

Code of practice for

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

Part 1: Fundamental and design
considerations

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- 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
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Contents

	Page
Committees responsible	Inside front cover
Foreword	iii
Section 1. General	
1.1 Scope	1
1.2 Definitions	1
Section 2. Fundamental considerations	
2.1 General	2
2.2 Comfort factors	2
2.3 Application factors	6
2.4 Statutory, structural and safety factors	15
2.5 Energy conservation and energy management	23
2.6 Quality and reliability	25
Section 3. Design considerations	
3.1 Types of systems	28
3.2 Basis of design	29
3.3 Energy conversion subsystem design	34
3.4 Distribution subsystem design	48
3.5 Corrosion control and water treatment	61
3.6 Thermal insulation	64
3.7 Plant room ventilation	64
3.8 Automatic controls	65
3.9 Electrical requirements	73
3.10 Noise and vibration	75
3.11 General layout and operational facilities	76
Appendix A Bibliography	78
Figure 1 — Typical 24 h load profile and temperature decay curve (based on 9 am to 5 pm occupancy)	33
Figure 2 — Principal flue types	44
Figure 3 — Simplified representation of principal system temperature relationships	49
Figure 4 — Principal circuit arrangements	52
Figure 5 — Typical air vent arrangements	56
Figure 6 — Pump and feed location	59
Figure 7 — Vent arrangement for multiple boilers	60
Figure 8 — Typical multiple boiler control arrangements	68
Figure 9 — HWS control	72
Figure 10 — Location of sensors in pipes and ducts	74
Table 1 — Recommended design values for resultant temperature, t_c (heating season)	3
Table 2 — Levels of relative humidity, for an internal temperature of 21 °C, at which condensation will occur at various outside temperatures	5
Table 3 — Air temperatures for educational accommodation	8
Table 4 — Recommended resultant temperatures for industrial work	14
Table 5 — Recommended temperatures for storage spaces	15

	Page
Table 6 — Recommended minimum oil storage and handling temperatures for classes E, F and G fuel oils	38
Table 7 — Typical ranges of excess air	41
Table 8 — Thermal expansion characteristics of piping materials	56
Publications referred to	80

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 design of low temperature hot water heating systems.

The other two Parts are:

- Part 2: *Selection of equipment;*
- 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 80, 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 fundamental considerations and the design considerations which need to be taken into account in the design of low temperature hot water (see 1.2.1) 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 the inside back cover. 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], Health and Safety Executive (HSE) Guidance Note PM5 [3] and section three of this Part of BS 6880.

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. Fundamental considerations

2.1 General

The object of providing heating facilities in buildings is to provide (during periods when heating is appropriate) thermal conditions under which people can live in comfort and work safely and efficiently, and also to contribute to the protection of the building fabric and its contents from deleterious effects of cold weather.

The purpose of this section is to relate the various controllable factors to the comfort and well-being of the people using the building, and to certain aspects of the building fabric and its contents. Thus the requirements of the system can be clearly established sufficiently early in the design process that those aspects of building design and use which affect its thermal performance can be developed together.

The thermal conditions within a building may not be entirely determined by the heating system, since they depend on the interaction of various other factors with the heating system. These include the thermal inertia of the building fabric, natural and artificial ventilation, extraneous air leakage into the building, solar effects, evaporation of moisture and heat produced from other sources within the building. It is therefore important that the heating system design takes account of such factors to the extent that they can be evaluated at the design stage, and that those concerned with other aspects of the building design, and with its use, should appreciate these effects if a satisfactory and energy efficient system is to be achieved. Detailed guidance for the designer on these matters is given in the CIBSE Guide [1] and the CIBSE Building Energy Code [2]. Further information in respect of ventilation and air conditioning is given in BS 5720 and BS 5925.

Certain industrial process and storage situations may impose particular requirements on the heating system. While this code does not refer in detail to such situations, or to other applications which impose requirements additional to those of occupant comfort, some general recommendations are given in 2.3.3.

2.2 Comfort factors

2.2.1 General

A wide range of external environmental conditions can be accepted by varying clothing or the degree of physical activity. Such comfort conditions, the lack of which can affect the welfare of people, are provided by controlling temperature, air movement and humidity. A heating system alone may enable all or some of these conditions to be controlled during those periods of the day or year when external temperature and humidity conditions are lower than the required comfort conditions.

It is considered impractical to cover all aspects of comfort conditions in this code of practice and therefore it is recommended that reference be made to the CIBSE Guide [1].

The factors that affect comfort and that are relevant to the design of heating systems are:

- a) resultant temperature (2.2.2);
- b) air movement and draught (2.2.3);
- c) infiltration and natural ventilation (2.2.4);
- d) humidity (2.2.5);
- e) solar effects (2.2.6);
- f) noise and vibration (2.2.7).

2.2.2 Temperature

2.2.2.1 General considerations. Certain minimum temperatures are required by legislation and by local regulations. Maximum permitted heating temperatures may be stipulated by legislation relating to energy conservation (see 2.4 and 2.5).

From the comfort aspect, it is important to take into account the effect of radiant temperature in fixing the desired air temperatures to maintain comfortable conditions. When heating is provided from radiating floors, ceilings, walls or other radiating surfaces, air temperatures may be reduced. Radiation losses to large windows or cold external walls may require an upward adjustment in air temperature.

A person's overall heat loss, and hence his feeling of warmth, depends not only on air temperature, but also on heat lost or gained by the body through radiation to or from the surroundings (radiant heat gain), air movement and the humidity of the air. Many attempts have been made to devise a single index that combines the effect of two or more of these separate variables. In practice the difference between these indices is small, provided that the various parameters do not vary beyond certain limits.

In some situations it may be necessary to provide shading to protect the occupants from heat gain due to solar radiation, as when large windows are used. It is not practical to compensate fully for solar heating purely by lowering air temperature, due to its intermittent nature.

2.2.2.2 Resultant temperature. The resultant temperature index is recommended for use in the UK and is widely used in the rest of Europe. It combines inside air temperature, mean radiant temperature and air velocity to form a single index known as dry resultant temperature, hereafter referred to as resultant temperature. This relationship is described fully in the CIBSE Guide [1].

2.2.2.3 Design air temperature. It should be noted that, despite the relevance of resultant temperature to establishing comfort conditions and heating requirements, the inside air temperature selected as the basis for design should be stated. The air temperature is easily measured within the heated space and legislation or regulations may state temperatures in this form.

Table 1 gives recommended design values for resultant temperature for the UK and the CIBSE Guide [1] sets out methods of calculating the outputs required from heating systems which take account of both radiant and convective heat transfers.

Table 1 — Recommended design values for resultant temperature, t_c (heating season)

NOTE This table is derived from Section A.1 of the CIBSE Guide [1] and is reproduced by permission of the Chartered Institution of Building Services Engineers.

Type of building	t_c °C
Art galleries and museums	20
Assembly halls, lecture halls	18
Banking halls	20
Bars	18
Canteens and dining rooms	20
Churches and chapels:	18
Vestries	20
Dining and banqueting halls	21
Exhibition halls	18
Factories:	
Sedentary work	19
Light work	16
Heavy work	13

Table 1 — Recommended design values for resultant temperature, t_c (heating season)

Type of building	t_c °C
Fire stations, ambulance stations:	
Appliance rooms	15
Watch rooms	20
Recreation rooms	18
Flats, residences and hostels:	
Living rooms	21
Bedrooms	18
Bed-sitting rooms	21
Bathrooms	22
Lavatories and cloakrooms	18
Service rooms	16
Staircase and corridors	16
Entrance halls and foyers	16
Public rooms	21
Gymnasia	16
Hospitals:	
Corridors	16
Offices	20
Operating theatre suite	18–21
Stores	15
Wards and patient areas	18
Waiting rooms	18
(See also DHSS Building Notes)	
Hotels:	
Bedrooms (standard)	22
Bedrooms (luxury)	24
Public rooms	21
Corridors	18
Foyers	18
Laboratories	20
Law courts	20
Libraries:	20
Stack room	18
Store rooms	15
Offices:	
General	20
Private	20

Table 1— Recommended design values for resultant temperature, t_c (heating season)

Type of building	t_c °C
Stores	15
Police stations:	
Cells	18
Restaurants and tea shops	18
Schools and colleges:	
Classrooms	18
Lecture rooms	18
Studios (see also DES Bulletins)	18
Shops and showrooms:	
Small	18
Large	18
Department store	18
Fitting rooms	21
Store rooms	15
Sports pavilions:	
Dressing rooms	21
Swimming baths:	
Changing rooms	22
Bath hall	26
(See also MOHLG Design Bulletin 4)	
Warehouses:	
Working and packing spaces	16
Storage space	13

NOTE 1 The figures in this table are for general guidance, and should be considered in conjunction with the more specific published requirements of individual user bodies where appropriate, such as the Department of the Environment, the Department of Health and Social Security and the Department of Education and Science. For further details of the publications referred to in this table see Section A.1 of the CIBSE Guide [1].

NOTE 2 Energy conservation legislation may from time to time impose maximum permissible temperatures which are lower than those quoted, such as the maximum of 19 °C for offices currently laid down in the Fuel and Electricity (Heating) (Control) (Amendment) Order (1980).

2.2.3 Air movement and draught

Air movement within an occupied space is desirable as it contributes to a feeling of freshness, although excessive movement should be avoided as this leads to complaints of draughts. Heating alone may have only a limited influence on air movement depending upon the type of system used. In practice there are only two system types that will have a significant effect on air movement, these are forced convectors and ducted air systems.

The presence of cold window surfaces, particularly those at high level or roof lights, can lead to down draughts of cold air. The positioning of heat emitters beneath windows will reduce the uncomfortable effects of such draughts and, by reducing the upward current of warm air from the emitter, generally improve the vertical temperature gradient within the room.

The velocity of an air current becomes more noticeable as the air temperature falls, owing to its increased cooling effect. The design of an air distributing system therefore has a controlling effect on the quantity and temperature of the air that can be introduced into a space. The quantity of fresh air should not be increased solely to create air movement; this should be effected by air recirculation within the space or by inducing air movement with the ventilation air stream. It is usually impractical to achieve good air distribution using forced convectors, so care should be taken in arriving at a decision to use this principle in a particular application. The location of individual units and the direction of warm air delivery are particularly important factors. Recommendations on the mechanical ventilation of buildings are made in BS 5720 and should be referred to where a ducted air system is being considered.

2.2.4 Infiltration and ventilation

Infiltration is the leakage of air through a building due to imperfections in the structure, mainly cracks around doors and windows, between cladding sheets, etc.

Natural ventilation is the air flow resulting from the designed provision of specified apertures such as openable windows, ventilators, etc. and can usually be controlled to some extent by the occupants.

Both infiltration and natural ventilation are dependant upon natural forces (particularly wind) and cannot be relied upon to provide a guaranteed rate of air interchange under all conditions. Infiltration may be far in excess of the ventilation air required and in other cases natural ventilation may be inadequate. Inadequate ventilation can cause problems of condensation and odour control, a feeling of stuffiness and possible hazards due to accumulation within the space of such contaminants as may be present. The CIBSE Guide [1] recommends ventilation rates and some local legislation requires certain minimum rates (see also BS 5720).

Section 3 includes data on infiltration rates for different types of building. The CIBSE Guide [1] sets out methods of calculating infiltration and natural ventilation rates. Methods of calculating natural ventilation rates are also given in BS 5925.

2.2.5 Humidity

2.2.5.1 Comfort considerations. The effect of humidity on thermal comfort only becomes significant outside the range of 40 % to 70 % relative humidity. The humidity within a heated space is only likely to fall below this range when large quantities of cold outside air are heated and supplied into the space, resulting in a low humidity level. Conversely, it is only likely to rise above this range when there is a combination of low ventilation rates and significant release of moisture from the occupants, their activities or other moisture generating processes.

2.2.5.2 Condensation. Condensation on surfaces or within the structure of a building can cause a nuisance and possible health hazard to occupants, as well as other undesirable effects (see 2.4.2.9). Table 2 indicates the likelihood of condensation on windows under varying conditions. This subject is treated more fully in the CIBSE Guide [1].

Table 2 — Levels of relative humidity, for an internal temperature of 21 °C, at which condensation will occur at various outside temperatures

NOTE This table is reproduced from Table 4 of BS 5720:1979.

Outside temperature	Relative humidity	
	Single glazing	Double glazing
°C	%	%
– 20	14	32
– 10	24	44
0	40	59
+ 10	61	74

2.2.6 Solar effects

Solar radiation entering a building through the windows can cause discomfort to the occupants, both directly by greatly increasing the mean radiant temperature to which the occupant is subjected, and indirectly by raising the air temperature. For this reason solar gains should not be assumed to contribute fully to the heating requirement since blinds or other shading devices will be required. In order to avoid overheating, solar gain should be considered when planning a heating system since one aspect of a building may require little or no heating whilst at the same time another aspect could be close to its maximum heating requirement.

2.2.7 Noise and vibration

2.2.7.1 General. All heating and ventilation systems produce noise, and this may cause annoyance or disturbances in:

- the space being treated;
- other rooms in the building;
- the environment external to the building.

In the case of the external environment particular care should be taken to avoid a nuisance, and local authorities have statutory powers to ensure that noise from plant is limited. BS 4142 describes a noise measurement procedure, the determination of corrected noise level and a method of rating the noise in these instances. It is important that expert advice be sought in dealing with noise and vibration matters, noting that prevention at the design stage is usually far less costly than subsequent rectification. Noise and vibration specifically related to air handling systems are covered in BS 5720.

2.2.7.2 Types of noise relevant to heating systems in buildings

2.2.7.2.1 Generated noise. Noise produced by boiler plant and related equipment can escape via ventilation and other openings and cause a nuisance to neighbours. Intermittent noise, such as is associated with certain types of burner, can be a particular nuisance, especially at night when people are trying to sleep.

2.2.7.2.2 Transmitted noise. Noise transmitted through the building structure is particularly acute in modern frame and reinforced concrete buildings. Such noise can be controlled by isolating machines from the structures and from pipework connected to the building, by the use of suitable mountings and pipe couplings.

2.2.7.3 Sources of noise

2.2.7.3.1 Central plant. Noise is produced by boilers, pumps, fans, heat pumps, etc.

2.2.7.3.2 Distribution systems. Noise is produced by excessive fluid velocity or throttling in pipes and valves. It is also produced by pick-up of noise or vibration from plantrooms, etc. and transmission along pipework, or by noise transfer from one occupied space to another by means of pipework.

2.2.7.3.3 Equipment in occupied rooms. Noise arises from fan convectors, unit heaters and by excessive throttling of valves serving heat emitters.

2.2.7.3.4 External sources. Intermittent noise arises from delivery of fuel, particularly solid fuels.

2.2.7.4 Noise rating. Continuous exposure to noise rating values above 85 can cause permanent damage to hearing. Such high levels are only likely to be associated with large boiler plant and can be treated by the use of attenuating equipment. It may be necessary to apply acoustic treatment to the structure to protect adjacent rooms.

2.2.7.5 Treatment within rooms. Where significant noise from a heating system is apparent within the occupied space, it is not usually practical to control it effectively by treatment of the room. It is therefore particularly important that care be taken to avoid such problems by:

- a) ensuring that fluid velocities are low and that principal mains do not run through the occupied space;
- b) ensuring that adequate provision is made for balancing the water distribution in a system to avoid excessive throttling at the emitters;
- c) ascertaining the noise levels created by fan convectors and unit heaters and, where a choice of fan speed is available, making a selection against acoustic and economic criteria.

2.2.7.6 Recommended levels of noise. The levels of environmental noise are most conveniently related to noise rating curves. These curves are attempts to relate the background noise level for annoyance and speech intelligibility for a given environment. Recommended noise ratings are given in the CIBSE Guide [1] and are referred to in BS 5720.

2.3 Application factors

2.3.1 General considerations

2.3.1.1 Nature of occupancy. The primary aim of any heating system is to provide comfortable conditions for the occupants of the building. Consequently the type of occupants and the nature of their activities have to be considered. For example, an internal temperature suited to sedentary staff would be quite unacceptable in a factory where heavy manual work is carried out. Guidelines for internal temperatures for various types of occupancy are given in Table 1.

2.3.1.2 Occupancy pattern. The pattern of occupancy should be considered, particularly in relation to the provision of satisfactory conditions at the commencement of the working period and to avoiding unnecessary operation of the heating system with consequent energy wastage.

Careful consideration should be given to the type of control which will provide the most efficient control of the heating system at all times of the heating season, taking account of variations in occupancy and climatic conditions and of the thermal response of the building fabric to such changes. A wide range of control options is available from simple time clocks to sophisticated optimization controls (see 3.8).

Some applications have to provide for occupancy outside normal working hours. This relates particularly to areas such as boardrooms, lecture theatres, restaurants, etc., where provision may have to be made in the design of the heating system to ensure that the total system does not have to be in operation to heat such areas. Similar situations arise in theatres and other buildings where occupancy is infrequent, but relatively dense for short periods.

2.3.1.3 Ownership, operation and maintenance. As far as is reasonably practicable at the design stage, selection of the heating system should take account of the technical implications of the ownership and tenancy arrangements, and of the expected arrangements for system operation and maintenance. This may include such factors as:

- a) zoning and isolation;
- b) metering;
- c) the possibility of areas being unoccupied;
- d) presence or otherwise of operating staff;
- e) type of maintenance service to be used;
- f) need for remote monitoring/control;
- g) location of alarm indications.

2.3.1.4 Building orientation and configuration. Whilst building orientation is not so important with a heating system as it is with air conditioning, it does influence both design and performance. Many buildings with LTHW radiator or convective heating systems have openable windows which can be a major source of air infiltration (see 2.2.4), even when closed. Some fresh air infiltration may be desirable, but excessive infiltration can become a source of discomfort and add considerably to the heating load, as all outside air introduced to the building has to be heated to the internal temperature.

The main factors which affect air infiltration to a building are the type of construction, particularly the windows, the height of the building, the degree of exposure to the elements and the wind speed. It follows therefore that a building of tall tower configuration on an exposed site will have a higher heating load due to infiltration than would a building of low-rise configuration of equivalent size in a city centre. If the orientation happens to be such that the longest side of the exposed building faces the prevailing wind, then the annual amount of infiltration will be at a maximum. Further information is given in 3.2.2.

Building configuration also has a significant influence on the heat loss due to conduction, particularly as the ratio of total external envelope area (roof, walls, etc.) to floorspace increases, as with excessively rectangular configurations or extensive single-storey developments.

2.3.1.5 Building construction and thermal response. The construction of a building has a major influence on the heating load. Factors to be considered include materials and thicknesses of walls, roof, ceiling and floors, the area and type of glazing and the degree of insulation which is to be incorporated. In some instances it may also be necessary to take account of moisture transfer through the walls and the possibility of interstitial condensation (see 2.4.2.9).

The rate at which a building loses heat after the heating system output has been reduced, and the time lag required to re-establish internal temperatures after shutdown depend upon a number of parameters inherent in the mass and thermal properties of the building fabric, including that of internal elements. Methods for detailed calculation of this are given in the CIBSE Guide [1]. These factors should be considered when intermittent heating is to be applied but are of less importance if heating is to be continuous.

2.3.1.6 Zoning. An LTHW heating system should be able to accommodate daily variations in external temperature and internal load variations due to movement of people, operation of lights, machines and equipment. One approach to this situation is the division of the system into a number of separate zones. Zones in a heating context may be defined as subsystems serving areas where, due to internal or external influences, the conditions might be expected to change relative to other areas.

The object of subdividing the system to serve individual areas or zones is to allow independent automatic control of each such area so that the heating may be modulated to compensate for heat gains or losses due to other causes, thus maintaining design temperatures in the area and minimizing energy input.

With LTHW heating, zoning is often on the basis of the different faces or external aspects of a building in relation to sun, exposure, shading, etc. In the case of multi-storey buildings the effects of increased exposure and different shading at the higher levels may call for subdivision of zones according to height as well as aspect.

2.3.1.7 Mechanical ventilation. In some applications it may be necessary to combine LTHW heating with mechanical ventilation, in order to provide appropriate environmental conditions within the building or in particular areas. This may arise due to such factors as:

- a) need to introduce outdoor ventilation air into those areas of a deep plan building not adequately served by natural ventilation;
- b) need to introduce air to make up air extracted from process equipment such as cooker hoods, etc.;
- c) requirements for a particular pattern of air movement within the space;
- d) need to maintain positive air pressures within the space;
- e) general suitability of forced warm air heating for a particular application.

Ventilation is covered in some detail in BS 5720, including detailed recommendations on fresh air quantities. In instances where LTHW heating is combined with mechanical ventilation the influence of one system on the other should be carefully considered as well as the effect on system load and configuration of heating the ventilation air.

It should also be noted that in situations where heating and ventilation are combined, opportunities may be presented for heat recovery by abstraction from the outgoing air stream.

2.3.2 General applications

2.3.2.1 Accommodation types. General guidance is given in 2.3.2.2 to 2.3.2.6 on the application of LTHW heating to common types of accommodation. It should be appreciated that these types of accommodation are not necessarily synonymous with types of building. For example, an office block may have a restaurant or a school may include laboratories. In some instances this situation may call for a building to use more than one type of heating system, in order to satisfy significant differences of accommodation type. Also, it should be appreciated that some of the factors listed are common to more than one type of application.

2.3.2.2 Office accommodation. Office buildings may include both external and internal areas. The external area may be considered as extending from approximately 4 m to 6 m inwards from the external wall and is generally subject to wide load variations due to daily and seasonal changes in outside temperature and solar radiation effects.

The heating system should be arranged and controlled so that it can respond to the changing conditions in the internal and external areas. The choice of heating system may be influenced by considerations of downdraughts and cold radiation, which are particularly associated with single glazed windows and rooflights in cold weather.

Internal areas of deep plan buildings tend to be more stable in terms of heating demand. Except where they have an exposed roof, or possibly ground floor parking, the heat emission from lights, personnel and office or other equipment is frequently adequate to maintain satisfactory temperature conditions, and in certain situations consideration may have to be given to heat removal rather than heating. In the case of deep plan offices, the heating system may operate in conjunction with ventilation of the core area. Ideally a core ventilation system would make maximum use of fresh air for cooling purposes, mixing it with recirculated air to provide a suitable supply air temperature. Such a system would require provision for heating the ventilation air during the coldest weather and periods of non-occupancy. (See BS 5720.)

Other considerations include:

- a) requirements for control of individual or groups of emitters by the occupants;
- b) layout and installation constraints imposed by requirements of flexibility of layout and partitioning;
- c) constraints imposed by occupancy or other considerations on the projection of heating equipment from walls, clear space underneath for floor cleaning, and integration with other services at the building perimeter;
- d) aesthetic standards of the installation in occupied rooms, and possible need for more than one standard of aesthetic treatment;
- e) provision for serving multiple tenancies and associated landlord areas;
- f) provision for extended use of limited areas such as conference rooms, social facilities, etc.;
- g) policy for the provision of year-round hot water services for sanitary and food service use.

It should be noted that there are statutory requirements for minimum and maximum temperatures associated with the heating of offices, laid down in the Offices, Shops and Railway Premises Act 1963 and the Fuel and Electricity (Heating) (Control) (Amendment) Order 1980, respectively.

2.3.2.3 Educational accommodation. Guidelines for the heating and ventilation of educational buildings have been issued by the Department of Education and Science which recommend the internal air temperatures shown in Table 3.

Table 3 does not apply to facilities catering specifically for the disabled where 21 °C is recommended throughout.

Allowance should be made for heating a minimum of 10 m³/h of fresh air per occupant from a total ventilation requirement of 30 m³/h, it being considered that the remainder is heated by occupants and other internal heat gains.

Table 3 — Air temperatures for educational accommodation

Location	Air temperature °C
Medical inspection and similar rooms	21
Classrooms	18
Dormitories	15
Gymnasia and similar areas	14

In nursery schools and those which cater for the handicapped, it is necessary to protect people from direct contact with low level heating surfaces, and dangerous projections should be avoided. If an accessible metallic surface is likely to have a temperature greater than 43 °C it should be protected by means of a suitable guard. Limiting the vertical temperature gradient within the occupied level is of importance. For further information see Department of Education and Science Design Note 17 [4].

The possibility of vandalism has to be acknowledged in some types of school and this may influence the type of system or equipment selected. This consideration tends to favour the use in occupied areas of equipment which is concealed, not readily accessible to occupants, or is particularly robust, and it can particularly affect the method of control adopted due to the vulnerability of certain types of control equipment. Similar considerations, and the avoidance of dangerous projections, etc. may apply in gymnasia and other areas of physical activity, in order to reduce the risk of injury to occupants and of accidental damage to the installation (see 2.3.3.3).

In respect of laboratories see **2.3.3.6**.

2.3.2.4 General circulation areas. General circulation areas are areas of the building subject to ambulant circulation of occupants or the general public. The nature of occupancy is generally transitory, but there may be small numbers of service or other personnel located in such areas for longer periods, sedentary or otherwise. General factors that need to be considered in these situations include:

- a) constraints imposed by functional layout requirements and aesthetic considerations;
- b) degree of clothing likely to be worn and the conflicting comfort requirements of transient and non-transient occupants;
- c) control of draughts at external doors;
- d) temperature gradient in high spaces;
- e) possible grading of temperature between the outside, the circulation area and the main parts of the building to reduce sudden temperature changes;
- f) lighting heat gains;
- g) the needs of security or other personnel located in such areas outside normal occupancy hours;
- h) possibility of vandalism.

Particular cases of the general type are the trading departments and other public areas of retail stores. In such stores, and particularly in the larger establishments, conditions tend to vary according to the trading pattern and type of goods on sale. Many areas have high lighting intensity for display purposes whilst others have varying occupancy patterns; in many cases they can be self-heating down to external temperatures of 5 °C, noting that deep planning of the space is typical. LTHW heating is often used in conjunction with ventilation or even air conditioning, and the varying pattern of heating requirements calls for careful consideration of the interrelationship of these systems under different occupancy conditions, and particular attention to zoning.

When planning the heating of stores it is important to consider the requirements of both staff and shoppers. In the winter sales staff are generally lightly clad compared to the shoppers. As the staff are relatively sedentary and have to be in the building all day, some compromise may have to be reached between the preferred conditions for staff and those for the shoppers.

In areas where occupancy patterns are more stable and display lighting levels lower, together with storage areas and administration offices, heating alone may suffice. Any radiators or convectors located in sales areas should be suitably protected from trollies or other vehicles used for movement of stock and should not be sited where they could cause injury to shoppers. Concealed flush-mounted heaters or high level radiant heaters may be appropriate. Flexibility in design is essential to accommodate future changes of layout or use, and this should be established early in the design process. Particular attention should be paid to stores entrances and the comfort of any service personnel located nearby. Whilst warm air curtains are frequently used in this situation, consideration should be given in the early planning of the building to other means of minimizing the influence of the external conditions upon the adjacent interior. By use of double doors or other architectural means it may be possible to reduce energy demands or even eliminate the need for door curtains.

2.3.2.5 Catering accommodation. This relates to areas used for the preparation and consumption of food and drink, whether as single-purpose establishments or as a food service facility within some other type of building.

Restaurants, bars and similar facilities have highly variable loads with a particular requirement for maintaining comfortable conditions during periods of low occupancy. Provision should be made for reducing the heat input automatically to allow for sensible heat gains from occupants and food service activities during peak periods, and also that from decorative lighting. It is important to coordinate the layout and appearance of the heating installation with the layout and decor of the rooms, particularly in respect of fixed furniture, counters, etc.

In many cases, particularly the larger restaurants, the heating system will be required to operate satisfactorily in conjunction with mechanical ventilation or air conditioning under a variety of occupancy conditions. The need for large volumes of air to be extracted from cooker hoods and above serverly counters should be recognized at an early stage and consideration given to the means of providing for the resulting loss of heat, whether by heating the incoming replacement air or by other means. Consideration should also be given to the potential for heat recovery which may be offered by such extraction from warm areas, noting that this may influence the type of heating to be used so that full advantage can be taken of relatively low grade heat.

In restaurants without a central supplementary ventilation system, consideration may also be given to heating by means of forced convector units of a type which incorporates a fresh air inlet facility. If such a system is used attention should be paid to operating noise levels and the avoidance of draughts. Heaters of this type should be applied so that the leaving air temperature does not drop below 25 °C. However, below 35 °C discomfort due to draughts may be felt.

It should be recognized that food service facilities may need to operate outside the normal working hours for other building areas. Also, the heating of kitchens should take account of the different operational patterns, for example periods of high heat gain when cooker hoods are in use, and periods when other kinds of work are in progress but with reduced or no extract from hoods.

Heating installations in kitchen areas should take account of requirements for hygiene, and should be located as far as may be practical to minimize build-up of dust, etc. and to facilitate cleaning. Particular attention should be paid to the possible build-up of grease, especially where convective heating is used.

2.3.2.6 Residential accommodation

2.3.2.6.1 General. The heating of the majority of individual dwellings served by independent LTHW heating systems is outside the scope of this code. In the context of this code, residential applications relate mainly to multiple private or public dwelling complexes which are served by central LTHW heating plants, residential institutions and those larger individual dwellings requiring a system of greater than 45 kW output.

The design of LTHW heating for residential accommodation should be based on the recommendations given in the CIBSE Guide [1]. (See also Table 1 which reproduces recommended design temperatures for individual rooms.) Some of the recommendations in BS 5449-1 are also relevant to dwellings in general, although that particular standard is limited to LTHW systems below 45 kW output.

An important factor in residential heating is that the LTHW heating system may not be required to provide the full heating requirement of every room in the dwelling. BS 5449-1 gives the following definitions in this respect.

part house central heating. The simultaneous heating of some of the spaces in the dwelling so as to maintain specified temperatures, based upon calculated heat losses.

background central heating. The simultaneous heating of all or some of the spaces in a dwelling to temperatures below those specified, based upon calculated heat losses.

NOTE In this context “specified” relates to Table 1 of BS 5449-1:1977, which is generally in accordance with the recommendations of the CIBSE Guide [1] reproduced as Table 1 of this Part of BS 6880.

Where a reduced standard of heating is proposed, it is particularly important that the design temperatures for each type of room or occupied space be clearly defined at the outset.

Residential heating tends to differ from that of other accommodation types due to additional factors which include:

- a) the occupancy pattern usually extends over the 7 days of the week, with different modes for weekdays and weekends;
- b) the number of hours per year for which the heating system is in use may be greater;
- c) the incidence of HWS loads may be particularly significant;
- d) thermal insulation requirements are different (see the Building Regulations);
- e) metering of usage by individual dwellings may be required;
- f) opportunities for concealment of the distribution installation may be very limited in certain types of housing;
- g) response of controls to the needs of individual occupants may be important;
- h) operation and maintenance resources may be particularly limited;
- i) the particular importance of regulating the flow to individual dwelling units.

2.3.2.6.2 Public housing. Minimum standards of heating for public housing were recommended in 1961 by the report “Homes for Today and Tomorrow” now published by the Department of the Environment (DoE) (the Parker Morris report) [5], followed by various circulars of the Ministry of Housing and Local Government [6]. At the time of drafting, individual housing authorities tend to establish their own standards which may depart from the Parker Morris criteria. The specific requirements for a particular project in this sector therefore need to be ascertained from the appropriate authority. See also DoE Circular 23/78 [7] on energy conservation in public sector housing.

2.3.2.6.3 Housing for the elderly. Whilst such accommodation may also be public housing, significantly higher space temperatures are recommended for the elderly and specific guidance is given in Ministry of Housing and Local Government Circular 82/69 [6]. Other factors to be considered include:

- a) fast system response to meet the needs of the individual occupant;
- b) controls that are easy to understand and manipulate;
- c) importance of warm feet and minimal vertical temperature gradient;
- d) avoidance of draughts;
- e) possible adverse effects of convective systems on people with respiratory disorders;
- f) protection from the dangers of contact with heat emitting surfaces by appropriate guarding or reduced system temperature;
- g) possibility of damage by wheelchairs, and the tendency to leave doors open to facilitate wheelchair movement.

The importance of warm feet to elderly people, particularly when sitting, may favour consideration of a heated floor system. However, considerations of system response may indicate the use of some other type of system in conjunction with the heated floor.

Accommodation for the elderly is usually heated for a substantially greater number of hours per year than other types of residential accommodation, thus affording more favourable conditions for investment in energy conservation.

2.3.2.6.4 Institutional residential accommodation.

This type includes such residential complexes as hostels, student residences, nurses homes, military barracks, penal and remand establishments, etc. The basic principles applicable to general-purpose residential accommodation are generally relevant. However, much of this type of accommodation has to be built to standards laid down by major public sector user bodies such as the Department of Education and Science, the Department of Health and Social Security, the Home Office, etc., whose specific requirements should be ascertained.

2.3.2.6.5 Hotel guest rooms. In hotels the occupancy pattern has a considerable bearing on the type of heating selected and its method of control. Guests may vary considerably in their temperature requirements, particularly at night, and consequently provision should be made for individual control of room temperature without affecting other rooms on the same circuit. Design temperatures tend to be higher than for other types of sleeping accommodation, particularly in luxury hotels (see Table 1).

Other factors which should be considered include:

- a) appearance of exposed equipment and relationship to decor;
- b) operation within appropriate noise levels, particularly at night;
- c) ease of maintenance and cleaning;
- d) siting of equipment so as not to interfere with furniture layout or impede efficient floor cleaning;
- e) effect of extract ventilation on the heat load;
- f) type of window curtains to be used.

Guest room heating is required to be available for operation 24 h/day, 7 days/week. The room may be unoccupied for most of the day and there should be provision for operating at reduced capacity. Consideration may be given to centralized control of heat emitters based on a day-to-day occupancy schedule. For UK applications and those in similar or colder climates, consideration should be given to the heating of bathrooms and provision for towel warming.

2.3.3 Special applications

2.3.3.1 General. Guidance on LTHW heating of certain more specialized categories of accommodation is given in 2.3.3.2 to 2.3.3.7. Whilst the basic principles applicable to comfort heating outlined in this section are generally relevant, in many of the more specialized applications considerations additional to those of occupant comfort are important. Also, these tend to be applications where space heating and mechanical ventilation are closely interrelated; BS 5720 gives further information concerning ventilation and the environmental requirements of these types of application.

2.3.3.2 Public assembly facilities. In this type of building the heating system normally has to operate in conjunction with mechanical ventilation or air conditioning. The main areas of assembly require the introduction of sufficient fresh air to meet minimum statutory requirements and also to ensure that the concentration of contaminants is maintained within acceptable limits under the most onerous conditions of occupancy, with particular reference to smoking (where appropriate); see also **2.2.4**. Direct LTHW heating (i.e. primarily radiant, as distinct from warm-air heating) is frequently used in conjunction with air handling systems to counteract down draught from large glass areas. Where direct heating is used it is recommended that provision is made to maintain minimum required temperatures during periods when the assembly areas are not in use. Depending upon the application, the air handling system would either be shut down during these periods or running at a much reduced output, in the interest of energy conservation. Opportunities may arise for recovery of heat from the exhaust air and its use for preheating the incoming air. Buildings of this type usually include several other types of accommodation such as offices, bars and restaurants which are covered in **2.3.2.2** and **2.3.2.5** and by the CIBSE Guide [1].

2.3.3.3 Physical recreation facilities. The choice of heating system for a recreational facility should take account of the types of activity to be accommodated, and the often conflicting requirements of participant and spectator areas. In some cases heating of participant areas may be required for extended periods when spectator areas are not in use.

Heating system elements (e.g. emitters, valves) should be detailed and installed so as to minimize risk of physical injury to participants. Where predominantly radiant heating is used in participant areas the emitters should be mounted at an appropriate high level, preferably at the walls.

Temperatures in areas of physical activity should not exceed 16 °C, but adjoining spectator areas require higher temperatures, typically 19 °C. Changing areas also have different requirements; the recommended design temperature is 22 °C.

Heating with a substantial radiant component is recommended, and heating system design should take account of the ventilation requirements of such areas which are imposed by the need to control humidity and odour.

Swimming bath halls are a particularly specialized application in this general category. A temperature of 26 °C is recommended, but the need for a substantial radiant component may suggest consideration of a heating system other than LTHW. The risk of corrosion arising from the presence of humid air and chlorine calls for specific measures to avoid external corrosion of system elements. A common solution is to use embedded pipe heating of walls, with system temperatures selected accordingly. The heating and ventilation requirements of swimming bath halls are closely interrelated, and opportunities may arise for heat recovery between the moisture-laden exhaust air and the incoming supply air required to control humidity. Heat pumps have been successfully applied for this purpose.

Although process heating is outside the scope of this code, it should be borne in mind that the LTHW heating system may be required to provide primary heat for the pool water heating installation.

2.3.3.4 Museums and art galleries. The comfort heating of staff and visitors is covered in **2.3.1** and **2.3.2** and in the recommendations of the CIBSE Guide [1]. However, the overriding consideration is the long-term preservation of the exhibits, both in the public galleries and in any ancillary areas where exhibits may be stored or undergo treatment. Stability of temperature is usually important and close humidity control is often required for exhibits susceptible to changes of moisture content; these requirements may indicate use of air conditioning in certain areas.

Air cleanliness is often important and care should be taken to minimize staining due to air movement, whether by forced or natural convection.

In all cases close consultation with the operators of the facility is recommended such that the environmental requirements of the various categories of exhibit are clearly defined at the outset by the appropriate specialists.

The siting of heat emitters should take account of displays and shelving. The appearance, finish and degree of concealment of heat emitters and other system elements and their relationship to interior design are important aesthetic considerations. In the case of tall spaces or those with galleries arranged around a central atrium particular care is required in the choice of system to prevent stratification, and due allowance should be made for the height effect (see Table B.1.3 of the CIBSE Guide [1]).

2.3.3.5 Health care facilities. A general hospital is a multifunctional institution, housing extremely diverse activities and as such contains examples of virtually every type of heating application considered by this code, and others of a specialized nature. For other types of health care facility such as long-stay hospitals, clinics, day centres, etc. the requirements are less diverse than those of the general hospital, but in many cases the requirements of individual areas correspond generally to those of the corresponding general hospital departments.

Detailed briefing on the design basis and other requirements for heating systems in UK state hospitals and related health care facilities are laid down in the Hospital Building Notes [8] and Hospital Technical Memoranda [9] of the Department of Health and Social Security, to which references should be made. Since some of this documentation has not been revised since energy conservation considerations have become more prominent, close consultation with the client body for a specific project is important in this and other respects. The following are some general considerations that are characteristic of the heating requirements of hospitals:

- a) diversity of accommodation types;
- b) considerations of hygiene and cleanability;
- c) close interrelationship between heating and mechanical ventilation in many departments;
- d) interrelationship between space heating and process equipment in certain departments;
- e) continuous occupancy of many areas for 365 days a year;
- f) need to differentiate between areas of occupancy during office hours and those of 24 h occupancy;
- g) the possibility of extensive distribution systems.

2.3.3.6 Laboratory accommodation. The type of heating to be used in a laboratory should be considered at the same time as the general layout of the laboratory. This is important so that the heating concept and layout suits that of the laboratory benches and the general distribution of piped services within the laboratory and adjacent corridors. Where bench layouts run around the outside walls or adjoin them at right angles, use of a heated ceiling may prove more suitable than wall-mounted heat emitters below window level. Consideration should be given to the heating implications of the replacement by fresh air of air exhausted from fume cupboards, noting that these may not operate continuously or all at once. Certain types of laboratory require general mechanical ventilation as well as that associated with fume cupboards, and this should be taken into account when determining the appropriate method of heating.

In any laboratory situation the specific requirements of the particular user need to be ascertained. Many such user bodies produce guidance information for those concerned with the design of their laboratories, such as the Department of Health and Social Services (pathology and related laboratories), the Department of Education and Science (educational laboratories) and the Home Office (forensic laboratories). The heating of radioactive laboratories is a specialized subject beyond the scope of this code.

2.3.3.7 Industrial and storage accommodation

2.3.3.7.1 General. Industrial and storage accommodation covers a wide range of accommodation requirements ranging from very small heating loads to the very large loads associated with major industrial complexes. Also, it is a field in which LTHW and a number of other heating media and systems all find application. This code only relates to that limited part of the industrial field of application for which LTHW systems are used, and is therefore not a comprehensive guide to industrial heating generally (see Section B.1 of the CIBSE Guide [1]).

In the larger industrial complexes, considerations of the economics of large-scale heat generation and of the distribution of LTHW over long distances tend to place an upper limit of feasibility on the use of LTHW as the sole heating medium in the context of a particular project. Where this arises, a higher temperature medium may be selected instead, or a composite system considered which uses a higher temperature primary fluid for the main distribution, with local heat exchange stations serving localized LTHW systems. Steam is often used in situations where the process specifically requires it. Another alternative is the distribution of the fuel itself to localized LTHW heating plants.

The thermal requirements of industrial and storage areas are determined by the comfort requirements of those working in such areas for a reasonable length of time, and may also be determined by process requirements or those of stored materials. In some instances the latter may conflict with comfort requirements or require closer control than is necessary for comfort purposes. Such process temperature requirements are often linked to other environmental requirements such as ventilation, humidity control, specific air movement patterns, etc. as in textile processes, paper manufacture and storage, lithographic printing, certain food processes, food storage and many others. These considerations are outside the scope of this code; general guidance on ventilation is given in BS 5720, the CIBSE Guide [1] and HSE Guidance Note EM22 [10]. The applications volume of the ASHRAE guide [11] gives information on the air conditioning aspects of a number of specific processes.

Some industrial processes emit substantial amounts of heat into the working area, particularly by radiation effect. In such cases the heating system may not be the major determinant of internal temperatures during the heating season; system performance requirements need to be clearly established in such cases, particularly if heating is required when the process is not operating. Natural ventilation is often used in this type of building and the effect of this on heating requirements needs to be considered; the same applies to air infiltration which can be particularly significant in buildings of light construction. For further guidance on natural ventilation see BS 5925.

This subclause is concerned with areas used for manufacturing, storage and activities which use similar types of accommodation. Other types of accommodation within industrial complexes such as offices, canteens and laboratories are covered in 2.3.2.2, 2.3.2.5 and 2.3.3.6.

2.3.3.7.2 Industrial applications. This subclause is concerned primarily with those heating situations where worker comfort is the main criterion for design. Statutory minimum temperatures are required by the Factories Act 1961. The CIBSE Guide [1] recognizes the importance of matching design temperature to the predominant type of activity applicable, and makes the general recommendations given in Table 4.

Table 4 — Recommended resultant temperatures for industrial work

Type of work	Resultant temperature
	°C
Sedentary	19
Light	16
Heavy	13

Where the ultimate user and the intended processes can be established at the design stage, the appropriate temperature should be discussed in the context of the specific application and existing practices in the industry. For further guidance see the CIBSE Guide [1] and Fanger “Thermal Comfort” [12].

A wide range of LTHW system options is available for this type of application, particularly in the context of emitters, including wall-mounted radiators and convectors for the smaller rooms, industrial type radiant panels and overhead continuous radiant strip, unit heaters (with or without the introduction of fresh air) and various types of ducted air system.

Under certain conditions (related to the degree of thermal insulation and rate of ventilation) the use of predominantly radiant heating can enable acceptable comfort conditions to be achieved at a lower level of air temperature than would be the case with a convective system. This in turn can result in lower operating costs; this topic is treated in more detail in Section B.1 of the CIBSE Guide [1]. When convective heating systems are used in areas of significant height, buoyance effects tend to cause a marked increase in temperature at higher levels, with consequent wastage of heat. This can be reduced by recirculation of air from the higher level back to the working level.

Other factors to be considered include:

- a) occupancy pattern and working hours;
- b) risk of condensation on susceptible equipment during periods of reduced temperature;
- c) policy for location and adjustment of thermostats;
- d) protection of emitters and other exposed system elements from accidental damage;

- e) relationship of the heating installation to factory layout, lighting layout, overhead cranes and conveyors, fire sprinklers, etc.;
- f) access for maintenance of overhead installations;
- g) heating implications of large doors, loading docks, etc.;
- h) heat recovery opportunities offered by process waste heat or ducted ventilation systems.

2.3.3.7.3 Storage applications. In the case of warehouses and storage areas the need for general heating of the whole area has to be established, and appropriate temperatures decided from consideration of the needs of stock, the work pattern and comfort requirements of operating staff and the user's preference. The CIBSE Guide [1] recommends the temperatures given in Table 5 as a general guide.

Table 5 — Recommended temperatures for storage spaces

Location	Resultant temperature
	°C
Working and packing spaces	16
Storage spaces	13

The proposed design temperatures should be clearly understood and agreed by all concerned. Where staff may be required to work in unheated or partially heated areas, the employer should take such steps as may be necessary, to ensure that the proposed conditions are acceptable, and that they are approved by the Inspector of Factories or other responsible authority.

Most of the considerations discussed in **2.3.3.7.1** and **2.3.3.7.2** are applicable to the heating of storage areas, but the following additional factors may also be important:

- a) constraints imposed by fixed racking layouts on system configuration and location of system elements, and their coordination with aisles, lights, fire sprinklers, etc.;
- b) the need for uniform clear headroom above the storage and mechanical handling areas;
- c) heating of loading and unloading dock areas and type of doors used;
- d) provision of localized heating for staff working in unheated storage areas;
- e) frost risks and the relationship between heating and fire sprinkler system types;
- f) risk of damage to stock from system leakage or other malfunctions;

- g) the risk to stored products of temperature and humidity.

2.4 Statutory, structural and safety factors

2.4.1 Statutory requirements

As well as the need for an LTHW heating system to comply with the requirements laid down in the current statutory legislation or any revisions currently in force, particular consideration should also be given to any relevant insurance company requirements. Formal approvals may be called for in respect of certain aspects of these requirements.

The following are the principal statutes concerned:

- The Building Regulations 1976
- The Building Standards (Scotland) Act 1970
- Clean Air Act 1968
- Control of Pollution Act 1974
- Energy Act 1976
- Energy Conservation Act 1981
- Factories Act 1961
- Fire Precautions Act 1971
- Gas Act 1972
- Gas Safety (Installation and Use) Regulations 1984
- Health and Safety at Work etc. Act 1974
- London Building Acts (Amendment) Act 1939
- London Gas Undertakings (Regulations) Act 1939
- Offices, Shops and Railway Premises Act 1963
- Water Act 1973
- The Electricity Acts

Whilst the relevance to this code of this legislation is mainly in the area of safety, other important matters are also covered, such as the following:

- a) energy conservation (see also **2.5**);
- b) environmental pollution;
- c) use of water.

It should be noted that these areas of legislation are particularly subject to continuing development.

Further guidance on fire safety in buildings is given in the Technical Memoranda of the CIBSE [13].

With regard to water installations reference should be made to relevant Water Bye-laws.

2.4.2 Structural factors

2.4.2.1 General principles. The installation of LTHW heating in a building requires structural provisions to accommodate the system and its equipment. Also, the physical and spatial requirements of certain elements of the installation may have a significant bearing on the structural concept, and need to be identified so that the structural and system designs may develop in a compatible manner. Attention is drawn to the structural requirements of the current Building Regulations, and to British Standards relevant to structural aspects of buildings and their servicing, in particular CP 3, CP 413 and BS 5588. (In respect of flues see **2.4.2.3**.) Early consultation is recommended with the public authorities concerned with fire prevention, life safety and fire suppression; also with relevant insurance interests.

Whilst the distribution element of an LTHW heating system is often a piped installation, it is acknowledged that air handling ductwork may be incorporated. Reference should be made to BS 5720 for a fuller treatment of the structural and safety aspects of air handling installations and equipment, particularly in respect of fire precautions and smoke control.

Certain aspects of an LTHW heating system may have an impact on building form, building layout, site planning and related aesthetic considerations. These matters may include the siting of fuel storage, location of heating plant, related accesses, routing of external pipework, noise and atmospheric pollution, location and height of flues and chimneys and location of any high level water tanks associated with the heating system. Early consultation between those concerned with such matters is recommended, with particular reference to the approximate sizes and elevations of relevant parts of the heating installation. Access to install the main items of equipment should also be considered at this stage.

2.4.2.2 Structural fire requirements. The installation of LTHW heating systems should have regard to the integrity of the building as a whole in respect of fire requirements. Certain aspects may have an important bearing on the structural concept for certain elements of the building, together with related considerations of compartmentation, type and thickness of construction, resulting structural loadings and fire brigade access.

Early consultation between those concerned with these aspects of design is recommended. These include the identification of fire compartments and associated walls and floors; the identification of principal ducts and shafts required to accommodate heating services; the siting and accommodation of all fuel storage, fuel handling and fuel utilization installations, associated flues and chimneys.

Where the LTHW heating system is being installed in an existing building, these considerations are particularly important since the possibilities of structural adaptation may be limited.

2.4.2.3 Provision for flues. Provision of flues is an important aspect of any fuel-fired heating installation, and appropriate structural provision for flues needs to be made so that they can function with safety, efficiency, and in compliance with atmospheric pollution requirements. In this context the flue is regarded as enclosing the full length of travel of products of combustion from where they leave the boiler or other fuel-fired equipment, up to where they are discharged to atmosphere, noting that elements of flue gas cleaning, heat recovery or fan dilution equipment may also be installed along this path. A flue as thus described will usually consist of near-horizontal sections leading to a final vertical section, and various configurations may be considered, such as independent flues, grouped independent flues and common flues. Other arrangements are possible, such as the vertical balanced flue. Flues may operate by natural or fan-assisted draught, or a combination of both.

The form of construction embraces many types of heat-resisting and structural materials, in configurations which can be summarized as:

- a) free standing chimneys;
- b) flues constructed as an integral part of the building structure;
- c) flues not integral with the building structure but supported by it.

Various important structural aspects should be considered at an early stage as relevant to the particular application including:

- 1) required dimensions of internal flue passage;
- 2) required height and elevation of point of discharge;
- 3) relative locations of the heating plant and the final flue stack or chimney, and allocation of a suitable flue route;
- 4) nature of the inner surface or lining and of the flue and its ability to resist heat, and to resist aggressive attack by products of combustion, particularly under minimum temperature conditions or where the condensing principle is applied (see **5.1.3.1** of BS 6880-2:1988);

- 5) provision for drainage of condensate;
- 6) method of support of all sections of the flue;
- 7) imposed dead loads, wind loads and general stability of flues and chimneys;
- 8) access for inspection, cleaning and maintenance, both internal and external as appropriate, noting that a tall chimney may carry a lightning conductor or aviation lights;
- 9) accommodation of thermal expansion and contraction of the flue;
- 10) effect on surrounding structures and equipment of heat and fume transferred from flues;
- 11) possibility and consequences of fire or explosion;
- 12) method of construction;
- 13) relationship between expected life of the flue and that of the building structure.

Attention is drawn to the particular requirements of the Building Regulations (Parts L and M) and corresponding sections of other bye-laws which may apply. Reference should also be made to BS 4076, BS 5410, BS 5440-1, BS 5854, British Gas Publication IM/11 [14] and the Clean Air Act "Memorandum on chimney heights".

2.4.2.4 Structural loadings

2.4.2.4.1 Major plant loads. Structural provision is required to support the major items of equipment and to carry the associated loads. These normally relate to such items as oil storage tanks, coal bunkers, hoppers, coal preparation equipment and conveyors, fuel oil pumping sets, boilers and other heat generation equipment, ash handling installations, chimneys, feed and expansion tanks and pressurization equipment, circulating pumps, calorifiers, platforms, electrical equipment, etc. Particular attention should be paid to items that may be located remote from the principal plant accommodation, such as feed and expansion tanks. Large pipes and headers may also impose significant structural loads.

It is important to consider the maximum operating weight of the installed equipment, having due regard to conditions which may be more severe than normal (e.g. tank overflow). Also, the extent to which the equipment is dependant on its foundation for structural rigidity should be understood.

2.4.2.4.2 Dynamic loads. Whilst dynamic loads are not usually significant in relation to the static loads associated with this type of equipment, particular items such as coal processing and handling equipment may require special consideration.

Items of rotating plant (or plant otherwise prone to vibration) should be carefully considered in relation to possible structure-borne vibration and means of isolation determined where appropriate.

2.4.2.4.3 Thermal forces. Whilst the degree of thermal expansion of LTHW pipework installations is less than that of systems operating at higher temperatures, it still has to be considered and may give rise to significant forces at designated anchors and guides. Thermal expansion of flues is also important (see 2.4.2.3). Thermal expansion should be considered when determining the foundation requirements of equipment such as boilers, calorifiers, etc. Certain types of fired equipment may need heat-resisting foundations.

2.4.2.4.4 Minor plant loads. Whilst smaller items of equipment and pipework may not usually present problems of structural loading, their means of support and vibration isolation need to be considered in principle at an early stage, particularly if consideration is being given to prefabricated building construction, or the use of lightweight construction for walls. Topics which may be relevant include fixing and support of such items as pipes, heated ceiling panels, in line mounted pumps, radiators, etc.

2.4.2.5 Building construction and finishes. Design of other elements of building construction should take account of the particular conditions of use to be expected in boiler rooms and similar accommodation. Finishes and drains are especially important and early consultation is recommended in respect of areas where special conditions may arise in use. Particular consideration should be given to providing for the supply of adequate volumes of combustion air to fired equipment at all times. For further information see BS 5410, BS 5440-2 and CIBSE Practice Note No. 2 [15] on this subject. Other matters to be considered include:

- a) provision of natural or other ventilation to limit ambient temperatures in boiler rooms and plant rooms;
- b) suitability for cleaning;
- c) exposure to fuel oil or containment of fuel oil;
- d) exposure to heat, aggressive chemicals, abrasive dusts, hot water, etc.

In respect of oil storage considerations see BS 5410.

2.4.2.6 Access to plant. Access to plant is referred to in principle in 2.4.2.1 as a major consideration to be taken into account during the initial planning of the building and the site. The types of plant to which this consideration relates are primarily those indicated in 2.4.2.4 in the context of structural loading, but it should not be over-looked that any item of plant may require access at some time.

In this context the access requirements which have to be considered in relation to both final building design and method and phasing of construction include:

- a) off-loading, lifting and moving into position;
- b) completion of related construction and installation work;
- c) major maintenance and repair or replacement operations and activities such as tube-cleaning which have particular space requirements;
- d) fuel delivery or ash removal;
- e) operation, where this itself requires structural provision in the form of platforms, etc.;
- f) firefighting.

2.4.2.7 Thermal expansion of fabric. In some parts of the building localized emission of heat may be sufficient to merit consideration of the effect of thermal expansion of the fabric. However, the incidence of such conditions should be minimized by the application of the energy conservation principles advocated in 2.5.

It should also be appreciated that during system commissioning, care may be needed to prevent excessive heating of parts of the building before the system is properly balanced and controls function correctly (see Section 3 of BS 6880-3:1988).

2.4.2.8 Embedded pipe systems. Very careful consideration should be given to all the factors relevant to the satisfactory installation and performance of embedded pipe systems in view of the extreme difficulty of making repairs or modifications after completion, and the potential which exists for damage to the system itself and to the associated elements.

Where such systems are to be built into floors, walls or ceilings, the selection of materials, detailed design and definition of installation and test procedures should follow the recommendations of such recognized codes of practice as may be available. Close collaboration between system designers, building element designers and system installers is recommended in relation to these matters and at all stages of the work, and with reference to the appropriate and proven experience of the relevant specialists. (See 3.7.2.5 of BS 6880-2:1988 and 2.6 of this Part of BS 6880).

In the context of the structural aspect of such systems, matters to be taken into account include:

- a) compatibility between the embedded pipe system and the associated building elements in all relevant respects, including physical and chemical compatibility and in terms of expected useful life;

- b) behaviour of the complete assembly of the main structural elements, insulating and other membranes, heating pipes, fixings, protective layers and finishes, under all expected conditions of operation;

- c) arrangement of circuits in relation to the structure so that necessary headers, regulators, valves, etc. can be accommodated and access afforded, both during commissioning and when in use;

- d) structural loading to be carried by the finished floor surface.

2.4.2.9 Protection of fabric. Whilst the primary function of LTHW heating systems in buildings is to heat the occupants and the contents of the building, heating of the building fabric itself is both a secondary function of the system and an inevitable effect of its operation.

Certain types of construction may have elements that need to be maintained above certain temperatures, or elements on which the formation of surface condensation or interstitial condensation is undesirable. Where these considerations apply, the designer of the building elements should seek experienced advice, in collaboration with the designer of the heating system. It should be appreciated that the trend towards higher standards of fabric insulation makes these considerations particularly important. For more detailed treatment of this subject see the CIBSE Guide [1].

2.4.3 Fire safety considerations

2.4.3.1 Fire and explosion risks. In the context of LTHW heating installations, fire risks can be divided into three major categories:

- a) fire and explosion risks inherent in the operation of the heating installation, which are mostly connected with the storage, handling and combustion of fuel;
- b) situations where the particular heating system may tend to reduce fire integrity of other elements of the building;
- c) fire and explosion risks associated with general housekeeping of boiler rooms and plant spaces.

This subclause is primarily concerned with category a) fire risks. Category b) largely relates to structural fire precautions (see 2.4.2.2) and the installation practice (see section 2 of BS 6880-3:1988), noting that where an LTHW heating system includes air handling ductwork, reference should be made to BS 5720 in respect of fire integrity of air handling systems, which is of particular importance. Category c) is not covered in detail, since it is a matter of general fire safety practice. However, its importance should not be overlooked, particularly at the commissioning stage of boilers and other fuel burning equipment.

In planning an LTHW heating system, the types of fire and explosion risk that may exist should be appreciated. Specialized guidance should be obtained where necessary and reference made to the appropriate regulations, codes, guidance notes, etc. so that the appropriate precautions can be incorporated in the design, and the necessary formal approvals obtained. Many British Standards relate to the fire safety aspects of LTHW heating installations, together with information published by other bodies such as the HSE, the Associated Offices Technical Committee (AOTC) and British Gas plc. It should also be noted that in addition to these recommendations, the Fire Authority having jurisdiction and also Fire Insurers may have specific requirements in respect of particular installations (henceforth referred to as insurer interest).

2.4.3.2 Fuel characteristics

2.4.3.2.1 Fuel specification. It is important to identify the precise fuel or fuels to be used in a given installation and to understand their characteristics. Commercial gaseous and liquid fuels are closely defined by widely accepted standards. The same applies in principle to the types of coal likely to be used in this context, although the classifications are of a broader nature. However, where consideration is given to the use of fuels such as waste or process gases, waste oils, woods or other fuels of a heterogeneous nature, then it is necessary to establish the relevant combustion parameters of a fuel and the extent of variability expected. Attention is also drawn to the influence of fuel specification on the sizing of chimneys in accordance with statutory requirements (see 3.3.5.3 and the Clean Air Act “Memorandum on chimney heights”).

2.4.3.2.2 Gaseous fuels. These are likely to be hydrocarbon gases, principally natural gas (mainly methane) or liquefied petroleum gases (LPG); coal gas may also be available in certain areas. Gaseous fuels present a degree of fire risk wherever there is a possibility of leakage. Explosions can readily occur wherever gas can accumulate in a confined space in the presence of air; incorrect combustion conditions can be an explosion risk within fired equipment, particularly lack of air supply and malfunctions when a burner is ignited. Certain hydrocarbon gases are heavier than air and can accumulate at low points, in trenches, etc. The possibility of gas leakage due to failure of shaft seals, diaphragms, etc. should be considered.

Where liquefied gases are used, the added hazards of site storage under pressure apply and very stringent safety measures are required. These relate to the siting, protection and general design of the installation, and arrangements for replenishment. Such installations should be in accordance with the recommendations of the Home Office Code of Practice for the Storage of LPG at Fixed Installations [16].

2.4.3.2.3 Liquid fuels. Fuel leakage and the possibility of its accumulation in low areas, trenches, etc. is a significant source of fire risk, also wherever fuel may drip on to hot surfaces. However, the degree of leakage and ignition risks is less as the grade of fuel becomes heavier and both viscosity and flash point increase (the latter is an index of its readiness to ignite under defined conditions). For the purposes of LTHW heating, class D (formerly gas oil) and heavier fuel oils complying with BS 2869 are most commonly used, but should a lighter grade fuel be considered, it should be clearly identified at an early stage so that due account may be taken by all concerned with fire safety and combustion matters. The heaviest grades of oil require heating in order to assist flow; the heating process introduces a further element of fire risk, particularly if electric. Explosions can occur within fired equipment for the same reasons as for gas fuels (see 2.4.3.2.2).

2.4.3.2.4 Solid fuels. The different nature of solid fuels introduces different fire risks. Any stockpile of such fuel is subject to the risk of spontaneous combustion, whereby combustion can take place without external ignition.

Whilst a solid fuel may consist of relatively large pieces, finer particles and dust are always present, and further degradation will arise whenever the material is handled. The presence of combustible dusts and air within an enclosed space constitutes a significant explosion risk, particularly if methane is present and sparks can be generated within the equipment. In some cases the solid fuel will be reduced to a fine form prior to combustion, thus greatly enhancing its combustibility and explosion potential.

2.4.3.3 Fuel storage and handling. Fuel storage and handling arrangements should be planned with specific regard to the particular fire risk characteristics of the fuel and of the surroundings of the installation. This applies at each stage between receipt of the fuel on site through to fuel combustion, particularly where the state of the delivered fuel is changed before combustion. Matters that require consideration from a fire safety aspect include the following.

- a) Safe unloading into storage of incoming fuel, minimizing spillage and with any necessary provision to avoid generation of sparks.
- b) Siting of the storage installation in relation to other buildings so as to avoid the probability of spread of fire, including burning fuel, from the storage installation to adjacent buildings or vice versa.
- c) Providing access and appropriate facilities for manual fire suppression (e.g. fire tender access, portable extinguishers, foam inlets, etc.) and consideration of automatic means of fire suppression where appropriate to the type of risk. It is particularly important that fire extinguishing media be those appropriate to the nature of the fuel and that clear instructions as to their mode of use are readily visible.
- d) Ensuring the fire extinguishing systems meet the requirements of the appropriate authorities.
- e) Making provision for automatic cut-off of the fuel supply in the event of fire in any related location which could be fuelled by a continuation of the fuel supply; this normally involves a proven method of fire detection.
- f) Safe siting and operation of any equipment concerned with handling or processing the fuel between storage and point of use, with particular attention to warning and shut-off in the event of undue temperature rise or drive overload.

g) Attention to minimizing the consequences of leakage and correct selection of electrical equipment and installations (this particularly applies to such items as gas boosters, fuel oil pumps, fuel oil heaters, solid fuel conveyors, mills, etc.).

h) Correct siting and operation of overfilling alarms and devices.

For further information see BS 799-5, BS 5410 and guidance information on coal and liquid fuel storage and handling published respectively by British Coal and various oil companies. In respect of gas installations, the Gas Safety (Installation and Use) Regulations 1984 apply in particular and are further explained in British Gas publication DM/4 [17]; for further information see CP 331, and also publications of British Gas in the IM series. The guidance of the Liquefied Petroleum Gas Industry Technical Association (LPGITA) should be sought in respect of liquefied petroleum gas storage and handling.

2.4.3.4 Combustion equipment

2.4.3.4.1 General. All combustion equipment should be compatible with the grades and types of fuel to be used. They should be correctly controlled and interlocked so that light-up, operation, modulation and shut-down can take place without risk of external fire, explosion or other adverse combustion conditions. Means of detecting outbreaks of fire external to the fired equipment should be installed so as to initiate action to shut off the fuel supply. It should be recognized that the ingress of significant amounts of foreign matter into burners can create dangerous combustion conditions; this can arise, for example, from surplus insulation material not cleared away before start up.

In addition to specific standards and codes referred to in this subclause in respect of particular fuel types, reference should be made to other appropriate standards and codes dealing with the safety of combustion installations in general; these include HSE Guidance Note PM5 [3] and the "Requirements for Automatically Controlled Steam and Hot Water Boilers" published by the Associated Offices' Technical Committee [18]. British Gas plc also publishes a list of tested and approved commercial gas appliances.

2.4.3.4.2 Gas burners. These burner installations should meet the requirements of the British Standards appropriate to the thermal rating. See BS 5885, BS 5978, BS 5986 and British Gas publication IM/18 [19]. It is important to ensure that gas supply pressure will normally be compatible with the requirements of the burner at all times.

2.4.3.4.3 Oil burners. Oil burner installations should meet the requirements of the British Standards appropriate to the thermal rating. See BS 799 and BS 5410. It is important to ensure that oil supply temperature will normally be compatible with the requirements of the burner at all times.

2.4.3.4.4 Solid fuel burners and stokers. Coal firing installations should meet the requirements of such British Standards as are applicable. See BS 749 and CP 3000. Further guidance is available in the British Coal publication "Technical data on solid fuel plant" [20].

In respect of other solid and waste fuels for which no appropriate standard exists, the same principles applicable to other types of burners and stokers should be followed where relevant, and account taken of any special fire risks inherent in the particular fuel.

2.4.3.4.5 Multiple fuel burners. These should meet the requirements applicable to comparable burners operating on the individual fuels. Particular attention should be paid to safe procedures for changeover from one fuel to another.

2.4.3.5 Flues. Flues should be designed, installed and maintained with due regard to potential fire and explosion risks such as:

- a) internal build-up of unburnt fuel or carbonaceous deposits;
- b) emission of particles likely to initiate combustion;
- c) transmission of undue heat to combustible materials;
- d) explosion, particularly where dampers are inserted between the fired equipment and the chimney.

Flues and chimneys should have suitable provision for regular internal inspection and cleaning. Where flue dampers are used these should be automatically interlocked with the combustion equipment by an approved system with the necessary fail-safe features.

2.4.3.6 Fire and smoke protection. A comprehensive review should be made of the complete fuel installation, from the primary storage through to the fired equipment and flues and appropriate means selected as necessary for:

- a) heat and smoke detection;
- b) initiation of fire alarms;
- c) manual and automatic fire suppression as necessary, using media appropriate to the types of fuel used;
- d) access for fire fighting and safe egress under fire conditions;

e) provision for evacuation of smoke from boiler rooms, tank chambers, etc., particularly where installed below ground level.

These measures should meet the prevailing statutory and local bye-law requirements and be acceptable to the Fire Authority having jurisdiction in respect of both fire prevention and fire suppression aspects, who should be consulted in accordance with the appropriate procedures. There may also be a fire insurer interest, whose requirements should be ascertained. For further guidance see BS 5306, BS 5588 and BS 5839, and guidance notes issued by Fire Authorities.

2.4.3.7 Insulating materials. These materials should be tested for surface spread of flame in accordance with BS 476-7 and should satisfy the relevant recommendations of CP 413 and the requirements of any relevant building regulations and standards. Attention should also be paid to fire-stopping and sleeve details used where pipes pass through fire compartment walls or floors.

2.4.4 General safety considerations

2.4.4.1 System temperatures. System temperatures associated with LTHW heating (see 1.2.1) are such that the maximum temperature of 105 °C recommended by BS 4086 for accidental contact with heated metal surfaces would not be reached. The same standard also recommends maximum temperatures for metal and plastic knobs. Particular classes of occupant require special consideration in this respect, such as nursery school children, the handicapped (see 2.3.2.3) and the elderly (see 2.3.2.6.3), which may influence emitter selection or call for the use of guards. However, the safety implications of exposed metal heat emitting surfaces should be considered wherever normal system temperatures exceeding 82 °C are proposed.

It should also be recognized that some system elements may present accessible surfaces at temperatures higher than LTHW temperatures (flues, etc.) and appropriate insulation or protection should be arranged.

2.4.4.2 System pressures. The LTHW system normal operating pressure should be within the limits recommended in HSE Guidance Note PM5 [3], noting that this is also related to system temperature.