BRITISH STANDARD

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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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Committees responsible for this British Standard

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

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Contents

Foreword

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

BS 6880 is published in three Parts which together form a full technical revision of CP 341.300-307:1956 which is withdrawn.

This Part gives recommendations on the 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.

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
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)

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:

a) the space being treated;

b) other rooms in the building;

c) 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 m^3/h of fresh air per occupant from a total ventilation requirement of 30 m^3/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 servery 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, routeing 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.

All equipment incorporated in the LTHW circuit should have pressure ratings compatible with the required system pressure (see also **3.4.7**). Where a system is to be pressurized by gravity from a header tank located at high level, for example in a roof space, consideration should be given to the static head which would result from the proposed tank location, since this may tend to be excessive in taller buildings. Pressure vessels should comply with BS 5500; and calorifiers and storage vessels should comply with BS 853 where they fall within its range of application. Storage vessels which are larger than those covered by BS 853 should comply with BS 5500.

2.4.4.3 *Pressurization equipment.* Where pressurization equipment powered by pumps, compressed gas, etc. is used, this should be rated to operate within a pressure range compatible with the normal and maximum operating pressures of the LTHW system. Such equipment should be constructed in accordance with the appropriate pressure vessel code or other appropriate pressure safety standard, and provided with the necessary devices to prevent the development of excess pressure detrimental to the LTHW system or the pressurization equipment. Such equipment should be tested and inspected in accordance with the requirements of the Health and Safety at Work, etc. Act 1974, noting that there may also be specific insurer interest in respect of such equipment. Diaphragm expansion vessels of certain sizes are covered by BS 4814 with which they should comply.

2.4.4.4 *Pressure and temperature responsive safety devices.* All equipment incorporated into the system where pressure energy may be generated, whether directly by pressure effects or indirectly by thermal effects, should be fitted with the appropriately rated pressure responsive safety devices, such that pressure in any part of the system cannot exceed the allowable margin above normal operating pressure (see BS 779 and BS 855). Such devices should be in accordance with BS 759, be regularly inspected and tested and be in accordance with any insurer interest. See also the HSE Guidance Note PM5 [3] for further information. Discharge pipes from such devices should vent to a safe location and their effect on the free capacity of the relief device should be taken into account. Particular care is required to prevent accidental obstruction of vent lines, due to trapped liquid or other causes.

Temperature responsive safety devices independent of the normal thermostatic controls should also be incorporated in connection with heat generating equipment so as to shut off the source of heat if an unsafe temperature is approached. Although this code is not concerned with secondary domestic hot water services, where consideration is being given to the use of an unvented domestic hot water supply (HWS) system in conjunction with an LTHW space heating system, particular consideration should be given to the possibility and consequences of an excessive energy input to the HWS system due to a malfunction in the LTHW system, and the mean of protecting against this eventuality.

2.4.4.5 *Refrigeration equipment.* Where heat pumps or other refrigeration equipment are used as part of an LTHW heating system, then reference should be made to BS 4434 in respect of safety considerations applicable to this type of equipment and associated pipework.

2.4.4.6 *Mechanical equipment.* All mechanical equipment associated with LTHW heating systems should be installed to comply with the standards required by HM Factories Inspectorate and relevant building regulations and British Standards. Fans and pumps should be installed such that they will operate in an entirely safe manner. Proper guards should be provided around belt drives; see BS 5304.

2.4.4.7 *Electrical equipment.* Any site-installed electrical work in connection with the installation of LTHW heating systems should comply with the current edition of "Regulations for the Electrical Equipment of Buildings", published by the Institution of Electrical Engineers (IEE) [21]. Consideration should be given to the need for equipotential bonding in accordance with the IEE regulations and experienced advice sought. Means of isolation should be provided adjacent to all remotely controlled electrical apparatus especially when motors are involved.

All electrical equipment associated with LTHW heating systems should be installed to comply with the standards required by HM Factories Inspectorate, relevant building regulations and British Standards, and with the electricity supply regulations.

It should be recognized that certain types of LTHW heating system use electrically powered or electrically controlled equipment within occupied accommodation, as well as in plant spaces.

In situations where a fire or explosion hazard might arise due to interaction between gaseous or other fuels and electrical equipment and installation, careful consideration should be given to the prevention of such hazard by physical segregation or other such means. Where this is not practicable, experienced advice should be obtained to ensure that the electrical installation is in accordance with the recommendations for the appropriate class of hazard (see BS 5345). The electrical aspects of gas-fired equipment should also comply with BS 5986 and those of oil-fired equipment be in accordance with BS 5410. Further guidance is also given in British Gas publications (IM series).

2.4.4.8 *Water and flooding.* Care should be taken to ensure that hazards are not likely to arise from flooding, due to escape of water or fuel from the system. Provision should be made so that draining down can be carried out safely. All aspects of LTHW heating installations should comply with the requirements for the safe and effective use of water, as laid down in the appropriate water bye-laws and as recommended in BS 6700. Particular attention should be paid to the avoidance of contamination of any water supply, both during normal and reasonably foreseeable abnormal circumstances. It should also be pointed out that particularly hazardous conditions can arise if pipe-freezing techniques are employed in confined spaces such as service tunnels, where the gas used can cause suffocation.

2.4.4.9 *Protective heating.* Attention is drawn to the protective functions which sometimes apply to LTHW heating systems, in respect of the building fabric, the frost protection of other mechanical services and of the LTHW system itself, particularly heater batteries on air heating equipment (see BS 6700).

2.5 Energy conservation and energy management

2.5.1 General

In the context of this code, energy conservation signifies the optimum use of energy to operate the heating system of a building, but this does not always mean the minimum use of energy. It should be appreciated that the space heating system in a building is not the only system that determines environmental conditions. Hence the effect of other factors on its operation should be taken into account in the context of energy conservation, particularly the effects of natural and mechanical ventilation (see also BS 5720).

It is axiomatic that general standards of comfort or particular environmental requirements within the building should not be sacrificed in an endeavour to achieve a low consumption of energy or that short-term economic and commercial considerations should unduly prejudice long-term considerations of primary energy conservation. Similarly nothing in this code overrides regulations related to health and safety.

For more detailed treatment of the determination of energy consumption and the design and control requirements for general comfort applications in new buildings, reference should be made to the CIBSE Building Energy Code [2]. Whilst the building energy code is concerned with various types of building services systems, in the context of this code attention is particularly drawn to Part 2 a) in that it specifically relates to buildings which are heated and naturally ventilated.

The extensive technical literature available on the subject of energy use in buildings includes Building Research Establishment Digest No. 191 [22], HMSO Building Bulletin No. 55 (Educational Buildings) [23] and publications by British Gas plc in the series “Studies in Energy Efficiency in Buildings” [24].

2.5.2 Energy targets

For the purpose of assessing the energy conservation efficiency of one system design against another, or in an existing building comparing one period of energy use against another, target consumptions may be established as follows.

a) *Demand targets.* Energy demand is mainly determined by location of the building, its structure and the equipment installed within it. Demand targets are readily applied to designs for new buildings and their services and are quoted as an average rate of primary energy use (in W/m^2).

b) *Consumption targets.* The energy actually consumed in a building is, in addition, determined by the manner in which the building and its services are used and is measured in units of energy (J/m^2).

Targets may be established according to varying climatic conditions and varying patterns of building use.

2.5.3 System design and operation

2.5.3.1 ***Systems***

2.5.3.1.1 The design of the system and its associated controls should take into account the following:

a) the nature of the application;

b) the type of construction of the building;

c) heating load patterns;

d) the desired space temperatures;

e) hot water supply (HWS) requirements;

f) permissible control limits;

g) minimizing the use of primary energy;

h) opportunities for heat recovery;

i) economic factors (including probable future cost and availability of fuel).

2.5.3.1.2 The operation of the system in the following circumstances should be considered when assessing the complete design:

a) in winter;

b) in summer (if applicable);

c) in intermediate seasons;

d) at night;

e) at weekends;

f) under frost conditions;

g) if electricity supply failure occurs and when the supply is restored.

2.5.3.1.3 It should be appreciated that the thermal properties of the building fabric in respect of its form, transmittance, admittance and other thermal characteristics have a major influence on its energy demand and consumption for heating. Similarly that fabric design to conserve heating energy in winter can lead in certain circumstances to the creation of cooling energy demands at other times of year.

2.5.3.1.4 Consideration should be given to changes in building load, and the system designed so that maximum operational efficiency is maintained under part load conditions. This is particularly important if use of heat generation equipment is being considered in summer, e.g. for HWS purposes. Similarly, consideration should be given to subdividing the system so that zones or applications with significantly differing characteristics (e.g. exposure, aspect, type of emitters used, occupancy pattern) can each operate in the most effective manner.

2.5.3.1.5 The temperature of the heating medium circulated within the system should be maintained at the level necessary to achieve the required output to match the prevailing load conditions with the minimum expenditure of energy.

Before selecting the nominal flow and return temperatures for the LTHW system, consideration should be given to the possibility of future changes of energy source in the interests of primary energy conservation. This may include foreseeable future developments which may tend to require significantly lower system operating temperatures, such as the use of recovered heat, source to water heat pumps and district heating which is linked to power generation.

2.5.3.1.6 The energy used for the transport of water within the system should be assessed and the transport factor should be not less than that quoted in the CIBSE Building Energy Code [2]. In some cases the air transport factors quoted in the same code may also be relevant.

2.5.3.1.7 Consideration should be given to the use of recovered energy wherever practicable and its use considered in the context of reduction of primary energy use. (See also **2.5.3.1.5**.)

2.5.3.1.8 Operation and maintenance procedures should be properly planned, in the interest of achieving and maintaining appropriate standards of energy efficient operation. (See also **2.6**.)

2.5.4 Equipment and installations

2.5.4.1 Attention is drawn to the need for all systems and their elements to comply with the relevant statutory requirements, including those of the Building Regulations, the Energy Act 1976 and the Energy Conservation Act 1981.

All equipment and components should be tested in accordance with the relevant British Standards where applicable.

2.5.4.2 To the extent that agreed test procedures exist, equipment suppliers should furnish upon request the energy input and output of the equipment, which should cover full and partial loads and standby conditions as required, in order that the energy consumption can be assessed over the whole range of operating conditions.

2.5.4.3 Where components from more than one supplier are used, or where the components of a single supplier are used in a combination for which published performance data does not exist, then the system designer should take the responsibility for ensuring that their function leads to optimum energy use.

2.5.4.4 Coefficients of performance ascribed to various items of equipment should not be less than those quoted in the CIBSE Building Energy Code [2].

2.5.4.5 The fuel(s) on which the system is intended to operate should be clearly specified, wherever possible by reference to a British Standard, and such fuels used for the operation of the system. Where it becomes necessary to consider use of a fuel of different characteristics from that originally intended, care is required in assessing its effect on the system and its performance and in the execution of any necessary modifications, having regard to both primary energy conservation and safety. Energy conservation equipment should be furnished with the information necessary for correct and efficient operation using the specified fuel(s).

2.5.5 Control system

Appropriate controls can make a significant contribution to energy conservation (see **3.8**). It is important to define clearly the parameters to which the controls are required to respond in order to satisfy the needs of the application and the appropriate level of accuracy. It is uneconomic to provide controls with a degree of accuracy greater than the application requires.

The integration of individual controls into an overall energy management system may contribute to energy-efficient operation and provide useful information on the behaviour of the complete system.

2.5.6 Commissioning

Proper commissioning of heat generation equipment and the complete heating system is essential to system performance as a whole, and to energy efficient operation in particular. At the commissioning stage many system parameters important to energy conservation should be checked and set up so that the intended mode of operation can be achieved, including:

a) efficient fuel conversion;

b) achieving required system capacity and correct distribution of flows;

c) mechanically efficient operation of equipment;

d) correct temperature settings and appropriate schedules;

e) correct functioning of all controls as a complete system, in the required modes.

(See also section 3 of BS 6880-3:1988.)

2.6 Quality and reliability

2.6.1 General

This clause sets out general principles. It does not list specific features or attributes relevant to system quality.

In the context of LTHW heating systems, quality is taken to mean the totality of characteristics or attributes of a complete, functioning system which bear on its ability to satisfy the requirements of the application including the expected life cycle of the installation. The term application encompasses a number of factors, including the nature of the particular building and the type of occupancy which the system is intended to serve. The term quality does not itself imply any particular standard of excellence.

Equipment and materials incorporated in the system should comply with the appropriate British Standards, unless in a particular case the use of items complying with another recognized standard is specifically agreed.

Reliability is a particularly important attribute of any heating system, which relates to the ability of a correctly operated and adequately maintained system to satisfy the requirements of the application in a consistent manner and without unforeseen interruptions to service, throughout the expected life of the system. This presupposes that the system continues to be used for purposes comparable to those for which it was originally intended.

2.6.2 Level of quality

2.6.2.1 *Subjective factors.* There are aspects of system quality that are difficult to define in strictly numerical terms, particularly since LTHW heating systems primarily serve the occupied spaces of buildings where people live or work. Two particular aspects should be noted in this context:

a) differences in comfort preferences and perception between different individuals;

b) aesthetic considerations.

Although these are aspects of subjective judgement, attention is drawn to extensive work by various researchers to quantify a), including the use of statistical techniques (see Fanger "Thermal Comfort") [12].

2.6.2.2 *Special considerations.* Although this code makes recommendations which relate to a general concept of desirable quality level, it is recognized that special considerations may apply to a particular project such that it is reasonable to propose specific departures from the certain recommendations of this code, such for example as might arise in the case of a temporary installation. It is recommended that any such proposals should:

a) be clearly defined at a stage sufficiently early that their overall effect can be properly considered and alternatives evaluated before a final choice is made;

b) be the result of consideration by an experienced designer;

c) take account of all statutory requirements;

d) be compatible with accepted good practice in the work of related professions and trades;

e) take due account of the requirements of the whole project and beyond the confines of immediate contractual relationships, having regard to likely effects on present and future owners and occupiers of the building, as well as on the public at large.

2.6.3 Quality assurance

2.6.3.1 *Overall approach.* Attention should be paid to defining quality requirements and monitoring and controlling their achievement throughout the processes by which the heating system and other related works proceed from initial concept through to completion. The same also applies to the quality of operation and maintenance throughout the life of the system. It is particularly important that quality standards be defined sufficiently early so that they can be fully effective, since failure to establish or to achieve the required quality at one stage of the process may inhibit its achievement in subsequent stages.

2.6.3.2 ***Individual stages***

2.6.3.2.1 *General.* The details of quality assurance procedures that may be appropriate to the multiplicity of operations relevant to LTHW heating systems are outside the scope of this code though some important aspects of the individual stages are highlighted in **2.6.3.2.2** to **2.6.3.2.6**. Quality systems and related procedures should comply with BS 5750.

2.6.3.2.2 *Initiation and briefing.* Important quality-related decisions arise at this early stage when the fundamental requirements of the system are established and initial concepts formulated. The quality of the documentation which records and interprets these early decisions such that they can be clearly understood is particularly important, which should also cover any of the matters referred to in **2.6.2.2**.

2.6.3.2.3 *System design and equipment selection.* This stage is of particular importance in respect of total and long-term system quality because activities at this stage include establishing overall quality requirements for subsequent work. Decisions made or neglected at this stage can impose serious constraints on the achievement of required quality in later stages. In particular this stage should be concerned with establishing:

a) the quality of the overall system design as defined in **2.6.1**;

b) quality requirements for equipment incorporated into the system and for related manufacturing operations, including the compatibility of all system elements with each other;

c) quality requirements for on-site construction and installation operations, and for testing;

d) procedures for commissioning; required accuracy for balancing, regulation and control; provision of design information for these purposes.

It is particularly important that provision should be made for physical access and other requirements necessary for carrying out commissioning, operation and maintenance.

Consideration should also be given to the long-term operation and maintenance arrangements for the system such that throughout all contract stages (and after their completion), provision is made for the necessary care, operation and maintenance, taking account of any phasing of the works.

2.6.3.2.4 *Installation, inspection and testing.* Quality assurance at this stage particularly relates to the following.

a) The activities of a large number of individual suppliers, contractors and specialists. These should be carried out in accordance with such quality assurance procedures as may be appropriate to each type of activity, having regard to the relevant British Standards and codes of practice, and within the overall quality requirements of the project.

b) The standard of test documentation and the related requirements of insurers, statutory bodies and other interests, including procedures related to establishing that the system and its elements are ready and safe to operate for commissioning purposes.

c) Ensuring that work at this stage is executed with due regard for the physical and other requirements of testing, commissioning, operation and maintenance.

d) Provision of comprehensive organized documentation relating to operation and maintenance of the system.

2.6.3.2.5 *Commissioning.* At this stage adherence to defined commissioning procedures and availability of design information are important considerations. The interface with the previous stage in respect of readiness to operate is particularly important. It should also be recognized that some aspects of this work may influence subsequent operation and maintenance, particularly in connection with energy consumption.

2.6.3.2.6 *Operation and maintenance.* During the remainder of the life of the system, operation and regular maintenance in accordance with defined procedures is necessary to achieve the objective stated in **2.6.1** "to satisfy the requirements of the application in a consistent manner and without unforeseen interruptions to service". In this regard, the application of planned inspection and maintenance checks and energy consumption audits is recommended.

Section 3. Design considerations

3.1 Types of systems

3.1.1 General

LTHW heating systems can be considered as four related subsystems:

a) *Utilization subsystem.* This produces the heating effect in the heated spaces and is the subsystem of which the occupant is usually most conscious.

b) *Distribution subsystem.* This transports the heating medium between the energy conversion subsystem and the utilization subsystem. It usually consists of an LTHW pipe circuit, but in some cases may include ductwork for transporting air which has been warmed by LTHW.

c) *Energy conversion subsystem.* This provides heat energy in the form of LTHW by conversion from fuel or by heat exchange from some other heat source.

d) *Control subsystem.* This subsystem controls the other subsystems so that the system as a whole operates in the intended manner.

There are several different types of subsystem within each of the groups a) to d) and various combinations are possible. Often more than one type are used together, where the nature of the application requires the main system to serve different purposes.

Some LTHW heating systems supply heat to air which is ducted to the heated space at a temperature sufficient to provide a heating effect. This distinguishes them from other mechanical ventilation systems where the air is only heated sufficiently to bring it close to the required room temperature, without additional heating effect. However, the characteristics of such systems are in other respects similar to mechanical ventilation systems, which are covered by BS 5720.

3.1.2 Utilization subsystems

These are most conveniently classified in terms of the type of heat emitter used, but it should be recognized that a system may need to use more than one emitter type, particularly where the system serves different types of accommodation (see **2.3**).

Principal types are as follows (see Section 3 of BS 6880-2:1988 for further information):

a) natural convectors (including radiators);

b) forced convectors;

c) heated ceilings and walls;

d) floor heating systems.

3.1.3 Distribution subsystem

The distribution subsystem comprises some form of LTHW piped circuit; in certain cases it may also include a ductwork subsystem for the transport of heated air (see **3.1.1**). Characteristic features which distinguish system types include:

a) method of circulation (gravity or pumped);

b) system temperatures;

c) pressurization (open or pressurized);

d) subdivision of system (circuits and zones);

e) piping configuration (one-pipe, two-pipe, etc.).

These aspects are further considered in **3.4**

3.1.4 Energy conversion subsystem

The energy conversion subsystem can take many forms, but is primarily identified in relation to the type of heat generation equipment and the source of energy used as indicated in a) and b).

a) *Fired heaters (or boilers):* heaters fired by commercial fuels (gas, oils, coal etc.) or by-product fuels arising from other processes.

b) *Unfired heaters:* systems which operate mainly by heat exchange from some heated medium to LTHW, with few exceptions (e.g. electrode boilers). They include calorifiers, heat pumps and indirect methods of electric water heating. They may also incorporate thermal storage and they may operate in conjunction with fired heaters (sometimes referred to as bivalent systems).

For further information see **3.3.6**, and Section 5 of BS 6880-2:1988.

3.1.5 Control subsystem

The control subsystem is not a physically identifiable section of the heating installation, but it encompasses all those functions whereby the total system and its component subsystems are controlled to operate in a predetermined manner. The controls relate to output, energy-efficient operation and the performance of safety and other protective functions.

The nature and complexity of the individual control elements and the extent to which they are linked together as a total control system tends to differ according to the needs of the particular application (see **3.8**).

3.2 Basis of design

NOTE When designing LTHW systems it is important that the factors covered in this clause, which form the basis of design, are established at the outset.

3.2.1 System capability

3.2.1.1 *External load variations.* During the heating season the system should be able to accommodate the effects of variations in outdoor temperature, wind and to some extent solar radiation.

3.2.1.2 *Internal load variations.* Where their contribution to the internal gains are significant the system should be able to compensate for variations due to the movement of people and the operation of lights, machines and equipment.

3.2.1.3 *Operating modes.* The system should be able to:

a) satisfy the maximum heating loads and operate as required under partial load conditions including at night and over weekends, and to provide frost protection where appropriate;

b) provide comfortable conditions within the limitations of a heating system without causing draughts or stuffiness, and with noise and vibration below the established criteria.

3.2.1.4 *Future expansion of use.* Where it is expected that there could be future expansion of the system, change in use of the building or the future provision of air conditioning, consideration should be given at the initial design stage to the degree of provision for future requirements that would be appropriate, noting that this might affect the choice of system.

3.2.2 External environment

3.2.2.1 *External design temperature.* The external temperature to be used in establishing the heating load should be selected with regard to the local weather conditions, economic considerations, the probable effects of any departure from inside design conditions caused by unusually extreme weather conditions, the thermal properties of the building and the proposed overload capacity of the system (see **3.2.5**).

3.2.2.2 *Frost protection.* In general, when considering frost protection of the building as a whole no other external design temperature need be considered. A heating system with sufficient capacity to maintain comfort conditions at normal UK external design temperatures should be fully capable of maintaining an inside temperature adequate for frost protection purposes with the lowest outside temperatures normally experienced in the UK.

Where a heating system serves heater batteries which are required to handle high proportions of fresh air, where areas such as boiler and plant rooms have substantial natural ventilation or where significant parts of the system are otherwise exposed to outside conditions, then consideration should be given to establishing an external design temperature for frost protection purposes which is at or close to the lowest temperatures normally experienced in the locality. For general guidance on the frost protection of water services see BS 6700.

3.2.2.3 *Exposure, wind and infiltration.* Infiltration heat loads caused by leakage of unheated air into the building may have a significant effect on the heating load and should be estimated with reference to records of wind velocity and direction for the location and consideration of building orientation, arrangement and construction, and the effect of major adjacent structures. For further information see Section A.4 of the CIBSE Guide [1].

3.2.2.4 *Pollution and noise.* In situations where the external environment is subject to significant atmospheric pollution, external traffic noise or aircraft noise, consideration will need to be given to the method of ventilation of the building which, in turn, may affect the heating system proposed and the need for mechanical ventilation. Local and national legislation lay down criteria for the design of chimneys to control atmospheric pollution arising from the combustion of fuels (see **2.4**). In respect of noise arising from the heating system see **2.2.7** and **3.10**.

3.2.2.5 *Solar and night time radiation effects.* The amount of solar radiation falling on the building depends on its geographical location, altitude and orientation and varies through the day and year. Whilst solar radiation should be taken into account when considering the thermal behaviour of the different aspects of the building, it should not normally be assumed to contribute to the heating of the building when calculating the maximum heating loads.

A proportion of the heat loss from a building is due to thermal radiation, and the surface resistances normally used in establishing the thermal transmittances of walls and roof include an allowance for radiant heat loss. In the case of roofs and other upward facing surfaces, under clear skies the section of sky towards which such surfaces radiate is at a much lower temperature than the surrounding air temperature; this results in much lower surface temperatures. In general this effect is offset by the thermal mass of the structure, but in some cases such (as within cavity roofs) very low surface temperatures can cause condensation problems. Such problems can generally be overcome by providing adequate ventilation of the roof cavity. Where a building is of lightweight construction together with poor roof insulation and extensive roof glazing the effects of radiation to the clear sky will be marked, particularly if the building is occupied at night. In these circumstances a lower outside design temperature and other means of offsetting this effect should be considered, noting that this situation would not normally arise in new construction in the UK, for which much higher standards of insulation now apply.

3.2.3 Internal environment

3.2.3.1 *Statutory requirements.* National or local statutory requirements relating to such matters as energy conservation, public safety and hygiene may have a bearing on the basis of design (see **2.4.1**).

3.2.3.2 *Internal air temperature.* As described in **2.2.2** the internal design temperature recommended as a criterion for comfort heating is resultant temperature (t_c) although legal requirements and special processes may require air temperature to be considered as well. The specific requirements of the application should also be considered (see **2.3**). Resultant temperature and air temperature are not used directly in the calculation of heat requirements.

The CIBSE Guide [1] recommends the use of environmental temperature (t_{ei}) for calculation of the fabric heat losses and air temperature (t_{ai}) to determine the ventilation heat requirements. These temperatures make allowance for the different types of heat transfer, principally convective and radiant, that occur within the heated space. Environmental temperature is defined in Section A.5 of the CIBSE Guide [1] and is a combination of air temperature and surface temperature since it recognizes that heat exchange between the fabric and the space is both convective and radiant. Air temperature is used only for determining the heat required to raise the temperature of infiltration air from the outside air temperature. These temperatures can be related to resultant temperature by means of factors given in Section A.9 of the CIBSE Guide [1] according to the type of heating system used. It is recommended that design air temperature should also be quoted, since it is used in legislation and also because controllers and thermometers respond predominantly to air temperature.

3.2.3.3 *Acceptable temperature range.* The optimum temperature for a particular application is that at which the majority of people will feel comfortable, the further the temperature varies from this point the greater the number of people who will feel uncomfortable. Section A.1 of the CIBSE Guide [1] includes data on the likely effects of such temperature variations. It should be accepted that offset in the controlled temperature will be inevitable, with rapidly changing loads, and will depend on the response time of the controls, the heating system type and the nature of the building fabric.

In heat loss calculations a uniform temperature throughout the height of the heated space is assumed. Certain types of heating cause vertical temperature gradients which lead to higher heat loss particularly through the roof. Additions to the calculated heat loss to allow for this are proposed in Section A.9 of the CIBSE Guide [1]. In certain applications the use of forced downwards circulation of air to counteract this effect may be beneficial.

3.2.3.4 *Air movement and draughts.* The effect of air movement caused directly or indirectly by the heating system, and the ability of the system to offset uncomfortable draughts caused by the building design are considered in **2.2.3**. Location of radiators and natural convectors beneath windows is a method of offsetting cold down-draughts. In order to reduce heat losses from the back of such emitters consideration should be given to the use of reflective films or additional insulation. Forced convection units such as fan convectors or unit heaters should be selected with sufficiently high air discharge temperature to avoid cold draughts (35 °C is usually appropriate), but at temperatures in excess of about 50 °C stratification effects (where a layer of warm air is formed at high level) may become marked and should be avoided. Forced convection units should be applied and located such that they do not create excessive air movement or unacceptable noise levels.

Unit heaters should be located so that they discharge towards areas of maximum heat loss.

3.2.3.5 *Relationship to ventilation systems.* In certain applications mechanical ventilation may be appropriate (see **2.3**). In such cases the ventilation system may be designed to provide all of the heating requirements or merely to supply air at the design room air temperature with a separate heating system to offset the building heat losses (see **2.3.1.7**). The provision of a separate heating system has the advantage that emitters can be located to offset the effects of areas of high heat loss. In order to achieve the required comfort temperature within the space an all air system will usually call for a higher air temperature which may lead to complaints of stuffiness, increased risk of stratification and energy wastage. A combined system using partially radiative emitters should enable a lower air temperature to be used to achieve the design temperature.

3.2.3.6 *Temperature gradient.* Because warm air will rise towards the ceiling, in a room designed to maintain a comfortable temperature up to about 2 m above the floor, higher temperature near to the ceiling will cause greater heat losses. This effect will vary with the type of heating system and will be greatest with a convective system. Rooms heated mainly by radiation will have a more even vertical temperature gradient and floor heating systems can virtually eliminate temperature gradient. Careful positioning of heat emitters can contribute to the reduction of temperature gradient. The CIBSE Guide [1] gives factors which allow for room height in calculating heat losses.

3.2.3.7 *Internal heat gains and losses.* When calculating the heat output required from a heating system, heat gains within the space should normally be ignored. Where there is continuous 24 h heating and there are permanent heat sources such as lighting, a fixed minimum occupancy, or constant process heat sources, then some reduction in the heat requirement may be considered.

The heat loss calculations assume that the heat emitter is free standing within the space and that all of its output enters the space. Where the emitter is embedded or mounted on the surface surrounding the heated space, a correction should be made for the additional heat loss that will occur because that part of the surface is exposed to the temperature of the emitter rather than of the room. This is referred to as back loss and its calculation is covered in Section A.9 of the CIBSE Guide [1]. Where the space under consideration is located adjacent to an unheated area or an area heated to a lower standard, heat will be lost to that area and allowance should be made in the heat loss calculations.

If there is any appreciable quantity of cold material entering the heated space, the estimated heat that will be absorbed by this should be added to the other heat losses.

3.2.3.8 *Calculation of heat losses.* The heat output from the heating system should be determined from the calculated heat losses. Methods of calculating the heat losses are set out in Section A.9 of the CIBSE Guide [1].

There are two methods given, the first based on supplying heat at a constant rate to maintain a specified temperature difference between the inside and the outside of the building. The second method should be used where it is intended that the building can be intermittently heated, (see **3.2.5**). Particular care is required when considering existing buildings which may be of heavy construction, where insulation may be well below current standards and where it may be difficult to determine accurately the thermal properties of the fabric.

3.2.3.9 *Noise.* Noise may be generated by the heating system within the occupied space or transmitted to it from system elements not in the occupied space (see **2.2.7.2**). The system should meet the noise rating criteria applicable to the occupancy and particular attention should be paid to the acoustic performance of forced convection and other air handling installations associated with the heating system (see BS 5720 and Section A.1 of the CIBSE Guide [1]).

3.2.4 Building fabric thermal properties

3.2.4.1 *Thermal transmittance and thermal inertia.* Aspects of building construction relevant to heating system design are outlined in **2.3.1.5**. In connection with the need for the thermal properties of the fabric to comply with statutory requirements it should be noted that the Building Regulations (1976) and related amendments lay down maximum transmittance values ("U" values) for various elements of the building envelope. It should be noted that energy conservation criteria can also be based on maximum allowable energy inputs for defined conditions, thus taking account of other sources of heat loss in addition to fabric transmittance.

Regulatory requirements tend to envisage heat loss only under steady conditions and do not take account of variations in external temperature or building occupancy. Consideration of this dynamic behaviour of the fabric is an important aspect of the design process. A building of massive construction, e.g. with masonry walls and concrete floors, is said to have a high thermal inertia and will react more slowly to changes in the external or internal environment than a building of light construction and correspondingly low thermal inertia. However, it should be noted that where heating is intermittent, the use of external insulation may lead to greater overall energy use than with comparable internal insulation. The thermal inertia can be further affected by the location of insulation; insulation applied near the outside of a massive building further increases heat storage capacity, and slows down its response to changes in the outside environment. Where a building has a relatively high thermal inertia, a higher external design temperature may be appropriate in cases where the stored heat capacity is sufficient to shield the inside from the relatively short periods of minimum temperatures. Section A.2.5 of the CIBSE Guide [1] gives external design temperatures for various locations in the UK appropriate to buildings of high and low thermal inertia.

3.2.4.2 *Intermittent operation.* If intermittent operation of the heating system is intended some additional capacity will be required, both in central plant and individual emitters, to bring the building up to the desired temperature after a period of overnight or weekend cooling. This additional capacity is defined in the CIBSE Guide [1] as overload capacity and will again depend upon the thermal inertia of the structure. The CIBSE Guide [1] makes recommendations for overload capacities in relation to the thermal inertia of the building and the heat emitter type (see Section A.9 of the CIBSE Guide) [1].

3.2.4.3 *Condensation.* Under both continuous and intermittent heating, there is a possibility of formation of condensation on inside surfaces or within the fabric (interstitial condensation). Should the temperature of any part of the fabric fall below the dew point condensation will form and may cause discomfort to the occupants and damage to fabric and finishes. Under steady state conditions the possibility of condensation forming on the inside surface can be overcome only by ensuring that the fabric is sufficiently well insulated to keep the inside surface temperature above the dew point by appropriately located insulation. This is particularly relevant when existing properties are upgraded, where the positioning of insulation on the inside surface of the building will raise the inside surface temperature, reducing both surface condensation and cold radiation effects. However, the possible advantages of thermal insulation applied towards the outside of the construction should be noted (see **3.2.4.1**).

Section A.9 of the CIBSE Guide [1] indicates a procedure for predicting this effect. Its importance to detailing of the fabric should be recognized, in addition to the thermal transmittance effect. It may call for use of an appropriate vapour barrier.

Due to the slow response of the building fabric to rises in air temperature, condensation may occur at occupation time if significant quantities of moisture are being produced. This problem can be overcome by preheating the building before it is occupied; the thermal inertia of the fabric has a significant influence on this effect. In some cases it may be necessary to provide a low level of background heating during unoccupied periods, both to protect the building from the effects of low temperature, and to avoid the formation of condensation.

3.2.5 Matching system output to load profile

The heating system should be sized and controlled so that its output follows the expected daily and seasonal variations in heating load (load profile, see Figure 1) as efficiently as possible (see also **3.8** and **3.3.6**).

Appropriate sizing of boilers (or other heat generators) is essential to achieve optimum thermal efficiency over the plant operating season to match accurately the heat demand. An anticipated annual load profile should be assessed, bearing in mind diversity factors applied to non-simultaneous loads, and low summer load conditions.

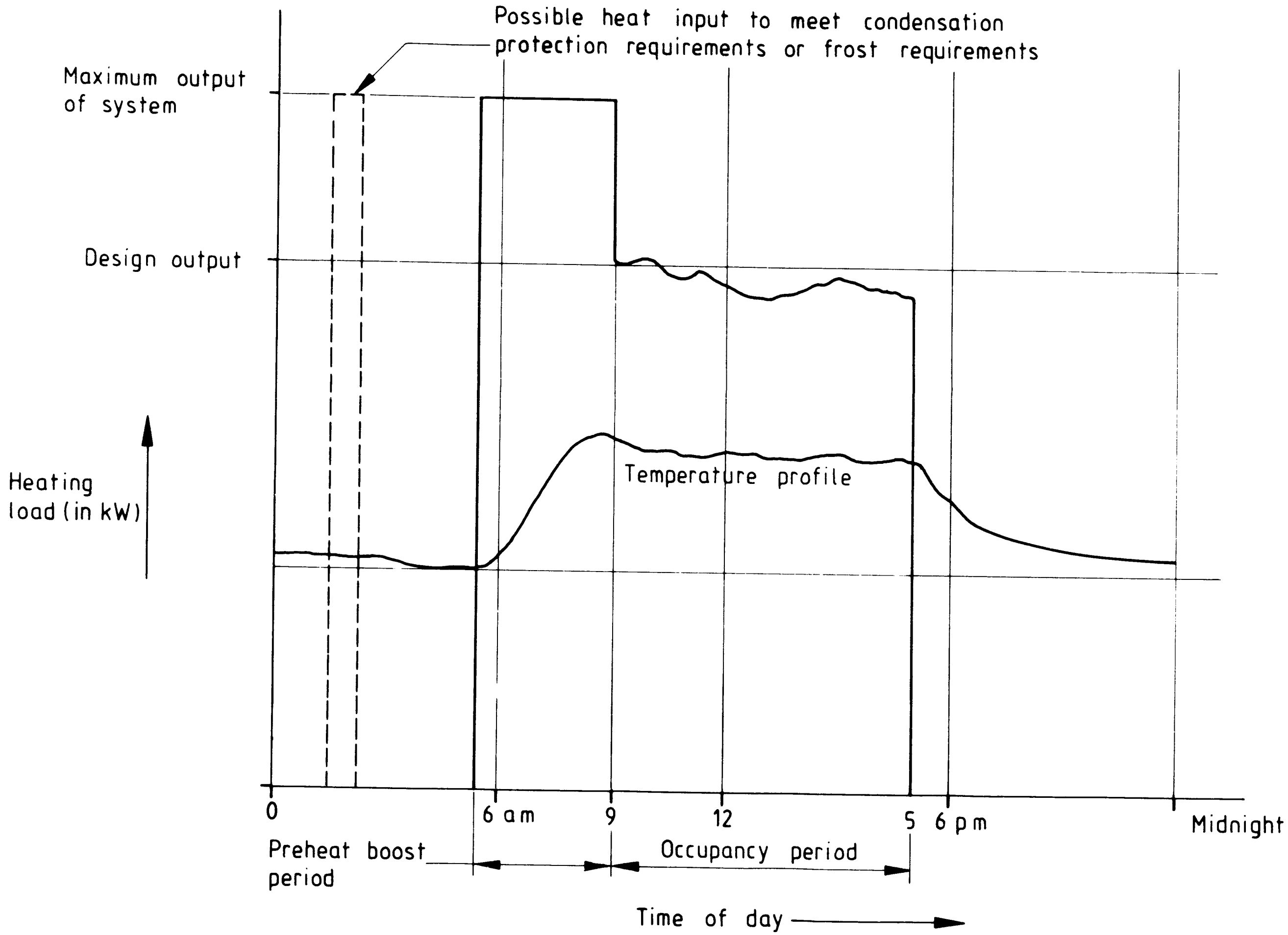


Figure 1 — Typical 24 h load profile and temperature decay curve (based on 9 am to 5 pm occupancy)

Boiler ratings should be selected with the object of meeting the load profile within the modulating range of the firing equipment, such that excessive on/off operation is avoided. This tends to favour the provision of boilers graded in size, for example two equally sized units with a smaller summer load unit, or the use of a modular boiler system (see **5.1.2.6** of BS 6880-2:1988). Where two or more boilers are interconnected, provision should be made to operate the number required to meet the current load, and the flow of water through the units that are not required should be reduced in accordance with the requirements of the Building Regulations Part Q. This subject is discussed further under **3.3.4.3**.

Where two boilers are required, it is often appropriate for each to be rated at two-thirds of the maximum winter heat load, since this tends to give adequate standby capacity when a unit is off load. With modular boilers the need for additional standby capacity is greatly reduced and depends on the modules proposed. The need for overload capacity should be taken into account as appropriate (see **3.2.4.2**). For further guidance see Section A.9 of the CIBSE Guide [1].

Load profiles may be applied to an entire building or to specific zones within a building. Knowledge of zone profiles can assist determination of how the heating system should be subdivided (see **3.4.2.3**).

3.2.6 Primary domestic hot water demand

3.2.6.1 *General.* Secondary HWS systems are outside the scope of this code. This code is only concerned with the use of LTHW space heating systems to supply primary heat to HWS systems in situations where this is an appropriate method of generating domestic hot water for the particular application. Water in the primary HWS circuit should be kept entirely separate from that in the secondary HWS system and the appropriate water bye-laws observed.

3.2.6.2 *HWS load.* The HWS demand of the building will place an additional peak thermal load on the LTHW system, depending on the maximum amount of hot water usage expected in the relevant period, its temperature and, in systems where secondary HWS storage is provided, on the rate of recovery of temperature required after draw-off.

Methods of determining HWS loads and related sizing parameters are given in Section B.4 of the CIBSE Guide [1]. It should be appreciated that HWS load estimation tends to be imprecise and is subject to considerable variations from day to day and according to occupancy patterns, and estimating information is largely based on statistical data. Whilst the CIBSE Guide [1] is the recommended basis for use in the UK, it should be acknowledged that recent research by the gas and electricity industries suggests that in certain situations it may be reasonable to use lower levels of HWS demand (see British Gas Guide to Hot Water Plant Sizing for Commercial Buildings [25] and Electricity Council Publication EC 4181 [26]); however, experienced judgement is called for, and the user of the building should be made aware of proposals to provide reduced HWS capacity.

3.2.6.3 *Summer HWS requirements.* It is important to achieve thermally efficient operation in summer, particularly where there are no other summer loads. This may indicate provision of a small boiler for summer use. However distribution system losses can be very significant, in which case other means of raising HWS in summer may be preferable.

3.2.6.4 *System arrangement and temperatures.* Use of a separate LTHW circuit is recommended for serving primary HWS requirements, with appropriate controls. The temperature in this circuit should relate to the required secondary HWS temperatures and the thermal rating of the primary/secondary heat exchanger (usually a coil or tube bundle in a storage calorifier). It should be noted that unfired and other heating systems using system temperatures lower than traditionally associated with LTHW boilers, may not be suitable to generate the full HWS requirement.

Careful consideration should be given, and appropriate safeguards applied, to the risks inherent in loss of control of primary LTHW temperature; this would be particularly important in a case where the secondary HWS system is not open-vented, such that an explosion risk can exist. Should such systems be permitted in the UK, the appropriate statutory regulations should be followed.

3.3 Energy conversion subsystem design

3.3.1 Fuel selection

3.3.1.1 *Initial considerations.* In selecting the fuel or other source of heat many important factors should be considered early in the design stage. Fuel selection has a major bearing on capital cost and on present and future operating costs.

The economic assessment of alternative fuels usually starts from consideration of the cost of the fuel in relation to its calorific value, expressed as MJ/kg of energy which would be released from the fuel when completely burnt under precisely specified laboratory conditions. However many modifying factors should be taken into account as well, including the following.

a) Gross or nett calorific value (see BS 526): the former is normally used in the UK and applies where useful heat is abstracted by condensing the products of combustion.

b) The efficiency of combustion under the conditions of the particular application. Different fuels and combustion equipment will differ in terms of the peak combustion efficiency which can be achieved. Also total annual fuel cost will be affected by the average year-round efficiency of the complete installation which tends to be significantly less than the peak value and much influenced by system and building characteristics, occupancy pattern, method of operation, etc.

c) Future trends in relative fuel economics.

In addition to the economic aspects, consideration should also be given to primary energy conservation (see **2.5** and the CIBSE Building Energy Code) [2]. Certain major energy users adopt a policy, which is recommended, of requiring a lower rate of return from energy conservation investments; the general tendency for energy prices to escalate faster than other costs is also relevant.

Other factors to be considered include availability, storage needs, delivery arrangements, ash disposal, flue requirements, reliability of supply, size of system and safety considerations (see **2.4.3**).

In certain situations it may be necessary to consider the use of a different fuel as a standby, to permit operation at times of failure of the main fuel supply. Similarly, planning for the introduction of an alternative fuel at some future date may be considered to provide against future uncertainties of availability or relative fuel prices.

3.3.1.2 *Fuel types and characteristics*

3.3.1.2.1 *General.* Fossil fuels commonly used for LTHW systems are natural gas, various fuel oils and coals (see **3.3.1.2.2** to **3.3.1.2.4**). Other fuels may be used, such as coal gas, liquefied petroleum gases, coke, peat, and various wastes and by-products (see **3.3.2**). Fire safety and related characteristics of fuels are covered in **2.4.3**. See also Section B.13 of the CIBSE Guide [1].

3.3.1.2.2 *Gases.* Natural gas (mainly methane) is the most commonly available gaseous fuel in the UK. Since it is piped direct to the installation from the national network it is not stored on site, and attention should be given to the likelihood and consequences of an interruption in supply. British Gas plc publishes data governing its calorific value and other relevant properties. Since natural gas has important applications for which other fuels are less suited, from time to time restrictions may be placed on the larger-scale use of gas in LTHW heating systems. Coordination of supply pressure with burner requirements and provision of appropriate controls is important (see **2.4.3**). Similar considerations apply to coal gas where available.

Liquefied petroleum gases (LPG) (commonly butane and propane) may be appropriate in certain circumstances. Butane and propane should comply with BS 4250. They can be stored on site; delivery is normally by road transport. Stringent safety requirements apply to the siting, installation and use of LPG storage facilities (see **2.4.3.2.2**).

3.3.1.2.3 *Fuel oils.* Fuel oils for heating purposes are refined in various classes specified in BS 2869, with which they should comply. These fuels are derived from crude oil which is separated into a large number of fractions, ranging from distillate types of low viscosity and low density, to residual types of high viscosity and higher density. Due to changes in the available crude oils and in the market pattern for oil products, the relative economics of using the various classes can change significantly. The actual properties of each class as specified in BS 2869 may be subject to review from time to time. These considerations are important for the selection of fuel oils since they can have an important effect on operating cost, storage and handling requirements, combustion equipment selection, flue gas corrosivity, etc.

Fuel oil selection is based on factors which include the following.

a) Cost per unit of calorific value contained in the fuel (see **3.3.1.1**).

b) Physical characteristics, the most important of which is viscosity, on which fuel oil classes are based. Viscosity determines whether it will flow readily at ambient temperature or require heating. Density is also relevant since calorific values tend to be expressed on a gravimetric basis whilst price is often on a volumetric basis.

c) Low temperature characteristics, which can be important in certain situations (see BS 6380).

d) Chemical composition; the important aspects are the content of water, sulphur and other elements likely to cause corrosion and pollution.

The properties of the various fuel oils are set out in Table 2 of BS 2869:1983. Class C2 (formerly kerosene) is the lightest class available for LTHW heating but is not normally used on systems of the size covered by this code. Class D (formerly gas oil) is commonly used, and is the heaviest of the distillate fuels. Residual classes E, F and G may also be considered for LTHW heating applications; in these cases the advantage of lower calorific cost has to be judged against the storage, handling and heating requirements, the need for different combustion equipment, greater operation and maintenance requirements and the corrosion and pollution factors. The heavier classes tend to be restricted to the larger installations, or to those where LTHW is generated indirectly from steam or high temperature hot water (HTHW) raised in industrial type boiler plant; the latter is outside the scope of this code. Sulphur content is of particular and growing importance due to the harmful nature of sulphur compounds and in particular the tendency to form sulphuric acid in the flue system or in the atmosphere.

NOTE At the time of drafting this code, UK environmental legislation was based on a policy of dispersal of such contaminants (see **3.3.5.3**), but the possibility of future measures requiring reduction in sulphur content of fuels should not be ignored.

3.3.1.2.4 *Coal.* Coal is the most commonly used solid fuel and is produced in a number of types and size ranges according to origin and subsequent processing. These types and size ranges are published by British Coal (see also BS 3323). The principal characteristics relevant to heating applications are as follows.

a) Cost per unit of calorific value (see **3.3.1.1**). Transport can be an important element of cost, along with ash removal, so that cost should be considered in the context of a specific site location, a specific source of coal and facilities for ash disposal.

b) Grading, which is a statistically based size classification and important to handling and combustion method.

c) Bulk density, which has a major bearing on the physical size of the storage facilities and any intermediate hoppers.

d) Chemical composition, particularly content of water, sulphur and any other elements relevant to considerations of corrosion and pollution. (See also comments in **3.3.1.2.3**.) Ash content affects the volume of ash to be removed. Ash content and coking qualities determine how the coal will behave during combustion; and have a major bearing on the type of combustion equipment that should be used.

The small and medium size grades are generally more suitable for direct use in LTHW installations; smokeless fuels such as coke and anthracite (graded in similar fashion to bituminous coals but with their own grade sizes and designations) are used in gravity feed appliances or may be hand fed. Peat and lignite are available in certain areas, their use being geographically restricted due to their relatively low calorific value per unit volume. Whilst use of such fuels has many parallels with coal utilization, definitions of the relevant characteristics and the maintenance of consistency are more difficult and factors indicated in connection with by-product fuels should be considered (see **3.3.2**).

The nature of coal is such that its properties cannot be classified as precisely as for refined fuel oils, and there is therefore greater variability of certain properties. Close collaboration is therefore required at an early stage with the coal supplier and those concerned with the specification and design of storage, handling and combustion equipment.

Coal also offers the possibility of reduction to pulverized form before combustion, which makes it easier to handle and control, the combustion process then being more similar to that of fuel oils.

Other considerations also affect the economics of coal use. Investment in handling facilities can be significant, and operation and maintenance tends to be more onerous than with gases and oils. The rate of heat release in combustion equipment tends to be significantly less, so boilers tend to be physically larger for comparable output.

Whilst a high level of automatic control can be achieved with coal-fired installations, there are aspects of coal-firing which make fully automatic operation more difficult than with oil and gas fuels including:

a) variations in the physical characteristics of the fuel which may interfere with handling and stoking;

b) difficulty of rapid modulation of output with some systems of combustion due to the mass of fuel in the furnace;

c) implications of ash removal and the tendency for its characteristics to vary.

3.3.2 Use of by-product fuels

3.3.2.1 *By-product fuel types.* The fossil-derived fuels described in **3.3.1** which originate from major fuel suppliers have defined qualities as indicated. Other fuels which may not be so accurately specified may be available including:

a) process by-product gases such as coke oven gas, sludge digestion gases, etc.;

b) waste oils;

c) waste wood, etc.

3.3.2.2 ***Special considerations***

3.3.2.2.1 *General.* The general considerations applicable to gas, liquid or solid fossil fuels respectively are largely relevant to by-product fuels (see **3.3.1**), but other factors should be taken into account, both for economic assessment and system design. Successful application of by-product fuels requires careful analysis based on knowledge of the factors relevant to each individual installation and the fuel proposed. Close collaboration is necessary with the source of the fuel, the specialist combustion and related equipment suppliers and the user of the installation, and may call for more technical analysis and preparatory work than is normally required for installations using regular fossil fuels. Particular factors to be considered are given in **3.3.2.2.2** to **3.3.2.2.9**.

3.3.2.2.2 *Source of fuel.* Sources of supply of by-product fuels may be limited.

3.3.2.2.3 *Availability.* Availability and reliability of supply should be considered for both short- and longer-term use, including the possibility of demand growth. The pattern of its production needs to be compared with the heat demand pattern of the building. Output may be seasonal or subject to prolonged stoppages; this may affect storage capacity required on site (where practical). Consideration should be given to the need for alternative fuels as standby.

3.3.2.2.4 *Quality.* The relevant properties (see **3.3.2.2.5** to **3.3.2.2.9**) may not be capable of definition with the precision associated with regular fossil fuels. Account should be taken of the variability to be expected of any property, and the possible influence of long-term changes in the source process.

3.3.2.2.5 *Calorific value.* The calorific value may be subject to short- and long-term variation, with a wider tolerance than with regular fuels, due to variations in composition. The basis of the assessed calorific value will need to be established and tests may have to be carried out. Also the basis of rating and testing the heat-generating equipment will need to be established where appropriate British or other standards do not exist.

3.3.2.2.6 *Size and bulk density of solid fuels.* The size and bulk density of solid fuels affects storage requirements, transport, handling and stoking, and is likely to be variable. Where the size grading is too irregular for the purpose, it may be necessary to introduce a size reduction or grading operation to achieve reasonable consistency.

3.3.2.2.7 *Transport and delivery.* The method of transport needs to be ascertained and particularly the details of delivery and off-loading at the consumer's premises.

3.3.2.2.8 *Combustion characteristics.* Special-purpose combustion equipment may be necessary, and in all cases close liaison with the equipment designers is necessary, who will need full information on the properties of the proposed fuels and their expected variability, together with the appropriate analysis. Special combustion tests or prototype work may also be necessary. The method of control and safety of the combustion process require particular attention, including potential dangers inherent in the mixing of more than one type of fuel.

The combustion air requirements may be significantly different from that for an installation of similar output fired by a regular fuel.

3.3.2.2.9 *General physical and chemical characteristics.* Other characteristics may affect storage, handling, combustion, ash removal, safety, corrosion and pollution. These may influence installation design, measures to control emission and ensure safety, and may indicate a need for pretreatment. They include the following, but each such fuel should be considered individually and all relevant characteristics ascertained:

a) moisture content;

b) dust content;

c) content of ash, tar or other residues;

d) content of sulphur, acidity and other hazardous elements or properties;

e) risks of spontaneous combustion or explosion.

These characteristics may apply to any such fuel, whether solid, liquid or gas. In particular it should be noted that by-product gases may contain dust; solid organic material may have a tendency to spontaneous combustion when stored under certain conditions (see **3.3.3.3**); finely divided organic materials are liable to explosion; waste oils can be acidic and contain very harmful substances.

NOTE Where use of such fuels is being considered, particularly in industrial situations, it may be more appropriate to utilize the by-product fuel in larger installations serving other purposes as well, and generate LTHW by heat exchange from the appropriate medium. Such installations are outside the scope of this code.

3.3.3 Fuel handling and storage

3.3.3.1 *Gases.* Where natural gas is used, storage does not arise. In cases where the burner is of the fan assisted or pressure type, a gas pressure booster with controls may be required. Meters should be accessible and be accommodated in accordance with the requirements of the gas undertaking with the required provision for isolation of the supply. (See the Gas Safety (Installation and Use) Regulations 1984 and British Gas Publications DM/4 [17] and IM/16 [27].)

With liquefied petroleum gases, storage is necessary and usually takes the form of one or more pressure vessels with reducing valve arrangements and a heated evaporator in certain circumstances. The siting of the vessel in relation to buildings or public thoroughfares is most important and should be in accordance with the Home Office Code of Practice for LPG installations [16] (see **2.4.3.2.2**), local authority and fire authority requirements. There may also be an insurer interest.

Particular attention is required to fencing, to the tendency of spilt gas to gravitate like a liquid with implications for surrounding areas and to site access and safety provisions to facilitate safe delivery. Recommended storage capacity is 3 weeks' supply at the maximum rate of consumption or 2 weeks' consumption at the same rate, plus the usual ordered quantity for one delivery.

3.3.3.2 *Fuel oils.* Oil storage tanks should preferably be located external to buildings where space and road vehicle access permit, particularly with the larger installations. Siting and installation should be in accordance with BS 799-5 and BS 5410-2. A bund wall enclosure should be provided, suitably sealed, to contain leaks and foreseeable spillage due to tank failure, with provision for preventing accumulation of water.

Attention is drawn to the need for the tank installation to comply with all statutory and bye-law requirements and those of the Fire Authority and insurer interests.

In certain situations installation within buildings may be necessary. The provision of a containing enclosure also applies in this situation, and particular attention should be paid to structural fire precautions, fire detection and suppression and all related safety matters (see also **2.4**).

Provision should be made for access appropriate to the type and maximum size of delivery vehicle normally expected, together with installation details necessary for safe delivery of the grade of fuel to be used. Guidance on such matters can be obtained from principal fuel oil suppliers.

Tank storage capacity is recommended of at least 3 weeks' consumption at the maximum rate of consumption or 2 weeks' capacity at the same rate, plus the usual ordered quantity for one delivery.

Class C and D oils can normally be stored without heating in UK conditions, but heavier grades require to be maintained at recommended minimum temperatures for storage and handling (see Table 6). However, where availability of fuel at all times is a critical consideration, it is recommended that classes C and D oils be maintained at between 0 °C and 5 °C by heating the tank, in order to avoid wax formation (see also BS 6380).

Table 6 — Recommended minimum oil storage and handling temperatures for classes E, F and G fuel oils

Class of fuel	Minimum storage temperature	Minimum handling or outflow from storage temperature
	°C	°C
E	10	10
F	25	30
G	40	50

These grades of oil are delivered in a warm condition, typically around 50 °C. Heated fuel tanks should be insulated and consideration given to the method of heating and its energy requirements when considering fuel economics and selection (see **3.3.1**).

3.3.3.3 *Solid fuels.* Provision for storage of solid fuel will depend on size of plant and method of firing. Storage arrangements range from a simple compound inside or outside the boiler house, with arrangements for hand firing or simple conveying, to the more complex arrangements appropriate to large installations. These may include underground reception bunkers with mechanical or pneumatic conveying, and overhead storage in the boiler house. It is recommended that the fuel supplier be approached on the question of fuel delivery and fuel storage arrangements at an early stage in the design process. Detailed guidance can be found in the British Coal series of publications "Technical data on solid fuel plant" [20].

Main fuel store capacity sufficient for at least 3 weeks' consumption at the maximum expected weekly usage is recommended. Where space is available, consideration may also be given to a longer-term back-up stock.

For satisfactory storage of coal and other solid fuels in stockpiles, a firm and well-drained underbase should be provided and for smaller stockpiles serving current consumption needs, consideration should be given to means of dividing the stock to facilitate good stockpile management on a "first in, first out" basis. Coal may lose some of its calorific value during the first two to three months storage, handling may cause physical degradation and dust, and prolonged undisturbed storage introduces the risk of spontaneous combustion, to prevent which there are appropriate management techniques (see British Coal publications [20]).

For long-term storage it is customary to accept the small initial reduction in coal quality in the residual stock, which is allowed to remain undisturbed although monitored for any sign of overheating. The plant is then operated using only the recently delivered coal.

General considerations of fire safety, vehicle access, etc. outlined for oil storage (see **3.3.3.2**) also apply to the siting of coal storage. However, the relative locations of delivery point, main stock, intermediate stocks and the coal firing installation are much more critical for coal and solid fuels because many of the mechanical handling techniques available are less flexible than with oil installations. Selection of the appropriate method of handling usually has to be made at an early stage. Similar considerations apply to methods of handling ash and its safe temporary storage prior to removal, noting that it may be hot and a potential fire risk.

Attention should be given to avoiding nuisance that may arise from dust associated with solid fuels, both within the boiler house, elsewhere on the project site and in the environment generally. Where external storage of solid fuels is proposed, attention should be given to the effects of the elements on the stored fuel, particularly wetness.

3.3.3.4 *Road traffic considerations.* Adequate access for the delivery of fuel should be provided using minimum road widths and turning requirements established with the fuel suppliers. An assessment should be made of the time required for discharging each load and appropriate provision made to avoid undue disturbance to traffic, particularly with larger installations in urban areas.

3.3.4 Boiler arrangement

3.3.4.1 *General.* Boiler and burner types and their application are covered in Section 5 of BS 6880-2:1988. However, selection of boilers is closely connected with that of fuels (see **3.3.1** and **3.3.2**), fuel and chimney arrangements (see **3.3.5**) and considerations of energy conservation (see **2.5**).

3.3.4.2 *Boiler location and grouping.* Many systems use a single central boiler installation. There is no clearly defined upper limit of size for LTHW systems but considerations of mains size, distribution system heat loss, pumping requirements and required boiler output tend to impose physical and economic limits to the size of LTHW systems that can be effectively served from a single heating plant. This limit is influenced by the extent to which the heating load is concentrated or dispersed; the latter tends to be less economic and gives rise to low seasonal efficiency due to excessive mains losses and other factors.

On larger projects these factors need to be considered and alternatives evaluated, such as:

a) subdivision into more than one system, each with its own boiler plant, strategically located;

b) adoption of a higher temperature heating medium with higher flow/return temperature differentials (i.e. not LTHW) for primary distribution to separate local LTHW systems.

It should be noted that the type of fuel has considerable bearing on this decision, and the effects of possible future changes of fuels should be considered, e.g. gas lends itself to piped distribution to a number of dispersed heating plants, whereas the implications of delivering, storing and handling coal may favour a central plant.

Location of the boiler installation should be carefully considered especially if future changes of fuel are likely. A ground level installation adjacent to open ground may be more flexible in this regard long-term. However, multi-storey buildings and restricted sites tend to indicate consideration of a roof-top heating plant.

3.3.4.3 ***Multiple boilers: arrangement and control***

3.3.4.3.1 *General.* Careful consideration should be given to the number of boilers appropriate to the application. This should take account of matching output and load (see **3.2.5**), standby requirements and the effect on installation cost and space of an increasing number of individual boiler units. In this context, a modular boiler unit may be appropriate (see **5.1.2.6** of BS 6880-2:1988). It is often found that two boilers can give a satisfactory arrangement.

Where an installation uses more than one boiler, particular care is required in system design, such that the group of boilers operates satisfactorily and efficiently over the required range of output. At the same time the arrangement needs to comply with statutory requirements and safety recommendations. It should be fully compatible with the LTHW heating system as a whole, particularly as regards hydraulic performance and control; an understanding of the relevant characteristics of the individual boiler units is also important, and the manufacturer's recommendations should be taken into account. Because of the variety of possible arrangements and differences in the characteristics and requirements of particular types of boiler, it is not practical to recommend a universally appropriate arrangement and control method. It is therefore recommended that each system should be specifically designed to suit the application, taking particular account of the factors given in **3.3.4.3.2** to **3.3.4.3.11** as appropriate. For further guidance see also Section F of the PSA Engineering Guide [28].

3.3.4.3.2 *Building regulations (Part Q).* This includes requirements that for oil and gas fired boiler installations exceeding 100 kW total output, the number of boilers in operation be automatically matched to the load, and that water flow be automatically reduced through any boiler not in operation. There is a general proviso that Part Q applies "only in so far as it is necessary for the purpose of furthering the conservation of fuel and power".

3.3.4.3.3 *HSE Guidance Note PM5 [3].* The recommendations of this document should be followed (see **2.4.4**), noting that it calls for sensing the water temperature, at or near the boiler flow outlet for the purposes of normal controls and independent overriding controls.

3.3.4.3.4 *Minimum water flow.* Manufacturers normally recommend specific minimum water flow rates through boilers; this is influenced by boiler type and construction.

3.3.4.3.5 *Minimum return temperature.* Manufacturers normally recommend minimum return water temperatures. Usually 60 °C, except for condensing boilers and similar types specifically designed to withstand the effects of lower temperatures.

3.3.4.3.6 *Sequence control.* Sequence control is the automatic matching of boilers to load calls, usually by means of a primary LTHW temperature sensor, step controller and sequence selector. Sequence control of multiple boilers is sometimes used directly without an individual boiler control thermostat; this is not recommended and is not in accordance with the recommendations of HSE Guidance Note PM5 [3].

3.3.4.3.7 *Total system flow.* Flow through the boiler system is often designed to be approximately constant over the load range. Some arrangements for the control of multiple boilers operate on the shut-off principle [see Figure 8 (a)], whereby most of the system flow is directed only through the boilers which are in operation. This tends to reduce progressively the total flow rate as boilers are shut down; the extent depends on the relationship between the hydraulic resistance of the boiler and that of the complete circuit. It is particularly marked with high resistance boilers. A separate primary circuit serving the boilers tends to facilitate a satisfactory hydraulic circuit (see also **3.8.3.2.3**). At no time should primary circuit flow be less than the total of that required by the secondary circuit or the total of the individual boiler flows. The primary circuit arrangement should be such as to minimize possible interaction between primary and secondary flows. Similar considerations apply if individual boiler pumps are used [see Figure 8 (c)].

3.3.4.3.8 *Flow temperature dilution.* Some arrangements for the control of multiple boilers operate on the bypass principle [see Figure 8 (b)] whereby flow is diverted from boilers which are not in operation. This gives rise to a flow temperature dilution effect, whereby water at return temperature mixes in the water header with water heated by operational boilers. The control method used needs to be compatible with system requirements. The bypass path should be arranged such that its hydraulic resistance can be adjusted to equal that of the boiler path in parallel, to assist constant system flow. This effect is more marked as the number of boilers increases, so it is desirable to limit the number of boilers (typically 2 or 3). This effect also applies to boilers with individual pumps feeding into a separately pumped constant flow primary circuit [see Figure 8 (c)]. For further information on the control of multiple boilers see **3.8.3.2.2**.

3.3.4.3.9 *Interlocks and protective measures.* Where automatic boiler sequencing, automatic boiler shut-off valves or automatic flue isolating dampers are used, particular attention should be given to the provision of appropriate safety interlocks with combustion systems, having regard to the dangers that may arise such as fire, explosion and equipment overheating. In particular the recommendations of HSE Guidance Note PM5 [3] should be followed, noting in particular the need to prevent build-up of heat in solid fuel fired equipment, which may require a time delay. In many cases, boiler manufacturers recommend interlocks such that combustion in a given boiler cannot commence until adequate water flow has been established. BS 6644 makes particular recommendations concerning the use of isolating valves on gas-fired boilers. See also BS 5978 with regard to manual gas isolation valves and BS 5978 and British Gas publication IM/11 [14] for requirements for automatic flue dampers on gas-fired boilers.

3.3.4.3.10 *Heat losses from boilers not in operation.* With certain types of boiler, the manufacturer may not favour reduction of water flow during intermittent operation, since it may be possible to satisfy Building Regulations Part Q by the use of automatic flow isolators, depending on the degree of heat loss (standing loss) in the isolated condition.

3.3.4.3.11 *Boiler header arrangement.* The reversed return system is recommended (see **3.4.2.4.3.1**).

3.3.4.4 *Heat recovery from flue gases.* Where consideration is given to heat recovery from flue gases (for any purpose) by means of heat exchangers or recuperators installed in the flue system attention should be paid to the implications for the remainder of the system such as low-temperature corrosion effects, particularly at part load (see **3.5**), the effects of added resistance in the flue gas path, access for cleaning, draining of moisture etc.

It should be noted that the scope for such heat recovery tends to become much reduced as boiler development enables higher efficiencies to be achieved by more effective sensible heat transfer, and abstraction of latent heat. (For condensing boilers see **5.1.3.1** of BS 6880-2:1988.)

3.3.4.5 *Operating temperatures and water circuits.* Boilers should be selected with regard to the full range of system flow and return temperatures required in normal operation. Many types of boiler are not suitable for return water entering the boiler at temperatures below 60 °C for reasons of gas-side corrosion (see **3.5**) and thermal stress. Applications calling for relatively low flow and return temperatures such as underfloor heating, operation in conjunction with heat pumps, thermal storage, etc. have to be carefully considered and appropriate water circuits and controls devised to achieve full compatibility between the distribution subsystem and the boilers over the operating range. This may call for the introduction of features such as additional pumped circuits, the blending of higher and lower temperature flows and the associated controls and provision to maintain hydraulic balance and stability within the system.

3.3.5 Flue and chimney design

3.3.5.1 *Combustion air provision.* A fuel-fired heat generation system requires the introduction of combustion air into the combustion equipment in quantities sufficient for complete combustion of the fuel under all normal operating conditions. The air quantity will always need to be in excess of the amount theoretically required by the fuel (noting that this has different values for systems designed for more than one fuel). The amount by which this quantity exceeds the theoretical requirement is defined as excess air and will vary according to the type of fuel and combustion system used. Typical ranges of excess air quantity are indicated in Table 7.

Table 7 — Typical ranges of excess air

Fuel	Excess air
	%
Gas	15 – 30
Oil	10 – 20
Coal	30 – 80

It is important to ensure sufficient excess air at all times to promote complete combustion; the unnecessary heating of unburnt air is a source of heat loss, which imposes upper limits on excess air quantities, and calls for suitable automatic controls and regular operational checks. Air quantity may be modulated to some extent according to load and heat loss can be further reduced by preventing airflow through the heater at times when the burner is shut down by means of an automatic flue damper. This calls for particular safeguards in view of the risk of explosion that exists where the passage of combustion air is unduly restricted, and these should meet the recommendations of HSE Guidance Note PM5 [3]. Boiler room ventilation is also a relevant consideration (see **3.7**); for detailed recommendations see CIBSE Practice Note No. 2 [15].

3.3.5.2 *Function of flues and chimneys.* The basic function of flues and chimneys is to enable the products of combustion to be discharged from the heat generation system in an appropriate manner and in a suitable location, having regard to the operational requirements of the system and to environmental considerations.

The flue and chimney system therefore handles a variety of gases (air and combustion products) which may contain aggressive or otherwise undesirable solid particles (dust, grit, carbon, etc.). See also **3.3.1** and **3.3.2**. The temperature and density of flue gases tend to vary considerably under different operating conditions and at different locations in the flue system. In order to achieve the required mass flow under these varying conditions, the necessary total pressure should always be available to overcome the resistance of the complete air and gas path. In natural draught systems, once used very extensively, the stack effect primarily determined by the height of the chimney is the only source of such pressure. In other systems mechanical draught is used in addition to such stack effect as the particular system may create.

3.3.5.3 *Environmental and statutory considerations.* Notification of the local authority of intent to install a new boiler plant is required, and of chimneys serving installations in excess of 345 kW. Detailed legislation governs the design of flues and chimneys, particularly the "Memorandum on chimney heights" issued under the Clean Air Act 1968 (see **2.4.1**). This takes account of different fuels (including those with a sulphur content of less than 0.04 %) and different localities, and a ruling should be obtained from the appropriate authority as to the classification of the site of the installation; attention should also be paid to the probable effect of adjacent buildings. It applies to boiler and furnace installations of 150 kW and above (reckoned as heat release into the combustion chamber).

The general intent of this legislation is to prevent emission of smuts and excessive smoke, and to ensure adequate dispersal of products of combustion, particularly sulphur compounds. This is achieved by various means including height, the maintenance of sufficient efflux velocities at the top of the chimney under all conditions of operation, and is assisted by maintenance of flue gas temperature by reducing heat loss from the flue and chimney system. There are special requirements in respect of fan diluted flues.

Chimney height is a fundamental parameter in this regard, and it differs considerably between fuel types in relation to their sulphur content. This is particularly relevant where a future change of fuels is envisaged. For fuels of negligible sulphur content, achieving adequate dilution of combustion products near ground level is the prime consideration. Means of periodically checking the flue gas in respect of smoke is advisable with fuels other than normal gases and distillate oils. Certain provisions of the Building Regulations (Parts L and M) relate to fuels and chimneys within the scope of this code.

3.3.5.4 *Structural considerations.* A wide range of materials and proprietary components is available for the construction of flues and chimneys (see **5.3.5** of BS 6880-2:1988), whose use should be determined in relation to the performance requirements for the flue systems (see **3.3.5.1**), structural considerations (see **2.4.2.3**), corrosion risks associated with certain conditions and types of fuel (see **3.3.1** and **3.5**) and thermal insulation requirements. In many cases these have a significant effect on the design of the building served by the heating system and should therefore be considered at an early stage.

3.3.5.5 ***Flue and chimney types***

3.3.5.5.1 *General.* Principal flue and chimney types are illustrated in Figure 2 and have features as described in **3.3.5.5.2** to **3.3.5.5.6** some of which may be combined in a particular system. For construction materials and other details see **5.3.5** of BS 6880-2:1988.

3.3.5.5.2 *All natural draught [see Figure 2 (a)].* The all natural draught type is described in **3.3.5.2**. In the case of many installations within the scope of this code, the practical chimney height is not likely to be sufficient to create adequate draught, so mechanically assisted draught is usually required (see **3.3.5.5.3**). However, gas boilers fitted with atmospheric type burners tend to use natural draught flues which incorporate draught diverters [see Figure 2 (b)]. These relieve the boiler combustion chamber of the full draught effect of the chimney by allowing air to be drawn into the chimney direct from the boiler room, so that the burner can operate under atmospheric conditions. See BS 5978-2 for specific requirements for flues for use with atmospheric gas burners.

3.3.5.5.3 *Mechanically assisted draught.* With the mechanically assisted draught type mechanical means assist the natural buoyancy or stack effect of the chimney. Assistance is usually provided by forced draught fans which force air into the combustion equipment, induced draught fans which draw air through the combustion equipment, or a combination of both [see Figure 2 (c) and Figure 2 (d)].

3.3.5.5.4 *Balanced flues.* Balanced flues achieve controlled draught conditions within the fired equipment by means of a single system for air supply and flue gas removal, so coupled that the two gas flows are always in balance [see Figure 2 (e)]. Normally the air inlet and flue gas outlet are close together, and are designed in such a way that the two flows do not mix. They can be advantageous on smaller installations, provided that the nature and location of the discharge meets the relevant requirements (see **3.3.5.3**). There are both horizontal and vertical arrangements, but they should be designed as an integral part of the boiler system and installed in accordance with the design and in such a manner that no additional resistance is introduced into the gas paths. They can operate in such a way that the flue gas preheats the incoming air.

3.3.5.5.5 *Flue gas dilution.* In gas-fired installations where provision of a flue and chimney creates particular difficulties, use of a controlled system of flue gas dilution may be considered [see Figure 2 (f)]. This allows the products of combustion to be discharged at a low level by dilution with air such that the carbon dioxide content of the diluted gases does not exceed 1%. Environmental considerations may limit the size and use of such a system and careful consideration should be given to the siting of the discharge and that all statutory requirements are observed. In all cases where flue gas dilution is to be considered, reference should be made to the requirements for fan diluted flues in the "Memorandum on chimney heights" (see **3.3.5.3**) and British Gas Publication IM/11 [14].

3.3.5.5.6 *Single and multiple chimneys.* With multiple boiler installations, each boiler may be provided with its own individual flue. This arrangement assists the maintenance of efflux velocities and flue gas temperature at low system loads. For purposes of support, such flues may be independent of each other or incorporated into a common windshield or other supporting structure. The latter arrangement is preferable from environmental considerations (see the "Memorandum on chimney heights"). In respect of gas-fired boilers BS 6644 indicates a preference for individual flues/chimneys; it indicates that common flues may be used where the boilers are in the same room.

Where multiple boilers discharge into a common flue, particular attention should be paid to conditions at times of low system load when gas velocity will be much reduced, and provision made for isolation of the individual boilers for cleaning and maintenance.

Products of combustion from coal-fired boilers and boilers fired by other fuels should not be allowed to mix together. The same applies wherever different boilers do not have similar draught arrangements (e.g. atmospheric and forced draught burners).

3.3.6 Unfired heat source systems

3.3.6.1 *General.* LTHW heating systems may derive all or part of their heat requirement from sources other than fuel-fired heaters. Various sources are considered briefly in this subclause, but it should be noted that most of them utilize fluids or other elements operating at temperatures or pressures in excess of those associated with LTHW.

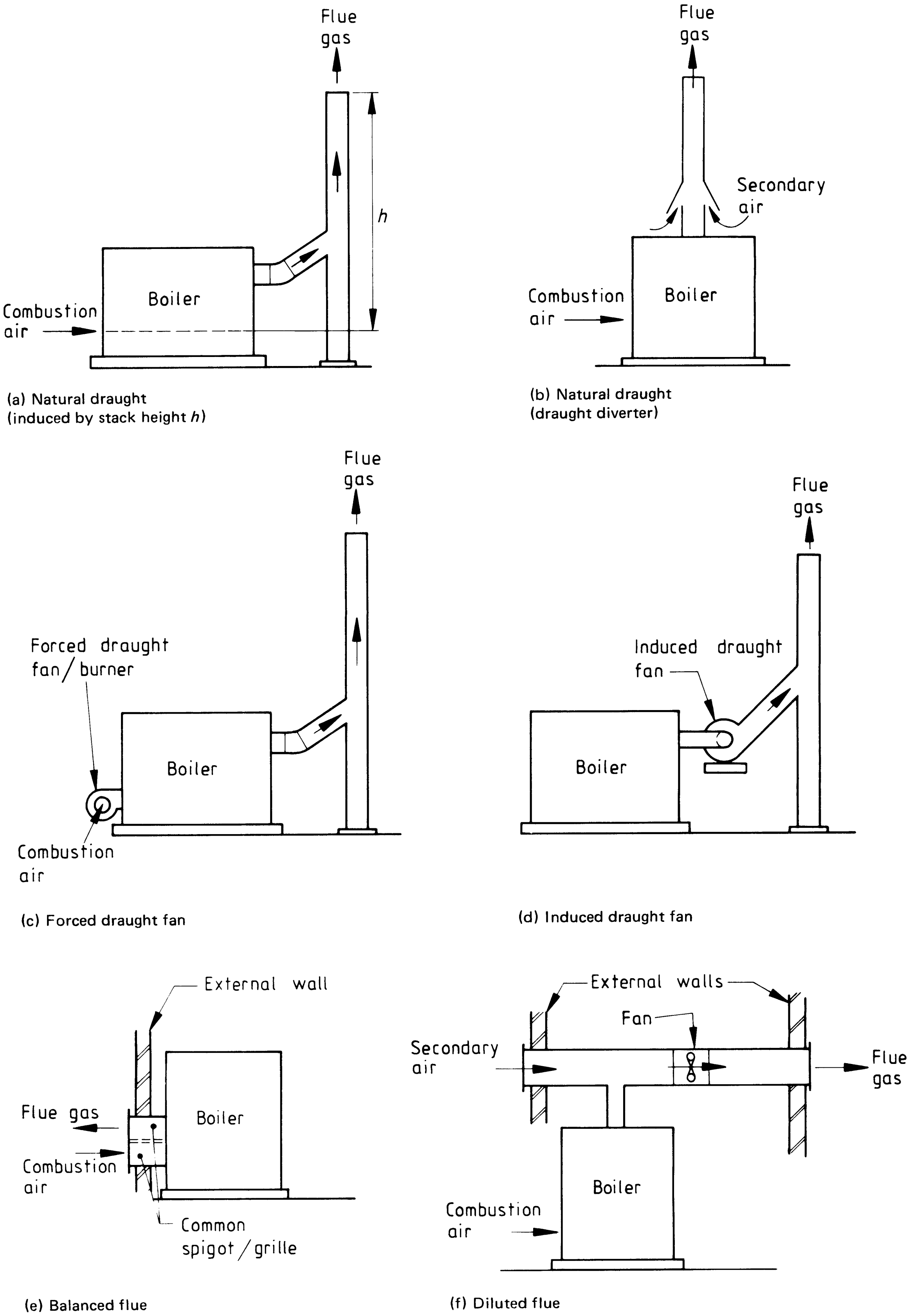


Figure 2 — Principal flue types

This code is concerned with that element of the energy conversion subsystem at the immediate interface with the LTHW distribution subsystem, rather than with equipment which generates the primary heating medium. Since the latter equipment tends to relate to many other areas of technology it is generally outside the scope of this code, but reference is made to certain types which are primarily intended for use with LTHW heating systems.

Systems with unfired heaters all operate by heat exchange from some primary heating medium, rather than by direct conversion of fuel. Certain electric systems operate by direct conversion of electricity. In this context, the energy conversion subsystem usually consists of a primary heat source/LTHW heat exchanger.

Principal types of unfired heater systems include:

a) calorifier systems (**3.3.6.2**);

b) electric resistance heat systems (**3.3.6.3**);

c) water sink heat pump systems (**3.3.6.4**);

d) heat recovery systems (**3.3.6.5**).

Such systems may operate in conjunction with thermal storage (see **3.3.6.6**). They may also operate in conjunction with fired heaters, where the fired heater is the secondary source providing heat above a base load.

Non-storage calorifiers in an LTHW system perform a function similar to that of an LTHW boiler, in that the required output is normally available at any time. This does not necessarily apply to the other types of system listed in a) to d), where output may be geared to other factors and where the design of these systems tends to be more complex and requires particular attention to factors such as:

1) daily and seasonal heating demand pattern;

2) daily and seasonal pattern of heat output available from the heat source, particularly in heat recovery situations;

3) relationships between available and required flow and return temperatures around the complete system, in its various operating modes;

4) effect of system temperatures and their variations on the performance and efficiency of equipment, particularly heat pumps;

5) arrangement of water circuits and controls to achieve the required modes of operation;

6) need for introduction of thermal storage into the LTHW system;

7) interpretation of equipment performance data where there is no British Standard or recognized code relevant to the application.

As a general principle, use of source energy tends to be more efficient as LTHW system temperature is reduced, but this calls for an increase in the size of emitter heat transfer surfaces. This may in turn call for greater system water flows and pumping energy, such that an appropriate compromise between initial and operating cost and energy conservation should be achieved for the particular application.

Where water is being considered as the heat source, use of the public supply is not usually permitted and abstraction of ground water is subject to licensing by the water authorities. Ground water and system water should be kept separate.

3.3.6.2 *Calorifier systems.* Calorifier systems are heat exchangers which heat LTHW from a higher temperature medium such as steam, pressurized water at temperatures greater than LTHW or thermal fluids. They are frequently of the non-storage type. The primary medium side of the installation should be in accordance with the safety and other system practices appropriate to the primary medium used, for example relief valves, pressure gauges and other mountings required with pressure vessels. There may also be an insurer interest.

Control is applied to primary medium flow (see **3.8**) and in the case of low pressure steam particular care is called for in the design of the controls and the condensate removal system to ensure satisfactory operation over the full range of output.

3.3.6.3 ***Electric resistance heat systems***

3.3.6.3.1 *General.* Use of electric resistance heat systems is not usually found to be economic for normal installations supplied from the public electricity supply unless it is associated with a significant thermal storage capacity such that advantage can be taken of special tariffs.

Even though such a system may prove economic in a given application, it should be appreciated that when electricity is used directly as a heat source a high primary energy fuel factor applies (see **2.5** and the CIBSE Building Energy Code [2]). The implications of the large electrical loads imposed by such equipment should be evaluated. Principal types of system are given in **3.3.6.3.2** to **3.3.6.3.4**.

3.3.6.3.2 *Electrode boilers.* Electrode boilers generate heat by the resistance effect of electricity passing between electrodes immersed in system water which is circulated through the boiler. Particular water quality requirements apply (see **3.5**). Control is usually by a mechanical system which moves the electrodes and is an essential part of the boiler. They are relatively little used, but can be applied to take advantage of special tariffs by operating in conjunction with a separate LTHW storage vessel (see **3.3.6.6**).

3.3.6.3.3 *Immersion heaters and LTHW storage.* In a system using immersion heaters and LTHW storage heat is generated by electric resistance heaters immersed in the system water but electrically isolated from it, usually contained in an LTHW storage vessel (see **5.5.3** of BS 6880-2:1988 and **3.3.6.6**).

3.3.6.3.4 *Immersion heaters and water storage at higher temperatures.* In a system using immersion heaters and water storage at higher temperatures there is a more complex arrangement than that in **3.3.6.3.3** but it gives greater thermal storage capacity per unit volume. It uses the same principle to heat primary water contained in a suitable pressure vessel to temperatures considerably higher than for LTHW. Secondary water is then heated by pumped circulation through tube bundles immersed in the vessel. It should be noted that proprietary systems of this kind tend to heat the secondary water (drawn from the LTHW system) to temperatures in excess of 100 °C, achieving the lower temperatures required for LTHW operation by controlled blending circuits. Correct functioning of controls is particularly important to prevent accidental high temperatures in the LTHW circuit (see also **3.3.6.6**).

3.3.6.4 ***Water sink heat pump systems***

3.3.6.4.1 *General.* Water sink heat pump systems produce LTHW by heat exchange from a refrigerant circuit. Heat source may be ambient air, ground water or other available low-grade heat source. Various prime movers may be used, but electric motors are the most common. Attention to the general principles set out in **3.3.6.1** is very important.

Characteristics of water sink heat pumps which are particularly relevant to LTHW system design are given in **3.3.6.4.2** to **3.3.6.4.6**.

3.3.6.4.2 *Heat source capacity.* The daily and seasonal pattern of heat source capacity and temperature needs to be investigated, as these may influence system output at certain times. When ambient air temperature falls to around 4 °C, air source heat pump output may be reduced by frosting effects at the evaporator and the need to use thermal energy for periodic defrosting. This is particularly significant under the winter humidity conditions typical of the UK, and care should be taken in interpreting performance data relating to equipment operating in significantly different climates. It is not usually significant at temperatures below minus 7 °C.

3.3.6.4.3 *System temperature.* Operation at system temperatures comparable with normal boiler practice is not normally practicable. Equipment availability and economic considerations tend to result in design flow temperatures of around 55 °C or less, hence favouring air heating and floor heating applications. This can be partially overcome by the use of combined systems (see **3.3.6.4.5**).

3.3.6.4.4 *Coefficient of performance (heating).* The concept of coefficient of performance (heating) (see **5.9.2** of BS 6880-2:1988) has a major bearing on the feasibility of heat pump systems, and will vary according to daily and seasonal changes in system temperatures and other parameters. It should be appreciated that the overall heating efficiency (heating coefficient of performance or COPH) improves considerably as the difference between the source and sink temperatures is reduced. Particular care is required in interpretation of COPH figures (see **3.3.6.1**).

For electric-driven heat pumps to operate at comparable running cost to fuel-fired systems, or at comparable primary energy usage, a certain minimum average COPH has to be achieved over the whole heating season, having regard to other electrical energy demand that may be imposed such as defrosting, fan motors, etc. In certain situations of combined heating and ventilation, a significant improvement in COPH may be obtained by the application of subcooling to preheat ventilation air.

3.3.6.4.5 *System capacity.* The characteristics of heat pumps described in **3.3.6.4.2** to **3.3.6.4.4**, particularly of the air-source type, impose limitations on the extent to which the heating demands of a building can be met economically by heat pumps alone throughout the whole season. This particularly applies to intermittently heated buildings requiring rapid warm-up. Also the output of air source heat pumps tends to decrease as ambient air temperature decreases, whereas heating load increases. For these reasons water sink heat pumps may be applied in combination with fuel-fired systems where one of the following arrangements is adopted:

a) a fuel-fired heater rated for full system load and a higher system temperature which takes over completely from the heat pump;

b) a fuel-fired heater which operates to provide additional heat input to boost system flow temperature.

The latter arrangement tends to be difficult to apply satisfactorily as an increase in system return temperature tends to reduce the contribution of the heat pump to total load. The economic division of capacity between the two types of heater is partly determined by the higher cost per unit output of the heat pump. It is often found that heat pump capacity of approximately 60 % of peak system demand is appropriate.

Overall system economics may also be assisted by the introduction of thermal storage to reduce load peaks and reduce the installed capacity of the heat pump. This can be achieved by the introduction of LTHW storage; it may also be inherent in the mass of a heated floor system, but this may introduce temperature control problems.

It should be appreciated that electrically driven heat pumps impose significant electrical demands and starting currents (see **3.9**). The technical and economic implications of this should be taken into account in the planning stage; this may be a particularly critical factor with existing buildings.

Where there is a need for cooling by refrigeration, the economics of heat pump application may be significantly improved, using reversible heat pumps capable of operating in heating or cooling mode.

3.3.6.4.6 *Refrigerant systems.* Heat pumps use refrigeration techniques similar to those used in air conditioning equipment, but tend to operate at higher system pressures, so that reciprocating compressors are widely used. The appropriate installation and safety practices should be followed (see BS 5720 and BS 4434-1).

3.3.6.5 *Heat recovery systems.* Heat recovery systems are systems where the heat input to the LTHW system is a by-product of some other process. It may be transferred to the LTHW by direct heated medium/LTHW heat exchange using appropriate heat exchangers (shell and tube, plate type, etc.), or it may be transferred via some other system interfaced between the source medium and the LTHW, such as a water sink heat pump. The latter would also serve to upgrade the source heat.

By-product heat sources which may be found on investigation to be suitable for LTHW heating in a particular application include:

a) low pressure steam arising from electricity generation;

b) heat abstracted from cooling circuits or exhaust gases of internal combustion engines used for driving generators, refrigeration plant, heat pumps, etc.;

c) heat recovered from flue gases;

d) heat rejected from the condensers of refrigeration equipment;

e) warm effluents.

This code is not concerned with the design or operation of the equipment and systems which abstract this by-product heat; its scope is limited to the LTHW heating circuit on the secondary side of such systems.

All such heat sources are characterized by the fact that the magnitude and variation with time of their heat output and temperature level is completely independent of the requirements of the space-heating load. This calls for careful analysis and comparison of the heat supply and heat demand profiles on a daily and seasonal basis. Particular attention should be paid to times when the heat source is shut down or when there is no heating load. Thermal storage may be appropriate (see **3.3.6.6**), to assist matching of supply and demand, noting that it is more effective as the frequency of supply fluctuation increases. Situations can also arise where by-product electricity is available (see **3.3.6.3**).

3.3.6.6 ***LTHW storage***

3.3.6.6.1 *Storage principle.* All LTHW systems have some thermal storage capacity inherent in the capacity of the LTHW circuit, heat generators and emitters, but this is not usually significant. Introduction of a relatively large volume of LTHW in a suitable vessel introduced into the LTHW circuit (see **5.5.3** of BS 6880-2:1988) permits accumulation of heat by allowing the average temperature of the stored water to rise and withdrawal by allowing it to fall.

3.3.6.6.2 *Purpose of storage.* In heating installations thermal storage is usually considered for one or both of the following reasons.

a) The heat supply and heat demand patterns do not coincide in time such that heat is available when not required, and vice versa.

b) Economic and energy conservation benefits can be obtained by sizing the heat generator for less than peak demand and providing for peaks by drawing on storage.

Situation a) is common in heat recovery situations or where energy is cheaper at certain times of day (e.g. electricity).

Situation b) tends to apply where heat generator capital cost is relatively high and where reduced fluctuation of output increases average efficiency.

3.3.6.6.3 *Design factors.* Analysis of daily and seasonal demand profiles and, in the case of heat recovery, supply profiles is necessary to establish whether the application of the storage principle is viable, and to establish the maximum thermal capacity required. It should be noted that more frequent cycling of the accumulation/withdrawal process assists viability. Other factors to be considered include the following.

a) Maximum and minimum temperature limits for the stored water; storage capacity is a direct function of this temperature difference but these temperatures should be selected to suit both the heat generation and heat emission processes at all relevant times.

b) Stratification; the storage vessel should be arranged to minimize mixing (see **5.5.3.2** of BS 6880-2:1988).

c) Size and construction of vessel (see **5.5.3** of BS 6880-2:1988), total weight, location and insulation.

d) Water circuitry and controls to permit the required modes of operation (see **3.8**).

It should be noted that such thermal storage vessels are usually classed as pressure vessels, to which particular design and fabrication requirements, safety features and inspection requirements apply (see Section 5 of BS 6880-2:1988, BS 5500 and the Factories Act). There may be an insurer interest.

The limited stored water temperature differences normally achievable with LTHW tend to limit application of LTHW storage. In some situations storage of a higher temperature medium can be beneficial, with heat transfer to LTHW (see **3.3.6.3.4**).

3.4 Distribution subsystem design

3.4.1 System temperatures

3.4.1.1 *General.* Establishing the flow and return temperatures on which LTHW system design is based has significant effects on pipe sizing, system pressures, the selection of heat emitters or heat emitting systems and hence on total system cost.

Conventional LTHW practice in the UK has tended to be based on flow and return temperatures of around 80 °C and 70 °C, respectively. The development of LTHW sources which operate most effectively at temperature levels lower than these, such as heat pumps and heat recovery equipment (see **3.3.6**), coupled with the development of heated floor systems and other types of emitter operating at lower temperatures, require that careful consideration be given to the selection of system temperatures. It should relate to the heat generation and emission systems most suited to the building, and should consider the relevance of foreseeable future trends. Guidelines are given in **3.4.1.2** to **3.4.1.4** and Figure 3 illustrates relationships between system temperatures.

3.4.1.2 *Flow temperature.* This is the maximum temperature of LTHW normally available in the distribution system, allowing for some small drop of temperature from that at the outlet of the heat generator. It may be maintained constant (as in many air-heating applications) or scheduled with reference to outside temperature, time or other parameters for control purposes (see **3.8**).

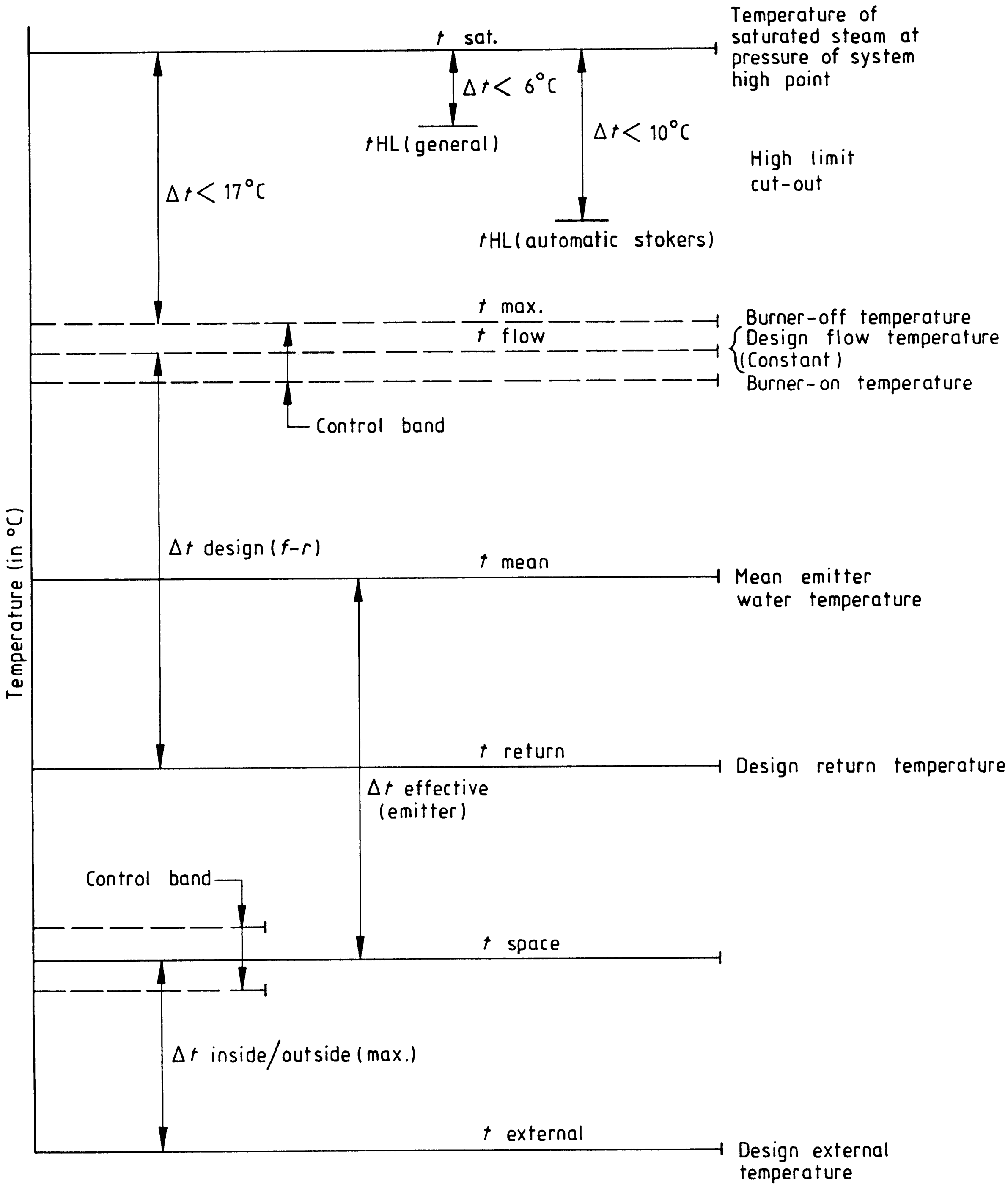
For the purposes of this code the upper limit of LTHW flow temperature is defined as 100 °C; this is only possible with a pressurized system. For open-vented systems the recommended limit is 83 °C. Important safety considerations relate to flow temperature (see **2.4.4**). Flow temperature in the range of 70 °C to 100 °C can be achieved with conventional fired boilers and by heat exchange from higher temperature media. However, certain types of hot water generator are best suited to lower temperatures, including:

a) condensing type boilers (see **5.1.3.1** of BS 6880-2:1988);

b) heat pumps (see **5.8** of BS 6880-2:1988);

c) various types of energy recovery systems (see **3.3.6.5**).

It should be noted that some types of emitter operate at lower flow temperatures (e.g. heated floors, see **3.7** of BS 6880-2:1988). Other types can be designed to operate at lower temperatures but capacity should be increased accordingly. A particularly important case is that of central plant air heater batteries which can offer potential for heat recovery.



NOTE These temperatures are laid down in HSE Guidance Note PM5 [3].

Figure 3 — Simplified representation of principal system temperature relationships

3.4.1.3 *Temperature differences.* The difference between the design flow and return temperatures determines the amount of heat that can be abstracted from a given mass flow. Many systems are designed for a nominal temperature difference of 11 °C, but greater temperature differences may be suitable as a design basis provided that all emitters are correspondingly rated, and necessary return temperatures are maintained at all times (see **3.4.1.4**). Heat emission of LTHW emitters is a function of the average temperature difference between the emitter surface and the space ambient (see Table B.1.4 of Section B.1 of the CIBSE Guide [1]).

Use of a greater flow/return temperature difference may result in capital cost savings if the effect of reduced pipe size is not outweighed by the extra cost of larger emitters. For a given size of pipe, mass flow and pumping power will be reduced by an increase in temperature difference. It can also assist the viability of LTHW thermal storage (see **3.3.6.6**).

3.4.1.4 *Return temperature.* Design return temperature is determined by flow temperature and temperature difference. Conventional (non-condensing) boilers require return temperature to be maintained above a certain level at all times to avoid flue gas condensation and possible corrosion on the gas side (typically 60 °C). Heat generating equipment may suffer excessive thermal stress if the difference between flow and return temperatures is greater than intended. Bivalent heating systems [see **3.1.4** (b)] in which a fuel-fired system provides supplementary heat at the same time as some other system operating at lower temperature (e.g. a heat pump) tend to need a low return temperature in order to share load between the two. Condensing boilers require relatively low return temperatures (typically below 60 °C, but it depends on type).

3.4.2 System configuration

3.4.2.1 *General.* Having established the basis of design, the general physical configuration of the system should be considered. Principal aspects are:

a) method of circulation (**3.4.2.2**);

b) subdivision of system (**3.4.2.3**);

c) piping configuration (**3.4.2.4**).

3.4.2.2 *Method of circulation*

3.4.2.2.1 *Gravity circulation.* Gravity or natural circulation operates by the buoyancy effect of heated water, without the assistance of a pump. Extensively used at one time, it is little used today for systems within the scope of this code, and is therefore not considered. For further information see older editions of the IHVE guide and heating textbooks (e.g. Faber and Kell, "The Heating and Air Conditioning of Buildings" [29]).

3.4.2.2.2 *Pumped circulation.* In the past the terms accelerated system and accelerator were used, rather than pumped system and pump.

3.4.2.3 *Subdivision of system.* Small or simple systems may consist of a single pumped circuit. Most systems tend to be subdivided in various ways to accommodate requirements such as:

a) different spatial zones within a large building or site (see **3.3.4**);

b) different aspect zones requiring individual control (see **2.3.1.6** and **3.8**);

c) different types of heat emitter (e.g. radiators and air heater batteries);

d) economy of pumping and manageable size of circuits;

e) maintenance of required minimum flow through boilers and minimum return temperatures (as recommended by the boiler manufacturers).

There are various methods of doing this, which often result in the use of a pumped primary circuit which operates in conjunction with a number of secondary subcircuits, each with a separate pump and controls (see **3.4.2.4**). In connection with c), use of radiators and other natural convectors on the same circuit should generally be avoided because of their different output characteristics (see **3.2.2** of BS 6880-2:1988). Where this is done, particular attention should be given to control and output characteristics.

3.4.2.4 *Piping configuration*

3.4.2.4.1 *One-pipe system.* In a one-pipe system, a single LTHW pipe loop (or several such loops in parallel) serves each emitter in turn. The available water temperature thus drops progressively around the system, so its field of application tends to be limited to systems smaller than covered by this code. See Figure 4 (a).

3.4.2.4.2 *Basic two-pipe system (direct return).* In a basic two-pipe system, two pipe loops are used together with the flow loop which supplies LTHW to the emitters and the return loop which receives LTHW from them (or several such pairs in parallel). This is the most common arrangement but there are many variants of this principle to suit particular applications. The layout is arranged so that the return takes a direct path back to the boiler. See Figure 4 (b).

***3.4.2.4.3** Two-pipe system variants*

3.4.2.4.3.1 *Reversed return system* [see Figure 4 (c)]. The reversed return system uses more piping but tends to give comparable pressure and temperature drops across each emitter with particular advantages for system balancing and pumping economy.

3.4.2.4.3.2 *Primary and secondary systems* [see Figure 4 (d)]. On larger systems it is often advantageous to create a primary pumped LTHW loop which distributes to secondary systems. Each secondary system has its own pump and controls. This simplifies balancing and control and leads to pumping energy economy. It is important to arrange the pipe connections so that the primary and secondary systems do not interact hydraulically (see CIBSE application manual) [30].

3.4.2.4.3.3 *Manifold systems* [see Figure 4 (e)]. The manifold system uses manifolds to serve a number of final subcircuits. It is extensively used in underfloor heating and can be applied to other systems. Care is required in accommodating the manifolds within the building and providing convenient access to them. It tends to be associated with the use of small diameter pipes and may result in relatively high pumping power and water transport factors (see CIBSE Building Energy Code) [2].

3.4.2.4.3.4 *Combined heating and cooling systems.* Whilst air conditioning is outside the scope of this code (see BS 5720), the space heating aspect of combined cooling and heating installations is generally within it. In these systems LTHW is usually distributed to terminal equipment on the two-pipe principle, but such systems tend to be described as two-pipe, three-pipe, or four-pipe, according to whether heating and cooling use separate pipe circuits (four-pipe) or shared circuits (two-and three-pipe).

Reversible unitary heat pumps use a LTHW circuit as a common heat source and sink, but such systems are outside the scope of this code since they are primarily intended for cooling.

3.4.2.5 *Concealment of piping.* The degree of piping concealment required within occupied areas needs to be considered at an early stage, in the context of practicability, cost, aesthetic and maintenance considerations, and particularly since it may influence emitter sizing (see **3.4.3.1**).

3.4.2.6 *Control arrangement.* It is important to ensure at an early stage that the proposed piping configuration and the required method of control are compatible with each other (see **3.8**, and Section B.11 of the CIBSE Guide [1]).

3.4.3 System sizing

3.4.3.1 *System thermal capacity.* The whole system should be arranged and sized so that the design heat loads in each part of the system can be met by an appropriate flow of LTHW within the applicable system temperature limits (see Section B.1 of the CIBSE Guide) [1]. The capacity of the total system should equal that of the individual parts of the system, subject to the following.

a) The capacity of each part of the system and of the whole should take account of all heat losses from pipework, equipment, etc. (Section B.1 of the CIBSE Guide [1] indicates methods of assessing and apportioning such losses.)

b) It may be permissible to reduce total system capacity by considerations of non-coincident demand or diversity in different parts of the building. This is a matter of experienced judgement and cannot apply unless the method of operation and the type of controls provided allow such diversity to be realised in practice.

Distribution piping should be thermally insulated (see **3.6**) except in places where heat loss from bare pipes appropriately located within occupied spaces is intended to make a calculated contribution to design heat emission.

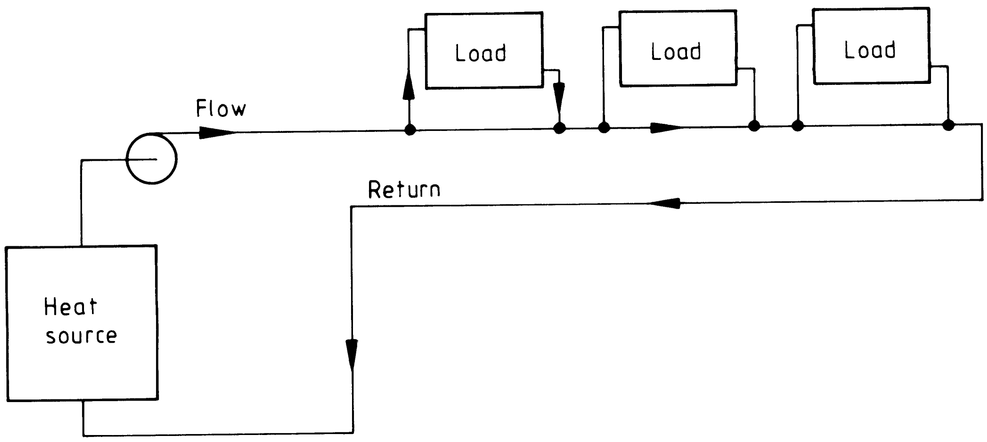
3.4.3.2 *Subdivision of the system.* Except for the smallest and simplest applications, LTHW heating systems usually need to be subdivided, having regard to:

a) the use of different emitter types to suit different occupancies within the building (e.g. radiators in some areas, heated ceilings or floors in others);

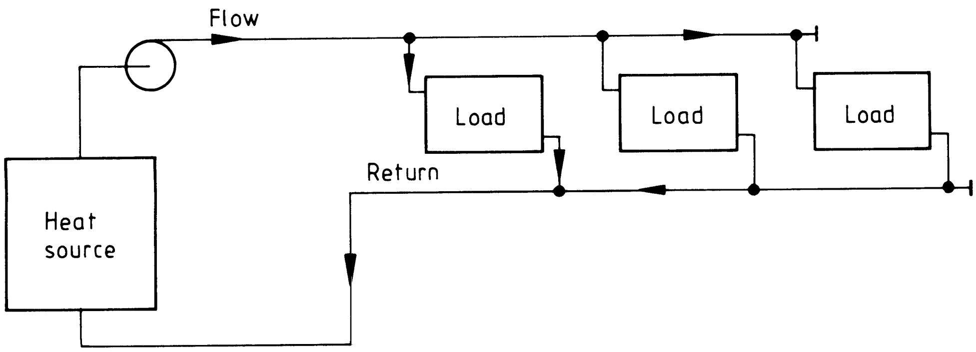
b) the mode of control required by different emitter types (e.g. constant temperature or variable temperature, see **3.8**);

c) zones of continuous and intermittent occupancy;

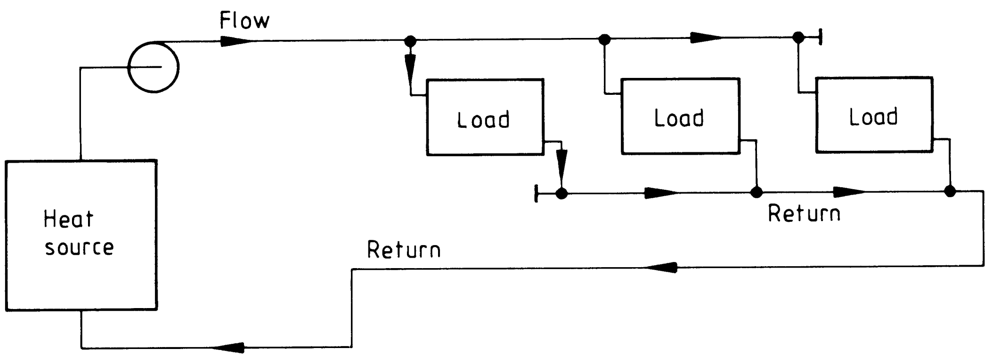
d) practical limitations, in terms of design, commissioning and operation, on the number of emitters on one circuit, which affects the size of pipes, pumps, control valves, etc.



(a) One-pipe system

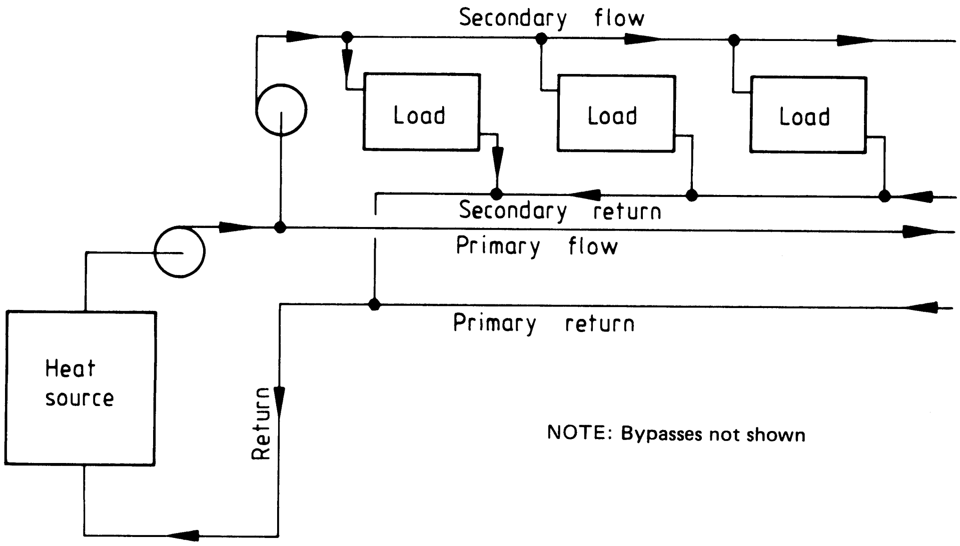


(b) Two-pipe system (direct return)

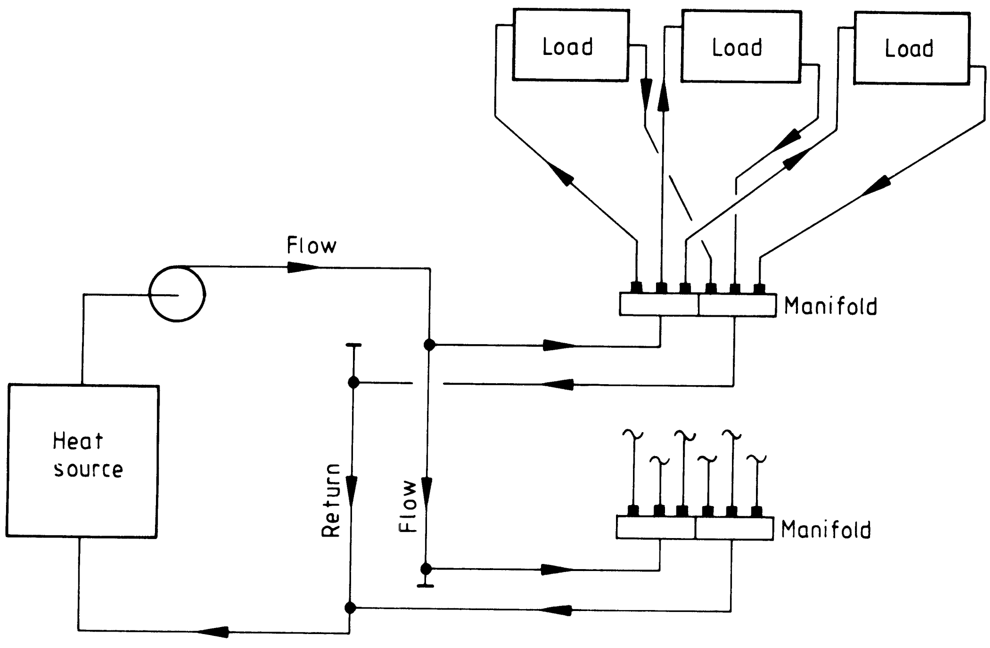


(c) Two-pipe system (reversed return)

Figure 4 — Principal circuit arrangements



(d) Pumped primary/pumped secondary system (direct return)



(e) Manifold system

Figure 4 — Principal circuit arrangements *(concluded)*

3.4.3.3 *System flow and resistance.* The thermal capacity of any section of the system is directly related to the mass of water flowing through it and its temperature drop. Having fixed the design temperature difference (see **3.4.1.3**) and determined the required flow, design judgement should be used to achieve an appropriate balance when sizing pipework, pumps and other system components, having regard to capital cost, operating cost and energy conservation, the possibility of noise and wear associated with excessive velocities and the problems resulting from air entrained at low water velocities (see **3.10**, and Section B.1 of the CIBSE Guide [1]). With pipework below 50 mm nominal bore, the restricted range of pipe sizes that is commercially available often makes it necessary to design for lower than the minimum recommended velocity; also oversized pipework may be installed to make provision for future extensions to the system. In these cases the pipework should be installed so as to encourage air bubbles to move by their own buoyancy, projections on the inner surfaces of the pipework should be avoided and metering devices should be installed at locations where air bubbles will not lodge at the inlet to the device and so distort the flow pattern. The concept of water transport factor explained in the CIBSE Building Energy Code [2] is a recommended basis for a satisfactory relationship between system resistance and pumping energy requirements.

For satisfactory system performance the required water flows should be established in all parts of the system. Ideally this should be achieved by system sizing, but in practice the introduction of valves or other appropriate means is necessary to enable the correct flows to be achieved when the system is commissioned (see Section 3 of BS 6880-3:1988).

The achievement of the required system flows is an important topic known as balancing and regulation and is covered extensively in the CIBSE Commissioning Code Series W [31] and the BSRIA "Manual for regulating water systems" [32] to which reference should be made, noting that in deciding the methods to be used a compromise has to be reached between accuracy, added system resistance and cost.

The following aspects of this topic should be noted in particular.

a) The method of checking system balance and total system flow to be used at the commissioning stage should be determined in principle by the designer and appropriate provision allowed for at the design stage.

b) Where flow measurement devices are used, the designer should state the required tolerances on system flows, taking account of the accuracy expected from the devices used.

c) Regulating valves, flow measurement devices and control valves are a source of system resistance which should be taken into account at the design stage.

d) For economy of pumping energy it is desirable to avoid supplying from a common pump subcircuits which have substantial differences in resistance.

The piping system should be designed so as to minimize resistance by minimizing changes of direction, using low resistance bends rather than elbows where practicable, at the same time allowing for the possibility of additional changes of direction proving necessary at installation stage. Adequate allowance should be made for all other components of system resistance, particularly emitters and control valves.

3.4.4 Pipework design

3.4.4.1 *General* (see also the CIBSE Guide [1]). Heating installations may include pipework for purposes other than for LTHW heating systems, the details of which are covered in more specialized publications. Types of pipework include the following.

a) *Refrigerant piping.* Heat pump installations include refrigerant piping. This is a specialized application and particular safety considerations apply (see BS 5720 and BS 4434-1).

b) *Fuel gas piping.* Particular safety considerations apply to fuel gas piping and various materials may be used (see **2.4.3**, CP 331-3, the Gas Safety (installation and use) Regulations 1984 and British Gas Publications in the IM series).

c) *Fuel oil piping.* Particular attention is required to leakage risks and soundness of joints in fuel oil piping (see **2.4.3**).

d) *Steam and condensate piping.* Whilst not part of the LTHW system, steam and condensate piping may arise in calorifier installations.

e) *Specialist systems.* Specialist systems include piping for the pneumatic handling of solid fuels and compressed air piping associated with pneumatic systems. (See British Coal series "Technical data on solid fuel plant" [20]).

3.4.4.2 *Pipework materials and engineering standards.* Various materials and system practices may be employed for LTHW and associated piping systems. Metal pipe, tube and associated fittings are covered extensively by British Standards.

It is particularly important that the piping, fittings, jointing techniques and related items used on any part of the installation should be mechanically compatible, suitable for the application and comply with the appropriate British Standards. Where innovative systems are considered for LTHW use and are not covered by appropriate British Standards, reference should be made to such certification as may have been issued by the British Board of Agrément and which relates to the specific product and application or, in its absence, by other recognized independent testing organizations. The pipework installation should be designed around a compatible system of pipework and fittings, taking due account of factors such as:

a) appropriate temperature and pressure ratings;

b) corrosion risks associated with use of dissimilar materials (see **3.5**);

c) method of connection to line-mounted equipment;

d) support requirements of pipework and line-mounted items;

e) mechanical protection requirements;

f) possible electrical continuity considerations (see **3.9**).

Substitution of one type of material for another should not be made except as a conscious design decision, having regard to the installation as a whole (see also **3.4.4.3**).

There being no other comprehensive code for building services the requirements of DOE Standard Specification (M&E) No. 3 [33] represent appropriate engineering standards and minimum quality requirements for LTHW and related pipework for a wide range of applications within the scope of this code.

3.4.4.3 *Plastics pipework.* Certain specific types of flexible plastics tube have been developed and are extensively used in connection with heated floor (embedded) systems (see **3.7** of BS 6880-2:1988).

If plastics pipework is considered for other aspects of LTHW piping, in the absence of appropriate British Standards, careful investigation of the particular application is called for, following the principles noted in **3.4.4.2**, and noting particular characteristics of the material concerned which may include the following.

a) Design stress/pressure relationship which is closely linked to operating temperature and age. 50 years is a generally accepted basis for comparative data in this respect. Implications of accidental system temperature excursions and proximity to higher temperature equipment should be taken into account.

b) Fundamentally different mechanical properties, with particular implications for support, bending and potential damage.

c) Coefficients of thermal expansion which can be several times those for steel pipe.

d) Actual bore sizes which are not identical to other types of pipe, hence friction data specific to the material should be used.

e) Although plastics do not corrode, they may permit diffusion of oxygen which contributes to corrosion of metal components (see **3.5**).

It is important that jointing and installation techniques closely follow the manufacturer's recommendations for the application, and that transition between plastics and metal elements are made with purpose-manufactured adaptors.

3.4.4.4 ***Pipework accessories***

3.4.4.4.1 *Isolating valves.* Isolating valves are normally fully shut or fully open and should be provided throughout the system to facilitate:

a) isolation of individual items of equipment, e.g. control valves and other accessories for inspection and/or maintenance;

b) subdivision of a system so that draining down can be achieved in convenient sections;

c) subdivision of a system in accordance with the needs of different occupancies.

Provision of isolating valves should be considered in conjunction with regulating valves, since certain types (such as double regulating valves) can perform both functions. However, it should be noted that some types of flow measurement valve are not suitable for isolation.

3.4.4.4.2 *Regulating valves.* Various types of regulating valves are available, some of which incorporate provision for isolation (see **3.4.4.4.1**).

3.4.4.4.3 *Flow measurement devices.* Various flow measurement devices are available based on the fixed-orifice or variable orifice principle, some of which are incorporated with isolating or regulating valves. The particular features of any such device need to be understood before selection, particularly the size and characteristics of the device in relation to its application, the location of the device within the system and the length of straight pipe required upstream and downstream of the device for accurate flow measurement (commonly 10 and 5 diameters respectively, but this is not a universal recommendation). It is important that a consistent system of pressure and temperature test points be used throughout the installation. See BSRIA "Manual for regulating water systems" [32].

3.4.4.4.4 *Radiator valves.* Radiator valves may be used for local manual control of radiators and other similar heating appliances. They may be either of the wheel or lock shield type, the latter being used for final balancing of flow through the heaters.

3.4.4.4.5 *Drain valves.* Emptying of circuits and items of plant should be provided by means of drain cocks or taps installed at low points and fitted with hose union connections.

3.4.4.4.6 *Air vents.* Air and other gases should not be allowed to accumulate in an LTHW system as they impede circulation and heat transfer, promote corrosion and impair the accuracy of flow measurement devices. Open vented systems should be arranged to be self-venting as far as possible. Where self-venting is not practicable, and with all sealed systems, air-venting should be arranged through automatic air vents with isolating valves and air bottles fitted at high points or by manual venting. Air vents are normally provided in radiators and some other types of emitter. Where manual venting of mains is used, an air bottle should be provided and the vent valve should be of the needle type, in an accessible location, having particular regard to safety in use (see also Figure 5 and **3.4.5.5.3**). Layout of pipework should be arranged to avoid airlocking.

3.4.4.4.7 *Provision for thermal expansion.* Provision should be made for the thermal expansion of pipework according to the extremes of temperature expected. Table 8 indicates the amount of expansion which may be expected on various types of pipe.

Table 8 — Thermal expansion characteristics of piping materials

Material	Approximate coefficient of linear expansion per °C	Approximate expansion of 10 m length over temperature difference of 80 °C
		mm
Steel	11×10^{-6}	9
Copper	17×10^{-6}	14
Typical plastics[a]	$70 - 180 \times 10^{-6}$	60 – 150

[a] Varies considerably according to type.

Expansion should preferably be taken up by flexibility inherent in the pipework arrangement. Where this is not practicable, expansion loops or bellows should be fitted with suitable pipe anchors and guides at an appropriate distance on each side. The anchors should be firmly fixed to a part of the structure capable of withstanding the thrust of the expanding pipe.

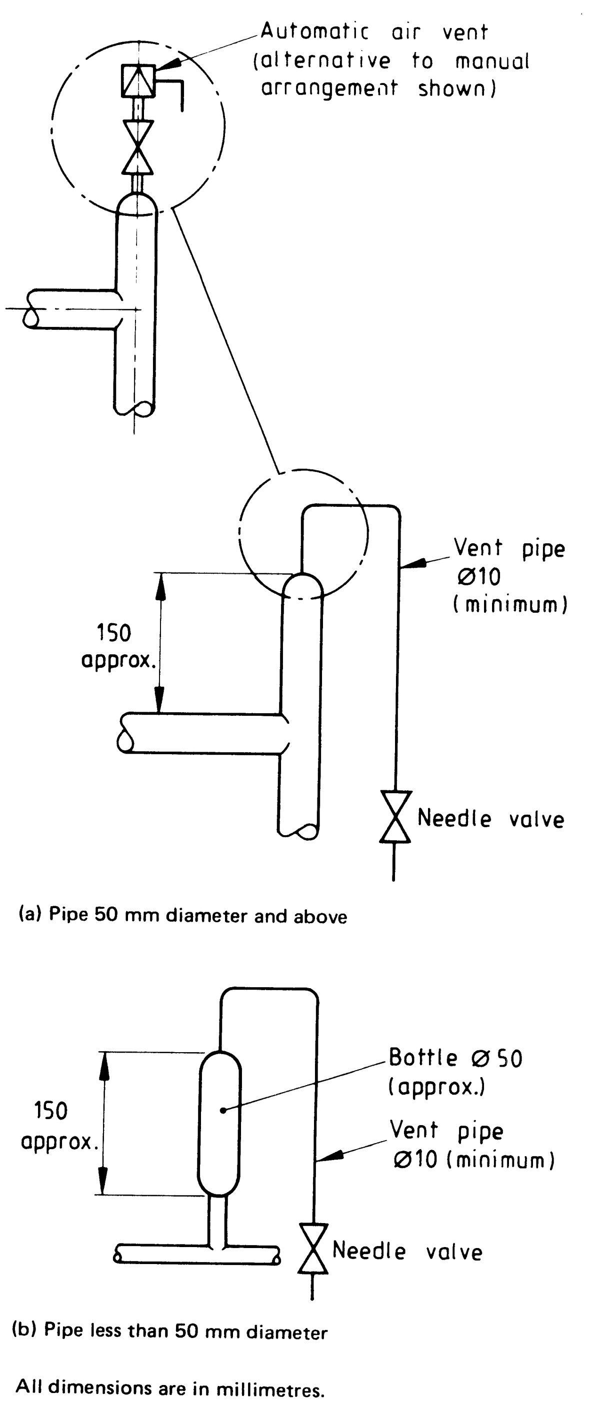


Figure 5 — Typical air vent arrangements

When selecting and fitting expansion bellows units the manufacturer's recommendations and those of BS 6129 should be followed and the appropriate guides and anchors provided. With both loops and bellows, pipe supports should be so arranged that movement of the pipework is unrestricted in the direction of expansion. Preferably expansion loops should be arranged horizontally; if this is not practical, venting or draining should be provided as appropriate.

Care should be taken when designing the pipework distribution system that branches from the main are sufficiently flexible to accommodate main expansion and that movement of the branch is not restricted by passing through walls, floors, etc. Where pipes subject to expansion pass through the building structure, properly designed sleeves should be provided. Where vertical mains are subject to expansion, consideration should be given to the need to provide spring-loaded supports at the top of the riser.

For further information on pipework flexibility and spacing of supports, refer to Section 16 of the CIBSE Guide [1].

3.4.4.5 *Pipework arrangement.* The design of pipework should assist the achievement of an orderly arrangement of neat appearance at the installation stage (see Section 2 of BS 6880-3:1988), particularly in areas exposed to view such as plant rooms. See also **3.11**.

3.4.5 Feed, expansion and pressurization

3.4.5.1 *General.* All LTHW systems require the following provisions for each separate circuit within the installation (i.e. circuits which are not interconnected):

a) feed of make-up water into the system where it is necessary to replenish water losses;

b) accommodation of the volumetric expansion and contraction of the system water over the full range of temperature from cold to maximum;

c) means of maintaining required system pressure.

These aspects are normally interrelated. Two principal methods of meeting these requirements are used:

1) open-vented systems (see **3.4.5.3**);

2) pressurized systems (see **3.4.5.4**).

It should be appreciated that all LTHW systems operate with water at a pressure in excess of atmospheric, and that the rise in pressure developed by circulating pumps is usually small in relation to the maximum pressure in the system.

In the case of tall buildings both types of system may need to be separated into vertical zones in order to limit the pressure on elements (emitters, valves, pipework, etc.) at lower parts of the system.

3.4.5.2 *System temperature and pressure.* Required minimum system pressure is closely related to maximum system temperature and should be such that boiling cannot occur in any part of the system. In practice this requires a safety margin below boiling point to allow safety controls to operate. The specific recommendations of HSE Guidance Note PM5 [3] in respect of hot water boilers should be followed in this regard noting that, inter alia, it calls for fuel supply to the boiler to be cut off if the flow temperature leaving the boiler approaches within 17 °C of the temperature of saturated steam corresponding to the pressure at the highest point in the system. It is recommended that the same principles should be applied to systems with heat sources other than boilers.

3.4.5.3 *Open-vented systems.* The three functions of feed, expansion and pressure regulation are performed by a feed and expansion tank located above the highest point of the system. System pressure is determined by the tank water level which is maintained by level control. Make-up water is fed by gravity to an appropriate point in the system by a cold-feed pipe solely for this purpose. Increase in system volume due to the thermal expansion of water is accommodated by the feed and expansion tank through the cold feed and expansion pipe. An open vent pipe connected to the highest point in the system (see Figure 6 (a) and Figure 6 (c) serves to expel air.

The size of feed and expansion tank should be related to the volume of water in the system, rather than to its heating capacity. Where future extension is envisaged, it is usually desirable to provide for this initially. Correct sizing of the cold feed, vent and overflow pipes is most important; Table B.1.20 of the CIBSE Guide [1] gives recommendations for these pipes (see also BS 6644). In respect of expansion tank capacity, this should be related to the system contents and maximum temperature range, such that the maximum expansion can be accommodated between the normal and overflow levels of the tank. For systems operating with flow temperatures of the order of 80 °C, it is recommended that this be not less than 5% of system contents.

Open systems are simple to operate and maintain, but have the disadvantage that the tank should be accommodated at a sufficient level above the highest point in the LTHW system such that the necessary pressurization can be achieved; this may call for a roof-top tank room. Also, an appropriate location for the tank may be remote from the heat generator, calling for a long cold feed pipe. Where these considerations make use of an open-vented system impractical, or when design system flow temperature exceeds 83 °C then a pressurized system is recommended.

3.4.5.4 *Pressurized systems.* In pressurized systems the functions of feed, expansion and pressurization are performed by mechanical equipment designed for the purpose, often as a proprietary unit (see Figure 6 (d). The same principles concerning the pressure and temperature relationship and the determination of expansion volume apply as with open-vented systems (see **3.4.5.3**), but the operating pressures also have to be established with reference to the particular type of pressurization equipment to be used and its control characteristics (see **4.4** of BS 6880-2:1988).

The principal advantage of a pressurized system is that equipment does not have to be located at a high point in the system. Location near to the heat generation plant is often desirable, to minimize pipe runs and for convenience for operation and maintenance.

Various types of equipment may be used for pressurized systems (see **4.4** of BS 6880-2:1988). These are classified in HSE Guidance Note PM5 [3] as follows, and the detailed safety measures required thereby should be incorporated as appropriate to the category of system:

Category B: closed pressurized systems with separate pressurizing vessels and provision for make-up of water.

Category C: sealed pressurized systems with separate pressurizing vessels and provision for make-up of water.

Category D: system pressurized by a feed pump and/or static head with provision for make-up water.

Sealed systems (category C) employ diaphragm vessel(s) to accommodate the full expansion volume.

3.4.5.5 ***System details***

3.4.5.5.1 *Water supply connection.* The feed system is normally the only point at which an LTHW system is connected to a water supply and the corresponding statutory requirements will apply (see **2.4.4.8**).

3.4.5.5.2 *Feed and expansion connections.* The cold feed pipe should not serve any other purpose. The positions of the cold feed and expansion connections in relation to heat generators and circulating pumps should be determined with regard to the hydraulic pressures expected at the relevant points around the circuit, and in particular to the relationship between pump head and system operating pressure.

Figure 6 (a) shows an arrangement with the pump in the return pipe and the feed connection close to the pump suction. In this case the pump head h is added to the static head H of the system (reckoned at the point of feed connection), and there is a danger of water being discharged out of the open vent unless it is arranged so that the height y is well in excess of the pump head h.

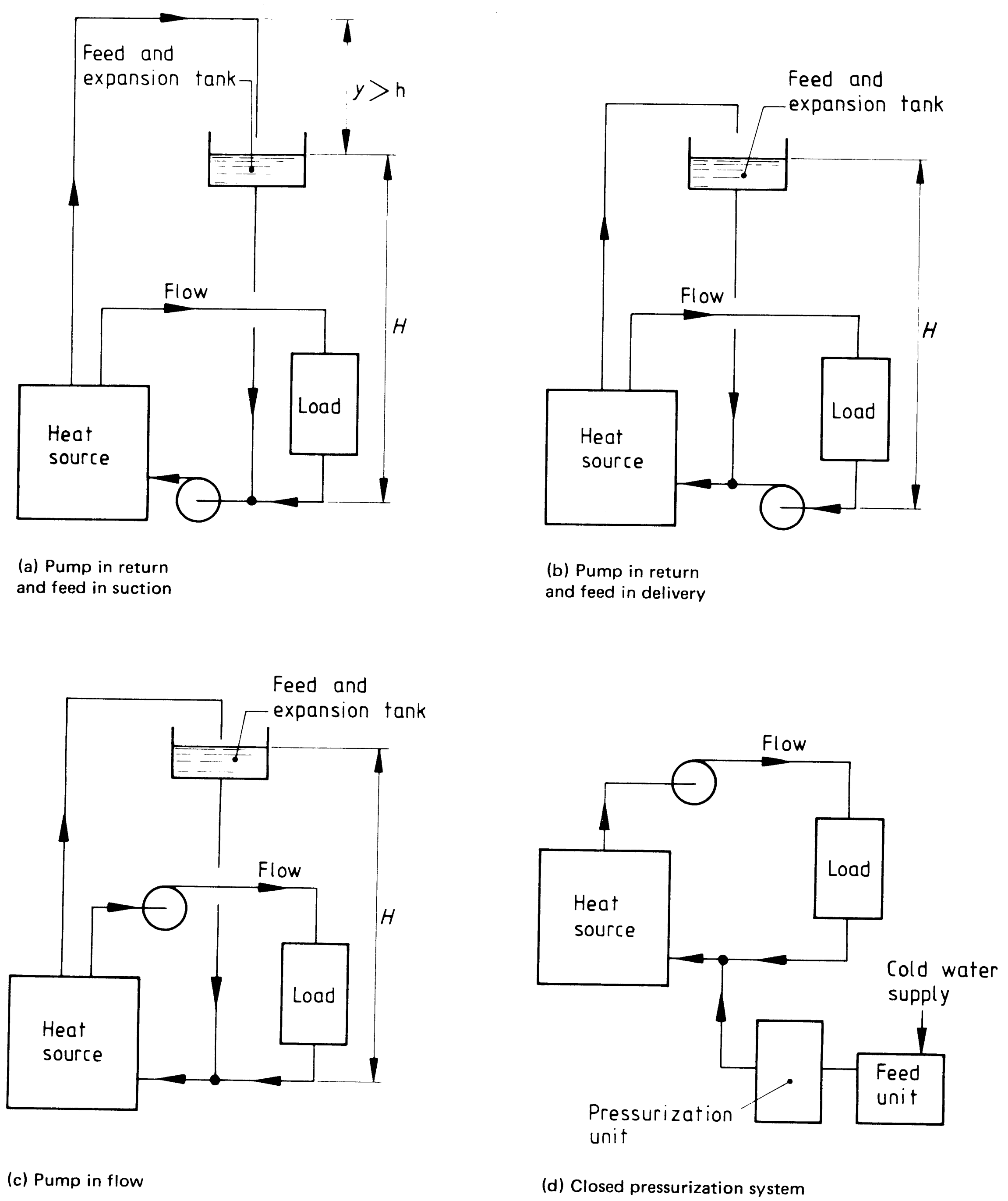
Figure 6 (b) shows an arrangement with the pump in the return pipe and the feed connection on the delivery side of the pump. In this case the pump head h is subtracted from the static head H, but pressures less than atmospheric may develop in high parts of the system causing aeration through open vent pipes, valve glands, etc.

Figure 6 (c) shows an arrangement which is commonly preferred, where the pump is in the flow pipe and the feed connection in the return. The pump head is added to the static head but there is no risk of discharging through the vent if it is connected on the suction side of the pump. The pump should be suitable for the maximum flow temperature and static head at pump suction should be adequate to prevent cavitation.

Figure 6 (d) shows a typical arrangement for a closed system using a pressurization unit, without intermediate vessel (see **4.4** of BS 6880-2:1988).

It should be appreciated that with any of these arrangements the feed connection is a point of substantially constant pressure, whereas elsewhere in the system the pressure will vary according to whether the pump is running or not. Where a separate primary circuit serves the boilers, it is usually found that the most suitable location for the primary pump is in the return.

The feed and expansion pipes should remain open to the system at all times and precautions should be taken to prevent freezing. The cold feed should be arranged such that it cannot be isolated from the heater, and where multiple heaters are used which can be individually isolated from the LTHW system, the feed and expansion pipes should be connected to the heater side of the return valve on each heater.



h is the pump head
H is the static head
y is the height of vent above the static head

Figure 6 — Pump and feed location

3.4.5.5.3 *Air venting.* A vent should be provided at all points at which air is likely to accumulate (see **3.4.4.4.6**). On open systems the vent may consist of an open pipe discharging at a point above the feed and expansion tank [see Figure 6 (a)], the vent being sufficiently high to avoid discharge of water under all normal conditions of service. On closed systems an air purger should be fitted. Allowance should be made for differences between water level in the vent pipe and that in the feed and expansion tank due to temperature and circulating pump head. The cold feed pipe should not be used as a vent. For recommended pipe sizes see Table B.1.20 of the CIBSE Guide [1]. (See also BS 6644.)

Each heat generator on an open system should be provided with a safety vent. This may also be the open vent for the system provided that it is not separated by an isolating valve from the highest point of the system and that the pipework rises continuously to that point. On multiple installations separate safety vents may be provided for each heat generator. If it is decided to utilize a common vent pipe, each heater should be connected to the vent via a three-way cock, so arranged that if the heater is isolated from the common vent, the third port is open to atmosphere (see Figure 7).

On pressurized systems a relief valve should be fitted to the heat generator together with the other safety features required by HSE Guidance Note PM5 [3]. (See also **2.4.4.4**.)

3.4.6 Utilization subsystem

The utilization subsystem consists of the heat emitters connected to the distribution system, which are covered in BS 6880-2.

3.4.7 Working pressures

Every element of the distribution subsystem, and those elements of emitters and energy conservation systems which contain LTHW, should have a pressure rating under the conditions of the application which is in excess of the maximum pressure expected in the LTHW circuit and compatible with the proposed system test pressure. Care should be taken in equipment selection since the standard pressure rating categories differ between different equipment types (e.g. pumps, boilers, calorifiers).

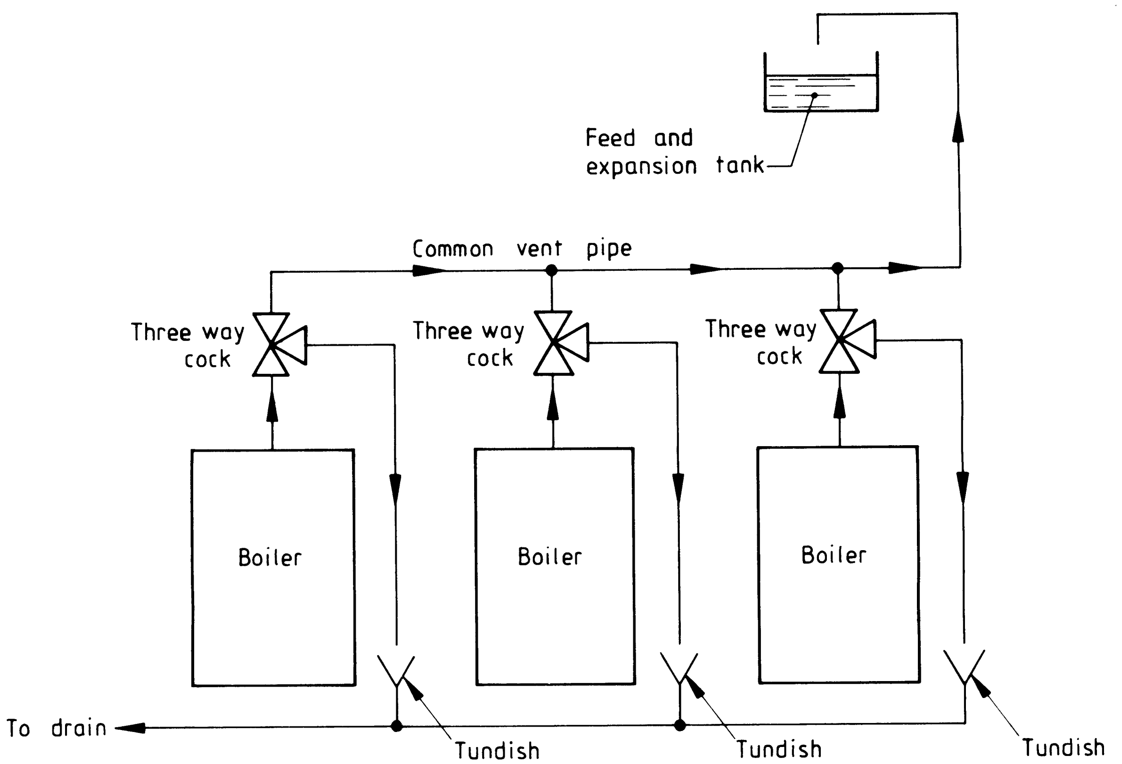


Figure 7 — Vent arrangement for multiple boilers

3.5 Corrosion control and water treatment

3.5.1 Corrosion processes

3.5.1.1 *General.* Corrosion of metals is the destruction of a metal or alloy by chemical or electrochemical reaction with its environment. In most cases this reaction is electrochemical causing eating away of a metal at the anodic areas and the formation of hydrogen at the cathodic areas.

The hydrogen may:

a) accumulate so as to coat the surface and slow down the reaction;

b) form bubbles and be swept away from the surface thus allowing the reaction to proceed;

c) react with the oxygen in the electrolyte to form water.

In addition, microbiological corrosion can occur owing to the presence of organic matter in the water and, in systems devoid of oxygen, sulphate-reducing bacteria can become active. Such bacteria are a common cause of corrosion of buried iron or steel structures found especially in water-logged clay soils; they are active in the pH range 6 to 8 and the corrosion that takes place can generally be identified by the presence of iron sulphide and often hydrogen sulphide.

3.5.1.2 *Metals in air.* An electrolyte (e.g. moisture) has to be present on a metal surface for corrosion to occur; no corrosion occurs in dry air.

However, natural atmospheres contain water vapour and, although practically no corrosion of iron takes place in pure air at 99 % r.h., with contaminants such as sulphur dioxide or solid particles of carbon present, corrosion will proceed as long as the metal remains wet.

3.5.1.3 *Metals in water.* The contaminants present in raw water form mineral acids that tend to accelerate the corrosion rate of ferrous materials. This will be influenced by pH value, temperature, hardness and oxygen aeration of the water. Further information on the mechanism of corrosion processes is given in Section B.7 of the CIBSE Guide [1].

3.5.2 Water system problems

3.5.2.1 *Corrosion.* The effects of water on metals will be accelerated in systems where dissimilar metals, e.g. copper and galvanized steel, are in contact. Copper alone can be immune to corrosion by virtue of the formation of an oxide film, which reduces the rate at which corrosion takes place. Water of pH 7 and below can however destroy the oxide film and cause copper to dissolve.

3.5.2.2 *Scale formation.* The main cause of scale formation is the calcium carbonate in the water. On removal or partial removal of the combined or associated carbon dioxide, calcium carbonate will precipitate as scale on system surfaces or settle out as sludge particles. The tendency to form scale depends on several interrelated factors which include temperature, pH, dissolved solids, calcium and other substances. It can be predicted, if water analysis is known, using the Langelier and other indices; treatment requirements can then be determined. Scale formation in LTHW systems can be minimized by attention to elimination of water loss, and use of appropriate water treatment. However, even small quantities can cause trouble with the moving parts of control valves, and also with tubular heat transfer elements in boilers and heat exchangers where it can lead to a significant reduction in output.

3.5.2.3 *Presence of air.* Since air is a major contributing factor to the corrosion process, provision for its elimination from water circuits is important for the control of corrosion. There are of course other reasons for the elimination of air from heating systems (see **3.4.4.4.6**). It is important to avoid inwards leakage of air as far as possible, but it will always tend to be absorbed at the water surface in an open feed tank.

In systems (such as underfloor heating) where plastics pipe is used, oxygen diffusion may take place, thus contributing to corrosion of metal elements of the system.

3.5.3 Selection of materials and corrosion protection

3.5.3.1 *General.* When selecting materials for construction it is necessary to consider the corrosion resistance to the service environment, the nature of the corrosion products that may be formed and their effects upon the functioning of the equipment, the suitability of the materials for fabrication and the possibility of local corrosion arising from details of design or construction. The overall economic balance during the projected life of the equipment should also be considered, since more expensive corrosion resistant material may be cheaper in the long run by avoiding the need for regular painting or other corrosion control measures. Ferrous materials are widely used. The less corrosion resistant forms may be protected in various ways including galvanizing, zinc or aluminium spray, cadmium plating, plastics dip coating and painting, but in LTHW heating applications these are not normally suitable for protection of ferrous material where it is in contact with the system water.

Copper is used for system pipework, usually on smaller systems; also for heating coil tubing. Copper base alloys are extensively used for valves, and calorifier tubes and other system components. Where aluminium is in contact with the system water, as may arise with the use of cast aluminium radiators and aluminium components in certain types of boilers, particular care and specialist advice in respect of water treatment is called for. Where the system is primarily of ferrous construction, there is a tendency to operate at relatively high pH (alkaline), but such conditions may be injurious to aluminium. A compromise treatment therefore needs to be established. Ferrous transition pieces should be fitted between aluminium and cuprous components in contact with system water. Aluminium is also used for heating coil fins. Where outside air flows over system components such as heater batteries, the possible adverse effects of atmospheric pollutants, etc. should be considered; marine atmospheres tend to be injurious to aluminium.

3.5.3.2 *Electrolytic action.* Because of the risk of electrolytic action where dissimilar metals are in contact in the presence of water, this situation should be minimized. Although it is desirable to avoid it altogether, practical and economic considerations may prevent this, and the following considerations should be borne in mind.

a) Small elements of less noble metal which are in contact with substantially larger amounts of more noble metal are particularly prone to electrolytic corrosion (see Section B.7 of the CIBSE Guide [1]).

b) The introduction of an electrical insulating medium between the dissimilar metals will reduce the electrolytic effect but the corresponding reduction of electrical continuity may have other undesirable consequences (see **3.9** and the lEE Regulations [21]).

Electrolytic action can also be reduced by inserting a metal of intermediate potential difference between metals giving a high potential difference. Where plastics materials are used the problem of corrosion does not arise but some form of ageing or a decrease in ductility may occur.

3.5.3.3 *Piping systems.* Corrosion will be reduced by selecting metals that are compatible in the galvanic series (i.e. the potential difference does not exceed 0.3 V). It can also be suppressed by providing a protective film or coating (e.g. protective paint) on the metal, by the use of a chemical inhibitor or by the application of cathodic protection (see **3.5.3.4**, **3.5.4.1** and Table B.7.5 of the CIBSE Guide [1]).

Places in the system where there is no water flow, i.e. deadlegs, should be avoided as they can promote the accumulation of substances which promote corrosion. Excessive water velocities and sharp changes of direction tend to introduce erosion as well as corrosion, to which copper-based metals are particularly vulnerable.

Feed and expansion tanks made of steel are particularly vulnerable to corrosion and where used should be suitably protected.

3.5.3.4 *External piping.* Whilst piping corrosion problems in LTHW systems are mainly associated with the inside surface of the piping, particular care is required to ensure the protection of pipework run externally in the ground or in ducts. Various techniques are available which include proprietary sheathed piping systems, wrapping techniques and cathodic protection (see also BS 4508).

Cathodic protection is a method of arresting corrosion between dissimilar metals by the production of a neutralizing electric current to oppose that produced by galvanic action.

Where protection is achieved by use of a protective coating or wrapping, great care in application and inspection is essential, as small unprotected areas are extremely vulnerable. The likelihood of ground water or water from other sources entering below ground ducts and penetrating thermal insulation should be recognized. Stray electric currents induced in buried pipework by magnetic fields associated with power cables, etc. can also contribute to corrosion.

3.5.3.5 *Boilers and heat exchangers.* Whilst the general considerations in **3.5.3.1** to **3.5.3.4** apply to boilers, it is important to be aware of the material which is in contact with the system water, such as cast iron, mild steel, etc. It is advisable to consult manufacturers of boilers and other heat transfer equipment as to the sensitivity of their equipment to the effects of corrosion, scale and sludge formation and preferred system water conditions. This is important with the introduction of modular boilers, condensing boilers and the continuing development of design in this field. In particular the implications of water passages of smaller cross section than in traditional practice should be indicated and appreciated. Corrosion prevention is important to obtaining satisfactory life of boilers. Condensation and resulting corrosion tend to occur when boilers are started from cold. The duration and frequency of this should be reduced by maintaining minimum system return temperatures, careful sizing of boilers and selection of minimum firing rates to avoid condensation. On multiple boiler installations consideration should be given to keeping warm the next boiler in sequence and minimizing air flow through boilers not on-line. There are particular implications for boiler flues (see **3.5.3.6**).

3.5.3.6 *Flues.* Flues of normal grade steels are particularly prone to corrosion arising from the formation of sulphuric acid in the products of combustion when they are cooled to temperatures in the region of 120 °C to 200 °C. This can be alleviated by material selection, and by maintaining the flue gas temperature above the critical temperature range by insulation and other means. However, the trend towards higher boiler efficiencies and the use of condensing boilers makes this aspect particularly important. Provision of condensate drainage and access to the bottom of flues are important. Similar considerations apply whenever recovery of heat from boiler flues is being considered, whether on new or existing installations.

Some systems (e.g. spray recuperators) use the principle of heating water by direct contact with flue gas, such that the water tends to become acidic and may pick up other impurities. Such water should not be circulated through the LTHW heating system, and an appropriate water to water heat exchanger should be introduced. Particular care should be taken with the selection of materials for the recuperation circuit in view of the corrosive conditions.

3.5.4 Water treatment method

3.5.4.1 *Corrosion prevention.* Particular treatment will depend on the materials and water properties. In selecting the best treatment to use, a water analysis is essential. Chemical inhibitors are classed as anodic, cathodic or mixed. The anodic type, such as chromates and nitrates, stop corrosion at the anode by forming an insulating and invisible film of anodic product. Cathodic inhibitors, such as salts of magnesium, zinc and nickel, reduce cathodic reaction by producing a visible coating on the metal and restricting the access of oxygen. It is important to maintain the correct content of inhibitor in the water to avoid localized and intensive corrosion such as would occur if a large cathodic area were to be combined with a small anodic area. Chemical inhibitors are generally only applicable to closed systems where the make-up is small and measurable. Such inhibitors should not be introduced into a system until the required precommissioning cleaning has been carried out (see **3.3** of BS 6880-3:1988). In some cases it may be possible to achieve adequate protection by pH correction alone; this depends on water quality.

It is also important to check periodically and maintain the required concentration of inhibitors, particularly at times when the system is likely to be drained down for some reason. System pH should be maintained within the limits recommended by the specialist supplier of the inhibitors for the particular application and water conditions; generally this will be well on the alkaline side of neutral. Special considerations apply to electrode boilers (consult manufacturer).

Different chemical inhibitors should never be mixed, and complete draining and flushing should take place before introducing a different inhibitor, and any necessary changes in system operating practice ascertained.

3.5.4.2 *Scale and sludge prevention.* Filling and replenishment of the system should use water of an appropriate quality; this may call for initial filling with suitably treated water. It should not be assumed, even with sealed systems, that loss of system water is so negligible that the quality of make-up does not matter. Also, should any loss of water occur by evaporation, this contributes to concentration of total dissolved solids.

3.5.4.3 *Safety aspects.* Water treatment chemicals can be hazardous to handle and appropriate safety precautions should be observed. Attention is also drawn to the requirements under water use legislation (see **2.4.1**) concerning prevention of contamination of potable water supplies by system water.

NOTE Aspects of corrosion control and water treatment which apply specifically to air conditioning systems, cooling systems, etc. are covered in BS 5720.

3.6 Thermal insulation

All system pipework, flanges, valves and other components which are not intended to emit useful heat, should be thermally insulated to an appropriate standard. For the standard of insulation in thermal terms the minimum requirements of the Building Regulations (Part L) apply. BS 5422 is recommended as an appropriate standard, but the standard for a given installation should also take account of the particular economic and energy conservation factors applicable (see CIBSE Building Energy Code) [2]. BS 5422 outlines methods for the determination of economic insulation thicknesses (see also Department of Energy Fuel Efficiency Booklet No. 8 [34]). Particular attention should also be paid to the insulation of heated oil tanks (see **3.3.3.2** and BS 799) heat generators, LTHW tanks and vessels, where excessive heat release into plant rooms may arise (see **3.7**). Higher standards than indicated in terms of energy conservation economics may be necessary. Insulation may also be necessary to prevent freezing of vulnerable parts of the system and to avoid danger of touching hot surfaces (see **2.4.4.1**). Principal valves should be insulated with removable boxes or similar covers. Mountings on boilers and vessels should be kept free of insulation and bolted ends on vessels or chests should have provision for easy removal.

The selection of suitable thermal insulating materials requires that consideration be given to their physical characteristics as follows.

a) Certain insulating materials are combustible or may, in a fire, produce appreciable quantities of smoke and noxious and toxic fumes.

b) Materials and their finishes should inherently be proof against rotting, mould and fungal growth and attack by vermin, and should be non-hygroscopic.

c) Materials should not give rise to objectionable odour at the temperature at which they are to be used.

d) The materials should not cause a known hazard to health during application, while in use, or on removal, either from particulate matter or from toxic fumes.

e) A low thermal conductivity should obtain throughout the entire working temperature range.

Steps should be taken to ensure that insulation is kept dry at all times as dampness causes a considerable reduction in efficiency. External pipework and pipework in trenches which may be subject to dampness should be properly waterproofed and sealed with appropriate materials. The covering on external pipework should not deteriorate significantly with age or due to solar exposure. Where insulation is likely to be damaged it should be protected after application with metal or other appropriate casing. No insulation should be applied before pipework has been tested.

Further detailed information on the properties, selection and use of thermal insulation materials is contained in the Building Regulations (Part L), the Asbestos Regulations 1969, the Health and Safety at Work, etc. Act 1974, BS 5970, BS 5422, BS 4508, and CP 3009.

3.7 Plant room ventilation

It is important to ensure that adequate quantities of combustion air can enter boiler rooms at all times to meet the maximum firing rate of the equipment when using any of the intended fuels. Preferably this should be achieved by natural means by the provision of adequate combustion air openings, usually in the form of grilles (see BS 6644); where mechanical ventilation is necessary, means of avoiding a dangerous situation in the event of failure should be provided, by duplicate plant, burner interlocks or other suitable means.

Boiler rooms and other plant rooms should be ventilated so as to provide satisfactory ambient conditions for operating personnel; a maximum temperature of 27 °C is recommended. It is also necessary to ensure that the ambient temperature on which the ratings of electrical or other equipment is based are not exceeded in normal operation. Detailed guidance on combustion and ventilation air is given in CIBSE Practice Note No. 2 [15] and in BS 6644 with respect to gas fired boilers.

Provision may be necessary to prevent undue heat transmission to adjacent spaces. It should be appreciated that thermal insulation standards for hot equipment, vessels, etc. that derive from building regulations requirements and economic criteria may not be adequate in terms of heat emission into plant spaces. Consideration should be given to the probable effect of adverse weather conditions such as frost, particularly when the system is not in operation, and appropriate measures incorporated. Exposed mains pipework and fresh air heater batteries may be particularly at risk in this regard (see **3.2.2.2**).

3.8 Automatic controls

3.8.1 References

Instrument and controls terminology is covered in BS 1523 and BS 5233. For further information see Section B.11 of the CIBSE Guide [1] and Section 9 of the PSA Engineering Guide, [28].

3.8.2 Types of control

3.8.2.1 *General.* Heating controls can generally be divided into time controls (**3.8.2.2**), temperature controls (**3.8.2.3**) and safety controls (**3.8.2.4**). Important requirements for various aspects of heating system controls are laid down in the Building Regulations 1976, Part Q.
(See also **3.3.4.3**.)

3.8.2.2 *Time controls.* Time controls start and stop the complete system or parts of the system with respect to occupancy and building preheat periods. They may be in the form of timeswitches with preset start/stop periods or optimizers which give a variable start time and normally a fixed stop time. Such time controls may be overridden in the event of low ambient or space temperatures for frost and condensation protection. Time controllers should preferably be fitted with reserve power operation in the form of batteries or spring reserve to cover periods of power failure.

3.8.2.3 *Temperature controls.* Temperature controls can generally be divided into three areas; the energy conversion system, the distribution system and internal temperature control for individual emitters or subcircuits. Temperature controls for the normal functioning of any part of a system may be supplemented by additional controls to override the normal control functions for safety reasons (see **3.8.2.4**).

3.8.2.4 *Safety controls.* Safety controls are supplementary to the time and temperature controls which govern normal operation and should be such as may be necessary to limit the development of hazardous situations due to system or equipment malfunction, maloperation or unforeseen conditions.

Such hazards include:

a) excessive LTHW system temperatures and pressures;

b) excessive temperatures and pressures that may arise in equipment associated with the LTHW system;

c) fire, explosion and smoke;

d) excessive emission of pollutants;

e) frost effects.

Certain safety controls are a statutory requirement, others are considered necessary and recommended by the code, either directly or by cross reference in the clauses dealing with statutory and safety aspects. Particular attention is drawn to the Gas Safety (Installation and Use) Regulations 1984, HSE Guidance Note PM5 [3], British Gas Publications in the IM Series, BS 799, BS 5410, BS 5885, BS 5978, and BS 6644.

There may be an insurer interest in certain aspects.

3.8.3 Design considerations

3.8.3.1 *General.* Important aspects of system control are outlined in **3.8.3.2** to **3.8.3.4**. The division into subsystems (energy conversion, distribution, etc.) is used to assist presentation. However, although many control functions relate to one of these subsystems, an overall control strategy needs to be developed that is suited to achieving the desired space conditions efficiently and with the necessary degree of accuracy for the application, it should also have regard to the expected occupancy pattern. Appropriate and compatible controls should be arranged for the various system elements, taking account of the type of operating staff expected. It is also important that all aspects of system design are compatible with the intended method of control, particularly piping and valve arrangements and equipment selection. Further guidance on controls can be found in the references quoted in **3.8.1**. In connection with ducted air heating systems, refer also to BS 5720.

3.8.3.2 ***Energy conversion subsystem***

3.8.3.2.1 *Safety controls.* Safety controls are important for all sources of energy and related system ancillaries such as pressurization equipment. In the case of boilers these should comply with HSE Guidance Note PM5 [3]; for other types of energy conversion the same principles should be considered and applied as relevant, together with such additional controls as the particular equipment may require. In respect of refrigeration equipment (e.g. heat pumps) the provisions of BS 4434-1 should be followed.

Where solid fuel-fired boilers require to be kept alight during periods of no heat demand, consideration should be given to the dissipation of surplus heat output.

3.8.3.2.2 *Multiple boiler control*

3.8.3.2.2.1 *General.* Installations with more than one boiler require particular care at the system design stage, in terms of the circuit arrangement, its hydraulic implications (see **3.3.4.3**) and the type of control used. The basic factors which determine control system requirements are set out in **3.3.4.3**.

Typical arrangements for multiple boilers are shown in Figure 8 (a), Figure 8 (b) and Figure 8 (c) but drawn with only two boilers. In deciding which arrangement to use it is important to be aware of the particular control characteristics inherent in each (see **3.8.3.2.2.2** and **3.8.3.2.2.3** following, also **3.3.4.3.8**).

Where flow temperature dilution occurs special care should be taken in selecting the system design flow water temperature, to allow the temperature of water leaving boilers that are firing to be elevated and remain within the requirements of HSE Guidance Note PM5 [3]. Any wrong selection of design flow temperatures or setting of thermostats can easily result in boiler cycling, defeating the object of sequence control.

It should be remembered that the purpose of HSE Guidance Note PM5 [3] is the prevention of the generation of steam at any point in a system, by ensuring that the highest temperature that occurs anywhere, including the boiler, is lower than the saturation temperature corresponding to the lowest pressure at any point in the system. The margins are intended to allow for the thermal time lags of the sensors.

3.8.3.2.2.2 *Return temperature control*. Where the boiler primary circuit flow is substantially constant the number of boilers producing heat, i.e. on line, can be controlled with respect to the return temperature. The burner firing should be controlled by the individual boiler control thermostat, set to comply with HSE Guidance Note PM5 [3]. The lead boiler should be on line with no influence from the sequence control system, which will bring other boilers on line with a reduction in return temperature. Therefore for a two boiler installation a single thermostat can be used to bring on the lag boiler. The thermostat should, however, have a switching differential of 2 °C to 3 °C.

Control from return temperature via a proportional controller and step controller should preferably ensure at least 2 °C temperature difference between sequenced boiler starts.

The temperature sensor for return temperature control should be in the common return to the boilers.

3.8.3.2.2.3 *Flow temperature control.* This may be used with both constant or variable flow primary circuits. Since it controls the actual system flow temperature, compensation can be applied (where appropriate). Proportional plus integral control should be used so that offset is eliminated (see **6.2.2** of BS 6880-2:1988). To assist stable control, adjustable integral action time and time delays may be necessary. This arrangement requires very careful setting up to provide stable control.

The maximum flow temperature that can be set should be less than the minimum flow temperature from an individual boiler. The minimum flow temperature from an individual boiler is the control thermostat setting less the switching differential with an additional small margin. (Individual boiler control thermostats should be retained to comply with HSE Guidance Note PM5 [3].)

Where flow temperature dilution occurs (see **3.3.4.3.8**) the flow temperature should either be set to the lowest flow temperature available when one boiler is on line, or compensated such that when anything other than the maximum number of boilers is required for heating the desired flow temperature is reduced. This problem requires very careful consideration and any wrong settings can easily result in all boilers being on line at all times, completely defeating the object of sequence control.

The temperature sensor for flow temperature control should be in the common flow from the boilers.

3.8.3.2.2.4 *Control of burners.* Burners whether on/off, high/low/off (see **5.1.4.3** of BS 6880-2:1988) or modulating should be controlled by the individual boiler control thermostat (or sensor/controller in the case of modulating burners) in order to comply with HSE Guidance Note PM5 [3].

NOTE HSE Guidance Note PM5 [3] implies that a control thermostat/sensor is required in addition to the safety thermostats on each boiler if there is any possibility of the self-resetting safety thermostat operating during normal boiler usage.

3.8.3.2.3 *Other operating controls.* Careful consideration should be given to the integration of heat generation equipment controls with those of the overall system (see **3.8.3.3**, **3.8.3.4**, **3.8.4** and **3.8.5**). Boilers are normally provided with integral control systems and as single installations may not require additional controls. Control of multiple boilers needs to be arranged according to the most efficient method of meeting the expected load variations appropriate to the type of combustion equipment and size of installation; this topic is closely related to the sizing of individual boilers in a multiple boiler installation (see also **3.3.4.3**).

Heat pumps are often provided with an integral control system. If the heat pump is the sole heat source, these controls should be self-sufficient, but where other heat sources are also utilized an overall control strategy is necessary (see **3.3.6**). This may require the heat pump to be interlocked with the other heat sources, dependent upon the system configuration.

Time control of the heating system of a building or parts of a heating system is dependent upon the size of the system and the usage of the building. The objective should be to provide heating for the minimum amount of time consistent with the occupancy pattern of the building (see **3.8.4**).

Water flow through boilers can, in principle, be on the basis of substantially constant flow or variable volume flow. Constant volume flow boiler installations are generally recommended to ensure that the manufacturer's minimum flow rates are maintained and to improve the temperature control stability and hydraulic stability for the boiler and associated system. Boiler primary pumps with separate system pumps are normally the best way of achieving this.

For multiple boiler installations the effect of flow through (or bypassing) off-line boiler, and of mixing with the flow through the on-line boilers should be considered and appropriate arrangements adopted. (See **3.3.4.3**.)

On very large installations, the pumping energy economies that can be achieved with a variable flow system may be sufficient to warrant consideration of this arrangement. However, the whole system needs to be designed for this purpose, including the controls for the distribution and emission subsystems, which tend to differ from those appropriate to constant volume practice. The hydraulic design of the system tends to be more complex and calls for particular attention to system stability at reduced flow, determination of the appropriate minimum flow rate and the method of achieving variable volume flow at the pumps such that stable operation is ensured and the intended energy savings can be achieved in operation.

Special control considerations arise in heat recovery situations where source availability and system heat requirement do not coincide, and where thermal storage is used. The controls need to be fully compatible with the intended mode of operation, should take account of relatively small temperature differences between different parts of the system and respond to short term variations and changes of operating mode over the working day and longer term trends over the operating season (see **3.3.6**).

3.8.3.3 *Distribution subsystem controls.* The temperature control requirements of the distribution system are primarily determined by the needs of the heat emitters which, in turn, derive from the temperature and time-related requirements of the individual spaces served (see **3.8.3.1**). However, there are important relationships between system temperatures, type of energy conversion equipment and method of system pressurization of system pressurization (see Figure 3 and HSE Guidance Note PM5 [3]).

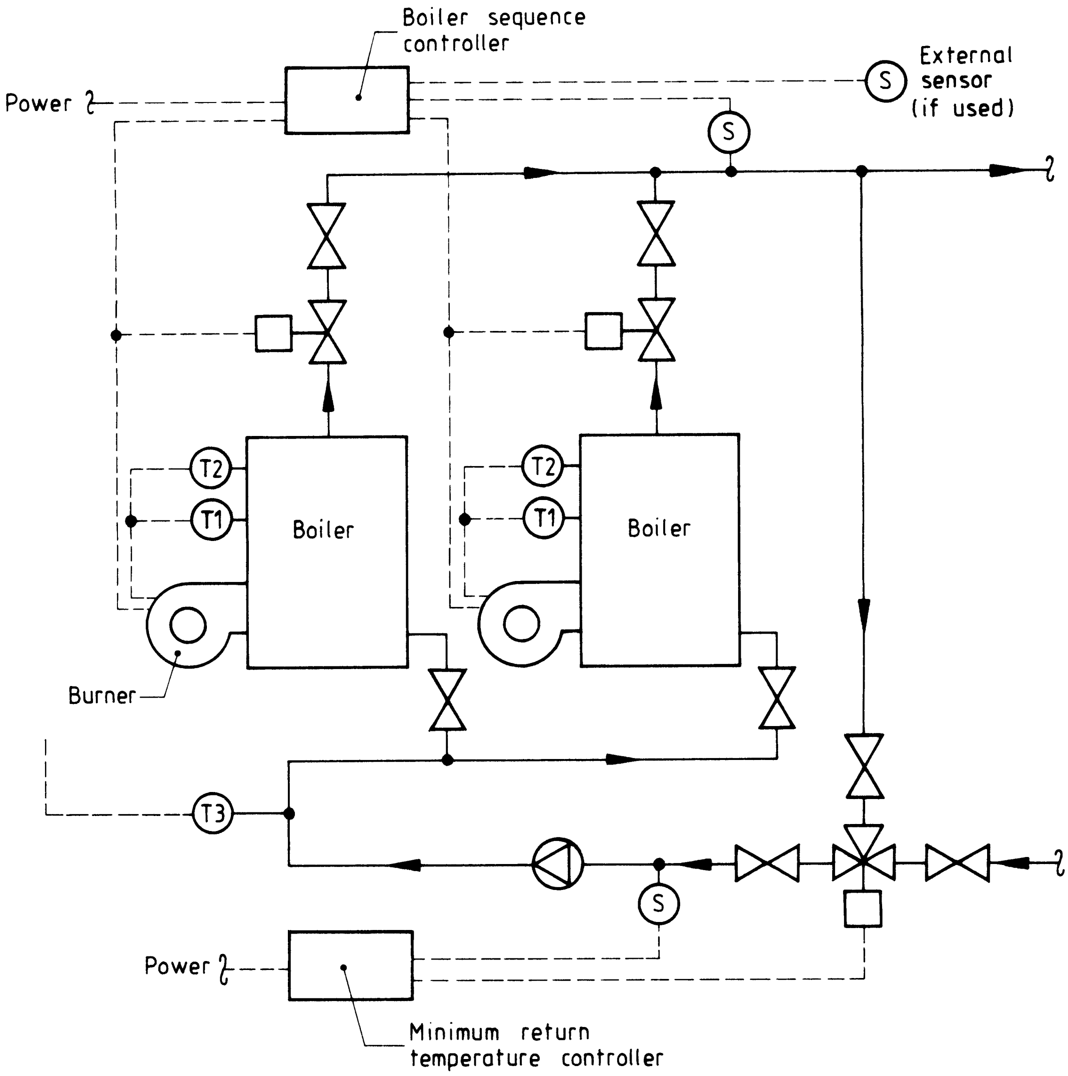
The use of compensated flow temperatures (whereby flow temperature is automatically geared to the prevailing external temperature) should be considered. Where the required heat output is primarily related to outside temperature and the occupancy pattern is consistent, then this method can provide an appropriate primary control and contribute to reduction of mains losses. This method is not suitable for forced convection situations where cold draughts would arise at times of reduced output. Where compensated circuits serve convectors, the minimum flow temperature should take account of the rapid decrease of output of natural convectors and the possibility of cold draughts with forced convectors. Consequently circuits serving convectors should ideally be separated from circuits serving radiators.

Limited resetting of the compensator from the internal temperature (or average of temperatures) is recommended where other internal temperature controls are not used. This will take some account of heat gains and losses in the space but should be limited because the internal temperature sensed may not be truly representative of the whole space. There can be added advantages in energy conservation and operating economics of a separate adjustable outside air thermostat located beside the compensated outside sensor and not subject to solar gain, acting to close the compensated valve and stop the relevant pump. The optimum setting for this thermostat will be influenced by the thermal characteristics of the building and energy conservation policy. It is recommended that compensated heating circuits be subdivided into separate zones, each with its own controls, where considerations such as the following apply:

a) use of additional internal controls is impracticable;

b) solar and wind factors require that different aspects of the building be controlled separately;

c) differences in occupancy require systems to operate at substantially different times.

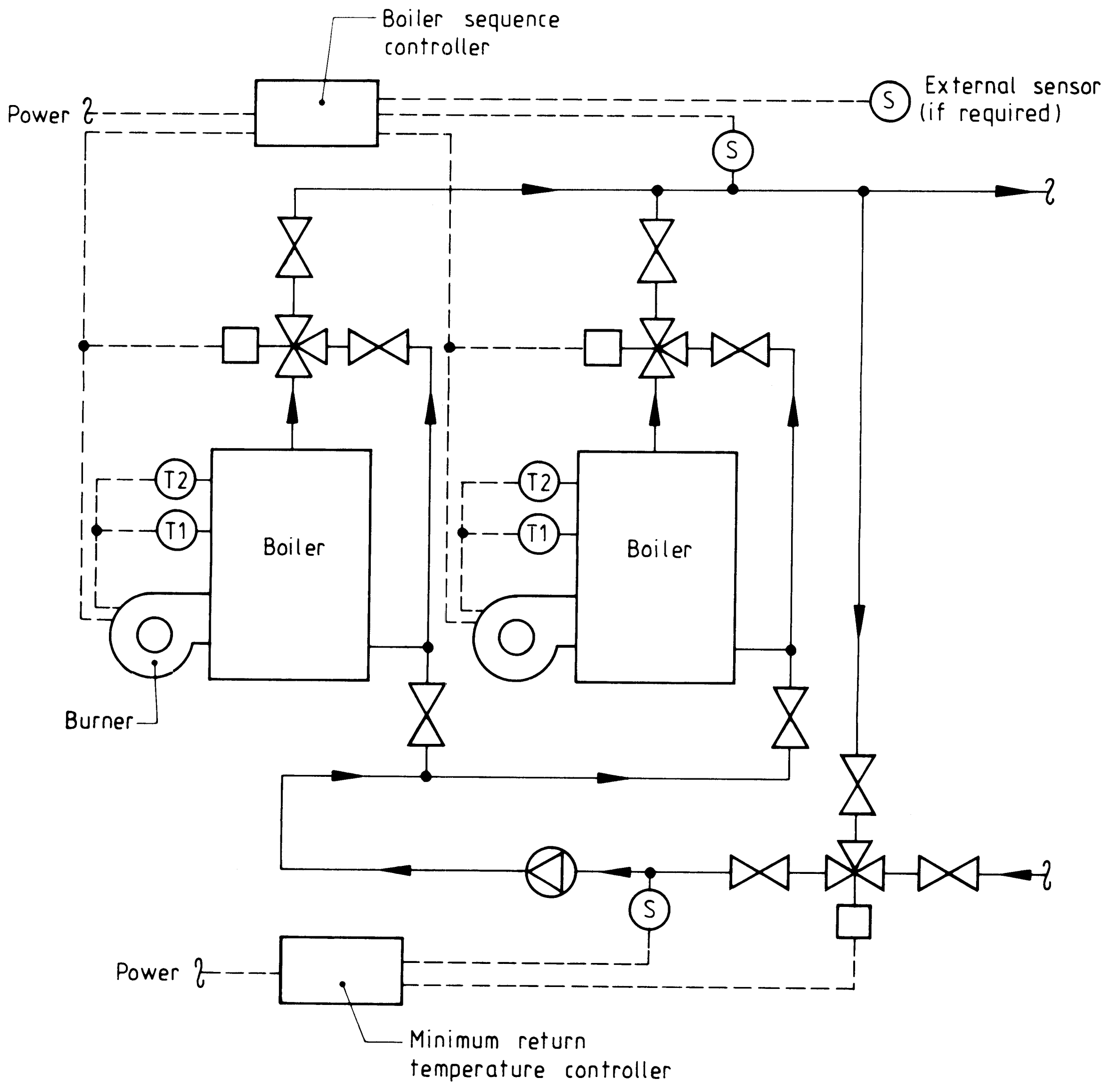


T1 is the boiler control thermostat
T2 is the boiler high-limit thermostat
S is the temperature sensor

NOTE. In the specific case of a two-boiler installation the sequence controller can be replaced by a control thermostat T3 which governs the lag boiler.

(a) Shut-off control

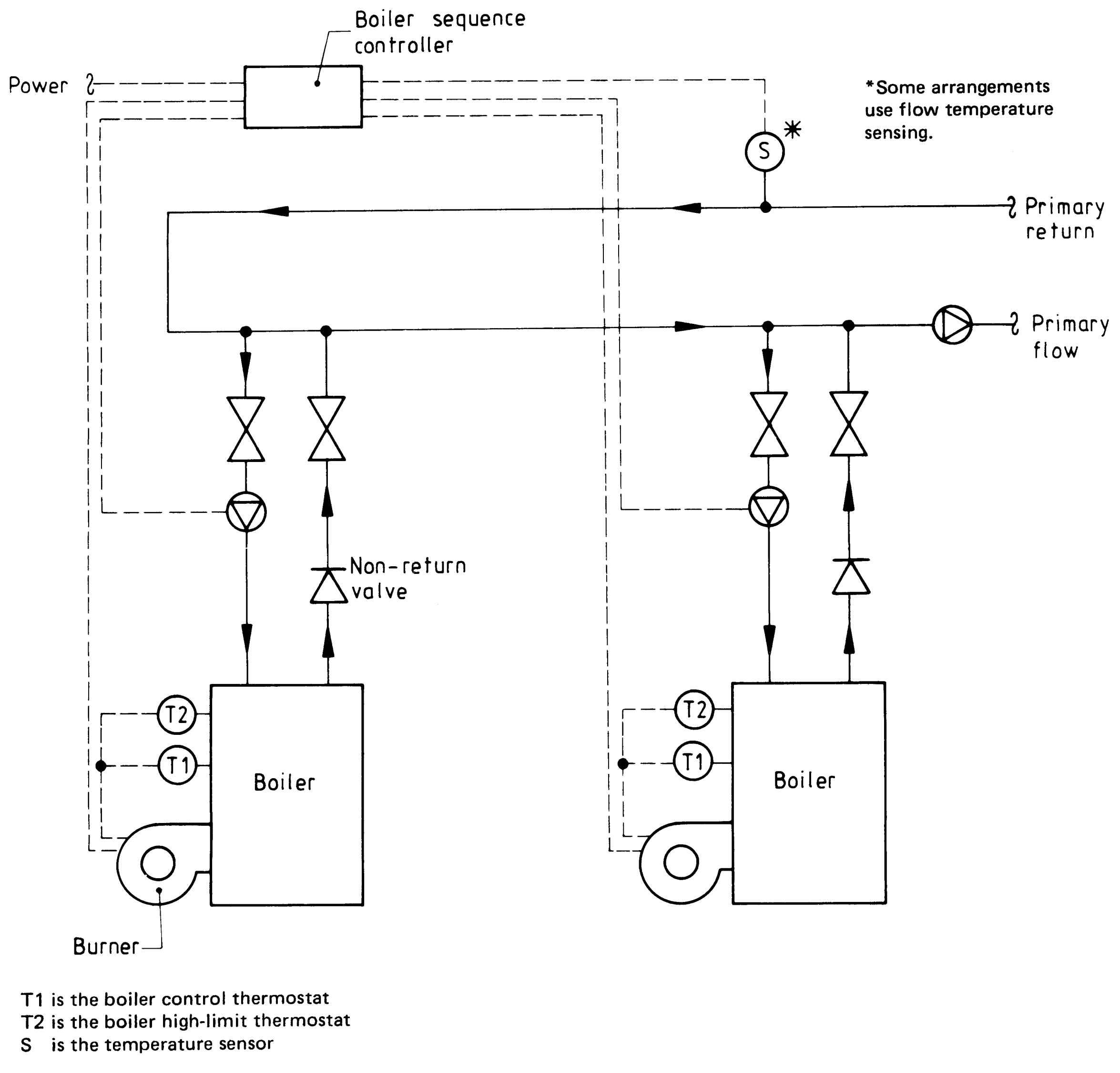
Figure 8 — Typical multiple boiler control arrangements



T1 is the boiler control thermostat
T2 is the boiler high-limit thermostat
S is the temperature sensor

(b) Bypass control

Figure 8 — Typical multiple boiler control arrangements *(continued)*



(c) Individual boiler circulating pumps

Figure 8 — Typical multiple boiler control arrangements *(concluded)*

Each zone circuit should then be controlled by a separate compensator with the outside temperature sensor located on the representative aspect of the building, but not subject to solar or wind influence. The distribution subsystem arrangement and controls should take account of the implications of primary HWS generation where relevant (see **3.2.6**).

Further information on system controls is given in Section 9 of the PSA Engineering Guide [28].

3.8.3.4 *Utilization subsystem.* Direct temperature control of emitters is necessary with forced convection systems such as ducted air heating. In the case of natural convection systems such as radiators, it may be possible to rely on distribution system temperature control, such as a compensated system (see **3.8.3.3**). However, the need for control of individual emitters (or groups of emitters within one room) should be considered as this contributes to comfort and assists energy conservation and operating economics under certain conditions of occupancy.

For control of natural or fan-assisted convectors, on/off control is commonly used, but modulating control should be used where it is required to maintain air flow, subject to limiting maximum and minimum flow temperatures. On/off control may also be used for radiators, but modulating control may be preferable.

Where flexibility is required to shut down certain areas at different times or to provide for selective temperature reduction at night, i.e. night setback of certain areas, then localized motorized valves controlled from appropriately located thermostats and time switches can be used.

For situations where accuracy of temperature control is particularly important, or in cases of large rooms where control of individual emitters is not practicable, then consideration should be given to the use of a modulating valve controlled by a proportional controller which receives signals from one or more room temperature sensors (in the latter case, on an averaging basis).

Thermostatic radiator valves are extensively used for control of individual radiators, and various types are available (see also **6.3.2.2** of BS 6880-2:1988 and Section 9 of the PSA Engineering Guide [28] for more detailed information). However, it should be appreciated that whilst these may offer a relatively low cost method of control, they tend to have high hydraulic resistance compared to that of the radiator itself, and therefore tend to have poor authority (see Section B.11 of the CIBSE Guide [1]) and to cause instability in overall system balance. This may call for corrective measures which increase the overall cost of the installation.

Further information on emitter control is given in Section 9 of the PSA Engineering Guide [28].

3.8.4 Intermittent occupancy

A time switch should be used to control the heating of an intermittently occupied building or zones of a building where the heating load is low or where the unoccupied period is short. (See also Building Regulations, Part L.) Occupancy sensing devices may be also be appropriate in certain situations.

Where a building is occupied during the night, consideration should be given to automatic resetting of emitter and system temperature controls where reduced night-time space temperature is acceptable.

Where a building is intermittently occupied the use of an optimizer control which serves to start the heating at the latest possible time prior to occupancy to achieve the desired temperature by occupancy time is recommended. Large zones of a building may also be controlled by separate optimizers where the occupancy or building construction of the zone varies from the remainder of the building.

Optimizers and time switches on intermittently occupied buildings should be overridden with respect to frost and condensation protection as required.

3.8.5 Primary HWS control

Where an LTHW heating system is being used to provide primary HWS requirements, this may influence system temperature and method of control. The Building Regulations (Part L) lay down specific requirements in connection with HWS controls.

Control of the HWS calorifier by the on/off method is recommended, with the thermostat located two-thirds of the way up the calorifier and operating a three-port valve. High limit overheat protection should be included where primary flow temperature to the calorifier exceeds 60 °C, such as a hand reset thermostat in the top of the calorifier operating a separate spring return two-port valve (see Figure 9).

3.8.6 Controls-operating methods

LTHW control systems are normally either self-acting, electric, electronic or pneumatically powered.

Combinations of systems are possible and indeed desirable for many systems, e.g. electric on/off control of radiators with electronic compensated distribution system control.

Pneumatic control systems tend not to be appropriate for LTHW systems due to the relative cost of a suitable clean and dry compressed air supply system, unless this is already available.

3.8.7 Layout considerations

3.8.7.1 *Pipe-mounted items.* Pipe-mounted temperature sensors and thermostats should preferably be mounted at bends in the pipework and be of greater length than the pipe diameter. Where sensors and thermostats have to be mounted in straight runs of pipe they should project at least as much as half the pipe diameter (see Figure 10). Control valves should be located as described in Section 9 of the PSA Engineering Guide [28].

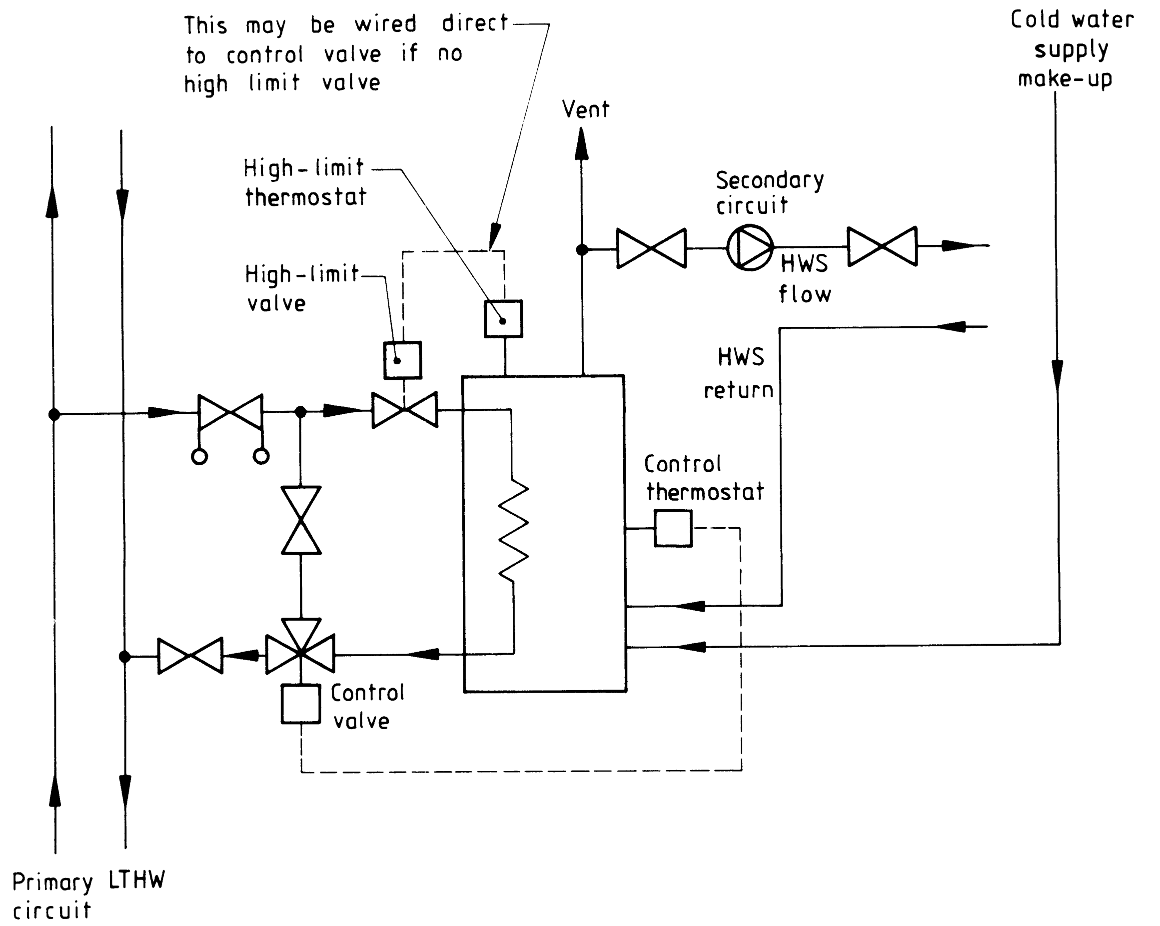


Figure 9 — HWS control

3.8.7.2 *Duct-mounted items.* Sensors remote from the air heater battery, i.e. off-coil, should be mounted at least 2 m away from the heater battery. Air heater battery frost protection thermostats should preferably be of the capillary type and mounted as close as possible to the preheater battery inlet. Sensors should be at least as long as half the width of the duct; if this is not possible, averaging element capillary sensors should be used (see Figure 10).

3.8.7.3 *Room-mounted items.* Room thermostats, humidistats and sensors should be wall or column mounted at 1.5 m above the finished floor level, unless otherwise indicated, and away from direct heat sources, and sources of draughts or direct sunlight. Where items are mounted in occupied spaces consideration should be given to the extent to which it is desirable for occupants to be able to adjust settings and risk of damage. Their appearance in relation to the design of the interior should also be considered, to the extent that available equipment options permit.

Controllers, whether panel or wall mounted, should be at a height between 1.0 m and 1.75 m from the finished floor.

3.8.7.4 *General.* All instruments, sensing elements, test points, etc., should be mounted in locations accessible from permanent walkways, ladders or platforms. Access should be left around instruments to enable maintenance to be carried out. Field-mounted instruments should be located so that they do not obstruct walkways or plant equipment access.

3.8.8 Centralized control and monitoring

Various systems are available which provide some degree of centralized control of heating (and other) building systems, together with the facility to monitor remotely a range of predetermined conditions at points around the system. Such systems are often loosely described in terms of building automation, building management and energy management systems. This code is primarily concerned with the control aspects of such systems rather than their use for information purposes.

Centralized systems do not provide modes of control that are not available from local controllers; they do however enable the user to be fully aware of the state of the system and to make changes to its operation in accordance with occupancy requirements, etc. They can also contribute to the efficient maintenance of the plant and by these means facilitate minimization of overall energy use.

Where complete systems are installed in a number of different buildings, they can be linked by telecommunication to a central monitoring station at a remote location, where operation can be observed, operational decisions taken and corrective instructions transmitted as necessary. This may contribute to efficient maintenance and energy use, and reduce the extent to which experienced staffing is necessary at the individual locations. Where such systems are to be installed, compatibility between control hardware and the building management system is very important. If an LTHW heating system is to be designed such that a building management system may be added at a later date, compatibility is particularly important and equipment should be selected with this in mind, to the extent that obsolescence permits.

Such systems vary considerably in their features and capabilities and are considered to be outside the scope of this code (see **6.4** of BS 6880-2:1988).

3.9 Electrical requirements

3.9.1 Electricity supply

The characteristics of the available power supply should be established and those responsible for building the electrical system advised of the approximate total electrical load which will arise from the LTHW system, and the size of the larger drives so that the load and starting current implications can be assessed. This is particularly important where electrical loads may arise which are significantly greater than those associated with a conventional boiler-fired installation, such as electric water heaters and electrically driven heat pumps.

Particular care is required in the case of heat pumps, where drive power requirements may be considerably in excess of those normally associated with LTHW heating systems.

3.9.2 Electrical design policy

In collaboration with those responsible for building the electrical systems, policy should be established in respect of electrical aspects of the LTHW system, including:

a) motor starting methods (see **3.9.5**);

b) desirability and method of power factor correction;

c) limitations and requirements that may be imposed on electrical equipment forming part of the LTHW installation, such as fault levels, fault protection and mechanical protection;

d) types of supply required (single-phase, three-phase three wire and three-phase four wire); this is particularly important in connection with controls;

e) location and grouping of motor starters, and possible requirements for standardization of electrical items.

3.9.3 Electrical safety

3.9.3.1 *Regulations.* For all electrical equipment and installations associated with the LTHW heating system the lEE Regulations [21] and the appropriate statutory requirements apply, including the Health and Safety at Work etc. Act 1974, the Electricity Supply Regulations, 1937 and the Factories Act, 1961.

NOTE Whilst the Factories Act may not apply to every building in which LTHW heating may be installed, it is recommended as an appropriate standard in the context of electrical installations associated with LTHW heating unless overruled by other statute.

Particular attention is drawn to the requirements of the above legislation in respect of provision of local means of isolation of electrical equipment. Attention to situations where equipment is electrically interconnected is also important, and certain safeguards are required. See also **2.4.4**.

3.9.3.2 *Hazardous environments.* If a system or any part of a system is associated with a potentially explosive or inflammable atmosphere then the installation should be in accordance with the British Standards appropriate to the category of hazard (see BS 5345).

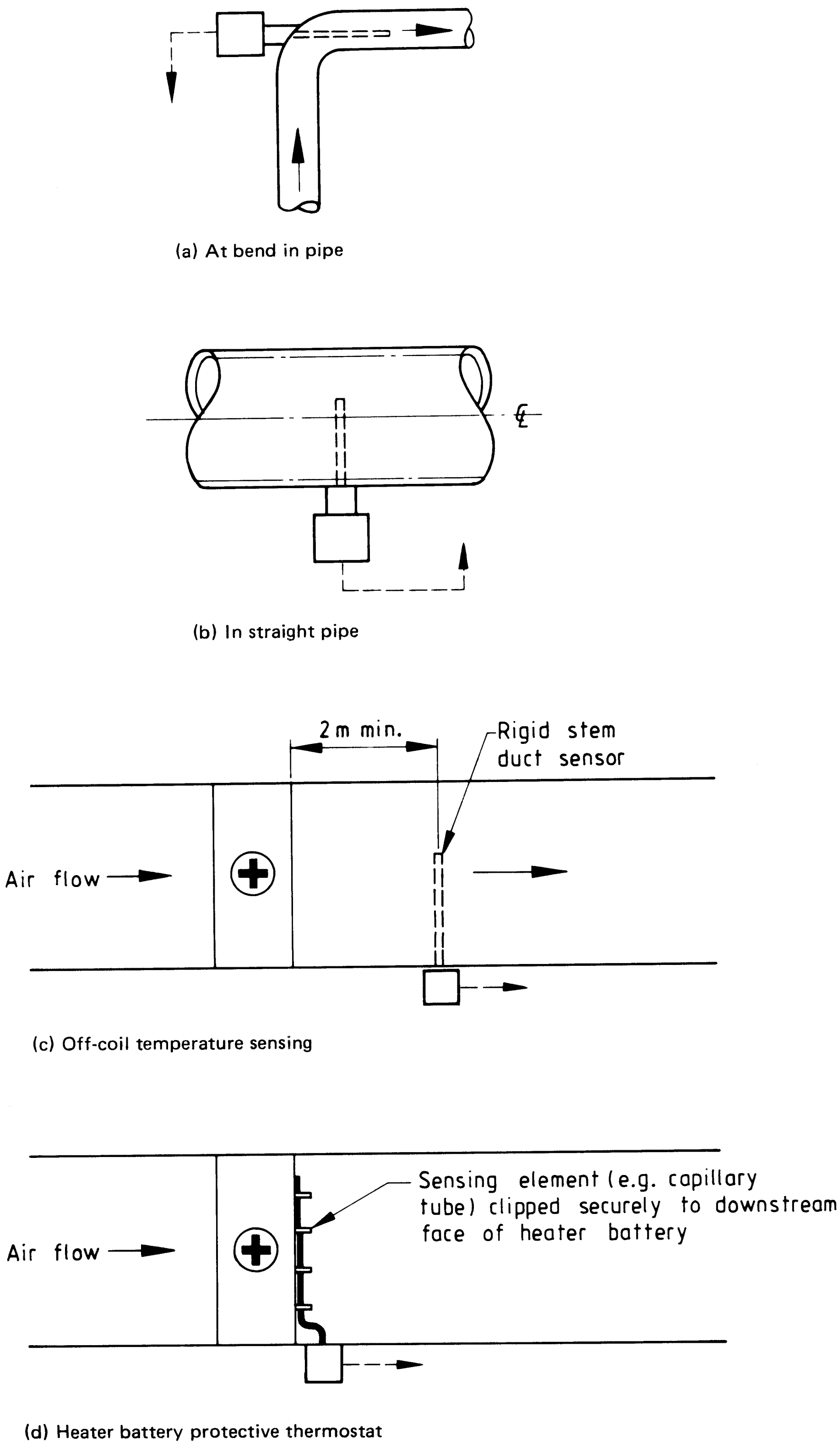


Figure 10 — Location of sensors in pipes and ducts

3.9.3.3 *Earthing and equipotential bonding.* All exposed metalwork of heating installations, should be bonded and earthed, and the continuity of bonding carefully checked. (See also **2.4.4.7** and the IEE Regulations [21].)

3.9.4 Electric motors

Motors should be rated in accordance with BS 4999-101. It should be noted that the standard ambient temperature on which motor ratings are based is 40 °C; if it is likely that this ambient temperature will be exceeded during normal operation, then a suitably derated motor should be used. The flow of cooling air to motors should not be impeded. Motor enclosure should be appropriate to the conditions expected in use in the intended location, and in accordance with the standard enclosures given in BS 4999-20.

Where use of motors in hazardous atmospheres is unavoidable they should comply with the requirements of the British Standards appropriate to the category of hazard (see BS 5345).

3.9.5 Motor control gear

Motor control gear should comply with BS 4941 and BS 5486 as appropriate, having particular regard to the frequency of starting required and the class of enclosure appropriate to the environment. Overload devices should be rated in relation to the normal running load of the motor in the particular application. (See also **3.9.3.2**.) Electrical protection should be compatible with that of the electrical distribution system as a whole. Motor starters and other electrical equipment should be positioned so as not to be affected by water should a break or overflow occur. If this is not possible then the equipment should be of waterproof design.

The maximum ratings of motors that may be started by direct-on-line (DOL) connection to the mains should be ascertained in the context of each project, according to the characteristics of the building electrical distribution system and local electricity supply authority requirements. Motors in excess of these ratings will require assisted starting.

Where DOL starting is not suitable, the method most likely to be applicable in the context of this code is star/delta assisted starting; it should be noted that motors need to be capable of receiving the necessary connections. However, in the case of unusually large pumps and loads such as electrically driven heat pumps, electric water heaters, etc., more specialized starting methods may be necessary and the advice of the equipment manufacturer should be sought (see also **3.9.1**).

Variable speed drives are not commonly used in LTHW installations, but may be considered in connection with, e.g. pumps for certain types of larger system (see **3.8.3.2.3**). When introduced to conserve energy it is important to use a speed control system that does not introduce additional losses which offset the energy savings required.

3.10 Noise and vibration

3.10.1 Noise sources

The types and sources of noise relating to a heating system are covered in **2.2.7**. Noise problems encountered in heating systems are likely to be mainly associated with forced convectors and air distribution systems, and these are covered mainly in BS 5720. However, central plant and water distribution systems may also be sources of noise and vibration.

3.10.2 Design principles

3.10.2.1 *System velocity and pump speed.* At the design stage noise created in piping systems can be minimized by avoiding excessive fluid velocities and by selecting pump speeds that are appropriate to the application and by designing pipework to avoid the presence of air (see **3.4.3.3**). In addition to being entrained within the system, air can be drawn out of solution in the water when the pressure is reduced in the upper floors of a building and its presence will contribute to the noise generated at points of sudden pressure drop and turbulence. Unless the situation is such that pump noise is not a significant factor, particular care should be exercised before deciding to use pumps operating above 1 500 r/min (50 Hz) or 1 800 r/min (60 Hz).

3.10.2.2 *Vibration.* Pumps and other equipment likely to generate noise or vibration should be isolated from the pipework and building by means of flexible connections and vibration isolators.

Vibration in a building is an undesirable sensation resulting from low frequency pressure waves being transmitted through both the structure and the air. In most situations it is the vertical vibrations that are important since floors have the greatest flexibility in this direction. In the selection of equipment for an installation, consideration should be given to the nature of the building construction and the intended mode of use.

Most anti-vibration mounts consist of either steel springs or rubber pads. Incorrect selection can lead to amplification of vibration rather than attenuation. It is therefore very important to select the correct stiffness of anti-vibration mounts in relation to the mass, frequency, etc. of the powered equipment. Vibration dampers should be fitted between machinery and all pipework, including the supports where applicable, and direct contact between pipework and building structure where applicable.

Care and experienced assessment of vibration modes and their effect is necessary in connection with the use of reciprocating machines, particularly when installing on structural floors or members.

3.10.2.3 *Public nuisance.* Consideration should be given to noise level and possible effects on areas surrounding the building, noting that local authorities have statutory powers to require the limitation of such noise. BS 4142 explains a noise measurement procedure, the determination of corrected noise level and a method of rating the noise for these instances.

3.10.2.4 *Building layout.* Noise and vibration effects, particularly those arising from central plant, should be considered during building planning and in the detailed design of plant spaces, etc. Particular aspects to be considered are:

a) locating plant spaces away from sensitive accommodation;

b) presence of windows immediately above or adjacent to plant spaces;

c) acoustic properties of plant room walls, ceiling, floor, doors, etc. (see also **3.7** in connection with plant room ventilation);

d) avoiding as far as possible the location of plant spaces in confined external areas such as courtyards, alleyways, etc., and orienting the installation such that noise is radiated away from likely areas of complaint.

3.11 General layout and operational facilities

3.11.1 Layout

Layout should take account of the operation of the system, adequate space being allowed for operational access, cleaning and maintenance. Space requirements for operations which call for minimum clear distances around equipment, such as tube cleaning, tube withdrawal, etc., should be ascertained at an early stage and maintained free of interference.

Consideration should be given to the appearance of pipework systems. Within the plant rooms or boiler house, all pipes and cable runs should be lined up vertically or horizontally. The arrangement of installations should be such that instruments and indicators can readily be seen from the appropriate working position. Valves and controls should be neatly arranged and accessible, preferably from the floor. Vent pipes should be grouped and run to tundishes.

Reasonable segregation of mechanical and electrical installations should be achieved (see CP 413). Access and locking arrangements should take account of the risks of unauthorized access by building occupants or the public. The access requirements of utility undertakings and the Fire Authority should be provided. All boiler rooms should have more than one safe exit route. Safe access should be provided to tank rooms and other areas where equipment is installed which requires periodic attention. (See also **2.4.2**.)

Attention should be paid to the requirements for ventilation of plant rooms (see **3.7**) and acoustic implications of equipment location and installation methods (see **3.10**).

Storage, workshops, amenity and toilet areas may also be required and their relationship to the boiler room or other main plant area should be considered (see **2.4** in respect of statutory requirements). On larger installations the need for space for records and technical documentation should be considered.

3.11.2 Maintenance access and facilities

Safe access should be arranged to all items of equipment requiring regular maintenance, and consideration given to overhead lifting provision where this is desirable for the safe execution of normal maintenance operations. There may also be specific requirements in connection with insurance inspections.

Access facilities should be so arranged that major items of plant can be brought into the plant room or removed as necessary, including such additional equipment as it may initially be intended to install at some future date.

In providing access for maintenance the following points should be considered.

a) Doorways, passageways, etc. should allow good access for operatives, tools and equipment.

b) All purpose-installed lifting beams or points in plant rooms or elsewhere should be free of obstruction.

c) Floor areas around major items of plant should be free from obstruction for the use of lifting equipment or scaffolding as may be required.

d) Purpose-installed access trap-doors in floors should be readily accessible, and safe to use.

e) Access should be facilitated to isolating and balancing valves, control valves, test points, etc. which are installed in ceiling spaces, service voids, ducts or other confined spaces. Where such equipment is installed in ceiling spaces, it is advisable to use a form of coding on the tile or panel, e.g. coloured buttons, to indicate the location and type of valve or other service.

Consideration should also be given at the design stage to the need for any fixed installations for maintenance use, such as fixed 110 V power distribution, extra-low voltage supplies for hand lamps, welding facilities, etc.
(see **2.3.7** of BS 6880-3:1988).

3.11.3 Commissioning access and facilities

Facilities for balancing and regulation need to be incorporated in the distribution system (see **3.4.3.3**). Access will be required to these during commissioning and monitoring the performance of the installation when in use. This has an important bearing on their location, noting in particular:

a) difficulty of access may affect accuracy of readings;

b) the system would normally be in operation.

Access may be required during commissioning to at least as much, if not more, of the installation as requires maintenance access. This has important implications for the phasing of the work such as completion of suspended ceilings, decorations, etc.

Appendix A Bibliography

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

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

2) Available from HMSO Publications Centre, PO Box 276, London SW8 5DT or from HMSO bookshops and accredited agents.

3) Available from British Gas plc, North Thames, Technical Services, 195 Townmead Road, Fulham, London SW6 2QQ.

4) Available from the Associated Offices Technical Committee, St Mary's Parsonage, Longside House, Manchester M60 4DT.

5) Available from British Coal, Hobart House, Grosvenor Place, London SW1 × 7AE or from Regional Technical Services Offices.

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