Copper Tube in Domestic Water Services

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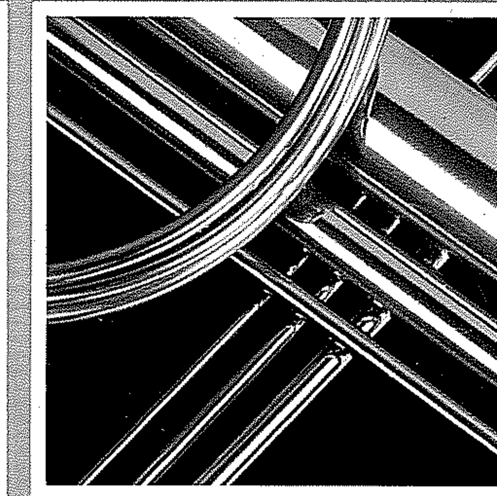

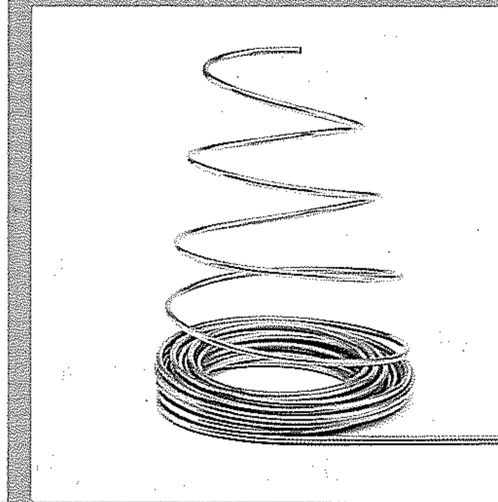

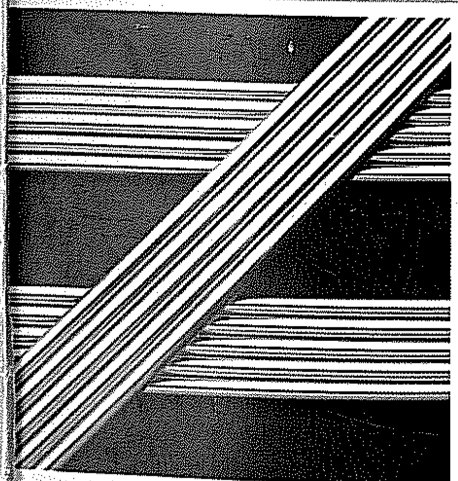

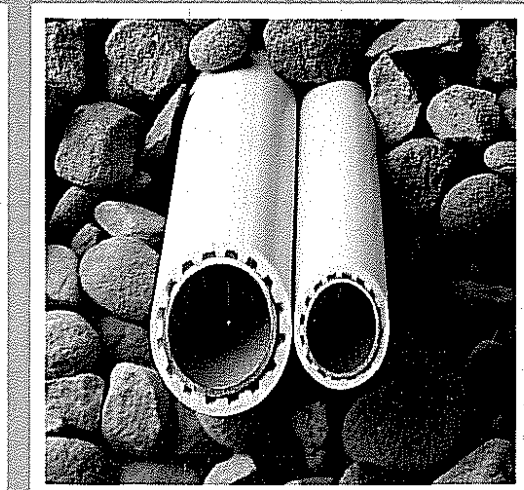

Copper Development Association

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Copper Development Association

Copper Development Association is a non-trading organisation sponsored by the copper producers and fabricators to encourage the use of copper and copper alloys and to promote their correct and efficient application. Its services, which include the provision of technical advice and information, are available to those interested in all aspects of existing and potential uses of copper. The Association also provides a link between research and the user industries and maintains close contact with other copper development organisations throughout the world.

Contents

Preface

Copper tubes for conveying water were first used about the year 2750BC. There is an example in the Berlin State Museum taken from the Temple of King Sa-Hu-Re at Abusir in Egypt. It formed part of a pipeline nearly 100m in length, made up of separate sections, each about 750mm long. The tube was folded up from thin hammered copper sheet, to a diameter of approximately 75mm and embedded in gypsum stone hewn out to a U shape.

The beginning of the Industrial Revolution saw an advance in the use of thick wall copper tube, which was jointed by means of screw threads. When the joints were being made they were sealed by the application of heat and tinman solder. During the early 1930s, with the advent of thin wall or light gauge copper tube, other methods developed; i.e. capillary and compression fittings; the cost of using copper for water services became competitive with other materials and a new era was opened to the plumber and heating engineer.

References

Throughout this publication references within the text are shown thus: *a) or *A) and are listed in References - Text at the end of the publication. Abbreviations are used as follows:

6700 - BS6700

MWB - Model Water Byelaws

BR - Building Regulations

In addition the text contains only the British Standard Specification number together with a hash (#). In each case the full title of the British Standards Specification is also given in the list of references at the end of the publication.

Introduction

This publication brings together basic information on a wide range of applications of copper tube in domestic water services. The data have been taken from a number of previous Copper Development Association and other publications and numerous references are listed. The majority of copper tubes and fittings available today have been developed over the past fifty years for use in hot and cold water services. During that period smaller diameter and thinner wall tubes have been introduced and the number of applications has increased significantly. New uses include underfloor heating, life safety sprinkler systems and solar heated domestic hot water systems. This publication does not set out to be a detailed design guide but rather to give basic information on the range of actual and potential applications for copper tube in domestic water services. A companion technical note TN39 entitled 'Copper in Domestic Heating Systems' covers the use of copper in a number of forms and products in a wide range of domestic central heating systems.

The purpose of this booklet is to assist the architect, designer and specifier as well as the operator in the understanding of the correct use of copper and copper alloys in domestic water service systems. Recent changes in the Building Regulations and the Model Water Byelaws as well as the replacement of British Standard Code of Practice CP 310 'Water Supply' by British Standards Specification BS6700 are widely referenced in this publication. In addition the introduction of unvented hot water systems and regulations concerning standards of water quality together with the incidence and dangers of Legionnaires' Disease have highlighted the potential advantages of copper in domestic water services. This has resulted in the development of new copper products including lead-free solder fittings and components for unvented domestic hot water systems.

It should be noted that corrosion problems have recently arisen in certain soft water installations in the United Kingdom and elsewhere. The cause and mechanisms are still being investigated at the time of publication of this Technical Note. Hence pending definitive results only general guidance can be given on good practices to reduce the potential incidence of the various forms of corrosion that may occur. The trouble may be due to a combination of effects, including changes in the water supply, defects in design, incorrect installation techniques and failures to observe recommended commissioning and maintenance procedures.

Advantages of Copper Tube

The properties that make copper tube the preferred material for domestic water services include the following:

- ease of installation
- ability to be easily joined and manipulated
- high strength and ductility
- ease of fabrication
- corrosion resistance
- suitability for use with potable and other waters
- potential as bactericide
- bio-fouling resistance
- availability in a range of metric sizes compatible with fittings and other system components
- guaranteed British Standard quality products

Copper Tubes

Copper tubes for domestic water services should be manufactured to BS 2871: Part 1#. This specification covers a range of sizes with appropriate tempers and wall thicknesses to meet a wide range of service requirements and conditions. Tubes to BS 2871: Part 1# are specifically designated for water, gas and sanitation applications and meet the requirements of BS 6700# *a) and the Model Water Byelaws# *b).

Information on dimensions and working pressures for tube to BS 2871: Part 1# is contained in the appendices J/1 to J/3.

It is recommended that copper tubes used should only be those approved under the 'Kitemark' scheme of the British Standards Institution. *a).

Condition

Copper tubes to BS 2871: Part 1# are supplied in the forms and conditions suitable for joining and fitting techniques as shown in Appendix J/4.

Maximum Working Pressure

The maximum working pressures at temperatures up to 110° C quoted in Appendices J/1 to J/3 have been calculated using the following formula:

$$P = 20Ft / (D - t)$$

where P = maximum working pressure (bar)
F = design stress (N/mm^2)
+ t = minimum wall thickness (mm)
+ D = maximum outside diameter (mm)
+ based on minimum and maximum tolerance as quoted in BS 2871: Part 1#.

Tubes installed underground, laid under floors or in other inaccessible places must be able to withstand twice the quoted working pressure. *c)

The values of F used in the above formula depend upon the condition of the tube and are listed below:

Condition		F (N/mm^2)
annealed	0	40.0
half hard	1/2H	59.0
hard	H	68.5

Tubes in the 1/2H and H condition locally annealed during fabrication e.g. during hot bending, silver brazing or the attachment of welded fittings, should have the working pressure calculated from the design stress F in the annealed condition. Certain large diameter and/or thick walled copper tubes may be subjected to over annealing during fabrication. This may result in the design strength being below that quoted for the annealed (0) condition. If in doubt in these circumstances the customer should seek advice from the tube manufacturer.

Design stress values (F) for copper tubes operating at temperatures in excess of 110°C up to a maximum of 200°C are given in BS 1306# and typical values for tube in the annealed (0) condition are as follows:

°C	150	175	200
N/mm^2	34	26	18

Values for intermediate temperatures may be interpolated as required.

Chemical Composition

The chemical composition of copper tubes to BS 2871: Part 1# shall comply with the requirements of BS 6017 Cu DHP designated C106 in tube form.

Note: BS 2871: Part 2 also specifies a range of copper and copper alloy tubes for use in more aggressive environments which are beyond the scope of this publication. (see CDA Technical Note TN28#)

Fittings

Various standard jointing techniques using either compression (Figs 1 & 4) or capillary (Figs 2 & 3) methods are available. *d) They employ gunmetal, brass (including dezincification resistant brass - see Appendix B) and wrought copper fittings manufactured to BS 864: Part 2# in sizes up to 67mm. Flanges and bolting to BS 4504: Part 2# are available for larger size copper tube. Copper tube may also be brazed *e) and welded *f) either directly or by means of copper or copper alloy weld 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
High Duty Fittings	- Silver Brazing Alloy to BS 1845# - End Feed - Pre-soldered
Socket Formed Joints	- Silver Brazing Alloy to BS 1845# - 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 'Kitemark'# scheme of the British Standards Institution and also listed in the UK Water Fittings Byelaws Scheme Directory#.

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 individual marking schemes for 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 BS 864: Part 2# and BS 219# are used exclusively in potable water installations. *g) The operating temperatures for capillary fittings are governed by the capabilities of the filler metal and reference should be made to the service temperatures and pressures quoted in Table A taken from BS 864: Part 2#.

Joining Dissimilar Metals *h

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. Copper and copper alloy compression fittings to BS 864: Part 3# are specified for polyethylene piping.

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.

e) Copper/lead: Copper tubing may be joined to lead piping by use of a copper or copper alloy adaptor with a mechanical joint between the adaptor and the lead pipe. The use of wiped joints is no longer permitted between the tail of the union adaptor and the lead piping.

Note: Copper pipe should not be incorporated into a lead piping system unless suitable precautions are taken to prevent corrosion. *i) & *j)

Reference should be made to the Model Water Byelaws *k) 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>lead> copper. An example is the pick up of 0.1mg/l or more of copper in water which encourages the corrosion of galvanised coatings.

Table A Maximum working temperatures and pressures for Compression and Capillary Joints (BS 864: Part 2#)

Service Temperature (°C)	Size (mm)	Hydraulic Pressure (bar)
30	6 to 54	16
	67	10
65	6 to 54	10
	67	6
110	6 to 54	6
	67	4
120	6 to 54	5 } Compression only
	67	3 } Compression only

Note: High duty fittings containing high melting point solders may operate at higher working temperatures and/or pressures. Other higher duty welded and flange fittings may also operate at higher pressures and/or temperatures. For these applications the fittings manufacturer should be consulted.

Design Considerations

Detailed layout and pipe sizing requirements are determined by the design engineer responsible for the system. *l) 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 note should ensure compliance with such statutory requirements, rules and regulations as may be applicable to the particular installation, including Building Regulations, Model Water Byelaws and British Standard Specification BS 6700#, formerly CP310.

Water Velocities *m)

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 2m/s. 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 BS 6700# *n) do not result in excessive water velocities in copper tubes. It is important to recognise that sluggish flow, at velocities below 0.5m/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 occuring 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 8m/s are required to produce cavitation in a typical elbow fitting. *o)

Note: Water flow resistance data for tubes and fittings are given in Appendix G.

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 risers.

(c) Drinking water pipework should be sized for the minimum practicable diameter but with velocities not exceeding 2m/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, eg 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.

(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.

Protection of Piping

Protection against frost damage is essential by use of adequate insulation. *p) 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 buried at least 750mm and not more than 1350mm underground where practicable. *q) This does not apply to pipes installed in the ground under permanent buildings or structures. *r)

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 750mm from the outside wall. The Model Water Byelaws illustrate examples of acceptable ways of pipes entering *s) and installed within buildings. *t)

3) The rising main to the storage cistern should be carried up on a warm inner wall.

4) If outside pipes have to be installed above ground they should be adequately insulated and draw-off points provided to drain down the exposed pipes in frosty weather. The draw off point should be installed above ground to prevent contamination. *u) 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.

Design Considerations (cont.)

Underground Services

When copper pipework is installed underground it shall be to BS 2871: Part 1 Table Y# *b) 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 wrapping. Underground services shall not be laid in contact with contaminating materials such as foul soil, or passing through any sewer, drain or cesspool. *v) In some areas the Water Authorities may specify that the copper tube is externally coated with a works applied polyethylene coating. *b) In addition all copper alloy fittings installed underground shall be dezincification resistant, to material specification BS 2872# or BS 2874#, designation CZ132, or dezincification immune, such as gunmetal. Compression fittings shall be of the manipulative type to BS 864: Part 2# Type B. *b) Precautions should be taken to minimize 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. *w) Pipes should be firmly anchored at bends to withstand thrust loads and should be capable of meeting a test pressure of twice the maximum working pressure. *c)

Expansion Joints

The coefficient of thermal expansion of copper is 16.8×10^{-6}/°C, hence a 1 metre length of copper tube becomes (1+0.0000168T) metre when heated by T°C. For example, an increase in temperature of 60°C will increase the length by one mm for every metre of tube. In the case 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 automatically. 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 5, 6 and 7.

Expansion bellows and expansion loops may be accepted as meeting the requirements of the Model Water Byelaws with regard to the expansion of pipes carrying hot water. *x) 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. *y)

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 Fig 8 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 B.

Table B

Spacings for Copper Tube Supports

Size of Pipe (O.D.)	Intervals for Vertical Runs	Intervals for Horizontal Runs
mm	m	m
15.0	1.8	1.2
22.0	2.4	1.8
28.0	2.4	1.8
35.0	3.0	2.4
42.0	3.0	2.4
54.0	3.0	2.7
67.0	3.6	3.0
76.1	3.6	3.0
108.0	3.6	3.0
133.0	3.6	3.0
159.0	4.2	3.6

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 9 and 10 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 (Fig 9) then the length of pipework each side of the joint, with a temperature difference of 60°C (140°F) can be 12.5m (1mm 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. *z)

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. *A) Pipes should be laid to avoid obstructions and across solid foundations to prevent local undulations causing airlocks. *B) 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. *A)

Design Considerations (cont.)

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 coke breeze. 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 the Model Water Byelaws preclude 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. *C) Allowable methods of installation are also shown in diagrammatic form in the Model Water Byelaws. *D)

Annealed copper in domestic hot water system applications is strong enough to withstand the compressive stresses set up since the coefficient of expansion of concrete is less than that of copper. That applies when the temperature of the water circulating in the embedded pipes does not exceed 60°C (140°F) provided that the straight line pipe runs between embedded fixing points do not exceed about 15m in length. In such cases no problems arise if the copper pipe is laid on the concrete base and covered with a sand and cement screed provided that access is provided as required by the Model Water Byelaws. *C), D)

Pipes conveying water at temperatures above 60°C (140°F), particularly if there are any branch connections, must be given facilities within the solid structure for thermal movement. Small diameter pipes (6 to 10mm) 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 (12 to 28mm) 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 repellant 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 35mm 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 Model Water Byelaws for excluded installations. *C)

Thermal Insulation

Consideration should be given to conserving energy by use of suitable thermal insulation for pipes conveying hot water. A range of factory insulated copper pipes are available from the major manufacturers. 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. *E) 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.

Frost protection can be achieved by means of trace heating cables attached to insulated pipework in exposed locations. *F) 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. *G) 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 to BS 5422# and 3958# are contained in the Model Water Byelaws# *H) and BS 6700# *I). It should be appreciated that smaller diameter pipes require proportionately greater thicknesses of insulation. (see comment Model Water Byelaw 49) 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. *J)

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 air layer to give improved insulation performance. The colour coding of pipework should be blue for water and yellow for gas. *K) It should be noted that white insulated copper tube is generally supplied for exposed central heating system pipework.

Jointing Methods

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:

Compression Joints

Type 'A' 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 half-hard and hard temper tube supplied in straight lengths and annealed tube up to and including 12mm OD, but should not be used with annealed tube above 12mm OD unless a suitable internal support is provided.

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

Type 'B' manipulative compression fittings 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 squared. 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 Type 'A' 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 make the joint. This type of fitting, namely to BS 864#: Part 2, Type 'B' shall be used for installations underground and shall be made from dezincification resistant or immune materials. *b) & *L)

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 BS 864: Part 2 and BS 219#. *M) 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 BS 1845# should be used. Brazing techniques and the design of brazed joints are detailed in BS 1723# and bronze welding in BS 1724#.

Copper tubes may be directly joined by the use of zinc-free 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 oxy-propane blowtorch. Copper alloy tubes and fittings require the use of a suitable flux and a compatible filler alloy. Copper tubes may also be joined directly by welding using a compatible welding rod or alternatively a weld type fitting may be used to join the tubes. In these circumstances, due to the amount of heat and the elevated temperatures introduced into the tube, the maximum working pressures must be calculated using annealed material design stresses. Note: These alternative joining techniques are not listed in the Model Water Byelaws but are detailed in BS 6700. *N)

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 'sand paper' or steel wool
4. Apply flux to tube end only
5. Insert tube fully up to stop and wipe off excess flux
6. Apply heat
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. If the soldering and brazing of joints is not performed according to accepted practice corrosion can result due to flux residues. Pipework should be flushed out immediately after soldering is completed. If excessive quantities of adherant corrosive flux residues remain in the pipework problems with internal corrosion or contamination of the water supply may occur.

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. Sometimes entrained air bubbles in the water from a leaking valve or an incorrectly made joint in an area of negative pressure, e.g. upstream of a pump or downstream of a partially opened valve, may also give rise to this form of corrosion.

General Procedures for all Fittings

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.

Jointing Methods (cont.)

Cutting to length

Table W tube in 6, 8 and 10mm OD sizes should be cut with a junior hacksaw. Rotary tube cutters are commonly used for cutting other copper tube up to 54mm size. Larger size cutters for tube up to 159mm 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 inch minimizes 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.

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, millbastard 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.

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.

Detailed Procedures for Capillary Fittings

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 the end of the socket of the fitting will be situated. Suitable cleaning materials include fine emery cloth (00), steel wool, and non woven nylon pads impregnated with silicon carbide or aluminium oxide abrasives. For the manual cleaning of sockets, particularly those of 28mm and smaller size, special wire brushes are more practicable 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.

Fluxing

The cleaned surfaces should be fluxed as soon as possible. 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.

Assembling

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

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 without disturbance.

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 and pre-tinning is not necessary. 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.

Adhesives

The Model Water Bylaws preclude the use of adhesives for the jointing of metal pipes when installed in inaccessible situations or where access is difficult. *O) In the case of copper pipes and fittings adhesive jointing is not recommended under any circumstances within a plumbing or heating system. Currently there is insufficient long-term evidence to guarantee the integrity of adhesive joints when compared with correctly made capillary or compression joints.

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. Light gauge copper tubes to BS: 2871 Part 1# Table X and Y may be supplied in 'half hard' temper in straight lengths, which gives them a desirable degree of rigidity and strength, and minimises damage in transit. Tubes to BS 2871: Part 1# Table W are supplied in the annealed condition as are BS 2871: Part 1# Table Y tubes as an alternative to the half hard condition. Tubes to both tables are supplied in long coils in the annealed condition. BS 2871: Part 1# Table Z tube is only supplied in the hard temper in straight lengths and is not suitable for bending.

Bending Light Gauge Copper Tubes

There is little difficulty in machine bending light gauge tubes as the necessary skills can be developed with practice. The bending of light gauge 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.

Steel Springs

Flexible spiral springs may be used as a loading to support the tube walls while the bend is made. Springs to BS5431 are available for bending tubes in all standard sizes from 10 to 22mm 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 22mm.

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. 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.

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 42mm 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 6, 8 and 10mm 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 light gauge tube, loaded or unloaded, according to wall thickness or the sharpness of the bend required.

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.

Commissioning

All systems should be throughly 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 BS 6700. *P) Ideally the systems should where appropriate, be correctly sterilised to BS 6700. *Q) 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 Appendix C for specific procedures associated with the prevention of Legionnaires' Disease.) In practice, however, long periods may elapse between the installation and bringing into use, espcially 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. Possibilities of copper pick-up by the water, as a result of failure to build up protective films in the pipes during the period prior to regular use, are generally only significant in a few areas with waters of particular characteristics. In case of doubt, it is advisable to consult the local Water Authority who should be able to indicate whether problems of this nature have been encountered in the area.

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. *R) 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. *S) In these circumstances it is important to ensure that the dead leg is flushed out thoroughly and treated as a precommissioned pipe.

Appendix A
Pitting Corrosion of Copper Tubes

It should be emphasised that the number of copper tubes affected by pitting corrosion is an extremely small percentage of the total amount manufactured and installed in the United Kingdom. The majority of copper tubes give satisfactory service over many years and this is reflected in the 25 year warranty given by British Copper Tube manufacturers in addition to the safeguards of the British Standard Specification BS2871# to which they are manufactured and the 'Kitemark' scheme under which they are produced, as well as the BS5750# by which a company's quality assurance procedures are assessed. Two forms of corrosion to which copper tubes are susceptible under specific circumstances are recognised and described in the literature.

"Type 1" This form of pitting corrosion can cause premature failure in copper cold water pipes carrying hard or moderately hard deep well waters. Two factors are involved in this form of attack. Firstly the water must be capable of supporting it; organic matter found in surface derived water provides inhibition against attack, and only deep well waters can support it. Secondly, attack occurs only when a thin film of carbon is formed within the bore of the tube during the manufacturing process. The cleaning processes now used by major manufacturers ensure that copper tubes meet the requirements of BS2871# concerning the absence of deleterious films in the bore. Since 100% non-destructive testing of copper tube is not practicable very occasional faulty lengths may occur. The requirements of the BS2871# and the manufacturers' warranties provide adequate safeguards against failure due to 'Type 1' pitting corrosion. Excessive use of flux resulting in flux runs within the bore of the tube may exacerbate this form of corrosion and should be avoided. Hence the need to limit the flux to the outside of the tube when making a joint.

"Type 2" This type of pitting corrosion is very uncommon in the United Kingdom; it rarely causes failure in less than about ten years. Carbon films are not a factor in this type of attack. It occurs in hot water pipes in some soft water areas specifically if the operating temperature is above 60°C. This should be borne in mind when specifying higher temperatures in an attempt to eliminate problems associated with Legionnaires' Disease. (See also section on Commissioning and Appendix C) One form of this pitting corrosion is associated with the presence of manganese in some soft waters.

This information has been taken from document MP568# of the BNF Metals Technology Centre from whom more detailed information on the form and appearance of the corrosion products may be obtained as well as advice on specific problems.

Discolouration of Water Supplies

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

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 main to ensure that there is adequate flow to avoid a build up of a sedimentary matter. Otherwise sediment may enter the building system and initiate discolouration 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 a 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 discolouration have developed.

Condition of Water

It is advisable to check the pH of the water supply entering the building on a regular basis. One of the most significant factors responsible for the internal deterioration of water mains and supply pipes is low pH of the water. The ideal pH level for water supplies is close to 8. If a pH of 6-6.5 or less is recorded, then the water should be treated to increase the value to an acceptable level. Low pH water may affect the mains and service pipes in the following ways:

(a) If the pH of water in concrete lined mains is low, (in some areas it may be as low as 5) there is every likelihood that the linings will deteriorate leading to deposits and possible corrosion, in the copper service pipe system.

(b) A low pH increases the cupro-solvency of the water. If this is combined with excessive water velocities (greater than 2m/s, either average or localised due to turbulence) there can be corrosion of the impingement type, in which the corrosion pits are scoured out and premature failure may result.

(c) A low pH increases the rate of dezincification of duplex brass fittings, possibly leading to premature leakage.

It should be pointed out that there are few public water supplies in this country with which copper cannot be used entirely satisfactorily, since such supplies are invariably treated to remove any acidity before being delivered to the mains. There are, however, some private water supplies derived from wells, boreholes and streams which are excessively corrosive towards most metals. In such conditions, copper is likely to be the best metal to employ.

Appendix A (cont.)

Condition of Water (cont.)

Untreated corrosive waters when carried in copper pipes may have a sufficiently solvent action on copper to produce a green colouration in combination with soaps. This colouration appears in the form of green stains upon sanitary fittings, or on cloths or sponges etc used with soapy water. While these stains may be inconvenient, they are not generally considered harmful. Green staining is more likely to occur with hot water than with cold, because the heating of an acid water increases its solvent action. Green stains on sanitary fittings can be removed by washing with a dilute solution (5 percent by volume) of hydrochloric acid, but care should be taken to rinse the article afterwards with a dilute soda solution and clean water.

Treatment of Acid Waters

In cases of persistant green staining an examination of the water is desirable to ascertain the most suitable treatment to correct the acidity, which may be due to organic acids, such as those found in waters from peaty catchment areas, or to the presence of free carbonic acid. Acidity of both kinds may be neutralised by dosing with an alkali such as lime, a treatment which is widely adopted in both public and private water supplies. It is important that lime dosing should be accurately controlled, particularly when the acid content varies from time to time, due for instance, to the varying amount of rainfall in peaty areas when the water collected in reservoirs tends to become increasingly acid during wet periods. In such cases lime dosing must be varied so that the acidity is neutralised sufficiently without adding excess lime liable to cause unnecessary scale in hot water pipes. Dosing with soda ash, which does not increase the hardness of the water, is also sometimes used. Alternative methods are to filter the water through coarsely ground limestone, magnesite, or chalk.

If the acidity of a water is due only to the presence of free carbonic acid it may be treated by any of the methods already described, alternatively up to 90 percent of the free CO may be removed by aeration. Aeration plants are obtainable in sizes suitable for small country house supplies from wells or for much larger water supplies, but they cannot be arranged to work under pressure. In cases where it is desirable to remove CO from water supplied from a main, it is sometimes preferable to employ a magnesite filter which can work under pressure and which takes up less space than the aeration apparatus.

The majority of waters sufficiently acid to attack copper appreciably are very soft so that the addition of some hardness by lime dosing or filtration through limestone or magnesite may be desirable. It should not be supposed, however, that hardness is necessarily an indication of freedom from acidity, because occasionally a hard water is found which is definitely plumbo-solvent and which may also have a solvent action on copper. Such waters usually have a hardness principally of the permanent type, which does not give protection to the inside of pipes by the formation of scale, and derive their acidity from free carbonic acid.

Appendix B
Dezincification Resistant Brass

For fittings such as joints, bends, stop-cocks and taps normal, duplex brass gives excellent service in contact with most UK potable waters. However in some areas of the country the presence of otherwise harmless constituents in the potable water makes it aggressive to duplex brass producing a form of attack known as dezincification. In such waters zinc can be leached from duplex brass leaving a mass of porous copper. Although the occurence of dezincification is small, local water authorities in sensitive areas recommend the use of materials resistant or immune to this form of corrosion. In 1980 British Standard Specifications were issued for a new type of brass which combined the economy and convenience of duplex brass with the corrosion resistance typical of more expensive materials. This new brass meets the demanding criteria set by the consumer authorities and has received full approval for use in contact with aggressive potable water and also for use underground where contaminated soil waters may have to be considered. Dezincification resistant brass is specified as forging stock and forgings in BS 2872# and as rods and sections in BS 2874# with the material designation CZ132. Fittings manufactured from material meeting the dezincification test and designated CZ132 are marked with the CR mark. The Model Water Byelaws *b) require that dezincification resistant or immune fittings, such as gunmetal, should be used for underground installations. In addition only fittings carrying the mark and listed in the Water Fittings and Materials Directory# are accepted as meeting this byelaw with regard to dezincification resistance or immunity.

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 as described in BNF MP 491# and known as meringue dezincification. Since water authorities may now obtain their supplies from a variety of sources and vary the areas served, it is not possible to give an accurate geographical indication of susceptible areas. The possibility that particular water supplies may cause dezincification should be checked with the local water authority operations controller before installing duplex brass fittings. In areas where the water supply is aggressive, dezincification can 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. (See also TN39 'Copper in Domestic Heating Systems'#)

Further details are contained in CDA Information Sheet 36 'Dezincification Resistant Brass' available free upon request from Copper Development Association.#

Appendix C
Calculating Tube Thickness

Once the design stress of the copper has been determined, and if the maximum working pressure and the specified external diameter of the tube is known, then the thickness required to withstand the internal pressure can be determined by the following formula:

$$t = pD/(2f+p)$$

where t = thickness (mm)
p = pressure (N/mm^2)
f = circumferential tensile stress (N/mm^2)
= design stress
D = outside diameter (mm)

The above formula applies only to thin wall tubes where the ratio k of external diameter to internal diameter is less than 1.1. The majority of tubes for building service applications meet this condition although an additional thickness allowance may be required for bending and in corrosive environments.

A modified and reorganised form of the above formula has been used to determine the maximum working pressures in the proposed revision of BS 2871:Parts 1 and 2 as follows:

$$P = 20Ft/(D-t)$$

where P = pressure (bar)

and using the following values for the design stresses for temperatures up to 110°C.

Condition	F (N/mm^2)
H	68.5
1/2H	59.0
0	40.0

Note: The design stresses for annealed copper tube at higher temperatures are contained in BS 1306# (see also Copper Tubes - maximum working pressure)

Appendix D
Copper and Legionnaires' Disease

Since the recent outbreaks of Legionnaires' Disease a number of measures have been introduced or recommended to prevent its occurence 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 based on a limited survey carried out by the PHLS to suggest that substantially 'all-copper' systems tend to be free of Legionella pneumophila. In addition research being carried out by INCRA# 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 recommendation to store water centrally at 60°C and to distribute water at temperatures no less than 50°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 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. L.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 cistern which complies in every respect with the water undertaking's byelaws. Oversized and unprotected cisterns 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 Water Supply Byelaws Guide (1986) and BS 6700. Individual water undertakings can advise on any relevant local water quality characteristics.

Within the National Health Service the method of sterilisation is recommended in HTM27#, whilst the Health and Safety Executive have issued Guidance Note EH 48# on the precautionary measures to be taken to combat Legionnaires' Disease in water supply and heating systems. The Chartered Institution of Building Services Engineers has also produced a Technical Memorandum TM13# 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.

Appendix E
Vented and Unvented Domestic Hot Water Systems

The 1986 issue of the Model Water Byelaws recognises the unvented hot water system by allowing the accommodation of expansion water in both cistern fed systems and systems connected directly to a supply pipe. *T) This is achieved by either an expansion vessel or within the pipework of the system itself. The preferred method is by means of an expansion vessel which accommodates the increase in volume due to thermal expansion without overflowing or creating undue pressure in the system.

The system with an expansion vessel must contain a check valve to prevent backflow of hot water into the supply pipe. *U) Expansion within an enlarged secondary system pipe is not allowed if any form of check valve is installed upstream to prevent backflow into the supply pipe. The enlarged pipe is to accommodate the expansion of heated water and at the same time provide sufficient cold water to be displaced back into the supply pipe. *U)

In conventional vented systems the vent pipe from the secondary system shall not vent into the combined feed and expansion cistern connected to the primary circuit. *V) Irrespective of the type of system copper tube is suitable for use throughout the hot water supply and distribution systems. The maximum working pressure within a sealed primary circuit is 3 bar, whilst in an unvented hot water storage vessel or secondary circuit it shall not exceed 6 bar. *X) The highest water temperature shall not exceed 100°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. *W) All copper tube listed in the proposed revision of BS 2871: Part 1# is capable of withstanding working pressures in excess of 6 bar at temperatures up to 110°C.

Pipe Sizing

Detailed methods of pipe sizing taking into account the recommended hot and cold water flow rates are contained within the Code of Practice for domestic water systems and hence they are not repeated in this Technical Note. *1)

However there are a number of minimum tube sizes required for specific pipe runs within the heating systems and these are listed below quoting the relevant outside diameter (O.D.) of the copper tube. The tube sizes quoted below are based on BS 2871: Part 1# Table Y which has the greatest wall thickness and hence the smallest nominal bore.

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 BS 6700 requirements.*I)

Open Vent Pipe

An open vent pipe should be fitted to every vented primary and secondary circuit and water heater systems. The vent pipe should not be less than 22mm O.D. The length of any vent pipe should be determined in accordance with the requirements of BS 6700#. *Y) 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.

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 BS 1566: Part 1#. 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.

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 28mm O.D. (or 22mm O.D. for small solid fuel back boilers.)

Indirect System

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

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 15mm O.D.

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 0.35 bar in excess of the pressure relief valve setting. All copper tube to BS 2871 Part 1# is capable of meeting this requirement up to a pressure relief valve setting of 10 bar.

Secondary Distribution System

BS 6700# tables the maximum lengths of uninsulated distribution pipes related to the bore size of the pipe. The equivalent copper tube sizes and lengths are as follows:

Largest O.D. along length of Distributing Pipe (mm)	Maximum length (m)
<= 15	20
>15 <22	12
>22 <28	8
>28	3

Appendix E (cont.)

Minimum Distribution Pipe Sizes

Outlet Fittings	Minimum Diameter of Tube (O.D.) mm
WC valve	15
Wash basin tap	15
Spray tap or mixer	10
Bath tap	22
Sink tap	15*
Urinal cistern	15
Shower head	15

* 22mm if same storey as feed cistern

Details of specific vented and unvented systems are beyond the scope of this Technical Note and reference should be made to the companion volume Technical Note TN39 'Copper in Domestic Heating Systems'#. However it should be appreciated that in order to meet statutory regulations unvented systems are required to have a number of protective devices to prevent explosion, including temperature and pressure relief valves. These protective devices should normally be factory installed. *Z) In the event of the operation of a relief valve the discharge shall be via an air break to a tundish. Copper is a suitable material for the discharge pipe from the temperature relief valve and shall be not less than the size of the valve outlet in diameter. Similarly vent pipework shall be sized to carry away the maximum energy output from the heater, hence the minimum outside diameter of 22mm.

The introduction of unvented systems provides new opportunities for copper as a piping material able to withstand the enhanced pressures and temperatures. At the same time it has maintained the reputation gained over many years for reliable, long term trouble free service in hot and cold water service systems.

See figures 11-14 for layouts of direct and indirect vented and unvented systems.

Appendix F
Prefabricated Copper Pipework

There are three situations where prefabrication can be applied with advantage. In the domestic field, identical pipework units can be developed for installation in a large number of houses, which need not themselves be identical. The second case is in large multi-occupational buildings such as hospitals, office blocks and high rise domestic accommodation, where a large number of units needed make it economical to design and prefabricate a special unit for that particular building. A third, rather different case, is the unusual building which poses pipework problems which can be most economically solved by one off prefabrications produced in the ideal conditions of a workshop.

Benefits

In every case the fact that the bending, brazing, welding, branch forming and assembly are done in a workshop environment instead of under the varied and often difficult conditions encountered on site, represents one of the major benefits of prefabrication. Local authorities and private developers alike are more than ever anxious to cut down pipework failures due both to difficult on site working conditions and to the shortage of skilled labour. Benefits for the designer include the opportunity to take a second look at the design both to improve the functional design and the economics of fabrication. The availability of fittings need not be an overriding consideration since bends can be pulled and branches inserted at any angle. For the contractor, the advantages of prefabrication include the virtual absence of scrap and the near elimination of pilfering, due to the problems of disposing of an identifiable complete unit. The difficulties of making accurate cost comparisons preclude the presentation of precise figures, but it has been suggested that savings of up to 40% can be obtained on installed costs by utilising prefabrication rather than on site methods. Having opted for prefabrication copper emerges as the preferred material, both because of its well known inherent properties such as corrosion resistance and for its ease of bending and fabrication which can be exploited to the full in the workshop environment.

Specialist Equipment

Considerable investment is necessary to produce pipework of the quality and in the quantities required to optimise the benefits of prefabrication. The equipment required includes machines capable of pulling thin wall copper tubes to tight radii and socketing, cutting, reaming and deburring machinery. In addition there is a need for annealing facilities, gas/air jointing equipment and adequate test facilities for quality control and to replace time consuming on-site testing. Building services engineers need to involve other specialists-consultants, architects, contractors and sub-contractors - in all stages of building design and construction. It is particularly necessary to include that specialist prefabricator as a member of this team. It is important to recognise that a prefabricated services system should be designed for the building and not vice versa. The flexibility of copper is such that, with good design practice, it can form the basis of a prefabricated unit suitable for any type of building service application. Although the need for detailed planning and collaboration brings a new dimension to the building services contract, the benefits are considerable, as recent examples have shown. A notable instance is the National Westminster Bank Tower, London, where the copper pipework for hot and cold water, soil and waste services was supplied in prefabricated units. The 259 units contain 2173 metres of copper tube, ranging in diameter from 35mm to 108mm, requiring 1810 machine bends and 1444 branch weld joints. Each of the 42 floors has three toilet ranges, three basin ranges and one urinal range. After fabrication and testing under factory conditions, the units were transferred to a holding warehouse for subsequent delivery to the site in bulk. It should be noted that the original plan to fit out a complete floor in two weeks was later reduced to a one week schedule.

Wider Applications

Although the most obvious examples of prefabricated services may appear to be found in big projects, it is capable of far wider applications. In both low and high rise housing prefabrication has advanced in step with the growth of industrialised building, but the trend now is to develop a complete bathroom/plumbing unit which, with equally easily produced variants, can meet the requirements of a number of different house designs. Prefabrication of this type need not be restricted to the new housing market where its flexibility makes it applicable both for the local authority and private developer sectors. It can be applied in conversion and modernisation work, either for upgrading an existing bathroom or where a small room is being converted to a bathroom/toilet.

Appendix G
Water Flow Resistance

Water flow resistance through compression and capillary fittings used with copper tube to BS 2871: Part 1: Table X

EQUIVALENT LENGTHS IN METRES

Nominal size (mm)	Temp of water (°C)	Tee (compression or capillary)			Reducing tee (compression or capillary)		Pitcher tee (compression)			Pitcher tee (capillary)			Elbow (compression)	Elbow (capillary)
	15·5	0·010	0·16	0·14	0·18	0·11	0·010	0·10	0·082	0·013	0·11	0·11	0·12	0·08
6	65	0·014	0·20	0·17	0·23	0·14	0·015	0·12	0·11	0·017	0·14	0·14	0·16	0·10
	115	0·016	0·21	0·19	0·25	0·15	0·017	0·13	0·12	0·019	0·16	0·16	0·18	0·11
	15·5	0·017	0·25	0·21	0·27	0·17	0·019	0·15	0·13	0·021	0·18	0·18	0·20	0·13
8	65	0·021	0·31	0·27	0·35	0·22	0·024	0·19	0·17	0·026	0·22	0·22	0·24	0·16
	115	0·024	0·33	0·29	0·38	0·24	0·026	0·20	0·19	0·030	0·24	0·24	0·27	0·17
	15·5	0·023	0·34	0·29	0·36	0·23	0·026	0·21	0·18	0·029	0·24	0·24	0·27	0·18
10	65	0·030	0·42	0·37	0·45	0·30	0·032	0·26	0·24	0·036	0·29	0·29	0·33	0·21
	115	0·032	0·46	0·41	0·50	0·33	0·037	0·28	0·27	0·041	0·33	0·33	0·37	0·24
	15·5	0·030	0·44	0·37	0·48	0·30	0·034	0·27	0·24	0·037	0·31	0·31	0·35	0·23
12	65	0·039	0·55	0·49	0·59	0·39	0·042	0·32	0·31	0·046	0·38	0·38	0·42	0·28
	115	0·041	0·59	0·52	0·65	0·42	0·047	0·36	0·35	0·053	0·41	0·41	0·48	0·30
	15·5	0·043	0·59	0·53	0·65	0·43	0·046	0·39	0·33	0·049	0·43	0·39	0·45	0·31
15	65	0·050	0·68	0·62	0·75	0·50	0·056	0·43	0·41	0·059	0·50	0·47	0·56	0·37
	115	0·054	0·78	0·68	0·85	0·56	0·062	0·47	0·47	0·067	0·54	0·53	0·63	0·40
	15·5	0·052	0·74	0·64	0·80	0·54	0·057	0·46	0·44	0·064	0·52	0·49	0·59	0·39
18	65	0·063	0·89	0·77	0·97	0·65	0·073	0·55	0·53	0·078	0·60	0·58	0·70	0·46
	115	0·067	0·95	0·84	1·1	0·70	0·076	0·58	0·58	0·084	0·63	0·61	0·76	0·49
	15·5	0·068	1·0	0·83	1·0	0·69	0·071	0·59	0·57	0·082	0·64	0·63	0·74	0·49
22	65	0·085	1·1	1·0	1·2	0·84	0·090	0·71	0·69	0·10	0·76	0·75	0·90	0·60
	115	0·089	1·3	1·1	1·5	0·94	0·10	0·78	0·79	0·11	0·84	0·83	1·0	0·65
	15·5	0·10	1·4	1·2	1·5	0·97	0·10	0·81	0·81	0·11	0·87	0·87	1·0	0·68
28	65	0·12	1·6	1·4	1·7	1·2	0·12	0·98	0·98	0·14	1·0	1·0	1·2	0·83
	115	0·13	1·7	1·5	2·1	1·3	0·13	1·1	1·1	0·16	1·1	1·1	1·4	0·89
	15·5	0·13	1·8	1·5	1·9	1·3	0·13	1·0	1·1	0·16	1·0	1·1	1·3	0·91
35	65	0·15	2·0	1·7	2·2	1·5	0·15	1·2	1·2	0·17	1·2	1·3	1·5	1·0
	115	0·16	2·3	2·0	2·5	1·7	0·17	1·4	1·4	0·20	1·3	1·4	1·7	1·2
	15·5	0·16	2·3	1·9	2·4	1·6	0·16	1·2	1·4	0·20	1·1	1·4	1·5	1·1
42	65	0·18	2·6	2·2	2·8	1·9	0·21	1·4	1·6	0·22	1·3	1·7	1·8	1·4
	115	0·20	2·9	2·5	3·2	2·1	0·22	1·7	1·8	0·25	1·5	1·9	2·0	1·5
	15·5	0·22	3·1	2·7	3·4	2·3	0·26	1·8	2·1	0·28	1·3	2·1	2·1	1·7
54	65	0·24	3·6	3·2	3·9	2·6	0·30	2·0	2·4	0·30	1·5	2·4	2·4	1·9
	115	0·26	4·0	3·4	4·3	2·8	0·32	2·2	2·5	0·33	1·5	2·5	2·6	2·0
	15·5	0·35	4·7	4·1	5·1	3·4	0·35	2·5	3·0	0·44	2·0	3·0	2·9	2·4
76·1	65	0·40	5·6	4·8	6·0	4·0	0·40	2·9	3·6	0·49	2·4	3·6	3·4	2·8
	115	0·49	6·0	5·2	6·6	4·3	0·42	3·1	3·9	0·49	2·9	3·9	3·8	3·0
	15·5	0·52	7·4	6·5	7·9	5·3	0·52	3·7	4·8	0·61	2·9	4·8	4·2	3·7
108	65	0·61	8·5	7·3	9·1	6·1	0·61	4·3	5·5	0·73	3·6	5·5	4·9	4·3
	115	0·61	9·4	7·9	10	6·5	0·67	4·6	6·0	0·80	3·7	6·0	5·2	4·7
	15·5	0·64	9·2	7·8	9·7	6·5	0·65	4·4	5·8	0·78	3·9	5·8	4·9	4·6
133	65	0·77	11	9·4	12	7·8	0·77	5·3	7·1	0·95	4·7	7·1	5·8	5·5
	115	0·78	12	10	13	8·4	0·84	5·7	7·6	1·0	4·9	7·6	6·3	6·0
	15·5	0·83	12	10	13	8·4	0·80	5·6	7·6	1·0	5·0	7·6	5·9	5·9
159	65	0·97	14	12	14	9·6	0·97	6·3	8·6	1·2	5·8	8·6	6·7	6·7
	115	0·98	15	12	16	10	1·0	6·7	9·3	1·2	6·1	9·2	7·2	7·2

EQUIVALENT LENGTHS IN METRES

Twin elbow (compression)		Twin elbow (capillary)		Bend (compression or capillary)	Return bend (compression)		Return bend (capillary)	Reducer (compression or capillary) D1/D2 = 2	Reducer D1/D2 = 3	Angle valve	Gate valve	Stop-cock	Temp of water (°C)	Nominal size (mm)
0·063	0·068	0·10	0·092	0·061	0·075	0·17	0·075	0·035	0·034	0·54	0·051	1·0	15·5	
0·078	0·085	0·12	0·12	0·078	0·096	0·21	0·096	0·046	0·043	0·68	0·066	1·3	65	6
0·083	0·091	0·14	0·13	0·085	0·11	0·23	0·11	0·049	0·047	0·72	0·074	1·4	115	
0·10	0·12	0·15	0·15	0·095	0·12	0·27	0·12	0·054	0·052	0·84	0·084	1·6	15·5	
0·12	0·13	0·19	0·18	0·12	0·15	0·33	0·15	0·069	0·064	1·0	0·11	2·1	65	8
0·13	0·14	0·21	0·20	0·13	0·16	0·36	0·16	0·072	0·069	1·1	0·12	2·2	115	
0·13	0·14	0·20	0·20	0·13	0·16	0·37	0·16	0·072	0·069	1·1	0·12	2·2	15·5	
0·16	0·18	0·25	0·25	0·16	0·20	0·45	0·20	0·091	0·083	1·4	0·15	2·7	65	10
0·18	0·20	0·28	0·28	0·17	0·22	0·50	0·22	0·096	0·091	1·5	0·17	2·9	115	
0·17	0·19	0·26	0·25	0·16	0·21	0·47	0·21	0·092	0·085	1·5	0·16	2·8	15·5	
0·21	0·23	0·33	0·31	0·20	0·25	0·57	0·25	0·11	0·10	1·8	0·20	3·6	65	12
0·22	0·25	0·36	0·35	0·22	0·28	0·65	0·28	0·12	0·11	1·9	0·22	3·8	115	
0·24	0·27	0·37	0·33	0·23	0·28	0·65	0·28	0·11	0·12	2·0	0·22	3·7	15·5	
0·28	0·31	0·44	0·41	0·26	0·35	0·75	0·35	0·12	0·14	2·3	0·26	4·6	65	15
0·30	0·33	0·47	0·45	0·29	0·37	0·85	0·37	0·13	0·15	2·6	0·28	5·0	115	
0·28	0·31	0·44	0·41	0·26	0·33	0·80	0·33	0·16	0·15	2·5	0·28	4·8	15·5	
0·35	0·39	0·53	0·48	0·32	0·40	0·96	0·40	0·19	0·18	3·0	0·34	5·8	65	18
0·36	0·40	0·57	0·52	0·34	0·42	1·1	0·42	0·19	0·18	3·2	0·36	6·1	115	
0·37	0·40	0·57	0·51	0·34	0·42	1·0	0·42	0·21	0·20	3·2	0·37	6·1	15·5	
0·46	0·50	0·68	0·61	0·41	0·50	1·2	0·50	0·24	0·23	3·9	0·44	7·4	65	22
0·49	0·54	0·76	0·67	0·46	0·55	1·4	0·55	0·26	0·24	4·2	0·49	8·1	115	
0·52	0·58	0·81	0·68	0·48	0·58	1·5	0·58	0·29	0·27	4·5	0·52	8·6	15·5	
0·64	0·70	0·95	0·83	0·58	0·67	1·7	0·67	0·34	0·31	5·5	0·61	10	65	28
0·68	0·75	1·0	0·90	0·63	0·73	1·9	0·73	0·35	0·31	5·7	0·68	11	115	
0·69	0·76	1·0	0·85	0·60	0·69	1·9	0·69	0·38	0·35	6·0	0·69	11	15·5	
0·80	0·86	1·2	1·0	0·71	0·80	2·2	0·80	0·45	0·42	6·8	0·77	13	65	35
0·87	0·96	1·3	1·1	0·80	0·85	2·5	0·85	0·48	0·44	7·6	0·87	14	115	
0·88	0·95	1·3	1·0	0·75	0·85	2·4	0·85	0·49	0·46	7·5	0·91	14	15·5	
1·0	1·1	1·5	1·2	0·89	1·0	2·8	1·0	0·55	0·52	8·9	1·0	16	65	42
1·1	1·2	1·6	1·3	1·0	1·1	3·2	1·0	0·58	0·55	9·6	1·2	18	115	
1·3	1·4	1·8	1·4	1·1	1·1	3·4	1·3	0·77	0·64	11	1·3	20	15·5	
1·5	1·6	2·1	1·6	1·2	1·3	3·9	1·4	0·87	0·72	12	1·5	22	65	54
1·5	1·7	2·2	1·7	1·3	1·3	4·3	1·4	0·87	0·71	13	1·6	25	115	
1·8	1·8	2·6	1·7	1·5	1·5	4·9	1·6	1·0	0·93	16	1·9	29	15·5	
2·2	2·4	3·1	2·4	1·8	1·8	6·0	1·9	1·2	1·0	19	2·4	34	65	76·1
2·3	2·5	3·2	2·5	1·9	1·9	6·6	2·0	1·2	1·2	20	2·5	37	115	
2·9	3·2	4·1	3·2	2·2	2·1	7·9	2·2	1·6	1·5	25	3·0	45	15·5	
3·3	3·7	4·6	3·7	2·5	2·4	9·2	2·6	1·8	1·7	29	3·5	52	65	108
3·5	3·8	4·9	3·8	2·7	2·5	10	2·7	1·9	1·8	31	3·7	56	115	
3·6	3·9	4·9	3·9	2·6	2·6	9·7	2·6	1·9	1·8	30	3·7	55	15·5	
4·3	4·7	5·8	4·7	3·2	3·1	11	3·1	2·3	2·2	37	4·5	67	65	133
4·5	4·9	6·3	4·8	3·4	3·1	13	3·0	2·4	2·3	40	4·8	72	115	
4·6	5·0	6·2	5·1	3·4	3·4	13	3·4	2·5	2·4	40	4·8	71	15·5	
5·3	5·8	7·1	5·8	3·8	3·8	14	3·8	2·9	2·7	45	5·5	82	65	159
5·5	6·1	7·5	5·9	4·0	3·8	16	3·8	3·0	2·8	49	5·9	89	115	

Water flow resistance through compression and capillary fittings used with copper tube to BS 2871: Part 1: Table Y

Nominal size (mm)	Temp of water (°C)	Tee (compression or capillary)			Reducing tee (compression or capillary)		Pitcher tee (compression)			Pitcher tee (capillary)			Elbow (compression)	Elbow (capillary)
		EQUIVALENT LENGTHS IN METRES												
	15·5	0·009	0·15	0·13	0·17	0·10	0·009	0·09	0·08	0·012	0·10	0·10	0·11	0·078
6	65	0·013	0·18	0·16	0·21	0·13	0·014	0·11	0·10	0·016	0·13	0·13	0·15	0·094
	115	0·014	0·19	0·17	0·23	0·14	0·015	0·12	0·11	0·017	0·14	0·14	0·16	0·10
	15·5	0·016	0·24	0·20	0·26	0·16	0·018	0·15	0·12	0·020	0·17	0·17	0·19	0·12
8	65	0·020	0·29	0·25	0·33	0·21	0·022	0·17	0·16	0·025	0·20	0·20	0·23	0·15
	115	0·022	0·31	0·28	0·36	0·22	0·025	0·19	0·18	0·028	0·22	0·22	0·25	0·16
	15·5	0·022	0·33	0·28	0·35	0·22	0·025	0·20	0·18	0·027	0·23	0·23	0·26	0·17
10	65	0·029	0·40	0·35	0·43	0·29	0·031	0·25	0·23	0·034	0·28	0·28	0·31	0·20
	115	0·030	0·43	0·38	0·47	0·31	0·034	0·26	0·26	0·039	0·31	0·31	0·35	0·22
	15·5	0·029	0·43	0·36	0·46	0·29	0·033	0·26	0·23	0·036	0·30	0·30	0·33	0·22
12	65	0·038	0·53	0·47	0·56	0·38	0·040	0·31	0·30	0·044	0·36	0·36	0·40	0·26
	115	0·040	0·57	0·51	0·63	0·41	0·046	0·35	0·34	0·052	0·40	0·40	0·46	0·29
	15·5	0·041	0·57	0·51	0·62	0·41	0·044	0·38	0·32	0·047	0·41	0·38	0·43	0·30
15	65	0·048	0·65	0·59	0·71	0·48	0·053	0·41	0·38	0·056	0·47	0·44	0·53	0·35
	115	0·052	0·74	0·65	0·81	0·53	0·059	0·45	0·44	0·064	0·52	0·50	0·60	0·38
	15·5	0·051	0·73	0·63	0·79	0·53	0·056	0·46	0·43	0·063	0·51	0·48	0·58	0·38
18	65	0·062	0·88	0·75	0·95	0·64	0·073	0·54	0·52	0·076	0·59	0·57	0·69	0·45
	115	0·066	0·93	0·82	1·0	0·68	0·075	0·57	0·57	0·082	0·62	0·60	0·75	0·48
	15·5	0·067	0·97	0·82	1·0	0·68	0·070	0·58	0·56	0·080	0·63	0·62	0·73	0·48
22	65	0·083	1·1	0·96	1·2	0·82	0·088	0·69	0·68	0·10	0·74	0·73	0·88	0·58
	115	0·086	1·2	1·1	1·4	0·91	0·095	0·76	0·77	0·11	0·82	0·80	0·98	0·63
	15·5	0·095	1·3	1·0	1·4	0·95	0·095	0·79	0·79	0·10	0·85	0·85	0·98	0·66
28	65	0·12	1·6	1·3	1·6	1·1	0·12	0·95	0·95	0·13	1·0	1·0	1·2	0·80
	115	0·12	1·7	1·5	2·0	1·3	0·13	1·0	1·1	0·15	1·1	1·1	1·3	0·87
	15·5	0·13	1·8	1·5	1·9	1·3	0·13	1·0	1·1	0·16	1·0	1·1	1·3	0·91
35	65	0·15	2·0	1·7	2·2	1·5	0·15	1·2	1·2	0·17	1·2	1·3	1·5	1·0
	115	0·16	2·3	2·0	2·5	1·7	0·17	1·4	1·4	0·20	1·3	1·4	1·7	1·2
	15·5	0·16	2·2	1·9	2·4	1·6	0·16	1·2	1·4	0·19	1·1	1·4	1·5	1·1
42	65	0·18	2·5	2·2	2·7	1·8	0·21	1·4	1·6	0·22	1·3	1·7	1·7	1·4
	115	0·20	2·9	2·5	3·2	2·0	0·22	1·7	1·8	0·24	1·4	1·8	2·0	1·5
	15·5	0·22	3·1	2·7	3·4	2·2	0·25	1·7	2·0	0·27	1·3	2·0	2·1	1·6
54	65	0·24	3·6	3·2	3·9	2·6	0·30	2·0	2·4	0·30	1·5	2·4	2·4	1·9
	115	0·26	4·0	3·4	4·3	2·8	0·32	2·2	2·5	0·33	1·5	2·5	2·6	2·0
	15·5	0·35	4·7	4·1	5·1	3·4	0·35	2·5	3·0	0·44	2·0	3·0	2·9	2·4
76·1	65	0·40	5·6	4·8	6·0	4·0	0·40	2·9	3·6	0·49	2·4	3·6	3·4	2·8
	115	0·49	6·0	5·2	6·6	4·3	0·42	3·1	3·9	0·49	2·9	3·9	3·8	3·0
	15·5	0·52	7·4	6·5	7·9	5·3	0·52	3·7	4·8	0·61	2·9	4·8	4·2	3·7
108	65	0·61	8·5	7·3	9·1	6·1	0·61	4·3	5·5	0·73	3·6	5·5	4·9	4·3
	115	0·61	9·4	7·9	10	6·5	0·67	4·6	6·0	0·80	3·7	6·0	5·2	4·7

Twin elbow (compression)		Twin elbow (capillary)		Bend (compression or capillary)	Return bend (compression)		Return bend (capillary)	Reducer (compression or capillary) D1/D2 = 2	Reducer D1/D2 = 3	Angle valve	Gate valve	Stop-cock	Temp of water (°C)	Nominal size (mm)
EQUIVALENT LENGTHS IN METRES														
0·059	0·064	0·089	0·086	0·057	0·070	0·16	0·070	0·033	0·032	0·50	0·048	0·96	15·5	
0·071	0·078	0·11	0·11	0·071	0·088	0·19	0·088	0·042	0·039	0·62	0·060	1·2	65	6
0·075	0·082	0·12	0·12	0·077	0·097	0·21	0·097	0·044	0·042	0·65	0·066	1·3	115	
0·092	0·10	0·14	0·14	0·090	0·11	0·26	0·11	0·051	0·049	0·79	0·079	1·5	15·5	
0·11	0·12	0·18	0·17	0·11	0·14	0·31	0·14	0·064	0·060	0·96	0·10	2·0	65	8
0·12	0·13	0·20	0·19	0·12	0·16	0·34	0·16	0·068	0·065	1·0	0·11	2·0	115	
0·13	0·14	0·20	0·19	0·12	0·15	0·36	0·15	0·069	0·066	1·1	0·10	2·1	15·5	
0·15	0·17	0·24	0·23	0·15	0·19	0·43	0·19	0·087	0·079	1·3	0·14	2·6	65	10
0·17	0·19	0·27	0·26	0·16	0·21	0·48	0·21	0·091	0·086	1·4	0·16	2·8	115	
0·16	0·18	0·25	0·25	0·16	0·20	0·46	0·20	0·089	0·082	1·4	0·16	2·7	15·5	
0·20	0·22	0·31	0·30	0·19	0·24	0·54	0·24	0·11	0·10	1·7	0·19	3·4	65	12
0·22	0·24	0·35	0·34	0·21	0·28	0·63	0·28	0·12	0·11	1·9	0·22	3·7	115	
0·23	0·25	0·35	0·32	0·22	0·27	0·62	0·27	0·10	0·11	1·9	0·21	3·6	15·5	
0·26	0·30	0·41	0·38	0·24	0·33	0·71	0·32	0·12	0·13	2·2	0·24	4·4	65	15
0·28	0·32	0·45	0·43	0·27	0·36	0·81	0·36	0·13	0·14	2·4	0·27	4·7	115	
0·28	0·30	0·43	0·41	0·25	0·33	0·79	0·33	0·16	0·15	2·5	0·28	4·7	15·5	
0·34	0·38	0·52	0·47	0·31	0·39	0·95	0·39	0·19	0·18	3·0	0·33	5·6	65	18
0·36	0·39	0·56	0·51	0·34	0·41	1·0	0·41	0·19	0·18	3·1	0·36	6·0	115	
0·36	0·39	0·56	0·50	0·34	0·42	1·0	0·42	0·20	0·19	3·2	0·36	6·1	15·5	
0·45	0·49	0·67	0·59	0·40	0·49	1·2	0·49	0·24	0·22	3·8	0·43	7·2	65	22
0·48	0·53	0·74	0·66	0·45	0·53	1·4	0·53	0·25	0·23	4·1	0·48	7·9	115	
0·50	0·57	0·79	0·66	0·47	0·57	1·4	0·57	0·28	0·27	4·4	0·50	8·4	15·5	
0·62	0·68	0·92	0·80	0·56	0·65	1·7	0·65	0·33	0·30	5·3	0·59	10	65	28
0·66	0·73	1·0	0·88	0·61	0·71	1·9	0·71	0·34	0·31	5·6	0·66	11	115	
0·69	0·76	1·0	0·85	0·60	0·69	1·9	0·69	0·38	0·35	6·0	0·69	11	15·5	
0·80	0·86	1·2	1·0	0·71	0·80	2·2	0·80	0·45	0·42	6·8	0·77	13	65	35
0·87	0·96	1·3	1·1	0·80	0·85	2·5	0·85	0·48	0·44	7·6	0·87	14	115	
0·87	0·94	1·3	1·0	0·74	0·84	2·4	0·84	0·48	0·45	7·4	0·90	14	15·5	
1·0	1·1	1·5	1·2	0·87	0·96	2·7	0·96	0·54	0·51	8·7	1·0	16	65	42
1·1	1·2	1·6	1·3	0·97	1·1	3·2	1·0	0·57	0·54	9·5	1·2	18	115	
1·2	1·4	1·8	1·4	1·0	1·1	3·4	1·2	0·75	0·63	11	1·3	19	15·5	
1·5	1·6	2·1	1·6	1·2	1·3	3·9	1·4	0·87	0·72	12	1·5	22	65	54
1·5	1·7	2·2	1·7	1·3	1·3	4·3	1·4	0·87	0·71	13	1·6	25	115	
1·8	1·8	2·6	1·7	1·5	1·5	4·9	1·6	1·0	0·93	16	1·9	29	15·5	
2·2	2·4	3·1	2·4	1·8	1·8	6·0	1·9	1·2	1·0	19	2·4	34	65	76·1
2·3	2·5	3·2	2·5	1·9	1·9	6·6	2·0	1·2	1·2	20	2·5	37	115	
2·9	3·2	4·1	3·2	2·2	2·1	7·9	2·2	1·6	1·5	25	3·0	45	15·5	
3·3	3·7	4·6	3·7	2·5	2·4	9·2	2·6	1·8	1·7	29	3·5	52	65	108
3·5	3·8	4·9	3·8	2·7	2·5	10	2·7	1·9	1·8	31	3·7	56	115	

Water flow resistance through compression and capillary fittings used with copper tube to BS 2871: Part 1: Table Z

EQUIVALENT LENGTHS IN METRES

Nominal size (mm)	Temp of water (°C)	Tee (compression or capillary)			Reducing tee (compression or capillary)		Pitcher tee (compression)			Pitcher tee (capillary)			Elbow (compression)	Elbow (capillary)
	15·5	0·011	0·17	0·15	0·19	0·12	0·011	0·11	0·09	0·014	0·12	0·12	0·13	0·09
6	65	0·015	0·21	0·18	0·25	0·15	0·016	0·13	0·12	0·018	0·15	0·15	0·17	0·11
	115	0·016	0·22	0·20	0·27	0·16	0·018	0·14	0·13	0·020	0·16	0·16	0·19	0·12
	15·5	0·018	0·26	0·22	0·28	0·18	0·020	0·16	0·14	0·022	0·18	0·18	0·20	0·13
8	65	0·022	0·32	0·27	0·36	0·23	0·024	0·19	0·18	0·027	0·22	0·22	0·25	0·16
	115	0·025	0·34	0·30	0·39	0·25	0·027	0·21	0·20	0·031	0·25	0·25	0·28	0·18
	15·5	0·024	0·36	0·30	0·38	0·24	0·027	0·22	0·19	0·030	0·25	0·25	0·28	0·18
10	65	0·031	0·44	0·38	0·47	0·31	0·034	0·27	0·25	0·037	0·30	0·30	0·34	0·22
	115	0·033	0·47	0·42	0·51	0·34	0·037	0·29	0·28	0·042	0·33	0·33	0·38	0·24
	15·5	0·031	0·46	0·38	0·49	0·31	0·035	0·28	0·25	0·038	0·32	0·32	0·36	0·23
12	65	0·040	0·56	0·50	0·60	0·40	0·043	0·33	0·32	0·047	0·38	0·38	0·43	0·28
	115	0·042	0·60	0·53	0·66	0·44	0·048	0·37	0·36	0·054	0·42	0·42	0·49	0·31
	15·5	0·045	0·63	0·57	0·68	0·45	0·049	0·42	0·35	0·052	0·45	0·42	0·48	0·33
15	65	0·053	0·71	0·65	0·78	0·53	0·059	0·45	0·43	0·062	0·52	0·49	0·59	0·39
	115	0·056	0·80	0·71	0·88	0·58	0·064	0·49	0·48	0·069	0·56	0·55	0·65	0·41
	15·5	0·053	0·76	0·66	0·82	0·55	0·058	0·47	0·45	0·066	0·53	0·50	0·60	0·39
18	65	0·064	0·91	0·79	1·0	0·66	0·075	0·56	0·54	0·079	0·61	0·59	0·71	0·47
	115	0·070	0·99	0·88	1·1	0·73	0·080	0·61	0·61	0·088	0·66	0·64	0·80	0·51
	15·5	0·070	1·0	0·86	1·1	0·72	0·074	0·61	0·59	0·085	0·67	0·65	0·77	0·51
22	65	0·088	1·2	1·0	1·3	0·87	0·094	0·73	0·72	0·10	0·79	0·78	0·93	0·62
	115	0·092	1·3	1·2	1·5	0·96	0·10	0·80	0·81	0·12	0·87	0·85	1·0	0·67
	15·5	0·10	1·5	1·2	1·5	1·0	0·10	0·84	0·84	0·12	0·91	0·91	1·0	0·71
28	65	0·13	1·7	1·4	1·7	1·2	0·13	1·0	1·0	0·14	1·1	1·1	1·3	0·85
	115	0·13	1·8	1·6	2·2	1·3	0·14	1·1	1·1	0·16	1·2	1·2	1·4	0·91
	15·5	0·13	1·9	1·6	2·0	1·3	0·13	1·1	1·1	0·17	1·1	1·2	1·3	0·96
35	65	0·16	2·1	1·8	2·3	1·5	0·16	1·3	1·3	0·18	1·2	1·4	1·5	1·1
	115	0·16	2·3	2·0	2·6	1·7	0·18	1·4	1·4	0·20	1·3	1·5	1·7	1·2
	15·5	0·16	2·3	2·0	2·5	1·6	0·17	1·3	1·4	0·20	1·2	1·5	1·6	1·2
42	65	0·19	2·6	2·3	2·8	1·9	0·22	1·5	1·7	0·23	1·3	1·7	1·8	1·4
	115	0·21	2·9	2·5	3·2	2·1	0·22	1·7	1·8	0·25	1·5	1·9	2·0	1·5
	15·5	0·23	3·2	2·8	3·5	2·3	0·26	1·8	2·1	0·28	1·3	2·1	2·2	1·7
54	65	0·24	3·6	3·2	3·9	2·6	0·30	2·0	2·4	0·30	1·5	2·4	2·4	1·9
	115	0·26	4·0	3·4	4·3	2·8	0·32	2·2	2·5	0·33	1·5	2·5	2·6	2·0
	15·5	0·35	4·7	4·1	5·1	3·4	0·35	2·5	3·0	0·44	2·0	3·0	2·9	2·4
76·1	65	0·40	5·6	4·8	6·0	4·0	0·40	2·9	3·6	0·49	2·4	3·6	3·4	2·8
	115	0·49	6·0	5·2	6·6	4·3	0·42	3·1	3·9	0·49	2·9	3·9	3·8	3·0
	15·5	0·52	7·4	6·5	7·9	5·3	0·52	3·7	4·8	0·61	2·9	4·8	4·2	3·7
108	65	0·64	8·5	7·3	9·1	6·1	0·61	4·3	5·5	0·73	3·6	5·5	4·9	4·3
	115	0·61	9·4	7·9	10	6·5	0·67	4·6	6·0	0·80	3·7	6·0	5·2	4·7
	15·5	0·64	9·2	7·8	9·7	6·5	0·65	4·4	5·8	0·78	3·9	5·8	4·9	4·6
133	65	0·77	11	9·4	12	7·8	0·77	5·3	7·1	0·95	4·7	7·1	5·8	5·5
	115	0·78	12	10	13	8·4	0·84	5·7	7·6	1·0	4·9	7·6	6·3	6·0
	15·5	0·83	12	10	13	8·4	0·80	5·6	7·6	1·0	5·0	7·6	5·9	5·9
159	65	0·97	14	12	14	9·6	1·0	6·3	8·6	1·2	5·8	8·6	6·7	6·7
	115	0·98	15	12	16	10	1·0	6·7	9·3	1·2	6·1	9·2	7·2	7·2

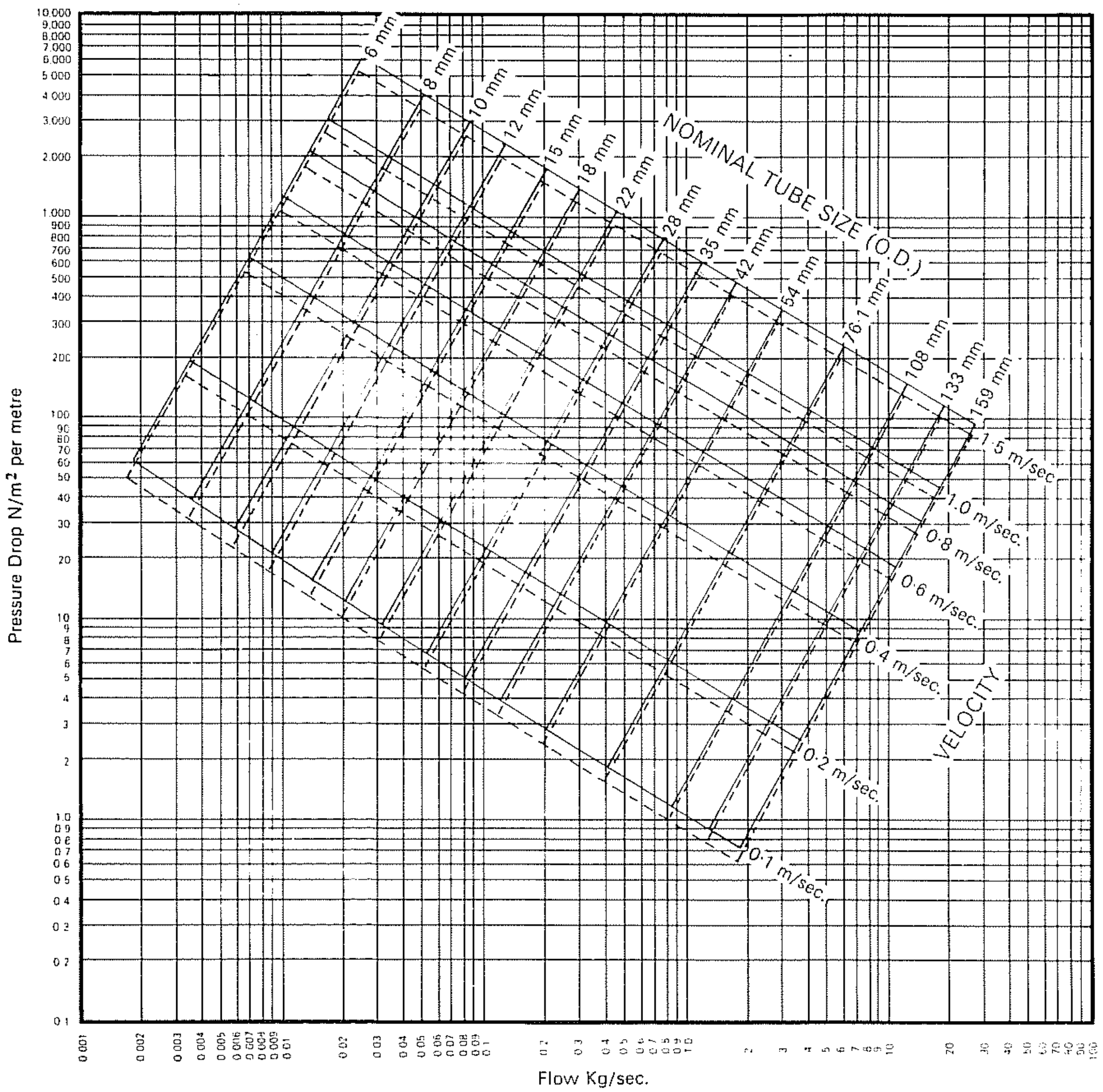
EQUIVALENT LENGTHS IN METRES

Twin elbow (compression)		Twin elbow (capillary)		Bend (compression or capillary)	Return bend (compression)		Return bend (capillary)	Reducer (compression or capillary) $D_1/D_2 = 2$	Reducer (compression or capillary) $D_1/D_2 = 3$	Angle valve	Gate valve	Stop-cock	Temp of water (°C)	Nominal size (mm)
0·069	0·074	0·10	0·10	0·067	0·082	0·19	0·082	0·038	0·037	0·59	0·056	1·1	15·5	
0·083	0·091	0·13	0·13	0·083	0·10	0·22	0·10	0·049	0·046	0·73	0·070	1·4	65	6
0·088	0·096	0·14	0·14	0·090	0·12	0·25	0·12	0·052	0·050	0·76	0·078	1·5	115	
0·10	0·12	0·16	0·15	0·10	0·12	0·28	0·12	0·056	0·054	0·87	0·087	1·6	15·5	
0·12	0·13	0·19	0·19	0·12	0·15	0·34	0·15	0·071	0·066	1·1	0·11	2·2	65	8
0·13	0·14	0·22	0·21	0·13	0·17	0·38	0·17	0·075	0·072	1·1	0·12	2·2	115	
0·14	0·15	0·21	0·21	0·13	0·17	0·39	0·17	0·075	0·072	1·2	0·12	2·3	15·5	
0·17	0·18	0·26	0·25	0·16	0·21	0·47	0·21	0·094	0·086	1·4	0·15	2·8	65	10
0·18	0·20	0·29	0·29	0·18	0·23	0·51	0·23	0·10	0·093	1·5	0·17	3·0	115	
0·18	0·19	0·27	0·26	0·17	0·21	0·49	0·21	0·10	0·088	1·5	0·17	2·9	15·5	
0·21	0·23	0·33	0·32	0·21	0·26	0·58	0·26	0·12	0·11	1·9	0·20	3·6	65	12
0·23	0·25	0·37	0·36	0·22	0·29	0·66	0·29	0·13	0·11	2·0	0·23	3·8	115	
0·25	0·28	0·39	0·35	0·24	0·30	0·68	0·30	0·11	0·13	2·1	0·23	3·9	15·5	
0·29	0·33	0·46	0·42	0·27	0·36	0·78	0·36	0·13	0·15	2·5	0·27	4·8	65	15
0·31	0·35	0·49	0·47	0·30	0·39	0·88	0·39	0·14	0·15	2·7	0·29	5·2	115	
0·29	0·31	0·45	0·42	0·26	0·34	0·82	0·34	0·16	0·15	2·6	0·29	4·9	15·5	
0·36	0·39	0·54	0·49	0·32	0·40	0·98	0·40	0·20	0·18	3·1	0·34	5·9	65	18
0·38	0·42	0·60	0·54	0·36	0·44	1·1	0·44	0·20	0·19	3·3	0·38	6·4	115	
0·38	0·42	0·60	0·53	0·35	0·44	1·1	0·44	0·21	0·20	3·3	0·38	6·4	15·5	
0·47	0·52	0·71	0·63	0·42	0·51	1·3	0·51	0·25	0·23	4·1	0·45	7·7	65	22
0·50	0·56	0·79	0·69	0·47	0·56	1·4	0·56	0·26	0·24	4·3	0·50	8·4	115	
0·54	0·61	0·84	0·71	0·51	0·61	1·5	0·61	0·30	0·28	4·7	0·54	8·9	15·5	
0·66	0·73	0·98	0·85	0·60	0·70	1·8	0·70	0·35	0·32	5·7	0·63	11	65	28
0·70	0·77	1·1	0·93	0·65	0·75	2·0	0·75	0·36	0·32	5·9	0·70	12	115	
0·73	0·80	1·1	0·90	0·63	0·73	2·0	0·73	0·40	0·37	6·3	0·74	12	15·5	
0·85	0·91	1·3	1·0	0·75	0·84	2·3	0·84	0·47	0·44	7·2	0·81	13	65	35
0·89	0·98	1·4	1·1	0·82	0·87	2·6	0·87	0·49	0·45	7·7	0·89	14	115	
0·90	0·97	1·3	1·0	0·77	0·87	2·5	0·87	0·50	0·47	7·7	0·93	14	15·5	
1·0	1·1	1·5	1·2	0·91	1·0	2·8	1·0	0·56	0·53	9·1	1·1	16	65	42
1·1	1·2	1·6	1·3	1·0	1·1	3·2	1·1	0·59	0·56	9·7	1·2	18	115	
1·3	1·4	1·9	1·4	1·1	1·1	3·5	1·3	0·79	0·65	11	1·3	20	15·5	
1·5	1·6	2·1	1·6	1·2	1·3	3·9	1·4	0·87	0·72	12	1·5	22	65	54
1·5	1·7	2·2	1·7	1·3	1·3	4·3	1·4	0·87	0·71	13	1·6	25	115	
1·8	1·8	2·6	1·7	1·5	1·5	4·9	1·6	1·0	0·93	16	1·9	29	15·5	
2·2	2·4	3·1	2·4	1·8	1·8	6·0	1·9	1·2	1·0	19	2·4	34	65	76·1
2·3	2·5	3·2	2·5	1·9	1·9	6·6	2·0	1·2	1·2	20	2·5	37	115	
2·9	3·2	4·1	3·2	2·2	2·1	7·9	2·2	1·6	1·5	25	3·0	45	15·5	
3·3	3·7	4·6	3·7	2·5	2·4	9·2	2·6	1·8	1·7	29	3·5	52	65	108
3·5	3·8	4·9	3·8	2·7	2·5	10	2·7	1·9	1·8	31	3·7	56	115	
3·6	3·9	4·9	3·9	2·6	2·6	9·7	2·6	1·9	1·8	30	3·7	55	15·5	
4·3	4·7	5·8	4·7	3·2	3·1	11	3·1	2·3	2·2	37	4·5	67	65	133
4·5	4·9	6·3	4·8	3·4	3·1	13	3·0	2·4	2·3	40	4·8	72	115	
4·6	5·0	6·2	5·1	3·4	3·4	13	3·4	2·5	2·4	40	4·8	71	15·5	
5·3	5·8	7·1	5·8	3·8	3·8	14	3·8	2·9	2·7	45	5·5	82	65	159
5·5	6·1	7·5	5·9	4·0	3·8	16	3·8	3·0	2·8	49	5·9	89	115	

Water flow resistance through copper tube to BS 2871: Part 1: Table X

———— 65°C

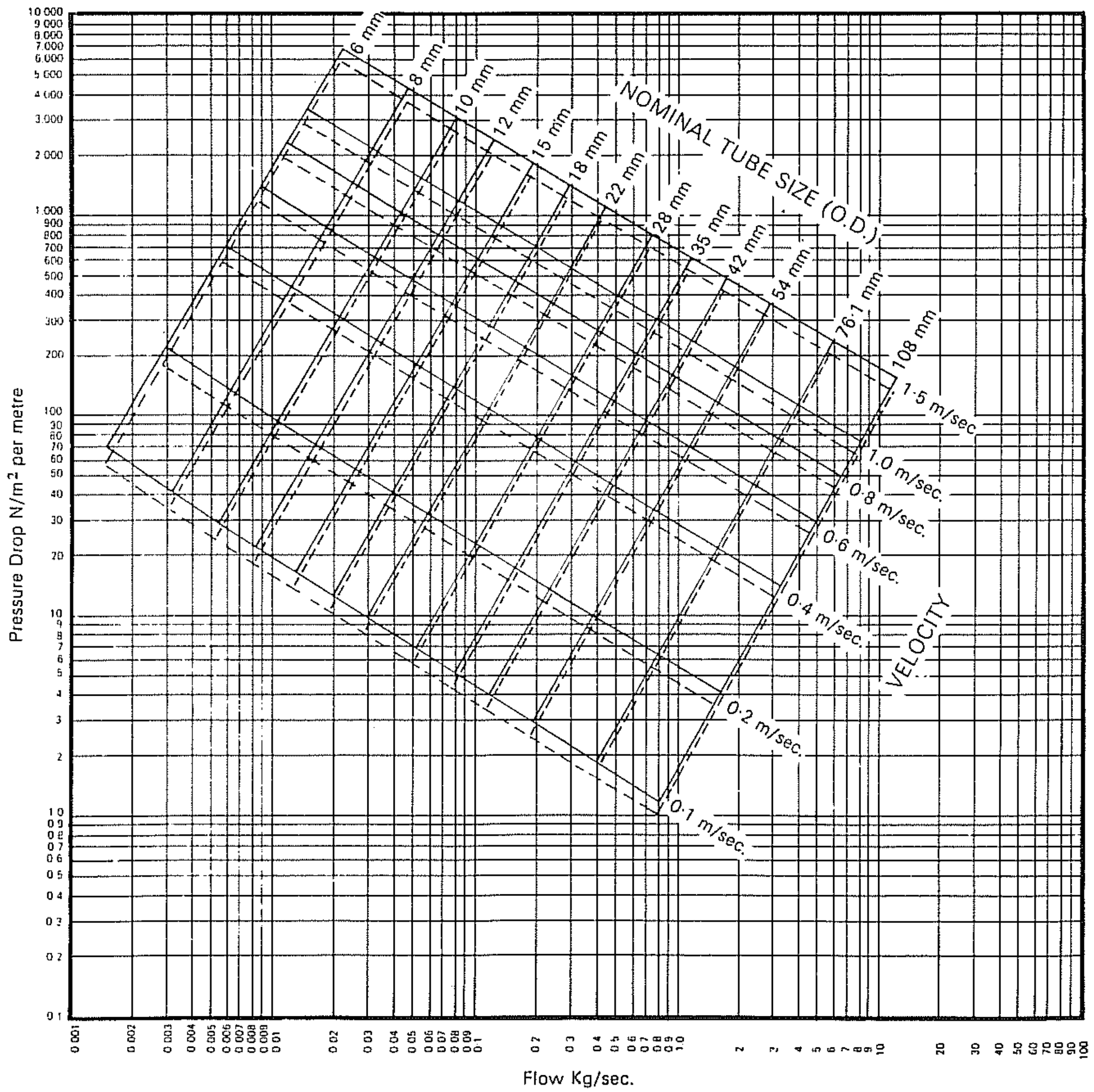
– – – – – – – 115°C



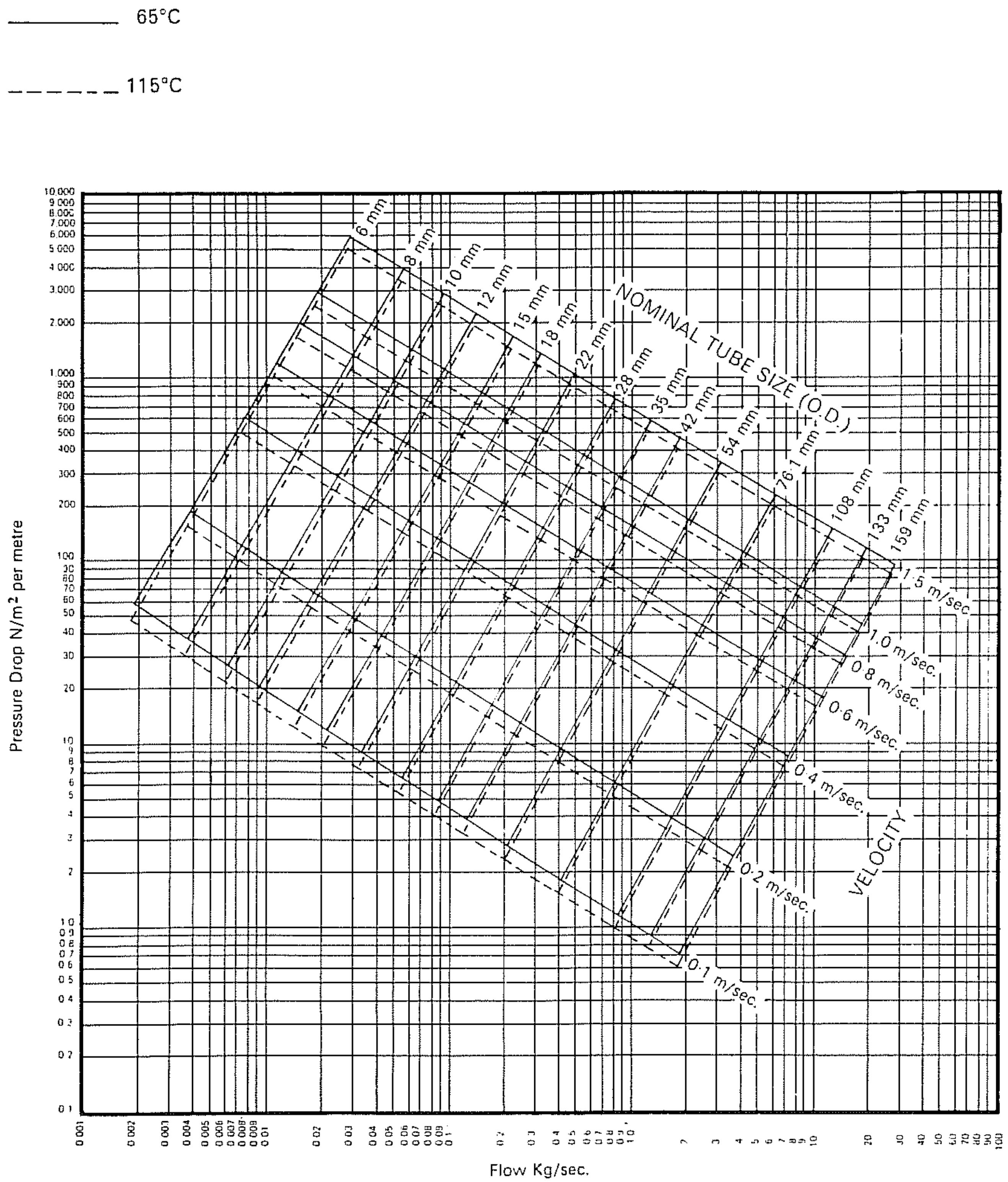
Water flow resistance through copper tube to BS 2871: Part 1: Table Y

———— 65°C

– – – – – – 115°C



Water flow resistance through copper tube to BS 2871: Part 1: Table X



Appendix H

Regulations and Statutory Requirements

Model Water Byelaws

The new Model Water Byelaws published in June 1986 form the basis of byelaws made by individual water undertakers for the purpose of water regulation.

Reference should be made to the relevant sections of the Model Water Byelaws and to the statutory documents of the individual water authority before any water supply installations or modifications are carried out. The byelaws are particularly concerned to prevent waste, misuse, undue consumption and contamination of the water supply.

The major changes to the Model Water Byelaws concern the following:-

a) the introduction of the direct connection to the supply pipes of apparatus providing hot water for use or the mixture of stored and mains supplied waters,

b) more stringent protection requirements for cold water storage cisterns and

c) to secure water economy by the reduction in the quantity of water used in WC and urinal flushing.

Users of this publication are referred to the Model Water Byelaws. In addition classified lists of approved fittings together with relevant installation requirements are contained in the Water Byelaws Advisory Service 'Water Fittings and Materials Directory'#.

The Building Regulations 1985
Materials and Workmanship

Any work to which a requirement of the Building Regulations applies must, in accordance with Regulation 7, be carried out with proper materials and in a workmanlike manner.

Compliance may be shown in a number of ways, for example by following the relevant British Standard or British Board of Agrément Certificate. Further guidance is given in the Approved Document on Materials and Workmanship.

Hot Water Storage

Part G3 of the Building Regulations requires that if the hot water storage system does not incorporate a vent pipe to atmosphere adequate precautions should be taken to prevent the temperature of the stored water at any time exceeding 100°C. The maximum working pressures quoted in this publication for copper tube are based on maximum operating temperatures not exceeding 110°C.

Insulation of Heating Services

Part L5 of the Building Regulations requires that hot water pipes should have adequate thermal insulation unless they are intended to contribute to the heating of part of a building that is insulated. The provisions meeting the requirements regarding maximum thermal conductivity and rates of heat loss are also tabled in L5.

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

British Standard Specification BS 6700

'Design, installation, testing and maintenance of services supplying water for domestic use within buildings and their curtilages'.

This Specification replaces the Code of Practice CP310 'Water Supply". It brings together in one publication virtually all aspects of hot and cold water supply within a building and its immediate surroundings. It does not cover water treatment, fire fighting systems and water supply for industrial treatments.

The term 'domestic water service' is defined as the system of pipes, fittings and connected appliances installed to supply a building with water for ablutionary, cleaning, sanitary, culinary and laundry purposes. The specification deals with the plumbing aspects of both the hot water conveyed for use and hot water conveyed for space heating. However it does not cover domestic central heating installation appliances.

The scope of this publication TN33 'Copper Tube in Domestic Water Services' is similar to that of the British Standard Specification whilst concentrating on aspects of copper tube usage.

Appendix J
Tables

J1 Table of metric sizes for copper and copper alloy tubes to BS 2871: Part 1

			TABLE W	TABLE X	TABLE Y	TABLE Z
Size of tube	Outside Diameter maximum	Outside Diameter minimum	Nominal thickness	Nominal thickness	Nominal thickness	Nominal thickness
mm	mm	mm	mm	mm	mm	mm
6	6.045	5.965	0.6	0.6	0.8	0.5
8	8.045	7.965	0.6	0.6	0.8	0.5
10	10.045	9.965	0.7	0.6	0.8	0.5
12	12.045	11.965		0.6	0.8	0.5
15	15.045	14.965		0.7	1.0	0.5
18	18.045	17.965		0.8	1.0	0.6
22	22.055	21.975		0.9	1.2	0.6
28	28.055	27.975		0.9	1.2	0.6
35	35.07	34.99		1.2	1.5	0.7
42	42.07	41.99		1.2	1.5	0.8
54	54.07	53.99		1.2	2.0	0.9
67	66.75	66.60		1.2	2.0	1.0
76.1	76.30	76.15		1.5	2.0	1.2
108	108.25	108.00		1.5	2.5	1.2
133	133.50	133.25		1.5	*	1.5
159	159.50	159.25		2.0	*	1.5

* Refer to BS 2871: Part 2 Table 5

J2 Maximum working pressure of metric copper tube to BS 2871: Part 1 (Half hard and hard)

	TABLE X	TABLE Y	TABLE Z
Size of tube	Maximum working pressures 1/2H condition	Maximum working pressures 1/2H condition	Maximum working pressures H condition
mm	bar	bar	bar
6	116	160	110
8	85	116	81
10	67	91	64
12	55	75	53
15	52	75	42
18	49	62	42
22	45	61	34
28	35	47	27
35	37	47	25
42	31	39	24
54	24	41	21
67	19	33	19
76.1	21	29	20
108	15	25	14
133	12	*	14
159	13	*	11

* Refer to BS 2871: Part 2 Table 5

Note: The above working pressures have been calculated from the formula on page 17 of this Technical Note at a temperature of 110°C and are proposed for inclusion in current revision of BS 2871: Part 1.

J3 Maximum working pressure of metric copper tube to BS 2871: Part 1 (Annealed)

	TABLE W	TABLE Y
	Maximum working pressures O condition	
Size of tube	Nominal thickness	
mm	bar	bar
6	78	108
8	58	79
10	54	62
12		51
15		51
18		42
22		41
28		32
35		32
42		27
54		28
67		22
76.1		19
108		17

Note: The above working pressures have been calculated from the formula on page 17 of this Technical Note at a temperature of 110°C and are proposed for inclusion in current revision of BS 2871: Part 1.

J4 Copper tubes to BS 2871: Part 1 are supplied in the following forms and conditions suitable for use with the joining and fitting techniques as specified:-

Table	Form		Temper			Fittings to BS 864		Joining		Comments
	Coil	Straight Length	0	1/2H	H	Capillary	Compression	Silver brazing	Welding	
W	√	–	√	–	–	√	√	–	–	Micro/mini bore heating systems
X	–	√	–	√	–	√	√	√	√	
Y	√	–	√	–	–	√	Manipulative	√	Autogeneous	Underground applications
Y	–	√	–	√	–	√	√	√	Autogeneous	Underground applications
Z	–	√	–	–	√	√	Non-Manipulative	–	–	Not recommended for bending

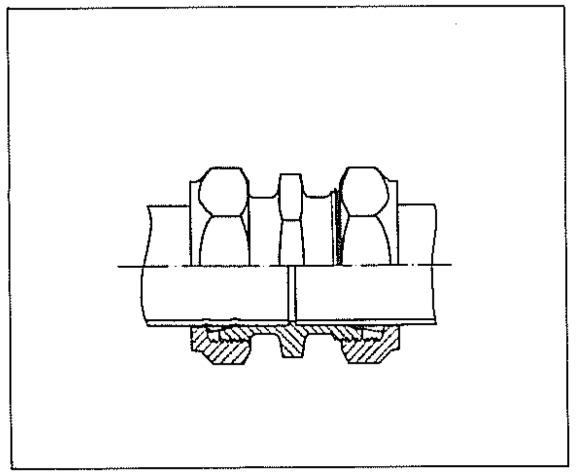


Figure 1 Compression fitting

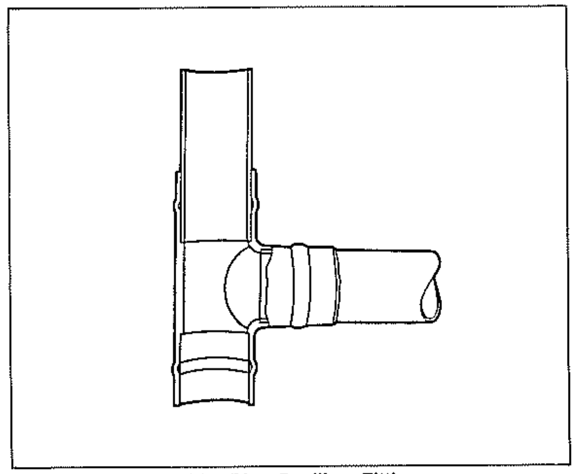


Figure 2 Integral Solder Ring Capillary Fitting

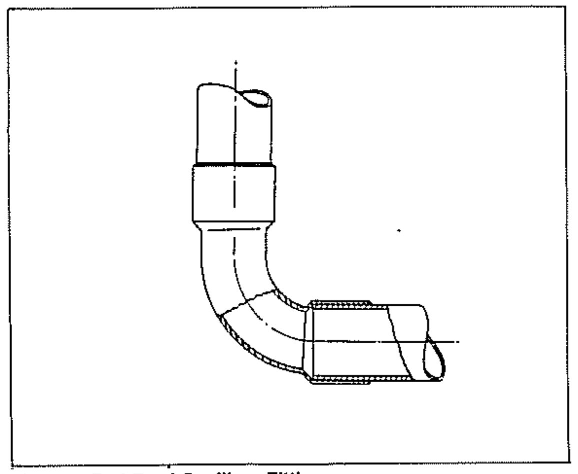


Figure 3 End Feed Capillary Fitting

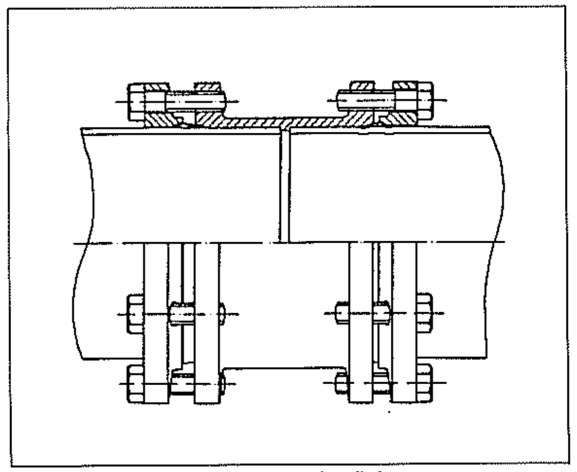


Figure 4 Large diameter compression fitting

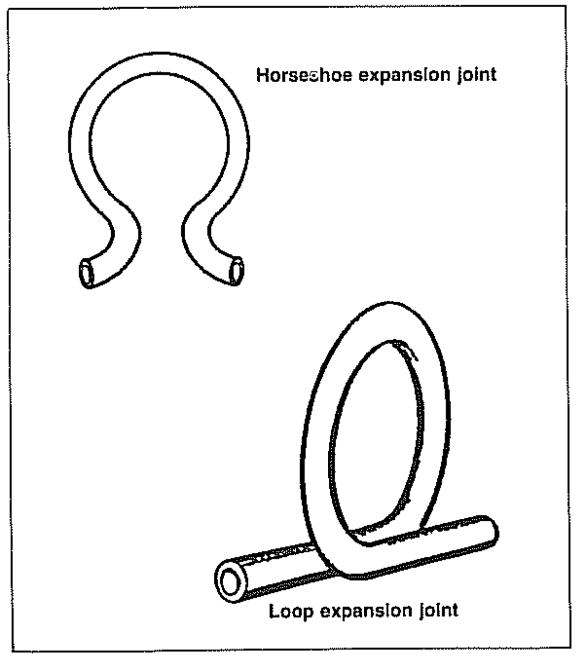


Figure 5

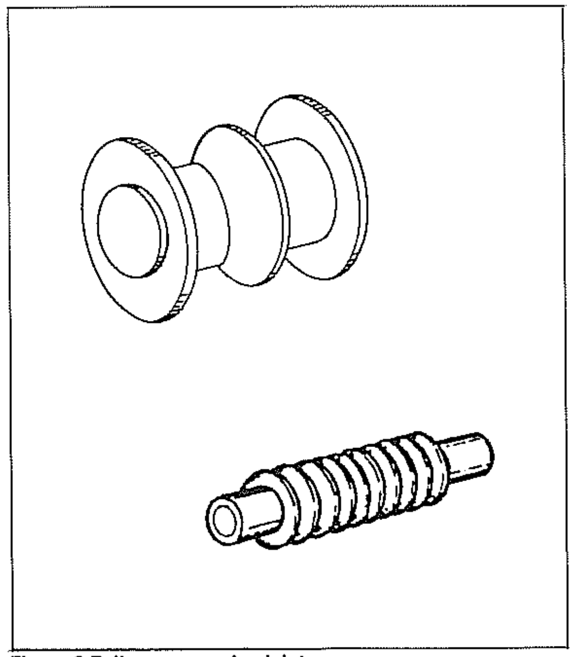


Figure 6 Bellows expansion joints

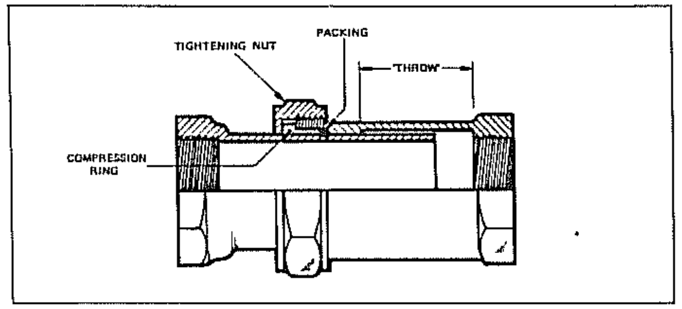


Figure 7 Gland type expansion joint

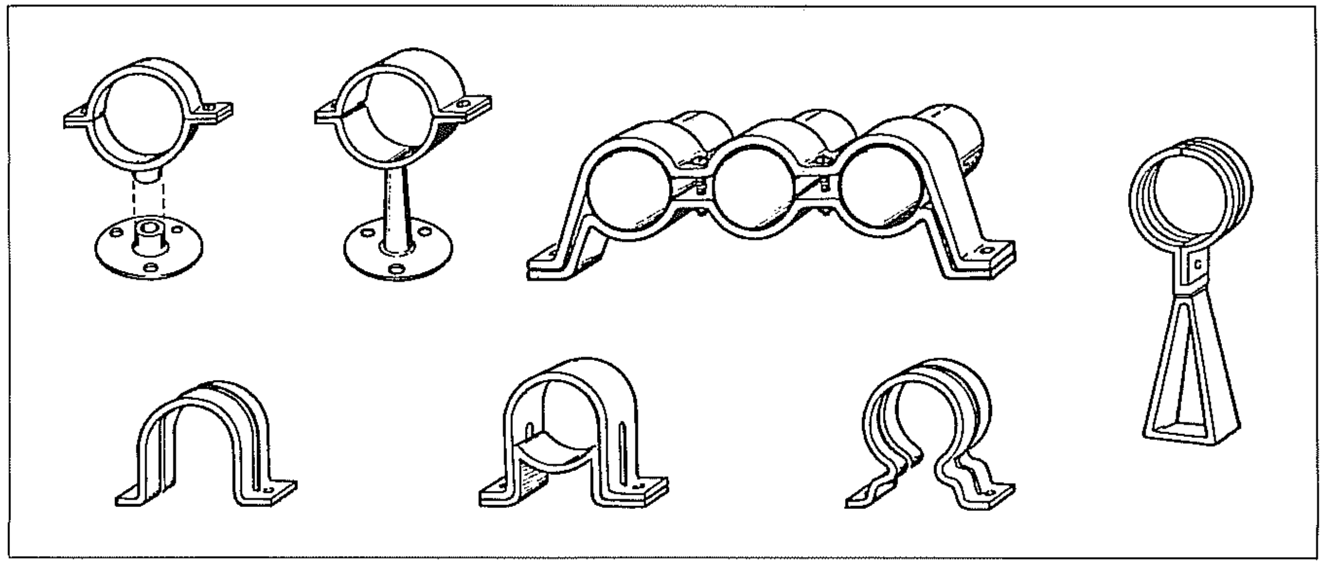


Figure 8 Fixings

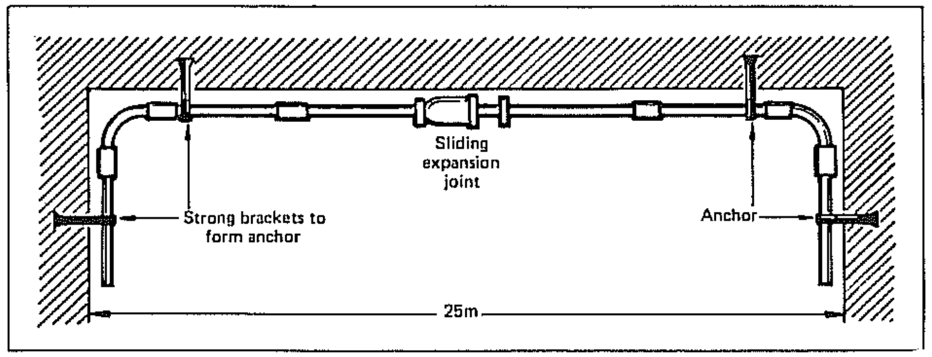


Figure 9 Method of fixing long lengths of pipework along a wall (Sliding expansion joint)

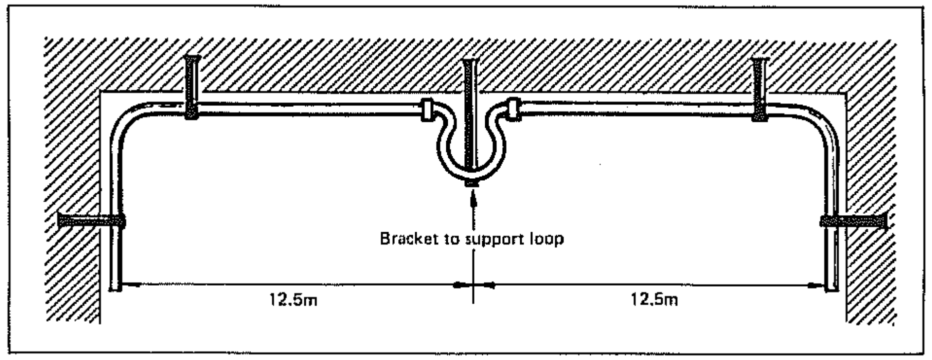


Figure 10 Method of fixing long lengths of pipework along a wall (Loop expansion joint)

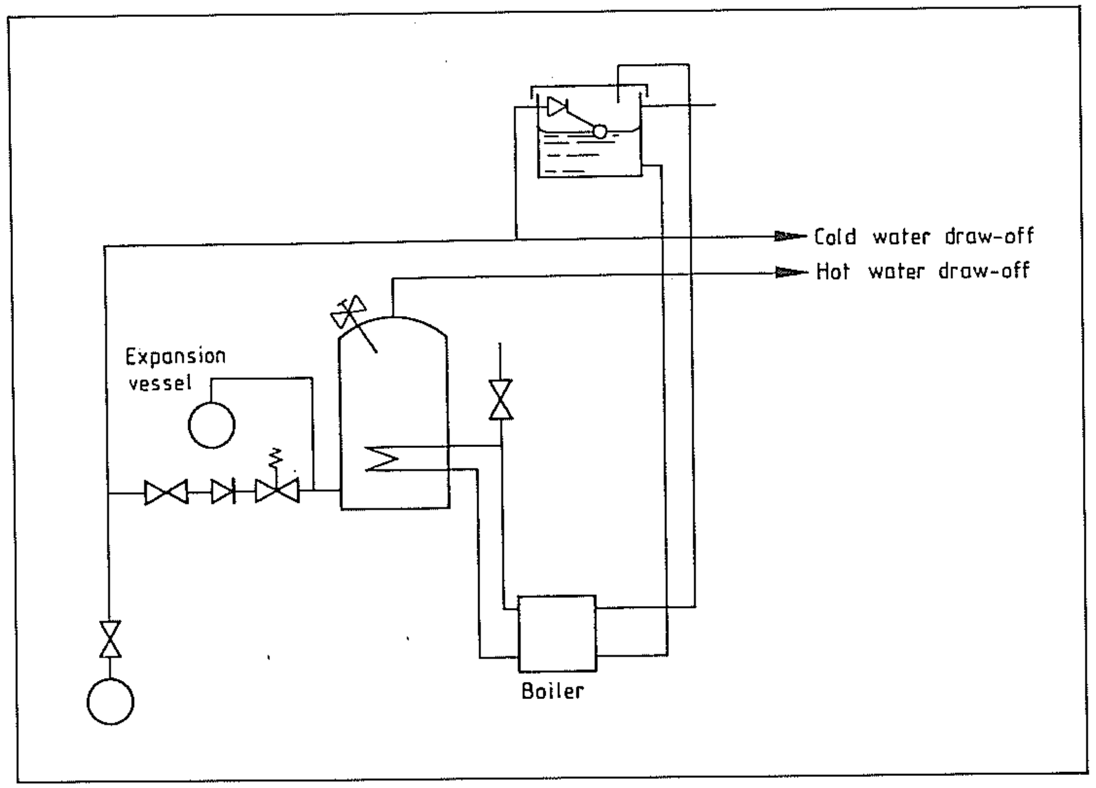


Figure 11 Indirect unvented (vented primary) system * α)

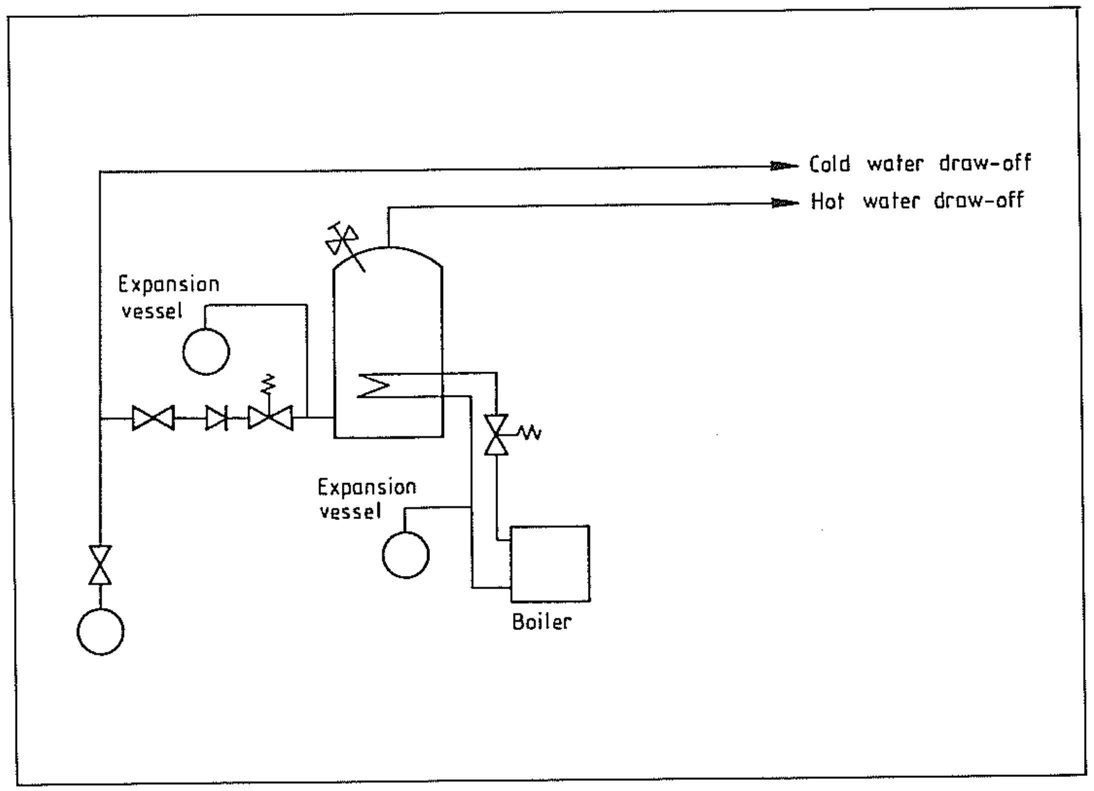


Figure 12 Indirect unvented (sealed primary) system * β)

Figures (cont.)

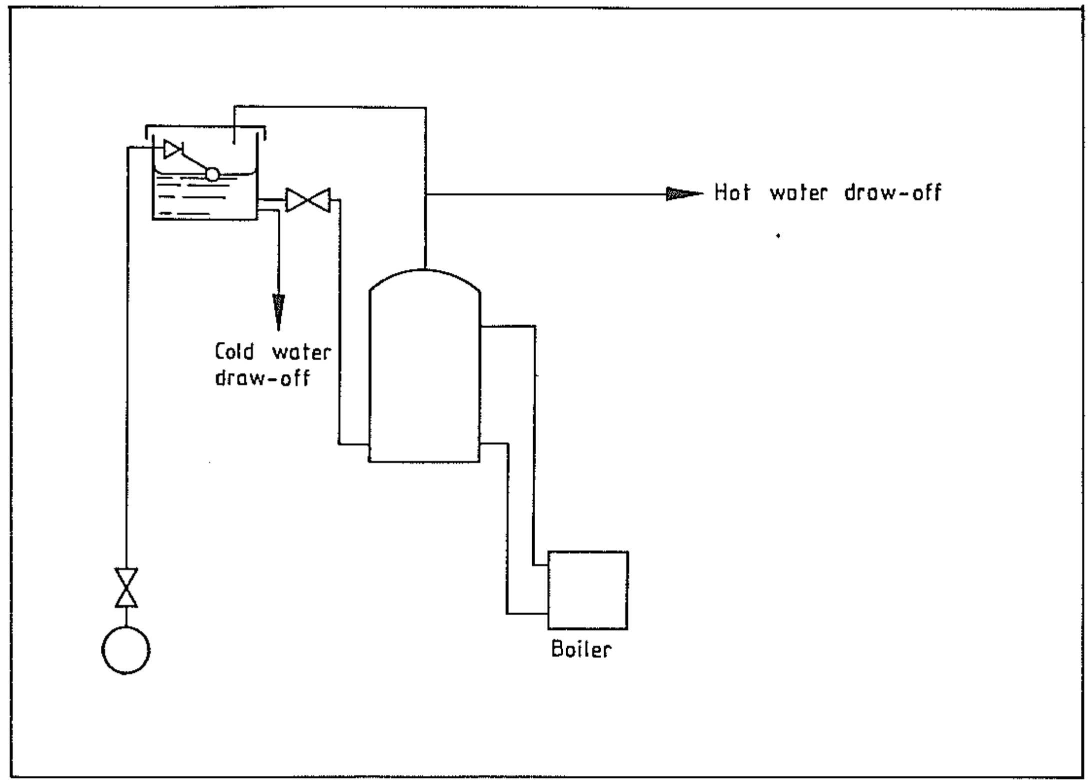


Figure 13 Direct (vented) system * γ)

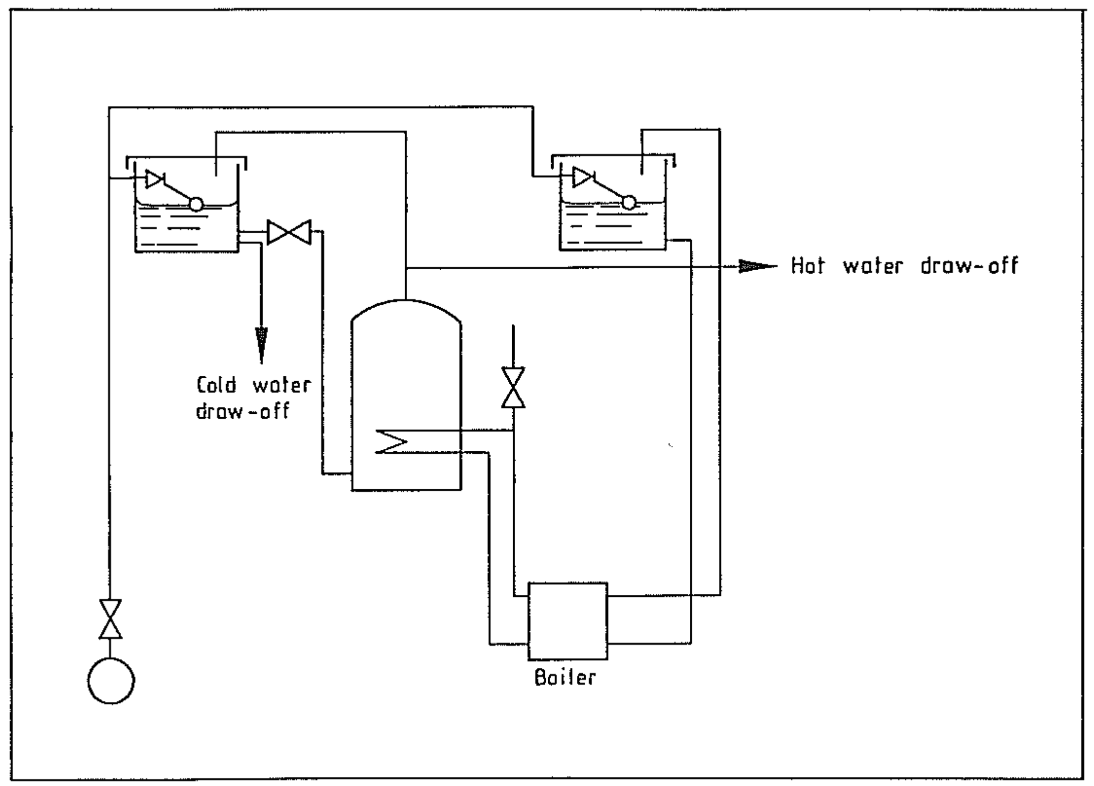


Figure 14 Indirect (vented) system * δ)

References

Text

a) 6700 3.32
b) MWB 51/52
c) MWB 53/54
d) MWB Dia 105-107
e) 6700 13.2.5.5.
f) 6700 13.2.5.4.
g) 6700 9.2.2. & MWB 7.1
h) 6700 13.3
i) MWB 10
j) 6700 3.3.4 & 6700 9.2.2
k) MWB 60
l) 6700.8
m) 6700 Table 5 Note
n) 6700 Table 4
o) 6700 B.2
p) MWB 49 & 6700.10
q) MWB 48.1/2
r) MWB 48.3
s) MWB Dia 93
t) MWB Dia 94
u) 670.4.5
v) MWB 5
w) 6700 4.3
x) MWB Dia 114
y) MWB Dia 113
z) 6700.5.3

A) MWB 54
B) 6700 5.4.1
C) MWB 58
D) MWB Dia 115
E) MWB 56
F) 6700.10.1
G) 6700.10.4
H) MWB 49
I) 6700 Table 9
J) MWB 52
K) BS1710 & BS4800
L) 6700.3.4
M) 6700.13.2.1 & MWB 7.1
N) 6700 & 13.2.5.3/5
O) MWB 57
P) 6700.14.4.5
Q) 6700.13.9
R) MWB 59
S) MWB 59 Note
T) MWB 90/92
U) MWB Dia 156
V) MWB 89
W) 6700.6.5.7.3
X) 6700.7.3
Y) 6700.7.2
Z) BR G3 & 6700.7
α) 6700 Fig 10
β) 6700 Fig 11
γ) 6700 Fig 8
δ) 6700 Fig 9

British Standard Specifications

BS 219 Specification for soft solders

BS 864 Specification for capillary and compression tube fittings of copper and copper alloy
Part 2 Specification for capillary and compression fittings for copper tube
Part 3 Compression fittings for polyethylene pipe

BS 1306 Specification for copper and copper alloy pressure piping systems

BS 1566 Copper indirect cylinders for domestic purposes.
Part 1 Specification for double feed indirect cylinders

BS 1710 Specification for identification of pipelines and services

BS 1723 Brazing

BS 1724 Specification for bronze welding by gas

BS 1845 Specification for filler metals for brazing

BS 2871 (draft) Specification for copper and copper alloys: Tubes
Part 1 Copper tubes for water, gas and sanitation
Part 2 Tubes for general purposes

BS 2872 Specification for copper and copper alloys: forging stock and forgings

BS 2874 Specification for copper and copper alloy rods and sections (other than forging stock)

BS 3958 Specification for thermal insulating materials

BS 4504 Specification for flanges and bolting for pipes, valves and fittings: Metric series
Part 2 Copper alloy and composite flanges

BS 4800 Specification for paint colours for building purposes

BS 5422 Specification for the use of thermal insulating materials

BS 5431 Specification for bending springs for use with copper tubes for water, gas and sanitation

BS 5750 Quality systems

BS 6700 Specification for the design, installation, testing and maintenance of services supplying water for domestic use within buildings and their curtilages

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