curve

The QH-curve shows the head at which the pump is able to deliver water at a given flow. Head is measured in meters of liquid column [mLC] - normally the unit meter [m] is applied (Figure 16.8).

The advantage of using the unit [m] as the unit of measurement for a pump's head is that the QH-curve, is not affected by the type of liquid the pump has to handle, but for applications involving water, head is often expressed in kPa.

For water @ 20⁰C, 1m head = 9.8kPa. For practical purposes a factor of 10 is useful – i.e. 1m head = 10kPa.

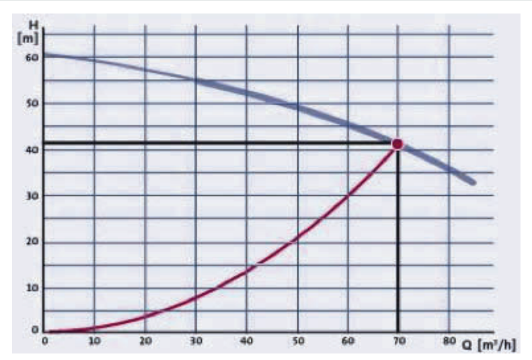

Figure 16.8
QH-Curve For A Centrifugal Pump

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Power Consumption - the P_2-curve

The relation between the power consumption of the pump and the flow is shown below. The P_2-curve of most centrifugal pumps is similar to the one in where the P_2 value increases when the flow increases (Figure 16.9).

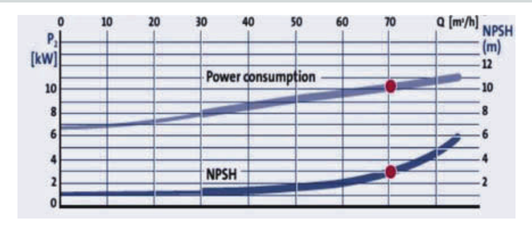

Figure 16.9
Power Consumption - The P_2-curve

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Efficiency - the η-curve

The efficiency is the relation between the supplied power and the utilised amount of power (Figure 16.10).

In the world of pumps, the efficiency η_P is the relation between the power, which the pump delivers to the water and the power input to the shaft.

For water at 20⁰C and with Q measured in m³/h and H in m, the hydraulic power can be calculated as:

$$P_H = 9.8 \times Q \times H \text{ (watts)}$$

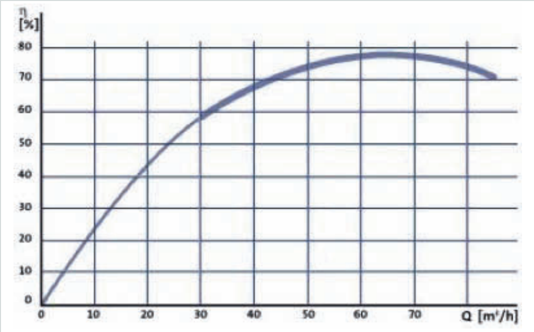

Figure 16.10
Efficiency Curve Of A Typical Centrifugal Pump

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As it appears from the efficiency curve, the efficiency depends on the duty point of the pump.

Therefore, it is important to select a pump, which, as well as fitting the flow requirements, is working in the most efficient flow area.

The duty at which the pump is most efficient is known as the Best Efficiency Point – often called the BEP.

In addition to this area of best efficiency being the area of lowest power consumption for the required duty, it is also the area of minimum mechanical stress on the pump, as the forces in the pumps are best balanced in this area.

This means that seals and bearings will last longer, reducing the cost of maintenance.

NPSH-curve (Net Positive Suction Head)

The NPSH-value of a pump – generally designated as NPSHR (NPSH required) - is the minimum ***absolute*** pressure that has to be present at the suction side of the pump to avoid cavitation. The NPSHR-value is measured in metres and depends on the flow - when the flow increases, the NPSHR-value increases as well (Figure 16.11).

For any flow rate in a given system we can calculate the NPSH Available – or NPSHA – which is a function of;

- Atmospheric pressure.
- Fluid vapour pressure – which is dependent on the fluid itself and its temperature.
- Suction lift, if any.
- Resistance in the suction line.

The NPSHR of a pump at a duty point needs to be less than the NPSHA of the system at that point to avoid cavitation problems. Usually a margin of at least 0.5m is required between NPSHA and NPSHR.

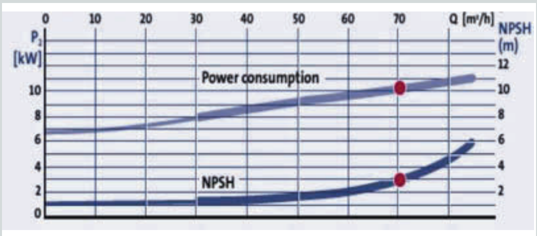

Figure 16.11
NPSH-curve (Net Positive Suction Head)

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Pump Performance Requirements

To select a pump for a particular building system, two major parameters have to be established first – the flow rate required, and the pump head, or pressure required.

The flow rate will be determined by:

- For water supply pumps – by the calculated demand on the system.
- For circulation pumps in heating systems – by the heat load to be served.
- For circulation systems for domestic heated water – by the heat loss of the circulation main.

Domestic heated water is interesting, and it needs to be understood that the purpose of a pump in this service is simply to keep domestic heated water circulating so that hot water is available at any draw-off point at any time. The flow rate is therefore governed by the heat loss of the circulation main.

System Characteristic Curves

A system characteristic curve, or system curve, describes the relationship between the flow, Q, through a given system and the head, H, of that system for that flow.

There are two basic types of systems – closed systems and open systems,

- A closed system is commonly found in mechanical systems and primary heated water circulation systems where boilers and storage tanks are separate. A closed loop where the fluid is circulated through a pipework loop, which will usually include appliances such as boilers, chillers, fan-coil units, radiators, filters, control valves, etc.

The head required for a circulation pump in a closed system is determined from the resistance or friction losses in the circuit – static height is irrelevant, as we are dealing with a closed circulation circuit.

- An open system is like a water supply system, where the pump is transferring the fluid from one point to discharge at another point. The head required for an open system is determined by the resistance or friction losses in the system, plus the static head arising from the height to the discharge point, plus the residual pressure required at the outlet.

System characteristic curves can be plotted on a graph, showing the variation of flow, Q with head, H. if it is plotted on the same set of coordinates as the Q-H curve of a pump, then the intersection of the pump curve and the system curve will show the operating point of that pump is that system (Figure 16.12).

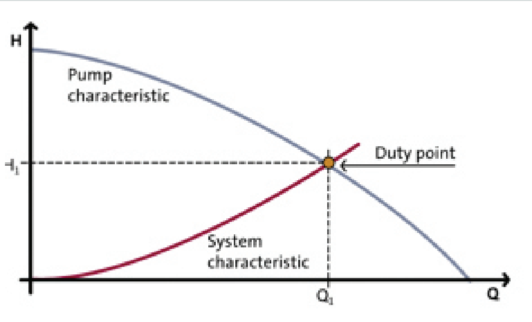

Table 16.12
The Point Of Intersection Between Pump Curve And The System Characteristic Is The Duty Point Of The Pump.

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Pump Selection

Water Supply Pump Systems

These pumps are generally specified to boost the pressure of a water supply from the town mains, or to pressurise water from a tank – e.g. for non-potable rainwater reticulation systems (Figure 16.13). In these systems with varying demand and a constant pressure requirement, the use of a variable-speed constant-pressure system is strongly recommended to reduce the pressure fluctuations, maintain pressure and reduce energy usage.
For flows under about 2 l/s, a single pump is adequate – although a standby pump may be desirable for reasons of reliability.

However for higher flows, a multi-pump system with cascaded variable-speed control is the best solution. A pump is selected to cover the system demand, or an extra pump can be added to the set to provide a measure of redundancy if a pump is offline for service.

In general, a larger number of smaller pumps will provide higher overall efficiency for widely-varying demands than a smaller number of larger pumps. In projects with limited space, these booster systems can use submersible pumps installed in a storage tank. Again we can have single or multi-pump systems with variable-speed constant pressure controls.

However the motor efficiency of a submersible motor is usually significantly lower than the efficiency of a dry-mounted motor.

Figure 16.13
Cold Water Boost Pumps

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Heating Circulation Systems

The best selection for heating systems is generally the inline circulator pump with a canned-rotor motor (Figure 16.14). These are sealless – reducing maintenance – and extremely quiet.

However they are limited to head requirements of less than about 10m or 100kPa. Higher heads are available from inline pumps with mechanical seals, which utilise standard electric motors, or end-suction motor pumps.

For low flows and higher heads, a multistage pump may be appropriate – but unless the system is quite extensive, the question needs to be asked as to whether the pipework system is well designed.

High friction losses usually arise from high velocities, which lead to high noise levels – which are rarely welcome in a building.

Figure 16.14
Heated Circulating Pumps

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Domestic Hot Water Circulators

Domestic hot water circulating pumps are selected as noted previously **Pump Performance Requirements.**

The materials used in the construction need to be satisfactory in handling potable water quality.

Unlike heating water systems, which are closed loop systems with chemical additives in the water to inhibit corrosion, domestic heated water systems are continually receiving fresh water with significant dissolved oxygen content, which can lead to corrosion of pumps.

Therefore the pump casing and impellers should be resistant to corrosion – stainless steel or bronze, or polymer for impellers of smaller pumps.

Common practice is to install a dual circulator set, with the pump duty switched on a regular schedule, and controls set up so that failure of one of the circulators will raise an alarm and start the other pump.

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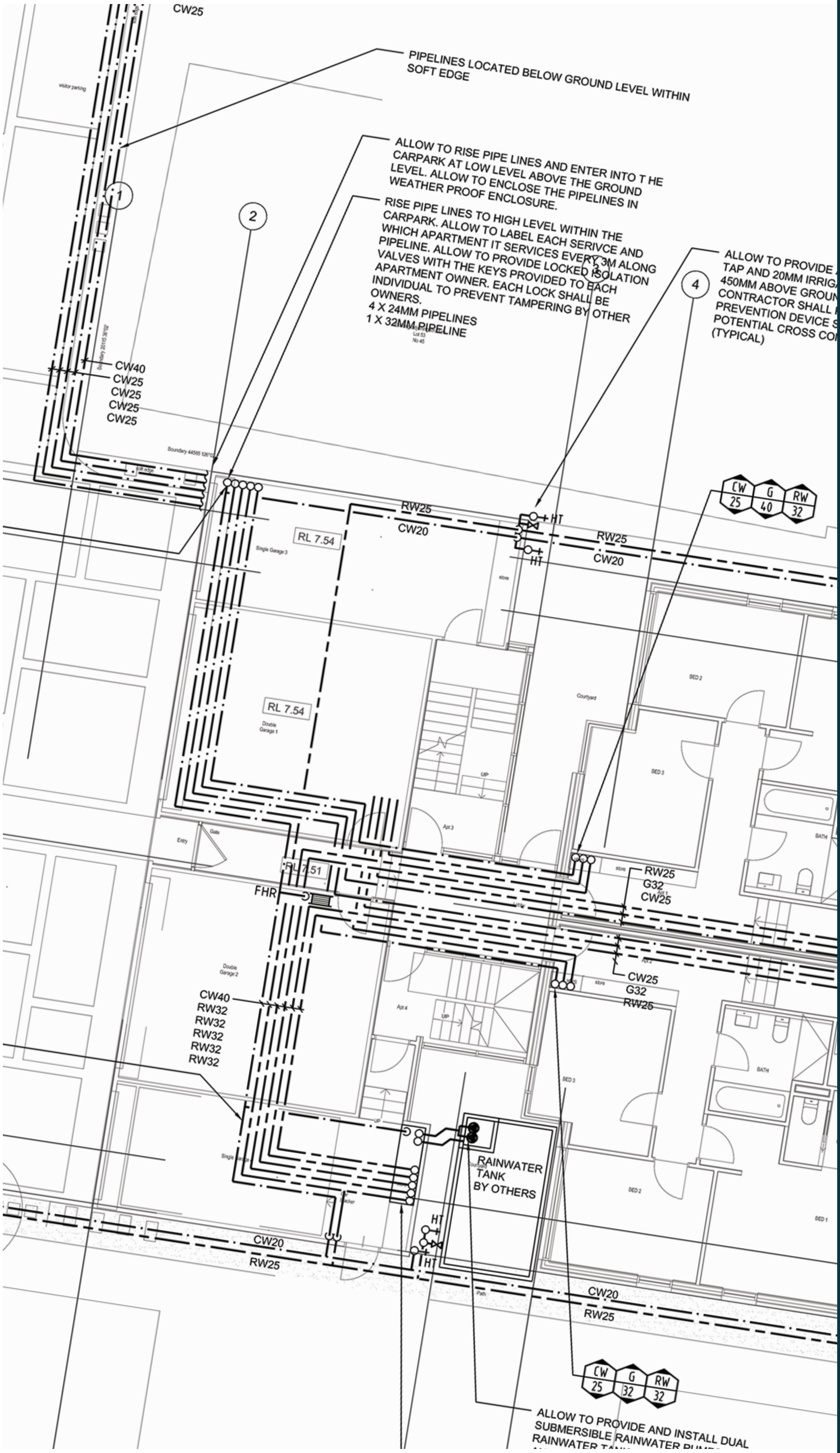

17

Chapter Seventeen

Chapter 17 – Pipe Sizing Guide and Design Methods

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Pipe Sizing Guide and Design Methods

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The influences of water velocities within pipework, pressure losses, pipe sizes and flow rates required may affect the pipe system and performance.

Introduction

This section of the Hydraulic Services Design Guide is intended to give the designer a basic knowledge of the considerations to be made in the systems design and pipe sizing.

The information provided is of a general nature to illustrate the principles of pipe sizing for pipework covering a range of building types and installations.

In order to successfully calculate pipe sizes required in copper piping systems it is necessary to first define the parameters, which will form the basis for the pipe sizing.

Influences on these parameters include, type of building, patterns of usage, quality of building, peak demand time, expected delivery time, pipe material properties, available water main pressure, minimum pressure requirements, need for redundancy etc.

These parameters will also influence the designer's choice of system to be used.

An understanding of the influences of water velocities within pipework, pressure losses, pipe sizes and flow rates required may affect the pipe system and performance within the piping system.

Peak Flow - Probable Simultaneous Water Flow

When designing a cold or heated water piping system, an assessment must be first made of the probable simultaneous flow at any time. In the majority of buildings it rarely happens that the total numbers of taps or sanitary fixtures are in use at the one time.

For economic reasons, it is usual to provide pipes which will allow for a flow which is less then what would be required if all taps were opened simultaneously. Water usage patterns may be used to calculate the probable simultaneous flow.

Water Usage Pattern

Water usage patterns for heated and cold water systems vary from building to building, however historical data will usually give a clear indication of when the peak period of water flow in the building occurs.

Where historical water use data cannot be used the water usage patterns are required to be calculated which may take into account the following factors.

- Total population.
- Hours and days of occupation.
- Geographical location within Australia.
- Ambient temperatures.
- Water conservation targets.
- Water consumption per use.
- Fixture and fitting probable simultaneous operation.
- Fixture and fittings flow rates.
- Groups of showers, spray taps and wash fountains.
- Commercial laundry equipment.
- Commercial dishwashing equipment.
- Mechanical services water usage e.g. Cooling tower make up water.
- Fire services water usage e.g. Test water.
- Irrigation water.
- Water feature water.
- Process water and equipment water.
- Building maintenance water.

Water usage patterns are used to forecast the water flow rates within the building to allow the designer to estimate when the building will use a peak water flow rate generally using a measurement of litres per/second.

Water usage patterns can be calculated over a variety of time durations to simulate the water use within buildings. Common water usage pattern time duration may include the following:

- Hourly.
- Daily.
- Weekly.
- Monthly.
- Annually.

Water usage information can be sourced from a variety of industry documentation, reports and standards. This information is used as a guide for the designer to calculate the actual water usage pattern.

The pipe sizing method incorporated with the Hydraulic Services Design Guide (as listed in Pipe Sizing Process Planning) is limited to water supplies from a mains pressure system and excludes those design consideration for;

- Water conservation, efficiency water use, water recycling and rainwater collection in the context of sustainable water management.
- The innovation of onsite sewer mining systems.
- National and international best practice in commercial/office buildings in the area of water recycling and water efficiency.
- Benefits of sustainable buildings to the environment and community.
- Monitoring for performance evaluation.

Simultaneous Water Flow

It would not be satisfactory to provide diversified flows when full flows are required. Some taps and fixtures requiring full flows these include:

- Groups of showers, spray taps and wash fountains.
- Commercial laundry equipment.
- Commercial dishwashing equipment.
- Mechanical services water usage e.g. Cooling tower make up water.
- Fire services water usage e.g. Test water.
- Irrigation water.
- Water feature water.
- Process water and equipment water.
- Building maintenance water.

After identifying full flow fixtures, fittings and equipment within the building these flow rates must be taken into account by adding it to the probable simultaneous flow required by all other taps and sanitary fixtures.

Cleaner's sinks and hose taps inside buildings are generally not counted in the design flow for the reason that they are in use by cleaning staff when all other occupants of the building have gone home. However individual branch pipelines should be sized to carry flows for all taps on that branch.

Expected Hot Water Delivery Times

Pipe sizing shall also allow for the expected delivery times of warm and heated water to the outlet of the fixture being used. This delivery time may be noticeable by the occupant when in use. The factors that may vary the delivery time may include:

- Pipe size.
- Volume of water needing to pass through the fixture to allow the correct water temperature to be reached.
- Length of pipeline from the hot water heater.
- Length of branch pipeline from a circulating hot water system.
- Heat loss and insulation of pipework.
- Time to heat the pipeline conveying the warm or hot water.
- Temperature of pipework.
- Time since last operation of fixture.

The designer shall take into account the delivery times to prevent water wastage and occupant frustration.

Note:
The Institute of Plumbing Australia – Selection and Sizing of Copper Tubes for Water Piping System - Barrie Smith. Section 4.11 Hot Water Piping Dead Leg

Available Watermain Flow And Pressure

Most water utilities endeavour to maintain a minimum pressure of 15 m head at ground level for each property at all times. However, although water utilities will quote expected maximum and minimum pressure heads that could occur in their watermains, usually no guarantees are given in excess of 15 m head.

Water utility will generally for a fee, provide data on the expected pressure and flow availability in their mains that can be used as the basis on which pipe sizing calculations are prepared. These statements are usually valid for 12 months. The designer must be mindful of large and or staged projects where the water flow and pressure available to site could change.

The water utility has the right to reduce the pressure within their system to 15 m head, which will require the pipe sizing within the building to be recalculated to confirm correct operation. The impact of any pressure reduction may necessitate the requirement for a pump and tank.

Water pressure management programs have been undertaken by water utilities to provide a number of outcomes associated with their water network.

These outcomes may include:

- Reduces water demand and leaks to help meet water conservation targets.
- Improves the reliability and continuity of supply by reducing pipe breaks.
- Reduces pressure fluctuations to achieve more consistent water pressure across our system.
- Extends the life of our water supply pipes and assets.

Minimum Pressure Requirements

Designers will need to consider and allow for the minimum pressure requirements of fixtures, fittings and equipment to ensure the correct operating conditions nominated by the manufacturer and or plumbing standards are adhered to. The designer shall also allow for all pressure losses through fixtures, fittings and equipment, which will limit the pressure available at the outlet for correct operation. Fixtures, fittings and valves require operational pressure that may influence the design pressure requirements. Minimum design and operational pressure of equipment/fixtures include:

- Thermostatic mixing valves and tempering valves.
- Backflow prevention devices.
- Instantaneous heated water heater.
- Combination heated water calorifier/flow water heater.
- Water filters.
- Water softeners.
- Boiling and chilled water units.
- Solenoid valves.

As a general design rule, water services systems should operate with outlet pressures ranging between 15 m head - 45 m head at the fixture outlet. Minimum design pressures to any fixture and or appliance should be checked with the manufacturer of the products during the design stage.

Maximum Pressure Requirements

Where pressures within the pipe network are required to be above 40 m head the designer shall consider the limitations of the installation. These limitations may include:

- Fixtures, fittings and equipment maximum operating pressures.
- Pipe material - safe working and test pressures.
- Pipe jointing type.
- Annealed pipe joints (reduced pressure rating).
- Pipe support and bracketing.
- Pressure zones in tall buildings for cold and heated water circulating systems.
- Pressure reducing valves, pressure limiting valves etc.

Where maximum pressure is created, a pumped system shall be considered to ensure that the pressure fluctuations do not lead to higher than the specified pump duty, which may cause hydraulic shock. Hydraulic shock or "water hammer" is an important design issue in discharge pipelines. Hydraulic shock is caused by three significant operations in water systems, namely valve operation, pump start-stop operations and pump drive failure.

Designers need to be cognizant of the conditions when hydraulic shock can occur and incorporate abatement measures into their designs. Abatement measures may include:

- Safety relief system of valves.
- Expansion tanks that control hydraulic shock.
- Flexible pump mounts.
- Flexible pump connections.
- Slow closing tapware.

The designer shall select system materials and products that will be suitable for use in high water pressure installations, maintaining safe working pressure is in accordance with the standards and manufacturers requirements.

Velocity of Water Flow

The design of the water piping system is greatly influenced by the selected flow velocities. The recommended maximum velocities for copper tube are based on established permissible sound levels of moving water and entrapped air, and on the effects of corrosion (Table 17.1). Erosion in water piping systems is the impingement on the inside surface of the tube of rapidly moving water containing air bubbles or suspended solids. In some cases this may mean complete deterioration of the tube or pipe walls, particularly in areas of high turbulence such as at bends and elbows or the internal top surfaces of the pipe where there are entrained gases.

Since erosion is a function of time, water velocity and suspended matter in the water can affect the service life of the materials fixtures and fittings. The choice of design water velocities is a matter of judgement.

The velocities recommended for water flows in piping systems depend on the following six conditions:

- The service of which the pipe is used.
- The effects of erosion.
- The effects of hydraulic shock and noise.
- The type of piping material.
- The internal diameter of the piping material.
- The restrictions of pipe and fittings.

Recommended Water Velocities				
Service	Velocity Range m/s.			
	Recommended Design Velocity m/s	Institute of Plumbing Australia Selection and Sizing of Copper Tubes for Water Piping Systems	Australian Standards AS 3500.4 2015	British Standard BS 6700:2006 +A1:2009
Cold Water - Mains pressure water services pipelines	Up to 2.4 Up to 1.6 within Dwelling / Apartment	1.0 to 2.1	Max. 3.0	Max. 3.0
Cold Water - Gravity flow pipelines from upper level storage tanks – Top two floors only	0.1 to 0.4	0.1 to 0.4	Max. 3.0	Max. 3.0
Cold Water - Gravity flow pipelines from upper level storage tanks – below top two floors	1.0 to 2.1	1.0 to 2.1	Max. 3.0	Max. 3.0
Cold Water - Pump suction pipelines	1.2 to 2.1	1.2 to 2.1	Max. 3.0	Max. 3.0
Cold Water - Pump delivery pipelines	1.5 to 2.1	1.5 to 2.1	Max. 3.0	Max. 3.0
Heated water - Flow and return – circulating system	1.0	Not Specified	Max. 1.2	Max. 3.0
Heated water - Non-circulatory systems	2.0	1.0 to 2.1	Max. 3.0	Max. 3.0

Table 17.1
Recommended Water Velocities for Cold and Heated Water Supplies

Pressure Losses of the System

The design of a water piping system is limited by the pressure loss. Piping must be sized so as to provide the required flow at an acceptable pressure loss within the available pressure.

The minimum pressure required is to include all loses in the system, such as flow pressures at open ends, pipes and fittings friction losses and pressure loss due to vertical rise. Total system pressure losses must be less than the minimum water main pressure and pump pressure increases.

The designer shall assess the cost of an installation when selecting a pipe size. Where an increase in pipe diameter is chosen to reduce the pressure loss on large projects may be costly. Pipe materials have different properties that influence the pressure loss within the pipe and fittings used.

Pipe Sizing Guides

There are a number of useful design guides available to assist with pipe sizing and some 40 years ago Mr Barrie Smith wrote a book titled "Selection and Sizing of Copper Tubes for Water Piping Systems" This reference guide became the industry standard used to show the basis for sizing of water services for an extended period and still contains material that is helpful to the designer.

This book has not been updated to consider the advancement in reduced water flows and the AS/NZ 3500 flow rate requirements. There are a number of pipe sizing programs available to assist the designer with both simple and complex pipe sizing projects.

Approximately 20 years ago government and industry realised that our water supply was precious and worked to introduce a number of innovations to lessen the amount of water used in homes and businesses.

These innovations now include dual flush toilets, waterless and reduced flush urinals, WELS "Water Efficiency Labelling Scheme" rated tapware, which have reduced the total average daily water consumption throughout the Water Supply Authority area of operation.

Pipe Sizing Process Planning

The following pipe sizing process planning chart (Figure 17.1) gives the designer a pathway to follow and consider in completing the pipe sizing calculations on a project.

The importance of a system schematic drawing of the system with node points cannot be understated as it gives the designer a reference for his calculations and allows for a quick review of the project parameters and equipment that may affect the pipe sizing.

By providing a schematic sketch will also form a permanent record of the system loads and pipe sizes. There are a number of computer based pipe sizing programs available that provide worked examples of pipe sizing within buildings.

Info@wenning.com.au gives access to an electronic form of Barrie Smith book with worked examples and spreadsheet enclosed in Appendix B

Info@waterapp.biz gives access to a simple flow/pipe size checking application. See the new Free and Pro version Apps at www.copper.com.au

These basic programs give the designer a basis on which they can build to prepare calculations on pipe sizing and pressure losses within plumbing systems.

To some extent the principles of the Pipe Sizing Process Planning Chart (Figure 17.1), are embodied in the worked examples contained in Appendix B "Pipe Sizing Guide to the application of 'Selection and sizing of copper tubes for water piping systems' using Microsoft Excel" giving the designer the process to follow in understanding pipe sizing calculation.

Refer to worked examples of schematics and typical spreadsheets by Peter Wenning. When the pipe sizing is completed the calculations should be filed and dated as a reference document.

These calculations are used for the basis on which pumps for the project can be selected and to prove pipe sizes used in the system.

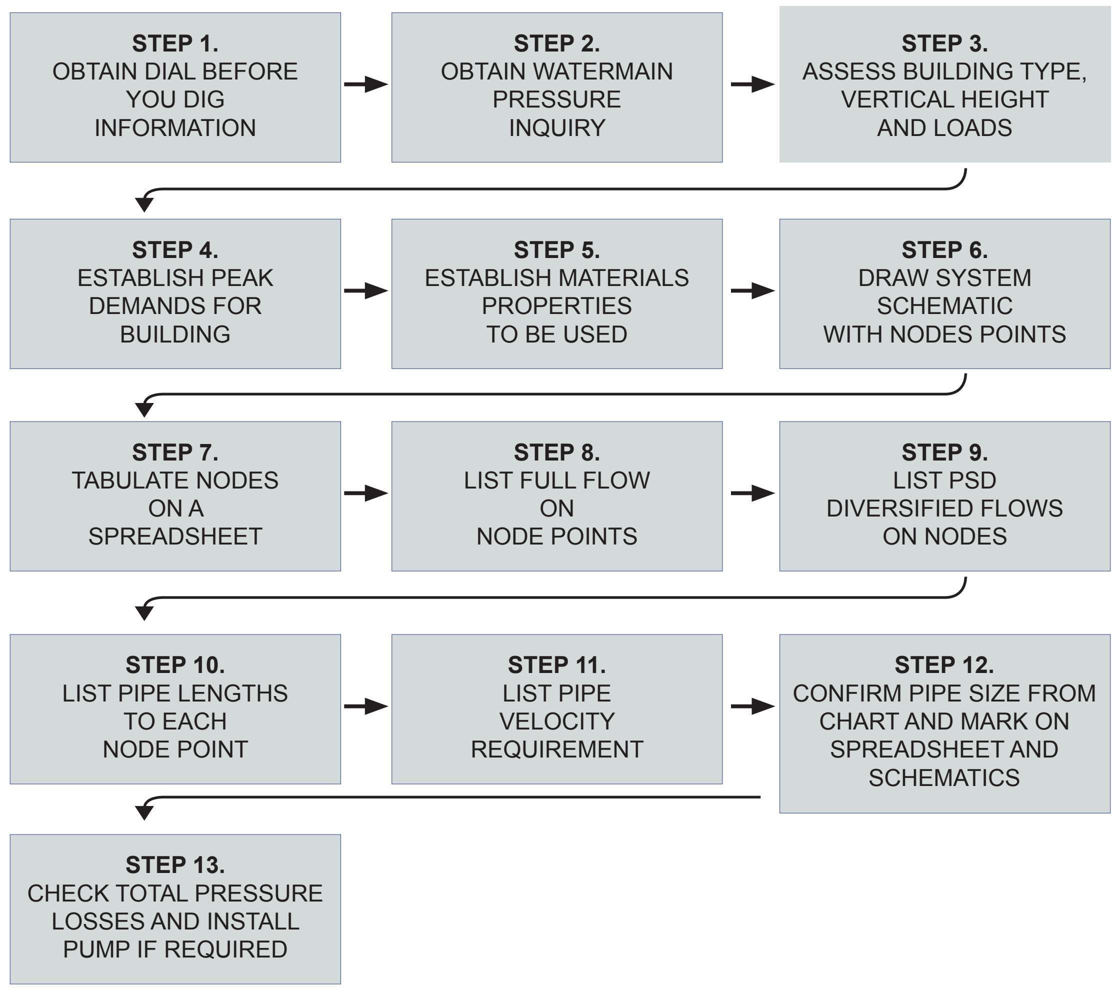

Figure 17.1
Pipe Sizing Process Planning Chart

Pipe Sizing Methods

There are many pipe sizing methods and programs available to hydraulic designers and plumbers today. The information required to complete pipe sizing is derived from those elements we have outlined throughout this guide. The process of copper tube sizing is now available in electronic format that allows the input of data based on the design criteria of the building type, the required flow and expected usage pattern.

Australian Standard AS 2200 and AS/NZS 3500 Water Supply provide the foundation for the pipe sizing principles covering the pressure loss and flow requirements through various types of fixtures and fittings. These values have been used to develop the following pipe sizing applications.

The pipe sizing applications and literature is provided complementary for the use with copper tubes to AS 1432 and must not be used for other material types and diameters.

Pipe Sizing – references;

- Institute of Plumbing – Selection and Sizing of Copper Tubes for Water Piping Systems: 1976, Author Barrie Smith.
- Pipe Sizing for Building Services: 2005, Author Paul Funnel.
- Pipe Sizing Guide, to the application of Selection and Sizing of Copper Tubes for Water Piping Systems: Author Perter Wenning – Appendix B.
- Pipe Sizing Excel Spreadsheet, Author Peter Wenning – Appendix B.
- WaterBiz Free and Pro-Version Apps: 2014, Author Ken Sutherland – www.copper.com.au

Introduction to Pipe Sizing

Plumbing Standard AS/NZS 3500 use the 'Index Length' method to size water pipes. The method involves working out the Hydraulic Grade required to determine sufficient pressure to the furthermost (or highest) fixture in the system. (This is referred to as the worst-case scenario or most hydraulically disadvantaged).

Once this has been determined, then all pipes in the entire network are designed with this hydraulic grade as a guide.
If it works for the worst case, then it must work for all the others along the service pipe. Friction losses are accounted for by the 'Equivalent length' method. Where bends and fittings are assigned a length of pipe that is 'equivalent' to the pressure loss through the fitting.

This method is suitable for most domestic and commercial plumbing systems. However it is not recommended for systems that specify a pressure requirement, as in fire systems. Municipal systems and large networks are also designed differently.

Flow

The Plumbing Code of Australia allocate a nominal flow or a number to each fixture, called a 'loading unit' (LU) or a 'fixture unit'. This number takes into account the flow of the fixture and the likely frequency of use. The Australian standard does not take into account WELS Rated tapware for pipe sizing. These numbers are added up, and a conversion formula within the Plumbing Standard derives the 'Probable Simultaneous Flow'.
If there is only one fixture, then the pipe must be sized for 100% of this flow requirement. However as the number of 'Loading Units' builds up, it becomes less likely that all fixtures will be operating at the same time. So as the number of LU's increases, the likely percentage of fixtures operating at any one time decreases, (to a certain minimum).

Pressure

The pressure in a pipe is dependent on how high the reservoir is above the point of discharge. The higher the tank above the house, the more pressure is available.

The pressure in a street main can vary substantially during the day. The minimum pressure must be used. This pressure is obtained from the Water Utility – Water Pressure Statement.
It is easier to understand hydraulics if we think of pressure in terms of height of water, this is called 'head' of water. Kilopascals

(kPa) is the pressures given to that height in metres/weight of water.

For instance 30.5m head = 299kPa (say 300kPa). Similarly with a pump, it is easier to think that a pump will raise water to a certain height, and it will gravitate from this point. It may be easier to think of it this way, if a vertical pipe is connected to a water main, the water would rise to a certain height. This height of water above the water main is the 'head' of water". The weight of which is the referred to as pressure.

In this case the water cannot rise higher than the water level in the reservoir, otherwise water would be flowing into the reservoir and not out. Because water always flows downhill! From a point of higher pressure to a point of lower pressure, from a high water level to a lower water level.

Water rises to the **Hydraulic Grade line**, (Figure17.2), this is what the Hydraulic Grade line represents. The pressure (height/head of water) is the reading achieved at a given point within the system.

So if we know the height (tank water level) of the start point, and the height of the water level at the end point, and the distance between, we can work out a grade.

All pipe formulas use this grade to calculate what pipe size we need (to carry a given flow). This is consistent for all pipes, both pressure pipes and gravity pipes.

A pressure pipe is obviously a pipe flowing under pressure as in water pipes. A gravity pipe is a pipe that flows without pressure as in sanitary drainage, and storm water pipes. If a gravity pipe is flowing full, we use the same formula as a pressure pipe, using the 'hydraulic' grade for the pressure pipe, and the actual grade for the gravity pipe.

AS/NZS 3500 nominates a maximum and minimum discharge pressure at any outlet within a building. This pressure requirement excludes the dynamic pressures within a building services supply system (mains piping) serving a number of dwellings/ apartments. Pressures above those within an dwelling/apartment requires a pressure reducing valve. The minimum is the pressure required to operate the fixture in question.

Friction

Friction within pipes and fittings cause loss of pressure. From the following calculation we can calculate what the head is available for friction loss. Friction is also dependent on the velocity of the flow, the faster the flow the more friction.

Bends and Fittings

Bends and fittings are allotted a length of pipe that would produce the same friction loss as the fitting. This is called the 'equivalent length' of that particular fitting. Because plumbing takes many bends and changes of direction, it is difficult to predict the exact number of fittings that may be used, and every design is different.

So, to allow for friction of bends and fittings, the Free-version pipe sizing application for pipe sizing increases the actual length by 50%. This is the total 'equivalent length' and is normally conservative. AS/NZS 3500 uses this method. Other Codes suggest this as a first trial. Read more about the implications of this later.

How conservative is the 'Equivalent Length' method?

Pressure loss (or Head Loss) in pipes, bends and fittings (B&F) depends on the water velocity. The faster water is flowing the more friction, the more head loss.

The formula is,

$$\text{Head loss} = K \frac{V^2}{2g}$$

Where:

m = Pressure loss in metres head
K = Lost head factor for fittings and valves
V = Flow velocity in metres per second - m/s
g = Gravitational acceleration 9.8 m/s^2

The important thing is that each fitting is allotted a 'k' value (head loss coefficient), or to obtain a full description of fittings and associated frictional loss at selected flows refer to "Selection and Sizing of Copper Tubes for Water Supply Systems" – Author Barrie Smith). These vary according to the pipe size, however some average values are shown below.

For example;

K value of Fittings

Fitting	K Value
90deg short radius bend	1.2
Tee branch (T)	1.75
Gate Valve fully open (GV)	0.2
Water Meter	7

Now lets say, the length to the furthermost fixture in a typical dwelling is about 30m, and the pipe is flowing at the recommended allowable velocity of say 2.4 m/s. This would equate to a 20mm flowing at 0.55 L/s.

Note:
The actual internal diameter (ID) of this (copper) pipe is about 17mm.

Say we have;

1x7(one water meter) + 2 x 0.2 (Gate valve) + 2 x 1.75 (Tees) + 6 x 1.2 (Bends), giving a total k about 18.

k	= 7 + 2x0.2 + 2x1.75 + 6x1.2
	= 18.1
Head Loss B&F	= k x (V^2 / (2x9.81))
	= 18.1x(2.4^2 / (2x9.81))
	= 5.3m (52.1 kPa) (7.55 psi)

Head loss through 30m of 20mm (actual ID =17mm) @ 2.4m/s, 0.55 L/s = 13m.

Head Loss B&F	= 5.3m
Head Loss Pipe	= 13m
B&F / Pipe Loss	= 5.3/13
	= 0.41
	= 41%

Therefore allowing 50% seems a reasonable figure.

This means that;

Using the Equivalent Length method

Total Head Loss	= 1.5 x 13
	= 19.5m

As you can see, allowing total friction to be 150% of the pipe friction allowance is a good *"rule of thumb method"*.

Allowing for slightly more friction than is actually there, means that our design is upgraded to compensate, which will result in slightly more pressure at the last fixture.

In practice however, these values tend to average out, some pipe sections exceed this amount, but most of the long straight runs of the bigger pipes are well under.

Pipe Friction

There are many standard formulas that calculate flow in pipes

Example; Manning, Colebrook White, Darcy, Hazen Williams etc.

Friction is accounted for by using a pipe material 'roughness coefficient' in the formulas. However all formulas give a similar result. These programs apply the formula used in the relevant Plumbing Codes.

Hydraulic Grade to the Furthest Outlet (Worst Case Scenario or Most Hydraulically Disadvantaged)

Think of the hydraulic grade as equivalent to the grade of a gravity (drainage) pipe flowing full, but not under pressure. The 'Hydraulic Grade Line' (HGL) is a line drawn on the diagram representing the pressure at all points along the pipeline.

The pressure is represented in terms of height/ head of water. This way we can also relate the changes in elevation of our fixture to the start connection point. Now we can graphically see the start pressure, the height difference, and the residual pressure.

If we draw a vertical line from any point along the pipeline to the Hydraulic Grade Line, the length of this line represents the pressure at that point. And as mentioned earlier it is also the height to which water will rise if a vertical pipe was connected at that point.

The Hydraulic Grade involves only four things;

- The start pressure (street main).
- The end pressure (residual head).
- The difference in elevation between the start and end points.
- The length between the start and end points.

The end point is the hydraulic worst case scenario or most hydraulically disadvantaged. Sometimes we don't know whether this will be a close high point. or a low point further away. In this situation we must check both.

You can see from the diagram the head that is available. This is the head that is available for friction losses. Divide this number by the 'equivalent' length and we have the hydraulic grade.

The steeper the grade results in a greater the flow in the pipe (just as in a gravity pipeline).

We've calculated the grade, we know the flow that we are trying to achieve, now use the formula to find the pipe size that will carry that 'flow' at that 'hydraulic grade'.

Normally this formula is some variant of the 'Hazen Williams' formula for pipe friction losses.

Note:
In practice the hydraulic grade is not a straight line unless the pipe is straight, and the size or flow does not change along the length of the pipeline.

Any head loss as in bends and fittings, will introduce a vertical drop in the line, and changes in size or flow will change the grade of the line.

Smaller pipes or larger flows make the line steeper, as there is more friction loss. This results in less pressure/head at the end of the pipe section.

Conversely larger pipes and/or less flow make the line flatter.

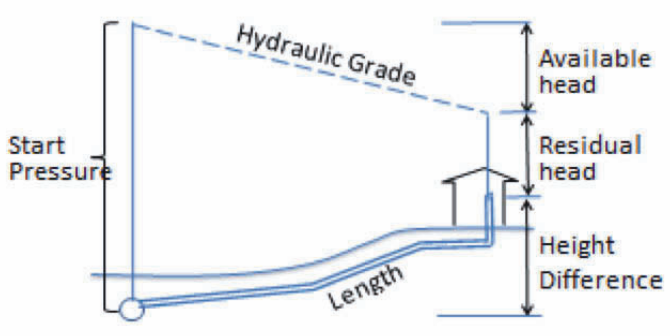

Figure 17.2
Available Head Pressure

Pipes

For the purposes of plumbing, pipes are given a 'nominal' size (DN). This may be different to the actual size. But it is the size that we refer to for purchasing. The pipe sizing apps program calculates the actual inside diameter required. Refer to AS 1432 Copper Tubes Specifications.

Maximum Allowable Velocity

The worlds major plumbing codes limit the velocity in pipework to a recommended 2.4 m/s or mandated 3 m/s, and sometimes even less for heated water services pipework.

There are three reasons for setting the maximum allowable velocity;

- To reduce piping noise.
- To reduce wear and tear on fittings.
- To reduce water hammer.

The **WaterBiz Free-version** of the pipe sizing programs uses the velocity below that permitted in the respective Plumbing Standard AS/NZS 3500.

The **WaterBiz Pro-version** allow the user to enter any value. However increasing the velocity above 3m/s should really only be done on straight runs with no bends or fittings, especially valves. But this will be outside the plumbing codes. It may be justified in irrigation, fire flows, etc, or even in an area of high pressure when the dwelling is a long way from the source.

Lowering the velocity on the other hand, would be advantageous. Lowering the allowable velocity increases the pipe size, increasing the allowable velocity reduces the selected pipe size.

So what is the effect of this in practice?

The velocity limitation applies when the available water pressure can easily push the required flow of water very fast through a small pipe, and still satisfy all the pressure loss requirements.

So to slow the velocity down, the water pipe must be increased in size (a bigger pipe can carry the same flow at a slower rate). Of course what this also means, is that the head loss is reduced, as the head loss is very dependent of the velocity. The greater the velocity, the greater the head loss. So the end result is, we end up with more pressure in the system.

The difficult and laborious way to size pipelines is to progressively calculate the head loss in every individual pipe. The object is to adjust all the friction/head loss in each pipe section so that the total head loss is as close as possible to the 'available head loss'.

This is necessary in systems where the end pressure must fall within certain limits, as in fire systems, and is recommended in certain Plumbing Codes. Usually this method involves a lot of trial and error. But is it necessary to recalculate the start pressure for every level of a high- rise building? And will this change the pipe sizes on each level, even if the Architecture is identical?

Minimum Residual Head

This is the pressure that we want to achieve at the last (furthest) fixture being the worst case scenario or most hydraulically disadvantaged. The Plumbing Standard AS/NZS 3500 suggests anywhere from 5 to 15m, sometimes even more for special fittings.

Manufacturers recommend a minimum of 11m (110kPa) for most mixing and tempering valves.

WaterBiz Free Version Pipe Sizing App

The **Free-version** of the program uses 15 m head (approx 150 kPa) as the residual head for Australia.

Note:
AS/NZS 3500 regulates not less than 5 m head but with the advent of mixing valves etc this has been increased within the program to reflect such valves and devices.

WaterBiz Pro Version Pipe Sizing App

The **Pro-version** which can be purchased online at www.copper.com.au allows the user to enter any value.

Water will always flow from a point of higher head (pressure) to a point of lower head (pressure) even if the difference is only millimeters (mm). It may not flow very fast under these conditions, (a flat hydraulic grade) but it will flow.

Standards & Code Differences

The Australian Plumbing Code has a 'Probable Simultaneous Flow' of approximately half the International Plumbing Code, the British Code, and the Uniform Plumbing Code.

The Plumbing Code of Australia has a one size fits all approach, which significantly reduces the design time, but produces a larger pipe size. This is the basic difference. Generally the results will be very similar.

Lets see how this works.

Australian Plumbing Code – AS/NZS 3500
All pipe sections are sized with the hydraulic grade to the worst case scenario or most hydraulically disadvantaged. (Figure 17.3).

The end pressure increases because pipes are not manufactured in the exact calculated size.

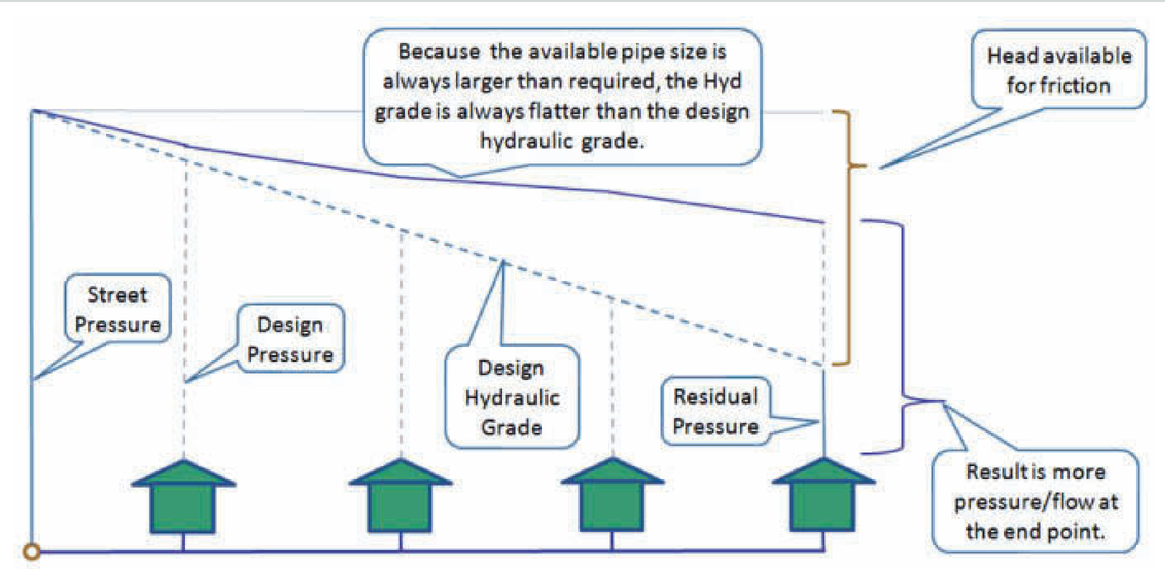

Figure 17.3
Design Hydraulic Grade Line – Australian Plumbing Code

International Copper Association Australia

International Plumbing Code

The hydraulic grade is recalculated for each section to try and finish as close as possible to the required end pressure (Figure 17.4).

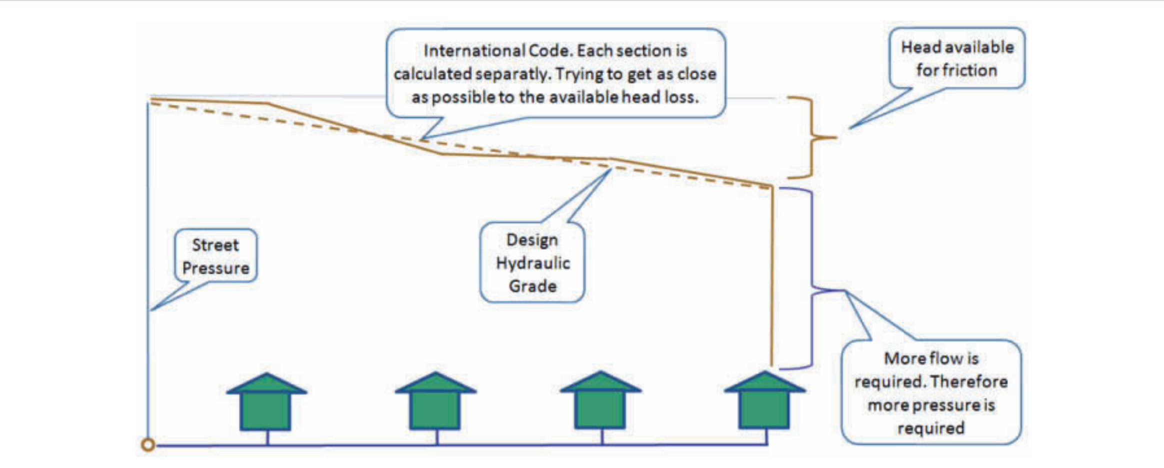

Figure 17.4
Design Hydraulic Grade Line – International Plumbing Code

International Copper Association Australia
Copper Alliance

The diagram is not strictly correct, but it is drawn like that to illustrate the point.

If we want to do things the conservative way (and the correct way) we count all the bends and fittings, and all the other head losses, then calculate the head loss in each pipe section, sum all the head losses and try to make this figure as close as possible to the 'available' head loss.

This is fine, but all the head losses are dependent on the flow velocity, which is dependent on the pipe size.

So we start with an estimate of the pipe size for each pipe section, and then use trial and error to end up with a total head loss, that is as close as possible to what is available for friction.

The end result is, we may or may not have succeeded in reducing a couple of pipe sizes. But are we any more correct? Given that it is impossible to accurately predict the number of bends and fittings the plumber will use, and the 'design' flow may or may never actually occur. Is there such a thing as over design in plumbing, (or is it just a better design) if increasing the pipe size reduces the pressure fluctuations?

WaterBiz Pro Version Pipe Sizing App

The Pro-version application allows input of the number of individual fixtures for large houses, or projects eg industrial buildings, office buildings, shopping centres etc. Also allows input of known flows and loading/fixture units.

Pro-version allows the user to change the **maximum allowable velocity.** This is useful for some other plumbing standards, or for heated water, or for some 5 star hotels that specify different velocities for different locations in the building.

Also allows the user to change the **minimum residual head.** Ideal for tanks (lower residual head), fire hose reels or hydrants (higher residual head), or other fixtures where the manufacturer requires a different minimum head for proper operation eg mixing valves.

The Pro-version also has a table that displays the capability of every copper tube size, for the calculated Hydraulic Grade.

That is;

How many dwellings each size can service.

- What flow (L/s) each diameter can supply.
- And what is the velocity in each pipe diameter.
- And how many Loading Units each pipe can handle.

The advantage of this is that it is not necessary to keep changing the number of dwellings to find the tube size, because it is obvious from the table.

For example, it might show that a DN25 copper tube adequately services 3 dwellings, and the next size up (32dia) servicing 8 dwellings. So no need to calculate the pipe size for all the dwellings from 3 to 8, as the answer will be 32mm dia.

Also, showing the flow capacity of each size will help in cases where the flow is known. For example, irrigation, some fire services, and some mechanical systems.

If the velocity shown is the maximum allowable, then we know that velocity is controlling the pipe size, not the pressure. Which means that we have sufficient pressure, which in-turn suggests that we should end up with more pressure at the end point than our desired minimum.

Pumps

Pro version also calculates pump duty. This is the required operating point of the pump. It is the flow required, and the pressure required at that flow.

If the hydraulic grade falls below 1:100 then a pump size is calculated. With this hydraulic grade a single residence will require around DN 50mm copper tube. Therefore a pump is necessary to increase the supply pressure to fixture outlets. However if the pump is above the tank, the start pressure is limited to -60kPa (6m). Centrifugal pumps will be struggling to draw (lift) that high.

When lifting water with a pump, is also necessary to check the NPSH (net positive suction head) of the pump with the manufacturer. Refer Chapter 16.

For instance, atmospheric pressure is about 10m, but this is already allowed for on our pressure gauge. Because when we read the pressure in a water main we are reading the pressure **above** atmospheric.

This means that on our gauge, a vacuum would read -10m (say100kPa).

So a pressure of -60kPa (-6m) on our gauge would be +40 kPa (4m) above a vacuum (10-6=4). This is a NPSH of 4m.

When the pump duty is calculated, use the pump kPa (or start) pressure, (shown on Free-version and Pro-version) as the 'Start Pressure' to calculate the pipe sizes.

The pump 'duty' point is not the figure that the local pump suppliers usually quote. The supplier normally advises the maximum pressure that the pump can supply (at no flow).

The Duty Point is the required pump pressure when the pump is operating at the 'design' flow. For centrifugal pumps (which is mainly what is used in plumbing situations) the pressure falls off with increasing flow.

However somewhere in the system the manufacturer, or pump supplier, will have a 'Pump Curve' that shows pump pressure associated will all flows that the selected pump can produce.

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Waterbiz Pipe Sizing Applications

These programs are designed to work on a mobile device and also on a PC.

Once opened the pages/programs will work off line.

Free-version will calculate copper water pipe sizes up to 50mm diameter.

Pro-version will calculate copper water pipe sizes up to 200mm diameter.

The Free-version is based on the number of dwellings, although fractional dwellings can be entered.

The Pro-version allows the user to enter any combination of individual fixtures, dwellings, and known flows.

Copper Tubes

The actual pipe sizes used within the WaterBiz Apps are taken from AS 1432, Copper Tubes -Type B (Table 17.2).

Free-Version 15-50		Pro-Version 15-200	
Nominal Dia DN(mm)	Actual I.D.(mm)	Nominal Dia DN(mm)	Actual I.D.(mm)
15	10.88	65	61.06
18	13.84	80	72.94
20	17.01	90	85.64
25	22.96	100	98.34
32	29.31	125	123.74
40	35.66	150	148.34
50	48.36	200	199.14

Table 17.2
Actual Pipe Sizes – Internal Diameters.

Cu International Copper Association Australia Copper Alliance

> **Note:**
> Although Australia and New Zealand have the same plumbing installation code; the Copper Pipes in NZ are manufactured to different standards. The Australian WaterBiz Free-version and Pro-version app is not suitable for use in New Zealand.

Pipe Sizes.
The internal diameters used in the programs are shown in Chapter 4 of this guide.

Minimum Velocity
The Free-version of the program uses 2.4 m/s for best design practice.
The Pro-version allows the user to enter any value.

> **Note:**
> The Australian Plumbing Code at present allows this to go to 3 m/s, however this is not recommended for cold and heated water supplies.

Minimum Residual Head
This is the pressure that would like to achieve at the last fixture (the worst case).

The Free-version of the program uses 15 m head (approx. 150kPa) as the residual head.

> **Note:**
> The Australian Plumbing Code is 5 m head, but this is too low to work modern devices.

The Pro-version allows the user to enter any head values.

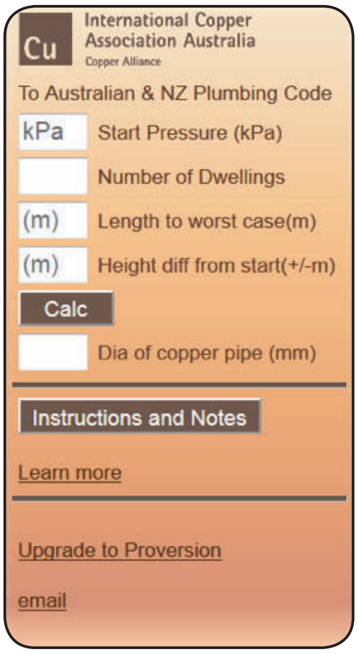
The Pro-version also has a table that displays the capability of every pipe size, for the calculated Hydraulic Grade.

That is:-

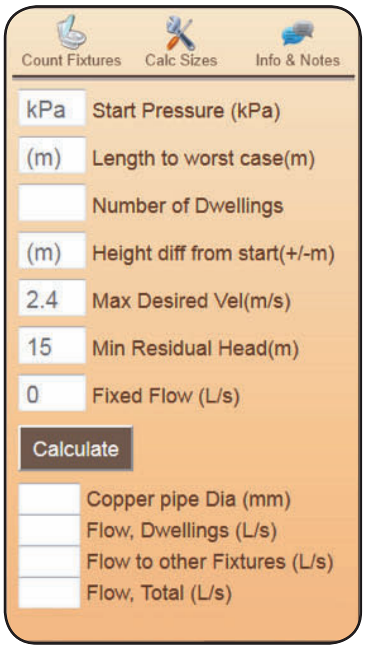
- How many dwellings each size can service.
- What flow (L/s) each diameter can supply.
- The velocity in each pipe diameter.
- The number of Loading Units each diameter can service.

Pro-version allows the user to change the maximum allowable velocity, and change the minimum residual head.

Pro-version also calculates the **Pump Duty**.



Free – Version
Screen shot



Pro – Version
Screen shot

18
Chapter Eighteen

Chapter 18 – Testing and Commissioning

EN 1057 version

International Copper Association Australia
Copper Alliance

Testing and Commissioning

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The installed pipework systems should be pressure tested for leaks in accordance with AS/NZS 3500.

Introduction

The purpose of testing plumbing services pipework is principally to ensure that the installed and assembled pipes and fittings have been carried out in accordance with the relevant standards, manufacturers installations and or industries requirements. For specific services and/or where the hydraulic specifications require, additional testing to further satisfy the intended performance duty of the system may be needed.

The Plumbing Code of Australia (PCA) has performance to satisfy requirements for cold and heated pipework, which states;
"a cold water service must be designed, constructed and installed in such a manner as to avoid the likelihood of leakage or failure including uncontrolled discharges"

A plumbing installation whether water, gasfitting and or sanitary services systems meeting the deemed to satisfy solution for the PCA list those procedure in AS/NZS 3500, AS 2419 and AS 5601 series documents.

Procedures for Testing Water Services are;

On completion of the installation all pipework systems shall be flushed-out to clean sand, copper filings and foreign matter from the system.

Prior to flushing operation, disconnect all thermostatic mixing valves, tempering valves, filters, screens, ball float valve inlets, backflow preventers and other appliances, which may be subjected to damage due to presence of foreign materials.

All systems should be thoroughly flushed out as soon as possible after installation.

The flushing should be undertaken until the flushed water runs completely clear.

When the system is connected to the permanent water supply with all taps and valves installed, all draw-off points should be opened until clear water exits the system. This will assist in the development of the protective internal film within the copper pipework.

In large installations, during long construction periods the flushing should be performed in sections and periodically. The flushing should begin at the most remote point on the system.

In multi-storey buildings supply from the street main or where the cold water is from a storage tank on flushing should commence on the upper level floor and working down the building level by level.

Stagnant water can be an issue with all pipe work and can cause internal pitting corrosion in copper under certain conditions, so it is important that if there is more than 8 weeks between installation and full system use is unavoidable —

- the system shall be kept completely full and clean water shall be flushed frequently (every 2 weeks) from each fixture until the system is used;

OR

- the system shall be drained completely and dried out by blowing air through the system, then, if practicable, the piping shall be sealed to prevent intrusion of water and foreign matter.

Ensure that the final installation is totally clear of any foreign matter and that such material does not affect the operation of valves, filters, screens and outlets. Chlorinated water supplied from Water Utilities mains is usually satisfactory for flushing and testing purposes.

Where rainwater or non-disinfected water is to be used for flushing and testing, water should be disinfected/chlorinated to ensure there are no contaminates in the water supply. Water services used to supply drinking water should be protected against contamination during installation, commissioning and repairs. If any water supply services is exposed to foreign substances or contaminated supply, the service should be flushed, chlorinated and tested before being placed in service.

Testing

As soon as possible after installation and flushing, the pipework system should be pressure tested for leaks in accordance with the relevant Australian Standard. Disconnect any equipment connected to the services system not rated to the test pressure, before testing commences. Before commencing any of the hydrostatic/ pressure tests, the person undertaking the test should ensure that the pipework system is properly supported and anchored to prevent movement of pipes or fittings during testing.

> **Note:**
> The required test pressure should be monitored at the lowest part of the pipeline or, if that is not possible, at some other convenient point and the test pressure adjusted to take account of the elevation difference between the lowest part of the pipeline and the test rig.

Gauges should have a current calibration certificate and should read within ±5% of the test pressure.

If any test proves to be unsatisfactory, the fault should be detected and rectified, and the pipework system should be re-tested. Rectification and retesting should continue until a satisfactory test result is achieved. Even if testing produces satisfactory results, any visible or detectable leaks should be rectified.

If thrust blocks are installed on the pipework, pressure testing should not commence before the curing time for the concrete has elapsed.

Systems to be Tested are;

- Cold and heated water services in accordance with AS/NZS 3500 series documents.
- Fire Sprinkler services AS 2118 and
- AS 1851
- Fire Hydrants services AS 24129 and AS 1851
- Fire hose reels services AS 2441

> **Note:**
> A summary of current Australian Standards and specific testing requirements are shown in Table18.2a and Table18.2b.

Preliminary

Testing is required by the plumbing installation code AS/NZS 3500 Part 1, 4 and 5 and may be required to be witnessed by a independent third party for verification. The issue of a Form 15 Fire Safety Certificate is usually required for essential services. There are two primary methods used for pressure testing water lines.

Preparation

As a minimum, before commencing any pressure test, the following preparations should be undertaken:

- Ensure the system is fully flushed to remove debris.
- Ensure the system is fully charged.
- Ensure all trapped air is bled from the system.
- Ensure all items of equipment that may be damaged by the test such as heaters, Thermostatic mixing valves etc. have their valves closed so as not to over pressurize them.
- Ensure all isolation valves are open within the system where applicable.
- Where fire hose reels are connected to the pipework system, ensure that all fire hose reel stop valves are closed.
- Ensure appropriate contingency measures are in place to mitigate water damage in the event of system failure under the test conditions.

> **Note:**
> - Closing the fire hose reel stop valve will ensure that fire hose reel does not become pressurized during the hydrostatic test.

Performing the Test

The test procedure should be as follows:

- Connect the inlet of a bucket pump or a portable pump to a water supply.
- Connect the outlet of the bucket pump or portable pipe to the pipework system.
- Pressurize the pipework system to just

above the system's normal static pressure.

- Whilst maintaining the pressure, check for leaks and the functionality of the non-return valve(s) or backflow prevention device.
- Ensure there is air within the pipework before commencing to pressure.
- Pressurize the pipework system at the elevation of the most remote point.
- Allow the pipework to stand without make-up water for a period of not less than 30 min. at the required pressure.
- During this period, check for leaks and the adequacy of the system supports (e.g. thrust block movement).
- At completion of the test, return the pipework system to the normal static pressure.

Reporting and Witnessing of Results

The following results should be reported:

Test Parameter	Results
Date of test	
Section of pipework	
Test pressure	....kPa
Duration of test	..................................minutes
Name and Signature of person conducting test	
Name and Signature of person witnessing test	

Table 18.1
Sample Test Report Record

<table>
<tr><th>System</th><th>Standard or Code</th><th>Test Pressure kPa</th><th colspan="2">Duration of Test</th></tr>
<tr><td>Cold Water</td><td>AS/NZS 3500.1 - Water Services Clause 16.3.1</td><td>1500kPa</td><td colspan="2">Not less than 30 minutes</td></tr>
<tr><td>Heated Water</td><td>AS/NZS 3500.4 - Heated Water Services Clause 11.3</td><td>1500kPa</td><td colspan="2">Not less than 30 minutes</td></tr>
<tr><td>Fire Hydrant</td><td>AS 2419.1 Fire Hydrant Installations Clause 8.4</td><td>1700kPa or 1.5 times the design pressure, whichever is the greater.</td><td colspan="2">No duration is given 2 hours recommended</td></tr>
<tr><td rowspan="4">Fire Hose Reel</td><td colspan="4">Pipes and Fittings used in hose reels systems shall comply with one of the following below;</td></tr>
<tr><td colspan="2">(a) AS 2419.1 where connected to fire hydrant systems</td><td></td><td></td></tr>
<tr><td colspan="2">(b) AS/NZS 3500.1 where connected to another water supply</td><td></td><td></td></tr>
<tr><td colspan="2">(c) AS 2118.1 where connected to automatic fire sprinkler systems</td><td></td><td></td></tr>
</table>

Table 18.2a
Summary of Installation Standards – Test Requirements

System	Standard or Code	Test Pressure kPa	Duration of Test
Fire Sprinkler	AS 2118.1 Automatic Sprinkler Systems Part 1: General Systems Clause 7.9.3	1.4MPa or 400kPa in excess of the maximum static working pressure whichever is the greater	2 hours
Fire Sprinkler: Wall Wetting	AS 2118.2 Automatic Sprinkler Systems Part 2: Drencher Systems Clause 5.3	1500kPa or 1.5 times the maximum working pressure whichever is the greater	2 hours
Fire Sprinkler: Residential	AS 2118.4 Automatic Sprinkler Systems Part 4: Sprinkler Protection for Accommodation Building not Exceeding Four Storeys in Height Clause 6.2	1.4MPa or 400kPa in excess of the maximum static working pressure whichever is the greater	2 hours
Fire Sprinkler Home Fire Sprinkler	AS 2118.5 Automatic Sprinkler Systems Part 5: Home Fire Sprinkler Systems Section 6	1500kPa	Not less than 30 minutes

Table 18.2b
Summary of Fire Sprinkler Standards - Test Requirements

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Allowable Make-up Water Used During Testing

The maximum amount of make-up water that may be used during hydrostatic testing to maintain the required hydrostatic test pressure can be determined by using the following formula:

$Q \leq 0.14 \times 10\text{-}3\ LDH$

Where:

Q = Maximum allowable make-up water, in litres per hour.
L = Length of the test section, in metres
D = Nominal diameter of the test section, in metres.
H = Average test head over the length of the test section, in metres (1 metre head = 9.81 kPa.).

Some designers or engineers may require a pressure test of 1500 kPa for a period of two hours. The Plumbing Code of Australia also list performance requirements for services.

Failure During Testing

During testing consideration should be given to failure of the pipe, pipe joints or fittings. It is not uncommon for an installer to have accidently not completed a joint or not appropriately bracketed the pipework before undertaking the pressure testing.

Note:
The allowable make-up water is not a leakage allowance, but is an allowance to cover the effects of the test head forcing small quantities of entrapped air into solution.

Note:
Check the maximum test pressure of the pipe material and any other materials that are connected to the system prior to any pressure testing.

This can result in flooding of a building, carpark, lift well, damage to electrical services and other items within a building. All joints should be thoroughly checked then rechecked to ensure they have been undertaken prior to any water being flushed into a system or testing being undertaken.

The installer should have on standby equipment to stop or mop up any water that has accidently been discharged. Signage should be installed at the water meter and major plant areas indicating that testing is in progress.

Any valves that could be opened during testing should be secured shut to prevent injury should the valve be opened and the high pressure released.

Records

Maintaining records of testing is advisable as in the future the test information can often be relied upon to prove the system integrity. The documents can help prevent legal action down the track.

The installer should have the pressure testing witnessed and signed off by an independent person/inspection body.

If drawings are available for an installation a separate set can be kept and marked up to record the progress of testing and when it was undertaken.

Commissioning

The following items that should be considered by the installer;

- Ensure all valves are operating satisfactorily.
- Ensure all taps and outlets are operating satisfactorily.
- Remove all entrapped air from the pipework system and valves.
- Ensure the heated water storage/delivery temperature is above 60^0C.
- Ensure that the Thermostatic Mixing valves and tempering valve have been commissioned and there temperatures checked.
- Ensure water hammer is not present in the system.
- Undertake a pressure and flow test for the fire hose reels in accordance with AS 2441.
- Undertake a pressure and flow test for the hydrant system in accordance with AS 2419.1.
- Ensure all valves are strapped and locked in accordance with AS 2441 and AS 2419.1

Safety When Testing

The size, shape, strength and rating of all parts of the testing aperture and connections should be capable of withstanding the pressures being exerted on the pipework system.

Consider providing safety guards to equipment to protect the user of the test rig should a hose burst.

Allow to have equipment on standby should a leak occur to prevent water damage to the site.

All State and Federal health and safety regulations should be observed when undertaking the testing.

19

Chapter Nineteen

Chapter 19 – Understanding the Sustainability of Copper

EN 1057 version

International Copper Association Australia
Copper Alliance

Understanding the Sustainability of Copper

Environmental Product Declarations: Understanding the Sustainability of Copper.

Introduction

Today, materials used in buildings are increasingly being tested for their environmental impact.

In Australia, the Green Building Council of Australia has introduced Life Cycle Analysis innovation credits in the Green Star Building rating tools. This rating system will cover components in buildings such as pipes and cabling.

This section of the Design Guide introduces the concept of Environmental Product Declarations and how Australian fabricators of copper tube have progressed to certify their products.

Background

Rating the environmental impact of all the components in buildings has become a major force in the Australia construction industry.

Lend Lease is just one of the leading companies mandating the use of whole-of-life cycle analysis (LCA) and summary LCA reports called Environmental Product Declarations (EPDs) in their $6 billion Sydney harbourside development Barangaroo. They now require EPDs to be provided by all suppliers specified on the project. By inference, the idea of specifying product on such a project that does not have or will imminently have an EPD may reflect on the consultant, so best make sure up front.

Market leading manufacturers like MM Kembla have already undertaken an LCA, Crane Copper is underway with its LCA and both will be able to provide EPDs as a result of their undergoing certification with the Australian based ecolabel Global GreenTag CertTM (GreenTag).

Likewise the Green Building Council of Australia's (GBCA) introduction of whole of building LCA into Green Star in 2014 will increase the need for specification of products with EPDs.

LCA is also being used to underpin certification programs such as GreenTag and its LCA Rate Program.

Certification Program – GreenTag

International Copper Association Australia
Copper Alliance

GreenTag's GreenRate program relates to the Green Building Council of Australia's (GBCA) Interiors tools' Materials Calculators that relate only to copper used decoratively or in furniture indoors.

Reference: www.globalgreentag.com

Understanding Sustainability: the easy way….

When we want to know how sustainable any specific product really is, our approaches in the past have been somewhat haphazard. Typically we used indicators we thought represented the most important issues and usually best suited measurement, e.g. energy and water consumption, recycled content, recyclability and so on, but missed entirely the inherent variability of manufacturing.

The same product manufactured using different supply chains can have wildly different sustainability outcomes.
What this means is we can't generalise about 'this material or that material' anymore and need to focus on using known techniques to study the impacts of specific products.

To evaluate the impacts, life cycle analysis (LCA) has been developed over the last 30 years. LCA is the process of considering all impacts of a product from its raw materials acquisition ('cradle') and processing, to manufacture and packaging ('gate') and sometimes to the end of a product's useful life including cleaning and maintenance and potential for recycling ('grave' or 'end of life fate'). Hence you will often hear about 'Cradle to Gate' or 'Cradle to End of life Fate' depending on the scope and boundaries of the LCA study.

These developments have meant the growing use of LCA in buildings. This is evidenced by leading companies mandating of the use of LCA (and summary LCA reports called Environmental Product Declarations or EPDs) such as Lend Lease in their $6 billion Sydney harbourside development Barangaroo and their requirement for LCA and EPDs to be provided by all suppliers prior to orders being issued.

Further evidence of the growth in importance of LCA, is the recent introduction by the Green Building Council of Australia of major new LCA Innovation credits in their Green Star® green building rating tools in Australia where increasingly from 2014 on all components in a building will fall within the 'Whole Building LCA' credit requirements including pipes and cabling. International green building rating schemes such as LEED (US and 134 other countries including Australia) and BREEAM (UK and 40 other countries) as well as HQE (France) and DGNB (Germany and 14 other countries) already include LCA based credits.

The importance of LCA and its simplified EPD reporting is that together they provide a more holistic view of products' impacts across a wider cross section of environmental and health impacts than typical pass/fail ecolabel systems.

In Australia both MM Kembla and shortly Crane Copper have undertaken supply chain specific LCA and provided that data to the Global GreenTag CertTM certification program.

Global GreenTag

Global GreenTag is the industry's only ACCC approved Certification Mark program. GreenTag comprises two 'separate' certification programs:

The GreenTag GreenRate program relates to the Green Building Council of Australia's (GBCA) Interiors tools' Materials Calculators. These would only relate to copper used decoratively within buildings or in indoor furniture.

The GreenTag LCARate program uses 'beyond LCA' whole-of-life, sustainability assess criteria (SACs) that are scored, weighted and turned into a GreenTag EcoPOINT score between +1 and -1, where the smaller the number the better.

The six SACs are:

- Synergy (how the product makes other systems more efficient);
- Heath and Ecotoxicity;
- Greenhouse Emissions (embodied carbon);
- Biodiversity impacts (physical);
- Life Cycle Analysis (Eco-indicator-99 score);
- Corporate Social Responsibility.

Depending on the EcoPOINT a Bronze, Silver, Gold or Platinum rating mark is awarded.

All of this information is then included in a Product Scorecard modelled on nutrition labelling and made available for viewing in the **www.globalgreentag.com** list of certified products.

Full Product Assessment Reports that provide transparent results of the certification assessment are then included on **www.ecospecifier.com.au**

What the product specific LCA of GreenTag demonstrates is that sustainability is more complex than being able to generally talk about 'materials', but using GreenTag EcoPoints and Certification Mark Ratings can dramatically simplify the job of making more sustainable decisions.


Certificate of Authorisation

This is also to Certify that the following product/s have been found in conformance with the ecospecifier global GreenTag* Scheme Standard for the Tier and Level noted herein:

Copper Tube - Plumbing [eco-point 0.43]
Copper Tube - Refrigeration [eco-point 0.43]

Green Star* Credits:
Mat: Recycled Content and Re-used Products and Materials (26% PC Recycled Copper)

Licenced Sites:
Port Kembla, NSW

Licence No.:
MMK-001-A-2012

Licenced Date:
5th April 2012

Re-certification Date:
5th April 2013

GreenTag* Standard version:
Standard Version 3.1

Sustainability Assessment Category	AVERAGE SCORES
Building Synergy	n/a
Health & Ecotoxicity	0.10
Biodiversity	0.18
LCA Score	0.41
GHG = 2.8kgCO$_2$e/lm*	0.95
Social Responsibility	0.40

20

Chapter Twenty

Chapter 20 – Industry Terminology

EN 1057 version

International Copper Association Australia
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Industry Terminology

Abbreviations, Symbols, Definitions, Terminology and Conversion.

Industry Terminology – Used in this E-Design Manual

Abbreviations & Symbols – Used in the E-Design Manual		
Abbreviations	**Symbols**	**Items**
BV		Balancing valve
B	-	Basin
Bth	-	Bath
CV		Check valve
CWM	-	Clothes washing machine
CW	-	Cold water
Cu	-	Copper
Dia	Ø	Diameter
DW	-	Dish washing machine
DCV		Double check valve
DFH		Dual fire hydrant
-		End cap
FHR		Fire hose reel
FH		Fire hydrant (single)
-		Flexible connection
FV		Float valve
-		Flow direction
HT		Hose tap
HW	-	Hot water
HWR	-	Hot water return
HWU	-	Hot water unit
IV		Isolation valve
LT	-	Laundry tub
NRV		Non return valve
-		Pipe dropper
-		Pipe riser
PLV		Pressure limiting valve
PRV		Pressure reduction valve
-		Pump
RPZD		Reduced pressure zone device
SHR	-	Shower
SK	-	Sink
-		Solenoid valve
SV		Stop valve
STR		Strainer
TPR		Temperature pressure relief valve
TMV		Thermostatic mixing valve
Un		Union
Ur	-	Urinal
WC	-	Water closet
WM		Water meter

Abbreviations & Symbols
– Used in the E-Design Manual

International Copper Association Australia
Copper Alliance

Industry Associations, Institutes and Authority Abbreviations for Water Supply Systems	
AGA	**Australian Gas Association** AGA is a licencing body governing the rules, regulations and approvals of all products and materials used on gas installations within Australia.
ANSI	**American National Standards Institute** Usually used as a dimensional spec for pipe, fittings and flanges. e.g. pipe to ANSI B36.10, flanges to ANSI Class 150.
AS	**Australian Standards** Standards are published documents setting out specifications and procedures designed to ensure products, services and systems are safe, reliable and consistently perform the way they were intended to. They establish a common language which defines quality and safety criteria.
BSP	**British Standard Parallel thread.** A type of Male Taper – Female Taper parallel thread used in most low pressure fittings and valves. This is the most common thread used in Australia and is used in most general plumbing, air, water and low pressure applications on AS 1074 pipe, galvanised, brass and black steel fittings.
DIN	**Deutsches Institut für Normung.** German standards organisation.
Standards Australia	Standards Australia is the nation's peak non-government Standards organisation. It is charged by the Commonwealth Government to meet Australia's need for contemporary, internationally aligned Standards and related services.
Standards Mark	A trademark of Standards Australia, granted under licence to products manufactured under a quality assurance program and that meet a specific Australian or International Standard.
WaterMark	WaterMark approval of a product indicates that it has been tested and has passed a number of requirements regarding its suitability for supplying water for household use and human consumption. WaterMark approval is mandatory for plumbing products intended to be connected to municipal water mains in all parts of Australia.

Industry Associations, Institutes and Authority Abbreviations for Water Supply Systems

International Copper Association Australia
Copper Alliance

Definitions

Access Opening: An opening in a building element, fitted with a removable cover, to allow maintenance of a concealed pipe, fixture or other apparatus.

Accessible: Capable of being reached for the purposes of inspection, maintenance, repair, or replacement, but may first require removal of an access panel, cover, door or similar obstruction.

Aerator: A device to introduce air into the flow of a liquid.

Air Gap: Water supply system - The unobstructed vertical distance through the free atmosphere between the lowest opening of water service pipe or fixed outlet supplying water to a fixture or receptacle and the highest possible water level of such fixture or receptacle.

Ambient Temperature: The average temperature of the atmosphere at a given location. This text refers to the ambient temperature of water to mean the most likely temperature of water in the water mains.

Back Flow Prevention: A device to prevent the reverse flow of water from a potentially polluted source into a potable water supply system.

Bracket: A projecting support for a shelf, pipe or other part.

Cavitation: The formation, growth and collapse of vapour cavities in a liquid following a drop in pressure usually associated with a large local increase in velocity, as in a pump.

Dead Leg: A branch pipe in a hot water system containing dead water.

Design Life: The period of time, stated by the manufacturer, that a device or system is expected to perform without requiring major maintenance or replacement.

Dezincification: Corrosion of copper/zinc alloys involving loss of zinc leaving a residue of spongy or porous copper.

Dezincification Resistant (DR): A material that is not susceptible to corrosion of copper/zinc alloys involving loss of zinc leaving a residue of spongy or porous copper, (see AS 2345).

Drinking Water: Water that is suitable for human consumption, food preparation, utensil washing and oral hygiene (see AS/NZS 4020).

Dynamic Pressure:

- The pressure in pipework under flow conditions (also called flow pressure).
- The pressure resulting from a change in velocity of the fluid stream (also called hydraulic shock—see water hammer).

Expansion Loop: A loop in a pipeline, which, by flexing, can accommodate expansion and contraction movements due to temperature change.

Flow Pressure: The pressure recorded while there is a flow from the outlet/fixture.

Fire Service: A service comprising water pipes, fire hydrants, fire hose reels, fittings, and including water storage or pumping facilities, which is installed solely for firefighting and extinguishing purposes in and around a building or property. Under certain conditions part of a fire sprinkler system may be included.

Fixture: A receptacle with necessary appurtenances designed for a specific purpose, the use or operation of which results in a discharge into the sanitary plumbing or sanitary drainage installation.

Head Loss: The difference in pressure of a fluid between two points (one high the other low) expressed in metres head (m/h) kilopascals (kPa) or bar.

Head Pressure: The pressure at a given point in the pipe system. It can be expressed in metres head (m/h) kilopascals (kPa) or bar.

Header Tank: A water storage tank located at the top of a building.

Heated Water: Water that has been intentionally heated. It is sometimes referred to as hot water or warm water.

Heated Water Service: All parts of the installation including the water heater and all equipment and materials necessary to provide a supply of heated water at the specified outlets.

- Direct system—a heated water service in which the water supplied to the draw-off points is heated by a primary source of heat such as solid fuel, gas, electricity or oil.
- Indirect system—a heated water service in which the water supplied to the draw-off points is heated by means of a calorifier.

Installation: The construction of pipework and fixtures in position for service and use. The network of pipework and fixtures.

Joint: the result of a joining together of two or more parts of a construction

Loading Unit: A weighted factor, applied to a fixture or appliance, used for the estimation of simultaneous water usage rates, which takes into account the flow rate, length of time in use and frequency of use.

Maximum Working Pressure: The maximum pressure that can be sustained with a factor of safety, by the type and class of pipe or fitting for its estimated useful life under the anticipated working conditions.

Most Disadvantage Outlet: The fixture or outlet with the highest head loss, caused by a combination of friction in the pipe and fittings and the loss due to static head. It is not necessarily the furthest fixture or outlet from the water supply.

Network Utility Operator: A person who—
(a) Undertakes the piped distribution of drinking and/or non-drinking water for supply;

or

(b) Is the operator of a sewerage system or a stormwater drainage system.

Nominal Pressure (PN): An alphanumeric designation, for reference purposes, related to the mechanical characteristics of a component of a pipework system.

Notes:
- Nominal pressure is designated by the letters PN following by the appropriate reference number as specified in the relevant pipework component standard. The designation PN is not meaningful unless it is related to the relevant component standard number.
- The number following the PN designation does not represent a measurable value and, therefore, should never be used in calculations nor be followed by a unit.
- The maximum allowable working pressure of a pipework component depends on the material of the component, its design and working temperatures, and is given in tables of pressure/temperature ratings specified in the appropriate Standards.

Nominal Size (DN): A numerical designation of size, which is common to all components in a piping system other than components designated by outside diameters or by thread size. It is a convenient round number for reference purposes and is only loosely related to manufacturing dimensions.

Notes:
- Nominal size is designated by DN followed by a number.
- Not all piping components are designated by nominal size, for example, steel tubes are designated and ordered by outside diameter and thickness.
- The nominal size (DN) cannot be subject to measurement and is not to be used for purposes of calculation.

Non-Drinking Water: Any water other than drinking water.

pH: A measure of the acidity or alkalinity of a liquid. The pH scale extends from 0 (very acid) to 14 (very alkaline) with neutral solution having a value of 7.

Pipe: A single length of tube, usually of circular cross-section, used for the conveyance of fluids.

Pipe Clip: A fixing arrangement designed to fit around a pipe or fitting and having provision for fixing to a support.

Pipe Hanger: A device for suspending piping from a structure.

Pipe Support: A device for supporting and securing piping to walls, ceilings, floors or structural members.

Piping: A line of pipes, with or without valves or other fittings, connected together for the conveyance of liquids or gases.

Plumbing System: Fixtures, fittings, pipes, materials, or appliances other than the sanitary drain, used for the collection and conveyance of any wastes or wastewaters from any premises and includes all vents, flashing and water service connected therewith.

Pressure – Limiting Valve: A valve used to limit water pressure with minimum loss of flow.

Probable Simultaneous Demand: The probable maximum flow rate for pipework supplying multiple dwellings, based on the usage patterns in domestic installations.

Probable Simultaneous Flow Rate: The probable maximum flow rate in branch pipework within an individual dwelling, based on the loading units ascribed to the fixtures or appliances connected to the particular branch pipe.

Property Service: The pipes and fittings used or intended to be used for the supply of water to a property, from the water main up to and including the meter assembly, or to the stop tap if no meter is required.

Pump: A mechanical device generally driven by a prime mover, and used for raising fluids from a lower to a higher level or for circulating fluid in a pipework system.

Reduced Level: A surveying term referring to levels that are coordinated and relate to each other.

Regulatory Authority: The authority that is empowered by statute to exercise jurisdiction over the installation of water, plumbing, sewerage or stormwater works.

Residual Pressure: The excess pressure beyond that required to service the outlet after all head losses and static pressure has been taken into account.

Riser (Water Supply): Any vertical section of pipe for conveying water from a lower to a higher level (see also dropper).

Static Head: That part of the total head/ pressure, which is equal to the static height difference between the inlet and outlet of a pipe system.

Static Pressure: The pressure recorded when there is no flow or movement in the reticulating pipe system.

Strainer: A device for separating solid matter above a nominated size from liquid, to prevent such matter from entering a pump, valve, meter or pipework.

Tap:
A valve with an outlet used as a draw-off or delivery point including;

- Bib tap: A screw-down pattern or ceramic disc draw-off tap with horizontal inlet and free water outlet.
- Combined water taps coupled together with a common outlet nozzle, which may be either fixed or swivelling, so as to discharge hot, cold or mixed water.
- Draw-off tap: A tap for the purpose of drawing off water.
- Electronic tap: A tap activated by a sensor beam and solenoid valve. The temperature of the water is normally preset.
- Hose tap: A tap with an external screw thread on the outlet for the attachment of the coupling of a flexible hose.

- In-line tap: A tap with the centre-line of both the inlet and the outlet in-line.
- Isolating tap: An in-line tap for insertion into the pipeline to deliver water to a tap, valve, fixture, or combination thereof, and which is shut only for maintenance or failure of the downstream installation.
- Main tap: A tap installed in the main water supply line.
- Mixing tap: A tap into which hot and cold water entering through separate ports are mixed in a chamber and then delivered through a single common outlet, the temperature of the mixed water being controlled by the operation of a control handle or handles.
- Self-closing tap: A tap that is opened by pressure on, or by twisting the top of, the operating spindle. The tap, when the pressure is released, closes under the action of a spring or of water pressure.
- Spray tap: A tap that delivers a restricted rate of flow in the form of a spray.
- Stop tap: A screwdown pattern tap with horizontal inlet and outlet connections. It usually incorporates a loose jumper valve, permitting flow in one direction only.

Valve: A device for controlling the flow of a fluid, having an aperture that can be wholly or partially closed by the movement relative to the seating of a component in the form of a plate or disc, a door or gate, a piston, a plug or a ball or flexing of a diaphragm.

Wall Thickness: The thickness of the wall of a pipe, fitting or fixture, not including any lining or coating.

Water Hammer: Pressure surges in a closed pipe system as the result of a sudden change in velocity of the liquid, e.g., by a valve closure or pump start or stoppage.

Water-Hammer Arrestor: A device to lessen or eliminate water hammer.

Water Heater: An appliance, designed to provide heated water.

Water Service: That part of the cold water supply pipework from the water main up to and including the outlet valves at fixtures and appliances.

Water Supply:

- Grey water reuse systems: A system where grey water (wastewater but not soil or black water), is collected, not treated and re-used for acceptable purposes.
- Network utility operator's supply: Drinking water provided by a water distributor through a reticulated water system.
- Recycled water: Water that has been treated and provided for reuse by a water distributor through a reticulated water system.
- Reticulated disinfected - reclaimed water systems: A system where soiled water is collected, treated to acceptable minimum standards of controlled disinfection and then reticulated to properties.
- Water supply systems (alternative): Water sourced from other than Network Utility Operators Supply, i.e., river, bores or ground water, creek lakes or drinking water reclaimed after use.

Velocity: The speed at which water passed through the pipes.

Viscosity: The property of a fluid (in this case water) in resisting change in the shape or arrangement of its elements during flow. The lower the viscosity, the "thinner" the water and the more easily it flows.

Note:
Additional definitions for plumbing (cold and heated) services can be found in the installation standard for plumbing AS/NZS 3500 Part 0 Glossary of Terms.

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A

Appendix A

KEMBLA

Crane Copper Tube

watermark services group

AHSCA

The Association of Hydraulic Services Consultants Australia

Appendix A – Acknowledgments

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Acknowledgments

Together we can achieve excellence in training.

The Copper Alliance would like to thank the following people and companies for their contribution to this Hydraulic Design Guide Manual.

This manual will provide an excellent opportunity for Plumbers and Hydraulic Consultants, TAFE Teachers and Apprentices to appreciate the latest technology in the domestic, industrial and commercial plumbing market sectors.

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– *Flexistrut*

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– *Zetco.*

James Gorringe
– *Istilil Pty Ltd.*

Technical References

In compiling this design guide selected reference manuals, product brochures, standards and other technical literature were used to support the technical information included.

Rheem Commercial Hot Water
– *Rheem*

Grundfos System Guide
– *Grundfos*

Selection and Sizing of Copper Tubes for Water Piping Systems
– *Barrie Smith*

Pipe Sizing for Building Services
– *Paul Fennell*

Average Daily Water Use
– *Sydney Water*

Domestic Hot Water Circulation System
– *Danfoss*

Design Guide For Gas Centralised Hot Water Systems
– *Jemena NSW*

Design Consideration For Water Supplies In Apartment Building Flats
– *Anglicanwater*

Services Hot Water (SHW) Provisions Research Paper for Commercial Buildings
– *Australian Building Codes Board*

Pipe Hangers and Supports
– *Cooper B-Line*

Engineering and Piping Design Guide
– *Fiberglass Glass Systems*

Australian Drinking Water Guidelines 6. 2011
– *Australian Government, National Health and Medical Research Council, National Resource Management Ministerial Council*

Zetco Valves Design Manual
– *Zetco*

Various Reference Materials
– *Copper Development Association Inc.*

Australian and International Standards References

AS/NZS 3500 Plumbing Series Documents
– Standards Australia

AS 2419 Fire Hydrants
– Standards Australia

AS 2441 Fire Hose Reels
– Standards Australia

AS 3688 Metallic Fittings
– Standards Australia

AS 2118 Automatic Fire Sprinkler Systems
– Standards Australia

AS 4089 Copper Pipe and Fittings - Installation and Commissioning
– Standards Australia

AS 1432 Copper Tubes For Plumbing, Gasfitting and Drainage Applications
– Standards Australia

AS 4041 Pressure Piping
– Standards Australia

AS/NZS 5601 Gas Installations
– Standards Australia

Business Acknowledgments

Copper Alliance
– www.copperalliance.org

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– www.copper.com.au

MM Kembla
– www.kembla.com

Crane
– www.cranecopper.com.au

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– www.aquamax.com.au

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– www.zetco.com.au

Aquacell Pty Ltd.
– www.aquacell.com.au

Emerald Media Group Pty Ltd
– www.emeraldmediagroup.com.au

Appendix B

PIPE SIZING CALCULATIONS CU COLD WATER PIPING Based on max. Velocity of 2.0m/s @ 20⁰C through TYPE B Copper Tube Pipe System			
Pipe Size (MM)	Loading Units	Flow Rate (L/S)	Friction Loss at Peak Flow in M/100
20	25	0.40	28.31
25	55	0.60	19.24
32	100	1.00	14.39
40	160	1.60	11.67
50	360	2.60	9.48
63	760	4.00	6.76
75	1525	5.80	5.61
90	2480	8.00	4.18
110	4240	12.00	3.30

PIPE SIZING CALCULATIONS CU HOT WATER PIPING Based on max. Velocity of 1.6m/s @ 60⁰C through TYPE B Copper Tube Pipe System			
Pipe Size (MM)	Loading Units	Flow Rate (L/S)	Friction Loss at Peak Flow in M/100
16	5	0.20	41.07
20	13	0.30	29.85
25	45	0.50	25.40
32	75	0.80	17.33
40	120	1.20	12.23
50	240	2.00	10.52
63	490	3.20	7.89
75	1000	4.60	6.62
90	1960	6.80	5.52
110	3320	10.00	4.24

PROJECT FIXTURE TOTAL						
Fixture Description	Allowance Per Fixture		Fixture	Loading Unit (L.U.) Total		
	L/S	L.U.	No.	CW	HW	RCW
Basin	0.1	1	465	465	465	
Bath	0.3	8	12	96	96	
Cleaners Sink	0.2	3	18	54	54	
Water Closet	0.1	2	203			406
Drinking Fountain	0.05	0.5	1	0.5		
Sink	0.2	3	100	300	300	
Tub	0.2	3	2	6	6	
Shower	0.12	2	111	222	222	
Dishwashing Machine	0.2	3	25	75	75	
Boiling Water Unit	0.05	0.5	26	13	13	
Ice Machine	0.05	0.5	8	4	4	
Utensil Washer	0.2	3	16	48	48	
Flushing Sink	0.1	2	19	38	38	
Scrub Trough	0.2	3	4	12	12	
Hose Tap	0.3	8	31	248		
Baby Bath	0.2	3	13	39	39	
Bidet			1	2	2	
Total				1622.5	[illegible]	
Litres Per Sec (L/S)						

Appendix B – Pipe Sizing Guide

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Pipe Sizing Guide

Cu

Guide to the application of selection and sizing of copper tubes for water piping systems.

Gathering Information

The First Step for All Pipe Sizing

- The dimensions of the building including floor levels and location of all plumbing fixtures.
- Location of other services and obstacles.
- Planning the layout, determining the path of piping. This is critical, because the actual length of piping is an important contributing factor to the pressure losses.
- Obtaining pressure and flow information from the water authority.

Note:
Peter Wenning of Wenning Technical Services Pty Ltd has created this pipe sizing guide to the application of 'Selection and sizing of copper tubes for water piping systems' By **Barrie Smith**.

Pressure and Flow Data

- Pipe sizing for ***heated*** and ***cold*** water is based on the minimum available head. (AS/NZS 3500.1,3.3.1)
- Pipe sizing for ***fire hydrant installations*** is based on the residual pressure to the property available 95% of the time as determined by the water authority. (AS 2419.1,2.3.3)
- Pipe sizing for ***fire hose reels*** is based on the minimum available head. And must include allowances for probable simultaneous flows. (AS 2441)

Example:

Pressure and Flow Date Water Pressures:

Princes Highway – Dandenong, Melway: 89 K2
(typical sample application)

Thank you for your application dated for Mains Pressure and Flows.

Note:
That applications for Pressure and Flow information can now also be lodged via South East Water's Web page www.southeastwater.com.au by clicking on "Pressure and Flow Information".

The information you have requested is as follows:

1. Maximum Pressure - 46.0m head (450.8 kPa).
2. Minimum Pressure – 38.2m head (374.3 kPa).
3. > Flow of 10.0 l/sec at 37.6 m residual pressure.
   > Flow of 20.0 l/sec at 37.0 m residual pressure.
   > Flow of 30.0 l/sec at 36.3 m residual pressure.
   > Flow of 40.0 l/sec at 35.7 m residual pressure.
   > Flow of 50.0 l/sec at 34.9 m residual pressure.
4. Size and location of main: 225mm MSCL – 2.4m from West B.L. of Princes Highway (see attached plan).
5. Based on the reduced level at the tapping point of 44.0m (AHD).
6. Analysis of the South East Water's onfield monitoring equipment shows that a minimum residual pressure available for 95% at the time at this location is 42.6m (417.5 kPa).

‘Selection and Sizing of Copper Tubes for Water Piping Systems’ by Barrie Smith

Equivalent Length Method:	**Velocity and Pressure Loss Method:**
Calculating pressure losses through fittings relating the loss to that through an equivalent length of pipe. Only useful for flows <=1.5 m/s.	Calculating pressure losses through valves & fittings using data that gives the actual pressure loss. *As applied in this guide.*

Step 1: Draw External Layout and Assign Flow Rates

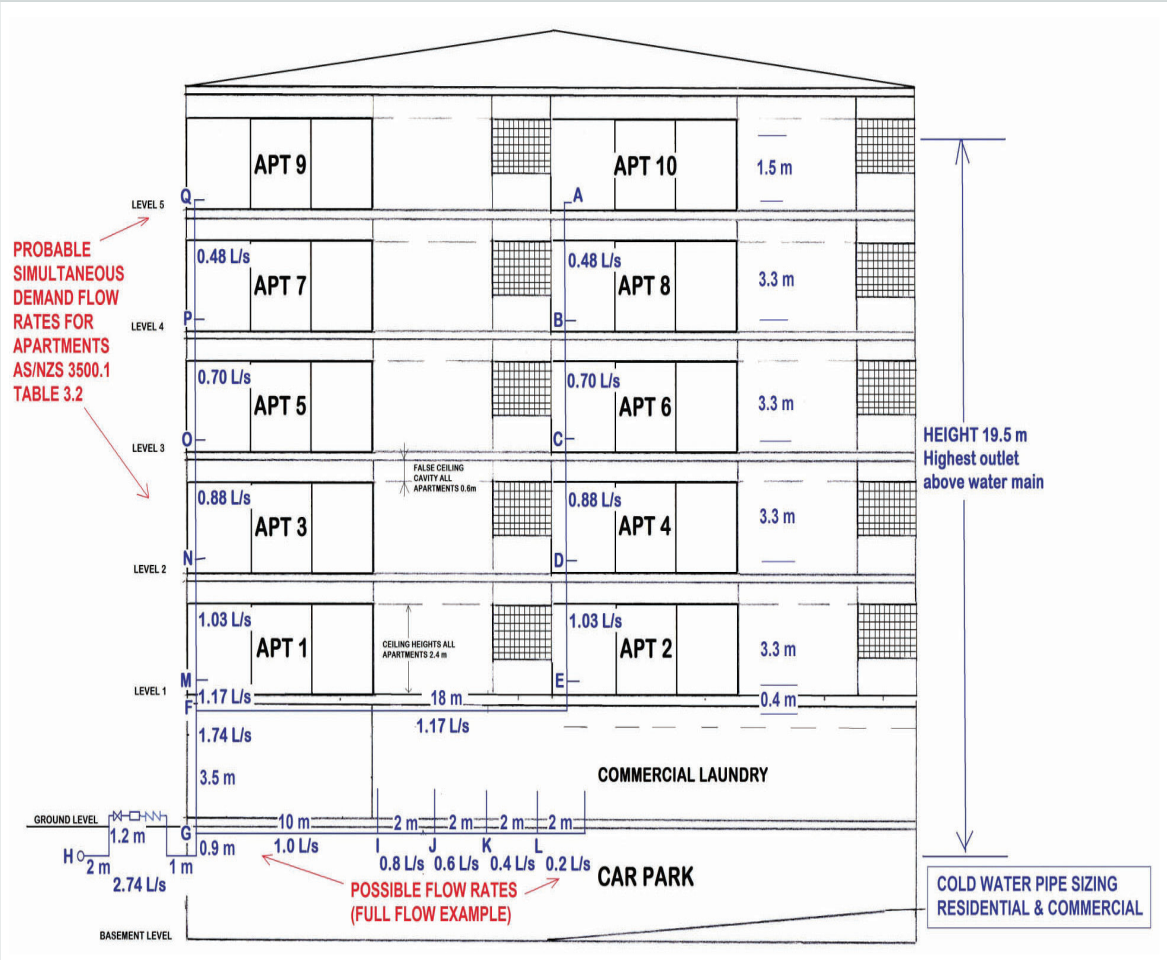

Figure 1
Draw External Layout and Assign Flow Rates

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Step 2: Draw internal Layout and Assign Loading Units

LU (Loading Units) assigned to fixtures from Table 3.1. (AS/NZS 3500.1).

Label Longest Run with Small Letters.

Pipe sections labelled with loading unit totals.

Enter labelled pipe sections and loading units into **Pipe Sizing Tabulation Sheet.**

Apartment 10 (Most disadvantaged outlet)

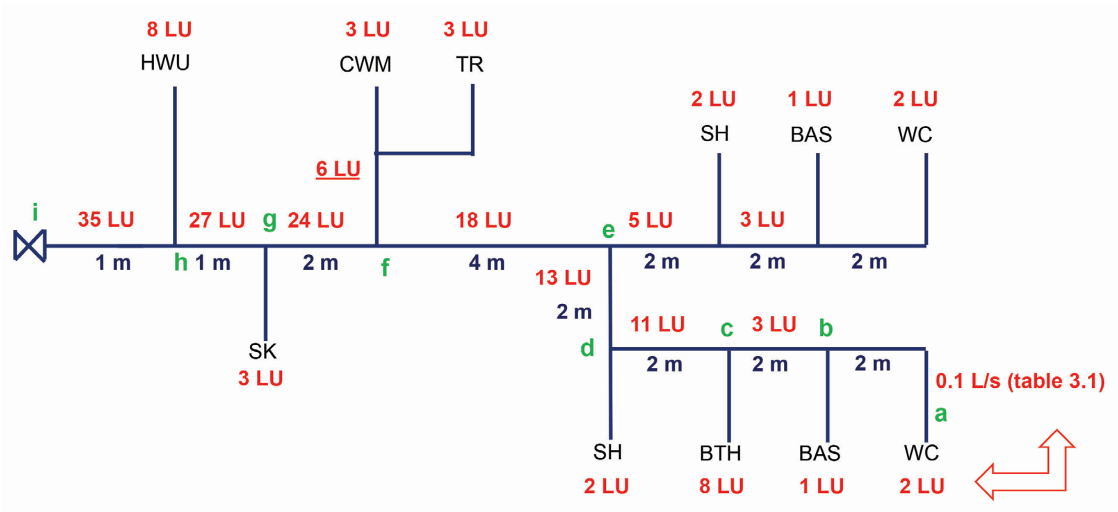
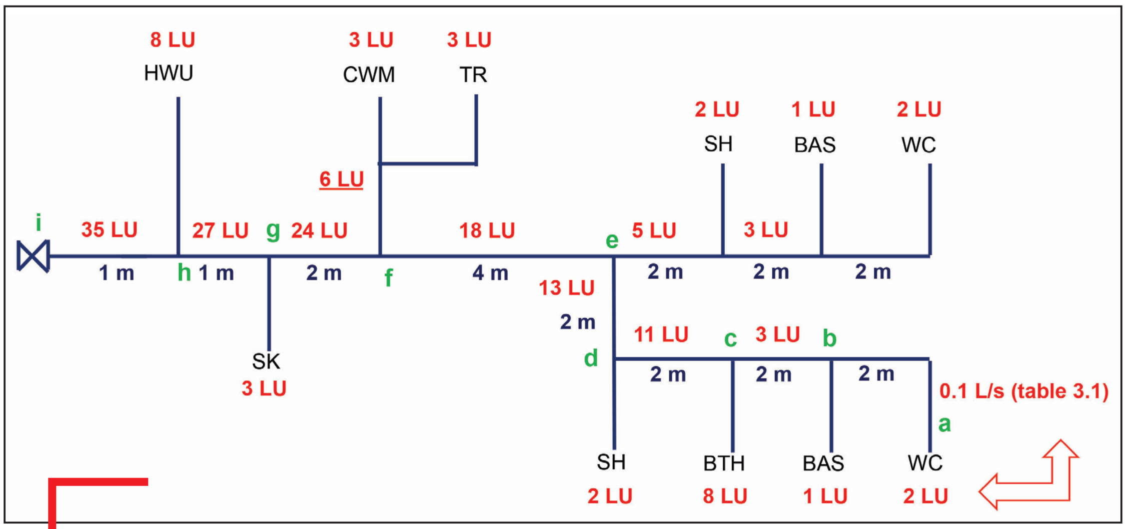


Figure 2
Draw Internal Layout and Assign Loading Units

Step 3: Enter basic data into Pipe Sizing Tabulation Sheet

For normal domestic situations, the internal cold water pipe sizing will be known, however the **Pressure Loss Must Still Be Calculated.**

In this example the pressure loss will be 4.175 m.



PIPE SIZING TABULATION SHEET												
FITTINGS AND VALVES VELOCITY PRESSURE LOSS METHOD												
PIPE SECTION	LOADING UNITS	FLOW RATE	FITTINGS & VALVES				PIPE SECTION LENGTH	PRESSURE LOSS PER 100 m TUBE	VELOCITY	TUBE SIZE	FITTINGS & VALVES PRESSURE LOSS	PIPE SECTION PRESSURE LOSS
					Head loss factor	Pressure loss each $m=K^*(v^2/2g)$						
Labelled	No	L/s	No	Type	K	m. head	m	m. head	m/s	DN	m. head	m. head
a-b	*	0.1					2			15		
a-b	*	0.1	1	elbow						15		
a-b	*	0.1	1	reducer						15		
b-c	3	0.14					2			20		
b-c	3	0.14	1	flow tee						20		
c-d	11	0.28					2			20		
c-d	11	0.28	1	flow tee						20		
d-e	13	0.3					2			20		
d-e	13	0.3	1	branch tee						20		

Entering Basic Data into Pipe Sizing Tabulation Sheet

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Step 4: Enter Flow Rates into Pipe Sizing Tabulation Sheet

The flow for a pipe to a single fixture is assigned from Table 3.1 in AS/NZS 3500.1. The flow to a pipe serving more than one fixture is based on the loading units from Table 3.3. For example 3 loading units = 0.14 L/s.

Step 5: Enter Tube Sizes into Pipe Sizing Tabulation Sheet

Under normal circumstances (other than internal of one domestic unit) pipe sizing is done progressively, calculated from the furthest point from the supply.

For normal internal domestic cold water pipe sizing the pipe sizes are known ie: DN 20 & 15. No more than 3 m of DN 15 branch (Ref AS/NZS 3500.1)

Step 6: Enter Pipe Lengths And Fittings Into Pipe Sizing Tabulation Sheet

The fittings must be related to the pipe section and flow.

Example:

The reducer for a-b is only carrying the flow for a-b. The flow tee at b-c is carrying the flow to two fixtures.

Note:
Flow tee vs branch tee.

Step 7: For Each Pipe Section, Determine The Velocity

The maximum velocity is 3 m/s, however it is best practice to keep the flow velocity at or around 2.2 m/s.

Note:
Maximum velocity for general services 3 m/s (AS/NZS 3500.1, 3.4) Maximum velocity for fire hydrant installations 4 m/s (AS 2419.1, 2.2.1)

PIPE SIZING TABULATION SHEET												
FITTINGS AND VALVES VELOCITY PRESSURE LOSS METHOD												
PIPE SECTION	LOADING UNITS	FLOW RATE	FITTINGS & VALVES				PIPE SECTION LENGTH	PRESSURE LOSS PER 100 m TUBE	VELOCITY	TUBE SIZE	FITTINGS & VALVES PRESSURE LOSS	PIPE SECTION PRESSURE LOSS
					Head loss factor	Pressure loss each m=K*(v²/2g)						
Labelled	No	L/s	No	Type	K	m. head	m	m. head	m/s	DN	m. head	m. head
a-b	*	0.1					2			15		
a-b	*	0.1	1	elbow						15		
a-b	*	0.1	1	reducer						15		
b-c	3	0.14					2			20		
b-c	3	0.14	1	flow tee						20		
c-d	11	0.28					2			20		
c-d	11	0.28	1	flow tee						20		
d-e	13	0.3					2			20		
d-e	13	0.3	1	branch tee						20		

Entering Basic Data into Pipe Sizing Tabulation Sheet

Step 7a: For Each Pipe Section, Determine The Velocity and Pressure Loss Per 100m

TABLE 2

CHAPTER 3	PRESSURE REQUIREMENTS AND LOSSES									
Topic No. 3.4	Description PIPE SIZING DATA – WATER AT 15 °C, THROUGH A.S. 1432 COPPER TUBES, TYPE B.									
FLOW Qℓ 0.01 to 0.50 LITRES PER SEC.	NOMINAL 10 mm		NOMINAL 15 mm		NOMINAL 18 mm		NOMINAL 20 mm		NOMINAL 25 mm	
	ACTUAL O.D. 9.52 mm		ACTUAL O.D. 12.70 mm		ACTUAL O.D. 15.88 mm		ACTUAL O.D. 19.05 mm		ACTUAL O.D. 25.40 mm	
	Velocity m/s	Head Loss m/100m	Velocity m/s	Head Loss m/100m	Velocity m/s	Head Loss m/100m	Velocity m/s	Head Loss m/100m	Velocity m/s	Head Loss m/100m
0.01	0.215	1.347	0.108	0.338	0.066	0.129	0.044	0.057	0.024	0.017
0.02	0.429	4.923	0.215	0.872	0.133	0.258	0.088	0.113	0.048	0.034
0.03	0.644	10.808	0.323	1.961	0.199	0.588	0.132	0.170	0.072	0.051
0.04	0.859	17.733	0.430	3.460	0.266	1.045	0.176	0.372	0.097	0.068
0.05	1.074	26.098	0.538	5.071	0.332	1.629	0.220	0.582	0.121	0.130
0.06	1.288	35.841	0.645	6.943	0.399	2.225	0.264	0.838	0.145	0.187
0.07	1.503	46.916	0.753	9.065	0.465	2.900	0.308	1.095	0.169	0.254
0.08	1.718	59.287	0.860	11.428	0.532	3.651	0.352	1.377	0.193	0.332
0.09	1.933	72.924	0.968	14.028	0.598	4.476	0.396	1.686	0.217	0.409
0.10	2.147	87.804	1.076	16.858	0.665	5.373	0.440	2.022	0.242	0.490
0.11	2.362	103.905	1.183	19.914	0.731	6.340	0.484	2.384	0.266	0.577
0.12	2.577	121.209	1.291	23.193	0.798	7.377	0.528	2.772	0.290	0.670
0.13	2.792	139.701	1.398	26.690	0.864	8.481	0.572	3.184	0.314	0.769
0.14	3.006	159.366	1.506	30.404	0.931	9.65[illegible]	0.616	3.622	[illegible].338	0.874
0.15	3.221	180.193	1.613	34.330	0.997	10.891	0.660	4.084	0.362	0.985

For Each Pipe Section, Determine The Velocity and Pressure Loss Per 100m

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Step 7b: For Each Pipe Section, Determine The Velocity and Pressure Loss Per 100m

Add the velocity and pressure loss for each pipe section and associated fittings.

0.14	3.006	159.366	1.506	30.404	0.931	9.653	0.616	3.622

PIPE SIZING TABULATION SHEET												
FITTINGS AND VALVES VELOCITY PRESSURE LOSS METHOD												
PIPE SECTION	LOADING UNITS	FLOW RATE	FITTINGS & VALVES				PIPE SECTION LENGTH	PRESSURE LOSS PER 100 m TUBE	VELOCITY	TUBE SIZE	FITTINGS & VALVES PRESSURE LOSS	PIPE SECTION PRESSURE LOSS
					Head loss factor	Pressure loss each m=K*(v²/2g)						
Labelled	No	L/s	No	Type	K	m. head	m	m. head	m/s	DN	m. head	m. head
a-b	*	0.1					2	16.858	1.076	15		
a-b	*	0.1	1	elbow					1.076	15		
a-b	*	0.1	1	reducer					1.076	15		
b-c	3	0.14					2	3.622	0.616	20		
b-c	3	0.14	1	flow tee					0.616	20		
c-d	11	0.28					2	12.191	1.232	20		
c-d	11	0.28	1	flow tee					1.232	20		
d-e	13	0.3					2	13.769	1.32	20		
d-e	13	0.3	1	branch tee					1.32	20		

For Each Pipe Section, Determine The Velocity and Pressure Loss Per 100m

Step 8: Calculate The Pipe Section Pressure Loss.

If using the Excel spreadsheet, this will be calculated for you. For example 2 metres x 3.622/100 = 0.072 m Head. Otherwise calculate manually.

PIPE SIZING TABULATION SHEET												
FITTINGS AND VALVES VELOCITY PRESSURE LOSS METHOD												
PIPE SECTION	LOADING UNITS	FLOW RATE	FITTINGS & VALVES				PIPE SECTION LENGTH	PRESSURE LOSS PER 100 m TUBE	VELOCITY	TUBE SIZE	FITTINGS & VALVES PRESSURE LOSS	PIPE SECTION PRESSURE LOSS
					Head loss factor	Pressure loss each m=K*(v²/2g)						
Labelled	No	L/s	No	Type	K	m. head	m	m. head	m/s	DN	m. head	m. head
a-b	*	0.1					2	16.858	1.076	15	0.000	0.337
a-b	*	0.1	1	elbow					1.076	15	0.000	0.000
a-b	*	0.1	1	reducer					1.076	15	0.000	0.000
b-c	3	0.14					2	3.622	0.616	20	0.000	0.072
b-c	3	0.14	1	flow tee					0.616	20	0.000	0.000
c-d	11	0.28					2	12.191	1.232	20	0.000	0.244
c-d	11	0.28	1	flow tee					1.232	20	0.000	0.000
d-e	13	0.3					2	13.769	1.32	20	0.000	0.275
d-e	13	0.3	1	branch tee					1.32	20	0.000	0.000

Calculate The Pipe Section Pressure Loss.

Step 9: Enter the Pipe Fitting 'K' Factors

Locate the correct table in the Barrie Smith book. View the <u>flow</u> Column and <u>pipe size</u> column. If using the Excel spreadsheet, only the 'K' factor is required. The 'K' factor is a pressure loss factor for fittings and valves.

TABLE 32

CHAPTER 3 — PRESSURE REQUIREMENTS AND LOSSES — TEES

Topic No. 3.5.2 — Description: PRESSURE LOSS DATA lost head $m = K \frac{v^2}{2g}$ — VELOCITY DETERMINED FROM FLOW THROUGH A.S.1432 TYPE B. COPPER TUBE PRESSURE LOSSES IN METRES HEAD FOR: TEES — LINE FLOW.

FLOW Qℓ Litres per Sec.	15 mm K = 0.9	20 mm K = 0.9	25 mm K = 0.9	32 mm K = 0.9	40 mm K = 0.9	50 mm K = 0.9	65 mm K = 0.9	80 mm K = 0.9	100 mm K = 0.9
0.10	0.053								
0.20	0.212	0.036							
0.30	0.478	0.080	0.024						

Enter the Pipe Fitting 'K' Factors

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TABLE 32

CHAPTER 3 — PRESSURE REQUIREMENTS AND LOSSES — TEES

Topic No. 3.5.2 — Description: PRESSURE LOSS DATA lost head $m = K \frac{v^2}{2g}$ — VELOCITY DETERMINED FROM FLOW THROUGH A.S.1432 TYPE B. COPPER TUBE PRESSURE LOSSES IN METRES HEAD FOR: TEES — LINE FLOW.

FLOW Qℓ Litres per Sec.	15 mm K = 0.9	20 mm K = 0.9	25 mm K = 0.9	32 mm K = 0.9	40 mm K = 0.9	50 mm K = 0.9	65 mm K = 0.9	80 mm K = 0.9	100 mm K = 0.9
0.10	0.053								
0.20	0.212	0.036							
0.30	0.478	0.080	0.024						

PIPE SIZING TABULATION SHEET

FITTINGS AND VALVES VELOCITY PRESSURE LOSS METHOD

PIPE SECTION	LOADING UNITS	FLOW RATE	FITTINGS & VALVES		Head loss factor	Pressure loss each $m=K*(v^2/2g)$	PIPE SECTION LENGTH	PRESSURE LOSS PER 100 m TUBE	VELOCITY	TUBE SIZE	FITTINGS & VALVES PRESSURE LOSS	PIPE SECTION PRESSURE LOSS
Labelled	No	L/s	No	Type	K	m. head	m	m. head	m/s	DN	m. head	m. head
a-b	*	0.1				0.000	2	16.858	1.076	15	0.000	0.337
a-b	*	0.1	1	elbow	2.2	0.130			1.076	15	0.130	0.000
a-b	*	0.1	1	reducer	1	0.059			1.076	15	0.059	0.000
b-c	3	0.14				0.000	2	3.622	0.616	20	0.000	0.072
b-c	3	0.14	1	flow tee	0.9	0.017			0.616	20	0.017	0.000
c-d	11	0.28				0.000	2	12.191	1.232	20	0.000	0.244
c-d	11	0.28	1	flow tee	0.9	0.070			1.232	20	0.070	0.000
d-e	13	0.3				0.000	2	13.769	1.32	20	0.000	0.275
d-e	13	0.3	1	branch tee	2.1	0.187			1.32	20	0.187	0.000

Enter the Pipe Fitting 'K' Factors

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Step 10: Calculate the Pipe Fitting Pressure Losses

When using the Excel spreadsheet, this will be calculated for you.

For example 0.9 x (0.616²/19.6) = 0.017 m Head. Otherwise calculate manually.

PIPE SIZING TABULATION SHEET													
FITTINGS AND VALVES VELOCITY PRESSURE LOSS METHOD													
PIPE SECTION	LOADING UNITS	FLOW RATE	FITTINGS & VALVES				PIPE SECTION LENGTH	PRESSURE LOSS PER 100 m TUBE	VELOCITY	TUBE SIZE	FITTINGS & VALVES PRESSURE LOSS	PIPE SECTION PRESSURE LOSS
					Head loss factor	Pressure loss each $m=K*(v^2/2g)$						
Labelled	No	L/s	No	Type	K	m. head	m	m. head	m/s	DN	m. head	m. head
a-b	*	0.1				0.000	2	16.858	1.076	15	0.000	0.337
a-b	*	0.1	1	elbow	2.2	0.130			1.076	15	0.130	0.000
a-b	*	0.1	1	reducer	1	0.059			1.076	15	0.059	0.000
b-c	3	0.14				0.000	2	3.622	0.616	20	0.000	0.072
b-c	3	0.14	1	flow tee	0.9	0.017			0.616	20	0.017	0.000
c-d	11	0.28				0.000	2	12.191	1.232	20	0.000	0.244
c-d	11	0.28	1	flow tee	0.9	0.070			1.232	20	0.070	0.000
d-e	13	0.3				0.000	2	13.769	1.32	20	0.000	0.275
d-e	13	0.3	1	branch tee	2.1	0.187			1.32	20	0.187	0.000

Calculate the Pipe Fitting Pressure Losses

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Step 11: Stop and Review, Sized Internal Piping

PIPE SIZING TABULATION SHEET												
FITTINGS AND VALVES VELOCITY PRESSURE LOSS METHOD												
PIPE SECTION	LOADING UNITS	FLOW RATE	FITTINGS & VALVES				PIPE SECTION LENGTH	PRESSURE LOSS PER 100 m TUBE	VELOCITY	TUBE SIZE	FITTINGS & VALVES PRESSURE LOSS	PIPE SECTION PRESSURE LOSS
					Head loss factor	Pressure loss each $m=K*(v^2/2g)$						
Labelled	No	L/s	No	Type	K	m. head	m	m. head	m/s	DN	m. head	m. head
a-b	*	0.1				0.000	2	16.858	1.076	15	0.000	0.337
a-b	*	0.1	1	elbow	2.2	0.130			1.076	15	0.130	0.000
a-b	*	0.1	1	reducer	1	0.059			1.076	15	0.059	0.000
b-c	3	0.14				0.000	2	3.622	0.616	20	0.000	0.072
b-c	3	0.14	1	flow tee	0.9	0.017			0.616	20	0.017	0.000
c-d	11	0.28				0.000	2	12.191	1.232	20	0.000	0.244
c-d	11	0.28	1	flow tee	0.9	0.070			1.232	20	0.070	0.000
d-e	13	0.3				0.000	2	13.769	1.32	20	0.000	0.275
d-e	13	0.3	1	branch tee	2.1	0.187			1.32	20	0.187	0.000
e-f	18	0.36				0.000	4	19.009	1.584	20	0.000	0.760
e-f	18	0.36	1	branch tee	2.1	0.269			1.584	20	0.269	0.000
f-g	24	0.42				0.000	2	24.989	1.848	20	0.000	0.500
f-g	24	0.42	1	flow tee	0.9	0.157			1.848	20	0.157	0.000
g-h	27	0.44				0.000	1	27.144	1.936	20	0.000	0.271
g-h	27	0.44	1	flow tee	0.9	0.172			1.936	20	0.172	0.000
h-i	35	0.51				0.000	1	35.309	2.244	20	0.000	0.353
h-i	35	0.51	1	flow tee	0.9	0.231			2.244	20	0.231	0.000
h-i	35	0.51	1	ball valve	0.27	0.069			2.244	20	0.069	0.000
											1.361	**2.813**

Sub-total
m.head
4.174

*Stop and Review,
Sized Internal Piping*

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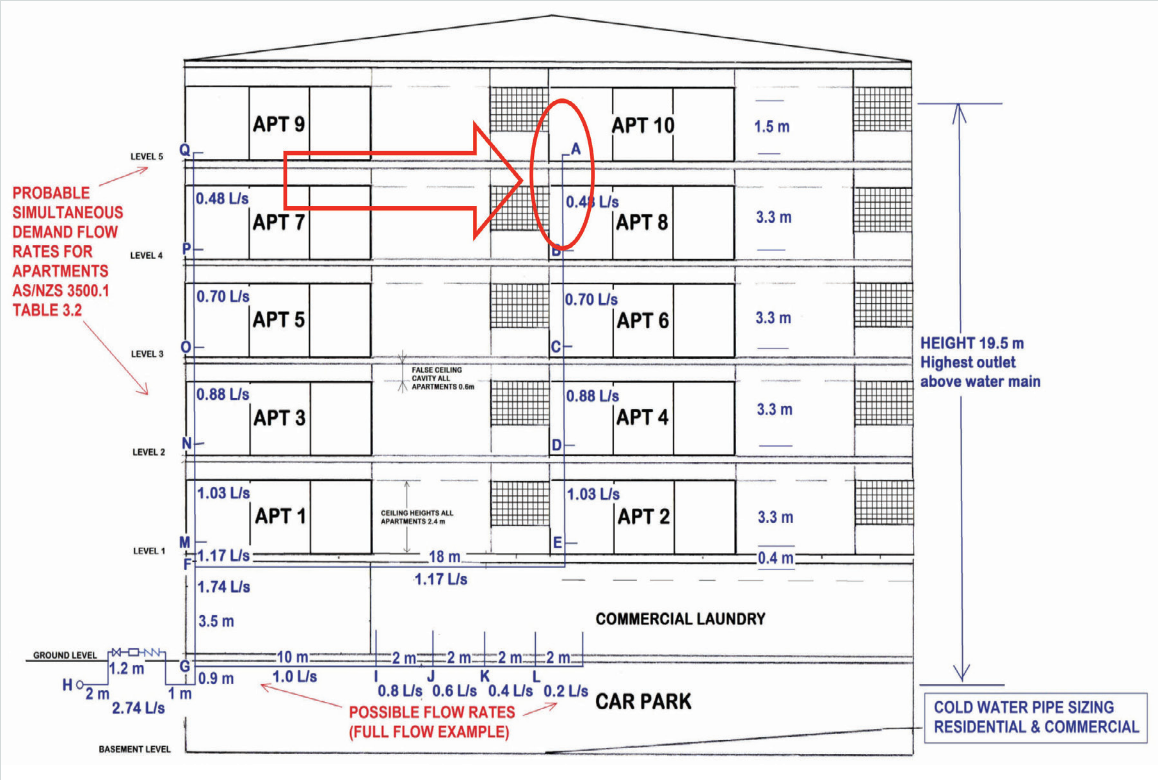
Step 12a: Calculate the Remaining and Pipe Fitting Pressure Losses.

Start from the most hydraulically disadvantaged apartment (APT).



Calculate the Remaining and Pipe Fitting Pressure Losses

Step 12b: Calculate the Remaining and Pipe Fitting Pressure Losses

Start from the most hydraulically disadvantaged apartment (APT).

Choose pipe sizes based on flow rates, and velocity < approx 2.2 m/s

0.47					3.124	82.319	2.068	30.525	1.135	7.256
0.48					3.191	85.486	2.112	31.692	1.159	7.531
0.49					3.257	88.706	2.156	32.878	1.183	7.811
0.50					3.324	91.981	2.200	34.084	1.208	8.095

PIPE SIZING TABULATION SHEET												
FITTINGS AND VALVES VELOCITY PRESSURE LOSS METHOD												
PIPE SECTION	LOADING UNITS	FLOW RATE	FITTINGS & VALVES				PIPE SECTION LENGTH	PRESSURE LOSS PER 100 m TUBE	VELOCITY	TUBE SIZE	FITTINGS & VALVES PRESSURE LOSS	PIPE SECTION PRESSURE LOSS
					Head loss factor	Pressure loss each $m=K*(v^2/2g)$						
Labelled	No	L/s	No	Type	K	m. head	m	m. head	m/s	DN	m. head	m. head
A-B		0.48				0.000	3.3	31.692	2.112	20	0.000	1.046
A-B		0.48	1	elbow	1.7	0.387			2.112	20	0.387	0.000
B-C		0.7				0.000	3.3	14.71	1.691	25	0.000	0.485
B-C		0.7	1	flow tee	0.9	0.131			1.691	25	0.131	0.000
C-D		0.88				0.000	3.3	22.13	2.125	25	0.000	0.730
C-D		0.88	1	flow tee	0.9	0.207			2.125	25	0.207	0.000

Calculate the Remaining and Pipe Fitting Pressure Losses

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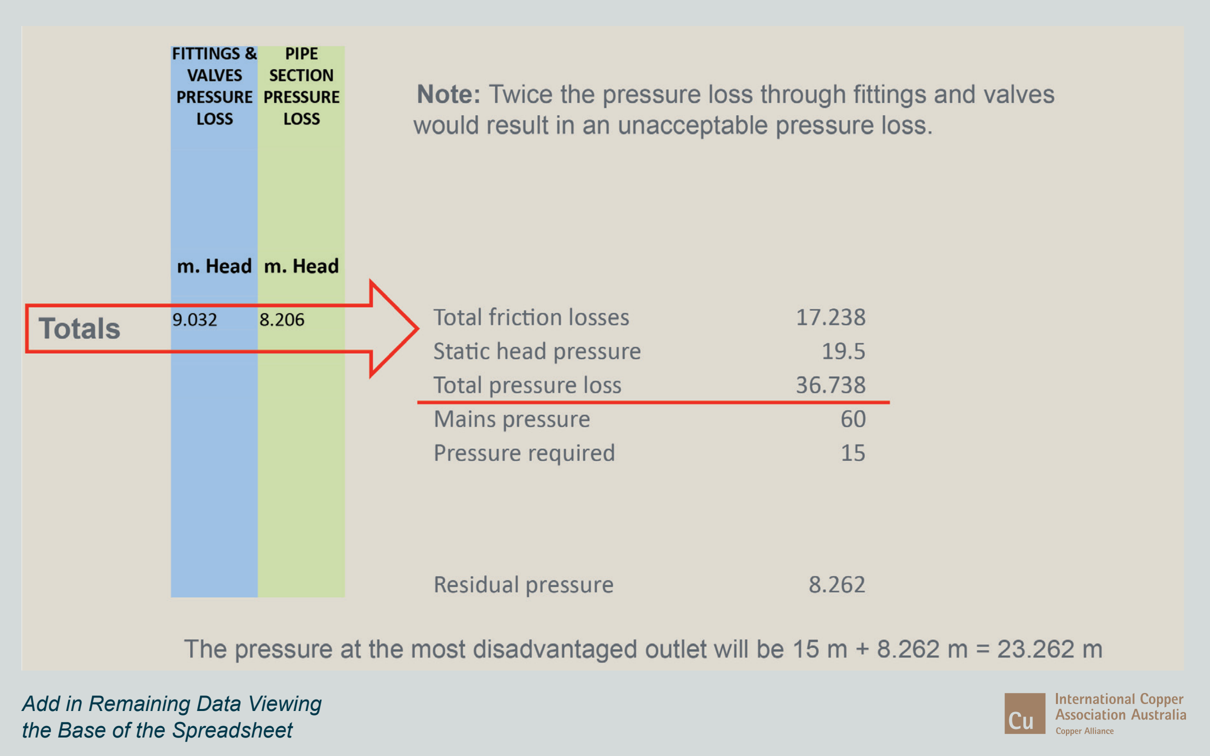
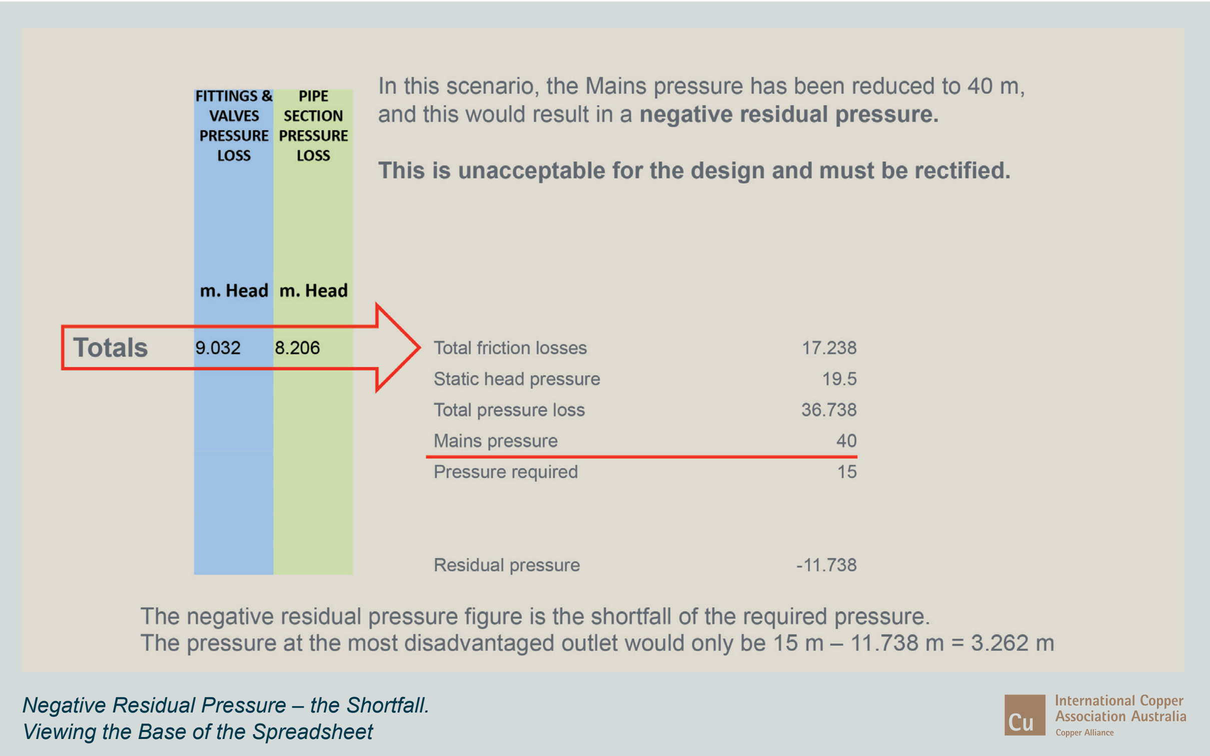
Step 13: Add in Remaining Data Viewing the Base of the Spreadsheet



Step 14a: Negative Residual Pressure – the Shortfall. Viewing the Base of the Spreadsheet



Step 14b: Negative Residual Pressure – Solutions

There are two main solutions to achieving the necessary residual pressure.

Reducing the pipe and fitting losses by increasing the size of the main riser.

- In our sizing example, there is a pressure loss of around 8 m from the outlet of the backflow device to Apartment 10.
- If the residual pressure were -11.738 m, it is obvious that increasing the pipe size would not solve the shortfall.

OR

Pumping

- Pumping is often installed in high-rise buildings.
- This could also include buildings that are classified as low rise buildings.
- While often the entire water supply to the building is pumped, it is good practice to design systems which include energy conservation, therefore only the upper floors imposing the negative residual pressure should be pumped.

Heated Water Pipe Sizing

The sizing for heated water is carried out to the same procedure as for cold water.

There are several notable differences, and the main principles are as follows:

- Pipe sizing in non-circulatory systems should be kept to a minimum for water and energy conservation. (minimal cold water draw off)
- Pipe sizing in circulatory systems should be kept to a minimum to minimise heat loss and to conserve energy. (PCA Performance requirement BP 2.3 (d)
- Flow rates must be adequate.

Note:
The Barrie Smith book PSD for residential cold water mirrors AS/NZS 3500.1. This book similarly contains PSD rates for residential hot water.

TABLE 56

CHAPTER 4	COLD AND HOT WATER PIPE SIZING
Topic No. 4.7	Description PROBABLE SIMULTANEOUS FLOW DATA – DIVERSITY OF FLOW FOR HOME UNITS, FLATS, TOWN HOUSES AND VILLA HOMES, COLD AND HOT WATER.

HOME UNITS, FLATS, TOWN HOUSES, VILLA HOMES.	PROBABLE SIMULTANEOUS FLOW Qℓ Litres per Second			HOME UNITS, FLATS, TOWN HOUSES, VILLA HOMES.	PROBABLE SIMULTANEOUS FLOW Qℓ Litres per Second			HOME UNITS, FLATS, TOWN HOUSES, VILLA HOMES.	PROBABLE SIMULTANEOUS FLOW Qℓ Litres per Second		
	COLD		HOT		COLD		HOT		COLD		HOT
No.	Max.	Min.		No.	Max.	Min.		No.	Max.	Min.	
1	0.48	0.48	0.40	35	3.74	2.99	2.63	68	5.79	4.68	5.10
2	0.70	0.54	0.56	36	3.81	3.04	2.70	69	5.85	4.73	5.18
3	0.88	0.68	0.67	37	3.88	3.10	2.78	70	5.91	4.78	5.25
4	1.03	0.80	0.75	38	3.95	3.15	2.85	71	5.96	4.82	5.33
5	1.17	0.91	0.78	39	4.01	3.21	2.93	72	6.02	4.87	5.40
6	1.30	1.01	0.80	40	4.08	3.26	3.00	73	6.08	4.92	5.48

Probable Simultaneous Flow Data for Domestic Applications

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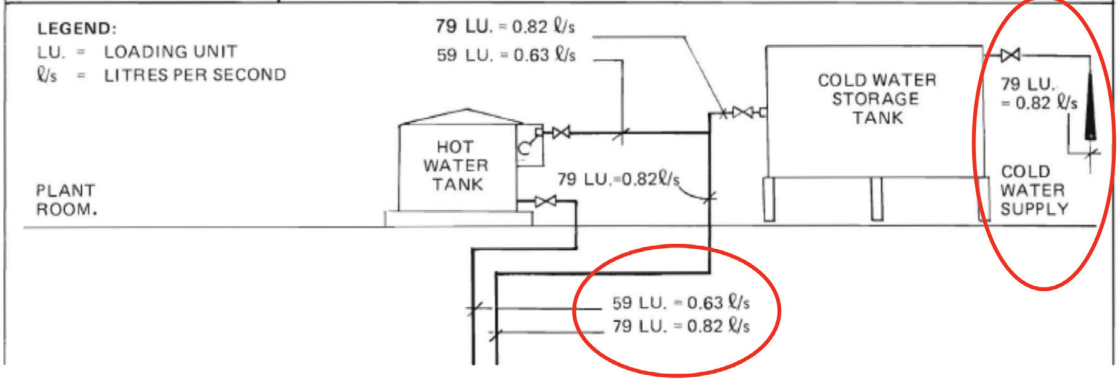
TABLE 49

CHAPTER 4	COLD AND HOT WATER PIPE SIZING
Topic No. 4.2	Description PROBABLE SIMULTANEOUS FLOW EXAMPLE – THE LOADING UNIT METHOD OF "PROBABLE SIMULTANEOUS FLOW"



For Domestic Applications, the Heated Water Flow Demand Operates Within the Total Cold Water Supply Demand.

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TABLE 47

CHAPTER 4	COLD AND HOT WATER PIPE SIZING
Topic No. 4.1	Description COLD AND HOT WATER FLOWS TO TAPS AND SANITARY FIXTURES

COL. 1 TAPS AND SANITARY FIXTURES	COL. 2 COMBINATION COLD & HOT WATER FLOW ℓ/s	COL. 3 COLD WATER FLOW 100% OF COL. 2 ℓ/s	COL. 4 HOT WATER FLOW % RELATED TO COL. 2 Combination Outlet 75% ℓ/s	COL. 4 Single Outlet 100% ℓ/s	COL. 5 LOADING UNITS FOR COLD & HOT WATER FLOW No.
BIB TAPS – Over any sanitary fixture other than listed below		0.22	–	0.22	3
BASIN	0.12	0.12	0.09	0.12	1
BASIN – With spray taps	0.04	0.04	0.03	0.04	½
BATH	0.30	0.30	–	0.30	8
CLEANER'S SINK	0.22	0.22	–	0.22	3
CISTERN – Urinal	0.08	0.08	–	–	2
CISTERN – Water closet	0.11	0.11	–	–	2
DRINKING FOUNTAIN	0.04	0.04	–	–	½

Other Than Apartments: Loading Units are Used to Obtain Flow Rates

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TABLE 48

CHAPTER 4	COLD AND HOT WATER PIPE SIZING
Topic No. 4.2	Description PROBABLE SIMULTANEOUS FLOW DATA. – DIVERSITY OF FLOW, LOADING UNITS TO LITRES PER SECOND

LOADING UNITS →	PROBABLE SIMULTA-NEOUS FLOW LITRES/ SEC.	LOADING UNITS →	PROBABLE SIMULTA-NEOUS FLOW LITRES/ SEC.	LOADING UNITS →	PROBABLE SIMULTA-NEOUS FLOW LITRES/ SEC.	LOADING UNITS →	PROBABLE SIMULTA-NEOUS FLOW LITRES/ SEC.
1	0.10	170	1.57	1440	5.60	2800	8.78
2	0.12	180	1.65	1480	5.68	2840	8.94
3	0.15	190	1.72	1520	5.76	2880	9.01
4	0.18	200	1.80	1560	5.91	2920	9.09
5	0.21	240	1.97	1600	5.98	2960	9.24
6	0.23	280	2.20	1640	6.06	3000	9.31

Other Than Apartments: PSF Data Can be Used to Obtain Flow Rates to Size for Both Cold and Hot Water.

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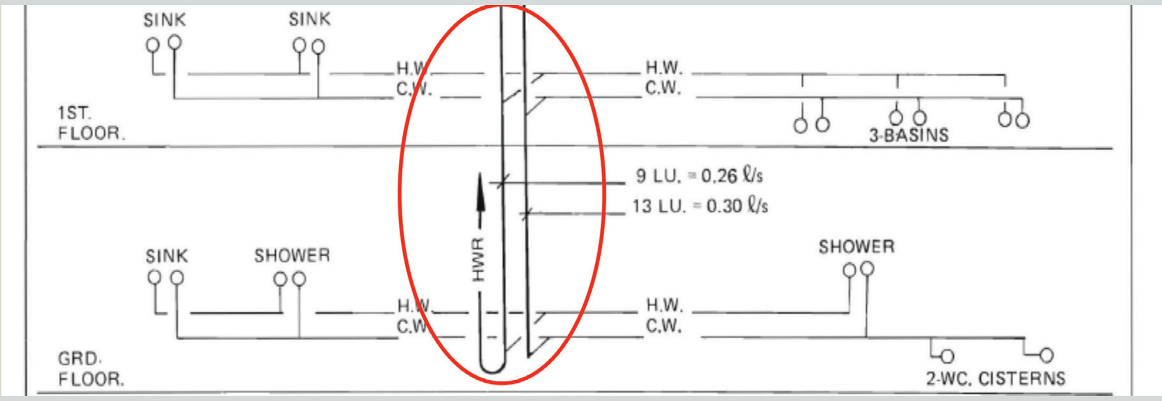

In A Circulatory System, the Flow Rate for the Hot Water Return Line is Obtained By Calculating the Total Watts Emission From the Pipework System, Both Flow and Return Pipelines.

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In a circulatory system, the flow rate for the hot water return line is obtained by calculating the total Watts emission from the pipework system, both flow and return pipelines.

Example Return Line Calculation

- Temperature drop from 60°C to 55°C at the return line.
- 40°C Ambient temperature difference.
- DN 25 copper pipe, 50 m long (10 apartments, 0.87 L/s, 2.1 m/s).
- DN 20 copper pipe, 50 m long.
- Using 13 mm Armaflex @ (DN 25: 11.6 W/m) & (DN 20: 9.6 W/m).
- $L = \frac{W \times 10^{-3}}{kJ/kg \times {}^{0}C}$ $L = \frac{(580+480) \times 10^{-3}}{4.2 \times 5L}$ $L = \frac{1.060}{21}$

Flow rate required = 0.05 L/s

For Small Projects, it is Common to Install a Grundfos Ups 20-60 or Similar to One or Two Circuits. Continuous Flows in Flow and Return Pipes Should Not Exceed a Velocity of 0.5 m/s.

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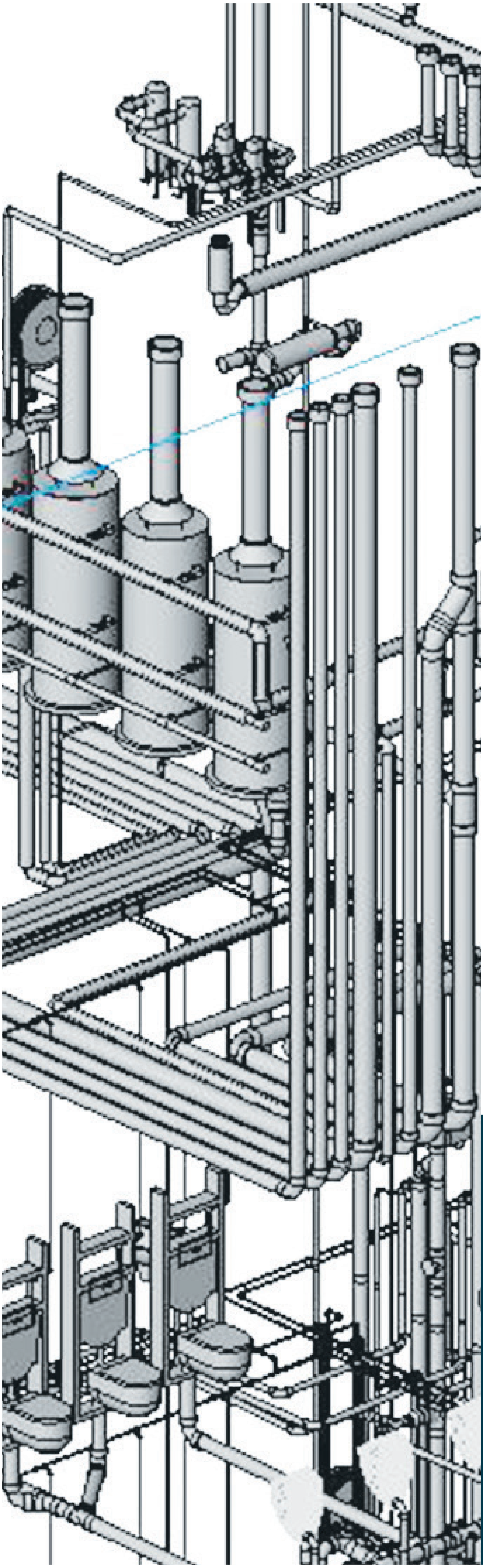
Index



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