BRITISH STANDARD

BS 5720:1979

Code of practice for

Mechanical ventilation and air conditioning in buildings —

(formerly CP 352)

UDC 697.9

Cooperating organizations

The Refrigeration, Heating and Air Conditioning Standards Committee, under whose direction this British Standard was prepared, consists of representatives from the following Government departments and scientific and industrial organizations:

Association of Consulting Engineers
Association of Manufacturers of Domestic Electrical Appliances
Boiler and Radiator Manufacturers' Association Limited
British Combustion Equipment Manufacturers' Association
British Gas Corporation*
British Refrigeration and Air Conditioning Association*
Building Services Research and Information Association
Chartered Institution of Building Services*
Department of the Environment (PSA)*
Department of Health and Social Security*
Engineering Equipment Users' Association
Electricity Supply Industry in England and Wales*
Heating and Ventilating Contractors' Association*
Hevac Association*
Institute of Fuel
Institute of Refrigeration*
Institution of Gas Engineers*
Lloyd's Register of Shipping
Manufacturers' Association of Radiators and Convectors Ltd.
Ministry of Defence*
National Coal Board
Society of British Gas Industries
Water-tube Boilermakers' Association

The organizations marked with an asterisk in the above list, together with the following, were directly represented on the committee entrusted with the preparation of this British Standard:

Greater London Council

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 Executive Board and comes into effect on 31 October 1979

The following BSI references relate to the work on this standard:
Committee reference RHE/23
Draft for comment 76/78546 DC

ISBN 0 580 10718 3

Amendments issued since publication

Amd. No.	Date of issue	Comments

Contents

Foreword

The original code of practice CP 352:1958 was prepared by a committee convened by the Institution of Mechanical Engineers and the Institution of Heating and Ventilating Engineers (now the Chartered Institution of Building Services) on behalf of the former Council for Codes of Practice for Buildings (Construction and Engineering Services).

The present revision has been prepared under the direction of the Refrigeration, Heating and Air Conditioning Standards Committee. CP 352 is now withdrawn.

Since the original code was published, the industry has undergone rapid development and services within buildings have become much more complex until today they often account for over 50 % of the initial capital cost. The services engineer is now recognized as an influential member of the building team.

In this context several aspects were clearly apparent; first the original code has become so outdated as to warrant completely rewriting, secondly much data included in the original code has been revised, expanded and extended in scope by other bodies more immediately involved and finally there had been identified a need for an overall guide to the whole complex process of ventilating and air conditioning a modern building written from the standpoint of the services engineer but with allied professionals in mind.

It is hoped that this code will be used by all those concerned with ensuring that a client obtains what he expects to receive, and who wish to understand the interrelation of the multitude of actions necessary to achieve that end. The decision that the code should be broadly based inevitably means that some users will not be engineers. It has been necessary therefore to include brief descriptions of certain systems and items of equipment which, it is hoped, will make the code intelligible to those without the specialist training of the services engineer.

A bibliography, together with addresses of the issuing authorities, is given in Appendix A

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

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

Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 96, an inside back cover and a back cover.

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

Section 1. General

1.1 Scope

This code deals with the work involved in design, installation, commissioning, operation and maintenance of mechanical ventilation and air-conditioning systems. The recommendations made in this code recognize the need to optimize the use of energy, reduce hazards and minimize effects detrimental to the environment. The increasing involvement of British engineers in projects overseas is noted and some guidance given in that context. In addition to this general section, the code is divided into the following seven sections:

Section 2. Fundamental requirements

Section 3. Design considerations

Section 4. Types and selection of equipment

Section 5. Installation

Section 6. Inspection, commissioning and testing

Section 7. Operation and maintenance

Section 8. Overseas projects.

1.2 References

1.2.1 *British Standards.* The titles of the British Standards referred to in this code are listed on the inside back cover, together with others that are applicable.

1.2.2 *Other publications.* 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 broad guidance only on certain topics. References in this category are:

a) for detailed design procedures:

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

The CIBS Guide

CIBS Building Energy Code

Technical Memoranda relating to fire and smoke control

Practice Notes relating to provision of combustion and ventilation air for boiler installations;

2) the "Ductwork Specifications" published by the Heating and Ventilating Contractors' Association (HVCA);

3) ASHRAE Handbooks published by the American Society of Heating, Refrigerating and Air Conditioning Engineers.

b) for detailed commissioning arrangements:

1) CIBS Commissioning Codes;

2) BSRIA Application Guides published by the Building Services Research and Information Association.

1.2.3 *Acts of Parliament, Regulations, etc.* Reference is made in the text to a number of Acts of Parliament and to various Regulations laid 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.

1.3 Definitions

The definitions of most terms used in this code are to be found in BS 5643. Other terms not in BS 5643 are defined where they occur in the text.

Section 2. Fundamental requirements

2.1 General

The object of providing ventilation and air-conditioning facilities in buildings is to provide conditions under which people can live in comfort and work safely and efficiently.

The purpose of this section of the code is to relate the various controllable factors to the comfort and well-being of the people using the building, so that the requirements of the system may be specified to the designers and the contractors.

Modern business and commercial premises often contain office and data processing equipment that in certain cases requires special standards of temperature and humidity control and of air filtration. Such requirements should be established when the building layout is planned, so that necessary provision can be made for local air-conditioning.

While this code does not refer in detail to factory production or assembly processes, or to hospitals, or to other such situations with special requirements, some general recommendations are given in **2.4.3**.

2.2 Necessity for mechanical ventilation and air-conditioning

2.2.1 *Ventilation.* Ventilation is the process of changing air in an enclosed space. A proportion of the air in the space should be continuously withdrawn and replaced by fresh air drawn in from external sources to maintain the required level of air purity. Ventilation is necessary to control:

a) *oxygen content,* preventing depletion of the oxygen content of the air;

b) *carbon dioxide and moisture,* preventing undue accumulation of carbon dioxide and moisture;

c) *contaminants,* preventing an undue concentration of body odours and other contaminants such as tobacco smoke;

d) *bacteria,* preventing an undue concentration of particles carrying bacteria;

e) *heat,* in some cases to remove body heat and heat liberated by the operation of electrical and mechanical equipment (e.g. artificial lighting and office machinery).

2.2.2 *Air conditioning.* Air conditioning is the control within predetermined limits of the temperature and humidity inside the building, accommodating the internal heat gains in conjunction with the external ambient conditions.

The air, as well as being filtered, is heated or cooled as necessary and moisture is added or extracted to give a controlled humidity.

2.3 Comfort factors

2.3.1 *General.* A wide range of external environmental conditions can be accepted by varying clothing or physical activity. It is desirable that the internal environment be controlled to minimize any variation. Such comfort conditions, the lack of which can affect the welfare of people, are provided by controlling the temperature, humidity and air movement. These factors interact with each other and with similar external factors and when in balance over a range of combinations can achieve acceptable conditions. Despite the need to produce a comfortable internal environment, care should be taken to avoid too great a difference with the external summer conditions thereby avoiding the effects of thermal shock on people and minimizing the energy use of the system selected.

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

The factors that affect comfort and that can be controlled by an air-conditioning installation are:

a) ventilation and air movement (**2.3.2**);

b) air purity and filtration (**2.3.3**);

c) resultant temperature (**2.3.4**);

d) humidity (**2.3.5**);

e) noise and vibration (**2.3.6**).

2.3.2 *Ventilation and air movement.* There are a number of factors that should be considered in deciding the ventilation rates of a building.

NOTE In addition to the mandatory requirements such as Building Regulations etc. (see **2.5**), further information on this subject can be obtained from the CIBS Guide and CP 3:Chapter I(C).

2.3.2.1 *Fresh air supply.* The fresh air supply is required to maintain an acceptably non-odorous atmosphere (by diluting body odours and tobacco smoke) and to dilute the carbon dioxide exhaled. This quantity may be quoted per person and is related to the occupational density and activity within the space. Table 1 gives minimum fresh air supply rates for mechanically ventilated or air-conditioned spaces.

The quantity and distribution of introduced fresh air should take into account the natural infiltration of the building.

The proportion of fresh air introduced into a building may be varied to achieve economical operation. When the fresh air can provide a useful cooling effect the quantity is controlled to balance the cooling demand. However, when the air is too cool, the quantity is reduced to a minimum to limit the heating load. Similarly, when the air is too warm or humid, the quantity is reduced to a minimum to reduce the cooling load.

2.3.2.2 *Transfer of heat/moisture.* Air circulation is required to transfer the heat and humidity generated within the building. In simple systems the heat generated by the occupants, solar heat and heat from electrical and mechanical equipment may be removed by the introduction and extraction of large quantities of fresh air. In more elaborate systems air may be recirculated through conditioning equipment to maintain the desired temperature and humidity. The air circulation rates are decided in relation to the thermal or moisture loads and the practical cooling or heating range of the air.

2.3.2.3 *Air movement*

a) *In rooms.* Air movement is desirable, as it contributes a feeling of freshness, although excessive movement should be avoided as this leads to complaints of draughts. The speed of an air current becomes more noticeable as the air temperature falls, owing to its increased cooling effect. The design of the air-distributing system therefore has a controlling effect on the quantity and temperature of the air that can be introduced into a space. The quantity of fresh air should not be increased solely to create air movement; this should be effected by air recirculation within the space or by inducing air movement with the ventilation air stream.

Table 1 — Recommended minimum fresh air supply rates for air-conditioning spaces[a]

Reproduced with permission from the CIBS Guide.

Typical type of space	Smoking	Outdoor air supply[b]		
		Recommended	Minimum (the greater of the two should be taken)	
		Per person	Per person	Per m^2 floor area
		dm^3/s[c]	dm^3/s[c]	dm^3/s[c]
Factories[de]	None			0.8
Offices (open plan)	Some			1.3
Shops, department stores and supermarkets	Some	8	5	3.0
Theatres[d]	Some			—
Dance halls[d]	Some			—
Hotel bedrooms[e]	Heavy			1.7
Laboratories[e]	Some	12	8	—
Offices (private)	Heavy			1.3
Residences (average)	Heavy			—
Restaurants (cafeteria)[ef]	Some			—
Cocktail bars	Heavy			—
Conference rooms (average)	Some	18	12	—
Residences (luxury)	Heavy			—
Restaurants (dining rooms)	Heavy			—
Board rooms, executive offices and conference rooms	Very heavy	25	18	6.0
Corridors	A per capita basis is not appropriate to these spaces			1.3
Kitchens (domestic)[e]				10.0
Kitchens (restaurant)[e]				20.0
Toilets[d]				10.0

[a] For hospital buildings (wards, operating theatres, etc.), see Department of Health and Social Security Building Notes.
[b] The outdoor air supply rates given take account of the likely density of occupation and the type and amount of smoking.
[c] 1 dm^3/s = 1 litre/s.
[d] See statutory requirements and local bye-laws.
[e] Rate of extract may be over-riding factor.
[f] Where queuing occurs in the space, the seating capacity may not be the appropriate total occupancy.

b) *In buildings.* Air flows within a building should be controlled to minimize transfer of fumes and smells, e.g. from kitchens to restaurants and the like. This is achieved by creating air pressure gradients within the building, by varying the balance between the fans introducing fresh air and those extracting the stale air. For example, the pressure should be reduced in a kitchen below that of the adjacent restaurant.

Care should be taken, however, to avoid excessive pressure differences that can cause difficulty in opening doors or cause them to slam. In other cases, such as computer rooms, the area may be pressurized to minimize the introduction of dust from adjacent areas.

2.3.2.4 *Fire and smoke control.* Air circulation systems may be designed to extract smoke in the event of a fire, to assist in the fire fighting operations and to introduce fresh air to pressurize escape routes.

2.3.3 Air purity and filtration

2.3.3.1 *General.* A ventilation or air-conditioning system installed in a building should clean, freshen or condition the air within this space. This can be achieved by providing the required amount of fresh air either to remove totally or to dilute odours, fumes, etc. (e.g. from smoking). Local extract systems may be necessary to remove polluted air from kitchens, toilets, etc. Special air filters may be required to remove contaminants or smells when air is recirculated.

Positions of air inlets and extracts to the system are most important and care should be taken in their location. Consideration should be given to relatively nearby buildings and any contaminated discharges from those buildings. Inlets should not be positioned near to any flue outlets, dry cleaning or washing machine extraction outlets, kitchens, WC's, etc. When possible, air inlets should be at high level so as to induce air from as clean an area as possible. If low-level intakes are used, care should be taken to see that they are positioned well away from roadways and car parks.

2.3.3.2 *Removal of particulate matter from air.* Efficient air filtration prevents fouling of the system and is of special importance in urban areas, where damage is likely to be caused to decorations and fittings by discoloration owing to airborne dust particles. In order to obtain maximum filtration efficiency with the minimum capital and maintenance expenditure, the utmost care should be given to the location of the air intake in relation to the prevailing wind, the position of chimneys and the relative atmospheric dust concentration in the environs of the building; the recommendations of **2.3.3.1** for siting of air inlets should not be overlooked. Air filtration equipment should be regularly serviced (see **7.4.2**).

Airborne dust and dirt can be generated within the building, from the personnel and their movements as well as by machines, such as those used for card sorting.

The degree of filtration necessary will depend on the use of the building or the conditioned space. Certain specialized equipment, normally associated with computers, will require higher than normal air filter efficiencies for satisfactory operation. It is important to ascertain the necessary standard of air cleanliness required for equipment of this type.

The choice of filtration systems will depend on the degree of contamination of the air and on the cleanliness required. A combination of filter types may well give the best service and the minimum operating costs.

Filter efficiency is conveniently referred to as its performance on standard test dusts. BS 2831 includes three different dust grades of which no. 1 (particle size range 0.03 µm to 2 µm) and no. 2 (particle size range 2 µm to 14 µm) are normally used.

The normal standard for intake filters in ventilating and air-conditioning applications in the United Kingdom is an efficiency of 95 % against BS 2831 test dust no. 2 although there may be a requirement for a higher efficiency to give increased protection against atmospheric staining.

Special applications, such as computer suites, pharmaceutical or food processing, and air systems having induction units, require a higher standard that is achieved by two stage filtration. The exact requirements will depend on the equipment or process involved.

2.3.3.3 *Removal of fumes and smells from air.* Fumes and smells can be removed from air by physical or chemical processes. These may be essential when the ambient air is heavily polluted, although it may be possible to limit operating costs by minimizing the thermal loads caused by the introduction of large quantities of fresh air. The decision to use odour-removing equipment will normally be made on economic grounds, but the arguments in its favour will be increased by the currently rising cost of fuel. Once this equipment is installed, it should be regularly serviced to ensure satisfactory performance (see **7.4.2**). Failure to do this can result in unacceptable conditions within the building.

2.3.4 Temperature

2.3.4.1 *General considerations.* Certain minimum temperatures are required by legislation and by local regulations. Maximum permitted heating temperatures may be stipulated by legislation relating to energy conservation.

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

When large windows are used, it may be necessary to provide shading to protect the occupants from solar radiation and to reduce the cooling load on the system. It is not practical to fully compensate for solar heating, owing to its intermittent nature, simply by lowering air temperature.

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

2.3.4.2 *Design temperatures.* It should be noted that, although comfort conditions and heat requirements are established in terms of resultant temperature, the design air temperature for air conditioning should be specified in terms of dry bulb temperature and relative humidity or wet bulb temperature.

Table 2 and Table 3 show the recommended design values for dry resultant temperature and comfort design conditions, respectively, for the United Kingdom. The relationship between air dry bulb temperature and dry resultant temperature is established in the CIBS guide.

2.3.5 Humidity

2.3.5.1 *Comfort considerations.* The controlled temperature levels should also be considered in relation to the humidity of the air. A high humidity reduces evaporative cooling from the body and hence creates the sensation of a higher temperature. Beyond certain limits, however, humidity produces disagreeable sensations.

For normal comfort conditions, relative humidity (r.h.) values between 40 % and 70 % are acceptable.

2.3.5.2 *Condensation.* Condensation can occur on windows when the surface temperature falls below the room air dew point temperature. This tendency is increased with low ambient temperatures, high wind velocities and high internal humidities.

For the United Kingdom with a room temperature of 21 °C and normal wind exposures, Table 4 details the room r.h. values at which condensation will occur at various outside temperatures.

2.3.5.3 *Electrostatic effects.* Low humidities can increase electrostatic effects, in particular on modern synthetic materials, for example on nylon carpets, which can rapidly accumulate high charges. These effects can be minimized by maintaining humidities greater than 40 %, but preferably by antistatic sprays and surface treatments.

2.3.5.4 *Dimensional changes.* Variations in humidity can cause problems with natural materials and others that may be hygroscopic and whose moisture contents change with the relative humidity of the air. This can lead to warping of woodwork and cracking of paintings; thus control of atmospheric conditions is particularly important in museums and art galleries. The important feature in these cases is the avoidance of rapid changes in temperature and humidity, the actual values being of lesser importance providing they are within the ranges 20 °C to 25 °C and 40 % r.h. to 55 % r.h.

2.3.5.5 *Computer rooms.* The temperature and humidity in computer rooms needs to be controlled within reasonably close limits, although this depends on the equipment involved. Humidity control within ± 5 % in the range 40 % r.h. to 60 % r.h. is normal.

2.3.6 Noise and vibration

2.3.6.1 *General.* Noise is unwanted sound. All ventilating and air-conditioning systems will produce noise, and this may cause annoyance or disturbance in:

a) the spaces being treated;

b) other rooms in the building;

c) the environment external to the building.

In the case of the external environment particular care should be taken to avoid a nuisance in the "silent" hours, and local authorities have statutory powers to ensure that noise from plant is limited. BS 4142 explains a noise measurement procedure, the determination of corrected noise level and a method of rating the noise in these instances.

It is important that expert advice be sought in dealing with noise and vibration problems, as for obvious reasons the most economical solutions should be used without impairing the performance.

2.3.6.2 *Types of noise in buildings*

2.3.6.2.1 *Externally created noise.* Exclusion of externally created noise is mainly dealt with by choice of building and window construction. The air-conditioning engineer should, however, ensure that noise does not enter via air inlets or exhausts: it may be reduced by suitable attenuators.

2.3.6.2.2 *Generated noise.* Noise produced by the air-conditioning and ventilation plant installed within the building can escape via ventilation grilles or door openings and can cause nuisance to neighbours. Equipment mounted outside the building may well need to be selected or installed with the noise problem in mind.

Another type of generated noise is created by the air-circulating system itself and its associated equipment. Fans are an obvious source, but noise can be produced by turbulence, which may cause vibration of the ducts themselves, and by air diffusers. This problem can be avoided by careful selection of equipment or by arranging that the noise be absorbed.

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

Another problem is the transmission of sound from one room to another via air ducting, ventilated ceilings or other continuous air space. Such sound includes the noise from machines and equipment and also of conversation, transmission of which can be embarrassing as well as annoying. Again, this problem can be met by careful design and the inclusion of sound-absorbing linings to ducts, attenuators, etc.

Table 2 — Recommended design values for dry resultant temperature, t_c (heating seasons)

Reproduced with permission from the CIBS Guide.

Type of building	t_c	Type of building	t_c
	°C		°C
Art galleries and museums	20	Hotels:	
Assembly halls, lecture halls	18	Bedrooms (standard)	22
Banking halls	20	Bedrooms (luxury)	24
Bars	18	Public rooms	21
Canteens and dining rooms	20	Corridors	18
Churches and chapels:	18	Foyers	18
Vestries	20	Laboratories	20
Dining and banqueting halls	21	Law courts	20
Exhibition halls	18	Libraries:	20
Factories:		Stack room	18
Sedentary work	19	Store rooms	15
Light work	16	Offices:	
Heavy work	13	General	20
Fire stations; ambulance stations:		Private	20
Appliance rooms	15	Stores	15
Watch rooms	20	Police stations:	
Recreation rooms	18	Cells	18
Flats, residences and hostels:		Restaurants and tea shops	18
Living rooms	21	Schools and colleges:	
Bedrooms	18	Classrooms	18
Bed-sitting rooms	21	Lecture rooms	18
Bathrooms	22	Studios (see also DES Bulletins)	18
Lavatories and cloakrooms	18	Shops and showrooms:	
Service rooms	16	Small	18
Staircase and corridors	16	Large	18
Entrance halls and foyers	16	Department store	18
Public rooms	21	Fitting rooms	21
Gymnasia	16	Store rooms	15
Hospitals:		Sports pavilions:	
Corridors	16	Dressing rooms	21
Offices	20	Swimming baths:	
Operating theatre suite	18 – 21	Changing rooms	22
		Bath hall	26
Stores	15	(See also MOHLG Design Bulletin 4)	
Wards and patient areas	18	Warehouses:	
Waiting rooms	18	Working and packing spaces	16
(See also DHSS Building Notes)		Storage space	13

Table 3 — Comfort design conditions for the United Kingdom (summer season)

Occupancy	Design criteria	
	Dry resultant temperature	Relative humidity
	°C	%
Continuous	20 to 22	50
Transient	23	50

NOTE The above values may be adjusted upwards in accordance with the recommendations of the CIBS Building Energy Code.

Table 4 — Levels of relative humidity, for an internal temperature of 21 °C, at which condensation will occur at various outside temperatures

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

2.3.6.2.4 *Intermittent noise.* Such noise arises from the stopping and starting of equipment, and the opening and closing of valves and dampers. This may or may not cause problems in the air-conditioned spaces, but it is often objectionable to plant operators and maintenance engineers.

2.3.6.3 ***Sources of noise***

2.3.6.3.1 *Central plant.* Noise is produced by boilers, pumps, fans, compressors, cooling towers, etc.

2.3.6.3.2 *Distribution systems.* Noise is produced by:

a) the effect of air velocity in ducts particularly through dampers or restrictions or air leakage;

b) drumming from duct walls;

c) turbulence;

d) excessive fluid velocity or throttling in pipes and at valves;

e) pick-up of noise or vibration from plant rooms, etc., and transmission along ductwork or pipework, cross-talk or noise transfer from one occupied space to another, etc.

2.3.6.3.3 *Sources in occupied rooms.* The noise arises from local fans, induction units, high velocity units, self-contained unit air conditioners, air flow through grilles and diffusers.

2.3.6.3.4 *Architectural treatment.* Open plan layouts, use of false ceilings, etc., can often cause noise problems.

2.3.6.4 *Noise ratings.* It is established that continuous exposure to noise rating values above 85 can cause permanent damage to hearing. This problem can be dealt with in two ways.

2.3.6.4.1 *Selection of treatment.* Noise levels can be reduced in the room by appropriate selection or acoustic shrouding of machines. In some cases, treatment of plant room walls and ceilings can alleviate the problem, but this is not usually economical or even adequate.

2.3.6.4.2 *Duration of exposure.* The problem can dealt with by ensuring that no one needs to be exposed continuously to excessive noise levels, and by providing hearing protection to be worn for maintenance or service duties.

2.3.6.5 *Recommended levels of noise.* The levels of environmental noise are most conveniently related to noise rating curves. These curves are attempts to relate the background noise level for annoyance and speech intelligibility for a given environment.

Table 5 gives recommended broadband continuous noise ratings for different situations, in the unoccupied condition.

2.4 Application factors

2.4.1 *General.* This subclause gives general guidance, for various applications, on the factors that usually influence the selection of the type, design and layout of the air-conditioning or ventilating system to be used. See also **2.6** and the CIBS Building Energy Code.

2.4.2 *Commercial applications.* The primary objective of the applications described under this heading is provision of comfort conditions for occupants.

2.4.2.1 *Offices.* Office buildings may include both external and internal zones.

The external zone may be considered as extending from approximately 4 m to 6 m inwards from the external wall, and is generally subjected to wide load variations owing to daily and annual changes in outside temperature and solar radiation. Ideally, the system(s) selected to serve an external zone should be able to provide winter heating and summer cooling. During intermediate seasons the external zone of one side of the building may require cooling at the same time as the external zone on another side of the building requires heating. The main factors affecting cooling load are usually window area and choice of shading devices; the other important factors are the internal gains owing to people, lights and office equipment. Choice of system may be affected by requirements to counteract downdraughts and cold radiation associated with single glazing during winter.

Internal zone loads are due almost entirely to people, lights and office equipment, which represent a fairly uniform cooling load throughout the year.

Other important considerations in office block applications may include requirements for individual control, partitioning flexibility serving multiple tenants, and operating selected areas outside of normal office hours. Areas such as conference rooms, board rooms, canteens, etc., will often require independent systems.

Experience indicates that for external building zones with large glass areas, e.g. greater than 60 % of the external facade, the air-water type of system, such as induction or fan-coil, is generally more economical than all-air systems and has lower space requirements. For external zones with small glass areas, an all-air system, such as variable volume, may be the best selection. For buildings with average glass areas, other factors may determine the choice of system.

For internal zones, a separate all-air system with volume control may be the best choice. Systems employing reheat or air mixing, while technically satisfactory, are generally poor as regards energy conservation.

Unitary systems may be suitable for both external and internal zones, particularly in the smaller and medium sized building, but are generally only cost-effective when the module size (area served by one unit) is relatively large.

2.4.2.2 *Hotel guest rooms.* In ideal circumstances, each guest room in a hotel or motel should have an air-conditioning system that enables the occupant to select heating or cooling as required to maintain the room at the desired temperature. The range of temperature adjustment should be reasonable but, from the energy conservation viewpoint, should not permit wasteful overheating or overcooling.

Guest room systems are required to be available for operation 24 h a day, 7 days a week. The room may be unoccupied for most of the day and provision for operating at reduced capacity, or switching off, is essential. Low operating noise level, reliability and ease of maintenance are essential. UK systems are frequently of the unitary or air-water type, and may be located either below window or at high level above the bathroom/lobby area. Fresh air introduced through the system is generally balanced with the bathroom extract ventilation to promote air circulation into the bathroom. In tropical climates, where the humidity is high, an all-air system with individual room reheat (and/or recool) may be necessary to avoid condensation problems.

Table 5 — Recommended broadband continuous noise ratings

Reproduced with permission from the CIBS Guide.

Situation	NR value
Concert halls, opera halls, studios for sound reproduction, live theatres (> 500 seats)	20
Bedrooms in private homes, live theatres (< 500 seats), cathedrals and large churches, television studios, large conference and lecture rooms (> 50 people)	25
Living rooms in private homes, board rooms, top management offices, conference and lecture rooms (20 to 50 people), multipurpose halls, churches (medium and small), libraries, bedrooms in hotels etc., banqueting rooms, operating theatres, cinemas, hospital private rooms, large courtrooms	30
Public rooms in hotels etc., ballrooms, hospital open wards, middle management and small offices, small conference and lecture rooms (< 20 people), school classrooms, small courtrooms, museums, libraries, banking halls, small restaurants, cocktail bars, quality shops	35
Toilets and washrooms, drawing offices, reception areas (offices), halls, corridors, lobbies in hotels etc., laboratories, recreation rooms, post offices, large restaurants, bars and night clubs, department stores, shops, gymnasia	40
Kitchens in hotels, hospitals, etc., laundry rooms, computer rooms, accounting machine rooms, cafeteria, canteens, supermarkets, swimming pools, covered garages in hotels, offices, etc., bowling alleys, landscaped offices	45
NR 50 and above NR 50 will generally be regarded as very noisy by sedentary workers, but most of the classifications listed under NR 45 could just accept NR 50. Noise levels above NR 50 will be justified in certain manufacturing areas; such cases should be judged on their own merits.	

NOTE 1 The ratings listed above will give general guidance for total services noise, but limited adjustment of certain of these criteria may be appropriate in some applications.

NOTE 2 The intrusion of high external noise levels may, if continuous during occupation, permit relaxation of the standards, but services noise should be not less than 5 dB below the minimum intruding noise in any octave band to avoid adding a significant new noise source to the area.

NOTE 3 Where more than one noise source is present, it is the aggregate noise that should meet the criterion.

NOTE 4 NR dBA value – 6

NOTE 5 Where impulsive and/or intermittent noise, or easily perceptible pure tones, are present, the design NR values in the table should be reduced by 5.

All fan-coils should be arranged so that if the fan is shut off the cooling coil control valve will close, otherwise excessive condensation and damage may result.

For UK applications, or in similar climates, consideration should be given to provision of bathroom heating.

2.4.2.3 *Restaurants, cafeterias, bars and nightclubs.* Such premises have several factors in common; highly variable loads, with high latent gains (low sensible heat factor) owing to occupants and meals, and high odour concentrations (body, food and tobacco smoke odours) requiring adequate control of fresh air extract volumes and direction of air movement. Particular attention should be paid to infiltration loads, operating noise levels, control of air movement (avoidance of draughts), and make-up air requirements for associated kitchens (to ensure an uncontaminated supply).

This type of application is generally best served by the all-air type of system, preferably with some reheat or return air bypass control to limit relative humidity. Either self-contained packaged units, or split-systems, or air handling units served from a control chilled water system may be used. Sufficient control flexibility to handle adequately the complete range of anticipated loads is essential.

2.4.2.4 *Department stores/shops.* For small shops and stores unitary air-conditioning systems (**3.1.2.3**) offer many advantages, including low initial cost, minimum space requirements and ease of installation.

For large department stores a very careful analysis of the location and requirements of individual departments is essential as these may vary widely, e.g. for lighting departments, for food halls, for restaurants, etc. Some system flexibility to accommodate future changes may be required.

Generally, internal loads (lighting and people) predominate. Important considerations include initial and operating costs, system space requirements, form of maintenance to be provided, and who will operate the system (very necessary in determining the type of control system to be installed).

The all-air type of system, with variable volume distribution from local air handling units (minimizing duct runs), may be the most economical. Facilities to take all outside air for "free-cooling" under favourable conditions should be provided. In this case, heating and cooling media would be piped from a central service.

Many newer department stores are "self-heating" down to an outside temperature of about 5 °C owing to their high internal loads, and heat recovery air conditioning (**3.1.3.2**) or various conservation measures (**4.12**) may be economically attractive.

2.4.2.5 *Theatres/auditoria.* Characteristics of this type of application are buildings, generally large in size, with high ceilings, low external loads, and high occupancy (producing a high latent gain and having a low sensible heat factor), which give rise to the requirements of large fresh air quantities and low operating noise levels. Theatres and auditoria may be in use only a few hours per day, and then in the evening after maximum outdoor temperatures of solar effects have occurred.

Air-conditioning is nearly always provided by the all-air type of system having the facility to take all fresh air for "free-cooling" when advantageous to do so, with equipment and controls arranged to handle light loads (partial occupancy), and to prevent relative humidity rising above a predetermined upper limit. Proper control of air distribution and avoidance of draughts is essential.

2.4.2.6 *Residential buildings.* Very few UK residences are air-conditioned. Some individual houses have unitary systems, and some luxury blocks of flats are provided with air-water systems. In this latter case, most of the considerations of **2.4.2.2** apply.

Some guidance on natural and mechanical ventilation of dwellings is given in CP 3:Chapter I(C).

2.4.3 Special applications

2.4.3.1 *Hospitals/operating theatres.* In many cases proper air-conditioning can be a factor in the therapy of the patient and in some instances part of the major treatment. For the majority of hospitals and operating theatres in the United Kingdom, reference may be made to the publications of the Department of Health and Social Security.

The main differences in application compared with other building types are:

a) restriction of air movement between various departments and control of air movement within certain departments, to reduce the risk of airborne cross infection;

b) a specific need for the ventilation and filtration equipment to dilute and/or remove particulate or gaseous contamination and airborne micro-organisms;

c) close tolerances in differing temperatures and humidities may be required for various areas;

d) the design should allow for accurate control of environmental conditions.

For a) and b) the air movement patterns should minimize the spread of contaminants as, for instance, in operating departments where the air flow should be such as to reduce the risk of periphery or floor-level air returning to the patient (owing to secondary air currents) whilst the general pressurization pattern should cause air to flow through the department from sterile to less sterile rooms in progression. In operating theatre suites a 100 % fresh air system is normally provided and air pressures in the various rooms are set by use of pressure stabilizers. Many types of air distribution pattern within operating departments are in use but generally they conform to high-level supply and low-level pressure relief or exhaust. There is also a need for a separate scavenging system for exhaled and waste anaesthetic gases both within theatre suites and where general anaesthetics may be administered. When zoning air distribution systems to compensate for exposure owing to building orientation and shape, consideration should be given to ensuring that the mixing of air from different departments is reduced to a minimum. This can be accomplished by the use of 100 % conditioned fresh air with no recirculation or, where recirculation is employed, by providing separate air handling systems for different departments based on the relative sensitivity of each to contamination (a degree of stand-by is provided by this system in that breakdown will affect only a limited section of the hospital). Where recirculated air is permitted, this should, of course, be coupled with proper filtering and disinfecting techniques.

Particular areas require specific treatment. For instance laboratories dealing with infectious diseases or viruses, and sanitary accommodation adjacent to wards, should be at a negative air pressure to any other area to prevent exfiltration of any airborne contaminants, and in extreme cases any exhaust to atmosphere should be passed through High Efficiency Sub-micron Particulate Air HEPA filters and/or sterilized. Operating theatres may contain around the operating table booths, curtained with plastic or having glass walls, in which air (recirculated within the theatre) is fed down through high efficiency filters above the table to give "laminar" flow down across the patient and out under the enclosing curtains or walling. Such arrangements have been found to give minimum bacterial count in the immediate vicinity of the operation wound site and are used where avoidance of cross infection is of critical importance.

2.4.3.2 *Computer rooms.* The equipment in computer rooms generates heat and contains components that are sensitive to sudden alterations and extremes of temperature and humidity as well as being sensitive to the deposition of dust. Exposure to conditions outside the prescribed limits can result in improper operation or the need for shut-down of the equipment. Manufacturers normally prescribe the conditions to be held. Typical conditions are air dry bulb, 21 ± 1.6 °C; r.h. 50 ± 5 %; filtration 80 % to BS 2831 test dust no. 1) or BS 3928.

A low-velocity recirculation system with re-heat is normally used with 5 % to 10 % fresh air make-up, which is allowed to exfiltrate from the room and ensure a positive internal pressure to prevent entry of dust and untreated air. The air distribution should be zoned to minimize temperature variations owing to fluctuations in heat load. Overhead air supply through ceiling plenums utilizing linear diffusers or ventilated ceilings is eminently suited to computer room application, permitting high air change rates to be achieved without undue discomfort to personnel. This arrangement may be used with either central or unitary air-conditioning plants. In addition to satisfying equipment requirements a well-designed overhead system is usually more satisfactory for comfort of personnel than a system using the floor void as a plenum and supplying cool air through grilles and extracting at high level, but some computer manufacturers design their equipment for this arrangement. In such cases the treated fresh air is introduced to the room at high level and sensible cooling only is performed by unit conditioners, placed around the room perimeter, extracting warm air at high level and returning cooled air to the underfloor void.

Background heating should be provided and controlled by a thermostat and a high limit humidistat to ensure reasonable environmental conditions in the event of shut-down or failure of the air-conditioning system.

The air-conditioning system should be reliable because failure to maintain conditions for only a short period may necessitate shut-down of the computer with a substantial monetary loss and possibly more serious consequences. The amount of standby plant installed, and the precautions taken, will depend on the particular circumstances.

2.4.3.3 *Clean rooms.* A clean room is a specially constructed enclosed area whose environment is closely controlled with respect to airborne particulates, temperature, humidity, air pressure, air flow pattern, air velocity and lighting.

Clean rooms are normally designated according to the maximum number of particles, of varying sizes from 0.5 μm to 25.0 μm allowable per cubic metre of a given air space. BS 5295 gives class 1, 2, 3 and 4 environments, which are designated in order of stringency of cleanliness.

To achieve these conditions a high standard of filtration using absolute or HEPA filters is required. The pattern of air flow is important, depending on the class and type of work, and can be categorized as conventional flow or unidirectional flow as follows.

a) *Conventional flow.* Air is supplied through conventional diffusers, flows generally downward and is removed near floor level. Using HEPA filters the contamination level can be reduced by 1.7×10^8 particles/m^3 to between 1.7×10^6 particles/m^3 and 3.4×10^6 particles/m^3. Nevertheless, airborne particles several hundred micrometres in diameter can still be present. The method does not afford protection from cross contamination.

b) *Unidirectional flow.* Air is introduced evenly from one entire surface of the room (such as the ceiling or a wall), flows at constant velocity across the room and is removed through the entire area of an opposite surface. Air velocities of 0.45 ± 0.1 m/s for horizontal flow and 0.3 ± 0.05 m/s for vertical flow are recommended.

The down-flow room consists of an entire ceiling of HEPA filters with a floor of open grating and provides the cleanest working environment at present available. It is also the most expensive in cost, but contamination can be reduced to less than 3×10^3 particles/m^3 of a size 0.5 μm or larger.

The cross-flow clean room employs the same filtration technique except that the air flows from one wall to the opposite wall. Downstream contamination in the direction of the air flow will occur up to 6.7×10^5 particles/m^3 at the dirty end of the room.

All unidirectional flow arrangements are applicable to work stations as well as entire rooms. In combination with conventional flow systems they can provide small areas with especially high degrees of contamination control.

All rooms should be maintained at static pressures sufficiently above atmospheric to prevent infiltration owing to wind or other effects (25 Pa is normally considered adequate). For certain processes, high heat output or noxious fumes may be exhausted direct to atmosphere and the necessary make-up air treated.

Humidity control is necessary to prevent corrosion, to prevent condensation on work surfaces, to eliminate static electricity, and to provide for comfort of personnel.

Close attention should be given to the construction and surface finishes of clean rooms.

Where possible, equipment requiring extensive servicing should be placed around the perimeter and an outside corridor provided from which maintenance can be carried out.

2.4.3.4 *Laboratories.* Requirements necessary for design determination are:

a) internal and external conditions;

b) thermal loads;

c) time during which conditions are to be maintained;

d) air flow rates;

e) air flow patterns;

f) contaminant control;

g) sound and vibration limits.

The designer should obtain all necessary information and fully explain to the researcher the performance capabilities and limitations of the intended design. Very often, laboratories and test facilities require exhaust arrangements for the conveyance of contaminants to the atmosphere, and the exhausted air needs to be replaced by large quantities of fresh air. Selection of outdoor design conditions, therefore, materially affects the size and cost of heating and/or cooling facilities. The hours and seasonal periods during which specific indoor conditions are required to be maintained should be specifically expressed since they determine whether the spaces should be served by individual ventilation, air-conditioning and refrigeration systems operable at any time of the day or year or by central plants operating on common daily and seasonal schedules.

Laboratories handling toxic materials or dealing with flammable vapours are normally equipped with fume cupboards that are connected to an exhaust system. Various arrangements are available and details are given in the CIBS Guide and other technical literature. The exhaust system may be constant volume or variable volume; the former is simple to balance, highly stable and is flexible with respect to the number and location of hoods, but may mean high operating costs because of the large replacement air volumes to be handled and treated. In most laboratories it is unusual for all the fume cupboards to be operating together and operating economies can be achieved by use of a variable volume system that reduces the air flow when cupboards or hoods are not in use or when they may be operated at less than full capacity.

In some cases make-up air for fume cupboards that is not heated or cooled can result in reduced running costs. Attention should be paid to the manner in which the air is introduced to the room so that no draughts that will reduce the effectiveness of the fume cupboard are produced at the face of the cupboard. For more detailed recommendations see BS 3202.

Care should be taken where fumes are exhausted to atmosphere to ensure that they are well away from any supply air intake points and will be readily dispersed into the atmosphere. Normally this can only be achieved satisfactorily by discharging through a stack. The method will depend on the number of exhaust points and quantity discharged, the toxicity or nuisance value and height and location of the building.

In some cases the exhausted materials need to be filtered or passed through a scrubber to prevent undue pollution of the atmosphere.

2.4.3.5 *Libraries, museums and art galleries.* It is important that the required conditions are discussed with experts at the particular museum or art gallery.

The indoor air temperatures and relative humidity (r.h.) should generally conform to those laid down in **2.3** and the CIBS Guide, but in the case of museums and art galleries normally a close control of r.h. is required. Also, it is important that rapid changes of temperature or r.h. do not occur; a rate of change of 5 °C or 10 % r.h. in 1 h is considered excessive. Since one of the principle reasons for installing air-conditioning in these buildings is the preservation of the contents, the plant will be running on a 24 h basis, and, when assessing the standby plant to be installed, the value of the contents being protected should be taken into account.

Air filtration, particularly in cities, is important and should generally be not less than 95 % to BS 2831 (test dust no. 2). Atmospheric pollution by SO_2 or SO_3 can be very injurious to paintings, old silver, etc. There is therefore a need to install scrubbing plant or carbon filters to extract such contaminants though even these may not provide the desired levels of purity.

Generally, all-air systems should be used to ensure adequate control of humidity, and where there are considerable variations in internal load (e.g. numbers of visitors) a variable volume system should prove the most economical solution.

A low noise level is obviously desirable, about NR 35 being reasonable.

2.4.3.6 *Industrial ventilation.* In industrial buildings ventilation is needed to provide the fresh air normally required for health and hygiene; use of natural or mechanical ventilation depends on the building configuration, the process, the number of personnel, etc. Frequently the movement of relatively large quantities of air, above normal hygiene needs, is required to remove heat emanating from process plant, to give increased air movement across the skin (increasing the sweat evaporation rate to give some degree of comfort), or to remove toxic or unpleasant fumes or vapour or dust.

These situations may be met by various combinations of general and local mechanical ventilation, with various arrangements for supply and exhaust air, as detailed in **3.1.1**.

The following are some of the factors that should be considered in the system design.

a) A supply system is not normally satisfactory without a complementary exhaust system and similarly any exhaust system requires "make-up air" that in low ambient temperatures should be tempered to avoid cold draughts.

b) The method of supply air distribution through grilles or diffusers should not give rise to uncomfortable air currents. Directional grilles, diffusers and nozzles designed specifically for industrial relief systems are commercially available.

c) Exhaust hoods and canopies should be designed to capture the unwanted fumes or dust irrespective of other air currents in the vicinity.

d) Because of the normally large volumes of ventilation air required all means of heat recovery should be considered. (See **3.1.3.2**.)

For control of contamination by gases, fumes and dusts, local exhaust systems will be suitable where the contamination originates at concentrated areas and is characterized by low or imperceptible air motion, requiring a capture velocity exceeding 0.14 m/s. High capture velocity with low air volume is desirable.

A system employing the dilution method will usually be indicated where the contaminant originates at scattered points dispersed generally throughout the area. Except for low rates of liberation of fumes, dilution ventilation requires such high volumes of air, without giving positive assurance of safety, that such systems should be used only as a last resort. A combination of local exhaust and dilution methods is often economical since well designed exhaust hoods or openings removing the bulk of the contamination will greatly reduce the air volumes required for dilution purposes.

Where dusts or fumes mixed, with air can produce explosive conditions it is essential that precautions such as the inclusion of pressure relief vents be taken. Reference should be made to publications of the Health and Safety Executive, and to relevant statutory requirements considered in **2.5**.

In the case of dust and fumes, the Guidance Notes of the Health and Safety Executive specify the threshold limit values (TLV's) for a wide range of chemical elements and compounds. The TLV of a substance is the concentration in air that, if exceeded, may be injurious to health.

2.4.3.7 *Industrial air conditioning.* The requirement for air-conditioning in industrial situations is normally connected with the process requirements. There may be a need, for instance, for controlled humidity conditions combined with some temperature control. The system employed will vary with the requirements of the application, type of building, etc., and no general guidelines can be laid down.

2.5 Statutory regulations/safety considerations

2.5.1 *Authorities and approval of schemes.* A ventilation or air-conditioning system should comply with the requirements laid down in the current statutory legislation or any revisions currently in force, and consideration should also be given to any relevant insurance company requirements.

Compliance with this code is not automatically deemed to satisfy statutory and legal requirements.

The following are the principal statutes concerned:

The Building Regulations 1976
The Building Standards (Scotland) Act 1970
Clean Air Act 1968
Control of Pollution Act 1974
Factories Act 1961
Fire Precautions Act 1971
Health and Safety at Work etc. Act 1974
London Building Acts (Amendment) Act 1939
Offices, Shops and Railway Premises Act 1963
Water Act 1973

2.5.2 Fire and safety considerations

2.5.2.1 *Design principles.* The installation of mechanical ventilation and air-conditioning systems may affect the fire risk within the building, both as regards structural protection and means of escape in case of fire, and may influence any necessary fire venting or fire fighting considerations.

The extent and detail of statutory control and other specialist interests may vary considerably according to the design, use, occupation and location of the building, and the type of system of mechanical ventilation and air-conditioning proposed. It is particularly important that the appropriate authority be fully consulted at an early stage.

The degree of control and the requirements imposed vary according to the circumstances of the case, depending on whether the control concerns means of escape (e.g. clearance of smoke in the event of fire), structural fire precautions (e.g. maintenance of structural fire separations), health of the occupants, conservation of energy, or any combination of these. Full details may have to be approved by the local authority in such cases as:

a) buildings controlled from the point of view of the means of escape (i.e. most buildings except dwelling houses) where recirculation of air is involved and/or where pressurized staircases are contemplated as part of the smoke control arrangements;

b) places of public entertainment;

c) flats and maisonettes where mechanical ventilation is necessary to lobbys and corridors as part of the smoke control arrangements;

d) large garages, motor repair shops and car parks, hotels, parts of buildings used for trades or processes involving a special risk, and departmental stores and similar shop risks in large buildings;

e) buildings within the scope of the London Building (Constructional) Bye-laws 1972 where mechanical ventilation is intended to supplement or take the place of the required minimum natural ventilation (such as in "sealed" buildings and underground rooms).

Reference can be made to CIBS Technical Memoranda 1 and 2, BS 5588-4, and CP 3:Chapter IV (itself or its separate Parts, as relevant).

2.5.2.2 *Structural considerations.* Where consideration is being given to the installation of equipment within buildings, a check should be made of the capability of the building to support the weight of the equipment. This check should include the route taken by the equipment to its final position. There should also be access from the road to the position selected for the plant. This access should include space for any crane lifts or for turning of delivery transport.

2.5.2.3 *Independent systems.* Certain areas of a building require separate and independent mechanical ventilation systems. These areas include:

a) staircases for control of smoke;

b) residential accommodation;

c) boiler chambers;

d) areas containing oil-immersed electrical plant;

e) lavatories, garages and car parks, certain trade uses.

For information concerning the design of systems for these areas, reference may be made to the CIBS Guide.

Extract systems from kitchen equipment should be separate from any other and the extracted air should not be recirculated. Where a fish fryer is used no fire dampers should be fitted in the ventilation extract duct unless any statutory requirement exists otherwise but adequate cleaning facilities should be provided. Canopy, ducting and lagging should be made from non-combustible material. Where ducting passes through other floors between the kitchen and the external weathering cowl, it should be enclosed in fire-resisting construction at least equal to the standard of fire resistance required in that floor.

2.5.2.4 *Fresh air quantities.* Certain legal requirements exist regarding the supply of fresh air to ventilation and air-conditioning plants. Section 7 of the Offices, Shops and Railway Premises Act, requires certain quantities of fresh air to be supplied by the ventilation system: these are given by Guidance Note no. 19 of the Health and Safety Executive; see also the London Building (Construction) Bye-law 1972 for the Inner London area.

Care should be taken when positioning air intakes to prevent the intake of contaminated air; see **2.3.3.1**. Discharges should be positioned where they will not cause problems from smells, etc.

2.5.2.5 *Ductwork and enclosures.* All ductwork should be constructed from non-combustible materials. In special circumstances it may be necessary to use plastics ductwork. In such cases additional measures may be required and advice of the building authority should be sought.

Any duct, the interior of which is liable in normal use to accumulate dust, grease or other flammable matter, should be provided with adequate means of access to facilitate cleaning and inspection.

As far as practicable, flexible joint connections should be avoided.

Considerable information on fire precautions for ventilation ductwork, including flexible connections, dampers and duct enclosures, is given in Appendix A of CP 413. Further information relating to firedampers is given in **4.3.1.3** and **4.3.2.3**.

2.5.2.6 *Thermal and acoustic insulation.* To reduce the spread of fire or smoke by an air-conditioning system, care should be taken with the choice of materials used for such items as air filters, silencers and insulation both internal and external. These materials should be tested for surface spread of flame to BS 476-7 and should satisfy the relevant recommendations of CP 413 and the requirements of any relevant Building Regulations and standards.

Some authorities require prior approval of any thermal and acoustic materials used in air-conditioning systems unless such materials are wholly non-combustible. See CP 413, BS 5422, CIBS Guide Section B5 and CIBS Technical Memorandum No. 1.

2.5.2.7 *Mechanical equipment.* All mechanical equipment associated with either ventilation or air-conditioning plants should be installed to comply with the standards required by HM Factories Inspectorate and relevant Building Regulations or British Standards.

2.5.2.7.1 *Fans.* Fans should be installed such that they will operate in an entirely safe manner. Proper guards should be provided around belt drives; see BS 5304.

2.5.2.7.2 *Refrigeration.* When installing refrigeration equipment for air-conditioning, reference should be made to BS 4434. This standard refers to the types of refrigerants that are permitted for use in air-conditioning systems for human comfort and covers the requirements for the plant room containing the refrigeration plant, access doors, ventilation of plant room and the materials that should be selected for construction of the plant. It is not desirable for refrigeration plant to be installed in the same room as a boiler.

2.5.2.8 *Electrical equipment.* Any site-installed electrical work in connection with the installation of ventilation or air-conditioning plant should comply with the current edition of "Regulations for the Electrical Equipment of Buildings", published by the Institution of Electrical Engineers.

Means of isolation should be provided adjacent to all remotely controlled electrical apparatus especially when motors are involved.

All electrical equipment associated with either ventilation or air-conditioning plants should be installed to comply with the standards required by HM Factories Inspectorate, relevant Building Regulations and Building Standards, and with the Electricity Supply Regulations.

2.5.2.9 *Gas/oil-fired equipment.* The installation of gas/oil-fired air heaters should comply with the Building Regulations and Building Standards. Direct-fired heaters may require a relaxation of Building Regulations and the local authority should be consulted.

Special attention should be given to the flueing and to the provision of combustion air and ventilation of the area containing the heater. (See CIBS Practice Notes 1 and 2.)

2.5.2.9.1 *Oil-fired air heaters.* Oil-fired air heaters should be installed to comply with the recommendations of BS 5410 to prevent the risk of fire or minimize the spread of fires from heater or oil storage tanks. Protection of the tank and heater may require either the provision of manual and automatic shut-off valves to shut-off oil supply or the provision of daily service tanks.

2.5.2.9.2 *Gas-fired air heaters.* Gas-fired air heaters should be installed to comply with the recommendations of the Gas Safety Regulations and with the following codes of practice:

CP 331-3

CP 332-4

BS 5440.

Heaters should preferably be selected from the British Gas list of Approved Commercial Appliances.

2.5.2.10 *Fire and smoke detection.* When the system involves the recirculation of air, consideration should be given to the installation of detection devices that would either shut off the plant and close dampers or discharge the smoke-laden air to atmosphere. Detectors may be advisable in certain circumstances even when the system is not a recirculatory one. Discharges should not be positioned near to fire escapes, main staircases or where they could be a hindrance to the work of fire authorities. The local Fire Authorities (and possibly Building Control) should be consulted.

A careful study of the operating characteristics of each type of sensing device should be made before selection. Smoke detectors are normally either of the optical or ionization chamber type. These can be used to either sound an alarm system or operate a fire damper or a series of fire dampers. Care should be taken with their siting as various factors affect the satisfactory operation.

Ionization type detectors are sensitive to high velocity air streams and if used in ductwork the manufacturer should be consulted.

Some authorities have regulations regarding the installation of smoke detectors and these require the detector to:

a) stop the input fan;

b) close a damper in the return air duct;

c) cause the smoke-laden air to be discharged to atmosphere;

d) operate a suitable alarm system.

In an the above instances the appropriate controls would require manual re-setting. Care should be taken if the supply fan is stopped as this can cause smoke to be circulated around the building in the supply ducting.

The Fire Research Station publish a number of notes on the control of smoke and fire within various types of building. Where they exist they should be consulted for details of smoke trapping, control and smoke removal.

See also CP 413 and BS 5588-4.

2.5.2.11 *Smoke control.* While it is essential that the spread of smoke through a building be considered in the design of fire protection systems for all types of applications, it assumes particular significance in high rise buildings, because the time necessary for evacuation may be greater than the time for the development of untenable smoke conditions on staircases, in lift shafts and in other parts of the building far away from the fire. Lifts may be filled with smoke or unavailable, and, if mass evacuation is attempted, staircases may be filled with people.

Most fire authorities now require that one or more "escape staircases", connecting to outdoors at ground level, should be maintained sufficiently free of smoke, to enable mass evacuation of high rise buildings.

Smoke may spread to areas outside a fire compartment owing to expansion (resulting from the temperature effects of the fire), the stack effect (caused by the outside-inside temperature difference), the wind effects, and the transfer around mechanical ventilation and air-conditioning systems. In particular, central systems have a potential for spread of smoke far beyond the origin of the fire. For this reason, many Regulations and fire authorities require that fan systems are turned off automatically when excessive smoke or temperature rise is sensed at some point in the building or in the ductwork system. Even in these circumstances, smoke dampers may be necessary to prevent the migration of smoke through the ductwork system and around the building.

Therefore, all air-handling systems of a building should be designed with fire protection and smoke control in mind incorporating, where appropriate, facilities to permit their operation for the control of smoke within the building in event of fire.

There is little experience with design of systems for smoke control or with their performance under real or simulated fire conditions. Their design requires that considerations be given to anticipation of the fire and smoke situations that may occur, recognition of the mechanism of smoke movement, knowledge of building air leakage and stack effect characteristics, and careful definition of smoke control objectives.

One method of using mechanical ventilation for smoke control favoured by many fire authorities is the positive pressurization of escape routes, principally escape staircases in high rise buildings. The use of pressure-controlled, ventilated lobbies may be required, in addition.

The pressurization systems for staircases use large volumes of outside air, preferable preheated in winter. The systems may be arranged to operate continuously at low speed, being increased to high speed in the event of fire, or arranged to operate only in emergency. Noise and draughts are not considered a problem in an emergency situation. Fans, starters and cabling should themselves be protected from fire and connected to an emergency electrical supply.

2.5.2.12 *Firemen's switches.* A means of control for the use of firemen should be provided to enable such parts of the mechanical ventilation and air-conditioning system as may be needed to be controlled in an emergency. The control should be in a glass-fronted box or otherwise so as to be accessible but protected to prevent operation by unauthorized persons. The control should be marked: "VENTILATION EMERGENCY CONTROL" and the "OFF" position clearly marked.

The siting of firemen's switches should be discussed with the local Fire Authority.

2.5.2.13 *Special applications.* Where areas of a building are ventilated or air conditioned for special purposes, such as computing or printing rooms, etc., there may be a need to take special measures to protect operating or maintenance staff working on the air-conditioning and associated plants. These can take the form of special alarm systems and means of escape and are particularly important where automatic fire extinguishing equipment is installed.

2.5.2.14 *Operation/maintenance.* Clear, brief instructions to the correct operating procedure for air-conditioning plant should be permanently displayed in the appropriate position. The installation should be under the regular supervision of a competent person.

The plant should be maintained in an efficient manner at all times while all or any part of the building is occupied.

Where the ductwork is liable to be contaminated internally with grease, dust, lint, etc., adequate means should be provided for regular cleaning and consideration given to the necessity of providing fire fighting facilities to combat a fire within the ductwork system. Any fire fighting equipment should be checked at regular intervals.

Regular checks should be made by the maintenance personnel to see that extracts for contaminated discharge or air from nearby buildings, etc., have not been sited near to any existing air-conditioning air intakes (see **2.3.3.1**).

Adequate maintenance should be given to all smoke detectors, smoke control dampers, fire dampers, firemen's switches and controls (see CP 413); particular care should be taken in industrial and other atmospheres where rapid accumulation of dust could impair the effectiveness of detectors or dampers. If gas detectors are installed they should be checked and serviced regularly.

2.6 Energy conservation and energy management

2.6.1 *General.* In the context of this code, energy conservation signifies the optimum use of energy to operate the ventilation and air-conditioning system of a building. Not always will this mean the minimum use of energy.

It is axiomatic that general standards of comfort or particular environmental requirements within the building should not be sacrificed in an endeavour to achieve a low consumption of energy. Similarly nothing in this code overrides regulations related to health and safety.

Although attention is drawn to specific aspects of energy conservation in this section of the code, it should be understood that a requirement for effective utilization of energy was a precondition when drafting each of the other sections.

It is intended that the code be somewhat flexible, so that designers are encouraged to adopt an innovative approach.

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

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

2.6.2.2 *Consumption targets.* The energy actually consumed in a building is, in addition, determined by the manner in which the building and its services are used and is measured in units of energy (J/m^2). Targets may be established according to varying climatic conditions and varying patterns of building use.

2.6.3 *Guidance.* For more detailed treatment of the determination of heating and cooling consumption and the design and control requirements for general comfort applications in new buildings and the operation of existing buildings, reference should be made to the "Building Energy Code" produced by the Chartered Institution of Building Services.

2.6.4 *Air-conditioning/ventilation.* Some of the more important aspects of establishing energy conservation requirements for ventilating and air-conditioning systems are given below.

2.6.4.1 ***Systems***

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

a) the nature of the application;

b) the type of construction of building;

c) external and internal load patterns;

d) the desired space conditions;

e) permissible control limits;

f) control methods for minimizing use of primary energy;

g) opportunities for heat recovery;

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

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

a) in summer;

b) in winter;

c) in intermediate seasons;

d) at night;

e) at weekends;

f) under frost conditions;

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

2.6.4.1.3 Consideration should be given to changes in building load and the system designed so that maximum operational efficiency is maintained under part load conditions. Similarly, the total system should be separated into smaller increments having similar load requirements so that each area can be separately controlled to maintain optimum operating conditions.

2.6.4.1.4 The temperatures of heating and cooling media circulated within the system should be maintained at the level necessary to achieve the required output to match the prevailing load conditions with the minimum expenditure of energy.

2.6.4.1.5 The energy used for the transport of air and water within the system should be assessed and transport factors should be not less than those quoted in the CIBS Building Energy Code.

2.6.4.1.6 Recovered energy should be used as much as possible.

2.6.4.1.7 Operation and maintenance procedures should be properly planned.

2.6.4.2 ***Equipment***

2.6.4.2.1 All equipment and components should be tested in accordance with the relevant British Standards; where no applicable standard exists, an agreed international or other standard and test procedure may be applied.

2.6.4.2.2 The equipment suppliers should furnish upon request the energy input and output of the equipment, which should cover full and partial loads and standby conditions as required in order that the energy consumption can be assessed over the whole range of operating conditions.

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

2.6.4.2.4 Coefficients of performance ascribed to various items of equipment should not be less than those quoted in the CIBS Building Energy Code.

2.6.4.2.5 Equipment which requires preventative maintenance should be furnished with all the necessary information.

2.6.4.3 *Control/system.* The designer should aim to select the simplest system of control capable of producing the space conditions required. It is uneconomical to provide controls with a degree of accuracy greater than that required by the application. Consideration should be given to the provision of centralized monitoring and control, thus achieving optimum operation (see **3.4.2**). Detailed application of controls is given in **3.4**.

Section 3. Design considerations

3.1 Types of system

3.1.1 *Ventilation systems.* In the interest of efficient use of energy and comfort of the occupants, it is imperative that all systems of ventilation should be considered in relation to the thermal characteristics of the building.

3.1.1.1 *Mechanical extract/natural supply.* The simplest form of extract system comprises one or more fans, usually of the propeller, axial flow or mixed flow type, installed in outside walls or in the roof. The discharge usually terminates in louvres or a cowl or a combination of both.

Alternatively, the system may comprise a range of ductwork arranged for general extraction of the vitiated air or for extraction from localized sources of heat, moisture, odours, fumes and dust. Such ductwork may be connected to centrifugal or axial flow fans that discharge through the wall or roof, terminating in louvres or cowls or a combination of both. The ductwork includes suitable extract points and dampers.

It is essential that provision for replacement air be made and consideration given to the location and size of inlet.

An extract system should be regarded as a palliative measure to meet the need for ventilation in particularly crowded rooms, offices or restricted areas in which local conditions are likely to prove objectionable as, for example, in lavatories, kitchens, plant rooms and sections of workshops or laboratories; or where there is a statutory requirement for ventilation.

3.1.1.2 *Mechanical supply/natural extract.* This system is similar in form to the extract system but arranged to deliver fresh air into the enclosed space. Such a system necessitates provision for the discharge of vitiated air by natural means. Where there is a requirement for the enclosed space to be at a slightly higher pressure than its surroundings (to exclude dust or smoke, for example), the discharge may be through natural leakage paths or balanced pressure relief valves, as may be required.

A ducted supply system will normally include an air-cleaning device and an air heater battery with automatic air temperature control. Ducted supply systems can provide better control of air movement and reasonable control of comfort conditions.

3.1.1.3 *Combined mechanical supply/extract.* This system is a combination of those described in **3.1.1.1** and **3.1.1.2** and comprises supply and exhaust ductwork systems or may employ a common fan with a fresh air inlet on the low pressure side. In the latter case, an interconnection may be provided to allow partial or full recirculation as required. The fresh air input side of such systems will normally be provided with an air filter and an automatically controlled air heater battery. The ductwork will include suitable dampers, grilles and diffusers.

As with ducted supply systems (see **3.1.1.2**), combined supply and extract systems can provide better control of air movement and reasonable control of comfort conditions.

3.1.2 *Air-conditioning systems.* Systems for air conditioning are basically similar to the ventilation systems described in **3.1.1**, but the need to control temperature and humidity within predetermined limits throughout the year demands the facility for heating, humidifying, cooling and dehumidifying.

Various types of refrigerating systems are available to accomplish the tasks of cooling and dehumidifying, which are an essential feature of air conditioning (see **3.1.3.1**). Systems of air conditioning may be conveniently grouped as all-air type, air-water type or unit type.

3.1.2.1 *All-air systems.* In the all-air type of air-conditioning system, the total heating and cooling load is catered for by controlling the supply air condition. Most plants operate on the recirculation principle, where a percentage of the air is extracted and the remainder mixed with incoming fresh air.

Low velocity or high velocity systems may be used, the latter requiring smaller ducts; however, fan energy is greater, careful acoustic treatment is essential, and higher standards of duct construction are needed.

3.1.2.1.1 *Constant volume.* Accurate temperature control is possible, according to the system adopted. Low velocity system variations include dehumidification with return air bypass, and multizone (hot deck/cold deck mixing). High velocity systems may be single or dual duct type.

The dual duct system uses two separate supply ducts, one carrying cold air, the other hot air, which are mixed in a terminal device (**4.3.1.2.1**) in the correct proportions in each space as dictated by individual room thermostats. Good temperature control of each space is provided, and, according to the particular plant layout adopted (e.g. all-air dehumidified), reasonable control of the average level of zone humidity may be achieved. Both capital and operating costs tend to be high compared with other systems.

3.1.2.1.2 *Variable volume.* Most UK conditioning systems operate at partial load for most of the year and the variable air volume (VAV) system is able to reduce energy consumption by reducing the supply air volume to the space under low load conditions. The VAV system is often arranged for cooling only, serving internal zones, or external zones in conjunction with a conventional heating system. Good temperature control is possible but care should be taken at partial load to ensure adequate fresh air supply and satisfactory control of air distribution and space humidity. Both single duct and dual duct VAV terminals are available (**4.3.1.2.1**).

3.1.2.2 *Air/water systems.* Control of conditions within the space is achieved by initial control of the supply air from a central plant but with the main and final control at a terminal unit within the conditioned space. The supply air provides the necessary ventilation air and a small part of the total conditiong. The major part of the room load is balanced by water through a coil in the terminal unit, which can be either a fan coil unit or an induction unit.

Depending on the degree of control required, the water-circulating system can be either of two, three or four pipe arrangement. With two pipe circulation a single flow and a single return circulate hot or chilled water as required. Such a system can only provide heating or cooling to the system on a changeover basis, so it is ineffective where wide modulations of conditions over short periods are required. The installed cost, however, is naturally the cheapest of the circulation systems. The three pipe system is a way of overcoming the disadvantages of the two pipe system without raising the installed cost too high. In this system a separate hot water flow and chilled water flow is taken to the terminal units but a common return is taken from them to the plant room. The best system from a control point of view is the four pipe system, where separate hot water and chilled water flows and returns are taken from the plant room to the terminal units. Although the most expensive method of circulating the water, it is the only satisfactory one if reasonable control is required.

3.1.2.2.1 *Fan coil system.* In the simplest layout, the units may be located against an outside wall with a direct, fresh air connection. A superior arrangement utilizes a ducted, conditioned, fresh air supply combined with mechanical extract ventilation.

Control of unit output may be achieved by fan speed and/or water flow/temperature control. Electric power is required at each terminal unit.

3.1.2.2.2 *Induction system.* High velocity air forced through jets in the terminal units induces room air into the unit and across the coils. Unit output may be controlled by water flow or air bypass arrangements.

3.1.2.3 *Unit systems.* Such systems are usually those incorporating one or more units or packaged air-conditioners having a direct expansion vapour compression refrigeration system. Similar units using chilled water from a central plant would be designated fan coil systems. Most units are only suitable for comfort application but specially designed units are also available for process and industrial applications.

3.1.2.3.1 *Single units.* Where the application is comparatively small a single unit will be sufficient; this can be either a room conditioner designed for a single area or a roof top or void unit that can serve several spaces by means of a ducting system. The system is complete and normally does not require connecting to a central plant room. The heating can, however, be provided by a coil in the unit, which will need connecting to a heat source.

3.1.2.3.2 *Multiple units.* In large applications units can be used in multiples to serve one large space or a number of smaller individual spaces. Consideration should be given to the availability of unit locations and the maintenance required. A multiple system can be so arranged that a common condenser water-cooling system can be connected to a large cooling tower for heat rejection and a heat source providing water to individual hot water coils.

3.1.3 Special systems for subsystems

3.1.3.1 *Refrigeration systems.* Two methods of refrigeration are currently in common use for air-conditioning systems. These are the mechanical (vapour compression) system and the absorption (heat operated) system. Types of refrigerating equipment are described in **4.10**.

3.1.3.1.1 *Vapour compression systems.* The mechanical vapour compression cycle utilizes the evaporation of a liquid refrigerant to absorb heat and lower the temperature at the evaporator. The compressor pumps this gas at high pressure to the condenser where the refrigerant vapour is liquefied and rejects heat to raise the temperature of its surroundings. A throttling device or expansion valve meters the flow of liquid refrigerant to the evaporator.

a) *Air cooling.* The evaporator is mounted directly in the air stream to be cooled and may be part of a built-up system or a unitary or room air conditioner. Air-cooling coils of the direct expansion type are described in **4.6.1.1.2**.

b) *Liquid chilling.* The evaporator is used to chill liquid, usually water, in a heat exchanger that may be one of the types described in **4.10.1.1.1**.

3.1.3.1.2 *Absorption systems.* The absorption cycle uses a solution that by absorbing the refrigerant replaces the function of the compressor. The absorbent/refrigerant mixture is then pumped to a higher pressure where the refrigerant is boiled off by the application of heat, to be condensed in the condenser.

Absorption machines are used in liquid-chilling applications and are described in **4.10.1.2**.

3.1.3.2 *Heat recovery systems.* A heat recovery air-conditioning system reclaims internal building heat, raises its temperature to a usable level, and redistributes this energy to perform useful heating in other areas.

A properly designed "balanced" system operates during all periods of the year to utilize all internal heat before taking heat from an external source such as a boiler. When an excess of internal heat is available this may be stored or rejected to outside. Under severe winter conditions, at nights or weekends, or at start-up there may be insufficient internal heat available, which requires heat to be provided by an external source.

Heat recovery systems typically employ multi-pipe hot and chilled water distribution circuits serving air-water systems of the induction or room fan-coil type. All-air systems, preferably using variable air volume distribution, and employing wide-range coils, may also be arranged for heat recovery.

Heat recovery may be obtained from refrigeration machines with reciprocating, screw or centrifugal compressors. Either standard condensers combined with plate exchangers or double or triple-bundle condensers may be used.

It should be noted that only low grade heat is obtainable as high condenser water temperatures will increase the consumption of power of the machine, and an economic balance should be sought.

Various types of heat recovery equipment are described in **4.12.1**.

3.1.3.3 *District cooling systems.* For very large projects, e.g. with a total refrigerating capacity above 10 MW, the centralized type of plant can take advantage of the large diversity usually found when many different buildings or air-conditioning systems are connected to a common chilled water distribution circuit.

Advantages include the use of larger and more efficient refrigeration machines with lower cost per kW of cooling, generally both as regards capital and operating costs; easier operation and maintenance; longer equipment life; less total plant space required; less noise and vibration in occupied areas; simplified cooling tower and electrical distribution and automatic control arrangements; inherent standby capacity and operating flexibility.

Particular attention should be paid to accurate determination of daily and annual load profiles, to the economics of chilled water pumping (optimum flow rates and temperature differentials), to best arrangement of refrigeration equipment (series, parallel or combinations), and to terminal control arrangements. Also extremely important is correct choice of piping materials, valves, and thermal insulation, and proper consideration should be given to support and expansion/anchor arrangements, and to corrosion control methods (**3.6**).

3.1.3.4 *Building-integrated systems.* A variety of air-conditioning systems, many of them proprietary, have been developed to permit a fully integrated design with the building, architectural, structural and electrical systems.

3.1.3.4.1 *Modular systems.* A predetermined module size is used to determine the design and location of air-conditioning terminals and room units, light fittings, telephone points, electrical outlets, etc., for open plan layouts with a view to minimizing modifications to services when portitioning layout is initially established or subsequently varied. The air distribution system may use ceiling air terminals, integrated air/light fixtures, or a combination of both.

3.1.3.4.2 *Floor systems.* These generally combine elements of the structural, mechanical and electrical systems, and may utilize performed steel duct or panels, or the concrete floor itself, for air distribution. Particular attention should be paid to load calculations, condensation control and fire precautions.

3.1.3.4.3 *Ventilating ceiling systems.* Also termed plenum supply systems, these are described in **4.3.1.1**.

3.1.3.4.4 *Precoordinated building subsystems.* These have been developed using a "Systems approach" design technique, which interrelates manufacturers' components (structural, lighting, HVAC, etc.) to determine their compatibility from a functional and dimensional standpoint, the air being to carry out as much as possible in the factory and reduce site operations to a minimum.

3.1.3.5 *Panel cooling systems.* Radiant panel systems are generally of the perforated metal, suspended, acoustic type with a pipe coil bonded to a metal face sheet. Panel systems may be used for summer cooling and winter heating, and arranged in small groups to provide good zone control, or as a large continuous area of maximum economy. Good comfort levels may be achieved with radiant loads treated directly, and with normal ventilation and air velocities in the occupied space. In some cases, wall, floor and structural arrangements may be simplified. Particular care should be taken in system design and operation to avoid condensation problems.

3.1.3.6 *Total energy systems.* The term "total energy" usually describes an on-site electrical generating system that is arranged to achieve maximum utilization of the input energy by salvaging the waste heat from the generating process.

A total energy system uses a prime mover (reciprocating engine or a turbine), a generator, and a waste heat recovery system. Prime movers are described in **4.13**.

Very careful technical and economic analyses of heating, cooling, electrical, and possibly domestic hot water, load profiles are required before the decision to use a total energy system can be justified. The most economical arrangement may be complex and include, for example, steam-turbine driven centrifugal water chillers with pass-out steam serving absorption machines, and incorporating waste heat boilers.

3.2 Basis of design. Establishing the "basis of design" is the first important step in designing an air-conditioning or ventilation system. In the case of air-conditioning, it is essential that the system be able to be integrated successfully with the space or building served, and with all the other mechanical and electrical systems within that building.

3.2.1 *System requirements.* An air-conditioning system should normally be capable of satisfying the following requirements.

3.2.1.1 *External load variations.* The system should be able to cope with the daily and annual variations in outdoor temperature, humidity, wind and solar radiations.

3.2.1.2 *Internal load variations.* The system should be able to handle the internal load variations owing to movement of people, and operation of lights, machines and equipment.

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

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

b) handle sensible/latent heat load ratios that may be different from (and more severe than) those occurring at maximum design conditions;

c) operate at all times to provide adequate ventilation, without causing draughts or stuffiness, and with noise and vibration below the established design criteria.

3.2.2 *The external environment.* The following factors should be considered, detailed information being given in the CIBS Guide.

3.2.2.1 *External design temperature and humidity.* These conditions should be selected with regard to local weather data, economic considerations, and the effects of departure from inside design conditions caused by extreme weather variations.

3.2.2.2 *Wind.* Infiltration loads (sensible and latent) owing to leakage of unconditioned air into the building should be determined according to records of wind velocity and direction, and consideration of building orientation, arrangement and construction.

3.2.2.3 *Solar radiation.* The amount falling on the building depends on its geographical location, altitude and orientation, and varies both hourly and from day to day throughout the year. This amount may be modified by local atmospheric effects (e.g. industrial haze), by shading of adjacent buildings, or by nearby reflective surfaces (e.g. water).

3.2.2.4 *Pollution and noise.* Local atmospheric pollution should be taken into account in the establishment of desired internal air cleanliness and filtration standards. External road traffic noise and contaminants, and aircraft noise, may have a bearing on the design of air intakes or exhaust points.

3.2.3 *The internal environment.* Factors to be considered include dry bulb temperature and relative humidity, surface temperatures of the enclosure, air purity, air motion (both velocity and direction), ventilation air quantity, noise and vibration, interactions with lighting (also colour), communications systems and space distribution, and permitted tolerances on design values. The most important of these comfort factors are dealt with in **2.3**.

3.2.4 *The building fabric.* The outer shape of the building to be air-conditioned generally has a major influence on the nature and size of that part of the load attributable to external effects. Factors to be considered include: materials and thicknesses of walls, roofs, ceilings, floors and partitions, and their relative positions in the structure; thermal and vapour transmittance coefficients; areas and types of glazing, external building finishes and colour (which affect the load owing to solar radiation); shading devices at windows, overhangs, etc. (which reduce solar radiation and light transmission).

It is important to distinguish between the instantaneous heat gain from external effects (the portion of these loads that enters the conditioned space) and the *actual* thermal load (the cooling load that the air-conditioning system has to handle).

The actual load is less than the instantaneous gain, owing to the heat storage of the building fabric. Methods of computing this load are given in the CIBS Guide.

3.2.5 *Internal loads.* These loads may be sensible and/or latent gains. Typical sources of internal loads include occupants, lights, machinery, equipment and appliances, products, adjacent spaces and the air-conditioning system *itself*. Data for estimating purposes is contained in the CIBS Guide.

3.2.5.1 *Occupants.* Heat and moisture liberated by occupants depends on surrounding environmental conditions and activity level (metabolic rate).

3.2.5.2 *Lights and machinery.* Heat from lighting fixtures depends upon lamp type (e.g. incandescent, fluorescent), fixture type (e.g. surface-mounted, recessed) and any special features, which may include provision for air supply or extraction through the fitting. With fluorescent fixtures, the heat from the control gear should be included.

Heat and moisture from machinery, equipment and appliances should be carefully evaluated, due allowance being made for diversity, difference between actual motor input and name plate data, etc. Certain loads may be minimized by use of local ventilation or exhaust hoods.

3.2.5.3 *Other loads.* Heat liberated by steam or hot water piping passing through conditioned spaces, water evaporated from open tanks, etc. are load sources.

In process or product applications, heat and moisture liberated from, or absorbed by, substances and materials (e.g. food, paper, textiles) should be carefully estimated.

Heat and moisture may be transferred from adjacent unconditioned spaces by transmission through the building structure, and by movement of air.

3.2.5.4 *System gains.* Heat and moisture transfer may take place to or from the air-conditioning system. One major source is heat pick-up from the air-conditioning fans or pumps, which transfer a portion of their energy to air or water circuits (ideally, this transfer should be limited: see discussion of energy conservation requirements in **2.6**). Additionally, on the cooling cycle, heat may be transferred to supply and return ducts passing through unconditioned spaces. Cooling effect may be lost by leakage of conditioned air from supply ductwork; leakage of unconditioned air into return ductwork may add to the cooling load. During winter, heat losses and duct leakage increase the system heat requirements.

3.2.6 *Ventilation rates/infiltration.* The amount of unconditioned air introduced into the system, either directly into the air conditioning plant or indirectly, by building infiltration, may constitute a major portion of the total cooling load, particularly with high outdoor wet bulb temperatures. Similarly, winter heating and humidification loads may be significantly affected.

Ventilation rates are discussed in **2.3.2**. Further information on this and on computation of infiltration loads is given in the CIBS Guide. Energy conservation requirements (see **2.6**) should also be taken into account.

3.2.7 *Arrangements of equipment/services.* Central plant and distribution services should be arranged or located to achieve minimum cost in use. However, in practice, there are various reasons why some departure from the optimum arrangement may be necessary, such as:

a) building size, configuration and aesthetics;

b) diversity of application in the building;

c) structural loading and space limitations;

d) location of incoming utilities;

e) location of fresh air and exhaust ducts having regard to recirculation or heat recovery;

f) plant noise and vibration;

g) accessibility for installation, maintenance and replacement.

Where heat recovery is to be employed, individual plant rooms adjacent to the space to be served may provide an economical and satisfactory solution. Self-contained air-conditioning units may be used instead of central plants but special care should be given to noise generation.

Cooling towers for cooling the condenser water are normally best located at roof level.

A duplicate fan and motor set are required in cases where ventilation is essential at all times e.g. internal lavatories, WC's, etc. In certain other cases, it may be necessary to provide standby motors and drives for fans etc.

In the case of an air-conditioning plant, complete duplication is not usually possible, owing to floor space and cost, but large areas of occupation should be served wherever practicable with distribution ductwork etc. from more than one air-conditioning plant so as to give some alleviation of conditions if any one plant fails. The total refrigerating load should be supplied by a multiple unit system arranged to take into account standby and part load requirements.

Consideration should be given to automatic changeover controls in such instances where internal conditions have to be maintained at all times particularly in unattended plant rooms.

Consideration should be given to both the appearance and function of inlet and outlet grilles, diffusers and louvres, exhaust fans, units, and air- and water-cooled condensers, to prevent nuisance to adjoining buildings and occupants. The location of external grilles and/or louvres, particularly those handling large volumes of air, can cause a nuisance with noise being emitted from the plant and the possible emission of offensive smells or "stale air" from exhaust outlets. External plant such as roof fan units, condensers and large ductwork may be considered a nuisance from appearance or noise and in the case of evaporative cooling towers from the carry-over of moisture.

3.2.8 *Access and facilities.* To enable the installation to provide satisfaction to owners and to provide comfort for the occupants, it is essential that the proper commissioning is carried out and that full facilities are provided for operation and maintenance.

To keep the plant operating at its optimum condition, regular preventive maintenance is essential.

Both these requirements necessitate adequate access to essential parts of the plant and, for maintenance, facilities for lifting and removal of plant items are required.

3.2.8.1 *Commissioning.* To allow the commissioning engineers to complete their task, sufficient access to the system should be given and towers or ladders should be made available for access to high points of the plant. Where the ductwork or plant is situated above false ceilings or is situated in builders' work ducts, there should be adequate access to dampers, valves and measuring points.

All air volume and pressure test points should be drilled and plugs fitted.

3.2.8.2 ***Operation/maintenance***

3.2.8.2.1 *Access.* Access for carrying out maintenance and the possible replacement of plant should be accommodated in the design and installation of the systems. Any alterations or additions to the building or plant after completion of the original installation should allow for proper access to be available to carry out maintenance work.

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

a) Doorways, corridors, passageways, etc., should be unrestricted to allow good access for operatives, tools and any replacement parts, or in some cases complete units, that may be required.

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

c) Floor areas in plant rooms or around major items of plant should be free from obstruction for the use of lifting equipment that may be required, such as temporary scaffolding, lifting legs, hydraulic mobile hoists and, in some cases, mobile cranes.

d) Purpose-installed access trap-doors in floors should be readily accessible, and they should be able to be opened without being a safety hazard or should be provided with safety guards or rails.

e) Sufficient access should be readily available around plant where regular and planned maintenance, cleaning and/or removal of parts of plant is to be carried out such as withdrawal of tube batteries and strainers, and the changing of filters and vee belt drives.

f) Suitable access and storage should be provided for such items as replacement filters or filter media, drums of lubricating oil, bottles of refrigerant, etc.

g) Access should be provided for plant, control equipment, balancing dampers, valves, test points, changeover dampers, etc. when installed in ceiling spaces, service voids, ducts or other confined spaces.

In buildings with systems installed in ceiling spaces, to eliminate the unnecessary dismantling of ceiling tiles or panels, it is advisable to use a form of coding on the tile or panel, e.g. coloured buttons, to indicate the location and type of equipment, such as damper, fire damper access panel in ductwork, motorized valve or damper, etc.

h) An access door or access facilities should be provided in ductwork sections, large fans, plenum chambers, air-handling units, for maintenance of parts within the plant.

3.2.8.2.2 *Facilities.* Proper welfare facilities and safety measures are required to be provided for all personnel carrying out work on installations. Details of such requirements under the various Acts of Parliament and Regulations are given in section two of this code.

It is advisable to have readily available safety notices, clearly indicating such information as electrical hazards, warning of maintenance work in progress, plant or section of plant being isolated, etc.

Suitable locks or locking devices should be used to prevent unauthorized interference with electrical equipment, valves or plant.

Local isolation should always be available for electrical equipment under the direct control of the operative working on the plant.

It is advisable to provide proper workshop and storage facilities for tools and spares.

With larger types of installations, suitable accommodation should be provided with adequate facilities for keeping records, manuals, drawings and planned maintenance charts.

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.

(230/250) V supply should not be used for electrical hand tools except in the workshop where they should comply with the relevant regulations.

(230/250) : (400/415) V supply portable transformer type electrical welding machines should be properly wired with the necessary isolator and fuses.

Special tools or implements may be provided with some types of equipment and it is advisable to ensure the proper control in the use of these items with records of issue and return to the workshop or stores.

Adequate fixed lighting compatible with the location is advisable in major items of plant where regular maintenance is to be carried out such as in large air-handling plant, filter chambers, humidifiers, etc.

Trailing electrical leads should be made up from the proper materials with any associated lamp protected by a suitable shield or cage.

Suitable means for draining down and for possible quick filling of water systems should be available. The use of fire hose reels for such purposes should not be allowed, in order to prevent loss, misuse or damage to the fire fighting facilities.

3.3 System design

3.3.1 Ductwork and air distribution systems

3.3.1.1 *Materials.* Ductwork is normally manufactured, erected and finished to the specifications of the HVCA. Designers should specify whichever is appropriate for the velocity, pressure and materials to be employed.

Ductwork may be manufactured from metal, plastics, resin-bonded glass fibre, asbestos cement, etc. The most commonly used material is galvanized steel. Where building materials, such as concrete or brick, are used in the formation of airways, the interior surface should be fire resistant, smooth, airtight and not liable to erosion.

3.3.1.2 *Design principles.* There are two main categories of ductwork systems.

a) *Low velocity, low pressure.* In these systems duct velocity is less than 10 m/s, and static pressures are less than 0.5 kPa for the distribution system and 1 kPa for the plant connections.

b) *High velocity, high pressure.* In these systems duct velocity is within the range 10 m/s to 40 m/s; positive static pressures in the system are between 0.5 kPa and 2.5 kPa, and negative static pressures up to 0.5 kPa.

3.3.1.3 *Ductwork design.* Design calculations made to determine the size and configuration of ductwork in respect of pressure drop and noise generation should conform to methods and data given in the CIBS Guide. Considerations relating to energy conservation are dealt with in **2.6** of this code.

Ductwork design should also take note of the CIBS publication "Recommendations relating the design of air handling systems to fire and smoke control in buildings".

3.3.1.4 *Layout considerations.* When designing ductwork, consideration should be given to:

a) coordination with building, architectural and structural requirements;

b) coordination with other services;

c) simplifying installation work;

d) providing facilities and access for commissioning and testing;

e) providing facilities and access for operation and maintenance;

f) meeting fire and smoke control requirements;

g) ensuring that the various parts of the ductwork system are readily identified by colour coding or symbols as described in the current HVCA ductwork specification.

3.3.2 *Piping and water distribution systems.* This subclause gives general guidance on the design and layout of the piping system, but excludes steam, condensate, and high and medium temperature hot water services.

3.3.2.1 *Materials.* Both steel piping with welded or flanged joints and copper piping are used. The use of plastics pipes for cold water in place of steel is becoming increasingly common, as they offer ease of installation with cleanliness and corrosion resistance. It is important, however, when plastics pipes are used to take due account of the high coefficient of expansion and lower mechanical strength when designing piping supports, expansion joints and pipe anchors.

The choice of materials for any installation will be governed by economic considerations, but care should be taken to minimize the possibility of corrosion when choosing material combinations. The use of corrosion inhibitor is recommended (see **3.6**).

3.3.2.2 *Design principles.* The system design should achieve the following two main objectives.

a) A good distribution of water to the various air coolers at all conditions of load.

This will be influenced by the method chosen to control the heat transfer capacity of the air coolers. Failure to achieve a good hydraulic design can lead to difficulties with system balancing to obtain acceptable control. Adequate provision should be made for measuring flow rates and pressure differentials.

b) An economic balance between pipe size and pumping cost.

Excessive water velocities should be avoided, as they can lead to noise at pipe junctions and bends.

When multiple water-chilling packages are to be used in a large system, the control of the machines and the arrangement of the water circulation should be considered as an integrated whole: it is not possible to obtain a satisfactory result by considering control and system design separately.

With larger systems and modulating control of machine capacity, there is normally no need to provide a buffer tank in the circuit. For smaller systems where refrigerating capacity is controlled in steps, a buffer tank is often useful to attenuate the temperature change caused by a capacity step and to minimize excessive cycling of the refrigerating compressor. Again, the choice should, be made after consideration of all the factors involved.

Temperature changes in the system lead to changes in the volume of the water, which has to be allowed to expand into a suitable expansion tank. It is essential that the point at which the tank is connected into the system be such that it is never shut off. It is normal practice to locate the tank above the highest point in the system, so that a positive pressure is maintained when all the pumps are stopped; if this is not possible, a closed tank can be installed at a lower level and pressurized by an inert gas.

For air-conditioning systems, water is the usual heat transfer medium used to convey the heat from the air coolers to the primary refrigerant in the evaporator. In certain special cases, when temperatures lower than ± 5 °C are required, an anti-freeze such as ethylene glycol may be added to depress the freezing point.

3.3.2.3 *Piping design.* The arrangements of the water piping will depend on the heating or cooling systems chosen as being the most suitable for the building. These systems are described in the design handbooks prepared by the CIBS and by the ASHRAE.

The water velocities normally used are dependent on pipe size but are usually in the range 1 m/s to 3 m/s. Noise can be caused by velocities in excess of 4 m/s but this is more likely to be caused by air left in the pipes by inadequate venting. Where materials other than steel are used, erosion can occur at the higher velocities particularly if the water is allowed to become acidic.

The power expended in circulating the water around the system is proportional to the pressure loss and the flow. It is therefore an advantage to design the system with a maximum water temperature rise and hence a minimum flow rate.

Air-conditioning systems operate for a large part of the time at less than the design load, and this means that operating costs can be minimized if the water quantity circulated can be reduced at light load. This should be done without affecting the water distribution.

3.3.2.4 *Layout considerations.* The layout of the main pipe runs should be considered in relation to the building structure, which will have to support their weight and carry the imposed axial loads. The positioning of expansion joints should be considered in relation to the branches, which may only accommodate small movements, and the pumps, which should not be subjected to excessive loads from the piping.

Provision should be made for venting air and any gas formed by corrosion processes from the high points in the system: failure to do this can lead to restricted water flows and poor performance.

New systems invariably contain debris of one sort or another left during construction, and this can cause trouble by blocking pipes, control valves and pumps if it is not removed during commissioning. Piping systems should be designed to permit proper cleaning and flushing and should include suitable strainers at appropriate locations. Reference should be made to CIBS Commissioning Code W.

3.3.3 *Thermal insulation.* Ventilation, air-conditioning and water distribution systems, including components within such systems, may be carrying heated or chilled fluids. Thermal insulation is required to prevent undue heat gain or loss and also to prevent internal and external condensation; a vapour seal is essential if there is a possibility of condensation within the insulating material.

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

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

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

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

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

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

Further detailed information on the properties, the selection and the use of thermal insulating and vapour sealing materials is contained in the following documents:

CP 3005

BS 3958

BS 5422

The Asbestos Regulations 1969

Health and Safety at Work etc. Act 1974

3.3.4 *Refrigerant piping for vapour compression systems.* This subclause considers refrigeration systems designed specifically for air-conditioning applications using the usual halocarbon refrigerants. A large proportion of the refrigeration systems are supplied in the form of packaged units, in which the piping and control systems are standardized.

While the design criteria mentioned here are applicable to the packaged units, they are intended to apply mainly to those systems that are custom built in the building and have relatively long pipe runs with major components on different levels. The design of these systems may need to be further complicated, by the need to control the air coolers to give humidity control, although it is not considered appropriate to deal with this subject in this subclause.

3.3.4.1 *Materials.* The refrigerants and the lubricating oil in the system are non-corrosive to all metals, with the exception of magnesium and of aluminium in certain circumstances. Aluminium alloys are widely used for compressor components.

Contamination of the refrigerant with water can lead to decomposition of the refrigerant with the resulting formation of acid products. These can also be produced very rapidly in the burnout of an hermetic motor and need to be removed completely or corrosion will occur.

The refrigerants and the oil will affect many jointing materials, so that these should be carefully selected. Refrigerating plant manufacturers can advise on suitable types.

Refrigerant lines are generally of copper in the smaller sizes, and of steel for larger sizes. It is important that all foreign matter should be excluded from the refrigerant system. All tubing should be obtained and stored in a clean, dry condition with the ends sealed until required for use.

During fabrication every effort should be made to exclude dirt and moisture, pipe ends should always be kept closed and pipes should be cleaned out after bending.

All welding, brazing and soldering materials should be selected for use in refrigerating systems and the standard of workmanship in making the joints should be high. It is important that flux, welding scale and debris be cleaned away before the pipes are fitted. Soft soldered joints are not recommended except for the capillary type fittings that are available for copper pipes.

Flare and compression type connectors are used for copper and some drawn steel pipes; these are completely satisfactory provided the joints are correctly made in accordance with the manufacturer's instructions. It is important that pipes are adequately supported as excessive movement owing to vibration can lead to fatigue failure of the joints or of the base pipe material, in particular with copper.

3.3.4.2 *Design principles.* Refrigerant piping systems should be designed for minimum pressure drop since pressure losses decrease useful cooling capacity and increase compressor input energy. It is necessary for account to be taken of changes in the state of the refrigerant, which occur as it circulates, and of refrigerant miscibility with compressor lubricating oil. System design should comply with all relevant statutory requirements and with the requirements for refrigeration safety in BS 4434.

Refrigerant piping systems should be designed to:

a) maintain a clean and dry system;

b) ensure correct distribution of liquid refrigerant to evaporators;

c) ensure that lubricating oil is always transported by the refrigerant flow back to the compressor and avoid accumulation and slug flow in the suction line;

d) protect compressors by:

1) preventing liquid refrigerant draining into or condensing in the compressor during shutdown;

2) preventing liquid refrigerant from entering the compressor during operation;

3) preventing excess suction gas superheat at compressor inlet.

3.3.4.3 *Piping design.* Refrigerant piping should be sized with due regard to pressure drop, the minimum gas velocities necessary for oil entrainment and return, and cost factors.

3.3.4.3.1 *Liquid lines.* The liquid line carries liquid refrigerant from the condenser to the expansion valve at the evaporator inlet.

Compressor lubricating oil is sufficiently miscible with refrigerant in the liquid phase to ensure that oil is always carried along with the refrigerant.

The expansion valve should be supplied with slightly subcooled liquid at a pressure just high enough for its proper operation. This means that pressure drop owing to friction plus the static head caused by the elevation of the expansion valve above the condenser or receiver, needs always to be less than the subcooling produced in the condenser, or in a liquid subcooler when one is fitted. This is particularly important when the liquid is feeding more than one expansion valve.

3.3.4.3.2 *Suction lines.* The suction line carries refrigerant vapour from the evaporator to the compressor. Its design is critical.

The velocity of the refrigerant vapour should be high enough to carry lubricating oil back to the compressor in horizontal and in vertical, upward flow, lines at minimum load conditions. Suction line pressure drop should be minimized to avoid adversely affecting compressor capacity and input energy requirements.

Under normal circumstances, it is good practice to use a suction line pressure drop of about 15 kPa for systems using refrigerant R-12[1)] and 20 kPa for those using R-22[1)], which corresponds to approximately 1 °C change in saturation temperature.

The mass velocity of the refrigerant vapour should be maintained within limits to ensure transport of the lubricating oil without producing excessive pressure drop. These considerations also limit the length of lines.

Additionally, suction lines should be designed to avoid traps that can accumulate oil and liquid refrigerant and lead to slugs entering the compressors. Long horizontal lines, when velocity is low, should be inclined to assist oil flow. It should also be impossible for oil from an active evaporator to drain into an idle evaporator.

3.3.4.3.3 *Discharge (hot gas) lines.* The discharge line carries refrigerant vapour from the compressor to the condenser.

The velocity of the refrigerant vapour should be high enough to carry lubricating oil through the system under all conditions of load. Discharge line pressure drop should be minimized to avoid adversely affecting compressor performance.

Under normal circumstances, it is good practice to use a discharge line pressure drop not exceeding 40 kPa. Minimum velocities are necessary to ensure satisfactory oil entrainment in vertical risers, and maximum velocities to limit noise and pressure drop.

Additionally, hot gas lines should be designed to prevent refrigerant and oil in the line from condensing and draining back into the compressor, particularly during shutdown; care should be taken to avoid hot gas pulsations developing excessive noise or vibrations.

3.3.4.4 ***Layout considerations***

3.3.4.4.1 *Evaporators.* The location of the air cooler will normally be controlled by the arrangement of the air ducting. Provision needs to be made for draining of condensate from the coil and for access to the expansion valve (refrigerant metering device), the fan and controls.

To provide efficient operation of the evaporator coil it is necessary to ensure counter flow of air and refrigerant.

It is preferable that the evaporator should be on the same level or above the compressor but on the same level or below the condenser or liquid receiver. This greatly simplifies the piping design.

3.3.4.4.2 *Compressors.* The machine unit should be reasonably remote from occupied areas, to minimize the risk of nuisance owing to noise and vibration. Plant room ventilation is necessary to dissipate the heat from the motor and the compressor, but the extent will depend on the size of the space relative to the heat input.

While the refrigeration units do operate without supervision, easy access for regular inspection and servicing is important.

3.3.4.4.3 *Condensers.* Where water-cooled condensers are used it is normal to arrange the condenser as a unit with the compressor and motor.

Evaporative or air-cooled condensers need to be located in positions where they can receive an adequate supply of ambient air. The normal position will be on a roof, where the only problem is to avoid recirculation of the exhaust air owing to the effect of adjacent structures or other condensers. If the condenser has to be located within the building, for aesthetic or other reasons, the exhaust air discharge will have to be arranged to avoid recirculation and the fan performance checked to ensure that it can overcome the additional duct resistance.

[1)] See BS 4434-1 for composition.

Provision needs to be made to control the condensing pressure, when ambient temperatures are low, to ensure adequate pressure differences within the system. This is particularly important when a water-cooling installation is to be started from cold in a low ambient temperature. Under these conditions it may be necessary to resort to locating the liquid receiver in a warm area, or to insulating it and heating it artificially. The condenser pressure should not be higher than absolutely necessary, as this would waste energy.

Where heat recovery from the condenser is to be used it is necessary to reject the surplus heat to the atmosphere in the normal way. This involves the operation of two condensers in parallel with a proportion of load carried by each. When the heat is recovered into water, two shell-and-tube condensers are used, often enclosed within a single shell. Control is obtained simply by proportioning the water flows through the two sets of tubes. When the useful heat is to be discharged into an air stream, via an air-cooled condenser, the relative positions of the two condensers should be considered in deciding on the method of connection and control, to avoid undesirable storage of liquid refrigerant in either condenser and consequent erratic performance.

3.3.4.4.4 *Accessories.* When the layout or method of control of the plant makes it unavoidable that liquid or oil slugs can return in the suction line, the compressor may be protected by fitting a vessel that traps the slug and meters it back into the line at an acceptable rate or evaporates the liquid by heat exchange and bleeds the oil back into the line.

A heat exchanger to heat the suction gas by cooling the main liquid flow may be fitted. This device can serve a number of purposes: it can partially evaporate liquid in the suction line; it can subcool the liquid flow where it has to rise; or it can improve the thermodynamic efficiency of the cycle, which is particularly true for refrigerant R-12 or R-502[2)].

A liquid subcooler may be located near the condenser or receiver and it may be cooled by water or by evaporating refrigerant.

Where an oil separator is necessary it is commonly mounted on the compressor unit.

Relief valves or bursting discs need to be fitted, to comply with the requirements of BS 4434. These should be connected to a vent pipe, to carry the gas vented outside the building. A single pipe can serve a number of valves, providing it is adequately sized. The relief devices are required to be connected to the vessels that may contain liquid refrigerant and it should not be possible for them to be isolated from the vessel.

3.3.5 Electrical power systems

3.3.5.1 *Voltage reductions.* Systems containing electric motors should not create voltage reductions on the public electricity supply, during motor starting, sufficient to inconvenience other users. The voltage reduction between phase and neutral at one junction point with other users should not exceed 3 % with infrequent starting (i.e. at not less than 2 hourly intervals). A limit of 1 % reduction applies to motors started more frequently. The maximum ratings of motors that may be started up by direct-on-line (DOL) connection to the mains without restrictions are:

Single phase 240 V, 746 W (1hp)

Single phase 480 V, 3 kW (4hp)

Three phase 415 V, 4.5 kW (6hp)

Large motors will normally have special starting devices. On occasions larger motors may be started DOL subject to the loading and other factors relating to the local distribution network. This can only be ascertained in discussion with the Area Electricity Board concerned.

When the system allows more than one motor to be switched simultaneously it may be necessary to use sequential switching to meet the overall voltage reduction requirements.

3.3.5.2 *Harmonic distortion.* Systems containing mercury or solid state inverters, rectifiers or thyristor-controlled regulators can introduce distortion to the mains waveform. In order to reduce interference with other users there are limits to the distortion that such equipment may induce. Advice should be obtained from the Area Electricity Board.

Single phase electrical appliances equipped with electronic devices for supply or control should comply with the requirements of BS 5406.

Single phase converters or a.c. regulators that theoretically produce no even harmonics and that are intended for industrial type equipment and battery charging should not exceed 5 kV A capacity at 240 V, 7.5 kV A at 415 V or 480 V. The use of single phase converters or a.c. regulators that produce both odd and even harmonics is deprecated.

3.3.5.3 *Private generation.* Where the system is powered from a privately generated electricity supply the restrictions in **3.3.5.1** and **3.3.5.2** need not apply. It should be realized, however, that excessive voltage reduction or harmonic distortion can adversely affect other equipment sensitive to this type of interference when connected to the same supply.

[2)] See BS 4434-1 for composition.

3.3.5.4 *Hazardous environments.* If a system or any part of a system is associated with an explosive atmosphere then the installation should be in accordance with CP 1003. Where fans are installed for the extraction of flammable vapours e.g. from a plant spraying booth then motors should be separated from the air stream.

3.3.5.5 *Motor starting systems.* Reduced voltage motor starting systems are used to reduce excessive voltage reductions during starting. The principal methods used are:

a) star/delta switching: 3 phase a.c. motors;

b) rotor resistance: 3 phase a.c. motors;

c) switched auto-transformer: a.c. motors;

d) series resistance: d.c. motors;

e) solid state voltage controller: d.c. motors.

3.3.5.6 *Variable speed.* Methods of speed control depend on the type of motor used. Table 6 lists the principal methods in use.

When variable motor speed is introduced to conserve energy it is important to use a speed control system that does not introduce additional losses to counterbalance the energy savings required.

The induction motor is an inductive load with a power factor at rated load between 0.7 and 0.9. In multi-motor or large motor installations there can be a real incentive to improve this power factor by using static power factor correction capacitors. Apart from financial gains in energy costs there can be reduced currents in feeder cables leading to reduced voltage drop and improvements in starting torque.

3.3.5.7 *Installation.* The relationship between motor losses and heat dissipation determines the continuous rating of the motor. Care should be taken to ensure the availability of cooling air. If this air is above ambient temperature under any condition the motor manufacturer should be informed at the time of ordering. The insulation life is reduced by 50 % for each 10 °C increase over the design permitted temperature.

Where several motors are controlled from a central point an isolator adjacent to each motor, or some means of guarding against inadvertent switching on during inspection and maintenance, should be installed.

Motors and controller should be protected before despatch and stored in suitable dry conditions on site prior to installation.

The controller and overload protection devices should be checked to ensure that they are correct for the motor.

Motors should be installed on purpose-made bases or mounting frames with facilities for drive shaft alignment. Adequate access should be available around the motor to facilitate replacement or readjustment.

Controllers and other electrical equipment should be positioned so as not to be affected by water should a break or overflow occur. If this should not be possible then the equipment should be of waterproof design.

All exposed metalwork of electrical equipment, including motors, should be bonded and earthed. Continuity of this bonding should be carefully checked.

All electric wiring should be in accordance with the current edition of the "Regulations for the Electrical Equipment of Buildings" published by the Institution of Electrical Engineers.

3.4 Automatic control system design

3.4.1 Automatic control systems

3.4.1.1 *Types of system.* Automatic control systems may be categorized according to the source of energy utilized for operating the various system components that are described in **4.9**. For further information see BS 5384.

3.4.1.1.1 *Electric.* An electric system uses alternating current at a mains voltage around 200 V to 250 V (generally 240 V), or may operate through a step-down transformer at a voltage around 20 V to 24 V; some specialized controls, or controls on packaged equipment (usually of US origin), may be operated at 110 V to 120 V through a step-down transformer. Electrical energy supplied to the controlled device is regulated by the controller, either directly or through relays.

Table 6 — Methods of speed control

Method	Motor type	Comment
Variable supply voltage	D.C.	Wide range
Pole amplitude modulation (PAM)	A.C. (squirrel cage)	2 or 3 switched speeds
Multi-wound motors	A.C. (squirrel cage)	Limited speed variation
Variable resistance in rotor circuit	A.C. (slip cage ring)	Limited speed variation
Variable frequency (usually combined with variable voltage in solid state controller)	A.C. (squirrel cage)	Wide range

3.4.1.1.2 *Pneumatic.* A pneumatic system uses compressed air as a source of energy. A controller takes air from a "main" at a pressure of around 100 kPa to 125 kPa gauge, and delivers it at variable pressure through a "branch" line to the controlled device.

3.4.1.1.3 *Electronic.* An electronic system uses electrical energy but employs an electronic "amplifier" to increase the minute voltage variations of the measuring elements to that required to operate standard electric devices.

3.4.1.1.4 *Self-acting.* A self-acting system combines the controller and controlled device into one unit and employs the power of the measuring system to produce the required control action, as in "sealed bellows", or "remote bulb" type measuring elements.

3.4.1.1.5 *Hydraulic.* An hydraulic system uses a suitable liquid, usually oil, under pressure as a source of energy and is generally used where large forces are required for operation of controlled devices, e.g. cylinder unloading of a reciprocating refrigeration compressor.

3.4.1.2 *Design principles*

3.4.1.2.1 *Benefits.* Automatic control of the temperature, humidity or other space conditions may be used:

a) to improve or maintain the comfort of the occupants, the efficiency of various manufacturing processes, or the life and quality of stored products;

b) to prevent wasteful overheating or overcooling and to save money through reductions in energy consumption (see also **2.6**);

c) to permit room conditions to be controlled and/or adjusted within reasonable preset limits.

3.4.1.2.2 *Functions.* Automatic control systems are applied to mechanical ventilation and air-conditioning systems for one or more of the following reasons:

a) to perform a *control* function: to maintain conditions of temperature, humidity or pressure at desired levels within predetermined limits;

b) to perform a *safety* function: to prevent conditions of temperature, humidity or pressure from exceeding safe limits and to prevent equipment from operating beyond them;

c) to perform an *operating* function: to stop and start systems and equipment in a predetermined (interlocked) sequence as required, to provide economical operating cycles, and to match system output to load conditions.

NOTE Although most automatic control systems control temperature, humidity or pressure (often by control of fluid flow) certain specialized controls may monitor, for example, carbon monoxide levels, or may be employed for fire or smoke detection.

3.4.1.2.4 *Basic considerations.* The design of the air-conditioning or ventilation plant, and the associated automatic controls, should take into account the nature of the application, building type and construction, external and internal influences on load patterns, the results it is desired to achieve, and economic factors (capital costs, operating costs, and energy conservation considerations).

3.4.1.2.4 *System requirements for proper control.* It is essential for the design of the air-conditioning or mechanical ventilating system and its automatic control system to be considered together. Cooling and heating coils, and associated automatic control valves and automatic control dampers, should be correctly sized; oversizing can be as troublesome as undersizing. Possible system load changes should be analyzed, particularly changes in the sensible and latent heat balances in air-conditioning systems. All equipment and system components should be capable of adjustment to deal not only with maximum and minimum conditions, but also with any load variations in between.

The effect of time lags in the system should be considered and the control selected accordingly.

Consideration should be given to method of system operation in summer, in winter, in intermediate seasons, under frost conditions, if the electricity supply fails, and when the supply is restored.

The strictest attention should be given to ensuring the safety of building occupants, the air-conditioning system, and the building itself, at all times. Special features may be required to be included for fire protection and smoke control.

3.4.1.2.5 *Equipment quality.* Selection of the permissible control limits is very important. The quality of the control equipment provided should be consistent with the accuracy of control required. It is equally important that equipment of suitable quality should be used in the air-conditioning system. Automatic controls can be made to provide almost any degree of accuracy, but it is useless to provide such controls unless the plant is capable of suitable response. It is neither good practice, nor economical, to select equipment that is capable of producing more precise control than the application requires.

3.4.1.3 *Layout considerations*

3.4.1.3.1 *Zoning.* The system should be divided into areas (in which the load patterns are similar) to permit separate control of each area: the smaller the controlled areas, the better the final control will be. Economic factors will, however, generally dictate the number of control zones.

3.4.1.3.2 *Controllers.* Controllers and sensing elements, whether installed within ductwork, in pipelines, in the conditioned space, or elsewhere, should be located where they measure a truly representative condition, which is not affected by solar effects or radiation from lights, by draughts, by vibration, by abnormal heat conduction, or by fluid stratification or stagnation effects.

3.4.1.3.3 *Controlled devices.* Automatic control valves and dampers should be properly selected and sized, and of a type and construction suitable for the intended duty. In particular, the pressure drop across the valves or damper should be made large enough to enable proper flow control to be achieved.

3.4.2 Centralized control and monitoring

3.4.2.1 *Types of system.* Central control and monitoring is often desirable or essential on large or complex installations. This centralized system may use the electric, electronic, or pneumatic controls described in **4.9**, in conjunction with the specialized equipment described in **4.9.1.4**.

3.4.2.2 *Design principles.* The objective of providing centralized control is to achieve optimum operation of ventilation, air conditioning and associated services to achieve savings in manpower and in the consumption of fuels and energy.

Centralized control may be used to accomplish any or all of the following functions:

a) starting and stopping of equipment;

b) adjustment of control points or of damper and valve positions;

c) monitoring for status indication or alarm detection;

d) measurement for value indication or alarm detection;

e) optimizing performance of plant;

f) alarm indication;

g) recording of events pertaining to normal and abnormal equipment operation;

h) maintenance programming.

3.4.2.3 *Layout considerations.* Layout is largely influenced by the types and arrangement of the various buildings, the types, numbers and locations of air-conditioning systems, the arrangements for providing the sources of heating and cooling, electrical distribution, load patterns, systems usage, etc. Management objectives will generally determine the relative number and type of functions (as listed in **3.4.2.2**) to be accomplished by the centralized control system, which in turn will determine its type and layout. In establishing the degree of equipment sophistication to be adopted, the skill of the plant operators should be taken into account.

3.5 Noise and vibration

3.5.1 Sound control

3.5.1.1 *Noise sources.* Undesirable sound may arise from:

a) central plant, e.g. boilers, pumps, fans, compressors, cooling towers, etc.;

b) distribution noise owing to:

1) air velocity in ducts particularly through dampers or restrictions or air leakage;

2) drumming from duct walls;

3) excessive fluid velocity in pipes and at valves;

4) pick-up of noise or vibration from plant rooms, etc. and transmission along ductwork or pipework, cross-talk or noise transfer from one occupied space to another.

c) noise sources in occupied rooms, e.g. local fans, induction units, high velocity units, self-contained unit air conditioners, air flow through grilles and diffusers.

d) architectural considerations, i.e. open plan, false ceilings.

3.5.1.2 *Design principles.* Noise can be transmitted through internal ductwork, external grilles (both inlet and exhaust), external louvres, open windows, etc. In the selection of equipment care should be taken to consider the likely effect the sound will have on the occupants of the building and whether it will give cause for complaint.

Sound absorbent material used in purpose-built attenuators or for lining ductwork, etc. should have the following characteristics:

a) high sound absorption coefficient over the required frequency range;

b) preferably non-combustible or at least will not sustain flame and not produce toxic fumes when burnt (see CP 413);

c) non-hygroscopic;

d) will not sustain mould growth or vermin;

e) does not absorb odours.

In addition, the following criteria should be satisfied.

f) The sound absorbent material, its covering and its adhesive should not disintegrate under vibration or ageing and should not be eroded by the air flow, taking into account the extremes of temperature and humidity likely to be encountered. Any casing enclosing sound absorbent material should be so constructed that no sharp edge is presented that could cut any protective coating under service conditions.

g) The surface of all sound absorbent materials should be covered with a suitable membrane sealed at all joints to prevent the entrainment of particles from the sound absorbent media as such entrainment can lead to a hazard in many applications.

h) Sound attenuating pads should, wherever possible, be mounted vertically; if this is not possible, then the sound absorbent material should be retained in a suitable enclosure to prevent collapse.

For general treatment there should be adequate mass in the walls, ceiling and floor of plant rooms to avoid breakouts of noise, and siting should be away from sensitive areas of the building.

When considering the environment external to the building particular care should be taken to avoid a nuisance in the "silent" hours, and local authorities have statutory powers to ensure that noise level from plant is limited. BS 4142 explains a noise measurement procedure, the determination of corrected noise level and a method of rating the noise in these instances.

When fitting sound attenuators to air-handling equipment and associated ductwork, it should be ensured that the air supply fan is capable of handling any increased air flow resistance.

The following further points should be taken into account when selecting equipment to meet the required noise levels.

1) Choice of fan with low sound power level consistent with the required performance and ensuring operation at maximum efficiency. To achieve this, smooth entry and exit flow are important.

2) By lining plenum chambers with sound absorbent material, high attenuation can be obtained quite cheaply particularly if inlet and outlet do not face each other.

3) The addition of purpose-made attenuators that fit into the line of ductwork; adequate space is needed for these.

4) Lining ductwork with sound absorbent material.

5) Duct sizes should be chosen to be compatible with the frequencies of the sound to be absorbed.

6) Consideration should be given to the possibility of noise transmission from the duct, which may necessitate increasing the mass of the duct construction.

7) Use of mitred bends preferably lined (preferable to lining ductwork).

8) Avoidance of the need for excessive throttling of air at grilles, diffuser dampers.

9) Acoustic treatment of air inlets and outlets external to the building.

3.5.1.3 *Layout considerations.* These will vary according to the building, some examples are as follows.

a) Single glazing on floors immediately above or below high level plant rooms might be unsuitable.

b) Critical rooms for noise, e.g. conference rooms, lecture theatres, etc., should be sited away from the plant room.

c) Restricted or confined areas, e.g. courtyards or alleyways, should be avoided when siting equipment outside, and the equipment should be orientated such that noise will be radiated away from the likely areas of complaint.

3.5.2 Vibration control

3.5.2.1 *Vibration sources.* Vibration in a building is an undesirable sensation resulting from low frequency pressure waves being transmitted through both the structure and the air. In most situations it is the vertical vibrations that are important since floors have the greatest flexibility in this direction.

3.5.2.2 *Design principles.* In the selection of equipment for an installation, consideration should be given to the building design and the way it will be used.

Most supports are made of either steel springs or rubber pads. Incorrect selection can lead to the transmission of vibration greater than with rigid supports. Thus it is important to select the correct stiffness of anti-vibration mounts. Vibration dampers should be fitted between machinery and all pipework and ductwork including the supports where applicable.

3.5.2.3 *Layout considerations.* As in **3.5.1.3** only examples can be given, and besides those already mentioned the following should be considered:

a) avoiding unbalanced reciprocating machinery in plant rooms above ground;

b) careful choice and siting of externally mounted items of equipment such as mechanical draught cooling towers, air-cooled condensers, etc;

c) the installation of all rotating machinery on suitable anti-vibration mountings, and the insulation of ductwork and pipework from their supports and from direct contact with the building structure.

3.6 Corrosion control and water treatment

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

The hydrogen may:

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

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

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

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

Iron bacteria, which have the ability to absorb oxygen and cause oxidation of iron, are another. They are characterized by the formation of slime, and create objectionable smells, affect water treatment plants and block filters.

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

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

Aluminium fins on copper cooling tubes can corrode when in contact with water of less than 500 M conductivity.

3.6.1.2 *Metals in water.* The contaminants present in raw water form mineral acids that tend to accelerate the corrosion rate of ferrous materials. This will be influenced by pH value, temperature, hardness and oxygen aeration of the water.

3.6.2 Water system problems

3.6.2.1 *Corrosion.* The above-mentioned effects of water on metals will be accelerated in systems where dissimilar metals, e.g. copper and galvanized steel, are in contact.

Copper alone can be immune to corrosion by virtue of the formation of an oxide film, which reduces the rate at which corrosion takes place. Water of pH 7 and below can, however, destroy the oxide film and cause copper to dissolve.

In open water circulation systems corrosion is more likely to be the major cause of trouble owing to the water absorbing oxygen and carbon dioxide from the atmosphere and where the make-up water has a high chloride content.

3.6.2.2 *Scale formation.* The main cause of scale formation in air-conditioning plants is the calcium bicarbonate in the water. On removal or partial removal of the combined or associated carbon dioxide, calcium carbonate will precipitate on heat transfer surfaces or ash particles of sludge in the main body of the water which eventually settle out to cause blockages in the pipe systems. On exposure to air, soft sludge can set into a hard compact condition, which may necessitate an acid descaling operation for its removal. The most susceptible items are humidifying equipment, evaporative coolers and water-cooled condensers.

In the case of humidifying equipment, water is introduced into the air stream either by spray washing or by spinning discs.

In the case of spray washers, eliminator plates prevent the escape of water droplets and surplus water runs back into the wash water tank. There is loss of water by evaporation and consequent increase in dissolved solids resulting in a tendency to form scale usually in layers of "egg shell" thickness that either crack or wash off eventually fouling the sprayer nozzles or blocking the strainers.

In the case of spinning discs the water absorbed by the air stream may deposit its contained salts within the air-conditioned space in the form of dust.

Steam humidifiers provide an alternative to mechanical water atomization for humidification. In hard water districts use of boiling pans results in scaling and deterioration of the element. In the case of electrode type steam humidifiers scaling up of the electrodes will occur more rapidly and excessive blowdown may be required.

In the case of evaporative coolers and water-cooled condensers, the following factors account for loss of the stabilizing carbon dioxide and the consequent formation of scale or sludge in the tower itself or in the condenser tubes and piping causing the bicarbonates in the water to increase to the saturation point at which scale or sludge will deposit.

a) Increase in water temperature as when passing a heat exchanger (e.g. condenser).

b) A rise in pH value of the water caused by the addition of alkali.

c) Degassing or scrubbing as when cascading through the cooling tower.

d) Increase in the total dissolved solids (TDS) in the circulating water owing to loss by evaporation.

3.6.2.3 *Organic growths.* Growths of algae and fungi are principally caused by airborne micro-organisms and spores that are deposited in cooling tower ponds and air washers or spray coil installations. Slimes, weed, fungi and sometimes moss can cause blockages of water spaces, impair the efficiency of heat transfer surfaces and cause rot and damage to wooden structures. Installations situated in rural areas are more susceptible than those in towns although it is known that local breweries and bakeries can be a source of fouling.

3.6.3 *Materials selection and corrosion protection.* When selecting materials for construction it is necessary to consider the corrosion resistance to the service environment, the nature of the corrosion products that may be formed and their effects upon the functioning of the equipment, the suitability of the materials for fabrication and the effects of design and fabrication limitation upon tendencies towards local corrosion. The overall economic balance during the projected life of the equipment should also be considered since more expensive corrosion resistant material may be cheaper in the long run by avoiding the need for regular painting or other corrosion control measures.

Ferrous materials are widely used. The less corrosion resistant forms may be protected in many ways including galvanizing, zinc or aluminium spray, cadmium plating, plastic dip coating and painting.

Copper and a variety of copper base alloys are widely used for condenser cooling and heating coil tubing. Aluminium and its alloys are also used.

Use of dissimilar metals in contact should be avoided or held to a minimum. Where dissimilar metals are employed, galvanic couples should be prevented through the use of insulating gasketing or organic coatings or both. Electrolytic action can also be reduced by inserting a metal of intermediate potential difference between metals giving a high potential difference. Where plastic materials are used the problem of corrosion does not arise but some form of ageing or a decrease in ductility may occur.

3.6.3.1 *Ductwork systems.* Normally the materials and methods of protection should conform to the recommendations in HVCA Ductwork Specifications. In certain cases the environmental conditions may require differing materials and/or protective treatment. Particular attention should be paid to surfaces in the vicinity of spray coils, washers or humidifiers; such surfaces should have an additional protective coating such as vinyl or epoxy resin.

3.6.3.2 *Water piping systems.* Corrosion will be reduced by selecting metals that are compatible in the galvanic series (i.e. the potential difference does not exceed 0.3). It can also be suppressed by providing a protective film or coating (e.g. protective paint) on the metal, by the use of a chemical inhibitor or by the application of cathodic protection (see **3.6.4.1**).

3.6.4 Water treatment method

3.6.4.1 *Corrosion prevention.* Particular treatment will depend on the materials and water properties. In selecting the best treatment to use a water analysis is essential. Chemical inhibitors are classed as anodic, cathodic or mixed. The anodic type, such as chromates and nitrates, stop corrosion at the anode by forming an insulating and invisible film of anodic product. Cathodic inhibitors, such as salts of magnesium, zinc and nickel, reduce cathodic reaction by producing a visible coating on the metal and restricting the access of oxygen. It is important to maintain the correct content of inhibitor in the water to avoid localized and intensified corrosion such as would occur if a large cathodic area were to be combined with a small anodic area. Chemical inhibitors are generally only applicable to closed systems where the make-up is small and measurable.

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

In chilled water systems, where the circuit is closed, some measure of protection can be obtained by oxygen-scavenging chemicals such as sodium sulphite or tannin compounds and by raising the pH value of the water to 9 or 9.5 by the addition of caustic soda, which also reacts to neutralize occluded carbon dioxide.

Proprietary corrosion inhibiting chemicals such as sodium borate, sodium nitrite, sodium silicate, etc. have been found to be effective. See also BS 2486.

3.6.4.2 *Scale prevention*. Before any effective treatment for scale prevention in cooling towers and condensers can be decided upon it is necessary to consider the analysis of the cooling water to be used, the water temperature to and from the tower, the recirculation rate and rate of loss by evaporation.

As water is lost by evaporation the dissolved salts remain in the circulating water. The cooling water sump level is maintained by the "make-up" supply, which introduces more solids. The concentration of TDS (Total Dissolved Solids) in the system will therefore increase. The concentration factor is normally determined as the ratio of the TDS in the system water to the TDS in the make-up water. This factor is important in all evaporative cooling systems irrespective of the treatment used to restrict the TDS to a predetermined amount. Depending on the treatment this factor will usually be within the range 1 to 5. To restrict the build-up of dissolved solids and to keep the concentration factor constant it is necessary to "purge" or "bleed-off" water from the system to waste. To minimize waste, water should be bled-off only when the system is operating.

In the case of spray washers and spray coils, the concentration of dissolved solids in the recirculating water may be controlled by continuous "bleed-off" when the system is operating.

Where spray washers, spray coils or spinning disc type humidifiers are used the only satisfactory method of avoiding scaling or the introduction of dust particles into the air stream is by the use of demineralized water. This needs to be combined with an inhibitor to avoid corrosion.

For steam humidifiers using boiling pans where hard water is supplied, some alleviation can be obtained by dosing the water with sodium metaphosphate from a dispenser cartridge installed in the cold water supply line to the pan. Scaling can be eliminated altogether by the use of water from a base exchanger but this entails higher costs. In both cases it is essential to provide a bleed-off to waste from the pan or frequent changing of the water to avoid excessively high densities.

Where the plant is small and not suitable for the installation of steam humidifiers or a base exchanger, water softener cartridges for demineralizing the water can be obtained.

3.6.4.3 *Organic growth control*. The treatment to minimize algae and slime growth consists of dosing the system with:

a) chlorine as sodium hypochlorite;

b) proprietary algaecides, which are mainly amine preparations but others such as tributyltin oxide, although very effective for particularly obstinate cases of fouling, are slightly toxic.

Where it is particularly necessary to keep concrete or plastics surfaces clean, then painting with chlorinated rubber paint not only discourages algae and slime growth but also provides a smoother surface to facilitate its easy removal.

Section 4. Types and selection of equipment

4.1 General

Air-conditioning equipment includes:

a) fans for moving air;

b) various devices for distributing air and regulating air volume flow;

c) apparatus for heating, humidifying, cooling and dehumidifying, and for filtering;

d) sound and vibration control devices;

e) automatic controls;

f) central refrigerating equipment;

g) room units;

h) energy conservation devices;

i) motor/starters.

4.2 Fans

Fans impart energy to the air to obtain the required air movement.

Basically there are five types, viz. centrifugal, axial, propeller, mixed flow and tangential. Each type has particular performance characteristics with regard to developed pressure/volume flow rate, power, efficiency and noise production and these should be considered in conjunction with other requirements, such as necessity for handling corrosive fumes or abrasive particles in the air stream, when selecting a fan for a particular duty. Fan performance data should be based on type tests in accordance with BS 848.

4.2.1 Type of fan

4.2.1.1 *Centrifugal*. Centrifugal fans may be:

a) forward curved, which in comparison with other types for equal capacity run at relatively low speed but have an overloading characteristic (i.e. at constant speed a reduction in pressure requirement will give increased volume flow rate and increased drive power requirement);

b) backward curved, which generally operate with higher efficiency and have a non-overloading power characteristic;

c) radial or paddle bladed, which have low efficiency but are inherently self-cleaning (i.e. any particles or dust are shed from the blades); they are generally used on industrial ventilation handling abrasive particles.

4.2.1.2 *Axial*. Axial flow fans generally develop less pressure than centrifugal fans for the same impeller diameter and speed but pressure may be increased by the use of guide vanes, by staging in series or by use of contra-rotating units. They may have overloading or non-overloading characteristics. Sound power levels tend to be higher than centrifugal fans. Axial flow fans are compact and can be mounted in line with ducting.

4.2.1.3 *Propeller*. Propeller fans are designed to operate against low resistance or free air conditions. They are frequently used for simple supply or extract ventilation (i.e. without ducting) and are used in some cooling towers and air cooled condensers. They may also be used to generate air movement in a closed space.

4.2.1.4 *Mixed flow*. Mixed flow fans or in-line centrifugal fans develop higher pressure than equally sized axial fans for the same volume flow and are often used in roof extract ventilation.

4.2.1.5 *Tangential*. Tangential fans or cross flow fans develop low pressure. The low ratio of diameter to length makes them suitable for certain types of fan coil units.

4.2.2 Selection factors

4.2.2.1 *Fan performance in a system*. Fan performance should match system requirements. Reference may be made to chapter B.3 of the CIBS Guide regarding fan theory and use of the fan laws.

Manufacturers' or tabular fan performance curves are an essential aid to fan selection and a typical graphical or tabular presentation may include information of fan size, speed, total pressure, fan static pressure, sound power levels and efficiency for various air volume flow rates at a stated air density.

If the flow rate is not equal to that required by design, then either the fan characteristic should be altered (usually by changing fan speed), or the system characteristic should be changed (usually by altering a damper setting).

Graphical methods of selection are useful in determining choice of fans to operate in parallel, or where considering fan application to systems where resistance changes occur owing to dirty filters, wet coils, modulating dampers, etc.

4.2.2.2 *Fan selection*. The selection of a fan involves choosing the most suitable combination of size, arrangement, type and class of construction to meet the required duty, while providing stable operation at an acceptable sound level and efficiency. The following factors should be taken into consideration:

a) air volume;

b) system resistance;

c) entering air conditions, i.e. dry bulb temperature, moisture content, air density and state of air, e.g. containing dirt or abrasive particles, corrosive fumes, or inflammable gases;

d) barometric pressure/altitude at location;

e) type of application or service (e.g. comfort, industrial, quiet);

f) type of system and possible changes in resistance owing to alternative modes of operation (e.g. dirty filters);

g) space available for fan motor and drive;

h) permissible weights, floor loadings both over installation access route and in final location;

i) fan arrangement, position of inlet(s) and outlet(s), and direction of discharge;

j) fan connections, type and size;

k) type of drive and arrangement, requirements of drive adjustment, type of bearing, drive guards, speed control or stand-by duty;

l) fan accessories: access doors, drain plugs, variable inlet or outlet dampers, vibration isolators and flexible connections;

m) special design features, special paints or protective finishes, split casings for ease of assembly (large centrifugal fans).

Fans should not be selected such that the speed of the impeller gives rise to stress near the limit of the mechanical strength of the impeller. A margin should be allowed to permit, for example, 5 % to 10 % speed increase to be made at site if found necessary owing to system alterations during construction. Motors, starters and wiring should be rated accordingly.

Fans should be both statically and dynamically balanced. Pulley changes may upset the dynamic balance of the complete assembly.

Proper selection of motors, drives and starters for fans is extremely important. General guidance is given in **3.3.5** and **4.13** and in section B.10 of the CIBS Guide.

Since fans normally start with equalized pressures at suction and discharge, there is no specific requirement of starting torque except as may exist in the case of large centrifugal fans for which the motor/starter combination should be selected accordingly, particular attention being paid to choice and setting of overload devices. Another possible problem is that if a small fan is driven by an oversized motor with overpowering torque the equipment may be damaged by the applied torque.

4.3 Air distribution and equipment

4.3.1 *Types of equipment*. Air distribution equipment includes dampers for air mixing or volume control, grilles, diffusers and various types of terminal or room units for distributing air and sometimes controlling its heating or cooling effect.

4.3.1.1 *Air terminal devices*. Design considerations in the choice of air distribution devices are covered in **2.3.2**, **2.5.2** and **3.3.1** of this code. Additional information is available in the CIBS Guide, section B.3.

Air distribution devices include various types of diffusers and grilles together with special devices such as integrated air/light units and perforated ceilings.

Ventilating ceiling systems are also termed plenum supply systems since supply air is blown into the void over a false ceiling to form a pressurized plenum. Special attention should be paid to plenum construction to prevent air leakage and heat transfer.

4.3.1.2 ***Terminals and room units***

4.3.1.2.1 *All-air systems*. The terminal units of all-air systems provide control over the conditioned air in terms of the quantity or temperature delivered. Normally these terminal units incorporate or have attached suitable air distribution devices such as diffusers or grilles.

Such systems are either:

a) *constant volume,* single duct with or without re-heat; or

b) *constant volume,* dual duct with mixing box for hot or cold air; or

c) *variable volume,* with air flow rate (rather than temperature) varied by load.

4.3.1.2.2 *Air/water units*

a) *Fan coil units*. These consist of a fan (or fans) with a water coil (or water coils) enclosed in a casing. Ductwork can be added to provide treated or untreated outside air.

b) *Induction units*. Treated primary air is ejected through a nozzle that induces room (secondary) air through the unit, which includes a water coil.

4.3.1.3 ***Dampers***

4.3.1.3.1 *Control dampers*. Control dampers are designed to control the flow of air in the ductwork system by varying the resistance to flow. They may be hand operated when their normal use is for carrying out the initial regulation of the air volume flows and outlets; alternatively, they may be arranged for automatic operation to provide air mixing, bypass or throttling control.

The following types of damper are available.

a) *Single blade damper*. This is generally restricted to small sizes and does not provide accurate control.

b) *Iris damper*. This is a circular damper with moving leaves that form a variable orifice.

c) *Multi-leaf, multi-blade or louvre damper*. This type has two or more blades linked together. In the parallel action type the blades are linked so that when operated they all rotate in the same direction. In the opposed action type adjacent blades are linked to rotate in opposite directions. The opposed action damper is much superior to the parallel action type when used for regulation purposes; it produces a better downstream flow characteristic.

Mixing dampers may comprise two dampers mechanically interlinked so that as one opens the other closes or two or more dampers linked through the control system to operate in unison.

By choice of suitable connecting linkages and mounting brackets the damper actuator, electric or pneumatic, can be located either inside or outside the duct as required.

4.3.1.3.2 *Fire dampers*. Fire dampers should be provided in ducted air distribution systems as required by local authority and by fire regulations. In general, fire dampers are required where air ducts pass through fire compartment walls, and where distribution ducts are contained in a builder's vertical work fire resistant shaft, in which case fire dampers may be required at the point where branch ducts enter or leave the shaft in each storey, and/or at the point where the ducts pass between floors.

Fire dampers are generally made from steel at least 1.6 mm thick and are held open by a fusible link set to operate at around 70 °C. The assembly should have at least the same fire resistance as the structure through which the duct passes.

Further details are given in section B.16 of the CIBS Guide, in CIBS Technical Memorandum no. 1, in the Building Regulations and in CP 413.

4.3.1.4 *General.* Accessories include equalizer grids and flow deflectors of various types for straightening air flow and ensuring positive flow from the distribution ducting to the outlets. Diffusers may be fitted with anti-smudge rings or frames to minimize marking of ceilings by dust-carrying induced (secondary) room air.

4.3.2 Selection factors

4.3.2.1 *Air terminal devices.* Grilles, diffusers and other air distribution devices may be selected from manufacturers' catalogues. These usually list air volume, velocity, throw, pressure drop, radius of diffusion and other characteristics, as well as noise levels. Since noise levels are usually quoted with wide open dampers, due allowance should be made for the increase in noise level that will occur if the damper requires to be throttled to achieve desired air flow or if there is not a smooth air entry into the device. Devices for exhaust applications should be chosen from types that minimize the effects of dirt deposition.

Control methods integral with terminal units should ensure there are no adverse effects on air distribution patterns during variable volume operation.

4.3.2.2 *Terminals and rooms units.* The various types of equipment described have different characteristics, such as noise and vibration levels, performance controllability, maintenance requirements, etc. When making a selection, these should be related to the requirements of the installation and due regard given to their compatibility with those requirements.

4.3.2.3 ***Dampers***

4.3.2.3.1 *Control dampers.* When selecting automatic control dampers consideration should be given to the required flow characteristics, pressure drop and mechanical suitability for the application. In particular, the damper actuator should have the required timing, stroke and torque rating. Some manufacturers' catalogues list the damper area that may be handled by a particular type and size of actuator. Hand dampers should be fitted with an operating lever or quadrant, a locking device and a damper position indicator.

4.3.2.3.2 *Fire dampers.* Fire dampers should provide the degree of fire resistance required by the local authority and by fire regulations. In general, single dampers usually provide up to 2 h fire resistance but when longer periods of protection are required it may be necessary to install double dampers, one either side of the fire break structure.

Fire dampers for use on high velocity distribution systems should have the blade located outside the air stream to prevent undesirable friction losses or noise generation problems. This arrangement is also preferable for low velocity systems. The curtain type fire damper, with a collapsible shutter held back by a spring mechanism, is particularly suitable for large ducts.

On large installations an external indication of damper position may be required as an aid to economic operation. The indication that a damper has "fired" may either be a mechanical "tell-tale" or illumination of a warning light. The latter type is particulary applicable where central control and monitoring systems are to be installed.

Transfer grilles fitted in doors, or in the building fabric between adjacent fire compartments, may be of intumescent painted honeycomb type (BRE Digest 158).

Provision should be made for access required for maintenance.

4.4 Air heating equipment

4.4.1 *Types of equipment.* Ducted appliances for "warming air" are normally termed "air heater batteries". The following media are used:

a) water, low temperature (up to 100 °C), medium temperature (100 °C to 120 °C) and high temperature (over 120 °C);

b) steam;

c) electricity;

d) hot gases;

e) gas;

f) oil;

g) solid fuel.

4.4.1.1 *Air heating coils.* The air heaters and their approaches should be so designed and arranged as to give a uniform velocity across the face area of the heater. Care should be taken to prevent undue resistance to the air flow. To assist in obtaining these conditions, the air heaters should not normally have more than five rows of tubes and the air velocity across the face should not normally exceed 3.5 m/s for finned (extended surface) heaters and 4 m/s for plain-type heaters. Exceptions are special heat recovery coils, electric air heaters, and certain types of high velocity heaters.

Finned heaters are more liable than plain tube heaters to become blocked or coated with dust and dirt; therefore, where finned heaters are installed, special attention should be paid to the provision of ready access to all parts of the batteries for cleaning purposes. Compressed air or steam are suitable media for the cleaning of this type of air heater.

Air heaters should have special protective finishes, e.g. galvanizing, to delay corrosion or damage owing to condensation or moisture carried through the heater by the air, where the heaters are used in conjunction with air washers and placed after them. Alternatively, copper or similar non-corroding metal should be used. Special precautions should be taken where the air may be acid laden.

4.4.1.1.1 *Hot water heated coils.* Comfort heating systems employing hot water usually require not more than one or two rows of tubes in the direction of air flow, in order to produce the desired heating capacity. To produce the greatest capacity, efficiently, without excessive water pressure drop through the coil, various circuit arrangements are used.

Generally, the resistance to the hot-water flow through the heater should not exceed 4 kPa in accelerated low pressure hot-water heating installations. In high pressure hot-water installations, the resistance to the water flow will probably be determined by other factors, e.g. the need to balance circuits.

The heaters should be served from hot-water flow and return mains with sufficient connections to each row or bank of tubes or sections to give uniform distribution of the heating medium.

The flow connections to the heater should generally be arranged at the lowest point of the heater, and the return connections at the highest, to aid venting. The expansion of the tubes when the heater is in operation should be considered and the necessary arrangements made to accommodate expansion and contraction. See also BS 5141-2.

Thermometer wells should be fitted in the pipes near the inlets and outlets of all air-heating batteries so that the temperature drop through the heater can be readily observed.

Parallel-flow and contra-flow arrangements are common in water coils. Counter-flow is the preferred arrangement to obtain the highest possible mean temperature difference.

4.4.1.1.2 *Steam heated coils.* For proper performance of steam heated coils, condensate and air or other non-condensables should be rapidly eliminated and the steam should be uniformly distributed to the individual tubes.

Non-condensable gases remaining in a coil, besides reducing output, cause chemical corrosion and result in early coil fracture.

Properly designed and selected steam distribution tube coils distribute the steam throughout the entire length of all primary tubes, even when the leaving air temperature is controlled by modulating the steam supply pressure. Thus more uniform leaving air temperatures are produced over the entire length and face of the coil than would result if a single-tube coil were used. As coil lengths increase, increases in coil tube diameters will produce more even steam distribution owing to better condensate removal from the coil.

To prevent waterlogging within the battery, care should be taken to remove the condensate as soon as it is formed; in some cases it may be desirable to provide for the condensate removal from the first bank of tubes of the heater. Difficulties may be experienced in operating air heaters under light load and these may be overcome by greater sectionalization of the controls.

When the entering air temperature is 0 °C or below, the steam supply to the coil should not be modulated. Coils located in series in the air stream, with each coil sized to be on or completely off in a specific sequence dependent upon the entering air temperature, produce a system in which there is little likelihood of a freeze-up. The use of bypass dampers could be considered, but care should be taken that cold air streams do not impinge on the coil through air gaps in the partially closed face dampers.

Necessary arrangements should be made to accommodate expansion and contraction.

Means should be provided, where necessary, for adequate venting of the steam space. Heaters should have connections for pressure gauges, which should be fitted at the steam inlet.

The steam condition at the battery should be dry but not superheated. See BS 5141-2 and BS 2486.

4.4.1.1.3 *Electric air heaters.* The air velocity through the heaters should be sufficient to permit the absorption of the rated output of the battery within its range of safe temperatures and the exact velocity determined in conjunction with the manufacturers of the heater. Electrical load should be balanced across the three phases of the electrical supply.

Where automatic temperature control is required, the heaters should be divided into a number of sections dependent upon the degree of control to be effected.

Each section of heater elements, which may be two rows of elements, should have its own busbars and connections and be capable of withdrawal from the casing, thus enabling the elements to be cleaned or repaired whilst the remainder is in operation. Each section should be capable of being isolated electrically before being withdrawn from the casing.

All heaters should be electrically interlocked with the fan motors, so that the electric heater will be switched off when the fan is stopped or when the air velocity is reduced to a level below that for which the heater has been designed.

The air velocity over the face of the heater is of particular importance in the design of electric air heaters, and the manufacturers should be given details of the maximum and minimum air velocities likely to occur.

With all electric air heaters, care should be taken to preclude the risk of fire under abnormal conditions of operation, by the use of a suitably positioned temperature sensitive trip of the manual reset type to cut off the electric supply.

4.4.1.2 ***Direct-fired air heaters***

4.4.1.2.1 *Gas fired*

a) *Flued.* These units should be designed so that the maximum heat transfer is consistent with minimum condensation obtained from the gas heated surfaces of the heater over which cold air may pass.

The heat exchanger is normally of the welded type using aluminized steel, stainless steel or similar materials. The material is welded to form a clam shell type or cylindrical tube and drum heat exchanger.

The heat exchanger surfaces should create the minimum of resistance to air movement and scrub all surfaces uniformly so enabling an efficient transfer of heat, quietly and smoothly.

Burners can be either of the atmospheric or of the automatic forced combustion type. The design should allow an adequate supply of air for combustion to the burners.

Depending upon the type of burner fitted to the heater, gas ignition, operation and safety controls should be fitted to the heater. Atmospheric burner control should include a flame failure device, solenoid control valve, pilot controls, ignition and, possibly, a governor.

Forced combustion burner systems should comply with the British Gas Standards for automatic gas burners. "Forced and induced draughts".

The heater should be fitted with an overheat type thermostat and either a pressure switch or an air flow proving device, so that the burner will not operate in the event of no air flowing through the heater, i.e. fan failure.

Depending upon the burner system employed, a flue system needs to be provided to remove the products of combustion to atmosphere. In the case of the atmospheric type burners, a draught diverter needs to be provided (in addition to the flue outlet) as part of the appliance. The positioning of flue terminations may be subject to statutory or other regulations.

A heater with an automatic gun type gas burner should be fitted either with a direct flue connection or with a stabilizer within the flue system.

Thermostatic control of the gas supply to the heater is required, so that the air-off temperature can be controlled. This can be achieved by two stage control that partly opens an hydrometer valve on low rate and completely on high rate.

Air heaters should be chosen from the British Gas list of tested and approved commercial appliances.

b) *Flueless.* A make-up air handling unit should consist of the following components:

1) air inlet louvres and bird guard;

2) filter bank with access for cleaning;

3) burner and profile plate (the latter controls the rate of combustion air);

4) air distribution fan (this may be either axial or centrifugal);

5) safety gas control system.

Normal operation of this type of air heater is that gas is supplied to a burner head and air passes outside the baffles at a designed velocity. Air paths within these baffles are arranged to provide the correct combustion air. Turndown ratios of up to 35 to 1 are obtainable, this variation of gas flow giving the required air temperature control.

A control system that satisfies the following sequence is required. Air flow to the unit is provided by an air switch; after a 30 s purge of the unit by the fan, the ignition spark and pilot gas valve are operated. On proving that the pilot has ignited, the main gas valve will open and the burner will light. Once alight the main burner will modulate to the temperature set by the room thermostat. Should at any time during the ignition sequence or running, flame failure or an interlock failure occur, then lock-out requiring manual reset will result.

Attention is drawn to building regulations regarding the installation of this type of heater.

Air heaters should be chosen from the British Gas list of tested and approved commercial appliances. This means the heaters have been tested to BS 3561 and relevant clauses of BS 1250 and any other necessary requirements of British Gas.

4.4.1.2.2 *Oil fired*. These units should be designed so that the maximum heat transfer is consistent with minimum condensation obtained from the oil heated surfaces of the heater over which cold air may pass.

The heat exchanger is normally of the welded type using aluminized steel, stainless steel or similar materials. The material is welded to form a clam shell type or cylindrical tube and drum heat exchanger.

The heat exchanger surfaces should create the minimum of resistance to air flow and wipe all heated surfaces uniformly so enabling an efficient transfer of heat to the air stream. It is essential that this be achieved without upsetting air flow or generating noise.

Burners are either of the vaporizing or pressure-jet type, the vaporizing burner only being used on low output equipment. The design of the burner should allow an adequate supply of air for combustion.

The burner should comply with the requirements of BS 799 and be provided with timing for controls, and safety devices for ignition failure and main flame failure.

The heater should be fitted with an overheat thermostat and either a pressure switch or air flow proving device, so that the burner cannot be operated in the event of no air or a restricted air flow through the heater.

Means need to be provided for removal of the products of combustion to atmosphere. These can be of the direct flue connection type or with a stabilizer. If a stabilizer is required, it is preferable that it forms part of the appliance.

Thermostatic control of oil to the heater is required so that the air-off temperature can be controlled. See BS 4256.

4.4.1.2.3 *Solid fuel fired*. Furnace-type air heaters should be of such a type that the maximum efficiency can be obtained from the furnace and flues for heating the air. The heaters should be made of cast iron or steel cased in brickwork or steel. The cast iron heaters should be made in sections, cemented and bolted together, while the steel type should be welded or riveted. All joints should be airtight so that the cold air can pass over the heated surfaces of the furnace and flues without becoming contaminated with the flue gases.

To avoid the risk of products of combustion being drawn into the air if the heater burns through, furnace-type heaters should be so arranged that the air is blown, and not drawn, through the heater.

Adequate draught should be provided for the furnace to avoid soot being deposited on the heating surfaces. The flues should be fitted with an adequate number of cleaning doors and provision made for cleaning out the tubes.

With a fan-furnace heating system, the fan should be controlled to start automatically when the correct temperature is obtained. In the event of a fan failure, provision should be made to damp down the furnace fire automatically to avoid damage to the tubes from overheating.

4.4.2 Selection factors

4.4.2.1 *Air heating coils*. In the selection of air heater batteries the following factors should be taken into consideration:

a) air volume to be handled (and conditions at which measured);

b) entering air conditions (dry bulb temperature, air density); air quality (possibility of dirt, corrosive or hazardous atmosphere); whether coils are to be used in freezing temperatures;

c) required leaving air dry bulb temperature;

d) available heating medium:

   1) water and steam: entering temperature and pressure; permissible heating medium temperature drop; allowable medium pressure drop;

   2) electricity: voltage and phase; maximum element temperature;

e) allowable air side face velocity;

f) allowable air side resistance (as it affects fan horse power);

g) heating medium connections:

1) water and steam: size, type, location, circuiting arrangement (provision for air release and drainage), provision for cleaning tubes;

2) electricity: type and location, circuiting arrangement; terminal box enclosure specification;

h) air side connections (flanges for duct mounting, etc.);

i) construction: materials for heaters, coils and extended surface; number of rows and arrangements; type of extended surface and spacing;

j) division of coil to suit control, manufacturing or installation arrangement, i.e. number of sections and rows;

k) air pressure at point of installation (and air leakage through coil casing) particularly when located at fan discharge on a high pressure system;

l) economy of coil selection as related to the associated system, i.e. flow rates, temperature rise, pressure drops, fan and pump horsepowers.

Where a pre-heater coil is provided and it is situated before an air filter, the heater should be either a plain tube or have wide spread fins for easy cleaning.

4.4.2.2 ***Selection of direct fired air heaters***

4.4.2.2.1 *Flued heaters.* The following factors should be taken into consideration:

a) air volume to be handled;

b) entering air conditions;

c) whether the air leaving temperature is suitable;

d) allowable air side resistance;

e) whether the unit is provided with all necessary safety controls;

f) whether the position of the flue outlet on the appliance is suitable for easy venting to atmosphere;

g) whether connection flanges for ductwork are provided;

h) whether an access door is provided for inspection of the pilot and main burner (access should also be available for cleaning the burner);

i) whether sight glasses or observation ports have been provided to see both pilot and main burner flames;

j) whether a suitable temperature control system is provided by the burner control system;

k) in the case of gas fired equipment, that the unit should be selected from the British Gas list of tested and approved commercial appliances.

4.4.2.2.2 *Flueless heaters.* Items a), b), c), g), h) and j) of **4.4.2.2.1** should be considered, together with the following:

l) whether the fan within the unit has sufficient pressure to suit the ductwork system;

m) whether the addition of moisture from the combustion products will adversely affect the space humidity required;

n) that the unit should be selected from the British Gas list of tested and approved commercial appliances;

p) that great care needs to be taken to ensure that the concentrations of combustion products delivered into occupied space are maintained well below the accepted tolerance levels: this will often limit the use of flueless heaters to the supply of make-up air only;

q) that the operation of flueless heaters should comply with relevant regulations.

4.5 Humidifiers

The types in common use add moisture into the air to be conditioned either in the form of a fine mist or spray, or by evaporation from a pad of absorbent material within the air stream, or by vaporizing water or injecting steam. The so-called air washer is also used for humidification but has other characteristics and therefore is described separately (see **4.6.1.2.1**).

4.5.1 *Humidifiers with water storage.* The water to humidify is stored within the unit and can be supplied automatically from the main supply on the smaller units manually as required.

In order to prevent contamination of the water mains through backsiphonage, the water inlet to appliances of this type should incorporate either a Type B Air Gap, or an approved type of pipe interrupter, or a combined check and anti-vacuum valve.

4.5.1.1 *Spray type.* Water is pumped from a storage tank at the bottom of the unit to one or more spray nozzles that inject a fine spray of water into the air stream. In larger units the movement of air through the duct system ensures adequate mixing of moisture in the air. Small room units incorporate a fan on the same spindle as the pump.

4.5.1.2 *Pan type.* Absorbent material is partially immersed in water stored in a pan at the base of the unit. Moisture is added to the air by evaporation from the wetted surface of the absorbent material.

4.5.1.3 *Mechanical pan type.* In this type the absorbent material, fixed to a drum or disc, is turned into the pan to absorb moisture and then into the air stream to allow it to evaporate.

4.5.1.4 *Steam generating pan type.* This type consists of an enclosed water tank connected to the main duct. By heating the water in the tank it is vaporized and picked up by the air stream passing over the tank.

4.5.2 *Humidifiers without water storage.* Water need not be stored within the unit, especially where the equipment used for humidification forms part of a central station plant, or where there is a suitable source of steam available.

4.5.2.1 *Spinning disc humidifier.* This is a unit in which a controlled quantity of water is discharged against a rapidly rotating disc and is thrown out by centrifugal force against circumferentially placed baffles to produce a fine mist discharging into the main air stream.

4.5.2.2 *Steam jet.* Steam generated by an external source is injected into the air stream. A suitable uncontaminated and odourless steam source needs to be made available locally to the installation.

4.5.3 *Selection factors.* Humidification can be achieved by placing separate humidifiers directly in the conditioned space. In order to maintain specified conditions, however, the control of the humidity should be incorporated into the overall system. Care should be taken when siting humidifiers to ensure that moisture does not impinge on any surface.

Water treatment is usually necessary to prevent solids being carried into the air stream and deposited within the humidifier or as a fine dust in the conditioned space. This is particularly important in the case of spinning disc or spray type humidifiers.

Care should be taken when selecting spray or evaporative type humidifiers as in certain circumstances they may well promote the growth of fungi, algae, bacteria, etc.

The selection of a particular type will depend on the size of the installation, availability of water and/or steam and the method used to condition and distribute the air.

4.6 Air cooling and dehumidifying equipment

4.6.1 Types of equipment

4.6.1.1 ***Air cooling/dehumidifying coils***

4.6.1.1.1 *Chilled water coils.* The coils are constructed from aluminium or copper fins on solid drawn copper tubes arranged in banks enclosed in a heavy gauge galvanized sheet steel casing including suitable drip trays at vertical height intervals not exceeding 900 mm to catch the condensate. The air velocity across the face should normally not exceed 2.5 m/s for finned (extended surface) cooling coils. The use of higher velocities generally requires the fitting of eliminator plates to prevent the carry-over of entrained moisture.

Cascade plates should normally be fixed to the coil if it is to be placed in a diagonal position to collect the condensate and direct it into the drip tray.

Control is achieved by modulation of the chilled water flow.

When used in corrosive or similar special applications, the coils can be manufactured from metals other than copper and special finishes are available.

4.6.1.1.2 *Direct expansion (DX) coils.* These coils are of similar construction to those for chilled water, in terms of tubes, fins, casing, etc. The major difference is one of circuits. In a direct expansion coil the control is obtained by splitting the coil into multiple circuits, each coil being fed by an individual compressor. The coil can be split in sections one above the other, in an interlaced split across the face, or in sections one bank or more behind the other.

4.6.1.2 ***Spray equipment***

4.6.1.2.1 *Air washers*

a) *Spray chamber type.* The air supply is ducted to and from a large chamber or casing containing a series of standpipes each having a number of water spray nozzles. The excess spray water is drained into a tank at the bottom of the chamber and recirculated to the nozzles by a pump. To avoid carry-over of moisture to other parts of the plant, eliminator plates are fitted to the downstream side of the chamber.

b) *Wet cell or capillary type.* This type is similar to the spray chamber type in its function but water is sprayed through a coarser nozzle onto cells packed with suitable fill such as glass fibre. The water percolates the cells through which air is drawn and a large surface area of contact for evaporation is thus provided. Again, surplus water drains into a tank and is recirculated by means of a pump.

4.6.1.2.2 *Evaporative air coolers.* These are, basically, evaporative type humidifiers similar to those described in **4.5.1**. In the process of evaporation heat is taken from the air so that the moisture within the humidifier can vaporize; thus the temperature of the air is reduced. The evaporative cooler has some form of fill material to increase the area of contact and a fan to blow air over the wet fill. Most evaporative coolers are of the unit free-standing type.

4.6.1.2.3 *Spray coils.* Often the cooling coils are incorporated within the washer and spray is directed across the coils. By this means a large area of contact is provided and the coil is also made more effective.

In order to prevent contamination of the water mains through backsiphonage, the water inlet to appliances of this type should incorporate either a Type B Air Gap, or an approved type of pipe interruptor, or a combined check and anti-vacuum valve.

4.6.1.3 *Unit dehumidifers.* By cooling air below its dewpoint the normal air-conditioning equipment automatically carries out a dehumidification function. However, if the dehumidification is required when cooling is not, then a separate unit may be used; this can dehumidify either by mechanical refrigeration or chemical means.

a) *Mechanical type.* Mechanical unit dehumidifiers are basically unit air conditioners operating on a direct expansion vapour compression system. In this case, the condenser coil is usually mounted downstream of the evaporator coil to reheat the cooled air before it enters into the conditioned space.

b) *Chemical type.* Chemical dehumidification relies on the absorption or adsorption properties of certain chemicals. Air is passed over a bed or cell containing a chemical such as silica gel or lithium bromide. When the cells are saturated they should be replaced or regenerated by heating to drive off the moisture.

4.6.2 Selection factors

4.6.2.1 *Air cooling and dehumidifying coils.* The type and size of coil depends on the media to be used, i.e. chilled water, brine or refrigerant, its operating conditions and the degree of control required.

It should be noted that the effectiveness of the bond between fin and tube can be affected by the operating conditions.

The temperature of the media, the temperature of the air, the velocity of the air over the coil and the proportions of latent heat removal to sensible heat removal all have a direct effect on the coil selection. Capacity and control are two major factors that determine whether a direct expansion coil is to be split.

4.6.2.2 *Spray equipment.* The selection of spray equipment is dependent on the degree of control over the operating conditions required. The equipment is mainly used to provide adiabatic humidification, although by circulating chilled water a degree of control over temperature can also be achieved.

4.6.2.3 *Unit dehumidifiers.* Whether a mechanical or chemical type is chosen depends on the degree of dehumidification required, the space available, and the simplicity of use necessary.

Because of the space needed and the complication of regeneration, chemical types are normally used only where dehumidification generally below 30 % is required. For dehumidification above this level mechanical types are more commonly used.

4.7 Air filters

NOTE In reading the following subclauses, reference should be made to BS 2831.

4.7.1 Types of equipment

4.7.1.1 *Panel or unit filters.* The use of panel or unit filters is normally confined to the smaller systems up to a maximum air flow of about 5 m^3/s. They are constructed in various size ranges, such as 450 mm × 450 mm, 500 mm × 500 mm and 600 mm × 600 mm, and operate at face velocities between 1.0 m/s and 2.5 m/s. The standard arrangement for filter frames is for "front withdrawal" but "side" or "rear" withdrawal frames may be obtained for some types. Characteristics of these filters are set out in **4.7.1.1.2** to **4.7.1.1.5**.

4.7.1.1.1 *Viscous impingement filter.* The efficiency range of these filters is 80 % to 90 % (test dust no. 2). They are usually of all metal construction between 50 mm and 100 mm thick and are serviced by washing and re-oiling. High dust holding capacity is obtained with little increase in pressure drop but efficiency may fall off rapidly with increase in dust load. These filters are primarily used for industrial or engine air intakes.

4.7.1.1.2 *Permanent dry type filter.* The efficiency of these filters is up to 95 % (test dust no. 2). They may be of fabric, processed from plastics or brush type with medium to high dust holding capacity, normally selected to operate with initial resistance of from 25 Pa to 55 Pa rising to 50 Pa to 125 Pa with use. Most dry type filters increase in efficiency with dust load but volume flow is reduced. Servicing is by washing, or by compressed air or vacuum cleaning.

4.7.1.1.3 *Dry replaceable media type.* The efficiency range of these filters is 95 % to 99 % (test dust no. 2) and with methylene blue penetration of 40 % to 50 % obtainable with some types. They usually consist of fabric or wadding media on metal frames arranged in pleated "W" or bag form to present a large filter surface area.

These filters are serviced by replacing the filter media upon a rise of 1½ to twice the initial resistance, which is normally between 35 Pa and 100 Pa. These filters usually have a high dust holding capacity and higher efficiency than normal and are commonly used as main filters or as a prefilter to a high efficiency filter.

4.7.1.1.4 *Throwaway type.* The efficiency of these filters is up to 95 % (test dust no. 2). They are generally of panel construction with filter media of fabric, plastics, glass or metal fibre mounted in a rigid wood, metal or cardboard frame. They usually have a low to medium dust capacity and are primarily used on the smaller plants where servicing requirements of a permanent type of filter would be disadvantageous.

4.7.1.2 *Automatic air filters.* Automatic air filters are primarily used on larger systems, where they usually give economic advantage over panel filters. Automatic filters are obtainable down to a rating of approximately 0.5 m^3/s. The air flow face velocity usually is between 2.00 m/s and 2.75 m/s. Velocities higher than this can give a reduction of overall size, but this leads to a penalty in increased resistance and the possibility of carry-over of the filter fibres or the wetting oil.

4.7.1.2.1 *Automatic viscous type.* The efficiency of these filters is up to 90 % (test dust no. 2). They may be of rotary screen, rotary panel or constantly cleaned fixed element type. Operation is normally time-switch controlled and the filters maintain a constant operating resistance of 50 Pa to 125 Pa according to type.

Servicing of these filters requires the removal by hand of the dust deposit as a sludge from the viscous fluid tank (automatic sludge removal may be obtained on some units) and mechanical maintenance is required for timer mechanism, driving motor bearings, etc. These filters are relatively expensive and of low efficiency against finer dust but can operate for extremely long periods with minimum attention.

4.7.1.2.2 *Automatic dry type.* These can be obtained with various grades of filter media (normally glass, acrylic or similar fibre) giving efficiencies of up to 95 % for standard density material rising to 98 % for more dense media. Air flow pressure drop for the media are 100 Pa to 125 Pa standard and 125 Pa to 150 Pa increased density. Advancement of the media is normally controlled by a pressure differential switch. The filter is arranged with two spools similar to a camera to wind the media across the air flow. To reduce the overall size of the filter some types are arranged to operate with the media drawn across the air flow in V, W or S pattern by the use of guides and/or rollers. Servicing consists mainly of replacement of media (in intervals of approximately 4 months to 9 months depending on length and type of media, amount of dust in the airstream and hours of operation). Automatic dry filters can be obtained suitable for horizontal or vertical mounting and for large systems are normally the most economic filter. These filters are suitable also as pre-filters to a high efficiency filter.

4.7.1.3 *Electrostatic air cleaners.* Typical efficiencies of these devices are 95 % (methylene blue), 99 % (test dust no. 2 when using pre- and after-filter), 95 % (test dust no. 2 when using pre-filter). These filters are efficient in the removal of large quantities of dust especially in the smaller particle range. Many manufacturers recommend the use of a pre-filter, which helps to even the air flow over the face of the cleaner, and after-filters are often used to collect large agglomerates that may break free from the collecting plates. The electrostatic cleaner is a two-stage unit, the first stage being a series of fine wires that give the dust particles a positive electrical charge and the second stage a series of parallel plates generally coated with a water-soluble viscous solution and charged negative or negative and positive alternatively. The voltage gradient causes the positively charged dust particles to be deposited on the negative plates.

Servicing is by switch off and washing down and recoating as necessary. This can be arranged for automatic control. Cells require regular inspection for burnt plates, also inspection and replacement of ionizing wires, rectifiers, etc., as necessary. A supply of hot water is required and the air flow has to be stopped during the servicing period.

This equipment operates on high voltage and suitable interlocks are required to ensure that access to live parts is only possible when power is off. Only skilled and experienced personnel should be authorized to attend to the equipment.

4.7.1.4 *High efficiency particulate air (HEPA) or absolute filters.* These are normally tested in accordance with BS 3928, having efficiency (sodium flame) 99 % to 99.995 %. They are invariably panel filters, most commonly 600 mm × 600 mm × 300 mm, rated for 0.500 m^3/s approximately at an initial resistance of 125 Pa to 300 Pa. Standard absolute filters use treated or glass paper media in honeycomb formation in a mild steel or wooden case. Other filters are constructed of materials giving suitability for operations in high humidities, high temperatures and chemically corrosive atmosphere. These filters will normally be used in conjunction with a pre-filter. Spark arrestor/flame traps are available for high temperature types. The life of a filter can vary from a few months to several years depending on the location and the efficiency of the pre-filter. It is important that the filter frames are properly sealed when in place and these filters should be tested in situ to detect any leak prior to commissioning and at regular intervals thereafter.

4.7.1.5 *Carbon pack filter.* This filter is used to remove odours, fumes, vapours, gases, etc. from air. The carbon may be activated or catalytic and is, to some extent, selective; it is available for most applications. This filter is used normally on defence installations for removal of war gases but commercial packs are obtainable to remove certain odours in systems using a large proportion of recirculated air. They may also be used to exclude from an internal environment gases, such as sulphur dioxide, which may be present in the external atmosphere, in order to protect personnel or sensitive materials such as works of art. The air flow face velocity is comparatively low, usually of the order of 1.75 m/s. These filters quickly become clogged with atmospheric dust and it is essential that an efficient pre-filter be used. The filters may be of "throw-away" pattern or suitable for regeneration by the manufacturer.

4.7.2 Selection factors

4.7.2.1 *Filter characteristics.* As dust builds up on a filter the pressure drop across it increases and the air flow volume rate will reduce. This needs to be allowed for when selecting the fan (**4.2.2**). Where a constant volume flow rate is important, hand or automatic dampers may be arranged in the system to compensate for increase in filter resistance. In the case of automatic roll filters the medium advances to maintain a virtually constant pressure drop across the filter.

4.7.2.2 *Filter selection.* When selecting a filter the following particulars should be considered:

a) The air flow rate for which the filter is designed.

b) The face velocity, which is the average velocity of air (m/s) entering the effective face area of the filter.

c) Resistance, i.e. difference between static pressure upstream and downstream specified for "clean" and "dirty" conditions when operated at the standard rating.

d) Efficiency, i.e. a measure of the ability of the filter to remove dust from the air:

$$N = 100\frac{(C_1 - C_2)}{(C_1)}$$

where

N is the filter efficiency
C_1 is the upstream concentration
C_2 is the downstream concentration

The concentrations may be expressed in terms of the number of particles of a particular size, of straining power (surface area) or of mass of dust. It is common practice to report the efficiency of air-conditioning filters on the basis of accelerated tests employing synthetic dusts that have a particular particle size or a small range of sizes. BS 2831 lays down two test methods: the first deals with determination of methylene blue efficiency using strain densities as a criterion, the second determines gravimetric efficiency and does not apply to air cleaning devices that preclude accurate weighing of the filter before and after use.

High efficiency particulate air (HEPA) or absolute filters are normally tested to BS 3928. These filters have efficiencies of 99.9 % and greater and will remove particles down to 0.1 µm.

e) Dust holding capacity, which is the mass of dust that a filter can retain air flow during a rise in pressure drop from its initial clean resistance to some arbitrary maximum value, usually twice the value of pressure drop when clean.

f) Economic considerations should take into account the initial capital cost, and the cost of replacement materials on cleaning operations and of the labour involved.

g) Possible fire hazards.

4.8 Sound and vibration control equipment

4.8.1 *Types of equipment.* Various types of equipment and materials may be incorporated into systems to reduce noise to satisfactory levels: attenuators for insertion into ductwork, duct lining materials (fitted internally for absorption and externally to minimize transmission), high velocity terminal units, "cross-talk" attenuators, and acoustic louvres for fresh air intakes or exhaust outlets.

Devices for minimizing machinery vibration to acceptable levels include compression materials and special isolation mounts and springs. Anti-vibration connectors and hangers are frequently used to minimize the transfer, from piping and ducting to the building structure, of vibrations from connected machinery and fluid turbulence.

4.8.1.1 ***Silencers***

4.8.1.1.1 *Duct attenuators.* Prefabricated or packaged attenuators are designed for mounting in ductwork to reduce the transfer of mechanical and air-generated noise along the air distribution pathways.

Attenuators are normally constructed with an outer metal shell of rectangular or circular cross section and fitted with various internal air passage configurations formed from splitters and/or linings of fibrous, inorganic sound absorbing material with a facing of similar denser material or of perforated or expanded metal.

The air passages and absorbing elements should be aerodynamically and acoustically designed to permit selection of the required amount of attenuation over a particular range of frequencies at various air flow resistances; the latter should preferably be as low as is practicable.

4.8.1.1.2 *Lining materials.* Materials should comply with the requirements listed in **3.5.1.2**.

a) *Attenuation materials.* The inside surfaces of ductwork and fittings may be lined with a layer of material having a high sound absorption coefficient to reduce the transmission of noise along the air distribution pathways. These materials effectively attenuate only the higher frequencies.

Internal duct lining material may be used alone or in conjunction with attenuators depending upon the amount of attenuation required. Air linings may be designed to provide both sound absorption and thermal insulation.

b) *Materials to reduce transmission.* The external surfaces of ductwork and fittings may be covered to minimize noise breaking out through the duct walls to the surrounding area, or flanking duct attenuators thus reducing their effectiveness. Very thick and dense materials are required to attenuate low frequency sound.

The external covering material should be selected for its noise reduction properties. The transmission loss across the ductwork and external lining depends primarily upon their combined mass, and conventional internal duct lining materials are not suitable by themselves.

4.8.1.1.3 *Terminal and room units.* Since these units are situated in the space they condition, noise generated is radiated directly into that space. As there is very limited means of attenuation, units should be chosen on the basis of manufacturers' data of noise levels where available. Noise from air outlets can be attenuated only by reducing air velocity through them.

4.8.1.1.4 *Cross-talk attenuators.* To provide the required attenuation duct linings, splitters, cells, outlet absorbers, prefabricated silencers may be used. Attenuation can also be achieved by extending the ductwork between any terminal point such that the increased natural attenuation will reduce sound transmission.

4.8.1.1.5 *Air intake/exhaust louvres.* Noise from these normally results from excessive air velocity through the louvre and accurate values should be obtained from manufacturers' data. It is most important to ensure that the approach conditions to a louvre supply a uniform flow distribution across its face. Local high flow spots will generate a disproportionate quantity of noise. Dampers placed behind outlet grilles, necessary for balancing, can cause undue noise if the pressure drop across them is too high. Care should be taken when siting air intake louvres to avoid excessive external noise from entering through them, or emanating from them.

4.8.1.2 ***Anti-vibration devices***

4.8.1.2.1 *Compression materials.* Sheets of suitable materials may be fitted between the base of the machines and the building structure.

Natural, neoprene and silicone rubber are often used; other materials to meet special service conditions are:

a) combination of rubber and steel shims;

b) cork;

c) glass fibre;

d) felt.

4.8.1.2.2 *Isolation mounts.* Rubber isolators moulded as mounts with some form of steel loading plate or as pads are designed for varying natural frequencies and deflections. They are used to isolate high frequency vibrations.

Cork is used with concrete for pump and refrigeration machinery foundations, particularly in basement locations. It is an effective isolator only for vibrations in excess of 50 Hz.

Glass fibre pads are made precompressed and coated with a flexible moisture-resistant covering. They can isolate vibrations down to 7 Hz and are used in applications where deflections range up to 7 mm. This material has superseded cork in many applications.

4.8.1.2.3 *Springs.* These usually comprise a combination of a free standing, laterally stable spring with top and bottom load plates and levelling bolt. Springs are also designed with vertical restraints (housed) to ensure a constant height if supported weight is removed, to reduce movement owing to wind loads and for systems requiring damping.

There are several spring mount designs that are a cross between open and housed mountings and are used in conjunction with concrete foundations or for machinery having large weight variations (e.g. cooling towers) to avoid undue strains on connecting pipework.

4.8.1.2.4 *Pipe connectors and hangers.* Pipe connectors are available in a variety of types depending on usage. Rubber hose connectors with back-up rings, or flexible metal hose, can accommodate lateral movement perpendicular to their length. Rubber expansion joints permit both axial and angular movement. Metal bellows expansion joints can also be used, with the added advantage of higher pressure and temperature capabilities. Mechanical pipe couplings are used with larger diameter pipe, having the necessary attenuating features already mentioned at comparatively low cost.

Pipe hangers consist of a steel spring, glass fibre pad or combination of both, retained within a welded steel bracket. They are necessary to prevent transmission to the building structure of vibrations that cannot be properly attenuated by flexible pipe connectors. These vibrations are usually encountered as a result of severe flow conditions or water hammer.

4.8.1.2.5 *Duct connectors.* These are made of flexible rubber or synthetic materials, but are not wholly effective in isolating vibration since they become rigid under pressure and are ineffective in damping pulsating flow. Transmission of vibration from ducts is not a common problem, but the best practice is to specify isolation hangers wherever ducts (especially in high pressure systems) are supported below critical areas.

4.8.2 *Selection factors.* It is recommended that all vibration and noise control design and installation should only be carried out by an engineer with the necessary specialist experience.

4.8.2.1 *Silencers.* The following factors should be taken into account when designing.

a) Plenum chambers should be lined with sound absorbent materials; high attenuation can be obtained quite cheaply particularly if inlet and outlet do not face each other.

b) Adequate space is needed for the addition of purpose-made attenuators that fit into the line of ductwork.

c) The lining of ductwork with sound absorbent material depends upon whether duct sizes are compatible with the frequencies to be absorbed.

d) The use of lined mitred bends is preferable to lining ductwork.

e) The need for excessive throttling of air at grilles and diffuser dampers should be avoided.

f) Air inlets and outlets external to the building should be acoustically treated.

g) Care should be taken in choosing and siting externally mounted items of equipment such as mechanical draught cooling towers, air cooled condensers, etc. and, where necessary, acoustic barriers should be erected or attenuators added.

h) Fans should be chosen with low sound power level consistent with the required performances and operation at maximum efficiency ensured. To achieve this, smooth entry and exit flow are important.

4.8.2.2 *Anti-vibration devices.* In ventilating and air-conditioning plant, vibrations usually arise from rotating machines or from reciprocating machines. The following should be noted;

a) All structural steel bases and concrete inertia bases should be designed with ample rigidity to resist all starting and operating forces without supplemental hold-down devices.

b) All rotating and reciprocating machinery should be installed on suitable anti-vibration mountings and ductwork and pipework insulated from their supports and direct contact with building structure.

c) Pulsating flow owing to bad ductwork configuration can cause vibrations to be transmitted to the building structure. Sharp changes in direction of ductwork should be avoided.

d) Care should be taken when specifying flat oval ductwork in high velocity systems. Width should not exceed 1 m and the aspect ratio should not exceed 3 : 1.

4.9 Automatic controls

4.9.1 *Types of equipment.* The basic components that are designed, selected and installed to work together to form a complete control system, together with their function, are shown in Table 7. Complete definitions and further information is given in BS 1523-1.

4.9.1.1 ***Sensing and measuring elements***

4.9.1.1.1 *Temperature elements*

a) A *bimetal element* comprises two thin strips of dissimilar metals fused together and arranged as a straight, "U"-shaped or spiral element. The two metals have different coefficients of thermal expansion, so a change in temperature causes the element to bend and produce a change in position.

b) A *rod and tube element* is composed of a high expansion metal tube inside which is located a low expansion rod with one end fixed to the rear of the tube so that temperature changes cause the free end of the rod to move.

c) A *sealed bellows element* is evacuated of air and charged with a liquid, gas or vapour, which changes in pressure or volume as surrounding temperature changes to result in a change of force or movement.

d) A *remote bulb element* consists of a sealed bellows or diaphragm to which a bulb or capsule is attached by means of capillary tubing, the entire system being filled with liquid, gas or vapour. Temperature changes at the bulb are communicated as pressure or volume changes through the capillary tube to the bellows or diaphragm.

e) A *resistance element* is constructed from wire or semi-conductor materials whose electrical resistance varies in a known manner with changes in temperature, and is used with electronic controllers.

f) A *thermocouple element* comprises a junction between two dissimilar metals that generates a small voltage related to the temperature.

4.9.1.1.2 *Humidity elements*

a) An *organic element* is selected for its hygroscopic properties and is usually made of human hair, paper, silk, wood, animal membrane or other materials that change length with changes in moisture content.

b) A *resistance element*, as employed in electronic systems, consists usually of two interleaved grids of gold foil, each connected to a terminal and mounted on a thin slab of insulating plastic material with a coating of hygroscopic salt (lithium chloride) on the block. A conductive path between adjacent strips of foil is formed, and the high electrical resistance of this circuit changes as the chemical film absorbs and releases moisture with changes in the relative humidity of surrounding air.

4.9.1.1.3 *Pressure elements*

a) *Low pressure* measuring elements for low positive pressure or for vacuum conditions, e.g. static pressure in an air duct, usually comprise a large slack diaphragm, or large flexible bellows. In one type of static pressure regulator two bells are suspended from a lever into a tank of oil, so that positive pressure under one of the bells moves the bell and an attached lever up (or down) to complete an electrical circuit. The majority of these elements sense differential pressure, and when combined with pitot tubes, orifice plates, and venturi meters may be used to measure velocity, flow rate or liquid level.

b) *High pressure* measuring elements, for pressure or vacuum measurements in the kPa range, are usually of the bellows, diaphragm or Bourdon tube type. If one side of the element is left open to atmosphere the element will respond to pressures above or below atmospheric.

4.9.1.1.4 *Special elements.* Special elements for various measuring or detecting purposes are often necessary for complete control in air-conditioning or ventilating systems, e.g. a "paddle-blade" type of air flow switch may be interlocked with an electric heater battery to prevent the battery from operating and overheating in the event of an air flow failure.

Other elements employed from time to time are for measuring smoke density, carbon monoxide (e.g. in road traffic tunnels or underground car parks) and carbon dioxide, and for flame detection.

Table 7 — Basic components of a control system

Element or component	Function
Sensing and measuring element of the controller (e.g. sensor, detector)	Measuring changes in one or more controlled conditions or variables
Controller mechanism	Translating the changes into forces or energy of a kind that can be used by the final control element
Connecting members of the control circuit; wiring for electric, piping for pneumatic, linkages for mechanical	Transmitting the energy or forces from the point of translation to the point of corrective action
Controlled device or actuator such as motor or valve	Using the force or energy to motivate the final control element and effect a corrective change in the controlled condition
Sensing and measuring element of the controller	Detecting the completion of the change
Controller mechanism, connecting means, and actuator or control device	Terminating the call for corrective change, to prevent over-correction

4.9.1.2 *Controllers.* Controlling elements normally regulate the application of either electrical or pneumatic energy. Controllers are mainly of three types: thermostats, humidistats and pressure controllers.

4.9.1.2.1 *Thermostats.* The following types of thermostat are in common use.

a) The *room* type responds to room air temperature and is designed for mounting on a wall.

b) The *insertion* thermostat responds to the temperature of air in a duct and is designed for mounting on the outside of a duct with its measuring element extending into the airstream.

c) The *immersion* type responds to the temperature of a fluid in a pipe or tank and is designed for mounting on the outside of a pipe or tank with a fluid-tight connection to allow the measuring element to extend into the fluid.

d) The *remote bulb* thermostat is used where the point of temperature measurement is some distance from the desired thermostat location, which may often be in the central panel. A *differential* type employing two remote bulbs may be used to maintain a given temperature difference between two points.

e) The *surface* type is designed for mounting on a pipe or similar surface and measuring its temperature, or to give an approximate measurement of the temperature of the fluid within the pipe.

f) The *day/night room* thermostat is arranged to control at a reduced temperature at night, and may be changed from day to night operation at a remote point by hand or time clock, or from a time switch built into the thermostat itself.

g) The *heating/cooling (or summer/winter)* thermostat can have its action reversed and, where required, its set point raised or lowered by remote control. This type of thermostat is used to actuate controlled devices, such as valves or dampers, that may regulate a heating medium at one time and a cooling medium at another.

h) The *multi-step* thermostat is arranged to operate in two or more successive steps.

i) A *master* thermostat measures conditions at one point and resets a set point of another (*sub-master*) thermostat or controller.

4.9.1.2.2 *Humidistats.* Humidistats may be of the room or insertion type. For example, a sub-master room humidistat may be used with an outdoor master thermostat to reduce humidity in cold weather and prevent condensation on windows. A wet bulb thermostat is often used for accurate humidity control, working in conjunction with a dry bulb controller.

4.9.1.2.3 *Pressure controllers.* Pressure or static pressure controllers are made for mounting directly on a pipe or duct. The controller may also be mounted remotely on a panel.

4.9.1.3 *Controlled devices*

4.9.1.3.1 *Automatic control valves.* An automatic control valve consists of a valve body designed to control the flow of fluid passing through it by use of a variable orifice that is positioned by an operator in response to signals from the controller. The fluid handled is generally steam or water, and the operator is usually of the electric motor or pneumatic actuator type. Since probably 75 % or more of all air-conditioning and mechanical ventilation systems utilize a valve of some sort as the final control element, proper control valve selection is one of the most important factors in attaining good system performance.

Valve components are defined and valve flow characteristics discussed in detail in BS 4740.

a) *Valve types.* The main types and their characteristics are summarized briefly below.

1) *Single seated valves* are designed for tight shut-off.

2) *Double seated valves* are designed so that the fluid pressure on the two discs is essentially balanced, reducing the power required to operate; this type of valve does not provide a tight shut-off.

3) *Pilot operated valves* utilize the pressure difference between upstream and downstream sides to act upon a diaphragm or piston to move the valve, and are usually single seated, for two position applications only, and used where large forces are required for valve operation.

4) *Low flow valves* may be as small as 3 mm port size and are used for accurate control of low flow rates.

5) *Three-way mixing valves* have two inlets and one outlet, and operate to vary the proportion of fluid entering each of the two inlets.

6) *Three-way diverting valves* have one inlet and two outlets and operate to divert or proportion the inlet flow to either of the two outlets.

7) *Butterfly valves* comprise a heavy ring enclosing a disc that rotates on an axis at or near its centre and may be used for shut-off where low differential pressures exist.

8) *Special multi-port valves* for various types of modulating/sequencing operation are available for control of both hot and chilled water to three and four pipe fan coil and induction unit systems.

b) *Valve operators.* Valve operators usually comprise an electric solenoid, electric motor or pneumatic actuator.

1) A *solenoid* is a magnetic coil that operates a moveable plunger to provide two position operation.

2) An *electric motor* is arranged to operate the valve stem through a gear train and linkage. Various types are available for different applications.

i) A unidirectional motor is used for two position operation, the valve opening during one half revolution of the output shaft and closing during the next half revolution.

ii) A spring return motor for two position control operation is energized electrically, driven to one position, and held there until the circuit is broken, when the spring returns the valve to its normal position.

iii) A reversible motor is used for floating or proportional operation and can run in either direction and stop in any position.

3) A *pneumatic actuator* usually comprises a spring-opposed flexible diaphragm or bellows connected to the valve stem, so that an increase in air pressure acts on the diaphragm or bellows to move the valve stem and compress the spring. When the air pressure is removed the spring will return the operator to its normal position.

4.9.1.3.2 *Automatic control dampers.* Control dampers are designed to control the flow of air in a ductwork system in much the same way as an automatic valve operates in a fluid circuit, that is by varying the resistance to flow.

a) *Damper valves*

1) The *single blade* damper is generally restricted to small sizes since it does not provide accurate control. When fitted in circular ductwork it may be referred to as a *butterfly* damper.

2) A *multi-leaf* damper is two or more blades linked together.

i) A parallel action multi-leaf damper has its blades linked so that when operated they all rotate in the same direction.

ii) An opposed action multi-leaf damper has adjacent blades linked to rotate in opposite directions when operated.

b) *Damper operators.* These may be electric motors of the unidirectional, spring return or reversible type fitted with suitable linkage mechanisms, or may be pneumatic actuators of a type designed for damper operation.

4.9.1.4 *Centralized control/monitoring equipment.* The centralized control system, which is shown diagrammatically in Figure 1, comprises three main parts: the remote location equipment, the transmission links, and the central equipment.

4.9.1.4.1 *Remote location equipment.* This includes:

a) *input devices* or sensors, which measure the condition of a variable;

b) *signal conditioning devices*, which convert the sensor signal to a type compatible with the requirements of the remote panel, transmission system, or the central equipment;

c) *output devices*, which provide a means for converting a command instruction, appearing at the remote panel, into a signal suitable for performing an operational function on external equipment;

d) *remote data collection panels* or remote enclosure, which act as termination points for the remote ends of the transmission links and for connections to the remote input and output devices.

4.9.1.4.2 *Transmission links.* The transmission link provides the means for communication between the central equipment and the remote data collection panel and may be classified according to a number of variables which include:

a) medium (wires or cables, telephone lines, microwave);

b) transmission mode (one direction only, one direction at a time, etc.);

c) data sequence (series, for 2-wire, parallel for multi-conductor, etc.);

d) wire or cable types;

e) signal types;

f) message format.

Other considerations include the physical arrangement of the transmission system, security and supervisory aspects.

4.9.1.4.3 *Central equipment.* This may comprise:

a) an *interface*, which provides a connection point and the signal conversion between the central processor and transmission links;

b) the *central processor*, which is the collection of equipment at the central control room containing the logic for management of the centralized control and monitoring system; the processor has the means to receive, transmit and present information, with the ability to process all data in an orderly fashion, and may or may not include a computer;

c) *peripheral devices* such as typewriters, printers, displays (digital type, projectors, or cathode ray tubes, etc).

4.9.2 Selection factors

4.9.2.1 *Common factors.* There are a number of factors to be considered in the selection of almost all control system components. These common factors include:

a) supply and working electricity voltage, phases, frequency and number of wires;

b) compressed air mains pressure and quality;

c) maximum and/or minimum temperatures, humidities or pressures to which components may be subjected;

d) restrictions on location, mounting positions, etc., or possible problems owing to duct, vibration etc.;

e) dimensions and weights;

f) finish and type of enclosure;

g) required accessories or fittings.

NOTE These common factors, and specific items detailed in **4.9.2.2**, should only be used as a general guide, and control manufacturers should be consulted in establishing exact requirements.

4.9.2.2 *Sensing/measuring elements.* Sensing and measuring elements frequently form an integral part of a controller and the selection factors to be considered for this arrangement are covered in **4.9.2.1**. However, a sensor may be designed and arranged for operation with a remote controller and other components, in which case some of the more important selection factors for temperature elements, for example, are as follows:

a) *pneumatic*

1) control operations, e.g. reverse or direct-acting;

2) sensing range, adjustable or non-adjustable;

3) provision for air filter;

4) pressure output;

5) provision for branch line pressure indication;

6) application, e.g. room, duct or immersion in pipeline.

b) *electronic*

1) function, e.g. for primary or secondary control;

2) temperature range;

3) authority range or throttling range adjustment;

4) nominal resistance and sensitivity;

5) provision for temperature indication;

6) application, e.g. room, duct or immersion in pipeline.

4.10 Refrigerating equipment

The refrigerating equipment used for air conditioning is almost invariably supplied in the form of a packaged unit, either to provide chilled water or in the smaller capacity range to provide direct air cooling. The performance characteristics of these packages are considered in this subclause together with the more important accessories.

4.10.1 Types of equipment

4.10.1.1 *Vapour compression water chillers.* These normally contain the complete refrigerating system, comprising the compressor, condenser, expansion device and evaporator together with the automatic control panel. The unit can be set down on to a solid foundation or, where it is necessary to minimize the transmission of noise and vibration, on resilient mountings. Pipe connections may need flexible couplings when resilient mountings are used; these should be considered in conjunction with the design of the pump mountings and the pipe supports.

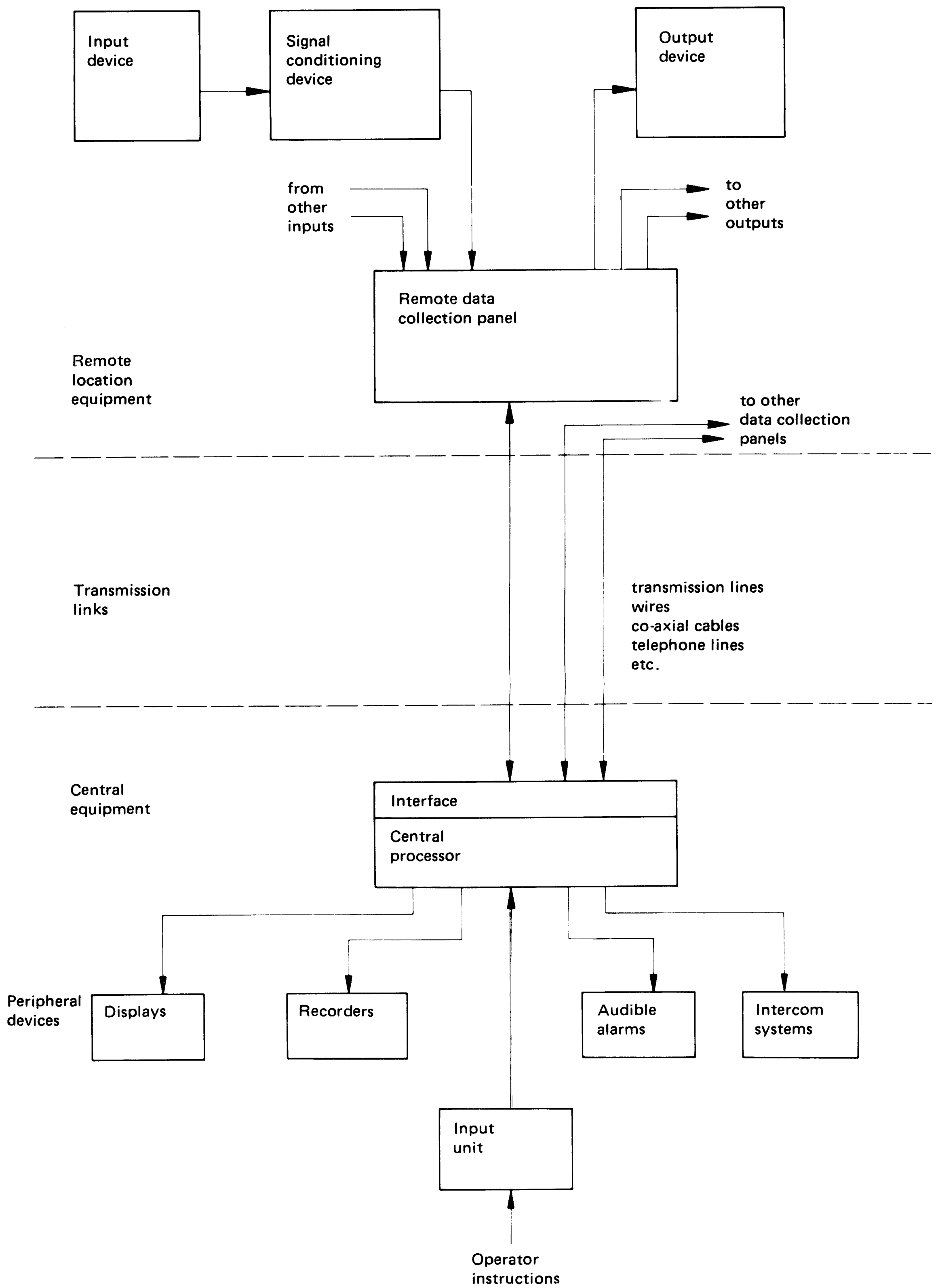

Figure 1 — Simplified block diagram of centralized control system

Capacity control is normally arranged to maintain an approximately constant temperature of the chilled water leaving the evaporator. This may be adequate for one or two packages, but a more elaborate central control system may be necessary for a larger number. The design of the refrigeration control system should be integrated, or be compatible, with the control system for the heat transfer medium circulated to the air coolers or to the heating system.

It is normal for an installation to have several water chilling packages, both to provide for stand-by and to enable the cooling load to be matched with the minimum consumption of power. Although most packages can reduce capacity to match the cooling demand, the consumption of power per unit of cooling increases; the resulting drop in efficiency is most serious below one-third capacity.

Power consumption can be reduced by taking advantage of a fall in the ambient temperature, which permits a corresponding fall in the condensing temperature and a consequent reduction in compressor power. There are practical limits to this reduction in power, however, as minimum pressure differences are required in the refrigerant circuit to ensure its correct operation.

It is important, for economy in operation, that the optimum equipment selection and design of the control system is achieved.

The classification of the packages is by type of compressor.

4.10.1.1.1 *Centrifugal compressors.* These compressors have an impeller that imparts to the refrigerant vapour a high kinetic energy, which is then transformed into pressure energy. For water chilling applications, compressors with one or two stages of compression are used. Two stage units often incorporate an interstage economiser for improving efficiency.

The compressor can be modulated down to approaching 10 % of full load capacity, provided there is some control of the condensing pressure.

Because of the nature of the compression process the flow through the compressor can become unstable if the compressor is called upon to produce a pressure rise in excess of its design limit. This phenomenon, known as surging, is a serious problem but one that only occurs under a fault condition. Typical faults are excessive fouling of the condenser, a partial failure of the condenser coolant flow or an accumulation of a non-condensable gas (air) in the condenser. Unchecked surging can lead to damage in the compressor or its drive and does markedly increase the noise level.

The use of low pressure refrigerants to suit the characteristics of the compressor in the smaller size range, means that the evaporator operates at below atmospheric pressure, thus a leak can draw in air and atmospheric moisture. These should be prevented from accumulating, since they interfere with the operation of the plant and cause corrosion.

The compressors may be driven either directly by an electric motor or via a speed-increasing gear train. Units are available in “open” form, i.e. compressor and motor are separate items, or in semi-hermetic form where the motor and compressor are contained in a common pressure-tight casing that is bolted together. This latter type eliminates the drive shaft gland seal (a potential point of leakage), which is necessary on the former.

Certain types of open centrifugal compressor could conveniently be directly driven by a steam or gas turbine. This arrangement could be advantageous when the refrigeration plant forms part of certain total energy systems.

The centrifugal compressor water chilling packages normally include a shell-and-tube water cooled condenser and a flooded shell-and-tube evaporator, but units are also available incorporating an air cooled condenser. The expansion device is commonly a form of fixed orifice but high pressure float regulating valves are also used.

4.10.1.1.2 *Screw compressors.* Two types are available, i.e. single and twin screw, and both are positive displacement machines. Compression of the refrigerant vapour is achieved by the progressive reduction of the volume contained within the helical flutes of the cylindrical rotor(s) as they rotate.

Oil is injected into the rotor chamber for sealing and lubrication purposes and is removed from the refrigerant discharge gas in an oil separator before the refrigerant passes on to the condenser. No oil separator is 100 % efficient and so a small quantity of oil always passes through with the refrigerant. On systems using a direct expansion evaporator this oil will circulate with the refrigerant. On systems using a flooded evaporator the oil is trapped in the evaporator and an oil recovery system is necessary.

With some systems the oil injected into the rotor casing also removes some of the heat generated during compression of the refrigerant, which makes an oil cooler essential in the oil circulation system. On other systems liquid refrigerant is injected into the compressor to remove the heat of compression instead of using the conventional oil cooler. Such an arrangement can impose a small capacity penalty on the plant and can introduce problems of control of the system.

The condenser most commonly used on packaged units is the water cooled shell-and-tube type, but equipment with air cooled condensers is also available. The expansion device used will depend on the evaporator type but it is often a thermostatic expansion valve (singly or in multiples) of conventional or modified form.

Screw compressors are available in open and semi-hermetic form (see **4.10.1.1.1** for definition) and are generally coupled direct to two-pole motors. The capacity of the compressor can be modulated down to 10 % of full load capacity.

4.10.1.1.3 *Reciprocating compressors.* These are available in a wide range of sizes and designs. They are almost invariably used in packages up to 200 kW cooling capacity and are available rated in excess of 1 000 kW.

Because the cylinders have automatic valves a single compressor may be used over a wide range of operating conditions with near optimum efficiency, whereas other types of compressor require detailed modification to give optimum efficiency at different conditions. This is, however, of minor importance for normal air-conditioning duties.

Capacity control is achieved by making cylinders inoperative, usually by propping open the suction valves. Thus, capacity reduction is in a series of steps rather than by modulation. Typically, an eight cylinder compressor would be unloaded in four steps. It is therefore necessary to allow for this stepwise operation in designing the chilled water temperature control system.

The evaporator is normally of the dry expansion type, to permit oil from the compressor to circulate round the system with the refrigerant. Shell-and-tube water cooled condensers are common, but any type of condenser can be used. With air cooled condensers it is normal practice to build the machine package so that it may be located on the roof in a unit including the condenser, although alternatives are available that separate the compressor and evaporator from the condenser.

It is common for the electric drive motors to be built into the compressor assembly; this is known as a "semi-hermetic" drive to distinguish it from the "hermetic", in which the compressor and motor are enclosed within a pressure vessel and cannot therefore be serviced.

The semi-hermetic compressor is more compact and is quieter in operation than the "open" drive compressor, but involves a more difficult service operation in the event of a motor failure. It gains in reliability, however, by avoiding the shaft seal of the "open" compressor.

It is recommended that multiple hermetic or semi-hermetic compressor units should not be connected to a common refrigerant system, as failure of one motor can precipitate failure of the others. Separate refrigerant circuits for each compressor should be used.

4.10.1.2 ***Absorption system***

4.10.1.2.1 *Indirect firing.* The lithium bromide/water absorption system can be powered by medium or high temperature hot water and low or medium pressure steam. The water is the refrigerant and the lithium bromide the absorbent. The four compartments enclosing the heat exchanger tube bundles for the condenser, evaporator, generator and absorber can be in a single or multiple pressure vessel arrangement. The whole assembly has to be maintained under a high vacuum, which is essential for the correct functioning of the unit. The water and absorbent solutions are circulated within the unit by electrically driven pumps.

Capacity control down to 10 % of full load capacity is achieved by modulating the flow of the heating medium in relation to the cooling demand. There is some loss in performance at part load, which can be compensated by refinements in the system design and control.

4.10.1.2.2 *Direct firing.* Direct firing of lithium chloride/water absorption plant is not common, owing to the greater difficulty of precise control of generator (desorber) temperature necessary to avoid crystallization. Ammonia/water systems can be and are direct fired, but are rarely used for water chilling duties except for small sized units, which are installed outside the building. There are two reasons for this, firstly capital costs are higher and secondly the danger to personnel in the event of leakage of the refrigerant.

Direct firing has the advantage that the losses in an indirect heating system are avoided, but in an air-conditioning installation where a boiler system is installed to provide heating the advantage is minimal.

4.10.1.3 ***Unitary equipment***

4.10.1.3.1 *Room air conditioners.* Room units are self-contained unit air conditioners having all the components (with the possible exception of the controls) in one casing or enclosure or are split systems where the components are split into two casings or enclosures. The self-contained units are usually designated window units or wall-mounted console units and the others as split room units.

4.10.1.3.2 *Unit air conditioners.* Where the unit serves a large area or several small areas it is referred to as a unit or packaged air conditioner. These can be self-contained as room units (although normally are roof or void mounting), or free standing with remote condensers or split systems. A free standing unit with remote condensers has the condenser and condenser fans separate from the other components of the system.

The split system resembles that for room conditioners. The air handling unit contains the evaporator, air handling fan and filter. The other unit, containing the compressor, condenser, and condenser fan, is referred to as the condensing unit or set.

4.10.1.3.3 *Room and unitary heat pumps.* Technically, all vapour compression refrigeration systems are heat pumps, but in this context the term refers to those units in which the refrigeration cycle can be reversed by means of a reversing valve making the inside evaporator a condenser and the outside condenser an evaporator. Thus the unit can change over from being a cooling unit taking heat from the space and rejecting it externally, to a heating unit taking heat from an external source and giving it to the conditioned space.

a) *Air source heat pumps.* These have an external air cooled condenser and, when the cycle is reversed, can take their heat from the outside air.

b) *Water source heat pumps.* These have a water cooled condenser and, when the cycle is reversed, can take their heat from a convenient water source. Water source units are often used in a heat reclaim system where a common condenser main joins all units. When some units are on a cooling cycle rejecting heat into the main, this heat can be used by other units that are on a heating cycle, making the system self-balancing. When out of balance, heat can be provided by another source or the excess heat rejected through a cooling tower.

4.10.1.4 ***Accessories and components***

4.10.1.4.1 *Oil heaters.* Electric oil heaters are necessary to keep the oil warm whenever it is exposed to the refrigerant. Heating minimizes dilution of the oil by the refrigerant, which if it is excessive can destroy the lubricating properties of the oil and cause foaming when the pressure falls. The heaters are normally switched on only when the compressor is stopped, as the oil is warmed by the friction heat when the compressor is running.

4.10.1.4.2 *Oil coolers.* Oil coolers are necessary on most modern high speed compressors of all types, to cool the oil when the compressor is running. In some cases cooling is only necessary when the compressor is off-loaded, as sufficient cooling is provided by the refrigerant flow when the compressor operates at full capacity. The cooling medium is usually the refrigerant for reciprocating and centrifugal compressors, where the cooling load is relatively small. This avoids the risk of system contamination in the event of leakage, when a water cooled unit is used, and simplifies piping. Screw compressors usually have water cooled oil coolers, as part of the compression heat has to be transmitted, although refrigerant cooled versions are practical.

4.10.1.4.3 *Oil separators.* Oil separators are not used for packaged units having reciprocating compressors, but may be necessary in systems that are site installed and have the system components widely separated in a way that can restrict the oil circulation in the system. The normal design separates the oil from the refrigerant vapour delivered by the compressor and returns the oil to the crankcase. An oil separator is always a part of a package containing an oil injected compressor.

4.10.1.4.4 *Pulsation dampers (hot gas mufflers).* The discharge from a reciprocating compressor is not uniform and, dependent on the number and phasing of the discharge impulses and the diameter and length of the discharge pipe, it is sometimes possible to create a resonant condition that can produce noise and mechanical vibration. Pulsation dampers are used to absorb the energy and make the gas flow more uniform. For small single or twin cylinder compressors dampers may be incorporated into the compressor design while for larger sizes the damper may take the form of a vessel that can be fitted as required in the compressor discharge pipe.

The discharge from a screw compressor, while being more uniform than from a reciprocating compressor, still includes an audible pulsation that can be attenuated by a pulsation damper. Where the compressor discharges directly into the oil separator the damper may be included in the separator design.

4.10.1.4.5 *Liquid receivers.* These units may be required in a refrigeration system for two reasons. Systems using an air cooled condenser almost invariably have a liquid receiver to ensure a constant supply of liquid refrigerant to the expansion device. The other function is to store refrigerant that has to be taken out of another component in the system for service purposes. On occasions it supplements, in this role, the storage capacity of a water cooled condenser.

4.10.1.4.6 *Dryers.* Refrigerant dryers are often installed in the liquid line, particularly on hermetic units, to remove moisture, which may have entered during service operations, and contaminants formed by the chemical breakdown of the refrigerant. The dryer contains a solid material that absorbs water held in solution in the refrigerant. The water is only completely removed from the system by removing the absorbent. Moisture indicators are recommended; these take the form of a small indicator that changes colour dependent on the moisture content of the refrigerant. The indicator is installed in the liquid line and viewed through a glass window, which also serves to indicate an undercharge of refrigerant by the presence of gas bubbles.

4.10.1.4.7 *Strainers.* Strainers are included in the refrigerant circuit, to protect vulnerable components from solid material that may have been left in during construction.

4.10.1.5 ***Condensers***

4.10.1.5.1 *Types.* Refrigerant condensers can be divided into three main types.

a) *Water cooled shell-and-tube type.* This is the type normally incorporated into the larger package units, to be fed with water from a central cooling tower. It consists of a horizontal pressure shell containing a number of tubes, usually with extended surface, through which the water is circulated. The refrigerant condenses on the outside of the tubes and the liquid is collected in the bottom of the shell.

Condensers are built having two separate tube bundles within the common shell, so that heat may be rejected to two separate water systems, one that circulates to the cooling tower and one to the air-conditioning equipment.

b) *Evaporative type.* This type is less often used in air conditioning. It comprises a tube bundle, in which the refrigerant condenses, enclosed within a sheet metal casing through which air is blown. Water is sprayed over the tubes to provide cooling as it evaporates into the air stream.

The problem with this design is that it is more costly and troublesome to run pipes to carry refrigerant from the plant room to the condenser, than water pipes to a cooling tower.

c) *Air cooled type.* The air cooled condenser has the advantage that it does not need water, but, because of the very low sensible heat capacity of air, very large volumes need to be passed over the condenser, which means that it is physically large, and the required fan power is greater than that of a cooling tower or evaporative condenser.

These condensers comprise a tube bundle, inside which the refrigerant condenses, with fins on the outside to provide an extended heat transfer surface. Atmospheric air is blown, or drawn, by propeller fans over the condenser to absorb the heat. On the larger sizes the tube bundle forms, a flat slab with an air plenum chamber on one side; this slab is mounted in a horizontal plane with the air flow being drawn in below and discharged vertically. This has the advantage that the air flow produced by the fans cannot be opposed or assisted by the wind as it could be if the slab were mounted vertically, and the profile is less obtrusive.

In some cases the compressor and evaporator are built into a unit with the condenser to be installed on the roof of the building, thus avoiding the necessity of a plant room but making service operations difficult and unpleasant to carry out when the weather is bad.

4.10.1.5.2 *Condenser pressure control.* Condenser pressure control is necessary for most packaged water chilling and air cooling units. With water cooled condensers, control is achieved by throttling the water flow to the condenser or by controlling the water temperature by by-passing the cooling tower. This latter method is preferred as it avoids low water velocities, which can increase fouling. Air cooled condensers in the larger sizes are controlled by varying the air flow over the tubes, and in the smaller sizes by causing the tubes to be partially filled with liquid refrigerant to reduce the effective surface. To achieve this liquid back-up, the system needs to contain additional refrigerant stored in a receiver under normal operating conditions.

4.10.2 *Selection factors.* It is necessary to consider the overall performance of the package when considering operation at part load, rather than only the part load performance of the compressor. By doing this it is possible to take advantage of the fall in condenser pressure with fall in load to compensate for the inefficiencies involved in unloading the compressor. This will give approximately linear reduction in power with reduction in capacity.

4.10.2.1 ***Vapour compression water chillers***

4.10.2.1.1 *Centrifugal compressors.* These units are best suited for the larger installations and are available in compact factory-assembled units from 400 kW cooling capacity upwards.

The minimum of moving parts in the compressor makes for reliable operation and infrequent need for overhaul. Competent maintenance is important, however, to ensure that air and moisture do not leak into the system on those machines that use the low pressure refrigerants. This is particularly important for those systems having hermetic motors, which can be damaged by the presence of moisture and can be expensive to repair.

Flexibility of control is an advantage but condenser fouling is to be avoided, not only to minimize power consumption but to avoid the risk of surging and reduction in capacity owing to abnormally high condenser pressure.

4.10.2.1.2 *Screw compressors.* Selection factors for the choice of units and their application are the same as for centrifugal compressors.

Positive compression avoids the risk of surging and capacity is less affected by high condenser pressures. Thus screw compressors are more adaptable for air cooled condensers and heat recovery systems. However, it should be remembered that the high condenser pressures sometimes used in heat recovery to obtain a high grade of heat result in a higher power consumption per unit of cooling. All the factors should therefore be considered on economic grounds before selecting such an arrangement.

4.10.2.1.3 *Reciprocating compressors.* The hermetic compressors, which are available up to10 kW to 15 kW cooling capacity, and the semi-hermetic compressors in the larger sizes are used to eliminate the need for a shaft seal and the risk of leakage. They are also quieter, cheaper and more compact than the open drive compressor units.

Servicing should be carried out with care to avoid the introduction of moisture into the system, as this could damage the motors and require an expensive repair including system decontamination.

Reciprocating compressors are more prone to noise and vibration problems than are the rotary types, although modern multi-cylinder designs are usually well balanced. They are suitable for variable operating conditions and use with air cooled condensers.

The compressor lubricating oil is allowed to circulate with the refrigerant; this avoids the necessity for fitting an oil separator, but requires care with the piping design and layout. Refrigerant is miscible to a degree with lubricating oil so it is important to heat the crankcase during off-cycle periods to minimize dilution of the oil and prevent condensation of refrigerant.

4.10.2.2 ***Absorption systems***

4.10.2.2.1 *Indirect firing.* The cooling towers and the water pumping system for an absorption water chilling plant will be larger than for a vapour compression plant as the heat rejected from the system is approximately double. The water make-up flow to the cooling tower will be increased in proportion to the duty. Air cooled condensers and absorbers are impracticable for the large absorption systems.

The control response of an absorption plant to a load change is slower than for the equivalent vapour compression plant; this is, however, not significant for air-conditioning applications as the rate of change in load is normally slow.

Noise and vibration levels are much lower than from a motor driven compressor, although the units may not be completely quiet in operation.

Fuel costs are the largest item in the running cost of an absorption plant. The ideal application is therefore one in which the absorption plant is supplied with rejected heat at a suitable temperature, such as exhaust steam from power generation or a compressor drive, as part of a total energy system. Electrical power demand is confined to the pump drives and the automatic controls, thus the use of absorption plant is attractive where power supplies are limited.

The maintenance requirements for an absorption plant differ from a vapour compression plant in that there is no compressor or lubrication system to service, but it is important to avoid the leakage of air into the unit, as it will cause corrosion and blanket the heat transfer surfaces. Crystallization of the lithium bromide can occur, blocking the flow passages in the heat exchanger, if operating temperatures are allowed to vary from the norm. Maintenance of the cooling water system and the circulating pumps will be similar.

4.10.2.2.2 *Direct firing.* The small direct fired units have the advantage that electric power consumption is minimal and gas or oil fuel is readily available. The specialist service required may, however, be less readily available.

4.10.2.3 *Unitary equipment.* Care should be taken that conditions under which the unit is to operate are clearly specified, as these conditions will affect the output and performance of the unit. This applies to those conditions inside and outside the conditioned space, the volume of air to be cooled, and whether the unit is to handle outside air for ventilation.

These matters will affect the type of unit selected and often the way it is to be installed. Space available, degree of control, noise limitations and ease of maintenance are also determining factors when considering which type of unit would be most suitable.

When considering heat pumps, the temperature of the external source is directly related to the unit's capacity to provide heat. Also, the needs of defrosting the air source coil and providing contaminant-free water for the water source should be considered.

4.11 Cooling towers

Cooling towers, which can cool water by contact with atmospheric air, exist in a wide range of designs. Cooling is achieved by evaporating a small proportion of the water into an air stream. Most water supplies contain impurities, which are concentrated by the evaporating process and which need to be removed (see **5.5.5**). The action of contacting the air stream with the water washes out dust, dirt and chemical contaminants from the air; these also need to be removed or neutralized. It is important, therefore, that, when practicable, cooling towers should be in the cleanest available location.

Precautions may be necessary against organic growths, which can foul the water system, the tower packing and the tower distribution system.

In order to prevent contamination of the water mains through backsiphonage, the water inlet to appliances of this type should incorporate either a Type B Air Gap, or an approved type of pipe interruptor, or a combined check and anti-vacuum valve.

See also BS 4485.

4.11.1 Types of equipment

4.11.1.1 *Natural draught.* This type of tower, by its nature, has to be larger than the forced draught design, as it relies on natural convection to obtain the air circulation. In consequence it is little used for air conditioning and related applications but it is used for very large loads, power stations being the classic example. A natural draught tower needs to be tall, to obtain the maximum chimney effect, or rely on the natural wind.

4.11.1.2 *Mechanical draught.* The usual design has the fan located at the top of the tower to discharge vertically upwards and to induce an air flow up over the tower packing over which the water flows. A vertical air discharge minimizes the chance of recirculation, but it is important that the cooling tower location should be chosen where there are no down draughts created by the wind flow over and around adjacent buildings.

The normal induced draught tower has the advantage that the air and water are in counter flow, but this may mean that the tower is relatively high.

Cross draught cooling towers, which have a lower profile, are available: in this case the air flows horizontally across the packing with the water trickling down at right angles to the air flow. This gives less efficient heat transfer but a more convenient shape. An induced draught arrangement is normal, with a vertical discharge from the fan. The low profile with air entry over the full height of the tower at either end does, however, increase the risk of air recirculation.

The induced draught towers are usually fitted with large low speed fans, which are quiet in operation but relatively inaccessible and subject to corrosion from the warm wet air discharge. Forced draught towers are available; these use a larger number of smaller and faster running fans, which tend to be noisier but are easily accessible and being mounted nearer to the foundations are less susceptible to vibration problems.

Tower packing may be of treated wood, or of a suitable plastic. Water distribution may be by sprays, via a rotating distributor or by a system of overflow troughs.

The mechanical draught towers should be designed so that no spray water is entrained with the exhaust air; however, spray entrainment is not unknown and it can cause problems. Where it can be critical this should be brought to the attention of the supplier when ordering.

4.11.1.3 *Closed circuit.* For certain applications fouling or corrosion from water circulated over a conventional cooling tower may be unacceptable. For these cases it is possible to use a closed circuit tower in which the water is circulated through cooling coils, which take the place of the packing of a conventional tower. A completely separate water supply is recirculated over the conventional tower. A completely separate water supply is recirculated over the coils to provide cooling; thus fouling and corrosion are confined to the outside of the coils and only the clean water, or any other medium, is in the coils.

The closed circuit cooling tower is in most respects similar to an evaporative refrigerant condenser [**4.10.1.5.1** b)], in which the refrigerant is inside the coil. It is possible to achieve a lower water temperature from a closed, circuit cooling tower than from a dry air cooled heat exchanger. The temperature will, however, be higher than from an open circuit tower, owing to the extra stage of heat transfer.

4.11.2 *Selection factors.* The critical factor that largely determines the size of the cooling tower is the "approach condition" (i.e. the difference between the re-cooled water temperature and the selected maximum air wet bulb temperature).

A guide to the suitable wet bulb temperatures for the British Isles may be obtained from isotherm charts given in BS 4485-3 (1 % and 5 % charts). More precise wet bulb temperature data may be obtained from the Meteorological Office. For cases where the re-cooled water temperature is critical of where the approach is less than 3 °C, the 1 % chart only is recommended.

If the design air wet bulb temperature is exceeded during periods of maximum cooling load, the re-cooled water temperature will rise above its design value and the implication of this on the plant performance should be considered. Factors that should be taken into account when considering the design wet bulb temperature are:

a) terrain (e.g. elevation above sea level);

b) site effects, e.g. discharge that can be drawn into the fan inlet from other cooling towers or flues.

Other factors to be considered for cooling tower selection are:

c) any height limitation or aesthetic requirements, and the question of drainback from the system;

d) siting with regard to adjacent walls and windows, other buildings and effects of any water carried over by the air stream;

e) noise levels, particularly during silent hours, and vibration;

f) materials of construction for the tower and fill packing (with expected life), and, in the case of the latter, the effect of high ambient or solar radiation temperatures when the tower is not in use, as well as the fire risk;

g) wind effects;

h) properties of water to be used and the total capacity of the system;

i) access for maintenance;

j) cleanliness of air inducted into the tower.

More detailed information on the above is available in "Guide to Mechanical Draught Evaporative Cooling Towers" published by the Cooling Water Association.

4.12 Heat recovery and equipment

4.12.1 Types of equipment

4.12.1.1 *Heat pumps.* Where air conditioning is required, the system can be used for heat recovery since a refrigeration system is a heat pump and the heat taken out by the evaporator is rejected by the condenser. For heat recovery a chilled water, rather than direct expansion, air-conditioning system is normally used. The hot water from the condenser is taken to a coil or storage tank prior to the cooling tower and used for heating purposes. If the unit is to be used without modification then a closed cooling tower should be used to avoid contamination of the condenser system. Alternatively, a "double bundle" condenser can be used; this is a condenser with two sets of coils, one serving the heat recovery system, the other serving an open cooling tower. Alternatively, plate heat exchangers are available.

Reverse cycle refrigeration systems, which are normally referred to as heat pumps, can be used as heat recovery devices. These systems operate on the same principles as the normal refrigeration cycle, except that the circuit includes an arrangement that allows the flow to be reversed thus making the evaporator the condenser and the condenser the evaporator. This allows for heat to be transferred in either direction. It can be used to transfer heat into or take heat out of a common water circuit. In such a system small water to air heat pumps are used similar to a room air conditioner. These are placed into the conditioned areas throughout the building served by a common water circuit. Also in this common circuit is placed a heat generator and a cooling tower. The temperature of this circuit is kept at a constant value. If the temperature of the circuit begins to drop because most units are taking heat from the water, the heat generator makes up the heat. Alternatively if the temperature begins to rise, because most units are adding heat, the cooling tower will reject this surplus. The surplus is sometimes directed to a storage tank for later use. For much of the time the system is in balance, some units removing heat from overheated areas and that heat being transferred to units in underheated areas. The heat pump can be used to raise the temperature of a low grade heat source to a usable temperature thus recovering heat that is normally thrown away.

4.12.1.2 ***Air to air recovery equipment***

4.12.1.2.1 *Closed loop coils.* The simplest heat recovery devices are known as "run-round" coils, or closed loop coils. These are air to water coils joined by pipework including a pump where heat is picked up in the higher temperature air stream and transferred through the pipework system to the coil in the lower temperature stream.

4.12.1.2.2 *Heat regenerators.* The thermal, or rotary, wheel is another heat recovery device that, like the run-round coils, need not form part of an air-conditioning system. A wheel consisting of some heat-retaining material is rotated by means of a geared electric motor within a casing. The casing is divided across the diameter of the wheel and the exhaust air connected to one half and the inlet air to the other. Heat, sensible and/or latent, is taken from the exhaust air by the wheel and held in the material. As the wheel turns, that section holding the heat is presented to the inlet air stream and raises the temperature of the cooler incoming air. Normally there is a purging section to ensure that contaminates from the exhaust air do not transfer to the incoming air.

4.12.1.3 ***Other devices***

4.12.1.3.1 *Heat pipes.* These are basically self-contained boiling-condensing systems capable of transferring large quantities of heat from a source to a sink with only a small temperature drop. They consist of a sealed container lined with a wick and charged with a working fluid. The wick provides the capillary flow to return the condensate from the condenser at the lower temperature to the boiler at the higher temperature.

4.12.1.3.2 *Plate heat exchangers.* These consist of a frame work containing an arrangement of parallel air paths separated by metal or glass vanes. Heat is transferred from one air stream to another across the walls. The air streams are normally counterflowing.

4.12.1.4 *Combination systems.* It is often feasible in heat recovery situations to use more than one device within a system. For example, where "free or fresh air cooling" is required then a thermal wheel, run-round coil or heat pipe could be used on the exhaust air in conjunction with, for example, a heat pump for use when the outside air temperature is too high or low to be used directly.

4.12.2 *Selection factors.* The main methods of conservation at present practised use equipment that recovers heat. In any building there will be spaces that during part of the year will have a surplus of heat that could be usefully used in another part. Alternatively, there may be spaces that need to be heated but require high ventilation rates and therefore throw away large quantities of heat in the exhaust air. Also, heat obtained from a low temperature source, which cannot be usefully employed, can be raised to a temperature where it does become useful. The equipment used can form part of an air-conditioning system or operate as part of a ventilation system. Whether the equipment actually conserves energy and is an economic proposition depends on two factors:

a) whether there is sufficient heat to recover;

b) whether there is a positive use of the heat after it has been recovered.

Care should also be taken to ensure that the amount of energy needed to recover the heat is not more than the heat recovered.

4.12.2.1 *Heat pumps.* If a building requires summer cooling and dehumidification then an air-conditioning system will be necessary. Therefore, in these circumstances, a heat pump can be considered to provide heat recovery. Whether a chilled water heat pump or reverse cycle direct expansion system is used will often depend on size. Larger systems above 170 kW cooling capacity would normally be chilled water type and smaller systems above 25 kW cooling capacity but below 170 kW cooling capacity would be reverse cycle direct expansion type. Below this capacity heat recovery is usually not warranted. Obviously there has to be a low temperature heat source available.

When using a chilled water system either a closed cooling tower or a "double bundle" condenser should be used to avoid contamination of the system.

4.12.2.2 *Air to air recovery equipment.* Heat exchanging devices should only be used when relatively large temperature differences between the media from which heat is recovered and the media to be heated exist, otherwise the heat transfer surfaces will be excessively large.

Consideration should be given to the type of heat to be transferred. Run-round coils, plate heat exchangers, heat pipes and certain thermal wheels will only transfer sensible heat. If latent heat is also to be transferred then a thermal wheel containing hygroscopic material is necessary.

If the system is to be kept simple then run-round coils or plate heat exchangers might be more suitable since thermal wheels have moving parts and motors to maintain.

Suitable air filters should be provided to avoid fouling heat exchanger surfaces, thus reducing their effectiveness. Problems may result from condensation in some applications.

4.13 Motive power equipment

4.13.1 Types of equipment

4.13.1.1 ***Electric motors and controllers***

a) *Motors.* Dimensions and ratings are given in BS 3979. General requirements are covered by BS 4999 whilst motors for miscellaneous applications, e.g. flameproof motors, are covered by BS 5000-99.

b) *Controllers.* These are covered by BS 587. Where the system fault current is greater than 12 kA then the supplementary specification BS 5486-1 also applies.

4.13.1.2 *Engines.* Engines (diesel, gas or dual fuel machines) can be used to drive refrigeration compressors, pumps, fans or generators. They can be used to drive either reciprocating, or screw or centrifugal refrigeration compressors.

Engines offer the advantage of variable speed control on open compressors. With engine-driven reciprocating compressors the accepted method of control is to reduce speed in stages to approximately 15 r/s and then unload cylinders as required.

Exhaust gases need to be taken to atmosphere and noise silenced. Since the engine block requires cooling, the cooling tower may have to be larger, or if an air cooled condenser is used, a separate block cooling radiator will be required. An air cooling device may also be required.

The plant room requires more ventilation for combustion air and to remove engine heat.

a) *Diesel engines.* These are normally slow speed engines designed to operate for long periods on oil. They require a minimum of maintenance and are designed for long service life between overhauls. These machines are used for industrial refrigeration or large reciprocating or screw compressors.

b) *Gas engines.* These operate similarly to the normal automobile engine, by the ignition of a gas-air mixture with a high voltage spark. They are lighter and easier to maintain than dual fuel engines. They are available in two types, an industrial engine of heavy construction within the 35 kW to 1 500 kW output range or converted automobile engines of the car or lorry type. The industrial type are more expensive but have a longer life. The automobile engines are converted to run on natural gas, enabling them to drive larger compressors.

The main advantages of using standard engines are that maintenance can be carried out by local mechanics, spares are readily available and if necessary a complete engine replacement is simple to obtain and fit.

c) *Dual fuel engines.* These are compression ignition engines that operate either on liquid fuel only, or on gas with injection of liquid fuel, the change from dual fuel to liquid being possible whilst the engine is running.

These engines are manufactured in sizes from 130 kW output upward; disadvantages are low power to weight ratios and the need for frequent and highly skilled maintenance. Capital cost of the plant tends to be higher than for spark ignition engines.

4.13.1.3 *Turbines.* Steam or gas powered turbines can be used as power units for driving refrigeration plant. They are normally used to drive large capacity plant of approximately 3 500 kW cooling capacity. The rejected exhaust heat should be recovered and utilized to produce additional chilled water by absorption plant, heating and domestic hot water. While it is possible to use waste gases in some absorption machines it is normal to use a waste heat boiler to generate hot water.

Gas turbines can be used in either a total energy concept or to drive compressors direct.

4.13.2 Selection factors

4.13.2.1 *Electric motors and controllers.* Standard motor designs should be used wherever possible both for economy an easier replacement. Speeds of normal a.c induction motors run on 50 Hz supplies vary to some extent on the loading. Table 8 shows the normal speeds available.

Table 8 — Motor speeds

Number of poles	Synchronous speed (i.e. no load)	Full load speed (approximately)
	r/s	r/s
2	50	48
4	25	24
6	16.5	15.5
8	12.5	11.5
10	10	9.5

BS 4999-30 gives various duty cycles; the user should decide which of these are applicable when selecting a motor of the correct rating.

Loads such as centrifugal fans present high inertial loads to the motor. Locked rotor current will be slow to fall to a normal running current, leading to overheating of the motor. The manufacturer should be informed of the application at the time of ordering.

BS 4999-20 defines the type of enclosure and degree of environmental protection given, which should be matched to the intended application.

If it is intended to vary the speed of the motor during use, the manufacturer should be informed at the time of ordering. If, for example, motor speed is to be controlled by a variable frequency inverter then some derating of the motor will be necessary owing to the harmonic content of the inverter output waveform.

4.13.2.2 *Engines.* The following factors should be considered when selecting engine driven equipment:

a) compatibility of engine and compressor;

b) noise level of the unit together with its associated silencing equipment;

c) method of cooling the engine, by either a fan cooled radiator or by providing cooling water from a cooling tower;

d) recovery of heat from the engine jacket and silencer; this can be either low pressure steam or hot water;

e) juxtaposition of engine and refrigeration controls;

f) provision of stand-by generation; with an engine it is possible to disconnect the refrigeration compressor and engage a generator so providing an emergency electrical supply;

g) type of engine to be used (heavy industrial or converted automobile);

h) type of speed control required. (It is possible to reduce engine speed before unloading cylinders.)

4.13.2.3 *Turbines.* The following factors should be considered when selecting turbine driven equipment:

a) capacity of refrigeration plant (for capacity under 3 500 kW, turbines are not generally used);

b) recovery of waste heat;

c) type of drive, either direct or by the use of reduction gear;

d) noise from the turbines (silencers have been developed that would allow a gas turbine to be sited in a quiet zone);

e) compatibility of turbine and compressor.

Section 5. Installation

5.1 General

This section of the code gives general guidance on the installation of air-conditioning and ventilation systems and equipment. It deals with the following systems: ductwork, water and refrigerant piping, electrical power, and automatic controls. Detailed information is given on the installation of air moving, heating, cooling, humidifying and dehumidifying apparatus with special sub-sections on motive power and water treatment equipment.

All statutory regulations and safety recommendations should be strictly observed, and careful thought given to the storage and protection of equipment and system components to prevent deterioration or damage.

5.2 Statutory regulations/safety considerations

5.2.1 *Safety, statutory and common law requirements and other regulations.* The subject of safety, statutory and common law requirements is considered to be far too complex to be dealt with in this code of practice and it is therefore advisable to obtain the detailed information from such sources as are quoted in **2.5**.

Some further guidance is given in the following:

CIBS Technical Memorandum No. 2

CIBS Technical Memorandum No. 3

Construction Safety: Policy, Organization, Administration issued by the National Federation of Building Trades Employers.

It is every employer's responsibility to ensure that all safety and other related regulations are complied with.

5.2.2 *HM Inspectors of Factories.* HM Inspectors of Factories should be consulted if any doubts arise regarding safety, health or welfare matters.

It should be noted that factory inspectors have power to enter and examine any premises that are subject to the Health and Safety at Work etc. Act 1974 or construction regulations to examine relevant registers and certificates and exercise the other powers specified in section 20 of the aforementioned Act. It is an offence to obstruct an inspector in the examination of such documents. Inspectors also have power to prosecute for breaches of the Act or construction regulations.

5.2.3 *Statute law.* All statute law is made by Act of Parliament, e.g. the Factories Act 1961. As its title suggests, this Act applies mainly to factories but there are sections that apply to "building operations" and "works of engineering construction".

The Factories 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:

Construction (General Provisions) Regulations 1961.

C(GP)

Construction (Lifting Operations) Regulations 1961.

C(LO)

Construction (Working Places) Regulations 1966.

C(WP)

Construction (Health and Welfare) Regulations 1966.

C(H and W)

There are a number of other regulations and Acts of Parliament affecting site works together with various amendments and details of these can be acquired from the various publications listed.

5.2.4 *Common law.* Under common law, which has been established by decisions or judgements in courts of law and has evolved over the years, 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.

5.2.5 *Factories Act: principal requirements.* The various headings given below are principal requirements from the Factories Act 1961 related to the construction industry and should be complied with as well as the detailed information in the various publications mentioned under **5.2.1**.

Notifications of accidents and diseases

Notifications 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

5.2.6 *Construction regulations: principal requirements.* The headings given below are principal requirements related to the construction industry and the detailed information under these headings can be obtained from the various publications mentioned under **5.2.1**.

Construction (General Provisions) Regulations 1961.

C(GP)

Construction (Lifting Operations) Regulations 1961.

C(LO)

Construction (Working Places) Regulations 1966.

C(WP)

Construction (Health and Welfare) Regulations 1966.

C(H and W)

NOTE Amendment April 1974.

Responsibilities of employers

Responsibilities of employees

Appointment of safety supervisors: see C(GP) Regulations 5 and 6

Excavations: see C(GP) Regulations 8 to 14

Dangerous fumes: see C(GP) Regulations 20 to 22

Fencing of machinery: see C(GP) Regulations 42 and 43

Electricity: see C(GP) Regulation 44 and Electricity Regulations

Temporary lighting: see C(GP) Regulation 47

Projecting nails and loose material: see C(GP) Regulation 48

Protection of eyes: see C(GP) Regulation 52

Protective clothing: see C(H and W) Regulation 15

Cranes: see C(LO) Regulations

Hoists: see C(LO) Regulations

Scaffolding: see C(WP) Regulations

Welfare facilities: see C(H and W) Regulations

5.2.7 *Other regulations relevant to the heating and ventilation industry*

Abrasive Wheels Regulations 1970

Asbestos Regulations 1969

Lead Paint Regulations SR and O, 1927 SBN 11-360519-26. (See also S1 1964 559 Lead Paint (Prescribed leaflet) Order 1964)

Employer's Liability (Defective Equipment) Act 1964

Employer's Liability (Compulsory Insurance) Act 1969

Offices, Shops and Railway Premises Act 1963

Electricity (Factories Act) Special Regulations 1908 and 1944

Fire Certificates (Special Premises) Regulations 1976

Protection of Eyes Regulations 1974

Highly Flammable Liquids and Liquefied Petroleum Gases Regulations 1972

5.2.8 *Documentation.* Some of the legislative regulations may be the responsibility of the main contractor under the contract, but it is every employer's responsibility to ensure that Acts of Parliament, regulations, notices to be displayed, registers, certificates and forms related to the work being carried out and to the employees are met. If in doubt, HM Factory Inspectorate should be consulted.

For guidance the various headings related to legislation are given below and full details of official forms, registers and certificates required can be obtained from HM Stationery Offices.

List of forms under the Factories Act 1961

List of forms under the Offices, Shops and Railway Premises Act 1963

Related legislation

Notices to be displayed by every employer

Circumstances to be notified to factory inspector and/or others

Registers and certificates to be kept

Asbestos Regulations 1969. First list of approved dust respirators

Ionizing Radiations (Sealed Sources) Regulations 1969

5.2.9 *Special considerations.* Recommendations may be issued from various authorities that are not legislative in themselves but can be considered by other legislation. An example is the Guidance Note No. 36 Safety in the Cases of Cartridge Operated Fixing Tools, which is covered by the Health and Safety at Work etc. Act.

Other Guidance Notes from the Health and Safety Executive are as follows:

No. 1 Dust Control — The Low-volume High-velocity System (2nd revision)

No. 17.5 Notes for the Guidance of Designers on the Reduction of Machinery Noise

No. 14 Health — Dust in Industry

No. 19 The Ventilation of Buildings: Fresh Air Requirements

No. 22 Metrication of Construction Safety Regulations

No. 25 Safe Operation of Automatically Controlled Steam and Hot Water Boilers

No. 29 Fire Risk in the Storage and Industrial Use of Cellular Plastics (revision)

No. 32 Guarding of Portable Pipe Threading Machines

No. 37 Ionizing Radiations: Radiography on Construction Sites (in preparation)

No. 39 Safe Use of Petroleum Based Adhesives in Building Operations

No. 47 Entry into Confined Spaces: Hazards and Precautions

No. 48 Permissible Openings in Fixed Guards

Reference is also recommended to:

Department of the Environment Report of the Committee on Backsiphonage in Water Installations.

5.2.10 Other regulations

5.2.10.1 *Building Regulations 1976 and Building Standards (Scotland) Act 1970* are enforced by local authorities and each authority has a measure of freedom in their application. It is, therefore, advisable to contact the local authority concerned regarding work covered by the Statutory Instrument. It should be noted that services such as sewers and the installation of sanitary conveniences, etc. required for site "welfare facilities" are covered by these regulations.

The officer acting for the local authority to enforce the regulations is the "building control officer" who should be allowed access to enter at all times.

5.2.10.2 *Water Act 1973.* This Act embraces the Water Resources Act 1963, Land Drainage Act 1930, River Board Act 1948, Water Act 1945 and several other Acts. Amongst other things, it established the regional water authorities and specified their functions.

It should be noted that Scotland and Northern Ireland are not covered by this Act. The water authorities control the use and connection of water services, sewers and drainage and are, therefore, directly concerned with the use and disposal of water when used with air-conditioning installations.

Bylaws made under the Water Act for preventing waste, undue consumption, misuse or contamination of water supplied by a water authority are enforced by that authority and cover such items as the use of pipework materials, water storage, protection of water fittings, taps, valves, etc., the testing of water supply systems, fittings and valves.

5.2.11 *Protective clothing and equipment.* Employers are obliged 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);

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 electrical 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 items listed, as appropriate (see section 143 of the Factories Act 1961).

It should be noted that employers cannot make deductions from wages in respect of items listed (see section 136 of the Factories Act 1961).

Legal requirements should be regarded only as a minimum.

The regular use of the items listed below should be strongly advised:

safety helmets complying with the requirements of BS 5240;

protective footwear complying with the requirements of BS 1870;

industrial gloves complying with the requirements of BS 1651.

Whether the above items are provided free or made available to employees at cost price is a matter for individual employers to decide.

The wearing of protective clothing, particularly helmets, might be made a condition of employment for operators on some projects.

Operators carrying out electric arc welding operations and oxyacetylene cutting should be provided with leather aprons, sleeves, gloves and skull caps.

It is the management's responsibility to see that legal requirements are observed. It is their duty to explain the advantages by proper instruction in the use, and by setting personal examples in the wearing, of protective clothing and by using protective equipment where applicable.

5.2.12 *Avoidance of nuisance.* Nuisance by the more widely used definition means anything obnoxious to the community or individual by offensiveness of smell 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 nuisance when installing ventilation and air-conditioning systems.

5.3 Site facilities

5.3.1 *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 (paragraphs 50 and 51).

5.3.2 *Access.* Access to sites and site accommodation usually determined at pre-contract stage by the architect, client or main contractor. Before setting up accommodation, it should be checked or noted (as applicable) that:

a) the access to the site accommodation will be suitable throughout the duration of the project and will not be affected by building progress;

b) access will 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 will be suitable for all types of weather conditions, including the winter;

d) good walking access is 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 is provided for access roads and paths for winter working conditions.

5.3.3 *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.

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 Regulations.

5.3.4 *Accommodation.* Areas for setting up site accommodation for building services sub-contractors are usually determined by others. It may be advantageous or necessary, particularly with larger projects, to include in the sub-contractors' site accommodation, part, or all, separate welfare facilities.

In setting up site accommodation, it should be verified that:

a) the accommodation is sited near main welfare facilities to minimize the walking distances for operatives using sanitary conveniences, washing facilities and eating facilities;

b) the accommodation will not be affected by, or impede, building progress;

c) all accommodation is confined to one area to provide easy control of stores, time keeping, good housekeeping and security;

d) accommodation is positioned as near main areas of work as possible to minimize the carrying of tools and materials from stores and workshop;

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

f) adequate lighting is provided in the accommodation areas for both safety and security reasons;

g) good clocking-in facilities with adequate weather protection and with sufficient wall space for displaying essential notices are provided;

h) fireproof cabinets for important documents are provided;

i) adequate fire-fighting facilities are available;

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

k) if inflammable materials are to be stored, proper storage facilities are provided and that they 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 are 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 is provided and good housekeeping is maintained;

n) if it is necessary to obtain large storage areas for ductwork and plant within the building.

With storage areas good access and security have to be ensured, that the ductwork or plant may remain in the storage area until required, without impairing other building trades progress, and that no damage will be caused to any finished work when ductwork is moved.

5.3.5 *Lifting facilities.* Cranes and hoists are usually provided by the main contractor, but it is advisable for the building services contractor to determine the conditions of contract 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 lifting essential equipment into plant rooms and, in particular, into high rise buildings.

Possible extra cost may be involved for the use of these facilities outside normal working hours.

It may be advisable for the services contractor to use independent lifting equipment for the unloading of vehicles and the placing of plant into plant rooms.

5.3.6 *Scaffolding.* Scaffolding provided by the main building contractor may only be available for use by building services sub-contractors for a limited period when erected for building operations, unless otherwise specified or agreed. It is, therefore, advisable that prior agreement is reached on the availability and the conditions of the use of scaffolding when required for the installation of mechanical services.

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.

Building services sub-contractors may require the provision of mobile towers for working above a specified height and it is essential that they are made aware of the conditions for using such towers and their responsibility for safety of operatives.

5.3.7 *Services (water and electricity).* Water for testing of pipework systems is usually provided by the main contractor or client and it is advisable to determine whether sufficient water and pressure are available for filling the systems for the progressive pressure testing, particularly with high rise buildings.

Electricity for lighting and power for the construction work is usually provided through the main contractor. 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 (see **3.2.8.2.2**).

Particular attention should be paid to the use of high voltage equipment, controls and wiring when using transformer type welding equipment.

It is the employer's responsibility to ensure that all regulations are strictly adhered to when employees use electricity for lighting and power tools.

5.4 Storage and protection

5.4.1 *General.* It is essential to provide adequate storage and protection of plant on site, at all stages of building progress, to ensure that it is in proper working condition, without any deterioration of the working parts and of the manufacturer's finishes, when the plant is put into operation and handed over.

5.4.2 *Manufacturer's guarantee.* It is good practice to have plant 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, as many manufacturer's guarantee periods commence from the date of delivery of plant to the site.

It is advisable to check with manufacturers, particularly where major items of plant are concerned such as refrigeration equipment, console control units, multi-stage pumps, etc., the conditions of the guarantee period if the plant is likely to stand without being commissioned or operated for a prolonged period of time.

5.4.3 *Delivery of plant to site.* It is advisable to arrange for manufacturers to provide lifting points, which are clearly indicated on the plant, to facilitate unloading and hoisting into position.

Care should be exercised, if hoisting plant without lifting points being provided, to ensure the centre of gravity is as central as possible to the lifting hook(s). With some types of plant it may be necessary to use spreader bars to prevent the crushing or rubbing effect of the lifting ropes, cables or chains.

Plant requiring protection of finishes, pipe connections and electrical controls is usually delivered with protection provided by the manufacturers and it may be necessary to remove such protection and open up control units to ensure it is delivered in good condition.

It is advisable to replace, and in fact it may be necessary to add to, the protection to the plant after checking and either installing it in position or placing it in storage.

5.4.4 *Storage.* Each consignment of plant delivered should be checked against the delivery note and copy of order, and, in particular, 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 plant. 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 plant before the building is ready for the installation of the plant. 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 all types of weather;

d) proper security;

e) storage area will be available until such time as the plant 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 checked:

f) adequate insurance cover;

g) additional cost of transport;

h) additional double handling;

i) possible use of lifting equipment or plant;

j) accessibility to site at a later date.

5.4.5 Protection of plant

5.4.5.1 *General considerations*. It is essential that all plant on site should be protected whether it is in storage or installed waiting to be put into operation.

Satisfactory security arrangements should be made to prevent unauthorized interference at all stages of the project.

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

Most plant 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 the handover. It is desirable that protective coatings be removed from metal areas before welding.

Special considerations should be given to the protection of bearings and of electrical, pneumatic and refrigeration plant 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.

Refrigeration plant, 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 periodical checks made of all glands, joints and pipework.

If the refrigeration plant 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 the plant and arrange for regular visits of a refrigeration service engineer.

It may be necessary to protect the plant on site using temporary heaters, dehumidifiers, silica-gel or other means to prevent moisture affecting plant while it is standing. In regard to the use of portable gas heaters with a high moisture content in the products of combustion, special consideration to provide adequate ventilation is necessary, particularly if drying out electrical plant. Large electric motors, compressors, fans and other such plant 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 plant 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 plant 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.

5.4.5.2 *Removal of protective coatings.* Plant may be delivered on site with protective coatings such as transparent sprayed 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 plant finish or working parts.

Before using any chemical cleaners or similar liquids, it should be ensured that no damage will be caused to the plant.

5.4.5.3 *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 plant after it is installed. The use of polyethylene sheeting should be checked as, being of petrochemical base, it may prove to be unsuitable.

5.4.5.4 *Protection of plant from other trades.* The use of plant 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 plant as well as being a safety hazard.

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

Ductwork should not be used as supports, or as a base for supports, for other services, as this may cause such problems as:

a) transmission of noise or vibration;

b) overloading of the duct supports;

c) air leakage;

d) distortion of ducts, which could affect the system performance.

5.5 Equipment installation

5.5.1 *Fans.* Fans, motors and drives should be easily accessible for operation, maintenance and repairs, and all drives should be adequately guarded in accordance with statutory regulations. Particular attention should be paid to the fan inlet and discharge connections to avoid excessive pressure drop or creation of air turbulence, which may affect fan performance. Fan bases and anti-vibration devices should be checked to ensure that they are in accordance with the design requirements and flexible electrical connections should be provided to motors.

Particular care should be taken in the off-loading and hoisting of fan equipment and to prevent damage by other trades after being placed in final position. Access routes are particularly important and care should be taken to ensure that adequate clearances and safe floor loadings are available. Large centrifugal fans may require to be delivered in component form with split casings and reassembled at site. Where fans have to stand on site for a long time prior to use the manufacturer should be consulted as to the precautions to be taken. This may include rotating the impeller by hand at regular intervals to avoid a permanent "set" in the fan shaft owing to deflection, and complete relubrication before start-up.

5.5.2 *Air distribution equipment.* Air distribution equipment includes fan sets, air distribution devices such as grilles and diffusers, and various types of terminal units, e.g. dual duct and variable air volume boxes.

All diffusers, grilles and terminal boxes should be properly protected during site storage and during installation to prevent damage to motors or operators and mechanical linkages and to prevent the ingress of dirt. Particular care should be taken to protect the decorative finish on grilles and diffusers. Checks should be carried out to ensure that accessories such as turning vanes and diffuser/grille dampers have been fitted and are correctly installed.

5.5.3 *Air heating equipment.* On arrival of such equipment at the site, the following should be checked:

a) that steam or water air heaters have been cleaned internally, all openings have been plugged and that all parts subject to deterioration through atmospheric conditions have been suitably protected;

b) in the case of electric heaters, that all the internal wiring, contacts, busbars and electric components including control gear have been delivered suitably protected from damp;

c) with gas or oil fired heaters, that inlet and outlet ducts, burner and control have been protected against dirt and damp;

d) on units with integral fans, that all motor supports are satisfactory and that fans rotate freely;

e) heaters should be checked for any signs of visible damage and to see if there are any special storage or installation instructions from the manufacturer; if not required for immediate installation, heaters should be stored in a dry weatherproof store.

If large air heaters require a base, it should be constructed from non-combustible rigid and durable material. The base should be levelled in all directions.

Where air heaters are suspended, their weight should be carried by independent support (including the ductwork flanges) and they should not be suspended from the ductwork itself.

The supports should be checked against the design drawings for correct positioning. If necessary, the architect or structural engineer should be consulted to ensure that the structure will take the weight of the heater.

5.5.3.1 *Steam or hot water heaters.* The following should be checked:

a) where heaters do not form part of an air handling unit, cleaning doors have been provided in the connecting ductwork;

b) that, when installed, the heater will not be subject to any air flow that will freeze the water in the coils;

c) when installing, that the heater airways are in a clean condition and have not been damaged;

d) that there is sufficient clearance around the heater for the efficient use of the cleaning door, removal of the heater, and access to shut-off valves, control valves, steam trap sets, strainers and any other similar accessories;

e) that there are sufficient valves on the associated pipe work to the heater to allow it to be isolated, drained and removed if required.

Consideration should be given to the provision of a valved bypass round the control valve to enable a service to be provided in the case of breakdown of the control valve.

5.5.3.2 *Electric air heaters.* The following should be checked:

a) that there is sufficient clearance for the efficient use of any access doors provided and for the removal of the battery or heater element;

b) that when access door is open complete electrical isolation takes place;

c) that, if an electrical heater is installed near to a cooling coil or humidifier, water from these units cannot be carried over into the electrical batteries;

d) if the heater elements are of the shielded type, that the air flow through the heater is in the correct direction and that a high temperature cut-out has been fitted.

5.5.3.3 *Gas or oil fired heaters.* The following should be checked:

a) that there is a sufficient combustion air supply for the burners from atmosphere;

b) that there is an adequate flue system provided and that the flue termination is located in a position where the wind can blow freely across it at all times;

c) that there is sufficient space around the heater to allow for servicing or the removal of the burner and heat exchanger if required;

d) that there is an isolation valve provided in the fuel supply;

e) that there is no possibility of a combustible surface being exposed to the hot surfaces of the heater or flue system.

5.5.3.4 *Furnace-type heaters.* Sufficient clearance should be provided to enable all flue and air passages to be cleaned or replaced, and for the efficient use of all soot doors and cleaning doors. The clearances necessary for any specific type of heater should be agreed with the manufacturer.

Where the furnace is hand-fired with solid fuel, a stoking space of not less than 1½ times the length of the combustion chamber should be provided, with a minimum of 1 m.

Where a mechanical underfeed-type stoker is employed, the clearances set out in BS 749 should be followed.

Where the furnace is fired by oil or gas, a minimum of 3 m should be provided to allow for adjustment, cleaning or renewal of the burner units.

5.5.4 *Humidifiers.* Where humidifiers are fitted into other plant or ducting, installation should take into account the following:

a) if fitted on or adjacent to the supply air duct, they should be so sited that they do not adversely affect any air heater in the system;

b) there should be at least 1 m of straight duct downstream of the injector nozzles;

c) the humidifier should be installed to ensure that, if an overflow or leakage of water occurs from the unit, no hazard or damage can take place; care should be taken especially in protecting electrical equipment.

Where humidifiers are free standing within the conditioned space care should be taken that the moisture being emitted does not impinge on to any adjacent surface or is not blown into an access or walk way.

Suitable means of filling the units should be considered and the siting of free standing units should take this into account.

5.5.5 *Air cooling/dehumidifying equipment.* The overall dimensions and weights should be such that the units of sub-assemblies can be moved to their ultimate position on site through existing openings or, where possible, prearranged access ways.

The holding charge (and oil in the case of a compressor) should be checked on delivery to site.

The following should also be checked:

a) that adequate access is available around all major items of plant for the withdrawal of tubes, fan shafts, coils or other items for replacement or maintenance;

b) that arrangements have been made to allow sufficient air flow to cooling towers, air-cooled condensers and similar equipment;

c) that all pipe inlets and outlets are sealed to prevent ingress of moisture and foreign bodies;

d) the general condition of framed, packaged units; in particular, that they are not distorted or twisted on arrival and, subsequently, after each and every removal to another part of the site; in addition and for the same purpose, it is recommended that a check be made of individual sections of the equipment;

e) that the control systems, wiring, capillary tubing, etc are provided with adequate protection against ingress of dirt and moisture;

f) that the insulation is not damaged.

Reference should be made to the CIBS Commissioning Code.

Physical checks should be made of all bases that have been provided for the equipment and then of the installation of the equipment on those bases, for correct level and alignment. A check should also be made that all anti-vibration mountings are installed correctly according to the manufacturer's instructions.

The insulation should be checked to be in accordance with the approved drawing.

Most cooling dehumidifying devices produce condensate and means need to be provided to dispose of this water. A trap should be formed and provided with an adequate height of water seal related to the internal pressure of the system to prevent the free flow of air through the drainage system; a visual method of checking the flow would be useful.

Checks should be made to ensure that intermediate drain trays (where specified) have been fitted, that eliminators (where provided) are correctly fitted, that adequate drainage facilities are available, that trays are adequately extended beyond exposed coils and that insulation is provided to coil return bends.

5.5.6 Air filters

5.5.6.1 *Location.* Filters are normally placed upstream of the main supply fan between the preheat coil (if fitted) and the cooling coil. As well as producing clean room air this protects cooling coils and other apparatus from deposition of dust. The system should be arranged to provide an even air velocity distribution across the filter face.

Where a high degree of filtration is required high efficiency filters, normally used in conjunction with pre-filters, are placed downstream of the fan and should be the last item of equipment before the discharge point. This ensures that any air leakage is outward and that contaminated air is not drawn into the system, also that any contamination from air handling equipment (e.g. carry-over of dust particles from humidifiers) is captured by the final filter.

Fresh air intakes should be as remote as possible from concentration of surface or roof dirt and positioned to avoid intake of fumes or odours. Weather louvres with a wire mesh bird screen should be fitted. In some cases the louvres may need acoustic treatment to reduce noise from or into the system.

Adequate access to facilitate servicing the filters should be provided and doors, ladders, catwalks, electric lighting, etc. included where necessary. A manometer indicating differential pressure across the filter bank should be fitted to determine the need for filter change; in the case of automatic roll filters this should be arranged to actuate the roll-on mechanism.

5.5.6.2 *Installation.* All ducts should be clean and free from builders' rubble and dust before filters are installed. The correct flow direction should be observed. The frame holding the filter media when in position should form an effective seal so that no air bypasses the filter.

Electrical components for automatic roll-on filters and electrostatic precipitators should comply with the requirements of the appropriate British Standards and should be installed and wired by competent electricians in accordance with the current edition of the Regulations for the Electrical Equipment of Buildings, published by the Institution of Electrical Engineers.

Doors and hatches giving access to live high voltage conductors of electrostatic precipitators should be equipped with locks under the control of an authorized person or protected by safety interlocks to ensure that inadvertent contact cannot be made with live conductors.

Before internal access to an electrostatic precipitator is permitted after isolation of the high voltage supply, safety earth connections should first be applied to the precipitator grid.

A means of isolation for the drive motor of a roll-on filter should be fitted as near as possible to the equipment.

5.5.7 Sound and vibration control equipment

5.5.7.1 *Equipment location.* Care should be taken in the selection and location of mechanical and electrical equipment, to ensure that the noise or vibration that it produces does not cause annoyance to occupants within the building where it is located, or to people in surrounding areas (either indoors or outdoors). Particularly careful consideration should be given to the siting of outdoor equipment, including cooling towers, air-cooled and evaporative condensers, remote condensing units, externally mounted fans and air handling units. Items that may cause considerable problems include reciprocating refrigeration machines and air compressors, high speed pumps (above 25 r/s) and large fan sets (above 50 kW motor power). Specialist advice is essential when large reciprocating machines are to be mounted on intermediate floors.

Proper consideration should be given to the siting of supply and exhaust louvres on the building exterior to prevent problems owing to unwanted sound passing outward (or inwards) through these openings.

Sound attenuators and lining materials in ductwork systems, and anti-vibration devices for equipment, should be located strictly in accordance with design requirements and manufacturers' recommendations, otherwise their performance in the system may be impaired.

If installed incorrectly, the sound absorbent material may be disintegrated by the air flow and may cause a considerable nuisance and health hazard (see also **3.5.1.2**).

5.5.7.2 *Installation of sound control equipment.* The materials typically employed for sound absorption within package attenuators, mixing boxes and room terminals, and used for ductwork lining, are generally susceptible to physical damage, and to severe deterioration if exposed to rain or water. It is essential that adequate protection is provided not only during storage and installation, but at all times up to system handover.

5.5.7.3 *Installation of vibration control equipment.* Anti-vibration devices include compression materials and rubber in shear isolators. These materials may be damaged physically, or by liquid such as oil, and adequate precautions are therefore essential. Where spring devices are fitted with limit stops to prevent excessive movement (e.g. on equipment with significant weight changes when filled or empty of water) there should be a compensatory pre-setting.

Flexible connectors should be protected against physical damage. Care should be taken to prevent any anti-vibration devices being loaded beyond their safe limits during erection of machinery.

5.5.8 *Refrigerating equipment.* This includes both packaged (factory assembled) water chilling equipment and direct expansion, site assembled installations; the latter are rarely employed in large comfort air-conditioning applications. Unitary direct expansion equipment is dealt with in **5.5.9**.

5.5.8.1 *Packaged equipment.* The installation operations for packaged refrigerating equipment include:

a) preparing the installation area;

b) delivery, off-loading and inspection of the equipment;

c) planning the equipment in its final location and securing in place, with anti-vibration devices where specified;

d) making the necessary water, electrical and control connections;

e) inspecting and checking the completed installation.

NOTE The equipment is then normally commissioned. These procedures are described in **6.4**, and detailed in the CIBS Commissioning Code, series R.

f) The usual final installation step is insulating connected water piping, where necessary.

Since packaged water chillers may employ reciprocating, centrifugal, or screw compressors, or may be of the absorption type, the manufacturer's detailed recommendations should be followed, as appropriate. In all cases, at step b), 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.

It is recommended that adequate space be provided for operating and maintenance purposes, particularly for cleaning or removal of chiller and condenser tubes, and for removal of compressor and motor. The plant room should have adequate ventilation and drainage, and the complete installation should comply with the requirements of BS 4434.

5.5.8.2 *Site assembled installations.* Where factory-made refrigerating equipment is connected by refrigerant piping on site to form a complete installation certain precautions should be observed.

Materials, design and layout considerations for refrigerating piping systems are dealt with in **3.3.4**. Information on refrigerating system components is given in **4.10.1.5**. The following precautions should be taken to ensure a satisfactory refrigerating piping system:

a) keep the piping system simple (use as few fittings as possible);

b) pitch all pipelines accurately to ensure proper flow of lubricating oil;

c) keep the system clear and free from air, moisture or other contaminants.

The installation should comply with the requirements of BS 4434.

5.5.9 *Unitary equipment.* Unitary or packaged air-conditioning equipment comprises one or more factory-made assemblies, the components of which are specifically designed to work together. It includes self-contained and split-system type air-conditioning units and packaged heat pumps of both the water-to-air and the air-to-air types.

Upon delivery all unitary equipment should be thoroughly inspected to ensure freedom from damage.

Equipment should be installed in accordance with the manufacturer's instructions and levelled to ensure proper refrigerant and lubricant flow and condensate drainage. Care should be taken not to damage unit casing, small bore piping or electric wiring. Air inlets and outlets should not be obstructed. Specified requirements to minimize transmission of noise and vibration should be observed.

When split-system or other equipment requires site-assembled refrigerant piping, the recommendations of **5.5.8.2** 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.

Electric wiring to unitary equipment should be in accordance with manufacturer's diagrams and with IEE (Institution of Electrical Engineers) or local statutory regulations. Packaged units normally have all internal wiring completed at the factory, while split systems require interconnecting wiring.

Where condenser water connections are to be installed the unit may use mains water to waste (deprecated) or a cooling tower recirculating system. Mains water systems require a water pressure regulating valve, strainer, thermometer pocket and manual isolating valve. Cooling tower systems require manual isolating valves and provision for draining; depending upon method of control, automatic regulating valves may be required. Particular care should be taken to provide adequate size and gradient for condensate drain connections from cooling coils.

Unitary equipment may be factory charged with refrigerants. Split systems generally require leak testing and evacuation-dehydration to be carried out on site. General procedures are described in the CIBS Commissioning Code, series R.

5.5.10 *Heat recovery equipment.* This includes heat pumps, air-to-air recovery equipment, and the other devices, solar collectors and combination systems described in **4.12**.

Heat pumps should be installed in accordance with the manufacturers' recommended procedures, but installation operations will generally follow the sequence described in **5.5.8.1** a) to f).

5.6 Systems installation

5.6.1 *Ductwork systems.* This subclause covers the major points to be considered during the installation of the air distribution systems for ventilation and air-conditioning installations. These systems comprise distribution ductwork and fittings (bends, tees, branches, etc.), hangers and supports, louvres, hand-operated and automatic control dampers, fire dampers, access and cleaning doors, test holes, etc., and thermal insulation.

5.6.1.1 *Ducting.* Ducting systems may be employed to convey fresh air, treated or conditioned supply air, recirculated or exhaust air.

Distribution ductwork is normally manufactured from galvanized sheet metal although other materials may be employed (see **3.3.1.1**). Air distribution may be at low velocity or high velocity (see **3.3.1.2**); in high velocity installations only the supply air is normally distributed at high velocity.

Good workmanship, air tightness, and system cleanliness should be foremost considerations. The interior of all ducting systems should be clean before erection and all open ends, which are left as the work progresses, should be temporarily sealed to prevent the ingress of dirt.

All ducting systems should be adequately supported and all fittings should be manufactured and installed in accordance with good practice as set out in current HVCA ductwork specifications so as to minimize air turbulence, noise generation, and friction loss. Particular attention should be paid to the selection and location of an adequate number of dampers of suitable type for flow regulation. Consultation with the system designer is recommended to ensure that the regulating procedures to be carried out at the commissioning stage may be achieved. Further information may be found in the CIBS Commissioning Code series A and in the BSRIA Application Guides 1/75 and 1/77.

Sufficient thermometers and other instruments, or test points and access doors, should be provided for commissioning and for operating and maintenance purposes. All duct joints should be properly made to ensure that minimum leakage is achieved. Where high velocity ductwork is to be pressure tested the procedure to follow is recommended in the current HVCA specification. Provision should be made for the possibility of dismantling ducting connections and equipment for servicing/removal and suitable precautions should be taken to prevent transmission of vibration. Material for flexible connections should comply with fire regulations. Ductwork should be adequately braced and stiffened to prevent "drumming". Where insulation incorporates a vapour seal, special care should be taken to ensure the continuity of that seal and to prevent any damage before handover. Procedures for the commissioning and regulating of air distribution systems are covered in detail in the CIBS Commissioning Code and the BSRIA Application Guides referred to above.

5.6.1.2 *Dampers.* All dampers should be checked to ensure that they are properly installed and that the blades and linkages move freely. Where tight shut-off is required checks should be carried out to ensure there is no undesirable leakage around damper frames or through the assembly in the closed position.

Fire dampers should be checked to ensure that they are correctly located and installed in accordance with the manufacturer's requirements, and that the cartridge or fusible link is accessible.

The location of all hidden fire dampers should be indicated.

5.6.2 *Water piping systems.* Types of water piping system may include chilled and condenser water, hot water and steam for heater batteries and heat exchangers, refrigerant lines in direct expansion systems, cold water feeds to cooling towers and humidifiers, and drain lines from central equipment and room units. These systems comprise distribution piping, fittings, valves, various special pipeline components, and thermal insulation. Equipment includes pump sets, heat exchangers and storage vessels, cooling towers and condensing equipment. In certain types of air-conditioning systems, such as multi-pipe heat recovery, the pipework arrangements can be very complicated and extensive.

5.6.2.1 *Piping.* 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 all open ends, which are left as the work progresses, should be temporarily closed with purpose-made metal or plastic caps, or blank metal flanges.

All piping systems should be adequately supported, with proper provision for expansion and contraction, for air control and venting, and for draining down. 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.

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. Provision should be made for the possibility of easily dismantling equipment connections for equipment servicing/removal and suitable precautions should be taken to prevent transmission of vibration. Where insulation incorporates a vapour seal special care is needed to ensure the continuity of that seal and to prevent damage before handover.

The cleaning, flushing and precommissioning checks for water systems are covered in the CIBS Commissioning Code series W.

5.6.2.2 *Pump sets.* Pumps, motors and drives should be readily accessible for operation, maintenance and repairs. All drives should be securely fenced 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. In open systems, as on cooling towers and washers, the pump should be located to ensure that the suction is flooded and the flow is not restricted, so that adequate net positive suction head is available. Consultation with the pump manufacturer is recommended in such cases. Pump suction and discharge piping should be properly supported so that no strain is placed upon the pump. Most pumps require inertia bags and anti-vibration devices.

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 "bridged-out" by incorrect installation procedures. Flexible electrical connections to motors should be provided.

5.6.2.3 *Equipment.* All equipment should be located and installed with adequate weather protection and means of guarding against damage by freezing. Pipe connections should be arranged to avoid strain being placed on the equipment and to avoid transmission of vibration. All heat transfer equipment should be protected against the effects of dirt and corrosion.

All waterside equipment should be able to be properly filled, vented and drained and should have the necessary facilities for isolation and flow regulation, and for taking flow, pressure drop or temperature measurements as necessary. Equipment on anti-vibration mounts may require limit stops to prevent excessive movement and strain on connecting pipework owing to the difference in levels in the filled and unfilled states.

Particular care should be taken in the off-loading and hoisting of all equipment and to prevent damage by other trades after the equipment has been placed in its final position. Access routes are particularly important and care should be taken to ensure that adequate clearances and safe floor loadings are available.

5.6.3 *Refrigerating piping systems.* 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.

Piping and components should be arranged to prevent liquid refrigerant from entering the compressor during operation and shut-down 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- and oil-equalizing piping may be required. (Further detailed information is given in ASHRAE Handbooks: Chapter 32 of "Fundamentals" (1977), and Chapter 26 of "Systems" (1976).) 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 CIBS Commissioning Code series R. Refrigerating systems should comply with the requirements of BS 4434.

During cold weather care should be taken to prevent frost damage to water-filled piping systems and equipment.

5.6.4 *Electric power systems.* The following should 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) if recommended by the manufacturer, that the motor is fitted with a correct starter incorporating a closely calibrated overload device according to design.

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.

Care should be taken to protect the equipment after installation by, for example, periodically turning the motor, and the ball and roller bearings, by hand.

5.7 Automatic control systems installation

5.7.1 *Protection.* Components of automatic control systems are particularly vulnerable to damage during delivery, while being stored at site and during the actual installation period. All control items should be consigned in such a manner that they can be reasonably handled during transit without damage. All containers should be plainly marked where special care has to be taken. In addition, many control items are particularly sensitive to atmospheric conditions and need to be protected from extremes of temperature and moisture, and from dirt, any of which may impair their performance.

All control items should be suitably protected at works prior to despatch to site. On arrival at site they should be properly stored and protected. Particular care should be taken after incorporation of control items into the installation, and it is essential to ensure that adequate temporary protection is provided to prevent damage during the commissioning stage and prior to handover.

Care should be taken to ensure that:

a) the windings, internal wiring and contacts of all electric motors, solenoids and switchgear are protected against damp or extremes of heat;

b) where loose packing material is used, precautions are taken to prevent it entering into the working parts of components;

c) the open ends of all tubes are sealed.

5.7.2 *Work on site.* Any special instructions issued by the manufacturers of the controls should be strictly observed.

5.7.2.1 *Electricity supply and wiring.* All electrical wiring should be installed in accordance with the current edition of the IEE (Institution of Electrical Engineers) Regulations and should be in accordance with the control equipment manufacturer's requirements.

Special care should be taken to ensure that all electrical cables possess physical and electrical characteristics suitable for the application, and that earthing suits the equipment.

All connections should be made in accordance with approved wiring diagrams.

In the case of electronic systems, it may be necessary to ensure that all control items are wired to the same phase of the supply.

5.7.2.2 *Pneumatic systems.* It should be noted that high standards of workmanship are required for the small bore copper or plastics pipelines of the controls compressed air distribution system, and that it is desirable to employ operatives experienced in this class of work if a neat and trouble-free installation is to be ensured.

An adequate supply of clean, dry, oil-free compressed air is essential to the operation of a pneumatic control system. Condensed moisture in the air lines may often be a cause of trouble. The main air compressor/receiver system should incorporate suitable moisture condensers, which may be water-cooled or air-cooled or of the chemical type. Standby compressors should be provided. In addition, air lines should be properly graded to permit any moisture to run to low points where suitable provision should be made for automatic or hand drainage.

Air compressor sets can be particularly troublesome from the point of view of noise and vibration, and compressor location and method of mounting should be fully considered at the design stage. During installation, care should be exercised to ensure that anti-vibration mounts are not "bridged-out" by incorrectly located piping or cable supports. The pneumatic system should be provided with adequate filters to prevent the ingress of foreign matter to the controllers. It is important that high pressure safety relief valves be incorporated at suitable points into the system.

5.7.2.3 *Location and access.* All sensing elements should be located so that they measure truly representative conditions. All instruments, such as thermostats, humidistats and pressurestats, should be securely fixed in position free from vibration and risk of mechanical damage. Thermostats and humidistats should be installed to avoid undesirable effects of extremes of heat, cold, dust or moisture. Where this is not practicable, protection shields should be fitted around the sensitive elements.

Arrangements should be made to ensure free air flow over the instrument wherever this is necessary for correct operation.

Duct-insertion type thermostats and humidistats should have the sensing elements correctly positioned in the air stream, adequately supported, and located where not subjected to radiation from heating coils.

Liquid immersion thermostats should be fixed with the maximum length practicable immersed in the moving liquid and where possible in line with the direction of flow. Care should be taken to ensure that thermostat wells are packed with the necessary heat-conducting fluid.

Where possible, controllers and other items requiring adjustment or maintenance should be mounted approximately 1.5 m above floor level. All controllers, sensing elements and control devices should be easily accessible, and when any of these items are installed within an air system, it is essential that proper access doors are provided.

5.7.2.4 *Automatic control valves.* All control valve bodies should be properly supported and the pipeline so designed and installed that no distortion of the valve body can occur. Manufacturers' instructions should be consulted and care taken to ensure that the actuating gear or spindle is in the correct plane. Sensitive phials and capillary tubing of pressure operated valves should be removed or otherwise protected until the installation can be completed. Runs of capillary tubing should be chosen to minimize the risk of mechanical damage. The tubing should be continuously supported and securely clipped and, to ensure full bore operation, sharp bends should be avoided.

5.7.2.5 *Piping systems.* Piping systems between the heating or cooling equipment and heat transfer units, into which automatic valves are fitted, should be carefully installed to ensure that adequate provision is made for drainage and air release, and the proper provision for expansion and contraction. It is good practice to provide isolating valves and a valved bypass to all control valves particularly in the larger sizes. On open water-circulating systems, e.g. to cooling towers, strainers should be provided.

5.7.2.6 *Automatic control dampers.* Dampers in air systems should be properly installed to avoid air leakage around the damper frame and minimize leakage losses through the damper blades within design limits when the blades are in the closed position. The operating units should be rigidly fixed as close as is practicable to the damper that is to be controlled. Operation of the damper/linkage/operator assembly should be checked to ensure there is no interference with movement over the complete range of travel.

5.7.3 *Drawings.* Detailed drawings of the complete automatic control system should be available before installation commences. These drawings should clearly indicate the arrangement of ports on valves and the location of sensing elements and indicators, and should provide all information necessary for correct installation and subsequent commissioning.

5.7.4 *Commissioning.* Commissioning should be carried out by suitably experienced personnel, and in accordance with the requirements of the design specification and the recommendations of the control equipment manufacturers. General commissioning procedures are described in the CIBS Commissioning Code series C.

Before commencing the commissioning of an automatic control system, it should be ensured that:

a) all control components have been installed in accordance with specified requirements and manufacturers' instructions;

b) all safety devices, including circuit interlocks and cut-outs, have been correctly inserted into the overall operating and control plan to carry out effectively the intended purpose;

c) all sensing elements have been located in a position to give good representation of the controlled variable;

d) all measuring instruments have been calibrated against certified standards.

Prior to commencing detailed checking and setting up on a particular system it should be ensured that:

1) full rated flow of the controlled media, and the pump and fan pressures, are within design tolerances;

2) the input temperature of the controlled media and the pressure at the input of the controlled device at full design flow conditions are each within specified design limits, and that the pressure difference across the device is to design requirements.

Section 6. Inspection, commissioning and testing

6.1 General

Inspection, commissioning and testing should be carried out meticulously if a satisfactory installation is to be handed over to the client. Adequate time should be allowed in the building programme to ensure they are carried out thoroughly and that all results are 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 in providing a complete installation and close collaboration and co-ordination of all concerned is essential.

Recommended procedures to be followed are detailed in Commissioning Codes published by the CIBS and specific aspects of inspection and checking are given in the relevant Parts of section 5.

6.2 Inspection and testing at works

The air-conditioning system will consist of various items of equipment produced by various manufacturers. Each manufacturer should give facilities for the inspection of his equipment during manufacture and on completion. He should be prepared to carry out an observed test at an agreed fee if called upon to do so 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 conforming to the relevant British Standard. Witnessed performance tests should be carried out in accordance with the relevant British Standard.

Any equipment that requires a hydraulic pressure test should be supplied with a testing 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 and a suitable fee negotiated.

6.3 Inspection and testing on site

Prior to setting to work and regulation, preliminary checks, testing and charging of the complete system should be carried out. The procedures given in the CIBS Commissioning Codes are recommended. It is important that all water systems should have been thoroughly flushed through and hydraulically pressure tested to 1.5 times the working pressure for a period of not less than 30 min.

High pressure air duct systems should also have been tested in accordance with the procedures given in HVCA Specificiations.

Procedures should be agreed with manufacturers to ensure compatibility with their equipment and that any guarantee is not invalidated.

6.4 Commissioning

6.4.1 *Setting to work.* Recommended procedures to be followed are given in section 2 of the CIBS Commissioning Codes quoted in **6.1** above. Normally certain specialist items of plant, such as refrigeration units, control systems, ventilated ceilings and certain types of humidifier, will be set to work by commissioning engineers from the particular manufacturers (see section 5) but it is important that their efforts are co-ordinated by a competent commissioning engineer who has a full understanding of the intended operation and performance of the complete system. It is important that the plant is set up to obtain fluid 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 supplied to the commissioning engineer (see also **3.2.8.1**).

In applications where temperature and humidity are to be maintained within close limits it may be necessary to simulate the maximum heat loads to ensure plant performance but in any case a load of at least 50 % is required when commissioning the refrigeration plant.

6.4.2 *Regulation.* Regulation is the process of adjusting the rates of fluid flow in a distribution system within specified tolerances. System regulation is the final stage in a sequence that starts with the design itself. If the needs of on-site regulation are not foreseen and provided for it may never 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 the flows of fluids through a system are correctly regulated and balanced and conform to design parameters otherwise the system cannot perform as intended and the desired internal environmental conditions will not be met.

Locating the necessary dampers in the right places is one of the basic requirements for effective system regulation. Any saving of final costs by the omission of dampers will soon be lost in the extra time taken in commissioning.

For rectangular ducts the opposed blade damper gives the best results because it produces the least downstream distortion when partly closed and has a wider setting range than louvre or butterfly dampers.

To carry out satisfactory regulation of a system a schematic diagram, showing all mains, branches, valves, etc. with the required flow, pressure drop and velocity appertaining to each run of duct or pipe, is required covering all fluid flows in the system. Also, adequate means of measuring flow or velocity should be provided.

For air flow in ducts, velocity measurements using a pitot tube with an adjustable manometer provides the most reliable results. It needs no calibration and is consistent. In practice the lower velocity limit for readability on the manometer is approximately 4 m/s to 5 m/s.

Recommendations on the number and positioning of measuring locations as well as details of holes and spacing are given in BSRIA Application Guides 1/75 and 1/77. These also present the range of instruments available with recommendations on the measuring techniques to be used, and also describe the techniques of proportional balancing to ensure that the designed air flows are obtained at each terminal point. The latter technique is also detailed in the CIBS Commissioning Code series A.

For water flow the principles of regulation by proportional balance are the same as for air and detailed procedures are set out in the CIBS Commissioning Code series W. Regulation is achieved by measuring the pressure drop across a device with a constant flow coefficient capacity index.

Balance is obtained by varying flow across the device so that the ratio of actual pressure difference to design pressure difference is the same across all devices. The device may be a venturi meter, orifice plate, or pressure-tapped valve used as a form of fixed orifice when fully open.

All instruments need to be calibrated at intervals of not more than six months and each instrument should carry a calibration record.

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. Any recommendations for tolerances given in the CIBS Commissioning Codes and BSRIA Application Guides should be followed.

Once the system has been regulated it is important that the setting of all balancing dampers, valves, etc. is clearly marked and that they are locked in position.

6.5 Performance testing

Performance testing is the evaluation of the performance of a commissioned installation. If the installation is to perform as required by the designer, tests outlined below should be carried out under actual operating conditions, usually after the building has settled down and been occupied.

It is necessary to distinguish between the two main types of test associated with mechanical and electrical services. One is to ascertain that the specified rated outputs of the various systems are achieved and forms part of commission testing, the other is to ascertain whether the installation will satisfy the design intentions and forms part of performance testing.

Since there is as yet no standard practice for performance testing the following method and tests are suggested.

6.5.1 *Suggested analyses for assessment of the installation to provide adequate internal comfort conditions*

6.5.1.1 *Air patterns.* Outlet grilles should give sufficient throw and adequate entrainment, should counteract convection currents and should be sufficiently flexible to cope with both heating and cooling loads where applicable.

6.5.1.2 *Noise and sound control.* Measurements should be taken with a sound level meter either using the "A" weighting scale or to draw up a noise criteria curve. Measurements should be taken in the following locations:

a) plant rooms;

b) occupied rooms adjacent to plant rooms;

c) outside plant rooms facing air intakes and exhausts and condenser discharge, to assess possible nuisance to adjacent accommodation; if the adjacent accommodation is a private residential building, tests may be required at night;

d) in the space served by the first grille or diffuser after a fan outlet;

e) in at least two of the spaces served by fan coil units or high velocity system terminal units (where applicable);

f) in any space where, by the addition of special silencing material or techniques, or by classification of use (e.g. lecture hall), a low level of noise is clearly required.

6.5.2 *Measuring the in situ performance to assess the ability of an installation to operate at design conditions.* For a continuously occupied building, e.g. a hospital, design conditions are reached when the installation has to operate at the design weather conditions. For an intermittently occupied building, e.g. an office block, supermarket, etc., design conditions are reached when the installation has to achieve preheating in a specified time.

Tests should be devised to relate the variables upon which the performance of the installation depends; a schematic layout can be conveniently used. Variables should be chosen to enable a linear (i.e. straight line) relationship to be constructed from in situ measurements. The resulting relationship should then be used to infer the performance at design conditions. Suitable relationships could be:

a) heating capacity to satisfy total energy demand for humidifying and heating load;

b) zone heater/cooler capacity to meet space heating/cooling loads;

c) cooling capacity to satisfy total energy demand for dehumidification and cooling load.

6.5.3 *Instrumentation and access.* Ideally, instrumentation for performance testing should be considered during the design stage, so as to enable adequate access for operators during normal operation.

6.6 Handover procedure

6.6.1 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. Some of these documents will be prepared by the system designer, whilst others will be produced by the suppliers of equipment or by the contractor who erects the installation.

The documentation required should be specifically stated in the contract so that the responsibility for ensuring that all relevant information is provided rests clearly with the air-conditioning contractor.

All the requisite information should be available at the time of handover. It is advisable for the client's representative to meet the air-conditioning contractor and designer some time before the anticipated handover date and review the progress of documentation and arrange any necessary training and familiarization.

6.6.2 Handover documentation should include the following:

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

b) "as fitted" installation drawings and the designer's operational instructions;

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

d) schedules of electrical equipment;

e) schedules of mechanical equipment;

f) test results and test certificates as called for under the contract, including any insurance or statutory inspection authority certificate;

g) copies of guarantee certificates for plant and equipment;

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

Section 7. Operation and maintenance

7.1 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 successfully a maintenance programme will depend upon the policy established by the building owner or manager, and the decision whether to provide for operation and maintenance of the system by a contract arrangement with a specialist external organization, or by use of suitably trained in house personnel, or by a combination of both.

The types of maintenance procedures that may be adopted are defined in BS 3811 and are reproduced here for convenience.

7.1.1 *Planned maintenance.* Maintenance organized and carried out with forethought, control and the use of records to a predetermined plan.

NOTE Preventive maintenance is normally planned. Corrective maintenance may or may not be planned.

7.1.2 *Preventive maintenance.* Maintenance carried out at predetermined intervals, or to other prescribed criteria, and intended to reduce the likelihood of an item not meeting an acceptable condition.

7.1.3 *Condition-based maintenance.* Preventive maintenance initiated as a result of knowledge of the condition of an item from routine or continuous checking.

7.1.4 *Running maintenance.* Maintenance which can be carried out whilst the item is in service.

7.1.5 *Shut-down maintenance.* Maintenance which can only be carried out when the item is out of service.

7.1.6 *Corrective maintenance.* Maintenance carried out to restore (including adjustment and repair) an item which has ceased to meet an acceptable condition.

7.1.7 *Emergency maintenance.* Maintenance which it is necessary to put in hand immediately to avoid serious consequences.

NOTE Terms which should not be used include "routine maintenance" and "scheduled maintenance".

7.2 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 in accordance with the skills required and the time required to perform scheduled routine tasks. The size of building, the building usage, the numbers and types of air-conditioning and ventilation systems, the types of equipment and components 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 unpredicted repairs or emergencies.

7.3 Records

7.3.1 *Record system.* Any 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.

7.3.2 *Operating and maintenance instruction manuals.* The purpose of these manuals is to provide organized information and instructions on the operation and maintenance of mechanical ventilation and air-conditioning systems including associated refrigerating plant and ancillary equipment, piping systems and electrical installations.

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

a) full descriptions of ventilation and air-conditioning 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 detailed in **7.3.2.1** and **7.3.2.2**. Information on presentation is to be found in BS 4884-2.

7.3.2.1 *Part I: systems.* A complete description of each mechanical ventilation or air-conditioning system should be provided together with the following information:

a) *description*

1) system function/services;

2) classification (e.g. high velocity, air-conditioning, supply);

3) basis of design;

4) performance characteristics;

5) system pressure test certificates (piping and ducting);

6) principal equipment and components;

7) distribution arrangements;

8) system schematic diagram with flow rates, temperatures and pressures;

9) automatic control diagram;

b) *operating instructions*

1) starting/stopping procedures;

2) adjustment and regulation;

3) seasonal changeover;

4) seasonal start-up;

5) seasonal shut-down;

6) logs and records;

c) *inspection and maintenance*

1) inspection schedule;

2) maintenance schedules and procedures;

3) inspection and maintenance records;

4) permits to work;

d) *reference drawings and documents*

1) design drawings;

2) working drawings;

3) "as fitted" record drawings;

4) copies of local authority/statutory approvals;

5) engineering specifications;

6) commissioning records;

7) performance test records (where applicable).

7.3.2.2 *Part II: equipment.* For each major piece of equipment the following information should be provided:

a) *description*

1) serial number/nameplate information;

2) catalogue data;

3) dimensions drawings;

4) materials of construction;

5) parts designations;

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

b) *operating characteristics*

1) performance curves, tables or charts;

2) safety devices;

3) temperature, pressure and speed limitations;

c) *operating instructions*

1) pre-start check list;

2) start-up procedures;

3) inspection during operation;

4) adjustments and regulations;

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;

e) *maintenance instructions*

1) routine maintenance schedule;

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 contracts.

7.3.3 *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.

7.3.4 *Operating log.* Details of daily operations should be entered in an operational log. This log should include a note of important operational temperatures, pressures, electrical data, etc. A particular note should be kept of overall plant fuel and energy consumption and where possible this should be recorded for individual pieces of equipment. Analysis of this data should enable plant performance to be monitored regularly and the plant to be operated at maximum efficiency.

7.4 Procedures

7.4.1 *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:

a) *safety requirements:* the greater the requirement the more frequent the inspection; 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 operation:* continuously operating plant requires more frequent checking than, for example, plant operating eight hours 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 mechanical ventilation and air-conditioning systems are considered under the convenient headings presented in **7.4.2** to **7.4.6**.

7.4.2 *Air handling systems.* Of all air handling components, fans require the most frequent inspection. At a minimum of monthly intervals the drive couplings, pulleys and vee-belts should be checked for wear and alignment, and bearings lubricated and checked for end play, wear or excessive operating temperature. A more thorough annual inspection should be made and the fan housing and impeller should be cleaned.

Filters should be kept clean to maintain the design flow within acceptable limits, bearing in mind that pressure drop is a useful guide to filter condition. Maintenance should follow manufacturers' recommendations, particularly in the case of automatic roll type and electrostatic filters.

Heating and cooling coils should be thoroughly cleaned on the air side surface to maintain rated heat transfer and should be checked for leaks and corrosion.

Weekly cleaning and inspection of air washers and humidifiers is recommended. Periodic inspection should cover spray nozzles, spray chamber interiors, pumps, strainers and washer fill materials. Suitable water treatment is essential.

The ductwork distribution should be checked annually for accumulations of dirt, breaks in insulation, loose brackets, leaking flexible connections and deteriorating duct joints. Particular attention should be given to intake and exhaust louvres, access doors, drain pans, and hand and motorized dampers.

7.4.3 *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. Pump seals, drive alignment and bearings should be checked periodically. Insulation, especially the vapour barrier on chilled water lines, should be examined for damage. Where water treatment is required it should be applied under specialist supervision.

7.4.4 *Controls and electrical equipment.* Electric 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 dampers, control valves, etc., should be observed.

7.4.5 *Refrigerating systems.* 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, screw and absorption machines require expert maintenance carried out in accordance with the makers' instructions, but it should be remembered that all ancillary equipment also needs attention.

7.4.6 *Condensing and heat transfer equipment.* Regular checks should be carried out on the mechanical and electrical components of cooling towers, evaporative condensers and air cooled condensers. Pumps and fans, spray nozzles, water tanks, dampers, etc., should be inspected; external and internal surfaces should be kept clean. Water treatment and "bleed-off" is recommended for towers and evaporative condensers.

The performance of water chillers and condensers should be regularly observed and inlet and outlet water temperatures and head pressures logged daily. Closed water systems, as normally employed with chillers, should require little attention providing the water pH value is maintained at a satisfactory level (normally between 7 and 8). Open water systems, as on condensing water circuits, require annual cleaning (by chemical means if necessary) together with such steps as appropriate to prevent formation of scale or corrosion. Provision of proper water treatment with adequate corrosion control is a very important consideration. (See **3.6**.)

7.5 Economic considerations

Economical operation of an installation after it has been set to work will depend upon 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 operation costs, including fuel and energy consumption, should be collected periodically so that deterioration in the performance and increases in cost may be seen at an early stage and measures taken to identify and rectify the causes.

In large 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 periodical checking of electricity, gas and water tariffs.

7.6 Safety considerations

All systems and equipment should be inspected and maintained to ensure compliance with all statutory requirements, and to ensure the safety of operating personnel and building occupants and of the building itself. The introduction of new safety legislation or amendments to existing requirements may require changes to be made from time to time in existing installations.

Section 8. Overseas projects

8.1 General

The majority of the recommendations and cautionary notes in sections one to seven of this code apply equally well to overseas projects. However, experience has shown that there are a number of additional factors to be considered in the design, installation, commissioning, and operation and maintenance of air-conditioning and ventilation systems in tropical and semi-tropical climates of the hot/dry or hot/humid type. Many problems may relate to lack of skilled labour or facilities, availability of equipment and materials, shipping and protection problems, etc., which are commonly encountered in the relatively under developed areas of the world.

8.2 Design

8.2.1 *Local calculations.* Particular care should be taken when establishing the basis of the air-conditioning or ventilation design. The selection of the design value of external dry bulb and wet bulb temperatures, fresh air quantities, and internal conditions warrants careful consideration as the effect on load calculations may be considerable. Accurate calculation of heat gains owing to solar radiation is essential and proper allowance should be made for clarity of atmosphere and for reflected radiation as may occur from large adjacent areas of sand or water. The effect of hot ground or roof surfaces may be to cause a significant increase in air dry bulb temperature at the location of fresh air intakes or air cooled condensers, and equipment ratings should be adjusted accordingly. Similarly, heat gains to ductwork or piping located externally to the buildings, or in unconditioned spaces, may constitute an unusually high proportion of the load.

8.2.2 Equipment and materials

8.2.2.1 *Selection.* Equipment and materials for use in air-conditioning systems in tropical and semi-tropical climates should be selected with due regard to the conditions under which they will be installed and required to operate. The effects of high temperatures and humidities, and of exposure to dust, sand and intense solar radiation should be considered. In many locations exposure to saline atmospheres or brackish water supplies, or abrasion by wind-blown sand particles, may lead to corrosion problems. Certain materials may be subject to attack by pests or insects, e.g. termites. Where plastics pneumatic control lines, or cooling tower packing, are used, consideration should be given to their suitability for withstanding not only the operating conditions, but also the conditions encountered during the course of erection, for many plastics start to soften at around 50 °C.

8.2.2.2 *Air handling plant.* Intake and exhaust louvres may require some form of sand trap. Filter material should be suitable for prevailing conditions and consideration should be given to the possible advantages of cleanable, compared with disposable, types. Surface finishes on the inside of air handling plant and heating/cooling coils, fans, etc., should be resistant to saline or other atmospheric conditions which may prevail.

8.2.2.3 *Ductwork.* Where ductwork is to be manufactured in the United Kingdom and shipped abroad to site, it may be desirable for it to be designed and manufactured in sizes suitable for stacking one piece inside another for shipping. Alternatively, it may be designed to be shipped in a "knocked down" form. In determining the methods of ductwork construction, particularly the types of joints and seams, consideration should be given to the quality of the operatives who will carry out the erection.

8.2.2.4 *Piping.* Materials used for piping, fittings, valves, pumps, etc., often have to be suitable for handling water that may be contaminated or corrosive. An analysis of the local water should be obtained and specialist advice sought regarding choice of materials and methods of water treatment. The quality, temperature, pressure and availability of water may have considerable bearing on plant selection and condensing methods.

8.2.2.5 *Insulation.* Insulating materials should be resistant to surrounding air at high temperatures and of high moisture content. The use of efficient vapour seals is essential where duct, pipe or equipment surfaces are below the dew point temperature of the surrounding air. Valve bodies, control valve actuators, condensate collection pans, coil return bends, pipe flanges and drain lines may be required to be insulated to avoid condensation problems. External insulation should be able to withstand prolonged effects of solar radiation, and should be insect- and vermin-proof. The insulation specification should take into account the skill of the operatives available to carry out the work.

8.2.2.6 *Automatic controls.* In general, the air-conditiong should be kept as simple as possible with suitable provision for "hand-running" in the event of failure of the automatic control systems. All control equipment and components should be selected bearing in mind not only the required duty and initial cost but, in particular, ease of maintenance, location of nearest service agents, availability of spare parts, and the experience or otherwise of the erection, operating and maintenance staff.

8.2.2.7 *Refrigerant equipment.* Particular care is needed in the selection of cooling equipment. Hermetic compressors may be difficult (or impossible) to service in the field. Unit air-conditioners should be suitable for the intended application, bearing in mind that in many cases the unit is mounted externally to the conditioned space, or that internal conditions may approach, or even exceed, ambient where usage is intermittent and the unit is turned off. For methods of rating and test BS 2852 and BS 3899 should be consulted. Water cooled condensers should be selected with adequate fouling factors. Air cooled condensers and cooling towers need protection/control where low ambient temperatures are encountered at certain times of the year.

8.2.2.8 *Electricity supply.* Details of the available electrical supply should be carefully checked and, in addition to establishing the exact voltage and frequency (and probable variations), the number of supply wires should be determined. For example, if a three phase supply is available with only three wires (i.e. no neutral), then it is not easily possible to obtain a single phase to neutral for control and coil currents, and step-down transformers may be required.

8.2.2.9 *Electrical equipment.* All motors, starters, switchgear, contactors, relays, etc., and electrical/electronic controls may require to be "tropicalized", i.e. protected against the adverse effects of high temperatures, high humidities, and sand or dust. All motors should normally be suitable for continuous running and suitably ventilated or cooled to prevent excessive temperature rise; hermetic motors should be fitted with high temperature cut-outs in the windings. All starters, particularly those associated with refrigeration compressors, should be rated for the anticipated duty (number of starts per hour). Electrical equipment enclosures may require ducted ventilation (or conditioned) air to dissipate heat. In locations where ambient temperatures exceed 35 °C dry bulb, the power consumption of refrigeration compressors working with air cooled condensers may approach double that commonly experienced in United Kingdom applications. Therefore, an accurate assessment of the total electrical power requirements of all air-conditioning systems and ancillaries should be made in the early design stages to ensure that the electrical distribution system is designed accordingly.

8.2.2.10 *Lubricating oils.* All lubricants for motors and drive bearings, fluids for dashpots, etc., should be selected for operating conditions that will be encountered.

8.2.2.11 *Other information*

a) Information available from the Technical Help to Exporters (THE) Department of the British Standards Institution.

b) CIBS Design Notes for the Middle East.

8.3 Installation

Many installation problems can be avoided if proper consideration is given to possible difficulties of site conditions and problems of availability, skills and supervision of site operatives. Careful choice of materials and jointing methods for piping, ducting and insulation are particularly important. Proper selection of equipment and whether shipped assembled or in sections, whether factory tested, etc., can have important technical and cost implications.

Arrangements for shipping and protection, both on the journey and at site, are of extreme importance. Equipment and materials should be adequately protected on long sea voyages, particularly where travelling as deck cargo. Additionally, they may be required to withstand the effects of overland journeys on poor roads, and loading/unloading by inexperienced personnel.

8.4 Inspection, commissioning and testing

The general recommendations in section 6 should be followed, but particular consideration should be given to the requirements for inspection, bearing in mind relative locations (makers' works and the job site), programming requirements, costs, and the severity of the conditions at the installed location.

Where equipment has to stand on site for long periods the manufacturers should be consulted to establish the precautions to be taken. With many items of equipment it is important that they are inspected and turned over by hand at regular intervals. All air-conditioning and ventilating systems and equipment should also be protected, and regularly inspected, during the installation period and until such time as they are handed over ready for use. All control devices, electric motors and starters, control panels and instrumentation require special consideration. Also, in the case of refrigeration equipment, manufacturers' procedures for pressure testing, dehydration and charging should be rigorously observed.

Commissioning and testing should generally be in accordance with CIBS Commissioning Codes. Care should be taken to ensure that all technical information, instrumentation and other facilities or equipment (e.g. torches, ladders, etc.) are available, and that all test data is accurately recorded.

8.5 Operation and maintenance

System design and equipment selection should take careful account of operating and maintenance requirements. In remote locations, with relatively unskilled operatives, simplicity is usually essential for any aspect of operation and maintenance, particularly with automatic controls (see **8.2.2.6**).

Appendix A Bibliography

In addition to the standards listed on the inside back cover of this document, reference is made in the text to the following specific publications.

NOTE The latest edition should always be used unless otherwise indicated.

American Society of Heating, Refrigerating and Air Conditioning Engineers, 345 East 47th Street, New York, N.Y. 10017.

Handbooks: *Fundamentals*, 1977, Ch. 32

Systems, 1976, Ch. 26

British Gas, 326 High Holborn, London WC1V 7PT.

List of tested and approved commercial appliances

Building Research Establishment (HMSO).

Digest 158

Building Services Research and Information Association, Old Bracknell Lane, Bracknell, Berkshire, RG12 4AH.

Application Guides 1/75 and 1/77

Chartered Institution of Building Services, 49 Cadogar Square, London SW1X 0JB.

Building Energy Code

Commissioning Codes, especially series A, C, R and W

CIBS Guide

Practice Notes 1 and 2

Technical Memoranda 1, 2 and 3

Cooling Water Association, Secretariat, Eridon Ltd. 74 Queensway, London N2.

Guide to Mechanical Draught Evaporative Cooling Towers

Department of the Environment (HMSO).

Report of the Committee on Backsiphonage in Water Installations

Fire Research Station (HMSO).

Notes on the control of smoke and fire

Health and Safety Executive (HMSO).

Guidance Notes (details given under **5.2.9** in this code)

Heating and Ventilating Contractors' Association, ESCA House, 34 Palace Court, Bayswater, London W2 4JG.

Specification for sheet metal ductwork, 1977
DW/141 *Welding Safety, 1978*

Institution of Electrical Engineers, Savoy Place, Victoria Embankment, London WC2.

Regulations for the Electrical Equipment of Buildings

Ministry of Housing and Local Government (HMSO).

Design Bulletin 4

National Federation of Building Trades Employers 82 New Cavendish Street, London W1.

Construction Safety: Policy, Organization, Administration

Index

In this index references are to clause and subclause numbers.

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Publications referred to

BS 476, *Fire tests on building materials and structures.*

BS 476-7, *Surface spread of flame tests for materials.*

BS 587, *Motor starters and controllers.*

BS 749, *Underfeed stokers.*

BS 799, *Oil burning equipment.*

BS 848, *Methods of testing fans for general purposes, including mine fans.*

BS 1250, *Domestic appliances burning town gas.*

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

BS 1523-1, *Process and kinetic control.*

BS 1651, *Industrial gloves.*

BS 1870, *Safety footwear.*

BS 2486, *Recommendations for treatment of water for land boilers .*

BS 2831, *Methods of test for air filters used in air conditioning and general ventilation.*

BS 2852, *Rating and testing room air-conditioners.*

BS 3202, *Recommendations on laboratory furniture and fittings.*

BS 3561, *Non-domestic space heaters burning town gas.*

BS 3811, *Glossary of maintenance terms in terotechnology.*

BS 3899, *Refrigerated room, air-conditioners.*

BS 3928, *Method for sodium flame test for air filters (other than for air supply to i.c engines and compressors).*

BS 3958, *Thermal insulating materials.*

BS 3979, *Dimensions of electric motors (metric series).*

BS 4142, *Method of rating industrial noise affecting mixed residential and industrial areas.*

BS 4256, *Oil-burning air heaters.*

BS 4434, *Requirements for refrigeration safety.*

BS 4485, *Water cooling towers.*

BS 4740, *Method of evaluating control valve capacity.*

BS 4884, *Technical manuals.*

BS 4884-2, *Presentation.*

BS 4999, *General requirements for rotating electrical machines.*

BS 5000, *Rotating electrical machines of particular types or for particular applications.*

BS 5000-99, *Machines for miscellaneous applications.*

BS 5141, *Air heating and cooling coils.*

BS 5141-2, *Method of testing and rating of heating coils.*

BS 5240, *General purpose industrial safety helmets.*

BS 5295, *Environmental cleanliness in enclosed spaces.*

BS 5304, *Code of practice for safeguarding of machinery.*

BS 5384, *Guide to the selection and use of control systems for heating, ventilating and air conditioning installations.*

BS 5406, *The limitation of disturbances in electricity supply networks caused by domestic and similar appliances equipped with electronic devices.*

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

BS 5422, *Specification for the use of thermal insulating materials.*

BS 5440, *Code of practice for flues and air supply for gas appliances of rated input not exceeding 60 kW (1st and 2nd family gases.).*

BS 5486, *Specification for factory-built assemblies of switchgear and controlgear for voltages up to and including 1 000 V a.c. and 1 200 V d.c.*

BS 5486-1, *General requirements.*

BS 5588, *Code of practice for fire precautions in the design of buildings.*

BS 5588-4, *Smoke control in protected escape routes using pressurization.*

BS 5643, *Glossary of refrigeration, heating, ventilating and air conditioning terms.*

CP 3, *Code of basic data for the design of buildings.*

CP 3:Chapter I (C), *Ventilation.*

CP 3:Chapter IV, *Precautions against fire.*

CP 3:Chapter IV-1, *Flats and maisonettes (in blocks over two storeys).*

CP 3:Chapter IV-2, *Shops and departmental stores.*

CP 3:Chapter IV-3, *Office buildings.*

CP 331, *Installation of pipes and meters for town gas.*

CP 331-3, *Low pressure installation pipes.*

CP 332, *Selection and installation of town gas space heating.*

CP 332-4, *Ducted warm air systems.*

CP 413, *Ducts for building services.*

CP 1003, *Electrical apparatus and associated equipment for use in explosive atmospheres of gas or vapour other than mining application.*

CP 3005, *Thermal insulation of pipework and equipment [in the temperature range of – 100 °F to + 1 500 °F (– 73 °C to + 816°)].*

Other useful standards (see **1.2.1** of the code)

BS 874, *Methods for determining thermal insulating properties, with definitions of thermal insulating terms.*

BS 2972, *Methods of test for inorganic thermal insulating materials.*

BS 5000, *Rotating electrical machines of particular types or for particular applications.*

BS 5000-2, *Turbine-type machines.*

BS 5000-11, *Small power electric motors and generators.*

BS 5000-16, *Type N electric motors.*

BS 5000-40, *Motors for driving power station auxiliaries.*

BS 5141, *Air heating and cooling coils.*

BS 5141-1, *Method of testing for rating of cooling coils.*

BS 5376, *Code of practice for selection and installation of gas space heating (1st and 2nd family gases).*

BS 5376-2, *Boilers of rated input not exceeding 60 kW.*

BS 5493, *Code of practice for protective coating of iron and steel structures against corrosion.*

CP 331, *Installation of pipes and meters for town gas.*

CP 331-1, *Service pipes.*

CP 331-2, *Low pressure metering.*

CP 332, *Selection and installation of town gas space heating.*

CP 332-1, *Independent domestic appliances.*

CP 332-3, *Boilers of more than 150 000 Btu/h (44 kW) and up to 2 000 000 Btu/h (586 kW) output.*

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