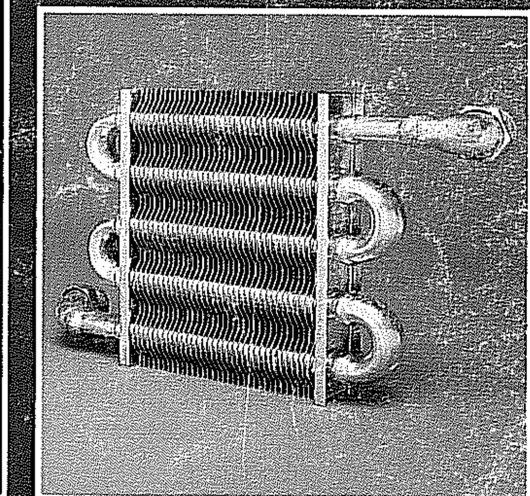
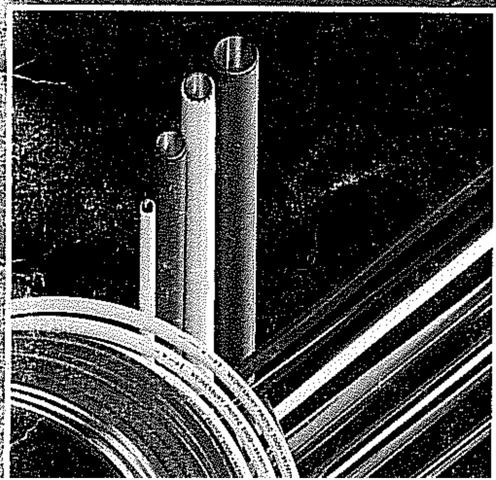
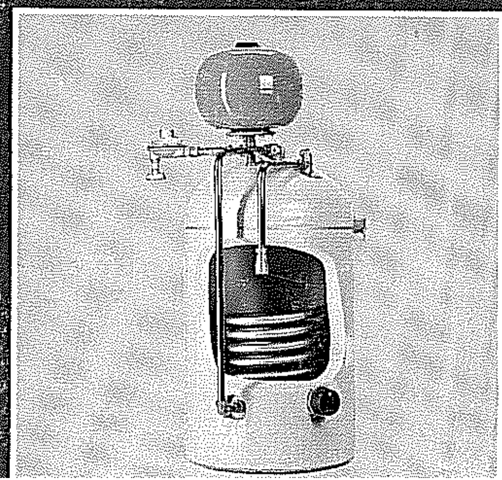
Copper in Domestic Heating Systems

TN 39







Copper Development Association

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BNFMTC BNF Metals Technology Centre
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IMI Range Ltd
MODUSSE Manufacturers Of Domestic Unvented Supply Systems Equipment

The views expressed are those of the Copper Development Association and do not necessarily represent the official opinions of the above organisations.

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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

The use of copper in heating and hot water systems is well established. This technical note has been produced to identify the main copper containing heating and hot water components and describe their correct and efficient use in a range of domestic installations in the public and private housing and commercial sectors.

The installation of heating and hot water systems should meet the requirements of the Building Regulations and relevant British Standard Specifications and comply with the Model Water Byelaws.

The Building Regulations 1985
Materials and Workmanship
Any work to which a requirement of the Building Regulations applies must be carried out with proper materials and in a workmanlike manner in accordance with Regulation 7.

Compliance may be shown in a number of ways, for example, by following an appropriate British Standard Specification or British Board of Agrément Certificate.

Further guidance is given in the Approved Document on Materials and Workmanship.

Sections of the Building Regulations referred to in this publication are G3 and L 2/3, 4 and 5.

Specifications and Codes of Practice
Particular attention has been drawn to British Standard Specification BS 6700 'Design, installation, testing and maintenance of services supplying water for domestic use within buildings and their curtilages' and BS 5449 'Code of practice for central heating for domestic premises', Part 1 'Forced circulation hot water systems', referred to throughout this publication as BS 6700 and BS 5449: Part 1.

Model Water Byelaws 1986
The new Model Water Byelaws published in June 1986 and amended in July 1987 form the basis of byelaws made by individual water undertakers for the purpose of water regulation.

Reference should be made to the relevant section of the Model Water Byelaws and 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 or contamination of the water supply.

References
The text contains only British Standard Specification numbers. The full title of each British Standard Specification is given in the list of references at the end of the publication.

Abbreviations throughout the text are used as follows:

MWB – Model Water Byelaw

BR – Building Regulation

Introduction

This publication aims to create an awareness amongst architects, designers, specifiers as well as craftsmen, teachers and students of the uses of copper and copper alloys in domestic heating and hot water systems, and also to give guidance on correct design and installation procedures.

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

a) The availability of fuels.
b) The equipment size and fuel storage requirements.
c) The controllability of fuel combustion.
d) The running costs.
e) The capital cost of the equipment.

The most common form of domestic heating installation is the wet central heating system using copper pipework to circulate heated water between the heat generator and heat emitters. It is to the copper based components used in this form of heating system that the information in this Technical Note mainly refers. Important design criteria including maximum recommended water velocities and pump and tube sizing are also covered with specific detail given to safe and efficient system operation.

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

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

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

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

Choice of Heating System

The first stage of the heating system design procedure is to determine the space heating requirement. This heating requirement will be equal to a summation of the heat loss through the building fabric and the heat loss via ventilation and can be calculated by following the design procedure set out in the CIBSE Guide or other recognised design guides. In all cases the U values of building fabric used in new buildings should meet the requirements set out in the latest edition of the Building Regulations (BR L2/3) and ventilation rates should be to the recommendations in BS 5449: Part 1.

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

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

When a boiler of the condensing type is used, the output, when operating in the non-condensing mode, should be considered as meeting the total calculated heat loss. N.B. The operating efficiency of condensing boilers increases with lower return temperatures. A greater design temperature drop will necessitate the use of larger heat emitters. High efficiency, low water content radiators with copper coil waterways can give double the heat output of a steel panel radiator of equivalent flat surface area.

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

Where a boiler supplies both heating and hot water services without priority controls additional boiler power of up to 2.0 kW may be required depending upon the likely consumption of hot water, secondary circulation heat losses and the storage capacity of the indirect cylinder.

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

Wet Central Heating Systems

Copper is the preferred material used in wet central heating systems for the circulating and domestic water distribution pipework. Usually space and domestic water heating are provided by a single heat generator, although the loads for both functions may be such that separate heat generators are required for efficient system operation. Systems combining two or more heat generators using different fuels are less common but are made possible by using copper pipework to connect each heat source to a central copper thermal storage cylinder as shown in Figure 1. Here, a solid fuel back boiler and gas boiler circulate primary heated water to a central thermal storage cylinder. The heating of mains pressure domestic hot water is carried out within an extended surface copper coil heat exchanger in the central store. Use of a water softener is advised in hard water areas to prevent the build up of scale inside the secondary heat exchanger coils and subsequent reduction in efficiency.

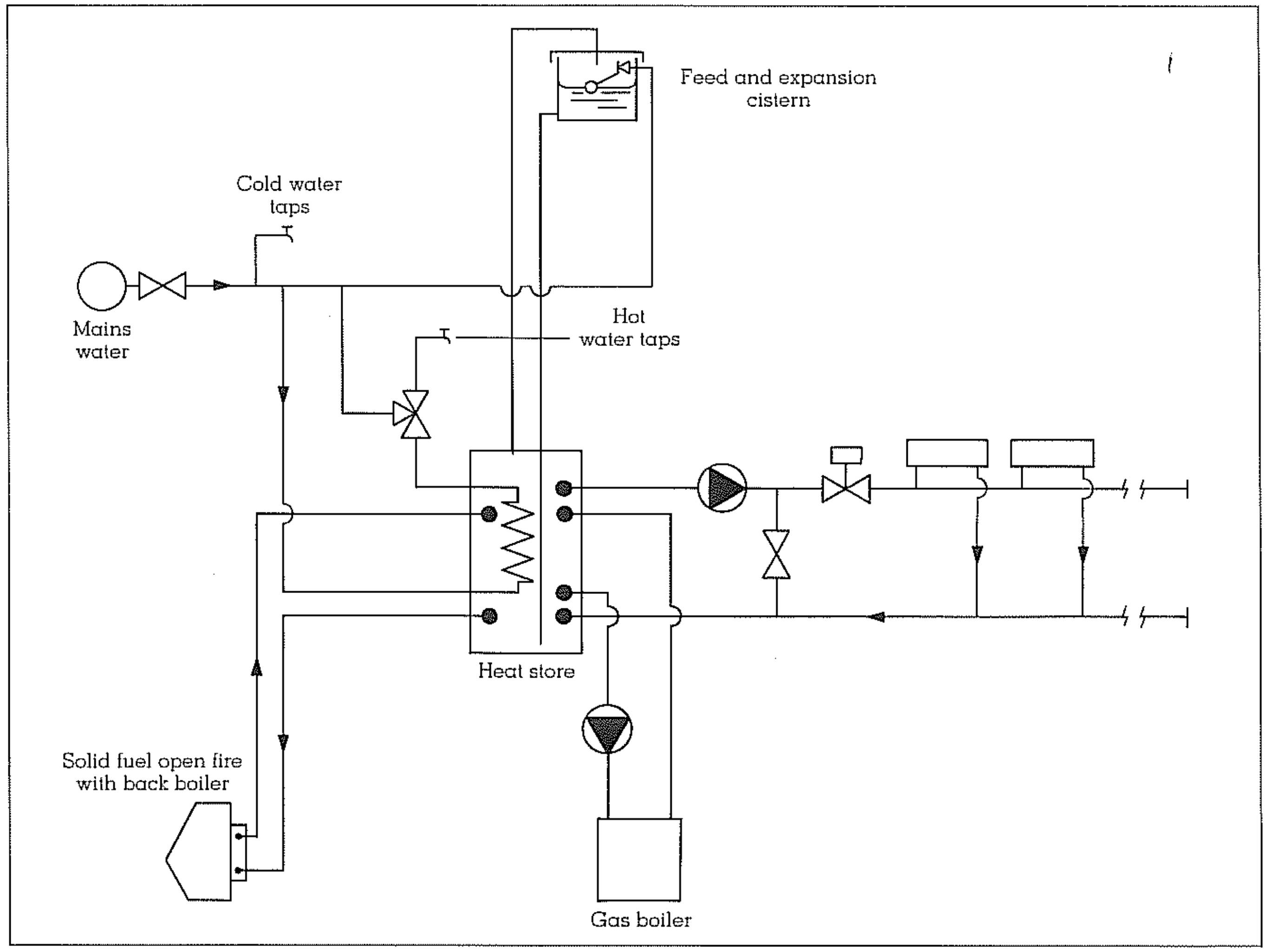


Figure 1 Schematic diagram of domestic hot water and heating system utilizing a central thermal storage cylinder.

As already discussed, wet central heating systems can utilize a range of heat generators and fuels. Water circulation is usually carried out in small-bore copper tubing to BS 2871: Part 1, Tables X, Y and Z, although copper tube to BS 2871: Part 1, Table W is also used for mini/micro-bore installations which can be significantly more economical in both labour and materials than conventional small-bore systems. (Figures 2 and 3). The range of metric sizes for copper tube to BS 2871: Part 1 are given in Appendix A.

In general, the conventional arrangement of small-bore pipework consists of a flow and return circuit extending to the index (furthest) radiator, with flow and return branches to intermediate radiators. In the mini/micro-bore system, radiators are fed by means of 6, 8 or 10mm OD pipe circuits from flow and return manifolds. It is not necessary to connect all the radiators to a single pair of manifolds although this arrangement is often advantageous for a bungalow. For buildings of more than one storey it may well be more convenient and economical to install a pair of manifolds for each floor, and by siting them in the most accessible position, the length of the mini/micro-bore copper circuits can be kept reasonably short, thereby saving material and reducing frictional resistance in the circuits to a minimum.

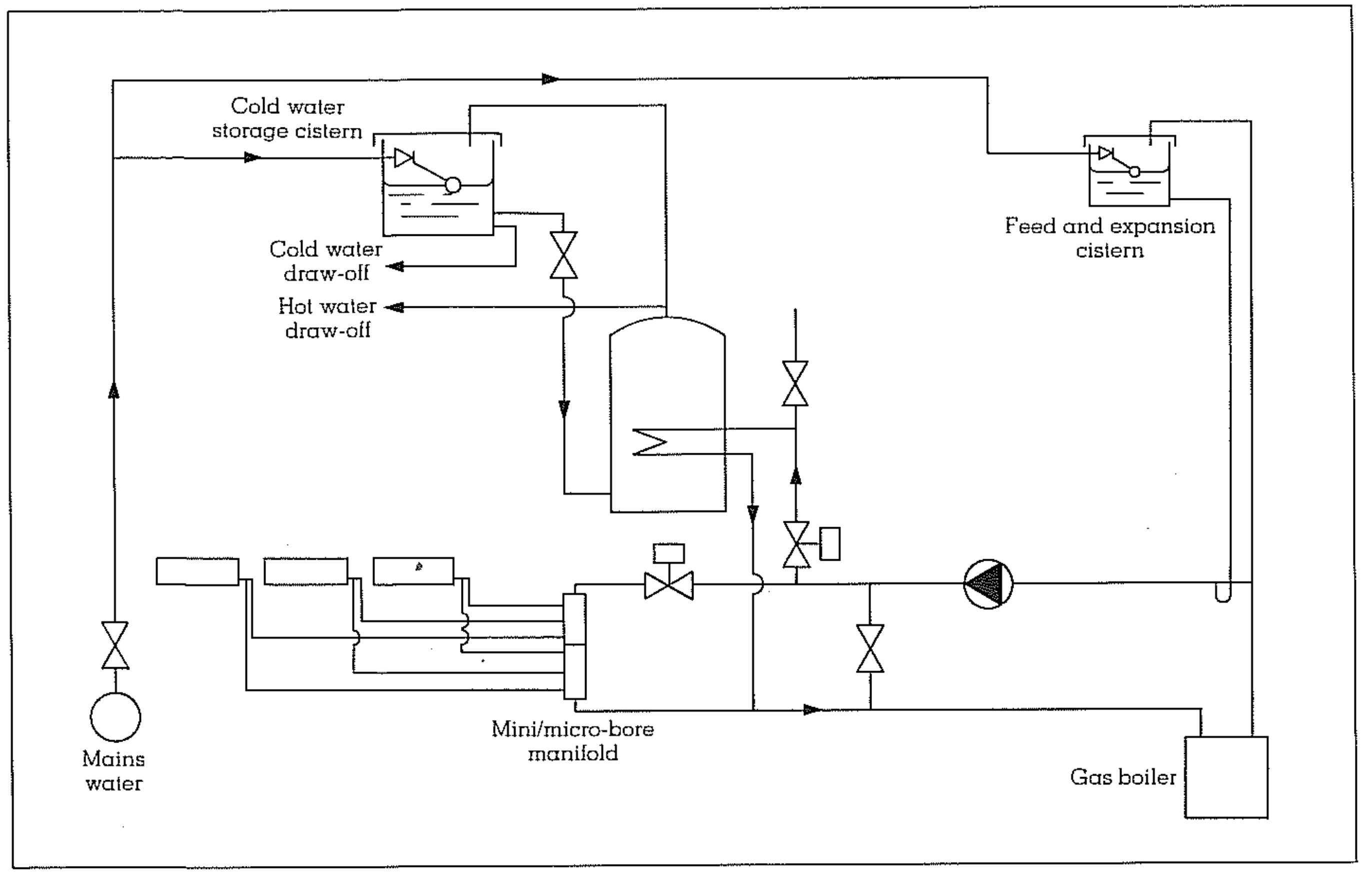


Figure 2 Schematic diagram of a mini/micro-bore heating system.

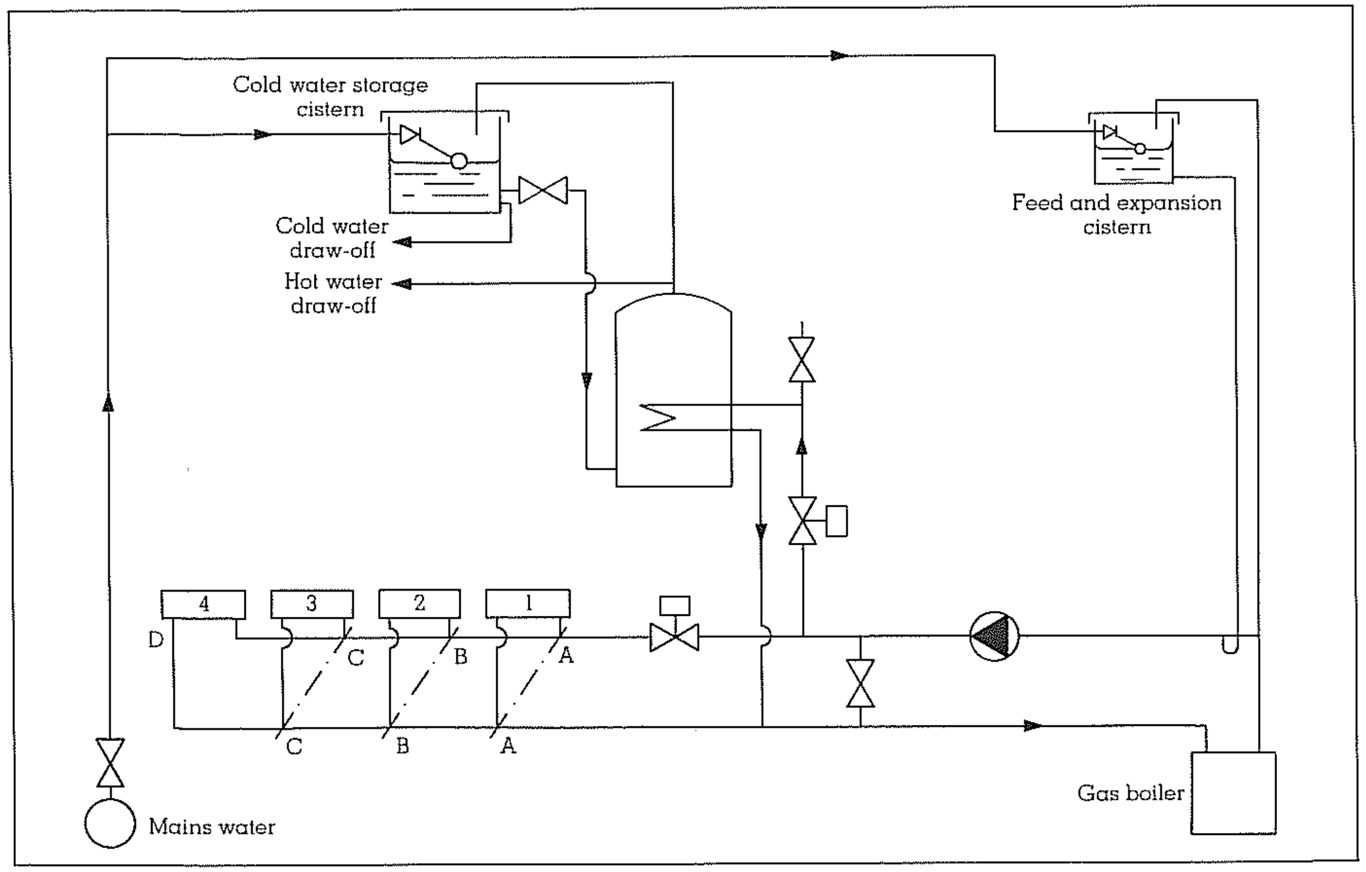


Figure 3 Schematic diagram of a small bore heating system.

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

Open Vented Systems

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

$$Q = \dot{m}.Cp.\Delta T$$

$$\text{or } \dot{m} = \frac{Q}{Cp.\Delta T}$$

where,
$\dot{m}$ = mass flow rate (kgs^{-1})
Q = Boiler output (kW)
Cp = Specific heat capacity of water (4.18 $kJkg^{-1}K^{-1}$)
ΔT = Temperature difference between flow and return (10K)

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

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

In the mini/micro-bore system shown (Figure 2), the mass flow rate from the boiler to the manifold will be calculated as above, whilst on the index circuit using the heat output of the index radiator. To ensure quietness in operation, the pipe circuits should be sized such that the water velocity does not exceed $1.5ms^{-1}$. Using the tables and charts in Appendix B of this publication together with the design parameters ie. the calculated mass flow rate and maximum water velocity, the pipe diameter and pressure drop may be determined. In order to determine the pump head required the resistance of the fittings, index radiator and boiler must be added to the calculated pressure drop. Tables of water flow resistances in copper fittings are given in Appendix B. When designing the mini/micro-bore heating system it may not be immediately evident which is the index circuit. Therefore it is important that the pressure drop in each circuit should be calculated and tabulated.

In the small bore heating system shown (Figure 3), the index circuit should be easier to determine although the pipe sizing calculations will have to take into account the change in mass flow rate after each radiator on the index circuit. The mass flow rate through the boiler will be calculated as above, thereafter the mass flow rate will be calculated using the heat outputs of the radiators in the index circuit. (Refer to Figure 3, small bore heating installation)

eg.

$$\dot{m} \text{ at A} = \frac{Q1 + Q2 + Q3 + Q4}{Cp.\ \Delta T}$$

$$\dot{m} \text{ A to B} = \frac{Q2 + Q3 + Q4}{Cp.\ \Delta T}$$

$$\dot{m} \text{ B to C} = \frac{Q3 + Q4}{Cp.\ \Delta T}$$

$$\text{and, } \dot{m} \text{ C to D} = \frac{Q4}{Cp.\ \Delta T}$$

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

For design purposes, the maximum water velocity in small bore heating systems is set at $1.0ms^{-1}$. Using the tables and charts in Appendix B the pipe diameters and pressure drop may be determined. Again the resistance of all fittings, index radiator and boiler must be included.

Consideration should now be given to the positioning of the pump, cold feed and expansion (F&E) pipe and open vent (OV) pipe. The OV pipe should run directly from the boiler rising continuously to discharge at a level over the feed and expansion cistern and through the cover. The OV pipe should have a minimum OD of 22mm. A separate F&E pipe with a minimum OD of 15mm should be fitted. No valve should be fitted in either the F&E pipe or OV pipe. The pressure difference between these two connections must be kept to a minimum to avoid excessive water movement in the OV pipe, therefore they are normally connected close together.

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

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

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

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

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

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

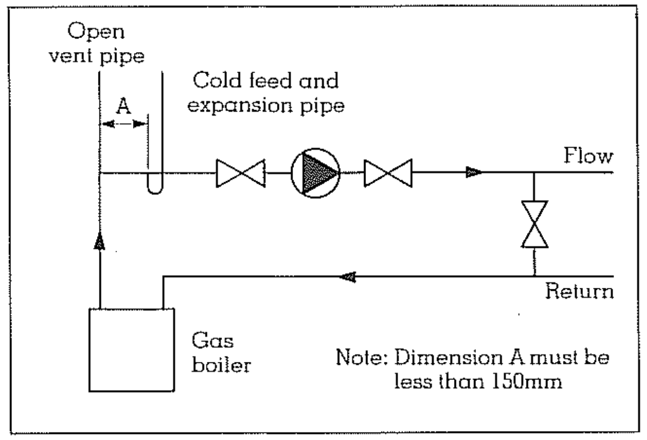
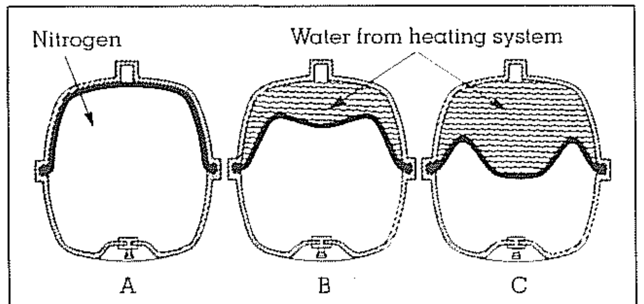


Figure 4 Close-coupled connection.

Sealed Systems

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

The vessel should be of the flexible diaphragm type, complying with BS 4814, containing air or nitrogen at a pressure not less than the static head pressure at the centre of the expansion vessel.



A Before the boiler has been fired the tank contains only air or nitrogen

B As the temperature rises the diaphragm moves to accept the increased water volume

C Position of diaphragm when water temperature has reached its maximum

Figure 5 Expansion tank with flexible diaphragm for sealed system.

The vessel should be connected to the system at a point close to the pump inlet in order to maintain positive pressures throughout the system. Installation should be in accordance with the manufacturer's instructions and with the recommendations in BS 5449: Part 1.

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

Copper Tubes

Generally, copper tube to be used in conventional heating systems is to BS 2871: Part 1, Table X (half-hard temper), and Table Y (half-hard or annealed condition). Copper tube to BS 2871: Part 1, Table Z can also be used, but because it is hard drawn thin wall tube, it cannot be bent. There is a mandatory requirement that tube installed underground must conform to BS 2871: Part 1, Table Y (MWB 51 and 52).

The type of copper tube recommended for mini/micro-bore installations is to BS 2871: Part 1, Table W (annealed condition) in purpose made coils. It can be obtained in standard coil lengths from approximately 10 to 50m which, together with its soft condition, facilitates ease and speed of installation. Copper tube coils to BS 2871: Part 1, Tables Y (annealed condition) should be used for mini/micro-bore installations underground. Tube to BS 2871: Part 1, Tables X and Y (half-hard temper) and Table Z (hard temper) are available in standard lengths of up to 6m. However increased labour costs incurred by additional jointing and fixing limit their use to flow and return headers fixed on the surface. These headers from boiler to manifolds need to be half-hard or hard temper tube to support the various ancillary equipment. The standard outside diameters of all tubes within BS 2871: Part 1 permit interchangeability.

Fittings should be of copper or copper alloy to BS 864: Part 2. Manipulative compression fittings Type 'B' are suitable for use with Tables W, X and Y copper tube to BS 2871: Part 1. Non-manipulative compression fittings Type 'A' are suitable for use on tube to BS 2871: Part 1, Tables W, X and Z and Table Y in the half-hard condition. If compression joints are used below ground, Type 'B' manipulative fittings must be used. These fittings shall be made from gunmetal or dezincification resistant brass to BS 2872 or BS 2874 material designation CZ132 (see CDA Information sheet IS36). Capillary fittings to BS 864: Part 2 may be used above or below ground on any tube to BS 2871: Part 1. Details of jointing procedures for copper tube are contained in CDA Technical Note TN33 'Copper Tube in Domestic Water Services'.

Copper has the highest thermal conductivity of all the engineering materials, typically 2.93 – 3.64 $Wcm^{-1}°C^{-1}$ for copper tube to BS 2871: Part 1, C106 at 20°C, therefore copper tube finds uses not only in circulation and distribution pipework but also as a heat exchanger in boilers, heat pumps, underfloor heating, radiators, indirect cylinders and solar panels.
The other major advantages of copper tube are:

- suitability for use with potable and other waters;
- high resistance to corrosion;
- absolute gas tightness–no oxygen diffusion;
- ability to be jointed and bent easily;
- high strength and ductility;
- resistant to temperature over 100°C;

and ease of prefabrication and installation.

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

Plastic Coated Copper Tube

Copper tube to BS 2871: Part 1, Tables W, X, Y and Z is available with plastic coatings in a range of colours to identify its use in service.
Generally, Blue or green – cold water services
Yellow – gas pipes
White – central heating pipes

It is available in straight lengths or coils with diameters ranging from 6mm to 54mm and a plastic coat thickness of 1mm : 6 to 28mm and 1.5mm : 35 to 54mm. The polyethylene coating gives protection against mechanical damage and corrosive environments. Plastic coated copper tube is also available with the inner surface of the plastic profiled to trap air, this forms a noise and thermal barrier.

Gas Pipework

Copper tube to BS 2871: Part 1, Tables W, X, Y and Z are also used for the distribution of natural gas in domestic and commercial properties and liquefied petroleum gas (LPG).

All aspects of the installation must comply with BS 6891 for natural gas and BS 5482 for LPG. The gas supply may be buried in a concrete screed, run below a suspended floor, or otherwise installed internally or externally to the building, subject to protection against corrosion or mechanical damage.

Gas-carcassing systems are available which consist of plastic coated copper gas tube with associated plastic termination units housing brass terminal fittings. The terminal fittings can be positioned as required and are similar in appearance and size to an electrical or aerial socket outlet. Gas appliances can be connected to the supply according to requirements allowing the home-owner the flexibility of installation usually associated with electrical installations. This has a particular advantage in houses where space heating is catered for by individual gas fires.

Heat Exchangers

Copper and copper alloy heat exchangers of the integrally finned or fin and tube construction are used in a variety of heat generators including:

- Low water content boilers;
- Modular boilers;
- Combination boilers;
- Instantaneous hot water heaters;
- Heat pumps;

and Condensing boilers (primary heat exchanger only).

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

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

Valves

A wide range of copper alloy taps and valves are employed in heating and hot water systems to facilitate safe and efficient operation and control water circulation, distribution and draw-off. Draining taps for hot and cold water installations and heating systems should be to BS 2879, diaphragm type float operated valves to BS 1212: Part 2., globe, globe stop and check, check and gate valves to BS 5154. Copper alloy valves used for other applications should meet the material requirements of the relevant British Standard Specification.

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

In some areas of the UK impurities in the potable water make it aggressive to duplex brass producing a form of attack known as dezincification. In these areas dezincification resistant brass (CZ132) fittings and valves should be used (see CDA IS36).

All copper alloy valves are available with capillary or compression ends to BS 864 Part 2.

Water Velocities

Problems can arise due to excessive water speeds which in extreme conditions can cause premature tube failure by one of several mechanisms including erosion/corrosion and/or cavitation. The recommended maximum water velocity for differing service conditions, assuming good design practice and installation procedures is $2ms^{-1}$ irrespective of tube outside diameter. Water flow resistance data are given in Appendix B. Further information regarding design considerations for copper tube including expansion joints, spacing for copper tube supports and protection of piping is contained in TN33 'Copper Tube in Domestic Water Services'.

Insulation

Hot water pipes should be insulated unless they are intended to contribute to the heating of part of the building which is insulated or they give rise to no significant heat loss. Insulation should meet the requirements of the Building Regulations and the Model Water Byelaws (BR L5 and MWB 49). Data on insulating materials and minimum thicknesses is given in the general note to MWB 49 and in BS 6700. Cold water supply pipes for domestic purposes should be installed so that, as far as is reasonably practical, the water will not be warm when drawn from the tap. If the cold supply cannot be installed away from the hot pipes then it should be adequately insulated. If neither of these measures are practicable the cold pipe should be installed below the hot pipe.

Underfloor Heating

Underfloor wet central heating systems using copper tube for circulating heated water to provide space heating are used throughout Europe in domestic, commercial and public buildings. Generally, the systems utilise a central boiler circulating heated water to a distribution manifold with control and shut-off valves on the feed and discharge pipes. The water is circulated under the floor surface which becomes the radiator. A correctly designed and installed system gives an even floor temperature and attains a room temperature distribution which approaches the ideal.

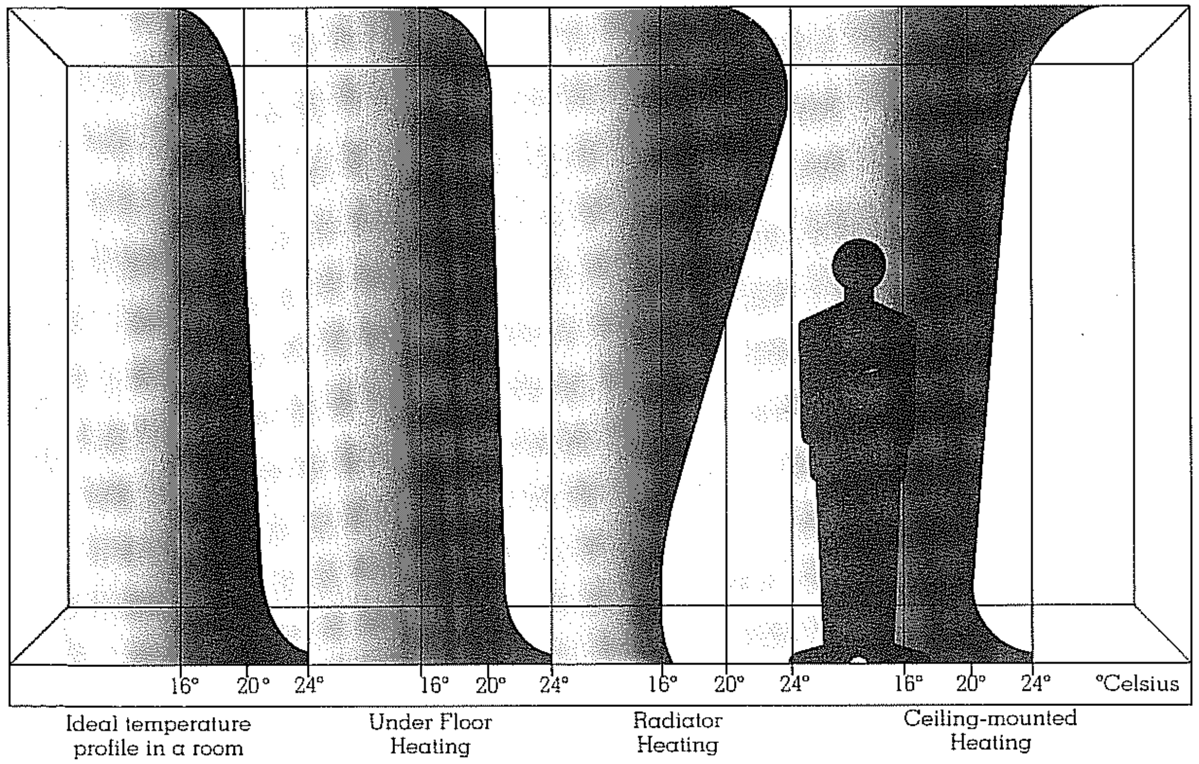


Figure 6 Temperature profile of different heating systems.

To prevent discomfort the surface temperature of the floor is limited to a maximum of 28°C. Systems are usually designed to achieve a surface temperature between 25° and 28°C, this limits the thermal output of the floor so the building must be well insulated. The flow water temperature is normally in the range 30° to 40°C, therefore the temperature difference between the circulating water and ambient air is less than in a conventional radiator system resulting in reduced heat loss through the feed pipes. Operating at these low water temperatures results in an increased boiler efficiency and allows for a wider selection of heat sources including condensing boilers, heat pumps and solar energy.

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

Plastic coated copper tube coils are normally used either 1) embedded in grooves in the heat insulating layer (Figure 7(a)) or 2) embedded in a floating floor on top of the insulating layer (Figure 7(b)). In the first case additional heat dissipating material has to be used to improve the heat transfer between floor and tube. In the second case the heat transfer is improved but greater care is required when installing the floor to prevent damaging the tube.

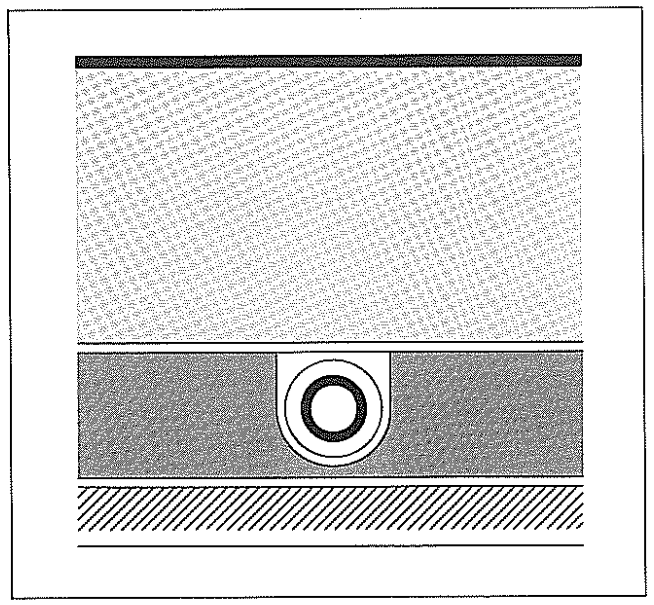


Figure 7(a) The circulating tubes are placed into the heat insulating and noise absorbing layer below the floating floor.

Underfloor Heating (cont.)

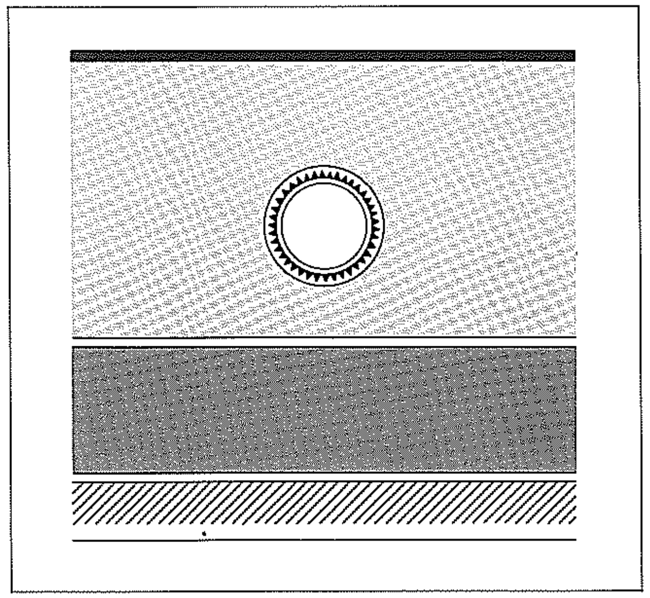


Figure 7(b) The circulating tubes are embedded directly into the floating floor.

Figures 6, 7(a) and 7(b) courtesy of Wieland-Werke AG

The plastic coating gives protection against mechanical or chemical damage and allows for longitudinal thermal expansion of the copper tube in the floor.

For further details of plastic coated copper tubes refer to the earlier section entitled Copper Tubes.

Installation of these systems in the UK should comply with the Model Water Byelaws.

The bedding of any pipe and associated joints forming part of a close circuit system of underfloor space heating in screed or in a properly formed chase in a wall or solid floor which is subsequently plastered or screeded will be accepted if the pipe and joints can be exposed for repair or replacement by removing the surface layers of the wall or floor. (MWB 58)

Heat Pumps

The heat pump is a device which extracts thermal energy from a low temperature source and upgrades it through use of a refrigeration system to a higher temperature for use for instance in space and water heating. They are economically attractive because the energy consumed to drive the refrigeration cycle is less than the heat output. The efficiency, coefficient of performance (COP), is defined as:

The useful heat energy supplied by the heat pump. : Energy used driving heat pump

Generally speaking, the heat pump utilises either air, ground water or running water as the heat source and air or water as the heat sink. Air/air (air heat source/air heat sink) heat pumps are generally used in commercial sectors. Air/water heat pumps are generally used in domestic installations combined with conventional radiator systems. The materials of construction of the heat exchangers (the evaporator tubes/coils and condenser tubes/coils) and the connecting pipework are predominantly copper.

Heat pumps operate at their highest efficiency when ambient air temperatures are high and output temperatures are low. Also the space heating requirement increases with decreasing ambient air temperatures. This results in a 'crossover' temperature where the heat output of a heat pump is equal to the space heating requirement. When ambient air temperatures rise above this temperature the available heat pump output will be in excess of the space heating requirement. Also, as the ambient air temperature falls below this 'crossover' temperature, the heat pump output will be insufficient to meet the heat requirement.

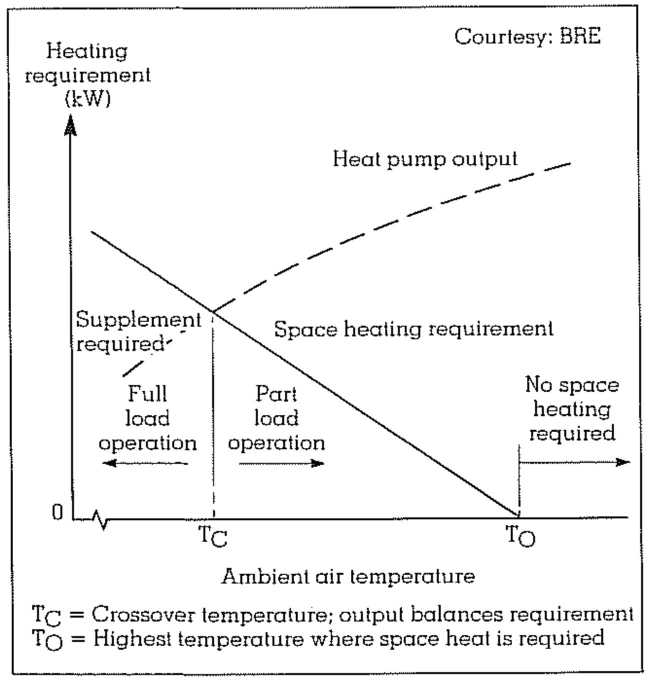


Figure 8 House space heating load and heat pump output: air temperature.

When designing heating systems the outside temperature is usually set at −1°C. A larger heat pump would be needed to meet the space heating requirement at this temperature (the 'crossover' temperature) than would be necessary if the heat pump was sized to match the heat requirement at a slightly higher design ambient air temperature with a boiler used to supplement the heat pump when temperatures drop down to −1°C. Also, when air/water heat pumps are used with a radiator system, large radiators may be necessary as many refrigerants limit the maximum available temperature from the heat pump to 60°C as opposed to the 82°C flow temperature in conventional central heating systems. Therefore some installations utilise a boiler to supplement and reduce the size of heat pump required.

Small heat pumps for domestic hot water only can prove economically advantageous installed in buildings with a high domestic hot water usage.

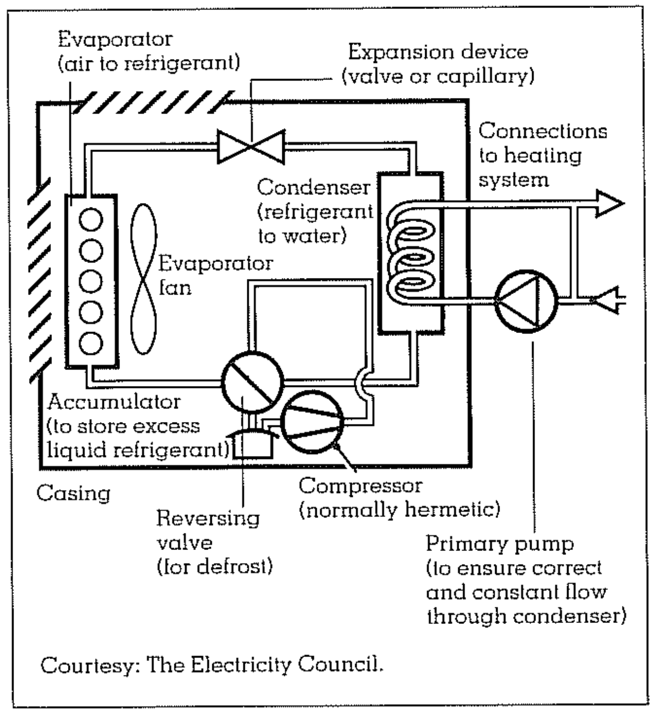


Figure 9 Typical self contained domestic heat pump.

Domestic Hot Water Heating

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

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

The open vented domestic hot water system utilises a copper cylinder to store hot water heated directly by a boiler or immersion heater, or indirectly by a boiler, solar panel, heat pump etc. In either case the cylinder is storage cistern fed and has a vent pipe of 22mm minimum OD running from the top of the cylinder rising continuously to a pre-determined height above the cold feed cistern and discharging through the cover.

Primary pipework for direct systems should be designed for gravity circulation with flow and return pipes between the boiler and cylinder run as directly as possible and not less than 28mm OD (22mm OD for small back boilers). Direct cylinders should meet the requirements of BS 699 and be supplied by a cold water feed cistern. In hard water areas where scale build up may obstruct the pipes between the boiler and cylinder an indirect system is advised.

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

The indirect cylinder is either of the double feed type complying with the requirements of BS 1566: Part 1 or the single feed type complying with the requirements of BS 1566: Part 2. The British Standard Kitemark provides the assurance that cylinders are manufactured in full compliance with the relevant BS Specification. In the double feed indirect cylinder primary water is circulated within a coil in the cylinder. Prevention of contamination of the secondary hot water within the single feed indirect cylinder is maintained by an air pocket separating it from the primary heating water. Installation of these types of cylinders should comply with the MWB 35, 36 and 37 and meet the requirements of BS 6700.

The recommended minimum storage capacity of the cold water feed cistern for small houses supplying hot and cold water outlets is 200 to 300 litres. In larger houses 100 litres per bedroom is recommended. (See BS 6700 para 5.3.3)

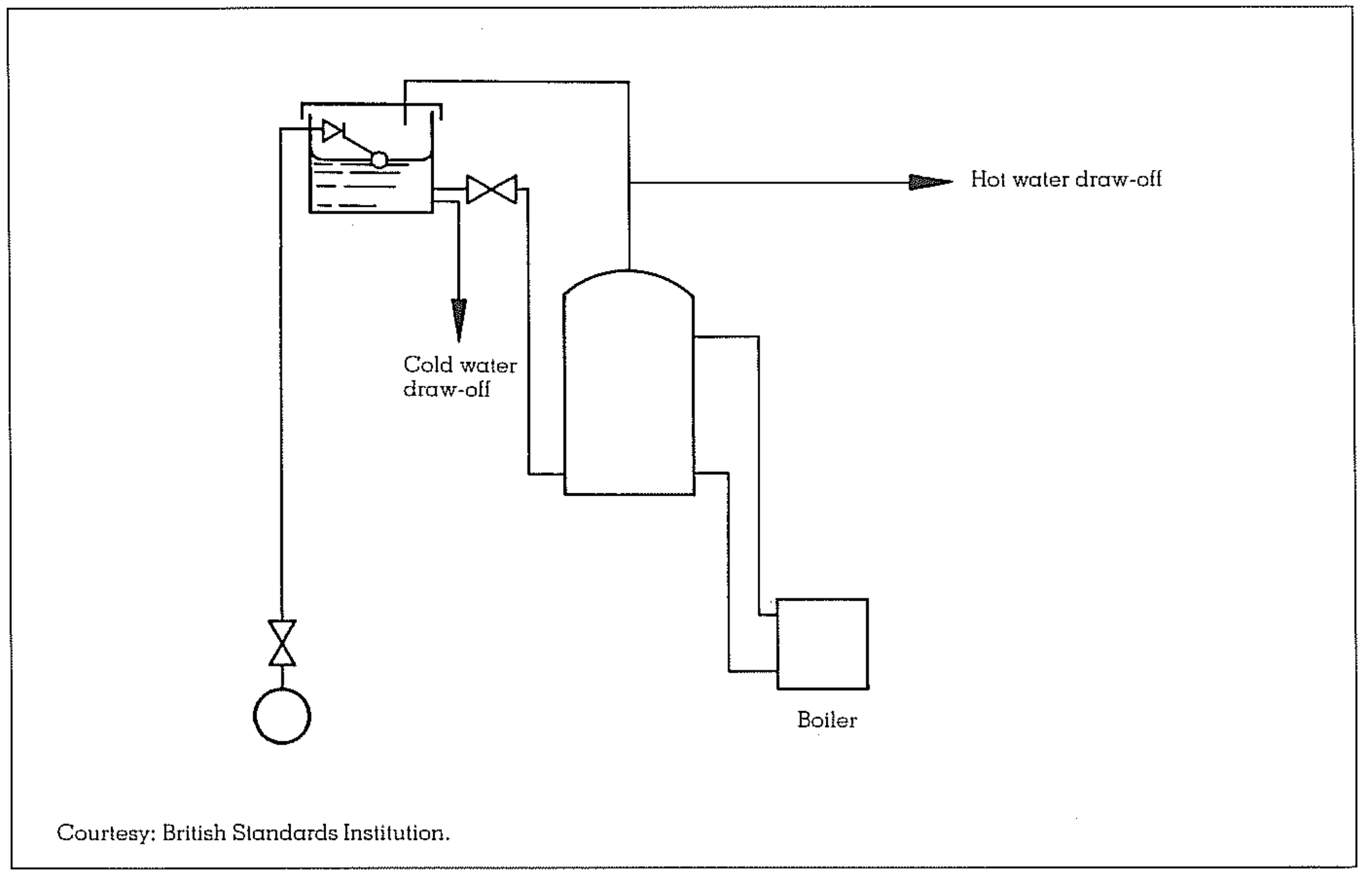
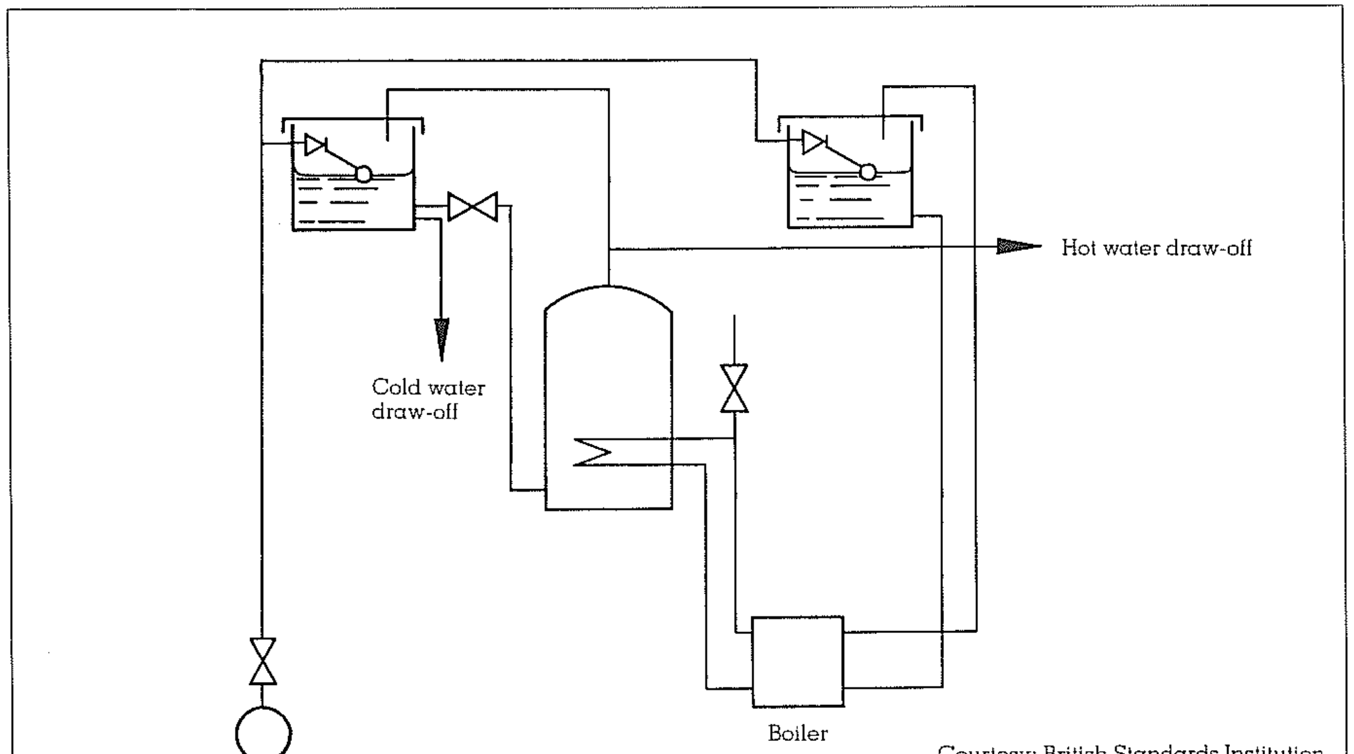


Figure 10 Direct (vented) system.



Courtesy: British Standards Institution.

Figure 11 Indirect (vented) system.

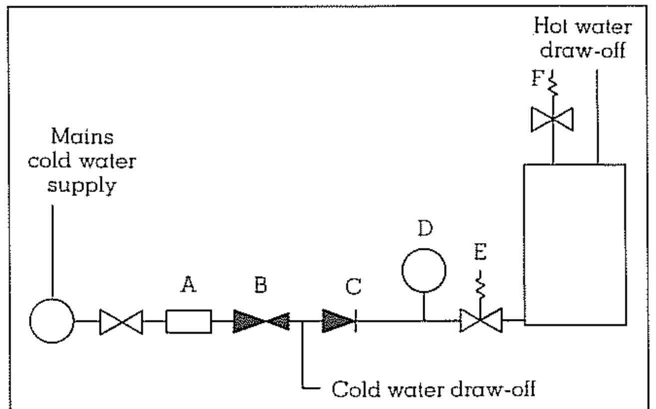
Combination type storage cylinders to BS 3198 incorporate the cold water feed cistern on top of the hot water cylinder. This type of storage cylinder must be installed at a high enough level to give adequate flow at the taps. The sole mechanical component in the open vented domestic hot water supply system is the ballvalve requiring occasional servicing. Hot and cold taps supplied from the same cistern means that balanced pressures are achieved without water hammer or outlet noise.

Unvented
The 1986 Model Water Byelaws permit bulk storage of hot water under mains or controlled pressure. The unvented storage cylinder can be connected directly to the mains or cistern fed and is without permanent venting.

Currently (May 1988), installation of these systems should comply with manufacturer's recommendations, the Building Regulations, the Model Water Byelaws and the British Board of Agrément certification. Section G3 of the Building Regulations states: "If hot water is stored and the storage system does not incorporate a vent pipe to atmosphere, there shall be adequate precautions to:

(a) prevent the temperature of the stored water at any time exceeding 100°C and

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



A – LINE STRAINER
B – INLET CONTROL VALVE
C – CHECK VALVE
D – EXPANSION VESSEL
E – EXPANSION VALVE
F – TEMPERATURE RELIEF VALVE

Figure 12 Diagrammatic arrangement of mains fed unvented hot water storage system.

Figure 12 illustrates the unvented domestic hot water system. The system shown can be supplied as a unit with all the ancillary equipment factory fitted and pre-set. The components included with the cylinder are:
A An in line strainer to ensure trouble free function of other devices downstream.
B A pressure regulating valve to BS 6283: Part 4 to overcome the fluctuations in pressure in the mains and supply water to the cylinder at a constant pressure.
C A check valve to BS 6282: Part 1 to prevent cross-flow between the hot and cold water supply.

D An expansion vessel to BS 6144 to accommodate the thermal expansion of the water.
E An expansion valve to BS 6283: Part 1 set to relieve pressure should the expansion vessel fail to accommodate the normal thermal expansion.
F A temperature relief valve to BS 6283: Part 2 or Part 3 set to open at 95°C max. and to discharge to waste. An air-break device is sometimes included to prevent implosion-collapse of the cylinder.

In addition to a thermostatic control to maintain the temperature of the stored water, a non-resetting energy cut out device to BS 3955: Part 3 should be incorporated.

In a directly heated system the thermal cut out should be on the storage cylinder. In an indirect system, the heating coil should only be connected to an energy supply fitted with a temperature operated energy cut out. (BR G3)

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

Pressure relief valves, expansion valves and temperature relief valves should comply with MWB 94 and 95. Accommodation of expansion water in cistern fed systems should comply with MWB 90. Accommodation of expansion water in systems connected to a supply pipe should comply with MWB 91. Capacity of the expansion vessel should comply with MWB 92. The cylinders can be heated directly (by gas or electricity) or indirectly. Indirect heating should be by double feed systems only.

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

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

Cylinders
All copper domestic hot water storage cylinders whether they be of the combination, open vented or unvented type, are manufactured from copper sheet to BS 2870 (C106, Phosphorus deoxidised non-arsenical copper) and factory tested to 1.5 times their working pressure, in compliance with the appropriate British Standard Specification. They should be installed with suitable means to facilitate isolation from the supply and draining down.

The primary heaters in double-feed indirect cylinders should be of the coil type manufactured from copper tube to BS 2871: Part 1 with a continuous fall to prevent the formation of air pockets.

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

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

Some immersion heaters are manufactured with copper sheathing around the heating element. Filler alloys used for brazing are of copper-silver-phosphorous or other corrosion resistant alloy which does not undergo dezincification and does not produce brittle joints, BS 3456: Part 2.21 refers. Silver-bearing alloys should comply with BS 1845.

Insulation of all hot water storage vessels should meet the requirements of the Building Regulations (BR L5). Factory insulated cylinders to BS 699, BS 1566: Parts 1 and 2 and BS 3198 meet this requirement.

Non-storage Systems
In this type of hot water heating system more commonly known as instantaneous water heaters, the water is heated as it passes through a copper heat exchanger. The heat source is either gas or electricity controlled automatically by the water flow. The heater operates on a minimum flow which should give a temperature rise of 55°C, the temperature rise at full flow is normally set at 45°C.

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

No provision is needed for expansion water in instantaneous water heaters. (MWB 91)

Another type of system is the water-jacketed tube heater or thermal storage unit (Figure 1). Here the water is heated as it passes through a copper heat exchanger contained within a copper cylinder of heated water in the primary circuit which can be vented or sealed. The cold water feed may be from the water main or from a storage cistern. When supplied directly from a main supply pipe the high pressure is contained within the coil, the cylinder is not pressurised. Expansion of the water must be accommodated such that there is no discharge from the system except in emergency situations. The amount of stored water in the cylinder (which in some designs can include the space heating circuit), the rate of heat input to it and the heat exchanger characteristics determine the amount and rate of flow of domestic hot water that can be provided without unacceptable temperature drop.

Solar Heating

Solar energy may be used to supplement a conventional domestic water heating system although in hot sunny weather solar energy may be sufficient to heat water to the required draw off temperatures. Many different designs of solar water heating systems are possible from simple direct feed gravity systems to more complex pumped circuits using two indirect storage cylinders or one cylinder with two indirect coils.

Detailed guidance on design and installation is contained within BS 5918.

Generally, solar collectors will be either the fin and tube, flat plate or evacuated tube type, all with selective surfaces: a selective surface is one that will achieve high absorptance and low emittance.

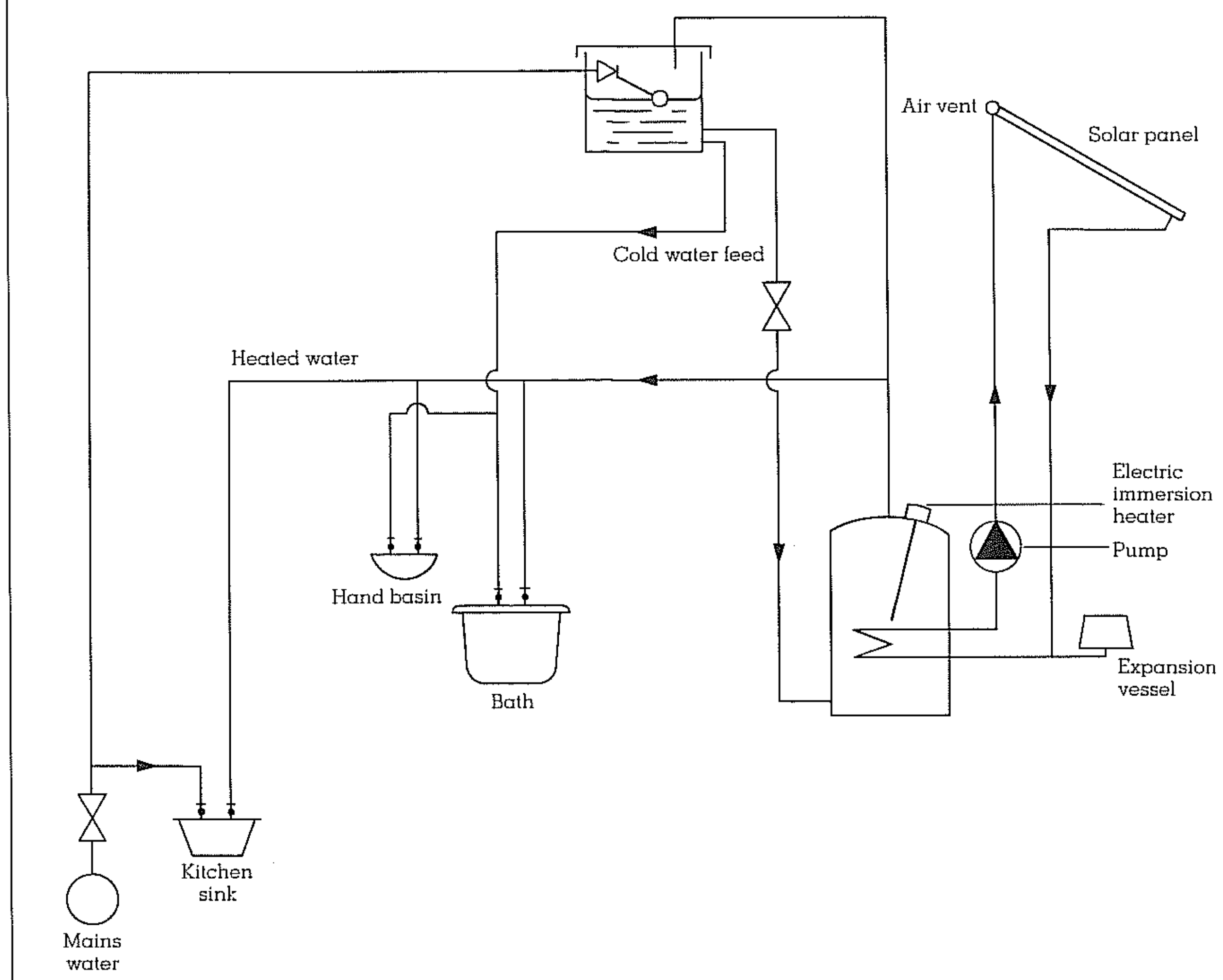


Figure 13 Schematic diagram of a pumped solar water heating system.

Because copper is a high thermal conductivity material it is important to ensure that in an all-copper domestic solar heating system all components apart from the exposed face of the collector are well lagged to prevent radiation loss to the external atmosphere and also the internal environment of the building. The conversion of incident solar radiation into usable heat in a solar heating system involves the transfer of heat through the body of the collector to the heat transfer fluid, which carries it away for storage and subsequent use. The efficiency of the thermal transfer is a function of the conductivity of the panel materials including the solder and the separate bonded tubes which may be spaced at greater distances with copper than with other materials of lower conductivity.

Systems requiring frost protection use non-toxic propylene glycol. It is advisable to have the glycol containing heat transfer fluid checked annually to ensure that excessive acidity has not been generated as this can increase the corrosivity of the heat transfer fluid.

A major factor in the selection of copper for solar heating systems concerns compatibility with other parts of the domestic hot water system. The most important mechanisms causing corrosion may be summarised as the presence of a) oxygen and b) mixed metal systems. A closed circuit system incorporates devices to allow for expansion and venting of the system hence reducing the pick-up of oxygen from the air and the single metal system reduces the susceptibility of components to corrosion, see Appendix C.

In designing the solar heating system it is advisable to ensure that water to be drawn off from the solar storage cylinder is always at a temperature no less than 55°C to prevent the growth of Legionella pneumophila, see Appendix D.

Solar Panels
The most common form of flat plate collector is the panel type, consisting of discrete waterways either formed integrally in the panel or separately from round or rectangular tube and attached to the collector plate by soldering, brazing or cleating. The solar generated heat is conducted from its point of origin to the nearest waterway, and then through the wall to the heat transfer fluid. Installers are advised to use high temperature solders to avoid the breakdown of joints under stagnation conditions. Temperatures of up to 200°C may be achieved in solar collector panels with matt black surface coatings.

Evacuated solar collectors use copper absorber plates contained within evacuated glass tubes. Heat is transferred to the water via a heat pipe with one end connected to the absorber plate and the other end immersed in the water in a manifold. Advantages of this system are: high efficiency due to the vacuum preventing heat loss from the absorber plate by conduction and convection, and ease of maintenance because failure of one collector tube only reduces the efficiency and does not cause a complete breakdown.

Heat Pipes
Heat pipes find uses not only in solar heating but also in heat recovery processes. A heat pipe is an hermetically sealed evacuated tube containing a mesh or sintered powder wick and a working fluid in both the liquid and vapour phase. When one end of the tube is heated the liquid turns to vapour absorbing the latent heat of vaporisation. The hot vapour flows to the colder end of the tube where it condenses and gives out heat. The use of the latent heat of the fluid enables heat to be transferred at 500 to 1000 times the rate compared with a solid metal rod and at temperature differences between the ends of the pipe as low as 2°C. Although the thermal conductivity of the materials of construction are not critical in heat pipe applications copper is widely used due to the requirement for a material compatible with a wide range of working fluids including organic fluids and water. This, together with the ready availability of suitable size tube, mesh and powder sizes coupled with the overall ease of fabrication makes copper a prime candidate material.

Appendix A

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

			TABLE W	TABLE X	TABLE Y	TABLE Z
	Outside diameter					
Size of tube	maximum	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	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.

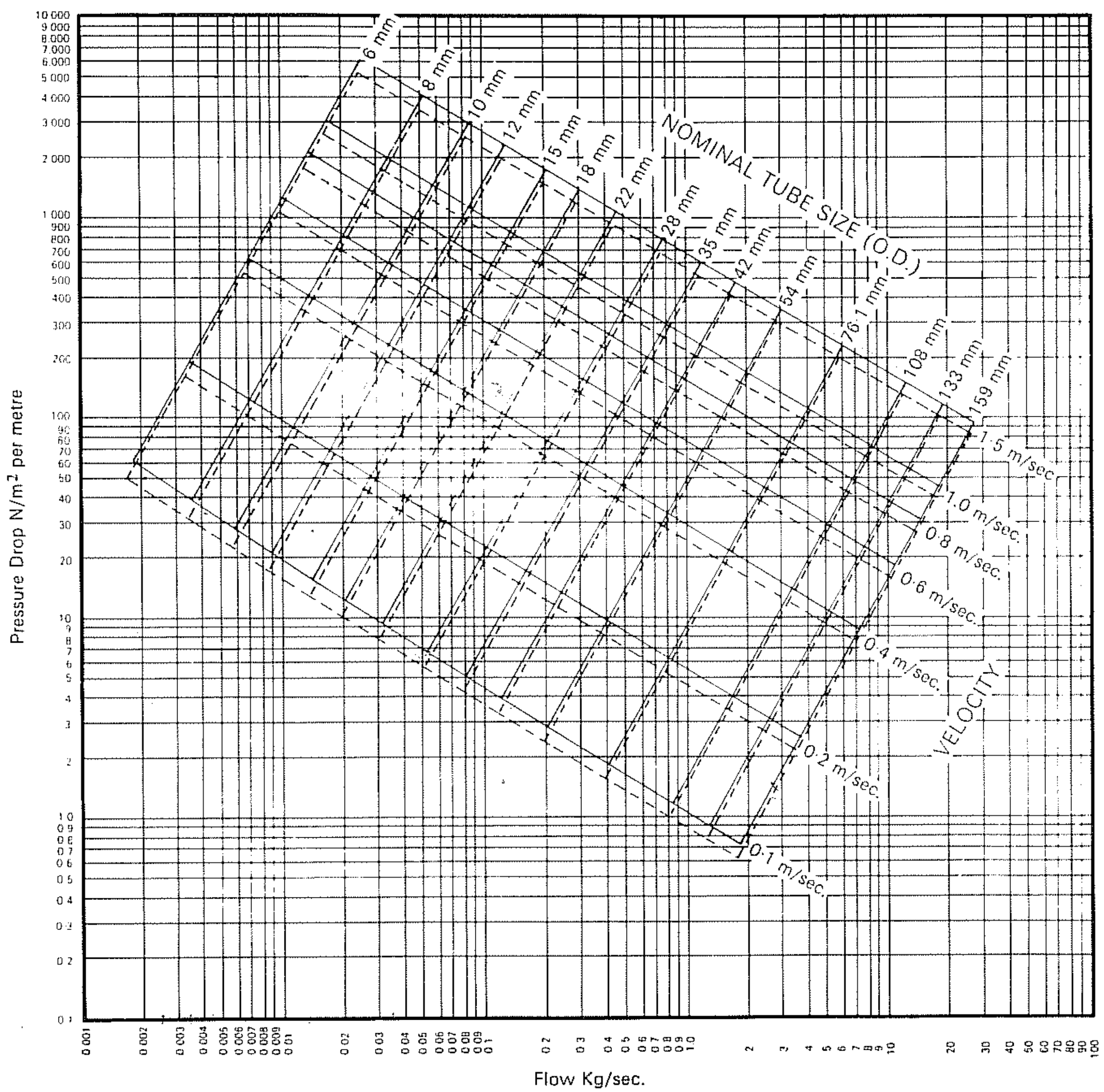
Appendix B

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

N.B. Values of water flow resistance through copper tube to BS 2871: Part 1, Table W are equivalent to those for Table X.

———— 65°C

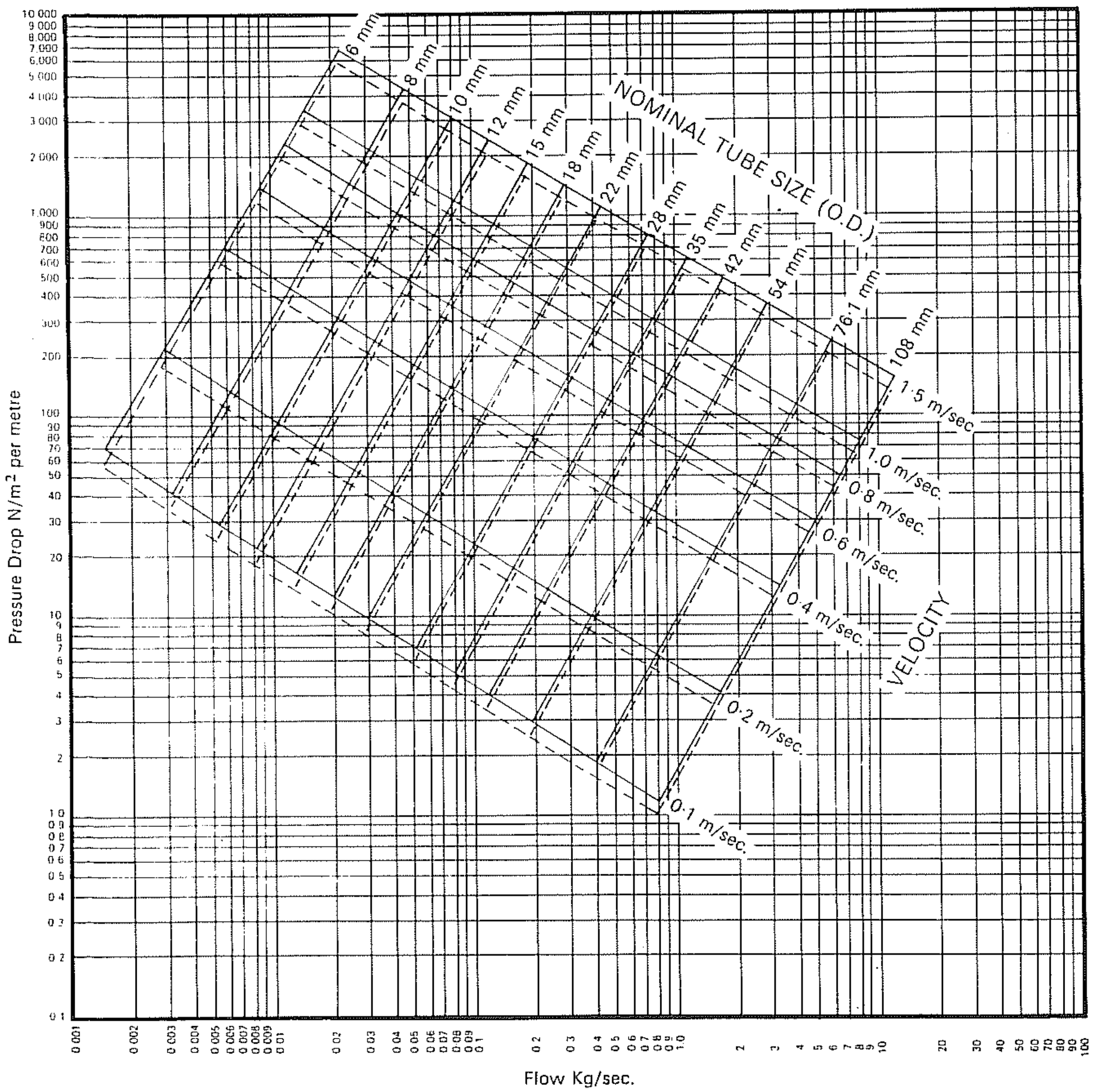
- - - - - - - 115°C



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

———— 65°C

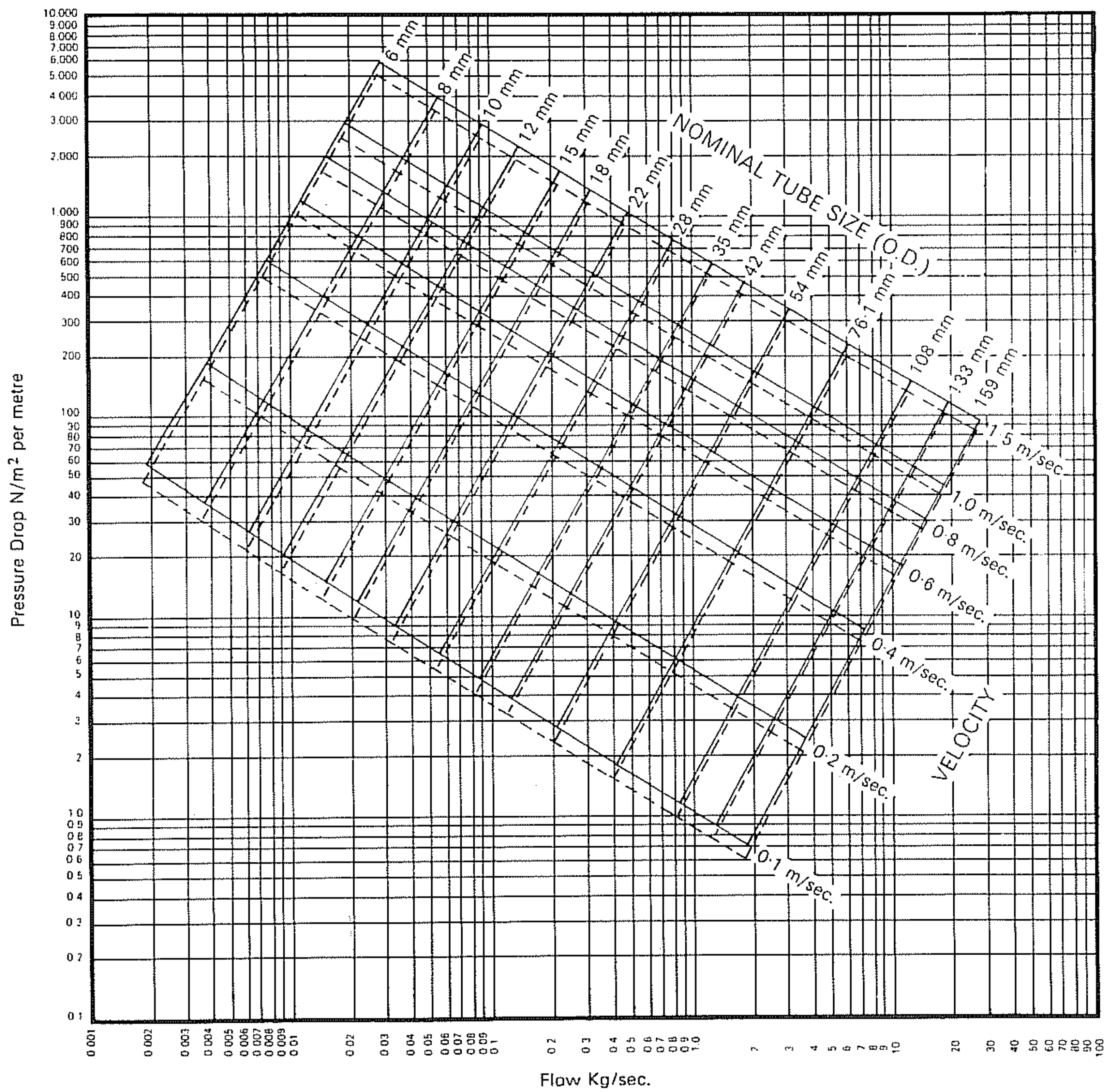
– – – – – – 115°C



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

———— 65°C

– – – – – – 115°C



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

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)
					D/1 D/1									
	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

Appendix B (cont.)

EQUIVALENT LENGTHS IN METRES

Twin elbow (compression)		Twin elbow (capillary)		Bend (compression or capillary)	Return bend (compression)		Return bend (capillary)	Reducer (compression or capillary)		Angle valve	Gate valve	Stop-cock	Temp of water (°C)	Nominal size (mm)
								D1/D2 = 2	D1/D2 = 3					
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)	EQUIVALENT LENGTHS IN METRES: Tee (compression or capillary)			Reducing tee (compression or capillary)		Pitcher tee (compression)			Pitcher tee (capillary)			Elbow (compression)	Elbow (capillary)
		[fitting diagram]	[fitting diagram]	[fitting diagram]	D'2 D'1 / D [fitting diagram]	[fitting diagram]	[fitting diagram]	[fitting diagram]	[fitting diagram]	[fitting diagram]	[fitting diagram]	[fitting diagram]		
	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

EQUIVALENT LENGTHS IN METRES: Twin elbow (compression)		Twin elbow (capillary)		Bend (compression or capillary)	Return bend (compression)		Return bend (capillary)	Reducer (compression or capillary)		Angle valve	Gate valve	Stop-cock	Temp of water (°C)	Nominal size (mm)
[fitting diagram]	[fitting diagram]	[fitting diagram]	[fitting diagram]	[fitting diagram]	[fitting diagram]	[fitting diagram]	[fitting diagram]	D1/D2 = 2	D1/D2 = 3					
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	0·61	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	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)		Angle valve	Gate valve	Stop-cock	Temp of water (°C)	Nominal size (mm)
								$\frac{D1}{D2}=2$	$\frac{D1}{D2}=3$					
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	

Appendix C
Corrosion in Heating Systems

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

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

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

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

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

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

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

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

2) Bimetallic corrosion.
Where dissimilar metals are exposed in oxygenated water, one of them, the less 'noble', will be corroded preferentially by galvanic action. In mixed metal systems, the metals most likely to be attacked are aluminium, steel and iron. If the less noble metal has a large surface exposed, as in a steel radiator, a small amount of corrosion can be tolerated.

3) Pitting corrosion.
Where excessive flux residues are present it is possible for localised corrosion to develop in the form of pits which may eventually penetrate the tubes in the form of pinholes. Manufacturers' recommendations for neutralisation and removal of flux residues should therefore be followed.

Pitting corrosion of copper tubes carrying fresh water in once-through or supply systems has occurred in certain areas where the water supply is aggressive. This was found to be due to the presence of surface films inside the tube; these are now removed by the manufacturer as a condition required by BS 2871. The BS 'Kitemark' gives this assurance.

In some areas where the water supply is very aggressive, pitting corrosion of supply pipes does still occur. Information on this can be found in CDA Technical Note TN33 'Copper Tube in Domestic Water Services'.

Corrosion Inhibitors.
In systems operating under ideal conditions, the use of corrosion inhibitors should not be necessary. The addition of recommended corrosion inhibitors can give extra protection during commissioning and working life and also in the event of slight variations from optimum operating conditions. Inhibitors should not be used when indirect single-feed cylinders are used. (MWB 37)

Appendix D
Legionella in Heating and Hot Water Service Systems

The bacterium Legionella pneumophila is probably present to some degree in all water systems. Since the recent outbreaks of Legionnaires' Disease a number of measures have been recommended to prevent multiplication of the bacteria. Two main factors which are known to decrease the multiplication rate of Legionella pneumophila are elevated temperature (above 46°C) and the dosing of water systems with free chlorine; (TN33 Appendix D – corrosion of copper systems when charged with 20–50ppm free chlorine for long periods). A number of materials have been recognised as potential sources of growth of the bacteria, copper as a bactericide however 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.

The optimum temperature for multiplication of the bacteria in the laboratory, as stated in the CIBSE Technical Memoranda TM13, is around 37°C. At higher temperatures the rate of multiplication of bacteria in the laboratory decreases and at 46°C it falls to zero. Bacteria will survive at higher temperatures but the survival time decreases from a matter of hours at 50°C to one of minutes at 60°C and practically zero at 70°C. For these reasons there is no viable legionella in space heating systems using hot water radiators operating at around 80°C. With respect to hot water systems, any residual free chlorine in the mains supply water rapidly disappears on heating. The main protection against multiplication of the bacteria is therefore temperature control and system cleanliness. The recommendation is to store water centrally at 60°C and to distribute water at temperatures no less than 50°C. Due regard must be taken here 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 (TN 33) and in hard water areas this situation will increase the precipitation of hardness salts in the pipes and cylinders. Thus cylinders 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. In copper systems viable organisms that have survived heating to temperatures above 50°C may be discouraged from multiplying in the downstream water. It should be recognised however that the presence in the water system of other unsuitable materials may protect the organism from the relatively hostile environment within a copper cylinder and pipes.

References

British Standard Specifications and Codes of Practice

BS 699 Specification for copper direct cylinders for domestic purposes.

BS 864 Capillary and compression tube fittings of copper and copper alloy.
Part 2 Specification for capillary and compression fittings for copper tubes.

BS 1212 Specification for float operated valves (excluding floats)
Part 2 Diaphragm type (brass body)

BS 1566 Copper indirect cylinders for domestic purposes.
Part 1 Specification for double feed indirect cylinders.
Part 2 Specification for single feed indirect cylinders.

BS 1845 Specification for filler metals for brazing.

BS 2870 Specification for rolled copper and copper alloys: sheet, strip and foil.

BS 2871 Specification for copper and copper alloys. Tubes.
Part 1 Copper tubes for water, gas and sanitation.

BS 2872 Specification for copper and copper alloys. Forging stock and forgings.

BS 2874 Specification for copper and copper alloys. Rods and sections (other than forging stock)

BS 2879 Specification for draining taps (screw down pattern).

BS 3198 Specification for copper hot water storage combination units for domestic purposes.

BS 3456 Specification for safety of household and similar electrical appliances.
Part 2.21 Electric immersion heaters.

BS 3955 Specification for electrical controls for household and similar general purposes.

BS 4814 Specification for expansion vessels using an internal diaphragm, for sealed hot water heating systems.

BS 5154 Specification for copper alloy globe, globe stop and check, check and gate valves.

BS 5449 Code of Practice for central heating for domestic premises.
Part 1 Forced circulation hot water systems.

BS 5482 Code of Practice for domestic butane – and propane – gas-burning installation.
Part 1 Installations in permanent dwellings.

BS 5918 Code of Practice for solar heating systems for domestic hot water.

BS 6144 Specification for expansion vessels using an internal diaphragm, for unvented hot water supply systems.

BS 6282 Devices with moving parts for the prevention of contamination of water by backflow.
Part 1 Specification of check valves of nominal size up to and including DN54.

BS 6283 Safety devices for use in hot water systems.
Part 1 Specification for expansion valves for pressures up to and including 10 bar.
Part 2 Specification for temperature relief valves for pressures up to and including 10 bar.
Part 3 Specification for combined temperature and pressure relief valves for pressures up to and including 10 bar.
Part 4 Specification for drop-tight pressure reducing valves of nominal size up to and including DN54 for supply pressures up to and including 12 bar.

BS 6700 Design, installation, testing and maintenance of services supplying water for domestic use within buildings and their curtilages.

BS 6891 Specification for installation of low pressure gas pipework of up to 28mm (R1) in domestic premises. (2nd family gases)

British Standards Institution, 2 Park Street, London W1A 2BS

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