

Code of practice for

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

Part 2: Selection of equipment

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BS 6880 is published in three Parts which together form a full technical revision of CP 341.300-307:1956 which is withdrawn.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

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

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

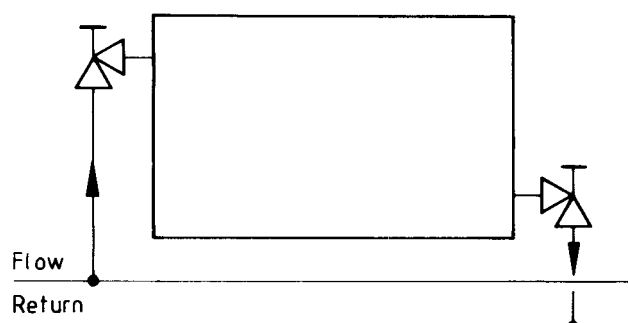
British Standards, particular care would be required in selection, installation and determination that the quality of such an installation is adequate for the application (see **2.6.1** of BS 6880-1:1988).

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).

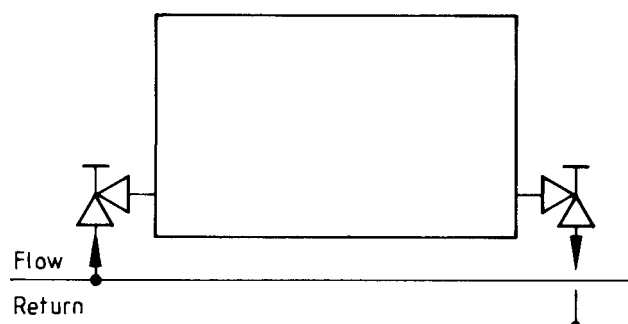
3.1.2.3 Other features. Panel radiators are normally wall mounted; the number of supports depends on the length, and all the support points provided should be used.

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.



(a) Top and bottom opposite end (TBOE)



(b) Bottom opposite end (BOE)

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 $2.4 \text{ m} \times 1.2 \text{ m}$ 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.

- Design LTHW flow and return temperatures and room temperature.
- 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:

$$q = k (t_m - t_{ai})^n$$

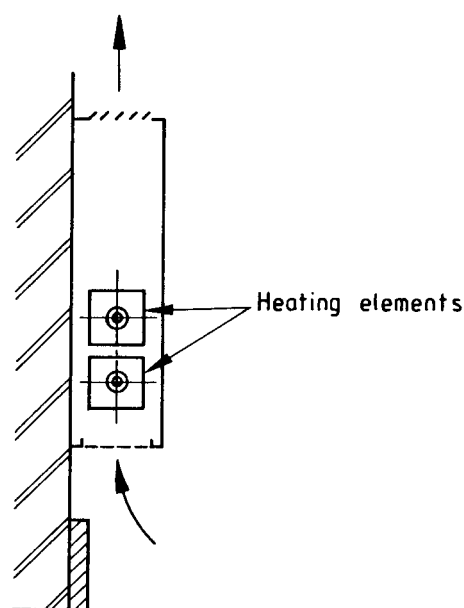
where

- 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.

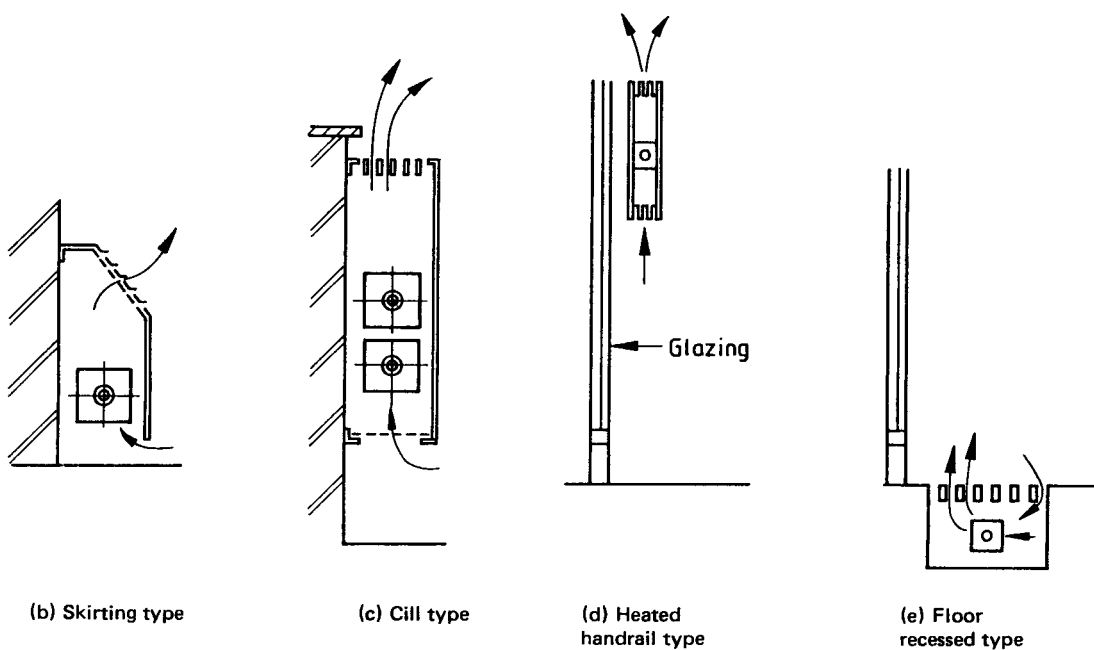
(See Section B.1 of the CIBSE Guide [1] and BS 3528.)

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

- Method of control of output (see 3.1.5.3.2) particularly whether individual unit control is required.
- Location, particularly in relation to external walls, windows and mounting height.
- Emitter surface temperature (wherever special safety considerations apply).
- General configuration, appearance and surface finish.
- 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).



(a) Typical natural convector unit (section at wall)



(b) Skirting type

(c) Cill type

(d) Heated
handrail type

(e) Floor
recessed type

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 bar¹⁾. 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.

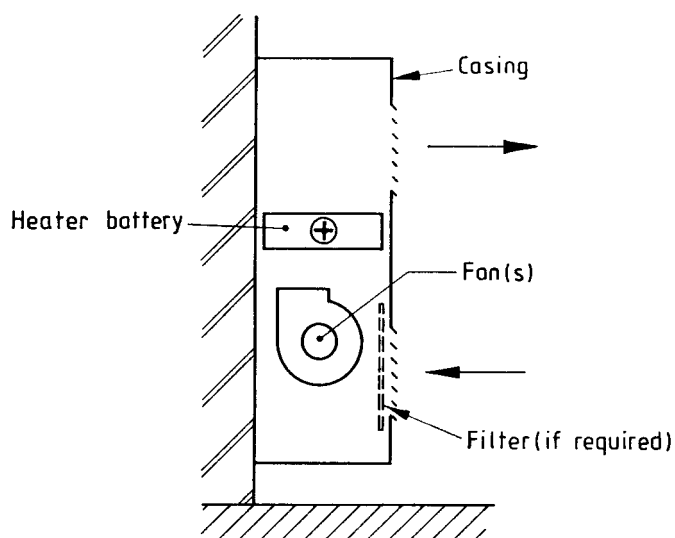
3.3.2 Fan convector and fan coil units

[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 m³/s of air volume.

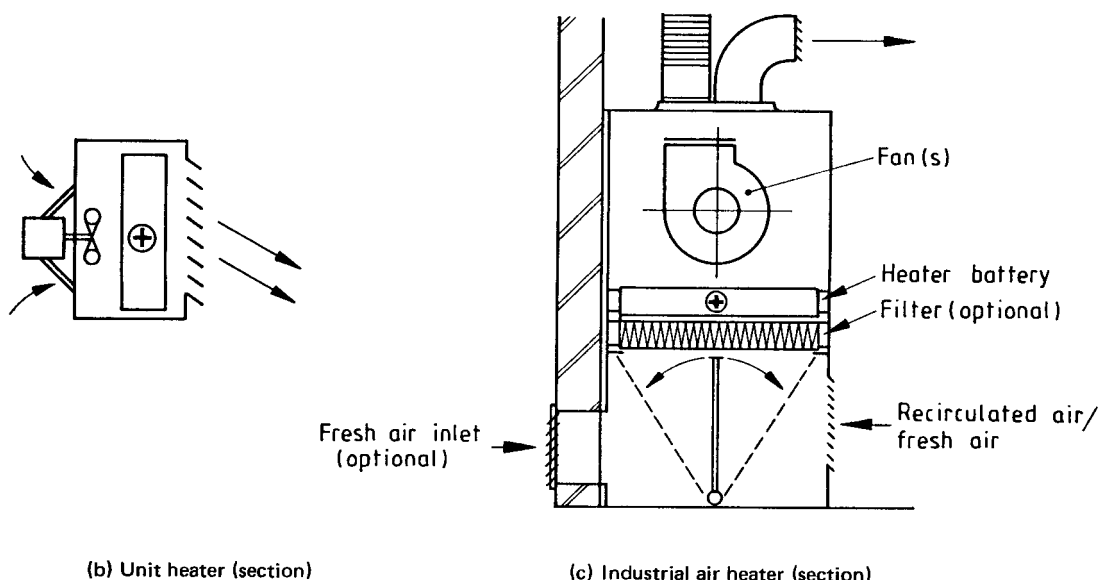
3.3.2.2 Construction. The heating element is usually of fin and tube construction, as described under 3.3.4.2. System corrosion implications should be considered and appropriate measures adopted (see 3.5 of BS 6880-1:1988).

¹⁾ 1 bar = 10⁵ N/m² = 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

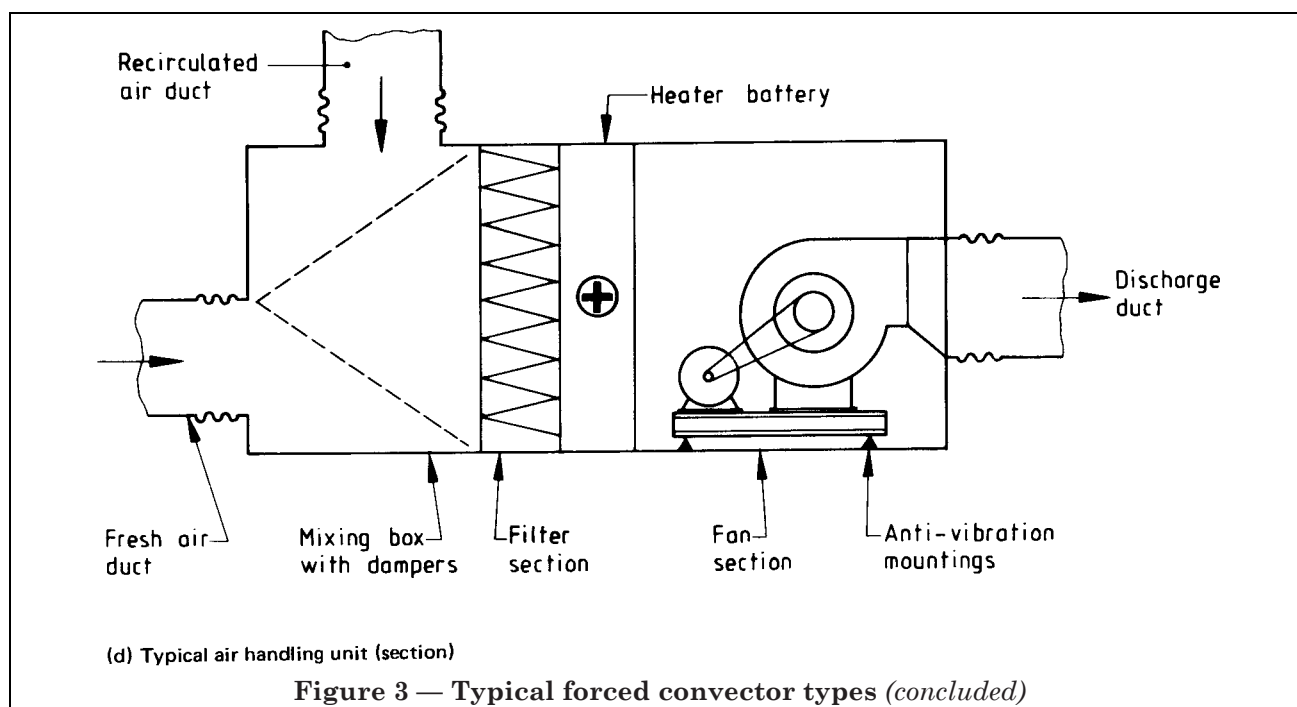


Figure 3 — Typical forced convector types (concluded)

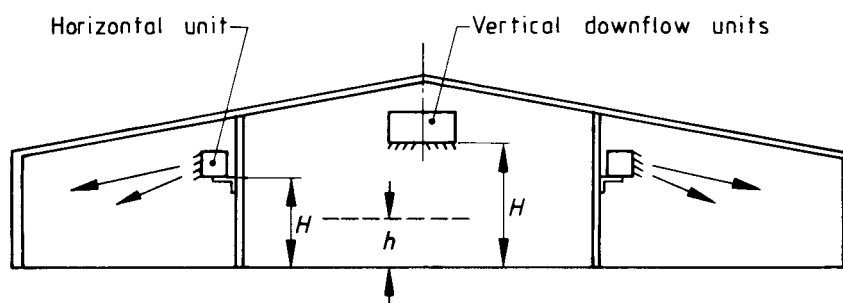
Air movement is generated by an integral fan unit, usually of the double inlet, double width centrifugal type, and often consisting of two fans on a common shaft. The drive motor is usually mounted on the same shaft, typically three-speed single phase, and of fractional horsepower. The equipment is enclosed 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).

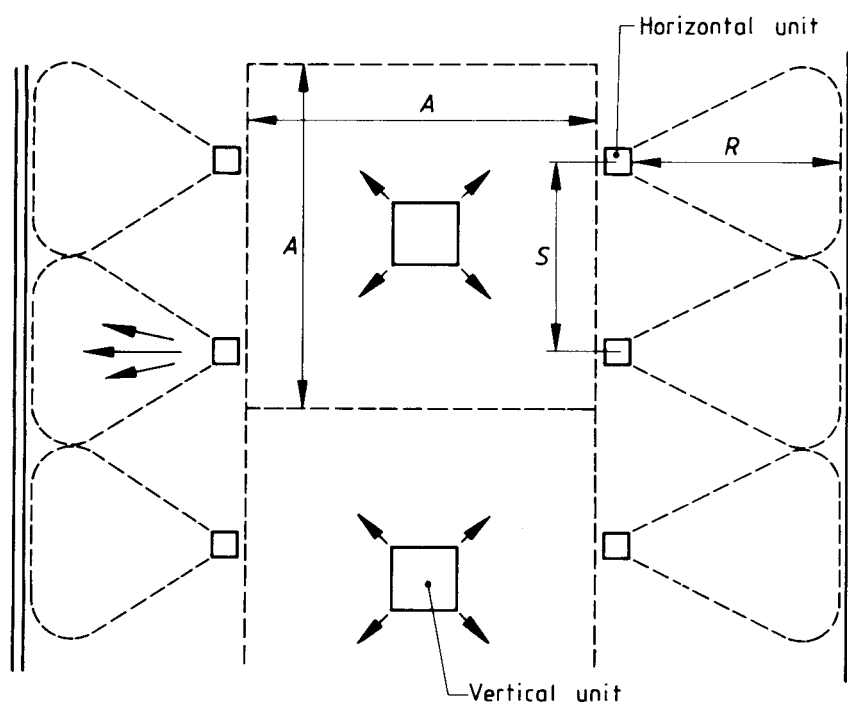
Most units incorporate a three-speed motor, giving a choice of output. Selection on the basis of output at medium speed is recommended, such that the high speed is only used for a limited warm-up period. A four position three-speed/off selector switch is typically provided, linked with thermostatic control 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

$A \times A$ 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 m³/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 m³/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 m³/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:

- air noise generated by the equipment and associated air handling accessories;
- vibration of the equipment casing and transmission of internal noise from motors, etc.;
- transmission of vibration to structures, particularly when equipment is mounted from relatively light roofs;
- 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/m² to 250 W/m².

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/m²); 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/m²) 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/m² 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/m² 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/m²) 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/m² 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).

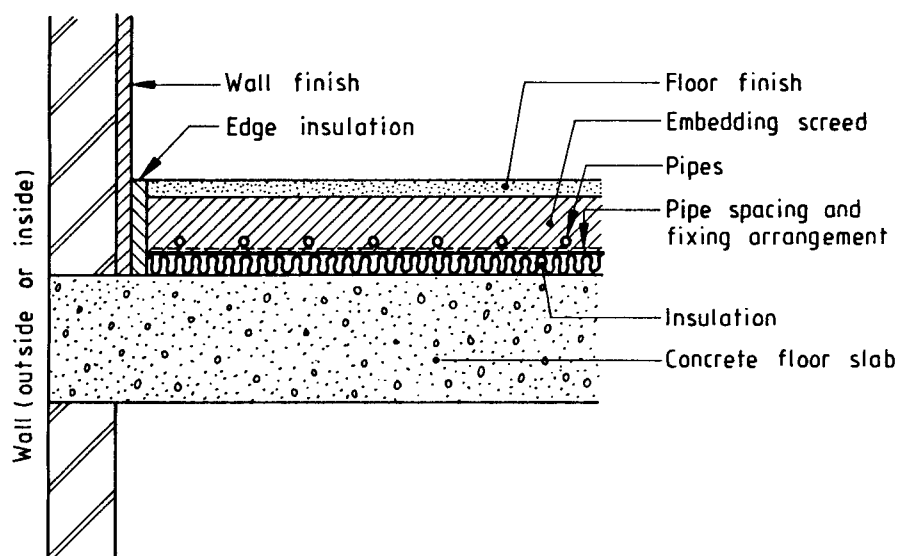
Plastics piping systems based on polypropylene, cross-linked polyethylene and polybutylene have been developed specifically for floor heating applications, but the development of plastics technology may lead to the use of other materials specifically developed and tested for the purpose. In the absence 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.

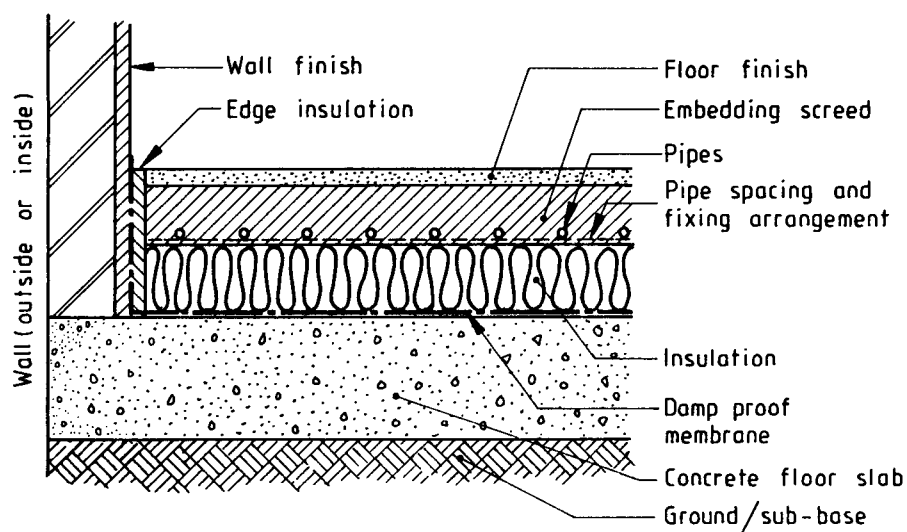
3.7.2.3 Tube spacing and fixing. The required tube spacing is determined by design considerations (see 3.8.4), subject to the influence of standard spacings. Tubes should be fixed in position at the required spacing and height using appropriate materials or proprietary components that will not rot or 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/m² 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