BRITISH STANDARD

BS 6880-2:
1988

Code of practice for

Low temperature hot water heating systems of output greater than 45 kW —

Part 2: Selection of equipment

UDC 621.181.25:621.18.064:697.27:697.326

Committees responsible for this British Standard

The preparation of this British Standard was entrusted by the Refrigeration, Heating and Air Conditioning Standards Committee (RHE/-) to Technical Committee RHE/23, upon which the following bodies were represented:

Association of Consulting Engineers
British Combustion Equipment Manufacturers' Association
British Gas plc
Building Services Research and Information Association
Chartered Institution of Building Services Engineers
Department of Health and Social Security
Department of the Environment (Property Services Agency)
Electricity Supply Industry in England and Wales
Health and Safety Executive
Hevac Association
Institute of Refrigeration
Institution of Gas Engineers
Ministry of Defence
Royal Institute of British Architects
Sealed Expansion Vessel Association

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Contents

Foreword

This Part of BS 6880 has been prepared under the direction of the Refrigeration, Heating and Air Conditioning Standards Committee.

BS 6880 is published in three Parts which together form a full technical revision of CP 341.300-307:1956 which is withdrawn.

This Part gives recommendations on the selection of equipment for low temperature hot water heating systems.

The other two Parts are:

— *Part 1: Fundamental and design considerations;*

— *Part 3: Installation, commissioning and maintenance.*

The policy adopted when writing this code has been to avoid repetition of material for which other bodies are the accepted authority, except in so far as limited extraction assists the understanding of this code. Consequently the code provides general recommendations only on certain topics. References in this category are as follows.

a) For detailed procedures:

1) publications of the Chartered Institution of Building Services Engineers (CIBSE), particularly:

i) CIBSE Guide [1];

ii) CIBSE Building Energy Code [2];

iii) technical memoranda relating to fire in buildings;

iv) practice notes relating to provision of combustion and ventilation air for boiler installations;

2) handbooks published by the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE).

b) For detailed commissioning arrangements:

1) CIBSE commissioning codes;

2) application guides published by the Building Services Research and Information Association (BSRIA).

It should be noted that references to such applications are deemed to refer to the current edition, whereas specific extracts reproduced in this code are from the edition current at the time of preparation of this code.

Whilst the recommendations made in this code generally relate to current practice, they are not intended to inhibit the use of innovative systems or equipment which an experienced designer considers appropriate to the application, and which meet all statutory requirements and the safety and general good practice recommendations of this code. It is desirable that the principal interested parties should be made aware of such proposals at the design stage.

Reference is made in the text to a number of Acts of Parliament and to various regulations made under them. Such lists are necessarily incomplete, and in any particular circumstance the users of this code should acquaint themselves with the relevant regulations in force at the time. Attention is drawn to the requirements of the Building Regulations of England and Wales, of Scotland, Northern Ireland and of Inner London.

Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 82, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

Section 1. General

1.1 Scope

This Part of BS 6880 gives recommendations regarding the types of low temperature hot water (see **1.2.1**) heating equipment which are in common use and the selection of such equipment when designing low temperature hot water heating systems of output greater than 45 kW, open vented or sealed. It is primarily intended for use by building owners, building managers, installers and associated professionals. It is not intended to serve as a detailed design guide (see foreword).

The recommendations recognize the need to optimize the use of energy, reduce hazards and minimize effects detrimental to the environment.

Solar heating is outside the scope of this code.

NOTE The titles of the British Standards publications referred to in this standard are listed on page 82. References in the text to other publications are identified in the text by numbers in square brackets, and are listed in Appendix A.

1.2 Definitions

For the purposes of this Part of BS 6880 the definitions given in BS 1523, BS 3533 and BS 5643 apply together with the following.

NOTE See also the CIBSE Building Energy Code [2].

1.2.1
low temperature hot water (LTHW)

water used as the heating medium such that its temperature does not exceed 100 °C at any point in the system, whether open or sealed

NOTE Various safety considerations may require that the actual design flow temperature of an LTHW system should be significantly less than 100 °C (see Section B.1 of the CIBSE Guide [1], HSE Guidance Note PM5 [3] and section 3 of BS 6880-1:1988).

1.2.2
boiler

an appliance designed for heating water either for space heating or for space heating combined with hot water supply

1.2.3
heat emitters

equipment emitting heat for the purpose of space heating

NOTE This equipment includes radiators, convectors, skirting heating and radiant panels.

1.2.4
radiator

a unit for space heating that warms the air by convection and provides radiation

Section 2. Principal equipment groups and standards

2.1 Principal equipment groups

The following classification into subsystems (see also **3.1** of BS 6880-1:1988) is used in this code.

a) *Utilization equipment* (see section 3). This is further classified in terms of natural convectors, forced convectors and floor, wall and ceiling panel systems.

b) *Distribution equipment* (see section 4). This includes circulating pumps and other equipment associated with distribution of LTHW from energy conversion to utilization equipment.

c) *Energy conversion equipment* (see section 5). This is further classified in terms of boilers and combustion equipment, boiler ancillaries and unfired heat sources (see **3.1.4** of BS 6880-1:1988).

d) *Automatic controls, instrumentation and monitoring* (see section 6). These are considered in relation to individual subsystems and the overall system.

2.2 Equipment standards

2.2.1 New and existing equipment

This code presupposes that new equipment is being installed. Where it is proposed to modify an existing installation or retain elements of it in an otherwise new installation, the extent of reuse of equipment should be established and understood by all interested parties at the outset, and steps taken to ensure its fitness for the purpose intended and compatibility between new and existing elements.

2.2.2 Compliance with British Standards

Equipment and materials should comply with British Standards where applicable.

2.2.3 Uniformity of equipment

Equipment intended to be similar which is incorporated in systems forming part of a single installation should be of uniform type and manufacture, to the extent that the needs of the application and performance factors allow.

2.2.4 Statutory compliance

Attention is drawn to the need for all equipment supplied for use in LTHW heating installations to meet the requirements of all relevant UK legislation (see **2.4** of BS 6880-1:1988); in addition to matters of safety this may extend to energy conservation and other matters. It is desirable that each individual item of equipment should so comply on arrival at the job site; it is necessary that it should so comply before putting it into use.

2.2.5 Energy conservation

It is a recommendation of this code that any LTHW system should at least meet the minimum energy conservation recommendations of the CIBSE Building Energy Code [2] (see **2.5** of BS 6880-1:1988). This includes certain recommendations in respect of the performance of individual items of equipment, noting that there may also be overruling statutory requirements in this context.

Section 3. Utilization equipment

3.1 Natural convectors: types

3.1.1 General

This clause considers various types of heat emitter which operate primarily by natural convection, both unitary and continuous (or perimeter) types. Unitary types are individually connected to the LTHW distribution subsystem. A number of such emitters may be used on one system, of various sizes; in certain circumstances a system may include more than one type. Thermal ratings, construction, test pressures, etc. are covered by BS 3528, with which they should comply. See also Table B.1.39 of the CIBSE Guide [1].

3.1.2 Radiators

3.1.2.1 *General.* Despite their name, approximately 70 % of the heat emission from LTHW radiators is by natural convection; some types use extended surfaces to increase the convective effect. The principal distinction between radiators and unitary natural convectors (see **3.1.5**) is that in the former, the heat emitting surface is normally directly exposed to the room, unless guards are fitted. They are very widely used and are available in various types, materials and finishes for unit outputs up to around 6 kW.

3.1.2.2 ***Construction***

3.1.2.2.1 *Panel type.* This is the most common type, usually manufactured from steel pressings welded together. These are commonly available as single panels and double panels (two single panels operating as one parallel connected unit) and variants of these with extended convection surfaces, often termed convector radiators. It should be noted that heat emission occurs from both front and back surfaces (see **3.2.3.7** of BS 6880-1:1988 in respect of back loss), also that the output of double panel radiators is significantly less than twice that of the corresponding single panel type.

They are usually manufactured in a limited number of standard heights primarily selected to suit installation below windows, different outputs are obtained by variation of length over a wide range, usually in small modular increments. The method of forming the top edge may be a relevant safety consideration in certain applications, in which case smooth edge types are preferable.

Steel panel radiators are particularly prone to corrosion and the recommendations of **3.5** of BS 6880-1:1988 should be followed.

The development of LTHW heating systems operating at lower temperature levels than associated with conventional boiler practice may promote the introduction of panel type radiators made of plastics; in the absence of appropriate British Standards, particular care would be required in selection, installation and determination that the quality of such an installation is adequate for the application (see **2.6.1** of BS 6880-1:1988).

3.1.2.2.2 *Column type.* These consist of separate vertical sections in a limited number of heights and widths, which are bolted together and sealed. The number of such sections determines the thermal output and overall length of the radiator. Each individual section has water passages formed within it, usually by casting. Construction is normally of cast iron or cast aluminium alloy, but pressed steel types also exist. The cast iron type tend to be much heavier than the steel panel. Cast types tend to have superior resistance to corrosion so that they may last considerably longer, and their superior strength can be an advantage in situations exposed to damage. Their width is considerably greater which affects projection distance from walls which can be critical in many applications. Cast iron column radiators were almost universally used at one time, but were then largely replaced by the steel panel type. However, cast column radiators still find application where long life is important or where features related to the variety of shape inherent in the casting process are important, such as cleanability or aesthetic effects. The use of cast aluminium radiators in a ferrous piping system has particular implications in respect of system corrosion and water treatment (see **3.5** of BS 6880-1:1988).

3.1.2.3 *Other features.* Panel radiators are normally wall mounted; the number of supports depends on the length, and all the support points provided should be used.

Fixing considerations are particularly important with the heavier types of column radiators. These can be wall mounted, but for the heavier types floor mounting with a top stay to a wall is preferable, with attention to sufficient space underneath for air flow and cleaning. The number of supports recommended by the manufacturer should be used and unsupported lengths exceeding 20 sections are not recommended. Particular care is required where any radiators are to be fixed to walls or partitions of light construction, which may call for use of special fixings and additional supports or stays. Radiators need to be readily removable for decoration.

Whilst radiators of various heights may be used on one system, some standardization of heights is desirable and these should follow a consistent pattern in relation to radiator location. Mounting height should also be related to the needs of floor cleaning equipment, electrical installations at skirting level, etc.

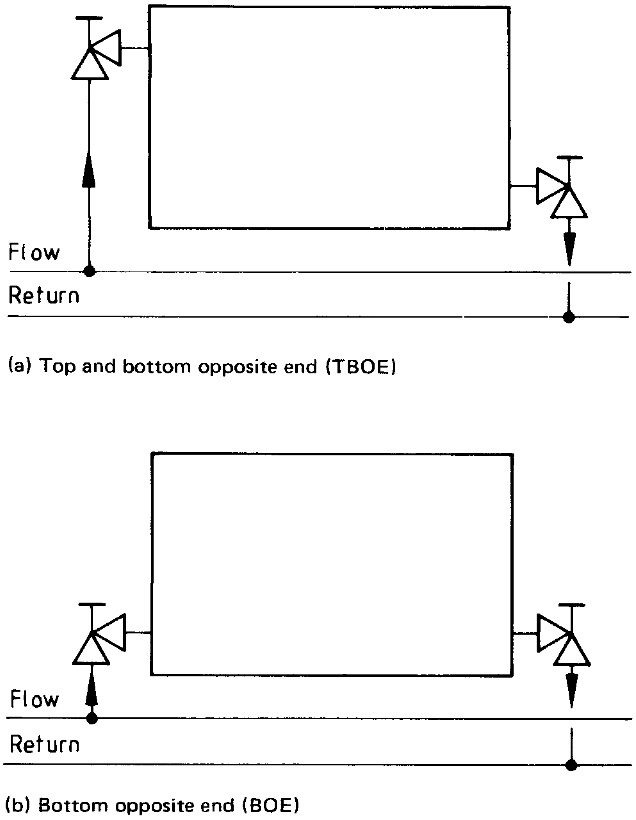


Figure 1 — Common radiator connections

Each radiator requires screwed connections for pipe entry and an air release cock at high level. The most efficient configuration is top flow, bottom return at opposite end, and is used for type testing purposes unless specified; however bottom flow, bottom return at opposite end is often preferred, although emission is reduced (see Figure 1).

Steel and cast iron radiators are normally only supplied with a protective finish and site decoration is usually necessary. Surface finish and various architectural features can affect thermal output (see Table B.1.5 of the CIBSE Guide [1]).

The temperature of radiator surfaces may be close to the system flow temperature, contributing a possible hazard for certain types of occupant, in which case safety guards may be appropriate (see **2.4.4.1** of BS 6880-1:1988). Accessories are available for certain types of radiator to direct convection currents away from walls to avoid staining of decorations.

3.1.3 Radiant panels

3.1.3.1 *General.* In principle radiant panels operate in a similar manner to radiators, but individual units are relatively large (typically 2.4 m × 1.2 m with an output of the order of 2 kW) and their construction is different since they are primarily used in industrial applications. They are designed mainly for use with higher temperature water or steam; they can be used with LTHW, but the reduction in output compared to high temperature hot water (HTHW) or steam tends to make them less suitable, except where low mounting heights preclude the use of higher temperature media.

3.1.3.2 *Construction.* Radiant panels usually take the form of a continuous circulating steel tube welded to a flat steel plate, such that operation at relatively high system pressure is possible. In some types the steel tube is exposed in others it is concealed behind the plate. The tube should be slightly pitched to facilitate drainage where the unit is mounted level. Various options exist, including enclosure and insulation of the reverse surface. Tube ends can be plain, screwed or flanged.

3.1.3.3 *Other features.* Mounting is by rod suspension or brackets connected to integral lugs. Dark finishes are preferable, to enhance radiant effect. Maintenance requirements are generally low.

In aggressive industrial atmospheres special finishes may be necessary. Relative freedom from the effects of dust is relevant to many industrial situations, and can be a particularly useful feature where cleanability and absence of dust trapping are important for safety reasons, since this type of panel can be built into a flush wall surface.

They can be mounted in a variety of ways, i.e. vertically, horizontally or inclined. This provides flexibility in industrial situations, particularly where overhead cranes are used. Back-to-back pairs are also used. When mounted horizontally to radiate downwards, a significant proportion of heat output is radiant when mean temperature is above 70 °C.

3.1.4 Continuous radiant strip

A continuous radiant strip takes the form of one or more parallel steel tubes welded to a steel strip surface and is made in standard lengths (typically up to 6 m). These are joined on site to form continuous lengths. Insulated and uninsulated types are available, also closing pieces to conceal the junction between sections. Applications of this type are mainly industrial, mounted horizontally overhead. Output in LTHW may be up to about 500 W/m run.

Supports should be spaced as recommended by the manufacturer and provision made in the installation for thermal expansion, venting and draining.

In addition to industrial applications, types are also available as a form of overhead perimeter heating for commercial and other types of building, by incorporation into false ceilings, cornices, etc.

3.1.5 Unitary and continuous convectors

3.1.5.1 *General.* Unitary and continuous convectors operate by convective heat transfer inducing an upwards movement of room air over a finned tube or other extended surface heating element, but one which is not directly exposed to the room itself. The radiant component of heat transfer is therefore secondary, and relatively small; also the temperatures of exposed surfaces are rather lower than with radiators. Since this type of heat emitter is often used in continuous lengths, particularly for perimeter heating, the descriptions in **3.1.5.1** to **3.1.5.3** relate primarily to that type. However, unitary versions are also used; their operating principle is the same, and construction is similar, except that they are made as individual units which are connected to a distribution system in a similar manner to radiators. The range of sizes and outputs is roughly comparable to that of radiators, typically up to about 1 500 W/m run.

3.1.5.2 *Construction* (see Figure 2). The heating element is usually a finned tube arranged in the lower part of a casing such that air enters from underneath the unit and is discharged near the top. (See **3.3.4.2** in connection with the construction of finned tube elements.)

Output is largely determined by the number of tubes (not usually more than two), the fin spacing and tube configuration. With continuous convectors the configuration may be:

a) a single tube;

b) two tubes in parallel which connect to flow and return headers at opposite ends;

c) two tubes in series (one of which may not have fins) with a return loop, and headers at the same end.

With continuous convectors the heating elements are in effect part of the distribution system and therefore the piping configuration should be developed to suit the intended convector arrangement. Particular attention should be given to location of headers and to location of isolating and regulating valves so that the installation can be broken down into manageable sections for balancing, maintenance, etc.

The heating element is usually supported from a wall (but there are various other arrangements, see **3.1.5.3**) and the casing fixed to the wall independently, with or without a backplate, as appropriate. Consideration should be given to the appropriate wall finish behind the convector. Provision for thermal expansion of continuous heating elements is an important consideration. Manufacturers supply expansion units and guides, which should be used in accordance with their recommendations. Casings are usually of sheet metal construction with factory applied final finish, but a considerable variety of configurations and special features is available (see **3.1.5.3**). Appearance and harmonization with decor is usually important, and for prestigious accommodation, purpose-designed casings of special materials may be appropriate.

3.1.5.3 ***Other features***

3.1.5.3.1 *Casing configuration.* Principal types of continuous convector available are generally intended for perimeter application and include low height skirting types, the extensively used cill level type for installation below windows and various types of heated handrails, etc. for installation in front of glazing. There are also types arranged for installation beneath a horizontal, floor level grille. Various arrangements are used for the direction of air discharge, and some types are designed to discourage use as shelves. Particular attention should be given to the detail of the back surface when installed in front of windows. Unitary convectors have a form usually similar to the cill level type.

3.1.5.3.2 *Control dampers.* Manually operated dampers are available to reduce output by restriction of air flow, in sections. It is important to appreciate that this does not give on/off control and may only reduce output by about 50 %.

3.1.5.3.3 *Coordination with building.* A continuous convector installation requires careful coordination with the building design and finished site dimensions should be checked before supply of components to site in all but the simplest installations. Particularly important are the details at projecting internal columns, corners and partition abutments. Staining of walls by air leakage between wall and casing should be avoided. Various matching accessories are available (closing pieces, corner pieces, "dummy" sections, valve boxes, internal baffles, seals, etc.) and they should be used where appropriate. In some types of building the extent to which a perimeter heating installation projects from the wall may have important implications. Some occupancies may call for special features to discourage tampering; these are available from some manufacturers. Consideration should be given to clear access underneath for floor cleaning equipment and air inlet, when determining mounting height.

3.1.5.3.4 *Coordination with other services.* Care is required regarding coordination with other services when planning continuous convector installations, particularly at skirting level in offices. Some continuous convector systems provide for incorporation of electrical services; where this is the case, the appropriate electrical safety requirements should be met (see **3.9** of BS 6880-1:1988) and the segregation requirements of any relevant communications or information systems cabling.

3.1.5.3.5 *Acoustic considerations.* Whilst natural convectors are normally quiet in operation, noise may arise from thermal expansion of the heating element, which calls for care in installation and use of appropriate accessories. There is also the possibility of water system noise (see **2.2.7** of BS 6880-1:1988) and of flanking transmission around abutting partitions, which calls for internal sound baffles. These should be purpose-made accessories where available.

3.2 Natural convectors: selection factors

3.2.1 Common factors

The following factors need to be considered for all types of natural convector.

a) Design LTHW flow and return temperatures and room temperature.

b) Required heat output and distribution of heat (see also BS 3528).

The heat output q (in kW) of all natural convectors can be derived from the equation:

$$q = k\,(t_{\mathrm{m}} - t_{\mathrm{ai}})^n$$

where

- k is a constant for a given type and size of convector;
- t_{m} is the mean temperature of LTHW (in °C);
- t_{ai} is the room air temperature (in °C);
- n is an index, typically 1.3 for radiators and 1.27 to 1.35 for other types.

(See Section B.1 of the CIBSE Guide [1] and BS 3528.)

Mixing of radiators and other natural convectors on the same circuit should preferably be avoided (see **3.4.2.3** BS 6880-1:1988).

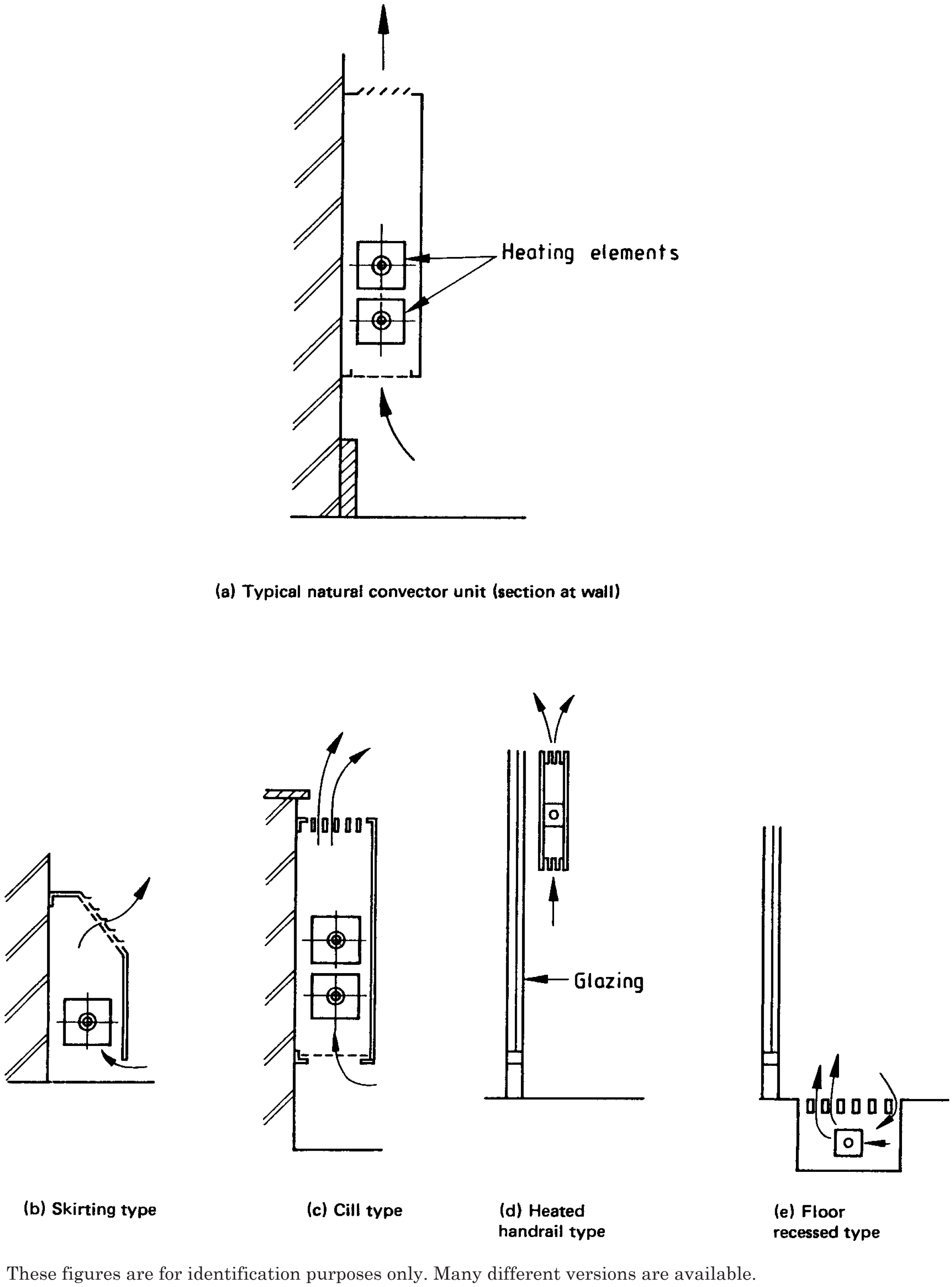
c) Method of control of output (see **3.1.5.3.2**) particularly whether individual unit control is required.

d) Location, particularly in relation to external walls, windows and mounting height.

e) Emitter surface temperature (wherever special safety considerations apply).

f) General configuration, appearance and surface finish.

g) Hydraulic resistance: particular care is required in the use of natural convectors on single-pipe systems for which special provisions may be necessary (manufacturers should be consulted in specific cases). The effect of low emitter resistance or control by individual valves should be noted (see **3.8.3.4** of BS 6880-1:1988).



NOTE These figures are for identification purposes only. Many different versions are available.

Figure 2 — Typical continuous natural convector types (section at wall)

h) Working pressure: BS 3528 calls for a minimum working pressure of 3.5 bar[1]. Certain types of radiator can be built to exceed this pressure if necessary. Emitters using steel tube elements are usually rated for considerably higher pressures than copper tube types.

NOTE The test pressure is not to be less than twice the working pressure.

i) Water content: there can be significant differences between individual types which may be relevant to speed of control response in certain situations.

NOTE The use of natural convectors to heat outside air by uncontrolled admission through a wall opening behind the unit is not recommended, although common at one time. For this reason no reference has been made to fresh air heating.

3.2.2 Particular factors

The following factors need to be considered for certain types of natural convector.

a) Water velocity: most types of continuous tube heating element have a minimum water velocity which should be maintained to achieve satisfactory heat transfer. This is particularly relevant to calculation of pressure drops in continuous convector or radiant strip systems.

b) Casing height and configuration usually offer many options (see **3.1.5**), and these can influence heat output significantly.

c) Tube and fin configuration and materials for continuous and unitary convectors (see **3.1.5**).

d) Form and material of radiators (see **3.1.2**) and internal corrosion protection.

e) Height and length of radiators (output is based on length variations within a range of standard heights).

f) Mounting height and row spacing of overhead radiant strip: minimum mounting heights apply (typically around 3 m with conventional LTHW temperatures) and relationship of row spacing to height above working plane is important (typically this should be less than 1.5 m but manufacturer should be consulted in specific cases).

g) Insulation of the back of heat emitters where heat transmission in that direction is undesirable.

Where natural convection heating elements are installed without their own casing in architectural enclosures, it is particularly important to prevent air from bypassing the heating element due to end leakage, etc.

3.3 Forced convectors: types

3.3.1 General

This clause considers various types of heat emitter which operate by forced convection, i.e. air is forced over a heating element, usually by a fan (see Figure 3 and Figure 4).

Forced convectors have many aspects in common with ventilation and air conditioning equipment including factors such as air movement and elements such as fans, air filters, ducts, diffusers, etc. This code deals with aspects specific to LTHW heating only and reference should be made to BS 5720 in respect of air movement and air treatment of forced convection heating installations.

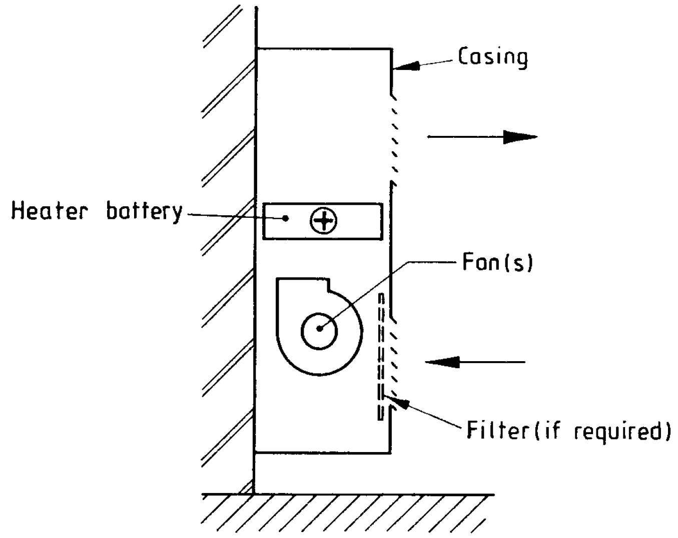
3.3.2 Fan convector and fan coil units

[see Figure 3(a)]

3.3.2.1 *General.* Since the principle of operation is the same, there is no fundamental difference between fan convectors and other unit type forced convection air heaters. However, for the purposes of this code fan convectors are regarded as those suitable for use in office and institutional accommodation, as distinct from industrial use. Fan coil units are mentioned since they may be used for heating, and in that respect similar considerations apply as for fan convectors. However, since they are usually associated with air conditioning they are not considered separately here; for further information and recommendations see BS 5720. Heating performance of both types is covered by BS 4856. A wide range of outputs is available, typically up to about 25 kW and 0.5 m^3/s of air volume.

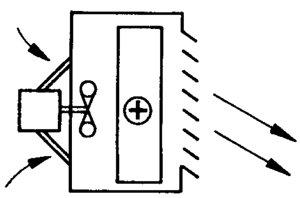
3.3.2.2 *Construction.* The heating element is usually of fin and tube construction, as described under **3.3.4.2**. System corrosion implications should be considered and appropriate measures adopted (see **3.5** of BS 6880-1:1988).

[1] 1 bar = 10^5 N/m^2 = 100 kPa.

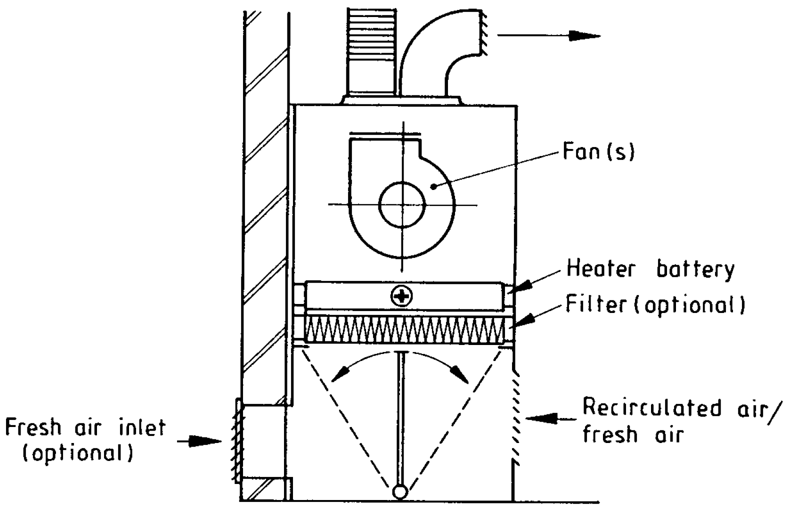


NOTE. A fan coil unit is similar in principle but may incorporate a cooling coil.

(a) Fan convector (section at wall)



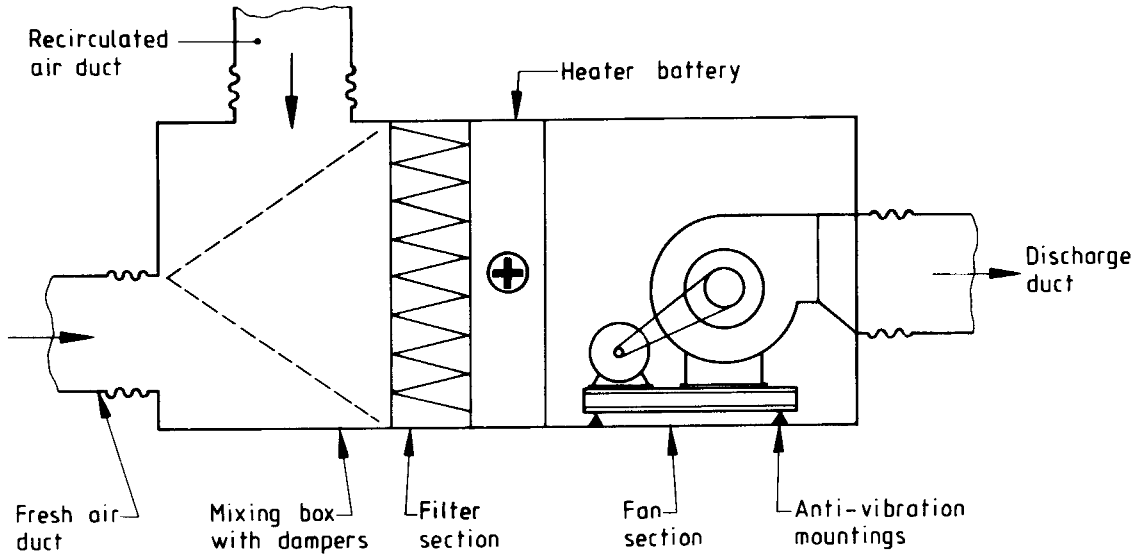
(b) Unit heater (section)



(c) Industrial air heater (section)

NOTE These figures are for identification purposes only. Many different versions are available.

Figure 3 — Typical forced convector types



(d) Typical air handling unit (section)

Figure 3 — Typical forced convector types *(concluded)*

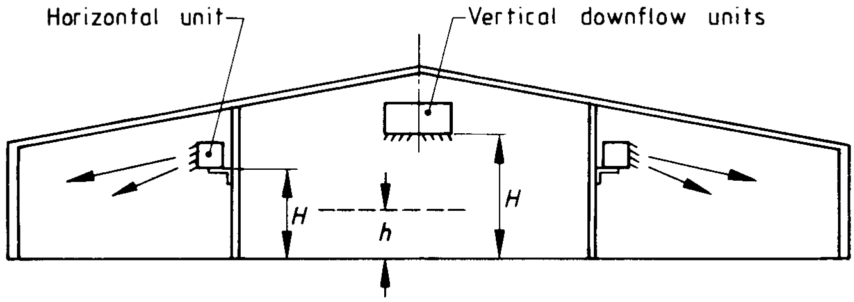
Air movement is generated by an integral fan unit, usually of the double inlet, double width centrifugal type, and often consisting of two fans on a common shaft. The drive motor is usually mounted on the same shaft, typically three-speed single phase, and of fractional horsepower. The equipment is enclosed in an external casing which may incorporate control features. Removable air filters are normally provided and are desirable to assist room air cleanliness and to minimize deposits on the heater battery. In view of the maintenance requirements of air filters, it is important that the user be aware that they are fitted. Acoustic considerations are particularly important with fan convector units, both in respect of air noise and vibration; hence speed selection is usually important, rotating parts should be statically and dynamically balanced and appropriate bearings (usually sleeve type) and resilient mountings should be used for both the motor and the fan/motor/baseplate assembly. Casing vibration should be avoided, and acoustic lining of the casing may be necessary.

3.3.2.3 *Other features.* Fan convector and fan coil units are available for wall mounting, ceiling mounting and for installation in concealed spaces such that the external casing is not used; it is important that acoustic data are related to the particular type to be used. Various special-purpose versions can be obtained, such as vertical floor to ceiling units which incorporate vertical LTHW flow and return headers, and vertical discharge units for use as door curtains in applications of limited opening height and width.

Connections are usually screwed and isolating and regulating valves may be fitted as part of the manufactured unit, which should also incorporate an air vent. Certain types will accept the limited addition of inlet/outlet ductwork, but its effect on air volume and thermal and acoustic performance should be established. By this means fan convectors can be used for the admission of outside air, in which case a suitable damper should be installed and particular precautions taken against frost risk (see **3.2.2.2** of BS 6880-1:1988 and BS 6700).

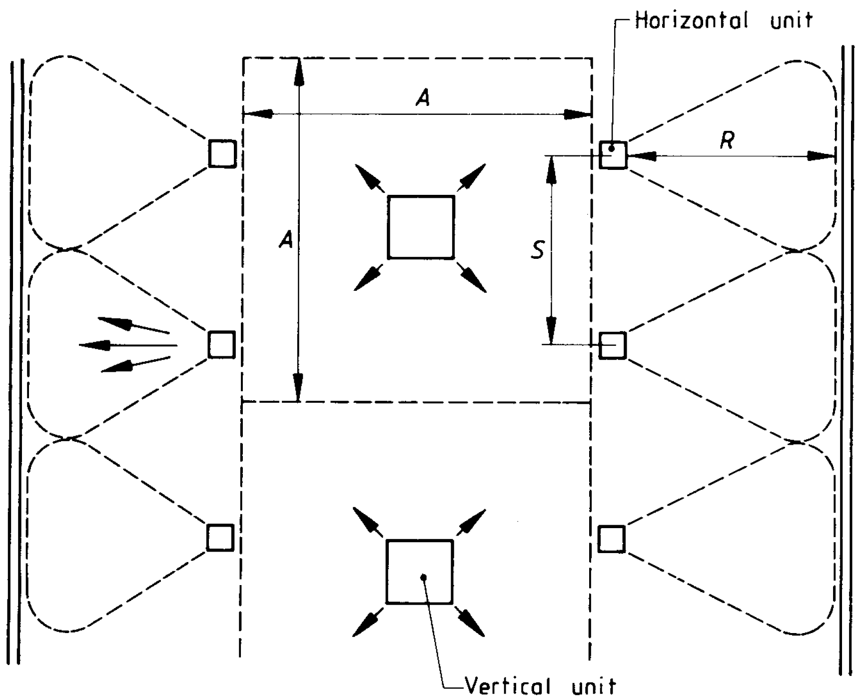
Most units incorporate a three-speed motor, giving a choice of output. Selection on the basis of output at medium speed is recommended, such that the high speed is only used for a limited warm-up period. A four position three-speed/off selector switch is typically provided, linked with thermostatic control options whereby the unit can be controlled between any two of the four selections. It should be noted that heat emission by natural convection when the fan is stopped (without automatic shut-off of the heater battery) may be of the order of 10 % to 15 % of rated output. There may also be an upper limit of system flow temperature imposed for the protection of the motor under this condition.

Casings are usually supplied with a factory-applied finish which should be well protected until completion of the installation, and selected with regard to the interior design of the accommodation where relevant.



H is the mounting height (maximum and minimum apply to each type)
h is the working level (usually 1.5 m)

(a) Section



R is the throw (horizontal unit)
S is the spacing
A X *A* is the coverage (vertical unit)

NOTE. *R* is usually taken as the distance at which velocity reduces to 0.25 m/s.

(b) Plan

Figure 4 — Typical arrangement of vertical and horizontal industrial unit heaters showing key dimensions

3.3.3 Unit heaters [see Figure 3(b)]

3.3.3.1 *General.* Unit heaters are a form of fan convector unit primarily associated with industrial type applications, and where considerations of noise and appearance tend to be less significant than with fan convector applications. Nevertheless, these factors should not be overlooked in any application.

3.3.3.2 *Construction.* The heating element is usually of fin and tube construction as described in **3.3.4.2**, arranged in one or more rows according to duty. Air is moved by a small direct driven fan, usually of the propeller type, but other types are used (e.g. mixed flow). The drive motor is usually mounted on the same shaft, and may be on the inlet or outlet side of the battery, subject to appropriate thermal rating. Motors may be three phase or single phase and a choice of speed is usually offered with a given size of unit, although normally operated on one speed only. With single-phase capacitor start motors, attention should be given to location of the capacitor to avoid heat damage. Where operation in potentially hazardous environments is required, the motor and associated electrical items should comply with the appropriate enclosure category (see **3.9** of BS 6880-1:1988).

3.3.3.3 *Other features.* Vertical and horizontal discharge configurations are available. The inlet may be fitted with a short length of ducting for the purpose of admitting fresh air, usually incorporating a recirculation damper so that it can be used for summer ventilation and partial fresh air admission in winter. Filters may also be fitted, in which case the user should be made aware. Short lengths of discharge ducting may also be used, e.g. to discharge air close to working level. Care should be taken in design when adding ducting to such units because of the marked effect of added resistance on air volume; it also tends to increase noise levels. In particularly dusty environments consideration should be given to the probable effect of dust on performance of filters, motors and heater elements, and frequency of cleaning; it may be that natural convectors would be more suitable. Where unit heaters are mounted in relatively high open spaces (e.g. factories, warehouses, etc.), attention should be given to the method of access for maintenance, particularly fan motors, controls and filters (if fitted). Method of operation of recirculation dampers (if fitted) and location of operators require special attention in these situations. Where the internal layout of the space can be ascertained at the design stage, the relationship of heater rows to gangways should be considered, in the interest of access.

3.3.4 Central air heaters

3.3.4.1 *General.* Central air heaters are various types of fan-powered LTHW air heaters arranged as a central system distributing warm air to several locations, usually by means of ductwork. Whilst operating on the same principle as unitary forced convectors, they tend to be large and to be associated with extensive ductwork distribution. More powerful types of fans are therefore used. The following are the principal types.

a) *Industrial air heaters* [see Figure 3(c)]. These are designed primarily for use in factories, warehouses and certain commercial applications of a similar nature, and where noise requirements are not demanding. They usually comprise a centrifugal fan, LTHW heater battery and casing incorporating an air inlet grille or duct spigot, air outlet duct spigot and supports. This type of unit may incorporate one or more rotatable louvered discharge heads for air distribution direct from the unit without ductwork. Outputs up to 200 kW and 6 m^3/s are typical.

A special purpose version of this type is available for industrial door warm air curtains; these are arranged for horizontal or vertical discharge through slots extending the width (or height) of the opening.

b) *Air handling units and plants* [see Figure 3(d)]. Air handling units are manufactured for a wide range of heating, ventilation and air conditioning (HVAC) applications in virtually any type of building; they can be used for warm air heating purposes but are normally associated with more complex HVAC systems. They can be assembled from standardized enclosed modules in capacities up to about 20 m^3/s and heating capacities of several hundred kilowatts. Weatherproof types for outdoor installation (e.g. rooftop) are available. Larger air handling plants can be specially built, either within prefabricated enclosures or in chambers constructed as part of the building. Air handling units and plants should be in accordance with BS 5720.

3.3.4.2 *Construction.* Construction of LTHW heater batteries, fans and other elements which may be associated with this equipment (e.g. air filters, dampers) should be in accordance with BS 5720. The following points specifically in connection with LTHW heater batteries should be noted.

a) Heater batteries are usually of the extended surface type comprising primary and secondary heating surfaces, typically tubes and fins, respectively. Tubes should be of drawn copper (complying with BS 2871-1), fitted into copper, bronze, steel or cast iron headers; fins should be non-ferrous (typically aluminium or copper). Alternatively steel tubes with steel fins and fitted into steel headers may be used, in which case the whole should be given appropriate anti-corrosion treatment at works. It is important that the secondary heating surfaces are in continuous mechanical contact with the primary heating surface. In the case of non-ferrous tubes, this is often achieved by mechanical expansion of the tube.

b) Comfort heating systems employing LTHW usually require not more than one or two rows of tubes in the direction of air flow, in order to produce the desired heating capacity. To produce the greatest capacity efficiently, without excessive water pressure drop through the coil, various circuit arrangements are used.These determine the number of parallel water flow paths through the battery, and also whether flow and return headers are on the same or opposite sides. As a general guide the resistance to LTHW flow through the heater should not exceed 4 kPa in pumped LTHW heating installations. Parallel-flow and counter-flow arrangements are used in LTHW coils. Counter-flow is the preferred arrangement to obtain the highest possible mean temperature difference.

c) The heaters should be served from flow and return mains with sufficient connections to each row or bank of tubes or sections to give uniform distribution of the heating medium. The flow connections to the heater should generally be arranged at the lowest point of the heater, and the return connections at the highest, to aid venting. The expansion of the tubes when the heater is in operation should be considered and the necessary arrangements made to accommodate expansion and contraction.

Thermometer wells should be fitted in the pipes near the inlets and outlets of all air-heating batteries so that the temperature drop through the heater can be readily observed. The incorporation of a flow measuring device in the pipework should also be considered to assist commissioning and subsequent performance checks.

3.3.4.3 *Other features.* Industrial air heaters can have a variety of mounting arrangements, including vertical freestanding, horizontal suspended, etc. Suitable supports and attachments should be provided for the intended method of installation. They may be arranged for ducted air discharge, or discharge from directionally adjustable diffusers mounted directly on the unit. Air inlet may be direct to the unit or ducted; the latter arrangement can be used for introduction of fresh air, usually controlled by means of an adjustable recirculation damper. Air filters may be incorporated. Fans are usually of the single-speed centrifugal type, belt driven by internal or external motors, resiliently mounted.

Central air handling plants may incorporate many other features according to the needs of the application such as humidifiers, and a wide range of air filter types (see BS 5720). Plants of this kind are often mounted on a rooftop or other exposed situation, in which case appropriate weatherproof construction should be used.

The acoustic performance of any air handling installation should be such as to achieve the noise criteria laid down or appropriate to the application (see BS 5720). Central air handling plants normally operate in conjunction with duct-mounted sound attenuators. In the case of industrial air heaters, whilst added attenuation may be possible, it is usual to limit their use to situations where acceptable acoustic conditions can be achieved without the use of added attenuation. Maintenance access is required for heater battery cleaning and removal, attention to motors and drives and removal of filters (if fitted).

3.4 Forced convectors: selection factors

3.4.1 General

It should be noted that the common factors relate primarily to thermal and air handling performance. However the particular factors are those which tend to determine the type of equipment to be used, noting that unit heaters and industrial air heaters are normally only used for industrial type applications.

The thermal performance of air heater batteries should be in accordance with BS 5141-2. The thermal, air handling and acoustic performance of fan convectors, fan coil units and unit heaters should be in accordance with BS 4856 which covers situations with added ducting and without.

3.4.2 Common factors

The following factors need to be considered for all types of forced convector.

a) Design LTHW flow and return temperatures (in °C) at the heater, known as entry water temperature (EWT) and leaving water temperature (LWT), respectively.

b) Design air temperatures at inlet to heater known as entry air temperature (EAT) and leaving air temperature (LAT), respectively.

c) Required heat output (in kW) (see note).

d) Required total air volume (in m^3/s at stated temperature); range of fresh air input (if required) is usually expressed as a percentage of total air volume.

e) Face velocity of air across heater battery (in m/s).

f) Added air resistance to either inlet or discharge from heater unit (in Pa).

g) Hydraulic resistance (in kPa) of heater battery, circuit configuration and appropriate water velocity.

h) Method of control of output, and choice of fan speed.

i) Location, arrangement, method of installation and appearance.

j) Working pressure of LTHW heater battery.

k) Method of control of output and precautions against freezing (fresh air inlet situations).

l) Acoustic performance of the equipment at the appropriate speeds.

m) Electric power supply requirements and method of starting.

Altitude also has an effect on equipment performance due to lower air density but this is not usually significant below 500 m above sea level.

NOTE The heat output q (in kW) of forced air convectors can be derived from the equation:

$$q = k \times D$$

where

k is a constant for a given type and size of heater and given air and water velocities;

D is the log mean temperature difference (LMTD); LMTD for a normal counterflow situation is given by the equation:

$$D = \frac{(t_1 - t_2) - (t_3 - t_4)}{\log_e \frac{(t_1 - t_2)}{(t_3 - t_4)}}$$

where

t_1 is LWT [see **3.4.2** a)];

t_2 is EAT [see **3.4.2** b)];

t_3 is EWT [see **3.4.2** a)];

t_4 is LAT [see **3.4.2** b)].

3.4.3 Particular factors

3.4.3.1 *General.* The factors given in **3.4.3.2** to **3.4.3.7** need to be considered for certain types of forced convector.

3.4.3.2 *Distribution and direction of warm air discharge.* Distribution and direction of warm air discharge is an important consideration with any forced convection system in order to achieve an even distribution in plan of air temperature and air movement. With unit equipment installations this will affect the number of individual units required, their location and their throw capacity (see **3.4.3.4** and Figure 4). As a general principle, discharge should be directed towards areas of maximum heat loss. With ducted discharge, similar considerations affect the number and disposition of outlets, for which normal mechanical ventilation design principles should be followed (see BS 5720).

3.4.3.3 *Leaving air temperature and mounting height.* The leaving air temperature is an important factor and should be selected to avoid creation of cold draughts, for which temperatures not lower than 35 °C are generally recommended for unit forced convectors in non-industrial type applications. In the latter lower temperatures may be acceptable where the location of discharge is such that air velocity is substantially reduced before reaching working level (see Table 1, and Section B.3 of the CIBSE Guide [1]).

It is important to avoid temperatures which inhibit downward projection of air, due to the tendency for less dense air to rise and resultant stratification or build-up of heated air at high level. Temperatures below 50 °C are recommended to minimize this effect, but the appropriate temperature should be established for the particular application, noting that in the case of unit heaters and similar equipment, LAT is closely related to mounting height and they should be considered together. It should be noted that increase of LAT tends to result in a smaller and cheaper unit, but these considerations should not be allowed to act to the detriment of satisfactory performance.

3.4.3.4 *Resistance to air flow.* The performance of fan convectors, fan coil units and unit heaters is very susceptible to the effects of quite small amounts of added external resistance and should be rated accordingly. Such equipment is not usually suitable for added resistances exceeding about 50 Pa. Similar considerations apply to industrial air heaters and central plants; these usually accept much greater added resistances, but air volume performance is still reduced.

In the case of industrial air heaters and certain other types of equipment, air distribution may be achieved by the use of relatively long throw adjustable diffusers. The length of throw is related to the velocity, at the discharge. Careful consideration should be given to spacing of units in relation to throw capability, buoyancy effects associated with LAT and the possibility of significant obstructions when the building is occupied.

3.4.3.5 *Equipment size and weight.* This is particularly important with industrial air heaters and central plants, and particular attention should be given to structural loading and method of support, especially where mounted on, or suspended from, roofs of industrial/warehouse type buildings.

In the case of smaller unit equipment, size, weight and support considerations are also particularly important where suspension from roofs of this type is required. Space and method of fixing are also relevant to most other applications, particularly in situations such as installation in ceiling voids and similar concealed spaces or where mounting on walls not of solid construction is considered.

3.4.3.6 *Air cleanliness.* Air filters are usually desirable with forced convectors, to prevent build-up of dust, etc. on the secondary heating surface, and to limit ingress of external dust in fresh air applications. If filters are used, consideration should be given to access for maintenance and to the appropriate type of filter (see BS 5720). Where it is proposed not to use filters, a relatively wide fin spacing is desirable (e.g. 3 mm or more). Where filters are required to achieve particular environmental conditions in the heated space, the appropriate mechanical ventilation practice should be followed (see BS 5720), noting that this may favour the use of central plant which offers wider scope in terms of filter types.

Table 1 — Maximum tolerable air velocities

Activity	Application	Maximum velocity (heating)
		m/s
Long sitting	Office work	0.2
Short sitting	Restaurants	0.3
Light work	Shops and light manufacturing	0.35
Heavier work in warm room	Dancing, cooking, heavier manufacturing	0.45

NOTE This table is an extract from Table B.3.1 of the CIBSE Guide [1] and is reproduced by permission of the Chartered Institution of Building Services Engineers.

3.4.3.7 *Acoustic and vibration factors.* These are important with any forced convection equipment, and it should be selected in the context of the requirements of the application, using appropriate performance data for the equipment (see also **3.10** of BS 6880-1:1988). It should be noted that whilst the permissible noise levels for an industrial installation may be higher than for other occupancies, the type of equipment considered (e.g. unit heaters, industrial air heaters) may be correspondingly noisier, hence careful selection is still important.

Particular aspects of acoustic performance which should be considered are:

a) air noise generated by the equipment and associated air handling accessories;

b) vibration of the equipment casing and transmission of internal noise from motors, etc.;

c) transmission of vibration to structures, particularly when equipment is mounted from relatively light roofs;

d) possible deterioration with age.

Vibration of the equipment casing and transmission of internal noise from motors can be particularly important in low background noise environments. Acoustic performance of fan convectors, fan coil units and unit heaters is covered by BS 4856, noting that a distinction is made as to whether or not added ducting is used. Fan convectors are often supplied with three-speed motors, but continuous operation on high speed is not usually acceptable. Thermal rating should be based on the speed appropriate to normal operation, but use of a higher speed for a limited warm-up period may be acceptable.

3.5 Heated ceilings and walls: types

3.5.1 General

LTHW heated ceilings operate by circulation of LTHW in an extensive system of pipework which heats ceiling surfaces with which it is in contact, primarily by conduction. The ceiling surface thus heated transfers heat to the room by radiation and convection.

Parts of walls can be heated in a similar manner, but are less common. Typical applications tend to be areas below windows and areas flanking window openings. Since the general principles are similar to ceilings, they are not considered in more detail. However it should be noted that since they tend to use vertical surfaces, heat emission per unit area under similar conditions is greater than for ceiling panels.

Heat output is determined by the mean temperature difference between the ceiling surface and the room (see **3.6**). Ceiling surface temperature may be subject to some variation due to the actual spacing of the heating pipes. In some applications it may be decided not to heat all areas of the ceiling (e.g. perimeter heating only). For normal ceiling heights of 2.4 m to 3.0 m, maximum ceiling temperatures of 55 °C to 60 °C are recommended. The mean LTHW temperature required to achieve this temperature depends on details of ceiling construction. All such systems transmit heat upwards as well as downwards, and in most applications it is desirable to maximize the latter and minimize the former.

General design principles for heated ceilings are given in Section B.1 of the CIBSE Guide [1].

3.5.2 Suspended metal ceilings

3.5.2.1 *General.* These are usually proprietary systems and much of the detailed design information required for a specific installation has to be obtained from the particular manufacturer. Continuity of manufacturer's involvement through the design, installation and commissioning stages is therefore desirable. Output is typically in the range 100 W/m^2 to 250 W/m^2.

3.5.2.2 *Construction.* LTHW is distributed via appropriate flow and return header pipework to pipe coils which form part of a proprietary ceiling system. The following two arrangements are common.

a) *Steel tube system.* Heating coils of steel tube, typically 22 mm outside diameter and protected externally against corrosion. The tubes are clipped to specially formed light metal ceiling panels, either of coated steel or aluminium, such that heat transfer takes place largely by conduction between tubes and panel edges. The ceiling panels are of modular form, carried in a suspension system similar to other suspended ceilings, but arranged so that suspension arrangements are coordinated with the heating tube. Aluminium panels are desirable where system weight is a limiting consideration. An insulating blanket of glass fibre or similar insulant is placed over the pipes, with reflective backing to limit upwards heat transmission. All tube joints should be welded and changes in direction made by bending. Care is required in formation of welded joints where the ceiling tubes join the system distribution pipework, in view of the small size of tube used and possible differences in material.

Various sizes of panel are available, as for other proprietary ceiling systems, e.g. 600 mm × 600 mm. Other arrangements are available, such as long strips, and panels which can be installed separately without forming a complete ceiling system.

For given temperatures, the heating of different areas can be varied by changing the tube spacing (typically 300 mm or 600 mm) or omitting tubes altogether.

b) *Copper tube system.* Similar in principle to the steel tube system, but used with aluminium panels, to which the tube is clipped or bonded. Soldered fittings should be used and changes of direction made by bending.

3.5.2.3 *Other features.* Compared with plaster ceilings and embedded ceiling systems, the low mass and high conductivity of metal ceilings gives them much faster thermal response. This is an advantage for control in most situations, particularly where rooms are subject to solar effects.

The system lends itself to zoning of areas and to matching heat output to plan shape of room. Features common to suspended ceiling systems in general also apply, i.e. modular construction which facilitates coordination with partitions, lighting, etc. Heated ceilings can also function as acoustic ceilings by using appropriate tiles and insulation. Fire performance may also be a relevant consideration, as with other types of ceiling (i.e. surface spread of flame, fire resistance and provision for fire compartmentation of ceiling voids where necessary). Thermal expansion should be provided for in the design of the ceiling system. This may affect location of the ceiling in relation to walls, and the relationship between the distribution pipework and the ceiling system.

In some situations it is possible to take advantage of the upwards heat transmission of the ceiling to heat limited amounts of fresh air introduced mechanically into the ceiling void. Use of heated ceilings where ventilation air is extracted via the ceiling void is not recommended. Space should be allowed above the ceiling to allow for proper installation of the complete system, valves, etc. and other elements (such as luminaires) that may be associated with it. In this context the ambient temperature expected above the ceiling should be checked.

Adequate provision should be made for venting and draining the complete system. Attention should also be given to arranging the piping so that the distribution pipework can be flushed out prior to commissioning without risk of significant quantities of dirt and scale settling in the panel tubing.

3.5.3 Suspended plaster and embedded ceilings

3.5.3.1 *General.* The considerations given in **3.5.2** in respect of metal ceilings also apply to suspended plaster ceilings, except for aspects directly related to the actual panel construction. These systems are not extensively used and are not discussed in detail.

3.5.3.2 *Construction*

3.5.3.2.1 *Suspended plaster ceilings.* Heating tubes similar to those for metal panel systems are tied to metal lath with which they should be in good contact so that it acts as a heat distribution membrane, usually below the pipes. The pipes are supported at intervals by a suspension system. A multi-coat plaster finish is applied to the underside and further plaster is applied above to act as insulation. Plaster formulation and technique are particularly critical if a satisfactory installation is to be achieved and significant cracking avoided. Slow controlled warm-up and extended drying out over a period of about 14 days is necessary. Design surface temperature should not exceed 50 °C, and system water temperature should be limited accordingly.

3.5.3.2.2 *Embedded ceilings.* In this arrangement the heating pipes are cast in the lower part of a structural concrete floor slab, with or without additional ceiling finishes. Steel or copper tube may be used, but copper is highly preferable since its life should equate to that intended for the structure. No mechanical joints should be used in embedded lengths and changes of direction should be made by bending. Design details will be influenced by structural design and construction considerations and should be such that the overall floor construction complies with the structural design code (e.g. concrete cover over pipes, typically 25 mm). Great care is also required in locations of fixings to such a ceiling, both during building construction and subsequently, due to the risk of perforating the pipes.

3.5.3.3 *Other features.* Both suspended and embedded ceilings suffer from inaccessibility and slow thermal response, particularly the embedded arrangement. With the latter, the required distribution of heating surface needs to be established before the floor is cast.

As with any heated ceiling, there is upward transmission of heat to the surface above, which may be the floor of an occupied space. This effect needs to be calculated and the expected floor temperature checked against comfort criteria (see **3.8.2**). Whilst top insulation can be incorporated in other systems to limit this effect, with the embedded arrangement there is a particular risk of unacceptable floor temperatures above. Also, where the surface above is an exposed roof, risk of interstitial condensation is particularly acute (see **2.4.2.9** and **3.2.4.3** of BS 6880-1:1988).

Very stringent procedures of inspection and testing are necessary with embedded or plaster ceiling systems to ensure the integrity of the piping system before it is embedded. Higher test pressures than those used for distribution pipework may be advisable (some authorities recommend three times working pressure), in which case the system should be planned so that testing at different pressures is practicable.

3.6 Heated ceilings and walls: selection factors

The selection of a heated ceiling or wall system involves choosing the most suitable type and layout which will efficiently provide the required heat output under the design conditions. Also it should satisfactorily perform all other functions required of the ceiling and blend satisfactorily with the other elements of the completed building, including foreseeable internal space divisions. The factors which follow are primarily related to suspended metal ceilings, as being the most common arrangement. Most of the factors mentioned are also relevant to wall systems, suspended plaster ceilings and embedded ceilings.

a) Ceiling height (in m) and surface temperature (in °C); these factors are related to each other (see **3.5**) and to mean LTHW temperature (in °C).

b) Ceiling system module.

c) Required heat output in downwards direction (in W/m^2); this is influenced by the thermal transmittance of the panel system upwards and downwards, and also on that of the ceiling/floor slab construction above (see Section B.1 of CIBSE Guide [1]).

d) Room environmental temperature (in °C).

e) Mean LTHW temperature (in °C).

f) Spacing of heating pipes.

g) Tube material.

h) Insulation and temperature requirements above the heating panel.

i) Required minimum water velocity in the heating pipes for heat transfer and air removal (0.5 m/s is recommended); system hydraulic resistance, pressure drop, limits to circuit length and considerations of hydraulic noise.

j) Hydraulic circuit arrangement for economic distribution, required control, zoning and balancing.

k) Method of control and speed of response required.

l) Working pressure.

m) Provision for thermal expansion.

n) Other required properties of ceiling (finish, acoustic performance, demountability, fire ratings, etc.).

NOTE The downward heat output q_d (in W/m^2) of a heated ceiling is given by the following equation:

$$q_d = k_d\,(t_{sc} - t_{ei})$$

where

- t_{sc} is the ceiling surface temperature (in °C);
- t_{ei} is the room environmental temperature (in °C);
- k_d is the coefficient of downward heat emission (in $W/m^2{\cdot}K$).

The coefficient k_d depends on various properties of the ceiling system and on other factors relating to the thermal characteristics of the ceiling/floor slab and whether the ceiling area is wholly or partially heated (see Section B.1 of the CIBSE Guide [1]).

3.7 Floor heating systems: types

3.7.1 General

3.7.1.1 *Systems available.* LTHW floor warming systems take the form of pipes permanently embedded in the floor construction, fed in sections from an LTHW distribution subsystem. They may be designed from first principles (see Section B.1 of the CIBSE Guide [1]). Proprietary systems are also available, in which case the specialist manufacturer's design data and procedure should be followed and arrangements made to ensure continuity of specialist involvement through the design, installation, testing and commissioning stages. Outputs of the order of 100 W/m^2 are typical with normal floor coverings, but output can be varied over a wide range and higher outputs are possible with hard floor coverings such as ceramic tiles. Before considering the details of such systems, three important characteristics should be recognized as given in **3.7.1.2** to **3.7.1.4**.

3.7.1.2 *Floor heating principle.* Correctly applied, floor heating is characterized by a relatively constant vertical temperature profile throughout most of the height of rooms of normal height. However the floor surface temperature has to be greater to achieve heat transfer.

This is shown by deriving the upward heat output q_u (in W/m^2) from the following equation:

$$q_u = k_u\,(t_{sf} - t_{ei})$$

where

- t_{sf} is the floor surface temperature (in °C);
- t_{ei} is the room environmental temperature (in °C);
- k_u is the coefficient of upward heat emission (in $W/m^2{\cdot}K$).

NOTE Heat emission from a floor heating system should also be considered in a downwards direction (see **3.7.2.4** and Section B.1 of the CIBSE Guide [1]).

Floor temperature in most applications is critical to the comfort of occupants between relatively narrow limits (see **3.8.2**), particularly when sedentary, as in an office situation. In circulation areas the floor temperature is less critical. In the case of sedentary elderly people, the warm floor effect can be particularly beneficial.

3.7.1.3 *Structural integration.* The fact that floor heating systems are generally embedded in the floor structure has the following major implications which affect its application.

a) The system should be fully compatible with the floor construction and its finishes (see **2.4.2.8** of BS 6880-1:1988). Where pipes are cast into a structural slab, structural design codes should be respected and the necessary structural approvals obtained.

b) The life of the system should be related to the intended life of the structure, unless specifically established otherwise. Floor heating systems are less suited to a change of use of building or of individual rooms than some other systems.

c) The thermal inertia of the floor construction has a heat storage effect. This may be beneficial at times, but it renders the heat output unresponsive to short-term changes in the room environmental temperature, as might arise from solar effects.

d) Design of the floor construction and that of the heating system should proceed together. The thermal characteristics of the floor construction, both above and below the heating elements, have a major effect on heat transfer and should be established at design stage. Also it is important that the intended use of individual rooms is established at the same time.

3.7.1.4 *Design practices.* In the absence of British Standards covering detailed design practice and system components, particular care should be taken in system design. This applies when designing from first principles (see Section B.1 of the CIBSE Guide [1]) or when interpreting proprietary system design information. In the case of the latter, it is important to ascertain that the system components have been proven in similar applications and that the design data relates to comparable circumstances. In the absence of British Standards for components which are embedded in the building construction, particular care in selection is required having regard to all relevant properties (see **3.7.2.2**) and certification for the purpose by the British Board of Agrément is advisable.

It should be recognized that floor heating may not be appropriate to all the space heating requirements of a particular building or a particular room. Availability of exposed floor surface in the appropriate location may impose limitations and floor temperatures should not be increased above acceptable comfort limits to overcome this. Such considerations may call for supplementary heating by other types of LTHW emitter, or other means. This can arise near large windows and where only occasional heating is required.

3.7.2 Construction

3.7.2.1 *General arrangement.* Pipe coils may be buried in structural concrete slabs provided that structural code requirements are observed (see **3.7.1.3**) and there is adequate concrete cover to the pipe (30 mm minimum and more typically 50 mm). A more common arrangement is indicated diagrammatically in Figure 5. This represents principal features typical of proprietary systems, particularly those based on plastic pipe, but it should not be regarded as a recommended detail. Specific installation details for proprietary systems should be worked out in close collaboration with the system manufacturer and the designers of the floor and finishes, and thermal sizing calculations performed for the specific solution adopted.

In the case of floor slabs in contact with the ground the use of a damp proof membrane is important to protect the thermal insulation and it should be returned up the wall behind the edge insulation strip [see Figure 5(b)]. Thermal expansion joints are an important consideration but are not shown (see **3.7.2.5**). It is important to appreciate that thermal performance depends on the thermal characteristics of the complete assembly of floor heating system and fabric elements, particularly the floor finishes and coverings. The thermal characteristics of the fabric below the heating elements are also important.

3.7.2.2 *Embedded piping materials.* Traditionally steel and copper pipes have been used. Steel is not recommended since its useful life is unlikely to be adequate due to corrosion; particular care with treatment and control of system water properties throughout the life of the installation are essential (see **3.5** of BS 6880-1:1988). Copper tube should be suitable for formation of bends by bending.

Plastics tubing is extensively used, particularly in proprietary systems. The material used should be proven and type tested for the specific purpose of floor heating and demonstrated to be entirely satisfactory for the intended working pressures, temperatures and all other relevant parameters, with adequate margin of safety. Since plastics materials tend to lose certain properties with age, it is recommended that tube selection be on the basis of properties after a life in use of 50 years, as predicted by recognized test procedures. Piping should be in accordance with CP 312 and BS 5955, and rated for duty at up to 4 bar gauge and 50 °C. Other properties particularly relevant to plastics pipe are as follows (see also **3.4.4.3** of BS 6880-1:1988):

a) flexibility: the proposed pipe spacing should be compatible with bending radius capability;

b) resistance to impact and creep effects;

c) maximum temperature which the pipe can safely withstand for a limited period of malfunction (100 °C to 110 °C is recommended);

d) coefficient of thermal expansion;

e) oxygen permeability: this is a characteristic of plastics pipes and has implications for corrosion of the remainder of the system (see **3.5** of BS 6880-1:1988).

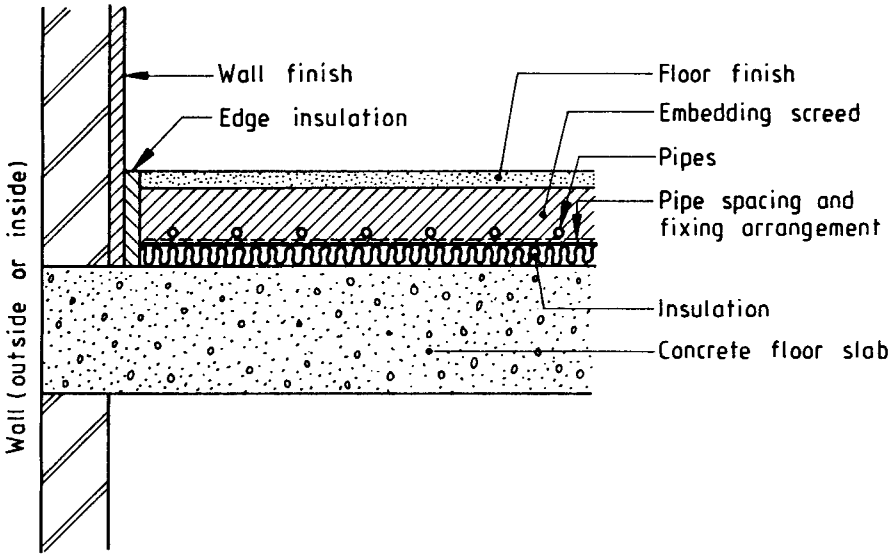
Plastics piping systems based on polypropylene, cross-linked polyethylene and polybutylene have been developed specifically for floor heating applications, but the development of plastics technology may lead to the use of other materials specifically developed and tested for the purpose. In the absence of appropriate British Standards, such materials should be selected as indicated in **3.7.1.4** and in this subclause. It should be noted that polypropylene, cross-linked polyethylene and polybutylene are not interchangeable and exhibit significant differences in terms of some of the properties noted.

As far as practicable, embedded plastics pipes should be laid in continuous lengths without joints. Where joints are unavoidable, they should only be made by using recognized heat fusion procedures proven for use with the specific material.

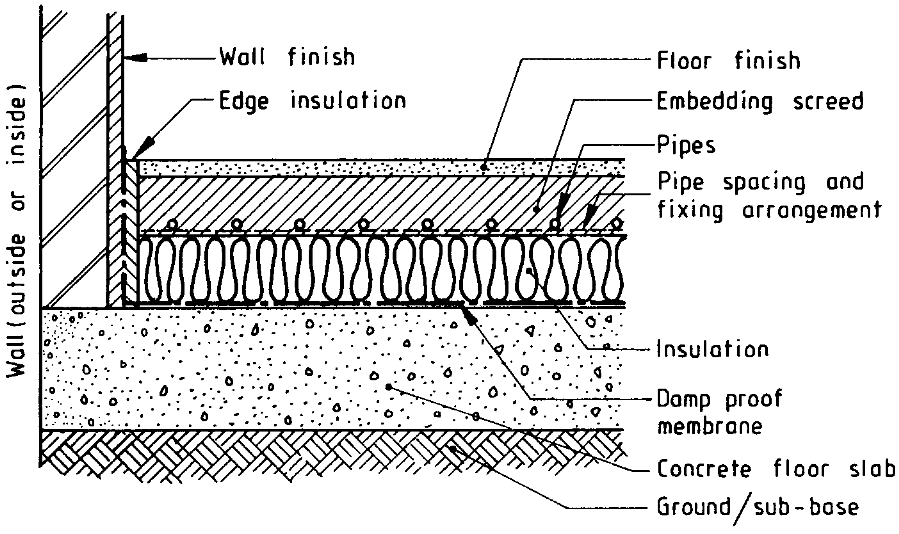
3.7.2.3 *Tube spacing and fixing.* The required tube spacing is determined by design considerations (see **3.8.4**), subject to the influence of standard spacings. Tubes should be fixed in position at the required spacing and height using appropriate materials or proprietary components that will not rot or otherwise seriously degrade or damage the piping or the fabric. Some systems use prefabricated panels made up from continuous lengths of tube, which are fed from floor and return headers, and attached to a conductive grid to promote heat dissipation between the panels.

3.7.2.4 *Thermal insulation.* Thermal insulation is usually necessary to ensure that a high proportion of system heat output is directed upwards and to minimize downwards heat loss and undesirable heat input to the ceilings of lower floors. Edge insulation is recommended (see Figure 5). The thermal insulation standards called for by the Building Regulations are a minimum statutory requirement. In the case of floor slabs in contact with the ground or other unheated spaces, an overall downwards thermal transmittance (U-value) of not more than 0.5 $W/m^2{\cdot}K$ is recommended by the CIBSE Building Energy Code [2]. A higher standard of insulation may prove economically justifiable in the particular case of heated floors in view of the greater temperature differences which apply. (See Section B.1 of the CIBSE Guide [1] for calculation procedures for heat loss.) Insulation should be compatible with the heating system elements and with the structural functions of the floor construction.

3.7.2.5 *Embedding screed.* Screed type and thickness should be determined in consultation with the designers of the fabric and the proprietary system manufacturer (where relevant). 50 mm thickness above the top of the pipe is typical. The formulation of the screed and method of application should be compatible with the heating system elements and the other elements of floor construction. Close collaboration is necessary at the design stage with the appropriate structural design specialists if a satisfactory combination of system and screed is to be achieved. It should be appreciated that underfloor heating poses particular problems in connection with screeding, including mechanical bonding of the screed to the floor slab, screed depth, thermal expansion and achieving a screed which flows all round the pipes and is well compacted. (See also CP 204 in respect of in situ floor finishes.) Particular slow warm-up and drying procedures are normally required, as described for ceilings (see **3.5.3.2**).



(a) Applied to suspended floor



(b) Applied to floor slab on ground

Figure 5 — Principal elements of floor heating system

Type and location of thermal expansion strips should be established by similar consultation. As a general guide, single areas in excess of 40 m^2 and single dimensions in excess of 8 m should be avoided.

3.7.3 Other system features

The main part of the system, i.e. that which is embedded in the floor, which corresponds to the utilization subsystem is covered by **3.7.1** and **3.7.2**. The remainder of the system, i.e. the distribution, energy conversion and control subsystems should follow similar practice to other aspects of LTHW systems, but adapted to the particular temperatures, layout and control requirements of a floor heating installation. Proprietary systems usually offer a complete range of compatible pumps, valves, controls, etc. It should be noted that manifold distribution is often used (see Figure 4(e) of BS 6880-1:1988). This calls for careful planning and accommodation of manifolds and associated valves in appropriate locations around the system such that they are unobtrusive yet fully accessible. Purpose-made cabinets with doors, recessed into walls at low level can be used. Various types of boiler are used but plastics piping should be terminated at least 350 mm away from the boiler connections.

Hydraulic circuit design should follow the general recommendations of this code. Particular design attention is required to avoid excessive differences of pressure drop and to facilitate balancing. Attention needs to be given to provision of means of draining, flushing out and venting and maintaining minimum water velocities to assist air movement (typically 0.5 m/s). See also **3.5.3.3** in respect of test pressures and **3.4** of BS 6880-1:1988.

3.8 Floor heating systems: selection factors

3.8.1 Heat output

Steady state heat requirements should be calculated as for other systems, but account should be taken of the thermal capacity of the floor construction and of its slow response to changing conditions (see **3.7.1.3**). The heat requirement of each room or area should be expressed in terms of watts of output required per square metre of floor area available. Some parts of the floor may not be available for effective floor heating (e.g. permanent fixtures). Also the heat requirement in different parts of a room should be related to the variations in design heat loss (adjacent to windows, etc.). It may be found that supplementary heating is required (see **3.7.1.4**).

In the case of multi-storey construction, account needs to be taken of heat transfer via the ceiling from upper floors, both to avoid overheating and to decide whether this is a useful contribution to room heat requirement.

3.8.2 Floor surface temperatures

This is a very important parameter since it governs heat output and is a major comfort factor (see **3.7.1.2**). Most individuals are sensitive to it depending to some extent on the nature of activity within the heated space. For general guidance, the maximum floor surface temperatures given in Table 2 are recommended.

Table 2 — Maximum floor surface temperatures

Use pattern	Floor temperature
	°C
Sedentary and standing	25
Circulation	27
Occasional (short-term)	29

It should be noted that floor surface temperature and heat output are closely linked to the specific floor finish and coverings. Also that it will tend to vary within a room according to the spacing of the embedded pipes and circuit configuration (see **3.8.4** and **3.8.6**). Risk of cracking and pattern staining of floor finishes should be considered.

3.8.3 LTHW system temperatures

As for other forms of heating, the LTHW flow temperature, mean temperature and overall temperature drop are important considerations. LTHW flow temperatures with directly embedded pipes should not exceed 55 °C and may be as low as 40 °C. This calls for circuits and control arrangements specifically designed to operate in this manner. Design temperature difference between flow and return should not exceed 11 °C. The relatively low temperature requirements of floor heating systems make them particularly suitable for use with heat pumps and other lower temperature heat sources.

3.8.4 Tube material, size and spacing

Tube materials are discussed in **3.7.2.2**. Steel and copper tubes tend to be nominal 15 mm and 20 mm sizes; sometimes 25 mm is used. In the case of plastics tubes, 20 mm outside diameter is a common size. Tube spacing will determine heat output and can be varied within a given space. It also affects the evenness of floor temperature. Minimum spacings are largely determined by tube bend radius considerations. Spacing should not normally exceed 300 mm in occupied rooms, and may be as low as 75 mm.

3.8.5 Floor construction and coverings

It is particularly important to appreciate that the system will emit heat both upwards and downwards. The latter is usually undesirable and should be minimized (see **3.7.2.4**). Also, the upward and downward coefficients of heat transfer are interrelated. Selection of floor construction and floor finishes should proceed in parallel with system design. Further information on the fabric thermal parameters and the effect of different types of floor covering is given in Section B.1 of the CIBSE Guide [1].

3.8.6 Hydraulic factors and circuit arrangements

Hydraulic resistance needs to be determined for each separate subcircuit and the resistances of different circuits should be reasonably comparable (see **3.7.3**).

A manifold distribution system is commonly used, with individual final circuits typically up to 120 m long. Circuit arrangement should be such as to minimize temperature variatons across the floor surface and enable the preferred bending radii to be used, according to tube type (see also **3.5.3.3** concerning test pressures).

Section 4. Distribution equipment

4.1 General

The equipment associated with the distribution subsystem of an LTHW heating installation promotes the required flow of LTHW around all parts of the circuit, maintains required system pressure and includes:

a) circulating pumps (see **4.2** and **4.3**);

b) pressurization equipment (see **4.4** and **4.5**);

c) pipeline-mounted ancillary items (see **3.4.4.4** of BS 6880-1:1988).

Pipeline ancillaries are extensively covered by British Standards, with which they should comply. Attention is drawn to the importance of compatibility of all items incorporated in the distribution system with each other, and with those elements of the other subsystems which are in contact with LTHW, particularly in respect of:

1) pressure ratings (see **3.4.7** of BS 6880-1:1988);

2) corrosion (see **3.5** of BS 6880-1:1988).

Where LTHW is used for forced air convection heating in central air handling equipment, the associated fans, ductwork and ductwork accessories can also be regarded as distribution equipment. Since such items are similar to those used in mechanical ventilation installations, they are not considered; for further information see **4.1** to **4.3** of BS 5720:1979.

4.2 Circulating pumps: types

4.2.1 General

Circulating pumps used for LTHW heating systems are almost invariably of the electric motor driven, centrifugal type. Other types are outside the scope of this code, but if used should not be inferior to those described herein in terms of function and general performance.

Applications include the relatively large volume pumps used in LTHW primary circuits, smaller pumps used on LTHW secondary circuits, where relatively high differential heads may be required, and large volume, low head types associated with boiler circuit flow.

Circulating pumps for use in LTHW heating systems should comply with BS 1394-1. Pump tests should be carried out in accordance with BS 5316-1. Electric motors should be in accordance with **3.9.4** of BS 6880-1:1988, noting that certain common types of circulating pump use special motors which are outside the scope of the dimensional standards for general-purpose motors. Motors may be single-phase or three-phase. Totally enclosed protection is preferred to classification IP 44 of BS 5490 or as specified in BS 4999-20. Motors should not run at speeds in excess of 1 500 r/min (1 800 r/min on 60 Hz supplies), except for cases of direct driven pumps where the required head cannot be achieved by an alternative selection, and where the noise and other limitations of higher speeds are acceptable.

Mechanical features such as screw threads, keyways, pipe flanges, etc. should comply with the appropriate British Standards. Shaft couplings, drive belts and other exposed rotating parts should be guarded in accordance with BS 5304.

4.2.2 Construction

4.2.2.1 *Configuration* (see Figure 6). LTHW circulating pumps are usually of the single-stage type since differential heads of up to about 160 kPa can be achieved at 1 500 r/min. Higher heads and higher pump speeds (see **3.10.2.1** of BS 6880-1:1988) should be avoided as far as possible by appropriate arrangement of the LTHW circuit. The inlet and outlet pipe connections of the pump casing are normally on the same centreline, i.e. of in-line form, for small and medium sizes: for flow rates in excess of about 15 L/s floor-mounted pumps tend to be required. The latter are usually of the single end-suction type; pumps large enough to require a double suction arrangement are unusual on LTHW systems.

Line-mounted pumps are arranged to be installed in horizontal or vertical pipelines. This gives a simple arrangement for the smaller sizes. Considerations of pump or motor bearings thrust capability and air trapping may impose limitations on shaft orientation and manufacturer's recommendations should be followed. With line-mounted pumps the motor shaft and impeller assembly can be withdrawn without removing the pump casing. For recommendations on pipe connections see **2.7.1.5** of BS 6880-3:1988.

In-line pumps should be capable of being supported by the pipework alone, but in some cases it will be necessary to support the pump directly, for which there should be provision on the pump casing. This may arise where the piping arrangement is unsuitable or where flexible connections are used (see **3.10.2.2** of BS 6880-1:1987).

Floor-mounted pumps may be of the vertical or horizontal shaft type. The horizontal shaft arrangement may be direct-driven, or belt driven from a motor which is often mounted on the pump casing. This gives the possibility of changing the pump duty, within the rating limits of the motor. Direct-driven, horizontal shaft pumps may have direct-mounted motors arranged for back pull-out which simplifies maintenance. Larger units tend to have foot-mounted motors on a common baseplate, with flexible drive coupling. Where noise or vibration is critical, the mounting for a floor-mounted pump may need to incorporate an anti-vibration element (see **3.10** of BS 6880-1:1988).

4.2.2.2 *Materials.* Pump bodies are generally of cast iron since this is normally suitable for use at the pressures and temperatures relating to LTHW systems, and subject to treatment of system water (see **3.5** of BS 6880-1:1988).

Impellers may be of cast iron or bronze, the latter having better wear resistant qualities. Impellers moulded from appropriate engineering plastics are used on some smaller pumps; it is important to ascertain realistic maximum duty temperatures for these and to ensure they are not exceeded. A renewable bronze wear ring is a desirable feature in pumps with cast iron impellers and bodies.

For further information see BS 1394-1.

4.2.2.3 *Seals and bearings.* Glanded pumps are driven by an external, standard pattern motor and require some form of shaft seal. The packed gland may be used, but is now relatively uncommon on new pumps of this type. If used, provision is required to collect and remove the flow of gland leakage which is necessary for its operation. Mechanical seals of various proprietary types are often used; it is important that the combination of materials for the fixed and rotating elements are compatible with the system water, having regard to temperature, pressure and chemical condition. Some seals of this type require an internal cooling water flow. Bearings are normally of the ball and roller sealed for life type. Glandless pumps have all rotating parts immersed in the system water and do not require a seal; special enclosed and sealed (canned rotor) motors are used for this purpose. Some provision should be made to prevent damage to the motor from particles suspended in the system. Some manufacturers incorporate an internal filter for this purpose. Bearings are water lubricated, usually of the sleeve type, which promotes quiet operation. This arrangement is used for smaller pumps; these are covered by BS 1394-1 for a power input range of 200 W to 2 000 W.

4.2.3 Other features

4.2.3.1 *Location.* Where to locate the pump in a system is governed largely by hydraulic considerations and is discussed in **3.4.5.5.2** of BS 6880-1:1988. Pumps should not be fitted at the lowest part of a system, to protect them from sediment. Duplicated pumps should be installed with non-return valves to prevent reverse flow, and isolating valves either side of the pump so it can be removed without disrupting the rest of the installation.

4.2.3.2 *Duty/standby arrangement.* Where interruption of circuit operation due to pump failure is not acceptable, pumps should be installed in pairs, of identical type, to afford duty/standby operation, with manual or automatic changeover on failure of a pump, as required. In-line pumps are available in various proprietary assemblies for this purpose with different valve arrangements. When selecting such arrangements, care is required to ensure that the required valve functions are defined and obtained (see **4.2.3.1**).

In assessing the need for standby pumps account should be taken of the time likely to elapse before maintenance personnel are available to remove the pump and the availability of a replacement pump of the same type and performance.

4.2.3.3 *Miscellaneous fittings.* Pumps should be provided with tapped bosses for the connection of pressure gauges to the suction and delivery sides of the pump. Pumps should be fitted with a means of automatically releasing air accumulated within the pump. If it is intended to use pump curves to check system flow, then appropriate pressure tapping points will be required, which should correspond as near as possible to the pump flanges and such that the pressure drop across any valves is excluded.

4.3 Circulating pumps: selection factors

4.3.1 Pump duty (volume)

The pump duty (volume) is derived from the heating capacity required in the circuit (in kW), expressed as a mass flow (in kg/s) for a given temperature drop (in °C). For ease of interpreting pump performance data this is usually converted to a volume flow (in L/s) at the mean system temperature. For the purposes of this clause constant volume is assumed, but variable volume may be used on some large installations. Pump flow may also be governed by the need to achieve minimum flow through boilers in accordance with the manufacturer's recommendations.

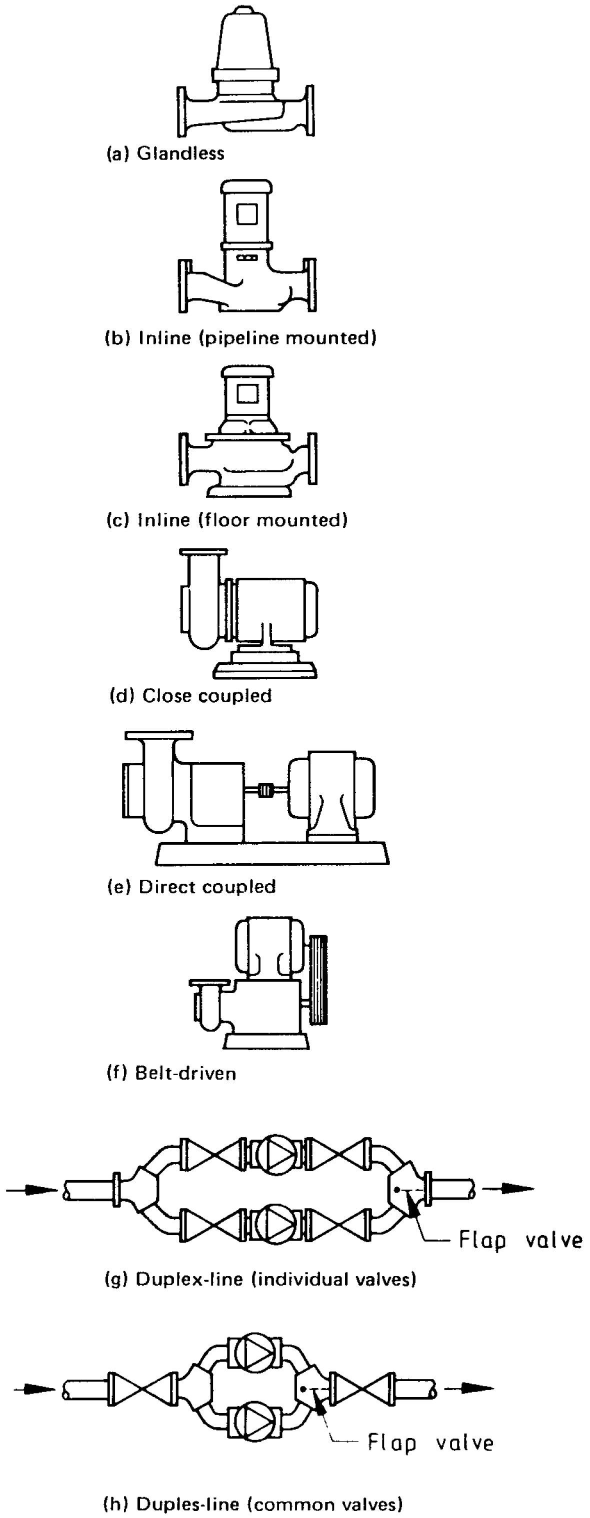


Figure 6 — Typical circulating pump types

4.3.2 Pump duty (head)

The pump duty (head) is the required head to overcome total system resistance at the design flow (in kPa). This should not be confused with the system static pressure (see **4.3.3**) which is usually much higher.

4.3.3 System pressure and temperature

The maximum static pressure and system temperature to which the pump will be subjected in operation should be specified and the pump should be selected accordingly. Table 3 indicates the pressure and temperature rating classes given in BS 1394-1.

Table 3 — Pressure and temperature classes for circulating pumps complying with BS 1394-1

Class	Maximum system temperature	Maximum working pressure
	°C	bar
Grade 1	90	3
Grade 2	120	4.5
Grade 3[a]	160	10.0

[a] Applies to glanded pumps only.

Care should be taken to ensure that pump and piping system test pressures are compatible.

Standard ambient temperature for motors is 40 °C; if higher ambient temperatures are expected, these should be specified and motors derated accordingly.

4.3.4 Speed

Pump rotational speed (in r/min) is often directly determined by motor speed, to which certain limitations may apply (see **4.2.1**). Use of a belt-driven pump offers the advantage of being able to adjust the output within limits of motor and drive rating by changing pulleys, but is usually only applicable to the larger, floor-mounted pumps.

Small pumps may be provided with a selection of motor speeds, which can assist matching pump and system heads. Some smaller pumps incorporate a variable by-pass arrangement by which output can be adjusted, but since this is inherently wasteful of energy, a correctly matched pump is to be preferred.

4.3.5 Pump performance factors

The hydraulic performance of a pump is expressed as a family of curves obtained by testing in accordance with the appropriate method (see Figure 7 and BS 5316-1). The duty point at which the pump is intended to operate (i.e. the required head and volume flow) should be at or near the point of maximum efficiency. This has a bearing on the overall efficiency of the distribution subsystem in terms of the water transport factor (see CIBSE Building Energy Code [2]). The power characteristic should be such that the motor would not be overloaded should the pump operate at some point on its curve away from the intended duty point.

The shape of the characteristic curve of the pump [i.e. head against flow, see Figure 7(a)] should be suitable for the application. Pump characteristic curves can have varying degrees of steepness; a flat curve is generally regarded as one where the closed head (i.e. head at no flow) is not more than 120 % of head at the maximum efficiency point. The shut head should not be less than that at other points on the curve, as this may lead to unstable operation.

The required degree of steepness should be considered in the context of the particular application, noting that with a flat curve the volume flow is very sensitive to change in head. This can be of assistance in regulating system flow, but with a steep curve the flow varies much less with change in head. This can be an advantage should the system operating head be different to that originally calculated. Pumps operating in parallel should be of the same type and have characteristic curves which are identical (within the tolerance limits of performance tests).

Where it is intended to use the pump curve and measured pump head as a means of estimating system flow (see **3.2** of BS 6880-3:1988), specific tests on the individual pump should be requested prior to despatch and the resulting curves obtained.

Net Positive Suction Head (NPSH) is a property of a specific pump design which governs the tendency to form vapour pockets on the suction side, known as cavitation. This promotes noise and mechanical damage and should be avoided. NPSH is not normally a critical factor in LTHW heating applications but it can become significant in situations where flow temperature tends to be high and static pressure at the pump suction tends to be low.

4.3.6 Noise

The circulating pump and its method of installation may make a significant contribution to system noise (see **3.10.2** of BS 6880-1:1988). BS 1394 does not cover acoustic aspects of pumps appropriate for use on systems within the scope of this code. Where noise is likely to be a relevant factor, noise data should be obtained from the pump manufacturer and consideration given to the need for features such as sleeve bearings, dynamic balancing, special motor, anti-vibration mounting of the pump and motor unit and resilient pipe connections.

4.3.7 Configuration and mechanical features

Various constructional features and accessories (see **4.2.3**) are relevant to pump selection for a given application and should be specified as appropriate to the application.

4.4 Pressurization equipment types

4.4.1 General

All LTHW systems require provision for:

a) introduction of water to make up for small leakage losses (e.g. pump seals) and to compensate for contraction of system water on cooling;

b) maintenance of reasonably constant static pressure;

c) provision for removal of excess system water volume due to expansion when heated from cold, in such a way that it is not wasted and can be reintroduced.

These functions are often provided by a feed and expansion cistern in which the water surface is always at atmospheric pressure (see **3.4.5** of BS 6880-1:1988 and Section B.16 of the CIBSE Guide [1]). They can also be provided by mechanical means, preferably using equipment specifically designed to provide all three functions. This arrangement is often used where the pressure requirement and building configuration are such that use of a feed and expansion cistern is not practicable. The need to prevent the generation of excess pressure in the system calls for certain control requirements and safety features (see HSE Guidance Note PM5 [3]). Certain major users have additional requirements in this regard which should be ascertained and complied with where appropriate. There may also be an insurer interest. Attention is drawn to the need for the connection of such equipment to the source of water to comply with the relevant water bye-laws, in particular where a 150 mm effective air gap is called for. Ball valves should be rated for the prevailing water pressure. Arrangements for the introduction of water treatment chemicals into the LTHW system should be separate from the pressurization equipment.

4.4.2 Classification

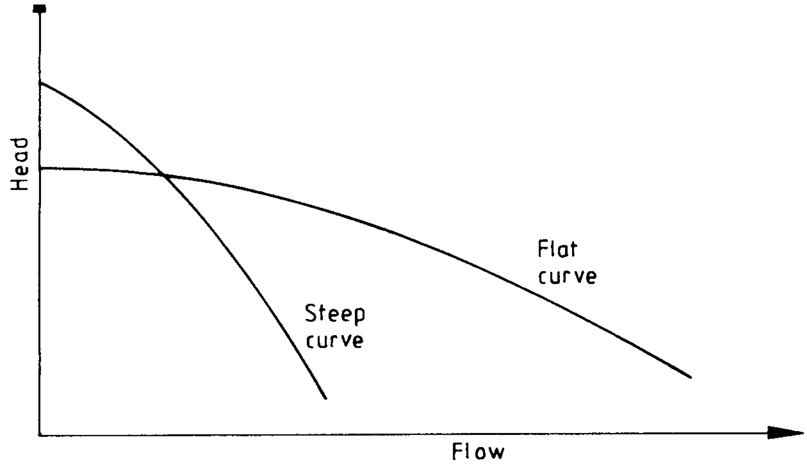
4.4.2.1 *General.* There are three principal types of mechanical pressurization equipment, which are classified by HSE Guidance Note PM5 [3] as types B, C and D as follows:

Type B: Closed pressurized system with separate pressurizing vessels and provision for make-up water (e.g. nitrogen cushion type). (See Figure 8(a).)

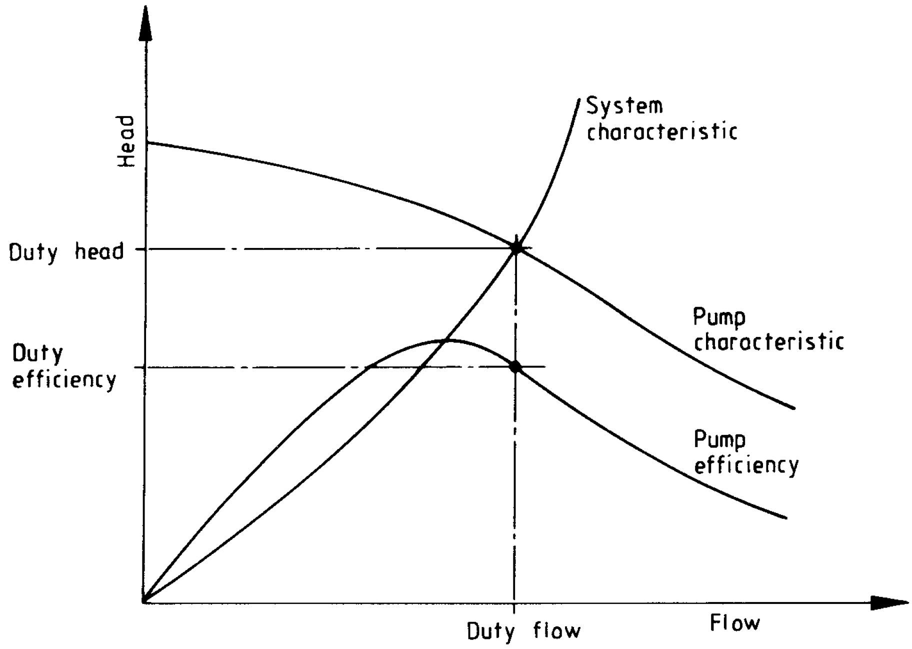
Type C: Sealed pressurized systems with separate pressurizing vessels and provision for make-up water (e.g. diaphragm type). (See Figure 8(b).)

Type D: System pressurized by a feed pump and/or static head, with provision for make-up water (e.g. constant running pump type). (See Figure 8(c).)

See also Section B.16 of the CIBSE Guide [1]. Figure 8 indicates the principal features of the three types.

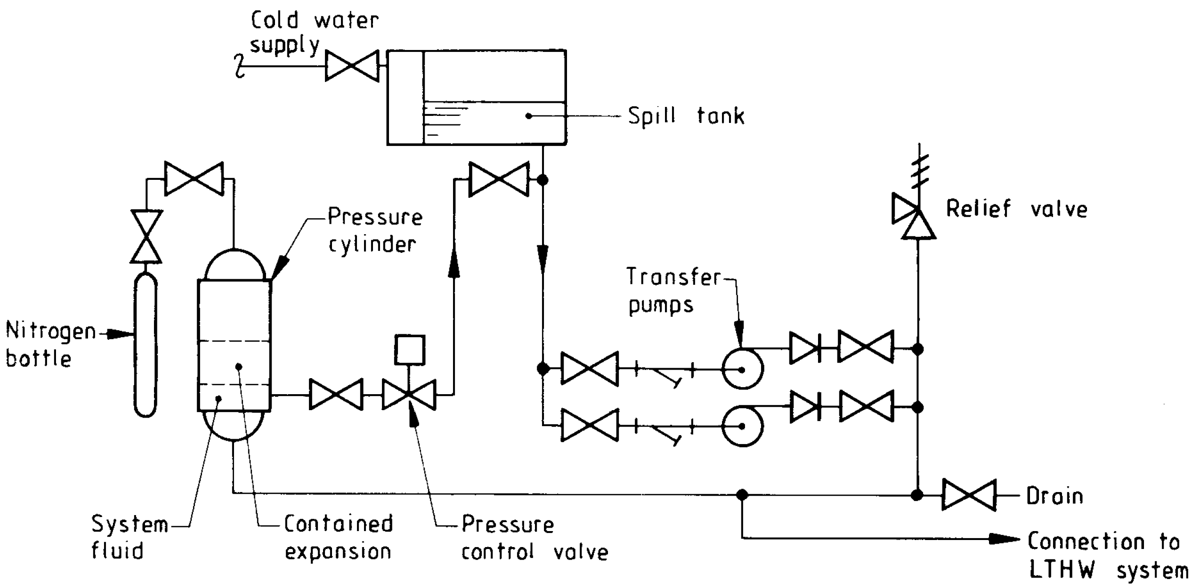


(a) Pump characteristic curves

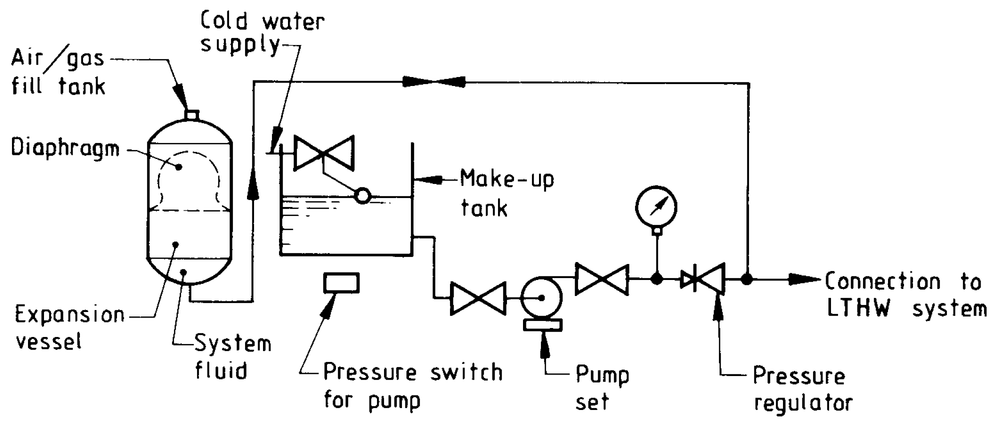


(b) Pump selection

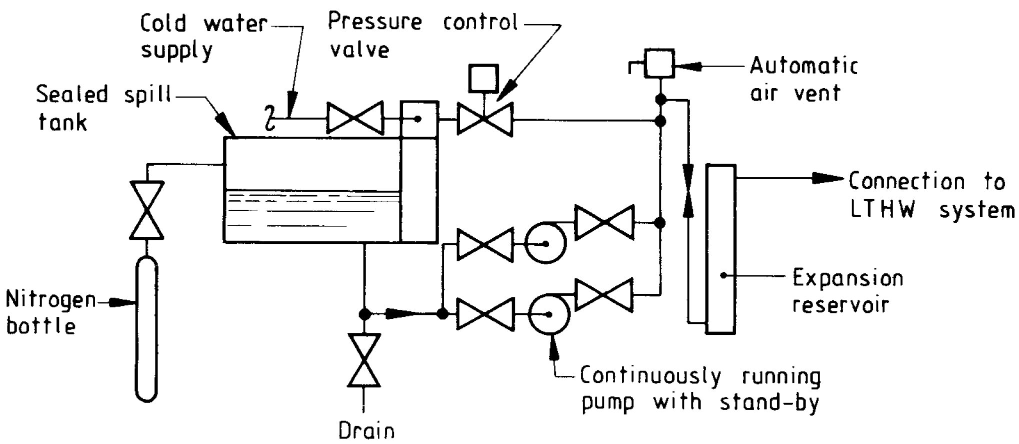
Figure 7 — Pump characteristics and selection



(a) Principal elements of type B system (nitrogen cushion)



(b) Principal elements of type C system (diaphragm expansion vessel)



(c) Principal elements of type D system (continuously running pump)

Figure 8 — Principal elements of feed and expansion systems

4.4.2.2 *Type B (closed pressurized) systems.* The principle of operation of type B systems is that system expansion forces water into a closed expansion vessel against the pressure of a contained gas (usually nitrogen). The system is controlled between predetermined upper and lower pressures, the difference between which should be less than 1 bar. The lower pressure should relate to that required to ensure that an adequate anti-flash margin is always maintained at the point of lowest pressure in the LTHW system (this should be at least 17 °C). Surplus water in the pressure vessel is arranged to spill via automatic pressure control valves into a spill tank which is either at atmospheric pressure or lightly pressurized with nitrogen. When the system cools, water is returned to the system by a return pump which only operates when required. Make-up water is added to the spill tank, using appropriate controls. In this way system water is not wasted, but it is important that the spill tank is designed so as to minimize pick-up of air by system water and inhibit internal corrosion (see **4.4.3**). A source of nitrogen under pressure (usually portable cylinders) is required to top up the pressure vessel.

4.4.2.3 *Type C (sealed pressurized) systems.* Type C systems are widely used and are suited to LTHW systems such that the full volume of expanded water can be contained at system pressure in a pressure vessel, without the need to spill into a larger tank at a lower pressure. A separate small pump and associated cold water break tank is required for the purpose of injecting water into the LTHW system to make up for leakage losses, etc. This may incorporate a small hydraulic accumulator to reduce the frequency of pump starting. The expansion vessel works on the principle of a flexible diaphragm which separates system water from the vessel gas change. This vessel is normally pressurized at the time of commissioning to suit the system and under normal circumstances it should not subsequently need alteration.

4.4.2.4 *Type D (constant running pump) systems.* Type D systems are also used on large systems. A pump runs continuously to generate the required pressure in the LTHW system. A second pump acts as standby, and is also controlled to cut in at an appropriate pressure differential and replenish the system with water as may be required due to thermal contraction or minor leakage. A spill tank and control valve is used as described for the type B system (see **4.4.2.2**). This arrangement is less satisfactory in terms of energy conservation since the pump runs continuously.

4.4.3 Construction

Diaphragm type expansion vessels should be constructed in accordance with BS 4814.

Careful consideration should be given to the choice of differential of temperature and pressure switches to ensure satisfactory operation of the system.

Any expansion vessel outside the scope of BS 4814 should be constructed in accordance with BS 5169, or BS 5500 as appropriate, protected internally and externally against corrosion and fitted with the safety features recommended by HSE Guidance Note PM5 [3] unless these are incorporated elsewhere in the system. Diaphragms may be fixed or replaceable; the latter are to be preferred and should be used on all vessels larger than those covered by BS 4814. Removable diaphragms require an access opening in the vessel which should be constructed in accordance with the appropriate pressure vessel code. Single or multiple expansion vessels may be used.

Pressurization equipment, including expansion vessels, water fill sets, control valves, spill tanks and all associated controls, electrical equipment and safety equipment should all be fully compatible and suitable for operation together for the intended duty. Where practicable, the use of an integrated set of equipment which has been assembled and tested together before arrival at site is to be preferred. Spill tanks should be treated to resist internal corrosion and consideration given to the means of minimizing contact between air and system water in the spill tank. Nitrogen gas and a floating blanket, i.e. a floating membrane on the water surface, may be used. All other pressurization system components wetted by LTHW should be selected so as to minimize internal corrosion. Control valves and other sensitive elements should be protected by strainers.

All system components should be suitable for operation at at least 100 °C. In special cases an intermediate vessel may be used, but this should be avoided where possible since it calls for extra equipment and floor space. It should be arranged so that the pressurization system is always protected against receiving LTHW at a temperature higher than that for which it is designed.

4.4.4 Other features

Diaphragm type (type C) pressurization systems should be connected to the LTHW system on the suction side of the circulation pump such that the pressurizing equipment becomes the neutral pressure point of the system (see Figure 6(d) of BS 6880-1:1988). With the other types (B and D), the pump should be connected to the discharge side of the circulating pump, so that the head of the latter is not added to the pressurization pressure. Replenishment (fill) water should be introduced by a permanent connection to the fill pump/break tank unit.

Venting of a pressurized system is particularly important as trapped air cannot escape naturally. Air separators and vents should be located in appropriate parts of the system. Piping arrangement should be such as to prevent gravity circulation from the LTHW system back into the expansion vessel. Draining provision should be made so that the pressurization equipment can be completely drained. The equipment should be provided with lockshield type isolating valves. A visible overflow should be provided from the cold water break tank or spill tank as appropriate.

It is recommended that duplicate pumps be fitted to both closed pressurized (type B) and constant running pump (type D) systems and that automatic spill valves are also duplicated. Non-return valves should be installed for each pump. Pump construction and seals should be compatible with system water pressure, temperature and quality.

Motors, starting controls and other electrical aspects of the installation should be in accordance with **3.9** of BS 6880-1:1988.

Recharging of nitrogen vessels may be manual or automatic. Safety measures appropriate to the use of high pressure gas cylinders should be incorporated and observed in operation, and arranged for changing cylinders without loss of system pressure. Sealed systems should have a suitable type of valved gas connection for occasional top-up of the gas cushion.

4.4.5 Pressurization equipment controls

The equipment should be fitted with sufficient controls, indicators and interlocks to ensure satisfactory and safe operation at all times.

Consideration should be given to the relationship between the heat generation (boiler) equipment and the pressurization system, noting that the rate of rise in system pressure is determined by the rate of heat release in the boiler installation. In particular, the following should be noted.

a) HSE Guidance Note PM5 [3] calls for certain provisions for safe boiler operation, according to the type of pressurization system used, and these should be provided, with the required control and interconnections and alarms. Whilst it may be possible to incorporate certain of these required features in other parts of the system, it is often convenient to incorporate them into the pressurization equipment at the time of manufacture. Whilst HSE Guidance Note PM5 [3] only relates to installations with boilers, it is recommended that its recommendations in this context be extended to other forms of heat generation to the extent that similar risks may apply.

b) The rate of system expansion likely to occur when one boiler fires through its full control range should be considered, in relation to the ability of the expansion system to accommodate it without cutting out at a high pressure; where multiple boilers are used with sequence control, interlinking of the two control systems may be advisable.

Control features which should be fitted include the following.

1) *Safety valves.* Pressurization systems should not rely on safety valves fitted to the boiler. On closed pressurized systems a safety valve should also be fitted to the vessel. On constant running pump systems an excess pressure relief valve should be provided.

2) *Water level indication.* Water level indication and low level alarm should be fitted to the pressure vessel of a type B (closed pressurized) system, and interconnected to boiler controls, all as required by HSE Guidance Note PM5 [3].

3) *Water level control.* This should be considered for spill tanks and cold water break tanks. It is also desirable on the vessel of a type B (closed pressurized) system, and a low water level alarm is required [see item b)].

4) *Pressure gauges.* These should be fitted to indicate system pressure, and to indicate vessel pressure on a type B (closed pressurized) system.

5) *Pressure controls.* Type B (closed pressurized) and type D (constant running pump) systems should incorporate high and low pressure controls, which operate on the controls for the automatic spill valves and pumps. Provision for adjustment of system pressure is also required.

Low pressure controls should be provided on all types of system as required by HSE Guidance Note PM5 [3].

Type D (constant running pump) systems should be provided with a high pressure control to operate as required by HSE Guidance Note PM5 [3] and provision to ensure that the system is sealed in the event of power failure.

Provision for adjustment of system pressure is also required.

4.5 Pressurization equipment: selection factors

NOTE See also Section B.16 of the CIBSE Guide [1].

4.5.1 Expansion volume

Expansion volume is the primary consideration for sizing a pressurization system since it governs the size of expansion vessels and spill tanks (where used). In the case of sealed systems it may influence choice of system working pressure. Expansion volume E (in L) is calculated from the following equation.

$$E = C\left(\frac{\rho_1 - \rho_2}{\rho_2}\right)$$

where

C is the system capacity (in L);

ρ_1 is the density of water at filling temperature[a] (in kg/m^3);

ρ_2 is the density of water at operating temperature[a] (in kg/m^3).

[a] See Table 4.

Table 4 — Density of water

Temperature	Density
°C	kg/m^3
0	1 000
20	998
40	992
60	983
80	972
100	958

NOTE This table is an extract from Section B.16 of the CIBSE Guide [1] and is reproduced by permission of the Chartered Institution of Building Services Engineers.

Accurate estimation of system capacity is not usually practicable, so it is advisable to add an appropriate margin of error. Standard vessels should be selected on the basis of the next larger available size. Consideration should also be given to the need to provide for future expansion of the LTHW system.

4.5.2 Vessel volume

Where an expansion vessel is being sized to receive the full expansion volume without spill to a spill tank, the volume of the expansion vessel V (in L) may be calculated from the following equation:

$$V = \frac{p_1 p_2 E}{1.013\,(p_2 - p_1)}$$

where

E is the expansion volume (in L);

ρ_1 is the absolute static pressure of system (in bar);

ρ_2 is the absolute final pressure in the expansion vessel (in bar).

See also Section B.16 of the CIBSE Guide [1], which indicates an alternative calculation method.

It should be noted that with sealed vessels, the vessel capacity may be considerably larger than the expansion volume, depending also on system pressure. The term acceptance is commonly used in this context to denote expansion volume as a proportion of vessel capacity.

4.5.3 System operating pressure

The system operating pressure should be selected in conjunction with the intended system flow temperature to ensure an anti-flash margin is always maintained at the point of lowest pressure in the LTHW system (this should be at least 17 °C). Where sealed expansion vessels are used, there is an economic compromise to be made between a larger vessel with lower system pressure, and vice versa.

The minimum system return temperature has a bearing on the amount of expansion volume which will arise during operation, as distinct from the expansion from cold condition for which the equipment should be sized.

When establishing system operating pressure, care should be taken to ensure that all system elements subject to such pressure are compatible (see **3.4.7** of BS 6880-1:1988).

Section 5. Energy conversion equipment

5.1 Boilers and combustion equipment: types

5.1.1 General

5.1.1.1 *British Standards.* LTHW boilers and related equipment are extensively covered by British Standards, of which the principal ones are summarized below.

a) *Boiler construction*

BS 779, *Cast iron boilers — Output 44 kW and above — Working pressure to 350 kPa (unless specifically indicated otherwise).*

BS 855, *Welded steel boilers — Output 44 kW to 3 MW — Working pressure to 450 kPa.*

BS 2790, *Shell boilers of welded construction — Larger outputs (not limited) — Maximum working pressures are well in excess of LTHW requirements.*

b) *Gas combustion equipment and controls*

NOTE 1 Later standards classify gas equipment in terms of kW input rather than kW output (as used for other fuels).

BS 5885, *Industrial gas burners — Input above 60 kW — Automatic gas firing, with forced or induced draught.*

BS 5978, *Safety and performance of gas-fired LTHW boilers — Input from 60 kW to 2 MW — Open flue types operating on low pressure district gas supplies.*

BS 5986, *Electrical safety and performance of gas-fired space heating equipment — Input 60 kW to 2 MW.*

BS 6644, *Specification for installation of gas-fired hot water boilers for rated inputs between 60 kW and 2 MW (2nd and 3rd family gases).*

NOTE 2 BS 5258-1 and BS 6798 relate to small gas fired boilers of less than 60 kW input, which would mostly be outside the scope of this code, but not entirely.

c) *Oil combustion equipment and controls*

BS 799, *Oil burning equipment — Part 2 Automatic and semi-automatic vapourizing burners — Part 3 Automatic and semi-automatic atomizing burners up to 36 L/h (i.e. up to approximately 400 kW output) — Part 4 Atomizing burners above 36 L/h (i.e. above approximately 400 kW output).*

BS 5410, *Code of practice for oil firing.*

d) *Solid fuel combustion equipment*

BS 749, *Underfeed stokers up to 550 kg/h (i.e. approximately 4 MW boiler output on coal).*

5.1.1.2 *General construction and safety.* All boilers should be constructed and designed for installation and commissioning in accordance with the relevant British Standards and codes of practice. The recommendations of HSE Guidance Note PM5 [3] “Automatically controlled steam and hot water boilers” should be followed where applicable, noting that there may also be an insurer’s interest in related aspects. Boilers and related combustion systems of special design should be made the subject of special arrangements in respect of manufacture and test, and the appropriate British Standards should be regarded as applicable for all materials used in their construction. Also, whilst HSE Guidance Note PM5 [3] may not be strictly applicable in such cases, the safety principles set out should still be followed, such that the installation is not less safe than the most similar installation to which PM5 applies.

Boilers and combustion equipment designed to recognized foreign standards may be acceptable, provided that they are in accordance with UK statutory recommendations, and with the recommendations of HSE Guidance Note PM5 [3], and are acceptable to the energy supply undertakings and relevant insurers for the intended purpose. Selection of equipment not covered by British Standards should only be made by a competent designer. Boilers should incorporate the features recommended in the CIBSE Commissioning Code B [4] to facilitate testing and commissioning.

When selecting the type of boiler for a particular application, account should be taken of the total hydraulic pressure conditions under which the boiler will need to operate. Systems in tall buildings or other major differences in elevation may require LTHW boilers operating at significant working pressures. The lack of uniformity between pressure ratings of different system elements should be recognized (see **3.4.7** of BS 6880-1:1988). For further information concerning boilers and combustion equipment in general see Section B.13 of the CIBSE Guide [1].

5.1.1.3 *Thermal efficiency.* The design and operation of the boiler and its combustion equipment has a very important effect on overall seasonal thermal efficiency. Equally, the required operation and maintenance should be carried out if the intended thermal efficiency is to be achieved under long term operating conditions (see **2.5** of BS 6880-1:1988 and section 4 of BS 6880-3:1988). Certain design features can contribute to this, such as readily cleanable flue passages, removable covers which are easily resealed and accessible burners, the correct functioning of which can be easily ascertained. Proposals in respect of the type testing of LTHW boilers are made in DD 65 (category 1 boilers).

Boiler manufacturers should provide thermal efficiency data over a range of load down to 50 % or less, in respect of each specific boiler/burner combination offered, for appropriate fuel types. Fuel properties should be based on the requirements of the appropriate British Standard (or British Gas specification). Pending the finalization of a test procedure and standard conditions, the manufacturer should state the conditions applicable to the thermal efficiency data. Pending the introduction of statutory requirements or British Standard recommendations in respect of the thermal efficiency of LTHW boilers within the scope of this code, the recommendations of Part 1 of the CIBSE Building Energy Code (1977 Edition) [2] should be followed, from which Table 5 is taken.

Table 5 — Recommended minimum boiler operating efficiencies (50 % to 100 %) full load

Boiler type	Thermal efficiency based on gross calorific value		
	Solid fuel	Liquid fuel	Gaseous fuel
	%	%	%
Sectional boilers up to 120 kW	70	72	70
Sectional boilers over 120 kW	72	74	72
Vertical multi-tube boilers	70	72	70
Shell boilers	70	80	78
Water tube boilers	70	80	78
Packaged or boiler/burner units	75	80	78

See also **3.3.5.1** of BS 6880-1:1988 concerning combustion air provision.

Part Q of the Building Regulations lays down certain requirements related to the efficiency of LTHW installations.

5.1.1.4 *System LTHW temperatures.* With any type of boiler it is important that the LTHW return temperature should be maintained above a minimum recommended by the manufacturer, usually 60 °C in respect of oil-fired, non-condensing boilers and possibly lower with certain gas boilers. This is to prevent formation of acid condensation in the flue system which tends to occur at flue gas temperatures of 150 °C and below. This may call for flow diverting arrangements to maintain this temperature under low load conditions, (see **3.3.4.3** of BS 6880-1:1988).

The boiler and the intended system flow and return water temperatures should be compatible. Whilst traditional practice is based on 11 °C temperature difference, the use of greater values may present advantages for other aspects of system design (see **3.4.1.3** of BS 6880-1:1988), but these should be related to boiler design requirements.

5.1.1.5 *Flue gas conditions.* The boiler installation should be operated such that the relevant statutory requirements in respect of flue gas discharges are met (see **3.3.5.3** of BS 6880-1:1988 and the Clean Air Act Memorandum on chimney heights). In respect of the larger oil and solid fuel fired installations (typically, over 1 200 kW total output), the following provisions are recommended, to assist monitoring of combustion conditions, both in respect of efficiency and emissions:

a) facilities for the determination of smoke density, linked to an alarm where appropriate;

b) flue gas temperature indication for each boiler;

c) draught gauges arranged to indicate draught conditions in each boiler;

d) facilities for the determination of flue gas composition for each boiler (this may be based on carbon monoxide, carbon dioxide or oxygen content).

Where these are not provided, any boiler installation should have fittings which facilitate occasional checking of flue gas conditions as indicated, using portable equipment.

5.1.1.6 *Corrosion and water treatment.* Proper water treatment and corrosion control is important for any boiler. The general recommendations of **3.5** of BS 6880-1:1988 should be followed, together with the specific recommendations of the boiler manufacturer, noting that the use of non-ferrous materials in boiler design to increase thermal performance has particular implications in this regard. Particular factors which should be considered include risks of lime scale deposition, the effect of relatively small section water passages on certain types of boiler and the presence of non-ferrous materials within the boiler (see **3.5.3** of BS 6880-1:1988).

5.1.1.7 *Acoustic considerations.* It should be appreciated that the combustion process generates noise, particularly where atomizing burners or forced draught is used. Attention should therefore be given to noise considerations both inside and outside the boiler room (see **3.10** of BS 6880-1:1988), and boiler manufacturers should provide sound power data in respect of the boiler/burner unit(s) as a whole.

5.1.2 Boiler types and construction

5.1.2.1 *General.* LTHW boilers and their combustion equipment each comprise various types which to some extent can be assembled in different combinations. Classification of types can therefore be based on boiler construction, boiler operating principle and type of combustion equipment. The approach adopted in this code is that of boiler construction, with additional notes about operating principle (see **5.1.3**). Combustion equipment is covered separately under **5.1.4**. Construction should comply with the appropriate British Standard (see **5.1.1**). The temperature of a normal concrete floor under a boiler should not be allowed to exceed 65 °C. This should not normally arise where the base of the boiler is water-cooled. Some boilers do not have a water-cooled base to the combustion chamber, such that a refractory hearth may be required. The requirements of the specific design of boiler in this regard should be ascertained.

5.1.2.2 *Cast iron sectional boilers.* Cast iron sectional boilers are made up of cast iron sections joined together by barrel nipples, the number of sections determining the duty of the boiler. This type is typically operated at pressures up to 350 kPa and its output is normally below 1 500 kW, although some boilers with water-cooled combustion chambers are produced for duties in excess of this. Also, BS 779 provides for pressures above 350 kPa. The boiler can be delivered in sections and assembled at site which is advantageous where access is limited (see **2.8.1.2** of BS 6880-3:1988 in respect of installation).

Sectional boilers are suitable for firing with liquid, solid or gaseous fuels. Thermal insulation applied between the boiler sections and the casing is needed in order to contribute to a good standard of thermal efficiency (see **5.1.1.3**) and avoid excessive heat emission into the boiler room.

Adequate water flow to manufacturer's minimum recommendations should be maintained at all times and it may be necessary on shutdown to maintain flow for a limited period to disperse residual heat in the furnace. This time lag should be considered where controls are arranged to shut down boilers in sequence and burners are interlinked with a shut-off valve.

5.1.2.3 *Low carbon steel sectional boilers.* Low carbon steel sectional boilers are similar in principle to cast iron sectional boilers, except that the sections are fabricated from steel. They should not be confused with other steel types which are not of sectional construction (see **5.1.2.4** and **5.1.2.5**). General recommendations made in **5.1.2** in respect of sectional boilers also apply. Output is usually below 1 500 kW.

5.1.2.4 *Welded steel boilers.* These are fabricated from steel plate, electrically welded and designed for medium pressure applications. The construction is normally arranged to provide multiple gas passes giving high combustion efficiency in a space saving boiler. Other metals may also be incorporated (see **5.1.1.6**). These boilers are normally designed for maximum working pressure of 450 kPa in the range 100 kW to 3 000 kW.

5.1.2.5 *Steel shell boilers.* These consist of a cylindrical steel shell which may be horizontal or vertical, having a furnace tube designed for automatic or hand firing. The tube is connected to the rear combustion chamber from which convection tubes are taken to provide two-pass or three-pass construction. Shell boilers are suitable for firing with solid, liquid or gaseous fuels and are frequently supplied as a packaged unit with matching burner. Various draught arrangements are possible, usually either forced draught or induced draught (see **3.3.5.5** of BS 6880-1:1988). Boilers of this type are manufactured in sizes up to 12 MW and are suitable for pressures up to 1 000 kPa and above. They are used only for the largest LTHW installations or where static pressure makes the use of other boilers impracticable.

5.1.2.6 *Modular boilers.* These consist of a number of small units, each with their individual burner, which operate as an assembly. Automatic controls shut down the individual units in sequence according to boiler load. Because each boiler, when in use, operates at full load the efficiency of the system at low load remains high. Other advantages are that the individual units tend to be small and can be easily moved into the building, whilst the breakdown of one unit may not seriously affect the performance of the whole system. For the purposes of this code, the term modular boiler is only applied to those proprietary, packaged assemblies which consist of a number of similar burner/combustion chamber modules with a common control system, each connected to common and integral flow and return headers, and to common and integral flues terminating in a single flue outlet. The complete assembly constitutes a single boiler; an installation may comprise more than one such boiler.

NOTE In some publications the term "modular" is sometimes also applied to multiple groups of similar boilers arranged to operate under a common sequence control, but with the flow, return and flue headers external to the boiler assemblies. The subject of operation of multiple boilers is covered in **3.3.4.3** of BS 6880-1:1988.

5.1.3 Other boiler types and operating modes

5.1.3.1 *Condensing operation.* Traditionally LTHW boilers operate by sensible heat transfer from the burning fuel and combustion products (mainly by radiation and convection). Combustion products are only cooled to a temperature such that condensation (and consequent corrosion) is not likely to occur in the boiler or flue system.

However, the quest for higher thermal efficiency has led to the development of boilers which also abstract latent heat from the combustion products, such that moisture is formed.

Higher thermal efficiencies are therefore quoted, noting that for comparative purposes figures based on the gross calorific value of the fuel should be used.

Various types are under development at the time of drafting and can be loosely identified as follows.

a) *Partially condensing.* Boilers designed with materials to resist acid corrosion, but which do not produce condensate under normal conditions. Provision for continuous removal of condensate should nevertheless be provided.

b) *Fully condensing.* Boilers designed with materials to resist acid corrosion and with provision for continuous removal of condensate. These are normally designed for a greater degree of condensing heat abstraction and hence lower mean operating temperatures.

Particular care is required in the application of such units, especially in regard to the following.

1) *LTHW return system.* The whole system should be designed to suit the return temperature which is required for the boiler to achieve condensing heat abstraction. This is lower than that associated with traditional boilers and may have a significant effect on the selection and sizing of the utilization subsystem; it may also affect total system economics, which should be considered There are possibilities for the efficient use of such boilers in conjunction with preheating of domestic hot water. The use of compensated controls can assist the application of condensing boilers (see **3.8.3.3** of BS 6880-1:1988).

2) *Boiler and flue construction.* All elements in the path of the products of combustion should be designed and selected so as to be suitable in respect of resistance to acid corrosion wherever this may occur in normal operation.

3) *Standards.* Such boilers are not at present covered by British Standards and should meanwhile be treated as boilers of special design, in the context of **5.1.1.2**.

4) *Condensate removal.* Where this is necessary, appropriate and safe drainage provision should be made, complying with the applicable regulations, noting that such condensate will tend to be acid, particularly with oil or solid fuel fired installations.

5.1.3.2 *Pulse combustion.* Air and fuel gas are initially ignited in a combustion chamber by means of a spark, and the heated gas generated is passed to a heat exchanger in pulses where it condenses. In doing so it gives up its heat to the LTHW, its pressure drops and fresh fuel is drawn into the combustion chamber. The process is continuous once started and high thermal efficiencies are claimed. Such boilers are not covered by British Standards and should meanwhile be treated as boilers of special design, in the context of **5.1.1.2**. It should be noted that they also operate on the condensing principle, and tend to be particularly noisy in operation.

5.1.3.3 *Boilers of limited thermal capacity.* Care is required in the application of certain designs of LTHW boiler which are designed to be compact and light in weight. Water passages tend to be small (e.g. drawn tubes), and materials different to those used in traditional designs; this tends to make them particularly sensitive to system water quality (see **3.5** of BS 6880-1:1988). Their inherent thermal capacity in relation to output tends to be low. Hydraulic resistance may be significantly higher than that of traditional types of comparable output.

5.1.3.4 *Waste and by-product fuel boilers.* For the purposes of this code, waste fuel is regarded as any gaseous, liquid or solid fuel not primarily manufactured for heating purposes and to which there is no applicable British Standard or British Gas specification. It is usually a waste material or a process by-product, but for the purposes of this code would also include wood, peat or other solid fuels outside the range of normal coals. Particular recommendations are made concerning such fuels in **3.3.2** of BS 6880-1:1988, and these are applicable to the design, rating and selection of waste fuel boilers. Many types of waste can be burned but some need considerable pretreatment before use. The variability of related physical and chemical properties is an important factor (see **3.3.2.2.9** of BS 6880-1:1988).

There are a number of purpose built units available, some of which burn waste alone whilst others combine the waste with a more conventional fuel such as coal or gas. The proper burning of waste for heat recovery purposes presents a number of problems and should be referred to specialists in this field (see also **5.1.4.5**). The use of waste oils should only be considered where the burner equipment is specifically designed and operated for that purpose.

Where practicable, the part of the boiler installation which is in contact with the system LTHW should be constructed in accordance with the British Standard for the appropriate boiler type (see **5.1.2**). In other cases, and also in respect of the special purpose combustion equipment usually associated with such installations, the recommendations in **5.1.1.2** in respect of boilers of special design should be followed, particularly in respect of HSE Guidance Note PM5 [3].

5.1.4 Combustion equipment

5.1.4.1 *General.* Combustion equipment and associated safety controls are extensively covered by British Standards (see **5.1.1**), British Gas publications (IM series) and HSE Guidance Note PM5 [3], with which they should comply. Equipment not covered by British Standards should be treated as indicated in **5.1.1.2** for boilers of special design. There may also be a specific interest on the part of an insurer or energy supplier in respect of combustion equipment and its operation.
See also **3.3.1** and **3.3.2** of BS 6880-1:1988 in respect of fuel types and selection. Burners should be specifically matched to the boiler they are intended to serve, in respect of performance, mounting and controls. Ease and safety of access for inspection and maintenance of burners is important; the use of hinged oil and gas burners facilitates this. Ventilation of boiler rooms adequate for combustion requirements is important (see **3.7** of BS 6880-1:1988 and CIBSE Practice Note PN2 [5]).

5.1.4.2 *Gas burners.* LTHW boilers fired by gas are normally provided with a burner which forms an integral part of the boiler package. Installation of the boiler and burner should be in accordance with the Gas Safety (Installation and Use) Regulations and the relevant British Standards (see **5.1.1**). Gas burning equipment covered by a British Gas approval scheme should be so approved (see British Gas list of tested and approved commercial gas appliances [6]).

Before designing a system for gas firing the gas supply undertaking should be approached to establish that an adequate gas supply can be made available, and the appropriate pressures established (see also **3.3.1.2.2** of BS 6880-1:1988). Principal gas burner types are as follows. They are all capable of operation on natural, liquefied petroleum gas (LPG) or manufactured gas, but the specific gas to be used should be identified.

a) *Atmospheric burners*. Atmospheric burners have aerated burner bars and rely on gas pressure alone for proper combustion. For this reason it is important to ensure that an adequate pressure is available to suit manufacturer's requirements (usually around 2 kPa). Atmospheric burners are not usually provided on boilers with ratings in excess of 800 kW and are only suitable where stable flue draught is available. A draught diverter on the flue connection is usually necessary with this type of burner (see Figure 2(b) of BS 6880-1:1988).

b) *Premixed burners*. In premixed burners gas is mixed with air in a fan which discharges to a cylindrical perforated burner which is surrounded by the water heating tubes. Such burners are frequently used on small boilers, particularly those of the modular types but can also be applied to larger installations.

c) *Fan-assisted burners*. Fan-assisted burners are most commonly used on the larger gas-fired boiler installations up to 4 500 kW. All air for combustion purposes is supplied by a fan which should overcome the resistance of both boiler and burner. Close control of combustion air is possible with this type of burner.

d) *Dual fuel burners*. Burners can be provided for alternative firing of either gas or oil, being arranged for changeover from one fuel to another. In such cases it is important to establish whether frequent changeover by means of control switches is required, or whether a more infrequent changeover is intended calling for some downtime for mechanical adjustment. The former arrangement requires fully duplicated controls for each fuel type.

5.1.4.3 *Oil burners.* For boilers within the scope of this code, oil burners are almost invariably of the atomizing type, the atomizing process usually being carried out mechanically. Any type of fuel oil can be used but that most commonly used for LTHW installations is class D (formerly Gas Oil); see **3.3.1.2.3** of BS 6880-1:1988 for further information.

The types of burners commonly used are as follows.

a) *Pressure jet burners*. Pressure jet burners consist of a centrifugal combustion air fan and a high pressure fuel pump which discharges oil into a nozzle designed to impart a high rotational velocity, breaking up the oil into droplets. Since atomization depends upon an adequate supply of oil into the nozzle, turn-down ratio is limited to about 2 : 1. It is therefore important to establish the appropriate mode of burner operation, which is usually either on/off or high/low/off in most LTHW boiler applications. Pressure jet burners are normally used for boilers with output up to about 4 500 kW.

b) *Rotary burners*. The rotary burner is normally used on larger boilers of the steel welded shell type, burning fuel grades heavier than class D. Oil (usually preheated) is introduced on to a rotating cup and centrifugal force throws oil droplets into the main air stream from a primary combustion air fan. There is also a secondary combustion air fan. This type of burner can operate over a wide turn-down range, typically of the order of 4 : 1 or 5 : 1, and it can be readily adapted for dual fuel applications. This type is relatively noisy in operation and specific sound attentuation measures are usually necessary, such as fan inlet attenuator and a removable acoustic hood.

5.1.4.4 *Solid fuel burners and stokers.* The choice of mechanical handling system used will depend upon the fuel available and the type and size of installation. See also **3.3** of BS 6880-1:1988. It should be appreciated that the nature of solid fuels renders them less flexible in use than gaseous or liquid fuels, such that particular attention is required in the early stages of a project to such factors as:

a) type and grade of fuel;

b) storage space and access for unloading/loading (see **2.4.3.3** of BS 6880-1:1988);

c) layout and structural requirements (see **3.3.3** of BS 6880-1:1988);

d) boiler house operating manpower/arrangements and maintenance implications (see **4.4.2** of BS 6880-3:1988);

e) arrangements for ash and grit removal (see **5.3.4.4**) and for cleaning of flue gas;

f) the risk of ignition or explosion of fuel particles or dust before it reaches the burner; appropriate safety features should be provided so that the requirements of section 31 of the Factories Act are met.

Coal and other solid fuel boilers should be supplied with an appropriate set of stoking tools to facilitate the safe execution of such manual operations as may be necessary. The proper use of coal can introduce significant economic benefits, and it should be noted that certain major authorities use financial assessment criteria which favour its use with respect to other fuels. For further information see also Section B.13 of the CIBSE Guide [1] and the British Coal series "Technical data on solid fuel plant" [7]. Particular attention is required in system design to ensure that residual heat is dissipated when boiler load is substantially reduced or a boiler is shut down (see **5.1.6.3**).

Principal types are as follows.

1) *Gravity feed burners.* Only the smaller installations up to about 500 kW output are suitable for gravity feed anthracite burners. They are simple to operate and the rate of combustion is regulated by modulation of the forced draught fan, giving a good turn-down ratio and a high thermal efficiency.

2) *Underfeed stokers.* Underfeed stokers are the most common type of stoker used for sectional and fabricated steel boilers rated up to about 1 500 kW. They can be adapted for direct bunker to burner feed, the coal being conveyed through a tube by means of a screw, the speed of which regulates the coal feed to the furnace. Primary air is provided by a forced draught fan. Underfeed stokers cannot handle as wide a range of coals as chain grate and coking stokers, and the maker's recommendations should be obtained as to suitability for specific fuel types and grades.

3) *Coking stokers.* Coking stokers are frequently used with shell boilers generating LTHW. Unit ratings are typically up to 4 500 kW boiler output. For larger outputs, twin stokers can be fitted. The coal is pushed into the boiler from the hopper by means of a ram where partial distillation of volatiles (known as coking) takes place. Subsequently the fuel travels forward onto the moving grate where it is burned. These stokers handle a wide range of coals but high coking coals 300 and 400 can be difficult to use. All coking stokers rely upon induced draught to achieve high outputs.

4) *Chain grate stokers.* Chain grate stokers are often applied to shell boilers and would only be considered for the larger LTHW applications. They are available in ratings up to 10 MW boiler output and are suitable for most coals, although not recommended for strongly coking coals. They consist of an endless chain grate which feeds a continuous supply of coal into the boiler furnace, the rate of feed being regulated by the speed of the grate drive. Chain grate stokers require a coal storage hopper located above the furnace inlet, a forced draught fan and may also be provided with an induced draught fan.

5) *Sprinkler stokers.* With sprinkler stokers the coal is fed pneumatically through the top of the boiler or from the furnace front onto a fixed grate. The conveying air forms part of the secondary air requirement. The systems are applied to shell boilers in the range 600 kW to 8 500 kW and are most suited to the burning of singles. They can be combined with burning of certain types of waste products which are shredded and blown across the grate together with grit from the arrester (see **5.1.4.5**). Manual de-ashing is necessary with the fixed grate, but mechanical de-ashing grates are also available.

6) *Fluidized bed systems.* In fluidized bed systems, the fuel is fed into a furnace bed consisting of particles of inert material which are continuously recycled. The fuel/bed mixture is fluidized by relatively high pressure air which holds the bed and the fuel in suspension whilst combustion takes place. In the absence of specific British Standards, the recommendations in **5.1.1.2** in respect of boilers of special design should apply. They are suitable for a relatively wide range of coal types from singles down to dust, and can therefore be advantageous with poor quality coals, provided that the ash arising can be readily disposed of. Thermal efficiency can be good. The systems lend themselves to automatic control, which in practice is their most important advantage. Compared with other types there are fewer moving parts in the combustion and hot gas zones, but wear and tear of the bed circulation equipment needs to be taken into account. Certain systems claim that SO_2 and NO_x in flue gases can be reduced by the use of additives to the bed.

5.1.4.5 *Solid waste burners and combustors.* These can take various forms dependent upon the waste fuel to be burnt (e.g. wood waste, refuse, straw). Typical methods include:

a) shredding and burning in conjunction with conventional fuel, suitable for certain types of refuse;

b) burning in a cyclone or other external combustor and transferring the hot gas to a waste heat boiler, suitable for wood wastes;

c) direct burning of waste in specially designed furnaces, suitable for straw and other agricultural products;

d) pyrolysis: the waste is burned in two stages, firstly with a restricted air supply which generates combustible gas which is then mixed with air in a burning chamber to give largely smoke free combustion; this can be suitable for many forms of industrial and other wastes.

More detailed treatment is outside the scope of this code and the application of solid waste combustion to LTHW heating should be handled by appropriate specialists. The variable nature of the material and the ascertaining of relevant properties are particularly important considerations (see **3.3.2** of BS 6880-1:1988). Since this equipment is largely of special purpose design, the recommendations of **5.1.1.2** in respect of boilers of special design are applicable.

5.1.5 Boiler mountings

LTHW boiler mountings should be in accordance with BS 759 and meet the appropriate requirements of HSE Guidance Note PM5 [3] and the requirements of the British Standard applicable to the boiler type (see **5.1.1.1**).

They should include the following:

a) safety relief valve connected directly to the boiler with no intervening isolating valve, rated in accordance with HSE Guidance Note PM5 [3];

b) provision for measurement of LTHW pressure;

c) provision for measurement of LTHW flow temperature at boiler outlet;

d) vent connection on open-vented systems; on all other systems provision such that thermal expansion of water in the boiler is accommodated at all times (see **4.4**);

e) key operated drain cock; in some applications it may be desirable to use a lockable type;

f) isolating valves on LTHW flow and return connections to each boiler, close to the boiler and preferably lockable;

g) valves, preferably lockable, on any interconnecting services which could cause LTHW to be discharged into an otherwise isolated boiler, including common vents (see **3.4.5.5.3** of BS 6880-1:1988);

h) provision for the connection of all necessary controls (see **5.1.6**).

The use of a low water cut-out alarm should also be considered among other safety devices.

Where a boiler is large enough for a man to enter, consideration should be given to the additional hazards that may arise. Valves indicated in items e), f) and g) should be lockable, and on multi-boiler installations consideration should be given to additional lockable flow and return isolating valves for each boiler, close to the common header.

5.1.6 Automatic boiler controls

5.1.6.1 *Automatic firing controls.* The following automatic firing controls should be provided to cut off the fuel supply to the burners or fuel and air supply to stokers in the event of the following:

a) flame failure/pilot failure (oil/gas fired boilers); the controls should be lock-out type requiring manual resetting;

b) failure to ignite the fuel within a specified time (oil or gas fired boilers); the controls should be lock-out type requiring manual resetting;

c) failure of forced or induced draught fan or of automatic flue damper, or boiler house ventilation system where relevant;

d) when the water at or near the boiler LTHW flow outlet rises to the predetermined temperature laid down in the HSE Guidance Note PM5 [3];

e) in non-vented systems, when the water level or LTHW system pressure approaches the values laid down in the HSE Guidance Note PM5 [3], according to the pressurization system category.

See also **5.1.1.1** in respect of specific British Standards relating to combustion systems, which should be followed as applicable.

5.1.6.2 *Overriding controls.* Independent overriding control should be provided to cut off fuel supply to the burners and fuel and air supply to stokers when the temperature of the water in the boiler rises to within the predetermined temperature laid down in the HSE Guidance Note PM5 [3], according to the type of combustion system. This control should be of the lock-out type requiring to be manually reset.

5.1.6.3 *Other control considerations.* Multiple boiler installations require some form of overall control (e.g. sequence control) so that the installation is operated as an entity and fall-off in thermal efficiency under part-load conditions is minimized (see **3.3.4.3** of BS 6880-1:1988). Note also the requirements of Part Q of the Building Regulations.

Where solid fuel stokers are used, or other combustion systems where there is a possibility of significant thermal inertia due to retained heat within the fuel bed, system controls should be arranged so that this heat can be safely dissipated when the boiler is shut down (see HSE Guidance Note PM5 [3]). The risks associated with power failure should be considered.

With automatically fired boiler installations, particularly those using gaseous or oil fuels, consideration should be given to means of safe shut-off of the total fuel supply to the boiler plant in the event of fire. This may take the form of a fail safe automatic valve in a safe location outside the boiler room and as close to the fuel storage tank as possible, operation of which is initiated by a suitably located fire sensing element of appropriate type. The fire authority should be consulted, and there may be an insurer interest (see **2.4.3.1** of BS 6880-1:1988). If a manually operated valve is used it should be readily accessible and identifiable in a safe location with clear directions as to use. (For further information on the safe shut-off of the fuel supply see BS 5410-2 and BS 799-5.)

5.2 Boilers and combustion equipment: selection factors

Factors to be considered include:

a) heat output (in kW);

b) fuel type(s) and supply conditions;

c) type of combustion equipment and range of output (as a percentage of full output);

d) thermal efficiency over required operating range (as a percentage, based on fuel GCV);

e) maximum LTHW flow temperature, minimum LTHW return temperature and design temperature difference (in °C);

f) maximum and minimum LTHW flows (in kg/s);

g) hydraulic resistance at maximum LTHW flow (in kPa);

h) static working pressure and required relief valve setting (in kPa);

i) flue and draught requirements;

j) electrical supply details (volts, frequency, phases and number of wires);

k) provisions for automatic control of individual and multiple boilers;

l) provision for changeover on dual fuel installations;

m) overall dimensions and space for cleaning, tube withdrawal.

In certain situations acoustic data for the complete boiler/burner combination may be required (see **5.1.1.7**).

It should be appreciated that the size and cost of a boiler of given output may vary significantly between available types. An important factor is the rate of heat transfer per unit area under rated conditions. This tends to be higher in the more compact units and, coupled with other factors such as heat exchanger material selection and thicknesses, may have a significant effect on the expected operational life of the boiler.

5.3 Boilers and combustion ancillaries: types

5.3.1 Fuel storage

5.3.1.1 *LPG vessels.* The storage of LPG is covered by the Home Office Code of Practice for the Storage of LPG at Fixed installations [8] (see **3.3.3.1** of BS 6880-1:1988) and the Code of Practice issued by the Liquefied Petroleum Gas Industry Technical Association (LPGITA) [9].

Spherical tanks for smaller installations normally have an integral supporting base. Cylindrical tanks are normally mounted above ground on concrete plinths. In some instances it is found necessary to provide underground storage; such installations should be carried out strictly in accordance with the Home Office Code of Practice [8], particular attention being paid to the provision of an unbroken protective coating on the steel tank and adequate protection above the tank to prevent any heavy load being imposed on the tank (e.g. vehicle wheel loads). The position of any buried vessels should be permanently marked. No LPG vessel should be completely filled with liquid, and the filling ratios laid down in BS 5355 should be observed. Filling should always be carried out by suitably trained and competent personnel.

LPG vessels should be provided with the following mountings and connections as a minimum:

a) liquid level gauge;

b) vessel pressure gauge;

c) line pressure gauge;

d) gas outlet valve;

e) liquid outlet;

f) first stage pressure regulator;

g) pressure relief valve;

h) contents gauge;

i) filling connection;

j) earthing boss;

k) drain valve.

Control is by means of the first stage pressure regulation. The final pressure regulator is normally situated close, but externally, to the boiler installation.

Depending on gas type and demand, a vaporizer may need to be fitted, controlled by a pressure controller located downstream of the first stage pressure regulator. The heat source and connection requirements for such a vaporizer needs to be determined, with particular regard to safety of operation in the particular location intended for the LPG storage installation.

5.3.1.2 *Oil storage tanks.* Fuel oil tanks should be constructed and installed in accordance with BS 799-5 and the appropriate construction standard. Horizontal, welded cylindrical, shop-fabricated storage tanks are covered by BS 2594, larger vertical butt-welded tanks by BS 2654. Tanks located in basements may be subjected to higher pressures than freestanding tanks outside; static pressures should be calculated and appropriate construction applied. Large tanks may be site-erected (see **2.8.2.2** of BS 6880-3:1988). In the case of buried tanks experienced guidance should be obtained in respect of bedding, backfill (or encasement) and drainage provision. Figure 9 shows typical horizontal (above ground) tank arrangements.

Tanks should, where possible, be sited close to the point of use; it is preferable to install outside the building but they may be located inside provided that proper provision is made for their accommodation (see BS 5410-2). The location of the tank should take account of access for delivery purposes. Daily service tanks fed by pump from the main storage tanks may be provided where the point of usage is remote from the main storage or where the location of main storage relative to point of usage makes gravity feed to the burner impracticable. Tanks require provision for the periodic removal of oil and sludge.

Tanks for class C and D oils do not normally require provision for heating the oil before distribution to the burners, but this may be advisable in certain conditions (see **3.3.3.2** of BS 6880-1:1988). Tanks for oils of heavier classes E, F, G, etc. will require provision for heating in order to achieve the storage temperatures recommended in **3.3.3.2** of BS 6880-1:1988. In the case of class E oil, an immersion heater may be appropriate. Tanks for class F and G oils will need provision for heating the oil by means of a heating coil and/or outflow heater to a temperature at which the oil can be pumped (see **3.3.3.2** and Table 6 of BS 6880-1:1988). Thermal insulation of heated oil storage tanks is recommended.

Heating medium for tank outflow heaters may be all electric, steam/electric, or steam/hot water. This needs to be determined according to availability, considerations of year round primary energy use and requirements for light-up from cold. The oil storage temperature of heated oil tanks should be automatically controlled, by a thermostat fitted at a level below that of the draw-off point. The distribution temperature of heated oil should be automatically controlled from a thermostat registering oil flow temperature. Extended oil lines for heated oils should be traced and insulated, the tracing elements being thermostatically controlled by means of a surface or immersion thermostat in the oil distribution system.

Transfer or daily service tanks holding heated oils will require tank heating arrangements. Such tanks should be arranged where possible to overflow back to a point where no fire hazard will be caused. A fire valve should be fitted at the outlet from the service tank.

All fuel oil tanks should be provided with mountings and connections as follows, and in accordance with the appropriate British Standards:

a) fill pipe, valve and connections to suit the intended mode of delivery;

b) vent;

c) outlet isolating valve;

d) contents gauge;

e) calibrated dipstick;

f) drain valve;

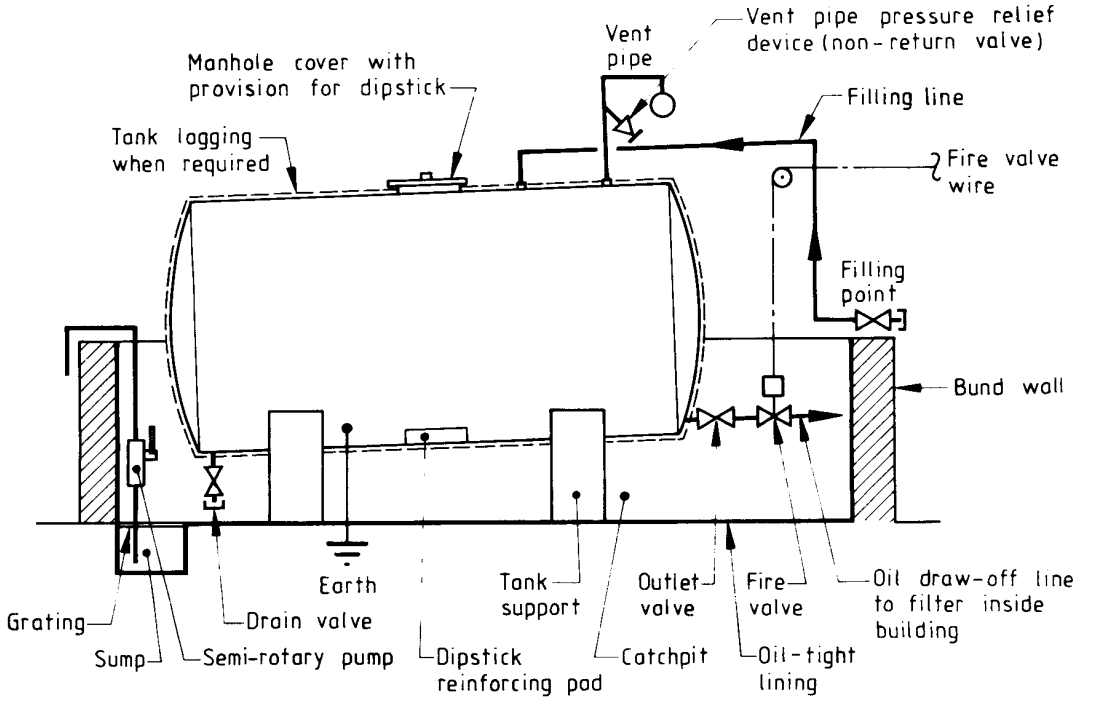
g) overfill alarm.

5.3.1.3 *Solid fuel bunkers and hoppers.* The design of any solid fuel bunker or hopper has to take account of:

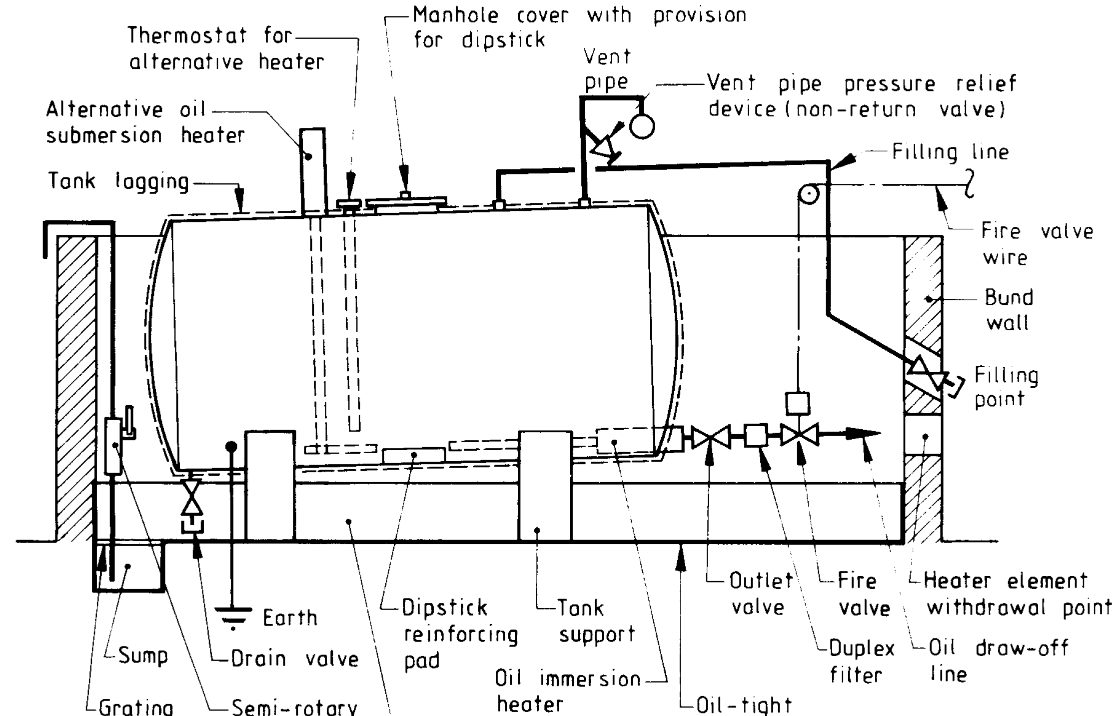
a) the method by which the fuel is delivered;

b) the angle of repose of the fuel;

c) the method by which the fuel will be withdrawn.



(a) Storage tank for distillate grades of oil fuel



(b) Storage tank for residual grades of fuel

Figure 9 — Typical arrangement of horizontal (above ground) oil storage tanks

Most bunkers are constructed from steel or concrete, in some instances with a lining of glass or plastics to assist movement and to reduce wear and corrosion of the bunker walls. Where delivery of coal is to be by tipper, an underground storage hopper is used having a covering grid of sufficient strength to take the weight of the delivery vehicle. On larger installations underground hoppers are frequently provided with conveyors to raise the coal to high level bunkers. Alternatively, tipper vehicles may discharge into ground level mechanical hoppers which can be tilted or otherwise made to move the coal to a discharge conveyor. If delivery is by conveyor vehicle, above ground storage can be provided having hatchways for the insertion of the conveyor.

Pneumatic delivery of coal is only possible with graded coals. It has the advantage of allowing bunkers to be designed for large above-ground stocks. Pneumatic delivery may also be effected directly into cylindrical silos and free-standing bunkers.

Whilst the location and type of bunker should be designed to suit the method of delivery, the design of the bunker base should be arranged to suit the method of extraction, e.g. conveyor, screw, etc. For information on the shape and construction of hoppers and bunkers see the British Coal publication “Technical data on solid fuel plant” [7]. If hoppers and bunkers are to be erected externally it is important to ensure that they are structurally adequate for this purpose.

Control of fuel delivery between underground bunkers and high level hoppers is normally regulated by the level of fuel in the hopper. Coal level controls operate on a number of principles, the major types being as follows:

1) diaphragm control, whereby the weight of the coal acting on a diaphragm operates a microswitch to activate or stop the coal feed;

2) mechanical/electrical, where a rotary blade registers the torque imposed on its shaft by the level of the coal;

3) a flap which rests on the coal heap in the hopper; as the heap rises, the flap activates a microswitch.

The design, installation, maintenance and operation of coal handling and storage systems should take account of the risk of spontaneous combustion (see **3.3.3.3** of BS 6880-1:1988) and of dust ignition and explosion. With regard to the latter, safety features should be incorporated and procedures adopted as appropriate to meet the objectives of section 31 of the Factories Act. (See also Institution of Chemical Engineers booklet “Guide to dust explosion prevention and protection”, Part 1, Venting [10]).

5.3.2 Fuel handling equipment

Mains gas is normally supplied at a pressure suited to gas appliances. Public gas undertakings are required to maintain minimum pressures.

Where fan-assisted gas burners are used on LTHW boilers, a higher gas supply pressure may be necessary to achieve a condition compatible with combustion air pressure and thus ensure proper flame shape. In such cases a gas pressure booster is required. It is very important that a booster does not draw gas from the main at such a rate that the pressure upstream of the booster falls below a minimum figure; adequate low pressure cut out controls are required to ensure that this cannot occur. The Gas Act 1972 requires that the area gas undertaking be notified when a booster is to be fitted. They should be consulted on the regulations and safety precautions to be applied. The booster should be selected to achieve the pressure requirement at the burner plus any estimated pressure losses in gas mains and fittings between burner and booster.

5.3.3 Fuel oil pumping and heating

5.3.3.1 *Fuel oil transfer pumps.* It is not always possible to transfer oil by gravity from the storage tank to the burner, in which case a pump will be necessary. Oil pumps feeding burners direct should have a duty in excess of the minimum burner requirement. They should be designed to maintain a constant oil pressure to the burning equipment and variations in flow rate should be accommodated by such methods as:

a) a variable volume pump;

b) a constant volume pump operating with a pressure control valve which bypasses excess oil back to the suction side.

Oil pumps transferring oil from the main storage tank to a daily service or similar tank may be of the positive displacement type with on/off control. If reciprocating pumps are used air bottles should be fitted to limit pressure fluctuations. It is normal practice for oil pumps to be provided with a standby. Each pump should be fitted with an integral pressure relief valve. Pumps should be installed as close as possible to the storage tanks so as to keep the suction pressure loss to a minimum. In some instances where the suction head is low it may be possible to dispense with a separate oil pump and utilize a pump which is incorporated in the oil burner.

Glands and packing should be resistant to the action of the oil being handled. Inlet and outlet connections of the pump should be fitted with plugged tappings to allow pressure/temperature readings to be taken, and with line isolating valves.

5.3.3.2 *Fuel heaters.* With heavier oils it is usual to raise the temperature of the oil in the tanks to normal storage temperature by means of steam or hot water coils, or immersion heaters and then to boost this to the circulating temperature by an outflow or line heater (see **5.3.1.2**). Where heaters are fitted it is necessary to ensure that oil carbonization does not occur due to excessive surface temperatures, especially at no flow conditions. The surface temperature of the heating element should not exceed 175 °C. Recommended oil handling temperatures are given in **3.3.3.2** and Table 6 of BS 6880-1:1988; some fuel oil suppliers publish extensive data on the sizing of fuel oil heating systems. Heaters should be constructed from materials resistant to corrosion and erosion due to contact with hot oil (see BS 799-4). Pressure relief valves to take account of expanding oil should be fitted to all oil heaters.

Electric heaters should be constructed so that all internal surfaces in contact with oil can be cleaned. All external metal should be earthed (see **3.9** of BS 6880-1:1988). Steam or hot water heaters should be constructed so that surfaces in contact with oil can be easily cleaned. Proper provision should be made for venting and steam trapping. Space should be left for the insertion and withdrawal of outflow and immersion heaters.

5.3.3.3 *Fuel oil filters.* Means should be provided for preventing solid matter in the oil from choking or damaging components of the oil burning system. Filtration is frequently provided in two stages:

Stage 1. Protects the pumps and similar equipment in the lines.

Stage 2. Protects the valves, atomizers and similar equipment with small orifices.

Filters should be located so that they may be easily cleaned, and use of duplicate filters allows one filter to remain in operation whilst the other is being cleaned. All materials should be suited to the oil being handled and the intended temperature of operation. Filter screens should not be finer than is necessary to provide adequate protection, otherwise excessive hydraulic resistance will be generated. Recommendations are given in BS 799-4.

5.3.3.4 *Heated fuel oil circulation systems.* Where fuel oil is heated for circulation, the individual components referred to in **5.3.3.1** to **5.3.3.3** need to be integrated into a complete fuel handling system which is compatible with the particular types of fuel, the burner type and control method and the vertical and horizontal relationship between the burners and the fuel tank. A typical hot-oil ring main arrangement is indicated in Figure 10, but particular burners and layouts may require different arrangements for satisfactory operation, e.g. separate oil spill lines from each burner.

5.3.4 Solid fuel handling

5.3.4.1 *Coal handling*

5.3.4.1.1 *Screw conveyors.* Screw conveyors consist of a screw within a tube or open-topped trough through which coal is conveyed by rotation of the screw. This type of conveyor may be used horizontally to convey coal from bunker to stoker, or it may be inclined for use as an elevator. Screw conveyors are generally confined to smaller applications handling 0.5 t/h to 10.0 t/h. When the base of the conveyor is in a ground hopper and the conveyor is handling wet washed smalls, i.e. coal with a specified upper size normally below 50 mm with no lower size limit, some form of agitation of the fuel needs to be provided by means of a vibrator or gyrator.

5.3.4.1.2 *Bucket elevators.* Bucket elevators consist of an endless belt or pair of chains to which buckets are attached at intervals to give a continuous elevating system. The primary feeder to the elevator from the bunker can be of the ram, reciprocating, vibrating or star type and should be in accordance with the elevator manufacturer's recommendations. Classified coals are produced by a wet system of coal preparation and hence contain free moisture; consequently some form of anti-corrosion treatment should always be applied. The design of the bucket may vary according to the coal handled. When used with smalls, steel buckets should have vitrified enamel finish to reduce coal adherence and as an anti-corrosion feature. A plastics bucket type has also been found to be suitable for application to most types of coal.

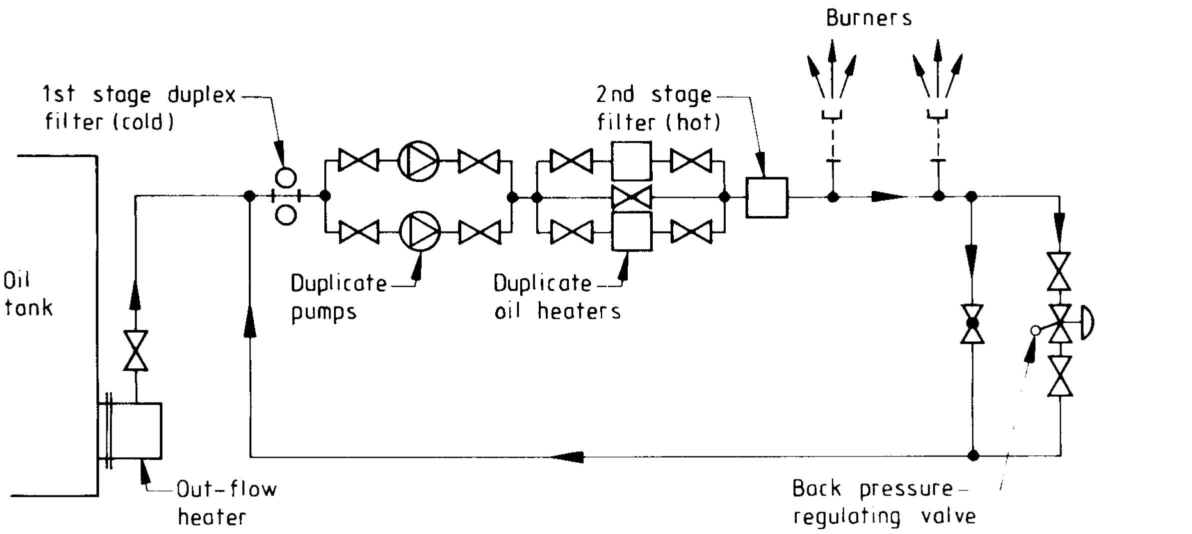


Figure 10 — Typical hot-oil ring main arrangement

Elevator capacities range up to 30 t/h. They can be installed vertically or at an angle of about 60°. The elevator can be used to transfer coal direct to the stoker hopper, or in conjunction with a horizontal conveyor.

5.3.4.1.3 *Belt conveyors.* Belt conveyors consist of a continuous belt onto which the coal is discharged for delivery to bunkers, etc. There are a number of belt designs all aimed at increasing carrying capacity for a given conveyor or width. Belt conveyors may be used to elevate coal provided that the angle is not greater than 25°. They can also be used to feed a number of points by being fitted with adjustable plates or ploughs designed to divert the coal from the belt into the various storage bunkers. These may be manually or automatically operated.

5.3.4.1.4 *Overhead monorail.* Coal handling is by means of an electric hoist and grab on an overhead monorail. This is used to collect fuel from the stockyard or storage area and transfer it into the boiler house bunkers and hoppers. Operation is normally by manual control, but automatic control is available.

5.3.4.1.5 *Drag link conveyors.* Drag link conveyors comprise a trough or duct through which coal is drawn by a continuous chain of bars, flights, or shaped links. The simple drag bar type may be used to convey coal in a trough across the tops of overhead bunkers, discharging into them through individual gates. The en-masse type comprises a duct completely filled with coal which is dragged through by specially shaped links, and can be routed in any vertical or horizontal direction.

5.3.4.1.6 *Pneumatic conveyors.* Two basic types of pneumatic conveying are used:

a) lean phase, where large volumes of air at high velocity convey coal in suspension through steel tubes to the point of delivery;

b) dense phase, where small volumes of air at high pressure push a slug of coal at low velocity through tubes to the point of delivery.

Dense phase conveying has the advantage that due to low coal velocity, wear on the tubes is reduced to the minimum. Pneumatic conveying is used for delivery from lorry to bunker or silo, as well as for conveying coal within the boiler house. Boilers are available for direct feed by means of pneumatic conveying, the air used for transportation assisting with combustion (see **5.1.4.4**).

5.3.4.1.7 *Miscellaneous conveyors.* Other types of conveyor are in use, including tubular or troughed vibratory conveyors, and a type comprising a flexible tube which moves bodily when containing coal, filling and discharging being effected by forcing open a longitudinal joint in the tube wall.

5.3.4.2 *Solid waste handling.* Due to the variability of solid waste materials, specific recommendations cannot be made in respect of handling, which needs to be designed by experienced specialists, given reliable data on relevant fuel properties (see **3.3.2** of BS 6880-1:1988). Some of the methods referred to in respect of coal handling may be suitable in certain cases.

Waste should preferably be stored reasonably close to the boiler plant, but under conditions where fire and wind dispersion can be controlled. With certain wastes particular measures will be necessary to protect operatives from harmful effects and also to ensure that flue discharges are safe at all times, particularly where dangerous emissions may arise in respect of which the regulations based on regular fuel may not be specific. In such cases, the environmental health authority should be consulted at the preliminary stage. Where waste contains high proportions of dust, such as waste from woodworking operations, handling should take account of the dangers of explosion inherent in such material (see **5.3.1.2**). Where bulky waste such as cartons, cardboard, etc. is to be burned, it normally requires prior compaction or other treatment.

5.3.4.3 *Instruments and controls for solid fuel handling.* Screw conveyors are frequently manually controlled on an on/off basis or by one of the methods described in **5.3.1.3**. Bucket elevators are normally controlled by a diaphragm switch fitted in the side of the delivery chute or by means of high and low level probes. Pneumatic conveying can be controlled by level switches in the bunkers which send signals for the feed cycle to commence, at the same time opening cut-off valves to the bunker requiring replenishment.

A mimic panel may be provided in the boiler house showing the status of bunkers and other equipment, in conjunction with automatic or manual control.

5.3.4.4 *Ash and grit disposal.* Fully mechanical ash removal systems are generally only applicable to large installations. The smaller LTHW systems tend to use manual methods and standard disposal containers. Sectional boilers are commonly fired by underfeed stokers and are usually hand cleaned; in some cases they have additional ash storage facilities to obviate the necessity for daily ash removal. Where mechanical ash removal is used the most common forms of extractor are the drag link, plough and vibratory types.

When ash is deposited into bins and trolleys means should be provided for removing these to a disposal point. If the boiler house is not at ground level hoists or a lift may have to be provided. Where the size of the plant warrants the cost, automatic transfer of ash from boiler house to disposal container is carried out by screw or vibratory conveyors. Ash is finally deposited in skips, bins or silos for removal. Steps should be taken to minimize nuisance arising from dust associated with ash stored in open containers.

With solid fuel-fired installations, some provision for removal of dust and grit from the flue gas in order to achieve acceptable emission standards and to protect adjacent property is usually necessary. This often takes the form of a gas-cleaning cyclone or grit arrestor, which should be specifically designed for the purpose and fully integrated with the design of the boiler, flues and draught arrangements.

5.3.5 Flues and chimneys

5.3.5.1 *General.* Flue and chimney installations should be designed in accordance with the applicable British Standard, in particular BS 4076 or BS 5854.

Very small gas-fired installations (below 60 kW input) coming within the scope of this code should be in accordance with BS 5440-1. However it should be noted that many types of flues and chimneys in common use are not covered by British Standards at the time of drafting. Flue and chimney arrangements should be such that the complete installation meets, and can be operated in accordance with, the requirements of the Clean Air Act 1968 in general, and the memorandum on chimney heights in particular (see **3.3.5.3** of BS 6880-1:1988). They should also be constructed so that any required monitoring of the flue gas conditions can be carried out (see **5.1.1.5**), and occasional inspection and cleaning. The structural implications of chimneys are particularly important (see **2.4.2.3** of BS 6880-1:1988) and they should conform to the relevant building control requirements. The basic principles of operating of boiler draught systems are described in **3.3.5.5** of BS 6880-1:1988. Further information is given in Section B.13 of the CIBSE Guide [1], BS 5410 (oil-fired) and British Gas publication IM/11 [11] (gas-fired).

Flues should be circular in section. If a flue has to be rectangular, it should ideally be square, but in no case should one side be more than 1.5 times the dimension of the other. Boilers should be sited as close as possible to chimneys to keep connecting flues as short as possible. Bends and fittings on flues should be kept to a minimum, and where bends occur, they should be fitted with access/explosion doors. Abrupt section changes should be avoided and where possible, flues should slope upwards towards the chimney. All horizontal and connecting flues should be insulated.

With certain types of burner, draught stabilizers may be required; the boiler manufacturer's recommendation should be obtained. However, with higher sulphur fuels, the regulation of draughts by stabilizers is not recommended; such regulation is best obtained by automatic modulating dampers which may also serve as flue isolators. Particular attention should be paid to the possibility of acid corrosion due to low flue gas temperatures (see **3.5** of BS 6880-1:1988 and **5.1.1.4** of this Part of BS 6880), especially where partial or fully condensing boilers are to be used. With individual chimneys and flues an alternative would be the use of a tight closing type of burner damper, thus ensuring that the damper is maintained in a cool clean environment.

The seasonal thermal efficiency of a boiler installation can be often improved by preventing the flow of cool air through the flue system of a boiler which is not being fired, by fitting an automatic flue isolation damper. Such devices should be specially designed and constructed for the purpose, regularly inspected and maintained. They should have appropriate control interlocks fitted and integrated into the burner safety controls system such that they fail safe and there is no possibility of burner operation if the damper is not fully open (see HSE Guidance Note PM5 [3] and British Gas publication IM/19 [12] and BS 5978).

Materials in common use for flue and chimney construction are described in **5.3.5.2** to **5.3.5.7**. Whilst the flue types described are generally suitable for forced draught or induced draught applications, it should be appreciated that leakage in either direction may promote corrosion. Inwards leakage may cause undue cooling of flue gases; outwards leakage (from pressurized flues or chimneys) may promote corrosion externally due to cooling of the leaked flue gases. Pressurized flues and chimneys should preferably be avoided.

5.3.5.2 *Steel.* Steel chimneys may be self-supporting or guyed (under the London Building Acts (Amendment) Act 1939 they have to be both); construction should be in accordance with BS 4076. Self-supporting stacks are anchored to a substantial foundation, whilst guyed stacks are carried on a foundation or structural support but rely upon guy wires for stability. Steel chimneys should be insulated to maintain the temperature of the internal surfaces above the acid dew point of the flue gases. Without insulation severe deterioration of the flue will take place, particularly at the flanged joints. The most common method of insulation has been to encase the flue in a polished aluminium casing, leaving an air gap of at least 6 mm. With large turn-down ratios and other causes of low flue gas temperatures, this form of insulation may prove insufficient. Alternatively, interior lining with a refractory material may be used. Multiple steel chimneys have a number of flues encased in a common wind shield which may be steel or concrete. The inner flues are insulated either by the application of mineral wool or by infilling the whole space around the flues with loose insulation. The construction of multiflue chimneys should incorporate expansion joints to take account of differential expansion, and provision should be made in the design of the external casing for the possible future removal or repair of inner flues. Where a steel chimney passes through a roof, a steel weathering ring and cravat will be required, purpose designed and detailed to suit the particular type of roof construction; this is particularly important with profiled sheet roofing.

5.3.5.3 *Brick.* Brick provides a more durable construction than steel and requires less maintenance, but an impervious lining of suitable refractory material is necessary. Deterioration of both brick and concrete chimneys usually occurs in the top 5 m approximately, due to flue gases being cooled below the acid dew point; for this reason the top section of the flue should be constructed from engineering or acid-resistant bricks. Ornamentation and overhangs at the top of the chimney tend to increase the possibility of corrosion. The possibility of thermal stresses in linings should be recognized and the recommendations of BS 4076 followed.

5.3.5.4 *Concrete.* Similar conditions to those for brick apply to concrete. Concrete chimneys are usually constructed from factory-made precast units having an outer wind shield and an inner flue lining, thus minimizing installation time. Concrete chimneys should be refractory, lined internally with an appropriate formulation, proven in the expected conditions and correctly applied.

5.3.5.5 *Resin-bonded, reinforced glass fibre.* Resin-bonded, reinforced glass fibre is not affected by low temperature corrosion, and may be appropriate in situations where low flue gas temperatures are expected. However, it has much lower temperature limitations than the other chimney materials described in this code (typically below 250 °C). As in the case of steel chimneys, thermal insulation should be applied to avoid soot emission and provision should also be made for high thermal expansion.

5.3.5.6 *Fibre-reinforced cement.* Fibre-reinforced cement is frequently used in gas-fired applications where temperatures are not likely to exceed 260 °C. The material is fairly resistant to the effects of corrosion, but nevertheless every effort should be made to prevent the formation of condensation. Fibre-reinforced cement flues should be supported at every socket, and where they are fitted to an appliance having an atmospheric burner the inclusion of a draught diverter is necessary to prevent any possibility of down-draught (see **3.3.5.5** of BS 6880-1:1988). The need for particular precautions when working with asbestos should be recognized (see **2.2.7** and **2.2.8** of BS 6880-3:1988).

5.3.5.7 *Modular insulated metal components.* Modular insulated metal components are factory-made standard sections and components from which non-self-supporting flues and chimneys may be built up on site, for small- and medium-sized applications. They are usually manufactured from double-skin, corrosion-resistant sheet metal with insulation sandwiched in between and a special jointing arrangement. Where such installations are used, materials should be selected for the specific flue gas type and temperatures. All components should be compatible and support should be provided in accordance with the manufacturer's recommendations. Where condensing boilers are used, the effective sealing of such chimneys is particularly important.

5.3.5.8 *Flue dilution systems* (see also **3.3.5.5.5** of BS 6880-1:1988). On gas-fired installations where it is difficult to install a natural draught flue, a fan dilution system may be appropriate, such that flue gases can be discharged at low level, provided that no nuisance would be caused thereby. Air is drawn into the duct carrying the flue gases by means of a fan specially constructed for this application, the amount of air being designed to limit CO_2 emission to no more than 1 %. Precautions against dilution fan failure should be incorporated. Vertical installations are possible up to large outputs (see British Gas publication IM/11 [11]). Flues may be constructed from cement-based sheet or steel sheet, strengthened with steel angle stiffeners; steel components should be suitably protected against corrosion.

5.4 Boilers and combustion ancillaries: selection factors

5.4.1 Selection factors for fuel storage

Selection factors for fuel storage installations include (as relevant):

a) fuel type;

b) capacity (volume or mass, as appropriate);

c) expected size of normal delivery;

d) method of delivery, access and connection requirements;

e) location, vehicle manoeuvering space and possible environmental considerations;

f) elevation with respect to combustion equipment;

g) ancillary service availability (e.g. heating).

5.4.2 Selection factors for solid fuel handling

The following selection factors are applicable to solid fuel handling.

a) Screw conveyors are suitable for size classified coals but use of smalls and fines can result in blockages. The method of conveying can also cause degradation of the coal if it is friable. The screw conveyor is of relatively low cost and subject to wear although replacement parts should be readily available.

b) Bucket elevators are suitable for all types of coal and are particularly applicable to the raising of coal from an external underground bunker to high level.

c) Belt conveyors are simple and quiet in operation and also have the advantage of low power consumption; plain belts are not suitable for steep lifting applications, for which ribbed and side wall belts are available.

d) Overhead monorail systems are mainly applied where fuel is stored in an external stockyard.

e) Pneumatic conveying, being a totally enclosed system, is a very clean method of coal conveyance. It also has the advantage of space saving both as regards the conveyor pipes and the bunkers. Boiler house roof heights are kept to a minimum and need to be no higher than is necessary for maintenance of the delivery pipes and diverter valves.

With any solid fuel handling system, the sizing of bunkers should be related to the expected pattern of fuel deliveries and to the boiler house shift pattern, noting that structural considerations may impose limitations on the capacity of overhead storage, where this is required.

5.5 Heat exchangers and thermal storage vessels: types

5.5.1 General

This clause is concerned with heat exchangers used for the generation of LTHW by heat exchange from some other heated fluid at a higher temperature, such that the two fluid streams do not mix. It is also concerned with thermal storage vessels which may operate by the use of a heat exchanger (as with a storage calorifier) or by direct mixing of primary LTHW (heat input) and secondary LTHW (heat output). Heat exchanger heat source fluids are typically:

a) steam;

b) higher temperature hot water (i.e. above 100 °C);

c) LTHW at a higher temperature than the system LTHW temperature, as may arise in heat recovery applications.

The term heat exchanger is used in this code to cover all types, including those traditionally referred to as calorifiers. This code is not concerned with heat exchangers/calorifiers intended for the production of domestic hot water. Heat exchangers associated with refrigerants are covered in **5.8**.

Where primary fluids other than steam or clean, treated hot water circulated in a closed circuit are to be used, particular attention should be paid to considerations of corrosion, erosion, scale formation, presence of solid particles, etc. in design and selection of the heat exchanger. These considerations are particularly important in heat recovery situations.

5.5.2 Principal types of heat exchanger and construction

5.5.2.1 *Shell and tube type.* Shell and tube type heat exchangers consist of an outer shell and chest of low carbon steel or cast iron and a bundle of copper tubes usually in the form of a two-pass or three-pass withdrawable "U" pattern arrangement [see Figure 11(a)]. The usual arrangement is for the LTHW to flow through the shell, guided by baffles, and the higher temperature heating medium to flow through the tubes. The shell may be arranged vertically or horizontally. The tubes may be of plain or extended surface type, expanded into a machined tubeplate. These are also referred to as non-storage calorifiers, to distinguish them from those which include storage capacity on the LTHW side (see **5.5.2.2**).

It should be appreciated that these heat exchangers often contain fluids at temperatures and pressures in excess of those associated with LTHW, and therefore their construction and fittings should be in accordance with the appropriate design codes and safety requirements. There may also be an insurer interest in the equipment. Shell and tube heat exchangers for use on LTHW heating systems should be designed, constructed and tested in accordance with BS 853 or BS 3274 (type 2 is usually preferred), according to the temperature and pressure ratings required. Pressure and temperature limits applicable to BS 853 for steel and cast iron shell calorifiers are given in Table 6.

Table 6 — Maximum working pressures and temperatures for calorifiers complying with BS 853 (grade A)

Item	Maximum pressure	Maximum temperature
	bar	°C
Shell	7	120
Tubes	17.5	300

For maximum working conditions in excess of those in Table 6 BS 3274 applies.

Heat exchangers should be provided with mountings and fittings on the LTHW (secondary) side as specified in BS 853, BS 3274 or BS 5500 as applicable, with particular reference to sizing of relief valves, etc. Mountings should comply with the relevant requirements of BS 759.

The following mountings and fittings apply:

a) relief valve;

b) pressure gauge;

c) thermometer;

d) open-vent pipe on systems open to atmosphere;

e) drain cock.

In the case of multiple installations, the venting arrangement should be as described for multiple boilers (see **3.4.5.5.3** of BS 6880-1:1988). The fitting of a bursting disc is recommended wherever the primary heating medium pressure exceeds that of the calorifier shell. Rating should be the greater of 1.5 times the shell working pressure, or the relief valve setting. This recommendation is made notwithstanding the fact that BS 853 does not call for a bursting disc unless the primary heating medium is hot water.

On the primary heating medium side, the following should be provided.

1) Means of thermostatic control of the primary fluid arranged to provide control and fail-safe shut-off in response to the secondary LTHW temperature in the shell; shut-off provision may not be necessary with LTHW/LTHW heat exchangers, depending on circumstances. The risk of overheating due to control valve leakage when shut should be considered.

2) Pressure gauge on the primary side where pressure is significantly in excess of secondary side pressure.

Pipe connections should comply with BS 4504 (flanged) or BS 21 (screwed). Provision should be made for lifting and otherwise facilitating removal of the tube bundle for maintenance and cleaning, except on the smallest sizes.

This calls for clear space to the side (horizontal units) or above (vertical units). Mounting feet should be designed and constructed as an integral part of the shell, with due allowance for thermal expansion. The shell and chest should be thermally insulated (see **3.6** of BS 6880-1:1988); the thickness should be at least equal to that recommended for the pipe size corresponding to the shell diameter; for sizes greater than 300 mm diameter the recommended thickness for flat surfaces should be used as a minimum. However, where the heat exchangers are to be installed in plant rooms with limited ventilation, the heat input to the room should also be considered and an increased thickness used where necessary.

5.5.2.2 *Storage type.* Storage type heat exchangers tend to be mainly associated with domestic hot water generation and storage, which is outside the scope of this code. However, in situations where it is required to introduce storage of LTHW for space heating purposes, this type may be appropriate. They normally consist of a tube bundle similar to that described for the shell and tube type, within a larger shell or vessel, usually of steel [see Figure 11(b)]. Shells may be horizontal or vertical; tube bundles are usually horizontal. Access handhole or manhole is required in the shell, as appropriate. Construction of steel shell storage calorifiers should be as specified in BS 853 well within the limits indicated in Table 6. Otherwise, construction should comply with BS 5500 or other recognized pressure vessel standard (see also **5.7**). The general considerations indicated in **5.5.2.1** in respect of the non-storage type apply, except where clearly only relevant to the latter.

5.5.2.3 *Plate type.* Plate type heat exchangers are extensively used in heat recovery applications where relatively small temperature differences may apply. They consist of a sandwich construction of alternating pressed thin plates sealed with edge gaskets and bolted together (see Figure 12). The two fluid streams pass through the passages formed between adjacent plates. A large heat transfer area is contained within a relatively small volume. At the time of drafting there is no British Standard covering this type of heat exchanger.

Construction and material selection should be appropriate to the duty conditions; critical items are the plate material (typically stainless steel) and the gasket (typically synthetic rubber). Normal LTHW temperatures are well within the capability of established types. Pressure ratings are not standardized; 5 bar is typical for LTHW applications and considerably higher pressures can be accommodated.

The plates are contained in a frame which is arranged with free space to permit opening of plates for inspection and cleaning. Plates can usually be added. General comments in **5.5.1** apply in connection with primary fluids where other than clean water. Thermal insulation is not usually practicable; the lower temperature fluid passes should preferably be adjacent to the end plates to reduce heat loss. Covers to protect the plate edges from dirt are available. The plates are normally arranged vertically, but there is a variety of possible connection and pass arrangements.

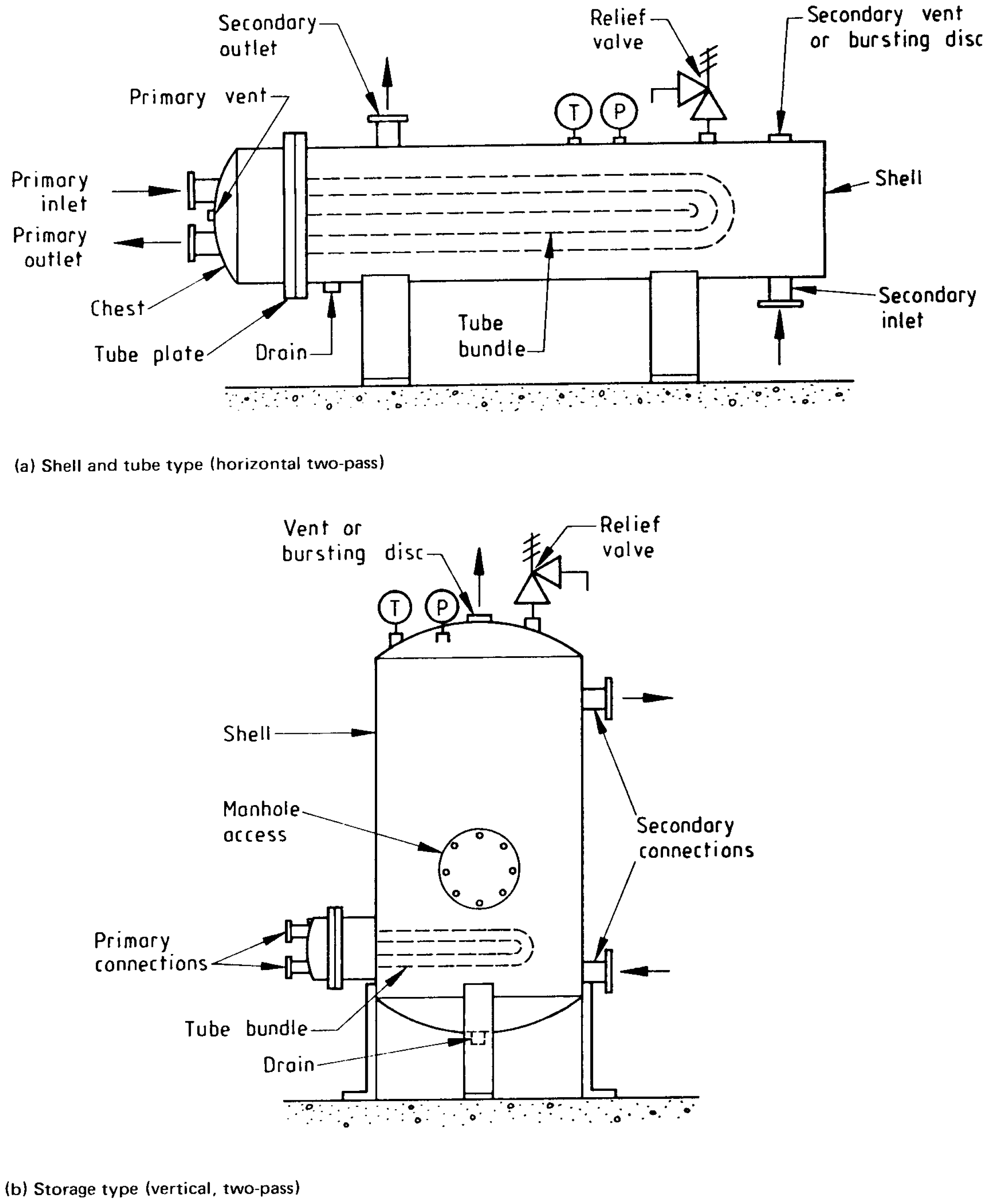


Figure 11 — Principal tube heat exchanger (calorifier) types

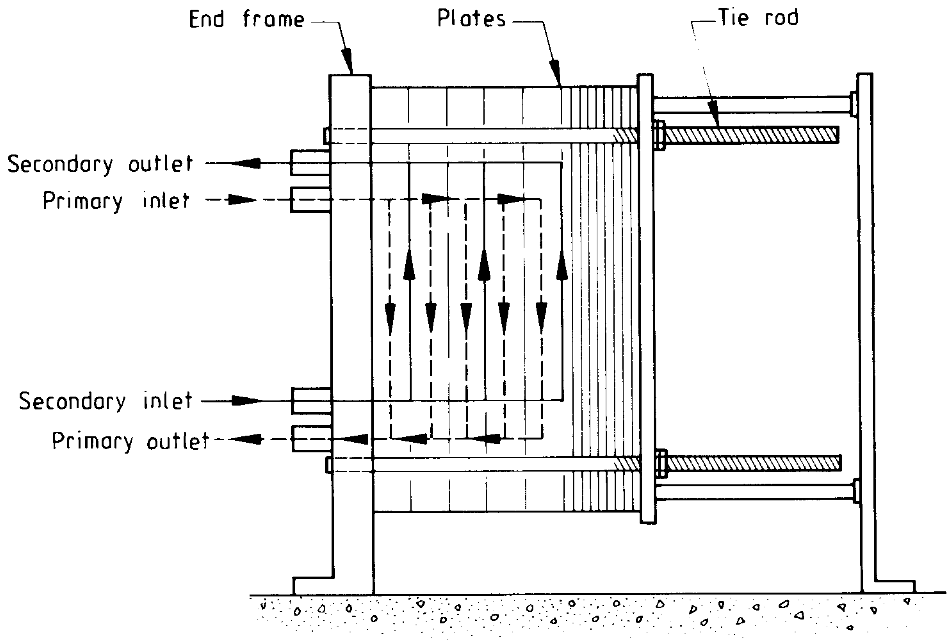


Figure 12 — Plate type heat exchanger

5.5.3 Thermal storage vessels

5.5.3.1 *Application.* Thermal storage vessels may be introduced into a system where it is required to accumulate available heat at times when it is not required, or to enable the load profile to be met by energy conversion equipment sized for less than peak demand (see Figure 1 and **3.2.5** of BS 6880-1:1988).

The thermal storage capacity of such a vessel is determined by the volume of water stored and the maximum and minimum temperatures (temperature range) between which its contents are allowed to fluctuate, such that heating loads can be served. The temperature range to be used needs to be carefully assessed and an optimization carried out which relates these to the amount of heat to be stored, vessel size, and to the effect of the lowest usable LTHW flow temperature on sizing the utilization subsystem (emitters). Consideration should also be given to the instrumentation and controls required so that operation under varying load conditions is as intended. The difficulty of controlling with respect to low differential temperatures should be appreciated, and the possible effects of control valve leakage considered. It should be appreciated that since the possible temperature range tends to be limited in LTHW situations, in a given case the storage of a higher temperature medium may prove more effective and occupy less space. This type of thermal storage is outside the scope of this code, but see also **5.7.2** and **5.7.3** for electric thermal storage vessels.

5.5.3.2 *Construction.* LTHW thermal storage vessels usually take the form of insulated cylindrical steel vessels, shop fabricated or site erected according to size. It should be appreciated that such vessels are classed as pressure vessels when used on LTHW systems. They should therefore be designed, constructed and tested in accordance with the requirements and procedures of a recognized pressure vessel standard, preferably BS 5500, except where the application is within the scope of storage calorifiers complying with BS 853, in which case that standard may be used. There may be an insurer interest in a thermal storage vessel.

For the efficient functioning of an LTHW thermal storage vessel it is usually necessary to discourage convection within the stored water and to promote stratification such that the temperature of the stored water increases steadily from a low level LTHW inlet to a high level LTHW outlet. This can never be fully achieved in practice, and careful attention to the internal construction of the vessel is necessary, incorporating such devices as baffles, sparge pipes, etc. The details, penetrations and attachments associated with these should be in accordance with the design rules of the applicable pressure vessel standard.

Such a vessel may be located within or outside a building and may constitute a major structural load. Attention should be given to the means of safe discharge of water for when the vessel is drained down. Particular care is required for determining the working pressure for design purposes, having regard to the maximum static pressure applicable to the LTHW system under the extreme of normal operating conditions, taking account of required relief valve settings. A clear understanding is required with the inspecting authority for the vessel if it is considered that, by virtue of the height of the vessel, the working pressure at the top is less than that lower down.

Manholes should be provided as necessary for internal inspection purposes, and internal ladders may be necessary on large vessels; such features should be located and detailed in accordance with the requirements of the pressure vessel standard. For storage vessels outside the scope of BS 853, a vent, pressure relief valve and anti-vacuum valve should be fitted, together with at least two temperature measurement points, one near the top and one at an appropriate lower level. Fittings should be incorporated in the design for all required attachments, including temperature sensors for control; a thermometer connection adjacent to these is useful for checking purposes. Insulating valves and drain fittings should be provided so that the installation can be readily drained down and rendered safe for entry. Pipe connections should comply with BS 4504 (flanged) or BS 21 (screwed). The vessel should only be filled with water that has been treated to the same standard as applies to the rest of the LTHW installation. Attention should be given to appropriate external and internal anti-corrosion protection, and provision of corrosion allowance in accordance with the pressure vessel standard.

Thermal insulation should at least meet the minimum requirements of BS 5422 for flat surfaces (see **3.6** of BS 6880-1:1988), having particular regard to weatherproofing in the case of externally located vessels. The desirability of a higher thermal standard of insulation should be assessed as part of the optimization procedure.

5.6 Heat exchangers: selection factors

5.6.1 General

In selecting heat exchangers it should be appreciated that for given fluid conditions and exchanger arrangement, the heat transfer rate Q (in kW) is primarily a function of the surface area available for heat transfer and the mean temperature difference between the two fluids. This can be derived from the following equation:

$$Q = c \times A \times D$$

where

- c is the constant for a given heat exchanger and defined fluid conditions (in $kW/m^2 \cdot K$);
- A is the effective heat transfer area (in m^2);
- D is the log mean temperature difference (in °C), a mathematical relationship between the various inlet and outlet temperatures (see **3.4.2**).

The term approach is also used to indicate the closenesss of the LTHW (secondary) outlet temperature to that of the primary heating medium; generally speaking, the smaller the approach, the larger the heat exchanger.

The size and cost of a given heat exchanger type is largely governed by the surface area. The temperature difference can have a significant effect on the effective performance of other parts of the system, particularly in heat recovery situations and when using heat pumps (see also **5.8**). This often gives rise to the need for optimization of these factors, and the smallest heat exchanger which will give the required output is rarely the most suitable selection. Fouling is also an important consideration in heat exchanger rating, and factors should be allowed where appropriate (see **5.6.3**); fouling provision tends to increase the heat exchanger size.

5.6.2 Basic sizing factors

Particular factors to be considered include:

a) required heat input to the LTHW side (in kW);

b) nature and temperature conditions (in °C) of the primary heating medium;

c) LTHW inlet and outlet temperatures (in °C) and relationship to primary medium temperatures in terms of mean temperature difference and approach;

d) flow pattern through the exchanger (counterflow is most commonly used in LTHW applications);

e) working pressures (in bar) on primary and secondary sides;

f) required primary medium flow (in kg/s) and resultant hydraulic resistance/pressure drop (in kPa);

g) required LTHW secondary flow (in kg/s) and resultant hydraulic resistance/pressure drop.

It should be noted that plate heat exchangers tend to have greater hydraulic resistance than the corresponding shell and tube type; this should be taken into account, particularly when assessing heat recovery economics.

5.6.3 Other factors

The required physical arrangement, types and sizes of pipe connections and provisions for cleaning and maintenance should be considered.

The nature of the fluids to be handled should be clearly established, with particular reference to the likelihood of corrosion, erosion, scale formation, deposition of slime or other residues and presence of solid particles (see also **3.5** of BS 6880-1:1988). This requires particular attention on the primary side, especially with heat recovery situations, water source heat pumps or use of open circuits. Appropriate fouling factors should be applied so that required performance can be achieved between cleaning intervals. On the LTHW side, a minimum fouling factor of 0.088 $m^2 \cdot K/kW$ should be applied. For other fluids and situations see "Standards of the Tubular Exchanger Manufacturers' Association" [13].

5.7 Direct electric energy conversion equipment

5.7.1 General

The use of electricity for the direct generation of heat should only be considered in special circumstances because of the high usage of primary energy inherent in this method (see Part 2 of the CIBSE Building Energy Code [2]); the same applies to off-peak LTHW storage heating systems, although annual estimated energy cost may be lower at the time the design is undertaken.

Where it is decided to use direct electric heat generation, in the absence of British Standards or codes applicable to the specific type of equipment, control of energy output should be provided, together with appropriate mountings including relief valve, vent or bursting disc, thermometer and pressure gauge such as to comply with the safety principles of Health and Safety Guidance Note PM5 [3], and such as to provide a standard of operational safety not inferior to that required for fuel-fired LTHW boilers.

Direct electric heating imposes heavy demands on the electricity supply and distribution system which should be planned and sized to handle the relatively high currents arising. Excessive voltage fluctuations and other disturbances should not be apparent on adjacent parts of the distribution system (see **3.9** of BS 6880-1:1988).

5.7.2 Electrode boilers

Where electrode boilers are used they should comply with BS 1894. These operate by the resistance effect of a heavy electric current passed directly through the system water, between electrodes. The conductivity of the system water is therefore particularly important and should be kept within the manufacturer's recommended limits. System water treatment should be compatible with these limits as well as with system corrosion considerations (see **3.5** of BS 6880-1:1988). The means of output control forms a major part of an electrode boiler installation, usually a mechanically operated system which varies the degree of immersion of the electrodes in the system water. The general safety principles indicated in **5.7.1** should be observed, together with the specific requirements of BS 1894. Electrode boilers operating at conditions in excess of those defined for LTHW (see **1.2.1** of BS 6880-1:1988) are outside the scope of this code. The special requirements of Chapter 55 of the IEE Regulations [14] in respect of electrode boilers should be observed.

5.7.3 Electric immersion storage heaters

Electric immersion storage heaters consisting of electric resistance heaters immersed in, and insulated from, LTHW system water. They are usually contained in a storage vessel and controlled so as to take advantage of preferential tariffs at night, etc. The general recommendations in **5.7.1** apply, and the LTHW storage vessels (classed as pressure vessels) should be in accordance with the recommendations of **5.5.3**.

A variant on this principle uses a high pressure storage vessel fitted with immersion heaters, which stores a body of water at temperatures in excess of that defined for LTHW. This body of water does not circulate and abstraction is indirect, by means of tubular heat exchangers immersed in the stored high temperature water through which the system LTHW is pumped. A system of controls, usually employing the blending principle, regulates the LTHW output; particular attention to safety of operation is important, to minimize the risk of introducing water at excessive temperatures into the LTHW system.

5.8 Heat pumps: types

5.8.1 General

The refrigerating equipment used for heat pumps for space heating is of a similar nature to that used in connection with air conditioning and operates on the same thermodynamic principles. However, certain aspects are of particular importance in the context of LTHW sink heat pumps and these are highlighted in this clause. For a general description of refrigerating equipment for building services see **4.10** of BS 5720:1979. Attention is drawn to the importance of a careful assessment of annual energy usage in terms of both cost and primary energy use, when considering the possibility of heat pump application (see **3.3.6.4.4** of BS 6880-1:1988).

It should be noted that this code is only concerned with LTHW space heating and does not extend to service water heating, air sink heat pumps or air conditioning applications. However, it is important to note that economic application of the heat pump principle may depend on the existence of a cooling requirement such that the investment in refrigeration equipment can be spread over both. In such cases the equipment for the heating cycle has to be selected having regard to the requirements of the cooling cycle. These may not be entirely compatible, leading to compromises which should reflect the relative importance of the two modes of operation, particularly in terms of energy use.

It should be appreciated that the successful application of heat pumps to building heating applications calls for more detailed analysis of the nature of the heating load and its variation with time (see **3.3.6** of BS 6880-1:1988) than is usually required with fuel-fired heat generators, particularly when ambient air is the heat source. It should be appreciated that with heat pumps it may not be feasible to provide sufficient capacity margin for warming up a building which has been allowed to cool down.

The economic application of air source heat pumps in the context of this code usually requires a supplementary source of heat (see **3.3.6.4.5** of BS 6880-1:1988), such that the heat pump, hydraulic circuit and controls have to operate in conjunction with another heat source (such as an LTHW boiler); they need to be fully compatible throughout the operating season. The proportion of design load to be carried by the heat pump should be assessed for each application, but experience shows that this is usually between 50 % and 75 %, typically around 60 %. Similar considerations may apply to other heat sources depending on their particular capacity and temperature characteristics.

For the design of heat pump systems a sound understanding is required of refrigeration principles and of those equipment design and external factors which affect the output and efficiency of heat pumps. This is particularly important in the absence of full equipment performance and test standards appropriate to heat pumps within the scope of this code (see BS 6901). Heat pump equipment used should be of a type specifically intended and suited for LTHW space heating applications within the scope of this code. Continuity of involvement of the refrigeration equipment manufacturer or other refrigeration specialist is recommended throughout all stages of the project through to commissioning.

5.8.2 Construction

5.8.2.1 *General.* It is difficult to categorize heat pump equipment into specific types. Each system consists of principal elements as follows (see also Figure 13) most of which may take various forms:

a) heat sources (see **5.8.2.2**);

b) refrigerants (see **5.8.2.3**);

c) expansion devices (see **5.8.2.4**);

d) evaporators (see **5.8.2.5**);

e) compressors and drives (see **5.8.2.6**);

f) condensers (see **5.8.2.7**);

g) heat sink fluid (LTHW in the context of this code).

In addition to these principal elements there are various special features, controls and system accessories to be considered (see **5.8.2.8**). Items b) to f) are often incorporated in a single equipment package, together with controls and instrumentation; in the case of air source heat pumps, the evaporator may be located at a defined distance away from the other elements (split system). This code is only concerned with vapour compression type refrigerating equipment. Theoretically absorption type equipment may also be used; this operates by direct input of heating medium rather than a main electric drive. However existing absorption systems present particular difficulties in heat pump applications, few of which have been undertaken. For further information see **4.10.1.2** of BS 5720:1979 relating to the absorption system.

5.8.2.2 *Heat sources.* Ambient air is a common heat source for smaller heat pumps; individual air to water heat pumps up to about 30 kW output are available. For larger outputs the size of the air handling elements becomes excessive; also they may need to be located remotely from the compressor/condenser unit. As with all heat pumps their output is closely governed by the heat source (air) temperature (output falls with falling ambient air temperature) and the heat sink temperature (output falls with rising heat sink temperature), among other factors. Building heat load normally increases with decreasing ambient temperature, whereas air source heat pump output reduces considerably. This is a major disadvantage of ambient air as a source, such that supplementary heating is almost invariably advisable. In some instances warm exhaust air at a fairly constant temperature may be available as a potential heat source, but other heat recovery methods may prove more attractive.

Water may be used as a heat source, with the advantage that its temperature tends to be reasonably constant and its specific heat capacity is far superior to that of air, in volumetric terms. Such water might be abstracted from the ground, or public supplies; large bodies of surface water may offer a possible source but very close control is required to avoid risk of freezing. However it should be appreciated that use of any such water is closely regulated by statutory bodies who should be consulted at a very early stage. Use of naturally occurring water should also be appraised by competent specialists, with particular reference to environmental effects, the interests of other users, and probable requirements for such water to be returned to source after use.

A warm effluent might also provide a heat source (considerations of fouling and corrosion may necessitate use of intermediate heat transfer). Cooling water which is used to convey reject heat from a process or building system may also be suitable. Such sources of waste heat may however lend themselves to other forms of heat recovery, depending on available temperature and the requirements of the application.

Where adequate water quantities are available at a suitable temperature, water to water heat pumps cover a very wide range of outputs, from small units up to units of several thousand kilowatts for large central machines with centrifugal or screw compressors. Units with reciprocating compressors of the order of 600 kW output are typical.

The ground (as distinct from ground water) is another potential heat source; however its insulating properties make for poor heat transfer such that it is not usually an economic proposition in this context.

5.8.2.3 *Refrigerants.* Refrigerant R-22 (see BS 4580) is commonly used for reciprocating compressors, as in air conditioning applications, particularly with packaged units it makes for compact equipment. However it should be appreciated that to generate LTHW at usable temperatures relatively high refrigerant pressures are required. It is therefore recommended that refrigerant pressures in condensers should not exceed 20 bar gauge. This has the effect of limiting LTHW flow temperature to around 45 °C with R-22. For higher temperatures the use of refrigerant R-12 should be considered, which has a recommended limit of around 75 °C. Centrifugal compressors used as heat pumps for LTHW normally use either refrigerant R-11 or R-12. It should be noted that the low pressure in an R-11 refrigerant system tends to be less than atmospheric such that inwards air leakage may occur.

Where supplementary heating is used (see **3.3.6.4.5** of BS 6880-1:1988) it is essential to ensure that under no circumstances can LTHW at a temperature higher than that of normal condenser operation enter the condenser. The dangerous nature of refrigerants in terms of toxicity and relatively high pressures should be recognized and appropriate safety practices adopted (see BS 4434).

It should be noted that where a system is intended to provide both winter heating and summer cooling modes of operation, the volume of refrigerant required may be different in each case such that a refrigerant receiver is necessary.

The equipment should incorporate some form of refrigerant filter-drier to ensure removal of entrained moisture. With split systems, where the refrigerant circuit is not contained within a single unit, provision is required for the safe purging and charging of the system. Equipment should be indelibly marked with the type of refrigerant and the mass of the charge.

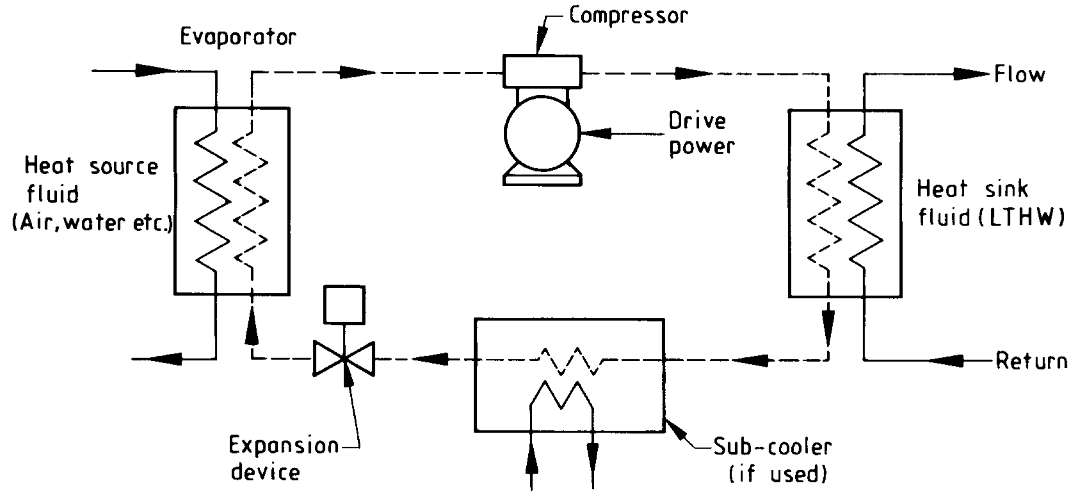


Figure 13 — Principal elements of heat pump system

5.8.2.4 *Expansion devices.* An expansion device provides the cooling effect, and divides the high pressure (condensing) side from the lower pressure (evaporating) side of the system. Thermostatic expansion valves with dry type evaporators are commonly used on air to water and smaller water to water units. The adjustable, externally equalized type is to be preferred as this gives better utilization of the evaporator surface under varying loads. For water to water units, flooded evaporators with float type expansion valves are also used. Thermostatic expansion valves tend to work at constant condensing temperature. However, the flooded evaporator arrangement can give significant operating economies where summer cooling is also required, since it can operate with condensing temperatures which vary to suit the load. Expansion valves should be protected by a strainer.

5.8.2.5 *Evaporators.* Evaporators abstract heat from the source fluid. For air source heat pumps they are similar in function and general construction to direct expansion (DX) cooling coils associated with air conditioning installations (see BS 5720). However, in heat pump applications, the following aspects are particularly important.

a) They are usually installed out of doors and should be suitably protected.

b) They handle unfiltered ambient air and may be susceptible to airborne fouling and corrosion.

c) The power requirement of the air handling fans is a significant consideration when assessing the overall energy efficiency of such units and is affected by air side pressure drop, fan type, efficiency and control.

d) They are prone to frost formation, particularly in UK ambient conditions below 4 °C. Effective defrosting is therefore required, noting that this also affects energy efficiency (see **3.3.6.4.2** of BS 6880-1:1988). Relatively wide fin spacing (at least 4 mm) and air velocity of at least 2.5 m/s helps to inhibit ice formation; wide fin spacing is particularly important on the first row, where most frost tends to form.

e) Effective provision for the removal of condensate is required, both as such, and in the form of melting ice during defrosting operations when greater flows are likely.

With water to water heat pumps evaporators usually take the form of shell and tube heat exchangers, designed for the purpose (see BS 5720). These may be of the dry expansion type, where the refrigerant is in the tubes, or of the flooded type, where the refrigerant is in the shell (see Figure 14). The flooded types have advantages in terms of system performance, associated with a float type expansion valve (see **5.8.2.4**). Effective return of oil from the evaporator to the compressor under all operating conditions is essential, and requires particular care in design with flooded evaporators or with split systems (see **5.8.2.1**).

Great care is required in sizing shell and tube heat exchangers, particularly in selecting appropriate design temperature differences and applying fouling factors (see **5.6.3**). It should be appreciated that whilst a given heat transfer surface may be adequate for the thermal load, a larger unit with lower temperature differences may be preferable in terms of overall system efficiency and operating economy.

Heat exchanger materials should be fully compatible with the heat source fluid, which may be in contact with the shell or the tubes depending on whether the evaporator is of the dry or flooded type respectively. This relates to the avoidance of corrosion, erosion, deposition of sediments, formation of scale or other surface films deleterious to heat transfer or mass flow. With open circuit systems it may be necessary to interpose a separate heat exchanger and closed secondary circuit so that the evaporator is not in contact with source fluid and appropriate water treatment can be applied. The evaporator should be arranged to facilitate cleaning, noting that quoted fouling resistances (see **5.6.3**) normally envisage seasonal cleaning and that flooded evaporators have a major advantage in that source fluid flows through the tubes.

5.8.2.6 *Compressors and drives.* Various compressor and drive types are available as in other areas of refrigeration practice. Detailed discussion of their design is outside the scope of this code but for a general description of basic types see BS 5720. This subclause is concerned with their application to LTHW sink heat pumps only, but recognizing that in some instances they will also be required to operate in cooling mode. It is important to appreciate that LTHW heat pump applications generally call for higher system pressures and compression ratios than air conditioning applications, for which the compressors should be specifically suited and with which all other refrigerant circuit elements should be compatible.

Compressors and drives should be readily accessible for maintenance; open drive machines should be installed such that the necessary drive motor cooling is achieved.

The two chief types of compressor relevant to this code are as follows.

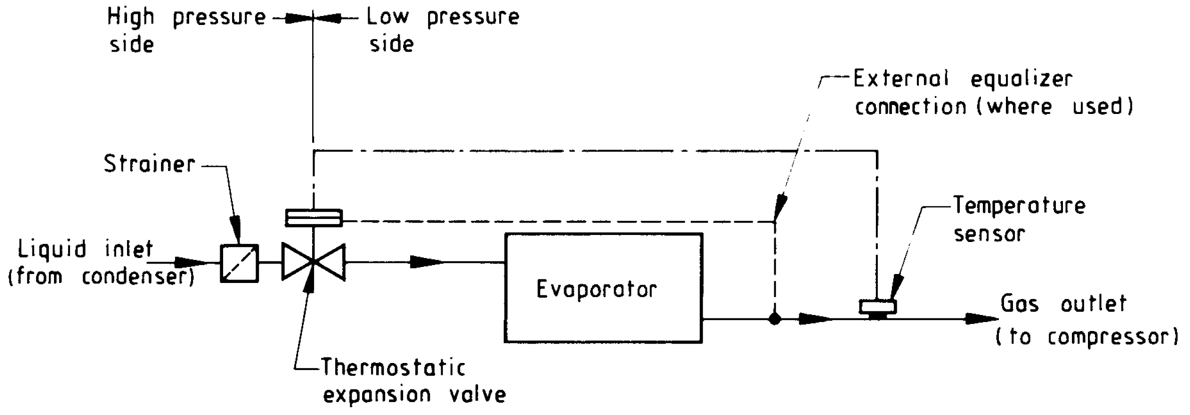
a) *Reciprocating compressors.* This type is extensively used for heat pumps, in unit sizes equivalent to system heat outputs of several hundred kilowatts. Multi-cylinder machines are normally used, thus affording the possibility of capacity control by individual cylinder unloading. Typically up to 16 cylinders are employed but more than one machine may be used. This can give partial protection against loss of output due to drive failure and increases the number of possible capacity steps available.

Single stage machines are extensively used, but two-stage machines offer greater efficiency at higher pressure ratios as might arise with LTHW temperatures in excess of 50 °C or source temperatures lower than normally experienced in the UK.

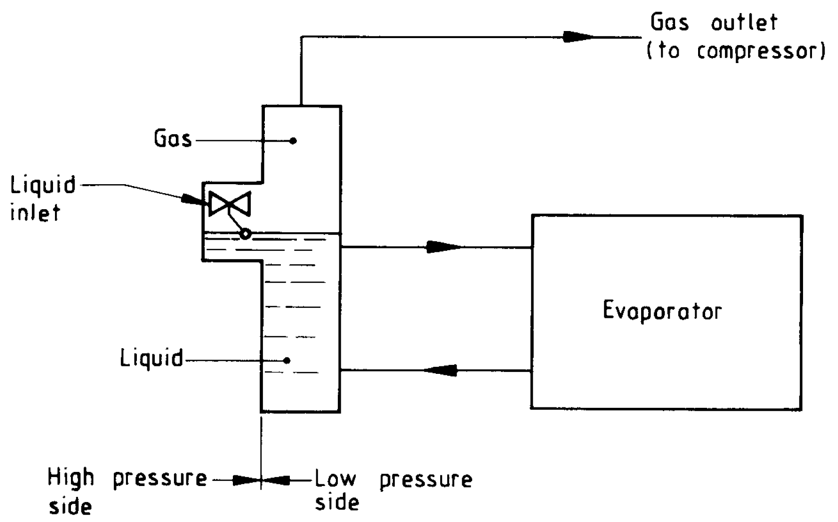
The refrigerant may be R-12 or R-22; the unsuitability of the latter for higher temperature applications should be noted (see **5.8.2.3**).

b) *Rotary compressors.* The screw type is increasingly used over a wide capacity range and tends to give a more compact unit that the reciprocating type. Oil is injected into the rotor chamber for sealing, cooling and lubrication and is removed from the compressed gas in an oil separator; a smaller quantity tends to remain and circulates with the refrigerant. The function and handling of oil is an important consideration with all refrigeration compressors (see **5.8.2.8.3**). Screw compressors are capable of output modulation down to as little as 10 % in some cases.

The suitability of either type of compressor for a given application depends on output, condensing temperature, and pressure ratio and part load performance. Careful assessment is required of relative system thermal efficiency under the partial loads likely to be encountered over most of the operating season, in order to determine the most suitable compressor type. The centrifugal type is generally less suited to LTHW heat pump applications in view of the need for high pressure ratios and stable operation at low loads. However, such machines with two or three compression stages have been used on large water source applications.



(a) Dry expansion evaporator with thermostatic expansion valve



NOTE. This shows low-pressure-side float control. High-pressure-side float control is also used.

(b) Flooded evaporator with float valve control

Figure 14 — Typical expansion valve arrangements

Drives may be of the open type (i.e. external driver with drive shaft seals on the compressor) or the semihermetic type (specially designed motor surrounded and cooled by refrigerant such that shaft seals are eliminated). The latter type is extensively used, and has advantages where equipment is operated unattended for long periods and skilled maintenance is not readily available. However it should be appreciated that the use of refrigerant for cooling tends to detract from the overall efficiency of the unit; also motor failure can cause contamination of the whole refrigerant circuit, with serious consequences. Preferably, multiple semihermetic compressors should not be connected to a common refrigerant system, as failure of one motor can precipitate failure of the others. Electric motors and associated electrical equipment should comply to the appropriate standards and requirements (see **3.9** of BS 6880-1:1988). Motors on open drive machines should be of standard industrial type, noting that on large machines high voltage motors may be appropriate. Motor overload protection of appropriate sensitivity should be provided. It should be appreciated that a heat pump will tend to have a drive power requirement well in excess of that normally associated with boiler-fired LTHW heating systems of similar output. This may have particular implications for the building electrical system and starting arrangements need careful consideration (see **3.9** of BS 6880-1:1988). Sequenced starting of compressors may be necessary to minimize current peaks. Other drivers may be used on open machines, such as internal combustion engines. These offer the possibility of incorporating heat recovery from engine exhaust and cooling systems into the LTHW system. For further information on internal combustion engines and other drives for refrigeration equipment see BS 5720.

Noise and vibration is an important consideration with all types of heat pump. Compressors should be dynamically balanced and appropriate anti-vibration mounts incorporated and flexible pipe connections should be incorporated where it is necessary to separate the machine from piping systems. It should be noted in this context that air source heat pumps tend to be installed externally and that evaporator fans as well as compressors contribute to the total sound power.

5.8.2.7 *Condensers*. In a LTHW sink heat pump the condenser usually takes the form of a shell and tube heat exchanger, generally construction of which is similar to the condenser of water-cooled chiller units (see BS 5720). They are usually incorporated in the same unit as the compressor. System LTHW normally passes through the tubes, whilst refrigerant condenses in the shell. It should be appreciated that such condensers operate at relatively high pressures and require relief valves (see also **5.8.2.8.6** c)]. Shell and tube heat exchangers should be designed, constructed and tested in accordance with BS 3274 or an equivalent internationally recognized code. Consideration should be given to the possible consequences for the LTHW circuit of tube leakage or tube failure. Tubes should be arranged to be readily accessible for cleaning, noting that fouling factors quoted (see **5.9**) usually assume seasonal tube cleaning.

The importance of careful sizing and optimum temperature differences should be appreciated, as discussed in connection with evaporators (see **5.8.2.5**). Tube material should be compatible with system LTHW and when considering system water treatment account should be taken of the tube material along with the other metals in the LTHW circuit (see **3.5** of BS 6880-1:1988).

5.8.2.8 ***Heat pump features, accessories and controls***

5.8.2.8.1 *General*. Various special features, controls and system accessories which should be considered are covered in **5.8.2.8.2** to **5.8.2.8.6**.

5.8.2.8.2 *Defrosting*. Air source heat pumps are prone to formation of ice on evaporator surfaces which reduces output, particularly in cold weather (below about 4 °C) when heating loads are greatest. This should be mitigated by appropriate evaporator design (see **5.8.2.5**), but some form of automatic defrosting is required. This can be achieved in various ways including hot gas defrosting (in which the roles of condenser and evaporator are temporarily reversed), warm water spray or electric resistance heating. Frequency of defrosting depends on operating and ambient conditions but at times it may be more than once per hour. Consideration should be given to the duration of defrosting and the consequence of loss of heat output to the LTHW system during defrosting. Duration depends on various factors, but 10 min should be a reasonable maximum in UK conditions. It should be appreciated that defrosting consumes energy and this should be taken into account in deciding the method to be used and when determining equipment performance under operating conditions (see **5.9.2**).

Control of defrosting may be on the basis of:

a) time;

b) evaporator air side pressure drop;

c) refrigerant air temperature differential.

It is most important that defrosting be controlled in such a manner that it does not operate any longer than is necessary, for which some form of refrigerant temperature sensing is required.

5.8.2.8.3 *Oil system*. As with other reciprocating and rotary machines, use of oil is necessary for lubrication, cooling and (for certain types) sealing. However, oil use assumes particular importance in refrigeration practice because oil and halocarbon refrigerants tend to be miscible and oil is carried around the refrigerant circuit. Particular factors needing careful design consideration include the following.

a) *Oil return to compressor*. Means of collecting and returning oil from the evaporator is an important part of a system, particularly with flooded evaporators (see **5.8.2.5**). This also has implications for the sizing, length and routing of suction gas lines in split systems. Oil return under part load conditions when gas velocity is reduced is a particularly important consideration, for which careful suction line sizing is essential.

b) *Oil heating*. To prevent accumulation of refrigerant in the oil when the compressor is not running, an automatic oil heater is required (e.g. crankcase oil heater in the case of reciprocating machines).

c) *Pump down cycle*. A pump down cycle is used with thermostatic expansion valve systems. It minimizes absorption of refrigerant by oil retained in the crankcase of a reciprocating compressor, by running the compressor until the evaporator is pumped down and crankcase pressure reduced to a low level before shutting down.

d) *Oil cooling*. Oil cooling is usually required and should be effected by an energy-efficient method.

There are further, special considerations in connection with oil use in screw compressors [see **5.8.2.6** b)] which are outside the scope of this code.

5.8.2.8.4 *Subcoolers*. Use of a subcooler for the refrigerant leaving the condenser (i.e. below the appropriate saturation temperature) can offer significant thermal performance advantages in certain types of system, and should be considered where a suitable source of cooling is available, particularly if it is practicable to reuse the heat abstracted (e.g. outside air supplied to a building for ventilation purposes).

5.8.2.8.5 *Pulsation dampers*. Also known as hot gas mufflers, pulsation dampers are usually necessary to smooth the discharge pressure irregularities inherent in reciprocating machines, but this feature can be incorporated in the compressor design in other ways.

5.8.2.8.6 *Refrigeration equipment controls*. Minimum control features that are required for refrigeration equipment in heat pump applications are given in a) to c), but detailed treatment is outside the scope of this code. It is essential that the refrigeration equipment controls are compatible in concept and in operation with those of the LTHW system and its mode of operation.

a) *Capacity modulation*. Means of adjusting compressor output to system load are necessary, and should be arranged to promote thermally efficient operation over the expected load range. With single reciprocating machines this can be achieved by progressive unloading of cylinders such that at least three capacity steps are available. Suction throttling of reciprocating machines is not recommended. With multiple machines, capacity of control should be integrated with sequential starting of individual machines (see **5.8.2.6**). In certain applications multispeed drives may be appropriate. The control system differential should be such as to avoid unnecessarily frequent cycling. Bypassing a proportion of the hot refrigerant gas as a means of adjusting output wastes energy and it should be avoided as far as practicable.

b) *Defrosting control*. Defrosting control is necessary on air source heat pumps and is discussed in **5.8.2.8.2**.

c) *General safety controls*. The following eventualities should be provided for by the use of appropriate controls. Alarms may also be appropriate in particular cases.

1) Excess refrigerant pressure; this should be reset manually. Consideration should be given to the consequences of fire in terms of build-up of refrigerant pressure; relief valve discharges should be piped to a safe external location.

2) Excess condenser water temperature; since LTHW heat pumps often operate in conjunction with supplementary heating, it is essential to ensure that under no circumstances does LTHW at a temperature in excess of the design condenser LTHW temperature get into the condenser circuit, because of the risk of excess pressure in the refrigerant circuit.

3) Low refrigerant pressure between evaporator and compressor.

4) Freezing of water source; low water temperature cut-out on water source heat pumps to prevent freezing.

5) Low oil pressure.

6) Interruption of water flow; motor overload protection and water flow switches or similar interlocks to prevent operation when LTHW or source water is not circulating.

5.9 Heat pumps: selection factors

5.9.1 General selection factors

The following factors are those which heat pumps have in common with other LTHW heat generating equipment.

a) Heat output (in kW); whilst this is primarily related to LTHW system demand, its assessment in the context of heat pumps requires particular care and optimization (see **3.3.6.4** of BS 6880-1:1988).

b) LTHW flow temperature and system flow/return temperature difference; this calls for particularly careful assessment and optimization in the case of heat pumps in view of limitations on effective use at temperatures in excess of about 45 °C. In many applications it is found that flow temperatures need to be in the region of 35 °C to 40 °C for economic operation, and temperatures in excess of 45 °C are not recommended. The temperatures quoted are an approximate guide and should relate to an optimum selection of temperature difference and hence condensing temperature, since it is the latter which affects system efficiency and maximum system pressure. The possibility of having to use a restricted flow temperature should be taken into account. This is also related to refrigerant type (see **5.8.2.3**). Some heat pump manufacturers recommend that the LTHW temperature differences should not exceed 10 °C.

c) LTHW flow (in L/s).

d) LTHW hydraulic resistance (in kPa) of heat pump installation.

e) LTHW system operating pressure (in bar).

f) Electrical supply details (volts, phases, frequency and number of wires).

g) Power demand (in kW) of heat pump equipment, noting the importance of ancillaries such as air source evaporator fans (see **5.8.2.5**) and defrosting (see **5.8.2.8.2**).

h) Motor starting requirements (see **5.8.2.6**).

i) Noise and vibration characteristics.

5.9.2 Specific selection factors

5.9.2.1 *General.* The factors given in **5.9.2.2** to **5.9.2.4** are particular to heat pumps. In order to appreciate the significance of all the factors listed it is necessary to also appreciate the principles of operation of a heat pump in relation to coefficient of performance as described in **5.9.2.2**.

5.9.2.2 *Coefficient of performance.* The thermal efficiency of a heat pump is known as the coefficient of performance or COPH; the letter H distinguishes heat pump situations from cooling applications. COPH can be derived from the following equation:

$$\text{COPH} = \frac{Q_L}{P_i}$$

where

Q_L is the heating effect (in kW);

P_i is the power input (in kW).

The COPH is closely related to the sink (or LTHW) temperature required and the temperature difference or stretch between that and the source temperature, both of which may be subject to variation under operating conditions (see Figure 15). The theoretical relationship is indicated by the concept of ideal or Carnot COPH thus:

$$\text{Cannot COPH} = 1 + \frac{T_e}{(T_c - T_e)}$$

where

T_c is the condensing temperature (in K);

T_e is the evaporating temperature (in K).

Hence COPH increases with increasing source temperature, with decreasing sink temperature, and with decreasing temperature difference between source and sink (or temperature stretch). It is therefore clear that COPH may vary substantially with load and time of year, and manufacturers should provide appropriate rating information of the type indicated in Figure 16. This is particularly important with air source heat pumps, since as source temperature decreases, so heating load normally increases.

In the absence of a complete list of appropriate British Standards for the performance and testing of LTHW heat pumps within the scope of this code, it is particularly important that the power demands of ancillaries (fans, defrosting, etc.) are clearly stated and taken into account when considering energy use, both at design load and at part loads (see BS 6901). The concept of average seasonal COPH is particularly important when evaluating heat pump applications (see also Section 1.95 of Part 1 of the CIBSE Building Energy Code [2], in respect of minimum performance of heat pumps).

5.9.2.3 *Supplementary heating.* Since refrigeration equipment tends to be relatively costly compared with LTHW boilers of comparable output, it does not usually prove economic to rate heat pumps for total system design load (see **3.3.6.4.5** of BS 6880-1:1988 and **5.8.2.3** of this Part of BS 6880); for the same reason, the introduction of thermal storage into the system may prove economic in certain cases. The heat pump, supplementary heating and system controls should be designed as compatible parts of an overall LTHW system and should prevent LTHW at temperatures exceeding the design condenser LTHW temperature from passing through the condenser under any circumstances.

5.9.2.4 *Other factors.* Other factors which should be considered include the following; detailed discussion is outside the scope of this code and the advice of refrigeration specialists experienced in LTHW heat pump application should be obtained.

a) Available source temperature (in °C) and its pattern of variation (see **3.3.6.4.2** of BS 6880-1:1988).

b) Source temperature difference and practical minimum source exit temperature (in °C), with particular reference to seasonal variations.

c) Source mass flow requirement (in kg/s).

d) Optimum proportion of total system demand to be provided by the heat pump type, and capacity of supplementary heating (see **3.3.6.4.5** of BS 6880-1:1988).

e) Desirability of incorporation of thermal storage (see **3.3.6.4.5** of BS 6880-1:1988).

f) Whether the heat pump is also required to operate in cooling mode.

g) Method of modulating heat pump capacity in relation to load (see **5.8.2.8.6**).

h) Type of equipment and maximum refrigerant circuit pressure (in bar) (see **5.8.2.3**).

i) Where more than one heat pump unit is used, careful analysis is required of the characteristics of the LTHW circuit and the part load operation requirements in order to determine the most suitable configuration for the multiple units and the approximate method of control.

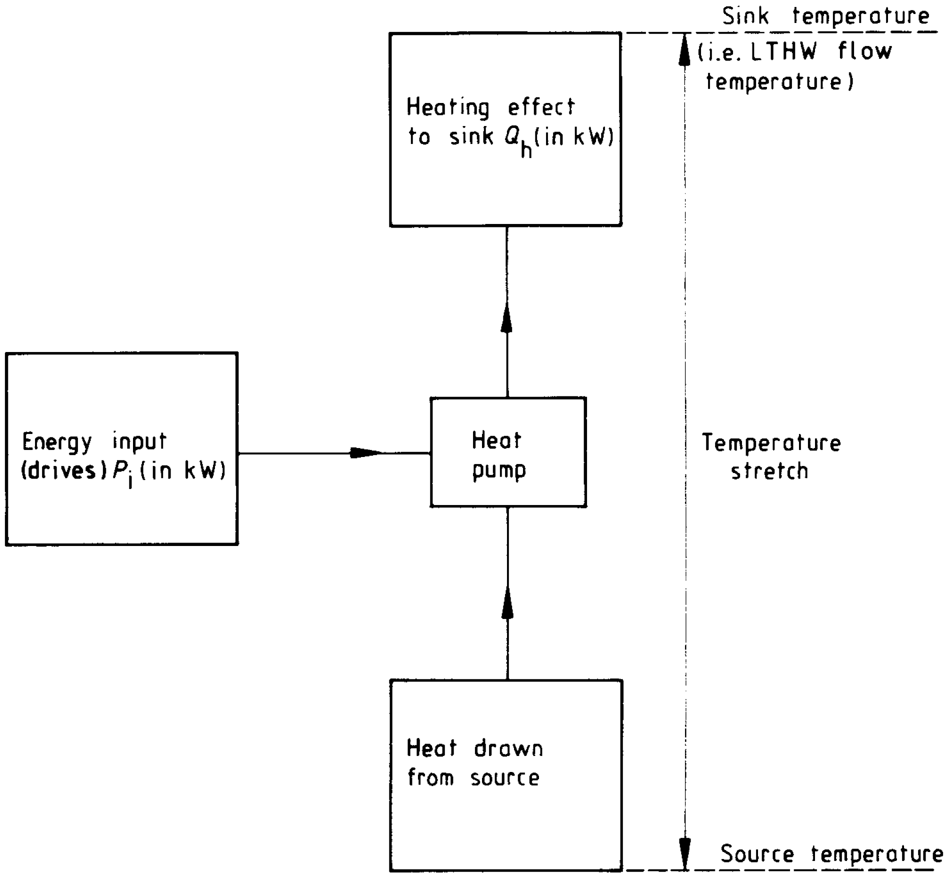
j) Number of compressor units and their arrangement; it should be appreciated that parallel operation of several heat pumps tends to be less efficient than parallel operation of compressor units with common evaporators and condensers.

k) Type of compressor and drive (see **5.8.2.6**).

l) Method of defrosting and energy implications.

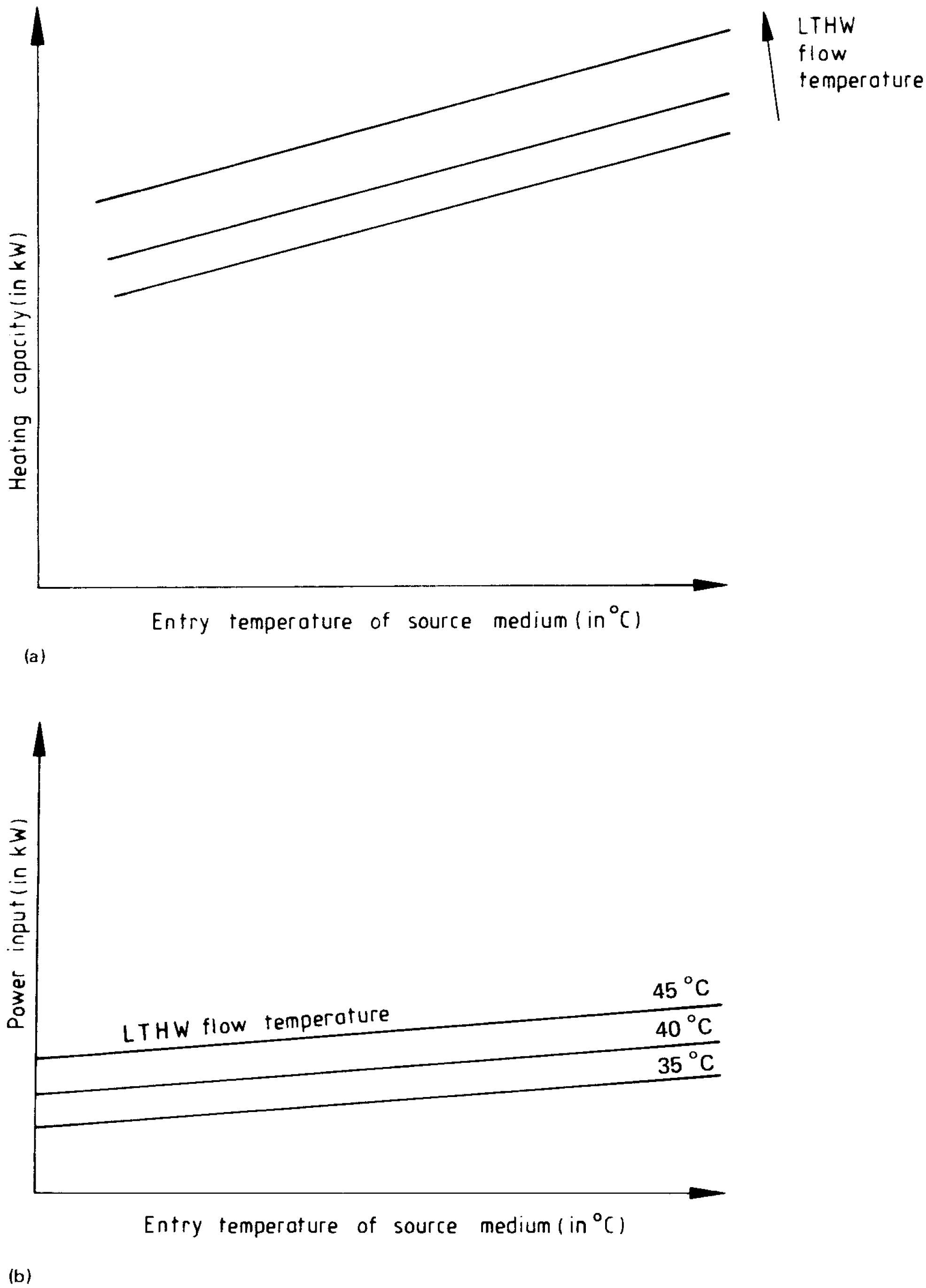
m) Heat exchanger rating parameters used for evaporator and condenser; importance of optimum temperature differences is explained in **5.8.2.5**; appropriate fouling factors should be applied to refrigerant/water heat exchangers according to the application. Typically minimum values of 0.088 $m^2 \cdot K/kW$ should be applied for LTHW condensers; for evaporators, account should be taken of the cleanliness and corrosive characteristics of the source water and higher values should be used (see "Standards of the Tubular Exchanger Manufacturers' Association" [13]). It should be appreciated that quoted values for fouling factors in this context assume that seasonal cleaning is carried out.

Most of these special factors are critical to system performance and efficiency, and performance data should be presented and interpreted in such a way that they are taken into account. In addition, other factors affecting efficient operation should be noted, such as incorrect refrigerant gas line sizing, inefficient expansion valves, and presence of gas in liquid lines. It is essential that all components of the heat pump unit should be compatible with each other and matched for optimal performance over the prevailing range of operating conditions expected in a given application. See also "Energy Savings in Refrigeration Systems" [15].



NOTE Coefficient of performance (heating) = Q_h/P_i.

Figure 15 — Basic heat pump performance concepts



NOTE Temperature differences on which data are based should be stated for both LTHW and source medium.

Figure 16 — Form of heat output and power input data for varying operating conditions

Section 6. Automatic controls, instrumentation and monitoring

NOTE For further information see references quoted in **3.8.1** of BS 6880-1:1988. For controls associated with air handling installations and refrigeration equipment see also BS 5720.

6.1 Control loops and sensing elements: types

6.1.1 Control loops

A control loop consists of a number of elements, depending upon whether the control is on/off or modulating. An on/off control generally consists of a sensing element (such as a thermostat) which itself transmits the control action to the element being controlled such as a two-position (on/off) control valve (see Figure 17). On/off control may also be used to switch a motor drive (such as a fan) usually indirectly by means of a motor starter. Modulating control is where the final control element can be held at any position between open and closed to maintain the desired conditions.

A control loop for modulating control generally consists of a sensing element, or elements, a controller and the final controlled elements, such as a modulating (multi-position) valve (see Figure 18). In this case the sensing element uses the variation of some physical quantity such as electrical resistance, to provide a proportional signal to the controller (known as an analogue signal), which then causes the controlled device to move to the required position. The controller usually draws on an external source of power to drive the controlled element. However, simple direct acting forms of modulating control are commonly used, such as thermal expansion devices; these can consist of a liquid filled sensing bulb connected to the controlled device by a capillary tube, or devices such as thermostatic radiator valves which combine these functions within one assembly.

6.1.2 Sensing and measuring elements

6.1.2.1 *General.* The type of sensing or measuring element used depends upon the parameter being sensed/measured, whether its output is analogue or digital and the range and the degree of accuracy/repeatability required for the application.

6.1.2.2 *Typical on/off action temperature sensing elements (thermostats).* The following types apply.

a) *Bimetal strip type:* a strip of two dissimilar metals bends due to temperature change, causing switch operation.

b) *Rod and tube type:* differential expansion between a rod and tube of different metals causes switch operation.

6.1.2.3 *Typical analogue temperature sensing elements.* The following types apply.

a) *Remote bulb (filled system) type:* a liquid or gas expands with temperature in a bulb and is forced down a capillary tube to move an actuator.

b) *Resistance bulb type:* electrical resistance increases in direct proportion to temperature, giving a temperature-related electrical signal.

c) *Thermistor type:* electrical resistance decreases with temperature rise in a non-linear manner.

d) *Thermocouple type (high temperature):* voltage is generated at the junction of dissimilar metals with temperature rise.

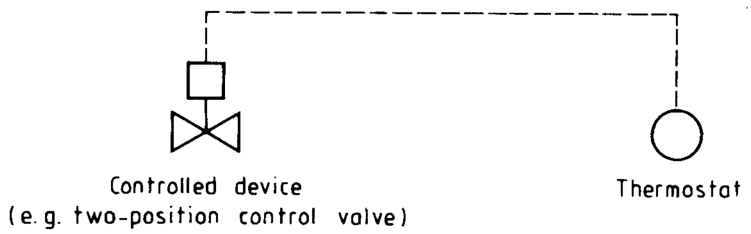


Figure 17 — Simple on/off control loop

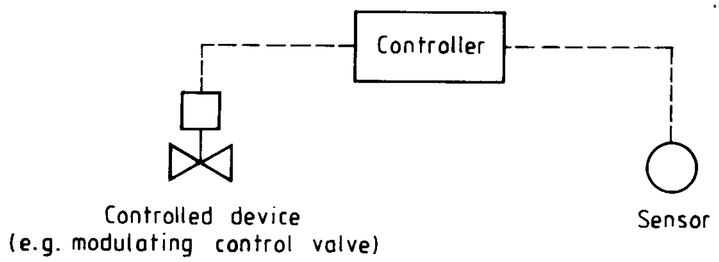


Figure 18 — Simple modulating control loop

6.1.2.4 *Typical flow sensing elements.* The following types apply.

a) *On/off type:* paddle flow switches and differential pressure switches.

b) *Analogue type:* orifice plates/venturi tubes with differential pressure elements and square root extractors, such that the signal is proportional to flow; also turbine meters and magnetic flow meters.

6.1.2.5 *Typical pressure (and differential pressure) sensing elements.* The following types apply and can operate in on/off or analogue mode.

a) *Bellows type:* the bellows expand in response to pressure.

b) *Diaphragm type:* the diaphragm moves in response to pressure or pressure difference.

c) *Bourdon tube type:* a curved tube tends to straighten in response to pressure.

For further information on these items see BS 5720.

Special elements are used for oxygen and pH sensing, etc., details of which are outside the scope of this code, but which may be applied in connection with boiler plant and water treatment.

6.2 Controllers: types

6.2.1 General

A controller is a device (usually electrical) which receives an analogue signal or signals from sensors and produces an output which acts upon a controlled device (see **6.3**) to produce the desired space or system condition. Controllers require a power supply to operate; for heating system controls this is normally an electrical supply, but pneumatic controllers are available. An important characteristic of a controller is the mode of its output, which can be loosely described as the mathematical relationship between its output and its input. Three basic modes of modulating control are in common use as described in **6.2.2**.

6.2.2 Controller modes

6.2.2.1 *Proportional (P) control.* P control is when the output of the controller is in direct proportion to deviation from the setpoint. Proportional control is satisfactory for a number of applications and can be preferable for some, e.g. sequence control of boilers from the return water temperature. It should be appreciated that there is always an offset from the setpoint with a proportional controller, such that the actual value differs from the setpoint by a small amount.

6.2.2.2 *Proportional and integral (P and I) control.* P and I control is the proportional control action modified by an integral action which summates the deviation from the setpoint over a period of time (the integral action time) and minimizes the offset. P and I control is essential where the setpoint has to be maintained within close limits; it also allows more stable controlled conditions, primarily because the proportional band can be set wider than would be acceptable with a proportional controller, without causing offset from the setpoint.

6.2.2.3 *Proportional and integral and derivative (PID) control.* The PID control is the P and I control action modified by a derivative action which gives an action in proportion to the rate of change of the deviation from the setpoint. PID control is offered by some manufacturers instead of P and I control; this should give better control where a fast response is required, but this is not usually necessary in HVAC applications.

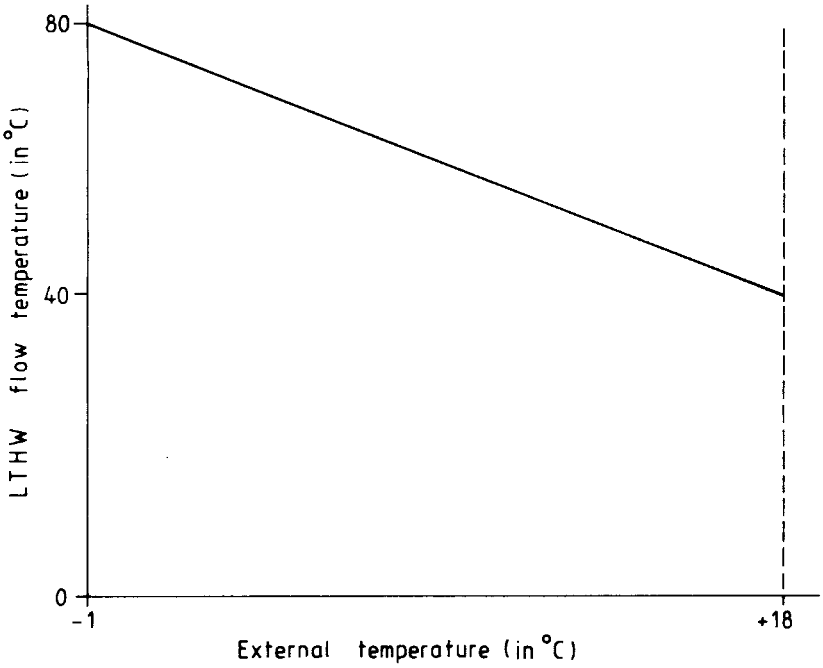


Figure 19 — Typical compensator schedule

6.2.3 Heating compensators

A common form of controller used with heating systems is known as a compensator. It adjusts the LTHW flow temperature in relation to the external temperature in accordance with a predetermined schedule (usually adjustable). Flow temperature usually increases as external temperature falls. In this manner the output of the utilization subsystem is increased as the heating load increases. The schedule has a characteristic slope (see Figure 19), which determines the reduction in flow temperature with increase in ambient temperature, and is adjustable over a preset range. Some controllers have maximum and/or minimum flow temperature limitations (see **3.8.3.3** of BS 6880-1:1988).

6.2.4 Timeswitch and optimizer control

6.2.4.1 *Timeswitch control.* The following two types of timeswitch apply.

a) *Intermittent occupation.* A timeswitch can be used to switch the heating on and off at a preset time each working day, and off over weekends. This takes no account of the prevailing ambient conditions and protection measures that will be necessary.

b) *Night set-back.* Where a building (e.g. residential accommodation) is continuously occupied, it may be acceptable for the space temperature to be reduced at night. This is achieved by a timeswitch resetting the space temperature controls and/or the system flow temperature, via the compensator.

6.2.4.2 *Optimizer control.* An optimizer is a device which starts and stops the heating system starting at the latest possible time to achieve internal temperature by the commencement of the occupancy period, thus avoiding unnecessarily long warm-up periods in mild weather. The optimizer responds to external and internal temperature and a preset programme which is related to the warm-up time of the building. Various degrees of sophistication of this principle are available including self-adaptive controllers which learn the characteristics of the building to provide more accurate warm-up periods.

6.2.4.3 *Protection.* The following two types of protection are required.

a) *Frost protection.* Intermittently heated buildings require protection against frost damage to the heating system and the building structure. Where pipework is prone to frost damage an external thermostat should switch on the pumps to circulate the water at a preset external ambient temperature and a pipe thermostat should bring on the heating to maintain a minimum temperature to avoid freezing. An internal (space) thermostat should bring on the heating to maintain a minimum space temperature during unoccupied periods.

b) *Condensation protection.* To prevent condensation an internal (space) thermostat should bring on the heating to maintain a minimum space temperature during unoccupied periods. This temperature will be higher than the frost protection temperature, therefore alleviating the need for the internal frost protection thermostat.

Where an optimizer is used for intermittent heating control, condensation and/or frost protection measures are often incorporated in the optimizer.

6.3 Controlled devices: types

6.3.1 Control valve: types

The most common form of controlled device or final control element is the control valve. Control valves for LTHW applications are generally of one of the following types.

a) *Butterfly valve:* generally used for boiler isolation [see Figure 20(a)].

b) *Rotary shoe valve:* generally used for compensated heating circuits as a three-port mixing valve [see Figure 20(b)].

c) *Lift and lay plug valve:* may be used in a three-port mixing valve configuration for compensated heating circuits, but has many other applications [see Figure 20(c)].

d) *Flexible flap valve:* used in small sizes for on/off control of heating emitters.

The control valve mechanism is operated by a powered device known as an actuator. Control valve actuators may be of the reversible motor type. In the case of plug valves, the variable voltage type may be used, where the valve plug position is in direct relation to the voltage applied. Variable voltage valve drives normally operate on the spring return principle and reversible motor valves may have spring return drives if it is desired to close (or open) the valve in the event of power failure.

6.3.2 Control valve: selection

6.3.2.1 *General.* The selection of control valve types depends on the application. Figure 21 and Figure 22 show examples of common control valve applications and indicate the relevant pressure drop relationships which are particularly important.

Three-port control valves are extensively used on LTHW systems, either as mixing valves or diverting valves as follows.

a) *Mixing valve.* A three-port valve; two ports for flow in, and one port for flow out. The action of the valve varies the ratio of the two ingoing flows for a theoretically constant outgoing flow.

b) *Diverting valve.* A three-port valve; one port for flow in, and two ports for flow out. The action of the valve varies the ratio of the two outgoing flows for a theoretically constant ingoing flow.

Circuits are also referred to as mixing and diverting.

A mixing valve can be used on the flow of a mixing circuit or on the return of a diverting circuit, whereas a diverting valve can only be used on the flow of a diverting circuit.

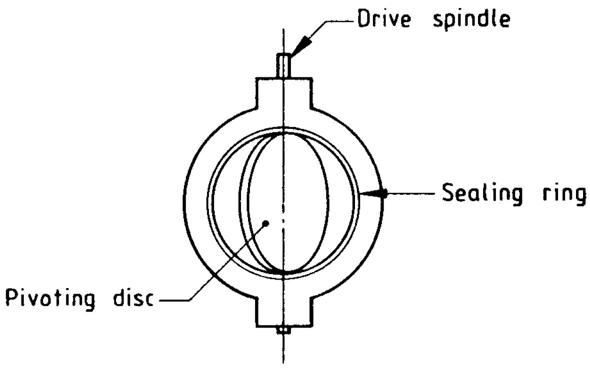
Rotary shoe valves are generally available as mixing or diverting valves. Lift and lay plug diverting valves are supplied by only some control manufacturers for LTHW use, whereas most manufacturers supply mixing valves. Lift and lay plug diverting valves are susceptible to out of balance forces and can be prone to chatter if the system is not carefully balanced.

It is generally recommended that circuits are designed to accept mixing type valves.

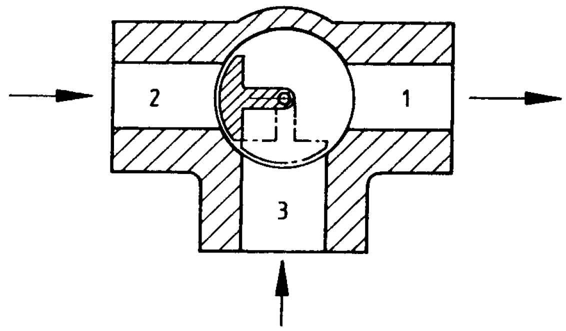
6.3.2.2 *Two-port valve.* (See Figure 21.) The two-port valve gives rise to variable flow through the load. Many thermostatic radiator valves operate on this principle, but it should be noted that control in such cases tends to be poor (see **6.3.3.1**) since valve pressure drop ΔP_1 tends to be high.

6.3.2.3 *Three-port mixing valve (mixing circuit).* (See Figure 22(a). With the three-port mixing valve (mixing circuit) the two flows meet at the control valve, which delivers a mixed flow to the load circuit. This gives rise to constant flow through the heat source; the latter should only be used within the limits of flow recommended by the boiler manufacturer. Where this is difficult to achieve, the use of a separate primary circuit should be considered (see also **3.3.4.3** and **3.8.3.2.3** of BS 6880-1:1988).

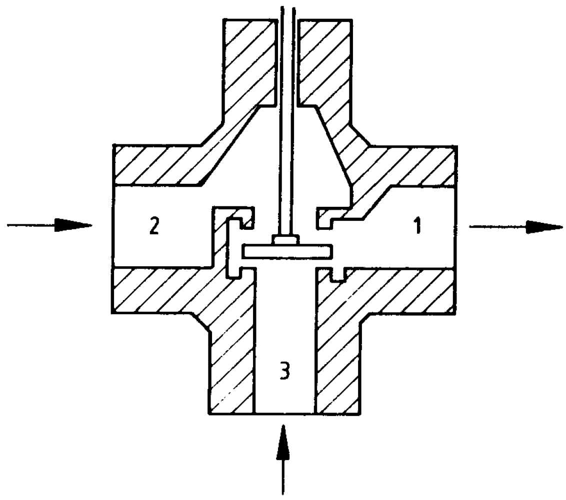
6.3.2.4 *Three-port mixing valve (diverting circuit).* (See Figure 22(b). With the three-port mixing valve (diverting circuit) flow is diverted away from the load circuit, such that load flow is variable (constant temperature). Heat source flow is constant.



(a) Butterfly valve



(b) Rotary shoe valve (three-port)



(c) Lift and lay plug valve (three-port)

Figure 20 — Typical control valves

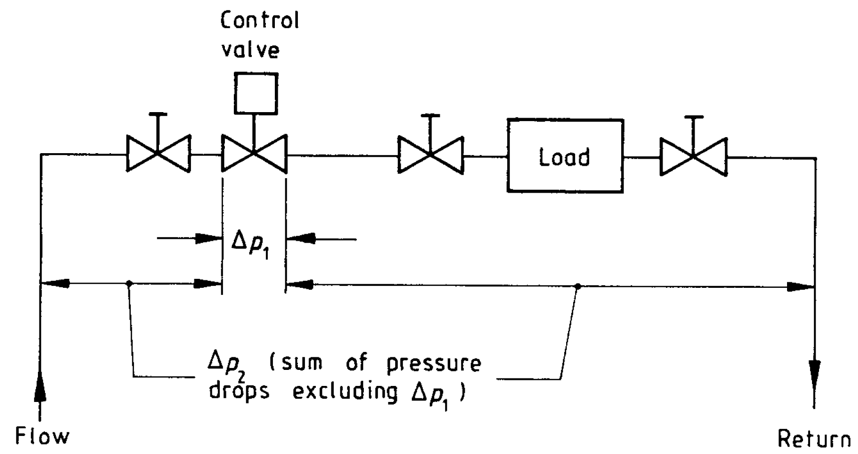


Figure 21 — Typical two-port control valve application

6.3.2.5 *Three-port mixing valve (injection circuit).* (See Figure 22(c). With the three-port mixing valve (injection circuit) there are two pumps, the primary pump (source circuit) and the secondary pump (load circuit). The figure shows a simple arrangement; a more complex arrangement is commonly used on larger systems where a main primary circuit serves a number of secondary circuits, each with a secondary pump (see **3.4.2.4** of BS 6880-1:1988). The characteristics of the load circuit are similar to Figure 23a), but source flow is constant. Secondary flow is not influenced by primary flow.

6.3.2.6 *Three-port diverting valve (diverting circuit).* (See Figure 22(d). With the three-port diverting valve (diverting circuit) the source flow is constant and load circuit flow is variable (constant temperature). It is important that the control valve is specifically suited to diverting mode operation (see also **6.3.2.1**).

6.3.3 Characteristics of control valves

6.3.3.1 *Valve authority.* This is an important concept which determines the ability of a given valve of a specific size to effectively control LTHW flow in a given application. Valve authority N is defined as the ratio of the pressure drop across the full open control valve to that across the controlled circuit and is derived from the following equation:

$$N = \frac{\Delta p_1}{\Delta p_1 - \Delta p_2}$$

where

Δp_1 is the pressure drop across the fully open control valve;

Δp_2 is the pressure drop across the controlled circuit.

Δp_1 and Δp_2 are identified in Figure 21 and Figure 22 and in CIBSE Applications Manual [16].

Recommended values of control valve authority which should be used in LTHW circuit design are indicated in Table 7.

Table 7 — Recommendations for control valve authority

Valve type	Authority
Two-port modulating valve	0.3 to 0.5
Thermostatic radiator valve	0.3 to 0.5
Three-port modulating (diverting) valve	0.3 to 0.5
Three-port modulating (mixing) valve	0.5 to 0.8

NOTE Valve selection should seek to ensure that valve authorities are at the high end of the quoted ranges with due consideration to the maximum velocity recommended by the manufacturer.

6.3.3.2 *Valve flow coefficient.* Valve sizing is aided by the use of a constant for the valve, known as the valve flow coefficient (A_v). In this code the coefficient refers to the number of m^3/s of water that will flow through a wide open valve with a pressure drop of 1 Pa. It should be noted that units other than the preferred (SI) units are often quoted and care should be taken to ensure consistency of units when referring to manufacturers' data.

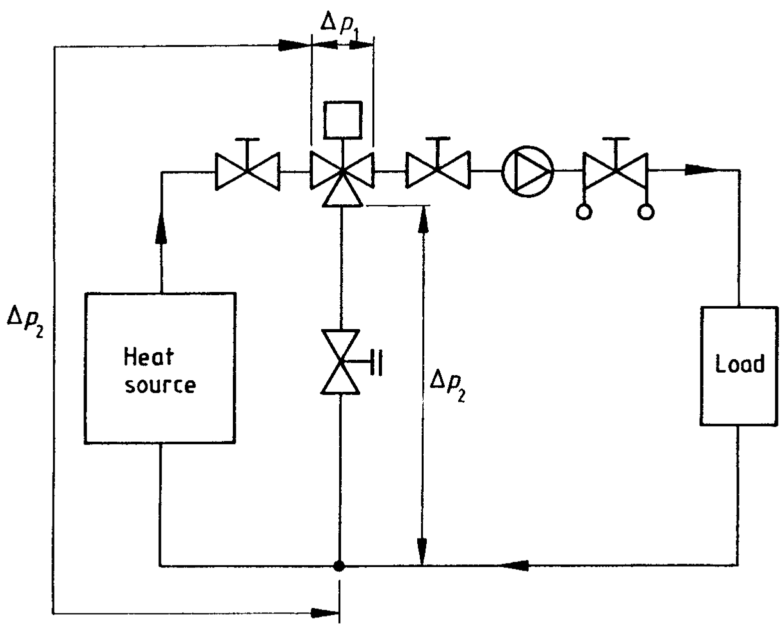
The pressure drop p (in kPa) through an LTHW control valve is given by the following equation (see also BS 5793-2):

$$p = \rho \times \left(\frac{Q}{A_v}\right)^2$$

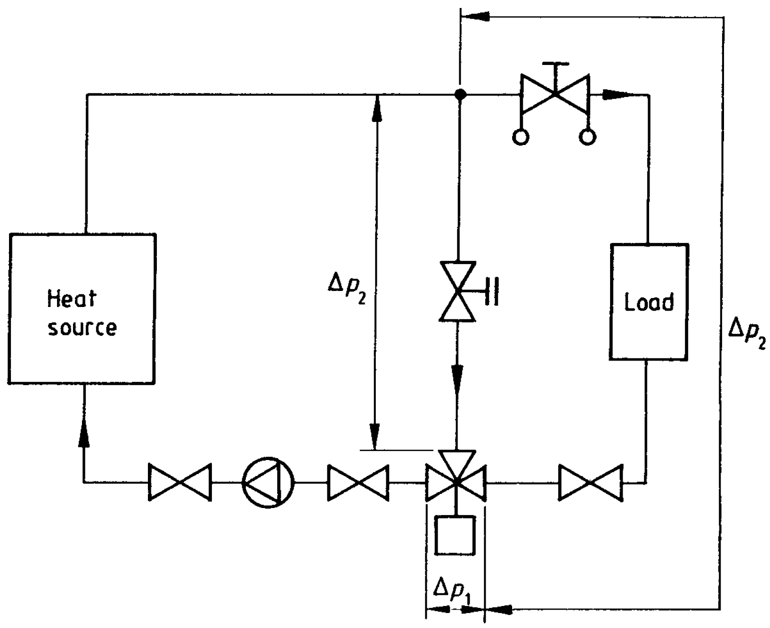
where

ρ is the density (in kg/m^3);

Q is the flow (in m^3/s).

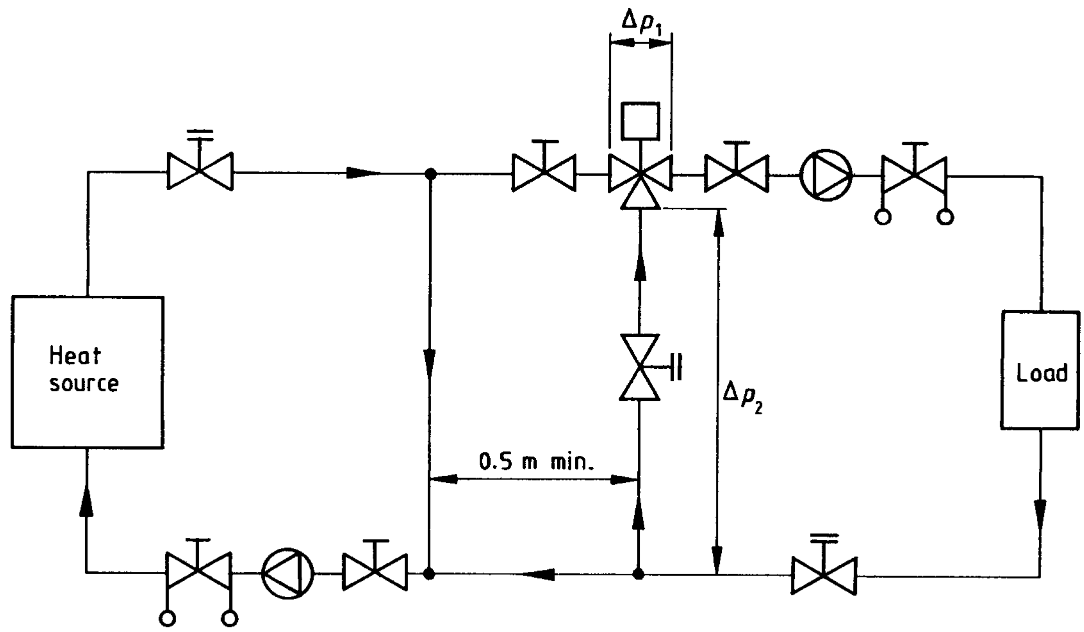


(a) Three-port mixing valve : mixing circuit

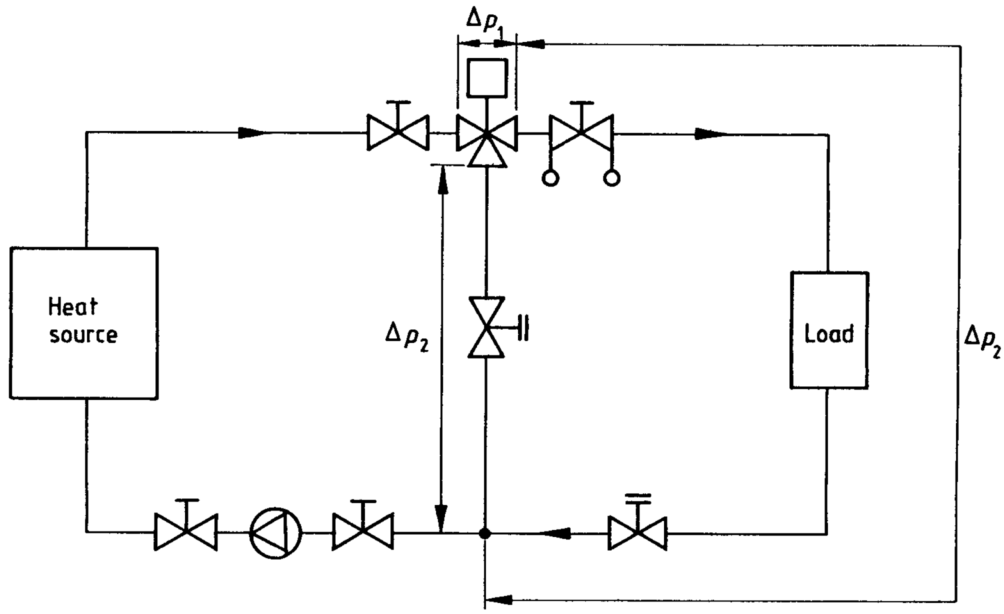


(b) Three-port mixing valve : diverting circuit

Figure 22 — Typical three-port control valve applications

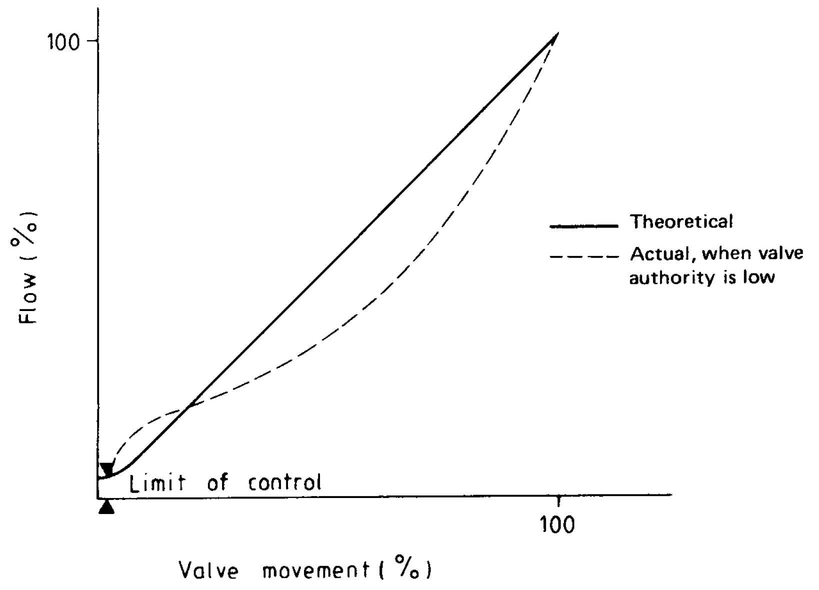


(c) Three-port mixing valve : injection circuit

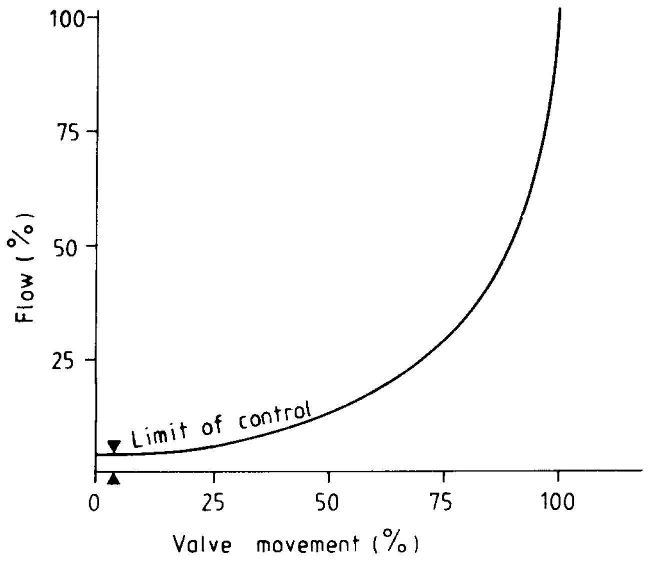


(d) Three-port diverting valve : diverting circuit

Figure 22 — Typical three-port control valve applications *(concluded)*



(a) Linear characteristic



(b) Equal percentage characteristic

Figure 23 — Typical control valve characteristics

6.3.3.3 *Control valve characteristics.* The characteristic of a control valve expresses the relationship between the area of valve opening and valve movement. In LTHW applications, control valve characteristics are usually one of the following.

a) *Linear characteristic*. Area flow is directly proportional to valve movement, assuming constant differential pressure [see Figure 23(a)].

b) *Equal percentage characteristic*. With unit change in lift, the area changes by a constant percentage of its instantaneous value. In many cases it is possible to select a valve of this type so that the overall characteristic of valve and load together approximates to linear. Parabolic and modified parabolic characteristics having a similar curve shape can be included in this category [see Figure 23(b)].

It should be noted that the actual flow relationship will only correspond to the characteristic if the differential pressure remains constant throughout. This is not the case in practice, and the amount of deviation will increase significantly as valve authority decreases below the recommended range [see **6.3.3.1** and Figure 23(a)].

Table 8 gives recommendations on control valve characteristics for LTHW heating applications.

Table 8 — Recommended control valve characteristics

Circuit type	Control valve characteristic
Compensated heating circuits	Linear
Room emitter control and constant water flow air heater batteries	Equal percentage or possibly linear
Variable flow heater batteries	Equal percentage

The accuracy of plug positioning can affect the choice of characteristic. Some manufacturers produce a range of valves with linear characteristics which can be used on all types of circuit due to the high positioning accuracy of within 0.2 % of travel.

The ratio of maximum flow to minimum controllable flow is known as the turndown ratio (or rangeability). The higher the turndown ratio, the better the control at low load. Most manufacturers produce valves with a turndown ratio of the order of 50 to 1. Some manufacturers of plug valves offer between 100 and 500 to 1 by accuracy of plug positioning. The full turndown on a control valve will be available only if the valve has been correctly sized. If the valve is oversized, the effective turndown ratio is reduced. The minimum turndown ratio normally acceptable is about 25 to 1.

6.3.4 Other features of control valves

6.3.4.1 *Pressure rating.* For LTHW purposes, pressure rating is usually related to the type of end connection. Screwed valves (of diameter 50 mm max.) are usually rated for 6 bar; flanged valves should be rated in accordance with BS 4504. Wafer type butterfly valves are usually rated for 6 bar.

6.3.4.2 *Pressure drop.* Pressure drop is an important feature, and is discussed in relation to valve authority (see **6.3.3.1**). It should be noted that some manufacturers construct valves with a higher pressure drop through the bypass port than through the main flow port. This makes it difficult to balance the corresponding pressure drops (both shown as $\Delta\rho_2$ on Figure 22(b) and Figure 22(c)] which is important for satisfactory control. Note the use of a manual regulating valve in the bypass lines in Figure 22 so that the pressure drops can be equalized at the commissioning stage. It is also important that the valve actuator is rated to overcome the maximum differential pressure expected across the valve in normal operation.

6.3.4.3 *Leakage rate.* The leakage rate of a control valve is the flow of fluid between one port of the valve and another, when the valve is shut to flow between these ports. The amount of leakage depends upon relative pressures, the type of valve and its construction. Only soft or resilient seat valves will give tight shut-off. Where a tight shut-off valve is not used, the heating effect caused by the leakage flow should be considered.

6.3.4.4 *Temperature rating.* The temperature rating of a valve is related to the materials of construction. Temperature ratings for valve bodies are usually in excess of LTHW system temperatures, e.g.:

Cast iron:	200 °C
Gun-metal	180 °C
Brass:	120 °C

However the temperature rating of the valve as a whole may be further limited by internal components such as rubber flappers, rotary shoes, etc.

6.3.4.5 *Bypass valves.* Bypass valves around control valves should only be installed where the maintenance of temperature in an area is essential, even in the event of a control valve failure. The function of a bypass valve is only for such an emergency.

6.4 Centralized control and monitoring: types

Systems performing this function in respect of LTHW installations and other building services systems are variously known as building automation, building management and energy management systems. There are two basic types available, and they may have centralized or distributed intelligence systems. However it should be appreciated that their capability extends well beyond the limits of LTHW heating, and the use of such systems should also be determined in relation to the other services installations in a building and other building management requirements.

Detailed description of such systems and their equipment is therefore outside the scope of this code.

6.5 Controls: selection factors

6.5.1 System characteristics

The selection of the mode of control of a closed loop temperature control system depends on the rate of response of the controlled system at the point at which the temperature is sensed. The rate of response of the system depends upon the thermal inertia of the system which is a function of the load side capacity of the system relative to the heat supply side capacity.

For systems where the demand side capacity is large relative to the supply side, such as storage calorifiers and space heating by radiators, on/off control is generally suitable.

For systems where the demand side capacity is small relative to the supply side such as air heaters, modulating control should be used. For systems using flow control it should generally be proportional plus integral to give stable control without offset. Where control is from return temperature, and the rate of flow of the system is constant, proportional control alone is normally satisfactory (see **6.2.2.1**).

6.5.2 Operating range

The operating ranges (e.g. maximum and minimum temperatures) of sensing elements and controllers available from HVAC controls manufacturers are usually suitable for typical LTHW installations, however care should be taken with equipment primarily designed for overseas use as the ranges and adjustments may not be suitable for use under UK conditions (e.g. compensators designed for use in Nordic climates).

The operating range (turndown) of modulating control valves depends on the application but is typically greater than 25 to 1. It should be noted that the turndown of a control valve will be affected if the authority of the valve is not within the recommended range (see Table 7).

6.5.3 Accuracy required

The accuracy and repeatability of each individual component of a control system should be such that when other influences are taken into account the system or space temperature remains within the specified tolerance.

Where on/off control is used the variation in temperature will be that caused by the switching differential and the gain or overshoot due to the on/off action and thermal response of the building as well as the system.

Where modulating control is used, overshoot is minimized with correct system selection and the variation in temperature will be that caused by instrument repeatability, system response, any inherent offset in the control system and the correct setting of the system. Care should be taken not to call for a degree of control accuracy to which it is unreasonable to expect the heating system to respond.

6.5.4 Other factors

Control valves and all other items subjected to LTHW system pressure should be suitably rated (see **6.3.4.1**). Where tight shut-off valves are required these should be specified but will possibly limit the choice of valves available. Manufacturers' recommendations should be followed in respect of power supply requirements for mains voltage equipment. Where controls work at supplying ratings other than 240 V/50 Hz, manufacturers' recommendations should be sought for types of transformers, etc.

6.5.5 Operational policy

Most LTHW control systems should be designed for automatic operation with no interference by occupants. Where a building management system monitors or controls the system, reset facilities from the operator station may be incorporated if required. There should, however, be no need for full time attendance to reset the control settings to meet changes in load, etc.

6.5.6 Safety factors

Where controls are required to perform safety functions, equipment which fails in a safe manner should be selected such as mains failure closure (spring return) of control valves when controlling high limit functions. Items of plant should comply with their individual safety requirements such as low/high temperature and pressure cut-outs, etc.

6.5.7 Energy and economic factors

The important contribution which a correctly applied and maintained system's control can make to minimizing energy use should be appreciated, and controls selected in accordance with an overall energy use policy (see **2.5** of BS 6880-1:1988). This may call for a certain degree of additional accuracy or sophistication, the extra cost of which may be offset by energy cost savings. The Building Regulations (Part Q) includes requirements concerning energy use in space heating.

Appendix A Bibliography

NOTE The latest edition of the publications listed should be used unless otherwise indicated.

1. CHARTERED INSTITUTION OF BUILDING SERVICES ENGINEERS. CIBSE Guide[2].

2. CHARTERED INSTITUTION OF BUILDING SERVICES ENGINEERS. CIBSE Building Energy Code[2].

3. HEALTH AND SAFETY EXECUTIVE. Guidance note PM5. Automatically controlled steam and hot water boilers. HMSO[3].

4. CHARTERED INSTITUTION OF BUILDING SERVICES ENGINEERS. Commissioning Code B. Boiler Plant[2].

5. CHARTERED INSTITUTION OF BUILDING SERVICES ENGINEERS. Practice Note PN2. Recommendations on the provision of combustion and ventilation air for boilers and other heating appliances: Installations exceeding 45 kW[2].

6. BRITISH GAS. List of tested and approved commercial gas appliances[4].

7. BRITISH COAL. Technical Data on solid fuel plant[5].

8. HOME OFFICE. Code of practice for the storage of LPG at fixed installations. HMSO[3].

9. LIQUEFIED PETROLEUM GAS INDUSTRY TECHNICAL ASSOCIATION. Codes of practice[6].

10. INSTITUTION OF CHEMICAL ENGINEERS. Guide to Dust Explosion prevention and protection[7].

11. BRITISH GAS. IM/11. Flues for Commercial and Industrial Gas Fired Boilers and Air Heaters[4].

12. BRITISH GAS. IM/19. Automatic Flue Dampers for Use with Gas Fired Space Heating and Water Heating Appliances[4].

13. TUBULAR EXCHANGER MANUFACTURERS ASSOCIATION. Standards of the Tubular Exchanger Manufacturers' Association..

14. INSTITUTION OF ELECTRICAL ENGINEERS. IEE Regulations[8].

15. PERRY E.J. Energy Savings in Refrigeration Systems.

16. CHARTERED INSTITUTION OF BUILDING SERVICES ENGINEERS. Applications Manual[2].

[2] Available from the Publications Department, Chartered Institution of Building Services Engineers, Delta House, 222 Balham High Road, London SW12 9BS.

[3] Available from HMSO Publications Centre, PO Box 276, London SW8 5DT or from HMSO bookshops and accredited agents.

[4] Available from British Gas plc., North Thames Technical Services, 195 Townmead Road, Fulham, London SW6 2QQ.

[5] Available from British Coal, Hobart House, Grosvenor Place, London SW1X 7AE, or from Regional Technical Services Offices.

[6] Available from the Liquefied Petroleum Gas Industry Technical Association (UK), 17 Grosvenor Crescent, London SW1X 7ES.

[7] Available from the Institution of Chemical Engineers, George E Davis Building, 165-171 Railway Terrace, Rugby CV21 3HQ.

[8] Available from the Institution of Electrical Engineers, Savoy Place, Victoria Embankment, London WC2 0BL.

blank

Publications referred to

BS 21, *Specification for pipe threads for tubes and fittings where pressure-tight joints are made on the threads (metric dimensions).*

BS 749, *Specification for underfeed stokers.*

BS 759, *Valves, gauges and other safety fittings for application to boilers and to piping installations for and in connection with boilers.*

BS 779, *Specification. Cast iron boilers for central heating and indirect hot water supply (44 kW rating and above).*

BS 799, *Specification for oil burning equipment.*

BS 799-2, *Vaporizing burners.*

BS 799-3, *Automatic and semi-automatic atomizing burners up to 36 litres per hour.*

BS 799-4, *Atomizing burners over 36 litres per hour and associated equipment for single burner and multi-burner installations.*

BS 799-5, *Oil storage tanks.*

BS 853, *Specification for calorifiers and storage vessels for central heating and hot water supply.*

BS 855, *Specification. Welded steel boilers for central heating and indirect hot water supply (rated output 44 kW to 3 MW).*

BS 1394, *Stationary circulation pumps for heating and hot water services.*

BS 1394-1, *Specification for safety requirements.*

BS 1523, *Glossary of terms used in automatic controlling and regulating systems.*

BS 1894, *Specification for electrode boilers of riveted, seamless, welded and cast iron construction for water heating and steam generating.*

BS 2594, *Specification for carbon steel welded horizontal cylindrical storage tanks.*

BS 2654, *Specification for manufacture of vertical steel welded storage tanks with butt-welded shells for the petroleum industry.*

BS 2790, *Specification for design and manufacture of shell boilers of welded construction.*

BS 2871, *Specification for copper and copper alloys. Tubes.*

BS 2871-1, *Copper tubes for water, gas and sanitation.*

BS 3274, *Specification for tubular heat exchangers for general purposes.*

BS 3528, *Specification for convection type space heaters operating with steam or hot water.*

BS 3533, *Glossary of thermal insulation terms.*

BS 4076, *Specification for steel chimneys.*

BS 4434, *Specification for requirements for refrigeration safety.*

BS 4504, *Specification for flanges and bolting for pipes, valves and fittings. Metric series.*

BS 4580, *Specification for number designation of organic refrigerants.*

BS 4580-1, *Flues.*

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

BS 4856, *Methods for testing and rating fan coil units, unit heaters and unit coolers.*

BS 4999, *Specification for general requirements for rotating electrical machines.*

BS 4999-20, *Classification of types of enclosure.*

BS 5141, *Specification for air heating and cooling coils.*

BS 5141-2, *Method of testing for rating of heating coils.*

BS 5169, *Specification for fusion welded steel air receivers.*

BS 5258, *Safety of domestic gas appliances.*

BS 5258-1, *Specification for central heating boilers and circulators.*

BS 5304, *Code of practice for safety of machinery.*

BS 5316, *Specification for acceptance tests for centrifugal, mixed flow and axial pumps.*

BS 5316-1, *Class C tests.*

BS 5355, *Specification for filling ratios and developed pressures for liquefiable and permanent gases.*

BS 5410, *Code of practice for oil firing.*

BS 5410-2, *Installations of 44 kW and above output capacity for space heating, hot water and steam supply purposes.*

BS 5422, *Specification for the use of thermal insulating materials.*

BS 5440, *Code of practice for flues and air supply for gas appliances of rated input not exceeding 60 kW (1st and 2nd family gases).*

BS 5490, *Specification for classification of degrees of protection provided by enclosures.*

BS 5500, *Specification for unfired fusion welded pressure vessels.*

BS 5643, *Glossary of refrigeration, heating, ventilating and air-conditioning terms.*

BS 5720, *Code of practice for mechanical ventilation and air conditioning in buildings.*

BS 5793, *Industrial-process control valves.*

BS 5793-2, *Flow capacity.*

BS 5854, *Code of practice for flues and flue structures in buildings.*

BS 5885, *Automatic gas burners.*

BS 5955, *Plastics pipework (thermoplastics materials).*

BS 5978, *Safety and performance of gas-fired hot water boilers (60 kW to 2 MW input).*

BS 5986, *Specification for electrical safety and performance of gas fired space heating appliances with inputs 60 kW to 2 MW.*

BS 6644, *Specification for installation of gas-fired hot water boilers of rated inputs between 60 kW and 2 MW (2nd and 3rd family gases).*

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

BS 6798, *Specification for installation of gas-fired hot water boilers of rated input not exceeding 60 kW.*

BS 6880, *Low temperature hot water heating systems of output greater than 45 kW.*

BS 6880-1, *Fundamental and design considerations.*

BS 6880-3, *Installation, commissioning and maintenance.*

BS 6901, *Specification for rating and performance of air source heat pumps with electrically driven compressors.*

CP 204, *In-situ floor finishes.*

CP 312, *Code of practice for plastics pipework (thermoplastics materials).*

DD 65, *Methods of type testing heating boilers for thermal performance.*

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