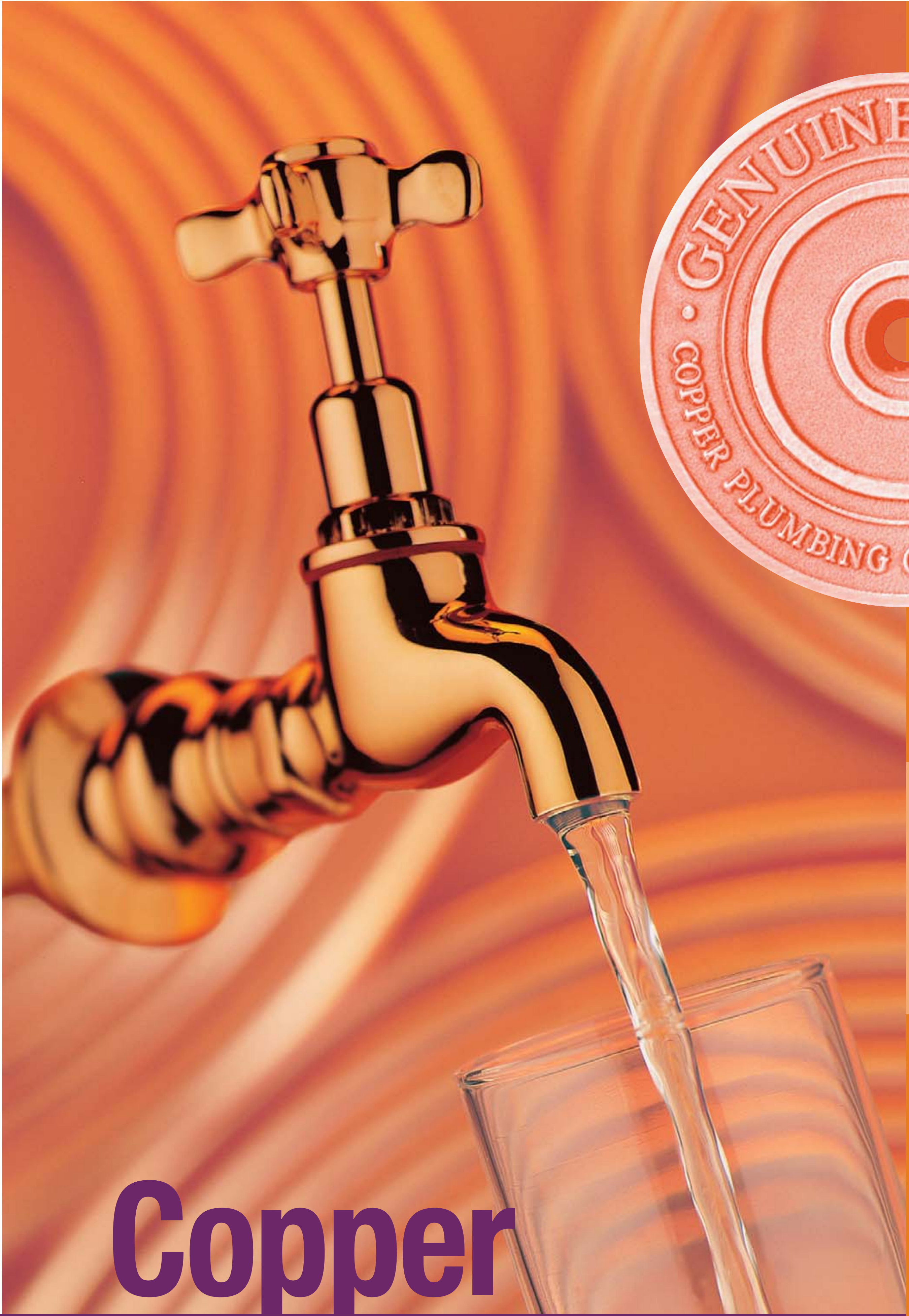

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Manual Includes 2 x DVDs

Copper

Introduction to Professional **Plumbing Skills**

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Foreword

The Copper Development Centre (CDC) Australia Limited, which supports the Australia copper tube and fittings industry, is committed to building on the high standards of professionalism strongly associated with copper plumbing systems.

To this end, the CDC Australia Limited has updated this educational resource for lecturers and students based upon a publication developed by the UK Copper Plumbing & Heating Systems Board, that is designed to help teach basic copper plumbing skills to new entrants to the profession.

"An Introduction to Professional Plumbing Skills" has been developed by the Copper Development Centre Australia Limited, with the help of Cliff Hensby, John Williamson of the CDC Australia Limited and representatives of various TAFE Plumbing Schools.

This training guide is designed to be used either;

On its own as a resource material, packed full of useful information to assist trainees with their personal studies.

Or in conjunction with colleges of Technical & Further Education or similarly accredited & qualified training colleges.

Interactive work sheets have been developed to introduce trainees to the necessary skills to measure, cut, bend, join and install copper tube and fittings to a high standard.

A series of reference materials which can be used as handouts to students covering pipework bending and installation methods are part of the package. In addition, a series of installation tips covering basic plumbing skills and a reference guide to copper tube in buildings are also included.

The package is only designed to be used as an introduction to basic copper installation practice, acknowledging that it takes years of practice to become a professional installer.

The Copper Development Centre Australia Limited is pleased to support the training of professional installers in Australia and we commend this guide to you.

John Fennell
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Contents

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Section 1

Introduction

Introduction

The Copper Development Centre of Australia Limited, which supports the Australia copper tube and fittings industry, is committed to building on the high standards of professionalism strongly associated with copper plumbing systems.

To this end, the CDC Australia Limited has produced as educational resource for lecturers, based upon a publication developed by the UK Copper Plumbing & Heating Systems Board, that is designed to help teach basic copper plumbing skills to new entrants to the profession - **"Make the Right Start"**.

"Make the Right Start" has been developed, by the UK Copper Plumbing & Heating Systems Board, with the help of Brian Curry, a plumbing lecturer at Oldham College. The material has been modified to suit Australian Standards and Codes of Practice.

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Introduction

1.1 Resource Materials For Lecturers

The educational pack contains a series of technical support notes for lecturers that can be copied and used in the form of hand-outs for students.

Section 2 contains the following resource materials:

- **Pipework installation method**

This section demonstrates a systematic method for fabricating and installing copper tube and fittings to a high standard quickly and efficiently.

- **A guide to bending**

Spring, hand and machine bending methods for copper tube are clearly illustrated.

- **Interactive work sheets**

A series of six student exercises and answer sheets have been designed to complement the essential work of the lecturer. Based around practical exercises, they have been developed to encourage trainees to study the technology of copper tube and fittings installation.

The exercise sheets have been designed to encourage trainees to study and refer to the various resource materials in the pack.

Exercises 1 to 5 will be useful for lecturers and instructions to students engaged in the plumbing trade course.

Section 3 contains the following resource materials:

- **Copper Tube in Buildings**

This is a comprehensive guide to the use of copper in plumbing and heating systems.

- **Installation Tips**

Written by Brian Curry and published by the "Professional Heating and Plumbing Installer" magazine in the U.K. These installation tips offer advice on the following subjects:

- Fixing copper
- Copper springs
- Jointing (Part I)
- Jointing (Part II)
- Pipework planning
- Pipe bending
- Copper connections
- Copper protection
- Copper underground

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Introduction

1.2 Copper Tube Advice And Installation Schemes

Basic Installation Course

The Installation Course can be used to introduce the skills necessary to measure, cut, bend, join and install copper tube in buildings to a very high standard. A series of demonstrations followed by practice will enable trainees to develop competency by using a simple systems based approach. Competency is measured by practical test and written assessment.

In addition to being useful for gradually developing the skill levels of students in the initial trade training courses, the techniques used on the course can be used to fast track mature students.

Regular updates on new products and installation procedures can be arranged between the course operator/lecturer and the Copper Development Centre of Australia Limited (CDCA).

The Centre recognises its role in this responsible support of those conducting formal courses.

The necessity of a continuing technique training process is acknowledged by the CDCA as essential to the maintenance & ongoing skills capabilities of all trainees and tradesmen. Consequently the CDCA intends to respond to the industry needs in this area as they arise.

Resources Required

The **"Make the Right Start"** learning pack is designed to simulate typical copper tube and fittings installation work.

The practical tasks can be carried out in the corner of a room or cubicle or on a purpose designed rig, connecting copper tube to handbasins, showers or hot water systems. Only ordinary hand tools and small bending machines are required.

The written exercises can all be completed by reference to the learning materials in the pack.

Section 2

An Introduction to Copper Plumbing Skills

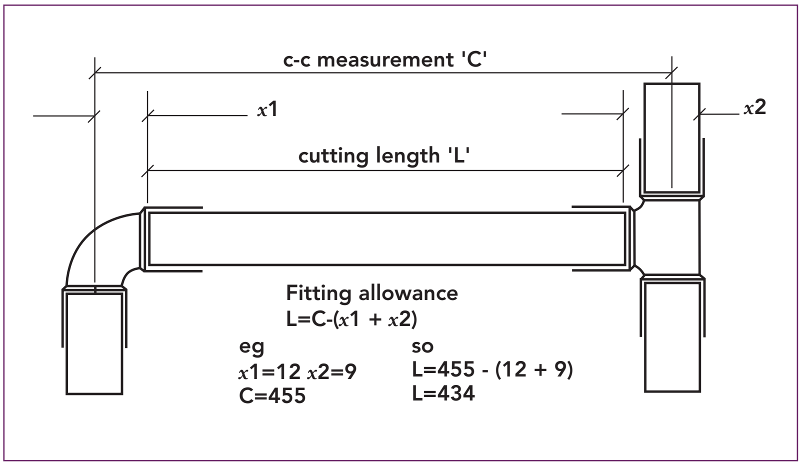
Section 2.1

Pipework installation method

2.1 Pipework installation method

Copper Tube and Fittings Pipework Prefabrication Method

The basic idea behind this simple method of prefabrication of pipework is to take as many measurements as possible in one operation. This is to eliminate waste from off cuts and the time consuming piecemeal preparation of individual pipes. By means of a systematic method, based loosely on production engineering techniques, useful savings of both time and materials can be made.



By subtracting the sum of the two fitting allowances or 'x' dimensions (one at each end of the pipe) the actual cutting length is determined.

Basic principles
The method relies on TWO basic principles:

FIRST, an understanding of the method of preparing clearly dimensioned single line sketches of the pipework to be fabricated by bending and jointing (either by the person who takes the measurements or by another operative);

SECOND the ability to determine accurate cutting lengths of pipe which allow for pipe bends, pipe fittings and clip stand off dimensions.

Fitting allowance
To enable the prefabrication of pipework from dimensions taken either from drawings or from actual structures it is necessary to have a method of calculating the actual lengths of pipe required.

To do this the operative needs to know the measurement from centre line of the fitting to the end of the pipe after it has been inserted into the fitting.

This fitting allowance we shall refer to as the '*x*' dimension. When allowing for fittings the various '*x*' dimensions are ALWAYS subtracted.

Note:
It is quite easy for the measurer to determine the various fitting allowances by measuring the actual fittings required when applying the system.

2.1 Pipework installation method

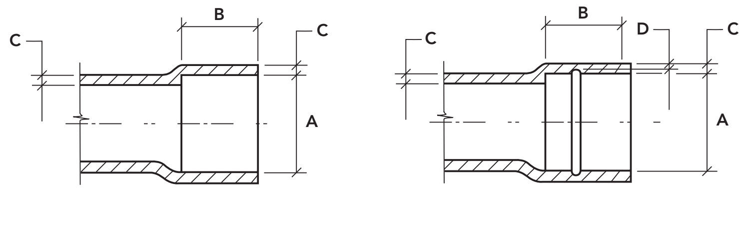
Some typical examples of the '*x*' dimension of a range of fittings are given . These are based on an insertion depth as shown in the following tables.

The Tables illustrated for long and short engagement capillary sockets are based upon AS 3688 - 1994 Clause 5.

It is essential & an easy task for the measurer to determine the various fitting allowances by measuring the actual fittings required when applying the system.

Individual fittings from manufacturers may vary slightly.

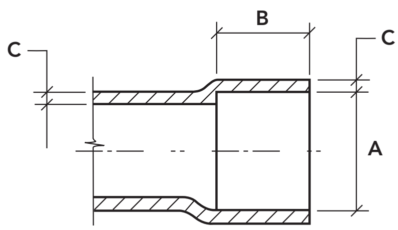
Dimensions of Long Engagement Capillary Sockets for use with Solder



(a) Socket (b) Grooved socket

1	2		3	4	5	6	7
Nominal Size	Internal Diameter of Socket (Dimension A) mm		Length of Socket Surface in Contact with Tube (Dimension B) mm	Minimum Wall Thickness			
				Tubular Sections mm		Forged and other Sections mm	
DN	Min.	Max.	Min.	(C)	(D)	(C)	(D)
15	12.72	12.82	9.0	0.77	0.7	1.8	1.1
18	15.90	16.00	11.0	0.88	0.8	1.8	1.1
20	19.07	19.17	13.5	0.88	0.8	1.8	1.1
25	25.42	25.56	17.0	1.04	0.9	2.2	1.4

Dimensions of Short Engagement Capillary Sockets for use with Brazing Alloy



1	2		3	4	5
Nominal Size	Internal Diameter of Socket (Dimension A) mm		Length of Socket Surface in Contact with Tube (Dimension B) mm	Wall Thickness (Dimension C)	
				Tubular Sections mm	Forged and other Sections mm
DN	Min.	Max.	Min.	Minimum at any point	Minimum at any point
15	12.72	12.82	7.5	0.77	1.8
18	15.90	16.00	7.5	0.88	1.8
20	19.07	19.17	7.5	0.88	1.8
25	25.42	25.56	7.5	1.04	2.2

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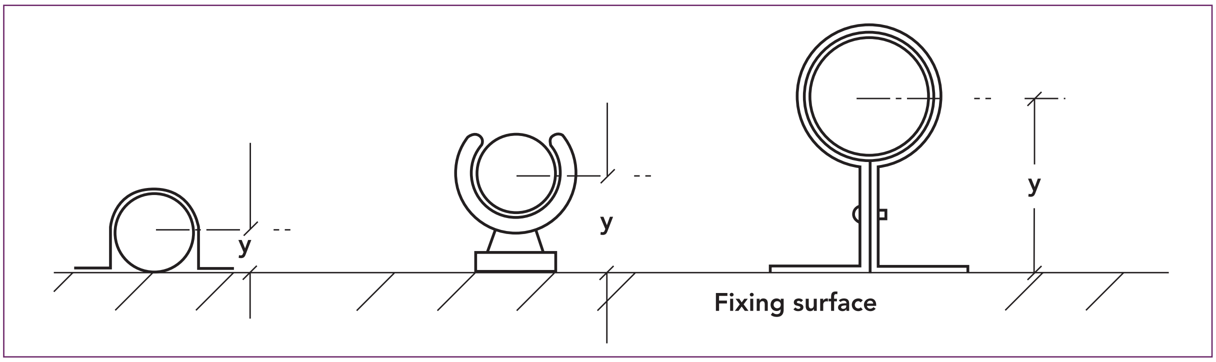
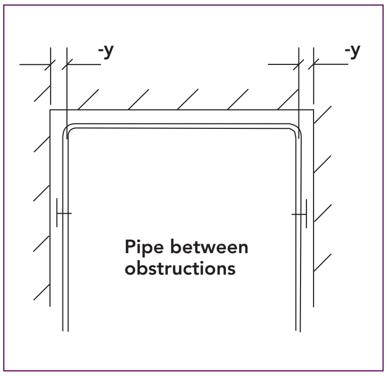
2.1 Pipework installation method



Clip stand off allowance

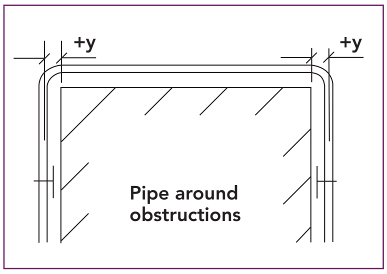
Another measurement which is required is the clip stand off allowance. This is the distance by which the pipe centre line is held off the surface to which the pipe is to be fixed. This clip stand off allowance we shall refer to as the 'y' dimension.

When allowing for clips there are THREE possibilities depending on whether the pipe is passing between, going around or going past obstructions:

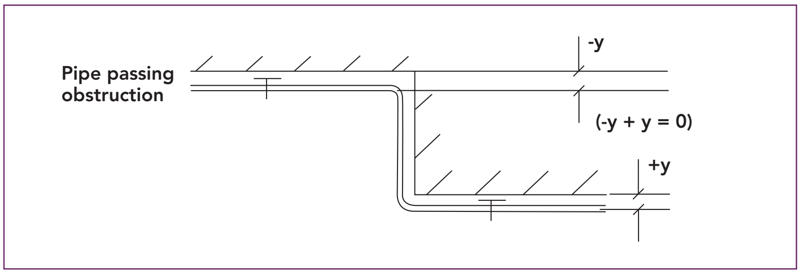


FIRST, when the pipe passes between obstructions the 'y' dimension must be SUBTRACTED from both ends;

Table of Typical Clip Stand-Off 'y' Dimensions (mm)		
	Tube Diameter	
	DN15	DN20
Copper Saddle Band	8	11
Plastic Stand Off Clip	22	24
Stand Off Clip	28	31



SECOND, when the pipe passes around an obstruction the 'y' dimension must be ADDED to both ends;



THIRD, when the pipe goes past an obstruction the 'y' dimension can be IGNORED because it is cancelled out.

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2.1 Pipework installation method

Variability of site work

To work effectively any system must be able to cope with the variability of site work! On a large job, where detailed drawings are available, basic pipework, for example risers and branches out in false ceilings and ducts, can often be dimensioned with sufficient accuracy from the drawings.

On small jobs without detailed drawings and in areas where there is a need to accommodate site variability or where dimensions are critical, then measurements can be taken on site.

If necessary, by using this system, hundreds of metres of pipework can by dimensioned from site in one day for later fabrication. This can be done either on site or in the workshop.

Also, where there are numbers of identical units, such as on housing sites, it is quite easy to fabricate batches of pipework from a single set of dimensions taken from one unit. By making use of the pipe which is gained when pipes are bent, or by the judicious addition of short extra lengths to the pipes in strategic places an allowance can be made for the inevitable variations in dimensions which occur from one unit to the next on site.

Applying the system

By using the pipe layout chart (an example appears on a later page) a simple plan and, if necessary, section of the work can be drawn on the squared grid. Next, actual measurements of the structure can be added.

Any pipes which require multiple bends can also be drawn on the isometric grid. This is so that the relative directions of the various bends can be illustrated.

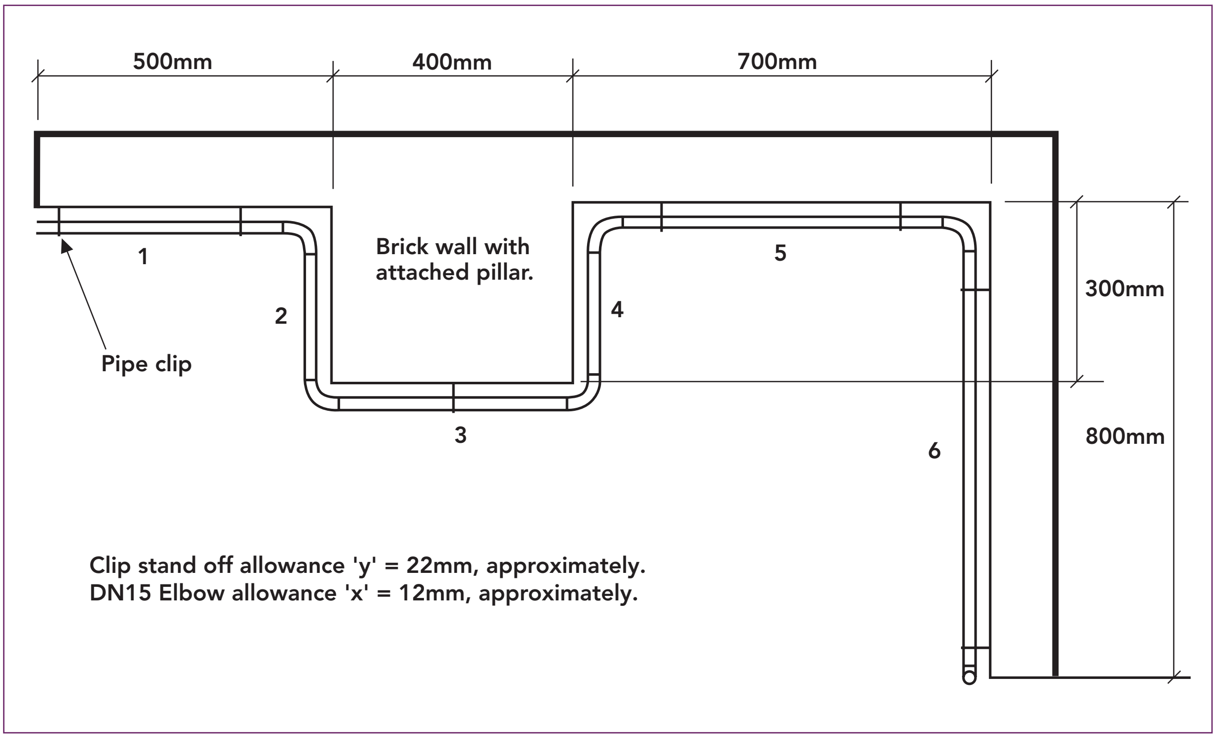
Next, pipe diameters and fitting details and allowances can be added to the diagram. The final stage of the measuring operation is to carry out a series of simple calculations to determine the actual cutting lengths of each pipe and any bending point dimensions by using the 'x', 'y' & 'z' dimensions for the fittings and clips to be used.

When these calculations are complete the pipework can be fabricated. Whether using a bending machine or fittings good productivity gains can be made. All pipes of a particular diameter should be cut and bent at one time so that the minimum amount of time will be spent setting up and adjusting machines. Once each pipe is cut and bent it can be marked with its number for easy identification on site by the installer.

Cost savings

Experience with this system has demonstrated that considerable savings can be made by the better use of site labour and materials. Piecemeal, time consuming installation is reduced and pipe cutting lengths can be optimized to reduce waste. If compression joints are to be used these can be made onto one end of each piece as it is fabricated. If necessary, the planning of pipe runs and calculation of cutting lengths can be done before materials arrive on site. Also, better control and utilization of stock can be maintained.

2.1 Pipework installation method



Complete this table below for pipes 4,5 and 6.

Pipe No.	Dia	Measured length	'x' dimension	'y' dimension	Cutting length
1	DN15	500mm	-1 @ 12	-1 @ 22	466mm
2	DN15	300mm	-2 @ 12	-	276mm
3	DN15	400mm	-2 @ 12	+2 ~ 22	420mm

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Copper Tube Installation Method - Pipe Layout Chart

Contract ______________________________ Sheet No. ____ of ____

Measured By ______________________________ Date ______________

Pipe No.	Dia	Measured Length	X Dim	Y Dim	Cut Length	Pipe No.	Dia	Measured Length	X Dim	Y Dim	Cut Length

X Dims		
Dia	Fittg	‘X’

Y Dims			
Dia	‘Y’	Dia	‘Y’

Section 2.2

A guide to bending

2.2 A guide to bending

Introduction

Copper tubes of DN15, DN18 and DN20 to AS 1432 for plumbing, gasfitting and drainage applications may be supplied in 'bendable' temper in straight lengths, which gives them a desirable degree of rigidity and strength, and minimizes damage in transit.

Other AS1432 tempers are annealed (soft) for coils and hard temper straights for sizes smaller than DN15 and greater than DN20.

The term 'temper' refers to the hardness and ductility of copper tube. Annealed temper tube is the softest and can be easily bent or formed in its as-supplied condition. Bendable temper is manufactured slightly harder. Such tubes have reduced formability but can be bent with standard hand benders and retain their rigidity. Hard drawn temper tube is the strongest, very rigid but the least formable. Where hard drawn tube is required to be expanded or bent, local annealing (softening) with heat to a dull red surface will reduce metal hardness to permit manipulation.

Bending copper tubes

There is little difficulty in machine bending tubes as the necessary skills can be developed with practice. The bending of tubes by hand methods, however may often be required, especially where a bend radius which is different to that of the machine former is required.

Steel springs

Flexible spiral springs may be used as a loading to support the tube walls while the bend is made. Springs are available for bending

Temper and Form

Thickness Type	Temper Min	Size Range		Form
		Max		
A	Hard drawn	DN6	DN200	Straight lengths
	Bendable	DN15	DN20	Straight lengths
	Annealed	DN6	DN40	Coils
B	Hard drawn	DN6	DN200	Straight lengths
	Bendable	DN15	DN20	Straight lengths
	Annealed	DN6	DN40	Coils
C	Hard drawn	DN10	DN25	Straight lengths
	Bendable	DN15	DN20	Straight lengths
	Annealed	DN10	DN25	Coils
D	Hard drawn	DN32	DN150	Straight lengths

DN10 to DN20 diameter, which is the maximum size recommended for spring loading. Only easy bends should be attempted as the minimum radius to the throat is approximately 3 diameters for all tube sizes. It is possible to bend tubes up to DN20 by hand without softening provided care is taken. But, there are advantages to be gained if the tube is softened by annealing. The advantages are that: the bend radius can be controlled more accurately; the position of the bend can be made more accurate, the bend throat is less likely to kink or ripple; the force required to pull the bend is less and so, possibly most importantly to prevent long term injury, the strain on the operatives knee is much reduced. Also, bends can be made much closer to the end of the tube possibly reducing waste due to long off-cut, however softening the tube will affect its working pressure, so care is necessary.

Setting out of spring loaded bends

When bends are to be formed, whether hand made or machine, they should be 'set out' to give an accurate position. There are two allied factors to consider when These are: the 'gain' of material when the bend is pulled and the bending point.

The 'gain' of material

When a pipe is bent to pass around a corner or obstruction the pipe effectively takes a 'short cut' and so pipe is gained. The actual amount of pipe 'gained' depends on the angle through which the bend is to be pulled and the bend radius to be used. This radius in turn depends on the diameter of the pipe.

As a general rule:

THE RADIUS OF A HAND PULLED BEND SHOULD NORMALLY BE EQUAL TO 4 TIMES THE OUTSIDE DIAMETER OF THE PIPE.

This radius is slightly greater than the radius of a typical machine made bend but, choosing a radius of 4 pipe diameters simplifies setting out.

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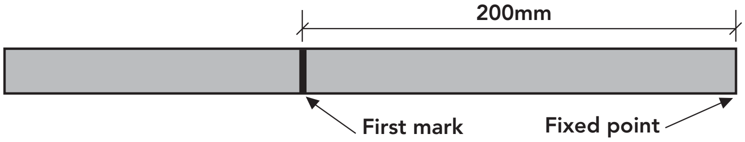
2.2 A guide to bending

Setting out a 90° bend

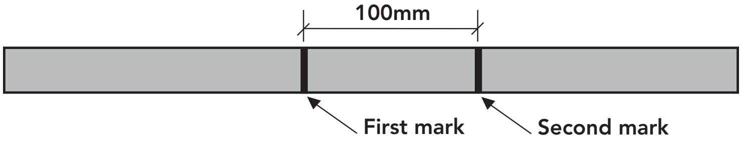
Example: Bend required is 200mm E to C on DN20 copper tube

RULE:	Radius of bend = 5 times diameter of tube.

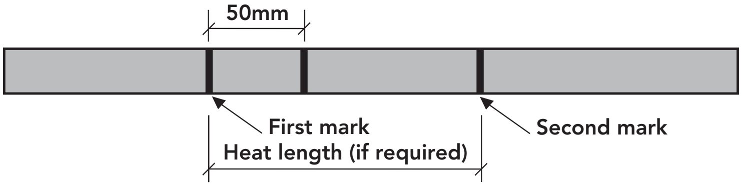
First; mark measured length (200mm from end of tube).



Second; measure back 5 tube diameters (100mm) and mark start of bend.



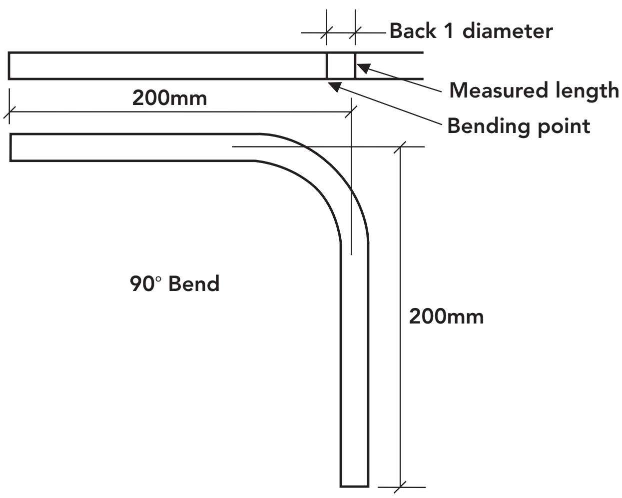
Third; measure forward 2 1/2 tube diameters (50mm) and mark finish of bend.



Now soften tube by annealing if necessary, insert spring and bend to required angle.

Note: The bend radius rule can be varied to suit but normally not less than 3 nor more than 6 times diameter of tube.

Bending point and finished 90° bend.



With a bend radius equal to 5 diameters the ‘gain’ is 1 pipe diameter. So, for a 90° bend the bending point (the centre of the bend and the position where the knee should be placed if it is used to form the bend) can be measured back 1 pipe diameter from the measured length towards the fixed point.

Spring removal after bending.

As the bend is pulled the throat and back of the bend tighten onto the spring. So, to make spring removal easy the bend should be pulled back to the correct angle required. This releases some of the pressure on the spring and should enable it to be pulled out easily, especially if the spring is given a slight twist in the direction it is coiled. The effect being to reduce the springs diameter.

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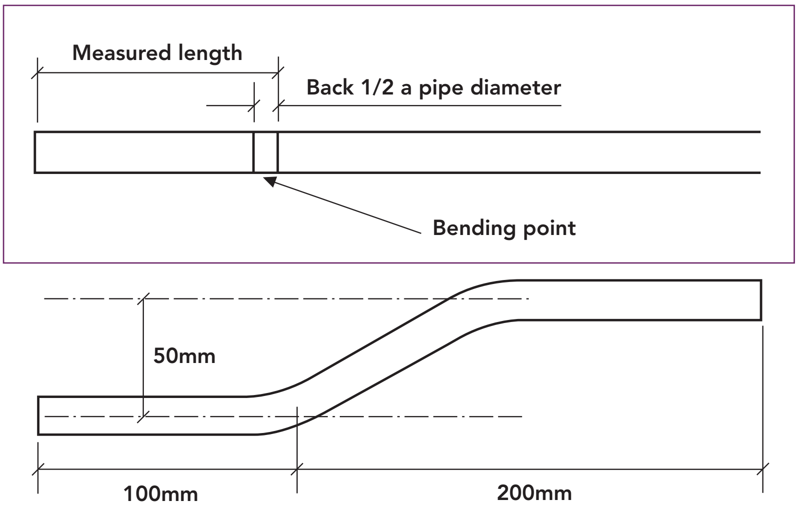
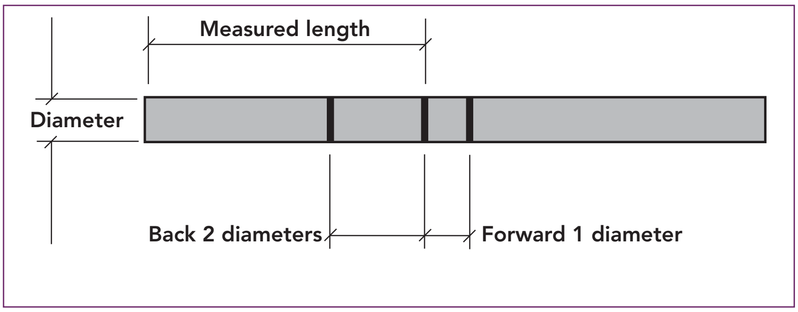
2.2 A guide to bending

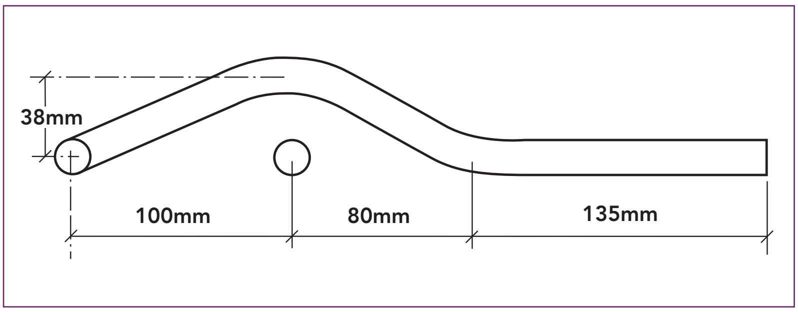
Bending point and finished 135° Doubleset



Setting out for softening 135° set



Typical fitting pipe passover set



Single and double sets.

When bends of less than 90° are to be made, say for single and double sets, the 'gain' will be proportionately less. If the set is to be pulled through 45° the bending point will be 1/2 a pipe diameter back from the measured length. Similarly, if it is necessary to soften the pipe by annealing then bend length will be half of that required for a 90° bend. Also, the start point for annealing will be two pipe diameters back from the measured length point and the finish point one pipe diameter forward from the measured length point.

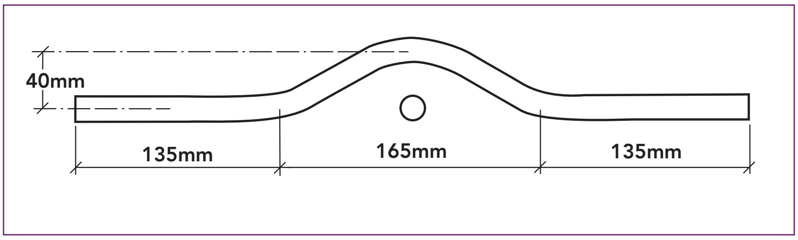
Crossover bends

The methods of setting out described for 90° bends and 45° sets can also be used when forming fitting and pipe passovers.

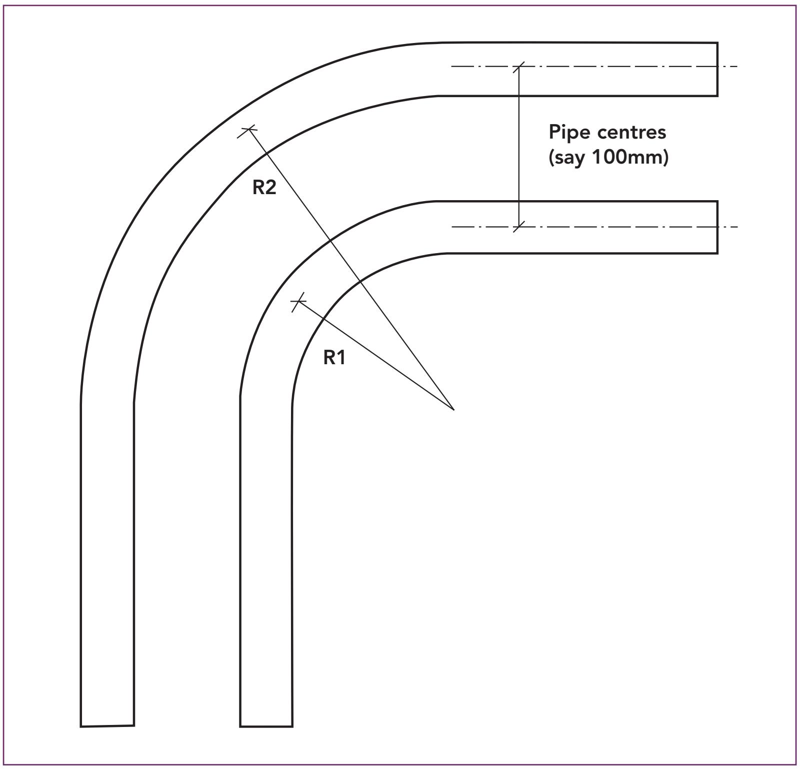
It is especially important to allow sufficient clearance where the pipes are to be insulated.

2.2 A guide to bending

Typical pipe crossover set



Maintaining pipe centres around bends



R1 = 5 times diameter of pipe
R2 = R1 +pipe centre spacing
eg. Two DN20 tubes @ 100mm centres
R1 = 4 x DN20 = 100mm
R2 = 100mm + 100mm = 200mm
So, set out inner bend as previous eg. measure back distance for outer bend = 200mm measure forward distance = 100mm (Both from first mark)
Note: This is not always possible when only machine bending is available. Try to arrange for the larger of two differing diameters to be on the outside.

Maintaining centres around 'matching' bends

One advantage that hand pulled bends can have over machine bends is that the radius of the bend can be varied. This enables pipe centres to be carried around bends. The appearance of the bends is improved because they 'match' due to the gap being even. The diagram shows how to establish the outer bend radius.

Maintaining pipe centres around bends

Once the radius is determined the start point is found by measuring back one bend radius from the measured length. The end of the bend is found by measuring forward 1/2 a bend radius, as for the simple 90° bend described previously.

2.2 A guide to bending

Bending by machine

The bending of copper tubes by machine can be carried out without filling as the special formers or mandrels employed support the sides of the tube preventing it from collapsing or becoming oval in section. The purchase of a bending machine will prove economical where numerous bends are required in the smaller sizes of tube. Machines of various types and sizes, worked by direct hand power, are constructed to bend copper tubes up to DN40 diameter, and are small and light enough to be transported to site. For diameters greater than this, ratchet action or geared machines should be used. A small tool for bending DN15, DN18 and DN20 tube, can be carried in the tool kit and bends can be made if necessary on a fixed pipe. The diagrams on pages 15 to 18 illustrate the methods of angles of sets for machine bends of all sorts. They are reproduced by courtesy of the Record Tool Company plc. (U.K.).

Distortion of tube in machine made bends

The design of bending machine formers enables the throat and sides of the bend in an unloaded tube to be supported against collapse. Corrugations will however, occur in the throat of a bend if the pressure of the roller on the back guide is exerted in the wrong place. The correct pressure point is slightly in front of the bending point, where the tube touches the former before bending takes place. These two points move forward maintaining the same distance apart as the bend is made. If the pressure point is advanced too far in front of the bending point, corrugations will occur. If the pressure roller is tightened too much the pressure point will be too far back and the tube will be excessively 'throated' or made oval in section.

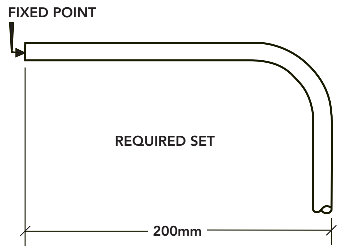
Section 2.3

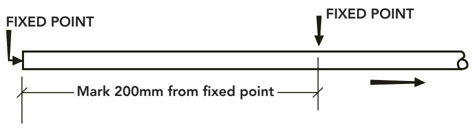
Bending of copper tubes

Bending of copper tubes

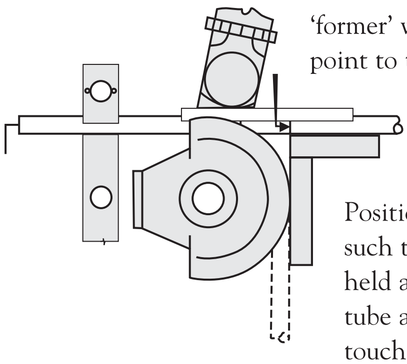
90° Sets – From a fixed point

NB. If distance is given to inside or centre of tube simply add on either the diameter or half diameter respectively to give the back of bend measurement and follow the same procedure as for outside measurement.





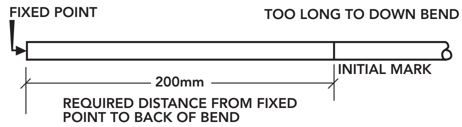
Place tube in 'former' with fixed point to the rear.



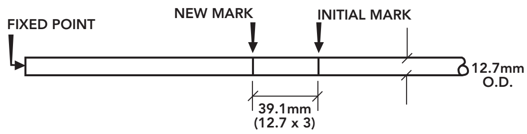
Position the tube such that a square held against the tube at the mark touches and forms a tangent to the leading edge of the 'former'.

DOWN BEND TO 90°

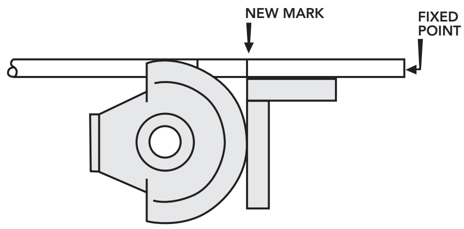
Where the remaining length of tube from the measured point is too long to down bend and where it is not convenient or possible to up-bend using the following method.



Deduct THREE times the outside diameter of the tube from the initial mark.



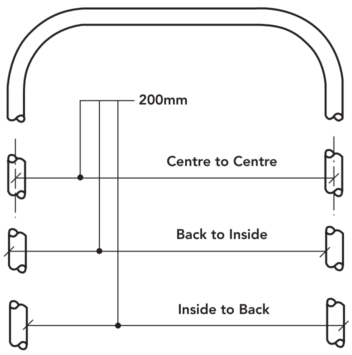
Place tube in 'former' with fixed point to the front, with mark at 90° to edge of 'former'.



This will give a 90° bend at the required distance from the fixed point to the back of the bend.

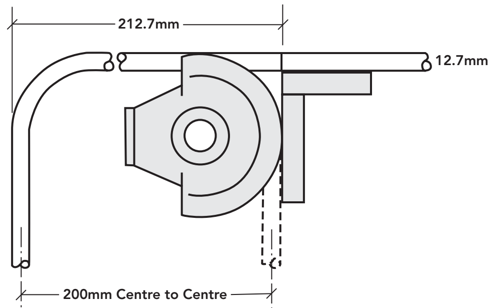
NOTE: The radii of the tube benders are variable and need to be taken into account.

Two 90° Sets



A centre to centre measurement can be measured as above.

By adding the outside diameter of the tube to be bent to the initial measurement of 200mm the bend can be treated as a measurement from back to back of bend (i.e. 200 + 12.7 = 212.7mm)



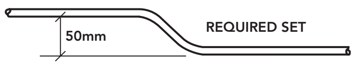
Size
DN15 = 12.7mm
DN18 = 15.88mm
DN20 = 19.05mm

Copper Quality is for keeps

Bending of copper tubes

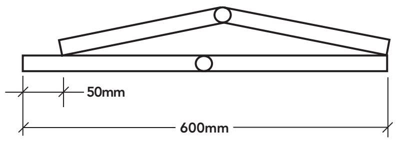
Double Sets

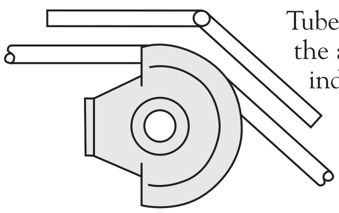
To ensure re-entry of the bent tube into the bending machine to complete the return set a determined angle of initial bend is required.



Determine the distance of set - say 50mm and deduct this distance from a 600mm rule.

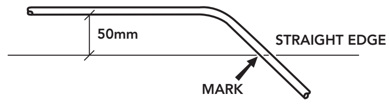
Place a second 600mm rule with the legs staggered between the 50mm and 600mm marks - this forms the initial angle of bend.



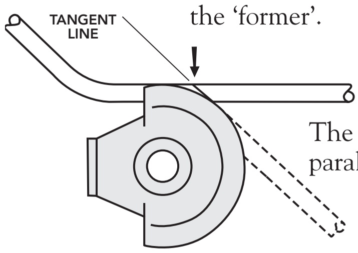


Tube can be bent using the angled rule to indicate the angle of the first set.

Remove the tube from the machine and mark the tube for the return set, making sure to measure the height of the obstacle from the inside of the tube.



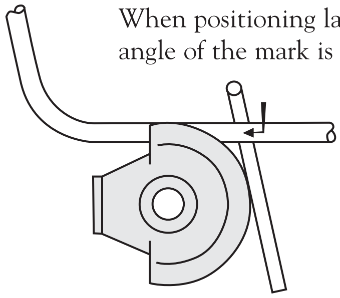
Re-position the tube in the machine ensuring that the mark on the tube forms a tangent to the edge of the 'former'.



The final set can be made parallel with the first.

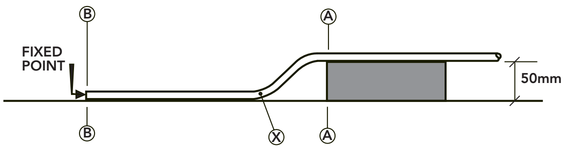
Down bend to angle of rule.

FOR LARGE SETS OF 75mm AND ABOVE

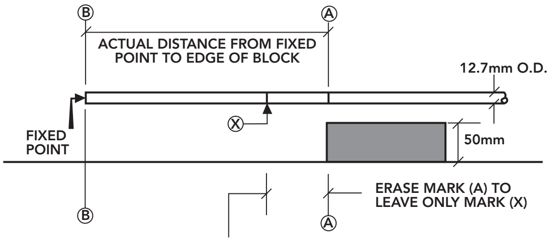


When positioning larger sets where the angle of the mark is increased and prevents it from making a tangent to the leading edge of the former, a rule can be used to extend and position the mark at the true point of tangency.

Double Sets – From a fixed point



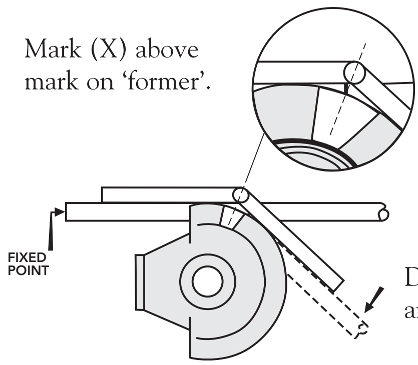
The centre of the first set (X) must be determined.



Measure back from Point (A) -80mm to give Point (X).
This measurement is determined by adding together the depth of block (50mm) to twice the diameter of the tube (2 x 12.7mm). (i.e. 50 + 12.7 + 12.7 = 75.4mm).

To form correct angle of bend, deduct 50mm (depth of block) from a 600mm rule (see 'double sets' above for illustration) and stagger the legs of a 600mm folding rule to 550mm apart.

Mark (X) above mark on 'former'.



Down bend to angle of rule.

Place tube in machine with fixed point at the rear. Position mark (X) above a mark on the 'former' which is obtained by placing angled rule parallel with the top edge of the tube and sliding rule along until other leg touches the leading edge of the 'former'. Mark 'former' by bisecting angle of rule.

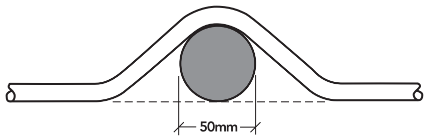
Follow procedure as for 'double sets'.

Copper Quality is for keeps

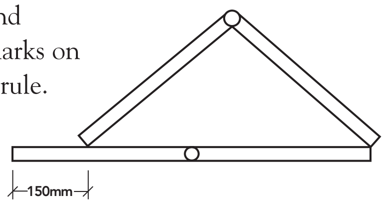
Bending of copper tubes

Crank Sets

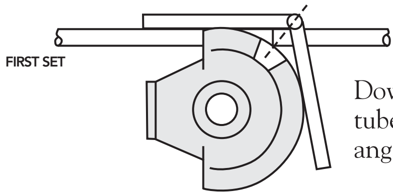
To obtain the correct angle for the first set, multiply the external diameter of obstacle - say DN50 tube by 3 (i.e. 50 x 3 = 150mm).



Stagger the legs of a 600mm folding rule between the 150mm and 600mm marks on the other rule.

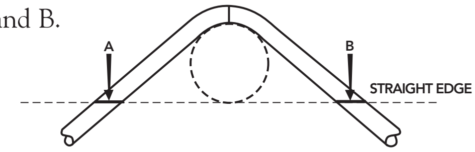


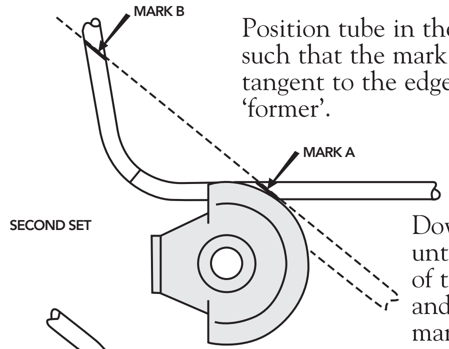
Having marked the centre of the set on the tube, the tube is positioned with the mark vertically above a mark on the 'former' which is determined by bisecting the angle of the rule when placed as below.



Down bend the tube to the angle of the rule.

Place tube over obstacle or measure 50mm from inside of first set to straight edge and mark the tube at A and B.

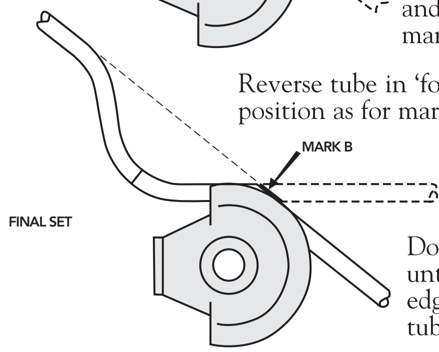




Position tube in the machine such that the mark A forms a tangent to the edge of the 'former'.

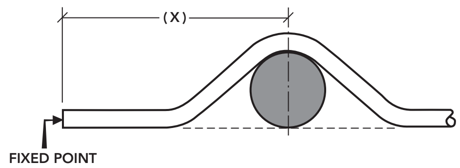
Down bend until top edge of tube is level and in line with mark B.

Reverse tube in 'former' and position as for mark A.

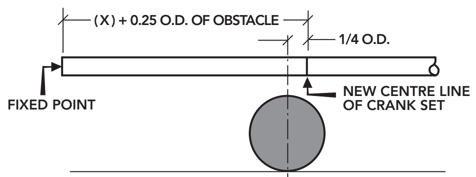


Down bend until the top edges of the tube are in line.

Crank Sets – From a fixed point

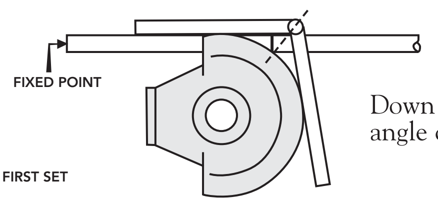


The centre of a crank set can be predetermined by simply adding 0.25 of the outside diameter of the obstacle to the actual distance from the fixed point to the centre of set.



Determine the angle of the first set by deducting THREE times the outside diameter of obstacle from a 600mm rule and setting the legs of a second folding rule to this distance (method employed in 'crank sets' above).

Place the tube in the machine with the fixed point at the rear and position the centre of set above a mark on the 'former' which is obtained by placing the angled rule parallel with the top edge of the tube and sliding rule along until other leg touches the edge of the 'former' and bisect the angle of the rule.



Down bend to angle of rule.

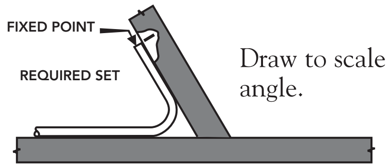
Continue to complete crank set as described in 'CRANK SETS' above.

NOTE: A series of crank sets can be formed on a straight length of tube at predetermined centres.

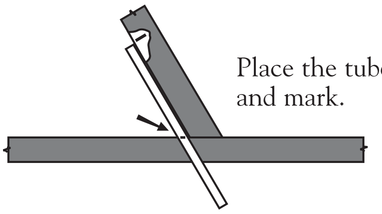
Copper Quality is for keeps

Bending of copper tubes

Sets Beyond 90° – From a fixed point

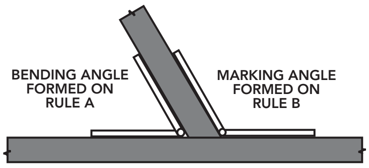


Draw to scale the required angle.



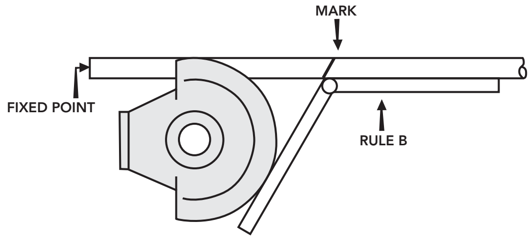
Place the tube in position and mark.

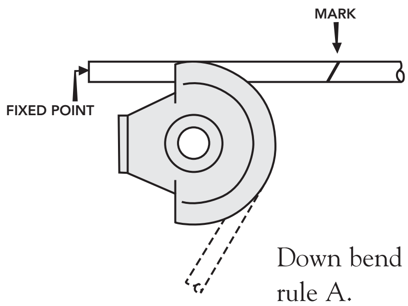
Form one folding rule A to the inside of the required angle (this will indicate the correct angle of bend to form in the machine).



Place the other folding rule B against the outside angle (this will enable the tube to be correctly positioned in the 'former').

Position the tube in the 'former', with the fixed point to the rear using rule B.

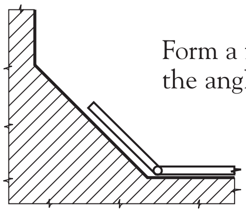




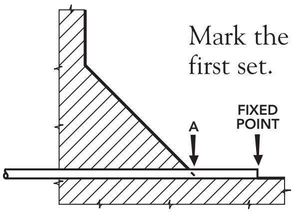
Down bend to angle of rule A.

Two Angled Sets

Draw full size the required set.

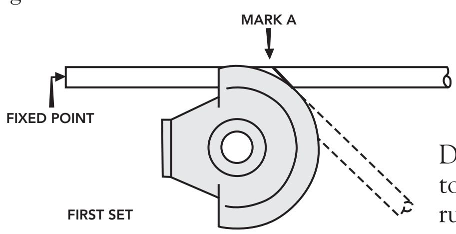


Form a folding rule to the angle of set.

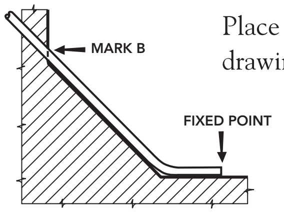


Mark the tube A for the first set.

Place tube in the 'former' with fixed point to the rear of the tube locator and position mark A in line with edge of 'former'.

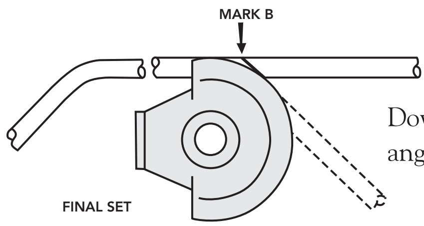


Down bend to angle of rule.



Place bent tube over drawing and mark B.

Re-positioning tube in 'former' with first set at the rear, lining-up mark B with edge of 'former'.



Down bend to angle of rule.

Copper Quality is for keeps

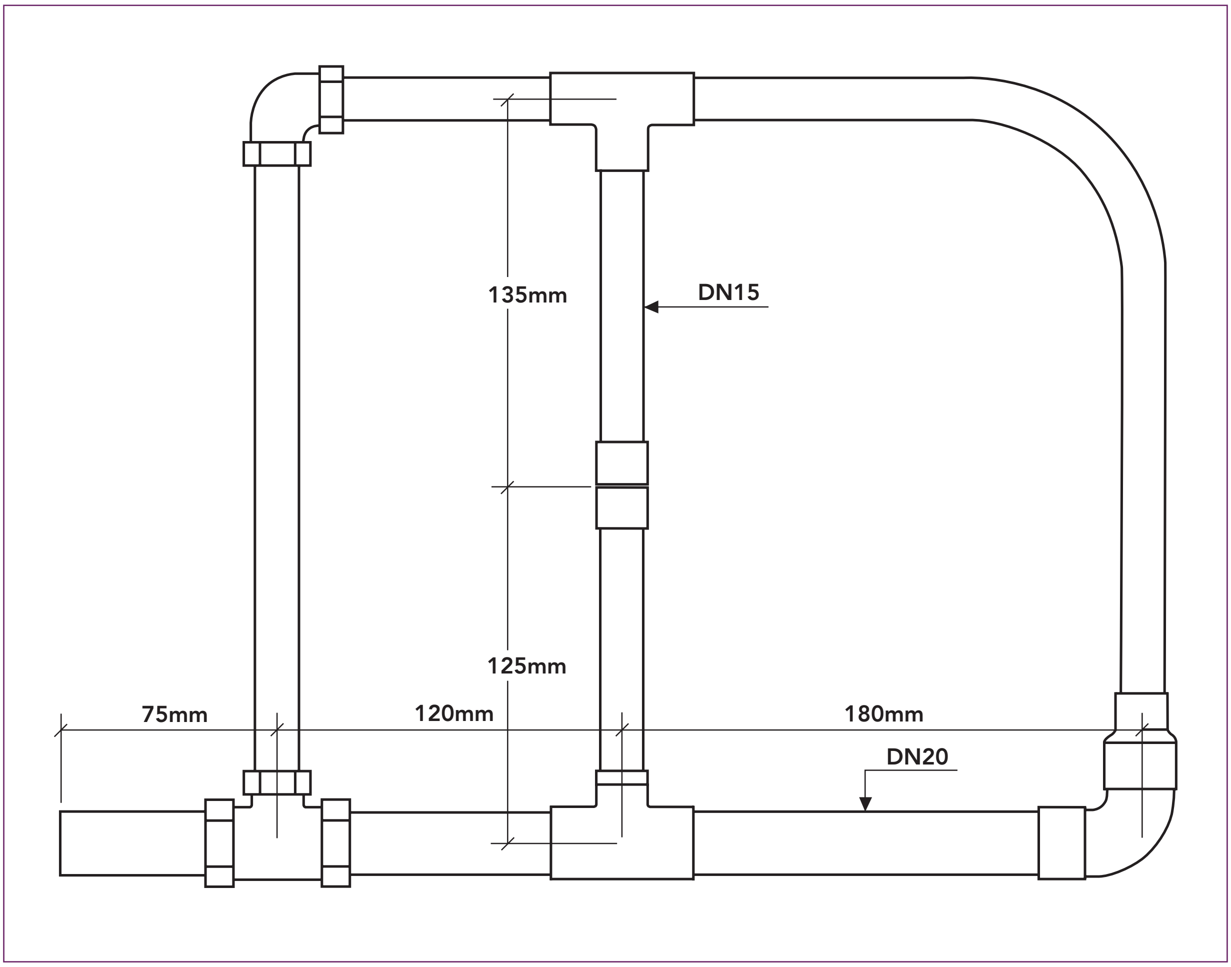
Exercise 1 - Copper tube jointing and bending

Preparation

Before any practical task can be done it is necessary to plan out the job and collect together the tools, equipment and materials required. The questions and tasks described on the next page are designed to help you to prepare for the copper tube exercise.

The drawing shows a small frame that can be made from DN15 and DN20 copper tube using a mixture of end-feed and integral solder ring capillary fittings as well as compression fittings. The practical skills that will be developed in making the exercise include: cutting tube to length; setting out; forming a 90° machine bend and jointing.

For a good standard of work to be achieved all dimensions would be correct within a tolerance of ± 3mm. Also, the tube would be cut square and free from burrs. The joints would be watertight when tested to mains pressure, have a neat appearance without tool marks, be free from solder runs and all traces of flux would be removed.



Copper Quality is for keeps

Exercise 1 - Copper tube jointing and bending

Tasks and Questions
References: Section 3.1 Copper Tube in Buildings, manufacturers fittings catalogues, installation method and bending guide.

1. Copper tube for use in plumbing, gas fitting and drainage systems is made to AS 1432. It is available in four 'Types' - A, B, C & D and three states of temper: soft (annealed), bendable and hard drawn. Bearing in mind the *MECHANICAL PROPERTIES OF COPPER TUBE,* what is the correct type and temper of tube to use for this exercise?

2. List the 5 stages required to make non-manipulative *COMPRESSION JOINTS.*

3. List the 8 stages required to make *CAPILLARY* soldered *JOINTS.*

4. What kind of solder must *NOT* be used when making end-feed joints on hot and cold water systems?

5. When soldering, why is the application of a *FLUX* required?

6. If an end-feed fitting is *OVERHEATED* before applying solder, what would be the result?

7. Why might a non-manipulative *COMPRESSION* fitting 'blow' off the tube on a mains cold water service pipe?

8. Using the *FITTINGS MANUFACTURERS CATALOGUES* select and note on the Material Requisition sheet all the fittings and total length of tube needed to make the exercise.

9. Following the example shown in the *PIPEWORK INSTALLATION METHOD* work out the cutting lengths for the various pieces of tube required to assemble the exercise and note them on the cutting list.

10. In order to form the 90° machine bend the *"BENDING POINT"* has to be found. This is so that the tube can be correctly positioned in the machine. How far from the end of the tube should the bending point be measured to form the bend in the exercise shown above?

Answer Sheet

Exercise 1 - Copper tube jointing and bending

1. Table ____________ Temper ____________

2. Stages required to make non-manipulative compression joints are: ____________

3. Stages required to make capillary soldered joints are: ____________

4. The type of solder that must NOT be used is ____________

5. Flux is needed to ____________

6. Overheating before applying solder causes ____________

7. The fitting might 'blow' because ____________

Copper Quality is for keeps

Answer Sheet
Exercise 1 - Copper tube jointing and bending

8. Materials Requisition

Catalogue Number	Diameter	Description	Quantity Required	Cost
			Total Cost	

9. Tube Cutting List

Tube Ref Number	Diameter	Measured Length	Fitting Allowance	Cutting Length

10. The bending point should be ________ mm from the end of the tube.

Copper Quality is for keeps

Exercise 2 - Copper tube jointing and bending

Preparation

The tasks and questions below are designed to help you form the bends accurately and correctly assemble the frame. In Exercise 1 the fittings required could be identified from the drawing so that you could select them from the fitting catalogue. People who install copper tube often have to decide on the particular pattern of fitting to use, from the many that are available, for a certain situation. In this exercise one of the skills you will start to develop is choosing fittings to use from a catalogue. The frame should be assembled using both capillary and compression fittings - you will have to decide which particular fittings are best to use.

Figure 1 - Tube bending exercise

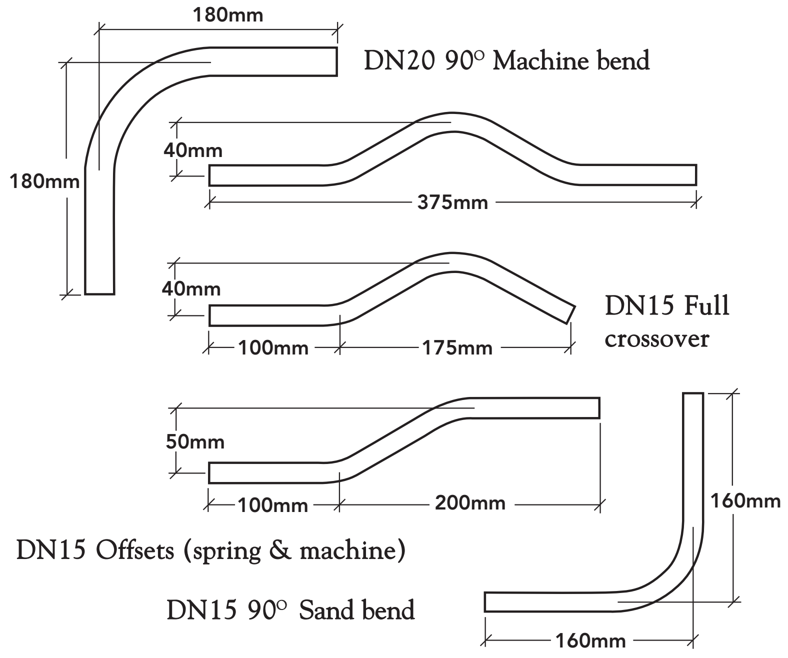


Figure 2 - Assembly exercise

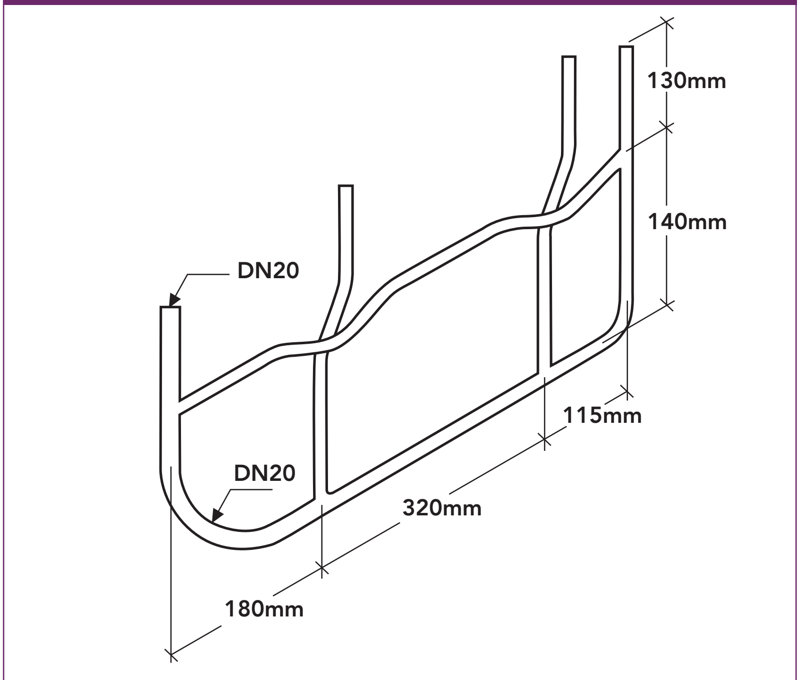


Figure 1 shows a series of spring and machine bends that can be fabricated from DN15 and DN20 copper tube. They are designed to build up your skills as you form each piece of tube. Once the bends have been made they can be assembled using a combination of capillary or compression fittings to complete the exercise shown in Figure 2. Alternatively fittings can be combined with silver brazing used to complete the joint. As with Exercise 1, a good standard of work would achieve a tolerance of ±3mm and the bends would be formed without throating, kinks or ripples. The spring bends would be to the correct radius and, once assembled, the frame would be free from solder runs and all traces of flux would be removed.

Copper Quality is for keeps

Exercise 2 - Copper tube jointing and bending

Tasks and Questions

References: Sections 2.2 Bending guide, manufacturers fittings catalogues.

1. What is the maximum recommended diameter of copper tube that can be bent using a spring?
2. When forming a 90° spring bend what are the minimum and maximum recommended radii of the bend?
3. When forming a 90° spring bend on DN15 tube:
   a) how far back from the measured length should the second mark be, showing the start of the bend?
   b) how far forward from the measured length point, should the third mark be, showing the finish of the bend?
4. How much tube is 'gained' when a 90° bend is formed if it has a radius of 4 tube diameters?
5. How can easy spring removal be achieved after forming a bend?
6. If tube centre spacing is to be maintained around two 90° bends on DN15 diameter tube that are to be fixed at 50mm centre to centre:
   a) what is a suitable radius for the inner bend?
   b) what will the correct radius be for the outer bend?
   c) how far back should the start mark be on the outer bend?
   d) how far forward should the finish mark be on the outer bend?
7. Why might corrugations occur when machine bending light gauge copper tube and where is the correct pressure point for the roller?
8. When positioning tube in the machine to form a simple 90° bend:
   a) should the fixed point be at the front or rear of the machine?
   b) if the bend required is to be 180mm from the fixed point to the centre of the tube after the bend what measurement should be added to give the back of bend mark?
   c) how can the mark be correctly lined up with the former in the machine?
9. When using a frame bender, if the length of tube to be bent is too long to down bend, how far back from the measured length initial mark should the new mark be made when reverse bending DN25 diameter tube?
10. When forming a double set from a fixed point on DN15 copper tube, how far should the bending point be measured back from the edge of the obstruction if the obstruction measures 40mm?
11. When forming a crank set, or crossover bend, to span an obstruction of 40mm:
    a) by what measurement should the folding rule be staggered to find the angle for the first bend?
    b) if the distance from the fixed point to the centre of the obstruction is to be 200mm, how far from the end of the tube should the bending point be marked?
12. When ordering fittings, what three essential items of information must be stated to ensure that the correct fitting will be supplied?
13. When ordering 'tee' fittings, how should the diameters of the ends of the tee be specified?
14. State three advantages of integral solder ring fittings?
15. Using the manufacturers catalogue, select a combination of integral ring capillary, compression & capillary silver brazed jointed fittings to enable the frame, shown in Figure 2, to be assembled. Note these on the materials requisition together with the total length of DN15 and DN20 tube required to form all the bends shown in Figure 1.

Answer Sheet

Exercise 2 - Copper tube jointing and bending

1. The maximum recommended diameter for spring bending is DN________.
2. The minimum spring bend radius is________ diameters and the maximum is________ diameters.
3. a) The second mark should be_______ mm back.
   b) The third mark should be_______ mm forward.
4. The amount of tube gained is____
5. Easy spring removal can be____
   ____
6. a) Inner bend radius _______ mm, b) Outer bend radius _______ mm,
   c) Back measurement _______ mm, d) Forward measurement _______ mm.
7. Corrugations can occur because____
8. a) The fixed point should be at the _________ of the machine.
   b) _______ mm should be added to the measured length.
   c) The mark can be lined up by ____
9. The new mark should be ____________________ from the initial mark.
10. The bending point should be ____________________ from the obstruction.
11. a) The folding rule should be staggered by_______ mm.
    b) The bending point should be _______ mm from the end of tube.
12. When ordering fittings, the three essential items of information are: ______________________
    ____
13. When ordering tees ____
14. Two advantages of integral ring fittings are: ______________________________
    ____
15. Two advantages of silver brazed capillary fittings are: ______________________________
    ____
16. Materials Requisition

Catalogue Number	Diameter	Description	Quantity Required	Cost
			Total Cost	

Copper Quality is for keeps

Exercise 3 - Copper tube planning and measurement

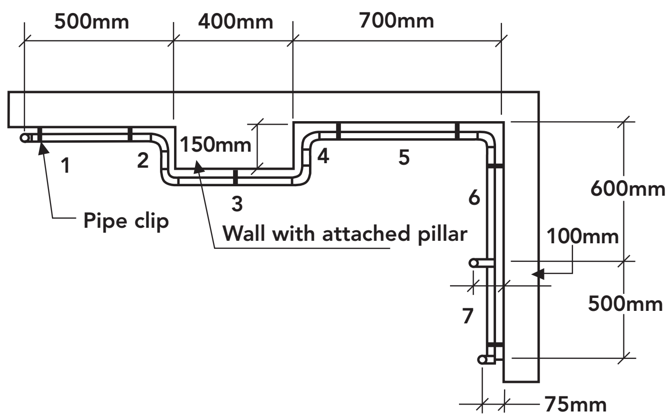
Preparation

Before any tube can be installed it is necessary to plan out the job and collect together the tools, equipment and materials required. The questions and tasks described below, are designed to help you to install the copper tube quickly and efficiently, in a professional manner and to a high standard, without waste of materials.

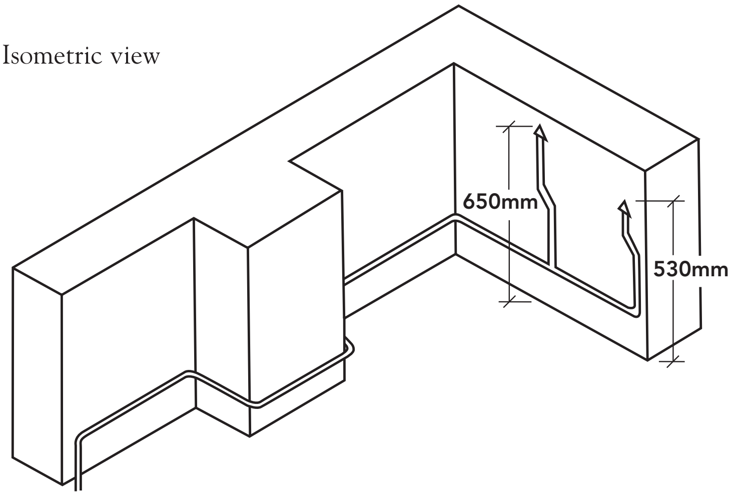
This exercise is designed to get you ready to install copper tube. The diagram shows a DN15 diameter cold water service pipe supplying water to a previously installed WC and washbasin in a typical washroom. It is normal practice, when installing tube for water services, to fix the tube plumb and level. Also, the tube must be adequately supported and it is important to ensure that any decorated surfaces remain undamaged both by hand and tool marks or blowtorch scorching.

Cold water service to washbasin & WC Cistern

Plan



Isometric view



Horizontal run of tube is 150mm to centre above floor level

Copper Quality is for keeps

Exercise 3 - Copper tube planning and measurement

Tasks and Questions

References: Sections 2.1 and 3 Copper tube in buildings, pipework installation method and manufacturers fittings catalogues.

1. When installing copper tube, what are the maximum spacings for tube support FIXINGS:
   a) for DN15, 20 and 25 horizontal tube?
   b) for DN15, 20 and 25 vertical tube?

2. When copper tube is installed in timber and metal framed walls:
   a) What are the options for securing tube where it passes through drilled holes in timber framework?
   b) List the alternatives for protecting copper where it passes through holes in metal framework.

3. How can a copper tube supplying the sanitary fittings as shown, be connected to DISSIMILAR MATERIAL such as a Polyethylene service entry pipe and what fitting would be best to use in this situation?

4. List, in a logical sequence, the order of tasks required to install the copper tube shown and leave the job completed ready for hand-over to the customer.

5. Using the FITTINGS MANUFACTURERS CATALOGUES, select and note on the Material Requisition sheet all the fittings, including valves for servicing and isolation, tube support clips and the total length of tube required to install the copper tube.

6. Following the example shown in the PIPEWORK INSTALLATION METHOD, measure up the fittings and clips you have selected and note the fitting allowances (X dimensions) and clip stand-off allowance (Y dimension) on the Pipe Layout Chart.

7. Using the techniques described in the PIPEWORK INSTALLATION METHOD, make a single line diagram of the pipe run as shown above on the Pipe Layout Chart and then number each piece of tube.

8. Using the techniques described in the PIPEWORK INSTALLATION METHOD, work out the cutting lengths for each piece of tube on the Pipe Layout Chart allowing for clips and fittings.

9. How can decorated wall surfaces be protected whilst capillary fittings are heated?

10. Once the installation work has been completed the job requires COMMISSIONING and can then be handed over to the customer. How should this task be carried out?

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Exercise 3 - Copper tube planning and measurement

Answer Sheet

1. Maximum spacings for tube supports are:

   a) horizontal tube DN15 _______ , DN20 _______ , DN25 _______ ;

   b) vertical tube DN15 _______ , DN20 _______ , DN25 _______ ;

2. a) The options for securing unlagged copper tube where it passes through holes drilled in timber framework are the use of ______________________________ or ______________________________.

   b) Alternatives for protecting copper passing through holes in metal framework are ____________________, ____________________ or ______________________________.

3. Copper tube can be connected to a Polyethylene service entry using ______________________________

4. The order of tasks required is: ______________________________

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Exercise 3 - Copper tube planning and measurement

Answer Sheet

5. Materials Requisition

Catalogue Number	Diameter	Description	Quantity Required	Cost
			Total Cost	

6 & 7. See separate pipe layout chart

9. Wall surfaces can be protected by using ______________________

____

____

10. Commissioning and handover tasks include ______________________

____

____

____

____

____

____

____

____

____

____

____

Copper Quality is for keeps

Copper Tube Installation Method - Pipe Layout Chart

Contract ______________________________ Sheet No. ____ of ____

Measured By ______________________________ Date ______________

Pipe No.	Dia	Measured Length	X Dim	Y Dim	Cut Length	Pipe No.	Dia	Measured Length	X Dim	Y Dim	Cut Length

X Dims		
Dia	Fittg	'X'

Y Dims			
Dia	'Y'	Dia	'Y'

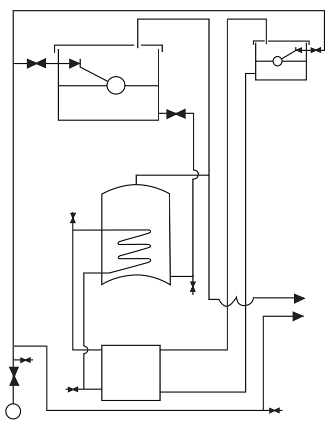
Exercise 4 - Copper tube hot and cold water installation

Preparation

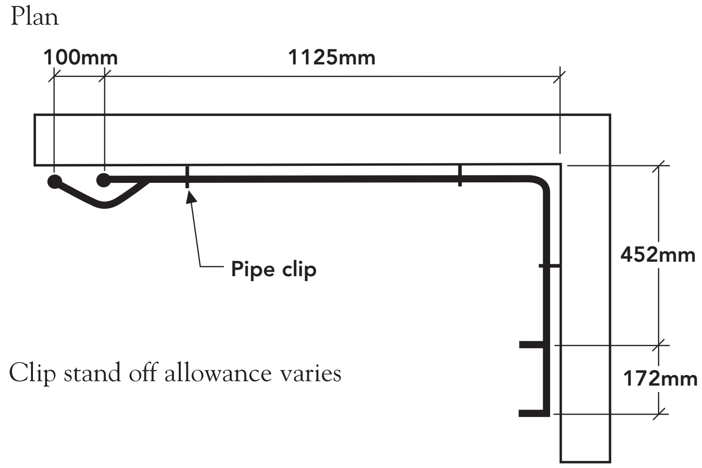
As with the previous exercises, before any tube be installed, it is necessary to plan out the job and collect together the tools, equipment and materials required. The questions and tasks described below are designed to help you to install copper tube quickly and efficiently with maximum use of bending techniques, to a high standard and without waste of materials.

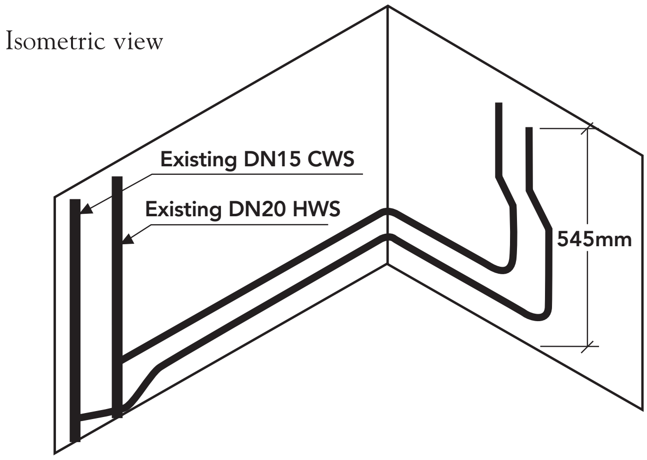
This exercise is designed to increases your skill levels in machine bending and installing copper tube. The diagram below shows DN15 diameter hot and cold water pipes supplying water to a new washbasin. These are to be extended is also shown as a schematic layout, it would require isolation and draining before the new section of pipework could be connected and the extended installation brought back into service.

Schematic of Hot & Cold Water System



New Hot and Cold Water Services to Washbasin





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Exercise 4 - Copper tube hot and cold water installation

Tasks and Questions

References: Sections 2.1, 2.2 and 3.1 Copper tube in buildings, pipework installation method, bending guide and manufacturers fittings catalogues.

When deciding on the BEST LAYOUT and METHODS OF PROTECTION for pipework a number of design factors have to be taken into account:

1. How should drinking water pipes be sized?
2. How can cold water services, particularly drinking water services, be protected against undue pick-up of heat?
3. Name three locations where protection against frost damage is essential?
4. When considering PROTECTION of PIPING, where is the best place to carry the rising main up to the storage tank/reservoir?
5. What are the minimum and maximum depths between which UNDERGROUND WATER SERVICES can be buried?
6. List on the Materials Requisition the total length of copper tube, the number of clips required and the FOUR fittings that are needed to install the new hot and cold water services to the washbasin.
7. Using the techniques shown in the Bending guide and Installation method, make a single line diagram of the new hot OR cold water pipe and, allowing for clip spacings and fittings, determine the measurements for the marking points required for bending the tube from one piece of copper using a machine.
8. List, in a logical order, the tasks required to safely isolate and drain down the hot and cold water system shown in schematic form above.
9. Whilst you are installing the new pipework the customer asks why copper tube is being used for the installation. What TECHNICAL and ECONOMIC FACTORS, or other reasons should be offered to show that copper is the best 'all round' choice for hot and cold water services?
10. Once the installation work is complete the system must be tested and brought back into service, by COMMISSIONING list the tasks required to carry out this work and leave the installation safe for the customer to use.

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Exercise 4 - Answer Sheet
Copper tube hot and cold water installation

1. Drinking water pipes should be sized ______________________________

____

____

2. Cold water services can be protected against undue pick-up of heat by either ______________________________

or by ______________________________

____

3. Three locations where insulation is essential are: ______________________________

____

____

____

4. The best place to carry the rising main up to the storage tank/reservoir is ______________________________

____

____

____

5. The minimum depth for an underground water service is ______ mm and the maximum is ______ mm

6. Materials Requisition

Catalogue Number	Diameter	Description	Quantity Required	Cost
			Total Cost	

7. See separate sheet Pipe layout chart

Copper Quality is for keeps

Exercise 4 - Copper tube hot and cold water installation

8. The tasks required to isolate and drain the system are:

9. Copper is the best 'all round' choice for hot and cold water pipes because:

10. The tasks required to bring the system safely back into service are:

Copper Quality is for keeps

Copper Tube Installation Method - Pipe Layout Chart

Contract ______________________________ Sheet No. ____ of ____

Measured By ___________________________ Date ____________

Pipe No.	Dia	Measured Length	X Dim	Y Dim	Cut Length	Pipe No.	Dia	Measured Length	X Dim	Y Dim	Cut Length

X Dims		
Dia	Fittg	'X'

Y Dims			
Dia	'Y'	Dia	'Y'

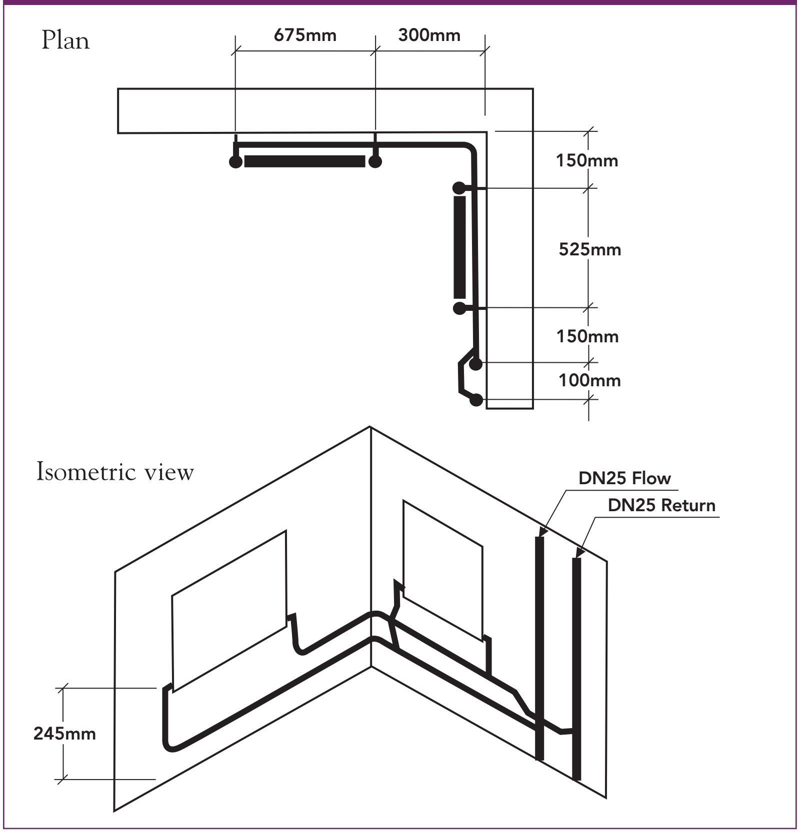
Exercise 5 - Copper tube central heating installation

Preparation

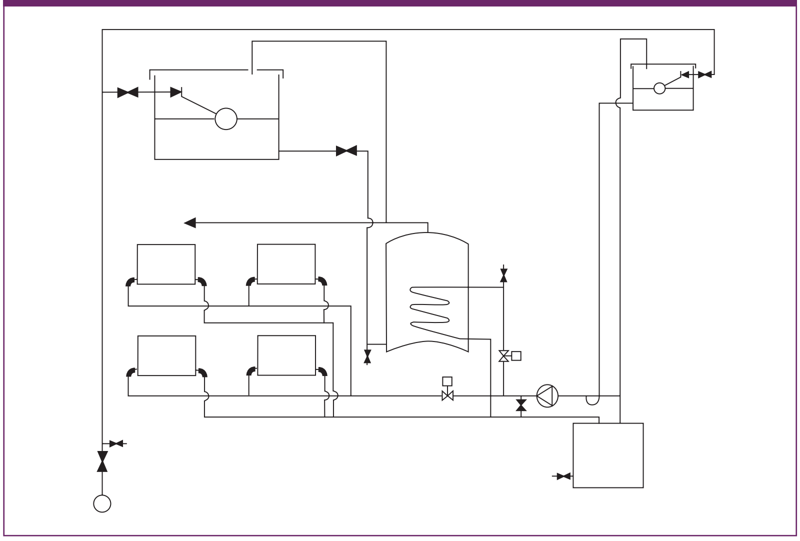
As with the previous exercises, before any tube can be installed it is necessary to plan out the job and collect together the tools, equipment and materials required. The questions and tasks described below are designed to help you decide on the best working methods and techniques to use, to enable you to install copper tube efficiently, to a high standard, without waste of materials and ensure that the system gives a long and trouble free service life.

This exercise is designed to increase your skill levels in planning and installing copper tube. The diagram below shows flow and return pipes feeding two new radiators to be fitted to an existing central heating system. The existing system is also shown as a schematic layout, as with the previous exercise it would require isolation and draining before the new section of pipework could be connected and the extended installation brought back into service.

Flow and Return to Radiators



Schematic of Hot Water & Heating System



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Exercise 5 - Copper tube central heating installation

Tasks and Questions

References: Sections 2.1, 2.2 and 3.1 Copper tube in buildings, pipework installation method, bending method and manufacturers fittings catalogues.

When installing copper tube in heating and hot water systems:

1. When considering THERMAL MOVEMENT, by how many millimetres will an 8 metre length of copper tube expand if it is heated by 60°C?
2. How can damage due to THERMAL MOVEMENT be prevented when copper tube passes through solid walls and floors?
3. What is the maximum length for straight pipe runs that can be installed before EXPANSION JOINTS have to be fitted?
4. When considering PUMP CAPACITY on small bore heating systems:
   a) what is the maximum water velocity to ensure quiet operation?
   b) what is the minimum diameter for the open vent pipe?
   c) what is the minimum diameter for the cold feed pipe?
5. Where the heating system uses a boiler with a finned copper heat exchanger a CLOSE COUPLED CONNECTION is recommended:
   a) what is the maximum distance between the connections?
   b) onto which pipe, flow or return, should the pump and close coupled connection be fitted?
6. PLASTIC COATED COPPER TUBE can be used where protection against mechanical damage and corrosion is required: what colour should be used for central heating services?
7. When considering the use of COPPER IN DOMESTIC HEATING SYSTEMS why are copper and copper alloys a good choice:
   a) for pipework and fittings?
   b) for heat exchangers in boilers and storage cylinders?
   c) valves?
8. List on the Materials Requisition the total length of copper tube, the number of clips, the valves and the fittings that can best be used to install the new flow and return pipes to feed the radiators.
9. Using the techniques shown in the Bending guide and Installation method, make a single line diagram of the new flow OR return pipe and, allowing for clip spacings and the chosen fittings, work out the cutting lengths and bending points required to install the tube.
10. A few months after installation a HEATING SYSTEM is found to suffer from CORROSION which resulted in the formation of pinholes and pits in the copper tube near to capillary soldered joints, this was as a result of faulty workmanship:
    a) what was the cause of the problem?
    b) how could the problem be avoided?

Copper Quality is for keeps

Answer Sheet
Exercise 5 - Copper tube central heating installation

1. The tube will expand by________ mm.

2. Damage due to thermal movement can be prevented by ____

____

3. The maximum length for straight copper pipe runs without the use of expansion joints is__________m.

4. a) the maximum velocity for quiet operation is ________ m/s.
   b) the minimum diameter for the open vent pipe is________ mm.
   c) the minimum diameter for the cold feed pipe is________ mm.

5. a) the maximum distance between connections is________ mm.
   b) the pump and close coupled connection should be fitted to the__________ pipe.

6. Plastic coated copper tube coloured____________ should be used for central heating services.

7. Copper and copper alloys are a good choice:

   a) for pipework and fittings because ____

   ____

   ____

   ____

   ____

   b) for heat exchangers in boilers and storage cylinder because ________________________________

   ____

   ____

   ____

   ____

   ____

   c) for valves because ____

   ____

   ____

   ____

   ____

   ____

   ____

   ____

Answer Sheet

Exercise 5 - Copper tube central heating installation

8a. Materials Requisition

Catalogue Number	Diameter	Description	Quantity Required	Cost
			Total Cost	

8b. The types of joint, fittings and valves selected for this work are best because ____________________

9. See separate Pipe layout chart ____________________

10. a) The cause of the problem was ____________________

b) The problem could be avoided by ____________________

Copper Quality is for keeps

Copper Tube Installation Method - Pipe Layout Chart

Contract ______________________________ Sheet No. ____ of ____

Measured By ______________________________ Date ____________

Pipe No.	Dia	Measured Length	X Dim	Y Dim	Cut Length	Pipe No.	Dia	Measured Length	X Dim	Y Dim	Cut Length

X Dims		
Dia	Fittg	'X'

Y Dims			
Dia	'Y'	Dia	'Y'

Section 3

Reference Guide

3 Reference Guide

Copper Quality is for keeps

Section 3.1

Copper tube in buildings

Copper tube in buildings

1 Pipework installation method

1.1 Technical and economic factors governing the use of copper tube in buildings.

Copper was used as a water conduit by the ancient Egyptians (at Abusir) as long ago as 2750 B.C. and was later widely used by the Romans as water pipes and cisterns. Indeed good examples of plumbing in copper are still to be seen at the archeological site of Herculaneum, destroyed by the eruption of Vesuvius in 79 A.D.

The advantages of copper as a plumbing material were rediscovered at the beginning of the twentieth century but because the pipes were relatively expensive, their use was restricted to prestigious public buildings and hospitals, where the initial costs were outweighed by its proven corrosion resistance, resulting in trouble free service and negligible maintenance costs. Copper tubing was expensive in those days because it could only be joined by threading and screwing, in a similar manner to that used today for joining iron and galvanised steel tubing. However in the 1930's, with the development of different types of fittings and light gauge copper tubing, which enabled the wall thickness to be reduced generally by over 50% and in some cases almost 75%, costs were dramatically reduced. Since the 1940's, copper has become the pre-eminent plumbing material in the developed countries of the world. In Australia and New Zealand it accounts for the majority of new installations and its use is also increasing rapidly in the developing countries. The reasons for this success derive from a combination of the properties of copper.

1.2 Resistance to corrosion.

Copper is highly resistant to corrosion not only from its surroundings but also to the many different qualities of water conveyed. Indeed, as demands for improved water quality have grown, and regulations governing the quality of water have become more stringent, copper tube manufacturers have developed their production techniques to meet these demands for higher quality tubes.

In accordance with the Plumbing Code of Australia (PCA), all plumbing products are to be authorized and comply with MP 52/Australian Standard AS 5200: Technical specification for plumbing and drainage products – Procedures for certification of plumbing and drainage products. Therein, it is specified that copper tube shall comply with AS1432 whilst the Standard for copper and copper alloy pressure fittings is AS3688. Both pressure tube and fittings require StandardsMark certification and be marked with the 'box of ticks' logo. Non-pressure fittings shall comply with either AS3517 or AS1589 and be WaterMarked licenced.

Australian copper tubes and fittings are manufactured to comply with stringent StandardsMark and WaterMark requirements which include compulsory ISO 9002 Quality System compliance, third party audits several times a year and product type tests.

Purchasers and installers should look for StandardsMark and WaterMark symbols of quality on product to ensure compliance with regulations.

Copper tube and fittings made to these standards, properly installed by competent plumbers in well designed systems will ensure long and trouble free service for the customer.

1.3 Mechanical strength.

Copper tubes have high mechanical strength, at least 200 N/mm^2 for annealed tubes and more than 300 N/mm^2 for hard drawn tubes. Copper tubes supplied in straight lengths are quite rigid and can be installed vertically or horizontally without sagging, with the minimum use of clips. They are highly resistant to knocks and accidental damage.

Their high thermal conductivity makes copper tubes highly resistant to fire damage and they are resistant to damage by rodents.

All these factors make copper a very reliable material for tubes.

1.4 Ease of working.

Copper is a very malleable metal and therefore can be bent and formed easily and quickly using appropriate techniques. Lengths of tubing can be joined with fittings using simple techniques and the variety of fittings available allows even complex systems to be installed quickly and efficiently. Copper tube also offers considerable aesthetic advantage. Indeed, whenever it is not possible to encase tubing or for any reason desirable to surface fix pipework, the use of copper, including plastics coated tubing, reduces the visual impact to a minimum.

Copper Quality is for keeps

Copper tube in buildings

1.5 Low pressure loss.

Pressure losses due to friction are lower for copper tubing than for the majority of other metals.

The internal surface of copper tubing is exceptionally smooth, but the major factor in achieving smooth flow characteristics is the design of fittings that do not restrict the cross section of the bore. Such factors reduce pressure loss as much as 60% when compared with certain other materials. These characteristics, combined with the good mechanical strength of copper, enable satisfactory flow performances to be achieved with smaller diameter tubes. The combination of all these advantages results in a reduction in: dimensions, the weight of metal used, costs and temperature lag in heating systems.

1.6 Bactericidal properties.

Copper has long been known for its algicidal and fungicidal properties. Recent work by ICA (International Copper Association) has shown the decisive role which copper can play in the destruction of certain bacteria. This work, has already confirmed these properties and has shown that copper contributes to general health due to its natural purifying effects. There is some evidence based on a limited survey carried out by the Health Bodies of the U.K. to suggest that substantially 'all-copper' systems tend to be free of Legionella pneumophila.

1.7 Favourable cost effectiveness.

The unique characteristics of copper piping combining long trouble-free service life, safety and weight savings due to the smaller diameters required readily explain the success of copper in building applications.

In addition, the ease of fabrication and installation of copper tubing, results in improved cost effectiveness of copper compared with other materials.

This cost effectiveness, resulting from the intrinsic properties of the metal, has been further enhanced in recent years by the increased availability of copper throughout the world, which has contributed to a substantial lowering of costs.

1.8 The material of the professional.

Copper tube is manifestly a material well suited for gas, water, sanitation, fire and heating services within buildings. It is easy to use and install, by a competent plumber.

Indeed the only recommendations necessary which apply to the use of copper are those relating to good design of the systems and a level of competent workmanship commensurate with the use of any high-performance material.

In this respect copper tubing is truly the material of the professional who will know how to ensure that the natural long life of the product is not compromised by poor design and faulty workmanship.

2 Characteristics and parameters of copper tube.

2.1 Characteristics of copper.

The copper used in the manufacture of tubes is Phosphorus deoxidised copper, high residual phosphorus alloy C12200 defined by Australian Standard AS 1432*.

The minimum copper content is 99.90% and the residual phosphorus content is between 0.015 and 0.040%.

This deoxidised copper is not affected by reducing atmospheres and consequently is well suited to soldering and brazing. The density of copper is 8.94 x 10^3kg/m^3 at 20°C, its melting point is 1083°C and its coefficient of linear expansion is 17.7 x 10^{-6} per °K.

* Related standards include: AS1569 & 1571, AS1572, ASTMB88, JISH3300, NZS3501 & EN1057.

Copper Quality is for keeps

Copper tube in buildings

2.2 Mechanical properties of copper tube.

The Australian Standard for copper tubes for plumbing, gasfitting and drainage applications is AS1432.

Copper tubes are available in three tempers, annealed, bendable and hard drawn and are designated Type: A, B, C and D. Type D is only available as hard drawn material. Type B is the most popular and general purpose form of tubing.

2.3 Dimensions of copper tube.

The dimensions of copper tubes to AS 1432 are given in Table 2.

2.4 Packaging.

Tubes to Type A, B and C bendable and hard drawn are normally supplied in 18m long coils or 6m straight lengths respectively. Types A and B are available in straight form for all sizes and in coil form for sizes DN6 to DN40 only.

Type C tube is available in both coil and straight form from DN10 to DN25 only.

Type D tube is available in straight form only from sizes DN32 to DN150.

Table 1. Temper and Form

Thickness Type	Temper	Size Range		Form
		Min	Max	
A	Hard drawn Bendable Annealed	DN6 DN15 DN6	DN200 DN20 DN40	Straight lengths Straight lengths Coils
B	Hard drawn Bendable Annealed	DN6 DN15 DN6	DN200 DN20 DN40	Straight lengths Straight lengths Coils
C	Hard drawn Bendable Annealed	DN10 DN15 DN10	DN25 DN20 DN25	Straight lengths Straight lengths Coils
D	Hard drawn	DN32	DN150	Straight lengths

Table 2. Sizes of copper tubes to AS 1432

Size of tube	Outside Diameter mm Maximum	Type A Thickness mm Nominal	Type B Thickness mm Nominal	Type C Thickness mm Nominal	Type D Thickness mm Nominal
DN6	6.35	0.91	0.71	N/A	N/A
DN8	7.94	0.91	0.71	N/A	N/A
DN10	9.52	1.02	0.91	0.71	N/A
DN15	12.70	1.02	0.91	0.71	N/A
DN18	15.88	1.22	1.02	0.91	N/A
DN20	19.05	1.42	1.02	0.91	N/A
DN25	25.40	1.63	1.22	0.91	N/A
DN32	31.75	1.63	1.22	N/A	0.91
DN40	38.10	1.63	1.22	N/A	0.91
DN50	50.80	1.63	1.22	N/A	0.91
DN65	63.50	1.63	1.22	N/A	0.91
DN80	76.20	2.03	1.63	N/A	1.22
DN90	88.90	2.03	1.63	N/A	1.22
DN100	101.60	2.03	1.63	N/A	1.22
DN125	127.00	2.03	1.63	N/A	1.42
DN150	152.40	2.64	2.03	N/A	1.63
DN200	203.20	2.64	2.03	N/A	N/A

Copper Quality is for keeps

Copper tube in buildings

2.5 Marking.

Tubes manufactured by firms which meet the Australian/New Zealand Standards and the requirements of the Plumbing Code of Australia are required to carry 'StandardsMark' identification.

During the manufacturing process the tube is incised at 0.5m intervals along the tube with at least the manufacturers trade mark the StandardsMark, the Australian Standard number, nominal size, thickness type.

eg. XYZ, StandardsMark
AS 1432 DN 15B BQ

This indicates the tube is manufactured by the XYZ company which has a StandardsMark licence and is produced to the AS 1432 of nominal size of DN15 Type B and of 'bendable' temper.

In addition 'Hard Drawn' and 'Bendable' copper tube to AS 1432 are colour coded with a continuous ink mark. Four colours are used to show the tube specification Types:

Type A - Green Type B - Blue

Type C - Red Type D - Black

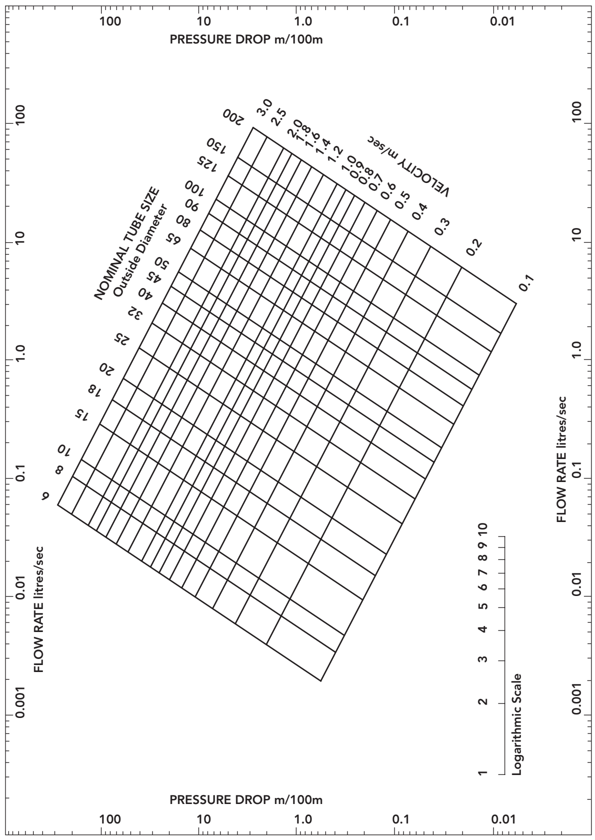
It should be noted that copper tubes are made from one alloy and are of similar quality. The word 'Types' refers to the four thickness categories with Type 'A' being the thickest and Type 'D' being the thinnest tube permitted for use by water authorities.

2.6 Pressure losses and flow rate.

A typical example of a nomogram for determining pipe size from: flow rate, velocity and pressure loss is given in Figure 2. Water velocities in a system should normally lie between 0.5 m/s below which any suspended matter may settle out and 3 m/s which is considered the maximum flow rate for water services associated with building projects.

The condition also conforms to AS/NZS 3500 standards. If the pipe size originally chosen gives rise to velocities outside these parameters a smaller or larger pipe size respectively should be adopted. Nomogram charts can assist by providing a quick reference to pipe sizes and the relationship between flow, pressure loss, velocity and pipe size.

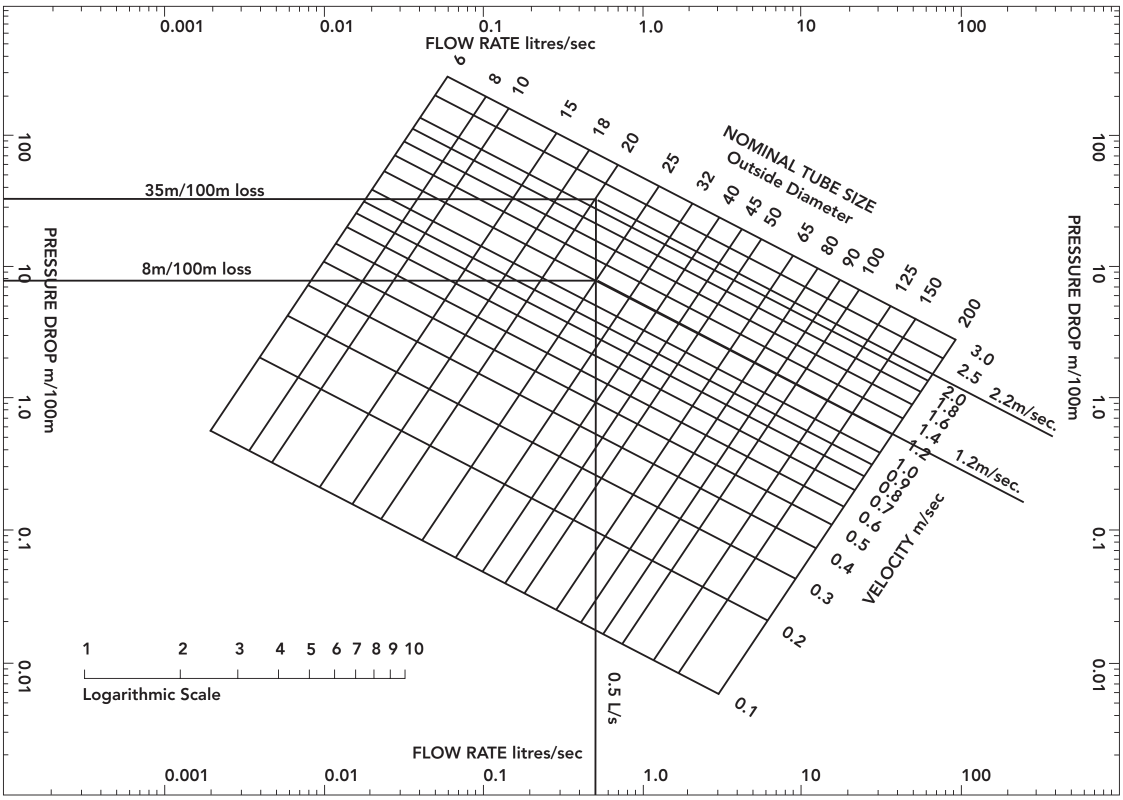
Figure 1 Determination of pipe diameter for cold water (water at 15°C) services



Nomogram used in pipe sizing exercises.

Copper tube in buildings

Figure 2 Illustrating differing conditions of flow and pipe size.



Pipe sizing may be determined using the appropriate section of AS/NZS 3500.1.

Figure 2 illustrates a quick method using a nomogram to ascertain various conditions relating to a chosen pipe diameter and the capabilities of the pipe size chosen.

Example:
A pipeline is required to supply a flow of 0.5 L/s and to remain within the parameters set by AS/NZS 3500. The line is to be installed within a residential unit complex. Using the nomograph establish the flow of 0.5 L/s on the scale at the bottom edge of the chart Extend this line towards the top of the graph till it bisects the line on both DN25 and DN20. Tracing the line from the, point of intersection horizontally to the left provides the pressure drop for the two pipe sizes at the flow of 0.5 L/s. Similarly by following the relevant line diagonally to the right the respective velocities can be established.

From this exercise it can readily be observed that while the DN20 pipe could supply the required 0.51 L/s flow the resultant pressure loss would be very substantial at 35m/100m and the velocity would be 2.2 m/s.

By contrast the line for the DN25 pipe shows a pressure loss of only 8m/l00m while the velocity is only 1.2 m/s.

The correct pipe size selection is therefore DN25.

Copper Quality is for keeps

Copper tube in buildings

2.7 Safe working pressure.

The safe working pressures for AS1432 copper tube at temperatures up to 50°C are shown in Table 6. Values at elevated temperatures may be calculated by multiplying AS1432 Psw figures at 50°C by the appropriate temperature factor, T. For tubes outside AS1432 sizes, values may be calculated by the following formula. Calculations are based on annealed tube to allow for softening at brazed joints.

$$P_{sw} = \frac{2000 \times S_D \times t}{D - t}$$

Where:

P_{sw} = Safe working pressure (kPa)

t = minimum thickness (mm)

D = outside diameter (mm)

S_D = maximum allowable design tensile stress for annealed tube (see below)

T = temperature factor

Values for S_D for various temperature ranges were taken from AS4041, Pressure Piping Code.

Table 5. Maximum allowable design tensile stress

Temperature range °C	Maximum allowable design tensile stress (S_D) (MPa)	T
up to 50	41	1.00
over 50-75	34	0.83
over 75-125	33	0.80
over 125-150	32	0.78
over 150-175	28	0.68
over 175-200	21	0.51

Note: *The testing pressure for copper plumbing installations should not exceed 1.5 times the safe working pressure.*

Table 6. Safe working pressure (Psw) and testing pressure (Pt) for temperature up to and including 50°C

Nominal size	Pressure (kPa)							
	Type A		Type B		Type C		Type D	
	Psw	Pt	Psw	Pt	Psw	Pt	Psw	Pt
DN6	11 320	16 980	8 560	12 840	-	-	-	-
DN8	8 810	13 220	6 700	10 050	-	-	-	-
DN10	8 350	12 530	7 220	10 830	5 520	8 280	-	-
DN15	6 100	9 150	5 290	7 940	4 070	6 110	-	-
DN18	5 750	8 630	4 810	7 220	4 180	6 270	-	-
DN20	5 560	8 340	3 970	5 960	3 450	5 180	-	-
DN25	4 750	7 130	3 500	5 250	2 560	3 840	-	-
DN32	3 750	5 630	2 780	4 170	-	-	2 040	3 060
DN40	3 100	4 650	2 300	3 450	-	-	1 690	2 540
DN50	2 310	3 470	1 710	2 570	-	-	1 260	1 890
DN65	1 840	2 760	1 370	2 060	-	-	1 010	1 520
DN80	1 900	2 850	1 520	2 280	-	-	1 130	1 700
DN90	1 630	2 450	1 300	1 950	-	-	970	1 460
DN100	1 500	2 260	1 200	1 800	-	-	890	1 330
DN125	1 200	1 800	960	1 440	-	-	830	1 240
DN150	1 300	1 950	1 000	1 500	-	-	800	1 200
DN200	910	1 370	720	1 090	-	-	-	-

2.8 Thermal movement.

Pipework systems expand and contract with changes in temperature and will be subject to undue stress if movement is restricted. Construction techniques and systems for hot water central heating have changed in recent years making it advisable always to consider the effects of thermal movement during both the design stage as well as during installation.

A simple formula for calculating expansion in copper piping is:

Expansion (mm) = tube length (m) x temperature rise (°C) x 0.0177. As an illustration, a copper tube 10 metres long carrying hot water at 60°C will expand by 10 x (60-20) x 0.0177 = 7.1mm from ambient temperature of 20°C.

In addition, assuming that temperature cycling of the system is 20°C there will be a continuous cycle of expansion and contraction of 3.6mm taking place. Table 7 gives the expansion in mm of copper tube for various tube lengths and changes in temperature.

It will be apparent from the examples that the stresses imposed can be considerable if no allowance is made for thermal movement.

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Temperature change (°C)	Length of tube (m)									
	1	3	5	6	7	8	9	10	12	25
30	0.5	1.6	2.7	3.2	3.7	4.2	4.8	5.3	6.4	13.3
40	0.7	2.1	3.5	4.2	5.0	5.7	6.4	7.1	8.5	17.7
50	0.9	2.7	4.4	5.3	6.2	7.1	8.0	8.9	10.6	22.1
60	1.1	3.2	5.3	6.4	7.4	8.5	9.6	10.6	12.7	26.6
70	1.2	3.7	6.2	7.4	8.7	9.9	11.2	12.4	14.9	31.0
80	1.4	4.2	7.1	8.5	9.9	11.3	12.7	14.2	17.0	35.4
90	1.6	4.8	8.0	9.6	11.2	12.7	14.3	15.9	19.1	39.8
100	1.8	5.3	8.9	10.6	12.4	14.2	15.9	17.7	21.2	44.2

Table 7. Copper pipework - Expansion and Contraction (mm)

Stress concentrations between 'fixed points' should be avoided wherever possible. Fixed points are typically found at radiators, valves and other fittings, especially tees. Anchoring the branch of a tee, or connecting a radiator by too short a spur, will prevent normal thermal movement.

Such cases are likely to lead to premature failure. Consideration should be given to incorporating expansion loops or bellows devices at appropriate points within the system (see section 4.5).

When continual thermal cycling is encountered, a horse shoe link or loop formed from one length of tube is recommended.

Wherever pipework is to be installed under screed or plaster, it is particularly important to make adequate provision for thermal movement. The preferred method is to lay tubing in ducts. Small diameter tubes may be laid in snake form. Do not embed pipework directly in concrete and take special precautions where tubes enter or leave the screed to ensure that 'fixed points' are not created and thermal movement can take-place. (See also recommendations of AS/NZS 3500).

3 General requirements for the use of copper tube.

3.1 Regulations and statutory requirements.

3.1.1 General References

AS/NZS 3500 was formulated and is periodically upgraded to respond to industry requirements in both Australia and New Zealand. Within both countries individual state or local authorities may also have as an adjunct to the standard, 'code of practice' documents. Where these exist, both documents must be referred to for relevant rulings.

Reference should be made to the relevant sections of the Australian Standards and to the statutory documents of the individual water authority concerned before any water supply installations or modifications are carried out.

The codes are particularly concerned to prevent waste, misuse, undue consumption and contamination of the water supply.

In addition, classified lists of approved fittings together with relevant installation requirements are available from Standards Australia and local authorities.

3.1.2 Standards and Codes. Materials and Workmanship.

Any work to which a requirement of the Plumbing Code of Australia (PCA), the Building Code of Australia (BCA), AS/NZS 3500, Gas Standards AS 3814 & AS 5601 and AS 1677 for refrigeration must be carried out with approved materials and in a workmanlike manner, in accordance with those requirements.

In regard to copper pipe installations, reference should also be made to Australian Standard AS 4809: "Copper pipe and fittings – Installation and commissioning". The Standard provides information on all aspects of copper pipe from design, product selection, installation techniques and commissioning.

Hot Water Storage.

Hot water heaters shall, in accordance with AS/NZS 3500 Part 4 - hot water comply with various Australian standards (see Clauses 4.2 and 5.3.1).

AS3142 Clause 3.1.4 stipulates that the maximum temperature of stored water permissible is 99°C.

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In non vented systems the associated temperature/pressure relief valve shall commence operating at no higher temperature than 93°C.

Insulation of Water Services

AS/NZS 3500 Part 1 – Water services and AS/NZS 3500 Part 4 – Heated water services indicate the requirements for insulation of piping to prevent damage due to excessive ambient temperature conditions and heat retention. Refer to Part 1 – Clause 5.19 “Protection against freezing” and Part 4 – Clause 4.12 “Protection against freezing” and Section 8 “Energy Efficiency”.

A range of insulating materials is available for copper tubes including factory applied plastic and post installation insulation. Reference should be made to the manufacturers’ literature for details of the thermal performance of insulation materials. It should be noted that some plastic coated copper tube is produced primarily for corrosion protection in aggressive environments such as acid soils, or to prevent damage prior and during installation. In these circumstances the insulating properties may not be adequate as thermal insulation for hot water applications.

3.1.3 Services Generally.

The work encompassed by the PCA, BCA, AS 4809, AS/NZS 3500, AS 3814 & AS 5601, relate to the design, installation, testing and commissioning of hot and cold water, gas and sanitation pipework and fixtures.

Broadly speaking, the documents stipulate the requirements of services which provide the supply and discharge of water and gas to comply with the needs of the community particularly in the residential, commercial and industrial sections of industry.

They do not address in detail the need for automatic fire sprinkler services, water treatment plants, medical services, specialist industrial services and refrigeration. While copper is used in all aspect of these and other services due to its excellent all round suitability, this document is not directed to those specialist fields.

3.2 The various uses of copper tubes.

Copper tubes are generally used in buildings for the following purposes:
Domestic hot and cold pressurised water supplies and lines subjected to head pressure from storage tanks.
Sanitary waste disposal and drainage.
Gas and oil heating services.
Fire services.
Central heating systems.
Air conditioning and chilled water services.
Refrigeration systems.

These various applications impose as many stresses on the tubes as the different conditions of use, such as: Wide variations of pressure; Expansion/contraction phenomena due to temperature variation; Chemical attack due to external or the characteristics of internal fluids; Stresses imposed on the tubes during installation.

It is therefore important to know details of the environment to which the pipework will be exposed and also the stresses to which it will subjected in order to assess the behaviour of the tubes.

3.3 Contact with other metals.

Whenever two dissimilar metals are in contact in an electrolyte containing dissolved oxygen, the assembly constitutes a galvanic (corrosion) cell in which the more noble metal is the cathode and the less noble metal is the anode, which tends to dissolve (corrode).

A consequence of this is that the more noble metal is cathodically protected by the less noble (base) metal. For example, galvanised (i.e. zinc coated) steel is protected by the preferential corrosion of the zinc coating and does not show significant rusting until the dissolution of the zinc coating is virtually complete.

In pipework, the jointing of copper to iron or steel should be avoided as far as possible, otherwise the iron or steel component will corrode preferentially. The corrosion of steel tanks commonly connected to copper pipes, is reduced by the insertion of electrically insulating washers and also by the size of the exposed surfaces, in this case a large anode and a small cathode. A steel pipe attached to a copper tank or cylinder will corrode at a significantly greater rate, since the relationship is one of a large cathode and a small anode.

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Similarly, iron or steel should not be installed downstream of copper in a circuit otherwise rapid corrosion of the iron or steel will occur. However, no undue corrosion damage will be experienced if the iron or steel is upstream of the copper. The conductivity of the water (electrolyte) also influences the rate of corrosion in that the higher the conductivity of the water, the greater will be the rate of any corrosion. It should be stressed that galvanic corrosion does not occur in the absence of an electrolyte i.e. in a dry environment. In accordance with good installation practice and the requirements of AS/NZS 3500 the use of insulation between bracket and pipe should be adopted at all times. The presence of dissolved oxygen in the water is a major factor in galvanic corrosion within systems. In the primary circuit of an indirect heating system for example, where the oxygen is quickly used up in superficial corrosion of the ferrous components and only small amounts of make-up water are involved, galvanic corrosion is minimal. In a direct hot water system, or where there is significant ingress of oxygenated water, due to over-pumping or leakage into the primary circuit of an indirect system, ferrous components, such as steel radiators may fail quite rapidly. Whilst steel radiators may fail due to other factors, such as excess flux residues from soldered joints being washed in, over 90% of all steel radiator failures are due to the ingress of oxygen into the primary system. A typical galvanic series is given in Table 8. In practice galvanic corrosion is not a serious problem unless the potential difference is greater than about 200 mV. (The 1/4 volt criterion).

3.4 Contact with other materials.

Copper is highly resistant to corrosion by most traditional building materials such as brick, plaster or concrete based on Portland cement. However, it should not be allowed to come into contact with acid plasters, acid cements or cokebreeze. AS/NZS 3500 preclude the installation of copper tubes or fittings within solid walls or floors, except where they may be readily exposed, or alternatively if installed in a sleeve or duct where they may be readily removed or replaced. Any tubes passing through solid walls (by the shortest route) must be sleeved.

Unprotected copper pipes should not be laid in screeds containing ammoniacal foaming agents nor allowed to come into contact with cleaning fluids which may contain ammonia or its derivatives.

Copper also has high corrosion resistance to attack by soils, but again there are well known conditions that are aggressive to all metals, even to copper. These include “made-up” ground containing wet ashes or clinker, poorly drained sites with a high chloride or sulphate content or wet soils containing decaying vegetable matter or nitrogenous fertilisers.

Table 8 - Galvanic series of metals and alloys. Corroded end: *anodic - least noble*
Magnesium
Magnesium alloys
Zinc
Aluminium-magnesium alloys
99% aluminium
Cadmium
Aluminium-copper alloys
Aluminium-copper-magnesium (Duralumin)
Steel or iron
Cast iron
Chrome-iron (active)
Ni-resist
18/8 chromium-nickel austenitic steel (active)
18/8 Mo-steel (active)
Hastalloy C
Lead-tin solders
Lead
Tin
Nickel (active)
Inconel (active)
Hastalloy A
Hastalloy B
Brasses
Copper
Bronzes
Copper-nickel alloys
Monel
Silver solder
Nickel (passive)
Inconel (passive)
Chrome-iron (passive)
18/8 chromium-nickel austenitic steel (passive)
18/8 Mo-chromium-nickel austenitic steel (passive)
Silver
Graphite
Gold
Platinum

Protected end:
cathodic - most noble.

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Furthermore, AS/NZS 3500 Part 1 - Section 5 prohibit the laying of underground services in contact with contaminating materials including such as foul soils, or passing through any sewer, drain or cesspit.

Underground services should be installed using tubing to AS1432. Copper Tubes for plumbing, gas fitting and drainage applications and all the fittings should be immune or resistant to dezincification. Any compression fittings should be of the manipulative type to AS 3688 Water Supply - Copper and copper alloy body compression and capillary fittings and threaded end connectors.

Unless the building materials or soils are known to be non aggressive to copper, it is advisable to use factory supplied plastic coated tube or to protect the tubes and fittings by means of a suitable corrosion protection system.

3.5 Behaviour of copper tubes in contact with different fluids.

3.5.1 Drinking water.

Copper tube is highly corrosion resistant in most potable waters. In isolated instances, problems have arisen due to unfavourable water chemistry. Stains on fixtures are usually eliminated by stopping drips from taps and use of a different cleaning agent. In the rare cases where metallic and astringent tastes are found in water, such occurences are often eliminated by running water from taps for a short period before using it.

Where these conditions are found in new homes, it is likely the situation will slowly improve as protective films buildup inside the tubes due to continual use. If a problem persists, the water supplier should be contacted.

When installing copper tube, it is important that the entire pipeline should be thoroughly flushed with clean water immediately on completion. In addition, the system should be flushed on a routine basis until the building is occupied. If there is a possibility of a delay in occupation, special precautions should be taken to ensure flushing is carried out to assist the development of protective internal films. Long periods of stagnation and dead end lines must be avoided.

3.5.2 Softened water.

Hard waters may be softened to avoid excessive deposits of scale in boilers and hot water services by replacing insoluble calcium and magnesium salts with soluble sodium salts. However, softening should be carried out with care since the softened water is almost always more aggressive than the raw water concerned.

Since there is no virtue in softening the cold water, cold supplies to hot water only, may be softened and then only to a total hardness of 120 p.p.m. as $CaCO_3$. Reference to the hot water heater manufacturer should be made.

3.5.3 Deionised water.

Deionised water is equivalent to distilled water, both anions and cations having been removed by ion exchange resins. It is to some extent aggressive to all but the exotic metals e.g. gold, platinum etc., and if required as pure water it should be conveyed in glass or other suitable materials.

If it is used as a heat transfer fluid, e.g. in air conditioning equipment, an appropriate inhibitor, such as benzotriazole should be added and the inhibitor level checked periodically to avoid corrosion.

3.5.4 Hydrazine and nitrites.

Hydrazine (or nitrites) are sometimes added to heating installations as corrosion inhibitors in mixed metal systems to avoid galvanic corrosion. Both may be converted to ammoniacal species, by breakdown or reduction, which can give rise to the corrosion of copper or its alloys (e.g. brass). When corrosion occurs the concentration of the inhibitor is often reduced, but this is precisely the wrong action, since ammonia is not aggressive to copper in the absence of oxygen and since hydrazine (and nitrites) are oxygen scavengers, their concentration should be increased to between 4 and 7 times the value of the dissolved oxygen content (in p.p.m.).

3.5.5 Household products.

There are several household products currently available which can attack copper, such as ammonia solutions and hypochlorite bleaches. Cleansers containing ammonia should not be allowed to come into contact with copper otherwise the copper tubing will blacken, or even show evidence of bright blue cupro-ammonium salts. Copper is not unduly susceptible to stress corrosion cracking. However, when in contact with these chemicals there is a risk of cracking in tubes that contain residual tensile stresses. Clearly hard and bendable tubing is at greater risk than annealed tubing, but any brass compression fittings offer the greatest risk, especially any compression nuts that have been overtightened. This applies particularly when cleaning floors in kitchens etc., where pipes are buried beneath the floor. Cleansers containing hypochlorites should be used with care for whilst hypochlorite solutions are excellent sterilising agents and widely used for this purpose, the strength of solution and exposure times need to be carefully controlled. To avoid any risk of attack, the strength of solution should be limited to approximately 50 p.p.m. as free chlorine for a period of no more than 4 hours. Sterilising solutions should not be left in systems overnight and when the process is complete, the system should be washed through with fresh water until the residual free chlorine level is down to 1 - 2 p.p.m. Similarly, the practice of leaving such cleaners in urinals and waste pipes overnight should be discouraged. Specifically designed toilet cleansers however based on "nitre cake" (sodium hydrogen sulphate) do not attack copper.

3.5.6 Various chemical products.

Although not strictly applicable to domestic situations, copper tubes are widely used in industry. Table 9 gives general information on the suitability of copper with various chemicals.

Copper tube in buildings

Table 9 - Suitability of copper with various chemicals

Acetic (Acid)	B
Acetic (Anhydride)	B
Acetone	A
Acetylene (see note 1)	D
Alchohols	A
Alum	B
Alumina	A
Aluminium Chloride	B
Aluminium Hydroxide	A
Aluminium Sulphate	B
Ammonia gas (Dry)	A
Ammonia gas (Wet)	C
Ammonium Hydroxide	D
Ammonium Chloride	D
Ammonium Nitrate	D
Ammonium Sulphate	D
Amyl Acetate	A
Amyl Alchohol	A
Aniline	D
Aniline (Dyes)	C
Asphalt (Dry)	A
Atmosphere Industrial	A/B
Atmosphere (Marine	B)
Atmosphere (Rural)	A
Barium Carbonate	A
Barium Chloride	B
Barium Hydroxide	A
Barium Sulphate	A
Barium Sulphide	C
Benzene	A
Benzine	A
Benzoic Acid	A
Beer	A
Bordeaux Mixture	A
Borax	A
Boric Acid	A
Brine	B
Bromine (Dry)	A
Bromine (Wet)	B
Butane	A
Butyl Alchohol	A
Butyric Acid	B
Calcium Chloride	C
Calcium Disulphide	B
Calcium Hydroxide	A
Calcium Hypochlorite	C
Cane Sugar Syrup	A
Carbolic Acid	B
Carbon Tetrachloride (Dry)	A
Carbon Tetrachloride (Wet)	B
Carbon Dioxide (Dry Gas)	A
Carbon Dioxide (Wet Gas)	C
Castor Oil	A
Caustic Soda	B
Chlorine (Dry)	A
Chlorine (Wet)	C
Chloroacetic Acid	C
Chloroform	A
Chromic Acid	D
Cider	A
Citric Acid	B
Coffee	A
Copper Chloride	C
Copper Nitrate	C
Copper Sulphate	B
Corn Oil*	A
Cotton Seed Oil*	A
Creosote	A
Crude Oil (Low Sulphur)	D
Drinking Water	A
Ethers	A
Ethyl Acetate	A
Ethyl Chloride	B
Ethylene Glycol (Inhibited)	A
Ethyl Alcohol	A
Ferric Chloride	D
Ferric Sulphate	C
Ferrous Chloride	C
Ferrous Sulphate	C
Fluorosilicic Acid	C
Formaldehyde	B
Formic Acid	B
Freon	A
Fruit Juice	B
Fuel Oil	A
Furfural	B
Gasoline	A
Gelatine	A
Glucose	A
Glue	B
Glycerine	A
Hydrobromic Acid	C
Hydrocarbons (Pure)	A
Hydrochloric Acid	C
Hydrofluoric Acid	D
Hydrogen	A
Hydrogen Sulphide (Dry)	A
Hydrogen Sulphide (Wet)	D
Kerosene	A
Lacquers	A
Lactic Acid	B
Lime	A
Linseed Oil *	B
Magnesia	A
Magnesium Chloride	B
Magnesium Sulphate	A
Mercury (and its salts)	D
Methyl Chloride (Dry)	A
Methyl Alcohol	A
Milk *	A
Mine Water (Acid)	C
Natural Gas	A
Nitric Acid	D
Nitrogen	A
Oleic Acid	B
Oxalic Acid	B
Oxygen**	A
Oxygenated Water	B
Palmatic Acid*	B
Potassium Sulphate	A
Propane	A
Rosin	A
Seawater	B
Silver Salts	D
Soaps (Solutions of)	B
Sodium Bicarbonate	B
Sodium Bisulphate	B
Sodium Bisulphite	B
Sodium Carbonate	B
Sodium Chloride	B
Sodium Chromate	B
Sodium Cyanide	D
Sodium Hypochlorite	C
Sodium Nitrate	B
Sodium Peroxide	C
Sodium Phosphate	B
Sodium Silicate	A
Sodium Sulphate	A
Sodium Sulphide	C
Sodium Hyposulphite	D
Solvents For Varnish	A
Steam	A
Stearic Acid *	B
Sugarbeet (Syrup)	A
Sulphur (Molten)	D
Sulphurous Anhydride (Dry)	A
Sulphurous Anhydride (Wet)	B
Sulphuric Anhydride (Dry)	A
Sulphuric Acid (80/95%)	B
Sulphuric Acid (40/80%)	C
Sulphuric Acid ((%)	B
Sulphurous Acid	B
Tannic Acid	A
Tar (Dry)	A
Tartaric Acid	B
Toluene	A
Trichloroacetic Acid	B
Trichloroethylene (Dry)	A
Trichloroethylene (Wet)	B
Turpentine	A
Varnish	A
Vinegar	B
Zinc Chloride	C
Zinc Sulphate	B

A = Resistant to corrosion
B = Resists corrosion well
C = Undergoes slow corrosion
D = Copper is not to be recommended in the presence of the substance considered

Note 1. Safe Industry Practice bans the use of copper alloys containing more than 70% copper for handling acetylene.

* = Product may deteriorate (auto-oxidation)
**= Tubes must be grease free

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Copper tube in buildings

4 Design considerations.

Detailed layout and pipe sizing requirements are determined by the design engineer responsible for the system. General notes for guidance bringing out some of the points that have proved important in practice are given in the following sections. Users of this technical publication should ensure compliance with such statutory requirements, rules and regulations as maybe applicable to the particular installation, including the PCA, BCA, AS 4809, AS/NZS 3500, AS 3814 and AS 5601.

4.1 Water velocities.

Problems can arise due to excessive water velocities which in extreme conditions can cause premature failure by one of several mechanisms including erosion/corrosion and/or cavitation. The maximum recommended water velocity in copper hot and cold water service pipes, irrespective of outside diameter, is 3 m/s. Refer to AS/NZS 3500 Part 1- Section 3 for velocity flow rates. If the pipe diameter initially chosen gives a design velocity greater than that recommended above, an appropriate larger diameter pipe should be used. Pipes should be sized to ensure that the maximum design flow rates given in AS/NZS 3500 do not result in excessive water velocities in copper tubes. It is important to recognise that sluggish flow, at velocities below 0.5 m/s, associated with the oversizing of pipework, especially in long horizontal runs may also cause problems resulting from the deposition of detritus. This may result in pitting corrosion, especially in the lower segments of the tube. Good design and operation is needed to avoid these possible problems. There is also a possibility of corrosion occurring in pipework running only partially filled. Cavitation may occur immediately following rapid changes in cross section, such as within outlet fittings and this will also result in noise which can be reduced by lowering the pressure and hence the water velocity. However cavitation is unlikely to occur in pipework because at normal pressures water velocities of between 7 and 8 m/s are required to produce cavitation in a typical elbow fitting.

4.2 Pipe layout.

An important objective, particularly in large and complex installations, is to avoid, where possible, pipe runs where stagnant or semi-stagnant conditions prevail for long periods. With some types of water such conditions tend to encourage the pick-up of trace quantities of metals, including copper, which can be avoided if there is a regular flow of water at reasonable velocities through the pipes.

Measures to reduce such problems include the following:

(a) Vertical riser or drop systems should be considered for use rather than a horizontal distribution system. In addition ring type mains incorporating short vertical risers will reduce stagnant areas.

(b) There should be an adequate number and size of washout valves on the underground main supply and also on the internal systems at the bottom of risers.

(c) Drinking water pipework should be sized for the minimum practicable diameter but with velocities not exceeding 3 m/s.

(d) Direction of the pipe fall or rise should be indicated on the installation drawings, with particular attention paid to eccentric reducers on end reduction tees. Branch connections from horizontal mains should be taken off the top or bottom as appropriate to ensure correct air venting and complete draining of the system on emptying.

(e) Separation of fire-fighting hose reel and drinking water supplies is normally desirable.

(f) Where necessary, cold water services should be insulated to avoid undue pick-up of heat, e.g. from adjacent hot water pipes. Alternatively they should be installed below hot water pipes.

(g) Any part of a system intended to be used only intermittently should be fitted with isolating valves as well as drain valves installed at the lowest point.

(h) Long branch main lines supplying only isolated or little used services should be avoided.

Copper tube in buildings

(i) Dead end lines or vertical drops to outlets which are rarely used can be sources of problems when sedimentary matter settles out in stagnant water.

4.3 Protection of piping

Protection against frost damage is essential by use of adequate insulation. This is particularly important in ventilated and unheated roof spaces, and similar unheated and / or draughty locations. The following precautions should be taken in the laying and fixing of cold water services:

1) Underground pipes should be installed with cover in accordance with AS/NZS 3500 Part 1 Section 5.

2) Service pipes protected by ferrules to the top of the main should be taken into the building at the same depth underground by use of a "swan's neck" and if uninsulated should rise vertically within the building at least 450mm from the outside wall.

3) The rising main to the storage cistern should be carried up within the building in a location free from physical damage or the effects of freezing conditions.

4) If outside pipes have to be installed above ground they should be adequately insulated and drawoff points provided to drain down the exposed pipes where frost conditions may occur. The draw off point should be installed above ground to prevent contamination. Insulation by itself will not prevent the freezing of water filled pipework over a period of time hence the need for drain down facilities. The only safe alternative is to provide trace heating in the absence of heated building protection.

4.4 Underground services.

When copper pipework is installed underground it shall be to AS/NZS 3500 and unless the soil or building materials are known to be non-aggressive, it is advisable to protect the outer surface of the tube by means of plastic sheathing or suitable protection system. Underground services shall not be laid in contact with contaminating materials such as foul soil, or passing through any sewer, drain or cesspool. In some areas the Authorities may specify that the copper tube is externally coated with a works applied plastic coating. In addition all copper alloy fittings installed shall be dezincification resistant, to material specification AS 3688. Compression fittings shall be of the manipulative type to AS 3688. Precautions should be taken to minimise the effects of ground movement on pipes and fittings buried underground. Where relative movement between the main and service pipes is anticipated the connection should be made with a flexible joint. Pipes passing through walls from unstable ground should be fitted with telescopic joints and to maintain gradients towards washouts and air vents, supports should be provided from stable foundations. Pipes should be firmly anchored at bends to withstand thrust loads and should be capable of meeting a test pressure of 1.5 the maximum working pressure.

4.5 Expansion Joints.

The coefficient of thermal expansion of copper is 17.7×10^{-6} per $^{\circ}$K, hence a 1 metre length of copper tube becomes (1+0.0000177T) metre when heated by through T $^{\circ}$C. For example, an increase in temperature of 60°C will increase the length by 1 mm for every metre of tube. In most cases of copper tube in domestic hot water and heating installations the limited size of rooms and hence straight pipe runs, together with the many bends and offsets that normally occur will result in thermal movement being accommodated in the design.

However where long straight pipe runs, exceeding 10m, are encountered, allowance for expansion should be made. Suitable types of expansion joint are shown in Figures 3 and 4.

Expansion Joints

Figure 3 Methods of accommodating expansion.

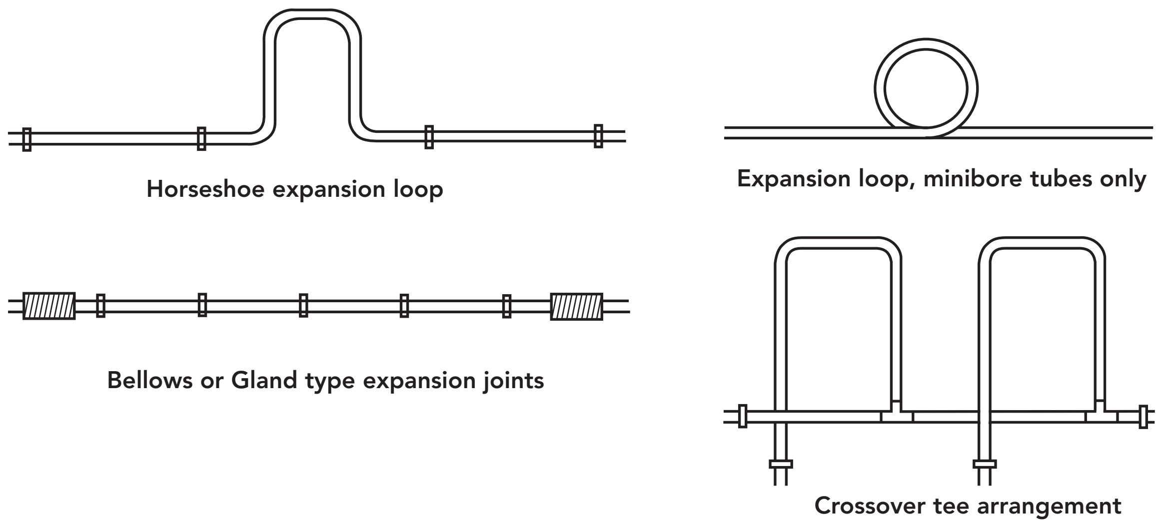
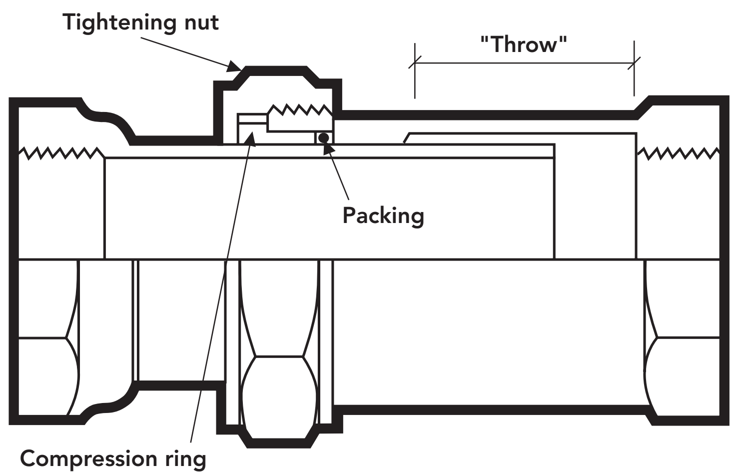


Figure 4 Gland Type Expansion Joint.



Expansion bellows and expansion loops may be accepted as meeting the requirements of the AS/NZS 3500 - Part 4 with regard to the expansion of pipes carrying hot water. Where copper tubes pass through walls, floors and ceilings, they should be able to move as a result of expansion and contraction. This can be arranged by passing the tube through a sleeve or length of larger diameter pipe fixed through the whole thickness of the wall, floor or ceiling, or by means of flexible joints on either side of the wall.

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Figure 5 A Range Of Typical Fittings.

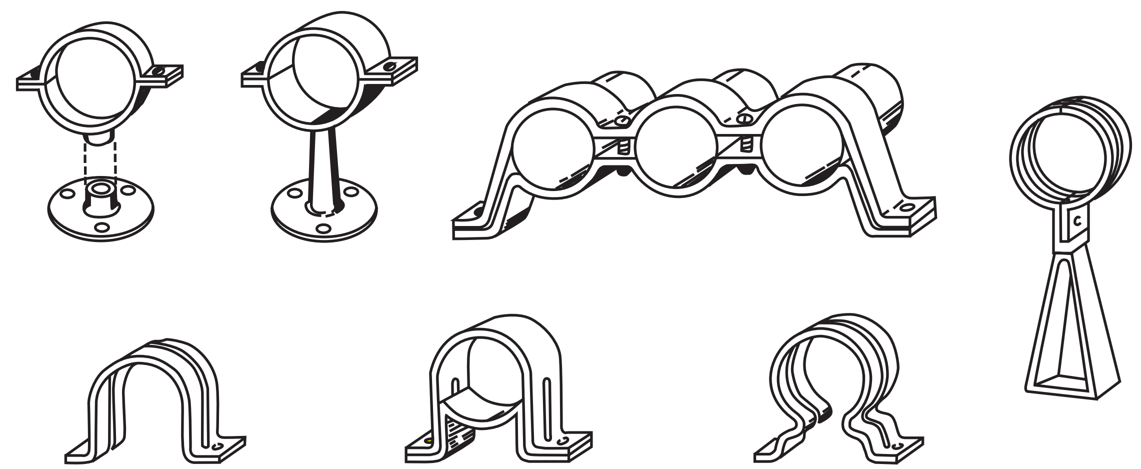


Figure 6A Method Of Fixing Long Lengths Of Pipework Along A Wall (Sliding Expansion Joint).

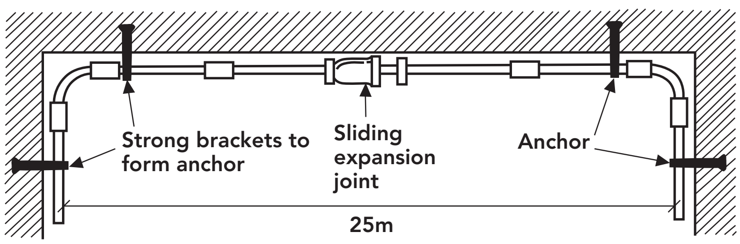
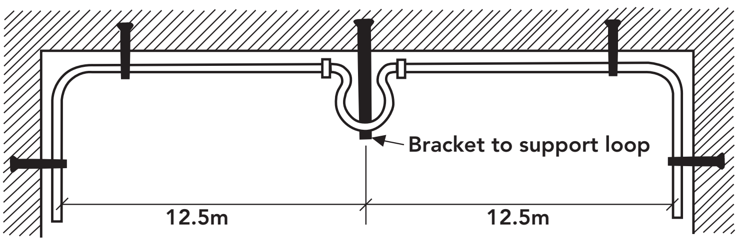


Figure 6B Method Of Fixing Long Lengths Of Pipework Along A Wall (Loop Expansion Joint).



4.6 Fixings

All pipework should be adequately supported. There are various types of fixing clips and brackets to meet specific requirements. A few of the fixings available are shown in Figure 5 but a greater selection is illustrated in manufacturers' catalogues and this information will help to decide the most appropriate pattern. Suitable intervals for pipe supports are given in Table 10.

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Table 10. Spacings for Copper Tube Supports from AS/NZS 3500 Parts 1 & 4			
Size of Pipe DN	Maximum intervals for support (m)	Size of Pipe DN	Maximum intervals for support (m)
10	1.5	50	3.0
15	1.5	65	3.0
18	1.5	80	4.0
20	1.5	90	4.0
25	2.0	100	4.0
32	2.5	125	4.0
40	2.5	150	4.0

Bracing should not be at less than 12m centres to avoid swaying when pipes are fixed by hanging brackets in suspended ceiling spaces. The distance between anchor fixings and expansion joints in hot water lines is determined by the type of joint used and the amount of movement within the joint itself. Figures 6A and 6B show how a pipe run should be anchored by means of two supports at each change of direction, with an expansion device in the centre. If the expansion joint has a 25mm depth of socket (Figure 6A) then the length of pipework each side of the joint, with a temperature difference of 60°C can be 12.5m (lmm of movement within the expansion joint permits 1m of pipe length between joint and anchor point). In order to avoid possible breakdown of branch joints connected to a heating or hot water main, it may be advisable to use the branch joints as anchor fixings. If however the branch is connected to the moving pipe the leg of the branch should be free to move. Suitable pads should be inserted between the pipe and clip to avoid abrasion due to thermal movement. All pipe runs should be aligned correctly to prevent undue strain. This is particularly important when fixing pipes to a plastic cistern. Suitably protected backing plates or washers without sharp edges should be fitted at the connection points between the pipes and the cistern.

4.6.1 Notching and drilling floor and roof joists.

Reference should be made to AS/NZS 3500.1, Clause 5.5.2 'Concealed Piping'.

4.7 Air locks and water hammer.

Air locks can be prevented by the design and installation of systems to facilitate the removal of air during filling and subsequent operation. Pipes should have a slight rise to a cistern, vent pipe or an automatic air release valve along their complete length and should wherever possible fall to the drain off points. Pipes should be laid to avoid obstructions and across solid foundations to prevent local undulations causing airlocks. Excessive pressure rises in pipework can lead to premature failure of joints and possible damage to fittings. If unacceptable water hammer occurs in a system due to the installation and operation of fittings and appliances suitable measures should be taken to limit the resultant pressure rises or surges. This can be achieved by fitting air or gas loaded vessels or special mechanical water hammer preventers.

4.8 Services embedded in concrete.

Copper has excellent resistance to corrosion by potable waters and is not attacked by normal types of cement, concrete or plaster. It should not be brought into contact with acid plasters, acid cements or cokebreeze. Cement additives such as foaming amines should also not be allowed to contact unprotected copper tube, nor cleaning fluids which may permeate through screeds to embedded copper pipes beneath. However AS/NZS 3500 precludes the installation of tubes and fittings embedded within solid walls or floors except where it may be readily exposed, or alternatively if installed in a sleeve or duct which may be readily removed or replaced.

Pipes conveying water at temperatures above 60°C which may occur particularly in heating services, and if there are any branch connections, must be given facilities within the solid structure for thermal movement.

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Small diameter pipes (DN6 to DN10) can be laid directly on the concrete base in a snake-like pattern and should be plastic sheathed, or similarly covered, to avoid adhesion of the final screed to the metal pipe. Larger diameter pipes (DN12 to DN25) should be laid in purpose made ducts not less than 50mm wide and 100mm deep. If insulating material is used it should be of a water repellent type. The insulated pipework within the ducts should then be covered with dry sand or similar to about 25mm above the top of the insulation. If the pipe run exceeds 10m in length, suitable expansion joints with permanent access points should be fitted. Pipes in excess of DN32 in diameter should be installed in accessible ducts, being suitably clipped or alternatively supported on roller fixings with horseshoe brackets at every 10m to avoid the pipe jumping from the rollers. Again reference should be made to the AS/NZS 3500.

4.9 Thermal insulation.

Consideration should be given to conserving energy by use of suitable thermal insulation for pipes conveying hot water. In addition supply pipes containing cold water for domestic purposes should be installed so that, as far as is reasonably practical, the water will not be warm when drawn from the tap. If the cold supply cannot be installed away from hot water pipes or other sources of heat then it should be adequately insulated. If neither of these measures are practicable then the cold pipe should be installed below the hot pipe. This requirement should not conflict with the need to provide adequate insulation and/or a source of heat to provide frost protection in otherwise unheated locations.

Thermal Conductivity of Insulating Materials

Example of material	Thermal conductivity (W/m.K)
Rockwool or fibreglass sectional pipe insulation (prefabricated sections)	0.032
Rockwool or fibreglass loose fit or blanket material	0.032 - 0.045
Foamed nitrile rubber	0.040
Loose vermiculite (exfoliated)	0.06 - 0.07
Flexible foamed plastic	0.070 - 0.07

Frost protection can be achieved by means of trace heating cables attached to insulated pipework in exposed locations. Where pipes and/or fittings cannot be positioned to provide adequate protection then they should be insulated and provided with a means of draining. If installed outside a building the insulation should be weatherproof. Generally these outside installations will be required to be fitted with a servicing and a draining valve inside the building.

Details of the recommended sizes and performance of thermal insulating materials may be found in AS 4426.

It should be noted that smaller pipes require relatively greater thickness of material than large. Adequate space should be allowed around tube fixings for the required thickness of insulation to be added after installation. Wherever possible the insulation should be continuous over tube and fittings but allowing access to valves for operation. Air spaces between pipework and the insulation will improve the overall insulating properties of the insulated pipework. The insulating material should be resistant to or protected by, suitable covering from mechanical damage, ingress of moisture, and vermin. In the case of insulated tubing to be installed underground it should also be resistant to attack by any corrosive chemicals within the subsoil.

In the case of factory insulated copper tubing manufacturers recommend procedures for insulating joints and fittings and for the removal and replacement of insulation during the jointing process. Data are also provided on the performance of insulated copper tube under different operating conditions. Additional advantages of factory insulated copper tube include the reduction in water flow noise, high quality appearance and surface finish, with no painting required and improved safety due to low surface temperatures when carrying hot water. Insulated copper tube sheathed with an internally castellated plastic coating traps an

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air layer to give improved insulation performance. Where required, colour coding of pipework should be blue for water and yellow for gas.

5 Jointing methods.

Various standard jointing techniques using either compression (Figs 8, 9 & 10) or capillary (Fig 11) methods are available. They employ copper alloy (including dezincification resistant brass) and wrought copper fittings manufactured to AS 3688 in sizes up to DN200. Flanges and bolting to AS 4087 are available for large copper tube. Copper tube may also be brazed and soldered either directly or by means of copper or copper alloy fittings. The most - common methods for joining copper tubes involve the use of the following:

Compression Fittings -
Type A - Non-manipulative
Type B - Manipulative

Capillary Fittings -
Soft Solder - End Feed
Integral Ring

Brazed - End Feed
Silver Brazing Alloy to AS 1167.1

Socket Formed joints -
Silver Brazing Alloy to AS 1167.1-
End Feed

All these methods of joining copper tubes have been used satisfactorily over a period of fifty years proving beyond doubt their suitability for water and other services. It is recommended that, where applicable, fittings used should also only be those approved under the "StandardMark" scheme.

The manufacturers of fittings for copper tubes provide literature describing their products and full instructions on the use of their fittings. This literature should always be consulted by the user, but the following notes are included for general guidance:

Table 11. Minimum Thickness for Thermal Insulation

Pipe Size	Thermal conductivity of insulating materials, (W/m.K)				
	0.03	0.04	0.05	0.06	0.07
	Minimum thickness required (mm)				
DN15	9	14	20	29	40
DN18	6	9	12	15	20
DN20	4	6	8	10	12
DN25	3	4	5	6	8
DN32	2	3	4	5	6

These insulation thicknesses were calculated, using the formulas given in BS 5422, to just prevent freezing of water initially at 15°C if exposed to an ambient temperature of -5°C for a period of eight hours.

If temperature falls below -5°C or freezing conditions extend for periods of longer than 8 hours, additional thickness of insulation may be necessary.

It is important to note that water will freeze first in small diameter pipelines.

5.1 Compression joints.

Non-manipulative compression fittings, as the name implies, do not require any working of the tube end. The joint is made tight by means of a loose ring or sleeve which grips the outside of the tube when the cap nut is tightened.

This type of fitting can be used on bendable and hard temper tube supplied in straight lengths and annealed tube up to and including DN15. A special nylon olive fitting has been developed for annealed tube. Making a non-manipulative compression joint requires the following steps:

1. Cut tube square
2. Remove burr inside and outside
3. Ensure outside surface is free from deep scratches or other mechanical damage
4. Insert tube fully up to the stop
5. Tighten fitting nut first by hand and then with a spanner.

Manipulative compression fittings, croxed and olive, require the end of the tube to be flared, cupped or belled with special forming tools (in some cases supplied by the fittings manufacturer) after the end of the tube has been cut and deburred. The formed end of the tube is compressed against a shaped end of the corresponding section on the fitting or against a loose thimble, when the cap nut is tightened. This type of fitting is not suitable for use with hard temper tube. The operations in making a joint are as for non manipulative fittings with the addition of the flaring, cupping or belling operation. Care should be taken to ensure that the tube is not distorted during cutting. Annealed tube should always be re-rounded using a suitable tool before offering to the fitting to

Jointing methods

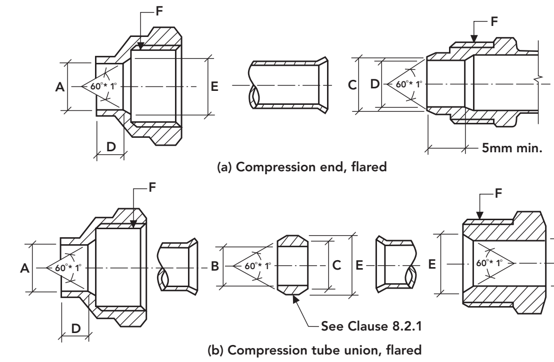
make the joint. This type of fitting, namely to AS 3688 Type 'B' shall be used for installations underground and shall be made from dezincification resistant or immune materials.

5.2 Capillary joints.

Capillary fittings have sockets made to close tolerances, so that a controlled small gap exists between the outside of the tube and the socket into which molten soft solder or brazing alloy is drawn by capillary action. The jointing metal may be incorporated in the fitting or may be fed into the capillary space during the jointing operation. The soft solders now used to meet water quality requirements are lead-free alloys as specified in AS 3688. Other solders having special properties, such as improved creep strength, can, in some cases be supplied to special order. For high pressure and/or temperature applications, appropriate brazing alloys covered by AS 1167.1 should be used.

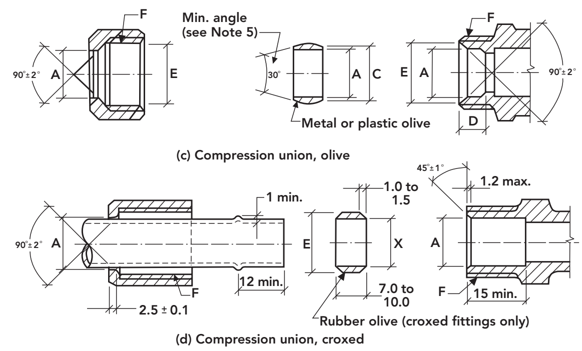
Copper tubes may be directly joined by the use of silver-phosphorus-copper self fluxing brazing alloys. The tube ends are formed, by special tools, to provide close tolerance capillary joints. The joints are filled by capillary action with a suitable brazing alloy filler rod using an appropriate fuel and blowtorch. Copper alloy tubes and fittings require the use of a suitable flux and a compatible filler alloy.

Figure 8 Typical Flared Compression Ends.



Normal Size DN	A		B		C		D	E	F* Thread size designation
	Min. mm	Max. mm	Min. mm	Max. mm	Min. mm	Max. mm	Min. mm	Min. mm	
15	12.8	13.0	9.9	10.5	12.0	12.3	6	15.7	1/2
18	16.0	16.2	13.3	13.6	15.2	15.2	6	19.0	5/8
20	19.1	19.4	15.8	16.4	17.7	18.0	9	21.8	3/4

Figure 9 Typical Olive and Croxed Compression Ends.



Nominal Size DN	A		C		D	E	F* Thread size designation
	Min. mm	Max. mm	Min. mm	Max. mm	Min. mm	Min. mm	
10	9.6	9.9	10.0	10.2	6	12.7	3/8
15	12.8	13.0	13.2	13.4	6	15.7	1/2
18	16.0	16.2	16.4	16.4	8	19.0	5/8
20	19.1	19.4	19.7	19.9	9	21.8	3/4
25	25.5	25.7	26.6	26.3	9	28.5	1
32	31.8	32.0	32.4	32.7	9	34.9	1 1/4
40	38.2	38.4	38.8	39.1	12	41.2	1 1/2
50	50.9	51.1	51.5	51.9	12	55.5	2
65	63.6	63.8	64.2	64.6	12	68.2	2 1/2

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Making a capillary joint requires the following steps:

1. Cut tube square
2. Remove burr inside and outside
3. Clean the tube and fitting socket with fine abrasive material
4. When required, apply flux to tube end only
5. Insert tube fully up to stop, twist tube to spread flux and wipe off excess flux
6. Apply heat till cherry red
7. Apply solder or brazing alloy (when using end feed fittings)
8. Allow joint to cool without disturbance and then clean

Overheating during the making of joints may cause excessive oxidation or burning of the pipe, resulting in subsequent deterioration by corrosion of that part of the system during service. Pipework should be flushed out immediately after soldering is completed. If excessive quantities of adherent corrosive flux residues remain in the pipework problems with internal corrosion or contamination of the water supply may occur.

5.2.1 Fluxes.

For soft solders there are several different types of flux, the purpose of which is to chemically clean the metal surface and also prevent re-oxidation of the surface during heating to enable the solder to run and 'wet' the surfaces to be joined. Ideally a flux should only be aggressive to the metal concerned at soldering temperatures, but this is difficult to achieve in practice. Only resin-based fluxes are essentially non-aggressive, but their cleaning power is limited. Whilst such fluxes are widely used for soldering electrical components, they are generally regarded as being too mild for plumbing work.

Figure 10 End Feed Capillary Fitting.

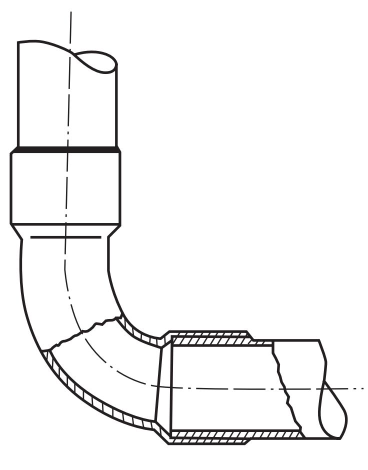
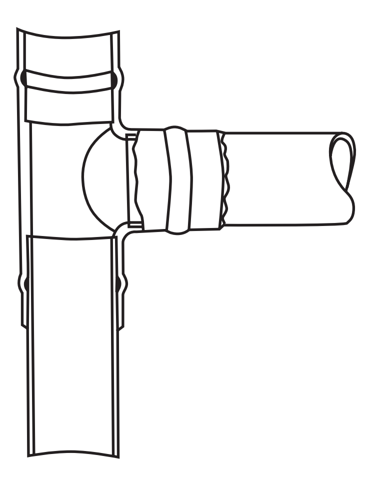


Figure 11 Integral Solder Ring Capillary Fitting.



Fluxes containing organic chlorides, bromides or fluorides, or zinc chlorides emulsified in a fatty base, such as tallow or mineral jelly, are the most commonly used in plumbing. They are all to some extent corrosive to copper, otherwise they could not clean the metal surfaces, and therefore must be used sparingly and any excess removed when soldering is completed. The so called 'self-cleaning' fluxes contain free hydrochloric acid and whilst they are excellent fluxes when used with extreme care, any slight excess is so corrosive that they cannot be recommended for general use.

Badly made joints or bends causing excessive turbulence or localised high water velocity may result in deterioration of the immediate area by means of impingement corrosion or cavitation erosion. This type of corrosion may be associated with low pH values of 6.5 and below.

5.3 Expanded joints.

Tubes of the same diameter may be joined end-to-end by expanding the end of one length with a purpose-built expansion tool to form a socket into which the mating tube is inserted, prior to brazing as in Section (C).

When making expanded joints:

- Tube ends must be cut square and internal burrs removed.
- Prior to expansion, the tube ends should be softened [annealed] uniformly to a dull red colour using a heating torch, then cooled.
- Use only purpose-built expansion tools that have been maintained in good working order.

5.4 Branch forming.

This practice reduces the need for fittings and the number of brazed joints. It is ideal for pre-fabrication, retrofit projects and where piping modifications are required during construction.

Hand and electric forming tools are available for rapid production of branches up to DN50. When using tools, follow the manufacturer's instructions. Tools may be available to make branches larger than DN50 or alternatively large branches for pressure piping and angled junctions in sanitary plumbing pipes may be manually formed by:

- Cutting an undersized oval hole in the main tube.
- For tee connections at 90^{o}, the dimension of the larger diameter of the oval hole should be equal to the diameter of the branch tube less allowance for an overlap which will form a collar not less than 4 times the main tube thickness once the socket has been formed.
- With entries at 45^{o} or greater, the diameter measurement is taken from the angular cut branch tube, making similar allowances for socket overlap.
- Heat the surface around the hole to a dull red colour and cool with a wet cloth.
- Insert a dressing pin into the oval hole then carefully and evenly form the socket to accept the branch tube. The pin can be manipulated by either hand or use of a mallet.
- If required, heat can be applied to soften metal around the hole during dressing out. Copper must not be over-heated past dull red, whereas brass is not to be worked in the 250^{o}-550^{o}C range to avoid embrittlement.
- The inserted branch must not penetrate or obstruct the main pipe bore.
- Branch formed joints must be silver brazed.

5.5 Roll-grooved joints.

Roll-grooved joints have been in use since 1925. Special copper tools are available to produce joints as are pre-grooved tees, elbows and reducing fittings.

When installing roll-grooved tube, refer to the specific system installation instructions. Some precautions are:

- Cut the pipe square. It must be free from distortion and deburred.
- Groove the pipe with the appropriate Australian copper grooving tool. Steel grooving roll sets must never be used.
- Ensure the gasket landing is smooth and clean.
- Measure the accuracy of the groove against the specification. Check pipe is not out of round.
- Apply lubricant to the external surface of both ends of pipe.
- Slide gasket onto the end of one pipe.
- Bring pipe ends together and slide gasket into place between grooves.
- Undo one bolt on the coupling and place coupling over gasket.
- Make sure that the coupling sits squarely in the grooves.
- Tighten bolts.
- Only Australian size couplings are to be used.
- Never disassemble joints unless they have been depressurised.

5.6 Push & Press-fit joints.

5.6.1 Push-fit joints

Various types of push-on fittings are approved for copper piping. It is important when using such fittings that:

- The fitting manufacturer's installation instructions are followed
- Tube ends are cut square and both the external and internal surface of tube ends are deburred to prevent damage of "O" rings.
- A tube cutter must be used to cut annealed temper (soft) tube
- Avoid flats and scratches on and near the engagement ends
- The depth of insertion is critical. Use a depth gauge.
- This type of fitting can be rotated
- Fittings can be disassembled for reuse providing appropriate tools are used and the fitting components are free from damage.
- Unless stated to the contrary, this type of fitting is not for gas applications or compressed air.

They are not to be used adjacent to solar heating panels or on piping with uncontrolled temperature in excess of 90^{o} C.

5.6.2 Press-fit joints

Press-fit copper fittings offer an ultra-fast, efficient method of joining AS 1432 Type A, B and C copper piping. Assembled press-fit systems provide secure, permanent, non-detachable joints without the need for flame, glue or separate collars. The fittings maintain the full flow bore of piping. Significant time saving can be achieved by temporarily assembling all pipes and fittings in a layout. The pressing tool can then be used to seal all joints in an efficient manner by working from one end of the layout to the other. It is important to note that fittings for water applications are colour coded green whilst those for gas piping are coded yellow.

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The fitting manufacturer's installation instructions are to be followed.

- Cut the copper tube at right angles (using tube cutter or fine-toothed steel saw).
- Debur the end of the copper tube on both the inside and outside.
- Check the o-ring is correctly seated within the fitting. (The o-rings are already pre-lubricated so do not apply oil or lubricants). Use only the original seals specific to the system.
- While turning slightly, slide the press fitting onto the tube until it stops.
- Mark the insertion depth.
- Insert the correct size jaws into the pressing tool and push the holding pin until it locks into place.
- Open the jaws and place them onto the fitting so the jaws are at right angles to the fitting. Check insertion point.
- Start pressing procedure by holding the trigger until the ram has completed the cycle.
- After completing the pressing procedure, the jaws can be opened again.

For gas piping installations, the following additional steps are important:

- Use only the original Yellow HNBR seals.
- Installation shall be made in accordance with Australian Standard AS5601 and these installation instructions.
- All copper tube must be compliant with Australian Standard AS1432-Copper tubes for plumbing, gasfitting and drainage applications and be Type A or B tube.
- The fittings are for use with gas in their vapoured state.

The fitting/tubing system shall not be used as a means of support and any undue stress or strain on the fittings is to be avoided.

5.7 General procedures for all fittings.

5.7.1 Measuring.

Measuring the length of tube is not really part of the jointing process, but inaccuracy can affect joint quality. If a piece of tube is too short it will not reach all the way into the socket of the fitting and a proper joint cannot be made. If the tube is too long it may not be possible to achieve correct alignment especially if the tube forms part of an installation partially fixed in length.

5.7.2 Cutting to length.

Type B tube in DN6, 8 and 10 sizes should be cut with a junior hacksaw. Rotary tube cutters are commonly used for cutting other copper tube up to DN50 size. Larger size cutters for tube up to DN150 are available. Straight end cuts can also be made manually with a hacksaw using a vice equipped with guides. A blade with 32 teeth per 254mm minimises burrs which should always be removed before fitting. Where many lengths are to be cut, the use of power equipment significantly reduces the time involved. Power hacksaws, circular saws (with fine metal cutting blades) and abrasive cut off wheels are all suitable. Guidance from equipment manufacturers should be sought in order to match the saw blade or abrasive disc to the cutting requirements. Whatever cutting method is used, it is important that the tools are in good condition to prevent distortion of the tube end and enable the tube end to be cut square to the axis.

5.7.3 Deburring of tube ends.

The tube cutter will leave a small burr, which should be removed, using the reamer attached to the cutter or some other appropriate tool. If the tube is cut with a hacksaw there may be both burrs and slivers, which should be removed and not allowed to enter the tube bore. This can be done with a flat metal reamer (most disc cutters are so equipped), a three sided reamer, or a half round, mill bastard file. If a flat metal reamer is employed, care should be taken to avoid expanding the tube end. Proper size and fit are necessary for sound joints.

5.7.4 Re-rounding of tube ends.

Before assembling the joint, it is good practice to ensure that the tube end is satisfactorily rounded. The tube end should be re-rounded as required with a suitable tool. It is good practice always to re-round annealed tube that has been supplied in coil form. Excessive ovality of the tube end will prevent the correct size gap being achieved with capillary fittings.

5.8 Detailed procedures for capillary fittings.

5.8.1 Cleaning.

In order to promote solder flow and bonding, the surfaces to be joined must be free from dirt, oxide films and residual grease and oil. The areas to be cleaned are the inside and end of the socket of the fitting and also the tube end for a distance up to 10mm beyond the point where

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the end of the socket of the fitting will be situated. Suitable cleaning materials include fine emery cloth (00), and non woven nylon pads impregnated with silicon carbide or aluminium oxide abrasives. For the manual cleaning of sockets, particularly those of DN25 and smaller size, special wire brushes are more practical than sand or abrasive pads. Machines are available which combine the functions of cleaning the tube ends and sockets using wire brushes. Where fast cleaning is desired but the purchase of a special machine is not warranted, a power drill mounted in a vice can be equipped with wire brushes to clean the inside of the fitting. Tube end fittings are made to close tolerances and abrasive cleaning should not remove a significant amount of metal. If too much metal is removed during cleaning, the capillary space may become so large that a poor joint will result.

5.8.2 Fluxing.

The cleaned surfaces should be fluxed as soon as possible. Apply adequate but not excessive flux, to the joining surfaces. Once fluxed, tube and fittings should be assembled promptly. If fluxed surfaces remain exposed, the flux will tend to pick up dust and dirt. Such entrapped particles tend to weaken the soldered joint. Flux should be thoroughly stirred when a new container is opened and also periodically during use. The flux can be applied with a small brush or a clean lint free cloth. Cloths are apt to pick up dirt and should be cleaned or changed as necessary. Tube ends should never be dipped in flux. Fingers should not be used to apply flux and it should be noted that flux is harmful to the eyes. All prepared joints should be completed within a single working day. Fluxed and assembled joints remaining unsoldered at the end of the day should be dissembled and wiped free of flux. They should be recleaned, refluxed and reassembled when work resumes. Particular care should be exercised to avoid leaving excess flux inside the completed joint. Only sufficient flux should be applied to the clean surface of the tube end to form a thin film over the surfaces to be joined.

5.8.3 Assembling.

The joint should be assembled by inserting the tube into the fitting socket making sure that the tube in firmly up to the tube stop. A small twist will spread the flux over the two surfaces. After removing any excess flux with a cloth, the joint is ready for soldering.

5.8.4 Heating.

Heat is usually applied with a propane or butane torch or with an air-acetylene or oxy-acetylene torch. The flame should be played on the fitting and kept moving to heat the whole joint area, so as to avoid local overheating. Excessive heat can char the flux and destroy its effectiveness and in some circumstances can cause cracking of cast fittings. In the case of integral-ring capillary fittings heating is continued until a complete ring of solder or brazing alloy appears around the mouth of the socket. Heating should then be stopped and the joint allowed to cool with-out disturbance. After heating allow the assembly to cool and then thoroughly flush the system internally on completion, preferably with hot water.

5.8.5 End feed fittings.

When the joint is hot enough, the solder or brazing alloy wire or rod should be applied to the mouth of the socket and should melt on contact with the tube. The flame should then be moved away. If the solder does not melt, remove the solder, continue to heat, then try again. For larger fittings a multiple tip or ring type torch may be useful. After the initial application of the solder, complete penetration and filling of the joint can be effected by alternating the application of heat and solder. If the metal is properly cleaned and fluxed, capillary action should draw all the solder needed into the joint. It is important that the clearances between the tube and fitting should not be excessive hence allowing the solder to be fed through the fitting into the bore of the tube causing blockage or disturbance to the water flow possibly resulting in premature failure due to cavitation.

5.9 Lead-free Solders.

Recent legislation has resulted in a ban on the use of lead containing solders in both new and repaired potable water systems. Major manufacturers of integral ring fittings have introduced lead-free solder fittings. In the case of end-feed fittings the onus is on the specifier and installer to ensure that lead-free, tin-copper or tin-silver solders, as specified in AS 3688 are used exclusively in potable water installations. The operating temperatures for capillary fittings are governed by the capabilities of the filler metal.

5.10 Joining dissimilar materials.

Copper tube and copper and copper alloy fittings may be used in combination with a wide range of other materials. Some of the more commonly used combinations are listed as follows:

a) Copper/cast iron: Copper tubing may be connected to cast iron piping by a copper or copper alloy union or ferrule. The union to cast iron pipe joint is a screwed connection, whilst the copper tube to ferrule is a compression or capillary joint.

b) Copper/UPVC: Copper tubing may be connected to large diameter UPVC mains piping by means of a saddle and union or ferrule. The joint between the copper tube and the union or ferrule is again a compression or capillary fitting. Tubes of smaller sizes may be connected by a copper alloy union adaptor with a compression or capillary fitting for the copper tube connection and a solvent weld screwed fitting between the UPVC pipe and the union.

c) Copper/polyethylene: Copper tube may be connected to polyethylene pipe by means of a copper or copper alloy union adaptor. Compression joints are used for both materials with an additional pipe liner for the polyethylene pipe connection.

d) Copper/stainless steel: Copper tubing may be joined to stainless steel piping by means of a copper or copper alloy compression or capillary fitting. The relative area relationship is of importance e.g. copper tube attached to the inside of stainless steel water storage vessel will suffer severe and rapid corrosion.

Reference should be made to tube manufacturers for recommendations concerning possible excluded combinations due to dissimilar metal corrosion problems affecting metals less corrosion resistant than copper and copper alloys. In particular the direction of flow in pipework should always be from the less noble to the more noble metal, e.g. galvanised steel > uncoated iron > copper. An example is the pick up of 0.1 mg/L or more of copper in water which encourages the corrosion of galvanised coatings.

6 Bending of copper tubes.

The bending of copper tubes by machine can be carried out without filling as the special formers or mandrels employed support the sides of the tube preventing it from becoming oval in section. Both machine and hand methods of bending are described below.

6.1 Bending thinner wall copper tubes.

There is little difficulty in machine bending thin wall tubes as the necessary skills can be developed with practice. The bending of thin wall tubes by hand methods, however, may often be required, especially in the larger sizes of tube, for which machines are expensive. The methods of bending when using various loading materials are described below.

6.2 Steel springs.

Flexible spiral springs may be used as a loading to support the tube walls while the bend is made. Springs are available for bending tubes in all standard sizes from DN10 to DN20 diameter, which is the maximum size for spring loading. Only easy bends should be attempted as the minimum radius to the throat is approximately 3 diameters for all sizes up to DN20.

6.3 Loading with low melting point alloys.

Low melting point or 'fusible' alloys can be employed, which can be maintained in the molten state at temperatures below the boiling point of water. The procedure is to plug one end of the tube and load with the compounds in their molten state.

Part Section of Australian Standard 3688

Water supply - Metallic fittings and end connectors

SECTION 1 SCOPE AND GENERAL

1.1 SCOPE

This Standard specifies requirements for metallic body pipe fittings and connectors for use with copper tubes and stainless steel pipes and tubes and adaptor fittings for connection to other pipe materials in water supply and gas systems where the normal working temperature does not exceed 95°C, and where the maximum operating pressure does not exceed 1.4 MPa. Products designed for a temperature in excess of 95°C are included where tested to the appropriate temperature criteria.

NOTE: For fittings used for gas applications, see AS 5601.

They solidify quickly and the tube can be bent to the required shape and then the filler is removed by dipping into a tank of boiling water, leaving the interior of the tube perfectly clean. Hot bending of tubes cannot of course be carried out with this type of loading, as the alloy is molten at the temperatures used for such bending.

6.3.1 Sandfill bending.

Forming a bend in copper tube can also be successfully achieved by first sealing one end of the tube with a pipe fitting, filling with clean dry sand, firmly compacted and capping the second end. Heat to ‘cherry’ red heat and bend while hot. Upon completion thoroughly clean out and flush with water prior to installation.

6.4 Bending by machine.

The purchase of a bending machine will prove economical where numerous bends are required in the smaller sizes of tube. Machines of various types and sizes, worked by direct hand power, are constructed to bend copper tubes up to DN40 diameter, and are small and light enough to be transported to site. For diameters greater than this, ratchet action or geared machines should be used. A small tool, for bending DN6, 8, 10 and 15 tube, can be carried in the toolkit and bends can be made if necessary on a fixed pipe. There are a number of suitable machines on the market, all capable of producing satisfactory bends in copper tube, loaded or unloaded, according to wall thickness or the tightness of the bend required.

6.4.1 Distortion of tube in machine made bends.

The design of bending machine formers enables the throat and sides of the bend in an unloaded tube to be supported against collapse. Corrugations will, however, occur in the throat of a bend if the pressure of the roller on the back guide is exerted in the wrong place. The correct pressure point is in front of the bending point, where the tube touches the former before bending takes place. These two points move forward maintaining the same distance apart as the bend is made. If the pressure point is advanced too far in front of the bending point, corrugations will occur.

Severe corrugations or flattened bends can adversely affect flow conditions in service, giving rise to localised impingement (corrosion erosion) or, in hot services, to fatigue cracking resulting from stresses set up by thermal movement being concentrated at the corrugations, (a ‘notch’ effect) whereas a smooth bend will absorb such stresses without damage.

Note: *If corrugations occur when using non-adjustable ‘handi-benders’ the pressure point can be moved forward by inserting a thin piece of strip steel between the back guide and the pressure roller to remedy the problem.*

7 Commissioning.

Procedures for pressure testing and commissioning water service piping are specified in Appendix C & D of Australian Standard AS 4809: “Copper pipes and fittings – Installation and commissioning”.

All systems should be thoroughly flushed out as soon as possible after installation to remove foreign matter. The flushing should continue until the flush water is completely clear, and the system should then be pressure tested, in accordance with AS/NZS 3500, at 1500kPa and held for at least 30 minutes. There should be no evidence of any loss of pressure during the test period.

Ideally the systems should, where appropriate, be correctly sterilized to AS/NZS 3500. **Water from reticulated systems (municipal water supply) is usually satisfactory for flushing and testing purposes. Where non-disinfected water is to be used for flushing and testing, water shall be disinfected.**
In AS 4809 Appendix D it is stated that sodium hypochlorite in liquid or solid form are preferred for disinfecting water because of their ease of use and availability. When test waters are required to be disinfected, a measured quantity of sodium hypochlorite should be stirred into the flushing or test water, immediately before use. The amount of free chlorine is to be adjusted to within the range of 1 to 2 mg/L. Only very small volumes of sodium hypochlorite are required for small quantities of water such as 10 L. A dispenser with 1ml divisions should be used for accuracy. The actual chlorine levels should be checked using a recognized chlorine test kit.

It is important to use the disinfected water immediately as chlorine dissipates rapidly when exposed to the atmosphere and sunlight. Care should be taken not to overdose the water.

Tests to prove the waters transmitted through the newly installed system are suitable for human consumption should be carried out as necessary and the system put immediately into full use so that there is never any protracted period when pipes are full or partially full of stagnant water. (See section 10 for specific procedures associated with the prevention of 'Legionnaires' Disease.) In practice, however, long periods may elapse between the installation and bringing into use, especially in large buildings with complex services. Consideration then has to be given to the action to be taken to minimise the possibility of water contamination problems that might develop. In any event it is necessary to flush out thoroughly and pressure test at the earliest possible moment after installation. Subsequent possible actions to cover protracted periods before putting the system into use are:

(a) to drain completely and dry out as far as possible by blowing air through the system, and then to seal off to prevent ingress of water and foreign matter. This is the preferred option as it reduces the potential for contamination through stagnant water, although it may prove difficult in practice in complex installations in large buildings.

(b) to keep the system completely full and to run water off from all draw off points to introduce fresh water into all the pipes regularly. Whenever possible the flushing water should be fed into the highest point and at the highest pressure the system will safely withstand, and be flushed out at low points through properly sized full bore valves or plugged wash out points as incorporated in the design. Any filters, meters, pumptraps, valves, controllers, non-return valves and items of equipment which may be damaged or prevent adequate flushing, should be removed during the flushing operation.

When the completed building is finally connected to the permanent water supply, and until it is occupied, all draw off points should be opened twice a week in sequence for a sufficient period of time to ensure that the water does not stagnate and to draw fresh clean water into the whole system to assist in the development of the normal protective internal films within the pipe system.

It is important to recognize that water services used to supply drinking water shall be protected against contamination during installation, commissioning and repairs. If any water supply service is exposed to foreign substances or contaminated supply, the service shall be flushed, chlorinated and tested before being placed in service.

7.1 General site operations.

It is important to ensure that all open pipe ends are correctly fitted with temporary caps at all times during construction. This particularly applies to external mains installed in open trenches that are eventually back filled. Surface and rainwater should be pumped continuously out of all open trenches during the whole of the time pipework is being installed. This includes night time and weekends/holidays. Every precaution should be taken to keep foreign matter (metal filings, cleaning materials, dirt etc.) out of all water installations at all times. If a fitting is disconnected at any time then every part of any pipe conveying water to that fitting shall be disconnected. This is to prevent contamination of the water supply by any stagnant water remaining in the pipe. It will also ensure that corrosion of the pipework and fittings does not occur due to stagnation conditions. This does not apply for 60 days to allow replacements to be obtained and fitted. In these circumstances it is important to ensure that the dead leg is flushed out thoroughly and treated as a precommissioned pipe.

8 Effects of water on copper tubes.

8.1 Installation features

Copper tubes have shown compatibility with the majority of potable waters. These waters establish a natural, protective internal surface film on the copper tubes.

Installation design should ensure that correct tube sizing controls water velocity within ranges recommended, avoids dead legs in the system and limits the use of tap outlets to those that will be used on a frequent basis.

Copper tube in buildings

During installation of the system, it is necessary to avoid contamination of the tube bores by debris and other matter, as these can give rise to corrosion problems subsequent to start up. Furthermore, on new installations, long periods where the water sits stagnant in the tube must be avoided. Accordingly, if there is to be a lengthy delay between testing of the system and start up, the lines should be effectively drained so that corrosion spots are not allowed to develop.

8.2 Water condition.

With most waters and under normal operating conditions, if these recommendations are followed, systems will remain free from any type of corrosion.

However, if there are wide variations in the chemistry of the water, especially variations of the pH level, away from neutral towards acidic or alkaline, corrosion problems may occur. Once identified, these should be addressed by suitable treatment of the supply water to ensure water chemistry is compatible with the plumbing system.

8.3 Discoloration of water supplies.

Substances that cause discoloration in water are undissolved solids such as rust (iron oxides), colloidal type suspensions of clay or silica, organic matter, deposited calcium carbonate and small amounts of copper salts usually combined with the above mentioned materials.

8.4 Water mains.

The layout and condition of the water main may be an important factor in the build up of sediments within the supply and distribution system. Large buildings with extensive distribution systems should not be connected at the end of a large water main. The water authority should be requested to establish a ring to ensure that there is adequate flow to avoid build up of sedimentary matter. Otherwise sediment may enter the building system and initiate discoloration problems either directly, or by causing corrosion resulting in slight dissolution of copper and contamination of the water. Very large ring mains on the low side of a building on a sloping block have been found to accumulate sludges due to very low draw off rates. Facilities for the flushing of mains should therefore be provided. Iron oxides from rusty steel water mains may deposit in the copper distribution pipe system and over a period of time may absorb copper causing the loose deposits to become greenish blue in colour. Normally, water flowing through the pipes at reasonable pressures will remove these loose deposits.

However, it has been found that in some cases stagnant water has remained in copper pipes for considerable periods, sometimes up to two years or more, during the construction period and in these instances problems of significant discoloration have developed.

9 Dezincification resistant brass.

In the past, brass fittings such as joints and bends have occasionally failed in service because the potable water has been sufficiently aggressive to cause dezincification. In these cases, brass components were made from materials which were not dezincification resistant. Accordingly, only old fittings will suffer from this particular type of corrosion which can be identified by its pink and brittle appearance of an overlying spongy copper deposit. These days it is mandatory that all such components are manufactured from special dezincification resistant brasses to ensure that this type of corrosion problem is eliminated.

"StandardsMark" products are manufactured from dezincification resistant material.

9.1 Waters causing dezincification.

Hard waters do not normally cause dezincification. This type of corrosion is found in certain areas with soft water containing critical combinations of chloride content, temporary hardness and pH and is known as meringue dezincification. Authorities obtain their supplies from a variety of sources. It is not always possible to give an accurate geographical indication of susceptible areas. In areas where the water supply is aggressive, dezincification may occur in water supply fittings such as stopcocks, tees, elbows and connectors. It is accelerated by increased temperature and the fittings in a domestic hot water system are therefore more susceptible than those in cold water systems. It does not occur in terminal fittings such as taps nor in closed loops as found in the primary circuit of a central heating system.

Copper tube in buildings

10 Copper and 'Legionnaires' Disease.

Since the recent outbreaks of 'Legionnaires' Disease a number of measures have been introduced or recommended to prevent its occurrence in both hot and cold water systems in institutional and other buildings with large plumbing heating and air conditioning systems. A number of the preventative measures have not adequately taken into account their effect on the materials within the system. Although a number of materials other than copper have been recognised as potential sources of growth of the bacterium Legionella pneumophila the potential role of copper as a bactericide has been largely overlooked. There is some evidence to suggest that substantially 'all-copper' systems tend to be free of Legionella pneumophila. In addition research being carried out by ICA tends to confirm this view with regard to other bacteria which are destroyed when in contact with copper based components.

However this is only part of the story as some of the steps being taken to control the growth of Legionella pneumophila may be associated with an unacceptable rate of corrosion of copper components. In particular whilst the dosing of water systems with 20-50ppm of free chlorine as a one-off or occasional disinfection measure of short duration (1-3 hours) is acceptable, it is inadvisable for a copper system to be left charged with water containing these levels of chlorine overnight or during lengthy periods between commissioning and coming into service. If carried out correctly, adequate disinfection can be achieved in a relatively short time and there is no advantage to be gained from these extended time periods. Low level continuous chlorination with 1-2ppm poses no problem and in any event this measure is not recommended for widespread preventative use but only for outbreak control in buildings associated with cases of disease.

With respect to hot water systems, and the requirement to store water centrally at 60°C there is a clear need to ensure due regard is taken of the necessity to avoid excessive water temperatures. In soft-water areas holding water for long periods at temperatures above 60°C can accelerate pitting corrosion of copper tube and in hard water areas this situation will increase the precipitation of hardness of salts in the pipes and calorifiers.

Thus calorifiers should be fitted with accurate temperature controls so as to achieve preservation of microbial quality without detriment to the longevity or cleanliness of the system.

Legionella pneumophila is killed within a few minutes at 60°C and between 50-60°C survives for only 1-2 hours. In copper systems viable organisms that have survived heating to temperatures above 50°C may be discouraged from multiplying in the downstream water but it should be recognised that the presence in the water system of other unsuitable materials may protect the organism from the relatively hostile environment within a copper calorifier and pipes.

All drinking water outlets should be connected either to the main supply directly or through a properly constructed and protected storage tank which complies in every respect with the water undertaking's requirements. Oversized and unprotected tanks provide opportunities for microbial growth and contamination of the water entering the system. Detailed advice on the design, construction and commissioning of water services is given in the AS/NZS 3500. Individual water undertakings can advise on any relevant local water quality characteristics.

Within the AS/NZS 3500.1 a method of sterilisation is recommended, see appendices H and I. Several state government departments of health, including the N.S.W. Health Department have issued publications giving guidance on minimising the risk of 'Legionnaires' Disease.

These documents set out general principles and have been written on the understanding that their successful implementation requires careful attention to the practical requirements of each water system and the building function.

Copper Quality is for keeps

Copper tube in buildings

11 Vented and unvented domestic hot water systems.

Unvented hot water systems rely upon the installation of adequate temperature/pressure control within the system to prevent a dangerous condition arising through excessive temperature and/or pressure within the heater. AS/NZS 3500.4 indicates the method and installation conditions to achieve this objective.

Vented systems rely upon the physical movement of hot water within the reticulation system, flowing into a reservoir or chamber.

The size of the reservoir which must be vented to open air, fitted with a loose fitting cover, is calculated to hold at least three times the amount of water volume caused by the expansion of water by the heating process within the system.

It is mandatory that no valve or obstruction of any description can be installed in the pipework between the heat source and the reservoir and relief area.

Irrespective of the type of system, copper tube is suitable for use throughout the hot water supply and distribution systems. The temperature of the water throughout the heater and reticulation shall not exceed 99°C at any point in the system. This is to prevent the generation of highly dangerous 'flash' steam from a pressurised system.

Note: *The expansion vessel in a sealed primary circuit shall be sized to accommodate the increase in volume of water when heated from 10°C to 110°C.*

11.1 Pipe sizing.

Detailed methods of pipe sizing taking into account the recommended hot and cold water flow rates are contained within AS/NZS 3500. However there are a number of minimum tube sizes required for specific pipe runs within the heating systems and these are listed in following text quoting the relevant outside diameter (DN) of the copper tube. The tube sizes quoted are based on AS 1432 Type 'A' which has the greatest wall thickness and hence the smallest nominal bore.

11.2 Cold water feed pipe.

The cold water feed pipe to a hot water storage vessel or water heater should be sized in accordance with the AS/NZS 3500 requirements.

11.3 Open vent pipe.

An open vent pipe should be fitted to every vented primary and secondary circuit and water heater system. The vent pipe should not be less than DN25. The length of any vent pipe should be determined in accordance with the requirements of AS/NZS 3500. In a pumped circuit due allowance should be made for the head induced by the circulating pump to prevent pumping over causing the introduction of air into the system. This can accelerate the rate of corrosion of metals **less noble than copper in a mixed metal system.**

11.4 Hot water storage vessels.

The heating coil in a hot water storage vessel will have been sized and installed by the manufacturer to meet the performance requirements of the vessel to AS 1056. The copper coil shall be of one piece construction to prevent the contamination of the primary and secondary circuits due to failure of any contained joints.

11.5 Direct systems.

Direct systems are designed for gravity circulation and the flow and return pipes between the boiler and storage vessel should not be less than DN25 (or DN20 for small solid fuel back boilers).

11.6 Indirect systems.

Pipe sizing will depend upon whether the hot water circuit is gravity fed or is pumped together with the heating circuit.

11.7 Vented primary circuit.

In the case of a gravity circuit the pipe sizing is as for the direct system. If the circuit is pumped the minimum diameter is DN15.

11.8 Sealed primary circuit.

The pipe sizing is as for the vented primary circuit. Indirect cylinders fitted in these circuits should have primary heating coils capable of operating at 35 kPa in excess of the pressure relief valve setting.

11.9 Secondary distribution systems.

AS/NZS 3500 Part 1 and Part 4 indicates the pipework required to be insulated.

Copper Quality is for keeps

12 Copper in domestic heating systems.

There are a range of heating system options available, from ducted warm air and wet central heating systems to individual room heaters, using gas, electricity, solid fuel, oil or LPG. The choice of system is influenced by a number of factors, namely:

a) The availability of fuels.

b) The equipment size and fuel storage requirements.

c) The controllability of fuel combustion.

d) The running costs.

e) The capital cost of the equipment.

The most common form of domestic heating installation is the wet central heating system using copper pipework to circulate heated water between the heat generator and heat emitters. Important design criteria including maximum recommended water velocities and pump and tube sizing are also covered with specific detail given to safe and efficient system operation.

Irrespective of the heating system type, the supply and storage of domestic hot water is best achieved using a copper cylinder and copper tubing. This can be an integral part of the total heating system or a separate package where individual room heaters are used. Solar heating and heat pumps are alternative methods of providing cheap domestic hot water, details of which are included under their respective sub-headings within the publication.

Good corrosion resistance and compatibility with a range of working fluids make copper and copper alloys suitable materials for all domestic hot water and heating system applications.

The high thermal conductivity of copper makes it ideal for use in heat exchangers. The ease of fabrication of copper tube and sheet and the range of jointing methods available simplifies the manufacture and installation of heating systems.

The good machinability of copper alloys and the range of forming processes results in the production of close tolerance, high strength, wear resistant and corrosion resistant valve bodies and fittings.

12.1 Choice of heating system.

The first stage of the heating system design procedure is to determine the space heating requirement. This heating requirement will be equal to a summation of the heat loss through the building fabric and the heat loss via ventilation and can be calculated by following the design procedure of recognised design guides. In all cases the U values of building fabric used in new buildings should be examined to ensure their adequacy for the specific task.

For wet central heating systems, the heat generator output rating should be at least equal to the total calculated heat loss, including non useful emission from the system pipework.

Modern gas-fired low water content boilers fitted with high resistance copper tube heat exchangers are for use with fully pumped systems. The low water content allows rapid heat up at the beginning of the heating period and rapid cooling at the end of the period thereby reducing flue losses and increasing overall efficiency. Because these boilers are for use with fully pumped systems only gravity fed domestic hot water heating is avoided reducing the size of the boiler required and the bore size of the pipework between the boiler and the cylinder.

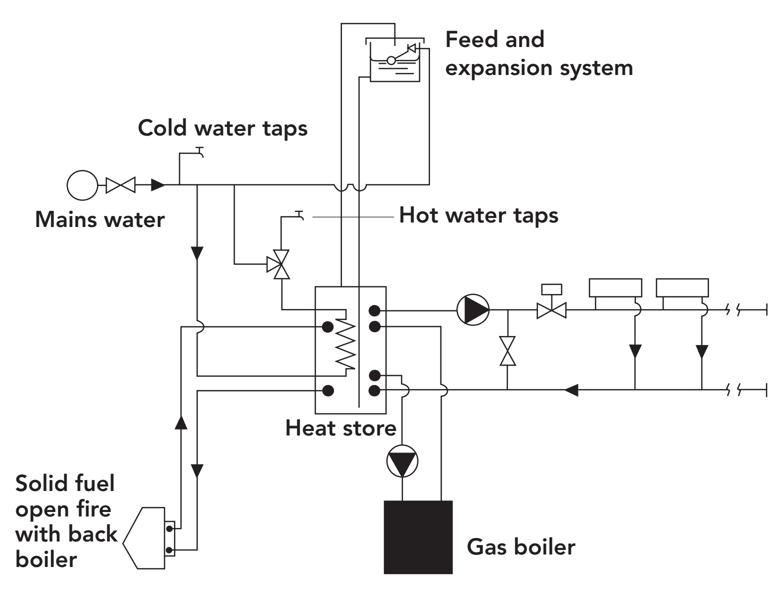
When a boiler of the condensing type is used, the output, when operating in the non-condensing mode, should be considered as meeting the total calculated heat loss.

N.B. The operating efficiency of condensing boilers increases with lower return temperatures. A greater design temperature drop will necessitate the use of larger heat emitters. High efficiency low water content radiators with copper coil waterways can give double the heat output of a steel panel radiator of equivalent flat surface area.

For off-peak electric heating the output is usually calculated in terms of energy stored and should be adequate to meet the daily (24 hour) heat requirement.

Where a boiler supplies both heating and hot water services without priority controls additional boiler power of up to 2.0 kW may be required depending upon the likely

Figure 12 Schematic Diagram of Domestic Hot Water and Heating System.



consumption of hot water, secondary circulation heat losses and the storage capacity of the indirect cylinder.

Having calculated the size of the boiler required, the method of distributing the heat from the boiler to each room must be decided upon.

12.2 Wet central heating systems.

Copper is the preferred material used in wet central heating systems for the circulating and domestic water distribution pipework.

Usually space and domestic water heating are provided by a single heat generator, although the loads for both functions may be such that separate heat generators are required for efficient system operation. Systems combining two or more heat generators using different fuels are less common but are made possible by using copper pipework to connect each heat source to a central copper thermal storage cylinder as shown in Figure 12.

Here, a solid fuel back boiler and gas boiler circulate primary heated water to a central thermal storage cylinder. The heating of mains pressure domestic hot water is carried out within an extended surface copper coil heat exchanger in the central store. Use of a water softener is advised in hard water areas to prevent the build up of scale inside the secondary heat exchanger coils and subsequent reduction in efficiency.

As already discussed, wet central heating systems can utilise a range of heat generators and fuels. Water circulation is usually carried out in small-bore copper tubing to AS 1432 for Mini/micro-bore installations can be significantly more economical in both labour and materials than conventional small-bore systems. (Figures 13 and 14). The range of metric sizes for copper tube to AS 1432 are as given earlier in Table 2 Section 2.3.

In general, the conventional arrangement of small-bore pipework consists of a flow and return circuit extending to the index (furthest) radiator, with flow and return branches to intermediate radiators. In the mini/microbore system, radiators are fed by means of DN6, 8 or 10 pipe circuits from flow and return manifolds.

It is not necessary to connect all the radiators to a single pair of manifolds situated near the boiler, although this arrangement is often advantageous for a bungalow. For buildings of more than one storey it may well be more convenient and economical to install a pair of manifolds for each floor, and by siting them in the most accessible position, the length of the mini/micro-bore copper circuits can be kept reasonably short, thereby saving material and reducing frictional resistance in the circuits to a minimum.

12.3 Design criteria.

Significant factors in the design of forced-circulation low pressure hot water heating systems are:
a) pump sizing and positioning and;
b) expansion allowances for both sealed and open vented systems.

12.4 Open Vented Systems.

Open vented systems, whilst evident sometimes in multi story development, are not commonly installed in Australia. The information in the following clauses 12.4.1 to 12.4.3 inclusive have been incorporated as valid U.K. practice the information is relevant to similar installations should they occur in Australia.

12.4.1 Pump capacity.

The pump must be capable of circulating the total mass of water for all circuits against a resistance equal to the pressure drop in the index circuit (the circuit with the greatest frictional resistance). The mass flow rate is calculated using the formulae:

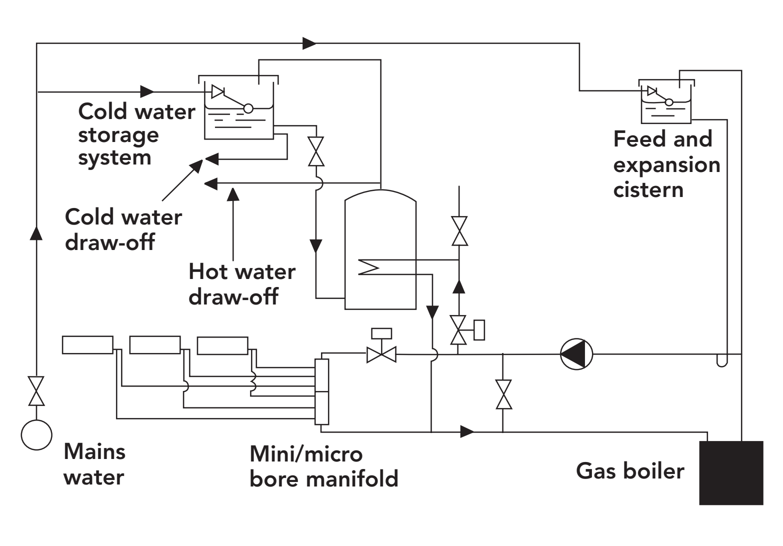
Q = M.Cp.T
or M = Q/Cp.T where,
M = mass flow rate (kg/s)
Q = Boiler output (kW)
Cp = Specific heat capacity of water (4.18 kJ/kg/ C)
T = Temperature difference between flow and return (10°C)

It is usual to allow a small margin on the flow rate of the pump to facilitate balancing the system and to permit future extensions. The design flow temperature should not exceed 82°C. The system design temperature drop should be 10°C unless the boiler is of the condensing or electric storage type.

The pipe diameters and pressure drop in the pipe circuits can be determined from the mass flow rate, flow temperature and the length of pipe runs. The pump head must be sufficient to meet the total pressure drop in the index circuit. This total pressure drop will be a summation of the pressure drop in the index pipe circuit, including all bends, elbows, tees, branches and valves, plus the pressure drop in the index radiator and boiler.

In the mini/micro-bore system shown (Figure 13), the mass flow rate from the boiler to the manifold will be calculated as above, using the index circuit and the heat output of the index radiator.

Figure 13 Schematic Diagram of Mini/Microbore Heating System.



To ensure quietness in operation, the pipe circuits should be sized such that the water velocity does not exceed 1.5m/s. In order to determine the pump head required the resistance of the fittings, index radiator and boiler must be added to the calculated pressure drop.

Tables of water flow resistances in copper fittings are as quoted previously. When designing the mini/microbore heating system it may not be immediately evident which is the index circuit. Therefore it is important that the pressure drop in each circuit should be calculated and tabulated.

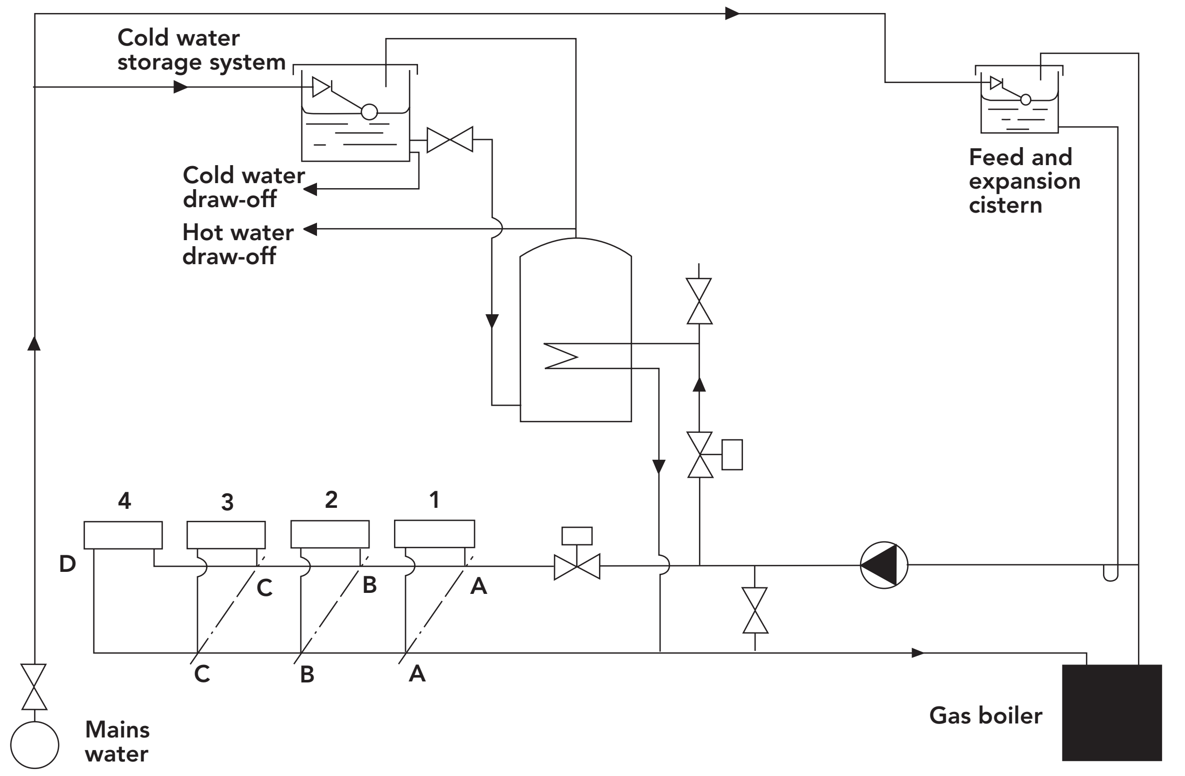
In the small bore heating system shown (Figure 14). The index circuit should be easier to determine although the pipe sizing calculations will have to take into account the change in mass flow rate after each radiator on the index circuit. The mass flow rate through the boiler will be calculated as above, thereafter the mass flow rate will be calculated using the heat outputs of the radiators in the index circuit. *(Refer to Figure 14, small bore heating installation)*
eg.

M at A = (Q1 + Q2 + Q3 +Q4)/Cp.T
M A to B = (Q2 + Q3 + Q4)/Cp.T
M B to C = (Q3 + Q4)/Cp.T
M C to D = Q4/Cp.T

where, Q1, Q2, Q3 and Q4 are the heat outputs of radiators 1,2,3 and 4 respectively.

For design purposes, the maximum water velocity in small bore heating systems is set at 1m/s. Using the nomogram for hot water the pipe diameters and pressure drop may be determined. Again the resistance of all fittings, index radiator and boiler must be included. Consideration should now be given to the positioning of the pump, cold feed and expansion (F&E) pipe and open

Figure 14 Schematic Diagram of Small Bore Heating System.



vent (OV) pipe. The OV pipe should run directly from the boiler rising continuously to discharge at a level over the feed and expansion cistern and through the cover. The OV pipe should have a minimum DN20. A separate F&E pipe with a minimum DN15 should be fitted. No valve should be fitted in either the F&E pipe or OV pipe. The pressure difference between these two connections must be kept to a minimum to avoid excessive water movement in the OV pipe, therefore they are normally connected close together.

The two main problems to overcome when positioning the pump and F&E pipe connection are:

1) To prevent air entrainment through minor leaks in valves and fittings due to a sub-atmospheric pressure being set up in the system (these leaks are often too small to let water escape). This problem is caused by the pump suction pressure being greater than the static pressure, governed by the height of the F&E cistern above the pump.

N.B. The static head should comply with the recommendations of both the boiler and pump manufacturer.

2) To prevent water pumping over into the F&E cistern through the OV pipe, or a reduction in pressure caused by the pump at the OV connection to the system which is great enough to lower the water level in the OV pipe below the point where it connects to the circulating pipework once again allowing air into the system.

Both these problems can give rise to noisy operation, reduction in efficiency and corrosion.

In modern gas fired domestic boilers fitted with high resistance copper heat exchangers it is recommended that both the OV pipe and the F&E pipe should be connected to the flow pipe. The F&E pipe should be connected not more than 150mm from the OV connection so that they are under virtually the same pressure (Figure 15). The pump is fitted in the flow close to the F&E connection to maintain the system at a pressure greater than the static pressure.

Copper tube in buildings

Figure 15 Close-Coupled Connection.

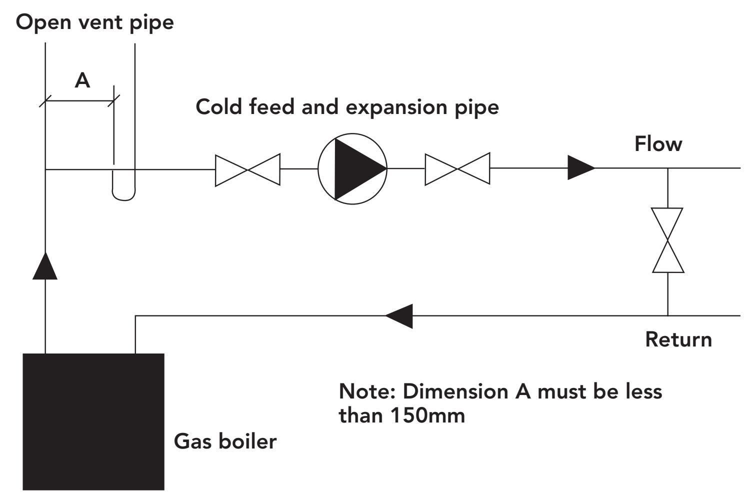
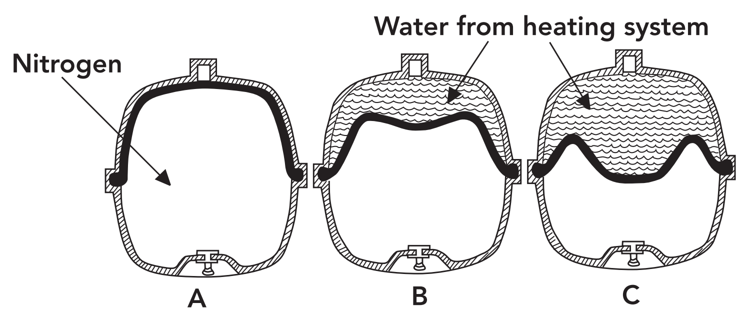


Figure 16 Expansion Tank with Flexible Diaphragm for Sealed System.



A Before the boiler has been fired the tank contains only air or nitrogen
B As the temperature rises the diaphragm moves to accept the increased water temperature
C Position of diaphragm when water temperature has reached its maximum

It is necessary to install either a by-pass or a diverting valve with a mid-position which is always open to one circuit. This is to ensure that there is always a route for feed water to the boiler.

12.4.2 Sealed systems.

The pump sizing design procedure is the same as for the open vented system. In a sealed system, a sealed expansion vessel is utilised which must have an acceptance volume sufficient to accommodate the volume change of system water when heated from 10ºC to 110ºC. The system should also be provided with a safety valve, a pressure gauge and means for system filling, make-up and venting.

The vessel should be of the flexible diaphragm type (Figure 16), complying with AS 1210, containing air or nitrogen at a pressure not less than the static head pressure at the centre of the expansion vessel.

The vessel should be connected to the system at a point close to the pump inlet in order to maintain positive pressures throughout the system. Installation should be in accordance with the manufacturer's instructions.

The flow water temperature and temperature drop can be increased to gain full economic advantage from the sealed system. This has the effect of reducing the overall size of the heat emitters. Additional savings are possible due to the reduction in mass flow rate of water and the pump head required resulting in smaller diameter pipe circuits.

12.4.3 Copper tubes.

Generally copper tube to be used in conventional heating systems is AS 1432 bendable and annealed temper. Hard drawn tube can also be used but it cannot be bent without prior annealing.

The type of copper tube recommended for mini/microbore installations is to AS 1432 Type B & C (annealed condition) in purpose made coils. It can be obtained in standard coil of approximately 30m lengths which, together with its soft condition, facilitates ease and speed of installation. Copper tube coils to AS 1432 Type B (annealed condition) should be used for mini/microbore installations underground. Straight tubes to AS 1432 are available in standard lengths of up to 6m. However increased labour costs incurred by additional jointing and fixing limit their use to flow and return headers fixed on the surface. These headers from boiler to manifolds need to be bendable or hard temper tube to support the various ancillary equipment. The standard outside diameters of all tubes within AS 1432 permit interchangeability.

Fittings should be of copper or copper alloy to AS 3688. Manipulative compression fittings Type 'B' are suitable for use with Type A, B and C copper tube to AS 1432. Non-manipulative compression fittings Type 'A' are suitable for use on tube to AS 1432 Type A, B and C.

If compression joints are used below ground, Type 'B' manipulative fittings must be used. These fittings shall be made from gunmetal or dezincification resistant brass. Capillary fittings to AS 3688 may be used above or below ground on any tube to AS1432.

Copper has the highest thermal conductivity of all the engineering materials, typically 305-355 w/(mK). Therefore copper tube finds uses not only in circulation and distribution pipework but also as a heat exchanger in boilers, heat pumps, underfloor heating, radiators, indirect cylinders and solar panels. The other major advantages of copper tube are:

suitability for use with potable and other waters;

high resistance to corrosion;

absolute gas tightness-no oxygen diffusion;

ability to be joined and bent easily;

high strength and ductility;

resistant to temperatures over 100°C;

and ease of prefabrication and installation.

In radiators, serpentine copper coils mechanically expanded into aluminium or steel channels, result in lightweight high efficiency heat emitters. The low water content of these units enables quick response to thermostatic controls and the corrosion resistant all copper waterway ensures a long operational life.

12.4.4 Plastic coated copper tube.

Copper tube to AS 1432 in selected sizes (refer to manufacturers literature) and is available with plastic coatings in a range of colours to identify its use in service.

Generally,

Green - water services

Yellow - gas pipes

Lilac - recycled water

It is available in straight lengths or coils with diameters ranging from DN6 to DN100. The plastic coating gives protection against mechanical damage and corrosive environments. Plastic coated copper tube is also available with the inner surface of the plastic profiled to trap air, this forms a noise and thermal barrier.

12.4.5 Gas pipework.

Installation

All work should be performed in accordance with Australian Standard AS 5601. The Standard specifies the requirements for the installation of copper piping for conveyance of fuel gases such as Town Gas, Natural Gas, Liquefied Petroleum Gas in the vapour phase, Tempered Liquefied Petroleum Gas, Simulated Natural Gas or any similar substance. Material requirements are specified in Clause 3.2 and Table 3.1 of AS 5601.

Copper pipe shall comply with AS 1432. Only Types A and B thicknesses are permitted. The maximum operating pressure is 200 kPa, unless authorization is granted for higher pressures. Where pressures are above 7 kPa, piping is not permitted beneath a building unless covered with an approved wrapping.

Various jointing techniques are permitted:

- Brazed capillary fittings, conforming to AS 3688 using canary yellow brazing alloy filler metal.
- Expanded brazed sockets can be used to join pipes and junctions may be formed in hard drawn pipe only.
- Copper alloy flared compression fittings to AS 3688 are approved but are not to be used in the ground beneath a building. Brass fittings buried in the ground must either be dezincification resistant or effectively coated to avoid corrosion.
- Soft soldered joints are not permitted.
- For other fittings and flanges, refer to Table 3.1 in AS 5601

Testing

The pressure testing of gas piping is specified in Appendix E of AS 5601. When testing consumer piping without appliances connected:

- Ensure all open ends are sealed.

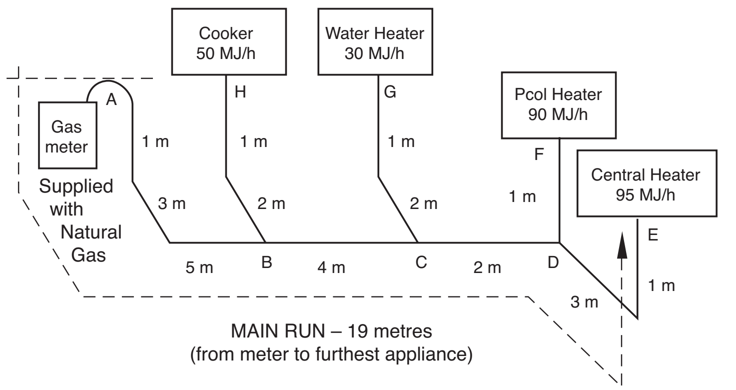
- Connect a pressure gauge, e.g. manometer, and pressurise the installed piping to 7 kPa or 1.5 times the operating pressure, whichever is higher.
- Isolate the pressure source and allow a suitable period for the temperature of the testing medium in the pipe to stabilize.
- Where the consumer piping volume does not exceed 30 litres (0.03 m^3), there is to be no loss of pressure during a test period of 5 minutes.
- Where volumes exceed 30 litres, increase the test period by an additional 5 minutes for every extra 30 litres or part thereof.
- The designated test period is for where a manometer is used as the test apparatus. The Technical Regulator should be contacted to determine an appropriate test period if alternative apparatus is to be used and also for direction on test requirements where test pressures exceed 400 kPa.

Approximate copper length for 0.03m^3	
Pipe Size (DN)	Approx. Length (m)
20	130
25	70
32	40
40	30
50	16
65	10
80	7.5
100	4

Pipe sizing

In AS 5061, Appendix F5, there is a method of pipe sizing with pipe sizing tables for various pipe materials and low-pressure gas applications. The following copper pipe sizing exercise is based on the AS 5601 example, which is used to size steel pipe.

Figure 12.4.5a – Typical pipe layout



Exercise: Determine the copper pipe sizes required for a typical natural gas system with 1.2 kPa pressure at meter.

Step 1 – Sketch the proposed piping layout (see Figure 12.4.5a), including gas meter, all appliances and the length of all sections.

Step 2 – Note the gas consumption, in megajoules per hour (MJ/h), for each appliance.

If appliances are rated in units different to MJ/h, these conversion factors can be of assistance:

Gas Consumption Unit	Conversion to MJ/h
Btu/h	Divide by 948
ft^3/h	Divide by 35.3 and multiply by the heating value of gas in MJ/m^3
m^3/h	Multiply by the heating value of the gas in MJ/m^3

Step 3 – Commencing at the meter, along the entire length of the **main run**, allocate a letter to each branch – see A to E inclusive.

Step 4 – Allocate a letter for each appliance.

Step 5 – Determine the length of the main run. The **main run** is the distance from the gas meter (A) to the furthest appliance-in this case the Central heater E. This is a distance of 19 m. The main run is the critical measurement for use throughout the pipe sizing calculations.

Step 6 – Draw up a chart with columns for: Pipe section; Gas flow; and Pipe size (see Figure 12.4.5b). Include each pipe section and the volume of gas flowing through each section.

Step 7 – From AS 5601 Appendix F, select the relevant pipe-sizing Table, taking into account the proposed piping material (**copper**), the type of gas (**natural gas**) and the allowable pressure drop (**use 0.075 kPa**). In this case, it would be Table F1.

Figure 12.4.5b – Chart for pipe sizes		
Pipe Size	Gas flow (MJ/h)	Pipe size (DN) – see Step 9
A – B	50 + 30 + 90 + 95 = 265	40
B – C	30 + 90 + 95 = 215	32
C – D	90 + 95 = 185	32
D – E	95	25
D – F	90	25
C – G	30	20
B – H	50	20

Step 8 – Under "Straight length of pipe", select the closest higher value for the **main run i.e. 19 m,** which was determined in Step 5. The nearest value to 19 m is 20 m.

The following pipe size (DN)/gas flow (MJ/h) values are taken from AS 5601 Table F1:
DN15/13; DN20/64; DN25/128; DN32/242; DN40/417; DN50/964; DN65/1816; DN80/2946; DN/100/6619; DN125/12274; DN150/19932

Step 9 – From the Table values, select the pipe size for each section in Figure 12.4.5b based on the total gas flow through the section. Enter the pipe size in the chart. Where the gas flow does not coincide with an actual value in the Table, the pipe size for the next higher gas flow value is to be recorded. Thus, for section "A – B" with total flow of 265 MJ/h, a DN 40 copper pipe is recorded in the chart.

Step 10 – Repeat Step 9 for each pipe section. Always use the **main run** as the reference length for all calculations.

12.4.6 Heat exchangers.

Copper and copper alloy heat exchangers of the integrally finned or fin and tube construction are used in a variety of heat generators including: Low water content boilers; Modular boilers; Combination boilers; Instantaneous hot water heaters; Heat pumps; and Condensing boilers (primary heat exchanger only).

Integrally finned tubes are those in which helical fins are extruded from the tube by a rolling process. Fin and tube type heat exchangers are those in which a copper tube is mechanically/hydraulically expanded into a stack of regularly spaced copper or aluminium fins pierced with a pattern of holes sized to receive the tube. Both of these processes increase the surface area of the heat exchange tube enabling high efficiency heat transfer to the water.

The heat exchanger is tinned to give added protection against possible corrosive constituents in flue gases.

12.4.7 Valves.

A wide range of copper alloy taps and valves are employed in heating and hot water systems to facilitate safe and efficient operation and control water circulation, distribution and draw off. Draining taps for hot and cold water installations and heating systems should be to AS/NZS 3718, diaphragm type float operated valves to AS 1910, globe, globe stop and check, check and gate valves to AS 1628. Copper alloy valves used for other applications should meet the material requirements of the relevant Australian Standard Specification.

Copper alloys are the preferred materials for use in water circulation or distribution systems because of their high strength, corrosion resistance and compatibility with the working fluid.

In some areas of the Australia impurities in the potable water make it aggressive to duplex brass producing a form of attack known as dezincification. In these areas dezincification resistant brass fittings and valves should be used.

All copper alloy valves are available with capillary or compression ends to AS 3688.

12.4.8 Solar heating

Due to its high thermal conductivity, corrosion resistance and elevated temperature performance, copper is an excellent material for solar heaters and connecting pipes. Specific requirements for solar heater installations are outlined in AS/NZS 3500.4.

In solar installations, care should be taken to accommodate expansion in piping and to insulate piping appropriately, particularly in areas where low temperatures can occur.

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12.4.9 Refrigerant piping

Copper is unsurpassed for refrigeration and air-conditioning applications due to its thermal conductivity, corrosion resistance, ductility and ease of fabrication. Tubes are manufactured to comply with a stringent internal cleanness limit specified in Standard AS/NZS 1571 and are factory capped to prevent ingress of moisture or contaminants during storage and handling prior to installation.

Standards AS/NZS 1677 and AS 4041 apply to the design, construction, installation, testing, inspection, operation, maintenance and safety of refrigeration systems. At the design stage, it is important to consider:

(a) Pressure capability of piping
Specify pipes of thickness that will withstand the operating pressures and temperatures associated with the proposed refrigerant. This is important, particularly in light of the higher pressures of modern replacement refrigerants such as R410A. **Check pipe manufacturers' brochures for pressure ratings – see the section "Product technical brochures" at the back of this manual.**

(b) Refrigerant compatibility
The refrigerant must be compatible with copper. Ammonia is not compatible.

(c) Expansion and vibration
Piping should be designed to accommodate expansion associated with temperature change and to minimize the potential for vibration to occur.

(d) Liquid hammer
Liquid hammer can produce excessive pressures that could lead to piping failure. Piping should be designed to avoid hammer conditions.

12.4.10 Medical gas piping

Copper pipe is widely used for medical gas installations. Only appropriately qualified personnel are to be involved in the design and installation of medical gas systems. The Standard applicable to this work is AS/NZS 2896. 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 its components is critical to the effective performance of medical gas lines. Factory sealed AS/NZS 1571 copper pipe is specified. As with refrigeration piping, it is important to select pipe thickness suitable for the temperatures and pressures in the system. For positive pressure lines, as-drawn temper AS/NZS 1571 copper pipe is required but the thickness must be no less than that specified for AS 1432 Type B pipes of equivalent diameter. Copper is also suitable for suction lines.

Special precautions are required when making joints in medical gas piping. During all heating and brazing operations, to prevent the formation of oxide and scale, piping is to be purged with protective gas in accordance with the procedures specified in the Standard. A 15% silver-copper-phosphorus filer metal is to be used for all brazing.

12.4.11 Steam piping

Copper pipe will offer an option for some steam applications due to its light-weight, workability, space conservation and corrosion resistance. Copper may not be suitable where steam is contaminated with chemicals or particulate matter.

Steam lines should be designed in accordance with AS 4041. At the design stage, care should be taken to:

- Specify pipes with thickness that will meet the temperature and pressure constraints on the system. Pipes should be no thinner than AS 1432 Type B.
- Accommodate the expansion and contraction forces developed in the system.
- Minimise the potential for the occurrence of steam hammer and vibration.

12.4.12 Water velocities.

Problems can arise due to excessive water speeds which in extreme conditions can cause premature tube failure by one of several mechanisms including erosion/corrosion and/or cavitation. The recommended maximum water velocity for differing service conditions, assuming good design practice and installation procedures is 3m/s irrespective of tube outside diameter. Water flow resistance data are as given earlier. Further information regarding design considerations for copper tube including expansion joints, spacing for copper tube supports and protection of piping is contained in AS/NZS 3500.1 Water Supply.

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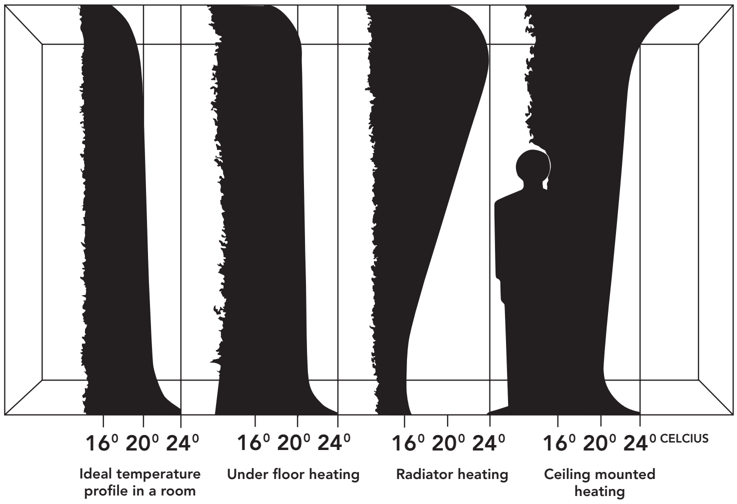
Figure 17 Temperature Profile of Different Heating Systems.



12.4.13 Insulation.

Hot water pipes should be insulated unless they are intended to contribute to the heating of part of the building which is insulated or they give rise to no significant heat loss. Insulation should meet the requirements of the PCA, BCA and AS/NZS 3500.

Data on insulating materials and minimum thicknesses is given in the AS/NZS 3500. Cold water supply pipes for domestic purposes should be installed so that, as far as is reasonably practical, the water will not be warm when drawn from the tap. If the cold supply cannot be installed away from the hot pipes then it should be adequately insulated. If neither of these measures are practicable the cold pipe should be installed below the hot pipe.

12.5 Underfloor heating.

Underfloor wet central heating systems using copper tube for circulating heated water to provide space heating are for example used throughout Europe in domestic, commercial and public buildings. Generally, the systems utilise a central boiler circulating heated water to a distribution manifold with control and shut-off valves on the feed and discharge pipes. The water is circulated under the floor surface which becomes the radiator. A correctly designed and installed system gives an even floor temperature and attains a room temperature distribution which approaches the ideal (Figure 17). To prevent discomfort the surface temperature of the floor is limited to a maximum of 28°C. Systems are usually designed to achieve a surface temperature between 25° and 28°C, this limits the thermal output of the floor so the building must be well insulated. The flow water temperature is normally in the range 30° to 40°C, therefore the temperature difference between the circulating water and ambient air is less than in a conventional radiator system resulting in reduced heat loss through the feed pipes.

Operating at these low water temperatures results in an increased boiler efficiency and allows for a wider selection of heat sources including condensing boilers, heat pumps and solar energy.

Due to the relatively low surface temperature of the heat emitter, the duration of the heat up period is increased when compared with radiator systems, although ambient air temperatures can be 2° to 3°C lower than with conventional systems whilst maintaining comfort levels. This is due to 50% of the heat being emitted by radiation. Conventional panel radiators which can be 70% plus convective produce convective air currents.

This movement of the air is considered to have a ‘cooling’ effect on the occupants of the room.

Plastic coated copper tube coils are normally used either:

1) embedded in grooves in the heat insulating layer (Figure 18a) or,

2) embedded in a floating floor on top of the insulating layer (Figure 18b). In the first case additional heat dissipating material has to be used to improve the heat transfer between floor and tube. In the second case the heat transfer is

Copper tube in buildings

improved but greater care is required when installing the floor to prevent damaging the tube. The plastic coating gives protection against mechanical or chemical damage and allows for longitudinal thermal expansion of the copper tube in the floor.

For further details of plastic coated copper tubes refer to the earlier section 12.4.4 entitled Plastic Coated Copper Tubes. Installation of these systems in Australia should comply with the PCA, BCA and AS/NZS 3500.

The bedding of any pipe and associated joints forming part of a close circuit system of underfloor space heating in screed or in a wall or solid floor which is subsequently plastered or screened will be accepted if the pipe and joints can be exposed for repair or replacement by removing the surface layers of the wall or floor.

Figure 18 (a) The circulating tubes are placed into the heat insulating and noise absorbing layer below the floating floor.

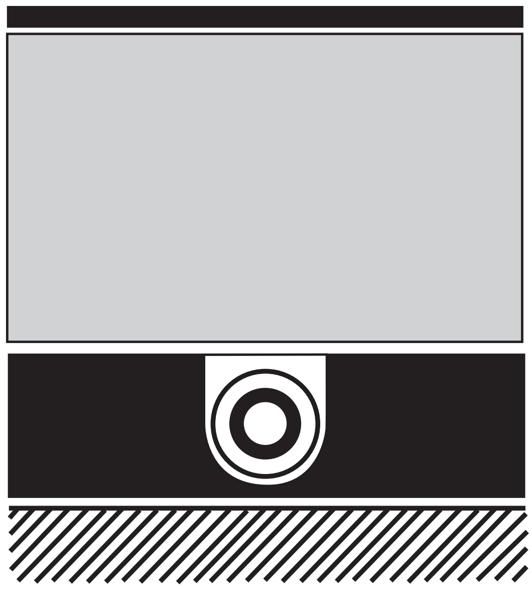
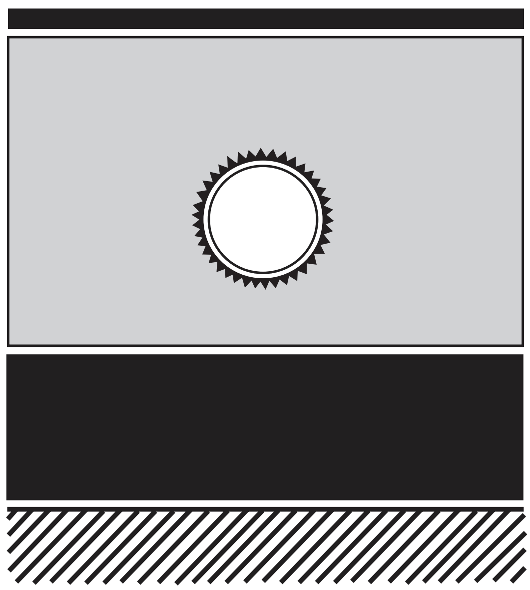


Figure 18 (b) The circulating tubes are embedded directly into the floating floor



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13 Domestic hot water heating.

Internationally, hot water supply systems are often combined with space heating systems but can be supplied as separate packages. The type of system can be divided into two categories: 1) storage and 2) non-storage. The storage systems can be sub-divided into two categories: 1a) open vented and 1b) unvented.

13.1 Storage systems.

13.1.1 Open vented.

The traditional type of water heating in dwellings of other countries over the last 60 years originally utilised a coal-fired back boiler or kitchen boiler. Today a gas-fired boiler and/or an immersion heater is more usually used.

The open vented domestic hot water system utilises a copper cylinder to store hot water heated directly by a boiler or immersion heater (Figure 19), or indirectly by a boiler, solar panel, heat pump etc (Figure 20). In either case the cylinder is usually cistern fed and has a vent pipe of minimum running from the top of the cylinder rising continuously to a pre-determined height above the cold feed cistern and discharging through the cover.

Primary pipework for direct systems should be designed for gravity circulation with flow and return pipes between the boiler and cylinder run as directly as possible and not less than DN25 (DN20 for small back boilers). Direct cylinders should meet the requirements of AS 1056.2 and be supplied by a cold water feed cistern. In hard water areas where scale build up may obstruct the pipes between the boiler and cylinder an indirect system is advised.

Indirect cylinders should always be used when domestic hot water and space heating are provided by one boiler.

The indirect cylinder is either of the double feed type complying with the requirements of AS 1056.2 or the single feed type complying with the requirements of AS 1056.2. The Australian 'StandardMark' provides the assurance that cylinders are manufactured in full compliance with the relevant Standards. In the double feed indirect cylinder primary water is circulated within a coil in the cylinder. Prevention of contamination of the secondary hot water within the single feed indirect cylinder is maintained by an air pocket separating it from the primary heating water. Installation of these types of cylinders should comply with the requirements of AS/NZS 3500.

The recommended minimum storage capacity of the cold water feed cistern for small houses supplying hot and cold water outlets is 200 to 300 litres. In larger houses approximately 100 litres per bedroom is recommended.

Combination type storage cylinders to AS 1056.2 incorporate the cold water feed cistern on top of the hot water cylinder. This type of storage cylinder must be installed at a high enough level to give adequate flow at the taps. The sole mechanical component in the open vented domestic hot water supply system is the ball valve requiring occasional servicing. Hot and cold taps supplied from the same cistern means that balanced pressures are achieved without water hammer or outlet noise.

Figure 19 Direct Vented System.

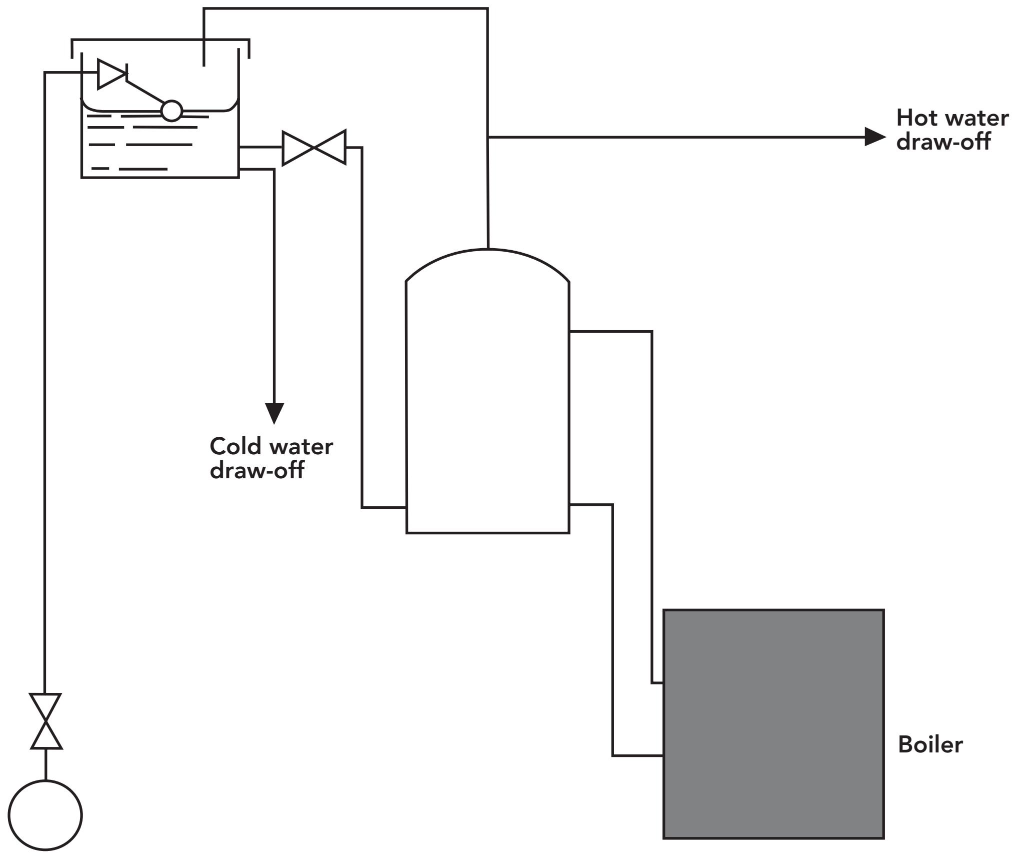
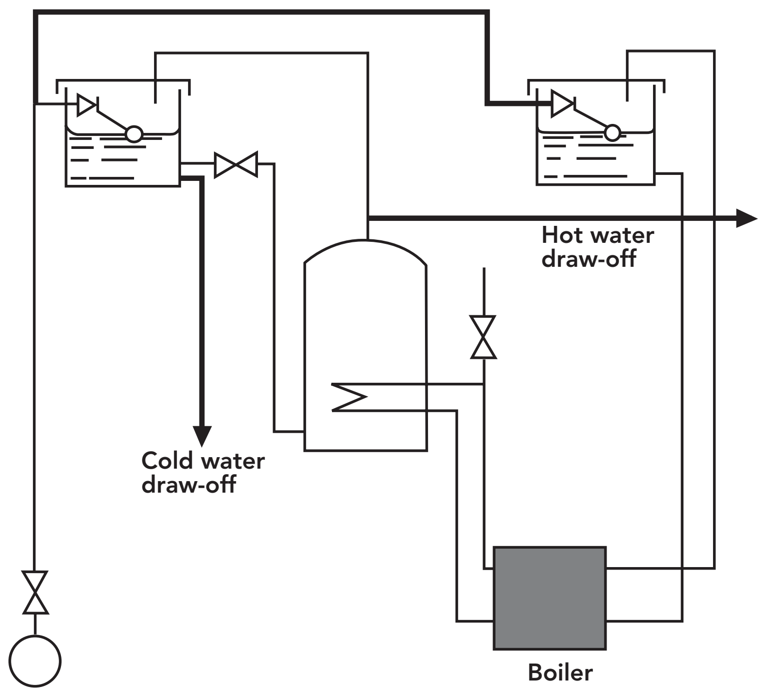


Figure 20 Indirect (Vented) System.



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13.1.2 Unvented.

The unvented storage cylinder can be connected directly to the mains or cistern fed and is without permanent venting.

Installation of these systems should comply with manufacturer's recommendations, the PCA, BCA and AS/NZS 3500. The installation of a mains pressure storage system which does not incorporate a vent pipe to atmosphere, shall be fitted with adequate precautions to:

(a) prevent the temperature of the stored water at anytime exceeding 99°C and

(b) ensure that the hot water discharged from safety devices is safely conveyed to where it is visible but will cause no danger to persons in or about the building.

The system shown can be supplied as a unit with all the ancillary equipment factory fitted and preset. The components included with the cylinder are:

A) An in line strainer to ensure trouble free function of other devices downstream.

B) A pressure regulating valve to AS 1357.1 and 2 to overcome the fluctuations in pressure in the mains is considered an advantage in supplying water to the cylinder at a constant pressure.

C) A check valve to AS 1357.1 to prevent cross-flow between the hot and cold water supply.

D) Expansion water discharge line to terminate in safe, visible location.

E) An expansion valve to AS 1357 set to relieve pressure should the system pressure rise above the normal thermal expansion, is considered advantageous. In hard water areas this valve is mandatory.

F) A temperature pressure relief valve to AS 1357 set to open at 93°C max. and to discharge to waste. An air-break device is sometimes included to prevent implosion-collapse of the cylinder. In addition to a thermostatic control to maintain the temperature of the stored water, a non-resetting energy cut out device to AS 1551 should be incorporated.

In a directly heated system the thermal cut out should be on the storage cylinder. In an indirect system, the heating coil should only be connected to an energy supply fitted with a temperature operated energy cut-out.

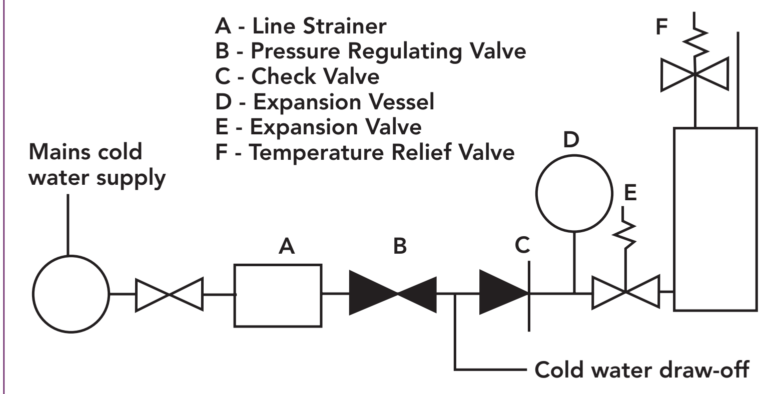
Copper alloy safety and control valves utilised on the unvented hot water storage unit will be manufactured to the previously mentioned Australian Standard Specifications.

Temperature/pressure relief valves, expansion valves and control valves should comply with AS 1357.

Copper is a prime candidate material for unvented cylinders due to its proven longevity and acceptance in the industry over many years.

The cost of a mains fed unvented domestic hot water system is much the same as the open vented system. The extra cost of stronger storage cylinders, larger mains and the need for safety controls is offset by savings due to requiring less fittings, smaller distribution pipes and omitting the cold water feed cistern in the unvented system.

Figure 21 Diagrammatic Arrangement of Mains Fed Unvented Hot Water Storage System.



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13.1.3 Cylinders.

All copper domestic hot water storage cylinders whether they be of the combination, open vented or unvented type, are manufactured from copper sheet to AS 1566 (Phosphorus deoxidised non-arsenical copper) and factory tested in compliance with the appropriate Australian Standard Specification. They should be installed with suitable means to facilitate isolation from the supply and draining down.

The primary heaters in double-feed indirect cylinders should be of the coil type manufactured from copper tube to AS 1432 with a continuous fall to prevent the formation of air pockets.

For direct cylinders, heating coil units are available which can be connected into the boiler primary circuit and inserted into the cylinder through the immersion tapping to convert it to an indirect cylinder. A converted direct cylinder is less efficient than a normal indirect cylinder due to the heating coil having restricted surface area and thus reduced heat transfer rate.

Other conversion units are available including heating coils installed in the top of either direct or indirect cylinders and connected to the mains to provide high pressure hot water. Again due to the restrictions on heating coil surface area and temperature of the stored domestic hot water (typically 60°C) the unit will not be as efficient (in terms of maintaining high flow rates and temperatures) as either unvented domestic hot water storage cylinders or water jacketed tube heaters/thermal storage cylinders connected to the mains supply.

Some immersion heaters are manufactured with copper sheathing around the heating element. Filler alloys used for brazing are of copper-silver-phosphorus or other corrosion resistant alloy which does not undergo dezincification and does not produce brittle joints. Silver-bearing alloys should comply with AS 1167.

Insulation of all hot water storage vessels should meet the requirements of the Building Code of Australia and AS/NZS 3500. Factory insulated cylinders to AS 1056 meet this requirement.

13.2 Non-storage systems.

In this type of hot water heating system more commonly known as instantaneous water heaters, the water is heated as it passes through a copper heat exchanger. The heat source is either gas or electricity controlled automatically by the water flow. The heater operates on a minimum flow which should give a temperature rise of 55°C, the temperature rise at full flow is normally set at 25°C.

Multi-outlet heaters work most efficiently when one tap is used at a time. Instantaneous water heaters of this type have relatively high power ratings necessitating an adequate electricity or gas supply.

Another type of system is the water-jacketed tube heater or thermal storage unit (Figure 12). Here the water is heated as it passes through a copper heat exchanger contained within a copper cylinder of heated water in the primary circuit which can be vented or sealed. The cold water feed may be from the water main or from a storage cistern. When supplied directly from a main supply pipe the high pressure is contained within the coil, the cylinder is not pressurised.

Expansion of the water must be accommodated such that there is no discharge from the system except in emergency situations. The amount of stored water in the cylinder (which in some designs can include the space heating circuit), the rate of heat input to it and the heat exchanger characteristics determine the amount and rate of flow of domestic hot water that can be provided without unacceptable temperature drop.

14 Corrosion in heating systems.

If a central heating system is designed, installed and operated correctly it is unlikely that there will be any problems with corrosion of its components.

In most cases the components of wet central heating systems are manufactured from a number of different metals. Mixed metal systems have been in use for many years with little trouble. Where problems have occurred, extensive investigations have shown that they are almost always the result of quite minor faults in the circuit layout. Rarely are the materials themselves at fault.

Normal fresh supply waters contain dissolved oxygen, the presence of which contributes to the corrosion potential of the water. In a closed-circuit primary system the oxygen is expelled from solution at operating temperature and the water then becomes non- aggressive.

Leaks and other corrosion problems which are found in a small number of systems can be caused by air getting into the circuit in more than usual amounts due to bad design, installation or operating practices.

For example:

1) Primary water is re-oxygenated if pumped over the vent pipe into the feed and expansion cistern. Negative pressure aeration occurs when air is sucked into the system either down the vent pipe or through minor leaks in fittings which are often too small to let water escape. Pumping over and negative pressure aeration can be prevented by correct location of the pump, open vent pipe and feed and expansion pipe as detailed in the earlier section 'Design criteria'.

2) In single feed systems the primary water is separated from the secondary domestic water by an air seal. This may break down and be bridged on boiling and allow mixing between secondary water (containing dissolved oxygen) and primary water, thus causing corrosion. The air seal will slowly re-form if the system is subsequently run at normal temperatures.

In the event of continual oxygen replenishment of the system water, there is a chance of some of the following problems:

1) Restricted water circulation. Corrosion of steel radiators will result in the build up of black or brown oxide powder in the bottom of the radiators or collection of nitrogen and hydrogen in the top of the radiators both of which can restrict water circulation and heat output.

2) Bimetallic corrosion. Where dissimilar metals are exposed in oxygenated water, one of them, the less 'noble', will be corroded preferentially by galvanic action. In mixed metal systems, the metals most likely to be attacked are aluminium, steel and iron. If the less noble metal has a large surface exposed, as in a steel radiator, a small amount of corrosion can be tolerated.
3) Pitting corrosion. Where excessive flux residues are present it is possible for localised corrosion to develop in the form of pits which may eventually penetrate the tubes in the form of pinholes. Manufacturers' recommendations for neutralisation and removal of flux residues should therefore be followed.

Pitting corrosion of copper tubes carrying fresh water in once-through or supply systems has occurred in certain areas where the water supply is aggressive.

14.1 Corrosion inhibitors.

Corrosion Inhibitors. In systems operating under ideal conditions, the use of corrosion inhibitors should not be necessary. The addition of recommended corrosion inhibitors can give extra protection during commissioning and working life and also in the event of slight variations from optimum operating conditions. Inhibitors should not be used when indirect single-feed cylinders are used.

Section 3.2

Australian Standard Specifications

Australian Standard Specifications

AS 1056.1
Storage water heaters.
General requirements.

AS 1056.2
Storage water heaters.
Specific requirements for water heaters with single shells.

AS 1167.1
Welding and brazing – Filler metals – Filler metal for brazing and braze welding.

AS 1210
Pressure vessels.

AS 1345
Identification of the contents of pipes, conduits and ducts.

AS 1357.1
Valves primarily for use in heated water systems – Protection valves

AS 1357.2
Valves primarily for use in heated water systems – Control valves

AS 1432
Copper tubes for plumbing, gasfitting and drainage applications.

AS 1569
Copper and copper alloys - Seamless tubes for heat exchangers.

AS/NZS 1571
Copper-Seamless tubes for airconditioning and refrigeration

AS 1572
Copper and copper alloys - Seamless tubes for engineering purposes.

AS1628
Water supply - Copper alloy gate, globe and non-return valves.

AS 1677.1
Refrigerating systems –
Refrigerant classification

AS 1677.2
Refrigerating systems – Safety requirements for fixed applications

AS 1834.1
Materials for soldering.
Solder alloys.

AS 1910
Water supply - float control valves for the use in hot and cod water.

AS 2700
Colour Standards for general purposes.

AS/NZS 2845.1
Water supply - Backflow prevention devices. Materials, design and performance requirements.

AS 2896
Medical gas systems – Installation and testing of non-flammable medical gas pipeline systems

AS/NZS 3718
Water supply – Tap ware

AS/NZS 3350.2.73
Safety of household and similar electrical appliances – Particular requirements – Fixed immersion heaters.

AS/NZS 3350.2.74
Safety of household and similar electrical appliances – Particular requirements for portable immersion heaters

AS/NZS 3500
Plumbing and drainage

AS 3688
Water supply – Metallic fittings and end connectors

AS 3814
Industrial and commercial gas-fired appliances

AS 4041
Pressure piping.

AS 4087
Metallic flanges for waterworks purposes.

AS/NZS 4331.2
Metallic flanges.
Cast iron flanges.

AS/NZS 4331.3
Metallic flanges.
Copper alloy and composite flanges.

AS 4426
Thermal insulation of pipework, ductwork and equipment - Selection, installation and finish.

AS 5200
Technical specification for plumbing and drainage products – Procedures for certification of plumbing and drainage products

AS 5601
Gas installations

AS ISO 9000
Quality Standards and handbooks.

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Section 3.3

References & Other Information Sources

References

"Copper, Made the Right Start"
Brian Curry and UK Copper Plumbing and Heating Systems Board

"Copper Pipeline Design Manual"
MM Kembla Tube and Fittings

"Selection and Sizing of Copper Tubes for Water Piping Systems"
Barrie Smith and The Institute of Plumbing Australia

Other Sources of Information

Plumbing Services Volume I - Basic Skills Water Supply.
Volume 4 - Mechanical Services.
R.J. Puffett and LJ. Hossack.

Plumbing and Mechanical Connection Magazine
Patchell Publishing Pty. Ltd.

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Section 3.4

Practical Solutions to Water Hammer

Practical solutions to water hammer

Index

About this section

This guideline provides practical solutions including illustrations on how to prevent water hammer in new installations and control water hammer on existing installations.

Why is water hammer more noticeable today?

- Mains water pressures have increased.
- Quick closing taps and single level mixer controls are used more frequently.
- Appliances with solenoids are no longer a luxury.

1. Introduction

This guideline was developed by the Copper Development Centre with technical support from Allan Archie, Crane Copper Tube, MCK Metals Pacific, Yorkshire Fittings and Cheiftain Products Australia.

Some homes are subjected to water hammer in plumbing pipes and a great deal of damage is occurring, not only to the pipes themselves, but also to expensive appliances, tap ware and fittings.

To prevent potential damage both elements related to water hammer need to be eliminated:

- NOISE which is auditory, alerts property owners to water hammer problems. Without the noise there will be no indication of a problem until damage is caused, or worse, a home is flooded by a burst appliance hose.
- SHOCK WAVES which will impose undesirable stresses on piping and appliances.

AS/NZS 3500.1 - the joint Australian/New Zealand Standard National Plumbing and Drainage, if followed will control water hammer in both Metallic and plastic pipes.

STANDARDS AUSTRALIA has kindly given permission to include sections of the Standard in this guideline. Standard AS/NZS 3500.1 can be purchased from the STANDARDS AUSTRALIA office in your state.

If all water hammer is to be prevented, it would be advisable to install a hammer suppression device at each automatic appliance solenoid and quick closing valve. To control costs, eliminate noise and minimise the impact of shock waves, a fabricated air chamber may be installed as an alternative, as suggested on page 89.

The disadvantages of the air chamber are:

- Air chambers will progressively lose air and gradually become ineffective. When such occurs and hammer noise returns, the air will need to be replenished. This can be achieved by turning the water off at the meter and draining all piping, automatically recharging the chamber with air. If convenient, this can be performed when changing a tap washer.
- The air chamber will not permanently eliminate all shock waves but will initially limit the impact on pipe, fittings and fixtures.

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Practical solutions to water hammer

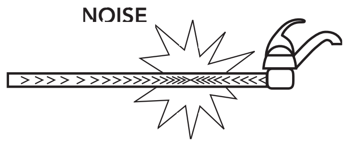
2. Facts about water hammer

- Water hammer can occur with or without the noise.
- The following will create water hammer: Quick closing valves; Solenoid valves; high pressure; Some hot water duo valves; Faulty and loose jumper valves.
- AS/NZS 3500.1, recommends the pressure should be no greater than 500 kPa at the outlet.
- Copper and other metallic piping systems tend to highlight the existence of water hammer by noise whereas plastics hide it.
- Your customers' plumbing system and appliances can be damaged by the impact of shock waves even without noise.
- The noise provides an early alert so that the problem can be rectified prior to damage occurring.
- Water hammer is avoidable regardless of the material being used.

THIS GUIDELINE PROVIDES SIMPLE STEP BY STEP PROCEDURES TO DETECT AND EFFECTIVELY CONTROL WATER HAMMER ON A PERMANENT BASIS.

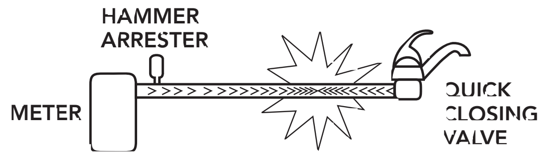
3. How water hammer is caused

The following shows how water hammer is caused and how it is rectified:



- A shock wave is generated at the face of a quick closing valve or solenoid because an incompressible column of water moving under pressure is stopped suddenly. The shock wave then ricochet's back from the face of the valve, through the stationary column of water at speed of up to 1280m/second.

Incorrect Fitment of Hammer Arrester



- The noise occurs where the shock waves rush through tubing which is not clipped appropriately resulting in banging and water noise.

Correct Fitment of Hammer Arrester

- The essence of water hammer control is to absorb the pressure spike as close to the point of impact as possible.

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Practical solutions to water hammer

4. Key steps to preventing water hammer in new installations

- Install a 500 kPa pressure limiting valve. This should be installed at the point of cold entry to the household water supply.
- Clip pipe as per AS/NZS 3500.1

  - Every 1.5m for copper (at least every 2nd stud)

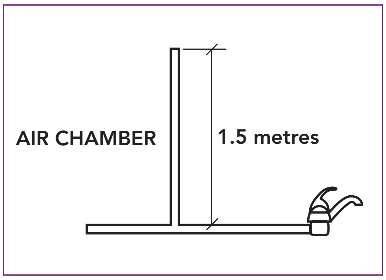
  - 0.6m to 0.7m for plastics.
- Only install a loose jumper valve prior to a lever tap if required of the contract or a special legislation, (it is not required by AS/NZS 3500.1).
- Install a ball valve at the meter if the meter incorporates a non-return valve.
- A larger size pipe will be needed to reduce the velocity to 3.0m/s if the pressure is in excess of 500 kPa.
- When penetrating a stud, ensure the silicon is evenly distributed around the pipe to prevent it banging on the stud.
- If the pipe runs along a stud add extra clips.
- Always use stand off clips. This eliminates water rush noises.
- Always install a hammer suppression device as close as possible to a quick closing tap or appliance.

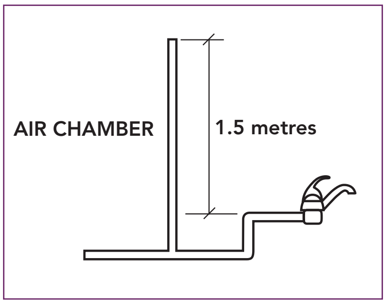
5. Steps to locate and eliminate water hammer

1. Determine whether the water hammer was introduced after the installation of a new dishwasher or washing machine. If so, this may be due to the faster closing solenoids in the new appliance. Install a hammer suppression device as close as possible to the new appliance. Immediately downstream of the laundry tap or water supply control valve supplying the machine is the preferred and most convenient location.
2. Check for faulty valves or washers. Hold the valve during water hammer to feel the vibration in the offending valve or tap. Replace the valve or install a spring loaded washer, (note, from the previous page, if a loose jumper valve is not required, remove it).
3. Install a water hammer suppression device on all new dishwashing and washing machine installations whether piping is metallic or plastic. This is the only way to prevent shock waves and protect these expensive appliances from premature mechanical damage or hose burst/flooding "accidents" over the longer term.
4. Reduce pressure to 500 kPa.
5. Check clipping on pipe. If the pipe is not clipped behind the wall a hammer suppression device will have to be installed as close as possible to the quick closing tap or valve causing the hammer.

6. How to construct air chambers

- Height of air chamber needs to be at least 1.5 metres above the hose tap.





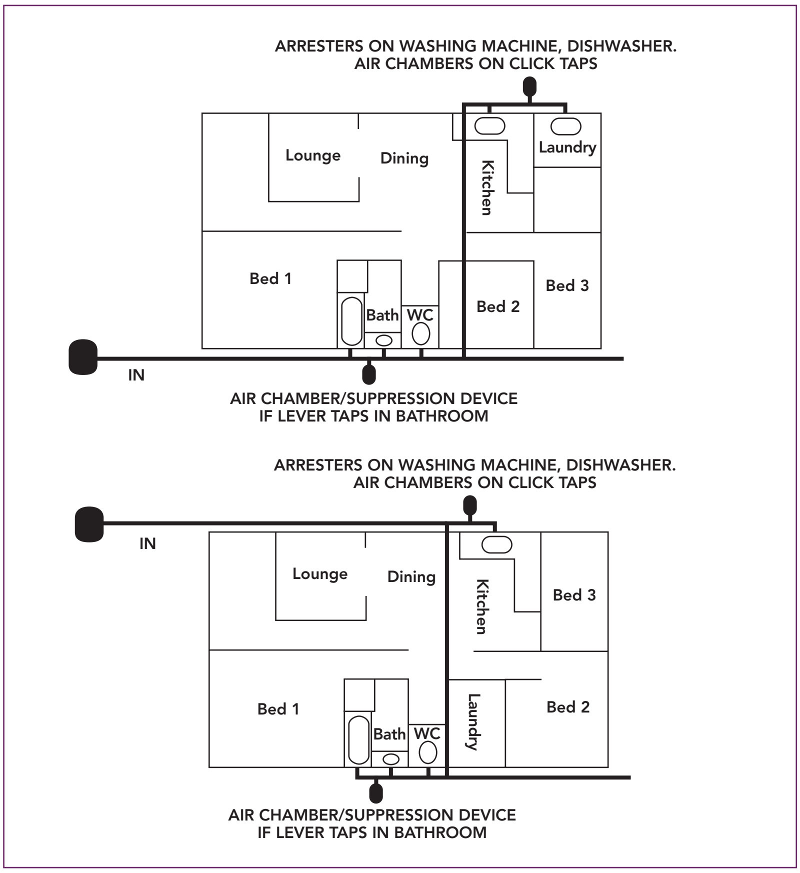
Prevent call backs

Prevent water hammer on completion of rough in by:

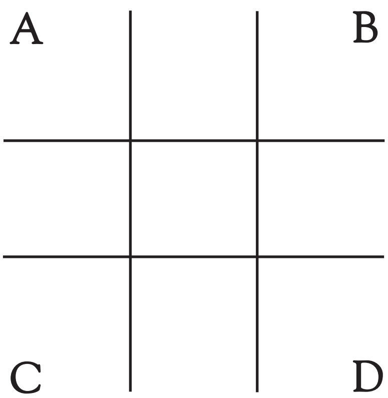
1. Checking the water pressure does not exceed 500 kPa.
2. Checking for shock waves by connecting a ball valve to the installation, preferably at the furthermost hose tap. Turn on the water and quickly shut off the ball valve. Any water hammer that exists will be heard and can be easily rectified prior to the walls being finished.

Practical solutions to water hammer

7. The following diagrams show general house layouts and the positioning of a hammer suppression device



8. Plumbing grid map to identify source of water hammer



To assist in describing the system you have installed to our technical expert on the copper help line, please draw the complete plumbing system on the grid map including the location of taps and appliances and the location of the noise.

9. Copper industry help line

If you have been unable to resolve the water hammer problem after reference to this guideline we have a service to assist by phone or fax.

By Phone

Call our technical expert, Allan Archie on 1800 HAMMER (1800 426637). Please complete the diagram opposite before calling to help identify the source of noise and problem quickly.

OR

By Fax

Fax number: 02 9331 4743.

Please fax through a diagram of the premises including pipe work, measurements and source of the noise.

We will respond to your query by return.

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