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BRITISH STANDARD

BS 6880-3: 1988

Code of practice for

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

Part 3: Installation, commissioning and maintenance

UDC 696.45/.46:621.181.25.182.2.183.325:621.18.018:697.27.326:614.8

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Committees responsible for this British Standard

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

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

This British Standard, having been prepared under the direction of the Refrigeration, Heating and Air Conditioning Standards Committee, was published under the authority of the Board of BSI and comes into effect on
29 February 1988

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The following BSI references relate to the work on this standard:
Committee reference RHE/23
Draft for comment 85/70687 DC

ISBN 0 580 16028 9

Amendments issued since publication

Amd. No.	Date of issue	Comments

Contents

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Foreword

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

BS 6880 is published in three Parts which together form a full technical revision of CP 341.300-307:1956 which is withdrawn.

This Part gives recommendations on the installation, commissioning and maintenance of low temperature hot water heating systems.

The other two Parts are:

— *Part 1: Fundamental and design considerations;*

— *Part 2: Selection of equipment.*

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.

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Summary of pages

This document comprises a front cover, an inside front cover, pages i and iv, pages 1 to 34, 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.

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Section 1. General

1.1 Scope

This Part of BS 6880 gives recommendations regarding the work involved in installation, commissioning, operation and maintenance 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 ClBSE Guide [1], HSE Guidance Note PM5 [3] and section three of BS 6880-1:1988).

1.2.2
boiler

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

1.2.3
heat emitters

equipment emitting heat for the purpose of space heating

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

1.2.4
radiator

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

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Section 2. Installation

2.1 General

This section of the code gives general recommendations on the installation of LTHW heating systems and equipment. It deals with the installation of the principal items of equipment associated with the utilization, distribution, energy conversion and control subsystems, including associated pipework installations, thermal insulation and electrical work.

Attention is drawn to the need to observe all statutory regulations and safety recommendations. Careful thought should be given to the storage and protection of equipment and system components to prevent deterioration or damage.

2.2 Statutory regulations/safety

2.2.1 Safety, statutory requirements and other regulations

Principal sources of reference are given in 2.4 of BS 6880-1:1988.

Some further guidance is given in the following, but it should be appreciated that the references quoted in this code are not fully comprehensive:

CIBSE Technical Memorandum No. 2 [4]

CIBSE Technical Memorandum No. 3 [5]

"Construction Safety: Policy, Organization, Administration" issued by the National Federation of Building Trade Employers [6]

"Safety Manual for Mechanical Plant Construction" issued by the Oil and Chemical Plant Contractors' Association [7].

It is every employer's responsibility to ensure that all safety and other related regulations are complied with. All individuals have a duty of care to others under the requirement of the Health and Safety at Work etc. Act, regardless of contractual relationships.

2.2.2 The Health and Safety Executive

The Health and Safety Executive should be consulted if any doubts arise regarding safety, health or welfare matters. It should be noted that inspectors have power to enter any premises that are subject to the Health and Safety at Work etc. Act 1974 or to Construction Regulations, to examine relevant registers and certificates and exercise the other powers specified in clause 20 of the aforementioned Act.

2.2.3 Statute law

The Health and Safety at Work etc. Act 1974 and associated regulations and legislation (The Factories Act 1961 and Offices, Shops and Railway Premises Act 1963) require that adequate steps be taken to safeguard the health, safety and welfare of persons at work, and others who may be affected by the work. The main sections of the Health and Safety at Work etc. Act relating to the supply and installation of heating equipment are:

Section 2, requiring employers to ensure the health, safety and welfare of their employees.

Section 3, requiring employers and the self employed to conduct their work in a way that does not put persons other than their employees at risk.

Section 6, which places an obligation on designers, manufacturers, importers and suppliers of equipment.

The Factories Act 1961, as its title suggests, applies mainly to factories but there are sections that apply to building operations and works of engineering construction.

The following topics, which relate to the construction industry, are covered in the Factories Act 1961 and attention is drawn to the need to comply with its requirements on these matters (see also **2.2.1**).

Sanitary accommodation

Steam boilers and air receivers

Welfare

Special Health and Safety Regulations

Notification of accidents and industrial diseases

Notification of work starting, if the work is for more than 6 weeks duration

Notification of employment of young persons

Keeping of records and posting of notices

2.2.4 Common law

Under common law, an employer has a "duty of care" for his employees. Basically, this means that an employer has, for example, to:

a) provide a safe place of work;

b) provide safe plant and equipment;

c) ensure a safe system of work;

d) make sure employees are competent to do the work given to them.

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2.2.5 Construction regulations: principal requirements

The Health and Safety at Work etc. Act gives the Minister responsible the power to make special regulations relating to safety and health in particular types of work. A number of such regulations exist relating to construction work. These comprise the main body of statute law affecting site work. The principal regulations are as follows.

Construction (General Provisions) Regulations 1961

Construction (Lifting Operations) Regulations 1961

Construction (Working Places) Regulations 1966

Construction (Health and Welfare) Regulations 1966

The following topics cover areas of requirements related to the construction industry, details of which can be found in the legislation quoted in **2.2.3**.

Responsibilities of employers

Responsibilities of employees

Appointment of safety supervisors

Excavations

Dangerous fumes

Fencing of machinery

Electricity and temporary lighting

Projecting nails and loose material

Protection of the eyes and protective clothing

Cranes and hoists

Scaffolding

Welfare facilities

In respect of installation work carried out in certain types of premises, the legislation listed in this subclause may not have statutory effect. Nevertheless, the observance of its requirements is recommended as a minimum standard of safety.

2.2.6 Other regulations relevant to the heating and ventilation industry

It should be appreciated that any person on a construction site or similar place of work may be exposed to the risks associated with all of the operations being carried out, rather than those associated with a specific trade. However, attention is drawn to the following statutory regulations and other recommendations which are directly relevant to those engaged in the installation of LTHW heating systems.

a) Statutory regulations

Abrasive Wheels Regulations 1970

Asbestos Regulations 1969

Employer's Liability (Defective Equipment) Act 1964

Employer's Liability (Compulsory Insurance) Act 1969

Electricity (Factories Act) Special Regulations 1908 and 1944

Fire Certificates (Special Premises) Regulations 1976

Protection of the Eyes Regulations 1974

Highly Flammable Liquids Petroleum Gas Regulations 1972

Gas Safety (Installation and Use) Regulations 1984

Asbestos Regulations 1969. First list of approved dust respirators

Ionizing Radiations (Sealed Sources) Regulations 1969

b) Other recommendations

Health and Safety Executive Guidance Notes

Other Health and Safety Executive Publications

"Approved Code of Practice and Guidance Notes on Work with Asbestos" [8]

HSE "Guide to the Asbestos (Licensing) Regulations 1983" [9]

Attention is also drawn to the particular hazards associated with refrigeration systems, where the requirements of BS 4434 apply. There is also a particular risk of suffocation associated with the use of certain pipe freezing techniques in confined spaces. The "Code of practice for reducing the exposure of employed persons to noise" [10] should also be noted.

Reference should also be made to 2.4 of BS 6880-1:1988 in respect of risks and safety requirements associated with installations and equipment which may form part of an LTHW heating installation, including fuel storage and combustion, rotating equipment, electrical installations and hazardous chemicals.

The provision of water to the site should be in accordance with the relevant Water Byelaws.

2.2.7 Protective clothing and equipment

Employers are required by law to provide the following.

a) Suitable protective clothing for operators working out of doors in rain, snow, sleet or hail.

b) Suitable protective clothing for operators working with asbestos or asbestos-based materials (see Regulation 8 of the Asbestos Regulations 1969).

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c) Insulation screens, hoods and gloves to prevent danger of electric shock (see Regulations 23 and 24 of the Electricity Regulations).

d) Goggles or screens:

1) when grinding metal, stone or similar materials with power driven wheels or discs;

2) when chipping or scaling painted or corroded metal surfaces or wire brushing them with power tools;

3) when cutting out or cutting off cold rivets or bolts;

4) when welding or cutting metal with electrical, oxyacetylene or similar equipment; this includes the provision of suitable welding screens for electric arc welding operations to protect others not involved with welding but in the vicinity of such operations;
(see Regulation 21 of the Construction (General Provisions) Regulations 1961).

e) Respirators to avoid breathing injurious fumes or dust (if adequate ventilation is impracticable); (see Regulation 20 of the Construction (General Provisions) Regulations 1961 and Regulation 8 of the Asbestos Regulations 1969).

f) Shelter accommodation for use when work is interrupted by bad weather (see Regulation 11 of the Construction (Health and Welfare) Regulations 1966).

g) Storage accommodation for protective clothing and equipment when not in use.

h) Safety nets, belts, harness, lines, etc. where it is not practicable to provide standing working platforms (see Regulation 38 of the Construction (Working Places) Regulations 1966).

Employees are required by law to wear and use the items listed, as appropriate (see section 143 of the Factories Act 1961).

Legal requirements should be regarded only as a minimum. The regular use of the following items should be strongly advised:

1) safety helmets complying with the requirements of BS 5240;

2) protective footwear complying with the requirements of BS 1870;

3) industrial gloves complying with the requirements of BS 1651.

Operators carrying out electric arc welding operations and oxyacetylene cutting should be provided with suitable aprons, sleeves, gloves and skull caps, in addition to eye protection [see **2.2.7** d)].

2.2.8 Avoidance of nuisance

Nuisance by the more Widely used definition means anything obnoxious to the community or individual by offensiveness of smell, noise or appearance, or by causing obstruction or damage, and may cause legal proceedings to be taken against the offending body or individual. Consideration should be given, therefore, to the avoidance of such nuisance when installing LTHW heating systems.

2.3 Site facilities

2.3.1 Legal responsibilities

Reference should be made to the relevant information regarding facilities that should be provided for site works in the Construction (Health and Welfare) Regulations 1966 and amendments. A particular amendment relating to welfare facilities is the amendment of 1 April 1974. Site offices are also covered by the Offices, Shops and Railway Premises Act 1963 (paragraph 50 and 51).

2.3.2 Access and site accommodation

Before setting up site accommodation, the following should be checked or noted (as applicable).

a) Access to the site accommodation should be suitable throughout the duration of the project and should not be affected by building progress.

b) Access should be suitable for the various types of vehicles delivering plant and equipment (with possible heavy and wide loads) to the stores and direct to plant rooms.

c) Access to sites will require approval by the Highways Authority; the routing and timing of the delivery of materials, and in particular large plant involving the use of a mobile crane positioned on the highway, may require police involvement in the control of traffic. Access should be suitable for all types of weather conditions, including the winter.

d) Good walking access should be provided from such places as car parking facilities to site accommodation and to places of work, considering wet weather and winter working conditions, with operatives carrying tools and materials. Adequate lighting should be provided for access roads and paths for winter working conditions.

2.3.3 Welfare facilities

Adequate first aid boxes, accommodation for clothing and the taking of meals, washing facilities and sanitary conveniences should be provided according to the number of persons employed on the site.

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Any sharing arrangement by various contractors should be recorded on the approved form "Register and certificates of shared welfare arrangements". It is the employer's responsibility to ensure that facilities provided comply with the relevant regulations.

2.3.4 Accommodation

In setting up site accommodation attention should be given to factors such as the following.

a) Proximity to main welfare facilities should be ensured.

b) The accommodation should not be affected by, or impede, building progress.

c) All accommodation should be confined to one area to provide easy control of stores, time keeping, good housekeeping and security.

d) Proximity to main areas of work should be ensured.

e) Where any separate welfare facilities are provided within the site accommodation either in part or as a complete unit and in addition to the main site facilities, it should be ensured that the provision of adequate water, sanitary conveniences, electrical and first aid services can be maintained at all times.

f) Adequate lighting should be provided in the accommodation areas for both safety and security reasons.

g) Clocking-in facilities should be provided, with adequate weather protection and with sufficient wall space for displaying essential notices.

h) Fireproof cabinets for important documents should be provided.

i) Adequate fire-fighting facilities should be available.

j) With the larger type of projects, controlled car parking facilities with proper and approved access to the site should be provided.

k) If inflammable materials are to be stored, proper storage facilities should be provided and should comply with the relevant regulations.

l) Any special security arrangements that may be necessary for offices and stores with alarm systems to meet insurance company requirements should be provided.

m) If small stores, messing and clothing accommodation local to major areas of work are provided within the building, adequate protection of any finished surfaces should be provided and good housekeeping should be maintained.

n) It should be ascertained whether it is necessary to obtain large storage areas for materials and equipment within the building.

It should also be ensured that storage areas have good access and security and that the equipment and materials may remain in the storage area until required without impairing other building trade progress, and that no damage will be caused to any finished work when they are moved.

2.3.5 Lifting facilities

Cranes and hoists may be provided by another contractor, but it is advisable for the LTHW heating installation contractor to determine the conditions for the use of these facilities. Such facilities as cranes and hoists may only be available when not being used by other contractors, and unless positive arrangements are made for the use of such plant, delays may occur in offloading, lifting essential equipment into plant rooms and, in particular into high rise buildings.

2.3.6 Scaffolding

Scaffolding may only be available for a limited period unless otherwise agreed. It is therefore desirable that prior agreement is reached on the availability and the conditions of the use of scaffolding when required for the installation of the LTHW installation.

Mobile platforms, or towers, may be provided in lieu of, or additional to, fixed scaffolding. It is advisable to determine the suitability and the exact conditions of use, together with availability, good surfaces to facilitate movement, the responsibility for erection, possible alterations to suit varying site conditions and dismantling. Particular attention should be given to the implementation of appropriate procedures for the use of such equipment; in particular, they should not be moved with anyone on them.

2.3.7 Services (water and electricity)

It is advisable to determine whether sufficient water and pressure are available for filling the system for progressive pressure testing, particularly with high rise buildings.

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It is essential that adequate lighting is provided and that all distribution equipment control and plug points comply with the relevant regulations. Electricity for power tools should be provided at the correct capacity and voltage. (230 V/250 V) supply should not be used for electrical hand tools except in workshops, where they should comply with the relevant regulations. When 110 V supply is not available for electrical hand tools, it is essential to provide suitable portable transformers properly wired with trailing leads and plug connections. (230 V/250 V): (400 V/415 V) supply portable transformer type welding machines should be properly wired with the necessary isolators and fuses. It is the employer's responsibility to ensure that all regulations are strictly adhered to when employees use electricity for lighting and power tools.

2.4 Storage and protection

2.4.1 General

It is essential to provide adequate storage and protection of equipment on site, at all stages of building progress, to minimize deterioration of the working parts and of the manufacturer's finishes.

2.4.2 Equipment

It is good practice to have equipment delivered and installed at the proper time related to the building progress, to minimize the period of time it is standing before being put into operation. It is advisable to check with manufacturers, particularly where major items of plant are concerned such as boilers, pressurization equipment, console control units, etc., as to the precautions to be taken where the equipment is likely to stand without being commissioned or operated for a prolonged period of time. This may also apply to smaller items with electrical equipment, such as fan convectors, etc.

2.4.3 Delivery of equipment

It is advisable to arrange for manufacturers to provide lifting points, clearly indicated, so that unloading and hoisting into position can be carried out in accordance with the Construction (Lifting Operations) Regulations 1961 (see **2.2.5**).

Protection of equipment delivered to site should be examined for suitability for site storage purposes and improved as necessary.

2.4.4 Storage

Each consignment of equipment delivered should be checked and such items as starter equipment should be reconciled with motor sizes and other plant ancillary equipment.

Drawings, wiring diagrams, installation, operating and maintenance instructions and keys are very often delivered with the equipment. It is advisable to collect such items and file them away until required to prevent them being damaged or lost.

It may be necessary to accept delivery of equipment before the building is ready for the installation of the equipment. It is necessary, therefore, to provide suitable storage facilities, which should meet the following conditions:

a) easy access at all times;

b) good unloading facilities;

c) protection against weather;

d) proper security;

e) available until such time as the equipment can be installed.

It may be necessary to use off-site storage and in addition to checking the items above, the following additional points should be taken into account:

1) adequate insurance cover;

2) additional cost of transport;

3) additional handling;

4) possible use of lifting equipment or plant;

5) accessibility to site at a later date.

2.4.5 Protection of equipment

2.4.5.1 *General considerations.* It is essential that all equipment on site should be protected whether it is in storage or installed. Satisfactory security arrangements should be made to prevent unauthorized interference at all stages of the project.

Control panels and other lockable equipment should always be locked when not being worked on and the keys removed for safe keeping.

Most equipment is provided with a works-painted finish, very often in special colours that are difficult to match by touching-up on site if damaged by other building operations or owing to deterioration from being exposed to the weather. It may be necessary and expensive to completely repaint or respray plant before it is acceptable for handover. It is usually necessary for protective coatings to be removed from metal areas before welding.

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Special consideration should be given to the protection of bearings and of electrical, pneumatic and refrigeration equipment to prevent ingress of moisture and dust, the presence of which, particularly in combination, can cause rapid deterioration of electric motor windings, contact points, terminals, switchgear, resistors, transistors, valves and printed circuits and may involve expensive and specialist remedial work with possible delays in obtaining replacements. Particular attention should be given to the protection of boilers and associated refractories. The manufacturer's recommendations should be ascertained and followed.

Refrigeration equipment, particularly packaged units, is usually delivered with a holding charge of refrigerant to minimize the possibility of air and moisture entering the refrigeration system. It is essential, therefore, for such equipment to be checked for leakages on delivery and periodic checks made of all glands, joints and pipework. If refrigeration equipment is likely to stand for a prolonged period of time before being commissioned, it is advisable to contact the manufacturer to seek his advice on checking it and arrange for regular visits of a refrigeration service engineer.

It may be necessary to protect the equipment on site using temporary heaters, dehumidifiers, silica-gel or other means to prevent moisture affecting it while it is standing. In regard to the use of portable gas heaters (which have a high moisture content in the products of combustion), special consideration to provide adequate ventilation is necessary, particularly if drying out electrical equipment. Large electric motors, compressors, and other such equipment with ball and roller bearings should be periodically rotated to reposition the shaft in order to prevent flattening of the bearings. The protection of the equipment should be maintained at all times during installation, particularly with control panels and monitoring consoles as damage and deterioration can occur if left exposed during the installation and connecting up of the wiring and/or pneumatic systems.

It is recommended that all bearings and moving parts are checked before running the equipment to ensure adequate lubrication is provided and that the lubricant is free from contamination. Manufacturers' recommendations should always be strictly adhered to when using lubricating oils and grease.

2.4.5.2 *Removal of protective coatings.* Equipment may be delivered on site with protective coatings such as transparent film, grease or varnish. The protective coats should be left on as long as possible and then removed as recommended by the manufacturer to prevent possible damage to the finish or working parts of the equipment. Before using chemical cleaners or similar liquids, it should be ensured that no damage will be caused to the equipment.

2.4.5.3 *Special protection.* With the use of many types of chemicals and cleaning agents by other trades in the building industry, it may be necessary to provide special protection of equipment after it is installed. Polyethylene sheeting, being of petrochemical base, may prove unsuitable.

2.4.5.4 *Protection of equipment from other trades.* The use of equipment as a platform and as a base for ladders, trestles, shuttering and any other such purposes should not be allowed, as it invariably results in damage to the equipment as well as being a safety hazard.

Insulation is always vulnerable to damage and may require special consideration regarding protection from other services and trades.

Pipework should not be used as supports for other services, as this may cause excessive loading, deflection and leakage.

2.4.6 Care and maintenance

Where equipment is to be operated between start-up and handover, arrangements for appropriate maintenance and operational supervision should be made.

2.5 Equipment and system installation: general

2.5.1 General principles

It should be appreciated that a successful LTHW system requires that design, installation and commissioning should be satisfactory and compatible. Nothing in these subclauses is intended to imply any particular division of responsibility between designer and installer. Equipment specifically associated with air handling systems (fans, ductwork, diffusers, etc.) is covered in **5.5** of BS 5720:1979.

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2.5.2 Foundations and fixings

Intended location of major equipment should be checked prior to moving into position to ensure availability of safe access (see **3.11** of BS 6880-1:1988) and that any structural or building provisions required in advance of installation are correct and ready for use. Floor-mounted equipment in plant rooms should be installed on plinths of consistent heights, so as to prevent accumulation of water around supports and fixings.

The intended methods of fixing, levelling and aligning equipment should be determined before moving into position, and sufficiently in advance to enable the appropriate structural or builder's work provision to be made. Holding down bolts or other mechanical items to be incorporated into the structure should be made available at the appropriate time and checked prior to building in. In the process of building in, provision should be made to facilitate minor positional adjustment.

2.5.3 Identification and information

All equipment should be clearly identified on arrival at site and its identity should be preserved through to project completion. Manufacturers' installation instructions for proprietary equipment should be kept available at site and the appropriate recommendations and procedures followed. Equipment on site should be checked in advance to ensure that it is in a suitable condition to install.

2.5.4 Protection

Particular attention should be given to the preservation of equipment during and after installation and arrangements made for recommended procedures such as regular rotation of shafts, etc. (see also **2.4.5**). Where painted finishes are protected by removable film, this should be left in position until all work is completed.

2.5.5 Location and access

Location of equipment should be such that safe clearances and access are allowed for the purposes of installation, testing, commissioning, operation and maintenance. In particular, attention should be paid to matters such as tube cleaning and withdrawal, statutory inspections, operation of valves and controls, reading of instruments and observation of warning signals. Such operations should normally be capable of being carried out from operating floor level, unless access platforms and ladders are specifically intended to be used in a particular situation.

Location of equipment should also be such that the design requirements are met, with particular attention to aspects which might detract from performance, such as excessively sharp bends, inadequate clear lengths of pipe at measuring devices or insufficient space to install or maintain equipment or system elements correctly.

2.5.6 Mechanical considerations

Relationship of pipework to equipment should be such that loads are not imposed on equipment which it is not intended to carry, whether finally, or during installation and testing. The mechanical alignment and freedom to rotate of equipment should be checked after fixing and again following attachment of pipework. Anti-vibration mountings, flexible connections and similar devices should be installed as required and such that they can operate as intended; correctness of type should be ascertained before fixing. Provisions for thermal expansion should not be prevented from functioning correctly. Any guides should be firmly supported and anchors properly connected and secure.

Equipment and systems should be installed in a manner that is consistent with the requirements for drainage and venting of the system and individual items, as appropriate. Equipment guards should be kept in place except when installation operations require their removal. Open ends should be temporarily closed where necessary to avoid ingress of dirt or other undesirable matter, and such closures removed prior to final connection and such cleaning as may be appropriate.

2.5.7 Electrical considerations

The correctness of electric motor and starter types and ratings should be checked as early as possible after arrival of equipment at site; also the availability of the necessary power and control wiring information. The possible need for the application of electrical continuity bonding (see **3.9.3.3** of BS 6880-1:1988) should be recognized and installation carried out such that it can be incorporated where required.

2.6 Utilization subsystem installation

2.6.1 Radiators

Assembly of sectional radiators on site is not recommended. Minimum clearance at the back of a radiator should be not less than 50 mm, or as the manufacturer recommends. Clearance underneath radiators should be as required for mechanical floor cleaning, access to electrical trunking, etc. and in no circumstances less than 150 mm.

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Radiators should be securely fixed, preferably using the manufacturer's purpose-made brackets, or a fixing which is no less satisfactory in particular instances where the use of the manufacturer's brackets is not practicable. The method of fixing should be appropriate to the construction of the mounting surface; particular care is required with lightweight block walls, lined walls, studded partitions, etc. At least two supports should be used; column radiators having more than 20 sections should be provided with additional supports. Radiators should be effectively restrained from being pulled away from the mounting surface under normal occupancy conditions.

Setting out of radiator locations should be such that the radiator can function as intended by the design, also with due regard to coordination with other services and building features (particularly cills and skirtings), overall appearance, relationship to pipework and fittings and method of drainage and venting. The need to subsequently remove radiators for painting should be recognized.

Attention should be given to access for cleaning, especially in hospital and other environments where ease of cleaning is particularly important. It should be noted that the use of bottom opposite end (BOE) radiator connections and appropriate supports may enable radiators to be swung downwards for cleaning, without removal. Vacuum cleaning may be used in some cases, particularly with high output radiators and other convectors with narrow air passages.

2.6.2 Other natural convectors

General principles of setting out and fixing apply as for radiators (see **2.6.1**). The correct relationship to building finishes should be observed and appropriate sealing used so that the convector may function as intended, also that satisfactory appearance of the complete installation is achieved and wall staining avoided. Use of a proprietary backplate (see **3.1.5.2** of BS 6880-2:1988) is preferred. Purpose-made accessories and fittings available from the equipment manufacturer should be used where appropriate. Heating elements should be checked and any damage rectified, particularly to fins. Covers should fit correctly, be readily removable and dampers (where fitted) operate freely. Care should be taken to protect finishes throughout the installation period through to completion.

With continuous convectors, further specific points require particular attention, including:

a) care in setting out and prior check of relevant building dimensions (see **3.1.5.3** of BS 6880-2:1988);

b) thermal expansion provision;

c) attention to details which may interfere with movement of expanding elements or cause noise on expansion (see **3.1.5.2** of BS 6880-2:1988);

d) access to valves and controls;

e) use of acoustic baffles at partitions having an acoustic function.

2.6.3 Forced convectors

Unit forced convectors of the wall-mounted fan coil and similar types should be installed in accordance with the principles indicated in **2.6.1** and **2.6.2**, and with particular attention to the following:

a) location in relation to power supply points, etc. such that the electrical installation can meet all the appropriate requirements;

b) avoidance of obstruction of air inlets and discharges;

c) access to controls;

d) where air filters are required, checking that the appropriate type is fitted, correctly installed and accessible for removal;

e) anti-vibration devices function correctly and the unit is satisfactorily installed with regard to acoustic considerations.

Suspended and other types of industrial unit heaters should be installed using purpose-designed brackets and stays as necessary so that loads are carried by the appropriate structural elements and undue movement is prevented. Unit heaters should not carry piping loads and should be arranged for heater battery removal without interference with pipe support. Particular consideration should be given to access for filter changing (where relevant) and general maintenance, also to location of control system items and remote controls such as recirculation damper operators. In respect of industrial air heaters and central air heating plant, see also **5.5** of BS 5720:1979.

The following recommendations apply to air heater batteries in general.

1) Air heater batteries on systems with fresh air input are particularly prone to frost damage, which may affect location and call for particular protective measures (see **3.2.2.2** of BS 6880-1:1988).

2) Before commencing installation and pipework the required header connections should be established and requirements for venting and drainage taken into account.

3) Heater batteries should be internally clean, and open ends temporarily sealed.

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2.6.4 Heated ceiling systems

With heated ceiling systems there is a particularly close relationship between system design, system installation and the construction of the building fabric, (see **3.6** of BS 6880-2:1988). In addition to the recommendations of **3.6** of BS 6880-2:1988 the following should be noted in the context of suspended metal ceilings.

a) A satisfactory installation requires careful setting out and dimensional checking, with particular reference to the coordination of the suspension system with other high-level services, the required location of heated and unheated panels to achieve the design intent, coordination with luminaires, other ceiling mounted items and building features.

b) The heating tube should be installed so as to avoid unacceptably tight bends; only the recommended jointing procedure should be used; particular care is required when joining panel heating tubes to LTHW distribution submains, so as to minimize area reduction at the joint; the intended heating circuit arrangement should be followed, and provision made for venting and draining.

c) Provision should be made to accommodate thermal expansion of the tube and panels in an acceptable manner.

d) Site hydrostatic testing of the tubing should take place before the ceiling panels are finally put in position (see also **3.5.3.3** of BS 6880-2:1988); sectional testing may be appropriate on large installations.

e) Ceiling panels should be installed such that their thermal and acoustic properties are not impaired and it is important that the thermal properties of the building construction above the ceiling panel should be as intended.

f) Provision should be made for access to valves, controls and measuring devices as necessary for commissioning and maintenance.

g) Appearance of the finished ceiling is particularly important in respect of alignment, level and integrity of finish, both when cold and at operating temperature.

See also **3.5.2** of BS 6880-2:1988 for information on proprietary suspended ceilings in relation to the heated ceiling insulation.

Similar considerations apply to suspended plaster or embedded ceilings, together with the following.

1) Hydrostatic testing should take place such that the system has been proven to be mechanically sound and pressure-tight before plastering commences.

2) The plaster mix should be appropriate for this specific purpose, and application and drying out should be carefully supervised.

3) A predetermined sequence of drying out and slow warm-up should be used (see **3.5.3.2.1** of BS 6880-2:1988).

2.6.5 Heated floor systems

With heated floor systems there is a particularly close relationship between system design, system installation and the construction of the floor fabric (see **3.7** of BS 6880-2:1988). In addition to the recommendations of **3.7** of BS 6880-2:1988, the following should be noted in the context of installation of heated floors.

a) Before commencement of installation, the floor construction should have been checked in accordance with the design requirements, with all required insulation, damp proof membranes, etc. correctly installed, fully effective and free of projections that might damage the heating elements.

b) The distance below finished floor level of the base on which the heating elements are laid should be as necessary to accommodate the elements, floor finishes and coverings and provide the required minimum screed depth.

c) The heating tubes should be carefully set out and fixed in accordance with the specialist supplier's recommendations and with particular reference to spacing in accordance with design requirements, observing minimum bending radii, providing for thermal expansion (see **3.7.2.5** of BS 6880-2:1988) and using continuous tube lengths as much as practicable; embedded joints should only be made by approved thermal fusion techniques.

d) Hydrostatic testing should take place such that the system has been proven to be mechanically sound and pressure-tight before installation commences.

e) With some proprietary flexible pipe systems it is recommended that screeding take place with the tubing under pressure (typically 4 bar[1)]).

f) The appropriate mix should be established in collaboration with the floor heating specialist; preparation, application and drying out of the screed should be carefully supervised.

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

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g) An appropriate sequence of drying out and slow warm-up should be established with the floor heating specialist and carefully followed (see **3.7.2.5** of BS 6880-2:1988) and the screed surface protected from trafficking during this process.

h) Floor finishes and coverings should not be applied until the drying out sequence is completed; it should be appreciated that certain types of floor finish are susceptible to damage if not laid so as to be compatible with the floor heating and any recommendations of the floor heating specialist concerning laying of finishes should be followed.

See also **3.7** of BS 6880-2:1988 concerning specialist involvement.

In the event of plastics pipe underfloor heating, the recommendations of BS 5955-9 concerning installation should be followed. Particular care should be taken to protect tube from damage during storage and handling, especially when cold, and from degradation by sunlight.

2.7 Distribution subsystem installation

2.7.1 Pipework

2.7.1.1 *Pipework installation in general.* This subclause refers mainly to steel and copper pipework. It does not refer to refrigeration pipework (see **2.8.5.4**). Where plastics pipework is particularly required by the design, the recommendations of BS 5955 should be followed (see also **3.4.4.3** of BS 6880-1:1988 and **3.7.2.2** of BS 6880-2:1988) and attention paid to electrical earth requirements (see **3.9** of BS 6880-1:1988).

Good workmanship and system cleanliness should be foremost considerations. All tubes should be reamed after cutting and should be free from rust, scale or other deposits. Tubes should be thoroughly cleaned before erection and open ends should be temporarily closed with purpose-made metal or plastics caps, or blank metal flanges.

Remnants of cut metal should not be left inside piping; it should be appreciated that presence of small particles of dissimilar metals inside radiators, etc. can promote intense local corrosion. When soldering, a water soluble flux should be used, without excess of either solder or flux. Copper tube complying with Table Z of BS 2871-1:1971 should not be bent.

Particular attention should be paid to the selection and location of an adequate number of valves for isolation and flow regulation, and where necessary for prevention of back-flow. See **3.4.4.4.1** of BS 6880-1:1988 concerning the provision of valves for sectional isolation.

Sufficient thermometers and gauges, or test pockets, should be provided for commissioning and for operating and maintenance purposes.
Dirt-sensitive items, such as small automatic control valves, should be protected by strainers. Valves, strainers and other pipeline components should be located in accessible positions. All piping should be installed at the correct gradient to ensure proper venting and draining. Open vent pipes should rise continuously. Provision should be made for the possibility of easily dismantling the equipment connections for equipment servicing/removal and suitable precautions should be taken to prevent transmission of vibration.

Pipework should be aligned at joints and changes of size effected by appropriate means and use of bushes should be avoided as far as possible.

Where pipes are installed in trenches or ducts the following recommendations apply.

a) The recommendations of CP 413 should be followed.

b) They should be readily removable without disturbing other pipes.

c) Covers should be readily removable.

d) Allowance should be made for movement of a pipe due to expansion or contraction and for counteracting any tendency of a pipe to lift off brackets or rollers.

e) Where a common pipehanger is used for two or more pipes, provision should be incorporated for the unequal pipe movements which may arise due to expansion.

f) Damage to pipe insulating covering due to movement of the pipe should be prevented.

Facilities should be provided for emptying the complete installation with the exception of small local dips under floors or in trenches. An emptying pipe of at least 38 mm with tap or cock should be connected to the lowest point of each section of the circulation mains for which isolation control has been provided. Dead legs (see **3.5.3.3** of BS 6880-1:1988) should be avoided except where specifically required for collection and removal of dirt.
Exposure to freezing conditions should be avoided by appropriate precautions. Vent and drain pipes should be protected against internal corrosion. Pipe materials, pipe fittings, flanges, joints, pipe threads, valves and other pipework accessories should comply with the appropriate British Standards.

When soldering only the minimum amount of solder and flux necessary to ensure a good joint should be used. Any internal residues should be capable of being removed by rinsing or dispersal by the system water during normal operation.

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Cleaning, flushing and precommissioning checks for water systems are covered in the CIBSE Commissioning Code Series W [11], and should be followed.

2.7.1.2 *Pipework supports and fixings.* Pipework should be neatly arranged and adequately supported. Support spacing should not exceed the distances recommended in Table 1 and Table 2 for steel and copper pipes respectively.

All pipes should be supported so as to allow free movement for expansion and contraction, particularly at the ends of long runs where a change of direction takes place. Attention should be paid to the support of larger valves, control valves and operators. The surface of pipes or pipe insulation should not be located closer than 20 mm from walls or 75 mm from floors.

Pipe supports should preferably be designed or selected for the purpose. Pipe supports, anchors and guides should only be attached to appropriate parts of the building structure, and where significant loads or expansion thrusts might arise the prior approval of the appropriate experienced party should be obtained. Fixings should be appropriate to the particular fabric detail and such as to give a secure fixing without damage to surrounding fabric or finishes. See also BS 3974 for guidance on the design and construction of pipe supports and fixings.

Where structural steel members are the only means of support for pipe hangers, the drilling of the structural steelwork should be avoided whenever possible by the use of special-purpose clips, securely bolted. The hangers should be articulated to allow free movement. Where drilling of the structure for the passage of pipes or their supports is unavoidable, prior approval should be obtained from the appropriate experienced party.

2.7.1.3 *Thermal expansion.* Expansion loops or other appropriate purpose made expansion devices should be provided wherever pipe expansion cannot be taken up by changes in direction. Loops should be properly formed from pipe. The location of expansion devices should be carefully related to the position of the fixed points or anchorage of the mains concerned to ensure that the expansion is totally cumulative at the expansion device position. In respect of continuous convectors see **3.1.5.2** of BS 6880-2:1988. Expansion loops should be properly supported, preferably in the horizontal plane. The appropriate pre-tensioning or cold draw should be incorporated after fixing of anchors. Particular care should be taken to ensure that lateral branches and their fixings are not subject to stress due to the thermal expansion of the associated main pipes, particularly where branches pass through walls, etc.

2.7.1.4 *Pipe sleeves.* Where LTHW pipes pass through walls, floors, etc., steel pipe sleeves of adequately greater size should be fitted to allow movement of pipes without damage to fabric. They should allow for correct fitting of any wall or floor plates required. Where pipes pass through fire walls or floors, adequately sized sleeves of appropriate length should be used, well packed with suitable non-combustible material, retained in position; attention is drawn to the need for the arrangement used to comply with the requirements of the Building Regulations and with those of the fire authority having jurisdiction.

2.7.1.5 *Pipe joints.* Joints in pipe which is permanently concealed should be butt-welded (see **2.7.1.6**). It is recommended practice to use butt-welded joints on pipes greater than 100 mm diameter. Where screwed joints are used at least one of the mating threads should be tapered, and appropriate jointing material should be used.

Dismantling points should be provided at appropriate distances and unions or flanges used. It is recommended practice to use flanges on all pipes greater than 50 mm diameter, with the appropriate type of joint face and gasket.

Mechanical pipe couplings using the grooved pipe principle can prove advantageous in certain situations, particularly where space is limited. In the absence of British Standards for this type of coupling, they should only be used where specifically incorporated in the design and where the type used has been proven for LTHW applications in accordance with the principles stated in **3.4.4.2** of BS 6880-1:1988. In particular it is important that the complete assembly of pipes, pipe grooves, coupling and sealing components are fully compatible and installed in accordance with the manufacturer's recommendations, particularly in respect of groove formation technique and accuracy and suitability of the sealing gasket for LTHW duty. Particular attention should be paid to provision for expansion movement and avoidance of angular deflections in excess of manufacturer's recommendations. If the use of such couplings is considered for pipe connections to reciprocating machines (e.g. heat pumps or other equipment prone to vibration), careful consideration should be given at the design stage to the ability of the proposed coupling to perform without risk of failure on this account.

Joints on copper pipework should be made using the appropriate type of proprietary fitting.

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Table 1 — Supports for steel pipework

Tube size	Maximum intervals for horizontal runs		Maximum intervals for vertical runs, bare or insulated
	Bare	Insulated	
mm	m	m	m
15	1.8	1.8	2.4
20	2.4	2.4	3.0
25	2.4	2.4	3.0
32	2.7	2.4	3.0
40	3.0	2.4	3.7
50	3.0	2.4	3.7
65	3.7	3.0	4.6
80	3.7	3.0	4.6
100	4.0	3.0	4.6
125	4.5	3.7	5.5
150	5.5	4.5	5.5
200	8.5	6.0	8.5
250	9.0	6.5	9.0
300	10.0	7.0	10.0

Table 2 — Supports for copper pipework

Tube size	Maximum intervals for horizontal runs		Maximum intervals for vertical runs, bare or insulated
	Bare	Insulated	
mm	m	m	m
15	1.2	1.2	1.8
22	1.2	1.2	1.8
28	1.8	1.5	2.4
35	2.4	1.8	3.0
42	2.4	1.8	3.0
54	2.7	1.8	3.0
65	3.0	2.4	3.7
76	3.0	2.4	3.7
108	3.0	2.4	3.7
133	3.7	3.0	3.7
159	4.5	3.7	3.7

2.7.1.6 *Pipe welding.* Electric arc welding should be carried out in accordance with BS 2971 (class II). Oxy-acetylene welding should be carried out in accordance with BS 2640 (class II). An alternative code of practice which may be used is that of the HVCA (TR5 "Welding of carbon steel pipework") [12], which covers both arc and gas welding. Butt-welded fittings should comply with the appropriate British Standard. Welding equipment and materials should comply with the appropriate British Standards and appropriate clothing and equipment should be used (see **2.2.7**). For further guidance see also the Welding Institute publications "Facts about Fumes" [13] and "Health and Safety in Welding and Allied Processes" [14], and the HVCA publication "Welding Safety" [15].

The fire hazards associated with welding and cutting operations should be recognized and appropriate precautions effected; this may call for a permit to work system, particularly in existing premises.

Where non-destructive examination of welds is required, the procedure and method of assessment to be adopted should be established before welding commences. Where radiographic examination is to be carried out, the appropriate safeguards should be effected (see BS 1542).

2.7.1.7 *Identification.* Pipes should be clearly identified in accordance with BS 1710. Circuit isolation valves and flow measurement valves should be clearly identified by readily legible permanent labels. Where such valves are concealed above false ceilings, consideration should be given to the use of a colour coded spot system to identify location.

2.7.2 Thermal insulation

2.7.2.1 *General.* The type and thickness of insulation to be applied to pipework, valves, heat exchangers and other LTHW system elements, together with the appropriate finishes required should be established by the design.

However, before installation of pipework commences the insulation requirements should be checked, with particular reference to the following.

a) Thickness, especially in relation to pipe spacing and clearances.

b) Finishes and their method of fixing, with particular reference to different categories that may apply, e.g.:

1) external, exposed;

2) plant rooms;

3) visible, in accommodation;

4) concealed, in accommodation.

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c) The use of removable valve boxes for valves and control valves.

d) Requirements for tanks, vessels, heat exchangers, boilers, flues, etc.

e) insulation details required at pipe supports and their protection.

For further guidance on insulation see **3.6** of BS 6880-1:1988 and BS 5970. In respect of buried mains see 3.5 of BS 6880-1:1988, and of asbestos see **2.7.2.2**.

All operations associated with the installation of thermal insulation should be carried out in accordance with the relevant recommendations of BS 5970. Insulation should not commence until the relevant section of pipework has been satisfactorily tested.

Consideration should be given to the need to insulate feed and expansion tanks, for frost protection. Fuel oil tanks may require thermal insulation (see **3.3.3.2** of BS 6880-1:1988). Refrigerant lines should be insulated and fitted with an effective vapour barrier in accordance with the recommendations of BS 5970. When carrying out thermal insulation good housekeeping is particularly important. Care should be taken to ensure that loose material is not deposited in equipment or elsewhere, and that it is cleared away before starting commissioning. Thermal insulation which accidentally finds its way into boilers and burners can present a significant risk of fire and explosion.

2.7.2.2 *Work with asbestos.* Any work associated with asbestos should be carried out in accordance with the Health and Safety Executive "Approved Code of Practice and Guidance Note on Work with Asbestos" [8] by contractors licensed under the Asbestos (Licensing) Regulations 1983 (see also **2.2.7** and **2.2.8**).

2.7.3 Pumps

Pumps, motors and drives should be readily accessible for operation maintenance and repairs. All drives should be securely guarded in accordance with statutory regulations. Particular attention should be paid to the pump inlet and discharge connections and location of valves and strainers to avoid excessive pressure drop, which may affect pump performance. Valves should be fitted to the suction and discharge of each pump, and flap valves should be checked for freedom of movement. Where duplex pump units are to be used, operational requirements should be taken into account before deciding whether to provide isolation for each pump, or for the pair of pumps together. Pumps should be checked before installation in respect of internal cleanliness, freedom to rotate and correct direction of flow. Orientation of the pump shaft should be in accordance with the manufacturer's recommendations in respect of axial thrust, etc.

Pump suction and discharge piping should be properly aligned. It should be supported so as not to impose loads on the pump, and so as to allow pump removal without disturbance of pipework. Pump connections may have flexible connectors or alternatively the immediately adjacent pipework may be provided with flexible anti-vibration hangers. In all cases care should be taken to see that such devices are not rendered ineffective by incorrect installation procedures. Flexible electrical connections to motors should be provided. Motors should be located away from hot surfaces and such that adequate cooling air can circulate. Provision should be made for air venting. Pumps should not be installed at the lowest point of a system, due to accumulation of sediment.

Where operation of a system is such that flow may stop completely during operation, consideration should be given to preventing overheating of the pump.

2.7.4 Pressurization equipment

In addition to the general recommendations in **2.5**, the following particular points apply to pressurization equipment.

a) It should be installed in a frost-free location.

b) It should be securely installed on masonry plinths or other suitable supports arranged to avoid risk of corrosion damage; anti-vibration provision should be made where pumps are incorporated if the location is likely to be sensitive in this regard (see **3.10** of BS 6880-1:1988).

c) Where gas cylinders are used for pressurization, provision for safe access and safe handling of gas equipment should be provided.

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d) Attention is drawn to the need for the details of any permanent connection to a water supply to comply with the appropriate water bye-laws (see **2.4.4.8** of BS 6880-1:1988). Ball-valves should be checked for suitability for the available water pressure.

e) Any cold water break tank should be fitted with a suitably piped overflow of at least 19 mm diameter.

f) A drain valve and lockable isolating valve should be fitted.

g) The piping should be arranged so that warm water does not circulate by gravity through the vessel (see **4.4.4** of BS 6880-2:1988).

h) Appropriate precautions should be taken to protect pumps, internal surfaces of spill tanks and expansion vessels from corrosion prior to putting into operation, also to prevent deterioration of flexible diaphragms.

i) All necessary information should be available to facilitate correct installation and wiring of such necessary controls, alarms, etc. as cannot reasonably be incorporated in the pressurization equipment before receipt at site.

2.8 Installation of energy conversion equipment

2.8.1 Boilers and combustion equipment

2.8.1.1 *Foundations and structures.* Foundations should have been checked and passed as ready to receive the plant before moving into position. On certain types of boiler a refractory sub-base may be required. Boilers should be fixed, and correctly located in relation to chimneys, access requirements, etc. Structures associated with related equipment (solid fuel hoppers, etc.) should be checked and passed as ready and safe before equipment erection proceeds. Fuel hoppers, etc. and associated structures should be checked and passed in respect of completeness and structural integrity before filling. Certain types of boiler require to be assembled on purpose-designed baseplates.

2.8.1.2 *Site assembly.* Site assembly should be carried out by experienced personnel in accordance with the manufacturer's instructions, particularly the assembly, sealing and tightening of sectional boilers and the mounting and connection of burner equipment. Burners should only be mounted to boilers using the proper attachments and fittings provided by the respective manufacturers.

2.8.1.3 *Care and protection.* Manufacturer's recommendations should be followed in respect of protection of boiler internals if left standing for a long period. Particular care is required to avoid damage to refractories and to protect and keep clean burners, controls and other sensitive items.

2.8.1.4 *Mountings and connections.* All necessary installation instructions, wiring and other connection diagrams should be available and the necessary connections identified. This particularly applies to electrical requirements, e.g. correct voltage, phases, number of wires, earthing and all other safety requirements (see **2.9**).

Piping connections should be in accordance with good pipework practice (see **2.7**) and boilers, etc. should be adequately safeguarded against undue piping loads and expansion thrusts. Suitable locations and method of mounting should be established for all field-mounted control and instrumentation elements (see **2.10**).

All necessary mountings and control elements should be checked as correct, fitted and functionally checked for the required modes of operation in accordance with statutory and insurer's requirements, and with the recommendations of the manufacturer and appropriate British Standards or other relevant codes of practice according to the type of fuel (see **3.3.1.2** of BS 6880-1:1988). This applies to any necessary item, whether or not fitted to the boiler itself, including such items as flue isolating valves and lighting-up gas installations.

2.8.1.5 *General.* Before commissioning, thermal insulation should be completed, clad as required and surplus material cleared away. Air supply arrangements to the boiler room should be checked as adequate; also that flue passages are not obstructed and that the correct grade of fuel is available at a pressure within the required limits.

2.8.2 Fuel storage and handling equipment

2.8.2.1 *Foundations.* Tank foundations should be checked and passed as ready to receive the equipment. The appropriate type of bedding or packing should be used.

2.8.2.2 *Tank installation.* Fuel oil tank installations should be installed in accordance with BS 799-5. Liquefied petroleum gas (LPG) tank installations should be installed in accordance with the Home Office Code of Practice [16] (see **2.4.3.2.2** of BS 6880-1:1988). Where tanks are site welded, the welding procedures, and test and inspection procedures required should be established before commencement of work. Internal and external corrosion protection of tanks should be complete and any required thermal insulation and cladding. Tanks should be drained of moisture before filling.

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2.8.2.3 *Mountings and connections.* All necessary mountings, pipework, electrical connections and control elements should be checked out and installed as recommended in **2.8.1.4**.

Fuel pumping and heating units should be fitted with the appropriate grade of filter. Pumps should be checked for alignment and freedom to rotate.

Underfeed stokers should be installed in accordance with CP 3000.

2.8.3 Chimneys and flues

2.8.3.1 *Foundations.* Foundations should be checked for correct setting out and completeness, and passed as ready to accept loads.

2.8.3.2 *Chimney erection.* Erection of chimneys should be done by experienced and trained personnel equipped with the appropriate tackle, etc. in accordance with the appropriate safety requirements (see **2.2**). Particular attention should be paid to the dangers of wind and of falling objects. Where site welding is required, the recommendations given in **2.8.2.2** also apply. Chimney and flue installation should be coordinated as necessary with all related builders' work. Erection of chimneys within the scope of BS 4076 should comply with the requirements of that standard. Guy ropes should be firmly anchored to appropriate places and correctly adjusted.

2.8.3.3 *Insulation and cladding.* Corrosion protection, thermal insulation and cladding should be complete and checked before means of access is removed. Attention should be paid to avoiding damage to cladding and to maintaining air gaps where required on clad chimneys.

2.8.3.4 *Lightning protection.* Lightning protection should be installed and tested in accordance with BS 6651.

2.8.4 Heat exchangers and thermal storage vessels

2.8.4.1 *Bases and supports.* The general principles indicated in **2.5.1** and **2.5.2** should be followed, together with the following recommendations.

a) Provision should be made to allow for controlled thermal expansion movement; where anchoring is necessary it should be at one point.

b) Support feet of copper vessels should be protected by bearing pads of lead.

c) The total weight of the complete and filled installation should be taken into account under the most arduous condition expected, including test conditions.

In certain cases non-storage calorifiers may be supported by purpose-designed cradles cantilevered from walls. These should only be used where the resultant static and other loads have been indicated to, and had prior approval by the party responsible for the structure, together with the proposed method of fixing.

2.8.4.2 *Access and clearances.* Location of the equipment and adjacent items should allow adequate and safe access for operation, inspection, cleaning, draining down and maintenance, including maintenance of insulation, when all associated fittings, pipework, thermal insulation, platforms, ladders, etc. are in place. Space should also be allowed for tube cleaning, tube withdrawal, and for withdrawal of any electric heating elements. Storage vessels and calorifiers should have walking access around them, except that a reduced clearance may be acceptable between a vertical circular vessel and one adjacent wall. As a general guide, minimum clearances (when the installation is complete) should be as follows.

a) 600 mm at top.

b) 225 mm at bottom, subject to adequate draining arrangements; in the case of vessels with the ends "dished" inwards, the minimum should be 450 mm. The location of heat exchangers and the associated LTHW pipework configuration should not be such as to prevent effective flushing and cleaning (see **3.3**), and adequately sized drains should be provided.

2.8.4.3 *Relief valves, vents, anti-vacuum valves and other mountings.* Relief valves, vents, anti-vacuum valves and other mountings should be correctly fitted and checked in respect of duty and settings. Relief lines and vents should be adequately sized and appropriately routed so that the device can function effectively and safely at all times. Trapping of water and risk of freezing in relief pipes, etc. should be prevented.

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2.8.4.4 *Vessels.* The following considerations apply to vessels in particular. The recommendations of the applicable pressure vessel code or other standard should be followed in respect of site operations. Particular attention should be paid to access and provision for required inspections during and after installation. Modifications to vessels and their mountings should not be made during installation unless prior approval has been obtained from the requisite authority under the vessel code. Care should be taken to prevent such vessels being subject to excessively low temperatures before being put into use, particularly when external. Vessels should be cleaned and free of debris before closing up. Internal and external corrosion protection should be maintained, and inspected prior to putting into use. When the system is filled, treated water of the quality required for the system as a whole should be used (see **3.5** of BS 6880-1:1988).

2.8.5 Installation of heat pumps

2.8.5.1 *Location and foundations.* Particular attention should be given to location and foundations, especially in connection with dynamic loads and the control of noise and vibration (see **3.10** of BS 6880-1:1988). It should be appreciated that heat pumps often incorporate reciprocating compressors; also, a heat pump is likely to be the highest powered single machine on the LTHW system with which it is associated.

Location and clearances should allow for adequate motor cooling at all times, and for cleaning and withdrawal of heat exchanger tubes or other surfaces as appropriate. The location of the unit and other equipment and services should be such that exposure to extraneous heat sources is avoided, as this can give rise to dangerous pressures in the refrigerant circuit.

Particular care is called for when siting air source heat pumps, having regard to:

a) noise emission to the surroundings;

b) unimpeded air flow to and from the unit;

c) avoidance of intake or discharge of air in such a manner as to interfere with other services or cause a nuisance;

d) provision for removal of condensate and melted frost.

2.8.5.2 *General mechanical installation.* The possibility of condensation forming on water heat source pipework should be recognized and appropriate measures used. Also, such pipework should be protected from risk of freezing due to exposure (see **3.2.2.2** of BS 6880-1:1988). There is also a risk of freezing due to a malfunction causing overcooling (see **5.8.2.8.6** of BS 6880-2:1988).

2.8.5.3 *Refrigerating equipment.* The manufacturer's detailed recommendations should be followed. In all cases it is essential to ensure the equipment arrives on site and is placed in position undamaged. Particular attention should be paid to refrigerant circuits, which should be tested (e.g. halide torch) to ensure there is no leakage and that the refrigerant holding charge is intact. When split-system or other equipment requires site-assembled refrigerant piping, the recommendations of **2.8.5.4** should be followed. There may be manufacturer's limitations on the total length of refrigerant pipework, or the height difference between condensing and evaporating units; if these limitations are exceeded system performance may be impaired.

For the use of mechanical pipe couplings with refrigerating equipment see **2.7.1.5**.

2.8.5.4 *Refrigeration pipework.* Where refrigerant piping systems are built up on site particular care should be taken to keep dirt and moisture out of the system. The installation should be carefully checked to ensure that the design requirements are met; this includes checking that correct pipe sizes have been used and that circuits are arranged to avoid excessive pressure drop and to ensure proper refrigerant feed to evaporators and return of oil (see also **2.8.5.3**).

Piping and components should be arranged to prevent liquid refrigerant from entering the compressor during operation and shutdown, to prevent excessive lubricating oil being trapped in the system, and to minimize any possible loss of lubricating oil from the compressor. Particular care is needed where multiple compressors are connected to a common circuit since pressure-equalizing and oil-equalizing piping may be required. (Further detailed information is given in ASHRAE Handbook: "Fundamentals" and "Systems" volume) [17]. It should be checked that sufficient isolating valves, sight glasses and dryers are provided to facilitate commissioning, operation and maintenance. Procedures for pressure testing, dehydration and charging of refrigerant lines are described in the CIBSE Commissioning Code Series R [18]. Refrigerating systems should comply with the requirements of BS 4434. Thermal insulation should be in accordance with the recommendations given in BS 5970.

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2.9 Electrical installations

All electrical work should be carried out in accordance with the current edition of the IEE Regulations [19] (see **3.9** of BS 6880-1:1988). The following should also be checked:

a) that all parts liable to deterioration through atmospheric conditions, ingress of dust, etc. have been protected before despatch and are stored in dry, suitable conditions on site;

b) where the main control of the motor is remote from the motor, that a suitable mains isolator has been fitted adjacent to the unit;

c) that the type of motor starter used is appropriate to the application and the requirements of the motor, particularly in respect of the type and setting of the overload device and other protective features.

All exposed metalwork of the electrical equipment, including motors, should be earthed and particular attention paid to the continuity of the system. Motors should be properly secured to purpose-made bases or mounting frames to minimize noise and vibration. Checks should be made that the bases are properly aligned and that the air circulation to the motor for cooling purposes is as recommended by the manufacturer and does not discharge onto any other equipment. Access should be available around the motor to enable it to be handled easily if a replacement is necessary, or if an adjustment to the drive is required. It is important to position electrical equipment, including starter panels, where they cannot be flooded with water if a break or overflow should occur. If this is not possible, the equipment should be made waterproof.

2.10 Installation of control equipment

2.10.1 General

All instruments and control equipment should be installed in accordance with the instrument manufacturer's recommendations.

All pipework connections and valves associated with the control valves should be of the required size, reducing in size only to connect to the control valve where this is smaller than line size. Pipework should be properly supported to ensure no distortion of valve bodies.

It is important that all electrical wiring to controls should be carried out in accordance with the appropriate statutory requirements and those of the IEE Regulations [19], adequately supported and protected, and with due attention to equipotential bonding requirements (see **3.9** of BS 6880-1:1988). Types of cable used should be suitable for the application and cable and termination types should be compatible. Pneumatic impulse lines should also be installed, supported and protected in accordance with appropriate practice and checked to ensure that internal surfaces are clean and dry.

Items mounted externally or in other exposed locations should be adequately protected against the weather and from corrosion. All control items should be located so that they are readily accessible for adjustment, service and replacement.

2.10.2 Access

All instruments, sensing elements, controllers, control valves, etc. should be mounted in locations accessible from permanent walkways, ladders or platforms. Access should be left around them to enable maintenance to be carried out. Field mounted items should be located so they do not obstruct walkways or plant equipment access.

Panel mounted controllers should be mounted between 1.0 m and 1.75 m from the finished floor or platform level to facilitate adjustment, service and replacement.

2.10.3 Sensing elements

All pipe, and equipment-mounted temperature sensors or thermostats should be in pockets to enable removal without draining down. Pockets should preferably be made of stainless steel, and should be screwed into suitable bosses.

Pipe-mounted temperature sensors and thermostats should preferably be mounted at bends in the pipework and be of greater length than the pipe diameter. Sensors and thermostats mounted in straight runs of pipe should be at least as long as half the pipe diameter. Mixed flow sensors should be located at least 12 pipe diameters from the point of mixing. Capillary sensors should be mounted on suitable supports with access for replacement.

External sensors should generally be positioned on a north face away from the influence of direct solar radiation and local heat gains. Room thermostats and sensors should generally be wall-mounted or column-mounted at 1.5 m above the finished floor level, away from direct heat sources.

Thermostats located in public or industrial areas should be protected against accidental or deliberate damage.

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2.10.4 Controllers and control panels

Controllers are normally located remote from the sensing and final control elements although there are controllers that can be combined with either. Separate controllers have the advantage that they can be mounted in clean, dry locations away from accidental damage, such as within control panels.

The general construction, location, standard of enclosure and wiring of control panels should be in accordance with the principles indicated in **2.9** for electrical equipment generally.

Careful attention should be given to ensuring that power supplies to controllers, etc. are correct in terms of voltage and number of wires and that appropriate local isolation is provided.

Where controllers, etc. are mounted in a common panel with other electrical equipment such as motor starters, etc., particular care should be taken with electrical safety requirements, such as segregation of voltages where appropriate and clearly indicating where items may be energized from remote sources. Controllers should preferably be mounted in separate panel compartments from electrical switch or contactor gear, to minimize electrical interference. Field-mounted instruments should have cable entries which comply with BS 4568-2. Instrument cables should be screened as recommended by the instrument manufacturer. Such screening should be earthed at one end only, generally at the controller and extended up to the actual panel-mounted item, rather than terminated at the panel terminals.

2.10.5 Control valves

All control valves should be capable of being isolated for maintenance purposes. Three-port control valves should be provided with an isolating valve on each port, that for the bypass port being of the double regulating type (see **6.3.4.2** of BS 6880-2:1988).

Where control valve bypass valves are installed, they should be clearly labelled with their normal operating position, and only authorized personnel should be allowed to open them. The valve should normally be locked in the closed to load position (see **6.3.4.5** of BS 6880-2:1988).

Control valves should be mounted upright wherever possible, and should never be mounted at more than 90° to the upright position. The manufacturer's recommendations on valve installation should be observed including those for the provision of strainers before control valves.

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Section 3. Inspection, commissioning and testing

3.1 General

Inspection, commissioning and testing should be carried out thoroughly. Adequate time should be allowed in the building programme so that this can be achieved. All results should be properly documented. It is recommended that the whole commissioning procedure should be under the guidance and control of a single authority. A number of different skills will be involved and close collaboration and coordination of all concerned is necessary. Recommended procedures to be followed are given in the Commissioning Codes published by CIBSE as follows:

Series B	Boiler plant [20]
Series W	Water distribution systems [11]
Series C	Automatic control systems [21]

Further guidance on detailed procedures and methods of measurement for regulation of water systems is given in the BSRIA "Manual for Regulating Water Systems" [22]. Commissioning of ducted air handling systems is outside the scope of this code, and is covered by BS 5720 and CIBSE Commissioning Code Series A (Air distribution systems, high and low velocity) [23]. These should be followed in the context of ducted air heating systems. Where heat pumps are used, the relevant procedures given in CIBSE Commissioning Code Series R (refrigerating systems) [18] should be followed.

It is recommended that the commissioning engineer be given an early opportunity to review the system in order to establish the appropriate method of commissioning. A full description of the intended mode of system operation together with a complete set of up to date drawings, control diagrams, and the manufacturer's operating instructions should be made available. Required system flows at each measuring point should be indicated, and for LTHW circuits the designer should state the required mass flow tolerances, as appropriate to the application. It should be noted that specific tolerances are not given in the CIBSE Code Series W [11]. These tolerances relate to the permissible variation in actual regulated flows. In assessing the results of commissioning procedures based on flow measurement devices, an understanding is necessary as to the level of accuracy which can be expected, according to the type of measuring device used and the physical and hydraulic conditions which apply to the particular installation (see BSRIA "Manual for regulating water systems") [22]. Appropriate selection of measuring devices (see **3.4.4** of BS 6880-1:1988) and their correct installation are particularly important.

On larger installations, commissioning in agreed sections may be appropriate, provided that the section is such that its behaviour will not be significantly affected by sections not yet commissioned.

Attention is drawn to the practical limits of accuracy of instrumentation used for boiler testing (see Section B.3 of the CIBSE Commissioning Code Series B [20]. Recommendations concerning proving of ancillary equipment (pressurization units, oil, coal and ash handling equipment) are given in the CIBSE Commissioning Code Series B [20].

3.2 Inspection and testing at works

LTHW systems usually consist of various items of equipment produced by various manufacturers. Each manufacturer should give facilities for the inspection of his manufacturing operations and inspection and test procedures. He should be prepared to carry out an observed test, given due notice, and should guarantee performance for the specified duty and conditions and, where appropriate, provide test certificates and/or performance curves or tables based on a type test carried out in accordance with the relevant British Standard. Witnessed performance tests should be carried out in accordance with the relevant British Standard. In respect of pump tests and pump curves see also **4.2** of BS 6880-2:1988.

In the case of pressure vessels (including any thermal storage vessel so classified), the requirements of BS 5500 or other applicable vessel standard should be followed. There may also be specific insurer requirements.

Any equipment that requires a hydraulic pressure test should be supplied with a test certificate on request and all such equipment should bear identity plates showing the maker's name, serial number, test pressure, safe working pressure and date of origin. Where no British Standard applies details of any required test should be agreed with the manufacturer.

Performance testing of boilers and associated combustion equipment at works (where required) should be carried out in accordance with the British Standard appropriate to the type of boiler, or other agreed procedure (see also **3.5.1**). Performance testing of air source heat pumps should be carried out in accordance with BS 6901 and account taken of the critical aspects and other factors indicated in **5.8** of BS 6880-2:1988.

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In connection with works testing, it should be appreciated that there is a distinction between the following (see BS 0).

a) *Type tests.* The test or series of tests directed towards proving a design and the manufacturing process.

b) *Tests on day to day production.* These are usually done on representative samples, but in some cases it may be required to apply certain tests to each item made.

3.3 Inspection and testing on site

Before commissioning the LTHW system all necessary preliminary checks and static testing of mechanical and electrical systems should be carried out using a systematic and documented procedure. It is important that these checks are carried out prior to start up or commissioning but not such that a significant idle period occurs between testing and commissioning. The procedures given in the CIBSE Commissioning Codes are recommended (see **3.1**).

A clear understanding of the proposed method of testing and inspection should be established before the work is carried out (see **3.1**).Thermal insulation should be inspected in accordance with the recommendations of BS 5970; for information on the testing of insulating materials see BS 2972.

The LTHW system should be thoroughly flushed through so that as much dirt, scale, etc. as practicable is removed from the system shortly before commissioning starts. A systematic procedure should be followed. The use of cleaning additives may be appropriate; they should be selected and applied on the advice of suitable specialists and under their supervision. Particular attention should be paid to the status of control and regulating valves where this is carried out, in view of the relatively small apertures associated with some types. Similar considerations may apply to other items of equipment.

All LTHW and other piping systems should be hydraulically pressure tested to at least 1.5 times the working pressure for a period of not less than 30 min. Such tests should be carried out prior to application of insulation and enclosure in ducts, trenches, etc. In the specific case of embedded pipe heating systems, higher test pressures may be required (see **3.5.3.3** of BS 6880-2:1988). Procedures should be agreed with manufacturers to ensure compatibility with their equipment and that their fitness for purpose or performance will not be adversely affected. Attention is drawn to the fact that the standard pressure rating categories of equipment which may be incorporated in LTHW systems are not entirely consistent (see **3.4.7** of BS 6880-1:1988). Gas piping installations should be tested for soundness in accordance with British Gas publication IM/5 [24].

All electrical and controls wiring should be checked and, as far as practicable, the controls' operation proved as being functionally correct. It is important that control wiring and other electrical wiring having a control function are checked as a complete system, and that the need to make wiring corrections during later stages is avoided.

3.4 Commissioning

3.4.1 General

Recommended procedures to be followed are given in the ClBSE Commissioning Codes (see **3.1**). Certain specialist items of equipment such as boilers, heat pumps, pressurization equipment, control systems and proprietary floor and ceiling heating installations should preferably be commissioned by, or under the supervision of, the manufacturer's commissioning staff. However, it is important that all commissioning is coordinated by a competent individual who has a full understanding of the intended operation and performance of the system. It is important that the system is set up to obtain LTHW flow rates and temperatures as specified by the designer and to this end all this information and full details of the intended operation of the plant should be given to the commissioning engineer (see also **3.1**).

With regard to the commissioning of gas-fired boilers reference should be made to BS 6644.

3.4.2 Balancing and regulation

Balancing is the process of achieving the correct proportion of total system flow through the various parts of the circuit. Regulation is the adjustment of such flows to the required values (in kg/s) and tolerances (see **3.1**).

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System regulation is the final stage in a sequence that starts with the design. If the needs of on-site regulation are not foreseen and provided for, it may not be possible to balance the system within the accepted limits. High costs can be involved in remedial work and the additional time spent on regulation. It is essential that system flows are correctly regulated and balanced and are in accordance with design parameters otherwise the system may not be able to perform as intended.

Locating the necessary regulating valves and flow measurement devices in the right places is one of the basic requirements for effective system regulation (see **3.4.4** of BS 6880-1:1988). Any saving of final costs by the omission of dampers will soon be lost in the extra time taken in commissioning. To carry out satisfactory regulation of a system a schematic diagram, showing all mains, branches, valves, emitters, etc. with the required flow appertaining to each run of pipe and each emitter is required. Numbering and permanent labelling of all regulating valves is recommended. Adequate means of measuring flow should be available.

The principle of proportional balancing should be used (see CIBSE Commissioning Code Series W [11] and the BSRIA "Manual for regulating water systems") [22]. The principle of balancing by matching return temperatures (whether by hand or other means) is not recommended except for final run-outs to emitters where provision of flow measuring devices is not practicable. It is not possible to achieve a high degree of accuracy on balancing a system and much time can be wasted trying to meet fine tolerances (see also **3.1**). Where three-way valve control is used (e.g. at air heater batteries), it is important that regulation be carried out so as to balance emitter pressure drops with those of the parallel paths before system regulation proceeds (see Section B.11 of the CIBSE Guide [1]).

Once the system has been regulated it is important that the setting of all regulating and/or flow measurement valves and associated flows are recorded and valves secured in the set positions.

3.4.3 Setting to work and controls commissioning

On completion of all necessary precommissioning checks, balancing and regulation procedures, the system should be prepared for start-up. Before applying heat to the system, it should be ensured that it is in an appropriate condition with regard to all aspects of safety to personnel, equipment and property. Heat should be applied gradually. The start-up procedures recommended by the manufacturers of any specialist equipment incorporated in the system should be followed. Pipe supports, sleeves, anchors, guides, etc. should be checked for correct operation under conditions of thermal movement.

Following a reasonable time for warm-up of the system and the building, controls and control valves should be checked for satisfactory operation and accuracy of control, including thermostatic and flow controls, time control devices, etc. Control set points, schedules, programmes, etc. should be adjusted for the intended mode of operation. However, such adjustments may be subject to limitations of weather, such that the work has to be completed at some subsequent time. Also, where the building is not to be put into use immediately but heating is required, considerations of energy conservation or possible damage to fabric may indicate setting up an appropriate reduced operating mode.

In carrying out commissioning and setting systems to work, particular attention should be paid to the following in order to avoid hazards and damage, and appropriate measures should be taken.

a) Surfaces may become hot to which personnel on site are not accustomed.

b) Overheating or underheating of individual spaces may introduce risks of damage to building finishes, etc.

c) Equipment which is operating, for whatever purpose, should be inspected and maintained as appropriate (see section 4).

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3.5 Performance testing

3.5.1 General

Performance testing is the evaluation of the performance of a commissioned installation in terms of its ability to achieve required performance under representative operating conditions. Whilst such tests may not always be specifically called for, any system should be capable of satisfactorily passing such tests once completed, tested and commissioned in accordance with the recommendations of this code. This presupposes that the conditions under which the test is carried out are sufficiently representative of design conditions for practical purposes. It should be appreciated that satisfactory performance of a building heating system also requires that the construction of the building should be as intended, and complete and inspected in all relevant respects. Performance testing of an LTHW heating system should (as a minimum) enable the following to be evaluated at one representative design condition:

a) adequacy of total system output;

b) adequacy of heat output to each directly heated space;

c) consumption of fuel (or other energy source).

Other characteristics may also be included in a performance test, such as temperature distribution, accuracy and response of temperature control and performance in respect of noise. The objectives of a performance test, the conditions under which it is to be carried out and the method of measurement to be used should be clearly established before the test is carried out. A performance test cannot be conclusive unless a standard of required performance has been established, preferably at the design stage. It is also preferable that appropriate and accessible test points and other relevant features are incorporated in the installation to facilitate performance testing. In respect of performance testing of air handling systems (including noise-related aspects), see **6.5** of BS 5720:1979. Methods of measurement and their accuracy should be in accordance with the appropriate British Standard where available.

Whether performance tests are intended or not, all elements of an LTHW system should be satisfactorily tested and commissioned in accordance with the recommendations of this code and with such requirements as may apply in a particular case. The satisfactory operation of the system should also be verified, only excepting those aspects which can only be demonstrated by a performance test as described in this subclause.

3.5.2 Energy conservation equipment

3.5.2.1 *Boilers.* Performance testing of LTHW boilers on site should be carried out in accordance with the relevant parts of the procedures described in BS 845 (testing steam and hot water boilers in general), until such time as it may be superseded by a more specific British Standard. It is important that the properties of the fuel used should be within the appropriate limits (see **3.3.1.2** of BS 6880-1:1988). In the case of installations burning waste materials or other non-standardized fuels with potentially variable properties (see **3.3.2** of BS 6880-1:1988), a particular understanding on the basis of test needs to be established in each case before the test is carried out. It should be appreciated that there are practical limitations to the accuracy of the results of fuel consumption tests of this kind (see foreword to BS 845 and appendix B.3 of the CIBSE Commissioning Code Series B [20]). It may be necessary to use a single flow measuring device to verify total system flow, which should be in accordance with BS 1042. Where such a device is not a permanent feature of the installation, due allowance for pressure drop should be made. It is necessary to provide an adequate and reasonably constant thermal load for the purpose of carrying out the test. Normally it is required to test at 100 % of rated thermal output or at the output corresponding to rated maximum thermal efficiency. Performance testing should not normally be carried out at less than 60 % of rated output.

3.5.2.2 *Other energy conservation equipment.* Similar principles should apply to the testing of types of energy conversion equipment other than fuel-fired boilers. In the absence of applicable British Standards, a specific basis of test should be established, having particular regard to the practical realities of the situation. This is particularly important in the case of heat pumps, and test procedures should be based on a clear understanding of their principles of operation and those factors that are critical to their thermal performance (see **5.8** of BS 6880-2:1988).

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3.5.3 Complete LTHW heating installation

3.5.3.1 *General.* A performance test on an LTHW building heating installation can normally only be based on an approximation to design conditions, since these include such variables as weather, the behaviour of the building fabric and the state of occupancy. Experienced judgement is required to establish test conditions that are sufficiently close to the design conditions, and to define a basis of projection on which corrections to test results can be based where appropriate. Such judgement should take account of the nature of the building, the type of heating system and other relevant parameters (see **3.5.3.2**).

3.5.3.2 *External factors affecting system performance*

3.5.3.2.1 *General.* This subclause considers various factors which have a bearing on system performance under operational conditions, and which should be considered when establishing the basis of a performance test and evaluating the results.

Minimum recommendations are made concerning the extent to which these factors should apply to a performance test. However, in specific instances more exacting performance may be called for, in which case the performance test should be such as to demonstrate the performance required; in such cases the performance expected should be established at the design stage.

3.5.3.2.2 *External conditions.* The following external environmental factors should be considered in performance testing.

a) *Temperature.* Ideally, testing should be carried out at the design outdoor air temperature. Where this is based on the CIBSE design method, the availability of the appropriate overload capacity should be demonstrated. It may be possible to carry out the test at some other external temperature and an appropriate correction factor used in assessing the results. Such correction factors should be established for the particular case as outlined in **3.5.3.1**. It is recommended that in such situations the performance test be carried out under conditions that are as close as practicable to the design conditions, such that corrections can be minimized.

b) *Wind.* Wind should be taken into account where exposure is regarded as severe, or for building heights in excess of 13 m.

c) *Solar effects.* Temperature measurements related to specific rooms should be taken when not exposed to direct solar radiation. Where the building is to be provided with curtains or blinds for use at night, these should be used at night (or suitable temporary provision made) to offset sky radiation effects.

3.5.3.2.3 *Building construction.* The following building construction features should be taken into account when performance testing.

a) *Thermal transmittance values.* Building fabric "U" values should be taken to be as derived by CIBSE method calculations (see Section A.3 of the CIBSE Guide [1]) for the materials and dimensions applicable. Where thicknesses are in doubt, spot checks may be necessary in situ.

b) *Infiltration.* Wind conditions to be taken account of as in **3.5.3.2.2** b). Building construction, including finishes, should be complete and constructional gaps or cracks within limits appropriate to the type of construction.

c) *Natural ventilation.* Fixed ventilators to remain open. Windows and adjustable natural ventilators to be closed.

d) *Mechanical ventilation.* Where this is intended to be in continuous operation and heating of the air so introduced is to be provided by the LTHW system, then it should be operated throughout the test. Air volumes should be checked and temperatures monitored during the test to ensure that they are in accordance with the design intent. If otherwise, an appropriate basis of test should be established.

e) *Other features of building.* Complete and fitted out as intended. Internal and external doors shut or open as normally intended under cold weather conditions. Where it is intended that certain spaces are heated indirectly by transfer from an adjacent space, then the appropriate provisions should be operational; curtains or blinds would not be used except as **3.5.3.2.2** c); loose floor coverings need not be in place, except in the case of heated floor systems.

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f) *Status of LTHW heating systems.* Complete, insulated, fully tested, balanced, regulated and otherwise satisfactorily commissioned, with controls functioning and set as appropriate. Energy conversion equipment set to produce mass flow and flow temperature corresponding to required system output. Emitters operating in the intended manner, and set for maximum output where manually controlled. The heating system will have already been operating after completion of commissioning for a period long enough to achieve stable conditions. This time will depend on type of building construction, but should not be less than 1 week of continuous or intermittent operation as appropriate.

g) *Building occupancy.* The building may or may not be normally occupied at the time of test. If unoccupied, allowance should be made for adjustment of manually operated emitter controls where appropriate. Artificial lighting only as appropriate to normal occupancy requirement.

3.5.3.3 ***System performance standards***

3.5.3.3.1 *General.* The following recommendations given in **3.5.3.3.2** to **3.5.3.3.6** are made as a minimum standard of system performance under test conditions. In specific instances more exacting performance may be required, calling for more stringent performance standards, which the test should reflect. In such cases, the standard of performance expected should be established at the design stage. The timing and duration of tests should be established with regard to the nature of the building, the heating system, the occupancy pattern and likely variations in external factors.

3.5.3.3.2 *Room temperature.* Unless otherwise specified, design room temperatures should be achieved at 1.5 m above the floor. For practical purposes air temperature is measured, using a sling thermometer or recording thermograph. In certain cases, globe or other special thermometer types may be called for in order to approximate to environmental temperature, in which case the basis of calculation should be established.

3.5.3.3.3 *Room temperature gradient.* No general criterion can be given for vertical temperature gradient, as this is influenced by system type and room height. The general good practice indications given in various parts of this code should be followed. Where this is particularly important, specific criteria should be established at the design stage, in conjunction with the selection of the heating system.

3.5.3.3.4 *Room horizontal temperature variation.* At 1.5 m above the floor, the room horizontal temperature variation should be within ± 2 °C of the design value, with the average not less than the design value, anywhere within the occupied area of the room. Unless otherwise indicated, this is the area in which occupants may be permanently located for much of the day, and generally not closer than 600 mm approximately to external walls, windows or heat emitters. Where spaces are indirectly heated by spill from adjacent spaces, these criteria may not be achieved; in such cases they should comply with the appropriate statutory minima.

3.5.3.3.5 *Air movement.* Significant adverse convection draughts should not be apparent to non-transitory occupants of occupied spaces. No general criteria are recommended in respect of forced convection systems, except the good practice indications given in various parts of this code. Where this is particularly important, specific criteria should be established at the design stage, in conjunction with the selection of the heating system (see also BS 5720).

3.5.3.3.6 *Room temperature variation with time.* Where a space is directly heated and not intended to be controlled manually by the occupants, then temperature variation with time should be within ± 2 °C of the design temperature. This degree of control should be maintained regardless of changes in external climatic conditions (except for direct solar gain effects), provided that other test conditions remain as indicated. It should be noted that to achieve the specified tolerance on room temperature the sensitivity of the temperature sensing device itself needs to be closer than the tolerance on room temperature.

3.6 Handover procedure

3.6.1 Handover documentation should contain all information that the user needs to enable the installation and equipment to be efficiently and economically operated and maintained. It should also provide a record of the outcome of any site testing, balancing and regulation carried out prior to handover. This information will be drawn together from the appropriate sources according to the procedures for the specific project, including the designers, equipment suppliers and the installation contractors. It should be available at the time of handover. It is desirable that representatives of the ultimate operators of the heating system meet those responsible for design and installation some time before the anticipated handover date and review the progress of documentation and arrange any necessary training and familiarization.

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3.6.2 Handover documentation should include the following:

a) the designer's description of the installation, including simplified flow diagrams for the complete installation;

b) preventive maintenance;
operating recommendations by the designer;

c) operation and maintenance instructions for equipment, manufacturer's spare parts lists and spares ordering information;

d) schedules of electrical and control equipment;

e) controls and electrical schematics and wiring diagrams;

f) schedules of mechanical equipment;

g) test results and test certificates as required, including any insurance or statutory inspection certificates;

h) list of keys, tools and spare parts that are handed over.

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Section 4. Operation and maintenance

4.1 Maintenance policy

Maintenance policy is defined in BS 3811 as "a strategy within which decisions on maintenance are taken". The personnel required to carry out the maintenance programme will depend upon the policy established by the building owner or manager, and also whether it is decided to provide for operation and maintenance of the system by an external specialist organization, by use of suitably trained in-house personnel, or a combination of both. Each maintenance programme should be based on records of the system as installed and its performance in use and such records should be systematically updated. The types of maintenance procedures that may be adopted are defined in BS 3811 and are:

a) planned maintenance;

b) preventive maintenance;

c) condition-based maintenance;

d) running maintenance;

e) shutdown maintenance;

f) corrective maintenance;

g) emergency maintenance.

4.2 Safety considerations

All equipment should be inspected and maintained to ensure compliance with all statutory requirements, and to ensure the safety of operating personnel, building occupants and the building itself. The introduction of new safety legislation or amendments to existing regulations may require changes to be made from time to time in existing installations. For guidance on safety legislation see **2.4** of BS 6880-1:1988 and **2.2** of this Part of BS 6880.

4.3 Personnel

The first essential of a successful maintenance programme is the provision of an adequately managed and trained staff to implement it. Maintenance staffing should be related to the skills and time required to perform scheduled routine tasks. The size of the building, the building usage, the numbers and types of LTHW heating systems and related equipment and controls provided, the degree of automatic operation, etc., should be considered in assessing the numbers and types of personnel to be employed. It is advisable to allow some reserve capacity to deal with unprecedented repairs or emergencies.

4.4 Records

4.4.1 Record system

A successful maintenance policy demands an adequate system of records. If maintenance is to be effective it should be properly planned and scheduled, and full advantage taken of standardized operation and maintenance procedures.

The central system of records should include a complete inventory of the systems, giving complete information on all equipment, components, distribution networks, electrical apparatus, controls and wiring, including:

a) performance and construction specifications;

b) manufacturers' drawings;

c) "as built" record drawings;

d) equipment catalogues;

e) system diagrams;

f) spare parts lists;

g) names, addresses and contacts of service organizations;

h) lists of tools and maintenance equipment required;

i) list of consumable items required.

4.4.2 Operating and maintenance instruction manuals

4.4.2.1 *General.* The purpose of operating and maintenance instruction manuals is to provide organized information and instructions on the operation and maintenance of the mechanical, electrical and controls equipment incorporated in the heating system, including ancillary installations such as fuel storage and handling. In the case of heat pumps, refrigeration equipment would also be included.

The operating and maintenance manuals should include the following essential data:

a) full descriptions of the LTHW, heating systems and equipment, including schedules of makers' serial/reference numbers;

b) operating instructions;

c) maintenance schedules and procedures.

It is often convenient to arrange the manuals in two major parts, as indicated in **4.4.2.2** and **4.4.2.3**. Information on presentation is to be found in BS 4884-2.

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4.4.2.2 *Part 1: Systems.* A complete description of the systems comprising the installation, including all related ancillary equipment should be included in Part 1. It is recommended that this is subdivided in the manner used in this code, i.e.:

a) energy conversion subsystem;

b) distribution subsystem;

c) utilization subsystem;

d) controls subsystem.

These subdivisions should include the following types of information, as appropriate.

1) Description:

i) system function/services;

ii) classification (e.g. variable temperature, constant temperature, etc.);

iii) basis of design;

iv) performance characteristics;

v) system pressure test certificates (piping and equipment);

vi) principal equipment and components;

vii) distribution arrangements;

viii) system schematic diagram with design flow rates and temperatures;

ix) automatic control diagrams.

2) Operating instructions:

i) starting/stopping procedures;

ii) adjustment and regulation;

iii) important energy conservation considerations;

iv) seasonal start-up;

v) seasonal shut-down;

vi) logs and records.

3) Inspection and maintenance:

i) inspection schedule;

ii) maintenance schedules and procedures;

iii) inspection and maintenance records;

iv) permits to work.

4) Reference drawings and documents:

i) design drawings;

ii) "as fitted" record drawings;

iii) copies of local authority/statutory approvals;

iv) engineering specifications;

v) commissioning records;

vi) performance test records (where applicable).

4.4.2.3 *Part 2: Equipment.* For each major piece of equipment the following information should be provided.

a) Description:

1) serial number/nameplate information;

2) catalogue data;

3) dimensioned drawings;

4) materials of construction;

5) parts designations;

6) equipment test certificates (works or type test);

7) electrical and controls schematics and wiring diagrams.

b) Operating characteristics:

1) performance curves, tables or charts;

2) safety devices;

3) temperature, pressure and speed limitations;

4) modes of control.

c) Operating instructions:

1) performance curves, tables or charts;

2) start-up procedures;

3) inspection during operation;

4) adjustment and regulation;

5) testing;

6) fault finding and troubleshooting;

7) safety precautions.

d) Inspection instructions:

1) normal and abnormal operating conditions;

2) inspection schedule and procedures;

3) records;

4) statutory inspection requirements.

e) Maintenance instructions:

1) maintenance schedules;

2) procedures;

3) records.

f) Spares:

1) parts list and reference numbers;

2) spares lists with reference numbers.

g) Service:

1) manufacturers' names, addresses and telephone numbers;

2) details of service arrangements.

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4.4.3 Work records

Complete records and reports should be kept of work performed, time expended and parts supplies used; this will assist in the identification of patterns of failure, design shortcomings or installation faults.

4.4.4 Operating log

Details of daily operations should be entered in an operating log. This log should include a note of important operational temperatures, pressures, electrical data, etc. A particular note should be kept of fuel and energy consumption. An analysis of this data should enable system performance to be monitored regularly and the system operated at optimum efficiency (see also BS 1374 in respect of log sheets for hot water boiler operation).

4.5 Procedures

4.5.1 General

The required frequency of routine checks, which may include inspection, adjustment, service and overhaul, will be properly established only by experience and depends on many factors, but in particular on local conditions. It should be borne in mind that although manufacturers' manuals are often excellent guides, they are based on average conditions, while extreme conditions often exist in practice; in which case this should be made known to the manufacturer before equipment is ordered. The maintenance and servicing programme for a given plant or piece of equipment may include routine checks of certain points at daily, weekly, monthly, quarterly, half-yearly and yearly intervals. The required frequency of routine checks depend on the following.

a) *Safety requirements.* The greater the requirement the more frequently inspection is needed; certain types of equipment and plant are subject to various statutory regulations.

b) *Severity of service.* More frequent inspection is required where the equipment is exposed to extremes of dirt, corrosion, friction, vibration, overloading or other hard usage.

c) *Hours of system operations.* Continuously operating plant requires more frequent checking than, for example, plant operating 8 h a day.

d) *Reliability.* Where breakdowns cannot be tolerated more frequent inspections are required.

e) *Age and condition of equipment.* As the equipment becomes older the frequency of inspections generally needs to be increased.

Routine checks of LTHW heating systems and principal types of related equipment are given in **4.5.2** to **4.5.11**. In respect of air handling equipment, see **7.4.2** to **7.4.6** of BS 5720:1979.

4.5.2 Boilers and combustion equipment

4.5.2.1 *General.* The overall objectives of the preventive maintenance of boilers and combustion equipment are to ensure:

a) that all safety-related systems are in working order and correctly set;

b) that LTHW heat supply to the building is not interrupted when required, due to avoidable plant or system failure;

c) that the required level of thermal efficiency and energy use is maintained;

d) that unacceptable emissions are avoided.

The manufacturer's recommendations should generally be followed as to service intervals, but the plan for a particular installation should take account of the practicalities of the situation, e.g. where plant is intended to operate unattended, daily checks are not practical; also where a six-monthly interval is recommended, a judgement (based on experience) should be made as to whether once per heating season would be adequate. Major work should be undertaken outside the heating season as far as possible.

General indications only are given in this code, in view of the wide range of equipment types covered. The manufacturer's recommended procedures should be followed in a specific case.

4.5.2.2 *Boilers.* Safety valves should be regularly maintained and periodically tested. HSE Guidance Note PM5 [3] recommends quarterly servicing and maintenance of hot water boiler controls in general, by competent personnel.

Operation of automatic flue dampers (if fitted) should also be checked at a similar interval. Boiler flueways and heating surfaces should be thoroughly cleaned at least once a year. Some shell boiler manufacturers recommend that this be done every 3 months.

Condition of refractories should be checked at least annually. On sectional boilers, the state of the tie rods should be checked annually, with particular attention to the manufacturer's recommendations.

When carrying out cleaning and maintenance work it is important to isolate burners and electrical supplies and to fully protect burners and related equipment from both damage and ingress of dust.

4.5.2.3 *Combustion equipment.* All safety-related controls should be checked regularly for correct operation and adjustment, and cleaned where necessary, including:

a) flame failure controls;

b) draught failure controls;

c) ignition and re-ignition sequences;

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d) all other safety interlocks;

e) instruments and alarms.

Keeping the burner assembly in a clean condition both inside and out is particularly important. Oil filters may need changing about once a month; this is influenced by the condition of the oil. Fuel supply pressure should be checked. The above operations should be carried out at least monthly; some manufacturers recommend greater frequency.

General servicing of other mechanical and electrical parts should be carried out at least seasonally including (according to the type of burner):

1) motors, drive belts, oil pumps, etc.;

2) burner nozzles;

3) parts in contact with fuel;

4) air-handling parts.

Combustion-related settings and performance should be checked at least seasonally. Servicing and performance checks should be carried out by trained and experienced burner maintenance personnel. See also CP 3000 in connection with the maintenance of underfeed stokers.

4.5.3 Fuel storage and handling equipment

Accumulated water and sludge should be drained from fuel tanks before each delivery. Automatic fuel shut-off valves and safety controls associated with oil heaters and trace heating (where used) should be checked with a similar frequency to boiler safety systems (see **4.5.2.3**). Oil pumping and heating equipment should be kept clean and free of water; the operating temperature and pressure should be checked regularly and adjusted as necessary. Oil pumps and drives should be serviced every season, as for burner equipment, noting that oil filters may require more frequent replacement.

Coal handling installations should be regularly checked and serviced, with particular attention to avoidance of conditions which could give rise to dust ignition or explosion conditions. Periodic cleaning should be carried out to prevent undue build-up of dust, protective devices should be regularly checked and maintained and any other steps necessary to meet the requirements of Section 31 of the Factories Act 1961 in this regard should be taken. For further guidance see the I.Chem.E. publication "Guide to Dust Explosion Prevention and Protection" [25]. Conveyors and elevators should be checked for wear on linkages, as should all other moving parts exposed to wear and abrasion.

Inspection and maintenance may need to be carried out more frequently than with other types of fuel-handling equipment, in view of the operating conditions. Where a compressed air system forms part of the fuel handling installation, in addition to the general maintenance of air compressors, valves, controls, etc., particular attention should be paid to regular checks on safety controls, relief valve operation and requirements for the inspection of air receivers (see **2.2.3**). See also **3.3.3.3** of BS 6880-1:1988 in respect of stock management.

4.5.4 Chimneys

Chimneys and flues normally need little maintenance, but periodic checking is advisable. The danger represented by a chimney which has become structurally unsound due to corrosion should be appreciated. Chimneys should be periodically examined visually and remedial action taken in respect of such items as:

a) insecure fixings, loose guys;

b) evidence of internal corrosion, particularly in the lower parts;

c) damage to insulation and cladding;

d) evidence of build-up of soot.

Where there is evidence of significant corrosion and a possible structural hazard exists, specialist advice should be sought, which may include non-destructive testing to determine metal thickness, etc. Lightning protection should be periodically tested in accordance with the recommendations of BS 6651.

4.5.5 Heat exchangers and vessels

LTHW calorifiers and heat exchangers require little maintenance provided that system water is maintained in an appropriate condition (see **3.5** of BS 6880-1:1988). A weekly visual check should be made for leaks. Statutory inspections should be carried out as required, otherwise an annual opening up for inspection and cleaning should normally be adequate. Safety valves associated with heat exchangers should be regularly maintained and periodically tested and bursting discs should preferably be replaced annually. For heat pump system heat exchangers see **4.5.6**.

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4.5.6 Refrigeration equipment associated with heat pumps

Many breakdowns can be traced to improper adjustment and operation of equipment. Particular care should be taken of safety controls, unloading devices, lubrication systems and compressor drives. Regular maintenance of expansion valves and other refrigerant flow control devices, solenoid valves and pressure regulators is essential. In the case of reciprocating compressors many failures are due to inadequate lubrication, metal fatigue, and liquid in cylinders; damage also occurs to valves, bearings, shafts and piston assemblies. Centrifugal and screw machines require specialized maintenance carried out in accordance with the manufacturer's instructions, but it should be remembered that all ancillary equipment also needs attention. The performance of the related heat exchangers (source/refrigerant or evaporator and refrigerant/LTHW or condenser) should be regularly observed and inlet and outlet temperatures logged daily. Refrigerant head pressure should also be logged daily. Regular inspection and cleaning of the heat source medium side of evaporators should be carried out on a schedule indicated by experience in the particular location. Occasional cleaning of the LTHW side of the condenser heat transfer surface should be carried out as necessary. The condition of LTHW system water should be checked and maintained (see **3.5** of BS 6880-1:1988). It is important that plant personnel appreciate the drop in performance that can result from poor heat transfer and other operational factors (see **5.9.2** of BS 6880-2:1988), which should be periodically checked.

4.5.7 Pumps

LTHW circulation pumps should be checked frequently (typically weekly) for excessive noise or vibration, excessive seal leakage, that pressure differential is as required and that the casing is free of air. It may be appropriate to change over duty and standby pumps at the same time. Belt drives should be checked and adjusted as necessary (typically once a month), and anti-vibration mountings and flexible pipe couplings checked. Grease lubricated bearings intended for replenishment should be greased as recommended (typically six-monthly), taking care not to overfill.

4.5.8 Pressurization equipment

The specialist manufacturer's detailed recommendations should be followed, having particular regard to:

a) correct functioning and integrity of all pressure-responsive and temperature-responsive safety devices, interlocks, etc.;

b) correct operation of automatic pumps and spill valves;

c) correct operation of system filling equipment;

d) protection of diaphragms (where used) from excessive temperature or pressure conditions, and occasional inspection of diaphragms and vessel interiors;

e) corrosion of internal surfaces of spill tanks and minimizing contact between air and system water;

f) cushion pressure on diaphragm vessels.

4.5.9 Piping systems

All pipework should be checked for leaks, external corrosion or other deterioration, particularly at joints adjacent to vibrating equipment. Pipe supports should be regularly inspected and strainers and traps should be cleaned. Both manual and automatic valves should be checked, cleaned and repaired where necessary, and glands tightened or repacked as appropriate. Pump seals, drive alignment and bearings should be checked periodically. Insulation, especially the vapour barrier of refrigerant lines, should be examined for damage. Water treatment should be applied under specialist supervision and periodically monitored and corrected (see **3.5** of BS 6880-1:1988).
Open-feed and vent systems should be checked periodically to ensure they are capable of accommodating system expansion and are not causing excessive water loss.

4.5.10 Heat emitters

Radiators and other emitters likely to accumulate gases should be periodically vented, at least at the beginning of each season. Drive belts and pulleys on belt-driven fans should be checked on a monthly basis and adjusted as necessary. Air filters on fan coil units, unit heaters, etc. should be cleaned or replaced at regular intervals as determined by experience, and at least once each season. The heat transfer surfaces of convector units should be cleaned, particularly if of the finned tube type.

4.5.11 Controls and electrical equipment

Electrical motors and switchgear should be periodically inspected, cleaned and lubricated. All maintenance should be carried out by a competent electrician.

Since control faults usually show up as operating conditions outside the normal permissible limits, a periodic check of set points and other adjustments should be made and any alterations recorded. At least once per year a complete functional check should be carried out and the system put through all conditions liable to be met, during which operation of control valves, etc. should be observed.

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4.6 Economic and energy use considerations

Economic operation of an installation after it has been set to work will be affected by the standard of maintenance it receives and/or the skill and judgement of the operators where the system is under manual control. Data on performance and operating costs, including fuel and energy consumption, should be collected periodically so that deterioration in performance and increases in cost may be seen at an early stage and measures taken to identify and rectify the causes.

In large or complex installations, the adoption of a regular monitoring system for plant performance is recommended. The monitoring process should enable plant output to be compared with fuel and energy consumption, and should extend to periodic review of electricity, gas and water tariff arrangements. For further guidance see **2.5** of BS 6880-1:1988 and Parts 2, 3 and 4 of the CIBSE Building Energy Code [2]. Part 4 of the CIBSE Code recommends minimum performance standards for energy use in building systems, and that of LTHW heating systems should be maintained above the recommended minima appropriate to the application.

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