SP 7 : Group 4 (2005): NATIONAL BUILDING CODE OF INDIA 2005 GROUP 4 [CED 46: National Building Code]

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# भारत की राष्ट्रीय भवन निर्माण संहिता 2005

## समूह 4

# NATIONAL BUILDING CODE OF INDIA 2005

## Group 4

# NATIONAL BUILDING CODE OF INDIA 2005

**GROUP 4**

PART 0 INTEGRATED APPROACH — PREREQUISITE FOR APPLYING PROVISIONS OF THE CODE

PART 8 BUILDING SERVICES

Section 1 Lighting and Ventilation
Section 2 Electrical and Allied Installations
Section 3 Air conditioning, Heating and Mechanical Ventilation
Section 4 Acoustics, Sound Insulation and Noise Control
Section 5 Installation of Lifts and Escalators

**BUREAU OF INDIAN STANDARDS**

**SP 7 (Group 4) : 2005**

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## FOREWORD

Construction programmes are interwoven in a large measure in all sectors of development, be it housing, transport, industry, irrigation, power, agriculture, education or health. Construction, both public and private, accounts for about fifty percent of the total outlay in any Five Year Plan. Half of the total money spent on construction activities is spent on buildings for residential, industrial, commercial, administrative, education, medical, municipal and entertainment uses. It is estimated that about half of the total outlay on buildings would be on housing. It is imperative that for such a large national investment, optimum returns are assured and wastage in construction is avoided.

Soon after the Third Plan, the Planning Commission decided that the whole gamut of operations involved in construction, such as, administrative, organizational, financial and technical aspects, be studied in depth. For this study, a Panel of Experts was appointed in 1965 by the Planning Commission and its recommendations are found in the 'Report on Economies in Construction Costs' published in 1968.

One of the facets of building construction, namely, controlling and regulating buildings through municipal byelaws and departmental handbooks received the attention of the Panel and a study of these regulatory practices revealed that some of the prevailing methods of construction were outmoded; some designs were overburdened with safety factors and there were other design criteria which, in the light of newer techniques and methodologies, could be rationalized; and building byelaws and regulations of municipal bodies which largely regulate the building activity in the country wherever they exist, were outdated. They did not cater to the use of new building materials and the latest developments in building designs and construction techniques. It also became clear that these codes and byelaws lacked uniformity and they were more often than not 'specification oriented' and not 'performance oriented'.

These studies resulted in a recommendation that a National Building Code be prepared to unify the building regulations throughout the country for use by government departments, municipal bodies and other construction agencies. The then Indian Standards Institution (now Bureau of Indian Standards) was entrusted by the Planning Commission with the preparation of the National Building Code. For fulfilling this task a Guiding Committee for the preparation of the Code was set up by the Civil Engineering Division Council of the Indian Standards Institution in 1967. This Committee, in turn, set up 18 specialist panels to prepare the various parts of the Code. The Guiding Committee and its panels were constituted with architects, planners, materials experts, structural, construction, electrical illumination, air conditioning, acoustics and public health engineers and town planners. These experts were drawn from the Central and State Governments, local bodies, professional institutions and private agencies. The first version of the Code was published in 1970.

After the National Building Code of India was published in 1970, a vigorous implementation drive was launched by the Indian Standards Institution to propagate the contents and use of the Code among all concerned in the field of planning, designing and construction activities. For this, State-wise Implementation Conferences were organized with the participation of the leading engineers, architects, town planners, administrators, building material manufacturers, building and plumbing services installation agencies, contractors, etc.

These Conferences were useful in getting across the contents of the Code to the interests concerned. These Conferences had also helped in the establishment of Action Committees to look into the actual implementation work carried out by the construction departments, local bodies and other agencies in different States. The main actions taken by the Action Committees were to revise and modernize their existing regulatory media, such as, specifications, handbooks, manuals, etc, as well as building byelaws of local bodies like municipalities at city and town levels, zilla parishads, panchayats and development authorities, so as to bring them in line with the provisions contained in the National Building Code of India. In this process, the Indian Standards Institution rendered considerable support in redrafting process.

Since the publication in 1970 version of the National Building Code of India, a large number of comments and useful suggestions for modifications and additions to different parts and sections of the Code were received as a result of use of the Code by all concerned, and revision work of building byelaws of some States. Based on the comments and suggestion received the National Building Code of India 1970 was revised in 1983.

Some of the important changes in 1983 version included : addition of development control rules, requirements for greenbelts and landscaping including norms for plantation of shrubs and trees, special requirements for low income housing; fire safety regulations for high rise buildings; revision of structural design section based on new and revised codes, such as Concrete Codes (plain and reinforced concrete and prestressed concrete), Earthquake Code, Masonry Code; addition of outside design conditions for important cities in the country, requirements relating to noise and vibration, air filter, automatic control, energy conservation for air conditioning; and guidance on the design of water supply system for multi-storeyed buildings.

The National Building Code of India is a single document in which, like a network, the information contained in various Indian Standards is woven into a pattern of continuity and cogency with the interdependent requirements of Sections carefully analyzed and fitted in to make the whole document a cogent continuous volume. A continuous thread of 'preplanning' is woven which, in itself, contributes considerably to the economies in construction particularly in building and plumbing services.

The Code contains regulations which can be immediately adopted or enacted for use by various departments, municipal administrations and public bodies. It lays down a set of minimum provisions designed to protect the safety of the public with regard to structural sufficiency, fire hazards and health aspects of buildings; so long as these basic requirements are met, the choice of materials and methods of design and construction is left to the ingenuity of the building professionals. The Code also covers aspects of administrative regulations, development control rules and general building requirements; fire protection requirements; stipulations regarding materials and structural design; rules for design of electrical installations, lighting, air conditioning and lifts; regulation for ventilation, acoustics and plumbing services, such as, water supply, drainage, sanitation and gas supply; measures to ensure safety of workers and public during construction; and rules for erection of signs and outdoor display structures.

Some other important points covered by the Code include 'industrialized systems of building' and 'architectural control'. The increase in population in the years to come will have a serious impact on the housing problem. It has been estimated that the urban population of India will continue to increase with such pace as to maintain the pressure on demand of accommodation for them. Speed of construction is thus of an utmost importance and special consideration has to be given to industrialized systems of building. With increased building activity, it is also essential that there should be some architectural control in the development of our cities and towns if creation of ugliness and slum-like conditions in our urban areas is to be avoided.

Since the publication of 1983 version of National Building Code of India, the construction industry has gone through major technological advancement. In the last two decades, substantial expertise has been gained in the areas of building planning, designing and construction. Also, lot of developments have taken places in the techno-legal regime and techno-financial regime, apart from the enormous experience gained in dealing with natural calamities like super cyclones and earthquakes faced by the country. Further, since the last revision in 1983 based on the changes effected in the Steel Code, Masonry Code and Loading Code as also in order to update the fire protection requirements, three amendments were brought out to the 1983 version of the Code. Considering these, it was decided to take up a comprehensive revision of the National Building Code of India.

The changes incorporated in the present Code, which is second revision of the Code, have been specified in the Foreword to each Part/Section of the Code. Some of the important changes are:

a) A new Part 0 'Integrated Approach — Prerequisite for Applying the Provisions of the Code' emphasizing on multi-disciplinary team approach for successfully accomplishing building/development project, has been incorporated.
b) New chapters on significant areas like structural design using bamboo, mixed/composite construction and landscaping have been added.
c) Number of provisions relating to reform in administration of the Code as also assigning duties and responsibilities to all concerned professionals, have been incorporated/modified. Also detailed provisions/performance to ensure structural sufficiency of buildings, have been prescribed so as to facilitate implementation of the related requirements to help safely face the challenges during natural disasters like earthquake.
d) Planning norms and requirements for hilly areas and rural habitat planning, apart from detailed planning norms for large number of amenities have been incorporated.
e) Fire safety aspects have been distinctly categorized into fire prevention, life safety and fire protection

giving detailed treatment to each based on current international developments and latest practices followed in the country.

f) Aspects like energy conservation and sustainable development have been consistently dealt with in various parts and sections through appropriate design, usage and practices with regard to building materials, construction technologies and building and plumbing services. Renewable resources like bamboo and practices like rain water harvesting have been given their due place.

g) The latest revised earthquake code, IS 1893 (Part 1) : 2002 'Criteria for earthquake resistant design of structures: Part 1 General provisions and buildings', has been incorporated, due implementation of the provisions of which in applicable seismic zone of the country, needs to be duly adhered to by the Authorities.

The Code now published is the third version representing the present state of knowledge on various aspects of building construction. The process of preparation of the 2005 version of the Code had thrown up a number of problems; some of them were answered fully and some partially. Therefore, a continuous programme will go on by which additional knowledge that is gained through technological evolution, users' views over a period of time pinpointing areas of clarification and coverage and results of research in the field, would be incorporated in to the Code from time to time to make it a living document. It is, therefore, proposed to bring out changes to the Code periodically.

The provisions of this Code are intended to serve as a model for adoption by Public Works Departments and other government construction departments, local bodies and other construction agencies. Existing PWD codes, municipal byelaws and other regulatory media could either be replaced by the National Building Code of India or suitably modified to cater to local requirements in accordance with the provisions of the Code. Any difficulties encountered in adoption of the Code could be brought to the notice of the Sectional Committee for corrective action.

This publication forms part of the National Building Code of India 2005 and contains the following Parts:

PART 0 INTEGRATED APPROACH — PREREQUISITE FOR APPLYING PROVISIONS OF THE CODE

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Section 4 Acoustics, Sound Insulation and Noise Control
Section 5 Installation of Lifts and Escalators

The information contained in this publication will essentially serve the concerned professionals in dealing with various building services.

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## Important Explanatory Note for Users of Code

In this Code, where reference is made to 'accepted standards' in relation to material specification, testing or other related information or where reference is made to 'good practice' in relation to design, constructional procedures or other related information, the Indian Standards listed at the end of the concerned Parts/Sections may be used to the interpretation of these terms.

At the time of publication, the editions indicated in the above Indian Standards were valid. All standards are subject to revision and parties to agreements based on the Parts/Sections are encouraged to investigate the possibility of applying the most recent editions of the standards.

In the list of standards given at the end of each Part/Section, the number appearing in the first column indicates the number of the reference in that Part/Section. For example:

a) good practice [8-1(1)] refers to the standard given at serial number 1 of the list of standards given at the end of Section 1 of Part 8, that is IS 7662 (Part 1) : 1974 'Recommendations for orientation of buildings : Part 1 Non-industrial buildings'.

b) good practice [8-1(27)] refers to the standard given at serial number 27 of the list of standards given at the end of Section 2 of Part 8, that is IS 2309 : 1989 'Code of practice for the protection of buildings and allied structures against lightning (*second revision*)'.

c) accepted standard [8-3(5)] refers to the standard given at serial number 5 of the list of standards given at the end of Section 3 of Part 8, that is IS 3315 : 1994 'Specification for evaporative air coolers (desert coolers) (*second revision*).

d) accepted standard [8-4(1)] refers to the standard given at serial number 1 of the list of standards given at the end of Section 4 of Part 8, that is IS 11050 (Part 1) : 1984 'Rating of sound insulation in buildings and of building elements: Part 1 Air-borne sound insulation in buildings and of interior building elements.

e) accepted standard [8-5(9)] refers to the standard given at serial number 9 of the list of standards given at the end of Section 5 of Part 8, that is IS 14665 (Part 3/Sec 1 and 2) : 2000 'Electric traction lifts: Part 3 Safety rules — Section 1 Passenger and goods lifts, Section 2 Service lifts'.

## INFORMATION FOR THE USERS

For the convenience of the users, the National Building Code of India 2005 is available as a comprehensive volume as well as in the following five groups, each incorporating the related Parts/Sections dealing with particular area of building activity:

| | | | |
|---|---|---|---|
| **Group 1** | **For Development, Building Planning and Related Aspects** | Part 0: | Integrated Approach — Prerequisite for Applying Provisions of the Code |
| | | Part 2: | Administration |
| | | Part 3: | Development Control Rules and General Building Requirements |
| | | Part 4: | Fire and Life Safety |
| | | Part 5: | Building Materials |
| | | Part 10: | Landscaping, Signs and Outdoor Display Structures |
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# NATIONAL BUILDING CODE OF INDIA

## PART 0 INTEGRATED APPROACH — PREREQUISITE FOR APPLYING PROVISIONS OF THE CODE

BUREAU OF INDIAN STANDARDS

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National Building Code Sectional Committee, CED 46

FOREWORD

In order to provide safe and healthy habitat, careful consideration needs to be paid to the building construction activity. Building planning, designing and construction activities have developed over the centuries. Large number of ancient monuments and historical buildings all over the world bear testimony to the growth of civilization from the prehistoric era with the extensive use of manual labour and simple systems as appropriate to those ages to the present day mechanized and electronically controlled operations for designing and constructing buildings and for operating and maintaining systems and services. In those days those buildings were conceptualized and built by master builders with high levels of artisan skills. Technological and socio-economic developments in recent times have led to remarkable increase in demand for more and more sophistication in buildings resulting in ever increasing complexities. These perforce demand high levels of inputs from professionals of different disciplines such as architecture, civil engineering, structural engineering, functional and life safety services including special aspects relating to utilities, landscaping, etc in conceptualization, spatial planning, design and construction of buildings of various material and technology streams, with due regard to various services including operation, maintenance, repairs and rehabilitation aspects throughout the service life of the building.

This Code, besides prescribing the various provisions, also allows freedom of action to adopt appropriate practices and provides for building planning, designing and construction for absorbing traditional practices as well as latest developments in knowledge in the various disciplines as relevant to a building including computer aided and/or other modern sensors aided activities in the various stages of conceptualization, planning, designing, constructing, maintaining and repairing the buildings. India being a large country with substantial variations from region to region, this Code has endeavoured to meet the requirements of different regions of the country, both urban and rural, by taking into consideration factors, such as, climatic and environmental conditions, geographical terrain, proneness to natural disasters, ecologically appropriate practices, use of eco-friendly materials, reduction of pollution, protection and improvement of local environment and also socio-economic considerations, towards the creation of sustainable human settlements.

This Part of the Code dealing with ‘integrated approach’ is being included for the first time. It gives an overall direction for practical applications of the provisions of different specialized aspects of spatial planning, designing and construction of buildings, creation of services, and proposes an integrated approach for utilizing appropriate knowledge and experience of qualified professionals right from the conceptualization through construction and completion stages of a building project and indeed during the entire life cycle. The ‘integrated approach’ should not only take care of functional, aesthetic and safety aspects, but also the operational and maintenance requirements. Also, cost optimization has to be achieved through proper selection of materials, techniques, equipment installations, etc. Further, value engineering and appropriate management techniques should be applied to achieve the aim set forth for the purpose of construction of a building fully meeting the specified and implied needs of spatial functions, safety and durability aspects, life and health safety, comfort, services, etc in the building.

The aim of the ‘integrated approach’ is to get the maximum benefit from the building and its services in terms of quality, timely completion and cost-effectiveness. In the team approach which is an essential pre-requisite for integrated approach, the aim clearly is to maximize the efficiency of the total system through appropriate optimization of each of its sub-systems. In other words, in the team, the inputs from each of the professional disciplines have to be so optimized that the total system’s efficiency becomes the maximum. It may be re-emphasized that maximizing the efficiencies of each sub-system may not necessarily assure the maximization of the efficiency of the total system. It need hardly to be stated that specified or implied safety will always get precedence over functional efficiency and economy. Further, progressive approach such as that relating to the concept of intelligent buildings would be best taken care of by the ‘integrated approach’ as laid down in this Part.

Quality systems approach and certification thereunder covering the various dimensions brought out above may go a long way in achieving the above goal of real integrated approach.

# NATIONAL BUILDING CODE OF INDIA

## PART 0 INTEGRATED APPROACH — PREREQUISITE FOR APPLYING PROVISIONS OF THE CODE

### 1 SCOPE

This Part covers guidelines to be followed for judicious implementation of the provisions of various Parts/ Sections of the Code.

### 2 TERMINOLOGY

**2.0** For the purpose of this Part, the following definitions and those given in Part 1 'Definitions' shall apply.

**2.1 Authority Having Jurisdiction** — The Authority which has been created by a statute and which, for the purpose of administering the Code/Part, may authorize a committee or an official or an agency to act on its behalf; hereinafter called the 'Authority'.

**2.2 Building** — Any structure for whatsoever purpose and of whatsoever materials constructed and every part thereof whether used as human habitation or not and includes foundation, plinth, walls, floors, roofs, chimneys, plumbing and building services, fixed platforms, *VERANDAH*, balcony, cornice or projection, part of a building or anything affixed thereto or any wall enclosing or intended to enclose any land or space and signs and outdoor display structures. Tents/ *SHAMIANAHS/PANDALS*, tarpaulin shelters, etc, erected for temporary and ceremonial occasions shall not be considered as building.

**2.3 Owner** — Person or body having a legal interest in land and/or building thereon. This includes free holders, leaseholders or those holding a sub-lease which both bestows a legal right to occupation and gives rise to liabilities in respect of safety or building condition.

In case of lease or sub-lease holders, as far as ownership with respect to the structure is concerned, the structure of a flat or structure on a plot belongs to the allottee/ lessee till the allotment/lease subsists.

NOTE — For the purpose of the Code, the word 'owner' will also cover the generally understood terms like 'client', 'user', etc.

### 3 GENERAL

**3.1** Buildings, shall be classified as Residential, Educational, Institutional, Assembly, Business, Mercantile, Industrial, Storage and Hazardous in groups and sub-division as classified in Part 4 'Fire and Life Safety'.

For further sub-classification of buildings and various related provisions thereof with respect to administration; development control rules and general building requirements; building materials; fire and life safety; structural design; constructional practices and safety; building and plumbing services; and landscaping, signs and outdoor display structures, other parts/sections of the Code may be referred to.

**3.2** The scope of various Parts/Sections of the Code which cover detailed provisions on different aspects of development of land/building construction activity, are given in Annex A, with a view to providing an overview for the users of the Code.

### 4 TEAM APPROACH

A land development/building project comprises the following major stages:

a) Location/siting,
b) Conceptualization and planning,
c) Designing and detailing,
d) Construction/execution, and
e) Maintenance and repair.

Each stage necessarily requires professionals of many disciplines who should work together as a well coordinated team to achieve the desired product delivery with quality, in an effective manner.

Appropriate multi-disciplinary teams need to be constituted to successfully meet the requirements of different stages. Each team may comprise need based professionals out of the following depending upon the nature, magnitude and complexity of the project:

a) Architect,
b) Civil engineer,
c) Structural engineer,
d) Electrical engineer,
e) Plumbing engineer,
f) Fire protection engineer,
g) HVAC engineer,
h) Environment specialist,
j) Town planner,
k) Urban designer,
m) Landscape architect,
n) Security system specialist,
p) Interior designer,
q) Quantity surveyor,
r) Project/construction manager, and
s) Other subject specialist(s).

### 4.1 Design Team

In building projects various aspects like form; space planning; aesthetics; fire and life safety; structural adequacy; plumbing services; lighting and natural ventilation; electrical and allied installations; air conditioning, heating and mechanical ventilation; acoustics, sound insulation and noise control; installation of lifts and escalators; building automation; data and voice communication; other utility services installations; landscape planning and design; urban planning; etc need to be kept in view right at the concept stage. The project requiring such multi-disciplinary inputs need a co-ordinated approach among the professionals for proper integration of various design inputs. For this, and to take care of the complexities of multi-disciplinary requirements, a design team of professionals from required disciplines shall be constituted at the appropriate stage. Here, it is desirable that the multi-disciplinary integration is initiated right from the concept stage. The team shall finalize the plan. The composition of the team shall depend on the nature and magnitude of the project. Design is an evolutionary and participatory process, where participation of owner constitutes a very important input at all stages, and the same shall be ensured by the design team.

To ensure proper implementation of the design, the design team, may be associated during the construction/ execution stage.

### 4.2 Project Management and Construction Management Teams

The objective of project management or construction management is primarily to achieve accomplishment of project in accordance with the designs and specifications in a stipulated time and cost framework, with a degree of assurance prior to commencement and satisfaction on accomplishment.

For large projects, separate teams of experienced professionals from the required disciplines may be constituted for project management and for construction management depending upon the complexities of the project. However, for smaller projects these teams may be combined. The teams shall be responsible for day-to-day execution, supervision, quality control, etc and shall ensure inter-disciplinary co-ordination during the construction stage. The team shall be responsible to achieve satisfactory completion of the project with regard to cost, time and quality. Some members of the design team may also be included in the project management team and/or associated actively during the project execution stage. It is important that leaders and members of project management/construction management teams, depending on the size and complexity of the project, are carefully selected considering their qualification, experience and expertise in these fields.

### 4.3 Operation and Maintenance Team

Operation, maintenance and repairs also require a multi-disciplinary approach to ensure that all the requirements of the users are satisfactorily met. During maintenance and repairs, the jobs requiring inter-disciplinary co-ordination have to be executed in such a manner as not only to cause least inconvenience to the user but also to ensure that there is no mismatch or damage to the structure, finishings, fittings and fixtures. For carrying out routine maintenance/repair jobs, utilization of the services of trained technicians preferably having multi-disciplinary skills should be encouraged.

Special repairs, rehabilitation and retrofitting are specialized jobs which demand knowledge of the existing structure/installations. Association of concerned specialists may be helpful for these works.

The Operation and Maintenance Team may also be known as Asset Management or Estate Management Team.

## 5 PLANNING, DESIGNING AND DEVELOPMENT

**5.1** The main functions of design team (*see* **4.1**) constituted for the planning, designing and development, are as under:

a) Formalization of design brief in consultation with the owner.

b) Site investigation/survey.

c) Preparation of alternative concept designs.

d) Selection of a concept in consultation with and with the consent of owner.

e) Sizing the system.

f) Development of design, covering :

   1) Integration of architecture, structure and services,

   2) Synthesis of requirements of each discipline, and

   3) Interaction with each other and with the owner.

g) Preparation of preliminary designs and drawings and obtaining owner’s approval.

h) Preparation of preliminary cost estimates for approval of owner.

j) Preparation of work-breakdown structure and programme for pre-construction activities.

k) Assisting client to obtain approvals of the Authority.

m) Preparation of detailed specification and construction working drawings with integration of engineering inputs of all concerned disciplines.

n) Preparation of detailed design of each discipline for various services.

p) Peer review/proof checking of the drawings/ designs in case of important projects, depending upon their complexity and sensitivity.

q) Preparation of detailed cost estimate.

r) Obtaining final approval of client.

s) Preparation of bill of quantities, specifications and tender documents.

**5.2** The following considerations, as may be applicable to the project, may be considered during planning, notwithstanding other relevant aspects specifically prescribed in concerned parts/sections of this Code; these considerations in general are with the objective of addressing to the important issues like environmental protection, energy conservation, cultural issues, creating barrier free built-environment, safety aspects, etc, all of these leading towards sustainable development, and have to be applied with due regard to the specific requirements of size and type of project:

a) Geoclimatic, geological and topographical features.

b) Varied sociological pattern of living in the country.

c) Effective land use to cater to the needs of the society in a most convenient manner.

d) Modular planning and standardization to take care of future planning giving due consideration to the specified planning controls.

e) Emphasis on daylight utilization, natural ventilation, shielding, and window area and its disposition; daylighting to be supplemented with an integrated design of artificial lighting.

f) Optimum utilization of renewable energy sources duly integrated in the overall energy system design; with consideration of active and passive aspects in building design including thermal performance of building envelope.

g) Rain water harvesting, and use of appropriate building materials considering aspects like energy consumption in production, transportation and utilization, recyclability, etc for promoting sustainable development.

h) Requisite mandatory provisions for handicapped persons.

j) Acoustical controls for buildings and the surroundings.

k) Promotion of artwork in buildings, specially buildings of importance.

m) Due cognizance of recommendations of the Archeological Survey of India with regard to national monuments and construction in archeologically important sites.

n) Due cognizance of relevant provisions of applicable coastal zone regulation act.

p) Conservation of heritage structures and areas.

q) Environmental and social impact analysis.

r) Design of services with emphasis on aspects of energy efficiency, environment friendliness and maintainability.

s) Integrated waste management.

t) Voice and data communication, automation of building services, and intelligent building; use of security and surveillance system in important and sensitive buildings, such as, access control for the people as well as for vehicle.

u) Interlinking of fire alarm system, fire protection system, security system, ventilation, electrical systems, etc.

v) Analysis of emergency power, standby power requirement and captive power systems.

w) Cost optimization through techniques like value engineering.

y) Adoption of innovative technologies giving due consideration to constructability and quality aspects.

z) Instrumentation of buildings and monitoring and use of information so generated to effect improvements in planning and design of future building projects.

## 6 CONSTRUCTION/EXECUTION (ACTUALIZATION)

**6.1** The main functions of the teams (*see* **4.2**) constituted for Project Management/Construction Management may be, to :

a) specify criteria for selection of constructors;

b) specify quality control, quality audit system and safety system;

c) short-list constructors;

d) have pre-bid meetings with the intending constructors;

e) receive and evaluate tenders;

f) select constructors;

g) execution and supervision;

h) monitor quality, time and cost control;

j) prepare/certify the completion (as-built) drawings; and

k) ensure availability of operation manuals for field use.

**6.2** Apart from the specific provisions laid down in the concerned Parts/Sections of the Code, the following considerations, as may be applicable to the project concerned, shall be given due attention:

a) Adopting scientific principles of construction management, quality management, cost and time control.

b) Engagement of executing and supervising agencies, which meet the specified norms of skills, specialization, experience, resourcefulness, etc for the work.

c) Ensuring inter-disciplinary co-ordination during construction.

d) Contract management and techno-legal aspects.

e) Completion, commissioning and trial run of installations/equipments and their operation and maintenance through the suppliers/other teams, where necessary.

f) Make available shop drawings as well as as-built drawings for the building and services.

g) Arrange all maintenance and operation manual from the concerned suppliers/manufacturers.

**6.3** The team of professionals (*see* **4.2**) shall work and monitor the project activities for successful construction/execution of the project with regard to cost, time, quality and safety.

## 7 OPERATION AND MAINTENANCE

**7.1** The team of professionals (*see* **4.3**) shall set up a system of periodic maintenance and upkeep of constructed buildings.

**7.2** The operation and maintenance team shall be responsible for preparation/application of operation and maintenance manual, and draw maintenance schedule/frequencies and guidelines for maintenance personnel. Apart from the specific provisions laid down in concerned Parts/Sections of the Code, the following, as may be applicable to the project concerned shall additionally be taken into account:

a) Periodic validation of buildings by competent professionals through inspection of the buildings in respect of structural safety and safety of electrical and other installations and ensuring that all fire safety equipments/systems are in proper working condition.

b) Preparation of preventive maintenance schedules for all installations in the building and strictly following the same; the record of the preventive maintenance to be properly kept.

c) Ensuring inter-disciplinary co-ordination during maintenance and repairs; deployment of trained personnel with multi-disciplinary skills to be encouraged.

d) Condition survey of structures and installations, identification of distress of various elements and initiating plans for rehabilitation/retrofitting well in time.

**7.3** The proposals for rehabilitation/retrofitting should be prepared after detailed investigations through visual inspection, maintenance records and testing as required and got executed through specialized agencies under the guidance and supervision of competent professionals.

# ANNEX A

(*Clause* 3.2)

## BRIEF DETAILS OF THE COVERAGE OF VARIOUS PROVISIONS UNDER DIFFERENT OTHER PARTS/SECTIONS OF THIS CODE

**A-1 PART 1 DEFINITIONS**

It lists the terms appearing in all the Parts/Sections of the Code. However, some common definitions are reproduced in this Part also.

**A-2 PART 2 ADMINISTRATION**

It covers the administrative aspects of the Code, such as applicability of the Code, organization of building department for enforcement of the Code, procedure for obtaining development and building permits, and responsibility of the owner and all professionals involved in the planning, design and construction of the building.

**A-3 PART 3 DEVELOPMENT CONTROL RULES AND GENERAL BUILDING REQUIREMENTS**

It covers the development control rules and general building requirements for proper planning and design at the layout and building level to ensure health safety, public safety and desired quality of life.

**A-4 PART 4 FIRE AND LIFE SAFETY**

It covers the requirements for fire prevention, life safety in relation to fire, and fire protection of buildings. The Code specifies planning and construction features and fire protection features for all occupancies that are necessary to minimize danger to life and property.

**A-5 PART 5 BUILDING MATERIALS**

It covers the requirements of building materials and components, and criteria for accepting new or alternative building materials and components.

**A-6 PART 6 STRUCTURAL DESIGN**

This Part through its seven sections provides for structural adequacy of buildings to deal with both internal and external environment, and provide guidance to engineers/structural engineers for varied usage of material/technology types for building design.

**A-6.1 Section 1 Loads, Forces and Effects**

It covers basic design loads to be assumed in the design of buildings. The live loads, wind loads, seismic loads, snow loads and other loads, which are specified therein, are minimum working loads which should be taken into consideration for purposes of design.

**A-6.2 Section 2 Soils and Foundations**

It covers structural design (principles) of all building foundations, such as, raft, pile and other foundation systems to ensure safety and serviceability without exceeding the permissible stresses of the materials of foundations and the bearing capacity of the supporting soil.

**A-6.3 Section 3 Timber and Bamboo**

**A-6.3.1** *Section 3A Timber*

It covers the use of structural timber in structures or elements of structures connected together by fasteners/ fastening techniques.

**A-6.3.2** *Section 3B Bamboo*

It covers the use of bamboo for constructional purposes in structures or elements of the structure, ensuring quality and effectiveness of design and construction using bamboo. It covers minimum strength data, dimensional and grading requirements, seasoning, preservative treatment, design and jointing techniques with bamboo which would facilitate scientific application and long-term performance of structures. It also covers guidelines so as to ensure proper procurement, storage, precautions and design limitations on bamboo.

**A-6.4 Section 4 Masonry**

It covers the structural design aspects of unreinforced load bearing and non-load bearing walls, constructed using various bricks, stones and blocks permitted in accordance with this Section. This, however, also covers provisions for design of reinforced brick and reinforced brick concrete floors and roofs. It also covers guidelines regarding earthquake resistance of low strength masonry buildings.

**A-6.5 Section 5 Concrete**

**A-6.5.1** *Section 5A Plain and Reinforced Concrete*

It covers the general structural use of plain and reinforced concrete.

**A-6.5.2** *Section 5B Prestressed Concrete*

It covers the general structural use of prestressed concrete. It covers both work carried out on site and the manufacture of precast prestressed concrete units.

**A-6.6 Section 6 Steel**

It covers the use of structural steel in general building construction including the use of hot rolled steel sections and steel tubes.

**A-6.7 Section 7 Prefabrication, Systems Building and Mixed/Composite Construction**

**A-6.7.1** *Section 7A Prefabricated Concrete*

It covers recommendations regarding modular planning, component sizes, prefabrication systems, design considerations, joints and manufacture, storage, transport and erection of prefabricated concrete elements for use in buildings and such related requirements for prefabricated concrete.

**A-6.7.2** *Section 7B Systems Building and Mixed/Composite Construction*

It covers recommendations regarding modular planning, component sizes, joints, manufacture, storage, transport and erection of prefabricated elements for use in buildings and such related requirements for mixed/composite construction.

**A-7 PART 7 CONSTRUCTIONAL PRACTICES AND SAFETY**

It covers the constructional planning, management and practices in buildings; storage, stacking and handling of materials and safety of personnel during construction operations for all elements of a building and demolition of buildings. It also covers guidelines relating to maintenance management, repairs, retrofitting and strengthening of buildings. The objective can be best achieved through proper coordination and working by the project management and construction management teams.

**A-8 PART 8 BUILDING SERVICES**

This Part through its five elaborate sections on utilities provides detailed guidance to concerned professionals/utility engineers for meeting necessary functional requirements in buildings.

**A-8.1 Section 1 Lighting and Ventilation**

It covers requirements and methods for lighting and ventilation of buildings.

**A-8.2 Section 2 Electrical and Allied Installations**

It covers the essential requirements for electrical and allied installations in buildings to ensure efficient use of electricity including safety from fire and shock. This Section also includes general requirements relating to lightning protection of buildings.

**A-8.3 Section 3 Air Conditioning, Heating and Mechanical Ventilation**

This Section covers the design, construction and installation of air conditioning and heating systems and equipment installed in buildings for the purpose of providing and maintaining conditions of air temperature, humidity, purity and distribution suitable for the use and occupancy of the space.

**A-8.4 Section 4 Acoustics, Sound Insulation and Noise Control**

It covers requirements and guidelines regarding planning against noise, acceptable noise levels and the requirements for sound insulation in buildings with different occupancies.

**A-8.5 Section 5 Installation of Lifts and Escalators**

It covers the essential requirements for the installation, operation, maintenance and also inspection of lifts (passenger lifts, goods lifts, hospital lifts, service lifts and dumb-waiter) and escalators so as to ensure safe and satisfactory performance.

**A-9 PART 9 PLUMBING SERVICES**

This Part through its two sections gives detailed guidance to concerned professionals/plumbing engineers with regard to plumbing and other related requirements in buildings.

**A-9.1 Section 1 Water Supply, Drainage and Sanitation (Including Solid Waste Management)**

It covers the basic requirements of water supply for residential, business and other types of buildings, including traffic terminal stations. This Section also deals with general requirements of plumbing connected to public water supply and design of water supply systems.

It also covers the design, layout, construction and maintenance of drains for foul water, surface water and sub-soil water and sewage; together with all ancillary works, such as connections, manholes and inspection chambers used within the building and from building to the connection to a public sewer, private sewer, individual sewage-disposal system, cess-pool, soakaway or to other approved point of disposal/treatment work. It also includes the provisions on solid waste management.

**A-9.2 Section 2 Gas Supply**

It covers the requirements regarding the safety of persons and property for all piping uses and for all types of gases used for fuel or lighting purposes in buildings.

## A-10 PART 10 LANDSCAPING, SIGNS AND OUTDOOR DISPLAY STRUCTURES

### A-10.1 Section 1 Landscape Planning and Design

It covers requirements of landscape planning and design with the view to promoting quality of outdoor built environment and protection of land and its resources.

### A-10.2 Section 2 Signs and Outdoor Display Structures

It covers the requirements with regard to public safety, structural safety and fire safety of all signs and outdoor display structures including the overall aesthetical aspects of imposition of signs and outdoor display structures in the outdoor built environment.

# NATIONAL BUILDING CODE OF INDIA

## PART 8 BUILDING SERVICES

### Section 1 Lighting and Ventilation

BUREAU OF INDIAN STANDARDS

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National Building Code Sectional Committee, CED 46

## FOREWORD

Illumination levels for different tasks are recommended to be achieved either by daylighting or artificial lighting or a combination of both. This Section, read together with Part 8 'Building Services, Section 2 Electrical and Allied Installations', adequately covers the illumination levels required and methods of achieving the same.

Ventilation requirements to maintain air quality and control body odours in terms of air changes per hour and to ensure thermal comfort and heat balance of body are laid for different occupancies and the methods of achieving the same by natural means are covered in this Section. The provisions on mechanical ventilation are covered in Part 8 'Building Services, Section 3 Air Conditioning, Heating and Mechanical Ventilation'.

Climatic factors which normally help in deciding the orientation of the buildings to get desirable benefits of lighting and ventilation inside the buildings are also covered in this Section.

This Section was first published in 1970. The first revision of the Section was brought out in 1983. In this revision, some provisions have been updated based on the information given in the SP 41 : 1987 'Handbook on functional requirements of buildings (other than industrial buildings)'; other major changes in this revision are:

a) Rationalization of definitions and inclusion of definitions for some more terms.
b) A climatic classification map of India based on a new criteria has been included.
c) Data on total solar radiations incident on various surfaces of buildings for summer and winter seasons have been updated.
d) Design guidelines for natural ventilation have been included.
e) For guidelines on mechanical ventilation, reference to Part 8 'Building Services, Section 3 Air Conditioning, Heating and Mechanical Ventilation' has been made, where these provisions have now been covered exhaustively.
f) Rationalized method for estimation of desired capacity of ceiling fans and their optimum height above the floor for rooms of different sizes have been included.
g) Design sky illuminance values for different climatic zones of India have been incorporated.

Energy efficiency is an important aspect being taken care of in this revision of the Code. Accordingly, the relevant requirements for energy efficient system for lighting and ventilation have been duly included in the concerned provisions under this Section.

The provisions of this Section are without prejudice to the various Acts, Rules and Regulations including the *Factories Act,* 1948 and Rules and Regulations framed thereunder.

The information contained in this Section in largely based on the following Indian Standards/Special Publications:

| | |
|---|---|
| IS 2440 : 1975 | Guide for daylighting of buildings (*second revision*) |
| IS 3103 : 1975 | Code of practice for industrial ventilation (*first revision*) |
| IS 3362 : 1977 | Code of practice for natural ventilation of residential buildings (*first revision*) |
| IS 3646 (Part 1) : 1992 | Code of practice for interior illumination: Part 1 General requirements and recommendations for building interiors (*first revision*) |
| IS 7662 (Part 1) : 1974 | Recommendations for orientation of buildings: Part 1 Non-industrial buildings |
| IS 11907 : 1986 | Recommendations for calculation of solar radiation on buildings |
| SP 32 : 1986 | Handbook on functional requirements of industrial buildings (lighting and ventilation) |
| SP 41 : 1987 | Handbook on functional requirements of buildings other than industrial buildings |

Provisions given in National Lighting Code (*under preparation*) may also be referred.

The following publication has also been referred to in the preparation of this Section:

Report on energy conservation in buildings, submitted to Department of Power, Ministry of Energy by Central Building Research Institute, Roorkee.

All standards, whether given herein above or cross-referred to in the main text of this Section, are subject to revision. The parties to agreement based on this Section are encouraged to investigate the possibility of applying the most recent editions of the standards.

# NATIONAL BUILDING CODE OF INDIA

## PART 8 BUILDING SERVICES

## Section 1 Lighting and Ventilation

**1 SCOPE**

This Section covers requirements and methods for lighting and ventilation of buildings.

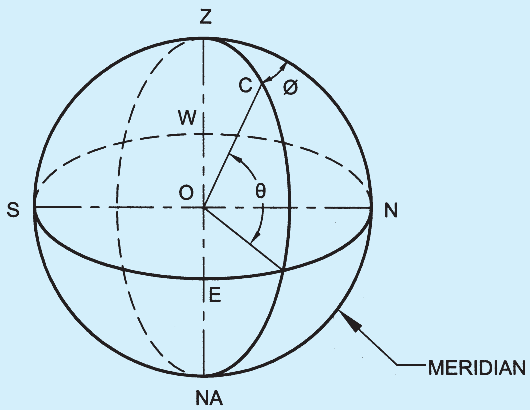
**2 TERMINOLOGY**

**2.0** For the purpose of this Section, the following definitions shall apply.

**2.1 Lighting**

**2.1.1** *Altitude* (θ) — The angular distance of any point of celestial sphere, measured from the horizon, on the great circle passing through the body and the zenith (*see* Fig. 1).

**2.1.2** *Azimuth* (ϕ) — The angle measured between meridians passing through the north point and the point in question (point *C* in Fig. 1).




REFERENCES

| | | | |
|---|---|---|---|
| *O* – | Observer's station | *S* – | Geographical south |
| *C* – | Celestial body | *E* – | Geographical east |
| *Z* – | Zenith | *W* – | Geographical west |
| *NA* – | Nadir | *N* – | Geographical north |

FIG. 1 ALTITUDE AND AZIMUTH OF A CELESTIAL BODY

**2.1.3** *Brightness Ratio or Contrast* — The variations or contrast in brightness of the details of a visual task, such as white print on blackboard.

**2.1.4** *Candela* (*cd*) — The SI unit of luminous intensity.

Candela = 1 lumen per steradian

**2.1.5** *Central Field* — The area of circle round the point of fixation and its diameter, subtending an angle of about 2° at the eye. Objects within this area are most critically seen in both their details and colour.

**2.1.6** *Clear Design Sky* — The distribution of luminance of such a sky is non-uniform; the horizon is brighter than the zenith, and when $L_z$ is the brightness at zenith, the brightness at an altitude (θ) in the region away from the sun, is given by the expression:

$$L_\theta = L_z \operatorname{cosec} \theta$$

when θ lies between 15° and 90°, and $L_\theta$ is constant when θ lies between 0° and 15°.

**2.1.7** *Colour Rendering Index (CRI)* — Measure of the degree to which the psychophysical colour of an object illuminated by the test illuminant conforms to that of the same object illuminated by the reference illuminant, suitable allowance having been made for the state of chromatic adaptation.

**2.1.8** *Correlated Colour Temperature (CCT) (Unit: K)* — The temperature of the Planckian radiator whose perceived colour most closely resembles that of a given stimulus at the same brightness and under specified viewing conditions.

**2.1.9** *Daylight Area* — The superficial area on the working plane illuminated to not less than a specified daylight factor, that is, the area within the relevant contour.

**2.1.10** *Daylight Factor* — The measure of total daylight illuminance at a point on a given plane expressed as the ratio (or percentage) which the illuminance at the point on the given plane bears to the simultaneous illuminance on a horizontal plane due to clear design sky at an exterior point open to the whole sky vault, direct sunlight being excluded.

**2.1.11** *Daylight Penetration* — The maximum distance to which a given daylight factor contour penetrates into a room.

**2.1.12** *Direct Solar Illuminance* — The illuminance from the sun without taking into account the light from the sky.

**2.1.13** *External Reflected Component (ERC)* — The ratio (or percentage) of that part of the daylight illuminance at a point on a given plane which is received by direct reflection from external surfaces as compared to the simultaneous exterior illuminance on a horizontal plane from the entire hemisphere of an unobstructed clear design sky.

**2.1.14** *Glare* — A condition of vision in which there is discomfort or a reduction in the ability to see significant objects or both due to an unsuitable distribution or range of luminance or due to extreme contrasts in space and time.

**2.1.15** *Illuminance* — At a point on a surface, the ratio of the luminous flux incident on an infinitesimal element of the surface containing the point under consideration to the area of the element.

NOTE — The unit of illuminance (the measurement of illumination) is lux which is 1 lumen per square metre.

**2.1.16** *Internal Reflected Component (IRC)* — The ratio (or percentage) of that part of the daylight illuminance at a point in a given plane which is received by direct reflection or inter-reflection from the internal surfaces as compared to the simultaneous exterior illuminance on a horizontal plane due to the entire hemisphere of an unobstructed clear design sky.

**2.1.17** *Light Output Ratio (LOR) or Efficiency* ($\eta$) — The ratio of the luminous flux emitted from the luminaire to that emitted from the lamp(s) (nominal luminous flux). It is expressed in percent.

**2.1.18** *Lumen (lm)* — SI unit of luminous flux. The luminous flux emitted within unit solid angle (one steradian) by a point source having a uniform intensity of one candela.

**2.1.19** *Luminance (At a point of a Surface in a Given Direction) (Brightness)* — The quotient of the luminous intensity in the given direction of an infinitesimal element of the surface containing the point under consideration by the orthogonally projected area of the element on a plane perpendicular to the given direction. The unit is candela per square metre ($cd/m^2$).

**2.1.20** *Luminous Flux* ($\phi$) — The quantity characteristic of radiant flux which expresses its capacity to produce visual sensation evaluated according to the values of relative luminous efficiency for the light adapted eye:

a) *Effective luminous flux* ($\phi_n$) — Total luminous flux which reaches the working plane.
b) *Nominal luminous flux* ($\phi_o$) — Total luminous flux of the light sources in the interior.

**2.1.21** *Maintenance Factor (d)* — The ratio of the average illuminance on the working plane after a certain period of use of a lighting installation to the average illuminance obtained under the same conditions for a new installation.

**2.1.22** *Meridian* — It is the great circle passing through the zenith and nadir for a given point of observation.

**2.1.23** *North and South Points* — The point in the respective directions where the meridian cuts the horizon.

**2.1.24** *Orientation of Buildings* — In the case of non-square buildings, orientation refers to the direction of the normal to the long axis. For example, if the length of the building is east-west, its orientation is north-south.

**2.1.25** *Peripheral Field* — It is the rest of the visual field which enables the observer to be aware of the spatial framework surrounding the object seen.

NOTE — A central part of the peripheral field, subtending an angle of about 30° on either side of the point of fixation, is chiefly involved in the perception of glare.

**2.1.26** *Reflected Glare* — The variety of ill effects on visual efficiency and comfort produced by unwanted reflections in and around the task area.

**2.1.27** *Reflection Factor (Reflectance)* — The ratio of the luminous flux reflected by a body (with or without diffusion) to the flux it receives. Some symbols used for reflection factor are:

$r_c$ = Reflection factor of ceiling.
$r_w$ = Reflection factor of parts of the wall between the working surface and the luminaires.
$r_f$ = Reflection factor of floor.

**2.1.28** *Reveal* — The side of an opening for a window.

**2.1.29** *Room Index* ($k_r$) — An index relating to the shape of a rectangular interior, according to the formula:

$$k_r = \frac{L.W}{(L+W)\,H_m}$$

where $L$ and $W$ are the length and width respectively of the interior, and $H_m$ is the mounting height, that is, height of the fittings above the working plane.

NOTES

**1** For rooms where the length exceeds 5 times the width, $L$ shall be taken as $L = 5W$.

**2** If the reflection factor of the upper stretch of the walls is less than half the reflection factor of the ceiling, for indirect or for the greater part of indirect lighting, the value $H_m$ is measured between the ceiling and the working plane.

**2.1.30** *Sky Component (SC)* — The ratio (or percentage) of that part of the daylight illuminance at a point on a given plane which is received directly from the sky as compared to the simultaneous exterior illuminance on a horizontal plane from the entire hemisphere of an unobstructed clear design sky.

**2.1.31** *Solar Load* — The amount of heat received into a building due to solar radiation which is affected by orientation, materials of construction and reflection of external finishes and colour.

**2.1.32** *Utilization Factor (Coefficient of Utilizaiton)* ($\mu$) — The ratio of the total luminous flux which reaches the working plane (effective luminous flux, $\phi_n$) to the total luminous flux of the light sources in the interior (nominal luminous flux, $\phi_o$).

**2.1.33** *Visual Field* — The visual field in the binocular which includes an area approximately 120° vertically and 160° horizontally centering on the point to which the eyes are directed. The line joining the point of fixation and the centre of the pupil of each eye is called its primary line of sight.

**2.1.34** *Working Plane* — A horizontal plane at a level at which work will normally be done (*see* **4.1.3.3** and **4.1.3.4**).

## 2.2 Ventilation

**2.2.1** *Air Change per Hour* — The amount of air leakage into or out of a building or room in terms of the number of building volume or room volume exchanged.

**2.2.2** *Axial Flow Fan* — A fan having a casing in which the air enters and leaves the impeller in a direction substantially parallel to its axis.

**2.2.3** *Centrifugal Fan* — A fan in which the air leaves the impeller in a direction substantially at right angles to its axis.

**2.2.4** *Contaminants* — Dusts, fumes, gases, mists, vapours and such other substances present in air as are likely to be injurious or offensive to the occupants.

**2.2.5** *Dilution Ventilation* — Supply of outside air to reduce the air-borne concentration of contaminants in the building.

**2.2.6** *Dry Bulb Temperature* — The temperature of the air, read on a thermometer, taken in such a way as to avoid errors due to radiation.

**2.2.7** *Effective Temperature (ET)* — An arbitrary index which combines into a single value the effect of temperature, humidity and air movement on the sensation of warmth or cold felt by the human body and its numerical value is that of the temperature of still saturated air which would induce an identical sensation.

**2.2.8** *Exhaust of Air* — Removal of air from a building or a room and its disposal outside by means of a mechanical device, such as a fan.

**2.2.9** *Fresh Air or Outside Air* — Air of that quality, which meets the criteria of Table 1 and in addition shall be such that the concentration of any contaminant in the air is limited to within one-tenth the threshold limit value (TLV) of that contaminant.

NOTES

**1** Where it is reasonably believed that the air of quality is unexpectable as indicated above, sampling and analysis shall be carried out by a competent authority having jurisdiction and if the outside air of the quality specified is not available, filtration and other treatment devices shall be used to bring its quality to or above the levels mentioned in Table 1.

**2** The list of contaminants given in Table 1 is not exhaustive and available special literature may be referred for data on other contaminants.

**Table 1 Maximum Allowable Contaminant Concentrations for Ventilation Air Contaminants Annual Average (Arithmetic Mean)**

(*Clause* 2.2.9)

| Contaminants | Annual Average (Arithmetic Mean) $\mu g/m^3$ | Short-Term Level (Not to exceed More than Once a Year) $\mu g/m^3$ | Averaging Period h |
|---|---|---|---|
| (1) | (2) | (3) | (4) |
| Suspended particulates | 60 | 150 | 24 |
| Sulphur oxides | 80 | 400 | 24 |
| Carbon monoxide | 20 000 | 30 000 | 8 |
| Photochemical oxidant | 100 | 500 | 1 |
| Hydrocarbons (not including methanes) | 1 800 | 4 000 | 3 |
| Nitrogen oxide | 200 | 500 | 24 |
| Odour: Essentially unobjectionable | | | |

**2.2.10** *General Ventilation* — Ventilation, either natural or mechanical or both, so as to improve the general environment of the building, as opposed to local exhaust ventilation for contamination control.

**2.2.11** *Globe Temperature* — The temperature measured by a thermometer whose bulb is enclosed in a matt black painted thin copper globe of 150 mm diameter. It combines the influence of air temperature and thermal radiations received or emitted by the bounding surfaces.

**2.2.12** *Humidification* — The process whereby the absolute humidity of the air in a building is maintained at a higher level than that of outside air or at a level higher than that which would prevail naturally.

**2.2.13** *Humidity, Absolute* — The mass of water vapour per unit volume.

**2.2.14** *Humidity, Relative* — The ratio of the partial pressure or density of the water vapour in the air to the saturated pressure or density respectively of water vapour at the same temperature.

**2.2.15** *Local Exhaust Ventilation* — Ventilation effected by exhaust of air through an exhaust appliance, such as a hood with or without fan located as closely as possible to the point at which contaminants are released, so as to capture effectively the contaminants and convey them through ducts to a safe point of discharge.

**2.2.16** *Make-up Air* — Outside air supplied into a building to replace the indoor air.

**2.2.17** *Mechanical Ventilation* — Supply of outside air either by positive ventilation or by infiltration by reduction of pressure inside due to exhaust of air, or by a combination of positive ventilation and exhaust of air.

**2.2.18** *Natural Ventilation* — Supply of outside air into a building through window or other openings due to wind outside and convection effects arising from temperature or vapour pressure differences (or both) between inside and outside of the building.

**2.2.19** *Positive Ventilation* — The supply of outside air by means of a mechanical device, such as a fan.

**2.2.20** *Propeller Fan* — A fan in which the air leaves the impeller in a direction substantially parallel to its axis designed to operate normally under free inlet and outlet conditions.

**2.2.21** *Spray-Head System* — A system of atomizing water so as to introduce free moisture directly into a building.

**2.2.22** *Stack Effect* — Convection effect arising from temperature or vapour pressure difference (or both) between outside and inside of the room and the difference of height between the outlet and inlet openings.

**2.2.23** *Tropical Summer Index (TSI)* — The temperature of calm air at 50 percent relative humidity which imparts the same thermal sensation as the given environment. TSI (in °C) is express as

$$0.745\ t_g + 0.308\ t_w - 2.06\sqrt{v} + 0.841$$

where

$t_g$ = Globe temperature, °C;
$t_w$ = Wet bulb temperature, °C; and
$v$ = Wind speed, m/s.

**2.2.24** *Threshold Limit Value (TLV)* — Refers to air-borne concentration of contaminants currently accepted by the American Conference of Governmental Industrial Hygienists and represents conditions under which it is believed that nearly all occupants may be repeatedly exposed, day after day, without adverse effect.

**2.2.25** *Velocity, Capture* — Air velocity at any point in front of the exhaust hood necessary to overcome opposing air currents and to capture the contaminants in air at that point by causing the air to flow into the exhaust hood.

**2.2.26** *Ventilation* — Supply of outside air into, or the removal of inside air from an enclosed space.

**2.2.27** *Wet Bulb Temperature* — The steady temperature finally given by a thermometer having its bulb covered with gauze or muslin moistened with distilled water and placed in an air stream of not less than 4.5 m/s.

## 3 ORIENTATION OF BUILDING

**3.1** The chief aim of orientation of buildings is to provide physically and psychologically comfortable living inside the building by creating conditions which suitably and successfully ward off the undesirable effects of severe weather to a considerable extent by judicious use of the recommendations and knowledge of climatic factors.

### 3.2 Basic Zones

**3.2.1** For the purpose of design of buildings, the country may be divided into the major climatic zones as given in Table 2, which also gives the basis of this classification.

**Table 2 Classification of Climate**

(*Clause* 3.2.1)

| Sl No. | Climatic Zone | Mean Monthly Maximum Temperature (°C) | Mean Monthly Relative Humidity Percentage |
|---|---|---|---|
| (1) | (2) | (3) | (4) |
| i) | Hot-Dry | above 30 | below 55 |
| ii) | Warm-Humid | above 30 | above 55 |
| | | above 25 | above 75 |
| iii) | Temperate | between 25-30 | below 75 |
| iv) | Cold | below 25 | All values |
| v) | Composite | *see* **3.2.2** | |

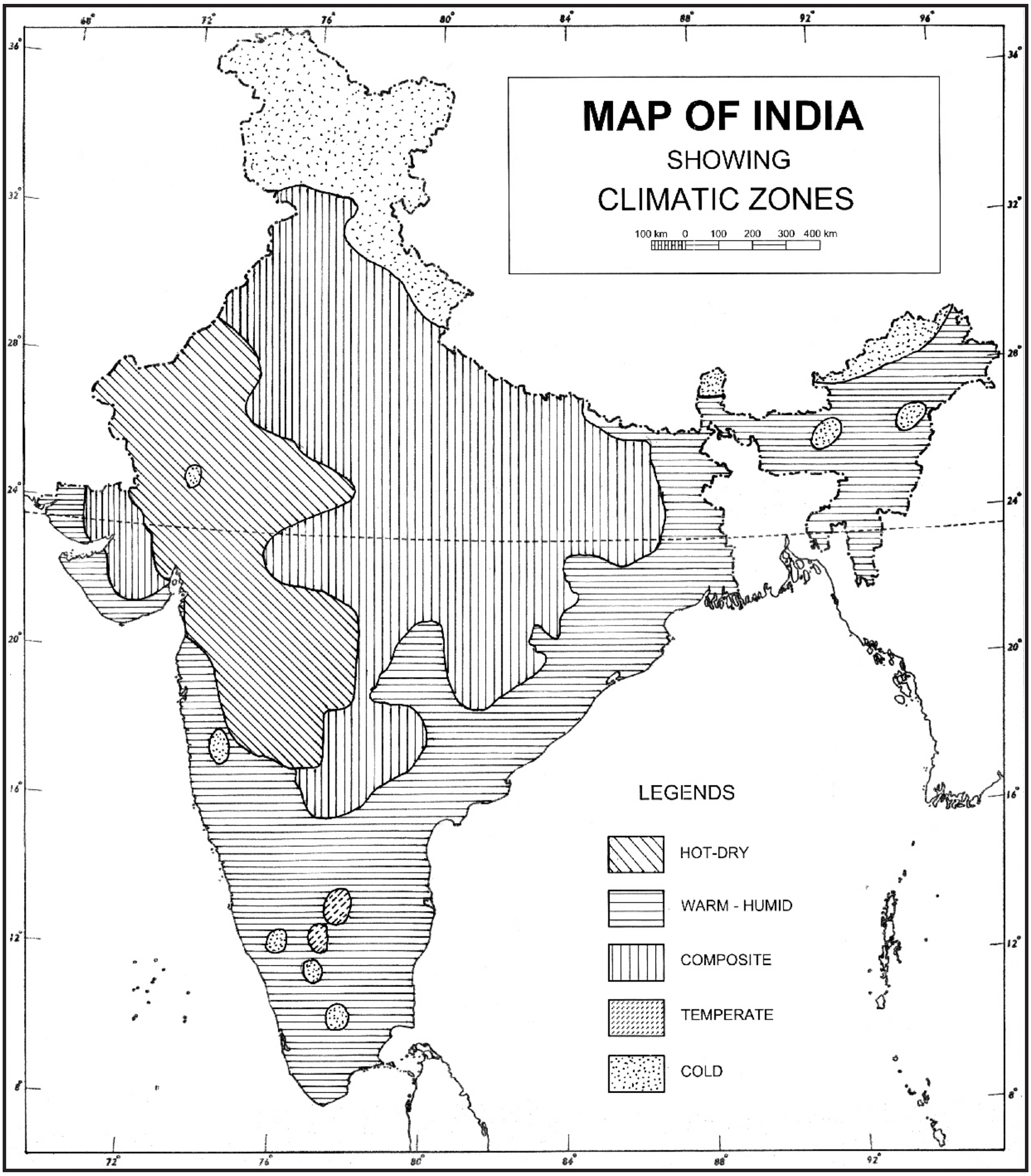
The climatic classification map of India is shown in Fig. 2.

**3.2.2** Each climatic zone does not have same climate for the whole year; it has a particular season for more than six months and may experience other seasons for the remaining period. A climatic zone that does not have any season for more than six months may be called as composite zone.

### 3.3 Climatic Factors

From the point of view of lighting and ventilation, the following climatic factors influence the optimum orientation of the building:

a) solar radiation and temperature
b) relative humidity, and
c) prevailing winds.




Based upon Survey of India Outline Map printed in 1993.



The territorial waters of India extend into the sea to a distance of twelve nautical miles measured from the appropriate base line.
The boundary of Meghalaya shown on this map is as interpreted from the North-Eastern Areas (Reorganisation) Act, 1971, but has yet to be verified.
Responsibility for correctness of internal details shown on the map rests with the publisher.
The state boundaries between Uttaranchal & Uttar Pradesh, Bihar & Jharkhand and Chhatisgarh & Madhya Pradesh have not been verified by Governments concerned.

FIG. 2 MAP OF INDIA SHOWING CLIMATIC ZONE

### 3.4 Solar Radiation

**3.4.1** The best orientation from solar point of view requires that the building as a whole should receive the maximum solar radiation in winter and the minimum in summer. For practical evaluation, it is necessary to know the duration of sunshine, and hourly solar intensity on the various external surfaces on representative days of the seasons. The total direct plus diffused diurnal solar loads per unit area on vertical surface facing different directions are given in Table 3 for two days in the year, that is, 22 June and 22 December, representative of summer and winter, for latitudes corresponding to some important cities all over India. From Table 3, the total heat intake can be calculated for all possible orientations of the building for these extreme days of summer and winter.

**3.4.1.1** Except in cold climatic zone, suitable sun-breakers have to be provided to cut off the incursion of direct sunlight to prevent heat radiation and to avoid glare.

### 3.5 Relative Humidity and Prevailing Winds

**3.5.1** The discomfort due to high relative humidity in air when temperatures are also high can be counteracted, to a great extent, by circulation of air with electric fans or by ventilation. In the past, simultaneously with heavy construction and surrounding *VERANDAHS* to counter the effect of sun's radiation, there was also an over emphasis on prevailing winds to minimize the adverse effects of high humidity with high temperatures. With the introduction of electric fan to effectively circulate air and owing to taking into account the rise in cost of construction of buildings, it would perhaps be better to shift the emphasis on protection from solar radiation where temperatures are very high. When, however, there is less diurnal variation between morning and mean maximum temperatures along with high humidity, as in coastal areas, the emphasis should be on prevailing winds.

**3.5.1.1** For the purpose of orientation, it is necessary to study the velocity and direction of the wind at each hour and in each month instead of relying on generalizations of a month or a period or for the year as a whole. This helps to spot the right winds for a particular period of day or night.

**3.5.1.2** It is generally found that variation up to 30° with respect to the prevalent wind direction does not materially affect indoor ventilation (average indoor air speed) inside the building.

**3.5.2** In hot-dry climate, advantage can be taken of evaporative cooling in summer to cool the air before introducing it into the building. But in warm humid climate, it is desirable either to regulate the rate of air movement with the aid of electric fans or to take advantage of prevailing winds.

### 3.6 Aspects of Daylighting

Since the clear design sky concept for daylighting takes care of the worst possible situation, orientation is not

**Table 3 Total Solar Radiation (Direct plus Diffused) Incident on Various Surfaces of Buildings in W/m²/day for Summer and Winter Seasons**

(*Clause* 3.4.1)

| Orientation | | Latitude | | | | | |
|---|---|---|---|---|---|---|---|
| | | 9°N | 13°N | 17°N | 21°N | 25°N | 29°N |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| North | Summer | 1 494 | 1 251 | 2 102 | 1 775 | 2 173 | 1 927 |
| | Winter | 873 | 859 | 840 | 825 | 802 | 765 |
| North-East | Summer | 2 836 | 2 717 | 3 144 | 3 092 | 3 294 | 3 189 |
| | Winter | 1 240 | 1 158 | 1 068 | 1 001 | 912 | 835 |
| East | Summer | 3 344 | 3 361 | 3 475 | 3 598 | 3 703 | 3 794 |
| | Winter | 2 800 | 2 673 | 2 525 | 2 409 | 2 211 | 2 055 |
| South-East | Summer | 2 492 | 2 660 | 2 393 | 2 629 | 2 586 | 2 735 |
| | Winter | 3 936 | 3 980 | 3 980 | 3 995 | 3 892 | 3 818 |
| South | Summer | 1 009 | 1 185 | 1 035 | 1 117 | 1 112 | 1 350 |
| | Winter | 4 674 | 4 847 | 4 958 | 5 059 | 4 942 | 4 981 |
| South-West | Summer | 2 492 | 2 660 | 2 393 | 2 629 | 2 586 | 2 735 |
| | Winter | 3 936 | 3 980 | 3 980 | 3 995 | 3 892 | 3 818 |
| West | Summer | 3 341 | 3 361 | 3 475 | 3 598 | 3 703 | 3 794 |
| | Winter | 2 800 | 2 673 | 2 525 | 2 409 | 2 211 | 2 055 |
| North-West | Summer | 2 836 | 2 717 | 3 144 | 3 092 | 3 294 | 3 189 |
| | Winter | 1 240 | 1 158 | 1 068 | 1 001 | 912 | 835 |
| Horizontal | Summer | 8 107 | 8 139 | 8 379 | 8 553 | 8 817 | 8 863 |
| | Winter | 6 409 | 6 040 | 5 615 | 5 231 | 4 748 | 4 281 |

a major problem for daylighting in buildings, except that direct sunshine and glare should be avoided. However, due allowance should be given to the mutual shading effects of opposite facades.

**3.7 Planting of Trees**

Planting of trees in streets and in open spaces should be done carefully to take advantage of both shades and sunshine without handicapping the flow of natural winds. Their advantage in abating glare and in providing cool and/or warm pockets in developed areas should also be taken. Some trees shed leaves in winter while retaining thick foliage in summer. Such trees will be very advantageous, particularly where southern and western exposures are concerned, by allowing maximum sun during winter and effectively blocking it in summer.

**3.8** For detailed information regarding orientation of buildings and recommendations for various climatic zones of country, reference may be made to good practice [8-1(1)].

## 4 LIGHTING

### 4.1 Principles of Lighting

**4.1.1** *Aims of Good Lighting*

Good lighting is necessary for all buildings and has three primary aims. The first aim is to promote work and other activities carried out within the building; the second aim is to promote the safety of the people using the building; and the third aim is to create, in conjunction with the structure and decoration, a pleasing environment conducive to interest of the occupants and a sense of their well-being.

**4.1.1.1** Realization of these aims involves:

a) careful planning of the brightness and colour pattern within both the working areas and the surroundings so that attention is drawn naturally to the important areas, detail is seen quickly and accurately and the room is free from any sense of gloom or monotony (*see* **4.1.3**);
b) using directional lighting where appropriate to assist perception of task detail and to give good modeling;
c) controlling direct and reflected glare from light sources to eliminate visual discomfort;
d) in artificial lighting installations, minimizing flicker from certain types of lamps and paying attention to the colour rendering properties of the light;
e) correlating lighting throughout the building to prevent excessive differences between adjacent areas so as to reduce the risk of accidents; and
f) installation of emergency lighting systems, where necessary.

**4.1.2** *Planning the Brightness Pattern*

The brightness pattern seen within an interior may be considered as composed of three main parts — the task itself, immediate background of the task and the general surroundings of walls, ceiling, floor, equipment and furnishings.

**4.1.2.1** In occupations where the visual demands are small, the levels of illumination derived from a criterion of visual performance alone may be too low to satisfy the other requirements. For such situations, therefore, illuminance recommendations are based on standards of welfare, safety and amenity judged appropriate to the occupations; they are also sufficient to give these tasks brightness which ensured that the visual performance exceeds the specified minimum. Unless there are special circumstances associated with the occupation, it is recommended that the illuminance of all working areas within a building should generally be 150 lux, even though the visual demands of the occupation might be satisfied by lower values.

**4.1.2.2** Where work takes place over the whole utilizable area of room, the illumination over that area should be reasonably uniform and it is recommended that the uniformity ratio (minimum illuminance divided by average illuminance levels) should be not less than 0.7 for the working area.

**4.1.2.3** When the task brightness appropriate to an occupation has been determined, the brightness of the other parts of the room should be planned to give a proper emphasis to visual comfort and interest.

A general guide for the brightness relationship within the normal field of vision should be as follows:

| | Maximum |
|---|---|
| a) For high task brightness (above 100 cd/$m^2$) | |
| 1) Between the visual task and the adjacent areas like table tops | 3 to 1 |
| 2) Between the visual task and the remote areas of the room | 10 to 1 |

b) For low and medium task brightness (below 100 cd/$m^2$): The task should be brighter than both the background and the surroundings; the lower the task brightness, the less critical is the relationship.

**4.1.3** *Recommended Values of Illuminance*

Table 4 gives recommended values of illuminance commensurate with the general standards of lighting described in this section and related to many occupations and buildings; These are valid under most of the conditions whether the illumination is by daylighting, artificial lighting or a combination of the two. The great variety of visual tasks makes it impossible to list them all and those given should be regarded as representing types of task.

**4.1.3.1** The different locations and tasks are grouped within the following four sections:

a) Industrial buildings and process;
b) Offices, schools and public buildings;
c) Surgeries and hospitals; and
d) Hotels, restaurants, shops and homes.

**4.1.3.2** The illumination levels recommended in Table 4 are those to be maintained at all time on the task. As circumstances may be significantly different for different interiors used for the same application or for different conditions for the same kind of activity, a range of illuminances is recommended for each type of interior or activity instead of a single value of illuminance. Each range consists of three sucessive steps of the recommended scale of illuminances. For working interiors the middle value of each range represents the recommended service illuminance that would be used unless one or more of the factors mentioned below apply.

**4.1.3.2.1** The higher value of the range should be used when:

a) unusually low reflectances or contrasts are present in the task;
b) errors are costly to rectify;
c) visual work is critical;
d) accuracy or higher productivity is of great importance; and
e) the visual capacity of the worker makes it ncessary.

**4.1.3.2.2** The lower value of the range may be used when:

a) reflectances or contrast are unusually high;
b) speed and accuracy is not important; and
c) the task is executed only occasionally.

**4.1.3.3** Where a visual task is required to be carried out throughout an interior, general illumination level to the recommended value on the working plane is necessary; where the precise height and location of the task are not known or cannot be easily specified, the recommended value is that on horizontal plane 850 mm above floor level.

NOTE — For an industrial task, working plane for the purpose of general illumination levels is that on a work place which is generally 750 mm above the floor level. For certain purposes, such as viewing the objects of arts, the illumination levels recommended are for the vertical plane at which the art pieces are placed.

**4.1.3.4** Where the task is localized, the recommended value is that for the task only; it need not, and sometimes should not, be the general level of illumination used throughout the interior. Some processes, such as industrial inspection process, call for lighting of specialized design, in which case the level of illumination is only one of the several factors to be taken into account.

**4.1.4** *Glare*

Excessive contrast or abrupt and large changes in brightness produce the effect of glare. When glare is present, the efficiency of vision is reduced and small details or subtle changes in scene cannot be perceived. It may be

a) direct glare due to light sources within the field of vision,
b) reflected glare due to reflections from light sources or surfaces of excessive brightness, and
c) veiling glare where the peripheral field is comparatively very bright.

**4.1.4.1** An example of glare sources in daylighting is the view of the bright sky through a window or skylight, especially when the surrounding wall or ceiling is comparatively dark or weakly illuminated. Glare can be minimized in this case either by shielding the open sky from direct sight by louvers, external hoods or deep reveals, curtains or other shading devices or by cross lighting the surroundings to a comparable level. A gradual transition of brightness from one portion to the other within the field of vision always avoids or minimizes the glare discomfort.

**4.1.5** *Lighting for Movement about a Building*

Most buildings are complexes of working areas and other areas, such as passages, corridors, stairways, lobbies and entrances. The lighting of all these areas should be properly correlated to give safe movement within the building at all times.

**4.1.5.1** *Corridors, passages and stairways*

Accidents may result if people leave a well-lighted working area and pass immediately into corridors or on to stairways where the lighting is inadequate, as the time needed for adaptation to the lower level may be too long to permit obstacles or the treads of stairs to be seen sufficiently quickly. For the same reason, it is desirable that the illumination level of rooms which open off a working area should be fairly high even though the rooms may be used only occasionally.

## Table 4 Recommended Values of Illuminance

(*Clauses* 4.1.3, 4.1.3.2, 4.3.2 *and* 4.3.2.1)

| Sl No. | Type of Interior or Activity | Range of Service Illuminance in Lux | Quality Class of Direct Glare Limitation | Remarks |
|---|---|---|---|---|
| (1) | (2) | (3) | (4) | (5) |
| **1** | **AGRICULTURE AND HORTICULTURE** | | | |
| **1.1** | Inspection of Farm Produce where Colour is Important | 300-500-750 | 1 | Local lighting may be appropriate |
| | Other Important Tasks | 200-300-500 | 2 | Local lighting may be appropriate |
| **1.2** | Farm Workshops | | | |
| **1.2.1** | General | 50-100-150 | 3 | |
| **1.2.2** | Workbench or machine | 200-300-500 | 2 | Local or portable lighting may be appropriate |
| **1.3** | Milk Premises | 50-100-150 | 3 | |
| **1.4** | Sick Animal Pets, Calf Nurseries | 30-50-100 | 3 | |
| **1.5** | Other Firm and Horticultural Buildings | 20-30-50 | 3 | |
| **2** | **COAL MINING (SURFACE BUILDINGS)** | | | |
| **2.1** | Coal Preparation Plant | | | |
| **2.1.1** | Walkways, floors under conveyors | 30-50-100 | 3 | |
| **2.1.2** | Wagon loading, bunkers | 30-50-100 | 3 | |
| **2.1.3** | Elevators, chute transfer pits, washbox area | 50-100-150 | 3 | |
| **2.1.4** | Drum filters, screen, rotating shafts | 100-150-200 | 3 | |
| **2.1.5** | Picking belts | 150-200-300 | 3 | Directional and colour properties of lighting may be important for easy recognition of coal and rock |
| **2.2** | Lamp Rooms | | | |
| **2.2.1** | Repair section | 200-300-500 | 2 | |
| **2.2.2** | Other areas | 100-150-200 | 3 | |
| **2.3** | Weight Cabins, Fan Houses | 100-150-200 | 3 | |
| **2.4** | Winding Houses | 100-150-200 | 3 | |
| **3** | **ELECTRICITY GENERATION, TRANSMISSION AND DISTRIBUTION** | | | |
| **3.1** | General Plant | | | |
| **3.1.1** | Turbine houses (operating floor) | 150-200-300 | 2 | |
| **3.1.2** | Boiler and turbine house basements | 50-100-150 | 3 | |
| **3.1.3** | Boiler houses, platforms, areas around burners | 50-100-150 | 3 | |
| **3.1.4** | Switch rooms, meter rooms, oil plant rooms, HV substations (indoor) | 100-150-200 | 2 | |
| **3.1.5** | Control rooms | 200-300-500 | 1 | Localized lighting of control display and the control desks may be appropriate |
| **3.1.6** | Relay and telecommunication rooms | 200-300-500 | 2 | |
| **3.1.7** | Diesel generator rooms, compressor rooms | 100-150-200 | 3 | |
| **3.1.8** | Pump houses, water treatment plant houses | 100-150-200 | 3 | |
| **3.1.9** | Battery rooms, chargers, rectifiers | 50-100-150 | 3 | |
| **3.1.10** | Precipitator chambers, platforms, etc | 50-100-150 | 3 | |
| **3.1.11** | Cable tunnels and basements, circulating water culverts and screen chambers, storage tanks (indoor), operating areas and filling points at outdoor tanks | 30-50-100 | 3 | |
| **3.2** | Coal Plant | | | |
| **3.2.1** | Conveyors, gantries, junction towers, unloading hoppers, ash handling plants, settling pits, dust hoppers outlets | 50-100-150 | 3 | |
| **3.2.2** | Other areas where operators may be in attendance | 100-150-200 | 3 | |
| **3.3** | Nuclear Plants | | | |
| | Gas circulation bays, reactor area, boiler platform, reactor charges and discharge face | 100-150-200 | 2 | |
| **4** | **METAL MANUFACTURE** | | | |
| **4.1** | Iron Making | | | |
| **4.1.1** | Sinter plant: | | | |
| | Plant floor | 150-200-300 | 3 | |

**Table 4 — *Continued***

| (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|
| | Mixer drum, fan house, screen houses, coolers, transfer stations | 100-150-200 | 3 | |
| **4.1.2** | Furnaces, cupola: | | | |
| | General | 100-150-200 | 3 | |
| | Control platforms | 200-300-500 | 2 | Local lighting may be appropriate |
| | Conveyor galleries, walkways | 30-50-100 | 3 | |
| **4.2** | Steel Making | | | |
| **4.2.1** | Electric melting shops | 150-200-300 | 3 | |
| **4.2.2** | Basic oxygen steel making plants | | | |
| **4.2.2.1** | General | 100-150-200 | 3 | |
| **4.2.2.2** | Convertor floor, teeming bay | 150-200-300 | 3 | |
| **4.2.2.3** | Control platforms | 200-300-500 | 2 | Local lighting may be appropriate |
| **4.2.2.4** | Scrap bays | 100-150-200 | 3 | |
| **4.3** | Metal Forming and Treatment | | | |
| **4.3.1** | Ingot stripping, soaking pits, annealing and heat treatment bays, acid recovery plant Picking and cleaning bays, roughing mills, cold mills, finishing mills, tinning and galvanizing lines, cut up and rewind lines | 150-200-300 | 3 | |
| **4.3.2** | General | 100-150-200 | 3 | |
| **4.3.3** | Control platforms | 200-300-500 | 2 | Local lighting may be appropriate |
| **4.3.4** | Wire mills, product finishing, steel inspection and treatment | 200-300-500 | 3 | |
| **4.3.5** | Plate/strip inspection | 300-500-700 | 2 | |
| **4.3.6** | Inspection of tin plate, stainless steel, etc | — | — | Special lighting to reveal faults in the specular surface of the material will be required |
| **4.4** | Foundries | | | |
| **4.4.1** | Automatic Plant | | | |
| **4.4.1.1** | Without manual operation | 30-50-100 | 3 | |
| **4.4.1.2** | With occasional manual operation | 100-150-200 | 3 | |
| **4.4.1.3** | With continuous manual operation | 150-200-300 | 3 | |
| **4.4.1.4** | Control room | 200-300-500 | 1 | Localized lighting of the control display and the control desks may be appropriate |
| **4.4.1.5** | Control platforms | 200-300-500 | 2 | |
| **4.4.2** | Non-automatic plants | | | |
| **4.4.2.1** | Charging floor, pouring, shaking out, cleaning, grinding fettling | 200-300-500 | 3 | |
| **4.4.2.2** | Rough moulding, rough core making | 200-300-500 | 3 | |
| **4.4.2.3** | Fine moulding, fine core making | 300-500-750 | 2 | |
| **4.4.2.4** | Inspection | 300-500-750 | 2 | |
| **4.5** | Forges (Severe vibration is likely to occur) | | | |
| **4.5.1** | General | 200-300-500 | 2 | |
| **4.5.2** | Inspection | 300-500-750 | 2 | |
| **5** | **CERAMICS** | | | |
| **5.1** | Concrete products | | | |
| | Mixing, casting, cleaning | 150-200-300 | 3 | |
| **5.2** | Potteries | | | |
| **5.2.1** | Grinding, moulding, pressing, cleaning, trimming, glazing, firing | 200-300-500 | 3 | |
| **5.2.2** | Enamelling, colouring | 500-750-1000 | 1 | |
| **5.3** | Glass Works | | | |
| **5.3.1** | Furnace rooms, bending, annealing | 100-150-200 | 3 | |
| **5.3.2** | Mixing rooms, forming, cutting, grinding, polishing, toughening | 200-300-500 | 3 | |
| **5.3.3** | Beveling, decorative cutting, etching, silvering | 300-500-750 | 2 | |
| **5.3.4** | Inspection | 300-500-750 | 2 | |

**Table 4 — *Continued***

| (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|
| **6** | **CHEMICALS** | | | |
| **6.1** | Petroleum, Chemical and Petrochemical Works | | | |
| **6.1.1** | Exterior walkways, platforms, stairs and ladders | 30-50-100 | 3 | |
| **6.1.2** | Exterior pump and valve areas | 50-100-150 | 3 | |
| **6.1.3** | Pump and compressor houses | 100-150-200 | 3 | |
| **6.1.4** | Process plant with remote control | 30-50-100 | 3 | |
| **6.1.5** | Process plant requiring occasional manual intervention | 50-100-150 | 3 | |
| **6.1.6** | Permanently occupied work stations in process plant | 150-200-300 | 3 | |
| **6.1.7** | Control rooms for process plant | 200-300-500 | 1 | |
| **6.2** | Pharmaceutial Manufacturer and Fine Chemicals Manufacturer | | | |
| **6.2.1** | Pharmaceutical manufacturer | | | |
| | Grinding, granulating, mixing, drying, tableting, sterilizing, washing, preparation of solutions, filling, capping, wrapping, hardening | 300-500-750 | 2 | |
| **6.2.2** | Fine chemical manufacture | | | |
| **6.2.2.1** | Exterior walkways, platforms, stairs and ladders | 30-50-100 | 3 | |
| **6.2.2.2** | Process plant | 50-100-150 | 3 | |
| **6.2.2.3** | Fine chemical finishing | 300-500-750 | 2 | |
| **6.2.2.4** | Inspection | 300-500-750 | 1 | Local lighting may be appropriate |
| **6.3** | Soap Manufacture | | | |
| **6.3.1** | General area | 200-300-500 | 2 | |
| **6.3.2** | Automatic processes | 100-200-300 | 2 | |
| **6.3.3** | Control panels | 200-300-500 | 1 | Local lighting may be appropriate |
| **6.3.4** | Machines | 200-300-500 | 2 | |
| **6.4** | Paint Works | | | |
| **6.4.1** | General | 200-300-500 | 2 | |
| **6.4.2** | Automatic processes | 150-200-300 | 2 | |
| **6.4.3** | Control panels | 200-300-500 | 2 | |
| **6.4.4** | Special batch mixing | 500-750-1000 | 2 | |
| **6.4.5** | Colour matching | 750-1000-1500 | 1 | |
| **7** | **MECHANICAL ENGINEERING** | | | |
| **7.1** | Structural Steel Fabrication | | | |
| **7.1.1** | General | 200-300-500 | 3 | |
| **7.1.2** | Marking off | 300-500-750 | 3 | Local lighting may be appropriate |
| **7.2** | Sheet Metal Works | | | |
| **7.2.1** | Pressing, punching, shearing, stamping, spinning, folding | 300-500-750 | 2 | |
| **7.2.2** | Benchwork, scribing, inspection | 500-750-1000 | 2 | |
| **7.3** | Machine and Tool Shops | | | |
| **7.3.1** | Rough bench and machine work | 200-300-500 | 3 | |
| **7.3.2** | Medium bench and machine work | 300-500-750 | 2 | |
| **7.3.3** | Fine bench and machine work | 500-750-1000 | 2 | |
| **7.3.4** | Gauge rooms | 750-1000-1500 | 1 | Optical aids may be required |
| **7.4** | Die Sinking Shops | | | |
| **7.4.1** | General | 300-500-750 | 2 | |
| **7.4.2** | Fine work | 1000-1500-2000 | 1 | Flexible local lighting is desirable |
| **7.5** | Welding and Soldering Shops | | | |
| **7.5.1** | Gas and arc welding, rough spot welding | 200-300-500 | 3 | |
| **7.5.2** | Medium soldering, brazing, spot welding | 300-500-750 | 3 | |
| **7.5.3** | Fine soldering, fine spot welding | 750-1000-1500 | 2 | Local lighting is desirable |
| **7.6** | Assembly Shops | | | |
| **7.6.1** | Rough work for example, frame and heavy machine assembly | 200-300-500 | 3 | The lighting of vertical surface may be important |
| **7.6.2** | Medium work, for example, engine assembly, vehicle body assembly | 300-500-750 | 2 | |
| **7.6.3** | Fine work, for example, office machinery assembly | 500-750-1000 | 1 | Localized lighting may be useful |

**Table 4 — *Continued***

| (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|
| **7.6.4** | Very fine work, for example, instrument assembly | 750-1000-1500 | 1 | Local lighting and optical aids are desirable |
| **7.6.5** | Minute work, for example, watch making | 1000-1500-2000 | 1 | Local lighting and optical aids are desirable |
| **7.7** | Inspection and Testing Shops | | | |
| **7.7.1** | Coarse work, for example, using go/no-go gauges, inspection of large sub-assemblies | 300-500-750 | 2 | Local or localized lighting may be appropriate |
| **7.7.2** | Medium work, for example, inspection of painted surfaces | 500-750-1000 | 1 | Local or localized lighting may be appropriate |
| **7.7.3** | Fine work, for example, using calibrated scales, inspection of precision mechanisms | 750-1000-1500 | 1 | Local or localized lighting may be appropriate |
| **7.7.4** | Very fine work, for example, inspection of small intricate parts | 1000-1500-2000 | 1 | Local lighting and optical aids are desirable |
| **7.7.5** | Minute work, for example, inspection of very small instruments | 2000 | 1 | Local lighting and optical aids are desirable |
| **7.8** | Points Shops and Spray Booths | | | |
| **7.8.1** | Dipping, rough spraying | 200-300-500 | 3 | |
| **7.8.2** | Preparation, ordinary painting, spraying and finishing | 200-500-750 | 2 | |
| **7.8.3** | Fine painting, spraying and finishing | 500-750-1000 | 2 | |
| **7.8.4** | Inspection, re-touching and matching | 750-1000-1500 | 2 | |
| **7.9** | Plating Shops | | | |
| **7.9.1** | Vats and baths | 200-300-500 | 3 | |
| **7.9.2** | Buffing, polishing burnishing | 300-500-750 | 2 | |
| **7.9.3** | Final buffing and polishing | 500-750-1000 | 2 | |
| **7.9.4** | Inspection | — | — | Special light to reveal fault in the surface of the material will be required |
| **8** | **ELECTRICAL AND ELECTRONIC ENGINEERING** | | | |
| **8.1** | Electrical Equipment Manufacture | | | |
| **8.1.1** | Manufacture of cables and insulated wires, winding, varnishing and immersion of coils, assembly of large machines, simple assembly work | 200-300-500 | 3 | |
| **8.1.2** | Medium assembly, for example, telephones, small motors | 300-500-750 | 3 | Local lighting may be appropriate |
| **8.1.3** | Assembly of precision components, for example, telecommunication equipment, adjustment, inspection and calibration | 750-1000-1500 | 1 | Local lighting is desirable. Optical aids may be useful |
| **8.1.4** | Assembly of high precision parts | 1000-1500-2000 | 1 | Local lighting is desirable. Optical aids may be useful |
| **8.2** | Electronic Equipment Manufacture | | | |
| **8.2.1** | Printed circuit board | | | |
| **8.2.1.1** | Silk screening | 300-500-750 | 1 | Local lighting may be appropriate |
| **8.2.1.2** | Hand insertion of components, soldering | 500-750-1000 | 1 | Local lighting may be appropriate |
| **8.2.1.3** | Inspection | 750-1000-1500 | 1 | A large, low luminance luminaire overhead ensures specular reflection conditions which are helpful for inspection of printed circuits |
| **8.2.1.4** | Assembly of wiring harness, cleating harness, testing and calibration | 500-750-1000 | 1 | Local lighting may be appropriated |
| **8.2.1.5** | Chassis assembly | 750-1000-1500 | 1 | Local lighting may be appropriated |
| **8.2.2** | Inspection and testing | | | |
| **8.2.2.1** | Soak test | 150-200-300 | 2 | |
| **8.2.2.2** | Safety and functional tests | 200-300-500 | 2 | |
| **9** | **FOOD, DRINK AND TOBACCO** | | | |
| **9.1** | Slaughter Houses | | | |
| **9.1.1** | General | 200-300-500 | 3 | |
| **9.1.2** | Inspection | 300-500-750 | 2 | |
| **9.2** | Canning, Preserving and Freezing | | | |
| **9.2.1** | Grading and sorting of raw materials | 500-750-1000 | 2 | Lamp of colour rendering group 1A or 1B will be required, if colour judgement is required |

**Table 4 — *Continued***

| (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|
| **9.2.2** | Preparation | 300-500-750 | 3 | |
| **9.2.3** | Canned and bottled goods | | | |
| **9.2.3.1** | Retorts | 200-300-500 | 3 | |
| **9.2.3.2** | Automatic processes | 150-200-300 | 3 | |
| **9.2.3.3** | Labelling and packaging | 200-300-500 | 3 | |
| **9.2.4** | Frozen foods | | | |
| **9.2.4.1** | Process area | 200-300-500 | 3 | |
| **9.2.4.2** | Packaging and storage | 200-300-500 | 3 | |
| **9.3** | Bottling, Brewing and Distilling | | | |
| **9.3.1** | Keg washing and handling, bottle washing | 150-200-300 | 3 | |
| **9.3.2** | Keg inspection | 200-300-500 | 3 | |
| **9.3.3** | Bottle inspection | — | — | Special lighting will be required |
| **9.3.4** | Process areas | 200-300-500 | 3 | |
| **9.3.5** | Bottle filling | 500-750-1000 | 3 | |
| **9.4** | Edible Oils and Fats Processing | | | |
| **9.4.1** | Refining and blending | 200-300-500 | 3 | |
| **9.4.2** | Production | 300-500-750 | 2 | |
| **9.5** | Mills-Milling, Filtering and Packing | 200-300-500 | 3 | |
| **9.6** | Bakeries | | | |
| **9.6.1** | General | 200-300-500 | 2 | |
| **9.6.2** | Hand decorating, icing | 300-500-750 | 2 | |
| **9.7** | Chocolate and Confectionery Manufacture | | | |
| **9.7.1** | General | 200-300-500 | 3 | |
| **9.7.2** | Automatic processes | 150-200-300 | 3 | |
| **9.7.3** | Hand decoration, inspection, wrapping and packing | 300-500-750 | 2 | If accurate colour judgements are required, lamps of colour rendering group 1A or 1B are used |
| **9.8** | Tobacco Processing | | | |
| **9.8.1** | Material preparation, making and packing | 300-500-750 | 2 | |
| **9.8.2** | Hand processes | 500-750-1000 | 2 | |
| **10** | **TEXTILES** | | | |
| **10.1** | Fibre Preparation | | | |
| **10.1.1** | Bale breaking, washing | 200-300-500 | 3 | |
| **10.1.2** | Stock dyeing, tinting | 200-300-500 | 3 | |
| **10.2** | Yarn Manufacture | | | |
| **10.2.1** | Spinning, roving, winding, etc | 300-500-750 | 2 | |
| **10.2.2** | Healding (drawing in) | 750-1000-750 | 2 | |
| **10.3** | Fabric Production | | | |
| **10.3.1** | Knitting | 300-500-750 | 2 | |
| **10.3.2** | Weaving | | | |
| **10.3.2.1** | Jute and hemp | 200-300-500 | 2 | |
| **10.3.2.2** | Heavy woolens | 300-500-750 | 1 | |
| **10.3.2.3** | Medium worsteds, fine woolens, cottons | 500-750-1000 | 1 | |
| **10.3.2.4** | Fine worsteds, fine linens, synthetics | 750-1000-1500 | 1 | |
| **10.3.2.5** | Mending | 1000-1500-2000 | 1 | |
| **10.3.2.6** | Inspection | 1000-1500-2000 | 1 | |
| **10.4** | Fabric Finishing | | | |
| **10.4.1** | Dyeing | 200-300-500 | 3 | |
| **10.4.2** | Calendaring, chemical treatment, etc | 300-500-750 | 2 | |
| **10.4.3** | Inspection | | | |
| **10.4.3.1** | ‘Grey’ cloth | 750-1000-1500 | 1 | |
| **10.4.3.2** | Final | 1000-1500-2000 | 1 | |
| **10.5** | Carpet Manufacture | | | |
| **10.5.1** | Winding, beaming | 200-300-500 | 3 | |
| **10.5.2** | Setting pattern, turfing cropping, trimming, fringing, latexing and latex drying | 300-500-750 | 2 | |
| **10.5.3** | Designing, weaving, mending | 500-750-1000 | 2 | |
| **10.5.4** | Inspection | | | |
| **10.5.4.1** | General | 750-1000-1500 | 1 | Local lighting may be appropriate |
| **10.5.4.2** | Piece dyeing | 500-750-1000 | 1 | Local lighting may be appropriate |

**Table 4 — *Continued***

| (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|
| **11** | **LEATHER INDUSTRY** | | | |
| **11.1** | Leather Manufacture | | | |
| **11.1.1** | Cleaning, tanning and stretching, vats, cutting, fleshing, stuffing | 200-300-500 | 3 | |
| **11.1.2** | Finishing, scarfing | 300-500-750 | 2 | |
| **11.2** | Leather Working | | | |
| **11.2.1** | General | 200-300-500 | 3 | |
| **11.2.2** | Pressing, glazing | 300-500-750 | 2 | |
| **11.2.3** | Cutting, splitting, scarfing, sewing | 500-750-1000 | 2 | Directional lighting may be useful. |
| **11.2.4** | Grading, matching | | 2 | Local lighting may be appropriate |
| **12** | **CLOTHING AND FOOTWEAR** | | | |
| **12.1** | Clothing Manufacture | | | |
| **12.1.1** | Preparation of cloth | 200-300-500 | 2 | |
| **12.1.2** | Cutting | 500-750-1000 | 1 | |
| **12.1.3** | Matching | 500-750-1000 | 1 | |
| **12.1.4** | Sewing | 750-1000-1500 | 1 | |
| **12.1.5** | Pressing | 300-500-750 | 2 | |
| **12.1.6** | Inspection | 1000-1500-2000 | 1 | Local lighting may be appropriate |
| **12.1.7** | Hand tailoring | 1000-1500-2000 | 1 | Local lighting may be appropriate |
| **12.2** | Hosiery and Knitwear Manufacture | | | |
| **12.2.1** | Flat bed knitting machines | 300-500-750 | 2 | |
| **12.2.2** | Circular knitting machines | 500-750-1000 | 2 | |
| **12.2.3** | Lockstitch and overlocking machine | 750-1000-1500 | 1 | |
| **12.2.4** | Linking or running on | 750-1000-1500 | 1 | |
| **12.2.5** | Mending, hand finishing | 1000-1500-3000 | — | Local lighting may be appropriate |
| **12.2.6** | Inspection | 1000-1500-2000 | 2 | Local lighting may be appropriate |
| **12.3** | Glove Manufacture | | | |
| **12.3.1** | Sorting and grading | 500-750-1000 | 1 | |
| **12.3.2** | Pressing, knitting, cutting | 300-500-750 | 2 | |
| **12.3.3** | Sewing | 500-750-1000 | 2 | |
| **12.3.4** | Inspection | 1000-1500-2000 | — | Local lighting may be appropriate |
| **12.4** | Hat Manufacture | | | |
| **12.4.1** | Stiffening, braiding, refining, forming, sizing, pounding, ironing | 200-300-500 | 2 | |
| **12.4.2** | Cleaning, flanging, finishing | 300-500-750 | 2 | |
| **12.4.3** | Sewing | 500-750-1000 | 2 | |
| **12.4.4** | Inspection | 1000-1500-2000 | — | Local lighting may be appropriate |
| **12.5** | Boot and Shoe Manufacture | | | |
| **12.5.1** | Leather and synthetics | | | |
| **12.5.2** | Sorting and grading | 750-1000-1500 | 1 | |
| **12.5.3** | Clicking, closing | 750-1000-1500 | 2 | Local or localized lighting may be appropriate |
| **12.5.4** | Preparatory operations | 750-1000-1500 | 2 | Local or localized lighting may be appropriate |
| **12.5.5** | Cutting tables and pressure | 1000-1500-2000 | 1 | Local or localized lighting may be appropriate |
| **12.5.6** | Bottom stock preparation, lasting, bottoming finishing, shoe rooms | 750-1000-1500 | 1 | Local or localized lighting may be appropriate |
| **12.5.7** | Rubber | | | |
| **12.5.7.1** | Washing, compounding, coating, drying, varnishing, vulcanizing, calendaring, cutting | 200-300-500 | 3 | |
| **12.5.7.2** | Lining, making and finishing | 300-500-750 | 2 | |
| **13** | **TIMBER AND FURNITURE** | | | |
| **13.1** | Sawmills | | | |
| **13.1.1** | General | 150-200-300 | 3 | |
| **13.1.2** | Head saw | 300-500-750 | 2 | Localized lighting may be appropriate |
| **13.1.3** | Grading | 500-750-1000 | 2 | Directional lighting may be useful |
| **13.2** | Woodwork Shops | | | |
| **13.2.1** | Rough sawing, bench work | 200-300-500 | 2 | |

**Table 4 — *Continued***

| (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|
| **13.2.2** | Sizing, planning, sanding, medium machining and bench work | 300-500-750 | 2 | |
| **13.2.3** | Fine bench and machine work, fine sanding, finishing | 500-750-1000 | 2 | Localized lighting may be appropriate |
| **13.3** | Furniture Manufacture | | | |
| **13.3.1** | Raw material stores | 50-100-150 | 3 | |
| **13.3.2** | Finished goods stores | 100-150-200 | 3 | |
| **13.3.3** | Wood matching and assembly, rough sawing, cutting | 200-300-500 | 2 | |
| **13.3.4** | Machining, sanding and assembly, polishing | 300-500-750 | 2 | Localized lighting may be appropriate |
| **13.3.5** | Tool room | 300-500-750 | 2 | |
| **13.3.6** | Spray booths | | | |
| **13.3.6.1** | Colour finishing | 300-500-750 | 2 | |
| **13.3.6.2** | Clear finishing | 200-300-500 | 2 | |
| **13.3.7** | Cabinet making | | | |
| **13.3.7.1** | Vaneer sorting and grading | 750-1000-1500 | 1 | |
| **13.3.7.2** | Marquetry, pressing, patching and fitting | 300-500-750 | 1 | |
| **13.3.7.3** | Final inspection | 500-750-1000 | 1 | Special lighting will be required |
| **13.4** | Upholstery Manufacture | | | |
| **13.4.1** | Cloth inspection | 1000-1500-2000 | 1 | Special lighting will be required |
| **13.4.2** | Filling, covering | 300-500-750 | 2 | |
| **13.4.3** | Slipping, cutting, sewing | 500-750-1000 | 2 | |
| **13.4.4** | Mattress making | | | |
| **13.4.5** | Assembly | 300-500-750 | 2 | |
| **13.4.6** | Tape edging | 750-1000-1500 | 2 | Local lighting may be appropriate |
| **14** | **PAPER AND PRINTING** | | | |
| **14.1** | Paper Mills | | | |
| **14.1.1** | Pulp mills, preparation plants | 200-300-500 | 3 | |
| **14.1.2** | Paper and board making | | | |
| **14.1.2.1** | General | 200-300-500 | 3 | |
| **14.1.2.2** | Automatic process | 150-200-300 | 3 | Supplementary lighting may be necessary for maintenance work |
| **14.1.2.3** | Inspection, sorting | 300-500-750 | 1 | |
| **14.1.3** | Paper converting processes | | | |
| **14.1.3.1** | General | 200-300-500 | 3 | |
| **14.1.3.2** | Associated printing | 300-500-750 | 2 | |
| **14.2** | Printing Works | | | |
| **14.2.1** | Type foundries | | | |
| **14.2.1.1** | Matrix making, dressing type, hand and machine coating | 200-300-500 | 3 | |
| **14.2.1.2** | Front assembly, sorting | 500-750-1000 | 2 | |
| **14.2.2** | Composing rooms | | | |
| **14.2.2.1** | Hand composing, imposition and distribution | 500-750-1000 | 1 | |
| **14.2.2.2** | Hot metal keyboard | 500-750-1000 | 1 | |
| **14.2.2.3** | Hot metal casting | 200-300-500 | 2 | |
| **14.2.2.4** | Photo composing keyboard or setters | 300-500-750 | 1 | |
| **14.2.2.5** | Paste up | 500-750-1000 | 1 | |
| **14.2.2.6** | Illuminated tables — general lighting | 200-300-500 | — | Dimming may be required |
| **14.2.2.7** | Proof presses | 300-500-750 | 2 | |
| **14.2.2.8** | Proof reading | 500-750-1000 | 1 | |
| **14.2.3** | Graphic reproduction | | | |
| **14.2.3.1** | General | 300-500-750 | 2 | |
| **14.2.3.2** | Precision proofing, retouching, etching | 750-1000-1500 | 1 | Local lighting may be appropriate |
| **14.2.3.3** | Colour reproduction and inspection | 750-1000-1500 | 1 | |
| **14.2.4** | Printing machine room | | | |
| **14.2.4.1** | Presses | 300-500-750 | 2 | |
| **14.2.4.2** | Premake ready | 300-500-750 | 2 | |
| **14.2.4.3** | Printed sheet inspection | 750-1000-1500 | 1 | |
| **14.2.5** | Binding | | | |
| **14.2.5.1** | Folding, pasting, punching and stitching | 300-500-750 | 2 | |
| **14.2.5.2** | Cutting, assembling, embossing | 500-750-1000 | 2 | |
| **15** | **PLASTIC AND RUBBER** | | | |
| **15.1** | Plastic Products | | | |
| **15.1.1** | Automatic plant | | | |

**Table 4 — *Continued***

| (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|
| **15.1.1.1** | Without manual control | 30-50-100 | 3 | |
| **15.1.1.2** | With occasional manual control | 50-100-150 | 3 | |
| **15.1.1.3** | With continuous manual control | 200-300-500 | 3 | |
| **15.1.1.4** | Control rooms | 200-300-500 | 1 | |
| **15.1.1.5** | Control platforms | 200-300-500 | 2 | Local lighting may be appropriate |
| **15.1.2** | Non-automatic plant | | | |
| **15.1.2.1** | Mixing, calendaring, extrusion, injection, compression and blow moulding, sheet fabrication | 200-300-500 | 3 | |
| **15.1.2.2** | Trimming, cutting, polishing, cementing | 300-500-750 | 2 | |
| **15.1.2.3** | Printing, inspection | 750-1000-1500 | 1 | |
| **15.2** | Rubber Products | | | |
| **15.2.1** | Stock preparation — plasticizing, milling | 150-200-300 | 3 | |
| **15.2.2** | Calendaring, fabric preparation, stock-cutting | 300-500-750 | 3 | |
| **15.2.3** | Extruding, moulding | 300-500-750 | 2 | |
| **15.2.4** | Inspection | 750-1000-1500 | — | |
| **16** | **DISTRIBUTION AND STORAGE** | | | |
| **16.1** | Work Stores | 100-150-200 | 3 | Avoid glare to drivers of vehicles approaching the loading bay |
| **16.1.1** | Unpacking, sorting | 150-200-300 | 3 | Avoid glare to drivers of vehicles approaching the loading bay |
| **16.1.2** | Large item storage | 50-100-150 | 3 | Avoid glare to drivers of vehicles approaching the loading bay |
| **16.1.3** | Small item rack storage | 200-300-500 | 3 | Avoid glare to drivers of vehicles approaching the loading bay |
| **16.1.4** | Issue counter, records, storeman's desk | 300-500-750 | 2 | Local or localized lighting may be appropriate |
| **16.2** | Warehouses and Bulk Stores | | | |
| **16.2.1** | Storage of goods where indentification requires only limited preparation of detail | 50-100-150 | 3 | |
| **16.2.2** | Storage of goods where identification requires perception of detail | 100-150-200 | 3 | |
| **16.2.3** | Automatic high bay rack stores | | | |
| **16.2.3.1** | Gangway | 20 | — | |
| **16.2.3.2** | Control station | 150-200-300 | 3 | |
| **16.2.3.3** | Packing and dispatch | 200-300-500 | 3 | |
| **16.2.3.4** | Loading bays | 100-150-200 | 3 | Avoid glare to drivers of vehicles approaching the loading bay |
| **16.3** | Cold Stores | | | |
| **16.3.1** | General | 200-300-500 | 3 | |
| **16.3.2** | Breakdown, make-up and dispatch | 200-300-500 | 3 | |
| **16.3.3** | Loading bays | 100-150-200 | 3 | Avoid glare to drivers of vehicles approaching the loading bay |
| **17** | **COMMERCE** | | | |
| **17.1** | Offices | | | |
| **17.1.1** | General offices | 300-500-750 | 1 | |
| **17.1.2** | Deep plan general offices | 500-750-1000 | 1 | |
| **17.1.3** | Computer work stations | 300-500-750 | 1 | |
| **17.1.4** | Conference rooms, executive offices | 300-500-750 | 1 | |
| **17.1.5** | Computer and data preparation rooms | 300-500-750 | 1 | |
| **171.6** | Filing rooms | 200-300-500 | 1 | |
| **17.2** | Drawing Offices | | | |
| **17.2.1** | General | 300-500-750 | 1 | |
| **17.2.2** | Drawing boards | 500-750-1000 | 1 | |
| **17.2.3** | Computer aided design and drafting | — | — | Special lighting is required |
| **17.2.4** | Print rooms | 200-300-500 | 1 | |
| **17.3** | Banks and Building Societies | | | |
| **17.3.1** | Counter, office area | 300-500-750 | 1 | |
| **17.3.2** | Public area | 200-300-500 | 1 | |
| **18** | **SERVICES** | | | |
| **18.1** | Garages | | | |
| **18.1.1** | Interior parking areas | 20-30-50 | 3 | |

**Table 4 — *Continued***

| (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|
| **18.1.2** | General repairs, servicing, washing, polishing | 200-300-500 | 2 | |
| **18.1.3** | Workbench | 300-500-750 | 1 | Local or localized lighting may be appropriate |
| **18.1.4** | Spray booths | 300-500-750 | 1 | |
| **18.1.5** | External apron | | | |
| **18.1.5.1** | General | 30-50-100 | — | Care should be taken to avoid glare to drivers and neightbouring residents |
| **18.1.5.2** | Pump area (retail sales) | 200-300-500 | — | *See* 'Retailing' |
| **18.2** | Appliance servicing | | | |
| **18.2.1** | Workshop | | | |
| **18.2.1.1** | General | 200-300-500 | 2 | |
| **18.2.1.2** | Workbench | 300-500-750 | 2 | Localized lighting may be appropriate |
| **18.2.1.3** | Counter | 200-300-500 | 2 | Localized lighting may be appropriate |
| **18.2.1.4** | Stores | 200-300-500 | 3 | |
| **18.3** | Laundries | | | |
| **18.3.1** | Commercial laundries | | | |
| **18.3.2** | Receiving, sorting, washing, drying, ironing, despatch, dry-cleaning, bulk machine work | 200-300-500 | 3 | |
| **18.3.3** | Head ironing, pressing, mending, spotting, inspection | 300-500-750 | 3 | |
| **18.3.4** | Launderettes | 200-300-500 | 3 | |
| **18.4** | Sewage Treatment Works | | | |
| **18.4.1** | Walkways | 30-50-100 | 3 | |
| **18.4.2** | Process areas | 50-100-150 | 3 | |
| **19** | **RETAILING** | | | |
| **19.1** | Small Shops with Counters | 300-500-750 | 1 | The service illuminance should be provided on the horizontal plane of the counter. Where wall displays are used, a similar illuminance on the walls is desirable |
| **19.2** | Small Self-Service Shops with Island Displays | 300-500-750 | 1 | |
| **19.3** | Supper Markets, Hyper-Markets | | | |
| **19.3.1** | General | 300-500-750 | 2 | |
| **19.3.2** | Checkout | 300-500-750 | 2 | |
| **19.3.3** | Showroom for large objects, for example, cars, furnitures | 300-500-750 | 1 | |
| **19.3.4** | Shopping precincts and arcades | 100-150-200 | 2 | |
| **20** | **PLACES OF PUBLIC ASSEMBLY** | | | |
| **20.1** | Public Rooms, Village Halls, Worship Halls | 200-300-500 | 1 | |
| **20.2** | Concert Halls, Cinemas and Theatres | | | |
| **20.2.1** | Foyer | 150-200-300 | — | |
| **20.2.2** | Booking office | 200-300-500 | — | Local or localized lighting may be appropriate |
| **20.2.3** | Auditorium | 50-100-150 | — | Dimming facilities will be necessary. Special lighting of the aisles is desirable |
| **20.2.4** | Dressing rooms | 200-300-500 | — | Special mirror lighting for make-up may be required |
| **20.2.5** | Projection room | 100-150-200 | — | |
| **20.3** | Churches | | | |
| **20.3.1** | Body of church | 100-150-200 | 2 | |
| **20.3.2** | Pulpit, lectern | 200-300-500 | 2 | Use local lighting |
| **20.3.3** | Choir stalls | 200-300-500 | 2 | Local lighting may be appropriate |
| **20.3.4** | Alter, communion table, chancel | 100-150-200 | 2 | Additional lighting to provide emphasis is desirable |
| **20.3.5** | Vestries | 100-150-200 | 2 | |
| **20.3.6** | Organ | 200-300-500 | — | |
| **20.4** | Hospitals | | | |
| **20.4.1** | Anaesthatic rooms | | | |

**Table 4 — *Continued***

| (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|
| **20.4.1.1** | General | 200-300-500 | — | |
| **20.4.1.2** | Local | 750-1000-1500 | — | |
| **20.4.2** | Consulting areas | | | |
| **20.4.2.1** | General | 200-300-500 | — | |
| **20.4.2.2** | Examination | 750-1000-1500 | — | |
| **20.4.3** | Corridors | | | |
| **20.4.3.1** | General | 100-150-200 | — | |
| **20.4.4** | Ward corridors | | | |
| **20.4.4.1** | Day, screened from bays | 150-200-300 | — | |
| **20.4.4.2** | Day, open to natural light | 150-200-300 (total) | — | |
| **20.4.4.3** | Morning/Evening | 100-150-200 | — | |
| **20.4.4.4** | Night | 5-10 | — | |
| **20.4.5** | Cubicles | | | |
| **20.4.5.1** | General | 200-300-500 | — | |
| **20.4.5.2** | Treatment | 750-1000-1500 | — | |
| **20.4.6** | Examination | | | |
| **20.4.6.1** | General | 200-300-500 | — | |
| **20.4.6.2** | Local inspection | 750-1000-1500 | — | |
| **20.4.7** | Intensive therapy | | | |
| **20.4.7.1** | Bad head | 30-50 | — | |
| **20.4.7.2** | Circulation between bed ends | 50-100-150 | — | |
| **20.4.7.3** | Observation | 200-300-500 | — | |
| **20.4.7.4** | Local observation | 750-1000-1500 | — | |
| **20.4.7.5** | Staff base (day) | 200-300-500 | — | |
| **20.4.7.6** | Staff base (night) | 30 | — | |
| **20.4.8** | Laboratories | | | |
| **20.4.8.1** | General | 200-300-500 | — | |
| **20.4.8.2** | Examination | 300-500-750 | — | |
| **20.4.9** | Nurses’ stations | | | |
| **20.4.9.1** | Morning/day/evening | 200-300-500 | — | |
| **20.4.9.2** | Night desks | 30 | — | |
| **20.4.9.3** | Night, medical trolleys | 50-100-150 | — | |
| **20.4.10** | Operating theatres | | | |
| **20.4.10.1** | General | 300-500-750 | — | |
| **20.4.10.2** | Local | 10 000 to 50 000 | — | Special operating lights are used |
| **20.4.11** | Pathology departments | | | |
| **20.4.11.1** | General | 200-300-500 | — | |
| **20.4.11.2** | Examination | 300-500-750 | — | |
| **20.4.11.3** | Pharmacies | 200-300-500 | — | |
| **20.4.11.4** | Reception/enquiry | 200-300-500 | — | |
| **20.4.11.5** | Recovery rooms | 200-300-500 | — | |
| **20.4.12** | Ward-circulation | | | |
| **20.4.12.1** | Day | 50-100-150 | — | |
| **20.4.12.2** | Morning/Evening | 50-100-150 | — | |
| **20.4.12.3** | Night | 3-5 | — | |
| **20.4.13** | Ward-bed head | | | |
| **20.4.13.1** | Morning/Evening | 30-50 | | |
| **20.4.13.2** | Reading | 100-150-200 | | |
| **20.4.14** | Night | | | |
| **20.4.14.1** | Adult | 0.1-1 | | |
| **20.4.14.2** | Pediatric | 1 | | |
| **20.4.14.3** | Psychiatric | 1-5 | | |
| **20.4.14.4** | Watch | 5 | | |
| **20.4.15** | X-Ray areas | | | |
| **20.4.15.1** | General | 150-200-300 | | |
| **20.4.15.2** | Diagnostic | 150-200-300 | | |
| **20.4.15.3** | Operative | 200-300-500 | | |
| **20.4.15.4** | Process dark room | 50 | | |
| **20.4.16** | Surgeries | | | |
| **20.4.16.1** | General | 200-300-500 | — | |
| **20.4.16.2** | Waiting rooms | 100-150-200 | — | |
| **20.4.17** | Dental surgeries | | | |
| **20.4.17.1** | Chair | Special lighting | | |

**Table 4 — *Continued***

| (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|
| **20.4.17.2** | Laboratories | 300-500-750 | — | |
| **20.4.18** | Consulting rooms | | | |
| **20.4.18.1** | General | 200-300-500 | — | |
| **20.4.18.2** | Desk | 300-500-750 | — | |
| **20.4.18.3** | Examination couch | 300-500-750 | — | |
| **20.4.18.4** | Ophthalmic wall and near-vision charts | 300-500-750 | — | |
| **20.5** | Hotels | | | |
| **20.5.1** | Entrance halls | 50-100-150 | | |
| **20.5.2** | Reception, cashier's and porters' desks | 200-300-500 | | Localized lighting may be appropriate |
| **20.5.3** | Bars, coffee base, dining rooms, grill rooms, restaurants, lounges | 50-200 | | The lighting should be designed to create an appropriate atmosphere |
| **20.5.4** | Cloak rooms, baggage rooms | 50-100-150 | 3 | |
| **20.5.5** | Bed rooms | 30-50-100 | — | Supplementary local lighting at the bed head, writing table should be provided |
| **20.5.6** | Bathroom | 50-100-150 | | Supplementary local lighting near the mirror is desirable |
| **20.5.7** | Food preparation and stores, cellars, lifts and corridors | — | — | *See* 'General Building Areas' |
| **20.6** | Libraries | | | |
| **20.6.1** | Lending library | | | |
| **20.6.1.1** | General | 200-300-500 | 1 | |
| **20.6.1.2** | Counters | 300-500-750 | 1 | Localized lighting may be appropriate |
| **20.6.1.3** | Bookshelves | 100-150-200 | 2 | The service illuminance should be provided on the vertical face at the bottom of the bookstack |
| **20.6.1.4** | Reading rooms | 200-300-500 | 1 | |
| **20.6.1.5** | Reading tables | 200-300-500 | 1 | Localized lighting may be appropriate |
| **20.6.2** | Catalogues | | | |
| **20.6.2.1** | Card | 100-150-200 | 2 | |
| **20.6.2.2** | Microfiche/Visual display units | 100-150-200 | 2 | |
| **20.6.3** | Reference libraries | | | |
| **20.6.3.1** | General | 200-300-500 | 1 | |
| **20.6.3.2** | Counters | 300-500-750 | 1 | Localized lighting may be appropriate |
| **20.6.3.3** | Bookshelves | 100-150-200 | 2 | The service illuminance should be provided on a vertical surface at the foot of the bookshelves |
| **20.6.3.4** | Study tables, carrels | 300-500-750 | 1 | |
| **20.6.3.5** | Map room | 200-300-500 | 1 | |
| **20.6.4** | Display and exhibition areas | | | |
| **20.6.4.1** | Exhibits insensitive to light | 200-300-500 | — | |
| **20.6.4.2** | Exhibit sensitive to light, for example, pictures, prints, rare books in archives | 50 to 150 | — | |
| **20.6.5** | Library workrooms | | | |
| **20.6.5.1** | Book repair and binding | 300-500-750 | 2 | |
| **20.6.5.2** | Catalogue and sorting | 300-500-750 | 2 | |
| **20.6.5.3** | Remote book stores | 100-150-200 | 3 | |
| **20.7** | Museums and Art Galleries | | | |
| **20.7.1** | Exhibits insensitive to light | 200-300-500 | — | |
| **20.7.2** | Light sensitive exhibits, for example, oil and temper paints, undyed leather, bone, ivory, wood, etc | 150 | — | This is a maximum illuminance to be provided on the principal plane of the exhibit |
| **20.7.3** | Extremely light sensitive exhibits, for example, textiles, water colours, prints and drawings, skins, botanical specimens, etc | 50 | — | This is the maximum illuminance to be provided on the principal plane of the object |
| **20.7.4** | Conservation studies and workshops | 300-500-750 | 1 | |
| **20.8** | Sports Facilities | | | |

**Table 4 — *Continued***

| (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|
| | Multi-purpose sports halls | 300-750 | — | This lighting system should be sufficiently flexible to provide lighting suitable for the variety of sports and activities that take place in sports halls. Higher illuminance of 1000-2000 lux would be required for television coverage |
| **21** | **EDUCATION** | | | |
| **21.1** | Assembly Halls | | | |
| **21.1.1** | General | 200-300-500 | 3 | |
| **21.1.2** | Platform and stage | — | — | Special lighting to provide emphasis and to facilitate the use of the platform/ stage is desirable |
| **21.2** | Teaching Spaces | | | |
| | General | 200-300-500 | 1 | |
| **21.3** | Lecture Theatres | | | |
| **21.3.1** | General | 200-300-500 | 1 | |
| **21.3.2** | Demonstration benches | 300-500-750 | 1 | Localized lighting may be appropriate |
| **21.4** | Seminar Rooms | 300-500-750 | 1 | |
| **21.5** | Art Rooms | 300-500-750 | 1 | |
| **21.6** | Needlework Rooms | 300-500-750 | 1 | |
| **21.7** | Laboratories | 300-500-750 | 1 | |
| **21.8** | Libraries | 200-300-500 | 1 | |
| **21.9** | Music Rooms | 200-300-500 | 1 | |
| **21.10** | Sports Halls | 200-300-500 | 1 | |
| **21.11** | Workshops | 200-300-500 | 1 | |
| **22** | **TRANSPORT** | | | |
| **22.1** | Airports | | | |
| **22.1.1** | Ticket counters, checking desks, and information desks | 300-500-750 | 2 | Localized lighting may be appropriate |
| **22.1.2** | Departure lounges, other waiting areas | 150-200-300 | 2 | |
| **22.1.3** | Baggage reclaim | 150-200-300 | 2 | |
| **22.1.4** | Baggage handling | 50-100-150 | 2 | |
| **22.1.5** | Customs and immigration halls | 300-500-750 | 2 | |
| **22.1.6** | Concourse | 150-200-300 | 2 | |
| **22.2** | Railway Stations | | | |
| **22.2.1** | Ticket office | 300-500-750 | 2 | Localized lighting may be appropriate |
| **22.2.2** | Information office | 300-500-750 | 2 | Localized lighting over the counter may be appropriate |
| **22.2.3** | Parcels office, left | | | |
| **22.2.4** | Luggage office | | | |
| **22.2.4.1** | General | 50-100-150 | 2 | |
| **22.2.4.2** | Counter | 150-200-300 | 2 | |
| **22.2.5** | Waiting rooms | 150-200-300 | 2 | |
| **22.2.6** | Concourse | 150-200-300 | 2 | |
| **22.2.7** | Time table | 150-200-300 | 2 | Localized lighting may be appropriate |
| **22.2.8** | Ticket barriers | 150-200-300 | 2 | Localized lighting may be appropriate |
| **22.2.9** | Platforms (covered) | 30-50-100 | 2 | Care should be taken to light and mark the edge of the platform clearly |
| **22.2.10** | Platforms (open) | 20 | — | Care should be taken to light and mark the edge of the platform clearly |
| **22.3** | Coach Stations | | | |

**Table 4 —** *Concluded*

| (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|
| **22.3.1** | Ticket offices | 300-500-750 | 2 | Localized lighting over the counter may be appropriate |
| **22.3.2** | Information offices | 300-500-750 | 2 | Localized lighting over the counter may be appropriate |
| **22.3.3** | Left luggage office | | | |
| **22.3.3.1** | General | 50-100-150 | 3 | |
| **22.3.3.2** | Counter | 150-200-300 | 3 | Localized lighting is appropriate |
| **22.3.4** | Waiting rooms | 150-200-300 | 2 | |
| **22.3.5** | Concourse | 150-200-300 | 2 | |
| **22.3.6** | Time tables | 150-200-300 | 2 | Local lighting is appropriate |
| **22.3.7** | Loading areas | 100-150-200 | 3 | |
| **23** | **GENERAL BUILDING AREAS** | | | |
| **23.1** | Entrance | | | |
| **23.1.1** | Entrance halls, lobbies, waiting rooms | 150-200-300 | 2 | |
| **23.1.2** | Enquiry desks | 300-500-750 | 2 | Localized lighting may be appropriate |
| **23.1.3** | Gatehouses | 150-200-300 | 2 | |
| **23.2** | Circulation Areas | | | |
| **23.2.1** | Lifts | 50-100-150 | — | |
| **23.2.2** | Corridors, passageways, stairs | 50-100-150 | 2 | |
| **23.2.3** | Escalators, travellators | 100-150-200 | — | |
| **23.3** | Medical and First Aid Centres | | | |
| **23.3.1** | Consulting rooms, treatment rooms | 300-500-750 | 1 | |
| **23.3.2** | Rest rooms | 100-150-200 | 1 | |
| **23.3.3** | Medical stores | 100-150-200 | 2 | |
| **23.4** | Staff Rooms | | | |
| **23.4.1** | Changing, locker and cleaners rooms, cloakrooms, lavatories | 50-100-150 | — | |
| **23.4.2** | Rest rooms | 100-150-200 | 1 | |
| **23.5** | Staff Restaurants | | | |
| **23.5.1** | Canteens, cafeterias, dining rooms, mess rooms | 150-200-300 | 2 | |
| **23.5.2** | Servery, vegetable preparation, washing-up area | 200-300-500 | 2 | |
| **23.5.3** | Food preparation and cooking | 300-500-750 | 2 | |
| **23.5.4** | Food stores, cellars | 100-150-200 | 2 | |
| **23.6** | Communications | | | |
| **23.6.1** | Switchboard rooms | 200-300-500 | 2 | |
| **23.6.2** | Telephone apparatus rooms | 100-150-200 | 2 | |
| **23.6.3** | Telex room, post room | 300-500-750 | 2 | |
| **23.6.4** | Reprographic room | 200-300-500 | 2 | |
| **23.7** | Building Services | | | |
| **23.7.1** | Boiler houses | | | |
| **23.7.1.1** | General | 50-100-150 | 3 | |
| **23.7.1.2** | Boiler front | 100-150-200 | 3 | |
| **23.7.1.3** | Boiler control room | 200-300-500 | 2 | Localized lighting of the control display and the control desk may be appropriate |
| **23.7.1.4** | Control rooms | 200-300-500 | 2 | Localized lighting of the control display and the control desk may be appropriate |
| **23.7.1.5** | Mechanical plant room | 100-150-200 | 2 | |
| **23.7.1.6** | Electrical power supply and distribution rooms | 100-150-200 | 2 | |
| **23.7.1.7** | Store rooms | 50-100-150 | 3 | |
| **23.8** | Car Parks | | | |
| **23.8.1** | Covered car parks | | | |
| **23.8.1.1** | Floors | 5-20 | — | |
| **23.8.1.2** | Ramps and corners | 30 | — | |
| **23.8.1.3** | Enterances and exits | 50-100-150 | — | |
| **23.8.1.4** | Control booths | 150-200-300 | — | |
| **23.8.1.5** | Outdoor car parks | 5-20 | — | |

It is important, when lighting stairways, to prevent disability from glare caused by direct sight of bright sources to emphasize the edges of the treads and to avoid confusing shadows. The same precautions should be taken in the lighting of cat-walks and stairways on outdoor industrial plants.

**4.1.5.2** *Entrances*

The problems of correctly grading the lighting within a building to allow adequate time for adaptation when passing from one area to another area are particularly acute at building entrances. These are given below:

a) By day, people entering a building will be adapted to the very high levels of brightness usually present outdoors and there is risk of accident if entrance areas, particularly any steps, are poorly lighted. This problem may often be overcome by arranging windows to give adequate natural lighting at the immediate entrance, grading to lower levels further inside the entrance area. Where this cannot be done, supplementary artificial lighting should be installed to raise the level of illumination to an appropriate value.

b) At night it is desirable to light entrance halls and lobbies so that the illumination level reduces towards the exit and so that no bright fittings are in the line of sight of people leaving the building. Any entrance steps to the building should be well-lighted by correctly screened fittings.

**4.1.6** For detailed information regarding principles of good lighting, reference may be made to good practice [8-1(2)].

## 4.2 Daylighting

The primary source of lighting for daylighting is the sun. The light received by the earth from the sun consists of two parts, namely, direct solar illuminance and sky illuminance. For the purposes of daylighting design, direct solar illuminance shall not be considered and only sky illuminance shall be taken as contributing to illumination of the building interiors during the day.

**4.2.1** The relative amount of sky illuminance depends on the position of the sun defined by its altitude, which in turn, varies with the latitude of the locality, the day of the year and the time of the day, as indicated in Table 5.

**4.2.2** The external available horizontal sky illuminance (diffuse illuminance) values which are exceeded for about 90 percent of the daytime working hours may be taken as outdoor design illuminance values for ensuring adequacy of daylighting design. The outdoor design sky illuminance varies for different climatic regions of the country. The recommended design sky illuminance values are 6 800 lux for cold climate, 8 000 lux for composite climate, 9 000 lux for warm humid climate, 9 000 lux for temperate climate and 10 500 for hot-dry climate. For integration with the artificial lighting during daytime working hours an increase of 500 lux in the recommended sky design illuminance for daylighting is suggested.

**4.2.3** The daylight factor is dependent on the sky luminance distribution, which varies with atmospheric conditions. A clear design sky with its non-uniform distribution of luminance is adopted for the purposes of design in this section.

**Table 5 Solar-Altitudes (to the Nearest Degree) for Indian Latitudes**

(*Clause* 4.2.1)

| Period of Year | 22 June | | | | | | 21 March and 23 September | | | | | | 22 December | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hours of Day (Sun or Solar) | 07 00 | 08 00 | 09 00 | 10 00 | 11 00 | 12 00 | 07 00 | 08 00 | 09 00 | 10 00 | 11 00 | 12 00 | 07 00 | 08 00 | 09 00 | 10 00 | 11 00 | 12 00 |
| Latitude | 17 00 | 16 00 | 15 00 | 14 00 | 13 00 | — | 17 00 | 16 00 | 15 00 | 14 00 | 13 00 | — | 17 00 | 16 00 | 15 00 | 14 00 | 13 00 | — |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) | (14) | (15) | (16) | (17) | (118) | (19) |
| 10°N | 18 | 31 | 45 | 58 | 70 | 77 | 15 | 30 | 44 | 59 | 72 | 80 | 9 | 23 | 35 | 46 | 53 | 57 |
| 13°N | 19 | 32 | 46 | 60 | 72 | 80 | 15 | 29 | 44 | 58 | 70 | 77 | 8 | 21 | 33 | 43 | 51 | 54 |
| 16°N | 20 | 33 | 47 | 61 | 74 | 83 | 14 | 29 | 43 | 56 | 68 | 74 | 7 | 19 | 31 | 41 | 48 | 51 |
| 19°N | 21 | 34 | 48 | 62 | 75 | 86 | 14 | 28 | 42 | 55 | 66 | 71 | 5 | 18 | 29 | 48 | 45 | 48 |
| 22°N | 22 | 35 | 49 | 62 | 75 | 89 | 14 | 28 | 41 | 53 | 64 | 68 | 4 | 16 | 27 | 36 | 42 | 45 |
| 25°N | 23 | 36 | 49 | 63 | 76 | 88 | 13 | 27 | 40 | 52 | 61 | 65 | 3 | 14 | 25 | 34 | 39 | 42 |
| 28°N | 23 | 36 | 49 | 63 | 76 | 86 | 13 | 26 | 39 | 50 | 59 | 62 | 1 | 13 | 23 | 31 | 37 | 39 |
| 31°N | 24 | 37 | 50 | 62 | 75 | 82 | 13 | 25 | 37 | 48 | 56 | 56 | — | 11 | 21 | 28 | 34 | 36 |
| 34°N | 25 | 37 | 49 | 62 | 73 | 79 | 12 | 25 | 36 | 46 | 53 | 56 | — | 9 | 18 | 26 | 31 | 33 |

**4.2.4** *Components of Daylight Factor*

Daylight factor is the sum of all the daylight reaching on an indoor reference point from the following sources:

a) The direct sky visible from the point,
b) External surfaces reflecting light directly (*see* Note 1) to the point, and
c) Internal surfaces reflecting and inter-reflecting light to the point.

NOTES

**1** External surface reflection may be computed approximately only for points at the centre of the room, and for detailed analysis procedures are complicated and these may be ignored for actual calculations.

**2** Each of the three components, when expressed as a ratio or percent of the simultaneous external illuminance on the horizontal plane, defines respectively the sky component (SC), the external reflected component (ERC) and the internal reflected component (IRC) of the daylight factor.

**4.2.4.1** The daylight factors on the horizontal plane only are usually taken, as the working plane in a room is generally horizontal; however, the factors in vertical planes should also be considered when specifying daylighting values for special cases, such as daylighting on class-rooms, blackboards, pictures and paintings hung on walls.

**4.2.5** *Sky Component (SC)*

Sky component for a window of any size is computed by the use of the appropriate table of Annex A.

a) The recommended sky component level should be ensured generally on the working plane at the following positions:
   1) at a distance of 3 m to 3.75 m from the window along the central line perpendicular to the window,
   2) at the centre of the room if more appropriate, and
   3) at fixed locations, such as school desks, black-boards and office tables.
b) The daylight area of the prescribed sky component should not normally be less than half the total area of the room.

**4.2.5.1** The values obtainable from the tables are for rectangular, open unglazed windows, with no external obstructions. The values shall be corrected for the presence of window bars, glazing and external obstructions, if any. This assumes the maintenance of a regular cleaning schedule.

**4.2.5.2** *Corrections for window bars*

The corrections for window bars shall be made by multiplying the values read from tables in Annex A by a factor equal to the ratio of the clear opening to the overall opening.

**4.2.5.3** *Correction for glazing*

Where windows are glazed, the sky components obtained from Annex A shall be reduced by 10 to 20 percent, provided the panes are of clear and clean glass. Where glass is of the frosted (ground) type, the sky components read from Annex A may be reduced by 15 to 30 percent. In case of tinted or reflective glass the reduction is about 50 percent. Higher indicated correction corresponds to larger windows and/or near reference points. In the case of openings and glazings which are not vertical, suitable correction shall be taken into account.

**4.2.5.4** *Correction for external obstructions*

There is no separate correction, except that the values from tables in Annex A shall be read only for the unobstructed portions of the window.

**4.2.6** *External Reflected Component (ERC)*

The value of the sky component corresponding to the portion of the window obstructed by the external obstructions may be found by the use of methods described in Annex B of good practice [8-1(3)].

These values when multiplied by the correction factors, corresponding to the mean elevation of obstruction from the point in question as given in Table 6, can be taken as the external reflected components for that point.

**Table 6 Correction Factor for ERC**

(*Clause* 4.2.6)

| Mean Angle of Elevation | Correction Factor |
|---|---|
| (1) | (2) |
| 5° | 0.086 |
| 15° | 0.086 |
| 25° | 0.142 |
| 35° | 0.192 |
| 45° | 0.226 |
| 55° | 0.274 |
| 65° | 0.304 |
| 75° | 0.324 |
| 85° | 0.334 |

**4.2.6.1** For method of calculating ERC, reference may be made to accepted standard (*see* Examples 10 and 11 given in Annex B of good practice [8-1(3)].

**4.2.7** *Internal Reflected Component (IRC)*

The component of daylight factor contributed by reflection from the inside surfaces varies directly as the window area and inversely as the total area of internal surfaces, and depends on the reflection factor of the floor, wall and roof surfaces inside and of the ground outside. For rooms white-washed on walls and ceiling and windows of normal sizes, the IRC will have sizeable value even at points far away from the window. External obstructions, when present, will proportionately reduce IRC. Where accurate values of IRC are desired, the same may be done in accordance with the good practice [8-1(3)].

**4.2.8** *General Principles of Openings to Afford Good Lighting*

**4.2.8.1** Generally, while taller openings give greater penetrations, broader openings give better distribution of light. It is preferable that some area of the sky at an altitude of 20° to 25° should light up the working plane.

**4.2.8.2** Broader openings may also be equally or more efficient, provided their sills are raised by 300 mm to 600 mm above the working plane.

NOTE — It is to be noted that while placing window with a high sill level might help natural lighting, this is likely to reduce ventilation at work levels. While designing the opening for ventilation also, a compromise may be made by providing the sill level about 150 mm below the head level of workers.

**4.2.8.3** For a given penetration, a number of small openings properly positioned along the same, adjacent or opposite walls will give better distribution of illumination than a single large opening. The sky component at any point, due to a number of openings may be easily determined from the corresponding sky component contour charts appropriately superposed. The sum of the individual sky component for each opening at the point gives the overall component due to all the openings. The same charts may also facilitate easy drawing of sky component contours due to multiple openings.

**4.2.8.4** Unilateral lighting from side openings will, in general, be unsatisfactory if the effective width of the room is more than 2 to 2.5 times the distance from the floor to the top of the opening. In such cases provision of light shelves is always advantageous.

**4.2.8.5** Openings on two opposite sides will give greater uniformity of internal daylight illumination, especially when the room is 7 m or more across. They also minimize glare by illuminating the wall surrounding each of the opposing openings. Side openings on one side and clerestory openings on the opposite side may be provided where the situation so requires.

**4.2.8.6** Cross-lighting with openings on adjacent walls tends to increase the diffused lighting within a room.

**4.2.8.7** Openings in deep reveals tend to minimize glare effects.

**4.2.8.8** Openings shall be provided with *CHAJJAHS*, louvers, baffles or other shading devices to exclude, as far as possible, direct sunlight entering the room. *CHAJJAHS*, louvers, etc, reduce the effective height of the opening for which due allowance shall be made. Broad and low openings are, in general, much easier to shade against sunlight entry. Direct sunlight, when it enters, increases the inside illuminance very considerably. Glare will result if it falls on walls at low angles, more so than when it falls on floors, especially when the floors are dark coloured or less reflective.

**4.2.8.9** Light control media, such as translucent glass panes (opal or matt) surfaced by grinding, etching or sandblasting, configurated or corrugated glass, certain types of prismatic glass, tinted glass and glass blasts are often used. They should be provided, either fixed or movable outside or inside, especially in the upper portions of the openings. The lower portions are usually left clear to afford desirable view. The chief purpose of such fixtures is to reflect part of the light on to the roof and thereby increase the diffuse lighting within, light up the farther areas in the room and thereby produce a more uniform illumination throughout. They will also prevent the opening causing serious glare discomfort to the occupants but will provide some glare when illuminated by direct sunlight.

**4.2.9** *Availability of Daylight in Multi-storeyed Block*

Proper planning and layout of building can add appreciably to daylighting illumination inside. Certain dispositions of building masses offer much less mutual obstruction to daylight than others and have a significant relevance, especially when intensive site planning is undertaken. The relative availability of daylight in multi-storeyed blocks of different relative orientations are given in Table 7.

**Table 7 Relative Availability of Daylight on the Window Plane at Ground Level in a Four-Storeyed Building Blocks (Clear Design-Sky as Basis, Daylight Availability Taken as Unity on an Unobstructed Façade, Values are for the Centre of the Blocks)**

(*Clause* 4.2.9)

| Distance of Separation Between Blocks | Infinitely Long Parallel Blocks | Parallel Blocks Facing Each Other (Length = 2 × Height) | Parallel Blocks Facing Gaps Between Opposite Blocks (Length = 2 × Height) |
|---|---|---|---|
| (1) | (2) | (3) | (4) |
| 0.5 *Ht* | 0.15 | 0.15 | 0.25 |
| 1.0 *Ht* | 0.30 | 0.32 | 0.38 |
| 1.5 *Ht* | 0.40 | 0.50 | 0.55 |
| 2.0 *Ht* | 0.50 | 0.60 | 0.68 |

**4.2.10** For specified requirements for daylighting of special occupancies and areas, reference may be made to good practice [8-1(4)].

## 4.3 Artificial Lighting

**4.3.1** Artificial lighting may have to be provided

a) where the recommended illumination levels have to be obtained by artificial lighting only,

b) to supplement daylighting when the level of illumination falls below the recommended value, and

c) where visual task may demand a higher level of illumination.

**4.3.2** *Artificial Lighting Design for Interiors*

For general lighting purposes, the recommended practice is to design for a level of illumination on the working plane on the basis of the recommended levels for visual tasks given in Table 4 by a method called 'Lumen method'. In order to make the necessary detailed calculations concerning the type and quantity of lighting equipment necessary, advance information on the surface reflectances of walls, ceilings and floors is required. Similarly, calculations concerning the brightness ratio in the interior call for details of the interior décor and furnishing. Stepwise guidance regarding designing the interior lighting systems for a building using the 'Lumen method' is given in **4.3.2.1** to **4.3.2.4.**

**4.3.2.1** *Determination of the illumination level*

Recommended value of illumination shall be taken from Table 4, depending upon the type of work to be carried out in the location in question and the visual tasks involved.

**4.3.2.2** *Selection of the light sources and luminaires*

The selection of light sources and luminaires depends on the choice of lighting system, namely, general lighting, directional lighting and localized or local lighting.

**4.3.2.3** *Determination of the luminous flux*

a) The luminous flux ($\phi$) reaching the working plane depends upon the following:

   1) lumen output of the lamps,
   2) type of luminaire,
   3) proportion of the room (room index) ($k_r$),
   4) reflectance of internal surfaces of the room,
   5) depreciation in the lumen output of the lamps after burning their rated life, and
   6) depreciation due to dirt collection on luminaires and room suface.

b) *Coefficient of Utilization or Utilization Factor*

   1) The compilation of tables for the utilization factor requires a considerable amount of calculations, especially if these tables have to cover a wide range of lighting practices. For every luminaire, the exact light distribution has to be measured in the laboratory and their efficiencies have to be calculated and measured exactly. These measurements comprise:

      i) the luminous flux radiated by the luminaires directly to the measuring surface,
      ii) the luminous flux reflected and re-reflected by the ceiling and the walls to the measuring surface, and
      iii) the inter-reflections between the ceiling and wall which result in the measuring surface receiving additional luminous flux.

   All these measurements have to be made for different reflection factors of the ceiling and the walls for all necessary room indices. These tables have also to indicate the maintenance factor to be taken for the luminous flux depreciation throughout the life of an installation due to ageing of the lamp and owing to the deposition of dirt on the lamps and luminaires and room surfaces.

   2) The values of the reflection factor of the ceiling and of the wall are as follows:

| | |
|---|---|
| White and very light colours | 0.7 |
| Light colours | 0.5 |
| Middle tints | 0.3 |
| Dark colours | 0.1 |

   For the walls, taking into account the influence of the windows without curtains, shelves, almirahs and doors with different colours, etc, should be estimated.

c) *Calculation for determining the luminous flux*

$$E_{av} = \frac{\mu \phi}{A}$$

or, $$\phi = \frac{E_{av} A}{\mu}$$ for new condition

and $$\phi = \frac{E_{av} A}{\mu d}$$ for working condition

where

$\phi$ = Total luminous flux of the light sources installed in the room inlumens;

$E_{av}$ = Average illumination level required on the working plane inlux;

$A$ = Area of the working plane in $m^2$;

$\mu$ = the utilization factor in new conditions; and

$d$ = maintenance factor.

In practice, it is easier to calculate straightaway the number of lamps or luminaires from:

$$N_{lamp} = \frac{E_{av} A}{\mu\ d\ \phi_{lamp}}$$

$$N_{luminaires} = \frac{E_{av} A}{\mu\ d\ \phi_{luminaires}}$$

where

$\phi_{lamp}$ = Luminous flux of each lamp in lumens,

$\phi_{luminaires}$ = Luminous flux of each luminaire in lumens,

$N_{lamp}$ = Total number of lamps, and

$N_{luminaires}$ = Total number of luminaires.

**4.3.2.4** *Arrangement of the luminaires*

This is done to achieve better uniformly distributed illumination. The location of the luminaires has an important effect on the utilization factor.

a) In general, luminaires are spaced 'a' metre apart in either direction, while the distance of the end luminaire from the wall is '½ a' metre. The distance '*a*' is more or less equal to the mounting height '$H_m$' between the luminaire and the working plane. The utilization factor tables are calculated for this arrangement of luminaires.

b) For small rooms where the room index ($k_r$) is less than 1, the distance '*a*' should always be less than $H_m$, since otherwise luminaires cannot be properly located. In most cases of such rooms, four or two luminaires are placed for good general lighting. If, however, in such rooms only one luminaire is installed in the middle, higher utilization factors are obtained, but the uniformity of distribution is poor. For such cases, references should be made to the additional tables for $k_r$ = 0.6 to 1.25 for luminaires located centrally.

**4.3.3** *Artificial Lighting to Supplement Daylighting*

**4.3.3.1** The need for general supplementary artificial lighting arises due to diminution of daylighting beyond design hours, that is, for solar altitude below 15° or when dark cloudy conditions occur.

**4.3.3.2** The need may also arise for providing artificial lighting during the day in the innermost parts of the building which cannot be adequately provided with daylighting, or when the outside windows are not of adequate size or when there are unavoidable external obstructions to the incoming daylighting.

**4.3.3.3** The need for supplementary lighting during the day arises, particularly when the daylighting on the working plane falls below 100 lux and the surrounding luminance drops below 19 cd/m$^2$.

**4.3.3.4** The requirement of supplementary artificial lighting increases with the *decrease* in daylighting availability. Therefore, conditions near sunset or sunrise or equivalent conditions due to clouds or obstructions, etc, represent the worst conditions when the supplementary lighting is most needed.

**4.3.3.5** The requirement of supplementary artificial lighting when daylighting availability becomes poor may be determined from Fig. 3 for an assumed ceiling height of 3.0 m, depending upon floor area, fenestration percentage and room surface reflectance. Cool daylight fluorescent tubes are recommended with semi-direct luminaires. To ensure a good distribution of illumination, the mounting height should be between 1.5 m and 2.0 m above the work plane for a separation of 2.0 m to 3.0 m between the luminaires. Also the number of lamps should preferably be more in the rear half of the room than in the vicinity of windows. The following steps may be followed for using Fig. 3 for determining the number of fluorescent tubes required for supplementary daylighting.

a) Determine fenestration percentage of the floor area, that is,

$$\frac{\text{Window Area}}{\text{Floor Area}} \times 100$$

b) In Fig. 3, refer to the curve corresponding to the percent fenestration determined above and the set of reflectances of ceiling, walls and floor actually provided.

c) For the referred curve of Fig. 3 read, along the ordinate, the number of 40 W fluorescent tubes required, corresponding to the given floor area on the abscissa.

**4.3.4** For detailed information on the design aspects and principles of artificial lighting, reference may be made to good practice [8-1(2)].

**4.3.5** For specific requirements for lighting of special occupancies and areas, reference may be made to good practice [8-1(5)].

**4.3.6** Electrical installation aspect for artificial lighting shall be in accordance with Part 8 'Building Services, Section 2 Electrical and Allied Installations'.

## 4.4 Energy Conservation in Lighting

**4.4.1** A substantial portion of the energy consumed on lighting may be saved by utilization of daylight and rational design of supplementary artificial lights.

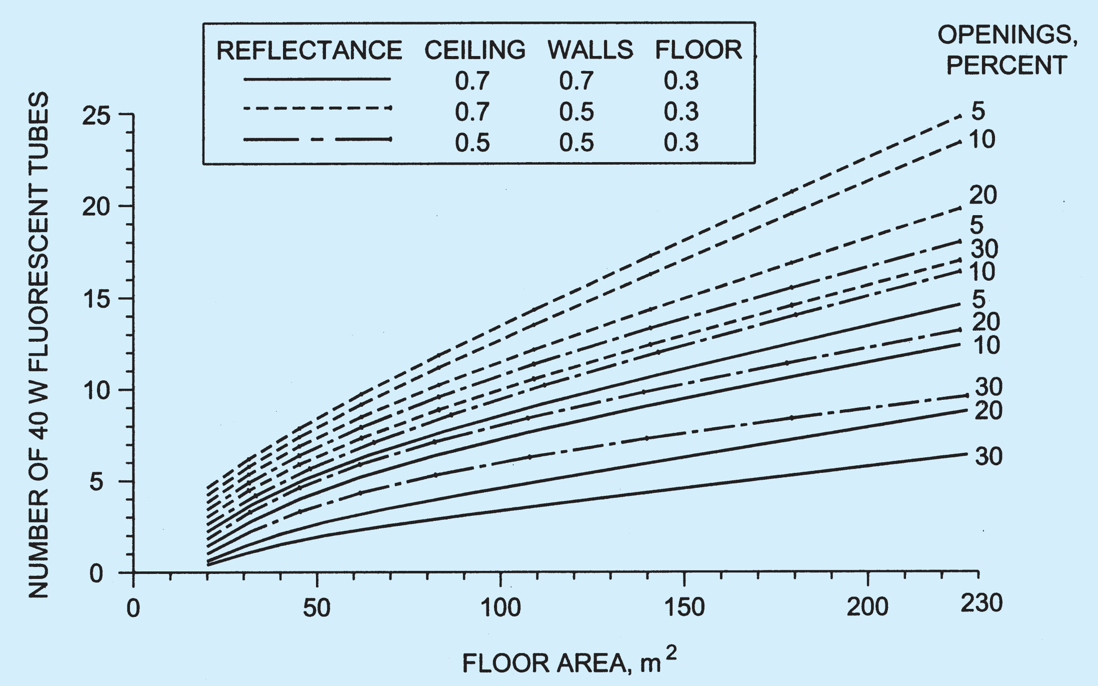



Fig. 3 Supplementary Artificial Lighting for 40W Fluorescent Tubes

**4.4.2** Daytime use of artificial lights may be minimized by proper design of windows for adequate daylight indoors. Daylighting design should be according to **4.2**.

**4.4.3** Fenestration expressed as percentage of floor area required for satisfactory visual performance of a few tasks for different separation to height (*S*/*H*) ratio of external obstructions such as opposite buildings may be obtained from the design nomograph (Fig. 4). The obstructions at a distance of three times their height or more (*S*/*H* > 3) from a window façade are not significant and a window facing such an obstruction may be regarded as a case of unobstructed window.

**4.4.3.1** The nomograph consists of horizontal lines indicating fenestration percentage of floor area and vertical lines indicating the separation to height ratio of external obstructions such as opposite buildings. Any vertical line for separation to height ratio other than already shown in the nomograph (1.0, 2.0 and 3.0) may be drawn by designer, if required. For cases where there is no obstruction, the ordinate corresponding to the value 3.0 may be used. The value of percentage fenestration and separation to height ratio are marked on left hand ordinate and abscissa respectively. The illumination levels are marked on the right hand ordinate. The values given within brackets are the illumination levels on the work plane at centre and rear of the room. The wattage of fluorescent tubes required per square metre of the floor area for different illumination levels is shown on each curve.

**4.4.3.2** Following assumptions have been made in the construction of the nomograph:

a) An average interior finish with ceiling white, walls off white and floor grey has been assumed.
b) Ceiling height of 3 m and room depths up to 10 m and floor area between 30 $m^2$ and 50 $m^2$ have been assumed. For floor area beyond 50 $m^2$ and less than 30 $m^2$, the values of percent fenestration as well as wattage per $m^2$ should be multiplied by a factor of 0.85 and 1.15 respectively.
c) It is assumed that windows are of metallic sashes with louvers of width up to 600 mm or a *CHHAJJA* (balcony projection) at ceiling level of width up to 2.0 m. For wooden sashes, the window area should be increased by a factor of about 1.1.
d) Luminaires emanating more light in the downward direction than upward direction (such as reflectors with or without diffusing plastics) and mounted at a height of 1.5 m to 2.0 m above the workplane have been considered.

**4.4.3.3** *Method of use*

The following steps shall be followed for the use of nomograph:

a) *Step 1* — Decide the desired illumination level depending upon the task illumination requirement in the proposed room and read the value of watts per square metre on the curve corresponding to the required illumination level.

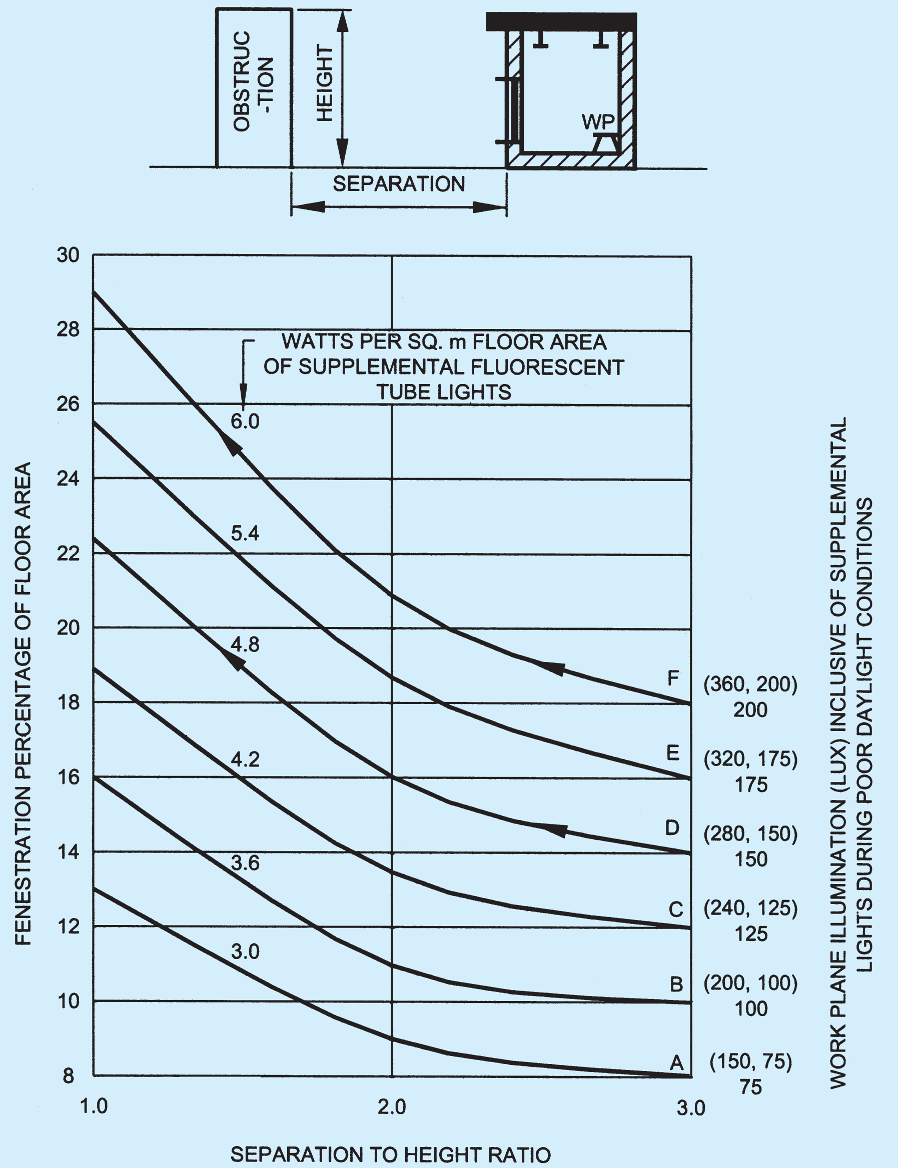



FIG. 4 NOMOGRAPH FOR DAYLIGHTING AND SUPPLEMENTAL LIGHTING DESIGN OF BUILDING

b) *Step 2* — Fix the vertical line corresponding to the given separation to height ratio of opposite buildings on the abscissa. From the point of intersection of this vertical line and the above curve move along horizontal, and read the value of fenestration percent on the left hand ordinate.

c) *Step 3* — If the floor area is greater than 50 $m^2$ and less than 30 $m^2$, the value of watts per square metre as well as fenestration percent may be easily determined for adequate daylighting and supplemental artificial lighting for design purposes. However, if the fenestration provided is less than the required value, the wattage of supplementary artificial lights should be increased proportionately to make up for the deficiency of natural illumination.

**4.4.4** For good distribution of day light on the working plane in a room, window height, window width and height of sill should be chosen in accordance with the following recommendations:

a) In office buildings windows of height 1.2 m or more in the center of a bay with sill level at 1.0 to 1.2 m above floor and in residential buildings windows of height 1.0 m to 1.1 m with sill height as 0.9 m to 0.7 m above floor are recommended for good distribution of daylight indoors. Window width can accordingly be adjusted depending upon the required fenestration percentage of the floor area.

b) If the room depth is more than 10 m, windows should be provided on opposite sides for bilateral lighting.

c) It is desirable to have a white finish for ceiling and off white (light colour) to white for walls. There is about 7 percent improvement in lighting levels in changing the finish of walls from moderate to white.

**4.4.5** For good distribution and integration of daylight with artificial lights the following guidelines are recommended:

a) Employ cool daylight fluorescent tubes for supplementary artificial lighting.

b) Distribute luminaries with a separation of 2 m to 3 m in each bay of 3 m to 4 m width.

c) Provide more supplementary lights such as twin tube luminaries in work areas where daylight is expected to be poor for example in the rear region of a room having single window and in the central region of a room having windows on opposite walls. In the vicinity of windows only single tube luminaries should be provided.

**4.4.6** *Artificial Lighting*

Energy conservation in lighting is effected by reducing wastage and using energy effective lamps and luminaires without sacrificing lighting quality. Measures to be followed comprise utilization of daylight, energy effective artificial lighting design by providing required illumination where needed, turning off artificial lights when not needed, maintaining lighter finishes of ceiling, walls and furnishings, and implementing periodic schedule for cleaning of luminaires and group replacement of lamps at suitable intervals. Choice of light sources with higher luminous efficacy and luminaires with appropriate light distribution is the most effective means of energy saving in lighting. However, choice of light sources also depends on the other lighting quality parameters like colour rendering index and colour temperature or appearance. For example, high pressure sodium vapour lamps, which have very high luminous efficacy, are not suitable for commercial interiors because of poor colour rendering index and colour appearance, but are highly desirable in heavy industries. Also the choice of light sources depends on the mounting height in the interiors. For example, fluorescent lamps are not preferred for mounting beyond 7 m height, when high pressure gas discharge lamps are preferred because of better optical control due to their compact size.

**4.4.6.1** *Efficient artificial light sources and luminaires*

Luminous efficacy of some of the lamps used in lighting of buildings are given in Table 8 along with average life in burning hours, Colour Rendering Index and Colour Temperature.

Following recommendations may be followed in the choice of light sources for different locations:

a) For supplementary artificial lighting of work area in office building care should be taken to use fluorescent lamps, which match with colour temperature of the daylight.

b) For residential buildings fluorescent lamps and/or CFLs of proper CRI and CCT are recommended to match with the colours and interior design of the room.

c) For commercial interiors, depending on the mounting heights and interior design, fluorescent lamps, CFLs and low wattage metal halilde lamps are recommended. For highlighting the displays in show windows, hotels, etc, low wattage tubular or dichroic reflector type halogen lamps can be used.

d) For industrial lighting, depending on the mounting height and colour consideration fluorescent lamps, high pressure mercury vappour lamps or high pressure sodium vapour lamps are recommended.

**4.4.6.2** For the same lumen output, it is possible to save 75 to 80 percent energy if GLS lamps are replaced with CFL and 65 to 70 percent if replaced with fluorescent lamps. Similar energy effective solutions are to be chosen for every application area.

Similarly with white fluorescent tubes recommended for corridors and staircases, the electrical consumption reduces to 1/4.5 of the energy consumption with incandescent lamps.

**4.4.6.3** Efficient luminaire also plays an important role for energy conservation in lighting. The choice of a luminaire should be such that it is efficient not only initially but also throughout its life. Following luminaries are recommended for different locations:

a) For offices semi-direct type of luminaries are recommended so that both the work plane illumination and surround luminance can be effectively enhanced.

b) For corridors and staircases direct type of luminaries with wide spread of light distributions are recommended.

c) In residential buildings, bare fluorescent tubes are recommended. Wherever the incandescent lamps are employed, they should be provided

**Table 8 Luminous Efficacy, Life, CRI and CCT of Light Sources**
(*Clause* 4.4.6.1)

| Sl No. | Light Source | Efficacy lm/W | Average Life h | CRI | CCT K |
|---|---|---|---|---|---|
| (1) | (2) | (3) | (4) | (5) | (6) |
| i) | Incandescent lamps<br>GLS 25 W-1 000 W | 8-18 | 1 000 | 100 | 2 800 |
| ii) | Tungsten halogen incandescent lamps<br>Mains-voltage types:<br>60 W-2 000 W<br>Low-voltage types with reflector have lower wattages | 10% higher than comparable GLS lamp | 2 000 | 100 | 2 800-3 200 |
| iii) | Fluorescent lamps (FTL) | | | | |
| | a) Standard lamps<br>38 mm (T12)<br>20 W-65 W<br>26 mm (T 8)<br>18 W-58 W | | | | |
| | Cool daylight | 61 | 5 000 | 72 | 6 500 |
| | Warm white | 67 | 5 000 | 57 | 3 500 |
| | b) Tri-Phosper lamps<br>38 mm (T12)<br>20 W-65 W<br>26 mm (T 8)<br>18 W-58 W | 88-104 | 12 000-18 000 | 85-95 | 2 700-6 500 |
| iv) | Compact Fluorescent Lamps (CFL)<br>5 W-25 W | 40-80 | 8 000 | Similar to FTL | |
| v) | High pressure mercury vapour lamps<br>80 W-400 W | 36-60 | 5 000 | 45 | 4 000 |
| vi) | Blended — Light lamps<br>MLL 100 W-500 W | 11-26 | 5 000 | 61 | 3 600 |
| vii) | High Pressure Sodium Vapour Lamps<br>50 W-1 000 W | 69-130 | 10 000-15 000 | 23 | 2 000 |
| viii) | Metal halide lamps<br>35 W-2 000 W | 69-83 | 10 000 | 68-92 | 3 000-5 600 |

NOTES

**1** The table includes lamps and wattages currently in use in buildings in India.

**2** Luminous efficacy varies with the wattage of the lamp.

**3** Average life values are from available Indian Standards. Where Indian Standard is not available, values given are only indicative.

**4** CRI and CCT values are only indicative.

**5** For exact values, it is advisable to contact manufacturers.

with white enamelled conical reflectors at an inclination of about 45° from vertical.

**4.4.7** *Cleaning Schedule for Window Panes and Luminaires*

Adequate schedule for cleaning of window panes and luminaries will result in significant advantage of enhanced daylight and lumen output from luminaries. This will tend to reduce the duration over which artificial lights will be used and minimize the wastage of energy. Depending upon the location of the building a minimum of three to six months interval for periodic cleaning of luminaries and window panes is recommended for maximum utilization of daylight and artificial lights.

**4.4.8** *Photocontrols for Artificial Lights*

There is a considerable wastage of electrical energy in lighting of buildings due to carelessness in switching off lights even when sufficient daylight is available indoors. In offices and commercial buildings, occupants may switch on lights in the morning and keep them on throughout the day. When sufficient daylight is available inside, suitable photo controls can be employed to switch off the artificial lights and thus prevent the wastage of energy.

**4.4.9** *Solar Photovoltaic Systems (SPV)*

Solar photovoltaic system enables direct conversion of sunlight into electricity and is viable option for lighting purpose in remote nongrid areas. The common SPV lighting systems are:

a) Solar lantern,
b) Fixed type solar home lighting system, and
c) Street lighting system.

**4.4.9.1** SPV lighting system should preferably be provided with CFL for energy efficiency.

**4.4.9.2** Invertors used in buildings for supplying electricity during the power cut period should be charged through SPV system.

**4.4.9.3** Regular maintenance of SPV system is necessary for its satisfactory functioning.

## 5 VENTILATION

### 5.1 General

Ventilation of buildings is required to supply fresh air for respiration of occupants, to dilute inside air to prevent vitiation by body odours and to remove any products of combustion or other contaminants in air and to provide such thermal environments as will assist in the maintenance of heat balance of the body in order to prevent discomfort and injury to health of the occupants.

### 5.2 Design Considerations

**5.2.1** *Respiration*

Supply of fresh air to provide oxygen for the human body for elimination of waste products and to maintain carbon dioxide concentration in the air within safe limits rarely calls for special attention as enough outside air for this purpose normally enters the areas of occupancy through crevices and other openings.

**5.2.1.1** In normal habitable rooms devoid of smoke generating source, the content of carbon dioxide in air rarely exceeds 0.5 percent to 1 percent and is, therefore, incapable of producing any ill effect. The amount of air required to keep the concentration down to 1 percent is very small. The change in oxygen content is also too small under normal conditions to have any ill effects; the oxygen content may vary quite appreciably without noticeable effect, if the carbon dioxide concentration is unchanged.

**5.2.2** *Vitiation by Body Odours*

Where no products of combustion or other contaminants are to be removed from air, the amount of fresh air required for dilution of inside air to prevent vitiation of air by body odours, depends on the air space available per person and the degree of physical activity; the amount of air decreases as the air space available per person increases, and it may vary from 20 $m^3$ to 30 $m^3$ per person per hour. In rooms occupied by only a small number of persons such an air change will automatically be attained in cool weather by normal leakage around windows and other openings and this may easily be secured in warm weather by keeping the openings open.

No standards have been laid down under the *Factories Act*, 1948 as regards the amount of fresh air required per worker or the number of air changes per hour. Section 16 relating to over-crowding requires that at least 14 $m^3$ to 16 $m^3$ of space shall be provided for every worker and for the purpose of that section no account shall be taken of any space in a work room which is more than 4.25 m above the floor level.

NOTE — Vitiation of the atmosphere can also occur in factories by odours given off due to contaminants of the product itself, say for example, from tobacco processing in a 'Bidi' factory. Here the ventilation will have to be augmented to keep odours within unobjectionable levels.

**5.2.2.1** *Recommended values for air changes*

The standards of general ventilation are recommended/ based on maintenance of required oxygen, carbon dioxide and other air quality levels and for the control of body odours when no products of combustion or other contaminants are present in the air; the values of air changes should be as follows:

| *Sl No.* | *Application* | *Air Change per Hour* |
|---|---|---|
| (1) | (2) | (3) |
| 1. | Assembly rooms | 4-8 |
| 2. | Bakeries | 20-30 |
| 3. | Banks/building societies | 4-8 |
| 4. | Bathrooms | 6-10 |
| 5. | Bedrooms | 2-4 |
| 6. | Billiard rooms | 6-8 |
| 7. | Boiler rooms | 15-30 |
| 8. | Cafes and coffee bars | 10-12 |
| 9. | Canteens | 8-12 |
| 10. | Cellars | 3-10 |
| 11. | Churches | 1-3 |
| 12. | Cinemas and theatres | 10-15 |
| 13. | Club rooms | 12, *Min* |
| 14. | Compressor rooms | 10-12 |
| 15. | Conference rooms | 8-12 |
| 16. | Dairies | 8-12 |
| 17. | Dance halls | 12, *Min* |
| 18. | Dye works | 20-30 |
| 19. | Electroplating shops | 10-12 |
| 20. | Engine rooms | 15-30 |
| 21. | Entrance halls | 3-5 |
| 22. | Factories and work shops | 8-10 |
| 23. | Foundries | 15-30 |
| 24. | Garages | 6-8 |
| 25. | Glass houses | 25-60 |
| 26. | Gymnasium | 6, *Min* |
| 27. | Hair dressing saloon | 10-15 |
| 28. | Hospitals-sterlizing | 15-25 |
| 29. | Hospital-wards | 6-8 |
| 30. | Hospital domestic | 15-20 |
| 31. | Laboratories | 6-15 |
| 32. | Launderettes | 10-15 |
| 33. | Laundries | 10-30 |
| 34. | Lavatories | 6-15 |
| 35. | Lecture theatres | 5-8 |
| 36. | Libraries | 3-5 |
| 37. | Living rooms | 3-6 |
| 38. | Mushroom houses | 6-10 |

| *Sl No.* | *Application* | *Air Change per Hour* |
|---|---|---|
| (1) | (2) | (3) |
| 39. | Offices | 6-10 |
| 40. | Paint shops (not cellulose) | 10-20 |
| 41. | Photo and X-ray dark room | 10-15 |
| 42. | Public house bars | 12, *Min* |
| 43. | Recording control rooms | 15-25 |
| 44. | Recording studios | 10-12 |
| 45. | Restaurants | 8-12 |
| 46. | Schoolrooms | 5-7 |
| 47. | Shops and supermarkets | 8-15 |
| 48. | Shower baths | 15-20 |
| 49. | Stores and warehouses | 3-6 |
| 50. | Squash courts | 4, *Min* |
| 51. | Swimming baths | 10-15 |
| 52. | Toilets | 6-10 |
| 53. | Utility rooms | 15-20 |
| 54. | Welding shops | 15-30 |

NOTE — The ventilation rates may be increased by 50 percent where heavy smoking occurs or if the room is below ground.

**5.2.3** *Heat Balance of Body*

Specially in hot weather, when thermal environment inside the room is worsened by heat given off by machinery, occupants and other sources, the prime need for ventilation is to provide such thermal environment as will assist in the maintenance of heat balance of the body in order to prevent discomfort and injury to health. Excess of heat either from increased metabolism due to physical activity of persons or gains from a hot environment has to be offset to maintain normal body temperature (37°C). Heat exchange of the human body with respect to the surroundings is determined by the temperature and humidity gradient between the skin and the surroundings and other factors, such as age of persons, clothing, etc, and the latter depends on air temperature (dry bulb temperature), relative humidity, radiation from the solid surroundings and rate of air movement. The volume of outside air to be circulated through the room is, therefore, governed by the physical considerations of controlling the temperature, air distribution or air movement. Air movement and air distribution may, however, be achieved by recirculation of the inside air rather than bringing in all outside air. However, fresh air supply or the circulated air will reduce heat stress by dissipating heat from body by evaporation of the sweat, particularly when the relative humidity is high and the air temperature is near body temperature.

**5.2.3.1** *Limits of comfort and heat tolerance*

Thermal comfort is that condition of thermal environment under which a person can maintain a body heat balance at normal body temperature and without perceptible sweating. Limits of comfort vary considerably according to studies carried out in India and abroad. The thermal comfort of a person lies between TSI values of 25°C and 30°C with optimum condition at 27.5°C. Air movement is necessary in hot and humid weather for body cooling. A certain minimum desirable wind speed is needed for achieving thermal comfort at different temperatures and relative humidities. Such wind speeds are given in Table 9. These are applicable to sedentary work in offices and other places having no noticeable sources of heat gain. Where somewhat warmer conditions are prevalent, such as in godowns and machine shops and work is of lighter intensity, and higher temperatures can be tolerated without much discomfort, minimum wind speeds for just acceptable warm conditions are given in Table 10. For obtaining values of indoor wind speed above 2.0 m/s, mechanical means of ventilation may have to be adopted (*see also* Part 8 'Building Services, Section 3 Air Conditioning, Heating and Mechanical Ventilation').

**Table 9 Desirable Wind Speeds (m/s) for Thermal Comfort Conditions**

(*Clause* 5.2.3.1)

| Dry Bulb Temperature, °C | Relative Humidity (Percentage) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 30 | 40 | 50 | 60 | 70 | 80 | 90 |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| 28 | * | * | * | * | * | * | * |
| 29 | * | * | * | * | * | 0.06 | 0.19 |
| 30 | * | * | * | 0.06 | 0.24 | 0.53 | 0.85 |
| 31 | * | 0.06 | 0.24 | 0.53 | 1.04 | 1.47 | 2.10 |
| 32 | 0.20 | 0.46 | 0.94 | 1.59 | 2.26 | 3.04 | ** |
| 33 | 0.77 | 1.36 | 2.12 | 3.00 | ** | ** | ** |
| 34 | 1.85 | 2.72 | ** | ** | ** | ** | ** |
| 35 | 3.20 | ** | ** | ** | ** | ** | ** |

* None

** Higher than those acceptable in practice.

**Table 10 Minimum Wind Speeds (m/s) for Just Acceptable Warm Conditions**

(*Clause* 5.2.3.1)

| Dry Bulb Temperature, °C | Relative Humidity (Percentage) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 30 | 40 | 50 | 60 | 70 | 80 | 90 |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| 28 | * | * | * | * | * | * | * |
| 29 | * | * | * | * | * | * | * |
| 30 | * | * | * | * | * | * | * |
| 31 | * | * | * | * | * | 0.06 | 0.23 |
| 32 | * | * | * | 0.09 | 0.29 | 0.60 | 0.94 |
| 33 | * | 0.04 | 0.24 | 0.60 | 1.04 | 1.85 | 2.10 |
| 34 | 0.15 | 0.46 | 0.94 | 1.60 | 2.26 | 3.05 | ** |
| 35 | 0.68 | 1.36 | 2.10 | 3.05 | ** | ** | ** |
| 36 | 1.72 | 2.70 | ** | ** | ** | ** | ** |

* None

** Higher than those acceptable in practice.

**5.2.3.2** There will be a limit of heat tolerance when air temperatures are excessive and the degree of physical activity is high. This limit is determined when the bodily heat balance is upset, that is, when the bodily heat gain due to conduction, convection and the radiation from the surroundings exceeds the bodily heat loss, which is mostly by evaporation of sweat from the surface of the body. The limits of heat tolerance for Indian workers are based on the study conducted by the Chief Adviser Factories, Government of India, Ministry of Labour and are given in his report on Thermal Stress in Textile Industry (Report No. 17) issued in 1956. According to this Report, where workers in industrial buildings wearing light clothing are expected to do work of moderate severity with the energy expenditure in the range 273 to 284 W, the maximum wet bulb temperature shall not exceed 29°C and adequate air movement subject to a minimum air velocity of 30 m/min shall be provided, and in relation to the dry bulb temperature, the wet bulb temperature of air in the work room, as far as practicable, shall not exceed that given in Table 11.

**Table 11 Maximum Permissible Wet Bulb Temperatures for Given Dry Bulb Temperatures**

(*Clause* 5.2.3.2)

| Dry Bulb Temperature °C | Maximum Wet-Bulb Temperature, °C |
|---|---|
| (1) | (2) |
| 30 | 29.0 |
| 35 | 28.5 |
| 40 | 28.0 |
| 45 | 27.5 |
| 50 | 27.0 |

NOTES

**1** These are limits beyond which the industry should not allow the thermal conditions to go for more than 1 h continuously. The limits are based on a series of studies conducted on Indian subjects in psychrometric chamber and on other data on heat casualties in earlier studies conducted in Kolar Gold Fields and elsewhere.

**2** Figures given in this table are not intended to convey that human efficiency at 50°C will remain the same as at 30°C, provided appropriate wet bulb temperatures are maintained. Efficiency decreases with rise in the dry bulb temperature as well, as much as possible. Long exposures to temperature of 50°C dry bulb/27°C wet bulb may prove dangerous.

**3** Refrigeration or some other method of cooling is recommended in all cases where conditions would be worse than those shown in this table.

## 5.3 Methods of Ventilation

General ventilation involves providing a building with relatively large quantities of outside air in order to improve general environment of the building. This may be achieved in one of the following ways:

a) Natural supply and natural exhaust of air;
b) Natural supply and mechanical exhaust of air;
c) Mechanical supply and natural exhaust of air; and
d) Mechanical supply and mechanical exhaust of air.

**5.3.1** *Control of Heat*

Although it is recognized that general ventilation is one of the most effective methods of improving thermal environmental conditions in factories, in many situations, the application of ventilation should be preceded by and considered along with some of the following other methods of control. This would facilitate better design of buildings for general ventilation, either natural or mechanical or both, and also reduce their cost.

**5.3.1.1** *Isolation*

Sometimes it is possible to locate heat producing equipment, such as furnaces in such a position as would expose only a small number of workers to hot environment. As far as practicable, such sources of heat in factories should be isolated.

In situations where relatively few people are exposed to severe heat stress and their activities are confined to limited areas as in the case of rolling mill operators and crane operators, it may be possible to enclose the work areas and provide spot cooling or supply conditioned air to such enclosures.

**5.3.1.2** *Insulation*

A considerable portion of heat in many factories is due to the solar radiation falling on the roof surfaces, which, in turn, radiate heat inside the building. In such situations, insulations of the roof or providing a false ceiling or double roofing would be very effective in controlling heat. Some reduction can also be achieved by painting the roof in heat reflective shades.

Hot surfaces of equipment, such as pipes, vessels, etc, in the building should also be insulated to reduce their surface temperature.

**5.3.1.3** *Substitution*

Sometimes, it is possible to substitute a hot process by a method that involves application of localized or more efficiently controlled method of heating. Examples include induction hardening instead of conventional heat treatment, cold riveting or spot welding instead of hot riveting, etc.

**5.3.1.4** *Radiant shielding*

Hot surfaces, such as layers of molten metal emanate radiant heat, which can best be controlled by placing a shield having a highly reflecting surface between the source of heat and the worker, so that a major portion of the heat falling on the shield is reflected back to the source. Surfaces such as of tin and aluminium have been used as materials for shields. The efficiency of the shield does not depend on its thickness, but on the reflectivity and emissivity of its surface. Care should be taken to see that the shield is not heated up by conduction and for this purpose adequate provision should be made for the free flow upwards of the heated air between the hot surface and the shield by leaving the necessary air space and providing opening at the top and the bottom of the sides.

**5.3.2** *Volume of Air Required*

The volume of air required shall be calculated by using both the sensible heat or latent heat gain as the basis. The larger of the two figures obtained should be used in actual practice.

**5.3.2.1** *Volume of air required for removing sensible heat*

When the amount of sensible heat given off by different sources, namely, the sun, the manufacturing processes, machinery, occupants and other sources, is known and a suitable value for the allowable temperature rise is assumed, the volume of outside air to be provided for removing the sensible heat may be calculated from:

$$Q_1 = \frac{2.976\,8\ K_s}{t}$$

where

$Q_1$ = Quantity of air in m$^3$/h,
$K_s$ = Sensible heat gained in W, and
$t$ = Allowable temperature rise in °C.

**5.3.2.2** Temperature rise refers mainly to the difference between the air temperatures at the outlet (roof exit) and at the inlet openings for outside air. As very little data exist on allowable temperature rise values for supply of outside air in summer months, the values given in Table 12 related to industrial buildings may be used for general guidance.

**Table 12 Allowable Temperature Rise Values**
(*Clause* 5.3.2.2)

| Height of Outlet Opening | Temperature Rise |
|---|---|
| (1) | (2) |
| 6 | 3 to 4.5 |
| 9 | 4.5 to 6.5 |
| 12 | 6.5 to 11 |

NOTES

**1** The conditions are limited to light or medium heavy manufacturing processes, freedom from radiant heat and inlet openings not more than 3 to 4.5 m above floor level.

**2** At the working zone between floor level and 1.5 m above floor level, the recommended maximum allowable temperature rise for air is 2°C to 3°C above the air temperature at the inlet openings.

**5.3.2.3** *Volume of air required for removing latent heat*

If the latent heat gained from the manufacturing processes and occupants is also known and a suitable value for the allowable rise in the vapour pressure is assumed:

$$Q_2 = \frac{4\,127.26 \times K_1}{h}$$

where

$Q_2$ = Quantity of air in m$^3$/h,
$K_1$ = Latent heat gained in W, and
$h$ = Allowable vapour pressure difference in mm of mercury.

NOTE — In majority of the cases, the sensible heat gain will far exceed the latent heat gain, so that the amount of outside air to be drawn by ventilating equipment can be calculated in most cases on the basis of the equation given in **5.3.2.1**.

**5.3.2.4** Ventilation is also expressed as m$^3$/h per m$^2$ of floor area. This relationship fails to evaluate the actual heat relief provided by a ventilation system, but it does give a relationship which is independent of building height. This is a more rational approach, because, with the same internal load, the same amount of ventilation air, properly applied to the work zone with adequate velocity, will provide the desired heat relief quite independently of the ceiling height of the space, with few exceptions. Ventilation rates of 30 to 60 m$^3$/h per m$^2$ have been found to give good results in many plants.

**5.4 Natural Ventilation**

The rate of ventilation by natural means through windows or other openings depends on:

a) direction and velocity of wind outside and sizes and disposition of openings (wind action), and
b) convection effects arising from temperature of vapour pressure difference (or both) between inside and outside the room and the difference of height between the outlet and inlet openings (stack effect).

**5.4.1** *Ventilation of Non-industrial Buildings*

Ventilation in non-industrial buildings due to stack effect, unless there is a significant internal load, could be neglected, except in cold regions, and wind action may be assumed to be predominant.

**5.4.1.1** In hot dry regions, the main problem in summer is to provide protection from sun's heat so as to keep the indoor temperature lower than those outside under the sun. For this purpose windows and other openings are generally kept closed *during day time* and only minimum ventilation is provided for the control of odours or for removal of products of combustion.

**5.4.1.2** In warm humid regions, the problem in the design of non-industrial buildings is to provide free passage of air to keep the indoor temperature as near to those outside in the shade as possible, and for this purpose the buildings are oriented to face the direction of prevailing winds and windows and other openings are kept open on both windward and leeward sides.

**5.4.1.3** In winter months in cold regions, the windows and other openings are generally kept shut, particularly during night; and ventilation necessary for the control of odours and for the removal of products of combustion can be achieved either by stack action or by some infilteration of outside air due to wind action.

**5.4.2** *Ventilation of Industrial Buildings*

In providing natural ventilation of all industrial buildings having significant internal heat loads due to manufacturing process, proper consideration should be given to the size and distribution of windows and other inlet openings in relation to outlet openings so as to give, with due regard to orientation, prevailing winds, size and configuration of the building and manufacturing processes carried on, maximum possible control of thermal environment.

**5.4.2.1** In the case of industrial buildings wider than 30 m, the ventilation through windows may be augmented by roof ventilation.

**5.4.3** *Design Guidelines for Natural Ventilation*

**5.4.3.1** *By wind action*

i) A building need not necessarily be oriented perpendicular to the prevailing outdoor wind; it may be oriented at any convenient angle between 0° and 30° without loosing any beneficial aspect of the breeze. If the prevailing wind is from East or West, building may be oriented at 45° to the incident wind so as to diminish the solar heat without much reduction in air motion indoors.

ii) Inlet openings in the buildings should be well distributed and should be located on the windward side at a low level, and outlet openings should be located on the leeward side. Inlet and outlet openings at high levels may only clear the top air at that level without producing air movement at the level of occupancy.

iii) Maximum air movement at a particular plane is achieved by keeping the sill height of the opening at 85 percent of the critical height (such as head level) for the following recommended levels of occupancy:
    1) For sitting on chair 0.75 m,
    2) For sitting on bed 0.60 m, and
    3) For sitting on floor 0.40 m.

iv) Inlet openings should not as far as possible be obstructed by adjoining buildings, trees, sign boards or other obstructions or by partitions inside in the path of air flow.

v) In rooms of normal size having identical windows on opposite walls the average indoor air speed increases rapidly by increasing the width of window up to two-third of the wall width; beyond that the increase is in much smaller proportion than the increase of the window width. The air motion in the working zone is maximum when window height is 1.1 m. Further increase in window height promotes air motion at higher level of window, but does not contribute additional benefits as regards air motion in the occupancy zones in buildings.

vi) Greatest flow per unit area of openings is obtained by using inlet and outlet openings of nearby equal areas at the same level.

vii) For a total area of openings (inlet and outlet) of 20 percent to 30 percent of floor area, the average indoor wind velocity is around 30 percent of outdoor velocity. Further increase in window size increases the available velocity but not in the same proportion. In fact, even under most favourable conditions the maximum average indoor wind speed does not exceed 40 percent of outdoor velocity.

viii) Where the direction of wind is quite constant and dependable, the size of the inlet should be kept within 30 to 50 percent of the total area of openings and the building should be oriented perpendicular to the incident wind. Where direction of the wind is quite variable the openings may be arranged so that as far as possible there is approximately equal area on all sides. Thus no matter what the wind direction be, there would be some openings directly exposed to wind pressure and others to air suction and effective air movement through the building would be assured.

ix) Windows of living rooms should open directly to an open space. In places where building sites are restricted, open space may have to be created in the buildings by providing adequate courtyards.

x) In the case of rooms with only one wall exposed to outside, provision of two windows on that wall is preferred to that of a single window.

xi) Windows located diagonally opposite to each other with the windward window near the upstream corner give better performance than other window arrangements for most of the building orientations.

xii) Horizontal louvers, that is a sunshade, atop a window deflects the incident wind upward and reduces air motion in the zone of occupancy. A horizontal slot between the wall and horizontal louver prevents upward deflection of air in the interior of rooms. Provision of inverted L type (Γ) louver increases the room air motion provided that the vertical projection does not obstruct the incident wind.

xiii) Provision of horizontal sashes inclined at an angle of 45° in appropriate direction helps to promote the indoor air motion. Sashes projecting outward are more effective than projecting inward.

xiv) Air motion at working plane 0.4 m above the floor can be enhanced by 30 percent using a pelmet type wind deflector.

xv) Roof overhangs help promoting air motion in the working zone inside buildings.

xvi) *VERANDAH* open on three sides is to be preferred since it causes an increase in the room air motion for most of the orientations of the building with respect to the outdoor wind.

xvii) A partition placed parallel to the incident wind has little influence on the pattern of the air flow, but when located perpendicular to the main flow, the same partition creates a wind shadow. Provision of a partition with spacing of 0.3 m underneath, helps augmenting air motion near floor level in the leeward compartment of wide span buildings.

xviii) Air motion in a building unit having windows tangential to the incident wind is accelerated when another unit is located at end-on position on down stream side.

xix) Air motion in two wings oriented parallel to the prevailing breeze is promoted by connecting them with a block on downstream side.

xx) Air motion in a building is not affected by constructing another building of equal or smaller height on the leeward side; but it is slightly reduced if the leeward building is taller than the windward block.

xxi) Air motion in a shielded building is less than that in an unobstructed building. To minimize shielding effect, the distances between two rows should be 8 *H* for semi-detached houses and 10 *H* for long rows houses. However, for smaller spacing the shielding effect is also diminished by raising the height of the shielded building.

xxii) Hedges and shrubs defect the air away from the inlet openings and cause a reduction in indoor air motion. These elements should not be planted at a distance of about 8 m from the building because the induced air motion is reduced to minimum in that case. However, air motion in the leeward part of the building can be enhanced by planting a low hedge at a distance of 2 m from the building.

xxiii) Trees with large foliage mass having trunk bare of branches up to the top level of window, deflect the outdoor wind downwards and promotes air motion in the leeward portion of buildings.

xxiv) Ventilation conditions indoors can be ameliorated by constructing buildings on earth mound having a slant surface with a slope of 10° on upstream side.

xxv) In case of industrial buildings the window height should be about 1.6 m and width about two-third of wall width. These should be located at a height of 1.1 m above the floor. In addition to this, openings around 0.9 m high should be provided over two-third length of the glazed area in the roof lights.

xxvi) Height of industrial buildings, although determined by the requirements of industrial processes involved, generally kept large enough to protect the workers against hot stagnant air below the ceiling as also to dilute the concentration of contaminant inside. However, if high level openings in roof or walls are provided, building height can be reduced to 4 m without in any way impairing the ventilation performance.

NOTE — For data on outdoor wind speeds at a place, reference may be made to 'The Climatic Data Handbook prepared by Central Building Research Institute, Roorkee, 1999'.

**5.4.3.2** *By stack effect*

Natural ventilation by stack effect occurs when air inside a building is at a different temperature than air outside. Thus in heated buildings or in buildings wherein hot processes are carried on and in ordinary buildings during summer nights and during premonsoon periods, the inside temperature is higher than that of outside, cool outside air will tend to enter through openings at low level and warm air will tend to leave through openings at high level. It would, therefore, be advantageous to provide ventilators as close to ceilings as possible. Ventilators can also be provided in roofs as, for example, cowl, ventpipe, covered roof and ridge vent.

### 5.5 Mechanical Ventilation

The requirements of mechanical ventilation shall be in accordance with Part 8 'Building Services, Section 3 Air Conditioning, Heating and Mechanical Ventilation'.

### 5.6 Determining Rate of Ventilation

**5.6.1** *Natural Ventilation*

This is difficult to measure as it varies from time-to-time. The amount of outside air through windows and other openings depends on the direction and velocity of wind outside (wind action) and/or convection effects arising from temperature or vapour pressure differences (or both) between inside and outside of the building (stack effect).

**5.6.1.1** *Wind action*

For determining the rate of ventilation based on wind action the wind may be assumed to come from any direction within 45° of the direction of prevailing wind. Ventilation due to external wind is given by the following formula:

$$Q = KAV$$

where

- $Q$ = Rate of air flow in m$^3$/h;
- $K$ = Coefficient of effectiveness, which may be taken as 0.6 for wind perpendicular to openings and 0.3 for wind at an angle less than 45° to the openings;
- $A$ = Free area of inlet openings in m$^2$; and
- $V$ = Wind speed in m/h.

NOTE — For wind data at a place, the local Meteorological Department may be consulted.

**5.6.1.2** *Stack effect*

Ventilation due to convection effects arising from temperature difference between inside and outside is given by:

$$Q = 7.0\,A\,\sqrt{h\,(t_r - t_o)}$$

where

- $Q$ = Rate of air flow in m$^3$/h;
- $A$ = Free area of inlet openings in m$^2$;
- $h$ = Vertical distance between inlets and outlets in m;
- $t_r$ = Average temperature of indoor air at height $h$ in °C; and
- $t_o$ = Temperature of outdoor air in °C.

NOTE — The equation is based on 0.65 effectiveness of openings. This should be reduced to 0.50 if conditions are not favourable.

**5.6.1.3** When areas of inlet and outlet openings are unequal, the value of $A$ may be calculated using the equation

$$\frac{2}{A^2} = \frac{1}{A_{inlet}^2} + \frac{1}{A_{outlet}^2}$$

**5.6.1.4** When both forces (wind and thermal) act together in the same direction, even without interference, the resulting air flow is not equal to the two flows estimated separately. Flow through any opening is proportional to the square root of the sum of the two heads acting on that opening.

Wind velocity and direction, outdoor temperature, and indoor distribution can not be predicted with certainty, and refinement in calculation is not justified. A simple method is calculate the sum of the flows produced by each force separately. Then using the ratio of the flow produced by thermal forces to the aforementioned sum, the actual flow due to the combined forces can be approximated from Fig. 5. When the two flows are equal, the actual flow is about 30 percent greater than the flow caused by either force acting independently (*see* Fig. 5).

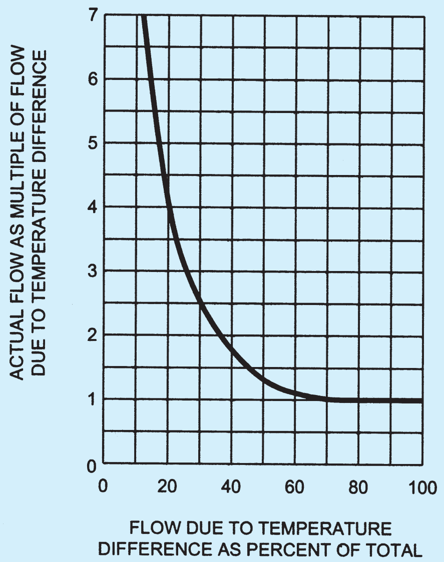



Fig. 5 Determination of Flow Caused by Combined Forces of Wind and Temperature Difference

Judgement is necessary for proper location of openings in a building specially in the roof, where heat, smoke and fumes are to be removed. Usually, windward monitor openings should be closed, but if wind is so slight that temperature head can overcome it, all openings may be opened.

**5.6.1.5** For method for determining the rate of ventilation based on probable indoor wind speed with typical illustrative example for residential building, reference may be made to good practice [8-1(6)].

**5.6.2** *Mechanical Ventilation*

The determination of rate of ventilation in case of mechanical ventilation shall be done in accordance with Part 8 'Building Services, Section 3 Air Conditioning, Heating and Mechanical Ventilation'.

**5.6.3** *Combined Effect of Different Methods of Ventilation*

When combination of two or more methods of general ventilation is used, the total rate of ventilation shall be reckoned as the highest of the following three, and this rule shall be followed until an exact formula is established by research:

a) 1.25 times the rate of natural ventilation,
b) Rate of positive ventilation, and
c) Rate of exhaust of air.

**5.6.4** *Air Movement*

The rate of air movement of turbulent type at the working zone shall be measured either with a Kata thermometer (dry silvered type) or heated thermometer or properly calibrated thermocouple anemometer. Whereas anemometer gives the air velocity directly, the Kata thermometer and heated thermometer give cooling power of air and the rate of air movement is found by reference to a suitable nomogram using the ambient temperature.

**5.7 Energy Conservation in Ventilation System**

**5.7.1** Maximum possible use should be made of wind induced natural ventilation. This may be accomplished by following the design guidelines given in **5.7.1.1**.

**5.7.1.1** Adequate number of circulating fans should be installed to serve all interior working areas during summer months in the hot dry and warm humid regions to provide necessary air movement at times when ventilation due to wind action alone does not afford sufficient relief.

**5.7.1.1.1** The capacity of a ceiling fan to meet the requirement of a room with the longer dimension $D$ metres should be about 55 $D$ $m^3$/min.

**5.7.1.1.2** The height of fan blades above the floor should be $(3H + W)/4$, where $H$ is the height of the room, and $W$ is the height of work plane.

**5.7.1.1.3** The minimum distance between fan blades and the ceiling should be about 0.3 metre.

**5.7.2** Electronic regulators should be used instead of resistance type regulators for controlling the speed of fans.

**5.7.3** When actual ventilated zone does not cover the entire room area, then optimum size of ceiling fan should be chosen based on the actual usable area of room, rather than the total floor area of the room. Thus smaller size of fan can be employed and energy saving could be achieved.

**5.7.4** Power consumption by larger fans is obviously higher, but their power consumption per square metre of floor area is less and service value higher. Evidently, improper use of fans irrespective of the rooms dimensions is likely to result in higher power consumption. From the point of view of energy consumption, the number of fans and the optimum sizes for rooms of different dimensions are given in Table 13.

**Table 13 Optimum Size/Number of Fans for Rooms of Different Sizes**

(*Clause* 5.7.4)

| Room Width m | Room Length | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 4 m | 5 m | 6 m | 7 m | 8 m | 9 m | 10 m | 11 m | 12 m | 14 m | 16 m |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) |
| 3 | 1 200/1 | 1 400/1 | 1 500/1 | 1 050/2 | 1 200/2 | 1 400/2 | 1 400/2 | 1 400/2 | 1 200/3 | 1 400/3 | 1 400/3 |
| 4 | 1 200/1 | 1 400/1 | 1 200/2 | 1 200/2 | 1 200/2 | 1 400/2 | 1 400/2 | 1 500/2 | 1 200/3 | 1 400/3 | 1 500/3 |
| 5 | 1 400/1 | 1 400/1 | 1 400/2 | 1 400/2 | 1 400/2 | 1 400/2 | 1 400/2 | 1 500/2 | 1 400/3 | 1 400/3 | 1 500/3 |
| 6 | 1 200/2 | 1 400/2 | 900/4 | 1 050/4 | 1 200/4 | 1 400/4 | 1 400/4 | 1 500/4 | 1 200/6 | 1 400/6 | 1 500/6 |
| 7 | 1 200/2 | 1 400/2 | 1 050/4 | 1 050/4 | 1 200/4 | 1 400/4 | 1 400/4 | 1 500/4 | 1 200/6 | 1 400/6 | 1 500/6 |
| 8 | 1 200/2 | 1 400/2 | 1 200/4 | 1 200/4 | 1 200/4 | 1 400/4 | 1 400/4 | 1 500/4 | 1 200/6 | 1 400/6 | 1 500/6 |
| 9 | 1 400/2 | 1 400/2 | 1 400/4 | 1 400/4 | 1 400/4 | 1 400/4 | 1 400/4 | 1 500/4 | 1 400/6 | 1 400/6 | 1 500/6 |
| 10 | 1 400/2 | 1 400/2 | 1 400/4 | 1 400/4 | 1 400/4 | 1 400/4 | 1 400/4 | 1 500/4 | 1 400/6 | 1 400/6 | 1 500/6 |
| 11 | 1 500/2 | 1 500/2 | 1 500/4 | 1 500/4 | 1 500/4 | 1 500/4 | 1 500/4 | 1 500/4 | 1 500/6 | 1 500/6 | 1 500/6 |
| 12 | 1 200/3 | 1 400/3 | 1 200/6 | 1 200/6 | 1 200/6 | 1 400/6 | 1 400/6 | 1 500/6 | 1 200/7 | 1 400/9 | 1 400/9 |
| 13 | 1 400/3 | 1 400/3 | 1 200/6 | 1 200/6 | 1 200/6 | 1 400/6 | 1 400/6 | 1 500/6 | 1 400/9 | 1 400/9 | 1 500/9 |
| 14 | 1 400/3 | 1 400/3 | 1 400/6 | 1 400/6 | 1 400/6 | 1 400/6 | 1 400/6 | 1 500/6 | 1 400/9 | 1 400/9 | 1 500/9 |

# ANNEX A

(*Clauses* 4.2.5, 4.2.5.2, 4.2.5.3 *and* 4.2.5.4)

## SKY COMPONENT TABLES

### A-1 DESCRIPTION OF TABLES

**A-1.1** The three sky component tables are as given below:

| | |
|---|---|
| Table 14 | Percentage sky components on the horizontal plane due to a vertical rectangular opening for the clear design sky |
| Table 15 | Percentage sky components on the vertical plane perpendicular to a vertical rectangular opening for the clear design sky |
| Table 16 | Percentage sky components on the vertical plane parallel to a vertical rectangular opening for the clear design sky |

**A-1.2** All the tables are for an unglazed opening illuminated by the clear design sky.

**A-1.3** The values tabulated are the components at a point *P* distant from the opening on a line perpendicular to the plane of the opening through one of its lower corners, and *l* and *h* are the width and height respectively of the rectangular opening (*see* Fig. 6).

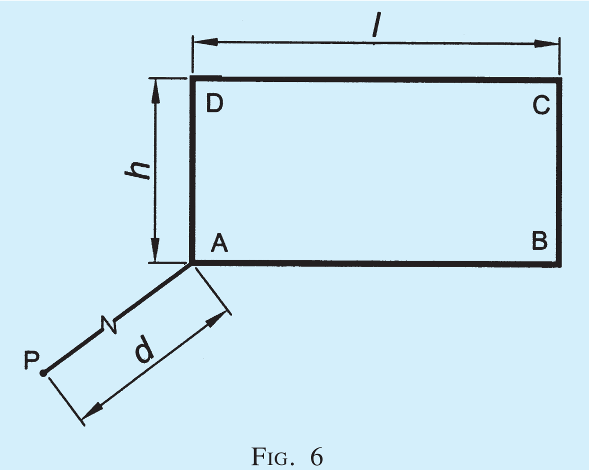



FIG. 6

**A-1.4** Sky component for different *h*/*d* and *l*/*d* values are tabulated, that is, for windows of different size and for different distances of the point *P* from the window.

**A-1.5** By suitable combination of the values obtained from the three tables, for a given point for a given window, the sky component in any plane passing through the point may be obtained.

### A-1.6 Method of Using the Tables

**A-1.6.1** Method of using the Tables to get the sky component at given point is explained with help of the following example.

**A-1.6.2** *Example*

It is desired to calculate the sky component due to a vertical window *ABCD* with width 1.8 m and height 1.5 m at a point *P* on a horizontal plane 3.0 m from the window wall located as shown in Fig. 7. Foot of the perpendicular *N* is 0.6 m below the sill and 0.9 m to the left of *AD*.

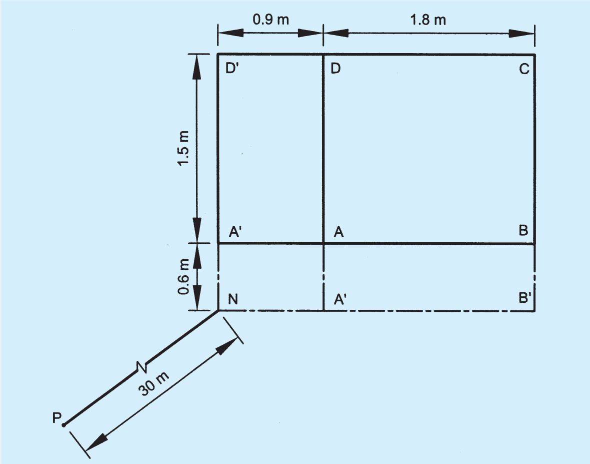



FIG. 7

Consider *ABCD* extended to *NB´CD´*

1) For *NB´CD´*
 $l/d = (1.8 + 0.9)/3 = 0.9$
 $h/d = (1.5 + 0.6)/3 = 0.7$
 $F_1 = 5.708$ percent (from Table 15)
2) For *NA´DD´*
 $l/d = 0.9/3 = 0.3$
 $h/d = (1.5 + 0.6)/3 = 0.7$
 $F_2 = 2.441$ percent (from Table 15)
3) For *NB´BA´*
 $l/d = (1.8 + 0.9)/3 = 0.9$
 $h/d = 0.6/3 = 0.2$
 $F_3 = 0.878$ percent (from Table 15)
4) For *NA´AA´*
 $l/d = 0.9/3 = 0.3$
 $h/d = 0.6/3 = 0.2$
 $F_4 = 0.403$ percent (from Table 15)

Since *ABCD* = *NB´CD´*–*NA´DD´*–*NB´BA´*+*NA´AA´*

Sky Component $F = F_1 – F_2 – F_3 + F_4$
$= 5.708–2.441–0.878+0.403$
$= 2.792$

### Table 14 Percentage Sky Components on the Horizontal Plane Due to a Verticle Rectandular Opeining for the Clear Design Sky

(*Clause* A-1.5)

| *l/d* → <br> *h/d* ↓ | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 | 1.0 | 1.1 | 1.2 | 1.3 | 1.4 | 1.5 | 1.6 | 1.7 | 1.8 | 1.9 | 2.0 | 3.0 | 4.0 | 5.0 | 10.0 | INF |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) | (14) | (15) | (16) | (17) | (18) | (19) | (20) | (21) | (22) | (23) | (24) | (25) | (26) |
| 0.1 | 0.036 | 0.071 | 0.104 | 0.133 | 0.158 | 0.179 | 0.198 | 0.213 | 0.225 | 0.235 | 0.243 | 0.250 | 0.256 | 0.261 | 0.264 | 0.268 | 0.270 | 0.272 | 0.274 | 0.276 | 0.284 | 0.286 | 0.287 | 0.288 | 0.288 |
| 0.2 | 0.141 | 0.277 | 0.403 | 0.516 | 0.614 | 0.699 | 0.770 | 0.829 | 0.878 | 0.918 | 0.950 | 0.977 | 0.999 | 1.018 | 1.033 | 1.046 | 1.056 | 1.065 | 1.072 | 1.079 | 1.110 | 1.118 | 1.122 | 1.125 | 1.125 |
| 0.3 | 0.300 | 0.589 | 0.859 | 1.102 | 1.315 | 1.499 | 1.653 | 1.782 | 1.888 | 1.976 | 2.048 | 2.108 | 2.157 | 2.197 | 2.231 | 2.259 | 2.282 | 2.302 | 2.318 | 2.333 | 2.401 | 2.421 | 2.429 | 2.436 | 2.437 |
| 0.4 | 0.460 | 0.905 | 1.322 | 1.702 | 2.041 | 2.337 | 2.590 | 2.804 | 2.984 | 3.134 | 3.258 | 3.361 | 3.446 | 3.516 | 3.574 | 3.623 | 3.664 | 3.699 | 3.728 | 3.753 | 3.873 | 3.909 | 3.922 | 3.935 | 3.937 |
| 0.5 | 0.604 | 1.189 | 1.741 | 2.247 | 2.700 | 3.099 | 3.444 | 3.740 | 3.992 | 4.204 | 3.383 | 4.553 | 4.659 | 4.765 | 4.853 | 4.928 | 4.990 | 5.043 | 5.088 | 5.126 | 5.312 | 5.366 | 5.387 | 5.408 | 5.410 |
| 0.6 | 0.732 | 1.443 | 2.114 | 2.732 | 3.289 | 3.781 | 4.211 | 4.582 | 4.900 | 5.171 | 5.401 | 5.596 | 5.761 | 5.901 | 6.020 | 6.121 | 6.208 | 6.281 | 6.344 | 6.397 | 6.661 | 6.739 | 6.769 | 6.798 | 6.802 |
| 0.7 | 0.844 | 1.665 | 2.441 | 3.159 | 3.808 | 4.385 | 4.891 | 5.330 | 5.708 | 6.034 | 6.311 | 6.548 | 6.751 | 6.924 | 7.071 | 7.198 | 7.307 | 7.400 | 7.481 | 7.551 | 7.902 | 8.006 | 8.047 | 8.087 | 8.092 |
| 0.8 | 0.942 | 1.858 | 2.727 | 3.532 | 4.262 | 4.914 | 5.488 | 5.989 | 6.423 | 6.798 | 7.119 | 7.395 | 7.632 | 7.836 | 8.011 | 8.162 | 8.292 | 8.405 | 8.502 | 8.587 | 9.029 | 9.164 | 9.217 | 9.268 | 9.276 |
| 0.9 | 1.026 | 2.025 | 2.974 | 3.855 | 4.657 | 5.375 | 6.011 | 6.567 | 7.051 | 7.470 | 7.832 | 8.144 | 8.413 | 8.645 | 8.846 | 9.019 | 9.170 | 9.301 | 9.415 | 9.515 | 10.045 | 10.214 | 10.280 | 10.345 | 10.355 |
| 1.0 | 1.099 | 2.169 | 3.188 | 4.135 | 5.000 | 5.776 | 6.465 | 7.071 | 7.600 | 8.060 | 8.458 | 8.803 | 9.102 | 9.361 | 9.585 | 9.780 | 9.950 | 10.098 | 10.228 | 10.343 | 10.957 | 11.162 | 11.243 | 11.323 | 11.335 |
| 1.1 | 1.161 | 2.294 | 3.372 | 4.377 | 5.296 | 6.124 | 6.861 | 7.510 | 8.079 | 8.576 | 9.008 | 9.383 | 9.709 | 9.992 | 10.239 | 10.454 | 10.642 | 10.806 | 10.951 | 11.078 | 11.776 | 12.017 | 12.114 | 12.209 | 12.224 |
| 1.2 | 1.215 | 2.401 | 3.531 | 4.586 | 5.553 | 6.425 | 7.204 | 7.893 | 8.498 | 9.027 | 9.489 | 9.892 | 10.243 | 10.549 | 10.816 | 11.050 | 11.254 | 11.434 | 11.593 | 11.732 | 12.509 | 12.786 | 12.900 | 13.013 | 13.030 |
| 1.3 | 1.262 | 2.493 | 3.668 | 4.767 | 5.775 | 6.687 | 7.503 | 8.226 | 8.863 | 9.422 | 9.912 | 10.339 | 10.713 | 11.040 | 11.326 | 11.577 | 11.797 | 11.992 | 12.163 | 12.314 | 13.167 | 13.478 | 13.609 | 13.742 | 13.762 |
| 1.4 | 1.302 | 2.573 | 3.787 | 4.924 | 5.968 | 6.915 | 7.764 | 8.517 | 9.183 | 9.769 | 10.283 | 10.733 | 11.127 | 11.473 | 11.777 | 12.044 | 12.279 | 12.487 | 12.670 | 12.833 | 13.758 | 14.102 | 14.251 | 14.404 | 14.427 |
| 1.5 | 1.337 | 2.643 | 3.891 | 5.060 | 6.136 | 7.114 | 7.991 | 8.772 | 9.664 | 10.073 | 10.609 | 11.080 | 11.493 | 11.857 | 12.176 | 12.458 | 12.707 | 12.927 | 13.122 | 13.295 | 14.289 | 14.666 | 14.832 | 15.006 | 15.033 |
| 1.6 | 1.367 | 2.703 | 3.981 | 5.179 | 6.283 | 7.287 | 8.190 | 8.996 | 9.710 | 10.341 | 10.897 | 11.386 | 11.817 | 12.196 | 12.531 | 12.826 | 13.088 | 13.319 | 13.525 | 13.708 | 14.768 | 15.176 | 15.359 | 15.555 | 15.585 |
| 1.7 | 1.394 | 2.756 | 4.060 | 5.283 | 6.412 | 7.440 | 8.366 | 9.192 | 9.927 | 10.577 | 11.151 | 11.657 | 12.104 | 12.498 | 12.846 | 13.154 | 13.427 | 13.669 | 13.885 | 14.078 | 15.199 | 15.638 | 15.838 | 16.056 | 16.091 |
| 1.8 | 1.417 | 2.803 | 4.129 | 5.375 | 6.526 | 7.574 | 8.520 | 9.366 | 10.119 | 10.786 | 11.376 | 11.898 | 12.359 | 12.766 | 13.127 | 13.446 | 13.730 | 13.983 | 14.208 | 14.409 | 15.590 | 16.058 | 16.274 | 16.516 | 16.554 |
| 1.9 | 1.438 | 2.844 | 4.190 | 5.456 | 6.626 | 7.693 | 8.656 | 9.520 | 10.289 | 10.972 | 11.577 | 12.112 | 12.587 | 13.006 | 13.378 | 13.708 | 14.002 | 14.264 | 14.498 | 14.707 | 15.944 | 16.441 | 16.673 | 16.937 | 16.980 |
| 2.0 | 1.456 | 2.880 | 4.244 | 5.527 | 6.714 | 7.798 | 8.778 | 9.656 | 10.440 | 11.137 | 11.755 | 12.303 | 12.789 | 13.220 | 13.603 | 13.943 | 14.246 | 14.516 | 14.758 | 14.975 | 16.265 | 16.790 | 17.037 | 17.325 | 17.372 |
| 3.0 | 1.559 | 3.087 | 4.553 | 5.937 | 7.223 | 8.403 | 9.478 | 10.448 | 11.321 | 12.103 | 12.804 | 13.431 | 13.993 | 14.496 | 14.947 | 15.353 | 15.718 | 16.048 | 16.346 | 16.676 | 18.301 | 19.051 | 19.432 | 19.943 | 20.046 |
| 4.0 | 1.600 | 3.168 | 4.676 | 6.100 | 7.426 | 8.646 | 9.759 | 10.768 | 11.678 | 12.498 | 13.235 | 13.897 | 14.493 | 15.030 | 15.514 | 15.951 | 16.347 | 16.706 | 17.033 | 17.330 | 19.241 | 20.142 | 20.623 | 21.322 | 21.495 |
| 5.0 | 1.620 | 3.208 | 4.735 | 6.179 | 7.525 | 8.765 | 9.897 | 10.925 | 11.854 | 12.693 | 13.448 | 14.128 | 14.742 | 15.296 | 15.798 | 16.252 | 16.664 | 17.040 | 17.382 | 17.695 | 19.740 | 20.740 | 21.293 | 22.148 | 22.393 |
| 10.0 | 1.648 | 3.263 | 4.818 | 6.289 | 7.662 | 8.930 | 10.089 | 11.144 | 12.100 | 12.965 | 13.747 | 14.454 | 15.094 | 15.674 | 16.201 | 16.681 | 17.118 | 17.518 | 17.885 | 18.222 | 20.491 | 21.681 | 22.390 | 23.676 | 24.238 |
| INF | 1.657 | 3.282 | 4.846 | 6.327 | 7.710 | 8.986 | 10.155 | 11.220 | 12.186 | 13.060 | 13.851 | 14.567 | 15.217 | 15.806 | 16.342 | 16.831 | 17.278 | 17.688 | 18.064 | 18.410 | 20.770 | 22.046 | 22.838 | 24.463 | 26.111 |

## Table 15 Percentage Sky Components on the Vertical Plane Perpendicular to a Vertical Rectandular Opening for the Clear Design Sky

(*Clauses* A-1.5 *and* A-1.6.2)

| **l/d** → <br> **h/d** ↓ | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 | 1.0 | 1.1 | 1.2 | 1.3 | 1.4 | 1.5 | 1.6 | 1.7 | 1.8 | 1.9 | 2.0 | 3.0 | 4.0 | 5.0 | 10.0 | INF |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) | (14) | (15) | (16) | (17) | (18) | (19) | (20) | (21) | (22) | (23) | (24) | (25) | (26) |
| 0.1 | 0.036 | 0.141 | 0.303 | 0.506 | 0.734 | 0.971 | 1.207 | 1.432 | 1.643 | 2.836 | 1.011 | 2.168 | 2.308 | 2.433 | 2.544 | 2.642 | 2.730 | 2.808 | 2.878 | 2.940 | 3.309 | 3.461 | 3.536 | 3.641 | 3.678 |
| 0.2 | 0.071 | 0.277 | 0.594 | 0.993 | 1.442 | 1.910 | 2.374 | 2.820 | 3.236 | 3.618 | 3.964 | 4.276 | 4.554 | 4.802 | 5.022 | 5.219 | 5.393 | 5.549 | 5.688 | 5.812 | 6.547 | 6.850 | 7.000 | 7.211 | 7.284 |
| 0.3 | 0.103 | 0.401 | 0.863 | 1.445 | 2.100 | 2.793 | 3.475 | 4.180 | 4.743 | 5.306 | 5.818 | 6.278 | 6.690 | 7.058 | 7.385 | 7.677 | 7.936 | 8.168 | 8.375 | 8.560 | 9.657 | 10.110 | 10.335 | 10.651 | 10.760 |
| 0.4 | 0.126 | 0.491 | 1.059 | 1.779 | 2.597 | 3.460 | 4.326 | 5.166 | 5.958 | 6.691 | 7.359 | 7.967 | 8.507 | 8.900 | 9.420 | 9.804 | 10.146 | 10.451 | 10.724 | 10.968 | 12.421 | 13.024 | 13.323 | 13.743 | 13.889 |
| 0.5 | 0.142 | 0.554 | 1.197 | 2.015 | 2.947 | 3.937 | 4.938 | 5.914 | 6.842 | 7.707 | 8.503 | 9.228 | 9.883 | 10.472 | 10.999 | 11.476 | 11.897 | 12.273 | 12.610 | 12.912 | 14.712 | 15.462 | 15.835 | 16.360 | 16.542 |
| 0.6 | 0.154 | 0.600 | 1.298 | 2.187 | 3.204 | 4.288 | 5.389 | 6.468 | 7.498 | 8.464 | 9.358 | 10.177 | 10.922 | 11.596 | 12.204 | 12.752 | 13.244 | 13.686 | 14.084 | 14.441 | 16.583 | 17.478 | 17.924 | 18.552 | 18.771 |
| 0.7 | 0.162 | 0.634 | 1.372 | 2.316 | 3.397 | 4.552 | 5.729 | 6.887 | 7.997 | 9.042 | 10.013 | 10.907 | 11.723 | 12.465 | 13.138 | 13.746 | 14.296 | 14.793 | 15.241 | 15.646 | 18.111 | 19.148 | 19.665 | 20.397 | 20.653 |
| 0.8 | 0.169 | 0.660 | 1.429 | 2.413 | 3.543 | 4.754 | 5.990 | 7.209 | 8.382 | 9.490 | 10.523 | 11.476 | 12.350 | 13.147 | 13.873 | 14.531 | 15.129 | 15.670 | 16.161 | 16.606 | 19.361 | 20.538 | 21.127 | 21.961 | 22.253 |
| 0.9 | 0.174 | 0.680 | 1.472 | 2.487 | 3.655 | 4.909 | 6.192 | 7.460 | 8.683 | 9.841 | 10.924 | 11.926 | 12.847 | 13.690 | 14.459 | 15.159 | 15.796 | 16.375 | 16.902 | 17.381 | 20.387 | 21.701 | 22.360 | 23.397 | 23.625 |
| 1.0 | 0.178 | 0.695 | 1.505 | 2.545 | 3.743 | 5.030 | 6.350 | 7.657 | 8.921 | 10.120 | 11.243 | 12.284 | 13.245 | 14.126 | 14.931 | 15.666 | 16.337 | 16.948 | 17.504 | 18.012 | 21.237 | 22.680 | 23.408 | 24.446 | 24.810 |
| 1.1 | 0.181 | 0.707 | 1.532 | 2.591 | 3.812 | 5.126 | 6.475 | 7.814 | 9.110 | 10.342 | 11.498 | 12.573 | 13.356 | 14.478 | 15.314 | 16.079 | 16.778 | 17.416 | 17.999 | 18.531 | 21.946 | 23.508 | 24.303 | 25.441 | 25.841 |
| 1.2 | 0.183 | 0.716 | 1.552 | 2.626 | 3.866 | 5.202 | 6.575 | 7.939 | 9.261 | 10.521 | 11.705 | 12.807 | 13.827 | 14.766 | 15.628 | 16.418 | 17.141 | 17.802 | 18.407 | 18.961 | 22.543 | 24.208 | 25.072 | 26.309 | 26.745 |
| 1.3 | 0.185 | 0.723 | 1.568 | 2.655 | 3.910 | 5.263 | 6.655 | 8.040 | 9.384 | 10.666 | 11.873 | 12.998 | 14.041 | 15.003 | 15.887 | 16.698 | 17.442 | 18.123 | 18.747 | 19.320 | 23.049 | 24.809 | 25.735 | 27.070 | 27.542 |
| 1.4 | 0.186 | 0.729 | 1.582 | 2.678 | 3.945 | 5.312 | 6.720 | 8.122 | 9.484 | 10.785 | 12.011 | 13.155 | 14.217 | 15.198 | 16.101 | 16.931 | 17.692 | 18.391 | 19.032 | 19.621 | 23.480 | 25.326 | 26.308 | 27.441 | 28.249 |
| 1.5 | 0.188 | 0.734 | 1.592 | 2.697 | 3.973 | 5.352 | 6.773 | 8.189 | 9.566 | 10.883 | 12.124 | 13.285 | 14.364 | 15.361 | 16.280 | 17.125 | 17.902 | 18.616 | 19.272 | 19.875 | 23.850 | 25.772 | 26.808 | 28.336 | 28.880 |
| 1.6 | 0.189 | 0.738 | 1.601 | 2.712 | 3.996 | 5.385 | 6.816 | 8.244 | 9.634 | 10.963 | 12.219 | 13.394 | 14.486 | 15.497 | 16.430 | 17.289 | 18.079 | 18.806 | 19.475 | 20.090 | 24.169 | 26.161 | 27.245 | 28.866 | 29.445 |
| 1.7 | 0.189 | 0.741 | 1.608 | 2.724 | 4.016 | 5.412 | 6.852 | 8.290 | 9.690 | 11.031 | 12.298 | 13.484 | 14.589 | 15.511 | 16.556 | 17.427 | 18.229 | 18.968 | 19.648 | 20.274 | 24.444 | 26.501 | 27.629 | 29.340 | 29.955 |
| 1.8 | 0.190 | 0.744 | 1.614 | 2.735 | 4.032 | 5.434 | 6.882 | 8.328 | 9.737 | 11.087 | 12.364 | 13.561 | 14.675 | 15.708 | 16.663 | 17.545 | 18.357 | 19.105 | 19.795 | 20.431 | 24.684 | 26.799 | 27.969 | 29.765 | 30.416 |
| 1.9 | 0.191 | 0.746 | 1.619 | 2.743 | 4.045 | 5.453 | 6.908 | 8.360 | 9.777 | 11.135 | 12.420 | 13.625 | 14.749 | 15.791 | 16.755 | 17.645 | 18.466 | 19.224 | 19.922 | 20.567 | 24.893 | 27.062 | 28.270 | 30.149 | 30.835 |
| 2.0 | 0.191 | 0.748 | 1.623 | 2.751 | 4.056 | 5.469 | 6.929 | 8.387 | 9.811 | 11.175 | 12.468 | 13.680 | 14.811 | 15.861 | 16.833 | 17.731 | 18.560 | 19.325 | 20.031 | 20.684 | 25.077 | 27.294 | 28.537 | 30.496 | 31.217 |
| 3.0 | 0.193 | 0.756 | 1.642 | 2.785 | 4.109 | 5.544 | 7.030 | 8.517 | 9.972 | 11.371 | 12.699 | 13.950 | 15.120 | 16.211 | 17.224 | 18.164 | 19.036 | 19.844 | 20.594 | 21.289 | 26.082 | 28.619 | 30.108 | 32.676 | 32.742 |
| 4.0 | 0.194 | 0.759 | 1.648 | 2.794 | 4.124 | 5.566 | 7.058 | 8.540 | 10.018 | 11.427 | 12.767 | 14.029 | 15.212 | 16.316 | 17.343 | 18.298 | 19.185 | 20.008 | 20.772 | 21.483 | 26.439 | 29.128 | 30.745 | 33.687 | 35.064 |
| 5.0 | 0.194 | 0.760 | 1.650 | 2.798 | 4.129 | 5.574 | 7.069 | 8.568 | 10.036 | 11.449 | 12.793 | 14.060 | 15.248 | 16.357 | 17.390 | 18.351 | 19.243 | 20.073 | 20.844 | 21.562 | 26.592 | 29.359 | 31.049 | 34.232 | 35.872 |
| 10.0 | 0.194 | 0.761 | 1.652 | 2.801 | 4.135 | 5.581 | 7.080 | 8.582 | 10.053 | 11.470 | 12.818 | 14.095 | 15.283 | 16.398 | 17.436 | 18.403 | 19.302 | 20.138 | 20.917 | 21.641 | 26.758 | 29.624 | 31.419 | 35.049 | 37.513 |
| INF | 0.194 | 0.761 | 1.652 | 2.802 | 4.136 | 5.582 | 7.081 | 8.584 | 10.056 | 11.473 | 12.822 | 14.095 | 15.288 | 16.404 | 17.443 | 18.411 | 19.311 | 20.148 | 20.928 | 21.654 | 26.785 | 29.672 | 31.490 | 35.274 | 39.172 |

## Table 16 Percentage Sky Components on the Vertical Plane Parallel to a Vertical Rectandular Opening for the Clear Design Sky

(*Clause* A-1.5)

| *l/d* → *h/d* ↓ | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 | 1.0 | 1.1 | 1.2 | 1.3 | 1.4 | 1.5 | 1.6 | 1.7 | 1.8 | 1.9 | 2.0 | 3.0 | 4.0 | 5.0 | 10.0 | INF |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) | (14) | (15) | (16) | (17) | (18) | (19) | (20) | (21) | (22) | (23) | (24) | (25) | (26) |
| 0.1 | 0.728 | 1.429 | 2.078 | 2.600 | 3.167 | 3.660 | 3.964 | 4.265 | 4.513 | 4.717 | 4.883 | 5.020 | 5.132 | 5.225 | 5.301 | 5.365 | 5.418 | 5.463 | 5.501 | 5.533 | 5.687 | 5.733 | 5.749 | 5.765 | 5.766 |
| 0.2 | 1.429 | 2.803 | 4.007 | 5.221 | 6.220 | 7.073 | 7.790 | 8.385 | 8.876 | 9.278 | 9.609 | 9.880 | 10.103 | 10.286 | 10.439 | 10.565 | 10.671 | 10.760 | 10.835 | 10.899 | 11.207 | 11.296 | 11.330 | 11.362 | 11.365 |
| 0.3 | 2.068 | 4.061 | 5.913 | 7.580 | 9.040 | 10.285 | 11.337 | 12.212 | 12.934 | 13.528 | 14.016 | 14.417 | 14.747 | 15.020 | 15.246 | 15.434 | 15.591 | 15.724 | 15.836 | 15.931 | 16.390 | 16.523 | 16.574 | 16.623 | 16.627 |
| 0.4 | 2.529 | 4.970 | 7.249 | 9.312 | 11.133 | 12.707 | 14.042 | 15.164 | 16.097 | 16.870 | 17.507 | 18.025 | 18.458 | 18.816 | 19.113 | 19.360 | 19.568 | 19.742 | 19.890 | 20.015 | 20.624 | 20.801 | 20.868 | 20.933 | 20.939 |
| 0.5 | 2.852 | 5.608 | 8.186 | 10.529 | 12.606 | 14.401 | 15.952 | 17.256 | 18.350 | 19.262 | 20.021 | 20.652 | 21.177 | 21.613 | 21.978 | 22.275 | 22.530 | 22.746 | 22.923 | 23.082 | 23.836 | 24.056 | 24.140 | 24.222 | 24.229 |
| 0.6 | 3.086 | 6.070 | 8.867 | 11.415 | 13.681 | 15.656 | 17.353 | 18.793 | 20.008 | 21.027 | 21.879 | 22.592 | 23.189 | 23.689 | 24.109 | 24.462 | 24.761 | 25.014 | 25.229 | 25.412 | 26.229 | 26.561 | 26.662 | 26.759 | 26.768 |
| 0.7 | 3.259 | 6.413 | 9.373 | 12.074 | 14.482 | 16.588 | 18.402 | 19.949 | 21.257 | 22.359 | 23.285 | 24.063 | 24.716 | 25.267 | 25.731 | 26.124 | 26.458 | 26.742 | 26.984 | 27.192 | 28.214 | 28.517 | 28.634 | 28.748 | 28.758 |
| 0.8 | 3.389 | 6.672 | 9.755 | 12.573 | 15.090 | 17.296 | 19.201 | 20.830 | 22.212 | 23.380 | 24.365 | 25.195 | 25.895 | 26.486 | 26.987 | 27.412 | 27.775 | 28.084 | 28.350 | 28.578 | 29.720 | 30.065 | 30.198 | 30.327 | 30.339 |
| 0.9 | 3.489 | 6.869 | 10.046 | 12.955 | 15.556 | 17.840 | 19.817 | 21.511 | 22.952 | 24.173 | 25.206 | 26.078 | 26.816 | 27.441 | 27.972 | 28.424 | 28.810 | 29.141 | 29.426 | 29.672 | 30.927 | 31.303 | 31.451 | 31.596 | 31.610 |
| 1.0 | 3.565 | 7.024 | 10.272 | 13.250 | 15.917 | 18.263 | 20.297 | 22.043 | 23.531 | 24.795 | 25.866 | 26.773 | 27.542 | 28.196 | 28.572 | 29.226 | 29.633 | 29.982 | 30.283 | 30.544 | 31.889 | 32.302 | 32.467 | 32.627 | 32.643 |
| 1.1 | 3.625 | 7.139 | 10.447 | 13.481 | 16.200 | 18.594 | 20.674 | 22.462 | 23.989 | 25.288 | 26.391 | 27.326 | 28.121 | 28.798 | 29.375 | 29.869 | 30.293 | 30.658 | 30.973 | 31.246 | 32.670 | 33.117 | 33.297 | 33.473 | 33.491 |
| 1.2 | 3.672 | 7.233 | 10.586 | 13.663 | 16.423 | 18.857 | 20.973 | 22.795 | 24.353 | 25.681 | 26.810 | 27.770 | 28.587 | 29.283 | 29.878 | 30.388 | 30.826 | 31.204 | 31.532 | 31.816 | 33.309 | 33.796 | 33.981 | 34.173 | 34.193 |
| 1.3 | 3.709 | 7.307 | 10.696 | 13.807 | 16.602 | 19.067 | 21.213 | 23.062 | 24.646 | 25.998 | 27.148 | 28.128 | 28.963 | 29.676 | 30.286 | 30.810 | 31.261 | 31.651 | 31.989 | 32.283 | 33.836 | 34.350 | 34.550 | 34.756 | 34.779 |
| 1.4 | 3.739 | 7.366 | 10.784 | 13.924 | 16.745 | 19.236 | 21.406 | 23.278 | 24.884 | 26.255 | 27.424 | 28.420 | 29.271 | 29.998 | 30.621 | 31.157 | 31.618 | 32.018 | 32.365 | 32.667 | 34.374 | 34.813 | 35.035 | 35.247 | 35.271 |
| 1.5 | 3.763 | 7.414 | 10.856 | 14.018 | 16.861 | 19.373 | 21.563 | 23.454 | 25.077 | 26.465 | 27.649 | 28.660 | 29.523 | 30.262 | 30.897 | 31.443 | 31.914 | 32.322 | 32.677 | 32.986 | 34.641 | 35.202 | 35.436 | 35.663 | 35.689 |
| 1.6 | 3.783 | 7.453 | 10.914 | 14.095 | 16.956 | 19.485 | 21.692 | 23.599 | 25.236 | 26.638 | 27.835 | 28.857 | 29.732 | 30.482 | 31.226 | 31.680 | 32.160 | 32.575 | 32.937 | 33.253 | 34.950 | 35.532 | 35.776 | 36.017 | 36.046 |
| 1.7 | 3.799 | 7.485 | 10.962 | 14.158 | 17.034 | 19.578 | 21.798 | 23.718 | 25.368 | 26.781 | 27.989 | 29.022 | 29.906 | 30.665 | 31.317 | 31.879 | 32.366 | 32.888 | 33.156 | 33.477 | 35.211 | 35.812 | 36.067 | 36.321 | 36.352 |
| 1.8 | 3.812 | 7.512 | 11.002 | 14.211 | 17.099 | 19.655 | 21.886 | 23.817 | 25.478 | 26.900 | 28.118 | 29.160 | 30.052 | 30.818 | 31.477 | 32.046 | 32.539 | 32.967 | 33.340 | 33.666 | 35.435 | 36.052 | 36.316 | 36.584 | 36.617 |
| 1.9 | 3.824 | 7.534 | 11.035 | 14.254 | 17.153 | 19.719 | 21.960 | 23.900 | 25.570 | 27.001 | 28.226 | 26.276 | 30.175 | 30.948 | 31.613 | 32.188 | 32.686 | 33.119 | 33.497 | 33.828 | 35.626 | 35.259 | 36.532 | 36.812 | 36.847 |
| 2.0 | 3.833 | 7.553 | 11.062 | 14.291 | 17.199 | 19.773 | 22.022 | 23.970 | 25.647 | 27.086 | 28.318 | 29.374 | 31.279 | 31.058 | 31.728 | 32.308 | 32.811 | 33.249 | 33.631 | 33.965 | 35.791 | 36.438 | 36.719 | 37.011 | 37.048 |
| 3.0 | 3.876 | 7.639 | 11.192 | 14.463 | 17.412 | 20.027 | 22.316 | 24.302 | 26.016 | 27.491 | 28.757 | 29.846 | 30.783 | 31.592 | 32.291 | 32.898 | 33.427 | 33.889 | 34.294 | 34.551 | 36.640 | 37.380 | 37.715 | 38.107 | 38.157 |
| 4.0 | 3.888 | 7.663 | 11.228 | 14.511 | 17.471 | 20.098 | 22.398 | 24.398 | 26.121 | 27.606 | 28.884 | 29.983 | 30.930 | 31.748 | 32.457 | 33.074 | 33.611 | 34.082 | 34.496 | 34.860 | 36.915 | 37.699 | 38.063 | 38.510 | 38.579 |
| 5.0 | 3.893 | 7.672 | 11.241 | 14.529 | 17.494 | 20.125 | 22.430 | 24.432 | 26.161 | 27.650 | 28.932 | 30.035 | 30.986 | 31.808 | 32.521 | 33.142 | 33.683 | 34.157 | 34.574 | 34.943 | 37.028 | 37.834 | 38.214 | 38.696 | 38.781 |
| 10.0 | 3.897 | 7681 | 11.254 | 14.546 | 17.515 | 20.150 | 22.459 | 24.466 | 26.199 | 27.693 | 28.978 | 30.085 | 31.041 | 31.867 | 32.584 | 33.208 | 33.753 | 34.231 | 34.652 | 35.024 | 37.144 | 37.978. | 38.382 | 38.927 | 39.057 |
| INF | 3.898 | 7.682 | 11.256 | 44.548 | 17.518 | 20.154 | 22.464 | 24.471 | 26.205 | 27.699 | 28.985 | 30.093 | 31.049 | 31.876 | 32.593 | 33.218 | 33.764 | 34.243 | 34.664 | 35.037 | 37.162 | 38.003 | 38.411 | 38.978 | 39.172 |

## LIST OF STANDARDS

The following list records those standards which are acceptable as 'good practice' and 'accepted standards' in the fulfillment of the requirements of the Code. The latest version of a standard shall be adopted at the time of enforcement of the Code. The standards listed may be used by the Authority as a guide in conformance with the requirements of the referred clauses in the Code.

| | *IS No.* | *Title* |
|---|---|---|
| (1) | 7662 (Part 1) : 1974 | Recommendations for orientation of buildings: Part 1 Non-industrial buildings |
| (2) | 3646 (Part 1) : 1992 | Code of practice for interior illumination: Part 1 General requirements and recommendations for building interiors (*first revision*) |
| (3) | 2440 : 1975 | Guide for daylighting of buildings (*second revision*) |
| (4) | 6060 : 1971 | Code of practice for daylighting of factory buildings |
| | 7942 : 1976 | Code of practice for daylighting of educational buildings |
| (5) | 1944 (Parts 1 & 2) : 1970 | Code of practice for lighting of public thoroughfares: Parts 1 and 2 For main and secondary roads (Group A and B) (*first revision*) |
| | 2672 : 1966 | Code of practice for library lighting |
| | 4347 : 1967 | Code of practice for hospital lighting |
| | 6665 : 1972 | Code of practice for industrial lighting |
| | 10894 : 1984 | Code of practice for lighting of educational institutions |
| | 10947 : 1984 | Code of practice for lighting for ports and harbours |
| (6) | 3362 : 1977 | Code of practice for natural ventilation of residential buildings (*first revision*) |

# NATIONAL BUILDING CODE OF INDIA

## PART 8 BUILDING SERVICES

### Section 2 Electrical and Allied Installations

BUREAU OF INDIAN STANDARDS

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National Building Code Sectional Committee, CED 46

## FOREWORD

This Section covers essential requirements for electrical and allied installations in buildings.

This Section was first published in 1970 and was subsequently revised in 1983. In the first revision, general guidance for electrical wiring installation in industrial location where voltage supply normally exceeds 650 V was included. This Section was also updated based on the existing version of the Indian Standards. The importance of pre-planning and exchange of information among all concerned agencies from the earlier stages of building work was emphasized.

As a result of experience gained in implementation of 1983 version of the Code and feedback received as well as revision of some of the relevant standards based on which this Section was prepared, a need to revise this part was felt. This revision has, therefore, been prepared to take care of these developments. The title of this Section has been modified from the erstwhile 'electrical installations' to 'electrical and allied installations' to reflect the provisions now being included on certain allied installations. The significant changes incorporated in this revision include:

a) The risk assessment procedure for lightening has been thoroughly changed apart from some other changes in the provision of lightning protection of building.
b) Some of the provisions of wiring have now been aligned with the latest practices.
c) Many existing definitions have been modified in line with current terminologies used at national and international level. Some new definitions have been added.
d) Provisions on installation of distribution transformer inside the multi-storeyed building have been incorporated.
e) Concept of energy conservation in lighting has been introduced.
f) Concept of various types of earthing in building installation has been incorporated.

This Section has to be read together with Part 8 'Building Services, Section 1 Lighting and Ventilation' for making provision for the desired levels of illumination as well as ventilation for different locations in different occupancies. Utmost importance should be given in the installation of electrical wiring to prevent short circuiting and the hazards associated therewith.

Notwithstanding the provisions given in this Section and the National Electrical Code, the provisions of the *Indian Electricity Act*, 2003 and the Rules and Regulations framed thereunder have to be necessarily complied with.

The information contained in this Section is largely based on the following Indian Standards/Special Publication:

| | |
|---|---|
| IS 732 : 1989 | Code of practice for electrical wiring installations (*third revision*) |
| IS 12032 (Part 11) : 1987 | Specification for graphical symbols for diagrams in the field of electrotechnology: Part 11 Architectural and topographical installation plan and diagrams |
| IS 4648 : 1968 | Guide for electrical layout in residential buildings |
| IS 2309 : 1989 | Protection of building and allied structures against lightning — Code of practice (*second revision*) |
| SP 30 : 1984 | National Electrical Code, 1985 |

All standards, whether given herein above or cross-referred to in the main text of this Section, are subject to revision. The parties to agreement based on this Section are encouraged to investigate the possibility of applying the most recent editions of the standards.

# NATIONAL BUILDING CODE OF INDIA

## PART 8 BUILDING SERVICES

## Section 2 Electrical and Allied Installations

**1 SCOPE**

This Section covers the essential requirements for electrical installations in buildings to ensure efficient use of electricity including safety from fire and shock. This Section also includes general requirements relating to lightning protection of buildings.

**2 TERMINOLOGY AND CONVENTIONAL SYMBOLS**

**2.1** For the purpose of this Section, the following definitions shall apply.

**2.1.1** *Accessory* — A device, other than current using equipment, associated with such equipment or with the wiring on an installation.

**2.1.2** *Apparatus* — Electrical apparatus including all machines, appliances and fittings in which conductors are used or of which they form a part.

**2.1.3** *Appliance* — An item of current using equipment other than a luminaire or an independent motor.

**2.1.4** *Bunched* — Cables are said to be 'bunched' when two or more are contained within a single conduit, duct, ducting, or trunking or, if not enclosed, are not separated from each other.

**2.1.5** *Cable* — A length of single-insulated conductor (solid or stranded), or two or more such conductors, each provided with its own insulation, which are laid up together. The insulated conductor or conductors may or may not be provided with an overall mechanical protective covering.

**2.1.6** *Cable, Armoured* — A cable provided with a wrapping of metal (usually in the form of tape or wire) serving as a mechanical protection.

**2.1.7** *Cable, Flexible* — A cable containing one or more cores, each formed of a group of wires, the diameters of the cores and of the wires being sufficiently small to afford flexibility.

**2.1.8** *Cable, Metal-Sheathed* — An insulated cable with a metal sheath.

**2.1.9** *Cable, PVC Sheathed-Insulated* — A cable in which the insulation of the conductor is a polyvinylchloride (PVC) compound; with PVC sheath also providing mechanical protection to the conductor core or cores in the cable.

**2.1.10** *Cable, Weatherproof* — A cable so constructed that when installed in uncovered locations, it will withstand all kinds of weather variations (*see* **2.1.80**, for definition of Weatherproofing).

**2.1.11** *Cable, XLPE* — A cable in which the insulation of the conductor is cross-linked polythene and the mechanical protection is provided for the core or cores by a sheath of a poly vinyl chloride compound.

**2.1.12** *Ceiling Rose* — A fitting (usually used to attach to the ceiling) designed for the connection between the electrical installation wiring and a flexible cord (which is in turn connected to a lampholder).

**2.1.13** *Circuit* — An assembly of electrical equipment supplied from the same origin and protected against overcurrent by the same protective device(s). Certain types of circuit are categorized as follows:

a) *Category 1 Circuit* — A circuit (other than a fire alarm or emergency lighting circuit) operating at low voltage and supplied directly from a mains supply system.
b) *Category 2 Circuit* — With the exception of fire alarm and emergency lighting circuits, any circuit for telecommunication (for example, radio, telephone, sound distribution, intruder alarm, bell and call and data transmission circuits) which is supplied from a safety source.
c) *Category 3 Circuit* — A fire alarm circuit or an emergency lighting circuit.

**2.1.14** *Circuit Breaker* — A mechanical switching device capable of making, carrying and breaking currents under normal circuit conditions and also of making, carrying for a specified time, and breaking currents under specified abnormal circuit conditions such as those of short circuit.

NOTE — A circuit breaker is usually intended to operate in frequently, although some types are suitable for frequent operation.

**2.1.15** *Circuit, Final Sub* — An outgoing circuit connected to one-way distribution board and intended to supply electrical energy at one or more points to current, using appliances without the intervention of a further distribution board other than a one-way board. It includes all branches and extensions derived from that particular way in the board.

**2.1.16** *Cleat* — An insulated incombustible support normally used for insulated cable.

**2.1.17** *Conductor, Aerial* — Any conductor which is supported by insulators above the ground and is directly exposed to the weather.

NOTE — Four classes of aerial conductors are recognized:

a) Bare aerial conductors,
b) Covered aerial conductors,
c) Insulated aerial conductors, and
d) Weatherproof neutral-screened cable.

**2.1.18** *Conductor, Bare* — A conductor not covered with insulating material.

**2.1.19** *Conductor, Earthed* — A conductor with no provision for its insulation from earth.

**2.1.20** *Conductor, Insulated* — A conductor adequately covered with insulating material of such quality and thickness as to prevent danger.

**2.1.21** *Conductor of a Cable or Core* — The conducting portion consisting of a single wire or group of wires, assembled together and in contact with each other or connected in parallel.

**2.1.22** *Connector* — The part of a cable coupler or of an appliance coupler which is provided with female contact and is intended to be attached to the flexible cable connected to the supply.

**2.1.23** *Connector Box or Joint Box* — A box forming a part of wiring installation, provided to contain joints in the conductors of cables of the installations.

**2.1.24** *Connector for Portable Appliances* — A combination of a plug and socket arranged for attachment to a portable electrical appliance or to a flexible cord.

**2.1.25** *Consumer's Terminals* — The ends of the electrical conductors situated upon any consumer's premises and belonging to him at which the supply of energy is delivered from the service line.

**2.1.26** *Cord, Flexible* — A flexible cable having conductor of small cross-sectional area. Two flexible cords twisted together are known as twin 'flexible cord'.

**2.1.27** *Core of a Cable* — A single conductor of a cable with its insulation but not including any mechanical protective covering.

**2.1.28** *Cut-out* — Any appliance for automatically interrupting the transmission of energy through any conductor when the current rises above a pre-determined amount.

**2.1.29** *Damp Situation* — A situation in which moisture is either permanently present or intermittently present to such an extent as to be likely to impair the effectiveness of an installation conforming to the requirements for ordinary situations.

**2.1.30** *Dead* — A portion of the circuit (normally expected to carry a voltage) at or near about earth potential or apparently disconnected from any live system.

**2.1.31** *Direct Earthing System* — A system of earthing in which the parts of an installation are so earthed as specified but are not connected within the installation to the neutral conductor of the supply system or to earth through the trip coil of an earth leakage circuit-breaker.

**2.1.32** *Distance Area or Resistance Area (for Earth Electrode only)* — The area of ground (around an earth electrode) within which a voltage gradient measurable with ordinary commercial instruments exists when the electrode is being tested.

**2.1.33** *Discrimination (Over-Current Discrimination)* — Co-ordination of the operating characteristics of two or more over-current protective devices such that, on the incidence of over-currents within stated limits, the device intended to operate within these limits does so, while the others do not.

NOTES

**1** Protective devices should have discrimination so that only the affected part (minimum section) of the circuit is isolated, even though a number of protective devices may be in the path of the over current.

**2** Distinction is made between series discrimination involving different over-current protective devices passing substancially the same over-current and network discrimination involving identical protective devices passing different proportions of the over-current.

**2.1.34** *Earth* — The conductive mass of the earth, whose electric potential at any point is conventionally taken as zero.

**2.1.35** *Earth Continuity Conductor* — The conductor, including any clamp, connecting to the earthing lead or to each other those parts of an installation which are required to be earthed. It may be in whole or in part the metal conduit or the metal sheath or armour of the cables, or the special continuity conductor of a cable or flexible cord incorporating such a conductor.

**2.1.36** *Earth Electrode* — A conductor or group of conductors in intimate contact with and providing an electrical connection to earth.

**2.1.37** *Earth Fault* — Accidental connections of a conductor to earth when the impedance is negligible, the connection is called a dead earth.

**2.1.38** *Earthing Lead* — The final conductor by which the connection to the earth electrode is made.

**2.1.39** *Earth Leakage Circuit Breaker System* — A system of earthing in which the parts of an installation, specified, to be earthed are so earthed through one or more earth leakage circuit-breakers or relays.

**2.1.40** *Enclosed Distribution Board* — An enclosure containing bus bars with one or more control and protected devices for the purpose of protecting, controlling or connecting more than one outgoing circuits fed from one or more incoming circuits.

**2.1.41** *Exposed Metal* — All metal parts of an installation which are easily accessible other than:

a) parts separated from live parts by double insulation;
b) metal name-plates, screw heads, covers, or plates, which are supported on or attached or connected to substantial non-conducting material only in such a manner that they do not become alive in the event of failure of insulation of live parts and whose means of fixing do not come in contact with any internal metal; and
c) parts which are separated from live parts by other metal parts which are themselves earthed or have double insulation.

**2.1.42** *Fire Survival Cable* — A cable which continues in service after exposure to a temperature of 900°C for 20 min or 700°C for 90 min.

**2.1.43** *Fitting, Lighting* — A device for supporting or containing a lamp or lamps (for example, fluorescent or incandescent) together with any holder, shade, or reflector, for example, a bracket, a pendant with ceiling rose, an electrolier, or a portable unit.

**2.1.44** *Flameproof Enclosure* — An enclosure which will withstand without injury any explosion of inflammable gas that may occur within it under practical conditions of operation within the rating of the apparatus (and recognized overloads, if any, associated therewith) and will prevent the transmission of flame which may ignite any inflammable gas that may be present in the surrounding atmosphere.

NOTES

**1** Hazardous areas are classified into different zones, depending upon the extent to which an explosive atmosphere could exist at that place. In such areas flame proof switchgear, fittings, accessories, have to be used/installed in flameproof enclosure.

**2** An electrical apparatus is not considered as flameproof unless it complies with the appropriate statutory regulations.

**3** Other types of fittings are also in vogue in wiring installations, for example, 'increased safety'.

**2.1.45** *Flame Retardant Cable* — Flame retardant cable with reduced halogen evaluation and smoke.

**2.1.46** *Fuse* — A device that, by the fusion of one or more of its specially designed and proportioned components, opens the circuit in which it is inserted when the current through it exceeds a given value for a sufficient time. The fuse comprises all the parts that form the complete device.

**2.1.47** *Fuse-Element — A* part of the fuse-link designed to melt under the action of current exceeding some definite value for a definite period of time.

**2.1.48** *Harmonics (Current and Voltage)* — All alternating current which is not absolutely sinusoidal is made up of a fundamental and a certain number of current harmonics which are the cause of its deformation (distortion) when compared to the theoretical sine-wave.

**2.1.49** *Inflammable* — A material capable of being easily ignited.

**2.1.50** *Installation (Electrical), of Buildings* — An assembly of associated electrical equipment to fulfil a specific purpose or purposes and having coordinated characteristics.

**2.1.51** *Insulated* — Insulated shall mean separated from adjacent conducting material or protected from personal contact by a non-conducting substance or an air space, in either case offering permanently sufficient resistance to the passage of current or to disruptive discharges through or over the surface of the substance or space, to obviate danger or shock or injurious leakage of current.

**2.1.52** *Insulation, Basic* — Insulation applied to live parts to provide basic protection against electric shock.

NOTE — Basic insulation does not necessarily include insulation used exclusively for functional purposes.

**2.1.53** *Insulation, Double* — Insulation comprising both basic and supplementary insulation.

**2.1.54** *Insulation (Electrical)* — Suitable non-conducting material, enclosing, surrounding or supporting a conductor.

**2.1.55** *Insulation, Reinforced* — Single insulation applied to live parts, which provides a degree of protection against electric shock equivalent to double insulation under the conditions specified in the relevant standard.

NOTE — The term 'single insulation' does not imply that the insulation must be one homogeneous piece. It may comprise several layers which cannot be tested singly as supplementary or basic insulation.

**2.1.56** *Insulation, Supplementary* — Independent insulation applied in addition to basic insulation in order to provide protection against electric shock in the event of a failure of basic insulation.

**2.1.57** *Linked Switch* — Switches linked together mechanically so as to operate simultaneously or in definite sequence.

**2.1.58** *Live or Alive* — Electrically charged so as to have a potential different from that of earth.

**2.1.59** *Locations, Industrial* — Locations where tools and machinery requiring electrical wiring are installed for manufacture or repair.

**2.1.60** *Locations, Non-Industrial* — Locations other than industrial locations, and shall include residences, offices, shops, showrooms, stores and similar premises requiring electrical wiring for lighting, or similar purposes.

**2.1.61** *Miniature Circuit Breaker* — Mechanical switching device capable of making, carrying and breaking currents under normal circuit conditions and also making carrying currents for specified times and automatically breaking currents under specified abnormal circuit conditions such as those of overload and short circuits.

**2.1.62** *Multiple Earthed Neutral System* — A system of earthing in which the parts of an installation specified to be earthed are connected to the general mass of earth and, in addition, are connected within the installation to the neutral conductor of the supply system.

**2.1.63** *Neutral Conductor* — Includes the neutral conductor of a three-phase four-wire system, the conductor of a single-phase or dc installation which is earthed by the supply undertaking (or otherwise at the source of the supply), and the middle wire or common return conductor of a three-wire dc or single-phase ac system.

**2.1.64** *Plug* — A device, provided with contact pins, which is intended to be attached to a flexible cable, and which can be engaged with a socket outlet or with a connector.

**2.1.65** *Point (in Wiring)* — A termination of the fixed wiring intended for the connection of current using equipment.

**2.1.66** *Residual Current Circuit Breaker* — A mechanical switching device design to make, carry and break currents under normal service conditions and to cause the opening of the contacts when the residual currents attains a giving value under specified conditions.

**2.1.67** *Service* — The conductors and equipment required for delivering energy from the electric supply system to the wiring system of the premises served.

**2.1.68** *Socket-Outlet* — Accessory having socket contacts designed to engage with the pins of a plug and having terminals for the connection of cable(s).

NOTE — A luminaire track system is not regarded as a socket-outlet system.

**2.1.69** *Switch* — A mechanical switching device capable of making, carrying and breaking current under normal circuit conditions, which may include specified operating overload conditions, and also of carrying for a specified time currents under specified abnormal circuit conditions such as those of short circuit.

NOTE — A switch may also be capable of making, but not breaking, short-circuit currents.

**2.1.70** *Switchboard* — An assembly of switchgear with or without instruments, but the term does not apply to a group of local switches in a final circuit.

NOTE — The term 'switchboard' includes a distribution board.

**2.1.71** *Switch Disconnectors* — A device used to open (or close) a circuit when either negligible current is interrupted (or established) or when the significant change in the voltage across the terminals of each of the pole of the disconnectors occurs; in the open position it provides an isolating distance between the terminals of each pole.

**2.1.72** *Switch Disconnector Fuse* — A composite unit, comprising a switch with the fuse contained in or mounted on the moving member of the switch.

**2.1.73** *Switchgear* — A general term covering switching devices and their combination with associated control, measuring, protective and regulating equipment, also assemblies of such devices and equipment with associated interconnections, accessories, enclosures and supporting structures, intended in principle for use in connection with generation, transmission, distribution and conversion of electric energy.

**2.1.74** *Usable Wall Space* — All portions of a wall, except that occupied by a door in its normal open position, or occupied by a fire place opening, but excluding wall spaces which are less than 1 m in extent measured along the wall at the floor line.

**2.1.75** *Voltage, Extra Low (ELV)* — The voltage which does not normally exceed 50 V.

**2.1.76** *Voltage, Low* (*LV*) — The voltage which normally exceed 50 V but does not normally exceed 250 V.

**2.1.77** *Voltage, Medium* (*MV*) — The voltage which normally exceeds 250 V but does not exceed 650 V.

**2.1.78** *Voltage, High (HT, HV)* — The voltage which normally exceeds 650 V but less than or equal to 33 kV.

**2.1.79** *Voltage, Extra High (EHT)* — The voltage, which normally exceeds 33 kV.

**2.1.80** *Weatherproof* — Accessories, lighting fittings, current-using appliances and cables are said to be of the weatherproof type, if they are so constructed that when installed in open situation they will withstand the effects of rain, snow, dust and temperature variations.

For definition of other terms reference may be made to accepted standards [8-2(1)].

### 2.2 Conventional Symbols

The architectural symbols that are to be used in all drawings, wiring plans, etc, for electrical installations in buildings shall be as given in Annex A.

For other graphical symbols used in electrotechnology, reference may be made to good practice [8-2(1)].

## 3 GENERAL REQUIREMENTS

### 3.1 Conformity with Electricity Act, 2003 and Rules Amended Up-to-date

The installation shall generally be carried out in conformity with the requirements of *The Electricity Act*, 2003 as amended up-to-date and the *Indian Electricity Rules,* 1956 framed thereunder and also the relevant regulations of the Electric Supply Authority concerned as amended from time to time. Extracts from the *Indian Electricity Rules,* 1956, referred to in this section, are given in Annex B.

NOTE — *Indian Electricity Rules* which are being revised would become applicable on their notification.

### 3.2 Materials

All materials, fittings, appliances, etc, used in electrical and allied installations, shall conform to Part 5 'Building Materials' and other related Indian Standards.

### 3.3 Coordination with Local Supply Authority

a) In all cases, that is, whether the proposed electrical work is a new installation or extension of an existing one, or a modification involving major changes, the electricity supply undertaking shall be consulted about the feasibility, etc, at an early date.
b) *Addition to an Installation* — An addition, temporary or permanent, shall not be made to the authorized load of an existing installation, until it has been definitely ascertained that the current carrying capacity and the condition of existing accessories, conductors, switches, etc, affected, including those of the supply authority are adequate for the increased load. The size of the cable/ conductor shall be suitably selected on the basis of the ratings of the protective devices. Ratings of protective devices and their types shall be based on the installed load, switching characteristics and power factor.

Load assessment and application of suitable diversity factor to estimate the full load current shall be made as a first step. This should be done for every circuit, submain and feeder. Power factor and efficiency of loads shall also be considered. Diversity factor assumed shall be based on one's own experience. Allowance should be made for about 15 percent to 20 percent for extension in near future and the design circuit is calculated for each circuit and submain. The wiring system to be adopted should also be decided in accordance with the environmental requirements. The sizes of wiring cables are decided not merely to carry the load currents, but also to withstand thermal effects of likely over currents and also ensure acceptance level of voltage drop.

### 3.4 Power Factor Improvement in Consumers' Installation

**3.4.1** Conditions of supply of electricity boards or licensees stipulate the lower-limit of power factor which is generally 0.85.

**3.4.2** Principal causes of low power factor are many. For guidance to the consumers of electric energy who take supply at low and medium voltages for improvement of power factor, reference shall be made in accordance with good practice [8-2(2)].

### 3.5 Execution of Work

Unless otherwise exempted under the appropriate rule of the *Indian Electricity Rules,* the work of electrical installations shall be carried out by a licensed electrical contractor and under the direct supervision of a person holding a certificate of competency and by persons holding a valid permit issued and recognized by any State government.

**3.6** Safety procedures and practices shall be kept in view during execution of the work in accordance with good practice [8-2(4)].

**3.7** Safety provisions given in Part 4 'Fire and Life Safety' shall be followed.

## 4 PLANNING OF ELECTRICAL INSTALLATIONS

### 4.1 General

The design and planning of an electrical wiring installation involve consideration of all prevailing conditions, and is usually influenced by the type and requirement of the consumer. A competent electrical design engineer should be involved at the planning stage with a view to providing for an installation that will prove adequate for its intended purpose, and safe and efficient in its use. The information given in **3** shall also be kept in view.

**4.1.1** The design and planning of an electrical wiring installation shall take into consideration, some or all of the following:

a) the type of supply, occupancy, envisaged load and the earthing arrangement available;
b) the atmospheric condition, such as cooling air temperature, moisture or such other conditions which are likely to affect the installation adversely;
c) the possible presence of inflammable or explosive dust, vapour or gas;
d) the degree of electrical and mechanical protection necessary;
e) the importance of continuity of service including the possible need for standby supply;
f) the probability of need for modification or future extension;
g) the probable operation and maintenance cost taking into account the electricity supply tariffs available;
h) the relative cost of various alternative methods;
j) the need for radio and telecommunication interference suppression;
k) case of maintenance;
m) safety aspects;
n) energy conservation; and
p) the importance of proper discrimination between protective devices for continuity of supply and limited isolation of only the affected portion.

**4.1.2** All electrical apparatus shall be suitable for the services these are intended for.

**4.1.3** *Co-ordination*

Proper co-ordination and collaboration between the architect, civil engineer and the electrical and mechanical engineer shall be effected from the planning stage of the installation. The provisions that will be needed for the accommodation of substation, transformer, switchrooms, service cable ducts, rising mains and distribution cables, sub-distribution boards, openings and chases in floors and walls for all required electrical installations, etc, shall be specified in advance.

**4.1.4** Before starting wiring and installation of fittings and accessories, information should be exchanged between the owner of the building/architect/electrical contractor and the local supply authority in respect of tariffs applicable, types of apparatus that may be connected under each tariff, requirement of space for installing meters, switches, etc, and for total load requirements of lights, fans and power.

**4.1.5** While planning an installation, consideration should be taken of the anticipated increase in the use of electricity for lighting, general purpose socket-outlet, kitchen heating, etc.

It is essential that adequate provision should be made for all the services which may be required immediately and during the intended useful life of the building, for the householder may otherwise be tempted to carry out extension of the installation himself or to rely upon use of multiplug adopters and long flexible cords, both of which are not recommended.

**4.2 Location and Requirement of Substation**

Information on location and requirements of a substation should cover the following:

**4.2.1** *Location*

a) The substation should preferably be located in separate building and could be adjacent to the generator room, if any. Location of substation in the basement floors should be avoided, as far as possible.
b) The ideal location for an electrical substation for a group of buildings would be at the electrical load centre on the ground floor.
c) The floor level of the substation or switch room shall be above the highest flood level of the locality.
d) Generally the load centre would be somewhere between the geometrical centre and the air conditioning plant room, as air conditioning plant room would normally be the largest chunk of load, if the building is air conditioned.
e) Substations with oil filled equipment will require great consideration for the fire detection, protection and suppression. Oil cooled transformers require a suitable soak pit with gravity flow to contain the oil in the event of the possibility of oil spillage from the transformer on its failure. Substations with oil filled equipment shall not be located in any floor other than the ground floor or a semi-basement. Such substations with high oil content may be housed in a separate service building or a substation building, which is not the part of a multi-storeyed building.
f) In case electric substation has to be located within the main multi-storeyed building itself for unavoidable reasons, then it should be located on the floor close to ground level, but shall have direct access from the street for operation of the equipments. The provision for installation and removal of substation equipments may be provided from inside the building.

g) Substations located within a multi-storeyed building shall not have oil filled transformers, even if it is at the ground level (*see* Part 4 'Fire and Life Safety'). Substations with very little combustible material, such as a Dry type transformer, with Vaccum (or $SF_6$) HT switchgear and ACB or MCCB for MV can be located in the basement as well as upper floors in a building with high load density in the upper floors. (Some functional buildings such as hospitals, air traffic control towers, computer centres are likely to have high loading in a few upper floors and in such cases, it may be preferable to provide oil-free substations at upper levels. This measure will decrease the current flow at various points, thereby contributing to reduction of vulnerability to fire).

h) The power supply control to any such substation or transformer (located at basement levels or upper floors) shall be from a location on ground floor/first basement level having direct access from outside so that in case of fire, the electrical supply can be easily disconnected.

j) Oil filled transformers may be used only in substations located in separate single or two storeyed service buildings outside the main building structure and there shall atleast 6 meter clear distance between the adjoining buildings and substation such that fire tender is able to pass between the two structures.

k) If dry type transformer is used, it may be located adjacent to medium voltage switchgear in the form of unit type substation. No separate room or fire barrier for the transformer is required, in a substation with oil free equipment. In such a case the room size will decrease. Layout of equipment has to keep the requirement that any one piece of equipment or sub-assembly can be taken out of service and out of the installed location, while keeping the remaining system in service.

m) The emergency power supply (such as Generating Sets) should not be allowed to be installed above ground floor or below first basement level of building. There shall be provision of separate direct escape and entry into these areas from outside so that in case of fire, electrical supplies can be disconnected to avoid additional losses which may be caused due to electrical supply, present at the time of fire.

n) For transformers having large oil content (more than 2 000 litres), Rule 64 of *Indian Electricity Rules,* 1956 as amended time to time shall apply.

p) Facility for connection from substation to adjoining building to feed essential emergency load in that building, such as escape route lighting, fire or sprinkler pumps, emergency communication systems shall be provided. Similarly, the essential emergency load switchboard of this building or building complex should be so as to be capable of receiving power for such loads from the adjoining building or building complex, with its own substation/DG sets shut off due to crisis conditions such as fire.

q) The availability of power lines nearby may also be kept in view while deciding the location of the substation.

r) For detailed information regarding location of transformers reference may be made to good practice [8-2(3)].

s) All door openings from substation, electrical rooms, etc should open towards outside.

t) For acoustical enclosures/treatment reference may be made to Part 8 'Building Services, Section 4 Acoustics, Sound Insulation and Noise Control'.

**4.2.2** *Type of Building for Substations*

The substations enclosure, that is, walls, floor, ceiling, openings, doors, etc shall have 2 hour fire rating (*see* Part 4 'Fire and Life Safety').

**4.2.3** *Layout of Substation*

In allocating the area of substation, it is to be noted that the flow of electric power is from supply company's room to HV room, then to transformer and finally to the medium voltage switchgear room. The layout of the room shall be in accordance with this flow, so as to optimise the cables, bus-trunking etc, Visibility of equipment controlled from the operating point of the controlling switchgear is also a desirable feature, though it may not be achievable in case of large substations.

**4.2.4** *Room/Spaces Required*

Generally the following rooms/spaces are required in a substation:

a) Supply company's switchgear room and/or space for meters.

b) *Capacity and Size* — The capacity of a substation depends upon the area of the building and its type. The capacity of substation may be determined based on the following load requirements:

**Table of Typical Allowances for Diversity**

| *Purpose of Final Circuit Fed from Conductors or Switchgear to which Diversity Applies* | *Individual Household Installations, including Individual Dwelling of a Block* | *Type of Premises Small, Shops, Stores Offices and Business Premises* | *Type of Premises Small Hotels, Boarding Houses etc.* |
|---|---|---|---|
| (1) | (2) | (3) | (4) |
| Lighting | 66% of total demand | 90% of total current demand | 75% of total current demand |
| Heating and power | 80% of total current demand upto 10 A<br>+40% of any current demand in excess of 10 A | 80% full load of largest appliance<br>+60% of remaining appliances | 80% full load of largest appliance<br>+60% of second largest appliances<br>+40% of remaining appliances |
| Cooking appliances | 10 A<br>+30% full load of connected cooking appliances in excess of 10 A + 5 A if socket-outlet incorporated in unit. | 80% full load of largest appliance<br>+60% full load of second largest appliance<br>+50% full load of remaining appliances | 80% of largest appliance<br>+60% of full load of second largest appliance<br>+50% full load of remaining appliances |
| Motors (other than lift motors which are subject to special consideration) | | 80% full load of largest motor<br>+60% full load of second largest motor<br>+50% full load of remaining motors | 80% full load of largest motor<br>+50% full load of remaining motors |
| Water heater | 80% full load of largest appliance<br>+50% of second largest appliance<br>+25% full load of remaining appliances | 80% full load of largest appliance<br>+60% of second largest appliance<br>+25% full load of remaining appliances | 80% full load of largest appliance<br>+60% of second largest appliance<br>+25% full load of remaining appliances |
| Floor warming installations | 50% | | |
| Water heaters thermal storage space heating installations | 50% | | |
| Standard arrangements of final circuits in accordance with IS 732 | 80% of current demand of largest circuit<br>+40% of current demand of every other circuit | 80% of current demand of largest circuit<br>+50% of current demand of every other circuit | |
| Socket outlets other than those included above and stationary equipment other than those listed above | 80% of current demand of largest point of +40% of current demand of every other point of. | 80% of current demand of largest point of +60% of current demand of every other point of | 80% of current demand of largest point of +60% of current demand of every point in main rooms (dinning rooms, etc) +40% of current demand of every other point of. |

NOTES

**1** For the purpose of the table an instantaneous water heater is deemed to be a water heater of any loading which heats water only while the tap is turned on and therefore uses electricity intermittently.

**2** It is important to ensure that the distribution boards are of sufficient rating to take the total load connected to them without the application of any diversity.

After calculating the electrical load on the above basis, a load factor of 70-90 percent is to be applied to arrive at the minimum capacity of substation. The area required for substation and transformer room for different capacities is given in Annex C for general guidance. For reliability, it would be necessary to split the load into more than one transformer and also provide for standby transformer as well as multiple sources, bus-section, etc.

c) *High Voltage Switch Room* — In case of substation having one transformer and one source of supply, the owner is required to provide one high voltage switch. In case of single point supply with two or more transformers the number of switch required will be one for incoming supply and one for each transformer. In case of duplicate supply two switches shall be provided with mechanical/electrical in locking arrangement where necessary in cables with switches. In case the number of incoming and outgoing switches exceed five, bus coupler of suitable capacity should invariably be provided. The floor area required in case of a single switch is roughly 4 m × 4 m and for every additional switch the length would be increased by 1 m.

d) Facility for connection from substation of adjoining building to feed emergency loads shall be permitted for feeding escape route and signage lighting as well as selected section of the fire protection system. Similarly on a reciprocal basis facility to feed the adjoining building for such emergency loads may be provided by necessary switchgear,

e) *Medium Voltage Switch Room* — The floor area required in respect of medium voltage switchgear room may be determined keeping in view the number and type of incoming/ outgoing bus coupler switches including likely expansion in future.

f) *Room for Standby Generator* — It is preferable to install the standby generator in service building. If installed in main building it shall be at the ground floor or at the semi basement, alternatively, in the first basement with facilities for forced ventilation. Adequate space shall be provided for storing of fuel. Compartmentation for fire protection with detection and first-aid protection measures is essential. Different type of requirements exist for the diesel engine and generator for the oil storage area and for the switchgear.

g) Facilities including space at appropriate positions, relative to the location of the installed equipment has to be kept in the layout design for removal of equipment or sub-assemblies for repair or maintenance. When it is located, other than the ground level with direct equipment access, a hatch or ramp shall be required.

h) Other environmental requirements under the provisions of *Environment Protection Rules,* 1986 as amended time-to-time shall be taken into account from the aspect of engine emissions including regarding the height of exhaust pipe and permitted noise levels/noise control.

j) The capacity of standby generating set shall be chosen on the basis of essential light load, essential air conditioning load, essential equipment load and essential services load, such as one lift out of the bank of lifts, one or all water pumps, etc. Having chosen the capacity and number of generating sets, required space may be provided for their installation (*see* Annex D for general guidance).

k) The generating set should preferably be housed adjacent to MV switchgear in the substation building to enable transfer of electrical load quickly as well as to avoid transfer of vibration and noise to the main building. Acoustics lining of the room shall be in line with the requirements of Central Pollution Control Board (CPCB). If DG Set is located outdoor, it shall be housed in acoustics enclosure. The generator house should have proper ventilation, fire fighting equipment, etc (*see also* **4.2.2**).

m) *Requirements of Room*

   1) The areas given above in respect of the different categories of rooms holds good if they are provided with windows and independent access doors in accordance with local regulations.

   2) All the rooms shall be provided with partitions up to the ceiling and shall have proper ventilation. Special care should be taken to ventilate the transformer rooms and where necessary louvers at lower level and exhaust fans at higher level shall be provided at suitable locations.

   3) In order to prevent storm water entering the transformer and switch rooms through the soak-pits, the floor level, the substation shall be at least 15 cm above

the highest flood water level that may be anticipated in the locality. Also, facility shall be provided for automatic removal of water.

4) The minimum height of high voltage switchgear room shall be 3.6 m below the soffit of the beam.

n) *Fire Compartmentation* — It is advisable to provide fire compartmentation of buildings and segregation of associated wiring. Busbar trunking of horizontal and vertical distribution type in place of cable based distribution system shall be used.

**4.3 Location of Switch Room**

In large installations other than where a substation is provided, a separate switch room shall be provided; this shall be located as closely as possible to the electrical load centre preferably near the entrance of the building on the ground floor or on the first basement level, and suitable ducts shall be laid with minimum number of bends from the points of entry of the main supply cable to the position of the main switchgear. The switch room shall also be placed in such a position that rising ducts may readily be provided therefrom to the upper floors of the building in one straight vertical run. In larger buildings, more than one rising duct may be required and then horizontal ducts may also be required for running cables from the switch room to the foot of each rising main. Such cable ducts shall be either be reserved for the electrical services only or provided with a means of segregation for medium and low voltage installations, such as call-bell systems; telephone installations, fire detection and alarm system, announcement or public address system. Cables for essential emergency services such as those related to fire detection, alarm, announcement should use either metal conduit in addition to physical segregation from power cables or use fire survival cables, so that the service is maintained even in the event of a fire at least for a period of about 20 min.

**4.4 Location and Requirements of Distribution Panels**

The electrical control gear distribution panels and other apparatus, which are required on each floor may conveniently be mounted adjacent to the rising mains, and adequate space should be provided at each floor for this purpose.

**4.5 Substation Safety**

The owner or the operator of any substation shall be collectively and severally be responsible for any lapse or neglect leading to an accident or an incidence of an avoidable abnormality and shall take care of the safety requirements as follows:

a) enclose the substation where necessary to prevent, so far as is reasonably practicable, danger or unauthorised access;

b) enclose any part of the substation, which is open to the air and contains live equipment which is not encased, with a fence or wall not less than 2.4 m in height to prevent, so far as is reasonably practicable, danger or unauthorised access;

c) ensure that, so far as is reasonably practicable, there are at all times displayed:

   1) sufficient safety signs of such size and placed in such positions as are necessary to give due warning of such danger as is reasonably foreseeable in the circumstances;

   2) a notice which is placed in a conspicuous position and which gives the location or identification of the substation, the name of each generator or distributor who owns or operates the substation equipment making up the substation and the telephone number where a suitably qualified person appointed for this purpose by the generator or distributor will be in constant attendance; and

   3) such other signs, which are of such size and placed in such positions, as are necessary to give due warning of danger having regard to the siting of, the nature of, and the measures taken to ensure the physical security of, the substation equipment; and

d) take all reasonable precautions to minimize the risk of fire associated with the equipment.

**4.6 Overhead Lines, Wires and Cables**

**4.6.1** *Height Requirement*

While overhead lines may not be relevant within buildings, regulations related to overhead lines are of concern from two different angles.

a) Overhead lines may be required in building complexes, though use of underground cables is the preferred alternative.

b) Overhead lines may be passing through the site of a building. In such a case the safety aspects are important for the construction activity in the vicinity of the overhead line as well as portions of low height buildings that may have to be constructed below the overhead lines.

For minimum distance (vertical and horizontal) of electric lines/wires/cables from buildings, reference may be made to Part 3 'Development Control Rules and General Building Requirements'.

c) Any person responsible for erecting an overhead line will keep informed the authority(s) responsible for services in that area for telecommunication, gas distribution, water and sewage network, roads so as to have proper co-ordination to ensure safety. He shall also publish the testing, energising programme for the line in the interests of safety.

**4.6.2** *Position, Insulation and Protection of Overhead Lines*

Any part of an overhead line which is not connected with earth and which is not ordinarily accessible shall be supported on insulators or surrounded by insulation.

Any part of an overhead line which is not connected with earth and which is ordinarily accessible shall be:

a) made dead; or
b) so insulated that it is protected, so far it is reasonably practicable, against mechanical damage or interference; or
c) adequately protected to prevent danger.

Any person responsible for erecting a building or structure which will cause any part of an overhead line which is not connected with earth to become ordinarily accessible shall give reasonable notice to the generator or distributor who owns or operates the overhead line of his intention to erect that building or structure.

Any bare conductor not connected with earth, which is part of a low voltage overhead line, shall be situated throughout its length directly above a bare conductor which is connected with earth.

No overhead line shall, so far as is reasonably practicable, come so close to any building, tree or structure as to cause danger.

In this regulation the expression "ordinarily accessible" means the overhead line could be reached by hand if any scaffolding, ladder or other construction was erected or placed on/in, against or near to a building or structure.

**4.6.3** *Precautions Against Access and Warnings of Dangers*

Every support carrying a high voltage overhead line shall, if the circumstances reasonably require, be fitted with devices to prevent, so far it is reasonably practicable, any unauthorised person from reaching a position at which any such line would be a source of danger.

Every support carrying a high voltage overhead line, and every support carrying a low voltage overhead line incorporating bare phase conductors, shall have attached to it sufficient safety signs and placed in such positions as are necessary to give due warning of such danger as is reasonably foreseeable in the circumstances.

Poles supporting overhead lines near the road junctions and turnings shall be protected by a masonry or earth fill structure or metal barricade, to prevent a vehicle from directly hitting the pole, so that the vehicle, if out of control, is restrained from causing total damage to the live conductor system, likely to lead to a hazardous condition on the road or foot path or building.

**4.6.4** *Fitting of Insulators to Stay Wires*

Every stay wire which forms part of, or is attached to, any support carrying an overhead line incorporating bare phase conductors (except where the support is a lattice steel structure or other structure entirely of metal and connected to earth) shall be fitted with an insulator no part of which shall be less than 3 m above ground or above the normal height of any such line attached to that support.

### 4.7 Maps of Underground Networks

**4.7.1** Any person or organization or authority laying cables shall contact the local authority in charge of that area and find out the layout of

a) water distribution pipe lines in the area;
b) sewage distribution network;
c) telecommunication network; and
d) gas pipeline network and plan the cable network in such a manner that the system is compatible, safe and non interfering either during its installation or during its operation and maintenance. Plan of the proposed cable installation shall be brought to the notice of the other authorities referred above.

**4.7.2** Suitable cable markers and danger sign as would be appropriate for the safety of the workmen of any of the systems shall be installed along with the cable installation. Notification of testing and energisation of the system shall also be suitably published for ensuring safety.

**4.7.3** Any person or organization or authority laying cables shall have and, so far it is reasonably practicable, keep up to date, a map or series of maps indicating the position and depth below surface level of all networks or parts thereof which he owns or operates.

Any map prepared or kept shall be available for inspection by any of the municipal authority, other service providers, general public provided they have a reasonable cause for requiring to inspect any part of the map.

## 5 DISTRIBUTION OF SUPPLY AND CABLING

### 5.0 General

In the planning and design of an electrical wiring installation, due consideration shall be made of all the prevailing conditions. It is recommended that advice of a competent electrical engineer be sought at the initial stage itself with a view to providing an installation, that will prove adequate for its intended purpose be reliable and safe and efficient.

A certain redundancy in the electrical system is necessary and has to be built in from the initial design stage itself. The extent of redundancy will depend on the type of load, its criticality, normal hours of use, quality of power supply in that area, coordination with the standby power supply, capacity to meet the starting current requirements of large motors etc.

### 5.1 System of Supply

**5.1.1** All electrical apparatus shall be suitable for the voltage and frequency of supply.

**5.1.2** In case of connected load of 100 kVA and above, the relative advantage of high voltage three-phase supply should be considered. Though the use of high voltage supply entails the provisions of space for the capital cost of providing suitable transformer substation at the consumer's premises, the following advantages are gained:

a) advantage in tariff;
b) more effective earth fault protection for heavy current circuits;
c) elimination of interference with supplies to other consumers permitting the use of large size motors, welding plant, etc; and
d) better control of voltage regulation and more constant supply voltage.

NOTE — Additional safety precautions required to be observed in HV installations shall also be kept in view.

In many cases there may be no choice available to the consumer, as most of the licensees have formulated their policy of correlating the supply voltage with the connected load or the contract demand. Generally the supply is at 400/230 volts, 11 kV (or 22 kV) for loads up to 5 MVA and 33 kV or 66 kV for consumers of more than 5 MVA.

**5.1.3** In very large industrial buildings where heavy electric demands occur at scattered locations, the economics of electrical distribution at high voltage from the main substation to other subsidiary transformer substations or to certain items of plant, such as large motors and furnaces, should be considered. The relative economy attainable by use of medium or high voltage distribution and high voltage plant is a matter for expert judgement and individual assessment in the light of experience by a professionally qualified electrical engineer.

### 5.2 Substation Equipment and Accessories

Substations require an approval by the Electrical Inspectorate. Such approval is mandatory before energizing the substation. It is desirable to get the approval for the general layout, schematic layout, protection plan etc, before the start of the work from the Inspectorate. All substation equipment and accessories and materials, etc, shall conform to relevant Indian Standards wherever they exist, otherwise the consumer (or his consultant) has to specify the standards to which the equipment to be supplied confirms and that shall be approved by the authority. Manufacturers of equipment have to furnish certificate of conformity as well as type test certificates for record, in addition to specified test certificates for acceptance tests and installation related tests for earthing, earth continuity, load tests and tests for performance of protective gear.

**5.2.1** *High Voltage Switchgear*

**5.2.1.1** The selection of the type of high voltage switchgear for any installation *inter alia* depends upon the following:

a) voltage of the supply system;
b) the prospective short-circuit current at the point of supply;
c) the size and layout of electrical installation;
d) the accommodation available; and
e) the nature of industry.

Making and breaking capacity of switchgear shall be commensurated with short-circuit potentialities of the supply system and the supply authority shall be consulted on this subject.

**5.2.1.2** Guidelines on various types of switchgear equipment and their choice for a particular application shall be in accordance with good practice [8-2(4)].

**5.2.1.3** In extensive installations of switchgear (having more than four incoming supply cables or having more than 12 circuit breakers), banks of switchgears shall be segregated from each other by means of fire-resisting barriers having 2 h fire resistance rating in order to prevent spreading of the risk of damage by fire or explosion arising from switch failure. Where a bus-bar section switch is installed, it shall also be segregated from adjoining banks in the same way [*see* 8-2(5)]. Except main LT panel, it would be preferable to locate the sub panels/distribution boards near load centre. Further, it should be ensured that these panels are easily approachable. The preferable location of panels shall be near the exitways.

**5.2.1.4** It should be possible to isolate any section from the rest of the switchboards such that work might be undertaken on this section without the necessity of making the switchboard dead. Isolating switches used for the interconnection of sections or for the purpose of isolating circuit-breakers of other apparatus, shall also be segregated within its compartment so that no live part is accessible when work in a neighbouring section is in progress.

**5.2.1.5** In the case of duplicate or ring main supply, switchgears with interlocking arrangement shall be provided to prevent simultaneous switching of two different supply sources. Electrical and/or mechanical interlocks may preferably be provided.

**5.2.2** *Cables*

**5.2.2.1** The smallest size of the cable that shall be used, will depend upon the method of laying cable, permissible maximum temperature it shall withstand, voltage drop over the length of the cable, the prospective short-circuit current to which the cable may be subjected, the characteristics of the overload protection gear installed, load cycle and thermal resistivity of the soil [*see also* 8-2(6)].

NOTE — Guidelines for correlation of the ratings of cables and characteristics of protective device are under consideration. Continuous current carrying capacity (thermal limit leading to permanent change in properties of the insulation) under the installed conditions, voltage drop under required load and the fault current withstand ability of the cable for the duration that the protective device controlling the cable installation will let go the fault current, operating voltage are the prime considerations.

**5.2.2.2** The advice of the cable manufacturer with regard to installation, jointing and sealing shall be followed.

**5.2.2.3** The HV cables shall either be laid on the cable rack/built-up concrete trenches/tunnel/basement or directly buried in the ground depending upon the specific requirement. It is preferable to use four core cable in place of three and half core to minimize heating of neutral core due to harmonic content in the supply system and also avoidance of overload failures. All cables shall be installed in accordance with good practice [8-2(6)].

**5.2.2.4** *Colour identification of cores of non-flexible cables*

| *Function* | *Colour Identification of Core of Rubber of PVC Insulated Non-flexible Cable, or of Sleeve or Disc to be Applied to Conductor or Cable Code* |
|---|---|
| Protective or earthing | Green and yellow or Green with yellow stripes [1)] |
| Neutral of a.c. single or three-phase circuit | Black |
| Phase R of 3-phase a.c. circuit | Red |
| Phase Y of 3-phase a.c. circuit | Yellow |
| Phase B of 3-phase a.c. circuit | Blue |
| Positive of d.c. 2-wire circuit | Red |
| Negative of d.c. 2-wire circuit | Black |
| Outer (positive or negative) of d.c. 2-wire circuit derived from 3-wire system | Red |
| Positive of 3-wire system positive of 3-wire d.c. circuit) | Red |
| Middle wire of 3-wire d.c. circuit | Black |
| Negative of 3-wire d.c. circuit | Blue |
| Functional Earth-Telecommunication | Cream |

[1)] Bare conductors are also used for earthing and earth continuity conductors. But it is preferable to use insulated conductors with green insulation with yellow stripes.

**5.2.2.5** *Colour, identification of cores of flexible cables and flexible cords*

| *Number of Cores* | *Function of Core* | *Colour(s) of Core* |
|---|---|---|
| 1 | Phase | Brown[1)] |
| | Neutral | (Light) Blue |
| | Protective or Earthing | Green & yellow |
| 2 | Phase | Brown |
| | Neutral | (Light) Blue[1)] |
| 3 | Phase | Brown |
| | Neutral | (Light) Blue[1)] |
| | Protective or Earthing | Green & yellow |
| 4 or 5 | Phase | Brown or Black[1)] |
| | Neutral | (Light) Blue[1)] |
| | Protective or Earthing | Green & yellow |

[1)] Certain alternatives are allowed in Wiring Regulations.

**5.2.3** *High Voltage Busbar Trunking/Ducting*

High voltage busbar trunking system is a type-tested switchgear and control gear assembly in the form of an enclosed system. HV bus bar system is used for transporting power between HV Generators, transformers and the infeed main switchgear of the main HV switchgear.

Generally three types of bus ducts namely non-segregated, segregated and isolated phase bus duct shall be used. The non-segregated bus ducts consists of three phase busbars running in a common enclosure made of steel or aluminium. The enclosure shall provide safety for the operational personnel and reduces chances of faults. The enclosures shall be effectively grounded.

Segregated phase bus duct are similar to non-segregated phased duct except that metal or insolation barriers are provided between phase conductors to reduce chances of phase to phase faults. However, it is preferable to use metal barriers.

In the case of isolated bus ducts, each phase conductor shall be housed in a separate non-magnetic enclosures. The bus duct shall be made of sections which are assembled together at site to make complete assembly. The enclosure shall be of either round or square shape and welded construction. The enclosures of all phases in general to be supported on a common steel structure. Provision of fire protection shall be provided in all openings in accordance with Part 4 'Fire and Life Safety'. Fire separation in openings shall be provided using materials having 2h fire resistance rating.

**5.2.4** *MV/LV Busbar Trunking/Rising Mains*

Where heavy loads are to be carried, busbar systems are preferred. The busbars are available for continuous run from point to point or with tap offs at standard intervals and have to be chosen as per specific requirement. MV/LV busbar trunking shall be a type-tested switchgear and control gear assembly in the form of an enclosed system. There are two types of MV/LV bus duct system for power distribution system:

a) Conventional type.
b) Compact and sandwich type.

Conventional type bus duct is used for large power handling between transformer and switchgear or between switchgear and large power loads, such as compressor drive motor etc. This type is generally used in plant rooms, riser shafts, substations etc.

Compact type is available either air insulated or sandwich type for use within areas of the building which are put to other higher (aesthetic) level of use. They could be used in false ceiling spaces or even in corridors and shafts for distribution without any false ceiling as they provide an aesthetically acceptable finish to merge with other building elements such as beams, ducts or pipes in functional buildings.

The class of protection shall be specific depending on the requirement at the place of installation. Protection class (IP xx) will automatically identify the ventilation, protection from weather, water, dust etc.

In modern building technology, high demands are made of the power distribution system and its individual components:

a) Long life and good service quality,
b) Safe protection in the event of fire,
c) Low fire load,
d) Low space requirement, and
e) Minimum effort involved in carrying out retrofits.

The high load density in modern large buildings and high rise buildings demands compact and safe solution for the supply of power. The use of busbar trunking system is ideal for such applications.

Bus bar trunking can be installed in vertical risers ducts or horizontally in passages for transmission and distribution of power. Busbar trunking systems allow electrical installations to be planned in a simple and clear fashion. In the building complexes, additional safety demands with respect to fire barriers and fire load and use of bus bar trunking meets this requirement.

Busbar trunking system reduces the combustible material near the area with high energy in comparison with other distribution systems such as cables and makes the building safe from the aspect of vulnerability to fire of electrical origin. In addition, unlike cable systems the reliability of a bus trunking system is vvery high. These systems also require very little periodic maintenance.

Choice of busbar trunking for distribution in buildings can be made on the basis of

a) reduced fire load (drastically reduced in comparison to the cable system),
b) reduced maintenance over its entire lifetime,
c) longer service lifetime in comparison with a cable distribution
d) enhanced reliability due to rigid bolted joints and terminations and extremely low possibility of insulation failure.

**5.2.5** *Transformers*

**5.2.5.1** General design objective while selecting the transformer(s) for a substation would be to provide at least two or more transformers, so that a certain amount of redundancy is built in, even if a standby system is provided. The total installed transformation capacity would be marginally higher than the anticipated maximum demand. With growing emphasis on energy conservation, the system design is made for both extremes of loading. During the periods of lowest load in the system, it would be desirable to operate only one transformer and switch in additional transformers as the load variation takes place in a day. The minimum size of a transformer would quite often depend on the minimum load that is anticipated over a period of about 4 h in a day. Total transformer capacity is generally selected on the basis of present load, possible future load, operation and maintenance cost and other system conditions and selection of the maximum size (capacity) of the transformer is guided by short-circuit making and breaking capacity of the switchgear used in the medium voltage distribution system. Maximum size limitation is important from the aspect of feed to a down stream fault.

For feeding final single phase domestic type of loads or general office loads it is advisable to even use transformers of capacity much lower than what the switchgear can handle, so that lower fault MVA is available in such areas and use of hand held equipment fed through flexible cords is safe.

For reasons of reliability and redundancy it is normal practice to provide at least two transformers for any important installation. Interlinking by tie lines is an alternative to enhance reliability/redundancy is areas where there are a number of substations in close vicinity, such as a campus with three or four multi-storeyed blocks each with a substation.

Ring main type of distribution is preferred for complexes having a number of substations.

**5.2.5.2** Where two or more transformers are to be installed in a substation to supply a medium voltage distribution system, the distribution system shall be divided into separate sections each of which shall be normally fed from one transformer only unless the medium voltage switchgear has the requisite short-circuit capacity. Provision may, however, be made to interconnect separate sections, through a bus coupler in the event of failure or disconnection of one transformer. *See* **4.2** for details of location and requirements of substation.

The transformers, that may at any time operate in parallel, shall be so selected as to share the load in proportion to their respective load ratings. While the general practice is to avoid operation of transformers in parallel for feeding final distribution in buildings, it is possible to use transformers with slightly different impedance or voltage taps to operate in parallel, but with appropriate protection. Installations designed for parallel operation of transformers shall have protection for avoiding circulating current between transformers, avoid overload of any one transformer due to reactance mismatch and the system shall be so arranged as to trip the secondary breaker in case the primary breaker of that transformer trips.

**5.2.6** *Switchgear*

**5.2.6.1** Switchgear (and its protective device) shall have breaking capacity not less than the anticipated fault level in the system at that point. System fault level at a point in distribution system is predominantly dependent on the transformer size and its reactance. Parallel operation of transformers naturally increases the fault level

**5.2.6.2** Isolation and controlling circuit breaker shall be interlocked so that the isolator cannot be operated unless the corresponding breaker is in open condition. The choice between alternative types of equipment may be influenced by the following considerations:

a) In certain installations supplied with electric power from remote transformer substations, it may be necessary to protect main circuits with circuit-breakers operated by earth fault, in order to ensure effective earth fault protection.
b) Where large electric motors, furnaces or other heavy electrical equipment is installed, the main circuits shall be protected from short-circuits by switch disconnector fuse or circuit breakers. For motor protection, the combination of contactor overload device and fuse or circuit breakers shall be Type-2 co-ordinated in accordance with accepted standards [8-2(7)]. Wherever necessary, back up protection and earth fault protection shall be provided to the main circuit.
c) Where mean of isolating main circuits is separately required, switch disconnector fuse or switch disconnector may form part of main switchboards.

**5.2.6.3** It shall be mandatory to provide power factor improvement capacitor at the substation bus. Suitable capacitor may be selected in consultation with the capacitor as well as switchgear manufacture depending upon the nature of electrical load anticipated on the system. Necessary switchgear/feeder circuit breaker shall be provided for controlling of capacitor bank.

Power factor of individual motor may be improved by connecting individual capacitor banks in parallel. For higher range of motors, which are running continuously without much variation in load, individual power factor correction at load end is advisable.

NOTE — Care should be taken in deciding the kVA rating of the capacitor in relation to the magnetising kVA of the motor. Over rating of the capacitor may cause injury to the motor and capacitor bank. The motor still rotating after disconnection from the supply, may act as generator by self-excitation and produce a voltage higher than supply voltage. If the motor is again switched on before the speed has fallen to about 80 percent of the normal running speed, the high voltage will be superimposed on the supply circuits and will damage both the motor and capacitor.

As a general rule, the kVAr rating of the capacitor should not exceed the no-load magnetising kVA of the motor.

Generally it would be necessary to provide an automatic control for switching in capacitors matching the load power factor and the bus voltage. Such a scheme would be necessary as capacitors permanently switched in the circuit may cause over voltage at times of light load.

**5.2.6.4** Sufficient additional space shall be allowed in substations and switchrooms to allow operation and maintenance and proper means shall be provided for isolating the equipment to allow access for servicing, testing and maintenance. Sufficient additional space shall be allowed for temporary location and installation of standard servicing and testing equipment. Space should also be allowed to provide for anticipated future extensions.

**5.2.6.5** Electrical installations in a room or cubicle or in an area surrounded by wall fence, access to which is controlled by lock and key shall be considered accessible to authorized persons only.

A wall or fence less than 1.8 m in height shall not be considered as preventing access unless it has other features that provide a degree of isolation equivalent to a 1.8 m fence.

**5.2.6.6** Harmonics on the supply systems are becoming a greater problem due to the increasing use of electronic equipments, computer, fluorescent, mercury vapour and sodium vapour lighting, controlled rectifier and inverters for variable speed drives, power electronics and other non-linear loads. Harmonics may lead to almost as much current in the neutral as in the phases. This current is almost entirely third harmonic. Phase rectification devices may be considered for the limits of harmonic voltage distortion may be considered at the planning stage in such cases.

With the wide spread use of thyristor and rectifier based loads there is necessity of providing a full size neutral; but this requirement is limited to the 3-phase 4-wire distribution generally in the 400/230 V system. As a result it is not desirable to use half-size neutral conductor, as possibility of neutral conductor overload due to harmonics is likely.

### 5.3 Reception and Distribution of Main Supply

**5.3.1** *Control at Point of Commencement of Supply*

**5.3.1.1** There shall be a circuit-breaker or miniature circuit-breakers or a load break switch fuse on each live conductor of the supply mains at the point of entry. The wiring throughout the installation shall be such that there is no switch or fuse unit in the earthed neutral of conductor. The neutral shall also be distinctly marked. In this connection, Rule 32(2) and Rule 50(1) of the *Indian Electricity Rules,* 1956 (*see* Annex B) as amended up to date shall also be referred.

**5.3.1.2** The main switch shall be easily accessible and situated as near as practicable to the termination of service line.

**5.3.1.3** On the main switch, where the conductors include an earthed conductor of a two-wire system or an earthed neutral conductor or a multi-wire system or a conductor which is to be connected thereto, an indication of a permanent nature shall be provided to identify the earthed neutral conductor. In this connection, Rule 32(1) of *Indian Electricity Rules,* 1956 (*see* Annex B) shall be referred as amended up-to-date.

**5.3.1.4** *Energy meters*

Energy meters shall be installed in residential buildings at such a place which is readily accessible to the owner of the building and the Authority. These should be installed at a height where it is convenient to note the meter reading, it should preferably not be installed below one metre from the ground. The energy meters should either be provided with a protecting covering, enclosing it completely except the glass window through which the readings are noted or should be mounted inside a completely enclosed panel provided with hinged or sliding doors with arrangement for locking.

In multi-storeyed buildings meters shall be installed with tapping point for meters of the rising main (bus trunking) on individual floors.

**5.3.2** *Main Switches and Switchboard*

**5.3.2.1** All main switches shall be either of metal-clad enclosed pattern or of any insulated enclosed pattern which shall be fixed at close proximity to the point of entry of supply. Every switch shall have an environmental protection level rating (IP), so that its operation is satisfactory in the environment of the installation.

NOTE — Woodwork shall not be used for the construction or mounting of switches and switch boards installed in a building.

**5.3.2.2** *Location*

a) The location of the main board should be such that it is easily accessible for fireman and other personnel to quickly disconnect the supply in case of emergencies. If the room is locked for security, means of emergency access, by schemes such as break glass cupboard, shall be incorporated.

b) Main switch board shall be installed in rooms or cupboards so as to safeguard against operation by unauthorized personnel.

c) Switchboards shall be placed only in dry situations and in ventilated rooms and they shall not be placed in the vicinity of storage batteries or exposed to chemical fumes.

d) In damp situation or where inflammable or explosive dust, vapour or gas is likely to be present, the switchboard shall be totally enclosed and shall have adequate degree of protection. In some cases flameproof enclosure may be necessitated by particular circumstances [*see* 8-2(8)].

e) Switchboards shall not be erected above gas stoves or sinks, or within 2.5 m or any washing unit in the washing rooms or laundries, or in bathrooms, lavatories or toilets, or kitchens.

f) In case of switchboards unavoidably fixed in places likely to be exposed to weather, to drip, or to abnormal moist temperature, the outer casing shall be weatherproof and shall be provided with glands or bushings or adopted to receive screwed conduit, according to the manner in which the cables are run.

g) Adequate illumination shall be provided for all working spaces about the switchboards when installed indoors.

**5.3.2.3** Metal-clad switchgear shall preferably be mounted on any of the following types of boards:

a) *Hinged-type metal boards* — These shall consist of a box made of sheet metal not less than 2 mm thick and shall be provided with a hinged cover to enable the board to swing open for examination of the wiring at the back. The joints shall be welded. There shall be a clear distance of not less than 2.5 cm between the teak wood board and the cover, the distance being increased for larger boards in order that on closing of the cover, the insulation of the cables is not subjected to damage and no excessive twisting or bending in any case. The board shall be securely fixed to the wall by means of rag bolts, plugs, or wooden plugs and shall be provided with a locking arrangement and an earthing stud. All wires passing through the metal board shall be protected by a rubber or wooden bush at the entry hole. The earth stud should commensurate with the size of earth lead/ leads. Alternatively, metal boards may be made of suitable size angle iron of minimum size 35 mm × 35 mm × 6 mm or channel iron of minimum size 35 mm × 25 mm × 6 mm frames work suitably mounted on front with a 3 mm thick mild steel plate and on back with 1.5 mm thick mild steel sheet. No apparatus shall project beyond any edge of panel. No fuse body shall be mounted within 2.5 cm of any edge of the panel.

NOTE — Such type of boards are particularly suitable for small switchboard for mounting metal-clad switchgear connected to supply at low voltages.

b) *Fixed-type metal boards* — These shall consist of an angle or channel iron frame fixed on the wall or on floor and supported on the wall at the top, if necessary. There shall be a clear distance of 1 m in front of the switchboards. If there are any attachments of bare connections at the back of the switchboard Rule 51(1)(c) of *Indian Electricity Rules,* 1956 shall apply. The connections between the switchgear mounting and the outgoing cable up to the wall shall be enclosed in a protection pipe.

NOTE — Such type of boards are particularly suitable for large switchboards for mounting large number of switchgears or high capacity metal-clad switchgear or both.

c) *Protected-type switchboard* — A protected switchboard is one where all of the conductors are protected by metal or other enclosures. They may consist of a metal cubicle panel, or an iron frame upon which is mounted metal-clad switchgear. They usually consist of a main switch, busbars and circuit breakers or fuses controlling outgoing circuits.

d) *Open-type switchboard* — An open type switchboard is one, which has exposed current carrying parts on the front of the switchboard. This type of switchboard is rarely used now-a-days but where this exists, a hand rail or barrier has to be provided to prevent unintentional or accidental contact with exposed live parts. They must be located in a special switch room or enclosure and only a competent person may have access to these switchboards.

NOTE — These boards may be existing in old installations. It is recommended that they be phased out. With the continuously increasing fault power feed due to increases in generation and strengthening of distribution systems, these open boards are a source of accidents.

**5.3.2.4** *Recessing of boards*

Where so specified, the switchboards shall be recessed in the wall. Ample room shall be provided at the back for connection and at the front between the switchgear mountings.

**5.3.2.5** *Marking of apparatus* [*see also* 8-2(9)]

a) Where a board is connected to voltage higher than 250 V, all the apparatus mounted on it shall be marked on the following colours to indicate the different poles or phases to which the apparatus or its different terminals may have been connected:

| *Alternating Current* | *Direct Current* |
|---|---|
| Three-phases — red, yellow, blue | Three-wire system — 2 outer wire, positive red and negative blue |
| 1 Neutral — black | 1 Neutral — black |

Where four-wire three-phase wiring is done, the neutral shall be in one colour and the other three wires in another colour as mentioned above or shall be suitably tagged or sleeved for fool proof identification.

b) Where a board has more than one switch, each such switch shall be marked to indicate which section of the installation it controls. The main switch shall be marked as such and where there is more than one main switch in the building, each such switch shall be marked to indicate which section of the installation it controls.

All markings shall be clear and permanent.

**5.3.2.6** *Drawings*

Before proceeding with the actual construction, a proper drawing showing the detailed dimensions and design including the disposition of the mountings of the boards, which shall be symmetrically and neatly arranged for arriving at the overall dimensions, shall be prepared along the building drawing. Such drawings will show the mandatory clearance spaces if any, and clear height below the soffit of the beam required to satisfy regulations and safety considerations, so that other designers or installers do not get into such areas or spaces for their equipment.

**5.3.2.7** Where a board has more than one switch, each such switch shall be marked to indicate which section of the installation it controls. The main switch shall be marked as such and where there is more than one main switch in the building, each such switch shall be marked to indicate which section of the installation it controls.

All markings shall be clear and permanent.

**5.3.2.8** *MV/LV Busbar chambers (400 V/230 V)*

Busbar chambers, which feed two or more circuits, must be controlled by a main disconnector (TP & N), or Isolating links or TPN MCB to enable them to be disconnected from the supply.

**5.3.3** *Distribution Boards*

A distribution board comprises of one or more protective devices against over current and ensuring the distribution of electrical energy to the circuits. Distribution board shall provide plenty of wiring space, to allow working as well as to allow keeping the extra length of connecting cables, likely to be required for maintenance.

**5.5.3.1** Main distribution board shall be provided with a circuit breaker on each pole of each circuit, or a switch with a fuse on the phase or live conductor and a link on the neutral or earthed conductor of each circuit. The switches shall always be linked.

All incomers should be provided with surge protection devices.

**5.3.4** *Branch Distribution Boards*

**5.3.4.1** Branch distribution boards shall be provided, along with earth leakage protective device (ELCB) (incoming), with a fuse or a miniature circuit breaker or both of adequate rating/setting chosen on the live conductor of each sub-circuit and the earthed neutral conductor shall be connected to a common link and be capable of being disconnected individually for testing purposes. At least one spare circuit of the same capacity shall be provided on each branch distribution board. Further, the individual branching circuits (outgoing) shall be protected against over-current with miniature circuit breaker of adequate rating. In residential/ industrial lighting installations, the various circuits shall be separated and each circuit shall be individually protected so that in the event of fault, only the particular circuit gets disconnected.

**5.3.4.2** Circuits shall be separate for installations at higher level such as those in the ceiling and at higher levels, above 1 m, on the walls and for installations at lower level such as sockets for portable or stationery plug in equipments. For devices consuming high power and which are to be supplied through supply cord and plug, separate wiring shall be done. For plug-in equipment provisions shall be made for providing ELCB protection in the distribution board.

**5.3.4.3** It is preferable to have additional circuit for kitchen and bathrooms. Such sub-circuit shall not have more than a total of ten points of light, fans and 6A socket outlets. The load of such circuit shall be restricted to 800 W. If a separate fan circuit is provided, the number of fans in the circuit shall not exceed ten. Power sub-circuit shall be designed according to the load but in no case shall there be more than two 16A outlets on each sub-circuit.

**5.3.4.4** The circuits for lighting of common area shall be separate. For large halls 3-wire control with individual control and master control installed near the entrance shall be provided for effective conservation of energy.

**5.3.4.5** Where daylight would be available, particularly in large halls, lighting in the area near the windows, likely to receive daylight shall have separate controls for lights, so that they can be switched off selectively when daylight is adequate, while keeping the lights in the areas remote from the windows on.

**5.3.4.6** Circuits for socket outlets may be kept separate circuits feeding fans and lights. Normally, fans and lights may be wired on a common circuit. In large spaces circuits for fans and lights may also be segregated. Lights may have group control in large halls and industrial areas. While providing group control consideration may be given for the nature of use of the area lit by a group. Consideration has to be given for the daylight utilization, while grouping, so that a group feeding areas receiving daylight can be selectively switched off during daylight period.

**5.3.4.7** The load on any low voltage sub-circuit shall not exceed 3 000 W. In case of a new installation, all circuits and sub-circuits shall be designed with an initial load of about 2 500 W, so as to allow a provision of 20 percent increase in load due to any future modification. Power sub-circuits shall be designed according to the load, where the circuit is meant for a specific equipment. Good practice is to limit a circuit to a maximum of four sockets, where it is expected that there will be diversity due to use of very few sockets in large spaces (example sockets for use of vacuum cleaner). General practice is to limit it to two sockets in a circuit, in both residential and non-residential buildings and to provide a single socket on a circuit for a known heavy load appliance such as air conditioner, cooking range etc.

**5.3.4.8** In wiring installations at special places like construction sites, stadium, shipyards, open yards in industrial plants, etc, where a large number of high wattage lamp may be required, there shall be no restriction of load on any circuit but conductors used in such circuits shall be of adequate size for the load and proper circuit protection shall be provided.

**5.3.5** *Location of Distribution Boards*

a) The distribution boards shall be located as near as possible to the centre of the load they are intended to control.
b) These shall be fixed on suitable stranchion or wall and shall be accessible for replacement/reset of protective devices, and shall not be more than 1.8 m from floor level.
c) These shall be of either metal-clad type, or air insulated type. But, if exposed to weather or damp situations, these shall be of the weatherproof type and, if installed where exposed to explosive dust, vapour or gas, these shall be of flameproof type in accordance with accepted standards [8-2(10)]. In corrosive atmospheres, these shall be treated with anti-corrosive preservative or covered with suitable plastic compound.
d) Where two and/or more distribution boards feeding low voltage circuits are fed from a supply of medium voltage, the metal case shall be marked 'Danger 415 V' and identified with proper phase marking and danger marks.
e) Each shall be provided with a circuit list giving diagram of each circuit which it controls and the current rating of the circuit and size of fuse element.
f) In wiring branch distribution board, total load of consuming devices shall be divided as far as possible evenly between the number of ways in the board leaving spare circuits for future extension.

**5.3.6** *Protection of Circuits*

a) Appropriate protection shall be provided at switchboards, distribution boards and at all levels of panels for all circuits and sub-circuits against short circuit, over-current and other parameters as required. The protective device shall be capable of interrupting maximum prospective short circuit current that may occur, without danger. The ratings and settings of fuses and the protective devices shall be co-ordinated so as to afford selectivity in operation and in accordance with accepted standards [8-2(1)].
b) Where circuit-breakers are used for protection of a main circuit and of the sub-circuits derived therefrom, discrimination in operation may be achieved by adjusting the protective devices of the sub-main circuit-breakers to operate at lower current settings and shorter time-lag than the main circuit-breaker.
c) Where HRC type fuses are used for back-up protection of circuit-breakers, or where HRC fuses are used for protection of main circuits, and circuit-breakers for the protection of sub-circuits derived there from, in the event of short-circuits protection exceeding the short-circuits capacity of the circuit-breakers, the HRC fuses shall operate earlier than the

circuit-breakers; but for smaller overloads within the short-circuit capacity of the circuit-breakers, the circuit-breakers shall operate earlier than the HRC fuse blows.

d) If rewireable type fuses are used to protect sub-circuits derived from a main circuit protected by HRC type fuses, the main circuit fuse shall normally blow in the event of a short-circuit or earth fault occurring on sub-circuit, although discrimination may be achieved in respect of overload currents. The use of rewireable fuses is restricted to the circuits with short-circuit level of 4 kA; for higher level either cartridge or HRC fuses shall be used. However, use of rewireable fuse is not desirable, even for lower fault level areas. MCB's provide a better and dependable protection, as their current setting is not temperable.

e) A fuse carrier shall not be fitted with a fuse element larger than that for which the carrier is designed.

f) The current rating of a fuse shall not exceed the current rating of the smallest cable in the circuit protected by the fuse.

g) Every fuse shall have its own case or cover for the protection of the circuit and an indelible indication of its appropriate current rating in an adjacent conspicuous position.

### 5.4 Voltage and Frequency of Supply

It should be ensured that all equipment connected to the system including any appliances to be used on it are suitable for the voltage and frequency of supply of the system. The nominal values of low and medium voltage systems in India are 240 V and 415 V ac, respectively, and the frequency 50 Hz.

NOTES

**1** The design of the wiring system and the sizes of the cables should be decided taking into account two factors:

a) *Voltage Drop* — This should be kept as low as economy permits to ensure proper functioning of all electrical appliances and equipment including motors; and

b) First cost against operating losses.

**2** In view of the latest development at the international level, nominal system voltages have been aligned with IEC recommendation and accordingly the nominal ac system voltage shall be changed from 240/415 V to 230/400 V with a tolerance of ± 10 percent.

### 5.5 Rating of Cables and Equipments

**5.5.1** The current-carrying capacity of different types of cables shall be chosen in accordance with good practice [8-2(12)].

**5.5.2** The current ratings of switches for domestic and similar purposes are 6A and 16A.

**5.5.3** The current ratings of isolators and normal duty switches and composite units of switches and fuses shall be selected from one of the following values:

16, 25, 32, 63, 100, 160, 200, 320, 400, 500, 630, 800, 1 000 and 1 250 A.

**5.5.4** The ratings of rewirable and HRC fuses shall be in accordance with good practice [8-2(13)].

**5.5.5** The current ratings of miniature circuit-breakers shall be chosen from the values given below:

6, 8, 10, 13, 16, 20, 25, 32, 40, 50, 63, 80, 100 and 125 A.

**5.5.6** The current ratings of moulded case circuit-breakers shall be chosen from the values given below:

100, 125, 160, 200, 250, 315, 400, 630, 800, 1 000, 1 250 and 1 600 A.

**5.5.7** The current ratings of air circuit-breakers shall be chosen from the values given below:

630, 800, 1 000, 1 250, 1 600, 2 000, 2 500, 3 200 and 4 000 A.

**5.5.8** The current ratings of the distribution fuse board shall be selected from one of the following values:

6, 16, 25, 32, 63 and 100 A.

### 5.6 Installation Circuits

| *Type of Circuit* | *Wire Size* | *Number of Circuits* |
|---|---|---|
| Lighting | 1.0 $mm^2$ | 2 or more |
| Socket-outlets 10 A | 2.5 $mm^2$ | Any number Areas such as kitchens and laundries 3 × double socket-outlets per circuit. Other areas up to 12 double socket-outlets |
| Socket-outlets 15 or 20 A | 2.5 $mm^2$ | 1 |
| Water heater 3 kW | 1.5 $mm^2$ | 1 |
| Water heater 3-6 kW | 2.5 $mm^2$ | 1 |
| Free standing electric range | 6.0 $mm^2$ | 1 |
| Separate oven and/ or cook top | 4.0 $mm^2$ | 1 |
| Permanently connected appliances including dish-washers, heaters, etc | 2.5 $mm^2$ | 1 above 10 A. Up to 10 A can be wired as part of a socket-outlet circuit |
| Submains to garage or out-building | 2.5 $mm^2$ | 1 for each |
| Mains cable | 16 $mm^2$ | 1 |

**5.6.1** *Selecting and Installing Cables*

**5.6.1.1** *Cable insulation types*

| | |
|---|---|
| For the mains cable | Tough plastic sheathed (TPS) cable |
| For installation wiring | Tough plastic sheathed (TPS) cables |
| For main earth or main equipotential wire | Polyvinyl chloride (PVC) insulated conduit wire |
| Underground installation and installation in cable trench, feeders between buildings etc., | PVC insulated, PVC sheathed armoured cables or XLPE insulated, PVC sheathed cables armoured cables |
| Installation in plant rooms, switch rooms etc, on cable tray or ladder or protected trench, where risk of mechanical damage to cable does not exist. | PVC insulated, PVC sheathed or XLPE insulated, PVC sheathed unarmoured cables |

For the purposes of this Code cables above 1 mm$^2$ must have stranded conductors. All cables when installed, must be adequately protected against mechanical damage. This can be carried out by either having additional protection, such as being enclosed in PVC conduit or metal pipes, or placing the cables in a suitable location that requires no additional protection. The cables for wiring circuits in electrical installation must have the appropriate wire size matching the requirement of the loads and the following table gives the recommendations for different types of loads.

**5.6.1.2** *Circuit wire sizes*

| *Circuits* | *Minimum Wire Size* | *Wire Colour* |
|---|---|---|
| 1-way lighting | 2 + E cable wires 1.5 mm$^2$ | Red-Black-Green or Green/Yellow |
| 2-way lighting control (straps between the 2 switches) | 3-wire cable 1.5 mm$^2$ | Red-White-Blue |
| Storage water heaters up to 3 kW | 2 + E cable 1.5 mm$^2$ (stranded conductors) | Red-Black-Green or Green/Yellow |
| Storage water heaters between 3 kW and 6 kW | 2 + E cable 2.5 mm$^2$ (stranded conductors) | Red-Black-Green or Green/Yellow |
| Socket-outlets and permanent connection units | 2 + E cable 2.5 mm$^2$ (stranded conductors) | Red-Black-Green or Green/Yellow |
| Submains to garages or out buildings | 2 + E cable 2.5 mm$^2$ (stranded conductors) | Red-Black-Green or Green/Yellow |
| Cooking hobs | 2 + E cable 4 mm$^2$ | Red-Black-Green or Green/Yellow |
| Separate ovens | 2 + E cable 4 mm$^2$ (stranded conductors) | |
| Electric range | 2 + E cable 6 mm$^2$ (stranded conductors) | Red-Black-Green or Green/Yellow |
| Mains | 2 wire cable 16 mm$^2$ (stranded conductors) | Red-Black |
| Main equipotential bonding wire | Conduit wire 4 mm$^2$ (stranded conductors) | Green or Green/Yellow |
| Main earth wire | Conduit wire 6 mm$^2$ (stranded conductors) | Green or Green/Yellow |

2 + E is also known as twin and earth

Switch or isolator controlling a water heater or geyser should not be located within 1 m from the location of a shower or bath tub, to avoid a person in wet condition reaching the switch or isolator. It is preferable to provide the control switch outside the bathroom near the entrance and provide an indication at the water heater. A socket or a connector block with suitable protection against water spray should be provided to connect the water heater. The above considerations apply to switches for outdoor lights and other appliances, with the object of avidance of operation of a switch when a person is wet. Sockets in kitchen, bathroom, toilet, garage etc, should not be provided within a height of 1 m from the ground level. Similar care has to be taken for installations involving fountains, swimming pools etc. Light fittings in such areas should be fed at low voltage, preferably through an isolating transformer with a proper earth leakage protection.

**5.6.2** *Requirements for Physical Protection of Underground Cables*

| *Protective Element* | *Specifications* |
|---|---|
| Bricks | a) 100 mm minimum width<br>b) 25 mm thick<br>c) sand cushioning 100 mm and sand cover 100 mm. |
| Concrete slabs | at least 50 mm thick. |
| Plastic slabs (polymeric cover strips) Fibre reinforced plastic | at least 10 mm thick, depending on properties and has to be matched with the protective cushioning and cover |
| PVC conduit or PVC pipe or stoneware pipe or hume pipe | The pipe diameter should be such so that the cable is able to easily slip down the pipe. |
| Galvanized pipe | The pipe diameter should be such so that the cable is able to easily slip down the pipe. |

The trench shall be backfilled to cover the cable initially by 200 mm of fill; and then a plastic marker strip over the full length of cable in the trench. Fill the trench shall be laid before filling the full trench. The marker signs where any cable enters or leaves a building shall be put. This will identify that there is a cable located underground near the building. If the cables rise above ground to enter a building or other structure, a mechanical protection such as a GI pipe or PVC pipe for the cable from the trench depth to a height of 2.0 m above ground shall be provided.

### 5.7 Lighting and Levels of Illumination

**5.7.1** *General*

Lighting installation shall take into consideration the many factors on which the quality and quantity of artificial lighting depends. The modern concept is to provide illumination with the help of a large number of light sources not of higher illumination level. Also much higher levels of illumination are called for, than in the past, often necessitating the use of fluorescent lighting suitably supplemented with incandescent fittings, where required.

**5.7.2** *Future Demand*

However, if for financial reasons, it is not possible to provide a lighting installation to give the recommended illumination levels, the wiring installation at least should be so designed that at a later date, it will permit the provision for additional lighting fittings or conversion from incandescent to fluorescent lighting fittings to bring the installation to the required standard. It is essential that adequate provisions should be made for all the electrical services which may be required immediately and during the intended useful life of the building.

**5.7.3** *Principles of Lighting*

When considering the function of artificial lighting, attention shall be given to the following principle characteristics before designing an installation:

a) illumination and its uniformity;
b) special distribution of light. This includes a reference to the composition of diffused and directional light, direction of incidence, the distribution of luminances and the degree of glare; and
c) colour of the light and colour rendition.

**5.7.4** The variety of purposes which have to be kept in mind while planning the lighting installation could be broadly grouped as:

a) industrial buildings and processes;
b) offices, schools and public buildings;
c) surgeries and hospitals; and
d) hostels, restaurants, shops and residential buildings.

**5.7.4.1** It is important that appropriate levels of illumination for these and the types and positions of fittings determined to suit the task and the disposition of the working planes.

**5.7.5** For specific requirements for lighting of special occupancies, reference shall be made to good practice [8-2(14)].

**5.7.6** *Energy Conservation*

Energy conservation may be achieved by using the following:

a) Energy efficient lamps, chokes, ballast, etc for lighting equipment.
b) Efficient switching systems such as remote sensors, infrared switches, master switches, remote switches, etc for switching ON and OFF of lighting circuits.
c) Properly made/connected joints/contacts to avoid loose joints leading to loss of power.

**5.8** In locations where the system voltage exceeds 650 V, as in the case of industrial locations, for details of design and construction of wiring installation, reference may be made to good practice [8-2(15)].

**5.9 Guideline for Electrical Layout in Residential Buildings**

For guidelines for electrical installation in residential buildings, reference may be made to good practice [8-2(16)].

A typical distribution scheme in a residential building with separate circuits for lights and fans and for power appliances is given in Fig. 1.

**5.10** For detailed information regarding the installation of different electrical equipments, reference may be made to good practice [8-2(17)].

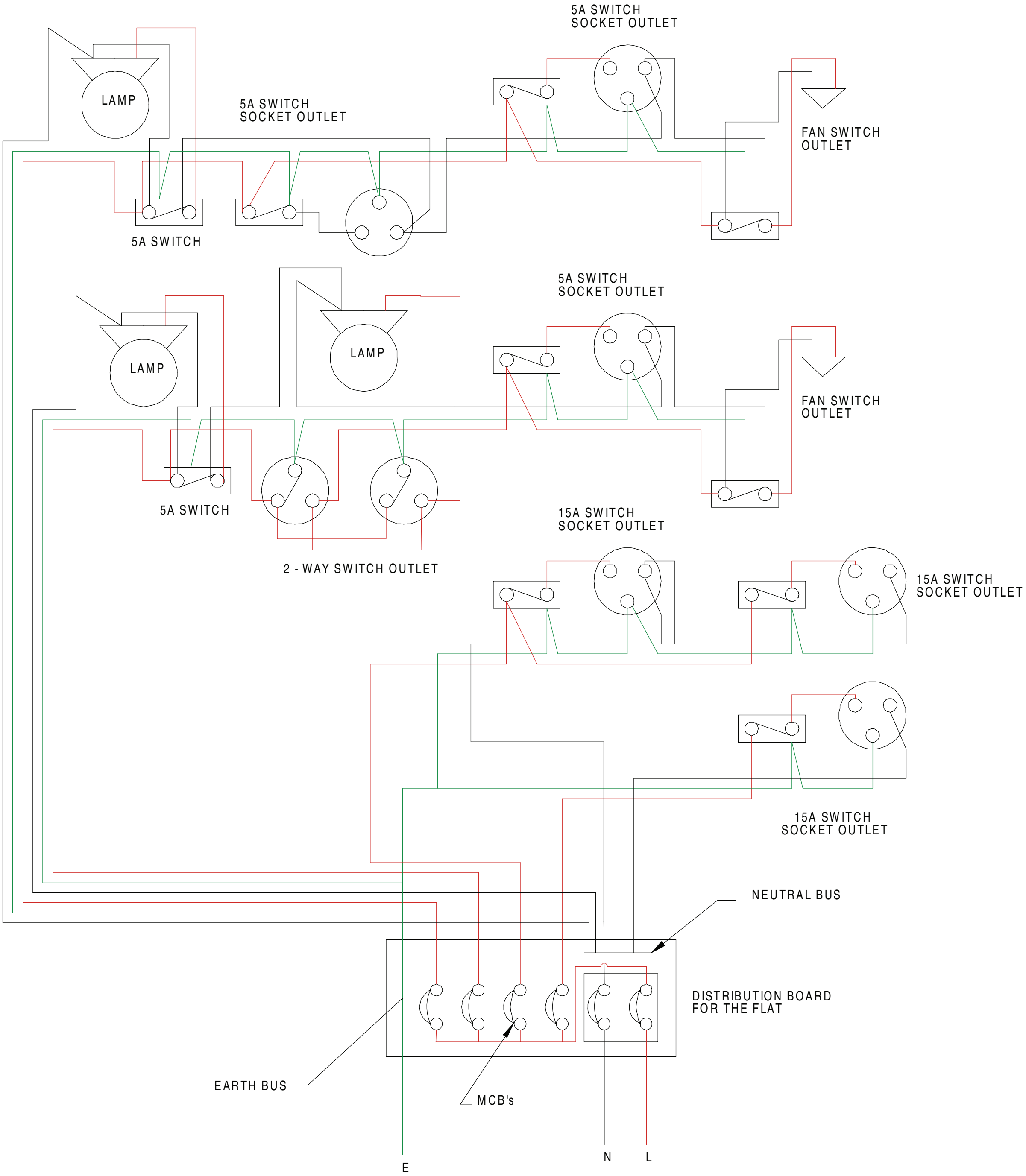



FIG. 1 WIRING DIAGRAM FOR A TYPICAL DISTRIBUTION BOARD SCHEME IN A RESIDENTIAL BUILDING FLAT

## 6 WIRING

### 6.1 Provision for Maximum Load

All conductors, switches and accessories shall be of such size as to be capable of carrying, without their respective ratings being exceeded, the maximum current which will normally flow through them.

**6.1.1** *Estimation of Load Requirements*

In estimating the current to be carried by any conductor the following ratings shall be taken, unless the actual values are known or specified for these elements:

| *Element* | | *Rating* (in W) |
|---|---|---|
| Incandescent lamps | | 60 |
| Ceiling fans / Table fans | | 100 |
| Ordinary socket outlet points | | 100 |
| Fluorescent tubes: | | |
| Length: | 600 mm | 25 |
| | 1 200 mm | 50 |
| | 1 500 mm | 90 |
| Power socket-outlet | | 1 000 |
| Air-conditioner | | 2 500 |

**6.1.2** Electrical installation in a new building shall normally begin immediately on the completion of the main structural building work and before finishing work such as plastering has begun except in the case of surface wiring which can be carried out after the plaster work. Usually, no installation work should start until the building is reasonably weatherproof, but where electric wiring is to be concealed within the structures as may be the case with a reinforced concrete building, the necessary conduits and ducts shall be positioned firmly by tying the conduit to the reinforcement before concreting. When shutters are removed after concreting, the conduits ends shall be given suitable anti-corrosive treatment and holes blocked off by putties or caps to protect conduits from getting blocked. All conduit openings and junction box openings, etc shall be properly protected against entry of mortar, concrete, etc during construction.

### 6.2 Selection of Size of Conductors

The size of conductors of circuits shall be so selected that the drop in voltage from consumer's terminals in a public supply (or from the busbars of the main switchboard controlling the various circuits in a private generation plant) to any point on the installation does not exceed three percent of the voltage at the consumer's terminals (or at two busbars as these may be) when the conductors are carrying the maximum current under the normal conditions of service.

**6.2.1** If the cable size is increased to avoid voltage drop in the circuit, the rating of the cable shall be the current which the circuit is designed to carry. In each circuit or sub-circuit the fuse shall be selected to match the cable rating to ensure the desired protection.

### 6.3 Branch Switches

Where the supply is derived from a three-wire or four-wire source, and distribution is done on the two-wire system, all branch switches shall be placed in the outer or live conductor of the circuit and no single phase switch or protective device shall be inserted in the middle wire, earth or earthed neutral conductor of the circuit. Single-pole switches (other than for multiple control) carrying not more than 16 A may be of tumbler type or flush type which shall be on when the handle or knob is down.

### 6.4 Layout and Installation Drawing

**6.4.1** The electrical layout should be drawn indicating properly the locations of all outlets for lamps, fans, appliances both fixed and transportable, motors, etc, and best suit for wiring.

**6.4.2** All runs of wiring and the exact positions of all points of switch-boxes and other outlets shall be first marked on the plans of the building and approved by the engineer-in-charge or the owner before actual commencement of the work.

**6.4.3** Industrial layout drawings should indicate the relative civil and mechanical details.

**6.4.4** *Layout of Wiring*

The layout of wiring should be designed keeping in view disposition of the lighting system to meet the illumination levels. All wirings shall be done on the distribution system with main and branch distribution boards at convenient physical and electrical load centres. All types of wiring, whether concealed or unconcealed should be as near the ceiling as possible. In all types of wirings due consideration shall be given for neatness and good appearance.

**6.4.5** Balancing of circuits in three-wire or poly-phase installation shall be arranged before hand. Proper Balancing can be done only under actual load conditions. Conductors shall be so enclosed in earthed metal or incombustible insulating material that it is not possible to have ready access to them. Means of access shall be marked to indicate the voltage present.

Where terminals or other fixed live parts between which a voltage exceeding 250 V exists are housed in separate enclosures or items of apparatus which, although separated are within reach of each other, a notice shall be placed in such a position that anyone gaining access to live parts is warned of the magnitude of the voltage that exists between them.

Where loads are single phase, balancing should be for the peak load condition based on equipment usage. Facility for change should be built into the distribution design.

NOTE — The above requirements apply equally to three-phase circuits in which the voltage between lines or to earth exceeds 250 V and to groups of two or more single-phase circuits, between which medium voltage may be present, derived therefrom. They apply also to 3-wire dc or 3-wire single-phase ac circuits in which the voltage between lines or to earth exceeds 250 V and to groups of 2-wire circuits, between which medium voltage may be present, derived therefrom.

**6.4.6** Medium voltage wiring and associated apparatus shall comply, in all respects, with the requirements of Rules 50, 51 and 61 of the *Indian Electricity Rules,* 1956 as amended up-to-date.

### 6.5 Conductors and Accessories

**6.5.1** *Conductors*

Conductors for all the internal wiring shall be of copper. Conductors for power and lighting circuits shall be of adequate size to carry the designed circuit load without exceeding the permissible thermal limits for the insulation. The conductor for final sub-circuit for fan and light wiring shall have a nominal cross-sectional area not less than 1.50 $mm^2$ copper. The cross-sectional area of conductor for power wiring shall be not less than 4.0 $mm^2$ copper. The minimum cross-sectional area of conductor of flexible cord shall be 1.50 $mm^2$ copper.

In existing buildings where aluminium wiring has been used for internal electrification, changeover from aluminium conductor to copper conductor may be made once the former goes beyond economical repairs.

NOTE — It is advisable to replace wiring, which is more than 30 years old as the insulation also would have deteriorated, and will be in a state to cause failure on the slightest of mechanical or electrical disturbance.

**6.5.2** *Flexible Cables and Flexible Cords*

Flexible cables and cords shall be of copper and stranded and protected by flexible conduits or tough rubber or PVC sheath to prevent mechanical damage.

**6.5.3** *Cable Ends*

When a stranded conductor having a nominal sectional area less than 6 $mm^2$ is not provided with cable sockets, all strands at the exposed ends of the cable shall be soldered together or crimped using suitable sleeve or ferrules.

**6.5.4** *Special Risk*

Special forms of construction, such as flameproof enclosures, shall be adopted where there is risk of the fire or explosion.

**6.5.5** *Connection to Ancillary Buildings*

Unless otherwise specified, electric connections to ancillary buildings, such as out-houses, garages, etc, adjacent to the main building and when no roadway intervenes shall be taken in an earthed GI pipe or heavy duty PVC or HDPE pipe of suitable size in the exposed portion at a height of not less than 5.8 m or by buried underground cables. This applies to both runs of mains or sub-mains or final sub-circuit wiring between the buildings.

**6.5.6** *Expansion Joints*

Distribution boards shall be so located that the conduits shall not normally be required to cross expansion joints in a building. Where such crossing is found to be unavoidable, special care shall be taken to ensure that the conduit runs and wiring are not in any way put to strain or damaged due to expansion of building structure. Anyone of the standard methods of connection at a structural expansion joint shall be followed:

a) Flexible conduit shall be inserted at place of expansion joint.
b) Oversized conduit overlapping the conduit.
c) Expansion box.

**6.5.7** *Low Voltage* (*Types of Wires/Cables)*

Low voltage services utilizes various categories of cables/wires, such as Fibre optic cable, co-axial, CAT 5, etc. These shall be laid at atleast minimum specified distance of 300 mm from any power wire or cable. Special care shall be taken to ensure that the conduit runs and wiring are laid properly for low voltage signal to flow through it.

### 6.6 Joints and Looping Back

**6.6.1** Where looping back system of wiring is specified, the wiring shall be done without any junction or connector boxes on the line. Where joint box system is specified, all joints in conductors shall be made by means of suitable mechanical connectors in suitable joint boxes. Wherever practicable, looping back system should be preferred. Whenever practicable, only one system shall be adopted for a building, preferably a looping back system.

**6.6.2** In any system of wiring, no bare or twist joints shall be made at intermediate points in the through run of cables unless the length of a final sub-circuit, sub-main or main or more than the length of the standard coil as given by the manufacturer of the cable. If any jointing becomes unavoidable such joint shall be made through proper cutouts or through proper junction boxes open to easy inspection, but in looping back system no such junction boxes shall be allowed.

**6.6.3** Joints are a source of problems in reliability and are also vulnerable to fire. They should be avoided or at least minimized. Where joints in cable conductors or bare conductors are necessary, they shall be mechanically and electrically sound. Joints in non-flexible cables shall be accessible for inspection; provided that this requirement shall not apply to joints in cables buried underground, or joints buried or enclosed in non-combustible building materials. Joints in non-flexible cables shall be made by soldering, brazing, welding or mechanical clamps, or be of the compression type; provided that mechanical clamps shall not be used for inaccessible joints buried or enclosed in the building structure. All mechanical clamps and compression type sockets shall securely retain all the wires of the conductors. Any joint in a flexible cable of flexible cord shall be effected by means of a cable coupler.

For flexible cables for small loads less than 1 kW, while it would be desirable to avoid joints, if unavoidable, joints can be made either by splicing by a recognised method or by using a connector and protecting the joint by suitable insulating tape or sleeve or straight joint. For application of flexible cable for loads of 1 kW or more, if joint is unavoidable, crimped joint would be preferred. Spliced joint should not be used for large loads.

There are different standard joints such as epoxy resin based joint, heat shrinkable plastic sleeve joint etc, and each one has its advantage and disadvantage. Selection has to be made on the basis of application, site conditions and availability of skilled licensed workmen.

**6.6.4** Every joint in a cable shall be provided with insulation not less effective than that of the cable cores and shall be protected against moisture and mechanical damage. Soldering fluxes which remain acidic or corrosive at the completion of the soldering operation shall not be used.

For joints in paper-insulated metal-sheathed cables, a wiped metal sleeve or joint box, filled with insulating compound, shall be provided.

Where an aluminium conductor and a copper conductor are joined together, precautions shall be taken against corrosion and mechanical damage to the conductors.

**6.6.5** *Pull at Joints and Terminals*

Every connection at a cable termination shall be made by means of a terminal, soldering socket, or compression type socket and shall securely contain and anchor all the wires of the conductor, and shall not impose any appreciable mechanical strain on the terminal or socket.

Flexible cords shall be so connected to devices and to fittings that tension will not be transmitted to joints or terminal screws. This shall be accomplished by a knot in the cord, by winding with tape, by a special fitting designed for that purpose, or by other approved means which will prevent a pull on the cord from being directly transmitted to joints or terminal screws.

## 6.7 Passing Through Walls and Floors

**6.7.1** Where conductors pass through walls, one of the following methods shall be employed. Care shall be taken to see that wires pass freely through protective pipe or box and that the wires pass through in a straight line without any twist or cross in wires on either ends of such holes:

a) The conductor shall be carried either in a rigid steel conduit or a rigid non-metallic conduit conforming to accepted standards [8-2(18)].

b) *Conduit colour coding*

The conduits shall be colour coded as per the purpose of wire carried in the same. The colour coding may be in form of bands of colour (4 inch thick, with centre-to-centre distance of 12 inches) or coloured throughout in the colour. The colour scheme shall be as follows:

| *Conduit Type* | *Colour scheme* |
|---|---|
| Power conduit | Black |
| Security conduit | Blue |
| Fire alarm conduit | Red |
| Low voltage conduit | Brown |
| UPS conduit | Green |

c) *Cable trunking/cable ways*

For the smaller cables, enclosures such as conduit and trunking, may be employed and PVC-insulated, with or without sheath, single-core cables installed following completion of the conduit/trunking system. As these cables are usually installed in relatively large groups, care must be taken to avoid overheating and to provide identification of the different circuits.

d) *Tray and ladder rack*

As tray provides continuous support, unless mounted on edge or in vertical runs (when adequate strapping or clipping is essential), the mechanical strength of supported cable is not as important as with ladder-racking or structural support methods. Consequently, tray is eminently suitable for the smaller unarmoured cabling while racks and structural support, except for short lengths, call for armoured cables as they provide the necessary strength to avoid sagging between supports. Both tray and ladder racks can be provided with accessories to facilitate changes of route, and as PVC and similar insulating materials are non-migratory (unlike the older types of impregnated cables) they provide no difficulty in this respect on vertical runs.

e) Insulated conductors while passing through floors shall be protected from mechanical injury by means of rigid steel conduit, non-metal conduit or mechanical protection to a height not less than 1.5 m above the floors and flush with the ceiling below. This steel conduit shall be earthed and securely bushed.

   Power outlets and wiring in the floor shall be generally avoided. If not avoidable, use false floor or floor trunking. False floor shall be provided where density of equipment and interconnection between different pieces of equipment is high. Examples are: Mainframe Computer station, Telecommunication switch rooms, etc.

   Floor trunking shall be used in large halls, convention centres, open plan offices, laboratory, etc.

   In case of floor trunking drain points shall be provided, as there could be possibility of water seepage in the case of wiring passing through the floors. Proper care should be taken for suitable means of draining of water. Possibility of water entry exists from: (1) floor washing, (2) condensation in some particular weather and indoor temperature conditions. At the design stage, these aspects have to be assessed and an appropriate means of avoiding, or reducing, and draining method will have to be built in.

   Floor outlet boxes are generally provided for the use of appliances, which require a signal, or communication connection. The floor box and trunking system should cater to serve both power distribution and the signal distribution, with appropriate safety and non-interference.

**6.7.2** Where a wall tube passes outside a building so as to be exposed to weather, the outer end shall be bell-mouthed and turned downwards and properly bushed on the open end.

### 6.8 Wiring of Distribution Boards

**6.8.1** All connections between pieces of apparatus or between apparatus and terminals on a board shall be neatly arranged in a definite sequence, following the arrangements of the apparatus mounted thereon, avoiding unnecessary crossings.

**6.8.2** Cables shall be connected to a terminal only by soldered or welded or crimped lugs using suitable sleeve, lugs or ferrules unless the terminal is of such a form that it is possible to securely clamp them without the cutting away of cables stands. Cables in each circuit shall be bunched together.

**6.8.3** All bare conductors shall be rigidly fixed in such a manner that a clearance of at least 25 mm is maintained between conductors or opposite polarity or phase and between the conductors and any material other than insulation material.

**6.8.4** If required, a pilot lamp shall be fixed and connected through an independent single pole switch and fuse to the bus-bars of the board.

**6.8.5** In a hinged type board, the incoming and outgoing cables shall be fixed at one or more points according to the number of cables on the back of the board leaving suitable space in between cables, and shall also, if possible, be fixed at the corresponding points on the switchboard panel. The cables between these points shall be of such length as to allow the switchboard panel to swing through on angle of not less than 90°. The circuit breakers in such cases shall be accessible without opening the door of distribution board. Also, circuit breakers or any other equipment (having cable size more than 1.5 sq. mm multistrand wire) shall not be mounted on the door.

NOTE — Use of hinged type boards is discouraged, as these boards lead to deterioration of the cables in the hinged portion, leading to failures or even fire.

**6.8.6** Wires terminating and originating from the protective devices shall be properly lugged and taped.

### 6.9 PVC-Sheathed Wiring System

**6.9.1** *General*

Wiring with Tough Rubber-Sheathed (TRS) cables had been the common system for low voltage installations. Now TRS wiring is phased out as better and durable insulating materials are available.

Wiring with PVC-sheathed cables is suitable for medium voltage installation and may be installed directly under exposed conditions of sun and rain or damp places.

**6.9.2** *PVC Clamps/PVC Channel*

Link clips had been the common system for wiring on wooden batten, which is now phased out. PVC clamps/ PVC channel shall conform accepted standards. The clamps shall be used for temporary installations of 1-3 sheathed wires only. The clamps shall be fixed on wall at intervals of 100 mm in the case of horizontal runs and 150 mm in the case of vertical runs.

PVC channel shall be used for temporary installations in case more than 3 wires or wires or unsheathed wires. The channel shall be clamped on wall at intervals not exceeding 300 mm.

**6.9.3** *Protection of PVC-Sheathed Wiring from Mechanical Damage*

a) In cases where there are chances of any damage to the wirings, such wirings shall be covered with sheet metal protective covering, the base of which is made flush with the plaster or brickwork, as the case may be, or the wiring shall be drawn through a conduit complying with all requirements of conduit wiring system (*see* **6.10**).
b) Such protective coverings shall in all cases be fitted on all down-drops within 1.5 m from the floor.

**6.9.4** *Bends in Wiring*

The wiring shall not in any circumstances be bent so as to form a right angle but shall be rounded off at the corners to a radius not less than six times the overall diameter of the cable.

**6.9.5** *Passing Through Floors*

All cables taken through floors shall be enclosed in an insulated heavy gauge steel conduit extending 1.5 m above the floor and flush with the ceiling below, or by means of any other approved type of metallic covering. The ends of all conduits or pipes shall be neatly bushed with porcelain, wood or other approved material.

**6.9.6** *Passing Through Walls*

The method to be adopted shall be according to good practice. There shall be one or more conduits of adequate size to carry the conductors [*see* **6.10.1**(a)]. The conduits shall be neatly arranged so that the cables enter them straight without bending.

**6.9.7** *Stripping of Outer Covering*

While cutting and stripping of the outer covering of the cables, care shall be taken that the sharp edge of the cutting instrument does not touch the rubber or PVC-sheathed insulation of conductors. The protective outer covering of the cables shall be stripped off near connecting terminals, and this protective covering shall be maintained up to the close proximity of connecting terminals as far as practicable. Care shall be taken to avoid hammering on link clips with any metal instruments, after the cables are laid. Where junction boxes are provided, they shall be made moisture-proof with an approved plastic compound.

**6.9.8** *Painting*

If so required, the tough rubber-sheathed wiring shall, after erection, be painted with one coat of oil-less paint or distemper of suitable colour over a coat of oil-less primer, and the PVC-sheathed wiring shall be painted with a synthetic enamel paint of quick drying type.

## 6.10 Conduit Wiring System

**6.10.1** *Surface Conduit Wiring System with Rigid Steel Conduits*

a) *Type and size of conduit* — All conduit pipes shall conform to accepted standards [8-2(19)], finished with galvanized or stove enamelled surface. All conduit accessories shall be of threaded type and under no circumstance pin grip type or clamp type accessories be used. No steel conduit less than 16 mm in diameter shall be used. The number of insulated conductors that can be drawn into rigid conduit are given in Tables 1 and 2.
b) *Bunching of cables* — Unless otherwise specified, insulated conductors of ac supply and dc supply shall be bunched in separate conduits. For lighting and small power outlet circuits phase egregation in separate conduits is recommended.
c) *Conduit joints* — Conduit pipes shall be joined by means of screwed couplers and screwed accessories only [*see* 8-2(19)]. In long distance straight runs of conduit, inspection type couplers at reasonable intervals shall be provided or running threads with couplers and jam-nuts (in the latter case the bare threaded portion shall be treated with anti-corrosive preservative) shall be provided. Threaded on conduit pipes in all cases shall be between 11 mm to 27 mm long sufficient to accommodate pipes to full threaded portion of couplers or accessories. Cut ends of conduit pipes shall have no sharp edges nor any burrs left to avoid damage to the insulation of conductors while pulling them through such pipes.
d) *Protection against dampness* — In order to minimize condensation or sweating inside the tube, all outlets of conduit system shall be properly drained and ventilated, but in such a manner as to prevent the entry of insects as far as possible.
e) *Protection of conduit against rust* — The outer surface of the conduit pipes, including all bends, unions, tees, conduit system shall be adequately protected against rust particularly when such system is exposed to weather. In all cases, no bare threaded portion of conduit pipe shall be allowed unless such bare threaded portion is treated with anti-corrosive

## Table 1 Maximum Permissible Number of Single-Core Cables up to and Including 1 100 V that can be Drawn into Rigid Steel and Rigid Non-Metallic Conduits

(*Clauses* 6.10.1 *and* 6.10.3.2)

| Size of Cable | | Size of Conduit (mm) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nominal Cross Sectional Area $mm^2$ | Number and Dia meter (in mm) of Wires | 16 | | 20 | | 25 | | 32 | | 40 | | 50 | | 60 | |
| | | (Number of Cables, *Max*) | | | | | | | | | | | | | |
| | | S | B | S | B | S | B | S | B | S | B | S | B | S | B |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) | (14) | (15) | (16) |
| 1.0 | 1/1.12[1)] | 5 | 4 | 7 | 5 | 13 | 10 | 20 | 14 | — | — | — | — | — | — |
| 1.5 | 1/1.40 | 4 | 3 | 7 | 5 | 12 | 10 | 20 | 14 | — | — | — | — | — | — |
| 2.5 | 1/1.80<br>3/1.06[1)] | 3 | 2 | 0 | 5 | 10 | 8 | 18 | 12 | — | — | — | — | — | — |
| 4 | 1/2.24<br>7/0.85[1)] | 3 | 2 | 4 | 3 | 7 | 8 | 12 | 10 | — | — | — | — | — | — |
| 6 | 1/2.80<br>7/1.06[1] | 2 | — | 3 | 2 | 6 | 5 | 10 | 8 | — | — | — | — | — | — |
| 10 | 7/1.40[1)] | — | — | 2 | — | 4 | 3 | 6 | 5 | 8 | 6 | — | — | — | — |
| 16 | 7/1.70 | — | — | — | — | 2 | — | 4 | 3 | 7 | 6 | — | — | — | — |
| 25 | 7/2.24 | — | — | — | — | — | — | 3 | 2 | 5 | 4 | 8 | 6 | 9 | 7 |
| 35 | 7/2.50 | — | — | — | — | — | — | 2 | — | 4 | 3 | 7 | 5 | 8 | 6 |
| 50 | 19/1.80 | | | | | | | | | | | | | | |

NOTES

**1** The table shows the maximum capacity of conduits for the simultaneously drawing of cables. The columns headed S apply to runs of conduit which have distance not exceeding 4.25 m between draw-in boxes, and which do not deflect from the straight by an angle of more than 15°. The columns headed B apply to runs of conduit which deflect from the straight by an angle of more than 15°.

**2** In case an inspection type draw-in box has been provided and if the cable if first drawn through one straight conduit, then through the draw-in box, and then through the second straight conduit, such systems may be considered as that of a straight conduit even if the conduit deflects through the straight by more than 15°.

1) For copper conductors only.

## Table 2 Maximum Permissible Number of Single-Core Cables that can be Drawn into Cable Tunelling and Ducting System (Casing and Capping)

(*Clauses* 6.10.1 *and* 6.10.3.2)

| Nominal Cross-Sectional Area of Conductor in $mm^2$ | 10/15 mm × 10 mm | 20 mm × 10 mm | 25 mm × 10 mm | 30 mm × 10 mm | 40 mm × 20 mm | 50 mm × 20 mm |
|---|---|---|---|---|---|---|
| (1) | (2) | (3) | (4) | (5) | (6) | (7) |
| 1.5 | 3 | 5 | 6 | 8 | 12 | 18 |
| 2.5 | 2 | 4 | 5 | 6 | 9 | 15 |
| 4 | 2 | 3 | 4 | 5 | 8 | 12 |
| 6 | — | 2 | 3 | 4 | 6 | 9 |
| 10 | — | 1 | 2 | 3 | 5 | 8 |
| 16 | — | — | 1 | 2 | 4 | 6 |
| 25 | — | — | — | 1 | 3 | 5 |
| 35 | — | — | — | — | 2 | 4 |
| 50 | — | — | — | — | 1 | 3 |
| 70 | — | — | — | — | 1 | 2 |

preservative or covered with suitable plastic compound.

f) *Fixing of conduit* — Conduit pipes shall be fixed by heavy gauge saddles, secured to suitable wood plugs or other plugs with screws in an approved manner at an interval of not more than 1 m, but on either side of couplers or bends or similar fittings, saddles shall be fixed at a distance of 300 cm from the centre of such fittings.

g) *Bends in conduit* — All necessary bends in the system including diversion shall be done by bending pipes; or by inserting suitable solid or inspection type normal bends, elbows or similar fittings; or fixing cast iron, *thermoplastic* or *thermosetting plastic material* inspection boxes whichever is more suitable. Conduit fittings shall be avoided as far as possible on conduit system exposed to weather; where necessary, solid type fittings shall be used. Radius of such bends in conduit pipes shall be not less than 7.5 cm. No length of conduit shall have more than the equivalent of four quarter bends from outlet to outlet, the bends at the outlets not being counted.

h) *Outlets* — All outlets for fittings, switches, etc, shall be boxes of suitable metal or any other approved outlet boxes for either surface mounting system.

j) *Conductors* — All conductors used in conduit wiring shall preferably be stranded. No single-core cable of nominal cross-sectional area greater than 130 mm$^2$ enclosed along in a conduit and used for alternating current.

k) *Erection and earthing of conduit* — The conduit of each circuit or section shall be completed before conductors are drawn in. The entire system of conduit after erection shall be tested for mechanical and electrical continuity throughout and permanently connected to earth conforming to the requirements as already specified by means of suitable earthing clamp efficiently fastened to conduit pipe in a workman like manner for a perfect continuity between each wire and conduit. Gas or water pipes shall not be used as earth medium. If conduit pipes are liable to mechanical damage they shall be adequately protected.

m) Inspection type conduit fittings, such as inspection boxes, draw boxes, bends, elbows and tees shall be so installed that they can remain accessible for such purposes as to withdrawal of existing cables or the installing of traditional cables.

**6.10.2** *Recessed Conduit Wiring System with Rigid Steel Conduit*

Recessed conduit wiring system shall comply with all the requirements for surface conduit wiring system specified in **6.10.1** (a) to (k) and in addition, conform to the requirements specified below:

a) *Making of chase* — The chase in the wall shall be nearly made and be of ample dimensions to permit the conduit to be fixed in the manner desired. In the case of buildings under construction, chases shall be provided in the wall, ceiling, etc, at the time of their construction and shall be filled up neatly after erection of conduit and brought to the original finish of the wall. In case of exposed brick/rubble masonry work, special care shall be taken to fix the conduit and accessories in position along with the building work.

b) *Fixing of conduit in chase* — The conduit pipe shall be fixed by means of staples or by means of saddles not more than 600 mm apart. Fixing of standard bends or elbows shall be avoided as far as practicable and all curves maintained by bending the conduit pipe itself with a long radius which will permit easy drawing-in of conductors. All threaded joints of rigid steel conduit shall be treated with preservative compound to secure protection against rust.

c) *Inspection boxes* — Suitable inspection boxes shall be provided to permit periodical inspection and to facilitate removal of wires, if necessary. These shall be mounted flush with the wall. Suitable ventilating holes shall be provided in the inspection box covers. The minimum sizes of inspection boxes shall be 75 mm × 75 mm.

d) *Types of accessories to be used* — All outlet, such as switches and wall sockets, may be either of flush mounting type or of surface mounting type.

   1) *Flush mounting type* — All flush mounting outlets shall be of cast-iron or mild steel boxes with a cover of insulating material or shall be a box made of a suitable insulating material. The switches and other outlets shall be mounted on such boxes. The metal box shall be efficiently earthed with conduit by a suitable means of earth attachment.

   2) The switches/socket outlets shall be adequately rated IP for various utilizations.

   3) *Surface mounting type* — If surface mounting type otulet box is specified, it shall be of any suitable insulating material and outlets mounted in an approved manner.

**6.10.3** *Conduit Wiring System with Rigid Non-Metallic Conduits*

Rigid non-metallic conduits are used for surface, recessed and concealed conduit wiring. Cable trunking and ducting system of insulating material are used for surface wiring.

**6.10.3.1** *Type and size*

All non-metallic conduits used shall conform to accepted standards [8-2(19)]. The conduit may be either threaded type or plain type in accordance with accepted standards [8-2(19)] and shall be used with the corresponding accessories {*see* accepted standards [8-2(19)]}. The conduits shall be circular or rectangular cross-sections.

**6.10.3.2** *Bunching of cables*

Conductors of ac supply and dc supply shall be bunched in separate conduits. For lighting and small power outlet circuits phase segregation in separate circuits is recommended. The number of insulated cables that may be drawn into the conduits are given in Table 1 and Table 2. In these tables the space factor does not exceed 40 percent.

**6.10.3.3** *Conduit joints*

Conduits shall be joined by means of screwed or plain couplers depending on whether the conduits are screwed or plain. Where there are long runs of straight conduit, inspection type couplers shall be provided at intervals. For conduit fittings and accessories reference may be made to the good practice [8-2(19)].

**6.10.3.4** *Fixing of conduits*

The provisions of **6.10.1**(f) shall apply except that the spacing between saddles or supports is recommended to be 600 cm for rigid non-metallic conduits.

**6.10.3.5** *Bends in conduits*

Wherever necessary, bends or diversions may be achieved by bending the conduits (*see* **6.10.3.8**) or by employing normal bends, inspection bends, inspection boxes, elbows or similar fittings.

**6.10.3.6** Conduit fittings shall be avoided, as far as possible, on outdoor systems.

**6.10.3.7** *Outlets*

In order to minimize condensation or sweating inside the conduit, all outlets of conduit system shall be properly drained and ventilated, but in such a manner as to prevent the entry of insects.

**6.10.3.8** Heat may be used to soften the conduit for bending and forming joints in case of plain conduits. As the material softens when heated, sitting of conduit in close proximity to hot surfaces should be avoided. Caution should be exercised in the use of this conduit in locations where the ambient temperature is 50°C or above. Use of such conduits in places where ambient temperature is 60°C or above is prohibited.

**6.10.3.9** Non-metallic conduit systems shall be used only where it is ensured that they are:

a) suitable for the extremes of ambient temperature to which they are likely to be subjected in service,
b) resistant to moisture and chemical atmospheres, and
c) resistant to low temperature and sunlight effects.

For use underground, the material shall be resistant to moisture and corrosive agents.

NOTE — Rigid PVC conduits are not suitable for use where the normal working temperature of the conduits and fittings may exceed 55°C. Certain types of rigid PVC conduits and their associated fittings are unsuitable for use where the ambient temperature is likely to fall below –5°C.

**6.10.4** *Non-Metallic Recessed Conduit Wiring System*

**6.10.4.1** Recessed non-metallic conduit wiring system shall comply with all the requirements of surface non-metallic conduit wiring system specified in **6.10.3.1** to **6.10.3.9** except **6.10.3.4**. In addition, the following requirements **6.10.4.2** to **6.10.4.5** also shall be complied with.

**6.10.4.2** *Fixing of conduit in chase*

The conduit pipe shall be fixed by means of stapples or by means of non-metallic saddles placed at not more than 80 cm apart or by any other approved means of fixing. Fixing of standard bends or elbows shall be avoided as far as practicable and all curves shall be maintained by sending the conduit pipe itself with a long radius which will permit easy drawing in of conductors. At either side of bends, saddles/stapples shall be fixed at a distance of 15 cm from the centre of bends.

**6.10.4.3** *Inspection boxes*

Suitable inspection boxes to the nearest minimum requirements shall be provided to permit periodical inspection and to facilitate replacement of wires, if necessary. The inspection/junction boxes shall be mounted flush with the wall or ceiling concrete. Where necessary deeper boxes of suitable dimensions shall be used. Suitable ventilating holes shall be provided in the inspection box covers, where required.

**6.10.4.4** The outlet boxes such as switch boxes, regulator boxes and their phenolic laminated sheet covers shall be as per requirements of **6.10.1**(h).

They shall be mounted flush with the wall.

**6.10.4.5** *Types of accessories to be used*

All outlets such as switches, wall sockets, etc, may be either flush mounting type or of surface mounting type.

## 7 FITTINGS AND ACCESSORIES

### 7.1 Ceiling Roses and Similar Attachments

**7.1.1** A ceiling rose or any other similar attachment shall not be used on a circuit the voltage of which normally exceeds 250 V.

**7.1.2** Normally, only one flexible cord shall be attached to a ceiling rose. Specially designed ceiling roses shall be used for multiple pendants.

**7.1.3** A ceiling rose shall not embody fuse terminal as an integral part of it.

### 7.2 Socket-Outlets and Plugs

Each 16 A socket-outlet provided in buildings for the use of domestic appliances such as air conditioner, water cooler, etc, shall be provided with its own individual fuse, with suitable discrimination with back-up fuse or miniature circuit-breaker provided in the distribution/sub-distribution board. The socket-outlet shall not necessarily embody the fuse as an integral part of it.

**7.2.1** Each socket-outlet shall also be controlled by a switch which shall preferably be located immediately adjacent thereto or combined therewith.

**7.2.2** The switch controlling the socket-outlet shall be on the live side of the line.

**7.2.3** Ordinary socket-outlet may be fixed at any convenient place at a height above 20 cm from the floor level and shall be away from danger of mechanical injury.

NOTE — In situations where a socket-outlet is accessible to children, it is necessary to install an interlocked plug and socket or alternatively a socket-outlet which automatically gets screened by the withdrawal of plug. In industrial premises socket-outlet of rating 20 A and above shall preferably be provided with interlocked type switch.

**7.2.4** In an earthed system of supply, a socket-outlet with plug shall be of three-pin type with the third terminal connected to the earth. When such socket-outlets with plugs are connected to any current consuming device of metal or any non-insulating material or both, conductors connecting such current-consuming devices shall be of flexible cord with an earthing core and the earthing core shall be secured by connecting between the earth terminal of plug and the body of current-consuming devices.

In industrial premises three-phase and neutral socket-outlets shall be provided with a earth terminal either of pin type or scrapping type in addition to the main pins required for the purpose.

**7.2.5** In wiring installations, metal clad switch, socket-outlet and plugs shall be used for power wiring.

NOTE — A recommended schedule of socket-outlets in a residential building is given below:

| *Location* | *Number of 5A Socket-Outlets* | *Number of 15A Socket-Outlets* |
|---|---|---|
| Bed room | 2 to 3 | 1 |
| Living room | 2 to 3 | 2 |
| Kitchen | 1 | 2 |
| Dining room | 2 | 1 |
| Garage | 1 | 1 |
| For refrigerator | — | 1 |
| For air conditioner | — | (one for each) |
| *VERANDAH* | 1 per 10 $m^2$ | 1 |
| Bathroom | 1 | 1 |

### 7.3 Lighting Fittings

**7.3.1** A switch shall be provided for control of every lighting fitting or a group of lighting fittings. Where control at more than one point is necessary as many two way or intermediate switches may be provided as there are control points.

**7.3.2** In industrial premises lighting fittings shall be supported by suitable pipe/conduits, brackets fabricated from structural steel, steel chains or similar materials depending upon the type and weight of the fittings. Where a lighting fitting is supported by one or more flexible cords, the maximum weight to which the twin flexible cords may be subjected shall be as follows:

| *Nominal Cross-Sectional Area of Twin Cord* $mm^2$ | *Maximum Permissible Weight* kg |
|---|---|
| 0.5 | 2 |
| 0.75 | 3 |
| 1.0 | 5 |
| 1.5 | 5.3 |
| 2.5 | 8.8 |
| 4 | 14.0 |

**7.3.3** No flammable shade shall form a part of lighting fittings unless such shade is well protected against all risks of fire. Celluloid shade or lighting fittings shall not be used under any circumstances.

**7.3.4** General and safety requirements for electrical lighting fittings shall be in accordance with good practice [8-2(20)].

**7.3.5** The lighting fittings shall conform to accepted standards [8-2(10)].

### 7.4 Fitting-Wire

The use of fittings-wire shall be restricted to the internal wiring of the lighting fittings. Where fittings-wire is used for wiring fittings, the sub-circuit loads shall terminate in a ceiling rose or box with connectors from which they shall be carried into the fittings.

**7.5 Lampholders**

Lampholders for use on brackets and the like shall be in accordance with accepted standards [8-2(21)] and all those for use with flexible pendants shall be provided with cord grips. All lampholders shall be provided with shade carriers. Where centre-contact Edison screw lampholders are used, the outer or screw contacts shall be connected to the 'middle wire', the neutral, the earthed conductor of the circuit.

**7.6 Outdoor Lamps**

External and road lamps shall have weatherproof fittings of approved design so as to effectively prevent the ingress of moisture and dust. Flexible cord and cord grip lampholders shall not be used where exposed to weather. In *VERANDAHS* and similar exposed situations where pendants are used, these shall be of fixed rod type.

**7.7 Lamps**

All lamps unless otherwise required and suitably protected, shall be hung at a height of not less than 2.5 m above the floor level. All electric lamps and accessories shall conform to accepted standards [8-2(22)].

a) Portable lamps shall be wired with flexible cord. Hand lamps shall be equipped with a handle of moulded composition or other material approved for the purpose. Hand lamps shall be equipped with a substantial guard attached to the lampholder or handle. Metallic guards shall be earthed suitably.

b) A bushing or the equivalent shall be provided where flexible cord enters the base or stem of portable lamp. The bushing shall be of insulating material unless a jacketted type of cord is used.

c) All wiring shall be free from short-circuits and shall be tested for these defects prior to being connected to the circuit.

d) Exposed live parts within porcelain fixtures shall be suitably recessed and so located as to make it improbable that wires will come in contact with them. There shall be a spacing of at least 125 mm between live parts and the mounting plane of the fixture.

**7.8 Fans, Regulators and Clamps**

**7.8.1** *Ceiling Fans*

Ceiling fans including their suspension shall conform to accepted standards [8-2(23)] and to the following requirements:

a) Control of a ceiling fan shall be through its own regulator as well as a switch in series.

b) All ceiling fans shall be wired with normal wiring to ceiling roses or to special connector boxes to which fan rod wires shall be connected and suspended from hooks or shackels with insulators between hooks and suspension rods. There shall be no joint in the suspension rod, but if joints are unavoidable then such joints shall be screwed to special couplers of 5 cm minimum length and both ends of the pipes shall touch together within the couplers, and shall in addition be secured by means of split pins; alternatively, the two pipes may be welded. The suspension rod shall be of adequate strength to withstand the dead and impact forces imposed on it. Suspension rods should preferably be procured along with the fan.

c) Fan clamps shall be of suitable design according to the nature of construction of ceiling on which these clamps are to be fitted. In all cases fan clamps shall be fabricated from new metal of suitable sizes and they shall be as close fitting as possible. Fan clamps for reinforced concrete roofs shall be buried with the casting and due care shall be taken that they shall serve the purpose. Fan clamps for wooden beams, shall be of suitable flat iron fixed on two sides of the beam and according to the size and section of the beam one or two mild steel bolts passing through the beam shall hold both flat irons together. Fan clamps for steel joist shall be fabricated from flat iron to fit rigidly to the bottom flange of the beam. Care shall be taken during fabrication that the metal does not crack while hammer to shape. Other fan clamps shall be made to suit the position, but in all cases care shall be taken to see that they are rigid and safe.

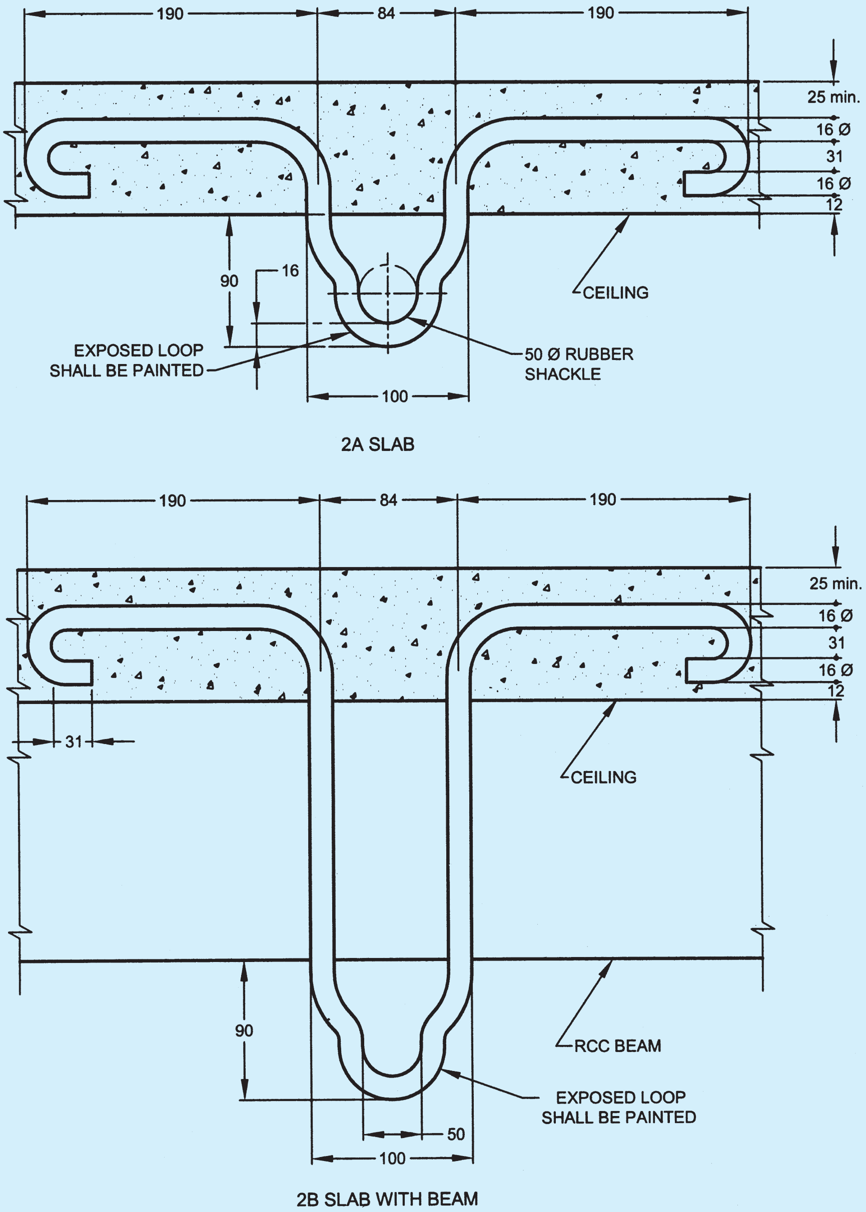
d) Canopies on top and bottom of suspension rods shall effectively conceal suspensions and connections to fan motors, respectively.

e) The lead-in-wire shall be of nominal cross-sectional area not less than 1.5 mm$^2$ copper and shall be protected from abrasion.

f) Unless otherwise specified, the clearance between the bottom most point of the ceiling fan and the floor shall be not less than 2.4 m. The minimum clearance between the ceiling and the plane of the blades shall be not less than 300 mm.

A Typical arrangement of a fan clamp is given in Fig. 2.

NOTE — All fan clamps shall be so fabricated that fans revolve steadily.




All dimensions in millimetres.

NOTES

**1** RCC slab steel reinforcement not shown.

**2** Fan clamp shall be placed in position such that its projecting arms in the line of length of beam.

FIG. 2 TYPICAL DESIGN OF FAN CLAMPS

**7.8.2** *Exhaust Fans*

For fixing of an exhaust fan, a circular hole shall be provided in the wall to suit the size of the frame which shall be fixed by means of rag-bolts embedded in the wall. The hole shall be neartly plastered with cement and brought to the original finish of the wall. The exhaust fan shall be connected to exhaust fan point which shall be wired as near to the hole as possible by means of a flexible cord, care being taken that the blades rotate in the proper direction.

## 7.9 Attachment of Fittings and Accessories

**7.9.1** In wiring other than conduit wiring, all ceiling roses, brackets, pendants and accessories attached to walls or ceilings shall be mounted on substantial teak wood blocks twice varnished after all fixing holes are made in them. Blocks shall not be less than 4 cm deep. Brass screws shall only be used for attaching fittings and accessories to their base blocks.

**7.9.2** Where teak or hardwood boards are used for mounting switches, regulators, etc, these boards shall be well varnished with pure shellac on all four sides (both inside and outside), irrespective of being painted to match the surroundings. The size of such boards shall depend on the number of accessories that could conveniently and neatly be arranged. Where there is danger of attack by white ants, the boards shall be treated with suitable anti-termite compound and painted on both sides.

**7.10 Interchangeability**

Similar part of all switches, lampholders, distribution fuse-boards, ceiling roses, brackets, pendants, fans and all other fittings shall be so chosen that they are of the same type and interchangeable in each installation.

**7.11 Equipment**

Electrical equipment which form integral part of wiring intended for switching or control or protection of wiring installations shall conform to the relevant Indian Standards wherever they exist.

**7.12 Fannage**

**7.12.1** Where ceiling fans are provided, the bay sizes of a building, which control fan point locations, play an important part.

**7.12.2** Fans normally cover an area of 9 $m^2$ to 10 $m^2$ and therefore in general purpose office buildings, for every part of a bay to be served by the ceiling fans, it is necessary that the bays shall be so designed that full number of fans could be suitably located for the bay, otherwise it will result in ill-ventilated pockets. In general, fans in long halls may be spaced at 3 m in both the directions. If building modules do not lend themselves for proper positioning of the required number of ceiling fans, such as air circulators or bracket fans would have to be employed for the areas uncovered by the ceiling fans. For this, suitable electrical outlets shall be provided although result will be disproportionate to cost on account of fans.

**7.12.3** Proper air circulation could be achieved either by larger number of smaller fans or smaller number of larger fans. The economics of the system as a whole should be a guiding factor in choosing the number and type of fans and their locations.

**7.12.4** Exhaust fans are necessary for spaces, such as community toilets, kitchens and canteens, and godowns to provide the required number of air changes (*see* Part 8 'Building Services, Section 1 Lighting and Ventilation'). Since the exhaust fans are located generally on the outer walls of a room appropriate openings in such walls shall be provided for in the planning stage.

NOTE — Exhaust fan requirement is based on the recommended air changes. Reference may also be made to Part 4 'Fire and Life Safety'. Exhaust fan requirement comes for catering to smoke extraction also. Basement areas depend on the system of fresh air fans and exhaust fans.

**7.12.5** Positioning of fans and light fittings shall be chosen to make these effective without causing shadows and stroboscopic effect on the working planes.

## 8 EARTHING

**8.1 General**

Earthing shall generally be carried out in accordance with the requirements of *Indian Electricity Rules*, 1956 as amended time to time and the relevant regulations of the Electricity Supply Authority concerned.

The main earthing system of an electrical installation must consist of:

a) An earth electrode;
b) A main earthing wire;
c) An earth bar (located on the main switchboard) for the connection of the main earthing wire, protective earthing wires and/or bonding wires within the installation; and
d) A removable link, which effectively disconnects the neutral bar from the earth bar.

NOTE — The requirements of (c) and (d) above must be carried out by the licensed electrician as part of the switchboard installation.

The main earthing wire termination must be readily accessible at the earth electrode.

The main earthing wire connection must:

a) be mechanically and electrically sound;
b) be protected against damage, corrosion, and vibration;
c) not place any strain on the various parts of the connection;
d) not damage the wire or fittings; and
e) be secured at the earth electrode

Use a permanent fitting (like a screwed-down plastic label or copper label, or one that can be threaded onto the cable) at the connection point that is clearly marked with the words: "EARTHING LEAD — DO NOT DISCONNECT" or "EARTHING CONDUCTOR — DO NOT DISCONNECT".

**8.1.1** All medium voltage equipment shall be earthed by two separate and distinct connections with earth. The contact area of earth conductor/plate shall be determined using guidelines specified in IS 3043.

Medium voltage systems of 400/230 V, 4-wire, 3-phase, systems are normally operated with the neutral solidly earthed at source. At medium voltage, Indian Electricity Regulations require that the neutral be earthed by two separate and distinct connections with earth. Source in the case of a substation (such as 11kV/ 400 V) would be the neutral(s) of the transformer(s). Neutral conductor of half the size of the phase conductor was permitted in earlier installations. But with the proliferation of equipment using non-linear devices and consequent increase in harmonics, the neutral will carry a current more than the notional out-of-balance current and as such neutral conductor shall be of the same size as the phase conductor.

In the case of high and extra high voltages, the neutral points shall be earthed by not less than two separate and distinct connections with earth, each having its own electrode at the generating station or substation and may be earthed at any other point provided no interference is caused by such earthing. The neutral may be earthed through suitable impedance. Neutral earthing conductor shall be sized at to have a current carrying capacity not less than the phase current.

**8.1.2** As far as possible, all earth connections shall be visible for inspection.

**8.1.3** Earth earth system shall be so devised that the testing of individual earth electrode is possible. It is recommended that the value of any earth system resistance shall be such as to conform with the degree of shock protection desired.

**8.1.4** It is recommended that a drawing showing the main earth connection and earth electrodes be prepared for each installation.

**8.1.5** No addition to the current-carrying system, either temporary or permanent, shall be made which will increase the maximum available earth fault current or its duration until it has been ascertained that the existing arrangement of earth electrodes, earth busbar, etc, are capable of carrying the new value of earth fault current which may be obtained by this addition.

**8.1.6** No cut-out, link or switch other than a linked switch arranged to operate simultaneously on the earthed or earthed neutral conductor and the live conductors, shall be inserted on any supply system. This, however, does not include the case of a switch for use in controlling a generator or a transformer or a link for test purposes.

**8.1.7** All materials, fittings, etc, used in earthing shall conform to Indian Standard specifications, wherever these exist.

**8.1.8** Earthing associated with current-carrying conductor is normally essential for the security of the system and is generally known as system earthing, while earthing of non-current carrying metal work and conductor is essential for the safety of human life, of animals and of property and it is generally known as equipment earthing.

### 8.2 Earth Electrodes

Earth electrode either in the form of pipe electrode or plate electrode should be provided at all premises for providing an earth system. Details of typical pipe and plate earth electrodes are given in Fig. 3 and Fig. 4.

Although electrode material does not affect initial earth resistance, care should be taken to select a material which is resistant to corrosion in the type of soil in which it is used. Under ordinary conditions of soil, use of copper, iron or mild steel electrodes is recommended. In case where soil condition leads to excessive corrosion of the electrode, and the connections, it is recommended to use either copper electrode or copper clad electrode or zinc coastal galvanized iron electrode. The electrode shall be kept free from paint, enamel and grease. It is recommended to use similar material for earth electrodes and earth conductors or otherwise precautions should be taken to avoid corrosion.

**8.3** As far as possible, all earth connections shall be visible for inspection and shall be carefully made; if they are poorly made or inadequate for the purpose for which they are intended, loss of life and property or serious personal injury may result.

To obtain low overall resistance the current density should be as low as possible in the medium adjacent to the electrodes; which should be so designed as to cause the current density to decrease rapidly with distance from the electrode. This requirement is met by making the dimensions in one direction large compared with those in the other two, thus a pipe, rod or strip has a much lower resistance than a plate of equal surface area. The resistance is not, however, inversely proportional to the surface area of the electrode.

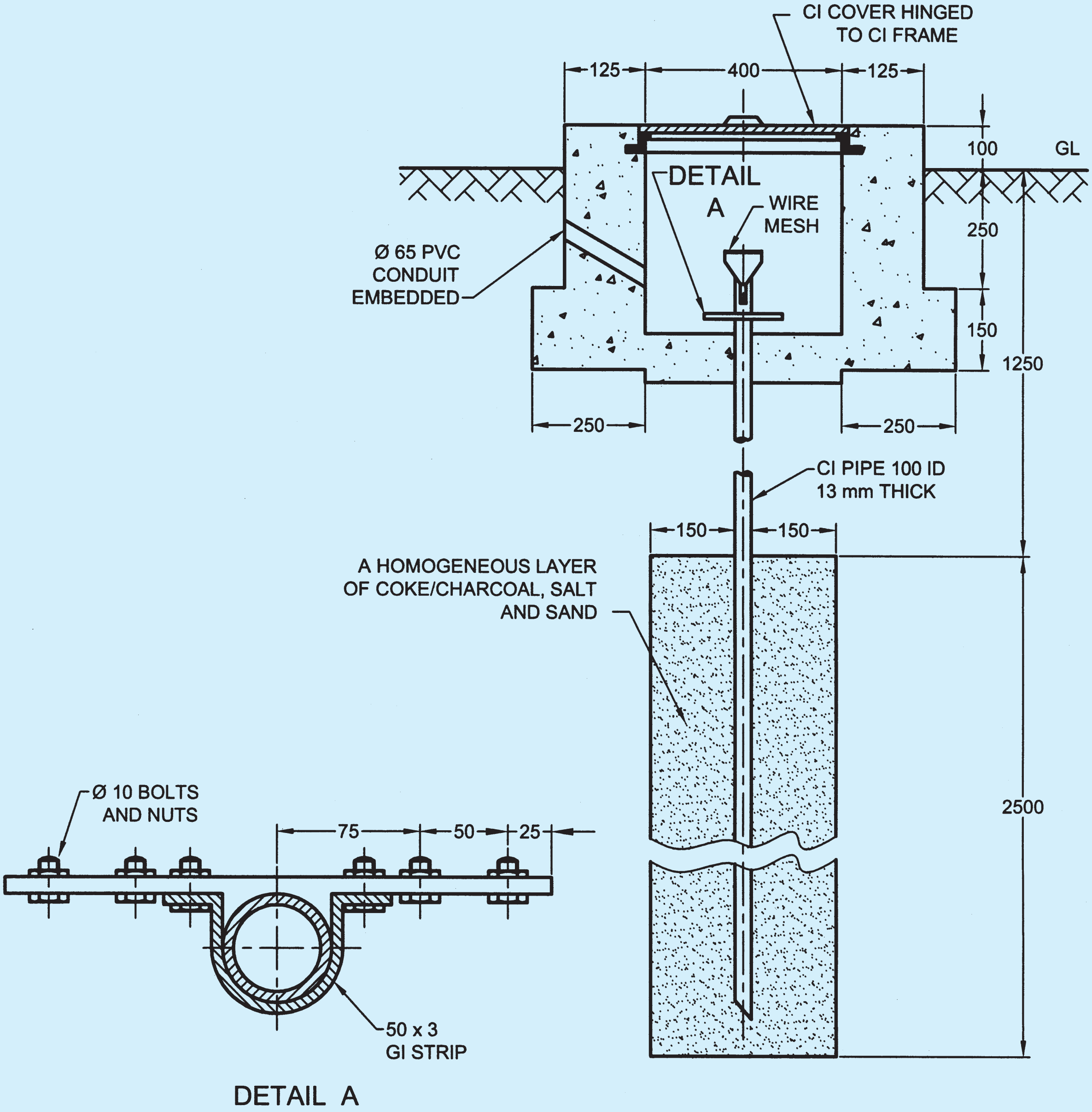
### 8.4 Equipment and Portions of Installations which shall be Earthed

**8.4.1** *Equipment to be Earthed*

Except for equipment provided with double insulation, all the non-current carrying metal parts of electrical installations are to be earthed properly. All metal conduits, trunking, cable sheaths, switchgear, distribution fuseboards, lighting fittings and all other parts made of metal shall be bended together and connected by means of two separate and distinct conductors to an efficient earth electrode.

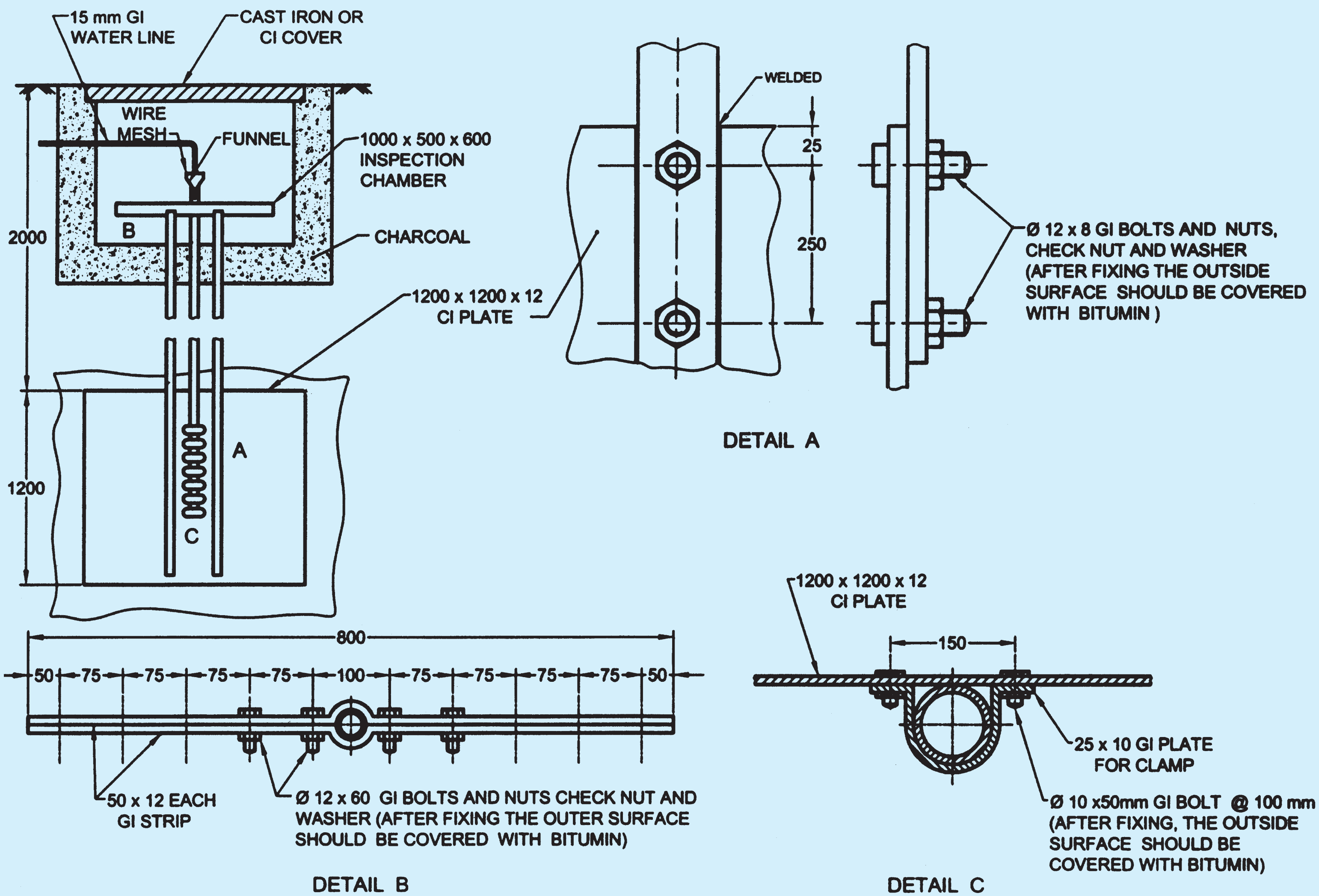
**8.4.2** *Structural Metal Work*

Earthing of the metallic parts shall not be effected through any structural metal work which houses the




All dimensions in millimetres.

FIG. 3 TYPICAL ARRANGEMENT OF PIPE EARTHING




All dimensions in millimetres.

FIG. 4 TYPICAL ARRANGEMENT OF PLATE EARTHING installation. Where metallic parts of the installation are not required to be earthed and are liable to become alive should the insulations of conductors become defective, such metallic parts shall be separated by durable non-conducting material from any structural work.

**8.5 Neutral Earthing**

To comply with Rule 32(1) of *Indian Electricity Rules* 1956, no fuses or circuit breakers other than a linked circuit breaker shall inserted in an earthed neutral conductor, a linked switch or linked circuit breaker shall be arranged to break or the neutral either with or after breaking all the related phase conductors and. shall positively make (or close) the neutral before making (or closing) the phases.

If this neutral point of the supply system is connected permanently to earth, then the above rule applies throughout the installation including 2-wire final circuits. This means that no fuses may be inserted in the neutral or common return wire. And the neutral should consist of a bolted solid link, or part of a linked switch, which completely disconnects the whole system from the supply. This linked switch must be arranged so that the neutral makes before, and break after the phases.

**8.6 System of Earthing**

Equipment and portions of installations shall be deemed to be earthed only if earthed in accordance with either the direct earthing system, the multiple earthed neutral system or the earth leakage circuit-breaker system. In all cases, the relevant provisions of Rules 33 and 61 of the *Indian Electricity Rules,* 1956 (*see* Annex B) shall be complied with.

The earthing of electrical installations for non-industrial and industrial buildings shall be done in accordance with good practice [8-2(24)].

**8.7 Classification of Earthing System**

The earthing systems are classified as follows:

a) *TN System* — A system which has one or more points of the source of energy directly earth, and the exposed and extraneous conductive parts of the installation are connected by means of protective conductors to the earth points of the source, that is, currents to flow from the installation to the earth points of the source.
b) *TT System* — A system which has one or more points of the source of energy directly earth, and the exposed and extraneous conductive parts of the installation are connected to a local earth electrodes or electrodes electrically independent of the source earth.
c) *IT System* — A system which has source either unearthed or earthed through a high impedance and the exposed conductive parts of the installations are connected to electrically independent earth electrodes.

## 9 INSPECTION AND TESTING OF INSTALLATION

**9.1 General Requirements**

**9.1.1** Before the completed installation, or an addition to the existing installation, is put into service, inspection and testing shall be carried out in accordance with the *Indian Electricity Rules,* 1956. In the event of defects being found, these shall be rectified, as soon as practicable and the installation retested.

**9.1.2** Periodic inspection and testing shall be carried out in order to maintain the installation in a sound condition after putting into service.

**9.1.3** Where an addition is to be made to the fixed wiring of an existing installation, the latter shall be examined for compliance with the recommendations of the Code.

**9.1.4** The individual equipment and materials which form part of the installation shall generally conform to the relevant Indian Standard Specification wherever applicable. If there is no relevant Indian Standard Specification for any item, these shall be approved by the appropriate authority.

**9.1.5** *Completion Drawings*

On completion of the electric work, a wiring diagram shall be prepared and submitted to the engineer-in-charge or the owner. All wiring diagrams shall indicate clearly, the main switch board, the runs of various mains and submains and the position of all points and their controls. All circuits shall be clearly indicated and numbered in the wiring diagram and all points shall be given the same number as the circuit in which they are electrically connected. Also the location and number of earth points and the run of each loads should be clearly shown in the completion drawings.

**9.2 Inspection of the Installation**

**9.2.1** *General*

On completion of wiring a general inspection shall be carried out by competent personnel in order to verify that the provisions of this Code and that of *Indian Electricity Rules,* 1956, have been complied with. This, among other things, shall include checking whether all equipments, fittings, accessories, wires/cables, used in the installation are of adequate rating and quality to meet the requirement of the load. General workmanship of the electrical wiring with regard to the layout and finish shall be examined for neatness that would facilitate easy identification of circuits of the system, adequacy of clearances, soundness, contact pressure and contact area. A complete check shall also be made of all the protective devices, with respect to their ratings, range of settings and co-ordination between the various protective devices.

**9.2.2** *Item to be Inspected*

**9.2.2.1** *Substation installations*

In substation installation, it shall be checked whether:

1) The installation has been carried out in accordance with the approved drawings;
2) Phase-to-phase and phase to earth clearances are provided as required;
3) All equipments are efficiently earthed and properly connected to the required number of earth electrodes;
4) The required ground clearance to live-terminals is provided;
5) Suitable fencing is provided with gate with lockable arrangements;
6) The required number of caution boards fire-fighting equipments, operating rods, rubber mats, etc, are kept in the substation;
7) In case of indoor substation sufficient ventilation and draining arrangements are made;
8) All cable trenches are provided with non-inflammable covers;
9) Free accessibility is provided for all equipments for normal operation;
10) All name plates are fixed and the equipments are fully painted;
11) All construction materials and temporary connections are removed;
12) Oil-level, busbar tightness, transformer tap position, etc, are in order;
13) Earth pipe troughs and cover slabs are provided for earth electrodes/earth pits and the neutral and LA earth pits are marked for easy identification;
14) Earth electrodes are of GI pipes or CI pipes or copper plates. For earth connections, brass bolts and nuts with lead washers are provided in the pipes/plates;
15) Earth pipe troughs and oil sumps/pits are free from rubbish and dirt and stone jelly and the earth connections are visible and easily accessible;
16) HT and LT panels are switchgears are all vermin and damp-proof and all unused openings or holes are blocked properly;
17) The earth bus bars have tight connections and corrosion-free joint surfaces;
18) Operating handle of protective device are provided at an accessible height from ground;
19) Adequate headroom is available in the transformer room for easy topping-up of oil, maintenance, etc;
20) Safety devices, horizontal and vertical barriers, bus bar covers/shrouds, automatic safety shutters/doors interlock, handle interlock are safe and in reliable operation in all panels and cubicles;
21) Clearances in the front, rear and sides of the main HV and MV and sub-switch boards are adequate;
22) The switches operate freely; the 3 blades make contact at the same time, the arcing horns contact in advance; and the handles are provided with locking arrangements;
23) Insulators are free from cracks, and are clean;
24) In transformers, there is any oil leak;
25) Connections to bushing in transformers for tightness and good contact;
26) Bushings are free from cracks and are clean;
27) Accessories of transformers like breathers, vent pipe, Buchholz relay, etc, are in order;
28) Connections to gas relay in transformers are in order;
29) Oil and winding temperature are set for specific requirements in transformers;
30) In case of cable cellars, adequate arrangements to pump out water that has entered due to seepage or other reasons;
31) All incoming and outgoing circuits of HV and MV panels are clearly and indelibly labelled for identifications;
32) No cable is damaged;
33) There is adequate clearance around the equipments installed; and
34) Cable terminations are proper.

**9.2.2.2** *Medium voltage installation*

In medium voltage installations, it shall be checked whether:

1) All blocking materials that are used for safe transportation in switchgears, contactors, relays, etc, are removed;
2) All connections to be earthing system are feasible for periodical inspection;
3) Sharp cable bends are avoided and cables are taken in a smooth manner in the trenches or alongside the walls and ceilings using suitable support clamps at regular intervals;

4) Suitable linked switch or circuit breaker or lockable push button is provided near the motors/apparatus for controlling supply to the motor/apparatus in an easily accessible location;
5) Two separate and distinct earth connections are provided for the motor/apparatus;
6) Control switch-fuse is provided at an accessible height from ground for controlling supply to overhead travelling crane, hoists, overhead bus bar trunking;
7) The metal rails on which the crane travels are electrically continuous and earthed and bonding of rails and earthing at both ends are done;
8) Four core cables are used for overhead travelling crane and portable equipments, the fourth core being used for earthing, and separate supply for lighting circuit is taken;
9) If flexible metallic hose is used for wiring to motors and other equipment, the wiring is enclosed to the full lengths, and the hose secured properly by approved means;
10) The cables are not taken through areas where they are likely to be damaged or chemically affected;
11) The screens and armours of the cables are earthed properly;
12) The belts of the belt driven equipments are properly guarded;
13) Adequate precautions are taken to ensure that no live parts are so exposed as to cause danger;
14) Ammeters and voltmeters are tested;
15) The relays are inspected visually by moving covers for deposits of dusts or other foreign matter;
16) Wherever bus ducts/rising mains/overhead bus trucking are used, special care should be taken for earthing the system. All tap off points shall be provided with adequately rated protective device like MCB, MCCB, fuses, ELCB, RCCB, etc;
17) All equipments shall be weather, dust and vermin proof; and
18) Any and all equipments having air insulation as media shall maintain proper distances between phases; phase to neutral; phase to earth and earth to neutral.

**9.2.2.3** *Overhead lines*

For overhead lines it shall be checked whether:

1) All conductors and apparatus including live parts thereof are inaccessible;
2) The types and size of supports are suitable for the overhead lines/conductors used and are in accordance with approved drawing and standards;
3) Clearances from ground level to the lowest conductor of overhead lines, sag conditions, etc, are in accordance with the relevant standard;
4) Where overhead lines cross the roads or cross each other or are in proximity with one another, suitable guarding is provided at road crossings and also to protect against possibility of the lines coming in contact with one another;
5) Every guard wire is properly earthed;
6) The type, size and suitability of the guarding arrangement provided is adequate;
7) Stays are provided suitably on the over-head lines as required and are efficiently earthed or provided with suitably stay insulators of suitable voltages;
8) Anti-climbing devices and Danger Board/ Caution Board Notices are provided on all HT supports;
9) Clearances along the route are checked and all obstructions such as trees/branches and shrubs are cleared on the route to the required distance on either side;
10) Clearance between the live conductor and the earthed metal parts are adequate;
11) For the service connections tapped-off from the overhead lines, cut-outs of adequate capacity are provided;
12) All insulators are properly and securely mounted; also they are not damaged.
13) All poles are properly grouted/insulated so as to avoid bending of pole towards tension; and
14) Steel poles, if used shall be properly earthed.

**9.2.2.4** *Lighting circuits*

The lighting circuits shall be checked whether:

1) Wooden boxes and panels are avoided in factories for mounting the lighting boards and switch controls, etc;
2) Neutral links are provided in double pole switch-fuses which are used for lighting control, and no protective devices (such as MCB, MCCB, fuses, ELCB, etc) is provided in the neutral;
3) The plug points in the lighting circuit are all of 3-pin type, the third pin being suitably earthed;

4) Tamper-proof interlocked switch socket and plug are used for locations easily accessible;
5) Lighting wiring in factory area is taken enclosed in conduit and conduit properly earthed, or alternatively, armoured cable wiring is used;
6) A separate earth wire is run in the lighting installation to provide earthing for plug points, fixtures and equipments;
7) Proper connectors and junction boxes are used wherever joints are to be made in conductors or cross over of conductors takes place;
8) Cartridge fuse units are fitted with cartridge fuses only;
9) Clear and permanent identification marks are painted in all distribution boards, switchboards, sub-main boards and switches as necessary;
10) The polarity having been checked and all protective devices (such as MCB, MCCB, fuses, ELCB, etc) and single pole switches are connected on the phase conductor only and wiring is correctly connected to socket-outlets;
11) Spare knockouts provided in distribution boards and switch fuses are blocked;
12) The ends of conduits enclosing the wiring leads are provided with ebonite or other suitable bushes;
13) The fittings and fixtures used for outdoor use are all of weather-proof construction, and similarly, fixtures, fittings and switchgears used in the hazardous area, are of flame-proof application;
14) Proper terminal connectors are used for termination of wires (conductors and earth leads) and all strands are inserted in the terminals;
15) Flat ended screws are used for fixing conductor to the accessories;
16) Use of flat washers backed up by spring washers for making end connections is desirable; and
17) All metallic parts of installation such as conduits, distribution boards, metal boxes, etc have been properly earthed.

**9.3 Testing of Installation**

**9.3.1** *General*

After inspection, the following tests shall be carried out, before an installation or an addition to the existing installation is put into service. Any testing of the electrical installation in an already existing installation shall commence after obtaining permit to work from the engineer-in-charge and after ensuring the safety provisions.

**9.3.2** *Testing*

**9.3.2.1** *Switchboards*

HV and MV switchboards shall be tested in the manner indicated below:

a) All high voltage switchboards shall be tested for dielectric test as per good practice [8-2(25)].
b) All earth connections shall be checked for continuity.
c) The operation of the protective devices shall be tested by means of secondary or primary injection tests.
d) The operation of the breakers shall be tested from all control stations.
e) Indication/signalling lamps shall be checked for proper working.
f) The operation of the breakers shall be tested for all interlocks.
g) The closing and opening timings of the breakers shall be tested wherever required for auto-transfer schemes.
h) Contact resistance of main and isolator contacts shall be measured.
j) The specific gravity and the voltage of the control battery shall be measured.

**9.3.2.2** *Transformers*

Transformers are tested in the manner indicated below:

a) All commissioning tests shall be in accordance with good practice [8-2(26)].
b) Insulation resistance on HV and MV windings shall be measured at the end of 1 min as also at the end of 10 min of measuring the polarization index. The absolute value of insulation resistance should not be the sole criterion for determining the state of dryness of the insulation. Polarization index values should form the basis for determining the state of dryness of insulation. For any class of insulation, the polarization index should be greater than 1.5.

**9.3.2.3** *Cables*

Cable installations shall be checked as below:

a) It shall be ensured that the cables conform to the relevant Indian Standards. Tests shall also be done in accordance with good practice [8-2(6)]. The insulation resistance before and after the tests shall be checked.

b) The insulation resistance between each conductor and against earth shall be measured. The insulation resistance varies with the type of insulation used and with the length of cable. The following empirical rule gives reasonable guidance:

Insulation resistance in megaohms

$$= \frac{10 \times \text{Voltage in kV}}{\text{Length in km}}$$

c) Physical examination of cables shall be carried out.

d) Cable terminations shall be checked.

e) Continuity test shall be performed before charging the cable with current.

**9.3.2.4** *Motors and other equipments*

The following test is made on motor and other equipment:

The insulation resistance of each phase winding against the frame and between the windings shall be measured. Megger of 500 V or 1 000 V rating shall be used. Star points should be disconnected. Minimum acceptable value of the insulation resistance varies with the rated power and the rated voltage of the motor.

The following relation may serve as a reasonable guide:

$$R = \frac{20 \times E_n}{1\,000 + 2P}$$

where

$R_i$ = Insulation resistance in megohms at 25°C.

$E_n$ = Rated phase to phase voltage.

$P$ = Rated power in kW.

If the resistance is measured at a temperature different from 25°C, the value shall be corrected to 25°C.

The insulation resistance as measured at ambient temperature does not always give a reliable value, since moisture might have been absorbed during shipment and storage. When the temperature of such a motor is raised, the insulation resistance will initially drop considerably, even below the acceptable minimum. If any suspicion exists on this score, motor winding must be dried out.

**9.3.2.5** *Wiring installation*

The following tests shall be done:

a) The insulation resistance shall be measured by applying between earth and the whole system of conductor or any section thereof with all fuses in place and all switches closed, and except in earthed concentric wiring, all lamps in position or both poles of installation otherwise electrically connected together, a dc voltage of not less than twice the working voltage, provided that it does not exceed 500 V for medium voltage circuits. Where the supply is derived from three-wire (ac or dc) or a poly-phase system, the neutral pole of which is connected to earth either direct or through added resistance the working voltage shall be deemed to be that which is maintained between the outer or phase conductor and the neutral.

b) The insulation resistance in megaohms of an installation measured as in (a) shall be not less than 50 divided by the number of points on the circuit, provided that the whole installation need not be required to have an insulation resistance greater than one megaohm.

c) Control rheostats, heating and power appliances and electric signs, may, if desired, be disconnected from the circuit during the test, but in that event the insulation resistance between the case of framework, and all live parts of each rheostat, appliance and sign shall be not less than that specified in the relevant Indian Standard specification or where there is no such specification, shall be not less than half a megaohm.

d) The insulation resistance shall also be measured between all conductors connected to one pole or phase conductor of the supply and all the conductors connected to the middle wire or to the neutral on to the other pole of phase conductors of the supply. Such a test shall be made after removing all metallic connections between the two poles of the installation and in these circumstances the insulation resistance between conductors of the installation shall be not less than that specified in (b).

**9.3.2.6** *Completion certificate*

On completion of an electrical installation (or an extension to an installation) a certificate shall be furnished by the contractor, counter-signed by the certified supervisor under whose direct supervision the installation was carried out. This certificate shall be in a prescribed form as required by the local electric supply authority. One such recommended form is given in Annex E.

**9.3.2.7** *Earthing*

For checking the efficiency of earthing, the following tests are done:

a) The earth resistance of each electrode shall be measured.
b) Earth resistance of earthing grid shall be measured.
c) All electrodes shall be connected to the grid and the earth resistance of the entire earthing system shall be measured.

These tests shall preferably be done during the summer months.

## 10 TELECOMMUNICATION AND OTHER MISCELLANEOUS SERVICES

### 10.1 Telecommunication Service

**10.1.1** House wiring of telephone subscribers offices in small buildings is normally undertaken by the Telephone Department on the surface of walls. But in large multi-storeyed buildings intended for commercial, business and office use as well as for residential purposes, wiring for telephone connections is generally done in a concealed manner through conduits.

**10.1.2** The requirements of telecommunication facilities like Telephone connections, Private Branch Exchange, Intercommunication facilities, Telex and Telegraph lines are to be planned well in advance so that suitable provisions are made in the building plan in such a way that the demand for telecommunication services in any part of the building at any floor are met at any time during the life of the building.

**10.1.3** Layout arrangements, methods for internal block wiring and other requirements regarding provisions of space, etc, may be decided defending as the number of phone outlets and other details in consultation with Engineer/Architect and user.

**10.2 Public Address System** — *See* Part 4 'Fire and Life Safety'.

### 10.3 Common Antenna System for TV Receivers

**10.3.1** In multistoreyed apartments, houses and hotels where many TV receivers are located, a common master antenna system may preferably be used to avoid mushrooming of individual antennas.

**10.3.2** Master antenna is generally provided at the top most convenient point in any building and a suitable room on the top most floor or terrace for housing the amplifier unit, etc, may also be provided in consultation with the architect/engineer.

**10.3.3** From the amplifier rooms, conduits are laid in recess to facilitate drawing co-axial cable to individual flats. Suitable 'Tap Off' boxes may be provided in every room/flat as required.

### 10.4 UPS System

An electrical device providing an interface between the mains power supply and sensitive loads (computer systems, instrumentation, etc). The UPS supplies sinusoidal a.c. power free of disturbances and within strict amplitude and frequency tolerances. It is generally made up of a rectifier/charger and an inverter together with a battery for backup power in the event of a mains failure with virtually no time lag.

In general UPS system shall be provided for sensitive electronic equipments like computers, printers, fire alarm panel, public address system equipment, access control panel, EPABX, etc with the following provisions:

a) Provisions of isolation transformers shall be provided where the capacity exceeds 5 kVA.
b) UPS shall have dedicated neutral earthing system.
c) Adequate rating of protective devices such as MCB, MCCB, fuses, ELCB, etc, shall be provided at both incoming and outgoing sides.
d) UPS room shall be provided with adequate ventilation and/or air conditioning as per requirement.

### 10.5 Inverter

In general inverter system shall be provided for house lighting, shop lighting, etc, with the following provisions:

a) Adequate rating of protective devices such as MCB, MCCB, fuses, ELCB, etc, shall be provided at both incoming and outgoing sides.
b) Earthing shall be done properly.
c) Adequate ventilation space shall be provided around the battery section of the inverter.
d) Care in circuit design to keep the connected load in such a manner that the demand at the time of mains failure is within the capability of the inverter. (If the inverter fails to take over the load at the time of the mains failure, the purpose of providing the inverter and battery back up is defeated.)
e) Circuits which are fed by the UPS or Inverter systems should have suitable marking to ensure that a workman does not assume that the power is off, once he has switched off the mains from the DB for maintenance.
f) UPS systems and Inverter systems have a very limited fault feeding capacity in comparison to the mains supply from the licensee's network. The low fault current feed may cause loss of discrimination in the operation of

MCB's, if the Inverter or UPS system feeds a number of circuits with more than one over current protective device in series (such as incoming MCB at the DB and a few outgoing MCB's). The choice of MCB's in such cases has to be done keeping the circuit operating and fault condition parameters under both (mains operation and UPS operation) conditions.

**10.6 Diesel Generating Set (less than 5 kVA)**

In general small diesel generating sets shall be provided for small installations such as offices, shops, small scale industry, hostels, etc, with the following provisions:

a) These shall be located near the exit or outside in open areas.
b) They shall be in reach of authorized persons only.
c) Adequate fire fighting equipment shall be provided near such installations.
d) Exhaust from these shall be disposed in such a way so as not to cause health hazard.
e) These shall have acoustic enclosure, or shall be placed at a location so as not to cause noise pollution.
f) Adequate ventilation shall be provided around the installation.
g) Adequate rating of protective devices such as MCB, MCCB, fuses, ELCB, etc, shall be provided.
h) Separate and adequate body and neutral earthings shall be done.

**10.7 Building Management System**

A building management/automation system may be considered to be provided for controlling and monitoring of all parameters of HVAC, electrical, plumbing, fire fighting, low voltage system such as telephone, TV, etc. This not only lead to reduction of energy consumption, it shall also generate data leading to better operation practice and systematic maintenance scheduling. The total overview provided by a Building Automation System, with a capability to oversee a large number of operating and environmental parameters on real time basis leads to introduction of measures which lead to further reduction in energy consumption.

It shall also help in reduction of skilled manpower required for operation and maintenance of large complexes. This system can further linked to other systems such as Fire alarm system, public address system, etc for more effective running of services.

This system can be used for analysis and controlling of all services in a particular complex, leading efficient and optimum utilization of available services.

**10.8 Security System**

Security System may be defined as an integrated Closed Circuit Television System, Access Control System, Perimeter Protection Systems, movement sensors, etc. These have a central control panel, which has a defined history storage capacity. This main control panel may be located near to the fire detection and alarm system.

These may be considered for high security areas or large crowded areas or complexes. High security areas may consider uncorded, high-resolution, black and white cameras inplace of coloured cameras. These may be accompanied with movement sensors.

Access control may be provided for entry to high security areas. The systems may have proximity card readers, magnetic readers, etc.

**10.9 Computer Networking**

Networking is the practice of linking computing devices together with hardware and software that supports data communications across these devices.

**10.10 Car Park Management System**

The Car Management System may be provided in multi-level parking or other parking lots where number of vehicles to be parked exceeds 1 000 vehicles. The Car Park Management System may have features of Pay and Display Machines and Parking Guidance System. The Pay and Display Machines may be manned and unmanned type. Parking guidance system needs to display number of car spaces vacant on various floors, direction of entry and exit, etc. This system can be of great benefit in evaluating statistical data's such as number of cars in a day or month or hour, stay time of various vehicles, etc.

## 11 LIGHTNING PROTECTION OF BUILDINGS

**11.1 Basic Considerations for Protection**

Before proceeding with the detailed design of a lightning protecting system, the following essential steps should be taken:

a) Decide whether or not the structure needs protection and, if so, what are the special requirements (*see* **11.1.1**) {*see* good practice for details [8-2(27)] }.
b) Ensure a close liaison between the architect, the builder, the lightning protective system engineer, and the appropriate authorities throughout the design stages.
c) Agree the procedures for testing, commissioning and future maintenance.

**11.1.1** *Need for Protection*

Structures with inherent explosive risks; for example, explosives factories, stores and dumps and fuel tanks; usually need the highest possible class of lightning protective system.

For all other structures, the standard of protection recommended in the remainder of the Code is applicable and the only question remaining is whether to protect or not.

In many cases, the need for protection may be self-evident, for example:

- where large numbers of people congregate;
- where essential public services are concerned;
- where the area is one in which lightning strokes are prevalent;
- where there are very tall or isolated structures; and
- where there are structures of historic or cultural importance.

However, there are many cases for which a decision is not so easy to make. Various factors effecting the risk of being struck and the consequential effects of a stroke in these cases are discussed in **11.1.2** to **11.1.8**.

It must be understood, however, that some factors cannot be assessed, and these may override all other considerations. For example, a desire that there should be no avoidable risk to life or that the occupants of a building should always feel safe, may decide the question in favour of protection, even though it would normally be accepted that there was no need. No guidance can be given in such matters, but an assessment can be made taking account of the exposure risk (that is the risk of the structure being struck) and the following factors:

a) Use to which the structure is put,
b) Nature of its construction,
c) Value of its contents or consequential effects,
d) The location of the structure, and
e) The height of the structure (in the case of composite structures the overall height).

**11.1.2** *Estimation of Exposure Risk*

The probability of a structure or building being struck by lightning in any one year is the product of the 'lightning flash density' and the 'effective collection area' of the structure. The lightning flash density, $N_g$, is the number of (flashes to ground) per km$^2$ per year.

NOTE — For the purposes of this Code, the information given in Fig. 5 on thunderstorm days per year would be necessary to be translated in terms of estimated average annual density $N_g$. The table below which indicates the relationship between thunderstorm days per year and lightning flashes per square kilometre per year:

| *Thunderstorm days/year* | *Lightning Flashes per km$^2$ per Year* | |
|---|---|---|
| | Mean | Limits |
| 5 | 0.2 | 0.1 – 0.5 |
| 10 | 0.5 | 0.15 – 1 |
| 20 | 1.1 | 0.3 – 3 |
| 30 | 1.9 | 0.6 – 5 |
| 40 | 2.8 | 0.8 – 8 |
| 50 | 3.7 | 1.2 – 10 |
| 60 | 4.7 | 1.8 – 12 |
| 80 | 6.9 | 3 – 17 |
| 100 | 9.2 | 4 – 20 |

The effective collection area of a structure is the area on the plan of the structure extended in all directions to take account of its height. The edge of the effective collection area is displaced from the edge of the structure by an amount equal to the height of the structure at that point. Hence, for a simple rectangular building of length *L*, width *W* and height *H* metres, the collection area has length $(L + 2H)$ metres and width $(W + 2H)$ metres with four rounded corners formed by quarter circles of radius *H* metres. This gives a collection area, $A_c$ (in m$^2$):

$$A_c = (L\times W)+2(L\times H)+2(W\times H)+\pi H^2 \quad \dots (1)$$

*The probable number of strikes (risk) to the structure per year is*:

$$P = A_c \times N_g \times 10^{-6} \quad \dots (2)$$

It must first be decided whether this risk *P* is acceptable or whether some measure of protection is thought necessary.

**11.1.3** *Suggested Acceptable Risk*

For the purposes of this Code, the acceptable risk figure has been taken as $10^{-5}$, that is, 1 in 100 000 per year.

**11.1.4** *Overall Assessment of Risk*

Having established the value of *P*, the probable number of strikes to the structure per year [*see* equation (2) in **11.1.2**] the next step is to apply the 'weighting factors' in Tables 3 and 4.

This is done by multiplying *P* by the appropriate factors to see whether the result, the overall weighting factors, exceeds the acceptable risk of $P = 10^{-5}$ per year.

**11.1.5** *Weighting Factors*

In Tables 3A to 3E, the weighting factor values are given under headings 'A' to 'E', denoting a relative degree of importance or risk in each case. The tables are mostly self-explanatory but it may be helpful to say something about the intention of Table 3C.

## Table 3 Overall Assessment of Risk

(*Clauses* 11.1.4 *and* 11.1.5)

### Table 3A Weighting Factor 'A' (Use of Structure)

| Use to Which Structure is Put | Value of 'A' |
|---|---|
| Houses and other buildings of comparable size | 0.3 |
| Houses and other buildings of comparable size with outside aerial | 0.7 |
| Factories, workshops and laboratories | 1.0 |
| Office blocks, hotels, blocks of flats and other residential buildings other than those included below | 1.2 |
| Places of assembly, for example, churches, halls, theatres, museums, exhibitions, departmental stores, post offices, stations, airports, and stadium structures | 1.3 |
| Schools, hospitals, children's and other homes | 1.7 |

### Table 3B Weighting Factor 'B' (Type of Construction)

| Type of Construction | Value of 'B' |
|---|---|
| Steel framed encased with any roof other than metal[1)] | 0.2 |
| Reinforced concrete with any roof other than metal | 0.4 |
| Steel framed encased or reinforced concrete with metal roof | 0.8 |
| Brick, plain concrete or masonry with any roof other than metal or thatch | 1.0 |
| Timber framed or clad with any roof ohte rthan metal or thatch | 1.4 |
| Brick, plain concrete, masonry, timber framed but with metal roofing | 1.7 |
| Any building with a thatched roof | 2.0 |

1) A structure of exposed metal which is continuous down to ground level is excluded from these tables as it requires no lighting protection beyond adequate earthing arrangements.

### Table 3C Weighting Factor 'C' (Contents or Consequential Effects)

| Contents or Consequential Effects | Value of 'C' |
|---|---|
| Ordinary domestic or office buildings, factories and workshops not containing valuable or specially susceptible contents | 0.3 |
| Industrial and agricultural buildings with specially susceptible [1)] contents | 0.8 |
| Power stations, gas works, telepone exchanges, radio stations | 1.0 |
| Industrial key plants, ancient monuments and historic buildings, museums, art galleries or other buildings with specially valuable contents | 1.3 |
| Schools, hospitals, children's and other homes, places of assembly | 1.7 |

1) This means specially valuable plant or materials vulnerable to fire or the results of fire.

### Table 3D Weighting Factor 'D' (Degree of Isolation)

| Degree of Isolation | Value of 'D' |
|---|---|
| Structure located in a large area of structures or trees of the same or greater height, for example, in a large town or forest | 0.4 |
| Structure located in an area with few other structures or trees of similar height | 1.0 |
| Structure completely isolated or exceeding at least twice the height of surrounding structures or trees | 2.0 |

### Table 3E Weighting Factor 'E' (Type of Country)

| Type of Country | Value of 'E' |
|---|---|
| Flat country at any level | 0.3 |
| Hill country | 1.0 |
| Mountain country between 300 m and 900 m | 1.3 |
| Mountain country between 900 m | 1.7 |

The effect of the value of the contents of a structure is clears the term 'consequential effect' is intended to cover not only material risks to goods and property but also such aspects as the disruption of essential services of all kinds, particularly in hospitals.

The risk to life is generally very small, but if a building is struck, fire or panic can naturally result. All possible steps should, therefore, be taken to reduce these effects, especially among children, the old, and the sick.

**11.1.6** *Interpretation of Overall Risk Factor*

The risk factor method put forward here is to be taken as giving guidance on what might, in some cases, be a difficult problem. If the result obtained is considerably less than $10^{-5}$ (1 in 100 000) then, in the absence of other overriding considerations, protection does not appear necessary; if the result is greater than $10^{-5}$, say for example $10^{-4}$ (1 in 10 000) then sound reasons would be needed to support a decision not to give protection.

When it is thought that the consequential effects will be small and that the effect of a lighting stroke will most probably be merely slight damage to the fabric of the structure, it may be economic not to incur the cost of protection but to accept the risk. Even though, this decision is made, it is suggested that the calculation is still worthwhile as giving some idea of the magnitude of the calculated risk being taken.

**11.1.7** *Anomalies*

Structures are so varied that any method of assessment may lead to anomalies and those who have to decide on protection must exercise judgement. For example, a steel-framed building may be found to have a low risk factor but, as the addition of an air termination and earthing system will give greatly improved protection, the cost of providing this may be considered worthwhile.

A low risk factor may result for chimneys made of brick or concrete. However, where chimneys are free standing or where they project for more than 4.5 m above the adjoining structure, they will require protection regardless of the factor. Such chimneys are, therefore, not covered by the method of assessment. Similarly, structures containing explosives or flammable substances are also not covered.

Results of calculations for different structures are given in Table 4 and a specific case is worked through in **11.1.8**.

**11.1.8** *Sample Calculation of Need for Protection*

A hospital building is 10 m high and covers an area of 70 m × 12 m. The hospital is located in flat country and isolated from other structures. The construction is of brick and concrete with a non-metallic roof.

Is lighting protection needed?

a) *Flashes/km²/year* — Let us say, for the protection of the hospital a value for $N_g$ is 0.7.

b) *Collection area* — Using equation (1) in **11.1.2**:

$$A_c = (70 \times 12) + 2\ (70 \times 10) + 2\ (12 \times 10) + (\pi \times 100)$$
$$= 840 + 1\ 400 + 240 + 314$$
$$= 2\ 794\ \text{m}^2$$

c) *Probability of being struck* — Using equation (2) in **11.1.2**:

$$P = A_c \times N_g \times 10^{-6} \text{ times per year}$$
$$= 2\ 794 \times 0.7 \times 10^{-6}$$
$$= 2.0 \times 10^{-3} \text{ approximately}$$

**Table 4 Examples of Calculations for Evaluating the Need for Protection**

(*Clauses* 11.1.4 *and* 11.1.7)

| Sl No. | Description of Structure | Risk of Being Struck (*P*) | | | Weighting Factors | | | | | Overall Multiplying Factor (Product of cols 6–10) | Overall Risk Factor (Product of cols 5 and 11) | Recommendation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Collection Area $A_c$ | Flash Density $N_g$ | *P* $A_c \times N_g \times 10^{-6}$ | 'A' Use of Structure (Table 3A) | 'B' Type of Construction (Table 3B) | 'C' Contents or Consequential Effects (Table 3C) | 'D' Degree of Isolation (Table 3D) | 'E' Type of Country (Table 3E) | | | |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) |
| i) | Malsonette, reinforced concrete and brick built, non-metallic roof | 3 327 | 0.6 | $2 \times 10^{-3}$ | 1.2 | 0.4 | 0.3 | 0.4 | 0.3 | 0.02 | $4 \times 10^{-5}$ | Protection required |
| ii) | Office building, reinforced concrete construction, non-metallic roof | 4 296 | 0.6 | $2.6 \times 10^{-3}$ | 1.2 | 0.4 | 0.3 | 0.4 | 0.3 | 0.02 | $5.2 \times 10^{-5}$ | Protection required |
| iii) | School, brick built | 1 456 | 0.7 | $1 \times 10^{-3}$ | 1.7 | 1.0 | 1.7 | 0.4 | 0.3 | 0.3 | $3 \times 10^{-4}$ | Protection required |
| iv) | 3 bedroom detached dwelling house, brick built | 405 | 0.4 | $1.6 \times 10^{-4}$ | 0.3 | 1.0 | 0.3 | 0.4 | 0.3 | 0.01 | $1.6 \times 10^{-4}$ | No protection required |
| v) | Village church | 5 027 | 0.6 | $3 \times 10^{-3}$ | 1.3 | 1.0 | 1.7 | 2.0 | 0.3 | 1.3 | $3.9 \times 10^{-3}$ | Protection required |

NOTE — The risk of being struck, '*P*' (col 5), is multiplied by the product of the weighting factors (col 6 to 10) to yield an overall risk factor (col 12). This should be compared with the acceptable risk ($1 \times 10^{-5}$) for guidance on whether or not to protect.

d) *Applying the weighting factors*

A = 1.7
B = 1
C = 1.7
D = 2.0
E = 0.3

The overall multiplying factor

= A × B × C × D × E
= 1.7

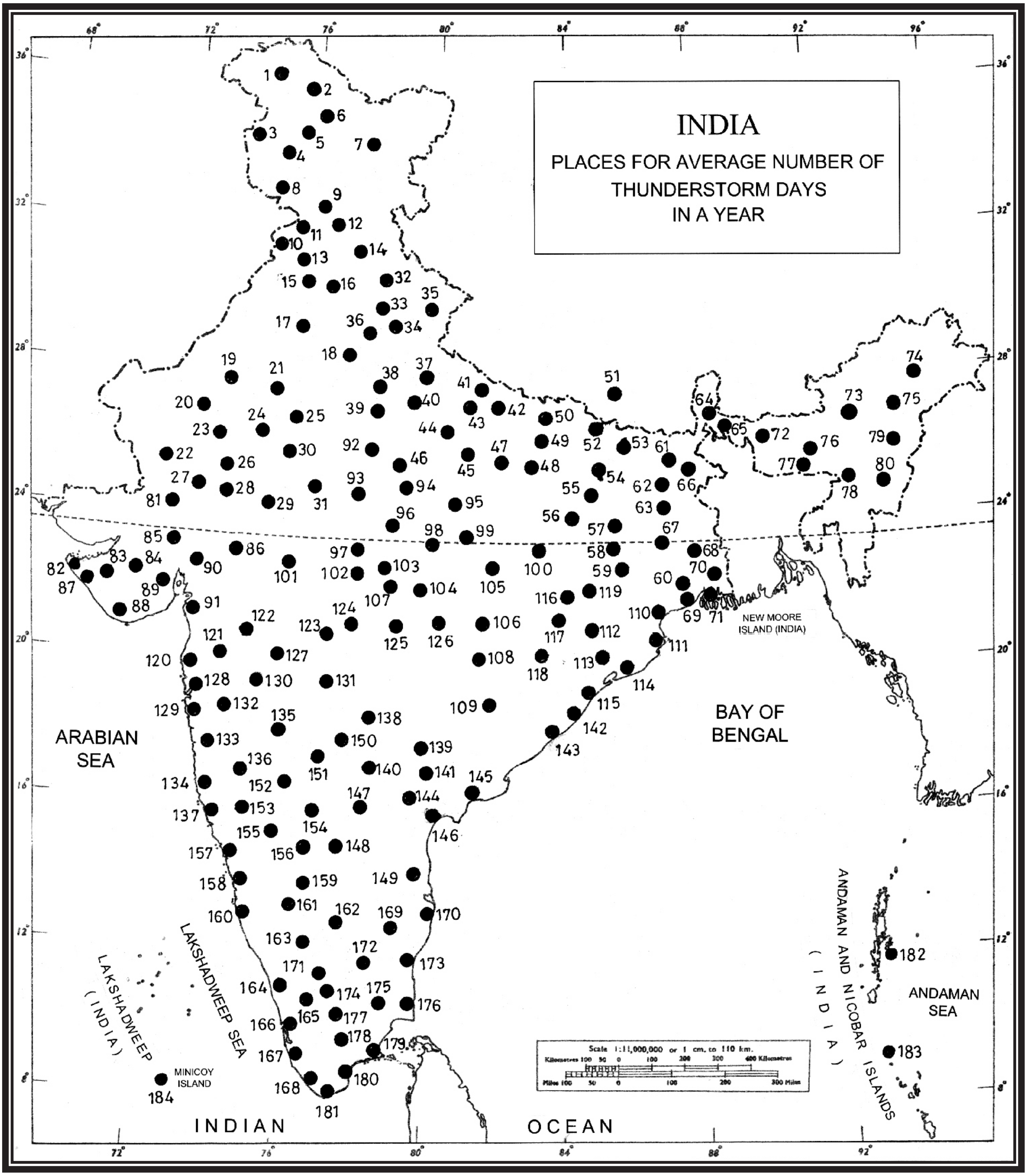
Therefore, the overall risk factor

$= 2.0 \times 1.7 \times 10^{-3}$
$= 3.4 \times 10^{-3}$

Conclusion: Protection is necessary.

**11.2** For detailed requirements of lightning protection of various structures, reference may be made to good practice [8-2(27)].

| *Sl No.* | *Name of Place* | *Annual Thunder-storm Days* | *Sl No.* | *Name of Place* | *Annual Thunder-storm Days* | *Sl No.* | *Name of Place* | *Annual Thunder-storm Days* |
|---|---|---|---|---|---|---|---|---|
| 1. | Gilgit | 7 | 63. | Dumka | 63 | 125. | Nagpur | 45 |
| 2. | Skardu | 5 | 64. | Darjeeling | 28 | 126. | Gondia | 10 |
| 3. | Gulmarg | 53 | 65. | Jalpaiguri | 68 | 127. | Aurangabad | 34 |
| 4. | Srinagar | 54 | 66. | Malda | 59 | 128. | Bombay | 16 |
| 5. | Dras | 3 | 67. | Asansol | 71 | 129. | Alibag | 12 |
| 6. | Kargil | 2 | 68. | Burdwan | 39 | 130. | Ahmadnagar | 10 |
| 7. | Leh | 3 | 69. | Kharagpur | 76 | 131. | Parbhani | 32 |
| 8. | Jammu | 26 | 70. | Calcutta | 70 | 132. | Pune | 22 |
| 9. | Dharmsala | 13 | 71. | Sagar Island | 41 | 133. | Mahabaleshwar | 14 |
| 10. | Amritsar | 49 | 72. | Dhubri | 8 | 134. | Ratnagiri | 6 |
| 11. | Pathankot | 4 | 73. | Tezpur | 27 | 135. | Sholapur | 23 |
| 12. | Mandi | 46 | 74. | Dibrugarh | 98 | 136. | Miraj | 25 |
| 13. | Ludhiana | 12 | 75. | Sibsagar | 103 | 137. | Vengurla | 39 |
| 14. | Simla | 40 | 76. | Shillong | 75 | 138. | Nizambad | 36 |
| 15. | Patiala | 26 | 77. | Cherrapunji | 49 | 139. | Hnamkonda | 43 |
| 16. | Ambala | 9 | 78. | Silchar | 33 | 140. | Hyderabad | 28 |
| 17. | Hissar | 27 | 79. | Kohima | 34 | 141. | Khammam | 26 |
| 18. | Delhi | 30 | 80. | Imphal | 49 | 142. | Kalingapatam | 20 |
| 19. | Bikaner | 10 | 81. | Deesa | 7 | 143. | Vishakapatnam | 46 |
| 20. | Phalodi | 14 | 82. | Dwarka | 5 | 144. | Rentichintala | 42 |
| 21. | Sikar | 17 | 83. | Jamnagar | 8 | 145. | Masulipatam | 20 |
| 22. | Barmer | 12 | 84. | Rajkot | 12 | 146. | Ongole | 25 |
| 23. | Jodhpur | 23 | 85. | Ahmedabad | 11 | 147. | Kurnool | 29 |
| 24. | Ajmer | 26 | 86. | Dohad | 17 | 148. | Anantpur | 22 |
| 25. | Jaipur | 39 | 87. | Porbandar | 3 | 149. | Nellore | 18 |
| 26. | Kankroli | 36 | 88. | Veraval | 3 | 150. | Bidar | 15 |
| 27. | Mount Abu | 5 | 89. | Bhavnagar | 11 | 151. | Gulbarga | 34 |
| 28. | Udaipur | 38 | 90. | Baroda | 8 | 152. | Bijapur | 9 |
| 29. | Neemuch | 28 | 91. | Surat | 4 | 153. | Belgaum | 31 |
| 30. | Kota | 27 | 92. | Gwalior | 53 | 154. | Raichur | 17 |
| 31. | Jhalawar | 40 | 93. | Guna | 33 | 155. | Gadag | 21 |
| 32. | Mussorie | 61 | 94. | Nowgong | 59 | 156. | Bellary | 22 |
| 33. | Roorkee | 74 | 95. | Satna | 41 | 157. | Karwar | 27 |
| 34. | Najibabad | 36 | 96. | Sagar | 36 | 158. | Honavar | 5 |
| 35. | Mukteswar | 53 | 97. | Bhopal | 44 | 159. | Chikalthana | 24 |
| 36. | Meerut | — | 98. | Jabalpur | 50 | 160. | Mangalore | 36 |
| 37. | Bareilly | 34 | 99. | Umaria | 37 | 161. | Hassan | 26 |
| 38. | Aligarh | 30 | 100. | Ambikapur | 29 | 162. | Bangalore | 46 |
| 39. | Agra | 24 | 101. | Indore | 34 | 163. | Mysore | 44 |
| 40. | Mainpuri | 23 | 102. | Hoshangabad | 37 | 164. | Kozhikode | 39 |
| 41. | Bahraich | 31 | 103. | Panchmarhi | 30 | 165. | Palghat | 35 |
| 42. | Gonda | 22 | 104. | Seoni | 51 | 166. | Cochin | 69 |
| 43. | Lucknow | 18 | 105. | Pendadah | 56 | 167. | Alleppey | 51 |
| 44. | Kanpur | 26 | 106. | Raipur | 34 | 168. | Trivandrum | 68 |
| 45. | Fatehpur | 24 | 107. | Chhindwara | 27 | 169. | Vellore | 25 |
| 46. | Jhansi | 20 | 108. | Kanker | 37 | 170. | Madras | 47 |
| 47. | Allahabad | 51 | 109. | Jagdalpur | 35 | 171. | Ootacamund | 24 |
| 48. | Varanasi | 51 | 110. | Balasore | 81 | 172. | Salem | 69 |
| 49. | Azamgarh | 1 | 111. | Chandbali | 75 | 173. | Cuddalore | 37 |
| 50. | Gorakhpur | 11 | 112. | Angul | 81 | 174. | Coimbatore | 40 |
| 51. | Kathmandu | 74 | 113. | Bhubaneswar | 46 | 175. | Trichchirapalli | 41 |
| 52. | Motihari | 38 | 114. | Puri | 33 | 176. | Nagappattinam | 15 |
| 53. | Darbhanga | 10 | 115. | Gopalpur | 34 | 177. | Kodaikanal | 82 |
| 54. | Patna | 33 | 116. | Jharsuguda | 85 | 178. | Madurai | 39 |
| 55. | Gaya | 38 | 117. | Sambalpur | 67 | 179. | Pamban | 5 |
| 56. | Daltonganj | 73 | 118. | Titlagarh | 24 | 180. | Tuticorin | 14 |
| 57. | Hazaribagh | 73 | 119. | Rajgangpur | 1 | 181. | Cape Comorin | 68 |
| 58. | Ranchi | 34 | 120. | Dahanu | 1 | 182. | Port Blair | 62 |
| 59. | Chaibasa | 70 | 121. | Nasik | 17 | 183. | Car Nicobar 1 | 18 |
| 60. | Jamshedpur | 66 | 122. | Malegaon | 13 | 184. | Minicoy 1 | 20 |
| 61. | Purnea | 52 | 123. | Akola | 20 | | | |
| 62. | Sabour | 76 | 124. | Amraoti | 32 | | | |




Based upon Survey of India Outline Map printed in 1993.



The territorial waters of India extend into the sea to a distance of twelve nautical miles measured from the appropriate base line.
The boundary of Meghalaya shown on this map is as interpreted from the North-Eastern Areas (Reorganisation) Act, 1971, but has yet to be verified.
Responsibility for correctness of internal details shown on the map rests with the publisher.
The state boundaries between Uttaranchal & Uttar Pradesh, Bihar & Jharkhand and Chhatisgarh & Madhya Pradesh have not been verified by Governments concerned.

FIG. 5 MAP OF INDIA SHOWING PLACES FOR AVERAGE NUMBER OF THUNDERSTORM DAYS IN A YEAR

# ANNEX A

(*Clause* 2.2)

## DRAWING SYMBOLS FOR ELECTRICAL INSTALLATION IN BUILDING

**A-1 WIRING**

**A-1.0** Remarks 'upwards' and 'downwards' apply only when the drawing is read the right way up.

**A-1.0.1** An arrow on the slant line indicates the direction of the power flow.

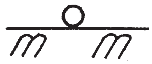
**A-1.0.2** The wiring terminates at the circle or the black dot.

**A-1.1 General Wiring**

**A-1.2 Wiring on the Surface** 

**A-1.3 Wiring under the Surface** 

**A-.1.4 Wiring in Conduit**

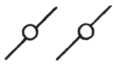
**A-1.4.1** *Conduit on Surface* 

**A-1.4.2** *Concealed Conduit* 

NOTE — The type of conduit may be indicated, if necessary.

**A-1.5** *Wiring Going Upwards* 

**A-1.6** *Wiring Going Downwards* 

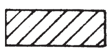
**A-1.7** *Wiring Passing Vertically through a Room* 

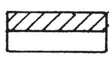
**A-2 FUSE BOARDS**

**A-2.1 Lighting Circuit Fuse Boards**

**A-2.1.1** *Main Fuse Board Without Switches* 

**A-2.1.2** *Main Fuse Board with Switching* 

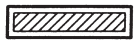
**A-2.1.3** *Distribution Fuse Board Without Switches* 

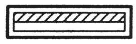
**A-2.1.4** *Distribution Fuse Board with Switches* 

**A-2.2 Power Circuit Fuse Boards**

**A-2.2.1** *Main Fuse Board Without Switches* 

**A-2.2.2** *Main Fuse Board with Switches* 

**A-2.2.3** *Distribution Fuse Board Without Switches* 

**A-2.2.4** *Distribution Fuse Board with Switches* 

**A-3 SWITCHES AND SWITCH-OUTLETS**

**A-3.1 One-Way Switch**

**A-3.1.1** *Single-Pole* 

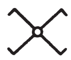
**A-3.1.2** *Two-Pole* 

**A-3.1.3** *Three-Pole* 

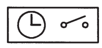
**A-3.2 Single-Pole Pull Switch** 

**A-3.3 Multiposition Switch for Different Degrees of Lighting** 

**A-3.4 Two-Way Switch** 

**A-3.5 Intermediate Switch** 

**A-3.6 Period Limiting Switch** 

**A-3.7 Time Switch** 

**A-3.8 Pendant Switch** 

**A-3.9 Push Button** 

NOTE — The use of the push button may be indicated, if desired.

**A-3.10 Luminous Push Button** 

**A-3.11 Restricted Access Push Button** 

**A-4 SOCKET-OUTLETS**

**A-4.1 Socket-Outlet, 6A** 

**A-4.2 Socket-Outlet, 16A** 

**A-4.3 Combined Switch and Socket-Outlet, 6 A** 

**A-4.4 Combined Switch and Socket-Outlet, 16 A**

**A-4.5 Interlocking Switch and Socket-Outlet, 6 A**

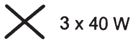
**A-4.6 Interlocking Switch and Socket-Outlet, 16 A**

## A-5 LAMPS AND LIGHTING APPARATUS

**A-5.0** Symbols **A-5.1** to **A-5.17.1** represent either the lamp or a group of lamps or the outlet for lamps. If it is desired to specify that the lamp is fixed to the wall or coiling, a vertical or horizontal line respectively may be added to the symbol.

**A-5.1 Lamp or Outlet for Lamp**

**A-5.1.1** *Group of Three 40-W Lamps*

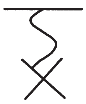



**A-5.2 Lamp, Mounted on a Wall**

**A-5.3 Lamp, Mounted on a Ceiling**

**A-5.4 Counter Weight Lamp Fixture**

**A-5.5 Chain Lamp Fixture**



**A-5.6 Rod Lamp Fixture**

**A-5.7 Lamp Fixtures with Built-in Switch**

**A-5.8 Lamp Fed from Variable Voltage Supply**

**A-5.9 Emergency Lamp**

**A-5.10 Panic Lamp**

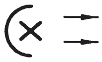
**A-5.11 Bulk-Head Lamp**

**A-5.12 Water-Tight Lighting Fitting**


**A-5.13 Battern Lamp Holder**


**A-5.14 Projector**

**A-5.15 Spot Light**



**A-5.16 Flood Light**

**A-5.17 Flourescent Lamp**

**A-5.17.1** *Group of Three 40-W Fluorescent Lamps*


## A-6 ELECTRICAL APPLIANCES

**A-6.1 General**

NOTE — If necessary, use designation is specify.

**A-6.2 Heater**

**A-6.3 Storage Type Electric Water Heaters**

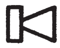
## A-7 BELLS, BUZZERS AND SIRENS

**A-7.1 Bell**

**A-7.2 Buzzer**

**A-7.3 Siren**

**A-7.4 Horn on Hooter**



**A-7.5 Indicator (at 'N' insert number of ways)**


## A-8 FANS

**A-8.1 Ceiling Fan**

**A-8.2 Bracket Fan**

**A-8.3 Exhaust Fan**

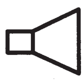
**A-8.4 Fan Regulator**

## A-9 TELECOMMUNICATION APPARATUS

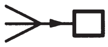
**A-9.1 Socket-Outlet for Telecommunications**

**A-9.2 Aerial**

**A-9.3 Loudspeaker**



**A-9.4 Radio Receiving Set**



**A-9.5 Amplifying Equipment**

**A-9.6 Television Receiving Set**

**A-9.7 Control Board (for Public Address System)**

**A-10 CLOCKS**

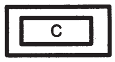
**A-10.1 Synchronous Clock**

**A-10.2 Impulse Clock Outlet**

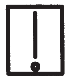
**A-10.3 Master Clock Outlet**

**A-11 FIRE ALARMS**

**A-11.1 Manual Operated Fire Alarm**




**A-11.2 Automatic Fire Detector Switch**



**A-11.3 Bell Connected to Fire Alarm Switch**

**A-11.4 Fire Alarm Indicator**


**A-12 EARTHING**

**A-12.1 Earth Point**

## ANNEX B

[*Clauses* 3.1, 5.3.1.1, 5.3.1.3, 5.3.2.3(b) *and* 8.6]

### EXTRACTS FROM INDIAN ELECTRICITY RULES, 1956

**B-1** The following are the extracts of some of the rules:

**Rule 32, Identification of Earthed and Earthed Neutral Conductors and Position of Switches and Cut-Outs Therein**

Where the conductors include an earthed conductor of a two-wire system or an earthed neutral conductor of a multi-wire system or a conductor which is to be connected thereto, the following conditions shall be complied with:

1) An indication of permanent nature shall be provided by the owner of the earthed or earthed neutral conductor, or the conductor which is to be connected thereto, to enable such conductor to be distinguished from any live conductor. Such indication shall be provided:
   a) Where the earthed or earthed neutral conductor is the property of the supplier, at or near the point of commencement of supply;
   b) Where a conductor forming part of a consumer's system is to be connected to the supplier's earthed or earthed neutral conductor at the point where such connection is to be made;
   c) In all other cases, at a point corresponding to the point of commencement of supply or at such other point as may be approved by an Inspector or any officer appointed to assist the Inspector and hold authorized under sub-rule (2) of Rule 4-A.
2) No cut-out, link or switch other than a linked switch arranged to operate simultaneously on the earthed or earthed neutral conductor and live conductors shall be inserted or remain inserted in any earthed or earthed neutral conductor of a two-wire system or in any earthed or earthed neutral conductor of a multi-wire system or in any conductor connected thereto with the following exceptions:
   a) A link for testing purposes, or
   b) A switch for use in controlling a generator or transformer.

NOTE — For the purpose of this rule, the relevant Indian Standards relating to marking and arrangement for switch gear, busbar, main connections, and auxiliary wiring may be referred to.

**Rule 33 Earthed Terminal on Consumer's Premises**

1) The supplier shall provide and maintain on the consumer's premises for the consumer's use a suitable earthed terminal in an accessible

position at or near the point of commencement of supply as defined under Rule 58;

Provided that in the case of medium, high or extra-high voltage installation, the consumer shall, in addition to aforementioned earthing arrangement, provide his own earthing system with an independent electrode, and maintain the same.

Provided further that the supplier may not provide any earthed terminal in the case of installations already connected to his system on or before the 30th June, 1966 if he is satisfied that the consumer's earthing arrangement is efficient.

2) The consumer shall take all reasonable precautions to prevent mechanical damage to the earthed terminal and its lead belonging to the supplier; and

3) The supplier may recover from the consumer the cost of installation of such earthed terminal on the basis laid down in sub-rule (2) of Rule 82.

**Rule 50 Supply and Use of Energy**

1) The energy shall not be supplied, transformed, converted or used or continued to be supplied, transformed, converted or used unless the following provisions are observed:

a) A suitable linked switch or a circuit breaker of requisite capacity to carry and break the current is placed as near as possible to, but after the point of commencement of supply, as defined under Rule 58, so as to be readily accessible and capable of being easily operated to completely isolate the supply to the installation, such equipment being in addition to any equipment installed for controlling individual circuits or apparatus.

Provided that where the point of commencement of supply and the consumer's apparatus are near to each other, one linked switch or circuit breaker near the point of commencement of supply shall considered sufficient for the purpose of this rule;

b) A suitable linked switch or circuit-breaker of requisite capacity to carry and break the full load current is inserted on the secondary side of a transformer, in the case of high or extra high voltage installation.

Provided however, that the linked switch on the primary side of the transformer may be of such capacity as to carry the full load current and to break only the magnetising current of the transformer.

Provided further that the provision of the clause shall not apply to transformers installed in sub-station upto and including 100 kVA belonging to the supplier.

Provided also that the provision of a linked switch on the primary side of the transformer shall not apply to the unit auxiliary transformer of the generator.

c) Except in the case of composite control gear designed as a unit; every distinct circuit is protected against excess energy by means of a suitable cut-out or a circuit-breaker of adequate breaking capacity suitably located and so constructed as to prevent danger from overheating, arcing or scattering of hot metal when it comes into operation and to permit of ready renewal of the fusible metal of the cut-out without danger.

d) The supply of energy to each motor or a group of motors or other apparatus, meant for operating one particular machine, is controlled by a suitable linked switch or a circuit-breaker or an emergency tripping device with manual reset of requisite capacity placed in such a position as to be adjacent to the motor or a group of motors or other apparatus, readily accessible to and easily operated by the person in charge and so connected in the circuit of that by its means all supply of energy can be cut-off from the motor or a group of motors or apparatus and from any regulating switch, resistance or other device associated therewith.

e) All insulating material is chosen with special regard to the circumstances of its proposed use, the mechanical strength being sufficient for the purpose, and so far as is practicable, is of such a character or so protected as to maintain adequately the insulating properties under all working conditions in respect of temperature and moisture; and

f) Adequate precautions are taken to ensure that no live parts are so exposed as to cause danger.

2) a) When energy is being supplied, transformed, converted or used, the

consumer or the owner of the concerned installation shall be responsible for the continuous observance of the provisions of sub-rule(1) in respect of his installation.

b) Every consumer shall use all reasonable means to ensure that where energy is supplied by a supplier no person other than the supplier shall interfere with the service lines and apparatus placed by the supplier on the premises of the consumer.

**Rule 51 Provisions Applicable to Medium, High or Extra-High Voltage Installations**

The following provisions shall be observed where energy at medium, high or extra high voltage is supplied, converted, transformed or used:

1) a) All conductors (other than those of overhead lines) shall be completely enclosed in mechanically strong metal casing or metallic covering which is electrically and mechanical continuous and adequately protected against mechanical damage unless the said conductors are accessible only to an authorised person or are installed and protected to the satisfaction of the Inspector so as to prevent danger.

Provided that rigid non-metallic conduits conforming to IS 2509 : 1963 'Rigid non-metallic conduits for electrical installation', may be used for medium voltage installation subject to any conditions as the Inspector or officer appointed to assist an Inspector may think fit to impose.

b) All metal works enclosing, supporting or associated with the installation, other than that designed to serve as a conductor shall, if considered necessary by the Inspector, be connected with earth.

c) Every switchboard shall comply with the following provisions, namely:

i) a clear space of not less than one metre in width shall be provided in front of the switchboard;

ii) if there are any attachments or bare connections at the back of the switchboard, the space (if any) behind the switchboard shall be either less than 10 cm, or more than 75 cm in width, measured from the farthest outstanding part of any attachment or conductor; and

iii) if the space behind the switchboard exceeds 75 cm in width, there shall be passage way from either end of the switchboard clear to a height of 1.8 metres.

2) Where an application has been made to a supplier for supply of energy to any installation, the shall not commence, or where the supply has been discontinued, recommence the supply unless he is satisfied that the consumer has complied in all respects with the conditions of supply, set out in sub-rule (1) of this rule and Rules 50 and 64.

3) Where a supplier proposes to supply or use energy at medium voltage or to recommence supply after it has been discontinued for a period of six months, he shall, before connecting or re-connecting the supply, give notice in writing of such intention to the Inspector.

4) If at any time after connecting the supply the supplier is satisfiedthat any provision of sub-rule (1) of this rule, or of Rules 50 and 64 is not being observed, he shall give notice of the same in writing to the consumer and the Inspector specifying how the provision has not been observed, and may discontinue the supply if the Inspector so direct.

**Rule 58 Point of Commencement of Supply**

The point of commencement of supply of energy to a consumer shall be deemed to be the point at the outgoing terminals of the cut-outs inserted by the supplier in each conductor of every service line other than an earthed or earthed neutral conductor or the earthed external conductor of a concentric cable at the consumer's premises.

**Rule 61 Connection with Earth**

1) The following provisions shall apply to the connection with earth of systems at low voltage in cases where the voltage between phases or outers normally exceeds 125 volts and of systems at medium voltage:

a) The neutral conductor of a three-phase four-wire system, and the middle conductor of a two-phase three-wire system shall be earthed by not less than two separate and distinct connections with earth both at the generating station and at the substation. It may also be earthed at one or more points along the distribution system or service line in addition to any connection with earth which may be at the consumer's premises.

b) In the case of a system comprising electric supply lines having concentric cables, the external conductor of such cables shall be earthed by two separate and distinct connections with earth.

c) The connection with earth may include a link by means of which the connection may be temporarily interrupted for the purpose of testing or for locating a fault.

d) i) In a direct current three-wire system the middle conductor shall be earthed at the generating station only, and the current from the middle conductor to earth shall be continuously recorded by means of recording ammeter, and if at any time the current exceeds one thousandth part of the maximum supply current, immediate steps shall be taken to improve the insulation of the system.

ii) Where the middle conductor is earthed by means of a circuit-breaker with a resistance connected in parallel, the resistance shall not exceed 10 ohms and on the opening of the circuit-breaker, immediate steps shall be taken to improve the insulation of the system, and the circuit-breaker shall be re-closed as soon as possible.

iii) The resistance shall be used only as a protection for the ammeter in case of earths on the system and until such earths are removed, immediate steps shall be taken to locate and remove the earth.

e) In the case of an alternating current system, there shall not be inserted in the connection with earth and impedance (other than that required solely for the operation of switch gear or instrument), cut-out or circuit-breaker, and the result of any test made to ascertain whether the current (if any) passing through the connection with earth is normal, shall be duly recorded by the supplier.

f) No person shall make connection with earth by the aid of, nor shall be keep it in contact with any water main not belonging to him except with the consent of the owner thereof and of the Inspector.

g) Alternating current systems which are connected with earth as aforesaid may be electrically interconnected, provided that each connection with earth is bonded to the metal sheathing and metallic armouring (if any) of the electric supply lines concerned.

2) The frame of every generator, stationary motor, portable motor, and the metallic parts (not intended as conductors) of all transformers and any other apparatus used for regulating or controlling energy and all medium voltage energy consuming apparatus shall be earthed by the owner by two separate and distinct connections with earth.

3) All metal casings or metallic covering containing or protecting any electric supply-line or apparatus shall be connected with earth and shall be so joined and connected across all junction boxes and other openings as to make good mechanical and electrical connections throughout their whole length.

Provided that where the supply is at low voltage, this sub-rule shall not apply to isolated wall tubes or to brackets, electrollers, switches, ceiling fans or other fittings (other than portable hand lamps and portable and transportable apparatus) unless provided with earth terminal.

Provided further that where the supply is at low voltage and where the installations are either new or renovated all plug sockets shall be of the three-pin type, having permanently and efficiently earthed.

The sub-rule shall come into force immediately in the case of new installations and in the case of existing installations the provisions of this sub-rule shall be complied with before the expiry of a period of two years from the commencement of those rules.

4) All earthing systems shall before electric supply lines or apparatus are energized, be tested for electrical resistance to ensure efficient earthing.

5) All earthing systems belonging to the supplier shall, in addition, be tested for resistance on dry day during the dry season not less than once every two years.

6) A record of every earth test made and the result thereof shall be kept by the supplier for a period of not less than two years after the day of testing and shall be available to the Inspector or any officer appointed to assist the Inspector and authorised under sub-rule (2) of Rule 4A when required.

**Rule 64 Use of Energy at High and Extra-High Voltage**

1) The Inspector shall not authorise the supplier to commence supply, or where the supply has

been discontinued for a period of one year and above, to re-commence the supply at high or extra-high voltage to any consumer unless:

a) all conductors and apparatus intended for use at high or extra-high voltage and situated on the premises of the consumer are inaccessible except to an authorised person and all operations in connection with the said conductors and apparatus are carried out only by an authorised person;

b) the consumer has provided and agrees to maintain a separate building or a locked weather-proof and fire-proof enclosure of agreed sign and location, to which the supplier shall at all times have access for the purpose of housing is high or extra-high voltage apparatus and metering equipment, or where the provision of a separate building or enclosure is impracticable, the consumer has segregated the aforesaid apparatus of the supplier from any other part of his own apparatus:

Provided that such segregation shall be by the provision of fire-proof walls, if the Inspector considers it to be necessary:

Provided further that in the case of an out-door installation the consumer shall suitably segregate the aforesaid apparatus belonging to the supplier from his own to the satisfaction of the Inspector.

c) all pole type substations are constructed and maintained in accordance with Rule 69.

2) The following provisions shall be observed where energy at high or extra-high voltage is supplied, converted, transformed or used:

a) All conductors or live parts of any apparatus shall ordinarily be inaccessible.

b) All windings, at high or extra-high voltage of motors or other apparatus within reach from any position in which a person may require to be suitably protected so as to prevent danger.

c) Where transformer or transformers are used, suitable provision shall be made, either by connecting with earth voltage or otherwise, to guard against danger by reason of the said circuit becoming accidentally charged above its normal voltage by leakage from or contact with the circuit at the higher voltage.

d) i) A substation or switch station with apparatus having more than 2 000 litres of oil shall not ordinarily be located in the basement where proper oil drainage arrangements cannot be provided.

ii) Where a substation or switch station with apparatus having more than 2 000 litres of oil is installed whether indoors or outdoors, the following measures shall be taken, namely:

(a) baffle walls shall be erected between the apparatus containing more than 2 000 litres of oil and the adjacent apparatus to prevent spread of fire and avoid damage;

(b) a drain valve of adequate size which shall be capable of being safely operated even when the apparatus has caught fire shall be provided, and such a valve shall be easily accessible to being operated and at the same time not susceptible to being operated inadvertently;

(c) the drain valve shall let out the oil to a covered drainage system which shall take away the oil to a place away from the danger zone;

iii) the above measures shall be taken in addition to other fire protection arrangements to be provided for quenching the fire in the apparatus;

iv) cable trenches inside the substations and switch stations containing cables shall be filled with sand, pebbles or similar non-inflammable materials, or completely covered with non-inflammable slabs.

e) Unless the conditions are such that all the conductors and apparatus for use at high or extra-high voltage may be made dead at the same time for other work thereon, the said conductors and apparatus shall be so arranged that they may be made dead in sections, and that work on any section made dead may be carried on by an authorised person without danger.

f) Only persons authorised under sub-rule (1) of Rule 3 carry out the work on live lines and apparatus.

g) Adequate precautions shall be taken to prevent unauthorised access to any part of the installation designed to be electrically charged at high or extra-high voltage.

## ANNEX C

[*Clause* 4.2.4(b)]

### AREA REQUIRED FOR TRANSFORMER ROOM AND SUBSTATION FOR DIFFERENT CAPACITIES

**C-1** The requirement for area for transformer room and substation for different capacities of transformers is given below for guidance:

| *Sl No.* | *Capacity of Transformer(s)* kVA | *Total Transformer Room Area, Minimum,* $m^2$ | *Total Substation Area (In Coming, HV, MV Panels, Transformer Roof but Without Generators), Minimum* | *Suggested Minimum Face Width* m |
|---|---|---|---|---|
| (1) | (2) | (3) | (4) | (5) |
| i) | 1 × 160 | 14.0 | 90 | 9.0 |
| ii) | 2 × 160 | 28.0 | 118 | 13.5 |
| iii) | 1 × 250 | 15.0 | 91 | 9.0 |
| iv) | 2 × 250 | 30.0 | 121 | 13.5 |
| v) | 1 × 400 | 16.5 | 93 | 9.0 |
| vi) | 2 × 400 | 33.0 | 125 | 13.5 |
| vii) | 3 × 400 | 49.5 | 167 | 18.0 |
| viii) | 2 × 500 | 36.0 | 130 | 14.5 |
| ix) | 3 × 500 | 54.0 | 172 | 19.0 |
| x) | 2 × 630 | 36.0 | 132 | 14.5 |
| xi) | 3 × 630 | 54.0 | 176 | 19.0 |
| xii) | 2 × 800 | 39.0 | 135 | 14.5 |
| xiii) | 3 × 800 | 58.0 | 181 | 14.0 |
| xiv) | 2 × 1 000 | 39.0 | 149 | 14.5 |
| xv) | 3 × 1 000 | 58.0 | 197 | 19.0 |

NOTES

**1** The above dimensions are overall area required for substation excluding generating set.

**2** The clear height required for substation equipment shall be minimum of 3.0 m below the soffit of the beam.

## ANNEX D

[*Clause* 4.2.4(j)]

### ADDITIONAL AREA REQUIRED FOR GENERATOR IN ELECTRIC SUBSTATION

**D-1** The requirement of additional area for generator in electric substation for different capacities of generators is given below for guidance:

| *Sl No.* | *Capacity* kW | *Area* $m^2$ | *Clear Height below the Soffit of the Beam* m |
|---|---|---|---|
| (1) | (2) | (3) | (4) |
| i) | 25 | 56 | 3.6 |
| ii) | 48 | 56 | 3.6 |
| iii) | 100 | 65 | 3.6 |
| iv) | 150 | 72 | 4.6 |
| v) | 248 | 100 | 4.6 |
| vi) | 350 | 100 | 4.6 |
| vii) | 480 | 100 | 4.6 |
| viii) | 600 | 110 | 4.6 |
| ix) | 800 | 120 | 4.6 |
| x) | 1 000 | 120 | 4.6 |
| xi) | 1 250 | 120 | 4.6 |
| xii) | 1 600 | 150 | 4.6 |

NOTE — The area and height required for generating set room given in the above table are for general guidance only and may be finally fixed according to actual requirements.

## ANNEX E

(*Clause* 9.3.2.6)

### FORM OF COMPLETION CERTIFICATE

I/We certify that the installation detailed below has been installed by me/us and tested and that to the best of my/our knowledge and belief, it complies with *Indian Electricity Rules,* 1956.

Electrical Installation at ____________________________________________

Voltage and system of supply

Particulars of Works:

a) Internal Electrical Installation

| | No. | Total Load | Type of system of wiring |
|---|---|---|---|
| i) Light point | | | |
| ii) Fan point | | | |
| iii) Plug point | | | |
| 3-pin 6 A | | | |
| 3-pin 16 A | | | |

| b) Others | Description | hp/kW | Type of starting |
|---|---|---|---|
| 1) Motors: | | | |
| i) | | | |
| ii) | | | |
| iii) | | | |
| 2) Other plants: | | | |

c) If the work involves installations of over head line and/or underground cable

1) i) Type and description of overheadline.
   ii) Total length and number of spans.
   iii) No. of street lights and its description.

2) i) Total length of underground cable and its size:
   ii) No. of joints:
   End joint:
   Tee joint:
   Straight through joint:

Earthing:

i) Description of earthing electrode
ii) No. of earth electrodes
iii) Size of main earth lead

Test Results:

a) Insulation Resistance

i) Insulation resistance of the whole system of conductors to earth…………….. Megaohms.

ii) Insulation resistance between the phase conductor and neutral

Between phase R and neutral ...................... Megaohms.
Between phase Y and neutral ...................... Megaohms.
Between phase B and neutral ...................... Megaohms.

iii) Insulation resistance between the phase conductors in case of polyphase supply.

Between phase R and phase Y ..................... Megaohms
Between phase Y and phase B ..................... Megaohms
Between phase B and phase R ..................... Megaohms

b) Polarity test:

Polarity of non-linked single pole branch switches

c) Earth continuity test:

Maximum resistance between any point in the earth continuity conductor including metal conduits and main earthing lead ......................... Ohms.

d) Earth electrode resistance:

Resistance of each earth electrode.

i) ......................... Ohms.
ii) ......................... Ohms.
iii) ......................... Ohms.
iv) ......................... Ohms.

e) Lightning protective system.

Resistance of the whole of lightning protective system to earth before any bonding is effected with earth electrode and metal in/on the structure…………………………Ohms.

| Signature of Supervisor | Signature of Contractor |
|---|---|
| Name and Address | Name and Address |
| ....................................................... | ........................................................... |
| ....................................................... | ........................................................... |
| ....................................................... | ........................................................... |
| ....................................................... | ........................................................... |

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**LIST OF STANDARDS**

The following list records those standards which are acceptable as 'good practice' and 'accepted standards' in the fulfilment of the requirements of the Code. The latest version of a standard shall be adopted at the time of the enforcement of the Code. The standards listed may be used by the Authority as a guide in conformance with the requirements of the referred clauses in the Code.

| | *IS No.* | *Title* |
|---|---|---|
| (1) | 8270 (Part 1) : 1976 | Guide for preparation of diagrams, charts and tables for electrotechnology: Part 1 Definitions and classification |
| | 1885 (Part 16/Sec 3) 1967 | Electrotechnical vocabulary: Lighting, Section 3 Lamps and auxiliary apparatus |
| | (Part 17) : 1979 | Switchgear and controlgear (*first revision*) |
| | (Part 32) : 1993 | Electrical cables (*first revision*) |
| | (Part 78) : 1993 | Generation, transmission and distribution of electricity — General |
| | 12032 | Graphical symbols for diagrams in the field of electrotechnology: |
| | (Part 6) : 1987 | Protection and conversion of electrical energy |
| | (Part 7) : 1987 | Switchgear, controlgear and protective devices |
| (2) | 7752 (Part 1) : 1975 | Guide for improvement of power factor in consumer installation: Part 1 Low and medium supply voltages |
| (3) | 5216 | Recommendations on safety procedures and practices in electrical work: |
| | (Part 1) : 1982 | General (*first revision*) |
| | (Part 2) : 1982 | Life saving techniques (*first revision*) |
| (4) | 10118 (Part 2) : 1982 | Code of practice for selection, installation and maintenance of switchgear and controlgear: Part 2 Selection |
| (5) | 1646 : 1997 | Code of practice for fire safety of buildings (general): Electrical installations (*second revision*) |

| IS No. | Title |
|---|---|
| (6) 732 : 1989 | Code of practice for electrical wiring installations (*third revision*) |
| 1255 : 1983 | Code of practice for installation and maintenance of power cables (up to and including 33 kV rating) (*second revision*) |
| (7) 13947 : 1993 | Specification for low-voltage switchgear and controlgear |
| (8) 2148 : 1981 | Specification for flame-proof enclosures of electrical apparatus (*second revision*) |
| (9) 5578 : 1985 | Guide for marking of insulated conductors (*first revision*) |
| (10) 1777 : 1978 | Industrial luminaire with metal reflectors (*first revision*) |
| 2206 | Flameproof electric lighting fittings: |
| (Part 1) : 1984 | Well-glass and bulkhead types (*first revision*) |
| (Part 2) : 1976 | Fittings using glass tubes |
| 3287 : 1965 | Industrial lighting fittings with plastic reflectors |
| 3528 : 1966 | Waterproof electric lighting fittings |
| 3553 : 1966 | Specification for watertight electric lighting fittings |
| 4012 : 1967 | Specification for dust-proof electric lighting fittings |
| 4013 : 1967 | Dust-tight electric lighting fittings |
| 5077 : 1969 | Decorative lighting outfits |
| 10322 (Part 5/ Sec 5) : 1987 | Luminaires: Part 5 Particular requirements, Section 5 Flood lights |
| (11) 8828 : 1996 | Electrical accessories — Circuit-breakers for over current protection for household and similar installations (*second revision*) |
| 13947 | Specification for low-voltage switchgear and controlgear: |
| (Part 1) : 1993 | General rules |
| (Part 2) : 1993 | Circuit-breakers |
| (Part 3) : 1993 | Switches, disconnectors, switch disconnectors and fuse combination units |
| (Part 4/Sec 1) : 1993 | Contactors and motor-starters, Section 1 Electro-technical contactors and motor starters |
| (Part 5/Sec 1) : 1993 | Control circuit devices and switching elements, Section 1 Electro-technical control circuit devices |
| (12) 3961 | Recommended current ratings for cables: |
| (Part 1) : 1967 | Paper insulated lead sheathed cables |
| (Part 2) : 1967 | PVC insulated and PVC sheathed heavy duty cables |
| (Part 3) : 1968 | Rubber insulated cables |
| (Part 5) : 1968 | PVC insulated light duty cables |
| (13) 2086 : 1993 | Specification for carriers and bases used in rewirable type electric fuses for voltages upto 650 V (*third revision*) |
| 13703 (Part 1) : 1993 | LV fuses for voltages not exceeding 1 000 V ac or 1 500 dc : Part 1 General requirements |
| (14) 2672 : 1966 | Code of practice for library lighting |
| 4347 : 1967 | Code of practice for hospital lighting |
| 6665 : 1972 | Code of practice for industrial lighting |
| 8030 : 1976 | Specification for luminaires for hospitals |
| (15) 732 : 1989 | Code of practice for electrical wiring installations (*third revision*) |
| (16) 4648 : 1968 | Guide for electrical layout in residential buildings |
| (17) 900 : 1992 | Code of practice for installation and maintenance of induction motors (*second revision*) |
| (18) 2412 : 1975 | Link clips for electrical wiring (*first revision*) |
| (19) 2667 : 1988 | Fittings for rigid steel conduits for electrical wiring (*first revision*) |
| 3419 : 1989 | Fittings for rigid non-metallic conduits (*second revision*) |
| 9537 | Conduits for electrical installations: |

| IS No. | Title |
|---|---|
| (Part 1) : 1980 | General requirements |
| (Part 2) : 1981 | Rigid steel conduits |
| (Part 3) : 1983 | Rigid plain conduits of insulating materials |
| 14772 : 2000 | Specification for accessories for household and similar fixed electrical installations |
| (20) 1913 (Part 1) : 1978 | General and safety requirements for luminaires: Part 1 Tubular fluorescent lamps (*second revision*) |
| (21) 1258 : 1987 | Bayonet lamp holders (*third revision*) |
| (22) 418 : 1978 | Tungsten filament general service electric lamps (*third revision*) |
| 1534 (Part 1) : 1977 | Ballasts for fluorescent lamps: Part 1 For switch start circuits (*second revision*) |
| 1569 : 1976 | Capacitors for use in tubular fluorescent high pressure mercury and low pressure sodium vapour discharge lamp circuit (*first revision*) |
| 2215 : 1983 | Specification for starters for fluorescent lamps (*third revision*) |
| 2418 | Specification for tubular fluorescent lamps for general lighting service: |
| (Part 1) : 1977 | Requirements and tests (*first revision*) |
| (Part 2) : 1977 | Standard lamp data sheets (*first revision*) |
| (Part 3) : 1977 | Dimensions of G-5 and G-13 lc-pin caps (*first revision*) |
| (Part 4) : 1977 | Go and no-go gauges for G-5 and G-13 lc-pin caps (*first revision*) |
| 3323 : 1980 | Bi-pin lampholders for tubular fluorescent lamps (*first revision*) |
| 3324 : 1982 | Holders for starters for tubular fluorescent lamps (*first revision*) |
| 9900 | Basic environmental testing procedures for electronic and electrical items: |
| (Part 1) : 1981 | General |
| (Part 2) : 1981 | Cold test |
| (Part 3) : 1981 | Dry heat test |
| (Part 4) : 1981 | Damp test (steady state) |
| (23) 374 : 1979 | Electric ceiling type fans and regulators (*third revision*) |
| (24) 3043 : 1987 | Code of practice for earthing |
| (25) 8623 (Part 1) : 1993 | Specification for low-voltage switchgear and controlgear assemblies: Part 1 Requirements for type-tested and partially type-tested assemblies (*first revision*) |
| (26) 10028 (Part 2) : 1981 | Code of practice for selection, installation and maintenance of transformers: Part 2 Installation |
| 11353 : 1985 | Guide for uniform system of marking and identification of conductors and apparatus terminals |
| (27) 2309 : 1989 | Code of practice for the protection of buildings and allied structures against lightning (*second revision*) |

# NATIONAL BUILDING CODE OF INDIA

## PART 8 BUILDING SERVICES

### Section 3 Air Conditioning, Heating and Mechanical Ventilation

BUREAU OF INDIAN STANDARDS

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National Building Code Sectional Committee, CED 46

## FOREWORD

This Section deals with various aspects of installation of air conditioning equipments and systems in buildings. The aspects covered include design goals and criteria, design of systems, performance requirements, available system options, pre-planning requirements, noise and vibration, safety aspects, energy conservation and management, building management systems and inspection, installation, testing and commissioning requirements.

Though all aspects of the air conditioning, heating and mechanical ventilation plant have been touched upon in this revision, care has been taken right through to look at them from the specific point of view of how they can be fashioned to impact beneficially on the building as a whole. Thus, topics like pre-planning, safety requirements, adequate provisions for maintenance, energy management, conservation strategies and noise pollution considerations have qualified for special attention.

Space requirements for various air conditioning systems vary considerably with the system adopted. In the scenario of ever-increasing available system options, it has become all the more necessary to consult an air conditioning engineer in this connection at the stage of pre-planning.

Weather data has now been included for as many as 58 stations based on data obtained from India Meteorological Department, Government of India. Till such information is collected for other cities, it is recommended that design work in these cities may be carried out according to the present (local) practice.

The first version of this Part was prepared in 1970 which was subsequently revised in 1983. As a result of experience gained in implementation of 1983 version of this Section and feedback received, a need to revise this Part was felt.

This revision has therefore been prepared. The significant modifications made in this revision include the following:

a) Definitions of several new terms like ozone depletion potential, global warming potential, indoor air quality, sick building syndrome, buildings related illnesses and thermal energy storage have been included.
b) A new clause on design criterion has been incorporated.
c) 'Indoor air quality' has been included as one of the factors that need to be controlled in the conditioned space.
d) For large and multi-storeyed buildings, independent air handling unit rooms have been recommended for each floor.
e) Inside design conditions for various applications have been included; they replace earlier Table 2 and Table 3.
f) The text on minimum outside fresh air has been revised in the light of currently accepted international norms. Recommended values for outside air requirements for ventilation purposes have been furnished for a wider variety and a larger number of applications.
g) New details have been added on temperature, humidity, and vibration and noise.
h) Application considerations, covering a wide variety of commercial applications, offices, hotels, restaurants, computer rooms, etc, have now been given in more details.
j) A new clause on statutory regulation/safety considerations has now been included.
k) Under the clause on design considerations, various system options available have been described.
m) The characteristics and application of options available in piping, water distribution systems and piping layout have been given prominently.
n) The text on air filters has been revised; focus is now on the approach to filtration in preference to a detailed description of ever increasingly available option of filter types.
p) The clause on energy conservation and energy management has been thoroughly revised. The concepts like energy targets, demand targets and consumption targets; the factors to be considered in system

design that influence energy aspects; the need for analysis of operation of systems during various seasons of the year, and the need to incorporate energy recovery strategies have been incorporated in this clause.

q) 'Automatic Controls' given in the 1983 version has now been replaced by Building Management System, which addresses not only the control function, but also has a telling impact on operation and maintenance as well, most importantly on the opportunities afforded to implement various energy conservation strategies.
r) The text on packaged air conditioners and room air conditioners has been revised and elaborated.
s) The text on heating has been completely revised.
t) The text had been thoroughly revised and additional details have been included under Symbols, Units, Colour Code and Identification of Services; Pipe Work Services; Duct Work Services; Valve Labels and Charts; and Inspection, Commissioning and Testing.
u) List of various parameters to be checked for performance of air handling unit, hydronic system balancing, and finally, the hand-over procedure, have been given.

This revision aims to make a difference in the quality of environment and in building usage, in response to growing concerns and expectations in with regard to indoor air quality, energy conservation, environmental impact and building safety.

The provisions on natural ventilation are given in Part 8 'Building Services, Section 1 Lighting and Ventilation'.

The provisions of this Section are without prejudice to the various Acts, Rules and Regulations including the *Factories Act*, 1948 and the rules and regulations framed thereunder.

The information contained in this Section is based largely on the following Indian Standards:

| *IS No.* | *Title* |
|---|---|
| 659 : 1964 | Safety code for air conditioning (*revised*) |
| 1391 | Specification for room air conditioners: |
| (Part 1) : 1992 | Unitary air conditioners (*second revision*) |
| (Part 2) : 1992 | Split air conditioners (*second revision*) |
| 2379 : 1990 | Colour code for identification of pipelines (*first revision*) |
| 3315 : 1994 | Specification for evaporative air coolers (desert coolers) (*second revision*) |
| 7896 : 2001 | Data for outside design conditions for air conditioning for Indian cities (*first revision*) |
| 8148 : 2003 | Specification for packaged air conditioners (*first revision*) |

Assistance has also been derived from the following publications in preparation of this Section:

BS 5720 : 1979 Code of practice for mechanical ventilation and air conditioning in building

Guidelines, Standards and Handbooks of American Society of Heating Refrigerating and Air Conditioning Engineers

Handbooks of Indian Society of Heating, Refrigerating and Air Conditioning Engineers

All standards, whether given herein above or cross-referred to in the main text of this Section, are subject to revision. The parties to agreement based on this Section are encouraged to investigate the possibility of applying the most recent editions of the standards.

# NATIONAL BUILDING CODE OF INDIA

## PART 8 BUILDING SERVICES

## Section 3 Air Conditioning, Heating and Mechanical Ventilation

**1 SCOPE**

This Section covers the design, construction and installation of air conditioning and heating systems and equipment installed in buildings for the purpose of providing and maintaining conditions of air temperature, humidity, purity and distribution suitable for the use and occupancy of the space.

**2 TERMINOLOGY**

**2.0** For the purpose of this Section the following definitions shall apply.

**2.1 Air Conditioning** — The process of treating air so as to control simultaneously its temperature, humidity, purity, distribution and air movement and pressure to meet the requirements of the conditioned space.

**2.2 Atmospheric Pressure** — The weight of air column on unit surface area of earth by atmospheric column. At sea level, the standard atmospheric or barometric pressure is 760 mm of mercury (1 033 mm of water column/101.325 kPa).

Generally atmospheric pressure is used as a datum for indicating the system pressures in air conditioning and accordingly, pressures are mentioned above the atmospheric pressure or below the atmospheric pressure considering the atmospheric pressure to be zero. A 'U' tube manometer will indicate zero pressure when pressure measured is equal to atmospheric pressure.

**2.3 Buildings Related Illnesses (BRI)** — The illness attributed directly to the specific air-borne building contaminants like the outbreak of the Legionnaire's disease after a convention and sensitivity pneumonitis with prolonged exposure to the indoor environment of the building.

Some of the other symptoms relating to BRI are sensory irritation of eyes, ears and throat, skin irritation, headache, nausea, drowsiness, asthma like symptoms in non-asthmatic persons. The economic consequences of BRI is decreased productivity, absenteeism and the legal implications if occupants IAQ complaints are left unresolved.

**2.4 Dewpoint Temperature** — The temperature at which condensation of moisture begins when the air is cooled at same pressure.

**2.5 Dry-Bulb Temperature** — The temperature of the air, read on a thermometer, taken in such a way as to avoid errors due to radiation.

**2.6 Duct System** — A continuous passageway for the transmission of air which, in addition to the ducts, may include duct fittings, dampers, plenums, and grilles and diffusers.

**2.7 Enthalpy** — A thermal property indicating the quantity of heat in the air above an arbitrary datum, in kilo Joules per kg of dry air (or in Btu per pound of dry air).

**2.8 Evaporative Air Cooling** — The evaporative air cooling application is the simultaneous removal of sensible heat and the addition of moisture to the air. The water temperature remains essentially constant at the wet-bulb temperature of the air.

**2.9 Fire Damper** — A closure which consists of a normally held open damper installed in an air distribution system or in a wall or floor assembly and designed to close automatically in the event of a fire in order to maintain the integrity of the fire separation.

**2.10 Fire Separation Wall** — The wall providing complete separation of one building from another or part of a building from another part of the same building to prevent any communication of fire or heat transmission to wall itself which may cause or assist in the combustion of materials of the side opposite to that portion which may be on fire.

**2.11 Global Warming Potential (GWP)** — The potential of a refrigerant to contribute to global warming.

Global warming can make our planet and its climate less hospitable and more hostile to human life, thus necessitating reduction in emission of green house gases such as $CO_2$, $SO_x$, $NO_x$ and refrigerants. Long atmospheric life time of refrigerants results in global warming unless the emissions are controlled.

GWP values of some of the refrigerants are given below:

| *Sl No.* | *Refrigerant* | *GWP Values* |
|---|---|---|
| (1) | (2) | (3) |
| i) | R-12 | 10 600 |
| ii) | R-22 | 1 900 |
| iii) | R-134a | 1 600 |
| iv) | R-123 | 120 |
| v) | R-407c | 1 980 |
| vi) | R-407a | 2 340 |
| vii) | R-410a | 2 340 |

The values indicated above are for an integration period of 100 years.

**2.12 Hydronic Systems** — The water systems that convey heat to or from a conditioned space or process with hot or chilled water. The water flows through piping that connects a chiller or the water heater to suitable terminal heat transfer units located at the space or process.

**2.13 Indoor Air Quality (IAQ)** — Air quality that refers to the nature of conditioned air that circulates throughout the space/area where one works or lives, that is, the air one breathes when indoors.

It not only refers to comfort which is affected by temperature, humidity, air movement and odours but also to harmful biological contaminants and chemicals present in the conditioned space. Poor IAQ may be serious health hazard. Carbon dioxide has been recognized as the surrogate ventilation index.

**2.14 Infiltration/Exfiltration** — The phenomenon of outside air leaking into/out of an air conditioned space.

**2.15 Ozone Depletion Potential (ODP)** — The potential of refrigerant or gases to deplete the ozone in the atmosphere.

The ODP values for various refrigerants are as given below:

| | |
|---|---|
| R-11 | 1.000 |
| R-12 | 0.820 |
| R-22 | 0.050 |
| R-123 | 0.012 |
| R-134a | 0.000 |
| R-407a | 0.000 |
| R-407c | 0.000 |
| R-410a | 0.000 |

Due to high ODP of R-11, R-12 and R-22, their use in the air conditioning and refrigeration is being phased-out. R-123 is also in the phase-out category of refrigerants.

**2.16 Plenum** — An air compartment or chamber to which one or more ducts are connected and which forms part of an air distribution system.

The pressure drop and air velocities in the plenum should be low. Generally, the velocity in plenum should not exceed 1.5 m/s to 2.5 m/s.

**2.17 Positive Ventilation** — The supply of outside air by means of a mechanical device, such as a fan.

**2.18 Psychrometry** — The science involving thermodynamic properties of moist air and the effect of atmospheric moisture on materials and human comfort. It also includes methods of controlling thermal properties of moist air.

**2.19 Psychrometric Chart** — A chart graphically representing the thermodynamic properties of moist air.

**2.20 Recirculated Air** — The return air that has been passed through the conditioning apparatus before being re-supplied to the space.

**2.21 Refrigerant** — The fluid used for heat transfer in a refrigerating system, which absorbs heat at a low temperature and low pressure of the fluid and rejects heat at a higher temperature and higher pressure of the fluid, usually involving changes of state of the fluid.

**2.22 Relative Humidity** — Ratio of the partial pressure of actual water vapour in the air as compared to the partial pressure of maximum amount of water that may be contained at its dry bulb temperature.

When the air is saturated, dry-bulb, wet-bulb and dewpoint temperatures are all equal, and the relative humidity is 100 percent.

**2.23 Return Air** — The air that is collected from the conditioned space and returned to the conditioning equipment.

**2.24 Shade Factor** — The ratio of instantaneous heat gain through the fenestration with shading device to that through the fenestration.

**2.25 Sick Building Syndrome (SBS)** — A term, which is used to describe the presence of acute non-specific symptoms in the majority of people caused by working in buildings with an adverse indoor environment. It could be a cluster of complex irritative symptoms like irritation of the eyes, blockened nose and throat, headaches, dizziness, lethargy, fatigue irritation, wheezing, sinusitis, congestion, skin rash, sensory discomfort from odours, nausea, etc. These symptoms are usually short-lived and experienced immediately after exposure; and may disappear when one leaves the building.

SBS is suspected when significant number of people spending extended time in a building report or experience acute on-site discomfort. The economic consequences of SBS, like BRI, are decreased productivity, absenteeism and the legal implications if occupants IAQ complaints are left unresolved.

**2.26 Smoke Damper** — A damper similar to fire damper, however, having provisions to close automatically on sensing presence of smoke in air distribution system or in conditioned space.

**2.27 Static Pressure** — The pressure that is required to be created by the fan over the atmospheric pressure to overcome the system resistances such as resistances in ducts, elbows, filters, dampers, heating/cooling coils, etc.

Static pressure is measured by a U tube manometer relative to the atmospheric pressure, which is considered as zero pressure. In exhaust systems, fan produces negative static pressure, which is again used to overcome the system resistances.

**2.28 Supply Air** — The air that has been passed through the conditioning apparatus and taken through the duct system and distributed in the conditioned space.

**2.29 Supply and Return Air Grilles and Diffusers** — Grilles and diffusers are the devices fixed in the air conditioned space for distribution of conditioned supply air and return of air collected from the conditioned space for re-circulation.

**2.30 Thermal Transmittance** — Thermal transmission per unit time through unit area of the given building unit divided by the temperature difference between the air or some other fluid on either side of the building unit in 'steady state' conditions.

**2.31 Thermal Energy Storage** — Storage of thermal energy, sensible, latent or combination thereof for use in central system for air conditioning or refrigeration. It uses a primary source of refrigeration for cooling and storing thermal energy for reuse at peak demand or for backup as planned.

**2.32 Water Conditioning** — The treatment of water circulating in a hydronic system, to make it suitable for air conditioning system due to its effect on the economics of air conditioning plant.

Untreated water used in air conditioning system may create problems such as scale formation, corrosion and organic growth. Appraisal of the water supply source including chemical analysis and determination of composition of dissolved solids is necessary to devise a proper water-conditioning programme.

**2.33 Water Hardness** — Hardness in water represented by the sum of calcium and magnesium salts in water, which may also include aluminium, iron, manganese, zinc, etc. A chemical analysis of water sample should provide number of total dissolved solids (TDS) in a water sample in parts per million (ppm) as also composition of each of the salts in parts per million.

Temporary hardness is attributed to carbonates and bi-carbonates of calcium and/or magnesium expressed in parts per million (ppm) as $CaCO_3$. The remainder of the hardness is known as permanent hardness, which is due to sulphates, chloride, nitrites of calcium and/or magnesium expressed in ppm as $CaCO_3$.

Temporary hardness is primarily responsible for scale formation, which results in poor heat transfer resulting in increased cost of energy for refrigeration and air conditioning. Permanent hardness (non-carbonate) is not as serious a factor in water conditioning because it has a solubility which is approximately 70 times greater than the carbonate hardness. In many cases, water may contain as much as 1 200 ppm of non-carbonate hardness and not deposit a calcium sulfate scale.

The treated water where hardness as ppm of $CaCO_3$ is reduced to 50 ppm or below, is recommenced for air conditioning applications.

*p*H is a measure of acidity, *p*H is a negative logaritham base 10, of the concentration of hydrogen ion in grams per litre. Water having a *p*H of 7.0 is neutral, a *p*H value less than 7 is acidic and *p*H value greater than 7 is alkaline. Water with *p*H less than 5 is quite acidic and corrosive to ordinary metals and needs to be treated.

**2.34 Wet-Bulb Temperature** — The temperature registered by a thermometer whose bulb is covered by a wetted wick and exposed to a current of rapidly moving air of velocity not less than 4.5 m/s.

Wet-bulb temperature is indicated by a wet bulb psychrometer constructed and used according to specifications.

## 3 PLANNING DESIGN CRITERIA

### 3.1 Fundamental Requirements

**3.1.1** The object of installing ventilation and air conditioning facilities in buildings shall be to provide conditions under which people can live in comfort, work safely and efficiently.

**3.1.2** Ventilation and air conditioning installation shall aim at controlling and optimizing following factors in the building:

a) Air purity and filtration,
b) Air movement,
c) Dry-bulb temperature,
d) Relative humidity,
e) Noise and vibration,
f) Energy efficiency, and
g) Fire safety.

**3.1.3** All plans, specifications and data for air conditioning, heating and mechanical ventilation systems of all buildings and serving all occupancies within the scope of the Code shall be supplied to the Authority, where called for *see* Part 2 'Administration'.

**3.1.4** The plans for air conditioning, heating and mechanical ventilation systems shall include all details and data necessary for review of installation such as:

a) building: name, type and location;
b) owner: name;
c) orientation: north direction on plans;
d) general plans: dimensions and height of all rooms;
e) intended use of all rooms;
f) detail or description of wall construction, including insulation and finish;
g) detail or description of roof, ceiling and floor construction, including insulation and finish;
h) detail or description of windows and outside doors, including sizes, weather stripping, storm sash, sills, storm doors, etc;
j) internal equipment load, such as number of people, motor, heaters and lighting load;
k) layout showing the location, size and construction of the cooling tower (apparatus), ducts, distribution system;
m) information regarding location, sizes and capacity of air distribution system, refrigeration and heating plant, air handling equipment;
n) information on air and water flow rates;
p) information regarding location and accessibility of shafts;
q) information regarding type and location of dampers used in air conditioning system;
r) chimney or gas vent size, shape and height;
s) location and grade of the required fire separations;
t) water softening arrangement; and
u) information on presence of any chemical fumes or gases.

**3.2 Pre-planning**

**3.2.1** *Design Considerations*

**3.2.1.1** Cooling load estimate shall be carried out prior to installing air conditioning equipment. Calculation of cooling load shall take into account the following factors:

a) Recommended indoor temperature and relative humidity;
b) Outside design conditions as specified in **4.4**;
c) Details of construction and orientation of exposures like roof, floor, walls, partition and ceiling;
d) Fenestration area and shading factors;
e) *Occupancy* — Number of people and their activity;
f) *Ventilation* — Requirement for fresh air;
g) *Internal Load* — Lighting and other heat generating sources like computers, equipment and machinery; and
h) Hours of use.

**3.2.1.2** The design of system and its associated controls shall also take into account the following:

a) Nature of application,
b) Type of construction of building,
c) Permissible control limits,
d) Control methods for minimizing use of primary energy,
e) Opportunities for heat recovery,
f) Energy efficiency,
g) Filteration standard,
h) Hours of use,
j) Diversity factor, and
k) Outdoor air quality.

**3.2.1.3** The operation of system in the following conditions should be considered when assessing the complete design:

a) Summer,
b) Monsoon,
c) Winter,
d) Intermediate seasons,
e) Night, and
f) Weekends and holidays.

**3.2.1.4** Consideration should be given to changes in building load and the system designed so that maximum operational efficiency is maintained.

**3.2.1.5** Special applications like hospitals/operating theatres, computer rooms, clean rooms, laboratories, libraries, museums/art galleries, sound recording studios, shopping malls, etc shall be handled differently.

**3.2.2** *Planning of Equipment Room for Central Air Conditioning Plant*

**3.2.2.1** In selecting the location for plant room, the aspects of efficiency, economy and good practice should be considered and wherever possible it shall be made contiguous with the building. This room shall be located as centrally as possible with respect to the area to be air conditioned and shall be free from obstructing columns.

In the case of large installations (500 TR and above), it is advisable to have a separate isolated equipment room where possible. The clear headroom below soffit of beam should be minimum 4.5 m for centrifugal plants, and minimum 3.6 m for reciprocating and screw type plants.

**3.2.2.2** The floors of the equipment rooms should be light coloured and finished smooth. For floor loading, the air conditioning engineer should be consulted (*see also* Part 6 'Structural Design, Section 1 Loads, Forces and Effects').

**3.2.2.3** Supporting of pipe within plant room spaces should be normally from the floor. However, outside plant room areas, structural provisions shall be made for supporting the water pipes from the floor/ceiling slabs. All floor and ceiling supports shall be isolated from the structure to prevent transmission of vibrations.

**3.2.2.4** Equipment rooms, wherever necessary, shall have provision for mechanical ventilation. In hot climate, evaporative air-cooling may also be considered.

**3.2.2.5** Plant machinery in the plant room shall be placed on plain/reinforced cement concrete foundation and provided with anti-vibratory supports. All foundations should be protected from damage by providing epoxy coated angle nosing. Seismic restraints requirement may also be considered.

**3.2.2.6** Equipment room should preferably be located adjacent to external wall to facilitate equipment movement and ventilation.

**3.2.2.7** Wherever necessary, acoustic treatment should be provided in plant room space to prevent noise transmission to adjacent occupied areas.

**3.2.2.8** Air conditioning plant room should preferably be located close to main electrical panel of the building in order to avoid large cable lengths.

**3.2.2.9** In case air conditioning plant room is located in basement, equipment movement route shall be planned to facilitate future replacement and maintenance. Service ramps or hatch in ground floor slab should be provided in such cases.

**3.2.2.10** Floor drain channels or dedicated drain pipes in slope shall be provided within plant room space for effective disposal of waste water. Fresh water connection may also be provided in the air conditioning plant room.

**3.2.2.11** *Thermal energy storage*

In case of central plants, designed with thermal energy storage its location shall be decided in consultation with the air conditioning engineer. The system may be located in plant room, on rooftop, in open space near plant room or buried in open space near plant room.

For roof top installations, structural provision shall take into account load coming due to the same.

For open area surface installation horizontal or vertical system options shall be considered and approach ladders for manholes provided.

Buried installation shall take into account loads due to movement above, of vehicles, etc.

Provision for adequate expansion tank and its connection to thermal storage tanks shall be made.

**3.2.3** *Planning Equipment Room for Air Handling Units and Package Units*

**3.2.3.1** This shall be located as centrally as possible to the conditioned area and contiguous to the corridors or other spaces for carrying air ducts. For floor loading, air conditioning engineer shall be consulted (*see also* Part 6 'Structural Design, Section 1 Loads, Forces and Effects').

**3.2.3.2** In the case of large and multistoried buildings, independent air handling unit should be provided for each floor. The area to be served by the air-handling unit should be decided depending upon the provision of fire protection measures adopted. Air handling unit rooms should preferably be located vertically one above the other.

**3.2.3.3** Provision should be made for the entry of fresh air. The fresh air intake shall have louvers having rain protection profile, with volume control damper and bird screen.

**3.2.3.4** In all cases air intakes shall be so located as to avoid contamination from exhaust outlets or to the sources in concentrations greater than normal in the locality in which the building is located.

**3.2.3.5** Exterior openings for outdoor air intakes and exhaust outlets shall preferably be shielded from weather and insects.

**3.2.3.6** No air from any dwelling unit shall be circulated directly or indirectly to any other dwelling unit, public corridor or public stairway.

**3.2.3.7** All air handling rooms should preferably have floor drains and water supply. The trap in floor drain shall provide a water seal between the air conditioned space and the drain line.

**3.2.3.8** Supply/return air duct shall not be taken through emergency fire staircase. However, exception can be considered if fire isolation of ducts at wall crossings is carried out.

**3.2.3.9** Waterproofing of air handling unit rooms shall be carried out to prevent damage to floor below.

**3.2.3.10** The floor should be light coloured, smooth finished with terrazzo tiles or the equivalent. Suitable floor loading should also be provided after consulting with the air conditioning engineer.

**3.2.3.11** Where necessary, structural design should avoid beam obstruction to the passage of supply and return air ducts. Adequate ceiling space should be made available outside the air handling unit room to permit installation of supply and return air ducts and fire dampers at air handling unit room wall crossings.

**3.2.3.12** The air handling unit rooms may be acoustically treated, if located in close proximity to occupied areas.

**3.2.3.13** Access door to air handling unit room shall be single/double leaf type, air tight, opening outwards and should have a sill to prevent flooding of adjacent occupied areas. It is desired that access doors in air conditioned spaces should be provided with tight sealing, gaskets and self closing devices for air conditioning to be effective.

**3.2.3.14** It should be possible to isolate the air handling unit room in case of fire. The door shall be fire resistant and fire/smoke dampers shall be provided in supply/return air duct at air handling unit room wall crossings and the annular space between the duct and the wall should be fire-sealed using appropriate fire resistance rated material.

**3.2.3.15** For buildings with large structural glazing areas, care should be taken for providing fresh air intakes in air handling unit rooms. Fire isolation shall be provided for vertical fresh air duct, connecting several air handling units.

**3.2.4** *Planning of Pipe Shafts*

**3.2.4.1** The shafts carrying chilled water pipes should be located adjacent to air handling unit room or within the room.

**3.2.4.2** Shaft carrying condensing water pipes to cooling towers located on terrace should be vertically aligned.

**3.2.4.3** All shafts shall be provided with fire barrier at floor crossings (*see* Part 4 'Fire and Life Safety').

**3.2.4.4** Access to shaft shall be provided at every floor.

**3.2.5** *Planning for Supply Air Ducts and Return Air*

**3.2.5.1** Duct supports, preferably in the form of angles of mild steel supported using stud anchors shall be provided on the ceiling slab from the drilled hole. Alternately, duct supports may be fixed with internally threaded anchor fastners and threaded rods without damaging the slabs or structural members.

**3.2.5.2** If false ceiling is provided, the supports for the duct and the false ceiling, shall be independent. Collars for grilles and diffusers shall be taken out only after false ceiling/boxing framework is done and frames for fixing grilles and diffusers have been installed.

**3.2.5.3** Where a duct penetrates the masonry wall it shall either be suitably covered on the outside to isolate it from masonry, or an air gap shall be left around it to prevent vibration transmission. Further, where a duct passes through a fire resisting compartment/barrier, the annular space shall be sealed with fire sealant to prevent smoke transmission (*see also* Part 4 'Fire and Life Safety').

**3.2.6** *Cooling Tower*

**3.2.6.1** Cooling towers are used to dissipate heat from water cooled refrigeration, air conditioning and industrial process systems. Cooling is achieved by evaporating a small proportion of recirculating water into outdoor air stream. Cooling towers are installed at a place where free flow of atmospheric air is available.

**3.2.6.2** Range of a cooling tower is defined as temperature difference between the entering and leaving water. Approach of the cooling tower is the difference between leaving water temperature and the entering air wet bulb temperature.

**3.2.6.3** *Types of cooling tower*

**3.2.6.3.1** *Natural draft*

This type of tower is larger than mechanical draft tower as it relies on natural convection to obtain the air circulation. A natural draft tower needs to be tall to obtain the maximum chimney effect or rely on the natural wind currents.

**3.2.6.3.2** *Mechanical draft*

The fans on mechanical draft towers may be on the inlet air side (forced draft) or exit air side (induced draft). Typically, these have centrifugal or propeller type fans, depending on pressure drop in tower, permissible sound levels and energy usage requirement. On the basis of direction of air and water flow, mechanical draft cooling towers can be counter flow or cross flow type.

**3.2.6.4** Factors to be considered for cooling tower selection are:

a) Design wet-bulb temperature and approach of cooling tower.
b) Height limitation and aesthetic requirement.
c) Location of cooling tower considering possibility of easy drain back from the system.
d) Placement 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 control.

f) Material of construction for the tower.

g) Direction and flow of wind.

h) Quality of water used for make-up.

j) Maintenance and service space.

k) Ambient air quality.

**3.2.6.5** The recommended floor area requirement for various types of cooling tower is as given below:

| | | |
|---|---|---|
| a) | Natural draft cooling tower | 0.15 to 0.20 $m^2/t$ of refrigeration |
| b) | Induced draft cooling tower | 0.10 to 0.13 $m^2/t$ of refrigeration |
| c) | Fibre-reinforced plastic | 0.07 to 0.08 $m^2/t$ of refrigeration |

**3.2.6.6** Any obstruction to free flow of air to the cooling tower shall be avoided.

**3.2.6.7** Structural provision for the cooling tower shall be taken into account while designing the building. Vibration isolation shall be an important consideration in structural design.

**3.2.6.8** Special design requirements are necessary where noise to the adjoining building is to be avoided.

**3.2.6.9** As given below, certain amount of water is lost from circulating water in the cooling tower:

a) *Evaporation loss* — In a cooling tower, the water is cooled by evaporating a part of the circulating water into the air stream. The amount of circulating water so evaporated is called 'evaporation loss'. Usually it is about 1 percent of the rate of water circulation.

b) *Drift loss* — A small part of circulating water is lost from the cooling tower as liquid droplets entrained in the exhaust air stream. Usually the drift loss is 0.1 percent to 0.2 percent of rate of water circulation.

c) *Blow-down/bleed-off* — To avoid concentration of impurities contained in the water beyond a certain limit, a small percentage of water in the cooling water system is often purposely drained off or discarded. Such a treatment is called 'blow-down' or 'bleed-off'. The amount of blow-down is usually 0.8 percent to 1 percent of the total water circulation.

If simple blow-down is inadequate to control scale formation, chemicals may be added to inhibit corrosion and limit microbiological growth.

Provision shall be made to make-up for the loss of circulating water.

**3.2.6.10** Provision for make-up water tank to the cooling tower shall be made. Make-up water tank to the cooling tower shall be separate from the tank serving drinking water.

**3.2.6.11** Make-up water having contaminants or hardness, which can adversely affect the refrigeration plant life, shall be treated.

**3.2.6.12** Cooling tower should be so located as to eliminate nuisance from drift to adjoining structures.

**3.2.7** *Glazing*

**3.2.7.1** Glazing contributes significantly to heat addition in air conditioned space; measures shall, therefore, be adopted to minimize the gain.

**3.2.7.2** While considering orientation of the building, (*see* Part 8 'Building Services, Section 1 Lighting and Ventilation') glazing in walls subjected to heavy sun exposure shall be avoided. In case it is not possible to do so, double glazing or heat resistant glass should be used. Glazing tilted inward at about 12° also helps curtail transmission of direct solar radiation through the glazing.

**3.2.7.3** Where sun breakers are used, the following aspects shall be kept in view:

a) The sun breakers shall shade the maximum glazed area possible, specially from the altitude and azimuth angle of the sun, which is likely to govern the heat load.

b) The sun breakers shall preferably be light and bright in colour so as to reflect back as much of the sunlight as possible.

c) The sun breakers shall preferably be 1 m away from the wall face, with free ventilation, particularly from top to bottom and are meant for carrying away the heat which is likely to get boxed between the sun breakers and the main building face.

d) The sun breakers shall be installed as to have minimum conduction of heat from sun breakers to the main building.

**3.2.7.4** Where resort is taken to provide reflecting surfaces for keeping out the heat load, care should be taken regarding the hazards to the traffic and people on the road from the reflected light from the surfaces.

**3.2.7.5** Day light transmittance for various type of glass is given in Table 1.

**Table 1 Day Light Transmittance for Various Types of Glass**

| Sl No. | Type of Glass | Visible Transmittance W/($m^2$ °C) |
|---|---|---|
| (1) | (2) | (3) |
| i) | 3 mm regular sheet or plate glass | 0.86 to 0.91 |
| ii) | 3 mm grey sheet glass | 0.31 to 0.71 |
| iii) | 5 mm grey sheet glass | 0.61 |
| iv) | 5.5 mm grey sheet glass | 0.14 to 0.56 |
| | 6 mm grey sheet glass | 0.52 |
| v) | 6 mm green/float glass | 0.75 |
| vi) | 6 mm grey plate glass | 0.44 |
| vii) | 6 mm bronze plate glass | 0.49 |
| viii) | 13 mm grey plate glass | 0.21 |
| ix) | 13 mm bronze plate glass | 0.25 |
| x) | Coated glasses (single, laminated, insulating) | 0.07 to 0.50 |

**3.2.8** *Roof Insulation*

**3.2.8.1** Under-deck or over-deck insulation shall be provided for exposed roof surface using suitable insulating materials. Over-deck insulation should be properly waterproofed to prevent loss of insulating properties.

**3.2.8.2** The overall thermal transmittance from the exposed roof should be kept as minimum as possible and under normal conditions, the desirable value should not exceed 0.58 W/($m^2$ °C).

**3.2.8.3** The ceiling surface of floors which are not to be air conditioned may be suitably insulated to give an overall thermal transmittance not exceeding 1.16 W/($m^2$ °C)

## 4 DESIGN OF AIR CONDITIONING

### 4.1 General

A ventilation and air conditioning system installed in a building should clean, freshen and condition the air within the space to be air conditioned. This can be achieved by providing the required amount of fresh air either to remove totally or to dilute odours, fumes, etc (for example, 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.

It is desirable that access doors to air conditioned space are provided with tight sealing gaskets and self closing devices for air conditioning to be effective.

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 any flue outlets, dry cleaning or washing machine extraction outlets, kitchen, water-closets, 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 position them well away from roadways and car parks.

### 4.2 Design Considerations

**4.2.1** *Types of System*

Systems for air conditioning need to control temperature and humidity within predetermined limits throughout the year. Various types of refrigerating systems are available to accomplish the tasks of cooling and dehumidifying, which are an essential feature of air conditioning. Systems for air conditioning may be grouped as all-air type, air and water type, all water type or unitary type.

**4.2.1.1** *All-air system*

This type of air conditioning system provides complete sensible and latent cooling, preheating and humidification in the air supplied by the system. 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 systems may be used. High velocity systems although require smaller ducts, are high on fan energy, require careful acoustic treatment and higher standards of duct construction.

**4.2.1.1.1** *Constant volume system*

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

**4.2.1.1.2** *Variable volume system*

Most Indian air 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 can be applied to interior or perimeter zones, with common or separate fans, with common or separate air temperature control. The greatest energy saving associated with VAV occurs at the perimeter zones, where variation in solar and outside temperature allow the supply air quantity to be reduced. 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.

**4.2.1.2** *Air and water system*

Control of conditions within the space is achieved by initial control of the supply air from a central plant but with main and final control at a terminal unit within the conditioned space. The supply air provides the necessary ventilation air and the small part of the total conditioning. The major part of 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 chilled or hot 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 lowest of all 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 these units 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 supply 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 throughout the year.

**4.2.1.3** *All water system*

In the simplest layout, the fan coil 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 out put may be achieved by fan speed and water flow/temperature control. Electric power is required at each terminal unit.

Provision of variable volume water flow system for chilled water circulation is recommended for varying load conditions. This may be incorporated with the help of constant volume primary chilled water circuit and variable flow secondary chilled water circuit having pumps with variable speed drives and pressure sensor to control the speed. This system allows better control on energy consumption under partial load conditions due to diversity or seasonal load variations.

**4.2.1.4** *Unitary 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 applications but specially designed units are also available for process and industrial applications.

**4.2.2** *Vapour Compression Water Chiller*

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 on resilient mountings. Pipe connection require flexible couplings; these should be considered in conjunction with the design of the pump mountings and the pipe supports.

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 large 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 cooler.

It is normal for installation to have several water chilling packages, both to provide for stand-by and 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 the 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 consequent reduction in the compressor power. It is important, for economy in the operation, that the optimum equipment selection and design of the control system is achieved.

The classification of the water chilling packages is by the type of compressor.

**4.2.2.1** *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 stage of compression are used. Two stage units often incorporate an interstate economizer for improving efficiency.

The compressor can be modulated down to approaching 10 percent of full load capacity, with some control of the condensing pressure. Because of the nature of 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 limits. This phenomenon, known as surging, is a serious problem but occurs only 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 to the compressor or its drive and does increase the noise level.

The use of low pressure refrigeration 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 these interfere with the operation of the plant and cause corrosion.

The compressors may be driven either directly by electric motor or via a speed-increasing gear train. Units are available in 'open' form, that is, 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. The latter type eliminates the drive shaft gland seal (a potential point of leakage), which is necessary on the former.

Certain types of open centrifugal compressors could conveniently be directly driven by a steam or gas turbine. This arrangement could be advantageous when the refrigeration plant forms part of total energy system.

The centrifugal compressor type water chilling packages normally include a shell-and-tube water cooled condenser and a flooded shell-and-tube evaporator, but unit are also available incorporating an air cooled condenser The expansion device is commonly an electronic expansion valve or high pressure float regulating valve.

**4.2.2.2** *Screw compressors*

Two types of screw compressors are available, that is, 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 with in 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 percent efficient and so a small quantity of oil always passes through with the refrigerant. On systems using a direct expansion evaporator the oil is trapped in the evaporator and an oil recovery system is necessary.

With some systems oil cooler is required in the oil circulation system, to remove the heat gathered by the oil during compression cycle. 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 penalty on the plant capacity.

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 electronic expansion valve (single or in multiple) of conventional or modified form.

Screw compressors are available in open and semi-hermetic form (*see* **4.2.2.1**) and are generally coupled direct to two-pole motors. The capacity of the compressor can be modulated down to 10 percent of full load capacity.

**4.2.2.3** *Reciprocating compressors*

These are available in a wide range of sizes and designs. They are almost invariably used in packages up to 120 TR cooling capacity.

Because the cylinders have automatic valves, a single compressor may be used over 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 in-operative, usually by propping open the suction valves, thus, capacity reduction is in a series of steps rather than by modulation. Typically, a four-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 package including 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 unit 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.

**4.2.3** *Absorption System*

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 mostly used in liquid-chilling applications. These are most suitable for hotels and hospitals where steam is readily available from the boilers.

**4.2.3.1** *Indirect firing*

The lithium bromide/water absorption system can be powered by medium or high temperature hot water and low or medium pressure steam. 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. Water and absorbent solutions are circulated within the unit by electrically driven pumps.

Capacity control down to 10 percent 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.

**4.2.3.2** *Direct firing*

Direct fired lithium bromide/water absorption plants have become common, by incorporating precise control of generator 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 or 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.

**4.3 System Design**

**4.3.1** *Ductwork and Air Distribution*

**4.3.1.1** *Materials*

Ductwork is normally fabricated, erected and finished to the requirements in accordance with accepted standard [8-3(1)]. Designers should specify the requirements as appropriate for the velocity and pressure, and materials to be employed. Ductwork is generally manufactured from galvanized steel sheet. Ductwork may also be manufactured from aluminium sheet for applications like operation theatres and intensive care units where stringent cleanliness standards are a functional requirement. Galvanized steel sheets shall be in accordance with the accepted standard [8-3(2)] whereas aluminium sheet shall be in accordance with the accepted standard [8-3(3)]. 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.

**4.3.1.2** *Ductwork design*

Design calculations made to determine the size and configuration of ductwork in respect of pressure drop and noise generation should conform to standard methods.

Ductwork design should also take into account the recommendations for fire protection (*see* Part 4 'Fire and Life Safety') relating to the design of air handling system to fire and smoke control in buildings.

**4.3.1.3** *Layout consideration*

When designing ductwork, consideration should be given to:

a) Co-ordination with building, architectural and structural requirements;
b) Co-ordination with other services;
c) Simplifying installation work;
d) Providing facilities and access for commissioning and testing;
e) Providing facilities and access for operating and maintenance;
f) Meeting fire and smoke control requirement; and
g) Prevention of vibration and noise transmission to the building/space.

**4.3.2** *Piping and Water Distribution System*

**4.3.2.1** *Materials*

Steel piping with welded or flanged joints is commonly used. Flanges for flanged joints are welded to pipes. The choice of materials or any installation will be governed by economic considerations, but care should be taken to minimize the possibility of corrosion when choosing material combinations.

**4.3.2.2** *Design principles*

The system design should achieve the following two main objectives:

a) A good distribution of water to the various heat exchangers/cooling coils at all conditions of load. This will be influenced by the method chosen to control the heat transfer capacity of air handling units. Failure to achieve good hydraulic design may lead to difficulties with system balancing. Adequate provision should be made for measuring flow rates and pressure differentials.
b) An economic balance between pipe size and piping cost.

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

When multiple water-chilling packages have 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 satisfactory result by considering control and system design separately.

Temperature changes in the system lead to changes in the volume of water, which has to be allowed to expand into a suitable expansion tank. It is essential that the point at which the expansion tank is connected into the system be such that it is never shutoff. It is normal practice to locate the expansion 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. Closed expansion tank with air separator in the chilled water system helps in improving the life and efficiency of chilled water piping and heat exchange equipment.

For central chilled water air conditioning systems, water is the usual heat transfer medium use to convey the heat from the air-handling units 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.

**4.3.2.3** *Piping design*

The arrangement of the water piping will depend upon the cooling or heating systems chosen as being the most suitable for the building.

The water velocity normally used are dependent on pipe size but are usually in the range 1 m/s to 3 m/s. Main headers in the plant room are designed for very low velocity around 1 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.

Friction factor in piping should not exceed 5 m of water for 100 m of pipe length. The power consumed in circulating the water around the system is proportional to the pressure loss (due to friction) and the flow. It is therefore an advantage to design system with a water temperature rise say 5°C-7°C which results in minimising the flow rate.

Air-conditioning system 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 partial load. This should be done with variable speed pumping systems.

**4.3.2.4** *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. The pumps 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 testing and commissioning. Piping system should be designed to permit proper cleaning and flushing and should include suitable strainers at appropriate locations.

**4.3.3** *Thermal Insulation*

**4.3.3.1** Air conditioning and water distribution systems carry chilled or heated 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 materials.

**4.3.3.2** The selection of suitable thermal insulating materials requires that consideration be given to 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) Material should not give rise to objectionable odour at the temperature at which they are to be used.
d) The material 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) It should have a low thermal conductivity throughout the entire working temperature range.
f) It should be non-flammable and should not support nor spread fire.
g) It should have good mechanical strength and rigidity otherwise it would have to be cladded for protection.

**4.4 Design Conditions**

**4.4.1** *Temperature*

**4.4.1.1** *General consideration*

Certain minimum temperatures may be required depending on type of application and by local regulations. Maximum permitted cooling temperatures may be stipulated by 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 large windows/curtain walls are used, it may be necessary to provide shading/north orientation 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 comfort, depends not only on the air temperature but also on the 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.

**4.4.1.2** *Design temperatures*

It should be noted that, although comfort conditions are established in terms of resultant temperature, the design air temperature for air conditioning should be as specified in this Section in terms of dry-bulb temperature and relative humidity or wet-bulb temperature.

**4.4.2** *Humidity*

**4.4.2.1** *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 (RH) values between 40 percent and 70 percent are acceptable.

**4.4.3** *Inside Design Conditions*

The inside design conditions for some of the applications are indicated in Table 2.

**4.4.4** *Outside Design Conditions*

The outside design conditions (dry-bulb and mean coincidental wet-bulb) taken shall be in accordance with the summary of the conditions given in the Table 3.

Values of ambient dry-bulb and wet-bulb temperatures against the various annual percentiles represent the value that is exceeded on average by the indicated percentage of the total number of hours. The 0.4 percent, 1.0 percent, 2.0 percent values are exceeded on average 35, 88 and 175 h in a year. The 99.0 percent and 99.6 percent values are defined in the same way but are usually reckoned as the values for which the corresponding weather elements are less than the design conditions for 88 h and 35 h, respectively.

Mean coincidental values are the average of the indicated weather element occurring concurrently with the corresponding design value.

After the calculation of design dry-bulb temperatures, the programme located the values of corresponding wet-bulb temperatures from the database for that particular station, the average of these values were computed, which were then called mean of coincidental wet-bulb temperature.

In the same way design wet-bulb temperatures and coincidental dry-bulb temperatures were evaluated.

*Selection*: The design values of 0.4 percent, 1.0 percent and 2.0 percent annual cumulative frequency of occurrence may be selected depending upon application of air conditioning system.

For normal comfort jobs values under 1 percent column could be used for cooling loads and 99 percent column

## Table 2 Inside Design Conditions for Some Applications

(*Clause* 4.4.3)

| Sl No. | Category | Inside Design Conditions | |
|---|---|---|---|
| | | Summer | Winter |
| (1) | (2) | (3) | (4) |
| i) | Restaurants | DB 23 to 26°C<br>RH 55 to 60% | DB 21 to 23°C<br>RH not less than 40% |
| ii) | Office buildings | DB 23 to 26°C<br>RH 50 to 60% | DB 21 to 23°C<br>RH not less than 40% |
| iii) | Radio and television studios | DB 23 to 26°C<br>RH 45 to 55% | DB 21 to 23°C<br>RH 40 to 50% |
| iv) | Departmental stores | DB 23 to 26°C<br>RH 50 to 60% | DB 21 to 23°C<br>RH not less than 40% |
| v) | Hotel guest rooms | DB 23 to 26°C<br>RH 50 to 60% | DB 23 to 24°C<br>RH not less than 40% |
| vi) | Class rooms | DB 23 to 26°C<br>RH 50 to 60% | DB 23 to 24°C<br>RH not less than 40% |
| vii) | Auditoriums | DB 23 to 26°C<br>RH 50 to 60% | DB 23 to 24°C<br>RH not less than 40% |
| viii) | Recovery rooms | DB 24 to 26°C<br>RH 45 to 55% | |
| ix) | Patient rooms | DB 24 to 26°C<br>RH 45 to 55% | |
| x) | Operation theatres | DB 17 to 27°C<br>RH 45 to 55% | |
| xi) | Museums and libraries | DB 20 to 22°C<br>RH 40 to 55% | |
| xii) | Telephone terminal rooms | DB 22 to 26°C<br>RH 40 to 50% | |

## Table 3 Summary for Outdoor Conditions

(*Clause* 4.4.4)

| Station | Cooling DB/MCWB | | | | | | Cooling WB/MCDB | | | | | | Heating DB/MCWB | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0.4% | | 1.0% | | 2.0% | | 0.4% | | 1.0% | | 2.0% | | 99.6% | | 99.0% | |
| | DB | MCWB | DB | MCWB | DB | MCWB | WB | MCDB | WB | MCDB | WB | MCDB | DB | MCWB | DB | MCWB |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) | (14) | (15) | (16) | (17) |
| Ahmedabad | 42.3 | 24.1 | 41.2 | 23.5 | 40.0 | 24.3 | 28.7 | 34.3 | 28.2 | 33.6 | 27.8 | 33.1 | 11.5 | 9.0 | 12.9 | 9.8 |
| Akola | 43.4 | 24.0 | 42.2 | 23.3 | 41.0 | 23.6 | 27.6 | 37.8 | 26.7 | 34.4 | 26.1 | 33.5 | 12.7 | 10.3 | 13.9 | 10.6 |
| Allahabad | 43.7 | 23.4 | 42.2 | 23.5 | 40.8 | 22.7 | 28.8 | 33.0 | 28.4 | 32.8 | 28.0 | 32.6 | 7.9 | 7.0 | 9.1 | 8.3 |
| Amritsar | 41.6 | 23.2 | 40.3 | 24.6 | 38.9 | 24.4 | 29.3 | 34.8 | 28.8 | 34.8 | 28.4 | 33.4 | 2.7 | 2.3 | 4.0 | 3.5 |
| Aurangabad | 40.3 | 22.1 | 39.3 | 22.9 | 38.3 | 21.3 | 26.3 | 36.2 | 25.3 | 33.1 | 24.7 | 31.4 | 10.6 | 8.2 | 12.0 | 9.1 |
| Bangalore | 34.7 | 19.6 | 34.0 | 19.6 | 33.1 | 19.2 | 23.5 | 28.9 | 22.9 | 28.2 | 22.5 | 27.7 | 14.9 | 13.0 | 15.7 | 13.8 |
| Barmer | 43.1 | 24.2 | 42.0 | 23.6 | 41.0 | 23.3 | 28.5 | 37.9 | 27.8 | 35.3 | 27.2 | 33.3 | 9.5 | 5.1 | 10.7 | 5.5 |
| Belgaum | 36.5 | 19.4 | 35.7 | 19.6 | 34.7 | 19.2 | 24.3 | 29.2 | 23.8 | 29.5 | 23.4 | 28.2 | 13.2 | 11.3 | 14.3 | 12.2 |
| Bhagalpur | 42.4 | 26.8 | 40.7 | 27.4 | 38.9 | 25.6 | 30.0 | 37.1 | 29.6 | 36.4 | 29.2 | 35.2 | 11.4 | 10.3 | 12.6 | 12.4 |
| Bhopal | 41.7 | 22.0 | 40.5 | 21.7 | 39.3 | 21.3 | 26.0 | 31.0 | 25.6 | 30.3 | 25.2 | 29.9 | 9.8 | 6.8 | 11.0 | 8.0 |
| Bhubaneshwar | 38.9 | 25.5 | 37.6 | 26.6 | 36.3 | 26.3 | 29.4 | 35.2 | 28.9 | 33.3 | 28.5 | 32.7 | 14.4 | 13.1 | 15.4 | 14.0 |
| Bikaner | 44.8 | 22.4 | 43.4 | 22.4 | 42.0 | 23.1 | 28.5 | 34.6 | 27.9 | 33.1 | 27.3 | 34.7 | 3.8 | 2.2 | 5.3 | 3.1 |
| Chennai | 38.4 | 26.2 | 37.3 | 26.7 | 36.3 | 26.4 | 29.1 | 33.8 | 28.6 | 33.2 | 28.1 | 31.9 | 19.5 | 20.2 | 18.7 | 19.3 |
| Chitradurg | 36.6 | 18.8 | 35.8 | 19.0 | 35.0 | 19.6 | 23.9 | 28.9 | 23.5 | 28.2 | 23.2 | 28.5 | 15.4 | 12.5 | 16.4 | 13.3 |
| Dehradun | 37.8 | 23.5 | 36.3 | 23.9 | 34.8 | 22.8 | 27.0 | 31.3 | 26.5 | 30.1 | 26.0 | 29.8 | 5.9 | 5.0 | 6.8 | 5.8 |
| Dibrugarh | 34.0 | 27.4 | 33.2 | 26.8 | 32.3 | 26.7 | 28.3 | 32.6 | 27.8 | 31.8 | 27.4 | 31.3 | 7.5 | 7.2 | 8.7 | 8.4 |
| Gorakhpur | 41.4 | 26.2 | 40.3 | 26.0 | 39.1 | 26.4 | 29.9 | 35.2 | 29.7 | 35.5 | 29.4 | 34.7 | 7.9 | 7.5 | 9.0 | 8.4 |
| Guwahati | 34.4 | 26.9 | 33.4 | 27.3 | 32.7 | 26.8 | 28.8 | 32.4 | 28.3 | 31.8 | 27.9 | 31.5 | 10.2 | 9.8 | 11.3 | 10.8 |

**Table 3 — *Concluded***

| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) | (14) | (15) | (16) | (17) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Gwalior | 43.9 | 23.0 | 42.5 | 22.9 | 41.3 | 23.5 | 27.9 | 32.9 | 27.6 | 32.4 | 27.3 | 32.7 | 4.9 | 3.8 | 6.4 | 5.3 |
| Hissar | 44.7 | 26.5 | 43.3 | 25.8 | 41.7 | 27.9 | 30.1 | 40.2 | 29.9 | 39.0 | 29.4 | 36.8 | 5.0 | 4.2 | 6.1 | 5.2 |
| Hyderabad | 40.4 | 22.5 | 39.2 | 22.5 | 38.2 | 22.4 | 25.6 | 33.7 | 25.2 | 32.4 | 24.8 | 32.0 | 14.4 | 12.4 | 15.5 | 12.9 |
| Imphal | 31.1 | 23.3 | 30.2 | 23.5 | 29.6 | 22.9 | 25.0 | 29.5 | 24.6 | 28.6 | 24.3 | 28.3 | 3.9 | 3.6 | 5.0 | 4.6 |
| Indore | 41.1 | 20.7 | 40.4 | 20.6 | 38.9 | 21.0 | 25.7 | 31.0 | 25.2 | 30.0 | 24.8 | 29.8 | 8.2 | 5.0 | 9.7 | 6.5 |
| Jabalpur | 42.6 | 22.7 | 41.2 | 23.2 | 39.8 | 22.5 | 26.8 | 31.8 | 26.4 | 32.0 | 26.0 | 31.2 | 7.8 | 6.7 | 9.3 | 7.6 |
| Jagdelpur | 39.4 | 22.3 | 38.6 | 22.5 | 37.4 | 22.4 | 26.4 | 32.4 | 25.9 | 31.8 | 25.4 | 30.7 | 8.9 | 7.9 | 10.1 | 8.7 |
| Jaipur | 42.8 | 22.5 | 41.4 | 22.6 | 39.4 | 22.6 | 27.4 | 33.1 | 27.0 | 32.1 | 26.6 | 31.7 | 6.4 | 4.5 | 8.0 | 5.8 |
| Jaisalmer | 43.7 | 23.7 | 42.5 | 23.1 | 41.4 | 23.5 | 27.7 | 34.8 | 27.3 | 34.5 | 26.9 | 34.4 | 5.0 | 2.5 | 6.5 | 3.7 |
| Jamnagar | 37.1 | 24.4 | 36.1 | 25.6 | 35.3 | 25.1 | 29.2 | 33.0 | 28.4 | 32.5 | 27.9 | 32.0 | 10.0 | 8.6 | 11.7 | 10.5 |
| Jodhpur | 42.0 | 23.2 | 40.8 | 23.0 | 39.6 | 22.7 | 28.0 | 35.4 | 27.4 | 33.7 | 26.9 | 33.8 | 7.5 | 4.3 | 8.7 | 5.4 |
| Jorhat | 34.4 | 28.2 | 33.6 | 27.7 | 32.9 | 27.3 | 28.7 | 32.7 | 28.3 | 32.1 | 28.0 | 31.8 | 9.6 | 9.0 | 10.6 | 10.1 |
| Kolkata | 37.2 | 25.4 | 36.2 | 26.1 | 35.2 | 26.5 | 29.5 | 34.3 | 29.0 | 33.4 | 28.6 | 32.7 | 12.0 | 10.9 | 13.1 | 12.9 |
| Kota | 43.5 | 23.0 | 42.4 | 22.6 | 41.2 | 22.6 | 27.3 | 35.2 | 26.8 | 33.0 | 26.5 | 31.8 | 9.9 | 6.7 | 10.8 | 7.6 |
| Kurnool | 41.6 | 23.2 | 40.3 | 24.6 | 38.9 | 24.4 | 29.3 | 34.8 | 28.8 | 34.8 | 28.4 | 33.4 | 2.7 | 2.3 | 4.0 | 3.5 |
| Lucknow | 42.0 | 24.2 | 40.8 | 24.8 | 39.3 | 24.5 | 28.8 | 33.3 | 28.4 | 32.4 | 28.0 | 32.2 | 7.5 | 6.8 | 8.4 | 7.7 |
| Mangalore | 33.9 | 24.4 | 33.9 | 24.0 | 33.4 | 24.2 | 27.1 | 31.0 | 26.7 | 31.0 | 26.4 | 30.7 | 19.7 | 17.0 | 20.5 | 18.1 |
| Mumbai | 35.3 | 22.8 | 34.3 | 23.3 | 33.5 | 24.0 | 27.9 | 31.8 | 27.5 | 31.3 | 27.2 | 31.1 | 16.5 | 13.9 | 17.8 | 14.8 |
| Nagpur | 43.8 | 23.6 | 42.6 | 23.9 | 41.4 | 23.6 | 27.3 | 31.2 | 26.6 | 33.2 | 26.2 | 31.9 | 11.5 | 9.4 | 12.8 | 10.2 |
| Nellore | 40.4 | 27.8 | 39.0 | 28.1 | 37.8 | 27.2 | 30.0 | 37.1 | 29.4 | 35.4 | 28.8 | 34.0 | 19.4 | 18.3 | 20.2 | 19.3 |
| New Delhi | 41.8 | 23.6 | 40.6 | 23.8 | 39.4 | 23.5 | 28.4 | 33.3 | 28.0 | 33.3 | 27.6 | 32.7 | 6.0 | 5.2 | 7.1 | 6.3 |
| Panjim | 34.0 | 24.8 | 33.5 | 25.2 | 33.0 | 25.2 | 27.7 | 32.3 | 27.4 | 31.5 | 27.0 | 30.9 | 19.6 | 17.8 | 20.3 | 18.7 |
| Patna | 40.7 | 23.4 | 39.5 | 23.7 | 38.0 | 24.7 | 29.0 | 33.9 | 28.6 | 33.1 | 28.3 | 32.6 | 8.0 | 7.6 | 9.2 | 8.6 |
| Pune | 38.4 | 20.5 | 37.4 | 20.4 | 36.3 | 20.6 | 24.8 | 30.9 | 24.4 | 30.6 | 24.0 | 29.6 | 9.2 | 8.0 | 10.3 | 9.2 |
| Raipur | 43.6 | 23.3 | 42.2 | 23.3 | 40.8 | 23.0 | 27.1 | 31.8 | 26.8 | 32.0 | 26.5 | 31.2 | 11.3 | 9.9 | 12.6 | 10.4 |
| Rajkot | 40.8 | 23.1 | 39.9 | 23.8 | 38.9 | 23.4 | 28.1 | 33.9 | 27.6 | 33.3 | 27.1 | 32.3 | 10.9 | 6.5 | 12.2 | 7.7 |
| Ramagundam | 43.4 | 25.6 | 42.2 | 25.1 | 40.7 | 25.8 | 28.3 | 37.3 | 27.9 | 35.6 | 27.4 | 34.4 | 12.5 | 11.2 | 13.7 | 12.5 |
| Ranchi | 38.9 | 22.1 | 37.7 | 21.8 | 36.4 | 21.5 | 26.2 | 31.7 | 25.6 | 30.4 | 25.2 | 29.2 | 9.1 | 7.2 | 10.4 | 8.3 |
| Ratnagiri | 34.1 | 22.4 | 33.4 | 23.2 | 32.8 | 23.6 | 27.6 | 31.1 | 27.3 | 30.8 | 27.0 | 30.2 | 18.3 | 14.9 | 19.2 | 16.5 |
| Raxaul | 38.6 | 23.1 | 36.9 | 24.5 | 35.5 | 24.6 | 28.9 | 33.0 | 28.4 | 32.0 | 28.1 | 31.8 | 7.5 | 7.3 | 8.5 | 8.2 |
| Saharanpur | 41.3 | 23.8 | 39.6 | 24.6 | 38.1 | 24.0 | 28.5 | 33.6 | 28.1 | 32.9 | 27.8 | 32.5 | 1.7 | 1.5 | 3.0 | 2.7 |
| Shillong | 24.2 | 19.7 | 23.5 | 19.4 | 22.8 | 18.9 | 20.7 | 23.3 | 20.3 | 22.7 | 19.9 | 22.2 | –1.0 | –1.1 | 0.1 | –0.5 |
| Sholapur | 41.1 | 21.6 | 40.1 | 21.6 | 39.1 | 21.2 | 26.6 | 32.6 | 25.8 | 32.1 | 25.1 | 31.5 | 16.3 | 12.4 | 17.2 | 12.5 |
| Sundernagar | 36.1 | 19.1 | 34.6 | 19.9 | 33.1 | 19.4 | 25.2 | 30.1 | 24.8 | 29.2 | 24.4 | 28 | 1.8 | 1.3 | 2.8 | 2.2 |
| Surat | 38.4 | 22.7 | 36.9 | 23.9 | 35.7 | 23.4 | 28.3 | 32.4 | 27.9 | 31.7 | 27.6 | 31.4 | 14.8 | 12.6 | 16.2 | 12.5 |
| Tezpur | 34.2 | 27.4 | 33.3 | 26.5 | 32.5 | 27.1 | 28.9 | 32.8 | 28.4 | 31.8 | 28.0 | 31.4 | 10.5 | 10.0 | 12.4 | 10.9 |
| Tiruchirapalli | 39.6 | 24.6 | 38.7 | 25.1 | 37.8 | 24.9 | 27.7 | 34.5 | 27.2 | 33.7 | 26.9 | 33.3 | 19.3 | 18.2 | 20.1 | 18.7 |
| Thiruvananthapuram | 33.9 | 26.0 | 33.4 | 26.1 | 32.9 | 25.9 | 27.7 | 32.4 | 27.4 | 31.9 | 27.0 | 31.0 | 21.6 | 20.1 | 22.2 | 20.8 |
| Veraval | 35.2 | 23.9 | 33.8 | 23.5 | 32.8 | 26.6 | 29.1 | 32.3 | 28.7 | 31.6 | 28.4 | 31.1 | 14.3 | 10.1 | 15.6 | 12.3 |
| Visakhapatnam | 36.4 | 26.5 | 35.6 | 27.3 | 35.0 | 27.1 | 29.2 | 33.8 | 28.8 | 33.0 | 28.4 | 32.5 | 15.4 | 14.9 | 16.8 | 16.2 |

NOTE — Abbreviations used:

DBT — Dry-bulb temperature
WBT — Wet-bulb temperature
MCDB — Mean coincidental dry-bulb temperature
MCWB — Mean coincidental wet-bulb temperature.

for heating loads. For critical applications values under 0.4 percent column could be used for cooling loads and 99.6 percent column for heating loads.

For critical jobs and high energy consumption applications, hourly load analysis should be evaluated using computer programmes.

For industrial and other specific applications, the design conditions shall be as per user's requirement.

Adequate movement of air shall always be provided in an air conditioned enclosure, but velocities in excess of 0.5 m/s in the zone between floor level and 1.5 m level shall generally be avoided; in the case of comfort air conditioning, recommended air velocity is 0.13 m/s to 0.23 m/s in this zone, except in the vicinity of a supply or return air grille.

**4.4.5** *Minimum Outside Fresh Air*

The fresh air supply is required to maintain an acceptably non-odorous atmosphere (by diluting body odorous and tobacco smoke) and to dilute the carbon dioxide exhaled. This quantity may be quoted per person and is related to the occupant density and activity within the space. Table 4 gives minimum fresh air supply rates for mechanically ventilated or air conditioned space. The quantity and distribution of introduced fresh air should take into account the natural infiltration of the building.

Table 4 specifies requirements for ventilation air quantities for 100 percent outdoor air when the outdoor air quality meets the specifications for acceptable outdoor air quality. While these quantities are for 100 percent outdoor air, they also set the amount of air required to dilute contaminants to acceptable levels. Therefore, it is necessary that at least this amount of air be delivered to the conditioned space at all times the building is in use.

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 shall be controlled to balance the cooling demand. However, when the air is too warm or humid the quantity may be reduced to a minimum to reduce the cooling load.

For 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, lighting, 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 re-circulated 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 and heating range of the air.

**4.4.6** *Air Movement*

a) *In air conditioned spaces* — 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 distribution system therefore has a controlling effect of the quantity and temperature of the air that may 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 re-circulation within the space or by inducing air movement with the ventilation air system.

b) *In buildings* — Air flow within a building should be controlled to minimize transfer of fumes and smells, for example 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 may cause difficulty in opening door or cause them to slam. In other cases, such as computer room, the area may be pressurized to minimize the introduction of dust from adjacent areas.

**4.4.6.1** *Fire and smoke control*

Air circulation system may be designed to extract smoke in event of a fire, to assist in the fire fighting operation and to introduce fresh air to pressurize escape routes.

**4.4.6.2** *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 within 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 recommendation for siting of air inlets given in **4.1**

## Table 4 Outdoor Air Requirements for Ventilation[1)] of Air Conditioned Areas and Commercial Facilities

(*Clause* 4.4.5)

| Sl No. | Application | Estimated Maximum[2)] Occupancy | Outdoor Air Requirement | | Remarks |
|---|---|---|---|---|---|
| | | Persons/100 m$^2$ | l/s/Person | (l/s)/m$^2$ | |
| (1) | (2) | (3) | (4) | (5) | (6) |
| i) | **Commercial dry cleaner** | 30 | 15 | | |
| ii) | **Food and Beverage Service** | | | | |
| | Dining rooms | 70 | 10 | | |
| | Cafeteria, fast food | 100 | 10 | | |
| | Bars, cocktail lounges | 100 | 15 | | Supplementary smoke removal equipment may be required. |
| | Kitchen (cooking) | 20 | 8 | | Make up air for food exhaust may require more ventilating air. The sum of the outdoor air and transfer air of acceptable quality from adjacent spaces shall be sufficient to provide an exhaust rate of not less than 27.5 m$^3$/h.m$^2$ (7.5 l/s.m$^2$). |
| iii) | **Hotels, Motels, Resorts, Dormitories** | | | | Independent of room size. |
| | Bedrooms | | 15 | | |
| | Living rooms | | | 15 | |
| | Baths | | | 18 | Installed capacity for intermittent use. |
| | Lobbies | 30 | 8 | | |
| | Conference rooms | 50 | 10 | | |
| | Assemble rooms | 120 | 8 | | |
| | Dormitory sleeping areas | 20 | 8 | | *See also* food and beverage services, merchandising, barber and beauty shops, garages, offices. |
| | Office space | 7 | 10 | | Some office equipment may require local exhaust. |
| | Reception areas | 60 | 8 | | |
| | Telecommunication centers and data entry areas | 60 | 10 | | |
| | Conference rooms | 50 | 10 | | |
| iv) | **Public Spaces** | | | | |
| | Corridors and utilities | | | 0.25 | |
| | Public restrooms, l/s/wc or urinal | | 25 | | Normally supplied transfer air. |
| | Locker and dressing rooms | | | 2.5 | Local mechanical exhaust with no re-circulation recommended. |
| | Elevators | | | 5.0 | Normally supplied by transfer air. |
| | Retail stores, sales floors and show room floors | | | | |
| | Basement and street | 30 | | 1.50 | |
| | Upper floors | 20 | | 1.00 | |
| | Storage rooms | 15 | | 0.75 | |
| | Dressing rooms | | | 1.00 | |
| | Malls and arcades | 20 | | 1.00 | |
| | Shipping and receiving | 10 | | 0.75 | |
| | Warehouses | 5 | | 0.25 | |
| | Smoking lounge | 70 | 30 | | Normally supplied by transfer air, local mechanical exhaust; exhaust with no re-circulation recommended. |
| v) | **Specialty Shops** | | | | |
| | Barber Shop | 25 | 8 | | |
| | Beauty Parlour | 25 | 13 | | |
| | Florists | 8 | 8 | | Ventilation to optimize growth may dictate requirements. |
| | Clothiers, furniture | | | 1.50 | |
| | Hardware, drugs, fabric | 8 | 8 | | |
| | Supermarkets | 8 | 8 | | |
| | Pet shops | | | 5.00 | |
| vi) | **Sports and Amusement** | | | | |
| | Spectator areas | 150 | 8 | | When internal combustion engines are operated for maintenance of playing surfaces, increased ventilation rates may be required. |
| | Game rooms | 70 | 13 | 2.50 | |
| | Ice arenas (playing areas) | | | | |

## Table 4 — *Concluded*

| (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|
| | Swimming pools (pool and deck area) | | | 2.50 | Higher values may be required for humidity control. |
| | Playing floors (gymnasium) | 30 | 10 | | |
| | Ballrooms and discos | 100 | 13 | | |
| | Bowling alleys (seating area) | 70 | 13 | | |
| vii) | **Theatre** | | | | |
| | Ticket booths | 60 | 10 | | |
| | Lobbies | 150 | 10 | | Special ventilation will be needed to eliminate special stage effects (for example, dry ice vapours, mists, etc). |
| | Auditorium | 150 | 8 | | |
| | Stages, studios | 70 | 8 | | |
| viii) | **Transportation** | | | | |
| | Waiting rooms | 100 | 8 | | |
| | Platforms | 100 | 8 | | Ventilation within vehicles may require special consideration. |
| | Vehicles | 150 | 8 | | |
| ix) | **Workrooms** | | | | |
| | Meat processing | 10 | 8 | | Spaces maintained at low temperature at (–10°F to + 50°F or –23°C to + 10°C) are not covered by these requirements unless the occupancy is continuous. Ventilation from adjoining spaces is permissible. When the occupancy is intermittent, infiltration will normally exceed the ventilation requirement. |
| | Photo studios | 10 | 8 | | |
| | Darkrooms | 10 | | 2.50 | |
| | Pharmacy | 20 | 8 | | |
| | Bank vaults | 5 | 8 | | |
| | Duplicating, printing | | | 2.50 | Installed equipment shall incorporate positive exhaust and control (as required) of undesirable contaminants (toxic and otherwise). |
| x) | **Education** | | | | |
| | Classrooms | 50 | 8 | | |
| | Laboratories | 30 | 10 | | Special contaminant control systems may be required for processes or functions including laboratory animal occupancy. |
| | Training shop | 30 | 10 | | |
| | Music rooms | 50 | 8 | | |
| | Libraries | 20 | 8 | | |
| | Locker rooms | | | 2.50 | |
| | Corridors | | | 0.50 | |
| | Auditoriums | 150 | 8 | | |
| xi) | **Hospital, Nurses and Convalescent Homes** | | | | |
| | Patient rooms | 10 | 13 | | Special requirements or codes provisions and pressure relationships may determine minimum ventilation rates and filter efficiency. |
| | Medical procedure | 20 | 8 | | |
| | Operating rooms | 20 | 15 | | |
| | Procedure Recovery and ICU | | 20 | 8 | Generating contaminants may require higher rates. |
| | Autopsy | | | 2.50 | Air shall not be re-circulated into other spaces. |
| | Physical therapy | 20 | 8 | | |
| | Correctional Cells | 20 | 10 | | |
| | Dining halls | 100 | 8 | | |
| | Guard stations | 40 | 8 | | |

[1] This table prescribes supply rates of acceptable outdoor air required for acceptable indoor air quality. These values have been chosen to dilute human bioeffluents and other contaminants with an adequate margin of safety and to account for health variations among people and varied activity levels.

[2] Net occupiable space.

should also be taken into account. Air filtration equipment should be regularly serviced.

Air borne dust and dirt may be generated within the building, from the interior finishes such as partitions, laminations, carpets, upholstery, etc, personnel and their movements as well as by machines such as, printers and fax machines.

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.

The normal standard for intake filters in ventilating and air conditioning applications is an efficiency of 95 percent for a particle size up to 15 µm although there may be a requirement for a higher efficiency to give increased protection against atmospheric staining.

Special applications, such as computer server rooms, clean rooms, healthcare, 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.

**4.4.6.3** *Removal of fumes and smells from air*

Fumes and smells may be removed from air by physical or chemical processes. These may be essential when ambient air is heavily polluted.

The decision to use odour-removing equipment will normally be made on economic grounds, this may become necessary by the currently rising cost of fuel. Once such equipment is installed, it has to be regularly serviced to ensure satisfactory performance. Failure to do this may result in unacceptable conditions within the building.

### 4.5 Statutory Regulation and Safety Considerations

**4.5.1** *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.

**4.5.2** *Fire and Safety Considerations*

Fire protection requirements of air conditioning systems shall be in accordance with Part 4 'Fire and Life Safety'.

**4.5.2.1** *Design principles*

The design of air conditioning system and mechanical ventilation shall take into account the fire risk within the building, both as regards structural protection and means of escape in case of fire.

The extent and detail of statutory control and other specialist interest 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 therefore particularly important that the appropriate safeguards are fully considered at the concept design stage of the building.

The degree of control and the requirements vary according to the application.

Full details may have to be approved by the Authority in following cases:

a) From the point of view of the means of escape (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; and
c) Large car parks, hotels, parts of building used for trades or processes involving a special risk, and departmental stores and similar shop risks in large buildings.

**4.5.2.2** *Ductwork and enclosures*

All ductwork including connectors fittings and plenums should be constructed of steel, aluminium or other approved metal or from non-combustible material. All exhaust ducts, 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. Also, the concerned provisions of Part 4 'Fire and Life Safety' shall be complied with.

**4.5.2.3** *Thermal and acoustic insulation*

To reduce the spread of fire or smoke by an air conditioning system, care should be taken for the choice of materials used for such items as air filters, silencers and insulation both internal and external (*see* Part 4 'Fire and Life Safety' and Part 5 'Building Materials').

**4.5.2.4** *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 applications even when the system is not a recirculatory one. Exhausts should not be positioned near the fire escapes, main staircases or where these could be a hindrance to the work of fire authorities. The local fire authorities 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 dampers. Care should be taken with their location 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. Activation of smoke detector should stop the air handling unit supply air fan, close the fire damper in supply and return air duct and operate a suitable alarm system.

In all the above instances the appropriate controls would require manual re-setting.

**4.5.2.5** *Smoke control*

While it is essential that the spread of smoke through a building to be considered in the design of air conditioning systems for all types of applications, it assumes special 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, staircase may be filled with people.

One or more escape staircase connecting to outdoors at ground level, should be pressurized, to enable mass evacuation of high rise buildings (*see also* Part 4 'Fire and Life Safety').

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

The pressurization systems for staircases use large volumes of outside air. The system may be designed to operate continuously at low speed, being increased to high speed in the event of fire, or to operate only in emergency. Noise and droughts are not considered a problem in an emergency situation. Fan motor and starter should be protected from fire and connected to the emergency electrical supply through cables with special fire resistant coating (*see also* Part 4 'Fire and Life Safety').

**4.6 Application Factors**

**4.6.1** *General*

This clause gives general guidance, for various applications, for the factors that usually influence the selection of the type, design and layout of the air conditioning or ventilating system to be used.

**4.6.1.1** *Commercial applications*

The primary objective of the application described under this heading is provision of comfort conditions for occupants.

**4.6.1.2** *Offices*

Office building 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 variation 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 summer cooling and winter heating. During intermediate seasons the external zone of one side of the building may require cooling and at same time the external zone on another side of the building may require heating. The main factors affecting load are usually window area and choice of shading devices. The other important factors are the internal gain owing to people, light and office equipment. Choice of system may be affected by requirements to counteract down draughts and chilling effect due to radiation associated with single glazing during winter.

Internal zone loads are entirely due to heat gain from 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 controls, partitioning flexibility serving multiple tenants, and requirement of operating selected areas outside of normal office hours. Areas such as conference rooms, board rooms, canteens, etc, will often require independent systems.

For external building zones with large glass areas, for example, greater than 60 percent of the external façade, the air-water type of system, such as induction or fan coil is generally 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 building 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.

**4.6.1.3** *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 view point, should not permit wasteful overcooling or overheating.

Guest room systems are required to be available for operation on a continuous basis. The room may be unoccupied for most of the day and therefore provision for operating at reduced capacity, or switching off, is essential. Low operating noise level, reliability and ease of maintenance are essential. Treated 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. Fan coil units are generally found to be most suitable for this kind of application with speed control for fan and motorised/modulating valve for chilled water control for cooling.

**4.6.1.4** *Restaurants, cafeteria, bars and night-clubs*

Such applications have several factors in common; highly variable loads, with high latent gains (low sensible heat factor) from 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 for 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 unit served from a central chilled system may be used. Sufficient control flexibility to handle adequately the complete range of anticipated loads is essential.

**4.6.1.5** *Department stores/shops*

For small shops and stores unitary split type air conditioning systems offer many advantages, including low initial cost, minimum space requirement and ease of installation.

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

Generally, internal loads from lighting and people predominate. Important considerations include initial and operating costs, system space requirements, ease of maintenance and type of operating personnel who will operate the system.

The all-air type of system, with variable volume distribution from local air handling units, may be the most economical option. Facilities to take all outside air for 'free-cooling' under favourable conditions should be provided.

**4.6.1.6** *Theatres/Auditoria*

Characteristics of this type of application are buildings generally large in size, with high ceiling, low external loads, and high occupancy producing a high latent gain and having low sensible heat factor. These 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 a day.

**4.6.1.7** *Special applications*

**4.6.1.7.1** *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 special application areas of hospitals such as operation theatres, reference may be made to specialist literature.

The main difference in application compared with other applications 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) 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 temperatures and humidities may be required for various areas; and
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 theatres 100 percent fresh air system is normally provided and air pressures in various rooms are set by use of pressure stabilizers. Many types of air distribution pattern within operation theatres are in use but generally they conform to high-level supply and low-level pressure relief or exhaust. There is also need for a separate scavenging system for exhaled and waste anaesthetic gases with in theatre suites where general anaesthetic may be administered.

When zoning air distribution systems to compensate for building orientation and shape, consideration should be given to ensure that the mixing of air from different departments is reduced to a minimum. This can be accomplished by the use of 100 percent conditioned fresh air with no re-circulation or, where re-circulation 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 so that breakdown will affect only a limited section of the hospital.

Laboratories and other areas dealing with infectious diseases or viruses, and sanitary accommodation adjacent to wards, should be at a negative air pressure compared to any other area to prevent exfiltration of any airborne contaminants. In extreme cases any exhaust to atmosphere from these areas has to pass through high efficiency sub-micron particulate air (HEPA) filters.

**4.6.1.7.2** *Computer rooms*

The equipment in computer rooms generates heat and contains components that are sensitive to sudden variations of temperature and humidity. These are sensitive to the deposition of dust. Exposure beyond the prescribed limits may result in improper operation or need for shut-down of the equipment. The temperature and humidity in computer rooms need to be controlled within reasonably close limits, although this depends on the equipment involved. The relative humidity may be controlled within + 5 percent in the range 40 percent to 60 percent. Manufacturers normally prescribe specific conditions to be maintained. Typical conditions are air dry-bulb: 21 ± 1.6°C; relative humidity 50 ± 5 percent; and filtration 90 percent down to 10 microns.

A low velocity re-circulation system may be used with 5 percent to 10 percent fresh air make-up which is allowed to exfiltrate from the room and ensure a positive pressure to prevent entry of dust and untreated air. The air distribution should be zoned to minimize temperature variations owing to fluctuation in heat load. Overhead air supply through ceiling plenums utilizing linear diffuser or ventilated ceilings is eminently suited to computer room application, permitting high air change rates to be achieved without undue discomfort to personnel.

The air conditioning system should be reliable because failure to maintain conditions for even a short duration can cause substantial monetary loss and possibly more serious consequence. As such standby equipment is recommended.

**4.6.1.8** *Residential buildings*

Very few residences are air conditioned. Some individual houses have unitary systems comprising of window/split air conditioners. Some large houses have VRV based splits and some luxury block of flats are provided with air-water systems. VAV also works well for some luxury applications with chilled water applications. In the latter case, most of the considerations of **4.6.1.3** apply.

## 5 NOISE AND VIBRATION CONTROL

### 5.1 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 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.

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.

### 5.2 Types of Noise in Building

**5.2.1** *Externally Created Noise*

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

**5.2.2** *Generated Noise*

Noise produced by the components of 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 and noise transmission by air diffusers. This problem can be avoided by careful selection of and installation equipment or by the noise absorbing devices.

**5.2.3** *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 pipe work 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 tackled by careful design and the inclusion of sound absorbing devices in ducts.

**5.2.4** *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. This should be considered by air conditioning designer.

**5.3** The source of noise in the air conditioning system could be from the following:

a) Chillers,
b) Pumps,
c) Pipe supports,
d) Ducts,
e) External noise in filteration though openings,
f) Fans,
g) Air noise through ducts, and
h) Compressors.

**5.4** The approach must always be to reduce the source noise rather than controlling them in the path

**5.5 Noise Control**

**5.5.1** *From Room Air Conditioners (RAC)*

The following measures should be adopted:

a) Selection of RAC which has the least noise at various fan speeds.
b) Install it at a serviceable height.
c) Install preferably in a wall or on a rigid window.
d) Provide only necessary slope as specified by the manufacturer, to avoid any unusual noise from the compressor because of tilting.
e) Install it preferably in the middle portion of the wall/window to avoid additional directivity (do not install at the end of a wall.
f) Ensure all leaks are sealed properly.
g) Avoid condenser facing any high noisy areas, such as road/factory to avoid any such noise predominantly entering into the room.
h) Do not provide any props at the back side bottom of the air conditioner unless specified by the manufacturer.
j) Prepare the opening to suit the chassis with wooden frame of adequate rigidity and thickness.

**5.5.2** *From Split Air Conditioner/Furred Inn*

The following measures should be adopted:

a) Install the evaporator only on a rigid wall/ceiling or on a pedestal.
b) Avoid installation over wooden/gypsum board partition. Should a need arise anchor the evaporator rigidly by using mild steel frame work from the roof to avoid vibration.
c) Provide proper ‘u’ trap in the condensate water line to ensure a good water seal, which will also avoid sound penetration into the room from outside.
d) If the capillary is in the evaporator, ensure that flow noise is avoided.
e) Ensure proper return air entry back to the coil, since blowers working at higher *static pressure* will create higher noise.
f) Select the condensers with top/side discharge depending upon location to avoid nuisance to neighbours.
g) Place condensers on rigid platform, properly supported propped and fixed firmly.
h) Ensure all screws, bolts and nuts are firmly tightened since stiffening is more advantageous in higher frequencies for vibration reduction.

**5.5.3** *Air Handling Units (Floor Mounted and Ceiling Suspended)*

The following measures should be adopted:

a) Selected indoor machine for specific air quantity and static pressure.
b) Suspend the indoor machine and ducts

without touching the members of the false ceiling or partitions.

c) Ensure that ducts/duct supports do not touch the evaporator.

**5.5.4** *From Plenum Chamber*

The following measures should be adopted/considered:

a) If possible and if pressures allow, expand the air to a plenum chamber (of 2.5 m/s for normal office), which is acoustically lined inside.
b) Stiffening of the plenum body is very critical since it could create a drumming noise.
c) Plenum chambers with sound absorbing material are frequently used as silencers in air conditioning and ventilating systems and in testing facilities to reduce flow velocity and turbulence. The attenuation of these devices may be due to both dissipative and reactive effects.

**5.5.5** *From Fans*

**5.5.5.1** *Centrifugal fans*

There are three basic types of centrifugal fans, backward curved, forward curved, and radial. Noise from centrifugal fans is dominantly a superimposition of discrete tones at the varying frequencies and broadband aerodynamic noise.

**5.5.5.2** *Axial fans*

Axial fans derive their name from the fact that the airflow is along the axis of the fan. To avoid a circular flow pattern and to increase performance, guide vanes are usually installed downstream of the rotor. Axial fans with exit guide vanes are called vane axial and those without guide vanes are called tube axial. Axial fans generally operate at higher pressures than centrifugal fans and are usually considered noisier. Common applications include heating and ventilation systems. Because of the large number of blades and high rotational speeds, noise from axial fans is generally characterized by strong discrete blade passing tones.

Variable inlet vane system may generate significantly low frequency noise as the vanes shut down. Additional attenuation with a corresponding additional pressure drop is required to attenuate the noise generated by the inlet vanes.

Variable speed motors and drives and variable pitch fan blade systems are actually quieter at reduced air output than at full output. The designer has the option of designing for maximum output as if the system were constant volume, or selecting the sound attenuation for a more normal operating point and allowing fan noise to exceed the design criteria on the rare occasions when the fan operates at full output.

**5.5.5.3** To reduce fan noise, the following should be adopted:

a) Design the air distribution system for minimum resistance, since the sound generated by a fan, regardless of type, increase by the square of the static pressure. Turbulence can increase the flow noise generated by duct fittings and dampers in the air distribution systems especially at low frequencies.
b) Examine the specific sound power levels of the fan designs for any given job. Different fans generate different levels of sound and produce different octave band spectra. Select a fan that will generate the lowest possible sound level, commensurate with other fan selection parameters.
c) Fans with relatively few blades (less than 15) tend to generate tones, which may dominate the spectrum. These tones occur at the blade passage frequency and its harmonies. The intensity of these tones depends on resonance with the duct system, fan design, and inlet flow distortions.
d) Select a fan to operate as near as possible to its rated peak efficiency when handling the required quantity of air and static pressure. Also, select a fan that generates the lowest possible noise but still meets the required design conditions for which it is selected. Using an oversized or undersized fan, that does not operate at or near rated peak efficiency, may result in substantially higher noise levels.
e) Design duct connections at both the fan inlet and outlet for uniform and straight airflow. Avoid unstable, gusting, and swirling inlet airflow. Deviation from accepted applications can severely degrade both the aerodynamic and acoustic performance of any fan and invalidate manufacturers ratings or other performance predictions.
f) Select duct silencers that do not significantly increase the required fan total static pressure.

**5.5.6** *From Chillers, Pumps and Pipes*

Sizing and selecting a chiller is an important aspect in noise control. The following guidelines may be considered for noise control:

a) For roof top installation of chillers, these may be placed on beams connected on the elevated levels of pillars on correctly chosen vibration isolators.

b) Water cooled chillers have less vibration. However, if air cooled chillers have to be chosen, choose them with fan of less speeds and compressors must be jacketed without compromising their ventilation requirement.

c) If much more silencing is required, plan a silencer on the exhaust of the fans and also an acoustic enclosure around the chillers. Care must be taken for the additional static demand in the fan.

**5.5.7** *From Ducting Work*

The following measures should be adopted:

a) Shorter ducts with flanges and bracings is very advantageous for noise reduction.

b) Choose the right thickness of sheets for ducting.

c) Provide calculated turning vanes in all bends.

d) Provide take off pieces in all branches and collars.

e) Minimize the number of terminals since each terminal of equal noise will create a higher overall noise inside the room — Two equal noise source increase the noise by 3 dB.

f) Velocities of supply and return ducts and also terminals are important for noise control.

g) For auditoriums, conference halls etc, choose the right silencers in the supply. Define a clear opening for return air and fix return air silencers (parallel baffle silencer). The pressure drop expected across these silencers varies from 6 mm to 10 mm of water column.

h) Selecting double skin air handling unit should be done with care. If used without supply and return air silencers it adds to the noise in the duct patch. However, by using double skin air handling unit the noise inside the plant room can be lowered.

j) Instead of insulating the plant room, increasing the density of the plant room wall and providing return air baffles in the return air patch is more helpful in noise reduction. The doors to the air handling unit room should be either with an attic entry or dense enough to avoid noise transmission.

k) Avoid terminal dampers and grilles if the noise criteria is of the order of NC 20 (recording studios).

m) If ducts have to be routed outside the conditioned space, the density of the insulating materials over the duct surface is very critical. Higher the density, lower is its noise transmitality and hence break in noise inside the duct can be avoided. The density is to be decided based on the outside noise level.

n) Selection of a proper terminal device helps in noise reduction.

p) VAV shall be planned along with relevant VFD or bypass arrangement. Otherwise the duct is subjected to variable pressures resulting in variable noise pattern.

q) Minimize flow-generated noise by elbows or duct branch takeoffs, whenever possible, by locating them at least four to five duct diameters from each other. For high velocity systems, it may be necessary to increase this distance to up to ten duct diameters in critical noise areas.

r) Keep airflow velocity in the duct as low as possible (7.5 m/s or less) near critical noise areas by expanding the duct cross-section area. However, do not exceed an included expansion angle of greater than 15°. Flow separation, resulting from expansion angles greater than 15°, may produce rumble noise. Expanding the duct cross-section area reduces potential flow noise associated with turbulence in these areas.

s) Use turning vanes in large 90° rectangular elbows and branch takeoffs. This provides a smoother transmission in which the air can change flow direction, thus reducing turbulence.

t) Place grilles, diffusers and registers into occupied space as far as possible from elbows and branch takeoffs.

u) Minimize the use of volume dampers near grilles, diffusers and registers in acoustically critical situations.

v) Vibration isolate ducts and pipes, using spring and/or neoprene hangers for atleast the first 15 m from the vibration-isolated equipment.

## 5.6 Structure Borne Noise

Most obvious paths for solid-borne noise are the attached piping and pump support systems. Oscillatory energy generated near the pump can be conducted as solid-borne noise for substantial distances before it is radiated as acoustic noise. It can be controlled using flexible couplings and mechanical isolation.

## 5.7 Measurement

Measurements should be taken with a sound level meter either using the 'A' weighting scale or to draw up a noise criteria curve (*see* Part 8 'Building Services, Section 4 Acoustics, Sound Insulation and Noise Control'). 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 occupied areas;
d) In the space served by the first grille or diffuser after a fan outlet; and
e) In at least two of the spaces served by fan coil units or high velocity system terminal units (where applicable).

## 6 MECHANICAL VENTILATION (FOR NON AIR CONDITIONED AREAS) AND EVAPORATIVE COOLING

### 6.1 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 from outside to maintain the required level of air purity. Ventilation is required to control the following:

a) *Oxygen Content* — Prevent depletion of the oxygen content of the air;
b) *Carbondioxide and Moisture* — To prevent undue accumulation;
c) *Contaminants* — To prevent undue rise in concentration of body odours and other contaminants such as tobacoo smoke;
d) *Bacteria* — To oxidize colonies of bacteria and fungas to prevent their proliferation.
e) *Heat* — To remove body heat and heat dissipated by electrical or mechanical equipment or solar heat gains.

Mechanical ventilation is one of several forms of ventilation options available. It usually consists of fans, filters, ducts, air diffusers and outlets for air distribution within the building. It may include either mechanical exhaust system or exhaust can occur through natural means.

Natural ventilation and natural exhaust are also options (*see* Part 8 'Building Services, Section 1 Lighting and Ventilation'). The scope of this section is therefore restricted to mechanical ventilation.

Ventilation controls heat, odours and hazardous chemical contaminants (in a building) that could affect the health and safety of the occupants. For better control, heat and contaminants, air may need to be exhausted at their sources by local exhaust systems. Usually such systems require lower air flows than general (dilution) ventilation.

Following considerations provide details regarding the various parameters that affect the type of ventilation system selected for a particular application, and the sizing of the ventilation plant:

a) The climatic zone in which the building is located is a major consideration. An important distinction that must be made is between hot-dry and warm-moist conditions. Hot-dry work situations occur around furnaces, forges, metal-extruding and rolling mills, glass-forming machines, and so forth.

   Typical warm-moist operations are found in textile mills, laundries, dye houses, and deep mines where water is used extensively for dust control.

   Warm-moist conditions are more hazardous than the hot-dry conditions.
b) Siting (and orientation) of the building is also an important factor. Solar heat gain and high outside temperature increase the load significantly; how significantly depends, on the magnitude of these gains particularly in relation to other gains for example the internal load.
c) The comfort level required is another consideration. In many cases, comfort levels (as understood in the context of Residential Buildings, Commercial Blocks, Office Establishments) cannot be achieved at all and therefore, what is often aimed at will be 'acceptable working conditions' rather than 'comfort'.

   Having surveyed the considerations above, there are many options available in mechanical ventilation — spot cooling, local exhaust, changes in work pattern — to choose from, for achieving the desired acceptable working conditions. The options available may need to be extended to evaporative cooling in order to achieve more acceptable working conditions when confronted with more hostile environmental conditions.

   It will be thus seen that there are many considerations involved in the selection and sizing of suitable ventilation and evaporative cooling plants to meet the requirements of any particular building and/or process. It is the interplay of these various factors listed above like climatic conditions, internal load, exposure to heat and hazardous substances and level of working conditions aimed at, that determines the option, which best meets the requirement and also, the capacity and other attributes of the option selected.

   Ventilation control measures alone are

frequently inadequate for meeting heat stress standards. Optimum solutions may involve additional controls, such as local exhausts, spot cooling, changes in work-rest patterns, and radiation shielding.

As a rule, it is the mechanical system that provides the best results and controls, for the more complex situations and more stringent requirements arising out of harsher environment and need for better working conditions.

**6.2 Beneficial Effects of Ventilation**

**6.2.1** *Fresh Air Supply*

Ventilation system provides the fresh air flow that is required to maintain an acceptable non-odorous atmosphere (by diluting body odours and tobacco smoke) and to dilute the carbon dioxide exhaled.

The quantity and distribution of introduced outside air takes into account infiltration, exhaust and dilution requirements of the building. Proportion of fresh air introduced into a building may be varied to achieve economical operation. When fresh air can provide useful cooling effect, the quantity should be controlled to match the cooling demand.

**6.2.2** *Transfer of Heat/Moisture*

Ventilation system helps air circulation that is required to transfer the heat and humidity generated within the building. Heat generated by the occupants, electrical and mechanical equipment, and solar heat gains may be removed by the introduction of adequate quantities of fresh air and by expelling or extracting of stale air.

**6.2.3** *Air Movement*

Ventilation system provides air movement that is necessary to create a feeling of freshness and avoid discomfort, although excessive movement should be avoided as this may lead to complaints of draughts. 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 system.

Air flow should be controlled to minimize transfer of fumes and smells. In addition, air pressure gradients may be created within the building, by varying the balance between the fresh air and extracting the stale air.

Care should be taken, however, to avoid excessive pressure differences that can cause difficulty in opening doors or cause them to slam.

**6.2.4** *Air Purity and Filteration*

Ventilation system installed in a building should deliver clean, fresh air to the space served. This may be achieved by providing the required amount of fresh air either to remove totally or to dilute odours, fumes, etc. Local extract systems may be necessary to remove polluted air from kitchens, toilets, slaughter houses, crematoria, etc. Special air filters may be provided to remove contaminants or smells when air is recirculated.

**6.2.5** *Removal of Particulate Matter from Air*

Efficient air filteration to prevent fouling of the system should be considered, where damage is likely to be caused by discolouration owing to airborne dust particles. In order to obtain the best performance from the filters provided, care should be taken to locate the air intake appropriately in relation to the prevailing wind, position of chimneys and relative atmospheric dust concentration in the environs of the building.

This will promote cleaner interiors and reduce dust loading of the filters. Adequate (space) provisions should be incorporated in plant layout to ensure that filters can be serviced regularly.

**6.2.6** *Fire and Smoke Control*

Ventilation system can 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.

**6.2.7** *Removal of Fumes and Smells from Air*

Fumes and smell may be removed from air by physical or chemical processes. Their removal may be essential when the ambient air is heavily polluted, although consideration must be given to limit the thermal loads caused by the introduction of large quantities of fresh air.

**6.3 Industrial Ventilation**

Industrial buildings form a major application of mechanical ventilation.

In industrial buildings, ventilation is needed to provide the fresh air normally required for health and hygiene and also, to mitigate thermal working conditions by assisting in removal of surplus heat due to equipment, people and building heat gains.

Following are some of the factors that should be considered in the system design:

a) A supply system would not be satisfactory without a complementary exhaust system. Similarly any exhaust system would require for complementary supply system.
b) Air should be supplied equitably through grilles, diffusers — and such other devices. Directional grilles, diffusers and nozzles designed specifically to alleviate the thermal conditions should be considered. Drafts should be avoided.

c) Ventilation systems may need to be supplemented by exhaust hoods and canopies designed to capture the unwanted fumes or dust right at the source irrespective of other air currents in the vicinity.

Many industrial ventilation systems shall handle simultaneous exposures to heat, toxic and hazardous substances. The number of contaminant sources, their generation rate and effectiveness of exhaust hoods are rarely known; there is no option but to depend on common ventilation/industrial hygiene practice in such situations.

Reference may also be made to good practice [8-3(4)].

## 6.4 Types of Ventilation Systems

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

**6.4.1** *Mechanical Extract/Natural Supply*

This is simplest form of extract system comprising one or more fans, usually of the propeller, axial flow or mixed flow type, installed in outside walls or on the roof. The discharge should terminate in louvers or cowls or a combination of both.

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

It is essential that provision for make-up air is made and that consideration is given to the location and size of inlet. Inlet should not be located in the vicinity of exhaust fan.

**6.4.2** *Mechanical Supply/Natural Extract*

This system is similar in form to the extract system but arranged to deliver fresh air positively 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 dampers, as may be required.

**6.4.3** *Combined Mechanical Supply and Extract*

This system is a combination of those described above and may comprise supply and exhaust ductwork systems or may employ a common fan with a fresh air inlet on the low pressure side.

## 6.5 Ventilation Rate and Design Coniderations for Non Air Conditioned Areas

**6.5.1** *General Ventilation*

The rate of air circulation recommended for different general areas is as given in Table 5.

**Table 5 Recommended Rate of Air Circulation for Different Areas**

(*Clause* 6.5.1)

| Sl No. | Application | Air Change per Hour |
|---|---|---|
| (1) | (2) | (3) |
| 1. | Assembly rooms | 4-8 |
| 2. | Bakeries | 20-30 |
| 3. | Banks/building societies | 4-8 |
| 4. | Bathrooms | 6-10 |
| 5. | Bedrooms | 2-4 |
| 6. | Billiard rooms | 6-8 |
| 7. | Boiler rooms | 15-30 |
| 8. | Cafes and coffee bars | 10-12 |
| 9. | Canteens | 8-12 |
| 10. | Cellars | 3-10 |
| 11. | Churches | 1-3 |
| 12. | Cinemas and theatres | 10-15 |
| 13. | Club rooms | 12, *Min* |
| 14. | Compressor rooms | 10-12 |
| 15. | Conference rooms | 8-12 |
| 16. | Dairies | 8-12 |
| 17. | Dance halls | 12, *Min* |
| 18. | Dye works | 20-30 |
| 19. | Electroplating shops | 10-12 |
| 20. | Engine rooms | 15-30 |
| 21. | Entrance halls | 3-5 |
| 22. | Factories and work shops | 8-10 |
| 23. | Foundries | 15-30 |
| 24. | Garages | 6-8 |
| 25. | Glass houses | 25-60 |
| 26. | Gymnasium | 6, *Min* |
| 27. | Hair dressing saloon | 10-15 |
| 28. | Hospitals-sterlising | 15-25 |
| 29. | Hospital-wards | 6-8 |
| 30. | Hospital domestic | 15-20 |
| 31. | Laboratories | 6-15 |
| 32. | Launderettes | 10-15 |
| 33. | Laundries | 10-30 |
| 34. | Lavatories | 6-15 |
| 35. | Lecture theatres | 5-8 |
| 36. | Libraries | 3-5 |
| 37. | Living rooms | 3-6 |
| 38. | Mushroom houses | 6-10 |
| 39. | Offices | 6-10 |
| 40. | Paint shops (not cellulose) | 10-20 |
| 41. | Photo and X-ray darkroom | 10-15 |
| 42. | Public house bars | 12, *Min* |
| 43. | Recording control rooms | 15-25 |
| 44. | Recording studios | 10-12 |
| 45. | Restaurants | 8-12 |
| 46. | Schoolrooms | 5-7 |
| 47. | Shops and supermarkets | 8-15 |
| 48. | Shower baths | 15-20 |
| 49. | Stores and warehouses | 3-6 |
| 50. | Squash courts | 4, *Min* |
| 51. | Swimming baths | 10-15 |
| 52. | Toilets | 6-10 |
| 53. | Utility rooms | 15-20 |
| 54. | Welding shops | 15-30 |

NOTE — The ventilation rates may be increased by 50 percent where heavy smoking occurs or if the room is below ground.

**6.5.2** *Kitchen (Industrial and Commercial) Ventilation*

Desired ventilation rates in the kitchens depend upon the type of equipment in use and the released impurity loads (including surplus heat). Ventilation Standards set up the guide lines for ventilation volumes, whereas surplus heat and impurity loads determine the actual airflows based on thermal considerations. The design for kitchen airflow must allow for sufficient ventilation.

Suggested design standards for exhaust airflows from different kitchen equipment based on their input power are as given in Table 6.

**Table 6 Design Exhaust Air Flow in l/s per kW of the Kitchen Equipment**

(*Clause* 6.5.2)

| Sl No. | Kitchen Equipment | Electricity based Equipment | Gas based Equipment |
|---|---|---|---|
| (1) | (2) | (3) | (4) |
| i) | Cooking pot | 8 | 12 |
| ii) | Pressure cooker cabinet | 5 | — |
| iii) | Convection oven | 10 | — |
| iv) | Roasting oven (salamander) | 33 | 33 |
| v) | Griddle | 32 | 35 |
| vi) | Frying pan | 32 | 35 |
| vii) | Deep fat fryer | 28 | — |
| viii) | Cooker/stove | 32 | 35 |
| ix) | Grill | 50 | 61 |
| x) | Heated table/bath | 30 | — |
| xi) | Coffee maker | 3 | — |
| xii) | Dish washer | 17 | — |
| xiii) | Refrigeration equipment | 60 | — |
| xiv) | Ceramic cooker/stove | 25 | — |
| xv) | Microwave oven | 3 | — |
| xvi) | Pizza oven | 15 | — |
| xvii) | Induction cooker/stove | 20 | — |

It is desirable to use compensating exhaust hoods for kitchen equipment installed within air conditioned spaces. The ventilation rates may be confirmed from the kitchen equipment supplier.

**6.5.3** *Car Parking Ventilation*

Ventilation is essential, in car parking areas to take care of pollution due to emission of carbon monoxide, oxides of nitrogen, presence of oil and petrol fumes and diesel engine smoke. These contaminants cause undesirable effect like nausea, headache, fire hazards, if applicable permissible limits for each of the contaminants noted are exceeded. Although four contaminants are listed above, the capacity of a system designed to tackle concentration of carbon monoxide, will be adequate to keep the other three contaminants also within their respective permissible limits.

The recommended ventilation rate will ensure that the CO level will be maintained within 29 mg/m$^3$ with peak levels not to exceed 137 mg/m$^3$.

For partially open garages, the requirement is stated in terms of area of wall/slab openings required to provide adequate ventilation. The value applicable is 2.5 percent to 5 percent of the floor area for free opening.

It is necessary to ensure at planning stage itself that adequate head room is available in the car parks for installing ventilation ducts if such ducting is involved.

**6.5.4** *Sizing the Plant*

Sizing the ventilation plant is essentially arriving at the air flow rate required. Based on various considerations already reviewed the sizing of the plant will be influenced by the following requirements:

a) Removal of sensible heat,
b) Removal of latent heat,
c) Make-up air — the flow rate required will depend upon local exhaust, and
d) Removal or dilution of the contaminants down to the permissible level.

The air flow rate arrived at will be the maximum of the flow rates calculated for the above requirements.

**6.5.4.1** Ventilation plant size is often expressed in terms of number of air changes per hour or cmh/m$^2$ of floor area. These expressions fail to evaluate the actual heat release provided by the plant. The unit, cmh/m$^2$ gives a relationship which is independent of the building height. This is a more rational approach than speaking in terms of air changes per hour. This is because, with the same internal load, the same amount of ventilation air, properly applied to the work zone with adequate velocity, will provide the desired heat relief quite independently of the ceiling height of the space, with few exceptions. Ventilation rates of 30 to 60 m$^3$/h per m$^2$ have been found to give good results in many plants. Notwithstanding these general observations, detailed design should be based on detailed thorough calculations after all necessary data has been evaluated and relevant considerations have been reviewed.

## 6.6 Evaporative Cooling

**6.6.1** Evaporative cooling is defined as the reduction of air dry-bulb temperature by the evaporation of water.

**6.6.2** When water evaporates into the air to be cooled, simultaneously humidifying it, the process is called direct evaporative cooling. When the air to be cooled is kept separate from evaporation process, and therefore is not humidified as it is cooled, then the process is called indirect evaporative cooling.

It is good practice to use 100 percent fresh air in the evaporative cooling. Re-circulation is not recommended, as it will lead to continuous increase in wet-bulb temperature of the air. When evaporative cooling is provided for comfort application, it may be supplemented by devices like ceiling fans and fan coolers to enhance air movement for circulation of air in internal areas in order to maximize evaporation of moisture from the skin.

**6.6.3** The geographic range for the evaporative cooling is based on cooler's ability to create or approximate human comfort and is limited by relative humidity in the atmosphere. It is more effective in dry climates (hot-dry climate zone) where wet-bulb depression is comparatively large. Factors to be considered — include those listed in **6.5.4**; In addition the following also apply:

a) Saturation efficiency of the cooler — higher the better;
b) Ambient weather design data;
c) Permissible temperature rise; and
d) Type of cooling application — residential, industrial, etc.

**6.6.4** The cooling load control, especially for industrial application shall be carried out in the following manner for effective evaporative cooling:

a) Minimize external heat loads by shading, use of heat reflective paints, roof insulation and sealing of gaps.
b) Minimize internal heat loads by shielding, use of reflective paints, insulation and installation of exhaust fans over the hot processes and machines.
c) Make building tight.
d) Wherever possible, exhaust of used washed air must be directed towards roof to partly cool the surface and trusses thereby reducing heat radiation.

**6.6.5** Two types of water distribution systems may be provided:

a) Once through or pump-less type.
b) Recirculating or pump type.

The first type is simpler and cheaper but consumes more water, needs constant drainage and has lower efficiency depending upon the temperature of water. The second type has higher cooling efficiency due to recirculate water approaching wet-bulb temperature conserves water and can operate with intermittent drainage. It is recommended to provide periodic bleed-off or blow down to remove accumulated mineral additions. This helps in reducing scaling of pads also.

**6.6.6** The air velocity across wetting pad is recommended between 1.0 and 1.5 m/s. The lower face velocity reduces evaporation as damp air film isolates the dry air from the wet surface. Higher face velocity may provide insufficient air-water contact time.

**6.6.7** Pad material should be such which provides maximum clean wet surface area with minimum airflow resistance. Materials, which have either good 'wick' characteristics or surface that spread water rapidly by capillary action, should be selected.

**6.6.8** In the ducted systems, all supply air diffusers, grilles and registers should be preferably adjustable.

**6.6.9** General room cooling *should* be supplemented with spot cooling in the hot workplaces.

**6.6.10** Reference may also be made to good practice [8-3(5)].

**6.7 Planning**

**6.7.1** *Planning of Equipment Room for Ventilation*

**6.7.1.1** In selecting the location of equipment room, aspects of efficiency, economy and good practice should be considered and wherever possible, it shall be made contiguous with the building. This room shall be located as centrally as possible with respect to the area served and shall be free from obstructing columns.

Proper location helps achieve satisfactory air distribution and also results in a less expensive installation.

**6.7.1.2** Equipment room should preferably be located adjacent to external wall to facilitate equipment movement and ventilation. It should also close to main electrical panel of the building, if possible, in order to avoid large cable lengths.

**6.7.1.3** Location and dimensions of shafts, for ducting, cables, pipes, etc (if envisaged), should be planned at the virtual stages itself if planning. They should be located adjacent to the equipment or within the room itself.

Evaporative cooling units (air washers) should be located preferably on summer-windward side. They should be painted white or with reflective coating or thermally insulated, so as to minimize solar heat absorption.

In locating the units, care should be taken to ensure that their noise level will not be objectionable to the neighbours. Appropriate acoustic treatment should be considered, if the noise levels cannot be kept down to permissible limits.

Exhaust air devices, preferably to leeward and overhead side may be provided for effective movement of air.

In the case of large installations it is advisable to have a separate isolated equipment room if possible.

The equipment room should be adequately dimensioned keeping in view the need to provide required movement space for personnel, space for entry and exit of ducts, the need to accommodate air intakes and discharge, operation, maintenance and service requirements.

**6.7.1.4** The floors of the equipment rooms should be light coloured and finished smooth. For floor loading, the air conditioning, heating and ventilation engineer should be consulted (*see also* Part 6 'Structural Design, Section 1 Loads, Forces and Effects').

Arrangements for draining the floors shall be provided. The trap in floor drain shall provide a water seal between the equipment room and the drain line. Water proofing shall be provided for floor slabs of equipment rooms housing, evaporative cooling units.

**6.7.1.5** Supporting of pipe within equipment rooms spaces should be normally from the floor. However, outside Equipment room areas, structural provisions shall be made for supporting the water pipes from the floor/ceiling slabs. All floor and ceiling supports make-up and drain connections pipes, ducting cables/cable trays etc, shall be isolated from the structure to prevent transmission of vibrations.

**6.7.1.6** Plant machinery in the plant room shall be placed on plain/reinforced cement concrete foundation and provided with anti-vibratory supports. All foundations should be protected from damage by providing epoxy coated angle nosing. Seismic restraints requirement may also be considered.

**6.7.1.7** Wherever necessary, acoustic treatment should be provided in plant room space to prevent noise transmission to adjacent occupied areas.

**6.7.1.8** In case the equipment is located in basement, equipment movement route shall be planned to facilitate future replacement and maintenance. Service ramps or hatch in ground floor slab should be provided in such cases. Also arrangements for floor draining should be provided.

The trap in floor drain shall provide a water seal between the equipment room and the drain line.

**6.7.1.9** In the case of large and multi-storied buildings, independent Ventilation/Air Washer Units should be provided for each floor. The area to be served by the air-handling unit should be decided depending upon the provision of fire protection measures adopted. The Units should preferably be located vertically one above the other to simplify location of pipe shafts, cable shafts, drainers.

**6.7.1.10** Openings of adequate size should be provided for intake of fresh air. Fresh air intake shall have louvers having rain protection profile, with volume control damper and bird screen.

**6.7.1.11** Outdoor air intakes and exhaust outlets shall be effectively be shielded from weather and insects.

**6.7.1.12** In all cases air intakes shall be so located as to avoid contamination from exhaust outlets or to from sources whose contamination concentration levels are greater than normal in the locality in which the building is located.

**6.7.1.13** Supply/Return air duct shall not be taken through emergency fire staircase. However, exception can be considered if fire isolation of ducts at wall crossings is carried out.

**6.7.1.14** Where necessary, structural design should avoid beam obstruction to the passage of supply and return air ducts. Adequate ceiling space should be made available outside the equipment room to permit installation of supply and return air ducts and fire dampers at equipment room wall crossings.

**6.7.1.15** Access doors to Equipment rooms should be through single/double leaf type, air tight, opening outwards and should have a sill to prevent flooding of adjacent occupied areas.

**6.7.1.16** It should be possible to isolate the equipment room in case of fire. The door shall be fire resistant. Fire/smoke dampers shall be provided in supply/return air duct at air handling unit room wall crossings and the annular space between the duct and the wall should be fire sealed using appropriate fire resistance rated material.

**6.7.2** In the planning stages itself, provision should be made for the following (if they are envisaged):

a) Space/routing/supports, etc for ducting; and
b) Openings in walls, slabs, roof etc, for passage of ducts, pipes, cables, etc, and for air intake, air exhaust, etc.

**6.7.3** Bleed-off and chemical water treatment, depending on quality of water available for make-up, should be planned.

## 7 UNITARY AIR CONDITIONER

**7.1** These are self-contained air conditioning units comprising a compressor and evaporator with fans for evaporator and air-cooled condenser. Unitary air conditioners are generally installed in windows and, therefore, they are also known as window air conditioners. It is designed to provide free delivery of conditioned air to an enclosed space, room or zone. It includes a prime source of refrigeration for cooling and dehumidification and means for circulation and filtration of air. It may also include provision to exhaust room air as also induce fresh air for ventilation in the room. In addition to basic cooling unit, there are several other optional features available, such as:

a) Means for heating during winter months.
b) Reciprocating or rotary compressor.
c) Swing louvers for better distribution of air in the room.
d) In addition to normal, dust filters, indoor air quality filters, such as bactericidal enzyme filters for killing bacteria, low temperature catalyst filter for removal of unpleasant odours, electrostatic filters to trap particles of smoke as well as suspended matters present in the air.
e) Digital LCD remote control which also indicates room temperature.

**7.2 Capacity**

Most of the manufacturers supply unitary air conditions in capacities of 3 500 W (1 TR), 5 250 W (1.5 TR) and 7 000 W (2 TR). However, some of them may be able to supply window air conditioners of 1 750 W (0.5 TR) and upto 10 500 W (3 TR) alongwith intermediate range. The capacity of windows air conditioners is rated at outside dry bulb temperature of 35°C and wet bulb temperature of 30°C and they are suitable for 230 V, single phase 50 Hz power supply. Nominal capacity of all the window air conditioners has to be de-rated due to high ambient temperatures in summer months in most of Indian cities. Also, generally a voltage stabilizer has to be installed to ensure that window air conditioner gets stabilized rated voltage.

**7.3 Suitability**

Unitary air conditioners are suitable for bedrooms, office cabins, general office area, hotel rooms and similar applications where normal comfort conditions are required upto a distance of 6 m from unitary air conditioner.

**7.4 Power Consumption**

Power consumption of window air conditioners of 1 TR (3 500 W) rated capacity should not exceed 1.55 kW/TR. However, in smaller sizes, the power consumption may exceed. Rotary compressors normally consume 7 percent to 8 percent less power compared to the above value for reciprocating compressors.

**7.5 Noise Level**

Noise level of window air conditioner inside the conditioned room should be as low as possible. However it should not exceed 65 dBA for 5 250 W (1.5 TR) or smaller capacity window air conditioners. Air conditioners with rotary compressors will have lower noise level as compared to those provided with reciprocating compressors.

**7.6 Location**

Unitary air conditioners should be mounted preferably at the window sill level on an external wall where hot air from air-cooled condenser may be discharged without causing nuisance. There should not be any obstruction to the inlet and discharge air of the condenser. Also while deciding location of the window air conditioners, care should be taken to ensure that the condensate water dripping does not cause nuisance. The opening for the air conditioner is generally made a part of windows or wall construction at the planning stage.

**7.7 Limitations**

Room air conditioners are not generally recommended in the following situations:

a) The width of the area exceeds 6 m.
b) Area requiring close control of temperature and relative humidity.
c) Internal zones where no exposed wall is available for the installation of room air conditioners.
d) Sound recording rooms where criteria for acoustics are stringent.
e) Special applications like sterile rooms for hospitals and clean room applications where high filtration efficiency is desired.
f) Operation theatres where 100 percent fresh air is needed and fire hazard exists depending on the type of anaethesia being used.
g) Where required to comply with the recommended fresh air requirement for ventilation.

**7.8** For detailed information regarding constructional and performance requirements and methods for establishing ratings of room air conditioners, reference may be made to accepted standard [8-3(6)].

## 8 SPLIT AIR CONDITIONER

**8.1** Split air conditioner has an indoor unit and an outdoor unit interconnected with refrigerant piping and power and control wiring. Indoor unit comprises of a filter, evaporator and evaporator fan for circulation of air in the conditioned space. Outdoor unit has a compressor, air-cooled condenser with condenser fan housed in a suitable cabinet for outdoor installation. Split air conditioner includes primary source of refrigeration for cooling and dehumidification and means for circulation and cleaning of air, with or without external air distribution ducting.

Split air conditioners may be provided with either reciprocating compressor or scroll compressor. Scroll compressor generally consumes about 10 to 12 percent less power compared to reciprocating compressor.

Various split air conditioners available may be categorised as under:

a) Exposed indoor unit, which is either a high wall unit or a floor-mounted unit.
b) Furred-in units (ceiling suspended unit), which is mounted in the ceiling and provided with a duct collar and grille.
c) Ducted indoor unit, which requires ducting for air distribution.

**8.2 Suitability**

Split air conditioners are suitable for wide range of applications including residences, small offices, clubs, restaurants, showrooms, departmental stores, etc.

**8.3 Capacity**

Split air conditioners are available in following capacities:

a) Indoor exposed units, 3 500 W (1 TR), 5 250 W (1.5 TR), 7 000 W (2 TR) or two indoor units of 3 500 W (1 TR) or 5 250 W (1.5 TR), connected with one outdoor unit of 7 000 W (2 TR) or 10 500 W (3 TR) capacity. These units are available with corded and cordless remote control.
b) Furred-in Units are available in capacities of 3 500 W (1 TR) and 5 250 W (1.5 TR) and may be provided with one outdoor unit or two outdoor units with two furred-in indoor units. These units are available with corded and cordless remote control.
c) Ducted split air conditioners (ceiling suspended ducted units) are available in capacities of 10 500 W (3 TR), 17 500 W (5 TR), 26 250 W (7.5 TR) and 52 500 W (15 TR). Ducted split air conditioners with scroll compressors are available in sapacities of 19 250 W (5.5 TR) and 29 750 W (8.5 TR).

**8.4 Location**

Split air conditioner indoor unit is mounted within the air conditioned space or above the false ceiling from where the air distribution duct is taken to the conditioned space to distribute the air. When the indoor unit is mounted in the false ceiling, inspection panel must be kept in the false ceiling to attend to the indoor unit including periodic cleaning of air filter. Outdoor unit is mounted at the nearest open area where unobstructed flow of outside air is available for air cooled condenser.

**8.5 Installation**

Ceiling suspended indoor units are provided with rubber grommet to reduce vibration. Outdoor units are mounted on a steel frame in an open area so that the fan of the air cooled condenser can discharge hot air to the atmosphere without any obstruction. Care should be taken to ensure that free intake of air is available to the outdoor air cooled condenser. Also precaution should be taken that hot air from any other outdoor unit does not mix with the intake of the other outdoor air cooled condenser.

**8.6 Limitations**

Split air conditioners are generally not recommended for:

a) For areas where fresh air is required for ventilation.
b) Where distance between indoor exposed unit or furred-in unit exceeds 5 m from the outdoor unit for units up to 7 000 W (2 TR) capacity. For larger ducted split air conditioners, the vertical distance between the indoor unit and the outdoor unit should not exceed about 6 m for units with reciprocating compressors. The horizontal distance between the indoor unit and outdoor unit should not exceed about 10 m for reciprocating compressors.
c) Area requiring close control of temperature and relative humidity.
d) Sound recording rooms where criteria for acoustics are stringent.
e) Special applications like sterile rooms for hospitals and clean room applications where high filtration efficiency is desired.
f) Large multi-storey buildings where multiplicity of the compressors may entail subsequent maintenance problems.
g) Where the length of air distribution ducting may exceed about 20 m.

**8.7** Reference may be made to accepted standard [8-3(7)].

## 9 PACKAGED AIR CONDITIONER

**9.1** Packaged air conditioner is a self-contained unit primarily for floor mounting, designed to provide conditioned air to the space to be conditioned. It includes prime source of refrigeration for cooling and dehumidification and means for circulation and cleaning of air, with or without external air distribution ducting. It may also include means for heating, humidifying and ventilating air.

The unit comprises a compressor, condenser and evaporator, which are interconnected with copper refrigerant piping and refrigerant controls. It also includes fan for circulation of air and filter. The unit is provided with compressor and fan motor starter and factory-wired safety controls.

Compressor is a device, which compresses low-pressure low temperature refrigerant gas to high-pressure high temperature super heated refrigerant gas. Compressors may be reciprocating type or scroll type for packaging unit applications.

Condenser condenses high pressure high temperature refrigerant gas to liquid refrigerant at approximately the same temperature and pressure by removal of sensible heat of refrigerant by external means of water cooling or air cooling.

The packaged units are also available with microprocessor-based controller installed in the unit for digital display of faults as also several other functions. The packaged unit can also be provided with winter heating package or humidification package. The packaged unit may be provided with either water-cooled condenser or a remote air cooled condenser with interconnected copper refrigerant piping. The units are available with reciprocating compressor as also scroll compressor, which consume about 10 to 12 percent lesser power. In a water-cooled condenser unit, condenser-cooling water is circulated through the cooling tower with necessary piping and pumpsets.

The water cooled condenser packaged unit gives higher capacity at lower power consumption as compared to an air cooled condenser packaged unit which gets considerably de-rated in capacity and also consumes more power in peak summer months in most of the cities of our country due to high ambient temperature.

Packaged units are generally available with vertical air discharge or horizontal air discharge.

**9.2 Suitability**

Packaged units are suitable for wide range of applications including offices, clubs and restaurants, showrooms and departmental stores, and computer rooms, etc.

**9.3 Capacity**

Normally the packaged air conditioners are manufactured in sizes of 17 500 W (5 TR), 26 250 W (7.5 TR), 35 000 W (10 TR) and 52 500 W (15 TR). Packaged units with scroll compressors are also available in capacity up to 58 100 W (16.6 TR).

**9.4 Location**

The packaged unit can be mounted within the air conditioned space with discharge air plenum or in a separate room from where the air distribution duct is taken to the conditioned space. While deciding location for the packaged unit, provision must be kept for proper servicing of the unit.

**9.5 Installation**

The packaged units are normally mounted on a resilient pad which prevents vibration of the unit from being transmitted to the building.

**9.6 Limitations**

Packaged air conditioner are not generally recommended for:

a) Large multi-storey buildings where multiplicity of the compressors may entail subsequent maintenance problems.
b) Where the length of air distribution ducting may exceed approx 20 m.
c) Where the vertical distance of air-cooled condenser from the packaged unit exceeds about 10 m. The sum of horizontal and vertical distances should be generally kept within 15 m.
d) Special applications like sterile rooms for hospitals and clean room applications where high filtration efficiency is desired.
e) Operation theatres where 100 percent fresh air is needed and fire hazard exists depending on the type of anesthesia being used.

**9.7** For detailed information regarding constructional and performance requirements and methods for establishing ratings of packaged air conditioners, reference may be made to accepted standard [8-3(8)].

**10 HEATING**

**10.1** The installations for air conditioning system may be used advantageously for the central heating system with additions such as hot water or boiler and hot water coils or strip heater banks.

**10.2** The heating equipments as described in **10.2.1** and **10.2.2** are generally used.

**10.2.1** *Hot Water Heated Coils*

Central heating systems using hot water usually required not more than one or two rows of tubes in the direction of air flow, in order to produce the desired heating capacity. To achieve high efficiency 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 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, for example, 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.

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

**10.2.2** *Electric Air Heater*

The air velocity through the heaters should be sufficient to permit the absorption of the rated output of the finned tube heaters 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-phase of the electrical supply.

Where automatic temperature control is required the heater 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 connection 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.

## 11 SYMBOLS, UNITS, COLOUR CODE AND IDENTIFICATION OF SERVICES

**11.1** Units and symbols to be used in air conditioning, ventilation and refrigeration system shall be in accordance with good practice [8-3(9)].

**11.2** Colour code for identification for various items in air conditioning installations for easy interpretation and identification is advisable. This shall promote greater safety and shall lessen chances of error, confusion or inaction in times of emergency. Colour shade shall be generally in accordance with good practice [8-3(10)].

**11.3** Colour bands shall be 150 mm wide, superimposed on ground colour to distinguish type and condition of fluid. The spacing of band shall not exceed 4.0 m.

**11.4** Further identification may also be carried out using lettering and marking direction of flow.

### 11.5 Services Identification

**11.5.1** *Pipe Work Services*

**11.5.1.1** The scheme of colour code for painting of pipe work services for air conditioning installation shall be as indicated in Table 7.

**11.5.1.2** In addition to the colour bands specified above, all pipe work shall be legibly marked with black or white letters to indicate the type of service and the direction of flow, identified as follows:

| | |
|---|---|
| High Temperature Hot Water | HTHW |
| Medium Temperature Hot Water | MTHW |
| Low Temperature Hot Water | LTHW |
| Chilled Water | CHW |
| Condenser Water | CDW |
| Steam | ST |
| Condensate | CN |

**11.5.2** *Duct Work Services*

**11.5.2.1** For duct work services and its insulation, colour triangle may be provided. The size of the triangle will depend on the size of the duct and viewing distance but the minimum size should not be less than 150 mm length per side.

The colour for various duct work services shall be as given below:

| *Services* | *Colour* |
|---|---|
| Conditioned Air | Red and Blue |
| Ward Air | Yellow |
| Fresh Air | Green |
| Exhaust/Extract/Recalculated Air | Grey |
| Foul Air | Brown |
| Dual Duct System Hot Supply Air | Red |
| Cold Supply Air | Blue |

**Table 7 Scheme of Colour Code of Pipe Work Services for Air Conditioning Installation**

(*Clause* 11.5.1.1)

| Sl No. | Description | Ground Colour | Lettering Colouring | First Colour Band |
|---|---|---|---|---|
| (1) | (2) | (3) | (4) | (5) |
| i) | Cooling water | Sea green | Black | French blue |
| ii) | Chilled water | Sea green | Black | Black |
| iii) | Central heating below 60°C | Sea green | Black | Canary yellow |
| iv) | Central heating 60°C to 100°C | Sea green | Black | Dark violet |
| v) | Drain pipe | Black | White | |
| vi) | Vents | White | Black | |
| vii) | Valves and pipe line fittings | White with black handles | Black | |
| viii) | Belt guard | Black yellow diagonal strips | | |
| ix) | Machine bases, inertia bases and plinth | Charcoal grey | | |

**11.5.3** *Valve Labels and Charts*

Each valve shall be provided with a label indicating the service being controlled, together with a reference number corresponding with that shown on the Valve Charts and 'as fitted' drawings. The labels shall be made from 3 ply (black/white/black) traffolyte material showing white letters and figures on a black background. Labels shall be tied to each valve with chromium plated linked chain.

## 12 ENERGY CONSERVATION, ENERGY MANAGEMENT, AUTOMATIC CONTROLS AND BUILDING MANAGEMENT SYSTEM

**12.1** In the context of this Code, energy conservation signifies the optimum use of energy to operate the air conditioning, heating and ventilation system of a building.

**12.2** It is axiomatic that general standards of comfort or specific environmental requirements within the building should not be compromised in an endeavour to achieve lower consumption of energy. Similarly nothing in this Code overrides regulations related to health and safety.

### 12.3 Considerations for Energy Conservation and Management

**12.3.1** *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.

**12.3.2** *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 are quoted as an 'average rate' of energy use ($W/m^2$).

**12.3.3** *Consumption Targets*

The energy actually consumed in a building is determined by the manner in which the building and its services are used and is measured in units of energy ($Wh/m^2$). Targets may be established according to varying climatic conditions and varying pattern of building use.

**12.3.4** *Air Conditioning/Ventilation*

Some of the more important aspects of establishing energy conservation requirements for air conditioning and ventilation system are given below.

**12.3.5** 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).
j) Opportunity for optimizing electrical installation and energy conservation by using thermal energy storage.

**12.3.6** The operation of the system for the following conditions has to be considered when assessing the complete design:

a) in summer;
b) in winter;
c) in intermediate seasons;
d) at night;
e) at weekends; and
f) restoration of power supply after intermittent failure.

**12.3.7** Consideration should be given to changes in building load in the system design 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.

**12.3.8** The temperature of heating or cooling media circulated with in the system should be maintained at the level necessary to achieve the required output to match the prevailing load conditions with the minimum consumption of energy.

**12.3.9** Energy recovery has to be maximized.

**12.3.10** Operation and maintenance procedures have to be properly planned.

**12.3.11** *Equipment Consideration*

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

**12.3.11.2** 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.

**12.3.11.3** Where components from more than one supplier are used in combination, for which published performance data do not exist then the system designer should take the responsibility for ensuring that their combination leads to optimum energy use.

**12.3.11.4** Equipment preventive maintenance schedule should be furnished along with all other required information.

## 12.4 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 the required by the application. Consideration should be given to the provision of centralised monitoring and control, thus achieving optimum operation.

## 12.5 Automatic Controls and Building Management System

**12.5.1** *Types of Equipment*

The basic components that are designed, selected to work together to form a complete control system, together with their function, are shown as follows:

The basic components of a control system are:

| *Element or Component* | *Function* |
|---|---|
| Sensing and measuring element of the controller (for example, sensor, transmitters, transducers, meters, 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 linkages for mechanical devices | Transmitting the energy or forces from the point of translation to the point of corrective action. |
| Controlled devices 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. |
| Controller mechanism, connecting means, and actuator or control device | Terminating the call for corrective change, to prevent over-correction. |

**12.5.2** *Sensing and Measuring Elements*

**12.5.2.1** *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) 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 change of force or movement.
d) 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) Resistance temperature detectors (RTDs) are temperature sensors containing either a fine

wire or a thin metallic element whose resistance increases with temperature and varies in a known manner. RTDs are characterised by their high degree of linearity, good sensitivity and excellent stability. RTDs are used with electronic controllers.

f) Thermocouple element comprises a junction between two dissimilar metals that generates a small voltage related to the temperature.

**12.5.2.2** *Humidity devices*

a) These devices have a hygroscopic organic polymer deposited on a water permeable substrate. The polymer film absorbs moisture until it is in balance with the ambient air. This causes a change in resistance or capacitance.

b) Resistance elements, as employed in electronic systems, consist 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 electric resistance of this circuit changes as the chemical film absorbs and releases moisture with changes in the relative humidity of surrounding air.

**12.5.2.3** *Pressure elements*

a) Low-pressure measuring elements for low positive pressure or for vacuum conditions, for example, 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 lever up (or down) to complete an electric 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 bellows, diaphragm or Bourdon tube type. If one side of the element is left open to atmosphere the element will respond to pressure above or below atmospheric.

**12.5.2.4** *Special elements*

a) Special elements for various measuring or detecting purposes are often necessary for complete control in air conditioning or ventilating systems, for example a 'paddle-blade' type of air flow switch may be interlocked with an electric heater battery to prevent battery from operating and overheating in the event of an air flow failure.

b) Other elements employed from time-to-time are measuring smoke density, carbon monoxide (for example in road traffic tunnels or underground car parks) and carbon dioxide, and for flame detection.

**12.5.2.5** *Controllers*

Controlling elements normally regulate the application of either electrical or pneumatic energy. Controllers are mainly of three types: thermostat, humidistats and pressure controllers.

**12.5.2.6** *Thermostats*

The following types of thermostats are in common use:

a) The room type responds to room air temperature and is designed for mounting on a wall.

b) The insertion thermostats respond to the temperature of air in a duct and are designed for mounting on the outside of a duct with its measuring element extending into the air stream.

c) The immersion type responds to the temperature of a fluid in a pipe or tank 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 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 temperature of the fluid with in the pipe.

f) The day/night room thermostat is arranged to control at a reduce 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 points 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 cooling medium at another.

h) The multi-step thermostat is arranged to operate in two or more successive steps.

j) A master thermostat measures conditions at one point of another (sub-master) thermostat or controller.

**12.5.2.7** *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.

**12.5.2.8** *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.

**12.5.2.9** *Controlled devices*

**12.5.2.9.1** *Automatic control valves*

An automatic control valve consists of a valve body 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. As 75 percent 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 systems performance.

Following are the details of various valve types and valve operators:

a) *Valve types* — The main type and their characteristics are summarized 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 essential 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 piston 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) Two way modulating valves have one inlet and one outlet and operate to modulate or proportion the flow through the heat exchange equipment.

   8) 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.

   9) Special multi-port valves for various type of modulating/sequences 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, brief details of which are given below:

   1) A solenoid is a magnetic coil that operates a movable plunger to provide two-piston 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, such as:

      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 valves 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 compress the spring. When the air pressure is removed the spring will return the operator to its normal position.

**12.5.2.9.2** *Automatic control dampers*

Control dampers are designed to control the flow of air in a ductwork system in much the same as an automatic valve operates in a fluid circuit, that is by varying the resistance to flow. Following are the details of various damper valves and damper operators:

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, which may be:
      i) A parallel action multi-leaf damper, having its blades linked so that when operated they all rotate in the same direction.
      ii) An opposed action multi-leaf damper, having 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.

**12.5.2.9.3** *Centralized control/monitoring equipment*

The centralized control system, which is shown diagrammatically in Fig.1, comprises three main parts: the remote location equipment, the transmission links, and the central equipment.

**12.5.2.9.4** *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; and

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.

**12.5.2.9.5** *Transmission links*

The transmission links 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 includes:

a) Medium (wires or cables, telephone lines, micro wave);
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; and
f) Message format.

Other considerations include the physical arrangement of the transmission system, security and supervisory aspect.

**12.5.2.9.6** *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).

**12.5.3** *Selection Factors*

**12.5.3.1** *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, phase, frequency and number of wires;
b) Maximum and/or minimum temperatures, humidities or pressures to which components may be subjected;
c) Restrictions or location, mounting positions,

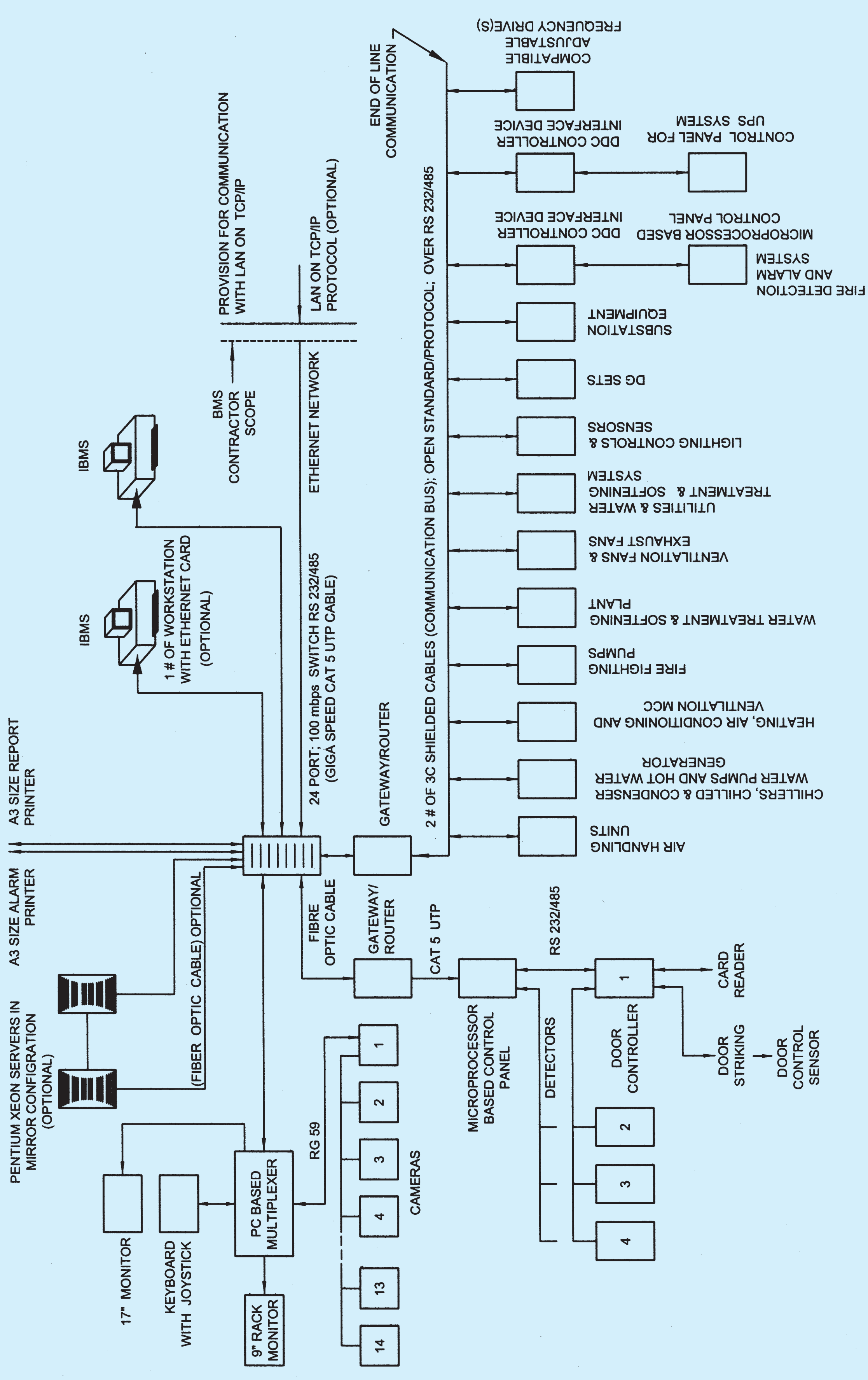


FIG. 1 SYSTEM CONNECTIVITY ARRANGEMENT FOR BUILDING MANAGEMENT SYSTEM

etc, or possible problems due to duct, vibration etc;

d) Dimensions and mass;

e) Finish and type of enclosure; and

f) Required accessories or fittings.

NOTE — These common factors, should only be used as a general guide, and control manufacturers should be consulted in establishing exact requirements.

**12.5.4** *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 may be as given in **12.5.3.1**. However, a sensor may be designed and arranged for operation with a remote controller and other components, in that case some of the more important selection factors for temperature elements, for example, may be as follows:

a) Control operations, for example reverse or direct-acting;

b) Sensing range, adjustable or non-adjustable;

c) Provision for air filter;

d) Pressure output;

e) Provision for branch pressure indication;

f) Application, for example room, duct or immersion in pipeline;

g) Application, for example room, duct immersion in pipeline;

h) Electronic;

j) Function, for example for primary or secondary control;

k) Temperature range;

m) Authority range of throttling range adjustment;

n) Nominal resistance and sensitivity; and

p) Provision for temperature indication.

## 13 INSPECTION, COMMISSIONING AND TESTING

**13.1** Inspection, commissioning and testing should be carried out meticulously if a satisfactory installation is to be handed over to the client. It should be ensured that these are carried out thoroughly and all results are properly documented. It is recommended that the whole commissioning procedure should be under the guidance and control of a single authority, to be identified by the client.

### 13.2 Inspection and Testing

All equipment and components supplied may be subjected to inspection and tests during manufacture, erection/installation and after completion. No tolerances at the time of inspection shall be allowed other than those specified or permitted in the relevant approved standards, unless otherwise stated. Approval at the time of inspection shall not be construed as acceptance unless the equipment proves satisfactory in service after erection.

High pressure air duct system should also be tested in accordance with the procedures.

**13.2.1** *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 manufacturing and on completion, as specified.

**13.2.2** *Inspection and Testing on Site*

Prior to commissioning, testing, adjusting and balancing, preliminary checks and charging of the complete system should be carried out. 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 8 h.

### 13.3 Commissioning, Testing, Adjusting and Balancing

**13.3.1** *Basic Considerations*

**13.3.1.1** The basic considerations are:

a) to test to determine quantitative performance of equipment;

b) to adjust to regulate for specified fluid flow rates and air patterns at terminal equipment (for example reduce fan speed, throttling etc); and

c) to balance to proportion within distribution system (sub mains, branches and terminals) in accordance with design quantities.

**13.3.1.2** The objective of testing, adjusting and balancing of air conditioning, heating and mechanical ventilation system shall be to:

a) verify design conformity;

b) establish fluid flow rates, volume and operating pressures;

c) test all associated electrical panels and electrical installation for earthing continuity and earth resistance;

d) take electrical power readings for each motor;

e) establish operating sound and vibration levels;

f) adjust and balance to design parameters; and

g) record and report results as per the specified formats.

**13.3.2** *System Testing, Adjusting and Balancing*

**13.3.2.1** *Refrigeration plant*

The refrigeration plant may be tested for the following:

a) Adjusting water flow rate through chiller and condenser by use of balancing valves.
b) Ascertaining the capacity by measurement of water flow rate and temperature of water at inlet and outlet of chilling machine.
c) Computation of power consumption.
d) Verifying operating noise level as per manufacturer instructions.

**13.3.2.2** *Air system*

**13.2.2.2.1** *Air handlers performance*

The testing, adjusting and balancing procedure shall establish the right selection and performance of the air handling units with the following results:

a) Air-in dry-bulb and wet-bulb temperature,
b) Air-out dry-bulb and wet-bulb temperature,
c) Leaving air dew point temperature,
d) Fan air volume,
e) Fan air outlet velocity,
f) Fan static pressure,
g) Fan power consumption,
h) Fan speed, and
j) Check for zero water retention in the condensate drain pan.

**13.3.2.2.2** *Air distribution*

Both supply and return air distribution for each air handling unit and for areas served by the air handling unit shall be determined and adjusted as necessary to provide design air quantities. It shall cover balancing of air through main and branch ducts.

**13.3.2.2.3** *Hydronic system*

The hydronic system shall involve the checking and balancing of all water pumps, piping network (main and branches), heat exchange equipment like cooling and heating coils, condensers, chillers and cooling towers in order to provide design water flows.

The essential preparation work, shall be done by the air conditioning contractor prior to actual testing, adjusting and balancing and shall ensure the following:

a) Hydronic system is free of leaks, hydrostatically tested and is thoroughly cleaned, flushed and refilled.
b) Hydronic system is vented.
c) Check pumps operation for proper rotation and motor current drawn etc;
d) Confirm that provisions for tabulation of measurements (temperature, pressure and flow measurements) have been made; and
e) Open all shut-off valves and automatic control valves to provide full flow through coils. Set all balancing valves in the preset position, if these values are known. If not, shut all riser balancing valves except the one intended to be balanced first.

Balancing work for both chilled water system and condenser water system shall be carried out in a professional manner and test reports in the specified format shall be prepared.

**13.4 Controls**

Since most of the control equipment used for air conditioning system is factory calibrated, hence physical verification before installation shall be carried out. In addition, manufacturers instructions should be followed for site calibration, if any.

**13.5 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 occupied areas;
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; and
g) Air handling unit (AHU) rooms and adjoining areas.

**13.6 Handover Procedure**

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.

Handover documentation should include the following:

a) Description of the installation, including simplified line flow and balance diagrams for the complete installation;

b) As-built installation drawings;

c) Operation and maintenance instructions for equipment, manufacturer's service maintenance manuals, manufacturer's spare parts list 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; and

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

## LIST OF STANDARDS

The following list records those standards which are acceptable as 'good practice' and 'accepted standards' in the fulfillment of the requirements of the Code. The latest version of a standard shall be adopted at the time of enforcement of the Code. The standards listed may be used by the Authority as a guide in conformance with the requirements of the referred clauses in the Code.

In the following list, the number appearing in the first column within parentheses indicates the number of the reference in this Part/Section.

| | *IS No.* | *Title* |
|---|---|---|
| (1) | 655 : 1963 | Specification for metal air ducts (*revised*) |
| (2) | 277 : 2003 | Specification for galvanized steel sheet (plain and corrugated) (*sixth revision*) |
| (3) | 737 : 1986 | Specification for wrought aluminium alloy sheet and strip for general engineering purpose (*third revision*) |
| (4) | 3103 : 1975 | Code of practice for industrial ventilation (*first revision*) |
| (5) | 3315 : 1994 | Specification for evaporative air coolers (desert coolers) (*second revision*) |
| (6) | 1391 | Specification for room air conditioners: |
| | (Part 1) : 1992 | Unitary air conditioners (*second revision*) |
| (7) | (Part 2) : 1992 | Split air conditioners (*second revision*) |
| (8) | 8148 : 2003 | Specification for packaged air conditioners (*first revision*) |
| (9) | 4831 : 1968 | Recommendation on units and symbols for refrigeration |
| (10) | 5 : 1994 | Specification for colours for ready mixed paints and enamels (*fourth revision*) |

# NATIONAL BUILDING CODE OF INDIA

## PART 8 BUILDING SERVICES

### Section 4 Acoustics, Sound Insulation and Noise Control

BUREAU OF INDIAN STANDARDS

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National Building Code Sectional Committee, CED 46

## FOREWORD

This Section covers the acoustical, sound insulation and noise control requirements in buildings. Emphasis is laid on planning of buildings *vis-a-vis* its surroundings to reduce noise and in addition sound insulation aspects of different occupancies are covered for achieving acceptable noise levels.

This Section was first published in 1970 and was subsequently revised in 1983. In the last revision mainly the following changes were made:

a) The approximate measured noise levels due to various types of traffic (air, rail and road) were given; and planning and design features of buildings against outdoor noise were elaborated;
b) Impact sound insulation in residential buildings was modified to grade system of impact sound insulation;
c) Recommendations regarding planning of open plan schools against noise were given;
d) Planning of office buildings with light weight partitions was specified;
e) Planning and design aspects of hotels and hostels, laboratories and test houses, and other miscellaneous buildings, such as, law courts and councils chambers, libraries, museums and art galleries, auditoria and theatres had been given;
f) Hearing damage risk criteria in industrial buildings were modified based on permissible exposure limits for a steady state noise level; and
g) The public address system was elaborated to cover public address system at passenger terminals.

In this revision, the following important changes have been made:

a) Large number of important definitions have been added in line with the present international practice of usage of terms in the field of acoustics, sound insulation and noise control.
b) Under Planning and Design against Outdoor Noise, a new clause on Highway Noise Barrier has been included.
c) The clause on public address system has been deleted.
d) A new clause on cinema has been added.
e) Existing Appendix A 'Constructional Measures for Sound Insulation of Buildings' and Appendix B 'Sound Insulation Values for Various Types of Materials and Construction' have been deleted and the following new informative annexes have been added:
    1) Annex A Noise Calculations
    2) Annex B Specification of Sound Insulation
    3) Annex C Noise Rating
    4) Annex D Outdoor Noise Regulations in India
    5) Annex E Special Problems Requiring Expert Advice
    6) Annex F Airborne and Impact Sound Insulation
    7) Annex G Basic Design Techniques for Noise Control in Air Conditioning, Heating and Mechanical Ventilation System
    8) Annex H Suggested Equipment Noise Data Sheet

There are two types of noises, that is, air-borne and structure-borne noise. To reduce the intensity of air-borne noise, sound absorbent materials may be used.

An absorbent material is one which reduces the intensity of sound reflected from its surface. It may be applied to walls, floors, ceilings or used as furnishings to reduce the sound level by absorption. However, the materials selected for sound absorption shall be consistent with fire safety requirements of the buildings.

To reduce the transmission of air-borne noise, sound insulating materials may be used. Sound insulating materials block the passage of noise through them by virtue of their mass and physical properties. The extent of noise reduction provided by a single homogeneous panel is proportional to the logarithm of mass per unit area. For high values of sound insulation, normally heavy panels are required. Thin sheets of materials do not have adequate mass for providing any appreciable sound transmission loss by themselves. However, when thin sheet materials are used in a double panel construction with an intervening air cavity, this special construction can give extremely high sound transmission loss values considering the mass of the partition, if designed properly. Porous materials lack the mass required to provide any appreciable sound transmission loss, and readily allow sound at most frequencies to be transmitted through them.

To reduce the transmission of structure-borne noise (such as, noise generated by impacts) special construction methods and elastic discontinuity in the structure may be used. Structure-borne noise reduction is effected by corner joints, changes in cross-section, changes in materials, etc, in construction. The reduction by these construction methods is, however, not appreciable specially when a large amount of noise reduction is required over a short distance. In such cases, introduction of an elastic discontinuity in the structure can result in a very large amount of noise reduction. The noise transmission is affected only above a certain lower frequency which depends on the material thickness and the elastic properties of the material. Bonded fibrous materials, rubber elastomers, cork, etc, are suitable for curtailing structure-borne noise transmission.

This Section is largely based on the following standards:

| | |
|---|---|
| IS 1950 : 1962 | Code of practice for sound insulation of non-industrial buildings |
| IS 3483 : 1965 | Code of practice for noise reduction in industrial buildings |
| IS 4954 : 1968 | Recommendations for noise abatement in town planning |
| IS 11050 | Rating of sound insulation in buildings and of building elements: |
| (Part 1) : 1984 | Airborne sound insulation in buildings and of interior building elements |
| (Part 2) : 1984 | Impact sound insulation |
| BS 8233 : 1999 | Code of practice for sound insulation and noise reduction for buildings |

In this revision, opportunity has been taken to update all references to relevant Indian Standards referred to in the text.

All standards, whether given herein above or cross-referred to in the main text of this Section, are subject to revision. The parties to agreement based on this Section are encouraged to investigate the possibility of applying the most recent editions of the standards.

# NATIONAL BUILDING CODE OF INDIA

## PART 8 BUILDING SERVICES

## Section 4 Acoustics, Sound Insulation and Noise Control

**1 SCOPE**

This Section covers requirements and guidelines regarding planning against noise, acceptable noise levels and the requirements for sound insulation in buildings with different occupancies.

**2 TERMINOLOGY**

**2.0** For the purpose of this Section, the following definitions shall apply.

**2.1 Ambient Noise** — The sound pressure levels associated with a given environment. Ambient noise is usually a composite of sounds from near and far sources none of which are particularly dominant.

**2.2 Audible Frequency Range** — The range of sound frequencies normally heard by the human ear. The audible range spans from 20 Hz to 20 000 Hz.

**2.3 A-Weighted Sound Pressure, $p_A$** — Value of overall sound pressure, measured in pascals (Pa), after the electrical signal derived from a microphone has been pased through an A-weighting network.

NOTE — The A-weighting network modifies the electrical response of a sound level meter with frequency in approximately the same way as the sensitivity of the human hearing system.

**2.4 A-Weighted Sound Pressure Level, $L_{pA}$** — Quantity of A-weighted sound pressure, given by the following formula in decibels (dBA):

$$L_{pA} = 10 \log_{10} (p_A / p_o)^2$$

where

$p_A$ = is the A-weighted sound pressure in pascals (Pa); and

$p_o$ = is the reference sound pressure (20 μ Pa).

NOTE — Measurements of A-weighted sound pressure level can be made with a meter and correlate roughly with subjective assessments of loudness, and are usually made to assist in judging the effects of noise on people. The size of A-weighting in 1/3 octave bands, is shown in Annex A (*see* **A-5**). An increase or decrease in level of 10 dBA corresponds roughly to a doubling or halving of loudness.

**2.5 Background Noise** — The sound pressure levels in a given environment from all sources excluding a specific sound source being investigated or measured.

**2.6 Break-in** — Unwanted sound transmission into a duct from outside.

**2.7 Break-out** — Unwanted sound transmission from inside a duct to the outside.

**2.8 Broad Band Noise** — Spectrum consisting of a large number of frequency components, none of which is individually dominant.

**2.9 Cross-Talk** — Unwanted sound transmission between one room and another room or space via a duct.

**2.10 Decibels** — Ten times the logarithm (to the base 10) of the ratio of two mean square values of sound pressure, sound power or sound intensity. The abbreviation for 'decibels' is dB.

**2.11 Effective Perceived Noise Level in Decibel (EPN dB)** — The number for rating the noise of an individual aircraft flying overhead is the effective perceived noise level in decibels (EPN dB). The effective perceived noise decibel value takes into account the subjectively annoying effects of the noise including pure tones and duration. In principle, it is a kind of time-integrated loudness level.

**2.12 Equivalent Continuous A-Weighted Sound Pressure Level, $L_{Aeq.T}$** — Value of the A-weighted sound pressure level in decibels (dB) of a continuous, steady sound, that within a specified time interval, *T*, has the same mean squared sound pressure as the sound under consideration that varies with time, given by the formula:

$$L_{Aeq.T} = 10 \log_{10} \left\{ \frac{1}{T} \int_0^T \frac{p_A^2(t)}{p_o^2} dt \right\}$$

where

$p_A(t)$ = is the instantaneous A-weighted sound pressure in pascals (Pa); and

$p_o$ = is the reference sound pressure (20 μ Pa).

NOTE — Equivalent continuous A-weighted sound pressure level is mainly used for the assessment of environmental noise and occupational noise exposure.

**2.13 Equivalent Sound Absorption Area of a Room, *A*** — Hypothetical area of a totally absorbing surface without diffraction effects, expressed in square metres ($m^2$) which, if it were the only absorbing element in the room, would give the same reverberation time as the room under consideration.

**2.14 Facade Level** — Sound pressure level measured 1 m to 2 m in front of the façade.

NOTE — Facade level measurements of $L_{pA}$ are usually 2 dB to 3 dB higher than corresponding free-field measurements.

**2.15 Free-Field Level** — Sound pressure level measured outside, far away from reflecting surfaces.

NOTE — Measurements made 1.2 m to 1.5 m above the ground and at least 3.5 m away from other reflecting surfaces are usually regarded as being free-field measurements. To minimize the effect of reflections the measuring position should be at least 3.5 m to the side of the reflecting surface (that is, not 3.5 m from the reflecting surface in the direction of the source). Estimates of noise from aircraft overhead usually include a correction of 2 dB to allow for reflections from the ground.

**2.16 Frequency** — The number of cyclical variations per unit time. Frequency is generally expressed in cycles per second (cps) and is also denoted as Hertz (Hz).

**2.17 Impact Sound Pressure Level, $L_i$** — Average sound pressure level in a specific frequency band in a room below a floor, when it is excited by a standard tapping machine.

**2.18 Indoor Ambient Noise** — Pervasive noise in a given situation at a given time, usually composed of noise from many sources, inside and outside the building, but excluding noise from activities of the occupants.

**2.19 Insertion Loss ($L_{IL}$)**

Insertion loss is generally defined as the difference, in decibels, between two sound pressure levels (or power levels or intensity levels) which are measured at the same point in space before and after a muffler or any other noise control device is inserted between the measurement point and the noise source.

**2.20 Noise** — Unwanted sound which may be hazardous to health, intrerferes with communications or is disturbing.

**2.21 Noise Exposure Forecast (NEF)** — The noise exposure forecast at any location is the summation of the noise levels in EPN dB from all aircraft types, on all runways, suitably weighted for the number of operations during day time and night time.

**2.22 Noise Rating (NR)** — Graphical method for rating a noise by comparing the noise spectrum with a family of noise rating curves.

NOTE — Noise rating is described in Annex C.

**2.23 Noise Reduction Co-efficient (NRC)**

A single figure descriptor of the sound absorption property of a material. It is the arithmetic mean of the sound absorption co-efficients at 250, 500, 1 000 and 2 000 Hz rounded off to the nearest multiple of 0.05.

**2.24 Normalized Impact Sound Pressure Level, $L_n$ —** Impact sound pressure level normalized for a standard absorption area in the receiving room.

NOTE — Normalized impact sound pressure level is usually used to characterize the insulation of a floor in a laboratory against impact sound in a stated frequency band (*see* Annex B).

**2.25 Octave Band** — Band of frequencies in which the upper limit of the band is twice the frequency of the lower limit.

**2.26 Percentile Level, $L_{AN,T}$** — A-weighted sound pressure level obtained using time-weighting '*F*', which is exceeded for *N* percent of a specified time interval.

*Example*:

$L_{A90,1h}$ is the A-weighted level exceeded for 90 percent of 1 h. Percentile levels determined over a certain time interval cannot accurately be extrapolated to other time intervals. Time-weighting '*F*' or '*S*' can be selected on most modern measuring instruments and used to determine the speed at which the instrument responds to changes in the amplitude of the signal. Time-weighting '*F*' is faster than '*S*' and so its use can lead to higher values when rapidly changing signals are measured.

**2.27 Pink Noise** — Sound with an uninterrupted frequency spectrum and a power which is steady within frequency band and proportional to centre frequency. An example is constant power level per octave band.

**2.28 Pure Tone** — A sound emitted at a single frequency.

**2.29 Rating Level, $L_{Ar}$,$T_r$** — Equivalent continuous A-weighted sound pressure level of the noise, plus any adjustment for the characteristic features of the noise.

NOTE — This definition is used for rating industrial noise, where the noise is the specific noise from the source under investigation.

**2.30 Reverberation Time, *T*** — Time that would be required for the sound pressure level to decrease by 60 dB after the sound source has stopped.

NOTE — Reverberation time is usually measured in octave or third octave bands. It is not necessary to measure the decay over the full 60 dB range. The decay measured over the range 5 dB to 35 dB below the initial level is denoted by $T_{30}$, and over the range 5 dB to 25 dB below the initial level by $T_{20}$.

**2.31 Sound** — A vibrational disturbance, exciting hearing mechanisms, transmitted in a predictable manner determined by the medium through which it propagates. To be audible the disturbance shall have to fall within the frequency range of 20 Hz to 20 000 Hz.

**2.32 Sound Exposure Level, $L_{AE}$** — Level of a sound, of 1 s duration, that has the same sound energy as the actual noise event considered.

NOTES

1 The $L_{AE}$ of a discrete noise event is given by the formula:

$$L_{AE} = 10 \log_{10} \left\{ \frac{1}{t_o} \int_{t_1}^{t_2} \frac{p_A^2(t)}{p_o^2} dt \right\}$$

where

$P_A(t)$ = is the instantaneous A-weighted sound pressure in pascals (Pa);

$t_2 - t_1$ = is a stated time interval in seconds (s) long enough to encompass all significant sound energy of the event;

$p_o$ = is the reference sound pressure level (20µ Pa); and

$t_o$ = is the reference time interval (1 s).

2 $L_{AE}$ is also known as $L_{AX}$ (single-event noise exposure level).

**2.33 Sound Power** — The acoustic power of a sound source, expressed in Watts.

**2.34 Sound Power Level, $L_w$** — The acoustic power radiated from a given sound source as related to a reference power level (typically $10^{-12}$ watts) and expressed in decibels as:

$$L_w = 10 \log \left\{ \frac{W}{10^{-12}} \right\}$$

where

$W$ = Acoustic power in watts.

By definition, 1 W therefore corresponds to 120 dB for $L_w$.

**2.35 Sound Pressure, $p$** — Root-mean-square value of the variation in air pressure measured in pascals (Pa), above and below atmospheric pressure, caused by the sound.

**2.36 Sound Pressure Level, $L_p$** — Quantity of sound pressure, in decibels (dB), given by the formula:

$$L_p = 10 \log_{10} (p/p_o)^2$$

where

$p$ = is the root mean square sound pressure in pascals (Pa); and

$p_o$ = is the reference sound pressure (20µ Pa).

NOTE — The range of sound pressures for ordinary sounds is very wide. The use of decibels gives a smaller, more convenient range of numbers. For example, sound pressure levels ranging from 40 dB to 94 dB correspond to sound pressures ranging from 0.002 Pa to 1 Pa. A doubling of sound energy corresponds to an increase in level of 3 dB.

**2.37 Sound Receiver** — One or more observation points at which sound is evaluated or measured. The effect of sound on an individual receiver is usually evaluated by measurements near the ear or close to the body.

**2.38 Sound Reduction Index, $R$** — Laboratory measure of the sound insulating properties of a material or building element in a stated frequency band.

NOTE — For further information *see* Annex B.

**2.39 Sound Source** — Equipment or phenomena which generate sound. Source room is the room containing sound source.

**2.40 Spectrum** — A quantity expressed as a function of frequency, such as sound pressure *versus* frequency curve.

**2.41 Standardized Impact Sound Pressure Level, $L'_{nT}$**— Impact sound pressure level normalized to a reverberation time in the receiving room of 0.5 s.

NOTE — Standardized impact sound pressure level is used to characterize the insulation of floors in buildings against impact sound in a stated frequency band (*see* Annex B).

**2.42 Speech Interference Level (SIL)** — A descriptor for rating steady noise according to its ability to interfere with conversation between two people. SIL is the arithmetic average of the sound pressure levels in the three octave bands with centre frequencies at 500, 1 000 and 2 000 Hz.

**2.43 Standardized Level Difference, $D_{nT}$** — Difference in sound level between a pair of rooms, in a stated frequency band, normalized to a reverberation time of 0.5 s.

NOTE — Standardized level difference takes account of all sound transmission paths between the rooms (*see* Annex B).

**2.44 Structure Borne Noise** — Generation and propagation of time dependent motions and forces in solid materials which result in unwanted radiated sound.

**2.45 Transient Sound** — Sound which is audible for a limited period of time, for example sound from over flight of an airplane.

**2.46 Third Octave Band** — Band of frequencies in which the upper limit of the band is $2^{1/3}$ times the frequency of the lower limit.

**2.47 Threshold of Hearing** — The lowest continuous sound pressure level which will create an auditory sensation for the average human ear. Any sound below these levels will be inaudible and any sound above the threshold will vary in loudness dependent on intensity.

**2.48 Vibration Isolation** — Reduction of force or displacement transmitted by a vibratory source, often attained by use of a resilient mount.

**2.49 Wavelength** — The length in space of one complete cycle of a sound wave.

$$\lambda = \frac{\text{(Speed of sound)}}{\text{(frequency)}} = \frac{(C)}{(f)}$$

**2.50 Weighted Level Difference, $D_w$** — Single-number quantity that characterizes airborne sound insulation between rooms but which is not adjusted to reference conditions.

NOTE — Weighted level difference is used to characterize the insulation between rooms in a building as they are; values cannot normally be compared with measurements made under other conditions {*see* good practice [8-4(1)]}.

**2.51 Weighted Sound Reduction Index, $R_w$** — Single number quantity which characterizes the airborne sound insulating properties of a material or building element over a range of frequencies.

NOTE — The weighted sound reduction index is used to characterize the insulation of a material or product that has been measured in a laboratory (*see* Annex B).

**2.52 Weighted Standardized Impact Sound Pressure Level, $L'_{nT, w}$** — Single number quantity used to characterize the impact sound insulation of floors over a range of frequencies.

NOTE — Weighted standardized impact sound pressure level is used to characterize the insulation of floors in buildings (*see* Annex B).

**2.53 Weighted Standardized Level Difference, $D_{n,Tw}$** — Single-number quantity, which characterizes the airborne sound insulation between rooms

NOTE — Weighted standardized level difference is used to characterize the insulation between rooms in a building (*see* Annex B).

**2.54 Weighted Normalized Impact Sound Pressure Level, $L'_{n.w}$** — Single number quantity used to characterize the impact sound insulation of floors over a range of frequencies.

NOTE — Weighted normalized impact sound pressure level is usually used to characterize the insulation of floors tested in a laboratory (*see* Annex B).

**2.55 White Noise** — A noise whose spectrum (level) density is substantially independent of frequency over a specified range and has equal power for any range of frequencies of constant band width.

## 3 PLANNING AND DESIGN AGAINST OUTDOOR NOISE

### 3.1 General

Planning against noise should be an integral part of town and country planning proposals, ranging from regional proposals to detailed zoning, and three-dimensional layouts and road design within built-up areas. Noise nuisance should be fully recognized in zoning regulations.

**3.1.1** Noise is either generated by traffic (road, rail and underground railway) or it arises from zones and buildings within built-up areas (industry, commerce, offices and public buildings). For planning, the noise survey should examine all the possible causes of noise and consider the various factors causing actual nuisance.

**3.1.2** Noise by night, causing disturbance of sleep, is more of nuisance than noise by day. For this reason, housing colonies that adjoin areas with heavy traffic movement during the night are liable to cause serious complaints. Also, the factories that work by night are liable to cause serious complaints if housing estates adjoin them. While planning, care should be taken that housing colonies are adequately setback from busy airports, state and national highways, factories, main railway lines and marshalling yards.

**3.1.3** There are two aspects of defence by planning. The first is to plan so as to keep the noise at a distance. Under this aspect comes the separation of housing from traffic noise by interposing buffer zones, and the protection of schools and hospitals by green belts, public gardens, etc. The second is the principle of shading or screening. This consists of deliberately interposing a less vulnerable building to screen a more vulnerable one or by providing a solid barrier, such as a wall, between the source and the location to be protected.

### 3.2 Traffic Noise Levels

**3.2.1** *For Air Traffic*

For guidance, approximate noise levels due to various types of aircrafts, measured on ground, when the aircrafts fly overhead at a height of 450 m, are given in Table 1.

**Table 1 Typical Noise Levels of Some Aircarft Types**

(*Clause* 3.2.1)

| Sl No. | Type of Aircraft | Flyover Noise Levels at 450 m with Take-off Thrust (EPN dB) |
|---|---|---|
| (1) | (2) | (3) |
| i) | Boeing 737 | 107 |
| ii) | Boeing 747-200 | 103 |
| iii) | Airbus A 300 | 101 |
| iv) | Concorde SST | 114 |

**3.2.2** *For Rail Traffic*

Noise levels of some typical railway traffic are given in Table 2.

**Table 2 Typical Noise Levels of Railway Trains**

(*Clause* 3.2.2)

| Sl No. | Type of Train | Noise Level at 30 m, Measured on the Side or in the Direction of Train, dB (A) |
|---|---|---|
| (1) | (2) | (3) |
| i) | Steam train, 60 km/h | 85 |
| ii) | Diesel train, 60 km/h | 83 |
| iii) | Electric train, 60 km/h | 77 |

**3.2.3** *For Road Traffic*

The level of noise generated by road traffic depends upon such factors as the number of vehicles passing per hour, the type of traffic, the preponderance of heavy vehicles, average speed, gradient and smoothness of traffic flow. The smoothness of traffic flow also affects variability of the noise and is governed by such things as roundabouts and traffic lights, and the volume of traffic and pedestrian movement with their effects on stopping, starting and overtaking. The level of traffic noise fluctuates continuously and the way it does has a considerable effect on the nuisance caused. For assessing traffic noise, noise is measured in dB(A). Because of the fluctuating nature of traffic, noise levels due to different volumes of traffic flow with a varying mix of vehicles are given in Table 3.

**Table 3 Typical Noise Levels Due to Free-Flowing Road Traffic**

(*Clause* 3.2.3)

| Sl No. | Type of Traffic | $L_{10}$ 30 m from Edge of Road, dB(A) |
|---|---|---|
| (1) | (2) | (3) |
| i) | 5 000 vehicles per 18 hour day (10 percent heavy vehicles), 50 kmph | 65 |
| ii) | 10 000 vehicles per 18 hour day (20 percent heavy vehicles), 60 kmph | 70 |
| iii) | 10 000 vehicles per 18 hour day (40 percent heavy vehicles), 80 kmph | 75 |
| iv) | 20 000 vehicles per 18 hour day (40 percent heavy vehicles), 80 kmph | 77 |

NOTE — The values are applicable to free flowing traffic without honking.

## 3.3 Outdoor Noise Regulations

The outdoor noise regulations in force from time-to-time shall be complied with (*see also* Annex D).

## 3.4 Planning and Design

**3.4.1** *For Air Traffic*

Near airports two sources of aircraft noise should be considered.

a) *Flyover noise* — Flyover noise is that which occurs under flight paths close to airports and is the most serious and common problem. As the aircraft passes overhead the noise level at any particular location rises to a peak and then decreases.
b) *Ground noise* — The noise emitted by an aircraft during ground operations is less variable in direction than flyover noise, but is usually of a longer duration.

**3.4.1.1** Aircraft noise may disturb sleep, rest and communication, and as such may be considered potentially harmful to health. It is important that no new development is carried out within areas where the expected noise levels will cause mental and physical fatigue or permanent loss of hearing. In case development in such areas is essential, adequate sound insulation shall be provided for the building.

**3.4.1.2** As the problems caused by aircraft noise have become more acute, a number of methods have been devised for evaluating noise exposure in the vicinity of airports. They all combine many factors into a single number evaluation. A commonly used criterion is the noise exposure forecast (NEF). The NEF is used primarily to develop noise contours for areas around airports. It has been accepted generally that noise exposure forecast levels greater than NEF 40 are unacceptable to people while levels less than NEF 25 are normally acceptable.

**3.4.1.3** While it is theoretically possible to provide sufficient insulation to achieve an acceptable indoor noise environment in the area of very high outdoor noise, there is a level above which aircraft noise seriously affects living conditions no matter how much sound insulation has been applied to the dwelling unit. For this reason it is recommended that no residential development be allowed beyond the NEF 35 level.

**3.4.1.4** During summer months, the windows are normally kept open for adequate ventilation. In view of this, no matter how much sound insulation is provided for the building structure, the noise level inside the room can never be less than 10 dB below the outdoor noise level. For very critical buildings, such as buildings necessary for maintaining and supplementing the airport services, and for commercial development, such as hotels, it is possible to provide sealed windows and to centrally air-condition the entire building. However, it is not feasible for most of the residential developments in the country. In such cases proper zoning regulations and siting of vulnerable buildings away from aircraft noise are of vital importance.

**3.4.2** *Rail Traffic*

This is a very serious source of noise in built-up areas, both by day and by night. Railway cuttings reduce the spread of noise, whereas embankments extend it. The elevated railway on viaducts or embankment is very common in built-up areas. The elevation increases exposure to noise but in addition the construction of the viaduct may effect the propagation of noise. In this respect solid embankments are preferable to built-up arches, which tend to act as sound boxes. Worst of all are the steel bridges, which greatly magnify the noise due to vibration. Uphill gradients are another feature tending to increase noise, especially of heavy goods trains.

**3.4.2.1** Wherever possible, no residential or public building zone should abut onto railway lines, especially on the marshalling yards which is particularly objectionable because of the shrill, clanging and intermittent noise they generate, often at night. The appropriate zones along side railway lines are industrial and commercial buildings other than office buildings. Where these precautions are not practicable and housing has to abut on to railway lines, every attempt may be made to house as few people as possible in the vicinity of the railway lines.

**3.4.2.2** Underground transportation system can be a major cause of disturbance for the neighbouring community. Very high noise levels are propagated to long distances by the underground high speed railway, as a result of wheel rail interaction. Both air-borne noise and ground or structure-borne vibration are potential sources of complaints. Noise control measures, therefore, need to be considered for the following:

a) In stations, where high noise levels are produced at the arrival and departure of trains;
b) In tunnels, during high speed train movement;
c) Where an underground rail transit system passes close to existing structures or high rise buildings adequate attention should also be paid to the problem of ground vibration transmitted to the building, and proper isolation should be provided for critical areas;
d) Wherever elevated railway tracks are provided, adequate measures should be taken to avoid the spread of noise in the surrounding built up areas; and
e) In transit cars, where sound insulation is of vital importance to provide comfortable conditions for the commuters.

**3.4.3** *Road Traffic*

**3.4.3.1** Convoys of long distance heavy trucks at night moving past through built-up areas cause serious noise complaints. On busy roads, the noise of continuous traffic may be a worse nuisance than that of railways. At least the same precautions may, therefore, be taken in the planning of dwellings in relation to arterial and trunk roads as with railways. Care may be taken that local housing roads do not provide short cuts for heavy traffic through residential areas. Hilly roads present the additional noise of gear changing. Trees with heavy foliage planted on both sides of carriageway help slightly to muffle the noise, provided the foliage extends for a considerable distance (30 m or above).

**3.4.3.2** Road traffic may give rise to serious nuisance particularly on busy thorough fares, between continuous high buildings in main streets, at the traffic lights, near bus stops, on steep slopes and in parking spaces and enclosed yards.

**3.4.3.3** For zoning and planning new buildings in urban areas it is recommended that external $L_{A10}$ is limited to a maximum of 70 dB(A) when the dwellings are proposed to have sealed windows and 60 dB(A) when the dwellings are proposed to have open windows. Indeed it is desirable to confine major new residential development to locations subject to $L_{A10}$ levels substantially lower than those given above.

It is recognized, however, that within the large urban areas, the use of sites where the external $L_{A10}$ is greater than 60-70 dB(A) can not always be avoided. In that case it is suggested to utilize such design solutions as barrier blocks in order to reduce external $L_{A10}$ noise levels to at least 60-70 dB(A) at any point 1.0 m from any inward looking façade. When the orientation of site and the density of development are such that this cannot be fully achieved some form of dwelling insulation will have to be provided. It should be appreciated that where open windows are a must, the occupants would have to put up with discomfort if the above conditions are not met.

**3.4.3.4** Certain other methods can often be utilized to provide economical and effective protection from noise:

a) Methods may be adopted to improve the smoothness of flow and reduce number of stopping and starting. This leads to an improvement even if it leads to increased flows. Flow linking of traffic lights, for example, may reduce noise nuisance.
b) Use of roads passing through residential areas may be prohibited to heavy commercial vehicles. An alternative would be to limit use by commercial vehicles to certain times of the day.
c) Use of honking may be prohibited near sensitive buildings, such as hospitals and the like.
d) Barriers may be provided to shield sites from noise.

## 3.5 Zoning

The zoning of the different cities shall be done by the town planning authorities, taking into account besides other aspects, the noise levels from different occupancies. Wherever necessary, experts in the field may be consulted. For detailed information on noise reduction for town planning schemes, reference may be made to good practice [8-4(2)].

## 3.6 Green Belts and Landscaping

Where relief from noise is to be provided by means of green belts these may be of considerable width and be landscaped. (In case of railway tracks, a minimum distance of 50 m to 70 m may be provided between the buildings and the tracks.) The extent of relief that may be derived from the above may be estimated only after considering other environmental factors. Only thick belts of planting (greater than 30 m) are of real value. Strong leafy trees may be planted to act as noise baffles. Shrubs or creepers may also be planted for additional protection between tree trunks; artificial mounds and banks should be formed where practicable. As little hard paving and as much grass as possible may be used. The creation of green belt is particularly advisable on the perimeter of aerodromes, along railway lines and arterial roads, through or past built-up areas and adjoining noisy industrial zones.

**3.7 Highway Noise Barriers**

Barriers are often the most effective means of reducing traffic noise around residential areas. They have the great advantage that they generally protect most or all of the site. In nearly all situations, a well-designed barrier of even a modest height (say 3 m) can at least ensure that all areas of open space are free from excessive noise levels.

There are two types of barriers that can be built to protect sites; one which are built solely for the purpose of reducing noise and two, which form part of the building complex (barrier blocks). Free standing walls and artificial mounds are typical examples of the first type while single and multi-storeyed dwellings and/or garages are the most common form of the second.

Of the two types, barrier blocks are more widely used because they are cheaper and also tend to form a more effective barrier overall because of their greater height and width. Barrier walls or mounds are more limited in their effect than barrier blocks for they protect little more than the area of the site close to ground level essentially because of the lack of height, as continuous walls much higher than 3 m are often difficult to construct.

**3.8 Special Problems Requiring Expert Advice**

The purpose of noise control is to ensure that people are neither harmed not disturbed by noise. In addition to provisions given in this Section, special advice may be required for more complex situations, such as those listed in Annex E.

## 4 PLANNING AND DESIGN AGAINST INDOOR NOISE

**4.1 Acceptable Indoor Noise Levels in Buildings**

The generally acceptable noise levels inside buildings are given in Table 4.

**Table 4 Acceptable Indoor Noise Levels for Various Buildings**

(*Clause* 4.1)

| Sl No. | Location | Noise Level dB(A) |
|---|---|---|
| (1) | (2) | (3) |
| i) | Auditoria and concert halls | 20-25 |
| ii) | Radio and TV studios | 20-25 |
| iii) | Cinemas | 25-30 |
| iv) | Music rooms | 25-30 |
| v) | Hospitals and cinema theatres | 35-40 |
| vi) | Apartments, hotels and homes | 35-40 |
| vii) | Conference rooms, small offices and libraries | 35-40 |
| viii) | Court rooms and class rooms | 40-45 |
| ix) | Large public offices, banks and stores | 45-50 |
| x) | Restaurants | 50-55 |

**4.2 Vulnerable Buildings**

Some buildings or parts of buildings are specially vulnerable to noise, for example, recording and radio studios, hospitals and research laboratories. These should not be sited near loud noise sources. Most vulnerable buildings contain some areas which are themselves noisy and in such buildings the less vulnerable elements should be planned to act as noise buffers. Most noisy buildings also contain quiet accommodation, which equally may be planned to act as a buffer between the noisy part of the building and adjoining vulnerable buildings.

**4.3** The details of site and internal planning and insulation requirements are covered under individual occupancies (**5** to **12**) as applicable to the respective character and sources of noise in different buildings.

**4.4 Sound Insulation of Non-Industrial Buildings by Constructional Measures**

The desired (acceptable) noise levels and the recommended insulation values for the various areas may be achieved by providing sound insulation treatments by constructional measures. The details of the same are given in Annex F. The recommendations given in Annex F are applicable to non-industrial buildings like residences, educational buildings, hospitals and office buildings.

**4.5 Special Problems Requiring Expert Advice** — (*see* **3.8** and Annex E).

## 5 RESIDENTIAL BUILDINGS

**5.1 Sources of Noise Nuisance**

**5.1.1** *Outdoor Noise*

The main sources of outdoor noise in residential areas are traffic (aeroplane, railways, roadways), children playing, hawkers, services deliveries, road repairs blaring loud-speakers and various types of moving machinery in the neighbourhood and building operations.

**5.1.2** *Indoor Noise*

**5.1.2.1** As far as indoor noises are concerned, conversation of the occupants, footsteps, banging of doors, shifting of the furniture, operation of the cistern and water closet, playing of radio, television, music system, cooling and ventilation machinery, etc, contribute most of the noise emanating from an adjacent room or an adjacent building. Noise conditions vary from time-to-time and noise which may not be objectionable during the day may assume annoying proportions in the silence of the night when quiet conditions are essential.

**5.1.2.2** In the case of flats the main sources of noise are from other flats and from stairs, lifts and access balconies. Plumbing noise is another cause. In semi-detached buildings, outdoor noises from streets are noticed more than indoor noises from neighbours.

**5.2 Recommendations**

**5.2.1** *Site Planning*

The most desirable method is to locate the residential buildings in a quiet area away from the noisy sources like the industrial areas, rail tracks, aerodromes, roads carrying heavy traffic, etc.

**5.2.1.1** To minimize ground reflection, the dwellings should be surrounded by the maximum amount of planting and grassed areas and the minimum amount of hard surfacing. This applies particularly to high density areas. Where for maintenance reasons a large amount of hard paving is necessary, it should be broken up by areas of planting and grassing. Narrow hard paved courts should be avoided between adjacent tall buildings.

**5.2.1.2** Roads within a residential area should be kept to a minimum both in width and length, and should be designed to discourage speeding. Area-wise planning, with zones from which vehicular traffic is altogether excluded will greatly help to reduce noise. Roads with through traffic should be excluded from residential areas, but where sites have to be developed adjacent to existing major roads the same principles should be observed in the siting of blocks as with railway lines as covered under **3.4.2.1.**

**5.2.1.3** Play areas for older children should be sited as far away from dwellings as possible. Special care should be taken with old peoples' dwellings. They should not be placed immediately adjacent to service entries, play spaces, or to any entrances where children may tend to congregate.

**5.2.2** *Internal Planning*

The orientation of buildings in a locality should be planned in such a way as to reduce the noise disturbance from neighbourhood areas. The non-critical areas, such as corridors, kitchens, bathrooms, elevators and service spaces may be located on the noisy side and the critical areas, such as bedrooms and living space, on the quiet side.

**5.2.2.1** *Windows and doors*

Windows and doors should be kept away from the noisy side of the building as given below, wherever possible:

a) When windows of a building, particularly those of bedrooms in apartments or flats, face roads carrying heavy traffic or other noises where the external noise is of the order of 80 to 90 dB(A), the building should be located at a distance of about 30 m from the road, but a distance of 45 m or more, where possible, should be aimed at for greater relief from noise;
b) When the windows are at right angles to the direction of the above type of noise, the distance from the road should be arranged to be about 15 to 25 m; and
c) In case another building, boundary wall or trees and plantations intervene between the road traffic and the house/flat further noise reduction is achieved and in such cases the above distances may be reduced suitably.

**5.2.2.2** *Layout plans*

It is desirable that rooms adjoining party walls and above/below party floors should be of similar use. By this means, bedrooms are not exposed to noise from adjoining living rooms, and there is less risk of disturbance of sleep.

In semi-detached houses, the staircase, hall and kitchen should adjoin each other on each side of the party wall, thus providing a sound baffle between rooms requiring quiet conditions.

Bedrooms should not be planned alongside access balconies, and preferably not underneath them. Where the approach is by an internal corridor, a sound baffle may usefully be provided by arranging internal passages and bathrooms between the corridor and the living room or bedrooms.

Water-closets should not be planned over living rooms and bedrooms, whether within the same dwelling or over other dwellings. Soil pipes should not be carried in ducts which adjoin living rooms or bedrooms unless the side of the duct next to these rooms is a solid wall containing no inspection openings. Refuse chutes should not be planned next to living rooms or bedrooms.

**5.2.3** *Sound Insulation*

**5.2.3.1** *Reduction of air-borne noise*

The weighted sound reduction index, $R_w$, of partitions between individual rooms or apartments of a building unit shall be as given in Table 5. These values may, however, be suitably increased, where required, for critical areas.

**Table 5 Sound Insulation Between Individual Rooms (Air-Borne)**

(*Clause* 5.2.3.1)

| Sl No. | Situation | $R_w$, dB |
|---|---|---|
| (1) | (2) | (3) |
| i) | Between the living room in one house or flat and the living room and bedrooms in another | 50 |
| ii) | Elsewhere between houses or flats | 45 |
| iii) | Between one room and another in the same house or flat | 35 |

NOTES

**1** Where communicating doors are provided, all doors should be so designed as to provide recommended insulation between the rooms.

**2** There are cases when a set of houses or flats have to be built for the people who work at night and sleep during the day. It is desirable to consider the design of at least one such room in each of the houses or flats which will provide an insulation of about 45 dB in that room.

**3** The insulation values referred to are applicable with doors and windows shut.

**5.2.3.2** *Suppression of noise at the source itself*

All items of equipment that are potentially noisy should be selected with care. Water-closet cisterns should not be fixed on partitions next to bedrooms or living rooms. Plumbing pipes should be isolated from the structures. Lift motors should be mounted on resilient supports. Access doors from machine rooms to internal staircases should be well fitting and of solid construction. Special noise control measures may be required for electrical and mechanical services such as diesel generators, outdoor air conditioning units, cooling towers, etc.

**5.2.3.3** *Reduction of air-borne noise transmitted through the structure*

Reduction of air-borne noise requires the use of rigid and massive walls without any openings. Openings are the major cause of penetration of noise through a barrier. While designing it should be borne in mind that all components should provide a sound transmission compatible with that of the rest of the barrier so that an equivalent amount of sound energy is transmitted through each portion of the barrier.

Ventilating ducts or air transfer openings where provided should be designed to minimize transmission of noise. For this purpose, some sound attenuating devices may be installed in these openings.

All partitions should be sealed effectively where they butt against rest of the structure. All doors and windows should be properly gasketed where a high degree of sound insulation is desired.

**5.2.3.4** *Reduction of structure-borne noise*

This requires the use of discontinuous or non-homogeneous materials in the construction of the structure.

**5.2.3.5** *Reduction of impact noise*

The floor of a room immediately above the bedroom or living room shall provide impact sound pressure level ($L'_{n, Tw}$) not greater than 60 dB. For example, 150 mm thick concrete floor with thick carpet (12 mm) covering would satisfy this requirement.

**5.2.3.6** Main staircases in blocks of flats are often highly reverberant. Some of the surfaces at least (for example, the soffits of stairs and landings) should be finished with sound absorbent materials wherever required.

## 6 EDUCATIONAL BUILDINGS

### 6.1 Sources of Noise Nuisance

**6.1.1** *Outdoor Noise*

The outdoor sources of noise produced on school premises, which cause disturbance within the school, include the noise arising from playgrounds, playing fields and open-air swimming pools. Though playgrounds are used mainly during break periods, they are also used for games and physical education at times when teaching is in progress in the adjoining class rooms.

**6.1.2** *Indoor Noise*

Indoor sources of noise are as follows:

a) Singing, instrumental and reproduced music which may take place in class rooms and in dining and assembly halls particularly in primary schools. In secondary schools, specialized music rooms are generally provided;
b) The movement of chairs, desks and tables at the end of one period may disturb a class engaged in a lesson in a room below;
c) The shutting and openings of doors and windows which may occur at any time during teaching periods;
d) Audio-visual presentations in class rooms;
e) Wood and metal workshops, machine shops (engineering laboratories), typing rooms etc,

which produce continuous or intermittent sound of considerable loudness;

f) Practical work carried out in general teaching areas;
g) Gymnasia and swimming pools;
h) School kitchens and dining spaces where food preparation and the handling of crockery and utensils persist for the greater part of the school day;
j) Corridors and other circulation spaces; and
k) Plumbing and mechanical services.

**6.2 Recommendations**

**6.2.1** *Site Planning*

Where outdoor noise nuisance exists from local industry, busy roads, railway, airfields, sport grounds or other sources beyond the control of the school authority, school buildings should be sited as far as possible from the sources of noise.

**6.2.1.1** Rooms should be planned in a manner so that the minimum amount of glazing is placed on the side facing the external noise.

**6.2.1.2** Noises arising from the activities of a school and from the use of the buildings after school hours may constitute a nuisance to occupants of surrounding property; therefore, it is desirable to place playgrounds, workshops, swimming pools, music rooms, assembly halls and gymnasia as far away as possible from buildings which require a quiet environment.

**6.2.2** *Internal Planning*

The following principles should be observed in the detailed planning of educational buildings:

a) *Grouping* — Noisy rooms should be separated from quiet ones, if possible. In general, it is desirable that rooms should be grouped together in accordance with the classification given in **6.2.4.1**.
b) *Windows and ventilators* — Windows of noisy and quiet rooms should not open on to the same courtyard or be near to one another. Roof lights and ventilators over noisy rooms should be avoided, if they are likely to be a source of nuisance to adjacent upper floors.
c) *Doors* — Swing doors into rooms should only be used where no problem of sound transmission exists. Reduction of insulation between rooms and corridors due to doors must be borne in mind. The type and method of fitting of doors is important and necessary care shall be paid in this respect.
d) Sliding partitions should only be used where essential.
e) *Open planning and circulation areas* — Where open planning is used to permit spaces, such as assembly halls, dining rooms or entrance halls to be used in association with each other or for circulation, the degree of disturbance caused by interfering noise to teaching areas needs careful consideration; traffic through such areas should be strictly controlled; full use should be made of sound absorbent treatments to reduce the spread of noise from one space to another (*see* **6.2.3**).

   If rooms have large glazed panels or ventilation openings facing directly on the circulation areas, human traffic passing by the rooms should be controlled. Preferably baffled ventilation system or double windows should be used. (Fan-lights over doors should be fixed and glazed).
f) *Furniture* — In all educational buildings, regardless of the character of the floor finish, rubber buffers should be fitted to the legs of chairs and tables.

**6.2.3** *Noise Reduction within Rooms*

Sound absorbent materials play a useful part in reducing the built-up or air-borne noise at source. In rooms, such as, classrooms, assembly halls and music rooms, a fairly short reverberation time under occupied conditions is one of the requirements of the acoustic design. The maximum reverberation times permissible for this purpose are usually short enough to give adequate noise control but in addition, the reverberation time should not be excessive under empty conditions, because noise may occur in these rooms with very few occupants. Table 6 gives the reverberation times often arranged in occupied rooms for acoustic reasons and the maximum times recommended in the empty rooms for noise reduction; the times given are for a frequency of 500 Hz, but they should not be greatly exceeded at any frequency. When rooms are used for a variety of purposes, the reverberation period appropriate to the major use should be adopted.

**6.2.3.1** Special attention should be given to noise reduction in schools for the deaf and schools for the blind. Deaf children are taught by means of hearing aids which cannot be used satisfactorily in high noise levels or in reverberant conditions. Blind children depend on good hearing for understanding speech and for detecting changes in environment. In both these types of schools, noise levels should be kept low and reverberation times short. As an example, the reverberation times in empty class-rooms should not exceed one second in schools for the blind or 0.5 second in schools for the deaf.

**Table 6 Reverberation Times in Schools**
(*Clause* 6.2.3)

| Sl No. | Room | Reverberation Time, s | |
|---|---|---|---|
| | | Usual for Acoustic Reasons (Full) | Maximum[1)] for Noise Control (Empty) |
| (1) | (2) | (3) | (4) |
| i) | Assembly halls | 1.0-1.25 according to size | 1.5-2.5 according to volume of hall |
| ii) | Music teaching rooms | 0.75-1.25 | 1.5 |
| iii) | Gymnasia and indoor swimming pools | — | 1.5 |
| iv) | Dining rooms | — | 1.25 |
| v) | Classrooms | 0.75 | 1.25 |
| vi) | Headmasters room and staff rooms | 0.5-1.00 | 1.0 |

1) Shorter reverberation times are desirable for noise control whenever possible.

**6.2.4** *Sound Insulation*

**6.2.4.1** *Air-borne noise*

For purposes of sound insulation, rooms in educational buildings may be classified as follows:

| | | |
|---|---|---|
| Class A | Noise Producing | Workshops<br>Kitchens<br>Dining rooms<br>Gymnasiums<br>Indoor swimming pools |
| Class B | Producing but needing quiet at times | Assembly halls<br>Lecture halls<br>Music rooms<br>Typing rooms |
| Class C | Average | General classrooms<br>Practical rooms<br>Laboratories<br>Offices |
| Class D | Rooms needing quiet | Libraries<br>Studies |
| Class E | Rooms needing privacy | Medical rooms<br>Staff rooms |

**6.2.4.2** The recommended minimum sound reduction ($D_w$) between rooms of the same class is as follows:

| | | |
|---|---|---|
| Class A | – | 25 dB |
| Class C or D | – | 35 dB |
| Class B or E | – | 45 dB |

**6.2.4.3** Where a room is likely to have a dual use, for example, a dining room to be used as a classroom, the higher sound insulation value should be used.

**6.2.4.4** The recommended minimum sound reduction ($D_w$) between rooms in different classes is 45 dB subject to the following:

a) In schools or institutes with a technical bias where noisy activities, such as sheet metal work, plumbing and woodwork, are likely to be practised extensively in normal hours, workshops should be regarded as a special category requiring more than 45 dB isolation ($D_w$) from rooms of any other class.

b) Assembly halls and music rooms are special cases in that, as well as producing noise, they also require protection from it and may need more than 45 dB isolation ($D_w$) from rooms in Class A, if the latter are very noisy.

c) Circulation spaces may vary from a long and frequented corridor to a small private lobby and it is therefore difficult to give precise recommendations to cover them. For partitions between rooms in Class C and most corridors, a $R_w$ of 35 dB for the partition itself is adequate. For partitions between rooms in other classes and corridors, more or less insulation may be necessary, depending upon the specific usage.

d) The problem of noise in circulation areas is as a rule greatly mitigated in schools by the fact that classes usually change rooms together at regular times. In colleges and evening institutes, however, this is much less true and in such buildings particular attention should be paid to insulation between rooms and corridors.

**6.2.4.5** *Open plan schools*

A new concept in school planning is the use of a large teaching area with simultaneous instructions imparted to several groups of students. These open plan teaching areas offer a different set of problems. Because of the limitations in achieving a great deal of attenuation across the space and related difficulties in noise control and speech interference, lecturing to a large number of students is not possible without interfering with neighbouring groups. The shape of such spaces may be as linear as possible with a width to height ratio of 5:1 or greater.

In addition, special measures are required to be introduced to reduce the level of intruding speech to an acceptable value so that the various teaching groups are not disturbed and adequate privacy is maintained. Judicious positioning of partial height barriers 1.8 m to 2.1 m in height can improve the sound attenuation between teaching groups and the use of reflective screens can reinforce the speech locally without reflecting it to unwanted areas.

**6.2.4.6** *Impact noise*

In the case of schools, the concrete floor of the room immediately above the teaching rooms shall provide an impact sound pressure level, $L'_{n, T_w}$ not greater than 70 dB. For example, a covering of 6 mm linoleum or cork tiles on concrete floor (hollow or solid) weighing not less than 220 kg/m$^2$ will usually meet the above requirement.

## 7 HOSPITAL BUILDINGS

### 7.1 General

Problems of noise control vary from hospital to hospital but the principles outlined below apply to all types. A quiet environment in hospitals is desirable for patients who are acutely ill. Staff require quiet conditions for consultations and examinations and also in their living and sleeping quarters. There have been rapid rises in noise levels in hospitals due to the higher levels of outdoor noise, increasing use of mechanical and mobile equipment (some of which is now brought much nearer to the patient in order to facilitate nursing procedure) and the introduction of loudspeaker, radio, television and call systems. Noise control in the hospital is made much more difficult by the extensive use of hard washable surfaces which reflect and intensify the noise. In most hospitals, windows to the open air and fanlights to corridors are usually open for the purpose of ventilation, admitting noise from outside and allowing it to spread through the building.

### 7.2 Sources of Noise Nuisance

**7.2.1** *Outdoor Noise*

This may be classified into two main categories:

a) Noise from sources outside the hospital premises, for example, traffic and industrial noises; and
b) Noise from sources outside the building but usually within the control of the hospital authority, for example, ambulances, motor-cars and service vehicles, fuel and stores deliveries, laundries, refuse collection, trucks and trolleys.

**7.2.2** *Indoor Noise*

A hospital is a complex building with many services and the numerous internal sources of structure-borne and air-borne noises are grouped into three main categories:

a) Noise consequent upon hospital routines. This category includes sources which transmit noise through both structure-borne and air-borne paths, many of which may be quite near to patients particularly those in wards, such as the following:
   1) Wheeled trolleys of various kinds, for food and medical supplies;
   2) Sterilizing equipment;
   3) Sluice room equipment including bedpan washers;
   4) Ward kitchen equipment;
   5) Footsteps;
   6) Doors banging;
   7) The handling of metal or glass equipment;
   8) Noises caused during maintenance and overhaul of engineering services; and
   9) Vacuum cleaners, mechanical polishers, etc.
b) Loudspeaker, radio or television, audible call system, telephone bells and buzzers, and other air-borne noises, such as loud conversation; and
c) Noises from fixed or mobile equipment and services not directly concerned with hospital routines. These include all the fixed services as given below:
   1) Plumbing and sanitary fittings;
   2) Steam hot and cold water and central heating pipes;
   3) Ventilation shafts and ducts;
   4) Fans
   5) Boilers;
   6) Pumps;
   7) Air compressors;
   8) Pneumatic tubes;
   9) Electrical and mechanical motors and equipment;
   10) Lifts;
   11) Laundry equipment; and
   12) Main kitchen equipment (refrigerators, mixers, steam boilers, etc).

### 7.3 Recommendations

**7.3.1** *Site Planning*

Hospital sites with their high degree of sensitivity to outside noise should be as far away from outside sources as may be compatible with other considerations, such as accessibility and availability of services. The building should be so arranged on the site that sensitive areas like wards, consulting and treatment rooms, operating theatres and staff bedrooms are placed away from outdoor sources of noise, if possible, with their windows overlooking areas of acoustic shadow.

**7.3.2** *Detailed Planning*

There is a very large number of unit and room classification in hospital design and in planning the units in relation to each other and to the common services (such as X-ray departments, operating theatre suits and main kitchens), noise reduction in the sensitive areas should be weighed carefully against other design factors. Special care in overall planning and internal planning against noise is required in the planning within the building of units which are themselves potential noise sources, for example, children's wards and outpatients' departments, parts of which require protection against noise.

**7.3.2.1** Unloading bays, refuse disposal areas, boiler houses, workshops and laundries are examples of service units which should be as far from sensitive areas as possible.

**7.3.2.2** The kitchen is a constant source of both air-borne and structure-borne noise and should preferably be in a separate building away from or screened from the sensitive areas. If this is not possible and the main kitchens must form part of a multi-storey building, noise control is easier if they are placed below and not above the wards and other sensitive rooms so as to facilitate the insulation of the equipment and machinery in order to reduce the transmission of structure-borne noise to a minimum.

**7.3.2.3** In ward units, the kitchens, sluice rooms, utility rooms, sterilizing rooms and other ancillary rooms, need to be placed quite near to the beds if they are to fulfil their purposes, which are all sources of noise. Some form of noise baffling between open wards and rooms of this kind will be needed.

**7.3.3** *Reduction of Noise at Source*

In view of the difficulty of suppressing noise in hospital buildings, it is important to eliminate noise at its source wherever possible.

**7.3.3.1** *Use of resilient material*

Mats of rubber or other resilient material on draining boards and rubber-shod equipment will greatly reduce noise from utility rooms, sluice rooms and ward kitchens. The use of plastics or other resilient materials for sinks, draining boards, utensils and bowls would also reduce the noise. Many items of equipment especially mobile equipment, such as trolleys and beds, may be silenced by means of rubber-tyred wheels and rubber bumper and the provision of resilient floor finishes (*see* **7.3.4.1**). The latter also reduces footstep noise. Silent type curtain rails, rings and runners should be used. Lift gates and doors should be fitted with buffers and silent closing gear. Fans and other machinery should be mounted on suitable resilient mountings to prevent the spread of noise through the structure.

**7.3.3.2** *Other measures*

Noise from water or heating pipes may be reduced by installing systems which operate at comparatively low pressure and velocities. Silencing pipes and specially designed flushing action reduce water closet noise at source and make structural measures easier to apply. The ventilation system should be designed so as not to create a noise problem. Silent closers should be fitted to doors.

**7.3.4** *Reduction of Noise by Structural Means*

**7.3.4.1** *Insulation*

Since the various departments or units may be planned in many ways, only general guidance on the insulation values for walls and partitions is given as below:

a) It is recommended that walls or partitions between rooms should normally have a $R_w$ of at least 40 dB. Higher values of $R_w$ of at least 45 dB are necessary where a noisy room is adjacent to one requiring quiet conditions. Doors should be solid with close fitting in the frames.
b) There is little insulation value in double swing doors and where these are fitted to a noisy room the opening should be planned so that it is screened from areas requiring quiet by a baffle lobby lined with absorbent material. Very high insulation values may be necessary in special cases and exceptional measures may be required.
c) Solid floors with floating finishes and resilient surfaces are necessary particularly between wards and other parts of the building. Ordinary timber board on joist floors should never be used.
d) Conduits, ventilation ducts, chases, etc, should be constructed so as not to form easy by-pass for disseminating noise about the building, and should be provided with sufficient sound insulation. Pipe ducts should be completely sealed around the pipes where they pass through walls or floors. Ducts carrying waste or water pipes should be lined with sound insulating material to prevent noise from the pipes passing through duct walls into the rooms through which they pass.

**7.3.4.2** *Absorption*

Most surfaces in hospitals should be easily cleanable, so as to prevent the build-up of bacteria which may cause cross-infection. Many sound absorbent materials of a soft nature and difficult to clean are unsuitable for use in some hospital areas and lose much of their effectiveness, if painted for hygienic reasons.

Some porous materials with very thin non-porous coverings (like mineral wool covered with thin plastic sheets) have good sound absorption and when covered with a perforated sheet metal facing can be used in most areas requiring a washable acoustical treatment. In noisy areas, such as corridors and waiting rooms, however, a wider choice of absorbents is available.

In the ward, bed curtains, window curtain etc, add to the absorbent properties of the room and help reduce reverberation in otherwise hard surfaced surroundings.

**7.3.5** Sensitive areas such as operation theatres, Doctors' consultation rooms, intensive care units (ICU) require special consideration against noise control. Apart from outdoor noise, a common problem is the transmission of sound between the consulting room and the waiting room. To ensure silence, a sound isolation $D_w$ of 45 dB (A), between the rooms shall be provided. If the doors are directly connected by a single communicating door it will not be possible to achieve these values of isolation $D_w$. To obtain 40-45 dB(A) insulation between communicating rooms, it is necessary to provide two doors separated by an air gap, such as a lobby or corridor.

## 8 OFFICE BUILDINGS

### 8.1 General

Modern office buildings are often noisier than older buildings due to the use of thinner and more rigid forms of construction, harder finishes, more austere furnishings and use of business machines.

### 8.2 Sources of Noise Nuisance

**8.2.1** *Indoor Noise*

Main sources of indoor noise include the following:

a) Office machines, such as typewriters, and printers;
b) Telephonic conversation;
c) Noise from the public admitted to the building;
d) Footsteps, voices and slamming of doors in circulation spaces, lift doors and gates;
e) Sound reproduction in staff training rooms, conference rooms and recreation rooms, etc;
f) Handling of crockery and utensils in canteens and kitchens; and
g) HVAC and lift machinery.

### 8.3 Recommendations

**8.3.1** *Site Planning*

Rooms demanding quiet conditions should be placed on the quiet side of the site. Even on quiet thoroughfares, these rooms should also not be planned at street level. They should also not be planned on enclosed yards used for the parking of cars, scooters, etc. Where, however, the problems cannot be resolved by planning, the provision of double windows may be necessary.

**8.3.2** *Detailed Planning*

**8.3.2.1** *Noise reduction within rooms*

The reverberation time should not exceed 1.0 s in all general offices of the types listed in **8.3.2.2** to **8.3.2.6**. In small private offices, the reverberation time should not exceed 0.75 second, in very large offices the reverberation time may be increased to 1.25 s. For canteens, the recommended maximum reverberation time is 1.25 s.

**8.3.2.2** *Large general offices*

The grouping of departments and machines together in one room should be avoided wherever possible. Where supervision is necessary the provision of glazed screens carried up to the ceiling should be considered. If it is essential to the work of an office for machine operators and clerks to work side by side in the same room, the machines should be enclosed by panels or low screens lined with absorbent material and the ceiling should be sound absorbent. In addition, the machines should be as quiet as possible in operation and mounted on suitable resilient mountings.

NOTE — A quiet area should be planned for prolonged telephonic conversation.

**8.3.2.3** *Light weight construction*

Modern construction methods and economy dictate the use of light weight construction for many office buildings. While the light weight materials lead to fast fabrication and erection and also effect considerable economy in the building structure, they may lead to tremendous sound insulation problems between adjacent offices and areas. Light weight construction is also frequently employed for the sub-division of large space into executive cabins and secretarial areas. Where such construction is considered desirable, efforts should be made to provide a double-skin panel. The panels should be isolated from each other as far as possible either by the use of separate framing or by the use of elastic discontinuities in the construction, and a sound absorbing material may be introduced in the air cavity between the panel. The partitions should be full height up to the bottom of the roof above and any openings required for air movement should be provided with sound attenuators compatible with the rest of the partition.

When light weight floors are provided in multi-use buildings, adequate attention shall be paid to the question of air-borne and structure-borne noise transmission from the upper floors to the floors below. For effective reduction of air-borne noise, a double panel hollow floor construction may be employed with some heavy sound damping material introduced between the panels and the panel isolated from each other. The sound damping material could be sand, mineral wool, etc. In case impact noise isolation is also required, the upper panel should be effectively isolated from the rest of the floors and building structure. The choice of the isolation layer would of course depend upon the lowest frequency of interest.

Another point to be kept in mind when going in for light weight construction is to ensure that the light weight panels are not in resonance with the natural frequencies of any mechanical equipment installed inside the building. Light weight materials have high natural frequencies well within the audio range and may resonate or vibrate due to an applied vibratory force. This vibratory force is caused by mechanical equipment, road traffic, rail traffic, etc. Special measures also need be taken to isolate either the source or the building so as to reduce the amount of vibration transmitted to the building structure.

**8.3.2.4** *Open plan offices*

A new concept in office planning is the use of open plan offices. Large open floor spaces are converted into an office area with senior executives, junior executives and secretarial staff all seated within the same area without the use of any partitions or walls. While this method of planning is appreciated, it leads to a problem of inadequate acoustical privacy between adjacent work spaces. Speech privacy in open plan offices is defined by the speech interference level of intruding noise. Speech privacy between two adjacent rooms or spaces is, therefore, a function of two key parameters; noise reduction of the intervening partition and background noise levels.

Special design measures are, therefore, required to reduce the level of intruding sounds at work places to acceptable low value so that people are not disturbed and adequate privacy is maintained. Some special measures which might be considered for such open plan offices are the use of an acoustical ceiling together with partial height barriers between work spaces, all designed to provide adequate privacy between adjacent work spaces. In addition use may have to be made of an electronic background masking noise system which provides a constant level of a generally acceptable background noise in the entire office area. The masking noise system is a very useful concept in open plan office design because by raising the background level at every workplace, intruding noises are made less disturbing. A background music system cannot serve as a noise masking system because the music does not have a constant spectrum or sound level. In fact the background noise masking system must be introduced gradually without the knowledge of employees. The air conditioning system can also be used to generate background masking noise if the noise level from the fans, ducts and grills is suitably tailored to generate the desired frequency spectrum. However, it is not simple to predict the noise level of air conditioning components accurately. On the other hand, the electronic system enables both the level and the spectrum of the background noise to be accurately adjusted to suit individual job requirements.

**8.3.2.5** *Office equipment rooms*

It is important that machines like typewriters, printer, etc, should be quiet in themselves and also be fitted with resilient pads, to prevent the floors or tables on which they stand from acting as large radiating panels. It is desirable to locate machines further apart and to apply sound absorbent treatment to the ceiling.

**8.3.2.6** *Banking halls*

If banking halls are large and lofty, noise nuisance tends to be aggravated. It is advisable to avoid high reflective ceilings. The worst effects may be reduced by segregating the noise from the quiet operations and screening one from the other and by applying sound absorbent materials to the surfaces of the ceilings, screens and nearby walls. Resilient flooring is also recommended.

**8.3.2.7** *Public offices and waiting spaces*

Noise nuisance may be minimized by the provision of resilient flooring, sound absorbent ceilings and heavy full height screens between the public space and the clerical office.

**8.3.2.8** *Canteens*

The provision of a sound absorbent ceiling, resilient flooring and the use of plastics trays and tables with ‘quiet’ tops are recommended.

**8.3.2.9** *Circulation spaces*

The effective length of long corridors should be limited by providing swing doors at intervals. Hard floor finishes and board and batten floors in corridors should be avoided. The provision of a sound absorbent ceiling in corridors is recommended. Floor ducts should be planned on one side of corridors.

The noise from slamming of doors may be reduced by fitting automatic quiet action type door closers. Door buffers are useful but may reduce insulation of air-borne sound due to the inevitable gaps between buffers. Continuous soft, resilient strip let into the door frames is preferable. The use of quiet action door latches is recommended.

Staircases and lifts should be isolated from quiet rooms and should have silent type doors.

**8.3.3** *Requirement of Sound Insulation*

With open window (single or double) the sound reduction ($D_w$) will be 5-10dB, and with sealed double windows it will be 40-45dB. Intermediate values are obtainable with closed openable windows (single or double) but only, of course, at such times as ventilation may be dispensed with. Having to choose between ventilation and noise exclusion is a serious handicap to efficient working in offices. In large office blocks on noisy sites, consideration should be given to the provision of sealed double windows and mechanical ventilation at least in the offices on the sides of the building exposed to noise.

**8.3.3.1** The insulation necessary between adjoining rooms, both horizontally and vertically, depends upon the amount of noise created within the rooms, the amount of intruding noise and whether it is important that conversation should not be overheard between rooms. Generally a sound isolation value ($D_w$) of 30 dB between one room and another room in office is recommended.

**8.3.3.2** The following list may be considered as broad classification of noise producing rooms and rooms requiring quiet though many offices fall into both categories. Where rooms in opposing categories are planned adjacent to each other, a sound reduction ($D_w$) of at least 45 dB should be provided between them.

| *Noise Producing Rooms* | *Rooms Requiring Quiet Conditions* |
|---|---|
| Entrance halls, staircases and corridors used by the public | Executive's rooms, Conference rooms and Board rooms |
| Lifts and lift halls | Interview rooms |
| Motor and plant rooms | Offices for one or two persons |
| Lavatories | Medical officer's rooms |
| Public offices | Sick rooms |
| Canteen and kitchens | Rest rooms |
| Office machine rooms and typing pools | Libraries |
| Recreation rooms | Telephoning rooms |
| Large general offices | |
| Cinemas and projection rooms | |

| | $D_w$ |
|---|---|
| a) rooms requiring quiet (as listed above) on a quiet site where privacy is required | 45 dB |
| b) Rooms requiring quiet (as listed above) but on a noisy site or where a lower degree of privacy is tolerable | 40 dB |
| c) Clerical offices in which noise does not constitute a major nuisance | 20-30 dB |

**8.3.3.3** It is recommended that the minimum sound reduction index, $R_w$ for floors should be 45 dB, and the floors should have a resilient finish.

## 9 HOTELS AND HOSTELS

### 9.1 General

Hotels and hostels are primarily used as dwelling units, and hotels also provide for public entertainment. The most serious risk of course is disturbance to sleep, and adequate care, therefore, need be taken to protect the occupants from being disturbed by outdoor and indoor noise.

**9.1.1** *Outdoor Noise*

Hotels near railway stations, airports, highways and those situated in highly urbanized areas are specially vulnerable to outdoor noise. The outdoor noise in many of the areas is of a high level even late at night and in the early morning. The noise could also be due to other types of activities such as building construction activity (pile driving, concrete mixing etc) and various types of portable utility equipment, such as compressors or generators.

**9.1.2** *Indoor Noise*

In so far as indoor noise is concerned, the noise could be due to the occupants themselves, which is transmitted from one room to the other. It could also be due to public functions and late night use of restaurants located in the hotel as also due to miscellaneous utility equipment installed for providing and maintaining the services in the hotel, such as, air conditioning equipment, pumping equipment, power laundry and kitchen. Sometimes hotels equipped with standby generators are a potential source of noise. Another source which could lead to disturbance to the occupants is the plumbing.

### 9.2 Recommendations

**9.2.1** *Site Planning*

While it is desirable to locate the hotel, or hostel away from an area where there is a high ambient noise level, many a time these have to be located in noisy areas for public convenience. Hotels near airports and railway stations are becoming popular because they are convenient for passengers in transit. Hotels located in the commercial areas of a city are also a commercially viable proposition and many a time this factor outweighs the other problems associated with such a location. When a reasonably quiet location is not possible, it is desirable that adequate measures be considered to provide a comfortable acoustical environment for the occupants.

**9.2.2** *Internal Planning*

Where a hotel is located in a noisy environment, the provision of sealed windows (single or double) and provision of an air conditioning system is desirable for rooms exposed to noise. The requirements for the windows would of course depend upon the level and character of noise in the area.

The general recommendations for satisfactory acoustical design of hotels and hostels are given in **9.2.2.1** to **9.2.2.7.**

**9.2.2.1** Hotels of all classes shall by necessity provide good protection against indoor noise. Since hotels can be considered as flats, the standards of protection recommended for flats are also applicable to hotels. Partition between guest rooms and between rooms, corridors and floors shall not be less than 115 mm brick wall plastered or equivalent. The floors shall have proper impact insulation. Special attention should be paid to built-in wall cupboards as these are potential areas of sound leakage. These will not serve as sound insulating partitions and may not be relied upon to increase the insulation value of partitions against which they may be built. In fact, partitions between adjoining rooms should be continuous behind the cupboards. Use of silent type door gear and cupboard catches is also highly desirable.

**9.2.2.2** Door openings on opposite sides of corridors shall be staggered and doors be provided with gaskets on head, sides and threshold. Inter-communicating doors should be double doors, fully gasketed. Doors should also have quiet action latches. Whenever possible, rooms should be entered through a baffle lobby. Wherever possible, corridor walls should not have ventilators unless they are double glazed and non-openable.

**9.2.2.3** Corridors and staircases may have resilient floor coverings and sound absorbent ceilings are desirable unless the corridor is fully carpeted. Staircases and lift wells may be cut off from corridors by means of swing doors and, if possible, isolated from guest rooms by linen stores or similar rooms. Room service pantries on floors can also be a source of noise and may be separated from corridors by baffle lobbies, unless the rooms themselves have baffle lobbies.

**9.2.2.4** Except within the same suite, bathrooms should not be planned next to bedrooms. Where this is unavoidable, internal pipe shafts with heavy walls, unpierced on bedrooms side may be used as means of separation. It is important to choose quiet type of sanitary fittings and to design the plumbing system so as not to create noise, that is by avoiding sharp bends, restrictions of flow, quick-action valves that might cause water hammer, etc.

**9.2.2.5** Air conditioning system should be quiet in operation. Care should also be taken that the air conditioning ducts do not lead to a cross-talk problem between rooms. Suitable acoustical lining would need to be provided in the ducts consistent with the fire safety requirements of the buildings.

**9.2.2.6** Large hotels often have banquet halls and conference halls which are separately hired out for public and private functions. Late night restaurants and night clubs are also popular and functions in all these areas may go on well into the night. It is therefore essential that these rooms be effectively isolated from bedrooms and effective insulation from all possible noise source is considered. Here it is not only necessary to consider the air-borne sound insulation but it is also necessary to consider the question of structure-borne and impact noise transmitted from areas where there might be dancing late into the night.

**9.2.2.7** While most of the noise problems encountered in hotels are applicable to hostels, the latter are normally of more economical construction and, therefore, cannot cater for special sound insulation provisions. However, as far as possible, precautions should be taken to provide comfortable conditions in hostel rooms. This is specially true for student hostels where each room is also a living room. Students might play music or have loud discussions late into the night.

This may disturb sleep or study of other students. Proper precautions should, therefore, be taken to provide satisfactory conditions.

## 10 INDUSTRIAL BUILDINGS

### 10.1 General

Industrial buildings are primarily producers rather than receivers of noise. The level of industrial noise commonly exceeds that from any other source with the exception of aircraft. As compared with traffic noise, its effects are less widespread but it is often more annoying in character.

**10.1.1** Many industrial noises contain very strong high frequency whines, screeches and clatter — these components are relatively more attenuated by passage through the air and by the insulation of light structure than are lower frequencies.

**10.1.2** Intermittent noises are either isolated explosions or reports, or noises of a periodic nature, such as those of pressure relief valves of blow off, or the noises of work occurring at random intervals, for example, hammering, grinding and sawing operations; the latter class may be especially irritating because of high frequency components.

### 10.2 Sources of Industrial Noise

**10.2.1** Noises in industrial buildings are mainly of indoor origin. Noise in factories and workshops is generally caused by machine tools and by operations involved in making and handling the product and they are classified into the following groups, depending upon how the noise energy is generated.

**10.2.1.1** *Impact*

Noise caused by impact is the most intense and widespread of all industrial noises. It is normally coupled with resonant response of the structural members connected to the impacting surface. Common sources of this type of noise are forging, riveting, chipping, pressing, tumbling, cutting, weaving, etc. Intense impact noise may also be produced during handling of materials as in the case of sheared steel plates falling one over another in collecting trays in a steel factory. Impact noise is usually intermittent and impulsive in character, but it may also be continuous as in the case of tumbling.

**10.2.1.2** *Friction*

Most of the noise due to friction is produced in such processes as sawing, grinding and sanding. Friction also occurs at the cutting edge on lathes and other machine tools and in brakes and from bearings. The spectrum of frictional noise often predominates in high frequency and is very unpleasant in character.

**10.2.1.3** *Rotation and reciprocation*

A rotating or reciprocating machine generates noise due to unbalanced forces and/or pressure fluctuations in the fluids inside the machines. In many cases, the moving surfaces radiate noise directly and in other cases, the pressure fluctuations are transmitted to the outer casings of the machine from where they are radiated as noise. Interaction of rotating component with the fluid stream can also give rise to pure tone components, such as the whine in a turbine. Since most machine casings have radiation efficiencies of unity in the higher frequency range, the amount of sound radiated is often substantial.

**10.2.1.4** *Air turbulence*

Noise may be generated by rapid variation in air pressure caused by turbulence from high velocity air, steam or gases. Common examples are the exhaust noise from pneumatic tools and air jets. The noise is intense, and broad based in character and the frequency criteria depends on the size of the jet. The intensity increases rapidly with the velocity of the air stream.

**10.2.1.5** *Noises with pure tone components*

Whining noise from turbines and humming noise from transformers come under this group.

**10.3 Noise Criteria**

**10.3.1** *Hearing Damage-Risk Criteria*

Continuous exposure to high noise levels may result in permanent noise induced hearing loss in the course of time. Damage-risk criteria specify the maximum levels and duration of noise exposure that may be considered safe. Generally accepted damage-risk criteria for exposure to continuous, steady broad band noise are shown in Table 7. Whenever the sound levels at the workers position in a factory exceed the levels and the duration suggested, feasible engineering controls shall be utilized to reduce the sound to the limits shown. If such controls fail to reduce sound levels within the levels of Table 7, personal hearing protection equipment shall be provided and used to reduce sound levels within the level shown.

**10.3.2** *Interference with Communication*

In factories where audible warning signals are used, or where an operator follows the operation of his machine by ear, the background noise should not be so loud as to mask the signal or desired sound (the information sound) to be heard. Noise may be the cause of accidents by hindering communication or by masking warning signals.

**10.4 Methods of Reducing Noise**

**10.4.1** *Noise Control by Location*

Machines, processes and work areas which are approximately equally noisy should be located together as far as possible. Areas that are particularly noisy should be segregated from quiet areas by buffer zones that produce and may tolerate intermediate noise levels.

**10.4.2** *Noise Reduction by Layout*

The office space in a factory should be as far as possible located preferably in a separate building. This building should not have a wall common with the production area. Where a common wall is unavoidable, it should be heavy with few connecting doors and no permanent openings.

**10.4.3** *Noise Reduction at Source*

**10.4.3.1** *Selection of machinery*

Noise should be reduced as near the source as possible. While the operational processes in a factory may be fixed and may have no quieter alternative, careful selection of the machine tools and equipment to be used may considerably help attaining lower noise levels in the machine shop.

**10.4.3.2** *Reducing noise from potential sources*

Impact that is not essential to a process should be quietened. Noise from handling and dropping of materials on hard surface may be reduced by using soft resilient materials on containers, fixing rubber tyres on trucks, trolleys, etc. Machine noise may be kept to a minimum by proper maintenance. Proper lubrication will reduce noise by friction conveyors, rollers, etc.

**Table 7 Permissible Exposure Limits for Steady-State Noise**

(*Clause* 10.3.1)

| Sound Level dB(*A*) (Slow Response) (1) | Time Permitted, *T* h min (2) |
|---|---|
| 85 | 16-00 |
| 86 | 13-56 |
| 87 | 12-08 |
| 88 | 10-34 |
| 89 | 9-11 |
| 90 | 8-00 |
| 91 | 6-58 |
| 92 | 6-04 |
| 93 | 5-17 |
| 94 | 4-36 |
| 95 | 4-00 |
| 96 | 3-29 |
| 97 | 3-02 |
| 98 | 2-50 |
| 99 | 2-15 |
| 100 | 2-00 |
| 101 | 1-44 |
| 102 | 1-31 |
| 103 | 1-19 |
| 104 | 1-09 |
| 105 | 1-00 |
| 106 | 0-52 |
| 107 | 0-46 |
| 108 | 0-40 |
| 109 | 0-34 |
| 110 | 0-30 |
| 111 | 0-26 |
| 112 | 0-23 |
| 113 | 0-20 |
| 114 | 0-17 |
| 115 | 0-15 |

NOTES

**1** Where the table does not reflect the actual exposure times and levels, the permissible exposure to continuous noise at a single level shall not exceed the time *T* (in hours) computed from the formula:

$$T = \frac{16}{2[0.2(L-85)]}$$

where

$L$ is the work place sound level measured in dB(A).

**2** When the daily noise exposure is composed of two or more periods of different levels, their combined effect should be considered rather than the individual effect of each. The combined levels may not exceed a daily noise dose, $D$ of unity where $D$ is computed from the formula:

$$D = \frac{C_1}{T_1} + \frac{C_2}{T_2} + ...... + \frac{C_n}{T_n}$$

where, $C_1$, $C_2$ ........... $C_n$ indicate the total duration of exposure (in hours) at a given steady-state noise level; and $T_1$, $T_2$, ......$T_n$ are the noise exposure limits (in hours) for the respective levels given in the table or computed by the equation in Note 1. Exposure to continuous noise shall not exceed 115 dB(A) regardless of any value computed by the formula for the daily noise dose, $D$ or by the equation given in Note 2.

**10.4.3.3** The noise from the radiating surfaces may be reduced by reducing the radiating area. For example, if the area is halved, the noise intensity will be reduced by 3 dB and at low frequencies the reduction will be much greater.

**10.4.3.4** Supporting structures for vibrating machines and other equipment should be frames rather than cabinets or sheeted enclosures. If an enclosure is used, precaution should be taken to isolate it and line it on the inside with sound-absorbent material. The noise radiated by machinery guards can be minimized by making them of perforated sheet or of wire mesh.

**10.4.3.5** *Reducing transmission of mechanical vibration*

A vibrating sources does not usually contain a large radiating surface but the vibration is conducted along mechanically rigid paths to surfaces that can act as effective radiator. If the rigid connecting paths are interrupted by resilient materials, the transmission of vibration and consequently the noise radiated may be greatly reduced. The reduction depends on the ratio of the driving (forcing) frequency of the source to the natural frequency of the resilient system. The natural frequency may be determined from static deflection under actual load as given in Fig. 1. Higher the ratio between the two frequencies, lesser is the transmissibility, which is defined as the ratio of the force transmitted through the resilient isolator to the exciting force applied to it. Transmissibility and the equivalent noise reduction for various frequency ratios are given in Fig. 2. For satisfactory operation, a ratio of 3:1 or more between the driving and natural frequencies is recommended.

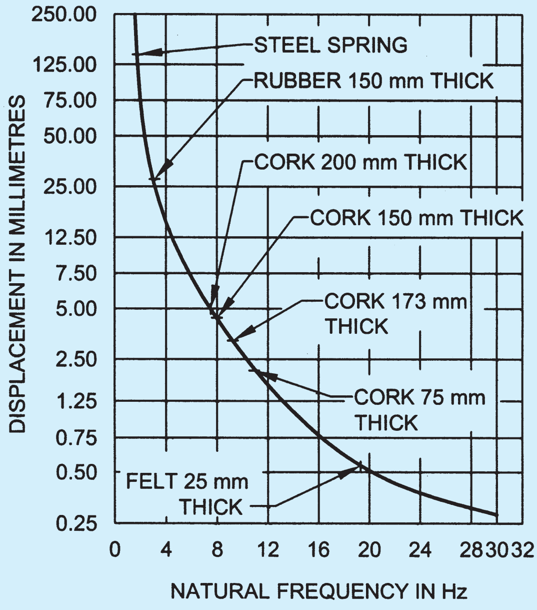



FIG. 1 RELATION BETWEEN STATIC DEFLECTION AND NATURAL FREQUENCY

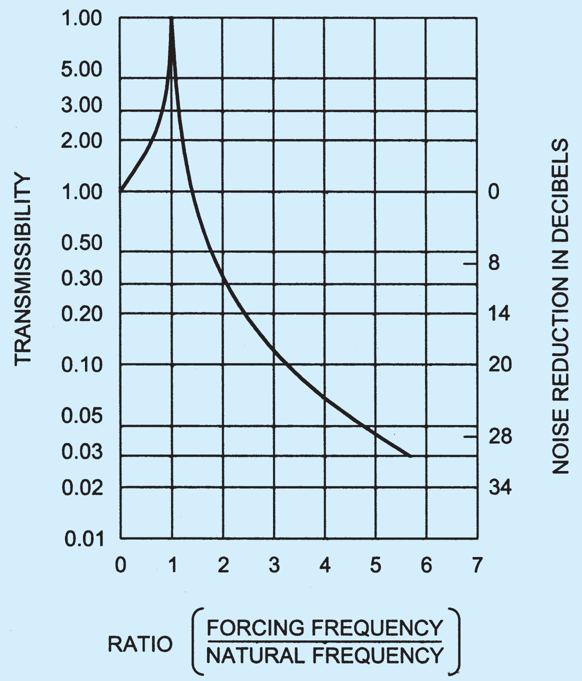



FIG. 2 TRANSMISSIBILITY AND EQUIVALENT NOISE REDUCTION FOR DIFFERENT RATIOS OF FORCING AND NATURAL FREQUENCIES

Materials for isolators and their position are given below:

a) *Material for Isolators* — Vibration isolators are usually made of resilient materials like steel in the form of springs, rubber cork and felt.

1) Because of the large range of deflections obtainable in coil springs, they may isolate vibrations over a large spectrum of low frequencies. Metal springs transmit high frequency (from about two hundred to several thousand c/s) very readily. Transmission of these frequencies can be reduced by eliminating direct contact between the spring and the supporting structure. Rubber or felt pads may be inserted between the ends of the spring and the surfaces to which it is fastened.

2) Rubber in the form of pads may be used to isolate very effectively engines, motors, etc. It may be used in compression or in shear. Some rubber mountings use rubber-in-shear as the primary elastic elements and rubber-in-compression as a secondary element which furnishes snubbing action if the mounting is subjected to an overload.

3) Felt or cork or both may be used as resilient mats or pads under machine bases. The load per unit area shall be chosen to produce enough deflection for the isolation required; and shall be such that at this deflection, it is not loaded beyond its elastic limit.

b) *Position of Isolator* — The normal position of the isolators is between the machine and its foundation. However, if the forcing frequency of the machine is low (less than 10 $H_z$) and vibration isolators with the requisite deflection for this location are not available, the machine may be bolted directly to an independent heavy inertia concrete base and the available vibration isolators used below the concrete base.

1) Large press and drop hammers which create serious impact vibration in heavy machine shops may be mounted rigidly on very massive blocks of concrete having weights several times greater than the weights of the supported machines. The inertia blocks may, in turn, be isolated from the building structure by large wooden blocks and with thick pads of cork.

2) In critical installations (*see* Note), attempt should be made to locate the resilient mounts in a plane which contains the centre of gravity of the mounted assembly. It is also preferable to locate the mounts laterally as far away as possible from the centre of the machine.

NOTE — Critical installations are those installations where transmission of vibration from these installations will seriously hamper the normal working.

3) Rigid mechanical ties between vibrating machine and building structure, short-circuit or reduce the effectiveness of isolators. Loose and flexible connections should be inserted in all pipes and conduits leading from the vibrating machine. Where flexible connections are impracticable, bends should be inserted into the pipes or the pipes themselves should be supported on vibration mounts for a considerable distance from the source.

4) *Flexibility of foundation* — The effect of flexibility of the foundation on the isolator transmissibility shall be considered in the selection of practical vibration isolating mountings. The simplified vibration isolation theory assumes a completely rigid foundation. However, in practice, this can never be

achieved. The foundation is never actually completely rigid. Generally, the relatively low stiffness of the isolation system permits the assumption of the foundation to be rigid. However, if the stiffness of the isolator is allowed to become comparable to the foundation stiffness (or greater), the deflection of the isolator will become smaller and the foundation will also deflect with increased transmissibility and decreased isolator efficiency. In a dynamic sense, supporting foundation or floors should have natural frequency as high and be as stiff as possible compared to the system being isolated. Good design practice requires that the isolators should be designed assuming a rigid foundation with the stipulation that the selected machine isolation system frequency should be well below the foundation frequency. This point should specially be kept in mind when installing machines at upper levels in buildings because supported slabs generally have lower natural frequencies (low stiffness) than slabs on grade in basement or ground floor locations.

**10.4.4** *Noise Reduction by Enclosures and Barriers*

**10.4.4.1** *Enclosures*

Air-borne noise generated by a machine may be reduced by placing the machine in an enclosure or behind a barrier. The enclosure may be in the form of close-fitting acoustic box around the machine such that the operator performs his normal work outside the box and thus is not subjected to the high noise levels of the machine. The enclosure may be made of sheet metal lined inside with an acoustical material.

Where size of the machine, working area and the operation do not permit close-fitting enclosures, the machine may be housed in a room of its own. The inside of the enclosure should be lined with sound-absorbing materials to reduce the noise level of the contained sound. The bounding walls of the enclosures shall also have adequate transmission loss to provide desired insertion loss.

**10.4.4.2** *Barriers*

A partial reduction of noise in certain directions may be obtained by 'barriers' or partial enclosures or partial height walls. Two-sided or three-sided barrier, with or without a top and invariably covered on the machine side with acoustic absorption material should face a wall covered with sound-absorbing material. If the top of the enclosure is open, the reduction may be increased by placing sound-absorbing material on the ceiling overhead.

**10.4.5** *Acoustical Absorption Devices*

**10.4.5.1** *Acoustical treatment of ceilings and side walls*

In order to reduce the general reverberant noise level in machine shops, acoustical material may be placed on the ceiling and side walls. With this treatment 3 to 6 dB reduction of middle and high frequency noise may be achieved. While the noise level at the source, affecting the operator, may not be reduced materially, the treatment would bring down the general noise level away from the source in reverberant field.

**10.4.5.2** *Functional sound absorbers*

For efficient noise reduction 'functional sound absorbers' may be clustered as near the machines as possible. These units may be suspended and distributed in any pattern to obtain lower noise levels within the machine shop. Compared on the basis of equal total exposed surface areas, functional sound absorbers have higher noise reduction coefficients (NRC) than conventional acoustical materials placed directly on ceilings and walls.

## 11 LABORATORIES AND TEST HOUSES

### 11.1 Sources of Noise

**11.1.1** *Outdoor Noise*

In a test house or laboratory, where research workers and scientists are engaged in performing sophisticated experiments, the external noise is mostly contributed by noise emitting buildings (workshops, machine rooms), airports, railway stations and general traffic noises. The outdoor sources of noise in a college laboratory include noises produced in a playground as well.

**11.1.2** *Indoor Noise*

The following sources mainly contribute to indoor noises in research institutions/college laboratories:

a) Workshops, machine rooms, cafeteria, etc;
b) Air-conditioning and exhaust fans;
c) Noise produced within the test house or laboratory while performing experiments; and
d) Typing or other machine noises, telephone service, lift, sanitary services, etc.

### 11.2 Recommendations

**11.2.1** *Site Planning*

While planning for a laboratory or test house, care should be taken in the design that no noise emitting installations should exist in its neighbourhood. However, where outdoor noises exist, such as from local factory, heavy traffic airports, railway lines, sport grounds or busy markets, buildings should be kept as far away as possible from the source of noise.

**11.2.1.1** The window and door openings towards the noise sources should be minimum. Minimum amount of glazing should be placed on walls directly facing the noise sources.

**11.2.2** *Internal Planning*

**11.2.2.1** Noisy places should be kept separate from the quiet ones. The location of laboratories or test houses should be so chosen that it is cut off from the noisy zones. Where there are offices attached to a laboratory, provision should be made to treat the offices and to use acoustical partitions, to achieve a sound isolation $D_w$ of at least 35 dB.

**11.2.2.2** In a laboratory, mostly hard reflecting surfaces and bare furnishings are found, which produce very reverberant conditions. The noise condition still deteriorates when noise producing instruments are switched on or a heavy object is dropped on the floor. Under these conditions, sound absorbing treatment of the space is very essential. Sound absorbing ceilings are recommended to deaden such noises. Rubber buffers may also be fitted to the legs of furniture.

**11.2.2.3** In large span laboratories or test houses where scientists and researchers are engaged in work and/or simultaneously busy in calculations or desk work requiring high degree of mental concentration, use of sound absorbing screens is recommended.

**11.2.2.4** Noise reduction between the test house or laboratory and corridors or general circulation space should be well kept in mind and due care should be taken of the type of doors and the manner of their fittings etc. Transmission of noise through service ducts, pipes, lifts and staircases should also be guarded.

Telephones should preferably be placed in a separate small enclosure or acoustically efficient telephone booth.

**11.2.2.5** To isolate a laboratory or a test house from structure borne noises originating from upper floor, sandwich type floor construction is recommended.

**11.2.2.6** Wherever the provision of double glazed windows is necessary to reduce the heat losses, care should be taken to provide sealed double windows rather than double glazing in a single window.

NOTE — Double glazed windows for sound insulation should have a minimum gap of 100 mm between the two glasses.

## 12 MISCELLANEOUS BUILDINGS

### 12.1 Law Courts and Council Chambers

It is important that law courts and council chambers be protected from the intrusion of outdoor noise and from indoor noise arising both from ancillary offices and circulation spaces. The general recommendations on site planning given in **3** apply to law courts and municipal buildings, but in the larger buildings at least, further protection against outdoor noise can be obtained by planning offices and other rooms around the court rooms or chambers, and separating the offices from the central rooms by means of corridors. This arrangement is usually convenient to the function of the buildings.

**12.1.1** The wall between the corridors and the central rooms should have a sound reduction index, $R_w$ of not less than 50 dB (for example 230 mm brick) to insulate against air-borne noise in the corridors. Entrances from halls or corridors into court rooms or council chambers should be through baffle lobbies with two sets of quiet action doors. Sound absorbing treatment on ceilings and upper parts or walls or entrance lobbies is recommended.

**12.1.2** The whole of the floor of the court room or chamber including steps and seating areas set aside for the public should have a resilient floor finish to reduce the noise of footsteps and shuffling of feet. Any tip-up seats should be quiet in action.

**12.1.3** Sound absorbing treatment applied for acoustic purposes serves also to reduce the build-up of noise within the room and, part of the treatment should be applied in a band to the perimeter of the ceiling to absorb intruding outdoor noise. It is often desirable to keep the centre part of the ceiling free of absorbent material for acoustic reasons.

### 12.2 Libraries, Museums and Art Galleries

Quiet conditions for reading and study are essential in these types of buildings and, since their occupancy is not noise producing, intruding noise is more noticeable and distracting. Every opportunity therefore should be taken to plan for noise defence, both in respect of siting of the building and internal planning. When possible, stack rooms, store rooms and administrative offices should be planned to screen reading rooms, print rooms and lecture rooms from noise sources. In public libraries, the reference library and lecture rooms should receive first consideration; the lending library, newspaper and periodical rooms have a higher background noise and are secondary in importance.

**12.2.1** In large libraries, museums and art galleries echoes from lofty, large domed or concave ceilings are often a nuisance. Small noises such as footsteps, coughs, chair scraping and closing of books are reinforced by reverberation, and concave surfaces even when treated with a sound absorbent may focus these noises. Treated flat ceilings, if not too high, obviate these troubles. Books on shelves in libraries constitute a valuable wall absorbent.

**12.2.2** Floor finishes are important. The impact noise of footsteps on marble, terrazzo or wood block flooring, and especially on hardwood strip and batten flooring, can be disturbing both within the room in which the noise is generated and the rooms below. On solid floors, resilient floor finishes, such as rubber, cork and linoleum on an underlay, are highly desirable. In the children's sections of libraries and museums they are essential. In existing buildings, rubber linoleum or vinyl asbestos tiles laid over the floor in the traffic areas are often a solution to the problem.

**12.2.3** Reference libraries in universities, research establishments, office buildings and science buildings having machines and testing benches, should be planned in a quiet part of the building. Walls enclosing the library should normally have a sound reduction index, $R_w$ of not less than 50 dB (for example 230 mm brick) and baffle lobbies should be planned between the library and halls and corridors. Walls facing on to corridors or other noisy areas should not have fanlights unless they are double glazed and non-operable.

## 12.3 Auditoria and Theatres

The sources of noise that have to be considered in concert halls, opera house, theatres and similar auditorium buildings are as follows:

a) Outdoor noise entering through walls, roofs, doors, windows or ventilation openings;
b) Noise from any other hall in the same building, especially if let out separately for revenue;
c) Noise from foyers, service rooms and other ancillary rooms, particularly rehearsal rooms; and
d) Noise from air conditioning plant, etc, and the cross-transmission of other internal noises via ventilating duct system.

**12.3.1** Because of greatly increased outdoor noise, all auditorium buildings now need more care in siting than formerly. For listening to speech or music, a very low background noise level is desirable; in concert halls especially the quietest possible conditions should be provided because the pauses and moments of silence which are an essential element of music cannot otherwise be given full value. Therefore, sites at cross-roads or close to steel railway bridges, religious places or near churches where bell ringing is practiced, should be avoided unless very high standards of structural sound insulation are contemplated. Sites adjoining underground railways may also prove unsatisfactory at basement levels owing to low-pitched noise or rumble transmitted through the ground; special isolation measure need to be adopted for isolating large buildings from ground vibration of this sort.

**12.3.2** Whenever possible, for concert halls and theatres on city sites a noise survey of the site should be made; a suitable sound reduction value for the structure of the building can then be chosen so as to keep down to certain maximum noise levels within the auditorium. The maximum octave-band sound pressure levels (SPL) recommended are given in Table 8.

**Table 8 Maximum Sound Pressure Levels Due to External and Mechanical Equipment Noise in Auditoria (dB)**

(*Clause* 12.3.2)

| Type of Auditorium | Centre Frequency (Hz) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 63 | 125 | 250 | 500 | 1 000 | 2 000 | 4 000 | 8 000 |
| Concert Halls [dB(A)-25] | 51 | 39 | 31 | 24 | 20 | 17 | 14 | 13 |
| Drama Theatres and Cinemas [dB(A)-30] | 55 | 44 | 35 | 29 | 25 | 22 | 20 | 18 |

**12.3.3** The minimum standard of sound reduction index, $R_w$ likely to be required for the envelope of an auditorium in a city to protect it against external noise is of the order of 65 dB for a concert hall or 55-60 dB for a theatre. This reduction should be provided on all sides, but it would be reasonable to make the $R_w$ for the roof 5 to 10 dB less provided the building is not unduly exposed to noise from aircraft in flight. Surrounding the auditorium with ancillary rooms and foyers is an obvious and invaluable planning method of obtaining the required insulation against outdoor noise.

**12.3.4** Ventilation intakes and returns are vulnerable features in the defence against external noise. They should be positioned so as to avoid exposure to noise, and in addition sufficient length of both inlet and outlet ducts should be provided with carefully designed silencers. The ventilation system should also be designed to avoid transmitting or adding to internal noise.

**12.3.5** The most serious internal noise problem arises when there are two halls meant for separate use in the same building, especially if one of them is a concert hall. The latter is a very loud potential source of noise and requires a high standard of protection against extraneous noise. In these circumstances it is doubtful whether a 'single' wall can be adequate for insulating the two halls unless it is designed with a wide unbridged cavity. Separation by planning is preferable.

**12.3.6** Other sources of internal noise are rehearsal rooms, scenery bays and workshops, stages of other halls where rehearsals or erection of stage sets might be in progress and foyers and bars where loud conversation might occur. The insulation of the internal walls should be adequate to protect the auditorium from these noise sources and the insulation should not be by-passed by openings, doorways, etc. The general noise due to banging of doors also needs to be taken care of; soft sealing materials should be provided for all doors to ensure quiet closing.

**12.3.7** For detailed acoustical design of auditoria and conference halls reference may be made to good practice [8-4(3)].

**12.4 Cinemas**

The main objective of the design should be to control noise from adjacent screens, the projection area, the foyer, and outside the cinema. The first of these, controlling noise from adjacent screens, is likely to be the most difficult with modern digital sound systems. As most cinemas are air conditioned, there will be some noise from services. To ensure reasonable listening conditions, this should be limited to 30 dBA. This will provide some masking of the noise from adjacent screens, but a high performance partition will still be essential. Masonry or lightweight construction may be used, and a typical performance specification for a lightweight wall separating two screens is given in Table 9. Cinema design, however, normally requires specialist acoustic advice.

**Table 9 Typical Sound Insulation Specification for Wall Separating Two Cinema Screens**

(*Clause* 12.4)

| Octave Band Hz | Sound Reduction Index $R$, dB |
|---|---|
| 63 | 38 |
| 125 | 44 |
| 250 | 50 |
| 500 | 61 |
| 1 000 | 57 |
| 2 000 | 58 |
| 4 000 | 57 |
| 8 000 | 55 |

## 13 NOISE FROM BUILDING SERVICES

**13.1** Mechanical, electrical, air conditioning, heating and mechanical ventilation, and other services are provided in almost all large buildings excluding residential, commercial and industrial buildings. Noise control measures should be incorporated during the design and installation of such services to adhere to the recommended outdoor and indoor noise criteria for the kind of occupancy. For detailed design of noise control for services, specialist advice should be sought.

Some basic design techniques for noise control in air conditioning, heating and mechanical ventilation system are given in Annex G.

**13.2** Control of noise from mechanical equipments can also be done by specifying noise control requirements while purchasing the equipments (*see* Annex H).

# ANNEX A

(*Clause* 2.4)

## NOISE CALCULATIONS

### A-1 GENERAL

Some of the simpler types of noise calculation are described in this Annex.

### A-2 ADDITION OF TWO NOISE LEVELS

To determine the combined sound pressure level ($L_c$) resulting from the sound pressure levels of two or more noise sources ($L_1$, $L_2$, etc), it is necessary to calculate and add the mean square values of their individual sound pressures and then convert this back to a sound pressure level. This can be done using the following formula:

$$L_c = 10 \log_{10} (10^{L1/10} + 10^{L2/10})$$

As the individual sound pressure levels are logarithms of the mean square sound pressures, they cannot simply be added arithmetically. Figure 3 shows a graphical method for adding the sound pressure levels from two independent sources to obtain the combined sound pressure level at a particular place. This graph may also be used for multiple sources by combining sources two at a time to produce virtual sources that can then be combined. The most accurate approach is to start with the lowest levels and work towards the highest.

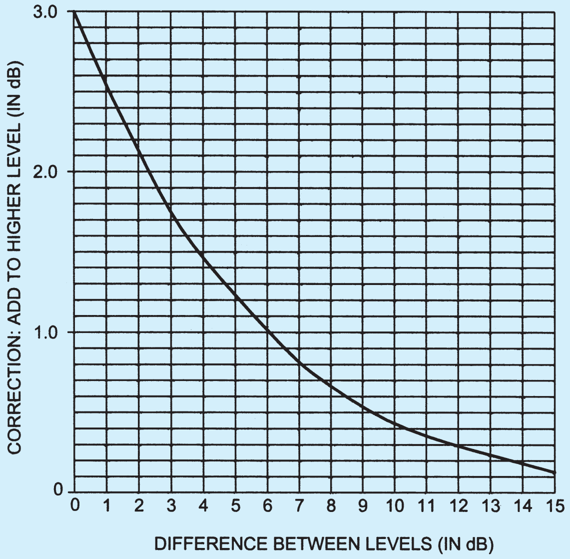



FIG. 3 THE ADDITION OF TWO NOISE LEVELS

The graph should be used with caution where the noise sources are not independent. For example, the sound pressure level from two large transformers fed with currents in phase will be very sensitive to the receiving position. This is because the effect of the constructive and destructive interference of the sounds from the two sources is very dependent on position.

## A-3 SUBTRACTION OF TWO NOISE LEVELS

When measuring noise from a source, the true noise level of the source alone will be less than that shown by the meter if the level of extraneous noise is less than about 10 dB below the total noise level. An estimate of the true source level can be obtained from Fig. 4.

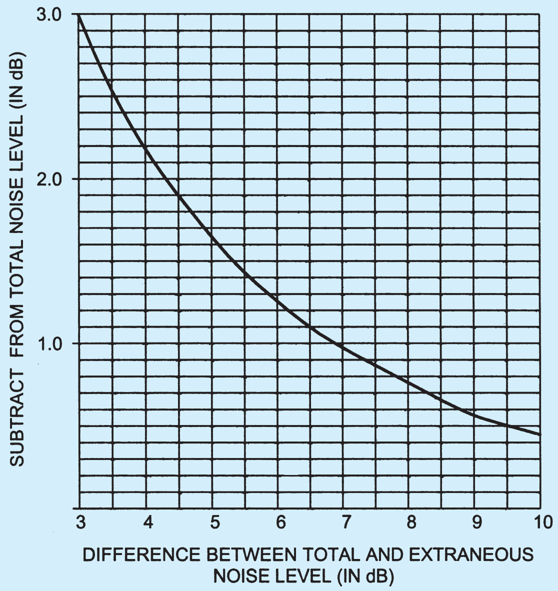



FIG. 4 SUBTRACTION OF NOISE LEVELS

## A-4 NON-UNIFORM COMPOSITE PARTITIONS

Figure 5 how to calculate the overall sound insulation of a composite partition consisting of two parts having different sound — insulating properties, for example a window in a wall. It may also be used to give an indication of the effect of gaps or holes in a partition by assigning a sound insulation value of 0 dB to the aperture.

## A-5 A-WEIGHTING CALCULATIONS

The equivalent A-weighted level is often required when data on a noise source is available as a set of octave band or one-third octave band levels. The conversion can be done manually, using the standard A-weighting values (Table 10) and the graph for combining levels (Fig. 3). For all but the simplest situations it is more convenient to use a computer spreadsheet to do the conversion.

**Table 10 Standard A-Weighting Values (dB)**

| Third Octave Band Center Frequency Hz (1) | A-Weighting dB (2) | Third Octave Band Centre Frequency Hz (3) | A-Weighting dB (4) |
|---|---|---|---|
| 10 | –70.4 | 500 | –3.2 |
| 12.5 | –63.4 | 630 | –1.9 |
| 16 | –56.7 | 800 | –0.8 |
| 20 | –50.5 | 1 000 | 0 |
| 25 | –44.7 | 1 250 | 0.6 |
| 31.5 | –39.4 | 1 600 | 1.0 |
| 40 | –34.6 | 2 000 | 1.2 |
| 50 | –30.2 | 2 500 | 1.3 |
| 63 | –26.2 | 3 150 | 1.2 |
| 80 | –22.5 | 4 000 | 1.0 |
| 100 | –19.1 | 5 000 | 0.6 |
| 125 | –16.1 | 6 300 | –0.1 |
| 160 | –13.4 | 8 000 | –1.1 |
| 200 | –10.9 | 10 000 | –2.5 |
| 250 | –8.6 | 12 500 | –4.3 |
| 315 | –6.6 | 16 000 | –6.6 |
| 400 | –4.8 | 20 000 | 9.3 |

## A-6 REVERBERATION TIME CALCULATION

An estimate of the reverberation time ($T$) of a room can be obtained from the Sabine formula:

$$T = \frac{(0.16V)}{\Sigma A_i}$$

where

$V$ = is the volume of the room in cubic metres ($m^3$);

$A_i$ = is the equivalent sound absorbing area in the room in square metres ($m^2$).

The $A_i$ are the absorbing areas of each surface, or other permanent fixture in the room. Each $A_i$ is determined by multiplying the area of that surface in square

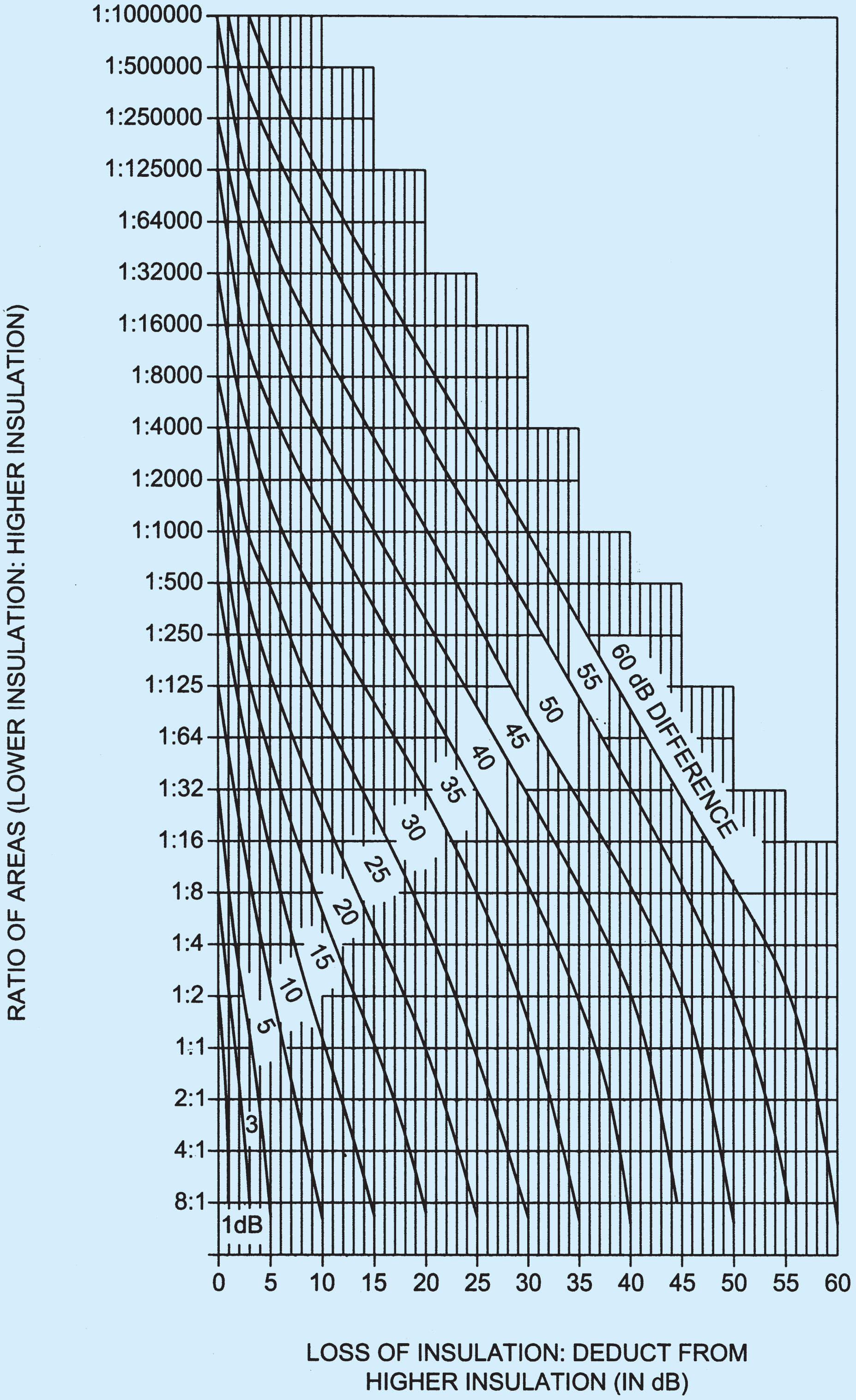



FIG. 5 SOUND INSULATION OF NON-UNIFORM PARTITIONS

metres ($m^2$) by its absorption coefficient $\alpha_{si}$. The surface of each significant fixture or feature of the room should be considered as well as the walls, ceiling and floor.

The total absorption is obtained by summing the individual $A_i$ values. As the values of $\alpha_{si}$ are frequency dependent, this calculation should be repeated for each octave band of interest.

An allowance should also be made for people and furnishings in the room.

# ANNEX B

(*Clauses* 2.24, 2.38, 2.41, 2.50, 2.51, 2.52 *and* 2.53)

## SPECIFICATION OF SOUND INSULATION

### B-1 GENERAL

Sound insulating elements work mainly by reflecting sound energy back into the source room, not by absorbing it. The methods of measurement and the terms used are described in **B-2** to **B-4**.

### B-2 INSULATION AGAINST AIR-BORNE SOUND

As per the standard tests, the insulation between a pair of rooms is measured either in third octave bands having centre frequencies which cover at least the range 100 Hz to 3 150 Hz, or in octave bands which cover at least the range 125 to 2 000 Hz. The noise is produced by a loudspeaker in one of the rooms (called the source room) and at each frequency the average noise levels are measured in the source room ($L_S$) and in the adjacent receiving room ($L_R$). The difference between these two levels ($D$) is a measure of the sound insulation between the rooms regardless of the transmission path(s) the sound energy followed to travel between the rooms. The equation is as follows:

$$D = L_S - L_R$$

The actual level in the receiving room depends on:

a) the sound insulation of the separating wall or floor,
b) the area of the separating wall or floor;
c) the volume of the receiving room;
d) the amount of flanking transmission (that is the importance of transmission paths other than the separating wall or floor); and
e) the amount of absorbing material (for example furniture) in the receiving room.

For field measurements, apart from the amount of absorption, these factors are a property of the building and should be taken into account by the measurement procedure. As the amount of absorbing material (for example soft furniture) in the room at the time of measurement is arbitrary, it should be allowed for separately. This is achieved by measuring the reverberation time ($T$) of the room in seconds (s), which is a measure of how long it takes a sound to die away after the source has been switched off. As the sound energy is dissipated as heat in the absorbing material ($T$), it is related to the total amount of absorption in the room. The receiving room level may then be corrected to the level it would be if the room had a standard reverberation time ($T_0$) which is typical of furnished rooms, and is taken to be 0.5 s. The corrected level difference is known as the standardized level difference, which has the symbol $D_{nT}$ and is calculated using the following equation:

$$D_{nT} = L_S - L_R + 10 \log_{10} (T/T_0)$$

For laboratory measurements, the insulation of the separating wall or floor being tested is required in a way which is independent of the actual measuring laboratory. For this reason, laboratories are designed to have minimal flanking transmission and a different correction is applied to account for the other factors. This correction is 10 log $_{10}$ $(S/A)$.

where

$S$ = is the common area of the separating wall or floor in square metres (m$^2$); and
$A$ = is the equivalent absorption area in the receiving room in square metres (m$^2$).

The laboratory corrected level difference at each frequency is known as the sound reduction index, which has the symbol $R$ and is calculated using the following equation:

$$R = L_S - L_R + 10 \log_{10} (S/A)$$

If the test wall or floor is mounted in a realistic way in the laboratory and flanking transmission will be low in the field, the sound reduction index may be used to predict its performance in the field. The relation between $D_{nT}$ and $R$ is $D_{nT} = R - 10 \log_{10} (3S/V)$

where

$S$ = is the area of the separating wall or floor in the field in square metres (m$^2$); and
$V$ = is the volume of the receiving room in the field in cubic metres (m$^3$).

This equation shows that if the source and receiving rooms have different volumes, $D_{nT}$ will depend on which is used as the source room; using the larger room as the source room will give lower value.

### B-3 INSULATION AGAINST IMPACT SOUND

The procedure to measure the impact insulation of floors is rather different. Instead of a loudspeaker, a machine containing five small hammers is placed on the floor. While the hammers strike the floor at a rate of 10 blows a second, the resulting noise level ($L_i$) is measured in the receiving room below at each of the same frequency bands used for airborne insulation. In the field, the receiving room levels are again 'corrected' to a standard reverberation time ($T_o$) of 0.5 s to give the standardized impact sound pressure level, $L_{nT}$, which is calculated as follows:

$$L_{nT} = L_i - 10 \log_{10} (T/T_o)$$

In the laboratory, the noise level depends mainly on the characteristics of the floor being tested and the amount of absorption ($A$ m$^2$) in the laboratory. It is therefore appropriate to correct the noise level to a standard area of absorption. The area used is 10 m$^2$. The resulting normalized impact sound pressure level is given the symbol $L_n$ and calculated as follows:

$$L_n = L_i + 10 \log_{10} (A/10)$$

### B-4 RATING SOUND INSULATION

Measurements of insulation against both air-borne and impact sound yield values in a number of frequency bands. To make this information more manageable, rating methods such as those in accordance with [8-4(1)] are used to reduce the frequency band values to single figure ratings. These single figure ratings should be good predictors of subjective assessments of insulation. However, this is not always the case and it is prudent to examine the full measurement data in critical situations. The impact insulation measured on a floor with a carpet is likely to be overestimated by this method.

The more common indices used to describe sound insulation are summarized in Table 11.

**Table 11 Common Indices Used to Describe Air-borne and Impact Sound Insulation**

(*Clause* B-4)

| Air-borne (*A*) Impact (*I*) | Lab (*L*) Field (*F*) | Measured Values | | Single Number Quantity | |
|---|---|---|---|---|---|
| | | Name | Symbol | Name | Symbol |
| (1) | (2) | (3) | (4) | (5) | (6) |
| *A* | *F* | Standardized level difference | $D_{nT}$ | Weighted standardized level difference | $D_{nT,w}$ |
| *A* | *L* | Sound reduction index | $R$ | Weighted sound reduction index | $R_w$ |
| *I* | *F* | Standardized impact sound pressure level | $L'_{nT}$ | Weighted standardized impact sound pressure level | $L'_{nT,w}$ |
| *I* | *L* | Normalized impact sound pressure level | $L'_n$ | Weighted normalized impact sound pressure level | $L'_{n,w}$ |

## ANNEX C

(*Clause* 2.22)

### NOISE RATING

**C-1** Noise rating (NR) is a graphical method for assigning a single number rating to a noise spectrum. It can be used to specify the maximum acceptable level in each octave band of a frequency spectrum, or to assess the acceptability of a noise spectrum for a particular application. The method was originally proposed for use in assessing environmental noise, but was later also found suitable for describing noise from mechanical ventilation systems in buildings. To make a rating, the noise spectrum is superposed on a family of NR contours; the NR of the spectrum corresponds to the value of the first NR contour that is entirely above the spectrum. The data for drawing NR contours (from NR 0 to NR 75) is given in Table 12 for the frequency range 31.5 Hz to 8 kHz.

**C-2** For computational methods the curves are defined by the equation:

$$L = a + bN$$

where

$L$ = is the octave band sound pressure level corresponding to NR level N; and

$a$ and $b$ = are constants for each frequency band, as given in Table 13.

NOTE — NR values can not be converted directly to dBA values but the following approximate relationship applies:

NR = dBA – 6

**C-3** Although the NR system is currently the preferred method for rating noise from mechanical ventilation system, other methods which are more sensitive to noise at low frequencies are available, but they are not yet widely accepted. Low frequency noise may be disturbing or fatiguing to occupants, but may not have much effect on the dBA or NR value.

**Table 12 Noise Rating Values**
(*Clause* C-1)

| Noise Rating | Octave Band Centre Frequency, Hz Sound Pressure Levels $dB_{re}$ 20µPa | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 31.5 | 63 | 125 | 250 | 500 | 1 000 | 2 000 | 4 000 | 8 000 |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
| NR75 | 106 | 95 | 87 | 82 | 78 | 75 | 73 | 71 | 69 |
| NR70 | 103 | 91 | 83 | 77 | 73 | 70 | 68 | 66 | 64 |
| NR65 | 100 | 87 | 79 | 72 | 68 | 65 | 62 | 61 | 59 |
| NR60 | 96 | 83 | 74 | 68 | 63 | 60 | 57 | 55 | 54 |
| NR55 | 93 | 79 | 70 | 63 | 58 | 55 | 52 | 50 | 49 |
| NR50 | 89 | 75 | 66 | 59 | 53 | 50 | 47 | 45 | 43 |
| NR45 | 86 | 71 | 61 | 54 | 48 | 45 | 42 | 40 | 38 |
| NR40 | 83 | 67 | 57 | 49 | 44 | 40 | 37 | 35 | 33 |
| NR35 | 79 | 63 | 52 | 45 | 39 | 35 | 32 | 30 | 28 |
| NR30 | 76 | 59 | 48 | 40 | 34 | 30 | 27 | 25 | 23 |
| NR25 | 72 | 55 | 44 | 35 | 29 | 25 | 22 | 20 | 18 |
| NR20 | 69 | 51 | 39 | 31 | 24 | 20 | 17 | 14 | 13 |
| NR15 | 66 | 47 | 35 | 26 | 19 | 15 | 12 | 9 | 7 |
| NR10 | 62 | 43 | 31 | 21 | 15 | 10 | 7 | 4 | 2 |
| NR5 | 59 | 39 | 26 | 17 | 10 | 5 | 2 | –1 | –3 |
| NR0 | 55 | 35 | 22 | 12 | 5 | 0 | –4 | –6 | –8 |

**Table 13 Values of *a* and *b***
(*Clause* C-2)

| Octave Band Centre Frequency Hz | *a* | *b* |
|---|---|---|
| (1) | (2) | (3) |
| 31.5 | 55.4 | 0.681 |
| 63 | 35.4 | 0.790 |
| 125 | 22.0 | 0.870 |
| 250 | 12.0 | 0.930 |
| 500 | 4.2 | 0.980 |
| 1 000 | 0.0 | 1.000 |
| 2 000 | –3.5 | 1.015 |
| 4 000 | –6.1 | 1.025 |
| 8 000 | –8.0 | 1.030 |

# Annex D

(*Clause* 3.3)

## OUTDOOR NOISE REGULATIONS IN INDIA

**D-1** Government notifications are issued from time-to-time on the allowable ambient noise levels in general and specifically in different zones of various metropolitan cities of India.

**D-2** Noise regulations and notifications are also issued from time-to-time specifying the maximum permissible sound levels from equipments commonly used in and around the residential areas and around sensitive buildings, specifically with regard to noise levels from electricity generating sets, construction equipment and HVAC utility equipment installed outdoors.

**D-3** These regulations should be referred to by the designer for the design of measures for control of external noise.

# ANNEX E

(*Clauses* 3.8 *and* 4.5)

## SPECIAL PROBLEMS REQUIRING EXPERT ADVICE

### E-1 GENERAL

Certain design problems require reliable advice of a kind which is not easy to find in published material. The advice of an expert should be sought for these kinds of problems, some examples of which are given in **E-2** to **E-9**.

### E-2 ACOUSTIC TEST ROOMS

The design of rooms in which acoustic measurements are carried out, such as reverberation chambers, free-field anechoic rooms and audiometric test rooms, usually requires the advice of an expert.

### E-3 PERFORMING SPACES

The design of theatres, opera houses, concert halls and similar performing spaces usually requires expertise in room acoustics and noise control. The intrusion of quite low levels of noise may seriously interfere with the enjoyment of the performance and distract the performers. The requirements for low noise levels often mean that more room has to be allocated for low velocity ventilation ductwork and the impact on the design of the ventilation system is often substantial.

### E-4 BROADCASTING AND RECORDING STUDIOS

Broadcasting and recording studios have requirements similar to those of performing spaces. For some infrequent intrusive noises, the requirements are sometimes relaxed on the grounds that a re-take of a recording can be done, but this can result in higher operating costs.

**E-5 AIRCRAFT NOISE**

As there are many variables affecting the level of aircraft noise heard on the ground, expert advice is almost always required. Contours of daytime $L_{Aeq,T}$ levels are available from most major airports. Where measurements of façade insulation are necessary a standard test method may be referred.

**E-6 GROUND-BORNE NOISE**

Projects involving ground-borne noise from underground trains usually require expert advice.

**E-7 LOW-FREQUENCY NOISE**

Projects involving low-frequency noise usually require expert advice as accurate measurement is difficult and there is a shortage of reliable data below 100 Hz.

**E-8 ACTIVE NOISE CONTROL**

Active noise control is the reduction of noise by cancellation with a similar noise (anti-noise) generated by electro-acoustic means. The technique is still under development, but commercial systems are available which successfully reduce low frequency noise from mechanical ventilation systems.

**E-9 NOISE SURVEYS**

Noise surveys are carried out for a variety of reasons, for example:

a) before construction, to establish the existing noise climate at the site of a proposed development where reliable prediction is impracticable, as an aid to the design of the building envelope, either to protect against external noise or contain internally produced noise;
b) during construction, to monitor noise from building activity, either to assess the likely nuisance to the local community or the risk of hearing damage to the work force;
c) at the end of a building contract to check the insulation of the building envelope, or the noise levels produced by the services;
d) as part of a planning requirement; and
e) to provide objective evidence to support or defend a legal action.

The expense of carrying out a comprehensive noise survey of any kind is likely to be high, so the cost-effectiveness of a full or partial survey should be weighed against alternatives such as prediction. A survey will generally be more accurate and can take account of factors such as prevailing wind conditions.

## ANNEX F

(*Clause* 4.4)

### AIR-BORNE AND IMPACT SOUND INSULATION

**F-1 GENERAL**

Air-borne sound refers to sources which produce sound by directly setting the air around them into vibration. Impact sound refers to sources which produce sound by impulsive mechanical excitation of part of a building (for example by footsteps, electric light switches, slamming doors). Many sources of impact sound also produce significant levels of airborne sound. The term structure-borne sound has no very precise meaning as the structure can be excited by both airborne and impact sources; it is often used to refer to sound that travels for long distances via the structure, especially in connection with vibrating machinery linked directly to the structure.

**F-2 DIRECT AND INDIRECT TRANSMISSION**

Figure 6 shows diagrammatically a pair of rooms in a house where the construction consists of solid walls, etc bonded together. Sound travelling from room 1 to room 2 may travel via the direct path *a-a* and by the many indirect, or flanking, paths shown. The term flanking transmission is usually used to mean transmission paths involving the structure, while the term indirect transmission includes flanking paths and airborne paths through gaps and ducts, etc. The indirect paths may limit the sound insulation attainable no matter how much the direct sound is reduced by the separating wall or floor. The indirect transmission can be reduced by measures such as the following:

a) Increasing the mass of the flanking walls;
b) Increasing the mass of the partition and bonding it to the flanking walls;
c) Introducing discontinuities in the indirect paths;
d) Erecting independent wall linings adjacent to the flanking walls to prevent energy entering the flanking construction; and
e) Sealing any air gaps and paths through ducts.

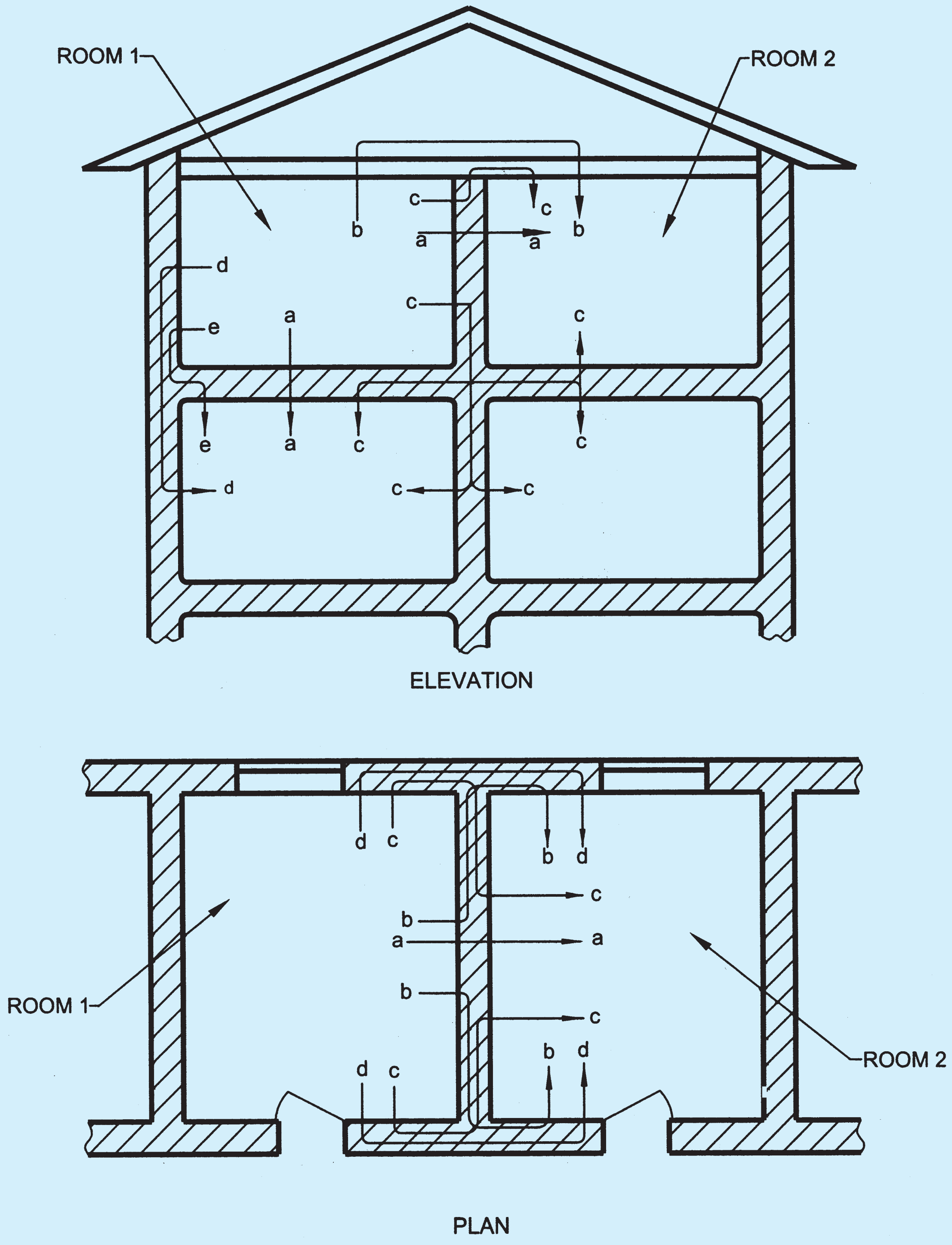



FIG. 6 TRANSMISSION PATHS (VIA THE STRUCTURE) OF NOISE ORIGINATING IN ROOM 1 (DIAGRAMMATIC)

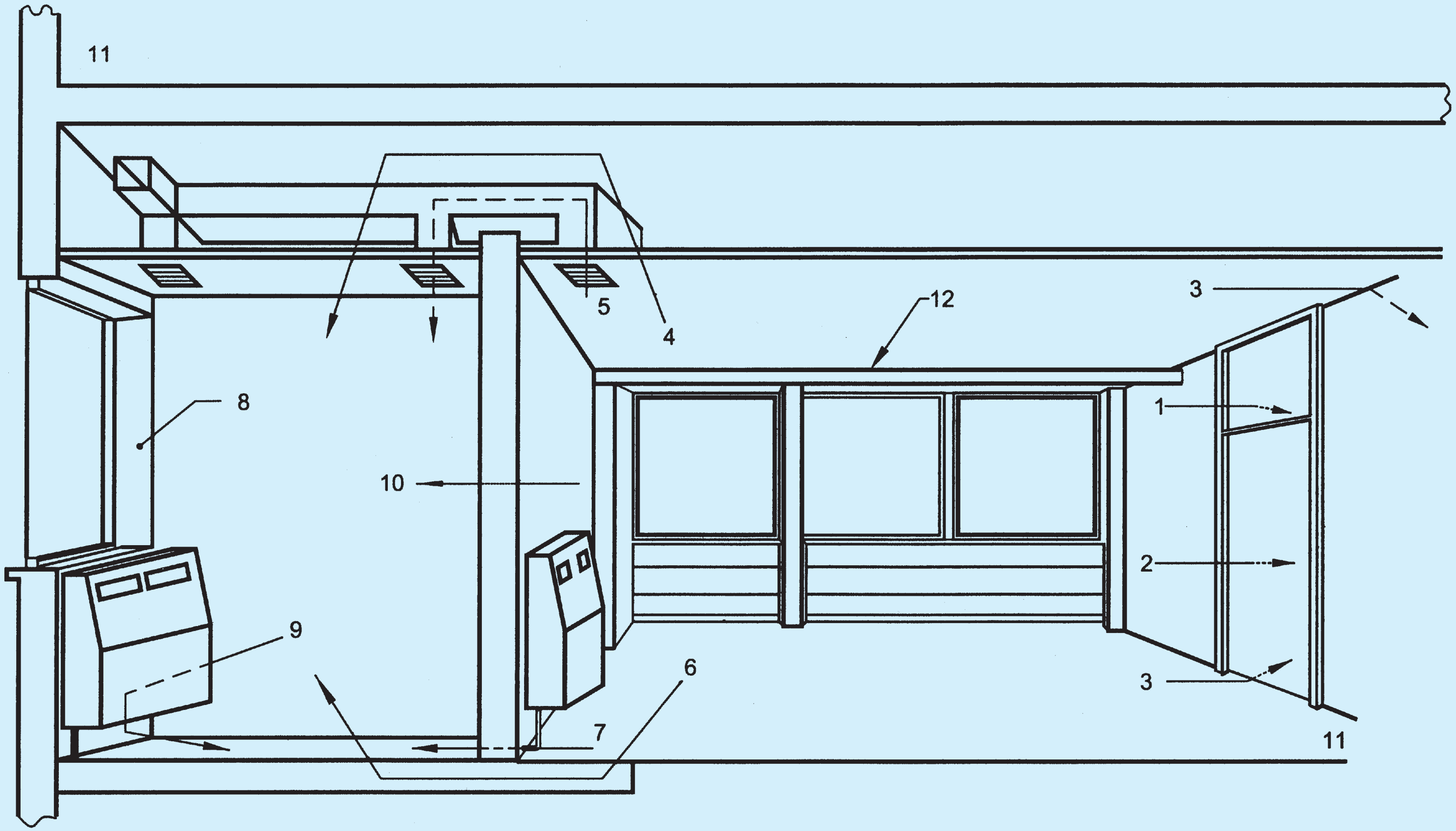
Figure 7 shows a number of indirect paths that have been found in offices.

It is important to remember that standard test laboratories are designed to minimize transmission by all paths other than the direct path. This makes it difficult to relate the results of laboratory measurements to those likely to be obtained in the field.

## F-3 AIR-BORNE SOUND INSULATION

### F-3.1 General

The sound insulation of structural elements such as




1 LIGHTWEIGHT PANELS ABOVE DOORS
2 DOORS
3 AIR LEAKS THROUGH GAPS, CRACKS OR HOLES
4 SOUND TRANSMISSION VIA SUSPENDED CEILINGS/PARTITIONS
5 COMMON VENTILATION SYSTEMS WITHOUT SILENCERS
6 COMMON FLOOR DUCT
7 ELECTRICAL OUTLETS AND SERVICE PIPES
8 LIGHTWEIGHT MULLIONS OR MULLION/PARTITION CLOSERS
9 CONTINUOUS SILL LINE HEATING
10 PARTITION PERFORMANCE
11 APPLIANCES
12 CONTINUOUS LIGHTING FITTINGS

FIG. 7 INDIRECT SOUND LEAKAGE PATHS

walls and floors always varies with frequency, the insulation rising in general as the frequency rises.

**F-3.2 Terminology**

Results from field measurements are usually expressed in terms of the weighted standardized level difference, while laboratory measurements are usually expressed in terms of the sound reduction index. In the absence of significant flanking transmission, the numerical difference between the weighted standardized level difference and the sound reduction index of a wall or floor is usually small for furnished rooms in dwellings, and so either quantity may be used in considering principles; for this purpose it is, therefore, convenient to use the general term insulation.

**F-3.3 Mass Law**

An approximate empirical relationship has been established between sound insulation and mass for single leaf constructions as shown in Fig. 8. This so called 'mass law' gives a useful first approximation to the behaviour of a single sheet or plate. In practice, the sound insulation predicted by the mass law may not be attained because of factors such as the coincidence effect, which is outlined in **F-3.4**. Results for specific materials vary around the value given by the mass law relationship, and so measured data should be used when available. Table 14 gives a lists of materials and indicates the sound insulation of a single, imperforate sheet when fixed to a suitable wood or metal framework. These values are useful, for example when assessing existing structures.

**Table 14 Sound Insulation of Imperforate Sheet Materials**

(*Clause* F-3.3)

| Material | Surface Mass kg/m$^2$ | Typical Weighted Sound Reduction Index, $R_w$ dB |
|---|---|---|
| (1) | (2) | (3) |
| 3 mm glass sheet | 7.0 | 26 |
| 12.5 mm plasterboard | 10.5 | 31 |
| 18 mm wood particle board | 8.0 | 27 |
| 19 mm plywood | 3.0 | 24 |
| 16 mm plywood | 4.5 | 24 |
| 1 mm steel sheet | 11.0 | 29 |
| 6 mm hardboard | 5.0 | 25 |
| 12 mm wood fibre insulation board | 4.0 | 24 |
| 13 mm mineral fibre board | 4.0 | 24 |
| 50 mm wood-wool screeded one side | 35.0 | 33 |

**F-3.4 The Coincidence Effect**

The coincidence effect occurs when the wavelength of the wave impressed on the panel by the incident sound wave is close to the wavelength of free bending waves in the panel. The effect of coincidence is to lower the sound insulation of a construction by as much as 10 dB below the level expected from its mass per unit area over a limited frequency range. The coincidence effect can be pronounced with thin lightweight partitions, resulting in loss of insulation at middle and high frequencies. Reducting the stiffness without a corresponding reduction of mass can raise the critical frequency above 3 150 Hz, and so improve the insulation over the important 100 Hz

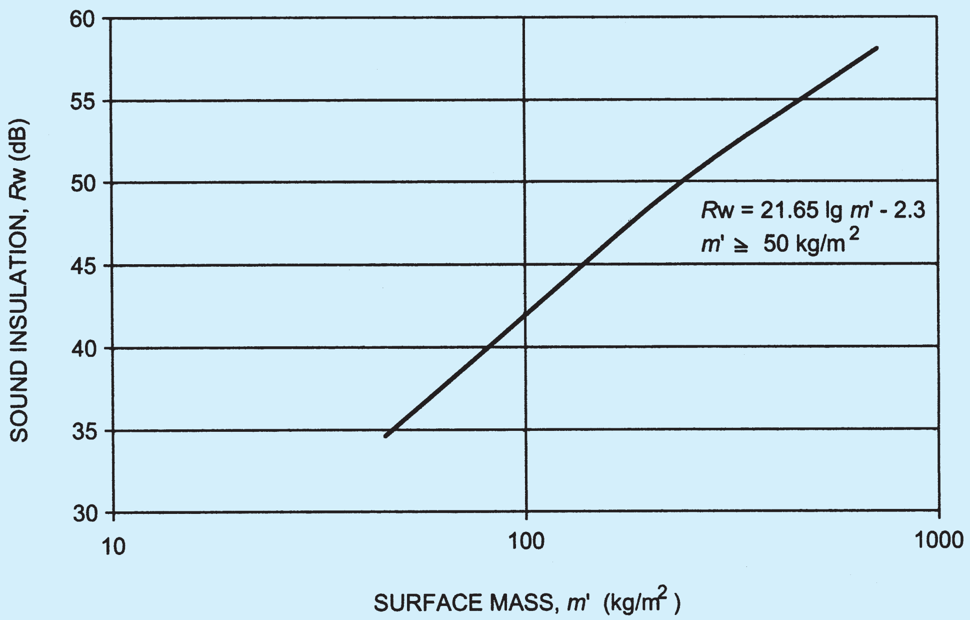



FIG. 8 MASS LAW CURVE

to 3 150 Hz range. An increase of stiffness will have the reverse effect.

It is possible to design lightweight stud partitions so that they perform to their maximum effect in the speech frequency region between 250 Hz and 2 000 Hz, that is between the mass-spring-mass and coincidence regions respectively.

The worst coincidence dips occur in materials such as plate glass and rigid metal sheets. Heavily damped materials such as lead sheets are least affected.

**F-3.5 Mass-Spring-Mass Frequency**

A double leaf wall can perform better than a single leaf wall of similar mass because the sound has to pass through two barriers. If the two leaves are not connected to each other, the insulation values of the two leaves may be added together. However, in practice the leaves are often connected by ties or studs, and the full insulation cannot be achieved. Even where the two leaves are isolated from each other, the full benefit can only be obtained above a certain frequency that depends on the cavity width. This is because the air in the cavity behaves like a spring connecting the leaves together, and causes a resonance at the mass-spring-mass frequency. Below this frequency, the two leaves behave more like an equivalent single leaf.

Making the cavity width wide can reduce the mass-spring-mass frequency, as in the case of sound insulating secondary glazing. The mass-spring-mass frequency ($F_0$) may be estimated from the following equation:

$$F_0 = 59.6\sqrt{\frac{1}{d}\left(\frac{1}{m_1}+\frac{1}{m_2}\right)}$$

where

$m_1$ and $m_2$ = the surface masses of the two leaves in kilograms per square metre (kg/m$^2$); and

$d$ = the cavity width in metres (m).

**F-3.6 Impact Sound Control**

A structure that receives an impact or has a vibrating source in contact with it behaves more like an extension of the source rather than an intervening element between source and listener. For this reason, a relatively small amount of impact energy may produce a loud sound and, if the structure is continuous, the sound may travel a long distance. Control is usually obtained by inserting a resilient surface at the point of contact with the source (for example laying a carpet on a floor) or by introducing a structural discontinuity.

Floating floors, which are an example of the latter approach, are a common method of controlling impact sound from footsteps. However, it should be noted that an effective floating floor may result in increased sound from impacts on the source side of the floor. The conventional forms of floating floor may be unsatisfactory if protection against the low-frequency content of impact noise is required (e.g. a dance floor over a restaurant).

**F-4 AIR-BORNE INSULATION VALUES OF WALLS AND AIR-BORNE AND IMPACT INSULATION VALUES OF FLOORS**

Table 15 and Table 16 give examples of common types of wall and floor construction with sound insulation in the ranges shown. The insulation indices are for field measurements accessed in accordance with [8-4(5)]. The insulation values given are necessarily approximate since examples of nominally identical constructions may show variations of several decibels. All the figures represent values expected in the field, that is in actual buildings. Many are based directly on field measurements, though other (in the absence of representative field measurements) have been assessed from laboratory data, with an allowance for typical flanking conditions in normal buildings. Variation in the amount of indirect transmission may affect significantly the insulation between two rooms separated by a given barrier. For example, the sound insulation of some types of floor may be reduced by indirect transmission along the walls supporting them, particularly if these walls are of lightweight masonry and carried past the floor.

**Table 15 Air-borne Sound Insulation of Walls and Partitions**

(*Clause* F-4)

| Sound Insulation $D_{nT,w}$ dB<br>(1) | Type of Wall or Partition<br>(2) |
|---|---|
| 26 to 33 | a) 1 mm steel sheet panels fixed to steel frame members to form demountable partition units 50 mm overall thickness. Mineral wool cavity insulation. |
| | b) Plywood or wood fibre board 12 mm thick nailed both sides of 50 mm × 50 mm timber framing members spaced at 400 mm centres. |
| | c) Paper faced strawboard or wood wool 50 mm thick panels plastered both sides. |
| | d) Chipboard hollow panels 50 mm thick tongued and grooved edges, hardboard faced. Joints covered with wood trim. |
| 33 to 37 | a) Lightweight masonry blockwork. Plaster or drylining on at least one side. Overall mass per unit area not less than 50 kg/m$^2$. |
| | b) Laminated plasterboard at least 50 mm thick fixed to timber perimeter framing, any suitable finish. Approximate mass per unit area 35 kg/m$^2$. |

**Table 15 — *Continued***

| (1) | (2) |
|---|---|
| | c) Timber stud partitions any size timbers greater than 50 mm × 50 mm, 400 mm centers, cross noggins, 9.5 mm plasterboard lining on both sides, any suitable finish. |
| | d) Metal stud partition, 50 mm studs 600 mm centres, clad both sides with 12.5 mm plasterboard, joints filled and perimeters sealed. Approximate mass per unit area 18 kg/m$^2$. |
| | e) 50 mm lightweight masonry blockwork, plastered both sides to 12 mm thickness or drylined with 9.5 mm plasterboard. |
| 37 to 43 | a) Lightweight masonry blockwork, plaster or dry lining on at least one side. Overall mass per unit area not less than 75 kg/m$^2$. |
| | b) Either 75 mm or 100 mm × 50 mm timber studs spaced 600 mm apart, 50 mm mineral fibre quilt in stud cavity. Frame lined on both sides with one layer 12.5 mm plasterboard. Approximate mass per unit area 19 kg/m$^2$. |
| 43 to 50 | a) Masonry wall, joints well filled. Either plaster or dry lining on both sides. Overall mass per unit area not less than 150 kg/m$^2$. |
| | b) 100 mm metal stud partition, 'C' section studs not greater than 600 mm spacing, not less than nominal 50 mm web depth. Clad on both sides with two layers of plasterboard of not less than 22 mm combined thickness. Mineral fibre quilt hung between studs. Approximate mass per unit area 35 kg/m$^2$. |
| | c) 75 mm × 50 mm timber framing using staged studs at 300 mm spacing with 25 mm stagger forward and back. Frame clad with two layers of 12.5 mm of plasterboard on both sides. Mineral fibre quilt hung between studs. Approximate mass per unit area 36 kg/m$^2$. |
| | d) 50 mm × 25 mm timber stud partition to form a 25 mm cavity, clad on both sides with minimum 38 mm wood wool slabs having their outer faces screeded or plastered. |
| | e) Solid autoclaved aerated concrete block 215 mm thick plaster or dry lined finish on both sides, blockwork joints well filled. Overall mass per unit area not less than 160 kg/m$^2$. |
| 50 to 54 | a) Two separate frames of timber studs not less than 89 mm × 38 mm, or boxed metal studwork with 50 mm minimum web depth. Studs at 600 mm maximum centres. A 25 mm mineral wool quilt suspended between frames. Frames spaced to give a minimum 200 mm overall cavity. Clad on outside of each frame with a minimum of 30 mm plasterboard layers (for example 19 mm plus 12.5 thickness). Approximate mass per unit area 54 kg/m$^2$.[1)] |
| | b) Either *in-situ* or pre-cast concrete wall panel not less than 175 mm thick and not less than 415 kg/m$^2$. All joints well filled.[1)] |
| | c) Brick wall nominal 230 mm thickness, weight (including plaster) not less than 380 kg/m$^2$. Plaster or dry-lined finish both sides. Brick work joints well filled.[1)] |
| | d) 'No fines' concrete 225 mm thickness, weight (including plaster) not less than 415 kg/m$^2$. Plaster or dry-lined finish both sides.[1)] |

**Table 15 — *Concluded***

| (1) | (2) |
|---|---|
| | e) Cavity lightweight aggregate block (maximum density of block 1 600 kg/m$^3$) with 75 mm cavity and wall ties of the butterfly wire type. Dry lined finish on both sides. Joints in blockwork well filled. Overall mass per unit area not less than 300 kg/m$^2$.[1)] |
| | f) Dense aggregate concrete block cavity wall with 50 mm cavity and wall ties of the butterfly wire type. Dry lined finish on both sides. Joints in block work well filled. Overall mass per unit area not less than 415 kg/m$^2$.[1)] |
| | g) Autoclaved aerated concrete block cavity wall consisting of two leaves, 100 mm blocks not less than 75 mm apart, with wall ties of the butterfly type. Plaster or dry line finish on both sides. Joints in blockwork well filled. Overall mass per unit area not less than 150 kg/m$^2$.[1)] |
| 54 to 60 | a) Two separate frames of timber studs not less than 100 mm × 50 mm spaced at 600 mm maximum centres. A 50 mm mineral wool quilt in each frame between studs. Frames spaced to give a minimum 300 mm overall cavity. Each frame clad on outside with three layers of 12.5 mm plasterboard nailed to framing. Approximate mass per unit area 51 kg/m$^2$.[1)] |
| | b) Two separate frames of boxed 'C' section galvanized nominal 150 mm steel studs 100 mm apart with a 400 mm overall cavity. 50 mm mineral wool quilt fixed to the back of one frame each frame clad on outside with three layers of 12.5 mm plasterboard by self drilling or tapping screws. Approximate mass per unit area 47 kg/m$^2$.[1)] |
| | c) Solid masonry with an overall mass per unit area of not less than 700 kg/m$^2$ fully sealed both sides.[1)] |
| | d) Dense aggregate concrete block solid wall 215 mm thick plaster finish to both surfaces. Overall mass per unit area not less than 415 kg/m$^2$.[1)] |
| | e) Cavity lightweight aggregate block (maximum density of block 1 600 kg/m$^3$) with 75 mm cavity and wall ties of the butterfly wire type. Plaster finish on both sides. Joints in blockwork well filled. Overall mass per unit area not less than 300 kg/m$^2$.[1)] |
| | f) Dense aggregate concrete block cavity wall with 50 mm cavity and wall ties of the butterfly wire type. Plaster finish on both sides. Joints in blockwork well filled. Overall mass per unit area not less than 415 kg/m$^2$.[1)] |

NOTES

**1** Construction details and workmanship are important if the levels of sound insulation indicated are to be achieved.

**2** Where plasterboard is specified it is assumed that the surface mass will be at least 6.5 kg/m$^2$ for 9.5 mm thick board, at least 8.5 kg/m$^2$ for 12.5 mm thick board, and at least 14.5 kg/m$^2$ for 19 mm thick board. If less dense plasterboard is used, the thickness should be increased.

[1)] When considering these constructions for separating walls, expert advice should be sought.

**Table 16 Air-borne and Impact Sound Insulation of Floor Constructions**

(*Clause* F-4)

| Sound Insulation dB<br>(1) | Type of Wall or Partition<br>(2) |
|---|---|
| $D_{nT,w}$ = 49 to 54<br>$L'_{nT,w}$ = 56 to 65 | a) A concrete floor having mass per unit area not less than 365 kg/m$^2$, including any screed or ceiling finish directly bonded to the floor slab; together with a floating floor or resilient floor covering equivalent to rubber or sponge rubber underlay or thick cork tile (for example carpet and underlay or sponge rubber backed vinyl flooring).<br>b) A solid floor consisting of:<br>1) a solid slab; or<br>2) concrete beams and infilling blocks; or<br>3) hollow concrete planks; together with a floating floor. A ceiling finish is required for a beam and block floor. In each case the slab should have a mass per unit area of at least 300 kg/m$^2$ including any screed or ceiling finish directly bonded to it.<br>Where a floating floor is laid over a floor of beams and hollow infill blocks or hollow beams along the top of the structural floor, it should be sealed and levelled before the resilient layer is put down. It is also essential to have due regard for conduits and pipework which should be laid and covered so as to prevent any short circuit of the floor's isolating properties.<br>If precast units are used as a structural floor, it is essential that the joints are filled to ensure that the sound insulation performance is maintained.<br>The resilient material is laid to cover completely the structural floor and turned up against the surrounding wall along all edges. The resilient layer is usually of mineral fibre, or a special grade of expanded polystyrene. When the screed is laid, it is important that none of the mix finds its way through the resilient layer to the structural floor, as this will short circuit the isolation between the two decks and significantly reduce the sound insulation.<br>c) A floor consisting of boarding nailed to battens laid to float upon an isolating layer of mineral fibre capable of retaining its resilience under imposed loading. With battens running along the joists, a dense fibre layer can be used in strips. The ceiling below to be of metal lath and plaster not less than 29 mm thick, with pugging on the ceiling such that the combined mass per unit area of the floor, ceiling and pugging is not less than 120 kg/m$^2$. This construction will only give values for $D_{nT,w}$ of 50 to 53 dB, and a value for $L'_{nT,w}$ of 75 dB.<br>d) A floor consisting of 18 mm tongued and grooved chipboard on 19 mm plasterboard laid on battens running parallel to the joists and supported on 25 mm thick mineral wool of about 90 kg/m$^3$ to 140 kg/m$^3$ density; 100 mm of fibre absorbent (as used for insulation in roof spaces) laid between the joists on top of the plasterboard ceiling.[1)]<br>e) A floor consisting of 18 mm tongued and grooved chipboard on 19 mm plasterboard floating on a 25 mm thick mineral wool layer of about 60 kg/m$^3$ to 80 kg/m$^3$ density; this on a 12.5 mm plywood platform; 100 mm of fibre absorbent laid between the joists on top of the plasterboard ceiling.[1)] |
| $D_{nT,w}$ = 32 to 36<br>$L'_{nT,w}$ = 80 to 85 | Timber joist floor consisting of 22 mm tongued and grooved floor boarding or equivalent fixed directly to floor joists. Ceiling of 12.5 mm plasterboard and skim with no floor covering. |

NOTES

**1** Construction details and workmanship are important if the levels of sound insulation indicated are to be achieved.

**2** Where plasterboard is specified it is assumed that the surface mass will be at least 8.5 kg/m$^3$ for 12.5 mm thick board, and at least 14.5 kg/m$^2$ for 19 mm thick board. If less dense plasterboard is used, the thickness should be increased.

[1)] In these types of floor construction, the ceiling may be 19 mm plus 12.5 mm plasterboard. It is imperative that the resilient layer is not punctured by nails.

In many cases, simple solid partitions give insulation values according to their mass (*see* **F-3.3**). Moreover, with partitions of this type there is usually little variation between field and laboratory test results unless the laboratory insulation exceeds 45 dB. Exceptions may occur in buildings that have not been specially designed to minimize common cavities and strongly coupled elements in lightweight panelling. The examples given are not exhaustive. Flanking structures are not listed since these can vary widely and are often dependent upon other factors such as thermal insulation, which are outside the scope of this Code.

## ANNEX G

(*Clause* 13.1)

### BASIC DESIGN TECHNIQUES FOR NOISE CONTROL IN AIR CONDITIONING, HEATING AND MECHANICAL VENTILATION SYSTEM

**G-1** When selecting fans and other related mechanical equipment and when designing air distribution systems to minimize the sound transmitted from different components to the occupied spaces that they serve, the following recommendations should be considered:

a) Design the air distribution system to minimize flow resistance and turbulence. High flow resistance increases the required fan pressure, which results in higher noise being generated by the fan. Turbulence increases the flow noise generated by duct fittings and dampers in the air distribution system, especially at low frequencies.

b) Select a fan to operate as near as possible to its rated peak efficiency when handling the required quantity of air and static pressure. Also, select a fan that generates the lowest possible noise but still meets the required design conditions for which it is selected. Using an oversized or undersized fan that does not operate at or near rated peak efficiency may result in substantially higher noise levels.

c) Design duct connections at both the fan inlet and outlet for uniform and straight air flow. Failure to do this may result in severe turbulence at the fan inlet and outlet and in flow separation at the fan blades. Both of these may significantly increase the noise generated by the fan.

d) Select duct silencers that do not significantly increase the required fan total static pressure.

e) Place fan-powered mixing boxes associated with variable volume air distribution systems away from noise-sensitive areas.

f) Minimize flow-generated noise by elbows or duct branch take-offs, whenever possible, by locating them at least four to five duct diameters from each other. For high velocity systems, it may be necessary to increase this distance to up to ten duct diameters in critical noise areas.

g) Keep airflow velocity in the duct as low as possible (7.5 m/s or less) near critical noise areas by expanding the duct cross-section area. However, do not exceed an included expansion angle of greater than 15°. Flow separation, resulting from expansion angles greater than 15°, may produce rumble noise. Expanding the duct cross-section area will reduce potential flow noise associated with turbulence in these areas.

h) Use turning vanes in large 90° rectangular elbows and branch takeoffs. This provides a smoother transmission in which the air can change flow direction, thus reducing turbulence.

j) Place grilles, diffusers and registers into occupied spaces as far as possible from elbows and branch takeoffs.

k) Minimize the use of volume dampers near grills, diffusers and registers in acoustically critical situations.

m) Vibration isolate all vibrating reciprocating and rotating equipment if mechanical equipment is located on upper floors or is roof-mounted. Also, it is usually necessary to vibration isolate the mechanical equipment that is located in the basement of a building as well as piping supported from the ceiling slab of a basement, directly below tenant space. It may be necessary to use flexible piping connectors and flexible electrical conduit between rotating or reciprocating equipment and pipes and ducts that are connected to the equipment.

n) Vibration isolate ducts and pipes, using spring and/or neoprene hangers for at least the first 15 m from the vibration-isolated equipment.

p) Use barriers near outdoor equipment when noise associated with the equipment will disturb adjacent properties if barriers are not used. In normal practice, barriers typically produce no more than 15 dB of sound attenuation in the mid-frequency range.

q) Table 17 lists several common sound sources associated with mechanical equipment noise. Anticipated sound transmission paths and recommended noise reduction methods are also listed in Table 18. Air-borne and/or structure-borne sound can follow any or all of the transmission paths associated with a specified sound source.

**Table 17 Sound Sources, Transmission Paths and Recommended Noise Reduction Methods**

[*Clause* G-1(q)]

| Sound Source | Path No. (*see* Table 18) |
|---|---|
| Circulating fans, grilles, registers, diffusers, unitary equipment in room | 1 |
| Induction coil and fan-powered VAV mixing units | 1, 2 |
| Unitary equipment located outside of room served; remotely located air-handling equipment, such as fans, blowers, dampers, duct fitting, and air washers | 2, 3 |
| Compressors, pumps, and other reciprocating and rotating equipment (excluding air-handling equipment) | 4, 5, 6 |
| Cooling towers; air-cooled condensers | 4, 5, 6, 7 |
| Exhaust fans; window air conditioners | 7, 8 |
| Sound transmission between rooms | 9, 10 |

**Table 18 Sound Transmission Paths and Recommended Noise Reduction Methods**

[*Clause* G-1(q) and *Table* 17]

| Path No. | Transmission Paths | Noise Reduction Methods |
|---|---|---|
| (1) | (2) | (3) |
| 1 | Direct sound radiated from sound sources to ear. | Direct sound can be controlled only by selecting quiet equipment. |
| | Reflected sound from walls, ceiling and floor. | Reflected sound is controlled by adding sound absorption to the room and to equipment location. |
| 2 | Air and structure-borne sound radiated from casings and through walls of ducts and plenums is transmitted through walls and ceiling into rooms. | Design duct and fittings for low turbulence; locate high velocity ducts in non-critical areas; isolate ducts and sound plenums from structure with neoprene or spring hangers |
| 3 | Airborne sound radiated through supply and return air ducts to diffusers in room and then to listener by Path 1. | Select fans for minimum sound power; use ducts lined with sound-absorbing material; use duct silencers or sound plenums in supply and return air ducts. |
| 4 | Noise transmitted through equipment room walls and floors to adjacent rooms. | Locate equipment rooms away from critical areas; use masonry blocks or concrete for equipment room walls and floor. |
| 5 | Vibration transmitted via building structure to adjacent walls and ceilings, from which it radiates as noise into room by Path 1. | Mount all machines on properly designed vibration isolators; design mechanical equipment room for dynamic loads; balance rotating and reciprocating equipment. |
| 6 | Vibration transmission along pipes and duct walls. | Isolate pipe and ducts from structure with neoprene or spring hangers; install flexible connectors between pipes, ducts, and vibrating machines. |
| 7 | Noise radiated to outside enters room windows. | Locate equipment away from critical areas; use barriers and covers to interrupt noise paths; select quiet equipment. |
| 8 | Inside noise follows Path 1. | Select quiet equipment. |
| 9 | Noise transmitted to an air diffusers in a room, into a duct, and out through an air diffuser in another room. | Design and install duct attenuation to match transmission loss of wall between rooms. |
| 10 | Sound transmission through, over, and around room partition. | Extend partition to ceiling slab and tightly seal all around; seal all pipe, conduit, duct and other partition penetrations. |

# ANNEX H

(*Clause* 13.2)

## SUGGESTED EQUIPMENT NOISE DATA SHEET

It is recommended that an equipment noise data sheet be furnished to intending bidders of mechanical equipment such as air conditioning, heating and mechanical ventilation machinery or diesel generating units specifying noise requirements at the time of request for quotation. Following is a sample noise data sheet suggested for the purpose:

**Sample of Equipment Noise Data Sheet for Noise Specification to be Sent to Suppliers**

**Equipment Description** ______________________ **Type** ______________________ **Item No.** ___________

| *Octave-Band Centre Frequency,* Hz | *Desired Sound Pressure Level,* $L_p$ | *Supplier to Complete* | | |
|---|---|---|---|---|
| | | Actual | Special Design | Special Noise Control Measures Recommended |
| (1) | (2) | (3) | (4) | (5) |
| 63 | | | | |
| 125 | | | | |
| 250 | | | | |
| 500 | | | | |
| 1 000 | | | | |
| 2 000 | | | | |
| 4 000 | | | | |
| 8 000 | | | | |

NOTES

**1** The measurements of SPL shall be at a distance of 1.0 m from the equipment and 1.5 m above grade or floor. The measurement method shall be described and the point of maximum levels furnished.

**2** Complete col 3 for actual levels of standard equipment.

**3** Complete col 4 for special design for low noise (if such alternative is available).

**4** Complete col 5 for noise control measures such as enclosure.

**5** Indicate if the equipment meets the specified noise levels without modification (Yes/No).

**6** If no, additional costs required:

For col 4 ___________________________________

For col 5 ___________________________________

It will be observed from the col 3, 4 and 5 that the buyer would get quotation for supply of a standard equipment at a price P-1, whose noise characteristics would be as per col 3. Col 4 would indicate acoustical performance for a special design at a price P-2. Col 5 would indicate the acoustical performance if the owners were to provide special noise control measures for the installation (whose broad details and approximate estimated cost is also furnished by the vendor).

## LIST OF STANDARDS

The following list records those standards which are acceptable as 'good practice' and 'accepted standards' in the fulfilment of the requirements of the Code. The latest version of a standard shall be adopted at the time of enforcement of the Code. The standards listed may be used by the Authority as a guide in conformance with the requirements of the referred clauses in the Code.

| *IS No.* | *Title* |
|---|---|
| (1) 11050 (Part 1) : 1984 | Rating of sound insulation in buildings and of building elements: Part 1 Air-borne sound insulation in buildings and of interior building elements |
| (2) 4954 : 1968 | Recommendations for noise abatement in town planning |
| (3) 2526 : 1963 | Code of practice for acoustical design of auditoriums and conference halls |
| (4) 11050 | Rating of sound insulation in buildings and of building elements: |
| (Part 1) : 1984 | Air-borne sound insulation in buildings and of interior building elements |
| (Part 2) : 1984 | Impact sound insulation |

# NATIONAL BUILDING CODE OF INDIA

## PART 8 BUILDING SERVICES

### Section 5 Installation of Lifts and Escalators

BUREAU OF INDIAN STANDARDS

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National Building Code Sectional Committee, CED 46

FOREWORD

This Section was first published in 1970 and was subsequently revised in 1983. This Section covers the essential requirements for installation of lifts and escalators in buildings. This Section shall, however, be read with Part 4 'Fire and Life Safety' from fire safety requirements point of view. The major changes in the last revision were addition of outline dimensions of different types of lifts and detailed requirements of escalators in buildings. Emphasis was laid on coordination between the engineer/architect and the lift manufacturer to arrive at the number and position of lifts for attaining optimum efficiency in serving the building with safety.

As a result of experience gained in implementation of 1983 version of the Code and feedback data received as well as revision of Indian Standards on which this Section was based, a need was felt to revise this Section. This revision has, therefore, been prepared to take care of these. The significant changes incorporated in this revision includes:

a) New clauses/recommendations have been added on Building Management System.
b) New clauses have been added on fireman's lift, infra-red light curtain safety and Braille button for blind people.
c) The provisions have been updated as per the revised standards on lifts on which this Section is based.
d) The list of Indian Standards as good practices/accepted standards has been updated.

The information contained in this Section is largely based on the following Indian Standards:

| *IS No.* | *Title* |
|---|---|
| 962 : 1989 | Code of practice for architectural and building drawings (*second revision*) |
| 4591 : 1968 | Code of practice for installation and maintenance of escalators |
| 14665 | Specification for electric traction lifts: |
| (Part 1) : 2000 | Guidelines for outline dimensions of passenger, goods, service and hospital lifts |
| (Part 2/Sec 1 & 2) : 2000 | Code of practice for installation, operation and maintenance, Section 1 Passenger and goods lifts, Section 2 Service lifts |
| (Part 3/Sec 1 & 2) : 2000 | Safety rules, Section 1 Passenger and goods lifts, Section 2 Service lifts |
| (Part 4/Sec 1 to 9) : 2001 | Components, Section 1 Lift buffers, Section 2 Lift guide rails and guide shoes, Section 3 Lift carframe, car, counterweight and suspension, Section 4 Lift safety gears and governors, Section 5 Lift retiring cam, Section 6 Lift doors and locking devices and contacts, Section 7 Lift machines and brakes, Section 8 Lift wire ropes, Section 9 Controller and operating devices |
| (Part 5) : 1999 | Inspection manual |

All standards, whether given herein above or cross-referred to in the main text of this Section, are subject to revision. The parties to agreement based on this Section are encouraged to investigate the possibility of applying the most recent editions of the standards.

# NATIONAL BUILDING CODE OF INDIA

## PART 8 BUILDING SERVICES

## Section 5 Installation of Lifts and Escalators

### 1 SCOPE

**1.1** This Section covers the essential requirements for the installation, operation and maintenance and also inspection of lifts (passenger lifts, goods lifts, hospital lifts, service lifts and dumb waiter) and escalators so as to ensure safe and satisfactory performance.

**1.2** This Section gives information that should be exchanged among the architect, the consulting engineer and the lift/escalator manufacturer from the stage of planning to installation including maintenance.

NOTE — The provisions given in this Section are primarily for electric traction lift; however, most of these provisions are also applicable to hydraulic lifts {*see* good practice [8-5(1)}.

### 2 TERMINOLOGY

**2.0** For the purpose of this Section, the following definitions shall apply.

**2.1 Automatic Rescue Device** — A device meant to bring a lift stuck between floors due to loss of power, to the nearest level and open the doors in order to allow trapped passengers to be evacuated. Such a device may use some form of internal auxiliary power source for such purpose, complying with all the safety requirements of a lift during normal run. The speed of travel is usually lower than the normal speed. In the case of manual doors on reaching the level, the device shall allow the door to be opened and in case of power operated doors the device shall automatically open the door.

**2.2 Baluster** — A short pillar slender above and bulging below.

**2.2.1** *Balustrade* — A row of balusters meant for supporting moving handrails.

**2.3 Bottom Car Runby** — The distance between the car buffer striker plate and the striking surface of the car buffer when the car is in level with the bottom terminal landing.

**2.4 Bottom Coutnerweight Runby** — The distance between the counter weight buffer striker plate and the striking surface of the counterweight buffer when the car is in level with the top terminal landing.

**2.5 Buffer** — A device designed to stop a descending car or counter weight beyond its normal limit of travel by storing or by absorbing and dissipating the kinetic energy of the car or counterweight.

**2.5.1** *Oil Buffer* — A buffer using oil as a medium which absorbs and dissipates the kinetic energy of the descending car or counterweight.

**2.5.1.1** *Oil buffer stroke* — The oil displacing movement of the buffer plunger or piston, excluding the travel of the buffer plunger accelerating device.

**2.5.2** *Spring Buffer* — A buffer which stores in a spring the kinetic energy of the descending car or counterweight.

**2.5.2.1** *Spring buffer load rating* — The load required to compress the spring by an amount equal to its stroke.

**2.5.2.2** *Spring buffer stroke* — The distance, the contact end of the spring can move under a compressive load until the spring is compressed solid.

**2.6 Call Indicator** — A visual and audible device in the car to indicate to the attendant the lift landings from which calls have been made.

**2.7 Car Bodywork** — The enclosing bodywork of the lift car which comprises the sides and roof and is built upon the car platform.

**2.8 Car Door Electric Contact** — An electric device, the function of which is to prevent operation of the driving machine by the normal operating device unless the car door is in the closed position.

**2.9 Car Frame** — The supporting frame or sling to which the platform of the lift car, its safety gear, guide shoes and suspension ropes are attached.

**2.10 Car Platform** — The part of the lift car which forms the floor and directly supports the load.

**2.11 Clearance**

**2.11.1** *Bottom Car Clearance* — The clear vertical distance from the pit floor to the lowest structural or mechanical part, equipment or device installed beneath the car platform aprons or guards located within 300 mm, measured horizontally from the sides of the car platform when the car rests on its fully compressed buffers.

**2.11.2** *Top Car Clearance* — The shortest vertical distance between the top of the car crosshead, or between the top of the car where no crosshead is provided, and the nearest part of the overhead structure or any other obstruction when the car floor is level with the top terminal landing.

**2.11.3** *Top Counterweight Clearance* — The shortest vertical distance between any part of the counterweight structure and the nearest part of the overhead structure or any other obstruction when the car floor is level with the bottom terminal landing.

**2.12 Control** — The system governing starting, stopping, direction of motion, acceleration, speed and retardation of moving member.

**2.12.1** *Single-Speed Alternating Current Control* — A control for a driving machine induction motor which is arranged to run at a single-speed.

**2.12.2** *Two-Speed Alternating Current Control* — A control for a two-speed driving machine induction motor which is arranged to run at two different synchronous speeds either by pole changing of a single motor or by two different armatures.

**2.12.3** *Rheostatic Control* — A system of control which is accomplished by varying resistance or reactance or both in the armature or field circuit or both of the driving machine motor.

**2.12.4** *Variable Voltage Motor Control (Generator Field Control)* — A system of control which is accomplished by the use of an individual generator for each lift wherein the voltage applied to the driving machine motor is adjusted by varying the strength and direction of the generator field.

**2.12.5** *Electronic Devices* — A system of control which is accomplished by the use of electronic devices for driving the lift motor at variable speed.

**2.12.6** *Alternating Current Variable Voltage (ACVV) Control* — A system of speed control which is accomplished by varying the driving and braking torque by way of voltage variation of the power supply to the driving machine induction motor.

**2.12.7** *Alternating Current Variable Voltage Variable Frequency (ACVVVF) Control* — A system of speed control which is accomplished by varying the voltage and frequency of the power supply to the driving machine induction motor.

**2.12.8** *Solid-State d.c. Variable Voltage Control* — A solid-state system of speed control which is accomplished by varying the voltage and direction of the power supply to the armature of driving machine d.c. motor.

**2.13 Counterweight** — A weight or series of weights to counter-balance the weight of the lift car and part of the rated load.

**2.14 Deflector Sheave** — An idler pulley used to change the direction of a rope lead.

**2.15 Door**

**2.15.1** *Door, Centre Opening Sliding* — A door which slides horizontally and consists of two or more panels which open from the centre and are usually so interconnected that they move simultaneously.

**2.15.2** *Door, Mid-Bar Collapsible* — A collapsible door with vertical bars mounted between the normal vertical members.

**2.15.3** *Door, Multipanel* — A door arrangement whereby more than one panel is used such that the panels are connected together and can slide over one another by which means the clear opening can be maximized for a given shaft width. Multipanels are used in centre opening and two speed sliding doors.

**2.15.4** *Door, Single Slide* — A single panel door which slides horizontally.

**2.15.5** *Door, Two Speed Sliding* — A door which slides horizontally and consists of two or more panels, one of which moves at twice the speed of the other.

**2.15.6** *Door, Vertical Bi-parting* — A door which slides vertically and consists of two panels or sets of panels that move away from each other to open and are so interconnected that they move simultaneously.

**2.15.7** *Door, Vertical Lifting* — A single panel door, which slides in the same plane vertically up to open.

**2.15.8** *Door, Swing* — A swinging type single panel door which is opened manually and closed by means of a door closer when released.

**2.16 Door Closer** — A device which automatically closes a manually opened door.

**2.17 Door Operator** — A power-operated device for opening and closing doors.

**2.18 Dumb Waiters** — A lift with a car which moves in guides in a vertical direction; has a net floor area of 1 $m^2$, total inside height of 1.2 m, whether or not provided with fixed or removable shelves; has a capacity not exceeding 250 kg and is exclusively used for carrying materials and shall not carry any person.

**2.19 Electrical and Mechanical Interlock** — A device provided to prevent simultaneous operation of both up and down relays.

**2.20 Electro-Mechanical Lock** — A device which combines in one unit, electrical contact and a mechanical lock jointly used for the landing and/or car doors.

**2.21 Emergency Stop Push or Switch** — A push button or switch provided inside the car designed to open the control circuit to cause the lift car to stop during emergency.

**2.22 Escalator** — A power driven, inclined, continuous stairway used for raising or lowering passengers.

**2.23 Escalator Installation** — It includes the escalator, the track, the trusses or girders, the balustrading, the step treads and landings and all chains, wires and machinery directly connected with the operation of the escalator.

**2.24 Escalator Landing** — The portion of the building or structure which is used to receive or discharge passengers into or from an escalator.

**2.25 Escalator Landing Zone** — A space extending from a horizontal plane 40 cm below a landing to a plane 40 cm above the landing.

**2.26 Escalator Machine** — The mechanism and other equipment in connection therewith used for moving the escalator

**2.27 Floor Levelling Switch** — A switch for bringing the car to level at slow speed in case of double speed or variable speed machines.

**2.28 Floor Selector** — A mechanism forming a part of the control equipment, in certain automatic lifts, designed to operate controls which cause the lift car to stop at the required landings.

**2.29 Floor Stopping Switch** — A switch or combination of switches arranged to bring the car to rest automatically at or near any pre-selected landing.

**2.30 Gearless Machine** — A lift machine in which the motive power is transmitted to the driving sheave from the motor without intermediate reduction gearing and has the brake drum mounted directly on the motor shaft.

**2.31 Goods Lift** — A lift designed primarily for the transport of goods, but which may carry a lift attendant or other persons necessary for the loading or unloading of goods.

**2.32 Guide Rails** — The members used to guide the movement of a lift car or counterweight in a vertical direction.

**2.33 Guide Rails Fixing** — The complete assy. comprising the guide rails bracket and its fastenings.

**2.34 Guide Rails Shoe** — An attachment to the car frame or counterweight for the purpose of guiding the lift car or counter weight frame.

**2.35 Hoisting Beam** — A beam, mounted immediately below the machine room ceiling, to which lifting tackle can be fixed for raising or lowering parts of the lift machine.

**2.36 Hospital Lift** — A lift normally installed in a hospital/dispensary/clinic and designed to accommodate one number bed/stretcher along its depth, with sufficient space around to carry a minimum of three attendants in addition to the lift operator.

**2.37 Landing Call Push** — A push button fitted at a lift landing, either for calling the lift car, or for actuating the call indicator.

**2.38 Landing Door** — The hinged or sliding portion of a lift well enclosure, controlling access to a lift car at a lift landing.

**2.39 Landing Zone** — A space extending from a horizontal plane 400 mm below a landing to a plane 400 mm above the landing.

**2.40 Levelling Devices**

**2.40.1** *Levelling Device, Lift Car* — Any mechanism which either automatically or under the control of the operator, moves the car within the levelling zone towards the landing only, and automatically stops it at the landing.

**2.40.2** *Levelling Device, One Way Automatic* — A device which corrects the car level only in case of under run of the car but will not maintain the level during loading and unloading.

**2.40.3** *Levelling Device, Two-Way Automatic Maintaining* — A device which corrects the car level on both under run and over-run and maintains the level during loading and unloading.

**2.40.4** *Levelling Device, Two Way Automatic Non-Maintaining* — A device which corrects the car level on both under run and over run but will not maintain the level during loading and unloading.

**2.41 Levelling Zone** — The limited distance above or below a lift landing within which the levelling device may cause movement of the car towards the landing.

**2.42 Lift** — An appliance designed to transport persons or materials between two or more levels in a vertical or substantially vertical direction by means of a guided car or platform. The word 'elevator' is also synonymously used for 'lift'.

**2.43 Lift Car** — The load carrying unit with its floor or platform, car frame and enclosing bodywork.

**2.44 Lift Landing** — That portion of a building or structure used for discharge of passengers or goods or both into or from a lift car.

**2.45 Lift Machine** — The part of the lift equipment comprising the motor and the control gear therewith, reduction gear (if any), brake(s) and winding drum or sheave, by which the lift car is raised or lowered.

**2.46 Lift Pit** — The space in the lift well below the level of the lowest lift landing served.

**2.47 Lift Well** — The unobstructed space within an enclosure provided for the vertical movement of the lift car(s) and any counterweight(s), including the lift pit and the space for top clearance.

**2.48 Lift Well Enclosure** — Any structure which separates the lift well from its surroundings.

**2.49 Operation** — The method of actuating the control of lift machine.

**2.49.1** *Automatic Operation* — A method of operation in which by a momentary pressure of a button the lift car is set in motion and caused to stop automatically at any required lift landing.

**2.49.2** *Non-Selective Collective Automatic Operation* — Automatic operation by means of one button in the car for each landing level served and one button at each landing, wherein all stops registered by the momentary actuation of landing or car buttons are made irrespective of the number of buttons actuated or of the sequence in which the buttons are actuated. With this type of operation, the car stops at all landings for which buttons have been actuated making the stops in the order in which the landings are reached after the buttons have been actuated but irrespective of its direction of travel.

**2.49.3** *Selective Collective Automatic Operation* — Automatic operation by means of one button in the car for each landing level served and by up and down buttons at the landings, wherein all stops registered by the momentary actuation of the car made as defined under non-selective collective automatic operation, but wherein the stops registered by the momentary actuation of the landing buttons are made in the order in which the landings are reached in each direction of travel after the buttons have been actuated. With this type of operation, all 'up' landing calls are answered when the car is travelling in the up direction and all 'down' landing calls are answered when the car is travelling in the down direction, except in the case of the uppermost or lowermost calls which are answered as soon as they are reached irrespective of the direction of travel of the car.

**2.49.4** *Single Automatic Operation* — Automatic operation by means of one button in the car for each landing level served and one button at each landing so arranged that if any car or landing button has been actuated, the actuation of any other car or landing operation button will have no effect on the movement of the car until the response to the first button has been completed.

**2.49.5** *Group Automatic Operation* — Automatic operation of two or more non-attendant lifts equipped with power-operated car and landing doors. The operation of the cars is co-ordinated by a supervisory operation system including automatic dispatching means whereby selected cars at designated dispatching points automatically close their doors and proceed on their trips in a regulated manner.

Typically, it includes one button in each car for each floor served and up and down buttons at each landing (single buttons at terminal landings). The stops set up by the momentary actuation of the car buttons are made automatically in succession as a car reaches the corresponding landings irrespective of its direction of travel or the sequence in which the buttons are actuated. The stops set up by the momentary actuation of the landing buttons may be accomplished by any lift in the group, and are made automatically by the first available car that approaches the landing in the corresponding direction.

**2.49.6** *Car Switch Operation* — Method of operation by which the movement of lift car is directly under the operation of the attendant by means of a handle.

**2.49.7** *Signal Operation* — Same as collective operation, except that the closing of the door is initiated by the attendant.

**2.49.8** *Double Button (Continuous Pressure) Operation* — Operation by means of buttons or switches in the car and at the landings any of which may be used to control the movement of the car as long as the button or switch is manually pressed in the actuating position.

**2.50 Operating Device** — A car switch, push button or other device employed to actuate the control.

**2.51 Overhead Beams** — The members, usually of steel, which immediately support the lift equipment at the top of the lift well.

**2.52 Over Speed Governor** — An automatic device which brings the lift car and/or counter weight to rest by operating the safety gear in the event of the speed in a descending direction exceeding a predetermined limit.

**2.53 Passenger Lift** — A lift designed for the transport of passengers.

**2.54 Position and/or Direction Indicator** — A device which indicates on the lift landing or in the lift car or both, the position of the car in the lift well or the direction or both in which the lift car is travelling.

**2.55 Rated Load (Lift)** — The maximum load for which the lift car is designed and installed to carry safely at its rated speed.

**2.56 Rated Load (Escalator)** — The load which the escalator is designed and installed to lift at the rated speed.

**2.57 Rated Speed (Lift)** — The mean of the maximum speed attained by the lift car in the upward and downward direction with rated load in the lift car.

**2.58 Rated Speed (Escalator)** — The speed at which the escalator is designed to operate. It is the rate of travel of the steps, measured along the angle of inclination, with rated load on the steps or carriage.

**2.59 Retiring Cam** — A device which prevents the landing doors from being unlocked by the lift car unless it stops at a landing.

**2.60 Roping Multiple** — A system of roping where, in order to obtain a multiplying the factor from the machine to the car, multiple falls of rope are run around sheave on the car or counterweight or both. It includes roping arrangement of 2 to 1.3 to 1 etc.

**2.61 Safety Gear** — A mechanical device attached to the lift car or counterweight or both, designed to stop and to hold the car or counterweight to the guides in the event of free fall, or, if governor operated, of over-speed in the descending direction. Any anticipated impact force shall be added in the general drawing or layout drawing.

**2.62 Service Lift** — A passenger *cum* goods lift meant to carry goods along with people.

Typically in an office building this may be required to carry food or stationeries, in a residential building to carry a bureau or accommodate a stretcher and in a hotel to be used for food trolleys or baggage. There is a need in such lifts, to take care of the dimensions of the car and the door clear opening in line with the type of goods that may have to be carried based on mutual discussion between supplier and customer. Also, such lifts shall have buffer railings in the car at suitable height to prevent damage to the car panels when the goods are transported. Typically such lifts, if provided with an automatic door, may use some means to detect trolleys and stretcher movement in advance to protect the doors against damage. The car floor load calculations and car area of such a lift is as in the case of a passenger lift except that these are not meant to carry heavy concentrated loads.

**2.63 Sheave** — A rope wheel, the rim of which is grooved to receive the suspension ropes but to which the ropes are not rigidly attached and by means of which power is transmitted from the lift machine to the suspension ropes.

**2.64 Slack Rope Switch** — Switch provided to open the control circuit in case of slackening of rope(s)

**2.65 Suspension Ropes** — The ropes by which the car and counter weight are suspended.

**2.66 Terminal Slow Down Switch** — A switch when actuated shall compulsorily cut off the high speed and switch on the circuitry to run the lift in levelling speed before reaching on terminal landings.

**2.67 Terminal Stopping Switch Normal** — Switch for cutting all the energizing current in case of car travelling beyond the top bottom landing or a switch cuts off the energizing current so as to bring the car to stop at the top and bottom level.

**2.68 Terminal Stopping Device Final** — A device which automatically cause the power to be removed from an electric lift driving machine motor and brake, independent of the functioning of the normal terminal stopping device, the operating device or any emergency terminal stopping device, after the car has passed a terminal landing.

**2.69 Total Headroom** — The vertical distance from the level of the top lift landing to the bottom of the machine room slab.

**2.70 Travel** — The vertical distance between the bottom and top lift handing served.

**2.71 Geared Machine** — A machine in which the power is transmitted to the sheave through worm or worm and spur reduction gearing.

## 3 GENERAL

**3.1** The appropriate aspect of lift and escalator installation shall be discussed during the preliminary planning of the building with all the concerned parties, namely, client, architect, consulting engineer and/or lift/escalator manufacturer. This enables the lift/escalator manufacturer to furnish the architect and/or consulting engineer with the proposed layout on *vice-versa*.

### 3.2 Exchange of Information

**3.2.1** If the proposed installation is within the scope of **6**, the guidelines laid down together with Fig. 1 will enable the preliminary scheme for the installation to be established.

Figure 1 shows only some of the typical arrangements and variations are possible with respect to number of lifts and the layout.

Although the recommended outline for the various classes of lifts given in **6** enables the general planning details to be determined by the architect, these should be finally settled at the earliest possible stage by detailed investigation with the purchaser's representative reaching agreement with the lift maker where necessary before an order is finally placed. This will enable a check to be made and information to be exchanged on such vital matters as:

a) the number, capacity, speed and disposition of the lifts necessary to give adequate lift service in the proposed building.
b) the provision of adequate access to the machine room.

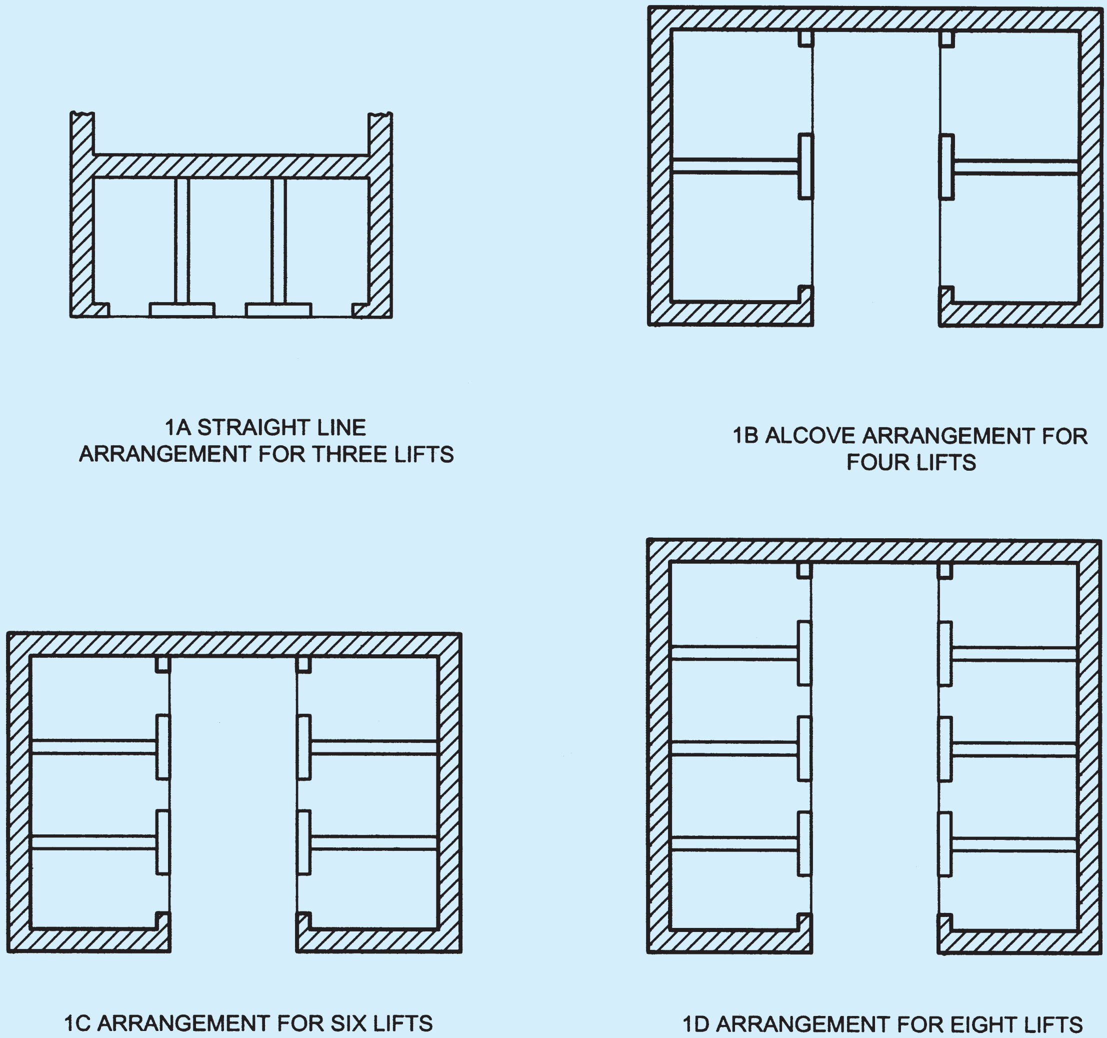



FIG. 1 ARRANGEMENT OF LIFTS

c) The loads which the lift will impose on the building structure, and the holes to be left in the machine room floor and cut-outs for wall boxes for push-buttons and signals;

d) The necessity for and type of insulation to minimize the transmission of vibration and noise to other parts of the building;

e) The special requirements of local authorities and other requirements set out in the 'planning permit';

f) The need for the builder to maintain accuracy of building as to dimensions and in plumb;

g) The periods of time required for preparation and approval of relevant drawings for manufacturing and the installation of the lift equipment;

h) The requirements for fixing guide brackets to the building structure;

j) The time at which electric power will be required before completion to allow for testing;

k) The requirements for electrical supply feeders, etc;

m) The requirements for scaffolding in the lift well and protection of the lift well prior to and during installation of equipment; and

n) Delivery and storage of equipment.

**3.2.2** *Information to be Provided by Architect or Engineer*

As a result of preliminary discussion (*see also* **6**), the drawings of the building should give the following particulars and finished sizes:

a) Number, type and size of lifts and position of lift well;

b) Particulars of lift well enclosure;

c) Size, position, number and type of landing doors;

d) Number of floors served by the lift;
e) Height between floor levels;
f) Number of entrances;
g) Total headroom;
h) Provision of access to machine room;
j) Provision of ventilation and, if possible, natural lighting of machine room;
k) Height of machine room;
m) Depth of lift pit;
n) Position of lift machine, above or below lift well;
p) Size and position of any trimmer joists or stanchions adjacent to the lift well at each floor;
q) Size and position or supporting steel work at roof levels;
r) Size and position of any footings or grillage foundations, if these are adjacent to the lift pit; and
s) In the case of passenger lifts whether the lift cage is required to carry household luggage, such as refrigerator, steel almirah, etc.

**3.2.2.1** The lift lobby should be designed appropriately since this has bearing on the traffic handling especially when more number of lifts are involved. In a dual line arrangement (lifts opposite to each other) the lobby can be between 1.5 times to 2.5 times the depth of one car. Typically, the more the number of lifts the bigger the multiple to be used. As an example a quadruplex may use 1.5 to 2 times where as an octoplex will need 2 to 2.5 times. For in-line (single line) arrangements, the lobby can be typically half of the above recommendations.

It is preferable that the lift lobby is not used as a thoroughfare but in such cases the lift corridor shall take into account space for people who are moving.

**3.2.2.2** The architect/engineer should advise the lift manufacturer, if the Authority has any special requirements regarding lifts in buildings in the administrative area concerned.

**3.2.2.3** The information contained under **3.2.1** and **3.2.2** is applicable for the installation of lifts only and in the case of escalator installations, the drawings shall provide the appropriate information.

**3.2.2.4** The architect/engineer should inform the lift/escalator manufacturer of the dates when the erection of the lift/escalator may be commenced and is to be completed so that sufficient time is allowed for the manufacture and erection of the lift/escalator.

**3.2.2.5** When submitting application for a building permit to the local Authority, the building plans shall include the details of lifts (number of lifts duly numbered, location, type, type of doors, passenger capacity and speed).

**3.2.3** *Working Drawings to be Prepared by the Lift/Escalator Manufacturer*

The lift/escalator manufacturer requires sufficient information for the preparation of working drawings and is usually obtained from architect's drawings supplemented by any information obtained from the site and by collaboration with the other contractors.

**3.2.3.1** Working drawings showing the layout of lift/escalator duly numbered, details of builders work, for example, holes in walls for guide fixing, holes in machine room floor for ropes and conduits, recesses for landing sills, supports for lift/escalator machine and loads imposed on the building should be submitted by the lift/escalator manufacturer to the architect/engineer for written approval.

### 3.3 Electrical Requirement

For information of the electrical engineer, the lift/escalator manufacturer should advise the architect/engineer of his electrical requirements. This information should be available early in the planning stage so that the electrical supply requirements of the lift(s)/escalator(s) may be included in the electrical provisions of the building and that suitable cables and switchgear may be provided.

**3.4** The requirements given under **4** to **13** deal with installation of lifts and **14** deal with the installation of escalators.

## 4 ESSENTIAL REQUIREMENTS

### 4.1 Conformity with *Lifts Act* and *Rules*

The installation shall be generally carried out in conformity with *Lifts Act* and *Rules* thereunder, wherever they are in force.

**4.1.1** It is the responsibility of the owner of the premises where the lift will be installed, to obtain necessary permission from the Authority before and after the erection of lifts and for subsequent operation of lift(s).

### 4.2 Conformity with *Indian Electricity Act and Rules*

All electrical work in connection with installation of electric lifts shall be carried out in accordance with the provisions of *The Indian Electricity Act*, 2003 and the provisions framed thereunder as amended from time to time, and shall also comply with the other provisions of Part 8 'Building Services, Section 2 Electrical and Allied Installations'.

**4.3 Conformity with Indian Standards**

**4.3.1** All materials, fittings, appliances etc used in electrical installation shall conform to Indian Standard specifications wherever these exist. In case of materials for which Indian Standard specifications do not exist, the materials shall be approved by the competent authority. For detailed specification for lifts, reference shall be made to accepted standards [8-5(2)].

**4.4 Conformity with Fire Regulations**

**4.4.1** The installation shall be carried out in conformity with Part 4 'Fire and Life Safety' and local fire regulations and rules thereunder wherever they are in force.

**4.5 Factor of Safety**

The minimum factor of safety for any part of the lift shall not be less than five. Higher factor of safety for various parts shall be applicable in accordance with accepted standards [8-5(3)].

**4.6 Additional Requirements for Passenger and Goods Lifts**

**4.6.1** *Bottom and Top Car Clearances*

**4.6.1.1** *Bottom car clearance*

When the car rests on its fully compressed buffer there shall be a vertical clearance of not less than 600 mm between the pit floor and the buffer striker plate or the lowest structural or mechanical part equipment or device installed. The clearance shall be available beneath the whole area of the platform except for:

a) guide shoes or rollers, safety jaw blocks, platform aprons, guards of other equipment located within 300 mm measured horizontally from the sides of the car platform; and
b) compensating sheaves.

Provided that in all the cases, including small cars, a minimum clearance of 600 mm is available over a horizontal area of 800 mm × 500 mm.

Provided also that in all the cases, when the car rests on its fully compressed buffers, there shall be a vertical clearance of not less than 50 mm between any part of the car and any obstruction of device mounted in the pit.

**4.6.1.2** *Top car clearance*

The vertical clearance between the car cross-head and the nearest overhead obstruction within 500 mm measured horizontally to the nearest part of the crosshead when the car platform is level with the top landing, shall be not less than the sum of the following;

a) The bottom counterweight runby.
b) The stroke of the counterweight buffer used.
c) One-half of the gravity stopping distance based on:
   1) 115 percent of the rated speed where oil buffers are used and no provision is made to prevent the jump of the car at counterweight buffer engagement; and
   2) Governor tripping speed where spring buffers are used.

   NOTE — The gravity stopping distance based on the gravity retardation from any initial velocity may be calculated according to the following formula

   $$S = 51\ V^2$$

   where

   $S$ = Free fall in mm (gravity stopping distance), and
   $V$ = Initial velocity in m/s
d) 600 mm.

Where there is a projection below the ceiling of the well and the projection is more than 500 mm, measured horizontally from the centre line of the cross-head but over the roof of the car, a minimum vertical clearance not less than that calculated above shall also be available between the roof of the car and the projection.

Provided that the vertical clearance between any equipment mounted on top of the car and the nearest overhead obstruction shall be not less than the sum of the three items (a), (b) and (c) as calculated above plus 150 mm.

**4.6.2** *Bottom Runby for Cars and Counterweights*

**4.6.2.1** The bottom runby of cars and counterweights shall be not less than the following:

a) 150 mm where oil buffers are used;
b) Where spring-buffers are used;
   1) 150 mm for controls as in **2.12.4** to **2.12.8**.
   2) Not less than the following for controls as in **2.12.2** to **2.12.3**.

| *Rated speed* m/s | *Runby* mm |
|---|---|
| Up to 0.125 | 75 |
| 0.125 to 0.25 | 150 |
| 0.25 to 0.50 | 225 |
| 0.50 to 1 | 300 |

**4.6.3** *Maximum Bottom Runby*

In no case shall the maximum bottom runby exceed the following:

a) 600 mm for cars; and
b) 900 mm for counterweights.

**4.6.4** *Top Counterweight Clearances*

The top counterweight clearance shall be not less than the sum of the following four items:

a) the bottom car runby;

b) the stroke of the car buffer used;

c) 150 mm; and

d) one-half the gravity stopping distance based on

1) one hundred and fifteen percent of the rated speed where oil buffers are used and no provision is made to prevent jump of the counterweight at car buffer engagement; and

2) governor tripping speed where spring buffers are used.

**4.7 Additional Requirements for Service Lifts**

**4.7.1** *Top and Bottom Clearances for Car and Counterweights*

**4.7.1.1** *Top car clearance*

The top car clearance shall be sufficient to avoid any protruding part fixed on the top of the car coming in direct contact with the ceiling or diverting sheave.

The clearance shall be calculated taking into account the following and shall not be less than the sum of the following four items:

a) The bottom counterweight runby,

b) The stroke of the counterweight buffer used,

c) The dimensions of the portion of the diverting sheave hanging underneath the ceiling in the lift well, and

d) 150 mm for compensating for gravity stopping distance and future repairs to the rope connections at counterweight and at the car or at the suspension points.

**4.7.1.2** *Bottom car clearance*

The bottom car clearance shall be maintained in such a way that the counterweight shall not come in contact with the ceiling or any part hanging underneath the ceiling, when the car completely rests on fully compressed buffers, provided the buffers are spring type mounted on solid concrete or steel bed.

In case of wooden buffers the bottom car clearance shall be maintained in such a way that the total downward travel of the car from the service level of the immediate floor near the pit, shall not be more than the top counterweight clearance, when the wooden buffers are completely crushed.

**4.7.1.3** *Top counterweight clearance*

The top clearance for the counterweight can be calculated taking into account the following and shall not be less than the sum of the following three items:

a) Car runby,

b) Compression of the buffer spring or height of the wooden block used as buffer, and

c) 150 mm to compensate for gravity stopping distance for counterweight and any future repairs to rope connections at the counterweight at the car ends or at the suspension points.

**4.7.1.4** *Runby for Cars and Counterweights*

The bottom runby for cars and counterweights shall not be less than 150 mm.

**4.7.1.5** *Maximum bottom runby*

In no case shall the maximum bottom runby exceed 300 mm.

**4.8** In order to maintain a safe work environment, and to avoid potential hazards, the following shall be provided:

a) caution sign shall be installed in the areas listed below where potential hazard exists:

1) Trip hazard in machine room; and

2) Caution notice against unauthorized use of rescue devices (for example, brake release device).

b) Use the hard hats for entry in pit and car top during construction period.

c) Warning sign shall be provided on the controller so also eliminate, the possibility of contact with any exposed or concealed power circuit.

d) Car top barricade system shall be provided as primary protection against fall, on car top.

e) Whenever work is carried out on the lift and lift is not required to be moved on power, notice shall be put on electrical main switch indicating requirement of de-energized condition.

f) During lift installation/maintenance, protection against fall shall be provided with suitable barricades for all open lending entrances.

**4.9 Planning for Dimensions**

**4.9.1** *General*

The dimensions of lift well have been chosen to accommodate the doors inside the well which is the normal practice. In special cases, the door may be accommodated in a recess in the front wall, for which prior consultation shall be made with the lift manufacturer.

**4.9.2** *Plan Dimensions*

**4.9.2.1** All plan dimensions of lift well are the minimum clear plumb sizes. The architect/engineer, in conjunction with the builder, shall ensure that adequate tolerances are included in the building design so that the specified minimum clear plumb dimensions are obtained in the finished work.

NOTE — The words 'clear plumb dimensions' should be noted particularly in case of high rise buildings.

**4.9.2.2** Rough opening in concrete or brick walls to accommodate landing doors depend on design of architrave. It is advisable to provide sufficient allowances in rough opening width to allow for alignment errors of opening at various landings.

**4.9.2.3** When more than one lift is located in a common well, a minimum allowance of 100 mm for separator beams shall be made in the widths shown in Tables 1 to 4.

**4.9.2.4** Where the governor operated counterweight safety is required under conditions stipulated in good practice [8-5(3)], the tabular values should be revised in consultation with the lift manufacturer.

**4.9.2.5** For outline dimensions of lifts having more than one car entrance, lift manufacturers should be consulted.

**4.9.3** *Outline Dimensions*

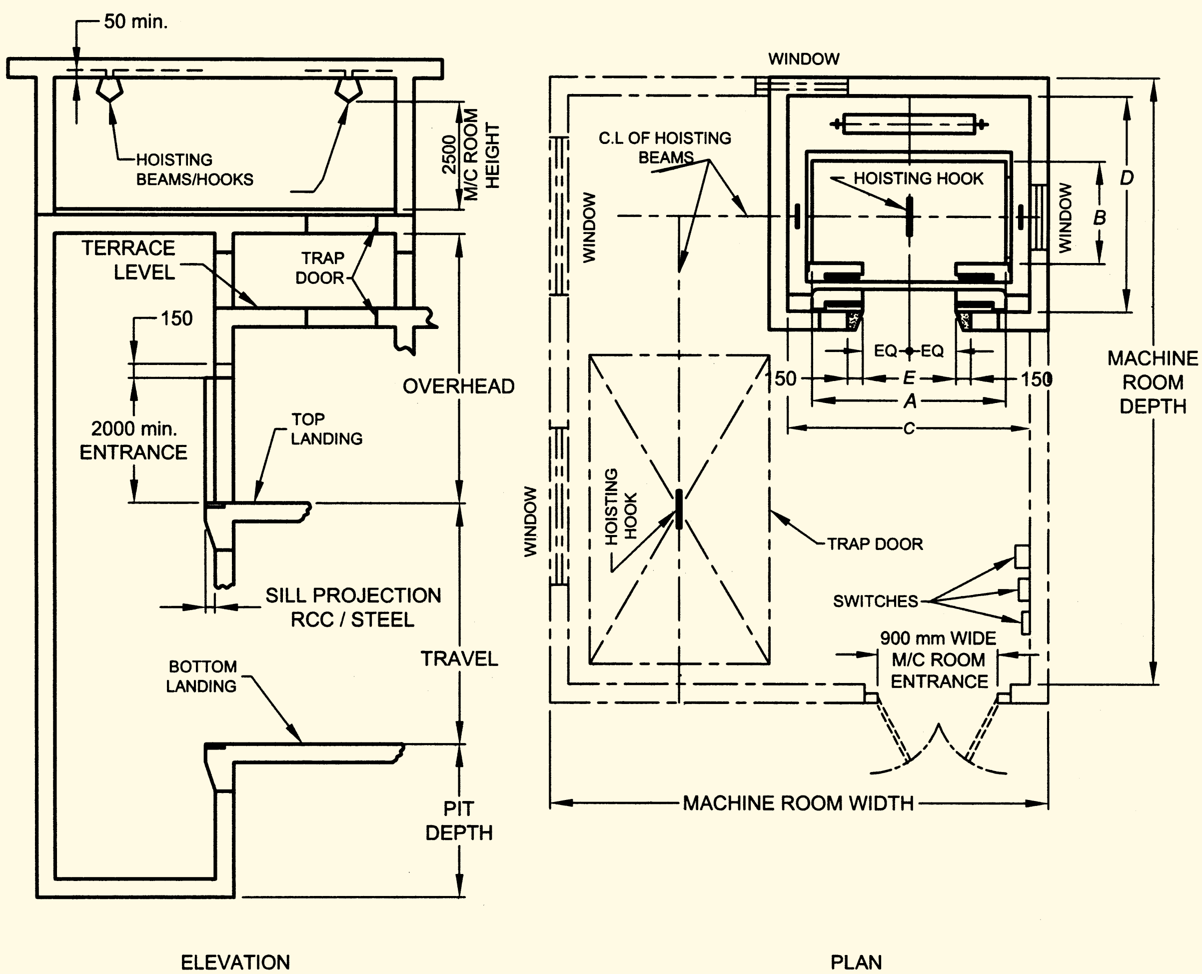
**4.9.3.1** The outline dimensions of machine-room, pit depth, total headroom, overhead distance and sill for four classes of lifts to which the standard applies are specified in Tables 1 to 4 as indicated below:

| | |
|---|---|
| Passenger lifts | Table 1 and 1A |
| Goods lifts | Table 2 |
| Hospital lifts | Table 3 |
| Service lifts | Table 1 and 1A |
| Dumb Waiter | Table 4 |

**Table 1 Recommended Dimensions of Passenger Lifts and Service Lifts**

(*Clauses* 4.9.2.3 *and* 4.9.3.1)

All dimensions in millimetres.



## Table 1 — *Concluded*

| Load | | Car Side | | Lift Well | | Entrance |
|---|---|---|---|---|---|---|
| Persons | kg | *A* | *B* | *C* | *D* | *E* |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) |
| 4 | 272 | 1 100 | 700 | 1 900 | 1 300 | 700, *Min* |
| 6 | 408 | 1 100 | 1 000 | 1 900 | 1 700 | 700, *Min* |
| 8 | 544 | 1 300 | 1 100 | 1 900 | 1 900 | 800 |
| 10 | 680 | 1 300 | 1 350 | 1 900 | 2 100 | 800 |
| 13 | 884 | 2 000 | 1 100 | 2 500 | 1 900 | 900 |
| 16 | 1 088 | 2 000 | 1 300 | 2 500 | 2 100 | 1 000 |
| 20 | 1 360 | 2 000 | 1 500 | 2 500 | 2 400 | 1 000 |

## Table 1A Recommended Dimensions of Pit, Overhead and Machine-Room for Passenger Lifts and Service Lifts

(*Clauses* 4.9.2.3 *and* 4.9.3.1)

All dimensions in millimetres.

| **Speed in m/s** | **Up to 0.70** | **> 0.70 ≤ 1.00** | **> 1.00 ≤ 1.50** | **> 1.50 ≤ 1.75** | **> 1.75 ≤ 2.00** | **> 2.00 ≤ 2.50** |
|---|---|---|---|---|---|---|
| (1) | (2) | (3) | (4) | (5) | (6) | (7) |
| Pit depth | 1 350 | 1 500 | 1 600 | 2 150 | 2 200 | 2 500 |
| Overhead | 4 200 | 4 250 | 4 800 | 4 800 | 5 200 | 5 400 |
| Machine-room Depth | *D* + 2 000 | | | *D* + 2 500 | | |
| Machine-room Width | *C* + 1 000 | | *C* + 1 200 | | *C* + 1 500 | |

NOTES

**1** The total overhead dimension has been calculated on the basis of car height of 2.3 m.

**2** In case of manually operated doors, clear entrance will be reduced by the amount of projection of handle on the landing door.

**3** All dimensions given above for lifts having centre opening power operated doors with counterweight at rear, are recommended dimensions primarily for architects and building planners. Any variations mutually agreed between the manufacturer and the purchaser are permitted. However, variation in:

a) Car inside dimensions shall be within the maximum area limits specified in accordance with accepted standards [8-5(4)].

b) Entrance width on higher side is permitted.

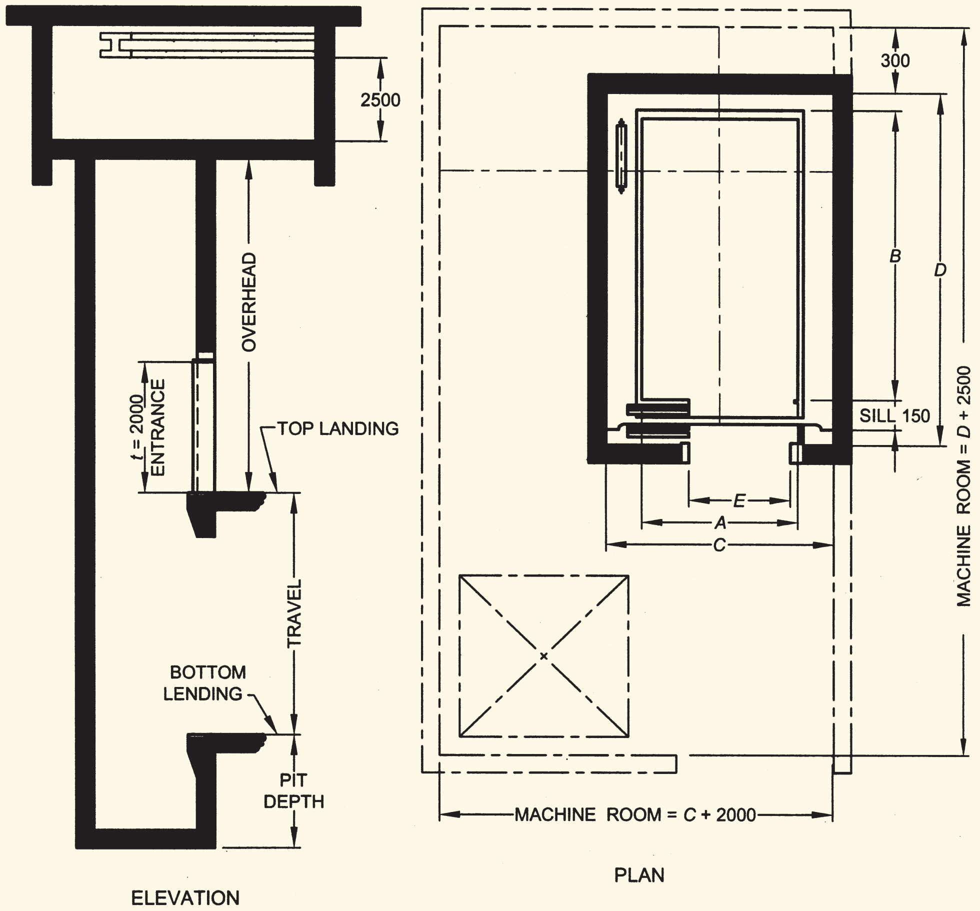
c) Entrance width on lower side is permitted up to 100 mm subject to minimum of 700 mm.

**4** Dimensions of pit depth and overhead may differ in practice as per individual manufacturer's design depending upon load, speed and drive. Recommended dimensions for pit depth, overhead and machine-room for different lift speeds are given in Table 1A. However, the pit depth and overhead shall be such as to conform to the requirements of bottom clearance and top clearance in accordance with the accepted standards [8-5(5)].

**Table 2 Recommended Dimensions of Goods Lifts (For Speeds Up to 0.5 m/s)**

(*Clauses* 4.9.2.3 *and* 4.9.3.1)

All dimensions in millimetres.




| Load kg | Car Inside | | Lift Well | | Entrance |
|---|---|---|---|---|---|
| | *A* | *B* | *C* | *D* | *E* |
| (1) | (2) | (3) | (4) | (5) | (6) |
| 500 | 1 100 | 1 200 | 1 900 | 1 500 | 1 100 |
| 1 000 | 1 400 | 1 800 | 2 300 | 2 100 | 1 400 |
| 1 500 | 1 700 | 2 000 | 2 600 | 2 300 | 1 700 |
| 2 000 | 1 700 | 2 500 | 2 600 | 2 800 | 1 700 |
| 2 500 | 2 000 | 2 500 | 2 900 | 2 800 | 2 000 |
| 3 000 | 2 000 | 3 000 | 2 900 | 3 300 | 2 000 |
| 4 000 | 2 500 | 3 000 | 3 400 | 3 300 | 2 500 |
| 5 000 | 2 500 | 3 600 | 3 400 | 3 900 | 2 500 |

NOTES

**1** The width of machine room shall be equal to be lift well width '*C*' subject to minimum of 2 500 mm.

**2** The total headroom has been calculated on the basis of a car height of 2.2 m.

**3** Clear entrance width '*E*' is based on vertical lifting car-door and vertical biparting landing doors. For collapsible mid-bar doors the clear entrance width will be reduced by 200 mm (maximum 1 800 mm).

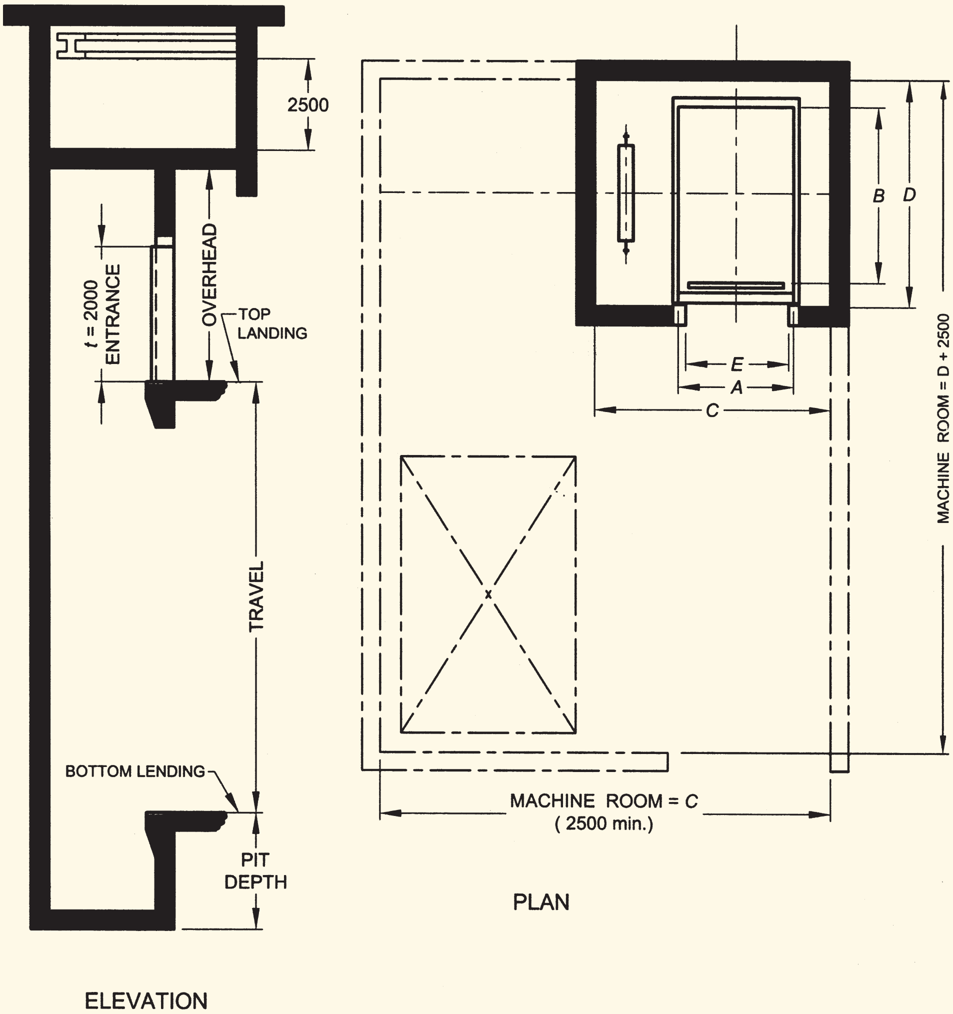
**4** All dimensions given above are recommended dimensions primarily for architects and building planners. Any variations mutually agreed between the manufacturer and the purchaser are permitted. However, variation in car inside dimensions shall be within the maximum area limits in accordance with accepted standards [8-5(4)].

**5** Dimensions of pit depth and overhead may differ in practice as per individual manufacturer's design depending upon load, speed and drive. However, the pit depth and overhead shall be such as to conform to the requirements of bottom clearance and top clearance in accordance with accepted standards [8-5(5)].

## Table 3 Recommended Dimensions of Hospital Lifts (For Speeds Up to 0.5 m/s)

(*Clauses* 4.9.2.3 *and* 4.9.3.1)

All dimensions in millimetres.




| Load | | Car Inside | | Lift Well | | Entrance |
|---|---|---|---|---|---|---|
| Persons | kg | *A* | *B* | *C* | *D* | *E* |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) |
| 15 | 1 020 | 1 000 | 2 400 | 1 800 | 3 000 | 800 |
| 20 | 1 360 | 1 300 | 2 400 | 2 200 | 3 000 | 1 200 |
| 26 | 1 768 | 1 600 | 2 400 | 2 400 | 3 000 | 1 200 |

NOTES

**1** The total headroom has been calculated on the basis of a car height of 2.2 m.

**2** In the case of manually-operated doors, clear entrance will be reduced by the amount of projection of handle on the landing door.

**3** Although 15 persons capacity lift is not standard one, this is included to cover lifts of smaller capacity which can be used in small hospitals.

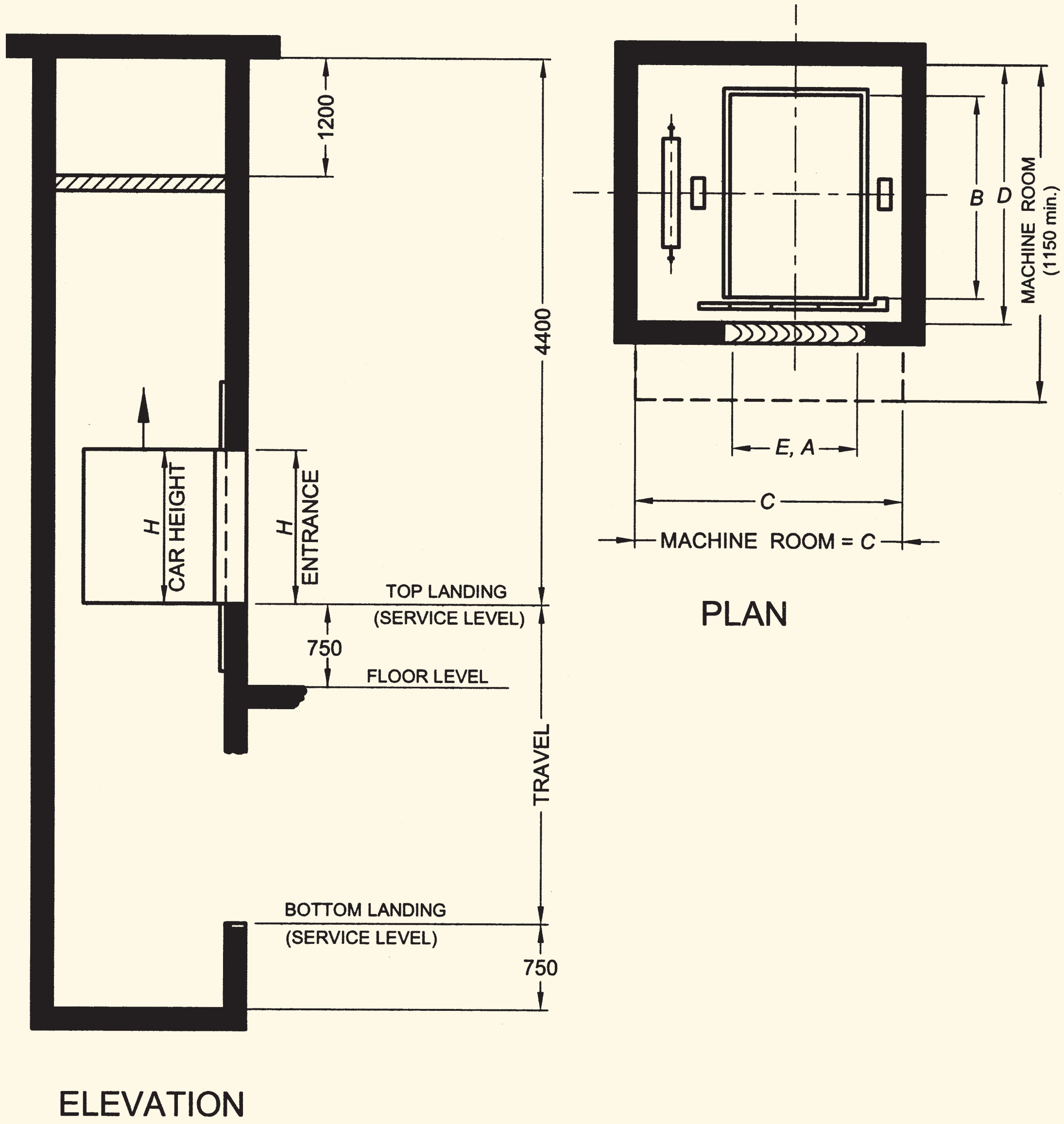
**4** All dimensions given above are recommended dimensions primarily for architects and building planners. Any variations mutually agreed between the manufacturer and the purchaser are permitted. However, variation in car inside dimensions shall be within the maximum area limits in accordance with accepted standards [8-5(4)].

**5** Dimensions of pit depth and overhead may differ in practice as per individual manufacturer's design depending upon load, speed and drive. However, the pit depth and overhead shall be such as to conform to the requirements of bottom clearance and top clearance in accordance with accepted standards [8-5(5)].

**Table 4 Recommended Dimensions of Dumb Waiter**
**(For Speeds Up to 0.5 m/s)**

(*Clauses* 4.9.2.3 *and* 4.9.3.1)

All dimensions in millimetres.




| Load kg | Car Inside | | | Lift Well | | Entrance |
|---|---|---|---|---|---|---|
| | *A* | *B* | *H* | *C* | *D* | *E* |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) |
| 100 | 700 | 700 | 800 | 1 200 | 900 | 700 |
| 150 | 800 | 800 | 900 | 1 300 | 1 000 | 800 |
| 200 | 900 | 900 | 1 000 | 1 400 | 1 100 | 900 |
| 250 | 1 000 | 1 000 | 1 200 | 1 500 | 1 200 | 1 000 |

NOTE — Entrance width '*E*' is based on assumption of provision of vertical biparting doors (no car door is normally provided).

**4.9.3.2** *Travel*

The tables have been established for a maximum travel of 30 m. For travels above 30 m, the lift manufacturer should be consulted.

**4.9.3.3** *Pit*

The pit depth of the lifts will normally accommodate compensating chains. If compensating ropes are required, pit depth shall be increased for all loads and speeds and lift manufacturer should be consulted.

**4.9.3.4** *Minimum floor to floor height*

Minimum floor to floor height for landings on same side for horizontally sliding door is $f + 750$ mm and for vertically biparting doors is $1.5f + 250$ mm, where '$f$' is clear entrance height in mm.

## 4.10 Lift Wells and Lift Well Enclosures

**4.10.1** *Lift Wells*

**4.10.1.1** No equipment except that forming a part of the lift or necessary for its operation and maintenance shall be installed in the lift well. For this purpose, the main supply lines shall be deemed to be a part of the lift and the underground cable, if laid along the lift well shaft, shall be properly clamped to the wall.

**4.10.1.2** Sufficient space shall be provided between the guides for the cars and the side walls of the lift well enclosure to allow safe and easy access to the parts of the safety gears for their maintenance and repairs; safety gears provided shall be in accordance with good practices [8-5(3)].

**4.10.1.3** Lift wells, together with the whole of the contained equipment and apparatus, shall be rendered fire resistant to the greatest possible extent (*see also* **4.4.1**).

**4.10.1.4** Every counterweight shall travel in juxtaposition to its car in the same lift well.

**4.10.1.5** It is undesirable that any room, passage or thoroughfare be permitted under any lift well. If unavoidable spaces for other uses may be permitted under the lift well, with the prior approval of the Lift Inspectorate Authority and the following provisions shall be made:

a) Spring or Oil buffers shall be provided for lift car and counterweight;
b) The pit shall be sufficiently strong to withstand successfully the impact of the lift car with rated load or the impact of the counterweight when either is descending at rated speed or at governor tripping speed;
c) The car and the counterweight shall be provided with a governor-operated safety gear; and
d) The forces required on the structure in the event of car buffering directly without safety gear application to be indicated in the general arrangement drawing.

**4.10.2** *Lift Well Enclosures*

**4.10.2.1** Lift well enclosures shall be provided and shall extend on all sides from floor-to-floor or stair-to-stair, and shall have requisite strength and in proper plumb.

**4.10.2.2** The inner sides of the lift well enclosures facing any car entrance shall, as far as practicable form a smooth, continuous flush surface devoid of projections or recesses.

NOTE — This requirement may be met in existing lift wells by filling any recesses or spaces between projections or alternatively by covering them with suitable sheet material. If it is not possible to render flush any objection or tops of recesses, they should be beveled on the under side to an angle of 60°, from the horizontal by means of metal plates, cement rendering or other fire-resisting materials. Where a car-levelling device is operative with car door opening, such interior surfaces shall always form a smooth flush surface below each landing level for a depth to at least the depth of the car-levelling zone plus the distance through which the lift car may travel of its own momentum when the power is cut-off.

**4.10.2.3** Where an open lift well would increase the fire risk in a building, the lift well enclosure shall be of fire-resisting construction (*see* Part 4 'Fire and Life Safety').

**4.10.2.4** Where wire grill or similar constructions is used, the mesh or opening shall be such that the opening between the bars shall reject the ball of 30 mm in diameter and the lift well enclosure shall be of sufficient strength to resist accidental impact by users of the staircase or adjoining floors or by materials or trucks being moved in the vicinity.

**4.10.2.5** Where the clearance between the inside of an open-type lift well enclosure and any moving or movable part of the lift equipment of apparatus is less than 50 mm, the openings in the enclosure shall be further protected by netting of square mesh of aperture not greater than one centimeter and of wire not smaller than one mm. (The provisions of this clause need not be adhered to for lift wells in factory premises, coming under the purview of *Factories Act*. In such cases provisions of **4.10.2.4** is sufficient.)

**4.10.2.6** There shall be no opening in the lift well enclosure permitting access to the lift car by passing under the counterweight.

**4.10.2.7** In case of a completely enclosed lift well, a notice with the word 'Lift' may be placed outside of each landing door.

**4.10.2.8** *Indicator*

Where lifts are installed in totally enclosed wells, position indicators are recommended to be provided at each floor; however, where position indicators are not provided, at least direction indicators or 'In Use' indicators shall be provided at each landing.

**4.10.2.9** *Landing doors*

Every lift well shall, on each side from which there is access to a car, be fitted with a door. Such a door shall be fitted with efficient electromechanical locking so as to ensure that it cannot be opened except when the lift car is at landing and that the lift car cannot be moved away from the landing until the door is closed and locked. If the door is mechanically locked, means should be provided for opening the same by means of special key during emergency or inspection.

**4.10.2.10** *Automatic devices for cutting off power*

An efficient automatic device shall be provided and maintained in each lift whereby all power shall be cut off from the motor before the car or counterweight lands on buffer.

**4.10.3** *Lift Pits*

**4.10.3.1** A lift pit shall be provided at the bottom of every lift.

**4.10.3.2** Pits shall be of sound construction and maintained in a dry and clean condition. Where necessary, provision shall be made for permanent drainage and where the pit depth exceeds 1.5 m suitable descending arrangement shall be provided to reach the lift pit. And a suitable fixed ladder or other descending facility in the form of permanent brackets grouted in the wall extending to a height of 0.75 m above the lowest floor level shall be provided. A light point with a switch shall also be provided for facility of maintenance and repair work.

**4.11 Machine Rooms and Overhead Structures**

**4.11.1** The lift machine, controller and all other apparatus and equipment of a lift installation, excepting such apparatus and equipment as function in the lift well or other positions, shall be placed in the machine room which shall be adequately lighted and rendered fire-proof and weather-proof.

**4.11.2** The motor generators controlling the speed of multi-voltage or variable voltage machines, secondary sheaves, pulleys, governors, floor selecting equipment may be placed in a place other than the machine room, but such position shall be adequately lighted, ventilated and rendered fire-proof and weather-proof.

**4.11.3** The machine room shall have sufficient floor area as well as permit free access to all parts of the machines and equipment located therein for purposes of inspection, maintenance or repair.

**4.11.4** The room shall be kept closed, except to those who are concerned with the operation and maintenance of the equipment. When the electrical voltage exceeds 220/230 V ac, a danger notice plate shall be displayed permanently on the outside of the door and on or near the machinery. Where standby generator is provided, it is necessary to connect fireman lift to the standby generator. Depending upon the capacity of the standby generator one or more other lifts may also be connected to the supply.

Rescue instruction with required tools and tackles if any shall be made available in the machine room.

All lifts which do not have any automatic transfer facility to an alternate supply, such as generators, shall be equipped with Battery Operated Automatic Rescue Device to bring the lift to the nearest floor and open the door in the event of power failure.

**4.11.5** The machine room shall be equipped with an insulated portable hand lamp provided with flexible cord for examining the machinery.

**4.11.6** If any machine room floor or platform does not extend to the enclosing walls, the open sides shall be provided with hand rails or otherwise suitably guarded.

**4.11.7** The machine room shall not be used as a store room or for any purpose other than housing the lift machinery and its associated apparatus and equipment.

**4.11.8** Machine room floor shall be provided with a trap door, if necessary. The size of the trap door shall be as per manufacturer's recommendation.

**4.11.9** The height of the machine room shall be sufficient to allow any portion of equipment to be accessible and removable for repair and replacement and shall be not less than 2 m clear from the floor or the platform of machine whichever is higher.

**4.11.10** It will be noted that generally lifts have machine rooms immediately over the lift well, and this should be arranged whenever possible without restricting the overhead distance required for normal safety precautions. In case where machine room provision on top is a limitation, either machine room less lift or basement drive or side drive lift can be considered.

**4.11.11** For detailed information regarding nomenclature of floors and storeys, reference may be made to good practice [8-5(6)].

**4.11.12** There should be a proper access planned for approach to the machine room taking into account need for maintenance personnel to access the machine room at all times of day and night and also the need to take heavy equipment. Any fixture such as a ladder provided should be secured permanently to the structure and should have railings to reduce the risk of falling.

**4.11.13** It is desirable that emergency exit may be provided in case of large machine rooms having four or more lifts.

**4.11.14** Where the machine room occupies a prominent position on roof of a building, provision should be made for lightning protection in accordance with good practice [8-5(7)] and Part 8 'Building Services, Section 2 Electrical and Allied Installations'.

**4.11.15** Wherever the machine room is placed, it should be properly ventilated. The ambient temperature of machine room shall be maintained between + 5°C and + 40°C.

**4.11.16** If located in the basement, it should be separated from the lift well by a separation wall.

### 4.12 Essential Features Required

**4.12.1** Power operated car doors on automatically operated lifts shall be so designed that their closing and opening is not likely to injure a person. The power operated car door shall be provided with a sensitive device which shall automatically initiate reopening of the door in the event of a passenger being struck or is about to be struck by the door, while crossing the entrance during closing movement. The effect of the device may be neutralized:

a) during the last 58 mm of travel of door panel in case of side opening doors

b) when panels are within 58 mm of each other in case of center opening doors.

The force needed to prevent the door from closing shall not exceed 150 N and this measurement shall not be made in the first third of the travel of the door.

In order to achieve this it is desirable that all power operated doors have a full length (covering at least 80 percent of the car door height from the bottom) infra red light curtain safety to retract the door in the event of coming across any obstacle during closing of the door.

**4.12.2** Single speed and two speed drives which are poor in levelling accuracy and energy consumption shall not be used for new lifts in view of availability of latest technology energy efficient Variable Voltage Variable Frequency drive systems with improved leveling accuracy.

**4.12.3** For passenger lifts with car call button control in car and with capacities of 16 passenger and above, it is recommended to have an additional car operating panel with call buttons on the opposite side to main panel for ease of access to buttons.

**4.12.4** Passenger lifts shall be provided with power operated doors which are imperforate.

## 5 DIMENSIONAL TOLERANCES

### 5.1 Lift Well Dimensions

Plan dimensions of lift wells given by the lift maker represent the minimum clear plumb sizes. The purchaser's representative, in conjunction with the builder, should ensure that adequate tolerances are included in the building design so that the specified minimum plumb dimensions are obtained in the finished work.

Dimensions in excess of these minimum plumb dimensions for lift well and openings (but not less) can be accommodated by the lift maker up to certain maximum values beyond which changes in design may be necessary involving additional expense or work by the builder. The purchaser's representative should take these factors into account when specifying the lift well structural dimensions on the basis of the constructional tolerance appropriate to the building technique.

### 5.2 Landing Door Openings

It is very important that finished landing openings should be accurate to design size and plumb one above the other for the full travel of the lift. In constructing the structural openings in concrete walls to lift wells it is not possible to achieve a degree of accuracy vertically which will allow doors and frames to be inserted in the opening without some form of masking or packing to overcome inaccuracies. Provisions should therefore be made in design by increasing the nominal height from design finished floor level and width of openings to each jamb and head.

In addition, the alignment of the outer face of the front wall of the lift well is of importance when architrave of fixed dimensions are called for, and in this case the alignment of the outer face from floor to floor should not vary to a greater extent than can be accommodate by the subsequent front wall finish, the architrave being set accurately plumb.

To facilitate accurate alignment of landing sills it is common practice to provide at each landing an independent threshold, the position of which can be adjusted.

### 5.3 Structural Limits for Lift Wells at any Level

If the net plumb well (dimensions *A* and *B* of Fig. 2) and the nominal structural entrance openings (dimensions *C* and *D* of Fig. 2) are defined by plumb lines, the actual wall should not encroach on these dimensions.

Dimension *K* (inside face of wall of Fig. 2) should fall within the following limits:

| | | |
|---|---|---|
| For wells upto 30 m | – | 0-25 mm |
| For wells upto 60 m | – | 0-35 mm |
| For wells upto 90 m | – | 0-50 mm |

When architrave are to be supplied by the lift maker dimension *L* (side of structural opening of Fig. 2) should fall within the limits of 0 and 25 mm and dimension *M* (outer face of the front wall of Fig. 2) should not vary to a greater extent than can be accommodated by the subsequent front wall finish, the architrave being set accurately plumb.

When the entrance linings are supplied by the builder, corresponding provision should be made for the finished openings to be accurately plumb one above the other for the full travel of the lift end to design size.

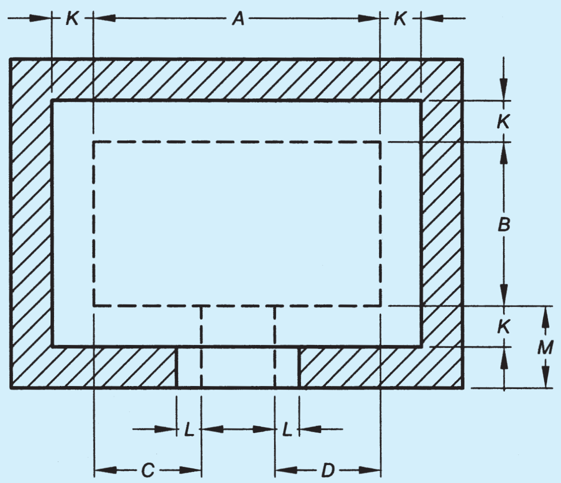



FIG. 2 LIFE WELL TOLERANCE

## 6 PRELIMINARY DESIGN

### 6.1 Number of Lifts and Capacity

**6.1.1** Two basic considerations, namely, the quantity of service required and the quality of service desired, determine the type of lifts to be provided in a particular building. Quantity of service gives the passenger handling capacity of the lifts during the peak periods and the quality of service is measured in terms of waiting time of passengers at various floors. Both these basic factors require proper study into the character of the building, extent and duration of peak periods, frequency of service required, type and method of control, type of landing doors etc. In busy cities patience, coefficient being low satisfaction cannot be obtained if lifts with adequate capacities and speeds are not provided. In view of many variables, no simple formula is possible for determining the most suitable lifts.

NOTE — It is recommended to do Traffic Analysis Study to ensure optimum provision of lifts for the building in consultation with lift manufacturers. In view of the dynamic situation it is recommended that a computerised software is used for Traffic Analysis Study.

**6.1.2** The number of passenger lifts and their capacities, that is load and speed, required for a given building depend on the characteristics of the building. The most important of these are:

a) Number of floors to be served by the lift;
b) Floor to floor distance;
c) Population of each floor to be served; and
d) Maximum peak demand; this demand may be unidirectional, as in up and down peak periods, or a two-way traffic movement.

It should be appreciated that all calculations on the traffic handling capabilities of lifts are dependent on a number of factors which vary according to the design of lift and the assumptions made on passenger actions. It follows, therefore, that the result of such calculations can only be put to limited use of a comparative nature. For instance, they can with advantage be used to compare the capabilities of lifts in a bank with different loads and speeds provided the same set of factors are used for all cases. On the other hand, they cannot be used to compare the capabilities of different makes of lift used for a given bank of lifts.

Different authorities and manufacturers differ widely in their methods of calculation, due to the variations in lift performance, especially with regard to rates of acceleration and deceleration and door operation times which form the components of performance time. Therefore, the calculations made by different organizations will not necessarily agree.

### 6.2 Preliminary Lift Planning

**6.2.1** *General*

Methods of calculating the traffic handling capabilities of lifts were first devised for office buildings. In due course detailed modifications were devised to suit other applications without altering the basic principles. The application to office buildings is still the most frequently used.

Therefore, the following method may be used as general guidance on preliminary lift planning for offices, bearing in mind the differences set out in **6.1.2**.

A lift installation for office building is normally designed to populate the building at a given rate and the three main factors to be considered are:

a) population or the number of people who require lift service.

b) handling capacity of the maximum flow rate required by these people.

c) interval or the quality of service required.

**6.2.2** *Population*

The first point to be ascertained from the eventual occupier is the total building population and whether this is likely to increase in the future.

If a definite population figure is unobtainable an assessment should be made from the net area and probable population density. Average population density can vary from about one person per 4 $m^2$ to one person per 20 $m^2$. It is essential, therefore, that some indication of the probable population density should be obtained from the building owner. If no indication is possible (a speculative development for example) population in the region of 5 $m^2$ per person for general office buildings is usually assumed.

**6.2.3** *Quantity of Service*

The quantity of service is a measure of the passenger handling capacity of a vertical transportation system. It is measured in terms of the total number of passengers handled during each five-minute peak period of the day. A five-minute base period is used as this is the most practical time over which the traffic can be averaged.

The recommended passenger handling capacity for various buildings is as follows:

| *Type of Building* | *Handling Capacity* |
|---|---|
| Office — Diversified tenants | 10 to 15 percent |
| Office — Single tenant | 15 to 25 percent |
| Residential | 7.5 percent |

**6.2.4** *Quality of Service*

The quality of service on the other hand is generally measured by the passenger waiting time at the various floors. The following shall be the guiding factor for determining this aspect.

*Quality of Service or Acceptable Interval*

| | |
|---|---|
| 20 to 25 seconds | Excellent |
| 30 to 35 seconds | Good |
| 34 to 40 seconds | Fair |
| 45 seconds | Poor |
| Over 45 seconds | Unsatisfactory |

NOTE — For residential buildings longer intervals should be permissible.

**6.2.5** *Traffic Peaks*

The maximum traffic flow during the up peak period is usually used as a measure of the vertical transportation requirement in an office building. The employees of all offices are subject to discipline and are required to be at their place in time. Consequently, the incoming traffic flow is extremely high and the arrival time is over a short period.

Sometimes it becomes necessary to reduce the maximum traffic flow by staggering the arrival of the employees so that different groups arrive at different times. This reduces the peak and also the requirement of lifts. However, many organizations may object to staggering and prefer to have all employees arrive at the same time since it is claimed that staggering will affect the proper co-ordination of business.

**6.2.6** *Capacity*

The minimum size of car recommended for a single purpose buildings is one suitable for a duty load of 884 kg. Generally, for large office buildings cars with capacities up to 2 040 kg are recommended according to the requirements.

**6.2.7** *Speed*

It is dependent upon the quantity of service required and the quality of service desired (*see* **6.2.3** and **6.2.4**). Therefore, no set formulae for indicating the speed can be given. However, the following general recommendations are made:

| *No. of Floors* | *Speed* |
|---|---|
| 4 to 5 | 0.5 to 0.75 m/s |
| 6 to 12 | 0.75 to 1.5 m/s |
| 3 to 20 | 1.5 m/s to 2.5 m/s |
| Above 20 | 2.5 m/s and above |

**6.2.8** *Layout*

The shape and size of the passenger lift car bears a distinct relation to its efficiency as a medium of traffic handling. A study of the most suitable proportions for these lifts reveal that the width of the lift well entrance is in reality, the basic element in the determination of the best proportions. In other words, the width of the car is determined by the width of the entrance and the depth of the car is regulated by the loading per square metre permissible under this Code. Centre opening doors are more practicable and efficient entrance units for passenger lifts.

**6.2.9** *Determination of Transportation or Handling Capacity During the Up Peak*

**6.2.9.1** The handling capacity is calculated by the following formula:

$$H = \frac{300 \times Q \times 100}{T \times P}$$

where

- $H$ = Handling capacity as the percentage of the peak population handled during 5 min period,
- $Q$ = Average number of passengers carried in a car,
- $T$ = Waiting interval in seconds, and
- $P$ = Total population to be handled during peak morning period. (It is related to the area served by a particular bank of lifts.)

The value of $Q$ depends on the dimensions of the car. It may be noted that the car is not loaded always to its maximum capacity during each trip and, therefore, for calculating $H$ the value of $Q$ is taken as 80 percent of the maximum carrying capacity of the car.

The waiting interval is calculated by the following formula:

$$T = \frac{RTT}{N}$$

where

- $T$ = Waiting interval in seconds,
- $N$ = Number of lifts, and
- $RTT$ = Round trip time, that is, the average time required by each lift in taking one full load of passengers from ground floor, discharging them in various upper floors and coming back to ground floor for taking fresh passengers for the next trip.

*RTT* is the sum of the time required in the following process:

a) Entry of the passengers on the ground floor,
b) Exit of the passengers on each floor of discharge,
c) Door closing time before each starting operation,
d) Door opening time on each discharging operation,
e) Acceleration periods,
f) Stopping and levelling periods,
g) Periods of full rated speeds between stops going up, and
h) Periods of full rated speeds between stops going down.

It is observed that the handling capacity is inversely proportional to waiting interval which in turn is proportional to *RTT*. Reducing the *RTT* of a lift from 120 to 100 increases its handling capacity by 20 percent.

The round trip time can be decreased not only by increasing the speed of the lift but also by improving the design of the equipment related to opening and closing of the landing and car doors, acceleration, deceleration, levelling and passenger movement. These factors are discussed below:

a) The most important factor in shortening the time consumed between the entry and the exit of the passengers to the lift car is the correct design of the doors and the proper car width. For comfortable entry and exit for passengers it has been found that most suitable door width is 1 000 mm and that of car width is 2 000 mm.
b) The utilization of centre opening doors has been a definite factor in improving passenger transfer time, since when using this type of door the passengers, as a general rule, begin to move before the doors have been completely opened. On the other hand, with a side opening door the passengers tend to wait until the door has completely opened before moving.

The utilization of centre opening doors also favours the door opening and closing time periods. Given the same door speed, the centre opening door is much faster than the side opening type. It is beyond doubt that the centre opening door represents an increase in transportational capacity in the operation of a lift.

**6.2.9.2** An example illustrating the use of the above consideration is given below:

| | |
|---|---|
| Gross area per floor | 1 100 $m^2$ |
| Net usable area per floor | 950 $m^2$ |
| No. of landings including ground | 15 |
| Assuming population density | 9.5 $m^2$ per person |
| Probable population in | |

$$P = \frac{14 \times 950}{9.5}$$

| | |
|---|---|
| Upper floors | 1 400 persons |
| Taking 20 passengers lift with 2.5 m/s the calculated *RTT* | 165 s |

$$Q = 20 \times 0.8 = 16$$

a) Taking No. of lifts, $N = 4$

$$T = \frac{RTT}{N} = \frac{165}{4} = 41\ \text{s}$$

$$H = \frac{300 \times Q \times 100}{T \times P} = \frac{300 \times 16 \times 100}{41 \times 1\,400}$$

$$= 8.3 \text{ percent}$$

b) Taking No. of lifts, $N = 6$

$$T = \frac{165}{6} = 27.6 \text{ s}$$

$$H = \frac{300 \times Q \times 100}{T \times P} = \frac{300 \times 16 \times 100}{27.6 \times 1\,400}$$

$$= 12 \text{ percent}$$

**6.3 Quiet Operation of Lifts**

Every precaution should be taken with passenger lifts to ensure quiet operation of the lift doors and machinery. The insulating of the lift machine and any motor generator from the floor by rubber cushions or by a precast concrete slab with rubber cushions, prevents transmission of most of the noise. In this connection, *see also* good practice [8-5(8)] and Part 8 'Building Services, Section 4 Acoustics, Sound Insulation and Noise Control' for some useful recommendations.

**6.4 Positioning of Lifts**

A thorough investigation should be made for assessing the most suitable position for lift(s) while planning the building. It should take into account future expansions, if any. Though each building has to be considered individually for purposes of location of lifts, factors influencing the locations of passenger and goods lifts are given in **6.4.2** to **6.4.4.**

The location of lifts may also conform to the travel distance requirements specified in Part 4 'Fire and Life Safety'.

**6.4.1** *Arrangement of Lifts*

The lifts should be easily accessible from all entrances to the building. For maximum efficiency, they should be grouped near the centre of the building. It is preferably not to have all the lifts out in straight line and, if possible, not more than three lifts should be arranged in this manner. It has to be kept in mind that the corridor should be wide enough to allow sufficient space for waiting passengers as well as for through passengers.

**6.4.1.1** In some cases when there are more than three lifts, the alcove arrangement is recommended. With this arrangement, the lift alcove lead off the main corridor so that there is no interference by traffic to other groups or to other parts of the ground floor. This arrangement permits the narrowest possible corridors and saves space on the upper floors. Walking distance to the individual lift is reduced and passenger standing in the center of the group can readily see all the lift doors and landing indicators. The ideal arrangement of the lifts depends upon the particular layout of the respective building and should be determined in every individual case. Some typical recommended arrangements are given in Fig. 1.

**6.4.2** *Passenger Lifts*

**6.4.2.1** *Low and medium class flats*

Where a lift is arranged to serve two, three or four flats per floor, the lift may be placed adjoining a staircase, with the lift entrances serving direct on to the landings. Where the lift is to serve a considerable number of flats having access to balconies or corridors, it may be conveniently placed in a well ventilated tower adjoining the building.

**6.4.2.2** *Office buildings, hotels and high class flats*

In general the arrangement as recommended in **6.4.1** is to be followed. However, in case this is not possible, it is desirable to have at least a battery of two lifts at two or more convenient points of a building. If this is not possible, it is advisable to have at least two lifts side by side at the main entrance and one lift each at different sections of the building for inter-communication. When two lifts are installed side by side, the machine room shall be suitably planned with sufficient space for housing the machine equipment. The positioning of lifts side by side gives the following advantages:

a) all machines and switch gear may be housed in one machine room,
b) the lifts can be inter-connected more conveniently from an installation point of view, and
c) greater convenience in service owing to the landing openings and each floor being adjacent.

**6.4.2.3** *Shops and departmental stores*

Lifts in shops and stores should be situated so as to secure convenient and easy access at each floor.

**6.4.2.4** For buildings with more than 12 floors, it is recommended to have provision of 1 stretcher/service lift in addition to the passenger lifts.

**6.4.2.5** For buildings with more than 12 floors, where passenger and service lifts are provided in one lobby it is recommended to have group control for all the lifts.

**6.4.3** *Goods Lifts*

The location of lifts in factories, warehouses and similar buildings should be planned to suit the progressive movement of goods throughout the buildings, having regard to the nature of position of the loading platforms, railway sidings, etc. The placing of a lift in a fume or dust laden atmosphere or where it may be exposed to extreme temperatures, should be avoided wherever possible. Where it is impossible to avoid installing a lift in an adverse atmosphere, the electrical equipment should be of suitable design and construction to meet the conditions involved.

**6.4.3.1** Normally goods lifts have lower speeds than passenger lifts for the same travel because traffic conditions are less demanding, and more time is required for loading and unloading.

**6.4.3.2** As loads for goods lifts increase in size and weight, so the operation of loading and unloading becomes more difficult. Therefore, it is usual to require greater accuracy of levelling as the capacity of the goods lift increases.

**6.4.3.3** A large capacity goods lift at high speed is often a very uneconomical preposition. The inherent high cost is enhanced due to the very small demand for such equipment, much of which is custom made. The high capital cost of the lift, building work and electrical supply equipment usually shows a much smaller return as an investment than more normal sizes of lifts.

**6.4.4** *Hospital Bed Lifts*

Hospital bed lifts should be situated conveniently near the ward and operating theatre entrances. There shall be sufficient space near the landing door for easy movement of stretcher.

It is convenient to place the passenger lifts in a hospital, near the staircases.

**6.5 Structural Considerations**

**6.5.1** Lift well enclosures, lift pits, machine rooms and machine supports besides conforming to the essential requirements given in **4**, should form part of the building construction and comply with the lift manufacturer's drawings.

**6.5.2** *Machine Room*

Floors shall be designed to carry a load of not less than 350 kg/m$^2$ over the whole area and also any load which may be imposed there on by the equipment used in the machine room or by any reaction from any such equipment both during periods of normal operation and repair.

**6.5.3** The side wall of the lift well may be made of reinforced cement concrete at least 150 mm thick so as to provide satisfactory anchoring arrangement for fixing. Reference shall also be made to Part 6 'Structural Design, Section 5 Plain, Reinforced and Prestressed Concrete, 5A Plain and Reinforced Concrete'.

**6.5.4** The total load on overhead beams shall be assumed as equal to all equipment resting on the beams plus twice the maximum load suspended from the beams.

**6.5.5** The factor of safety for all overhead beams and supports based on ultimate strength of the material and load in accordance with **6.5.4** shall be not less than the following:

| | |
|---|---|
| For Steel | 5 |
| For Reinforced Concrete | 7 |

The deflection of the overhead beams under the maximum static load calculated in accordance with above shall not exceed 1/1 500 of the span.

**6.6 Access to Machine Room and Lift Pits**

**6.6.1** Access to machine room above a lift well may be either from the roof or by an internal staircase with a proper arrangement for fixing.

**6.6.2** Access between a secondary floor and a machine room may be by ladder. Where a machine room entrance is less than 1.5 m above or below the adjacent floor or roof surfaces, a substantial permanently attached ladder may be used. Ladders shall be fixed at least 150 mm clear of any wall, beam or obstruction and shall extend at least to the landing level. Above the landing level and for a height of at least 1.15 m, either the ladder stringers shall be extended or suitable hand grips shall be provided.

**6.6.3** Where the machine room entrance is 1.5 m or more above or below the adjacent floor or roof surface, access shall be provided by means of stairs in accordance with the requirements given in **6.6.3.1** to **6.6.3.6**.

**6.6.3.1** The angle of inclination of the stair shall not exceed 50° from the horizontal and the clear width of the stair shall be not less than 600 mm.

**6.6.3.2** The tread shall have a non-slip surface which shall be not less than 150 mm wide for open stair construction and not less than 20 cm wide for closed stair construction.

**6.6.3.3** The rise of the stair shall not exceed 250 mm.

**6.6.3.4** A hand rail shall be provided on the outer stringer of all stairways fixed at a convenient height, but not less than 500 mm high measured vertically from the nosings, and not less than 1 m high on landings and platforms. Such hand rail shall have atleast 50 mm clearance between nearest permanent object at the corresponding side of the stair.

**6.6.3.5** Headroom clearance of not less than 2 m measured from the nosings of the stairway, shall be provided on every stairway.

**6.6.3.6** Heights of stairs over 5 m in length shall be provided with intermediate landings.

NOTE — Where compliance with any of the requirements specified in **6.61** to **6.6.3** is impracticable, applications for variation shall be made to the Authority, who may, vary such requirements.

**6.6.4** Access to a machine room in a basement may be provided from a corridor.

**6.6.5** Access to a machine room via the lift well shall be prohibited.

**6.6.6** The lift pit should be capable of being examined by a separate access. In the case of a battery of two lifts, it is possible to examine the lift pit through the adjoining one.

**6.7 Fire Protection**

To prevent fire from spreading by means of the lift well, lift well enclosures shall conform to the requirements given in Part 4 'Fire and Life Safety'. The machine room should be constructed of a suitable grade of fire-resisting material and precautions should be taken to minimize spread of fire from the machine room into the lift well (*see also* **7.3.14**).

**6.8 Requirements for Fireman's Lift**

**6.8.1** For buildings having height of 15 m or more atleast one lift shall meet the requirements of fireman's lift as given in **6.8.2**.

**6.8.2** The fireman's lift shall have the following minimum requirements:

a) Lift car shall have floor area of not less than 1.44 square meters. It shall also have a loading capacity of not less than 544 kg (8 persons).
b) Lift landing doors shall have a minimum of fire resistance of one hour.
c) Doors shall be of automatic operation for car and landing.

**6.8.3** Fireman's lifts in a building having more than 15 m or more height, shall work at or above the speed of 1.0 m/s so as to reach the top floor from ground level within one minute.

**6.8.4** *Operation Requirements of Fireman's Lift*

The lift shall be provided with the following as a minimum:

a) A two position switch at evacuation floor (normally main entrance floor) (ON/OFF), and
b) Buzzer and 'Fireman's lift' — light in car

**6.8.4.1** *Sequence of operation*:

a) *Return to evacuation floor (Phase 1):*
   1) Shall start when the switch at the evacuation floor is turned to the "ON" position or the signal from smoke detector (if provided by the Building Management System) is on. All lift(s) controlled by this switch shall cancel all existing car calls and separate from landing calls and no landing or car calls shall be registered. The buzzer and "fireman's lift" light shall be turned on. All heat and smoke sensitive door re-opening devices shall be rendered inoperative.
   2) If the lift is travelling towards the evacuation floor, it shall continue driving to that floor.
   3) If the lift is travelling away from the evacuation floor, it shall reverse its direction at the nearest possible floor without opening its doors and return non-stop to the evacuation floor.
   4) If the lift is standing at a floor other than the evacuation floor, it shall close the doors and start travelling non-stop to the evacuation floor.
   5) When at the evacuation floor the lift shall park with doors open.
   6) The buzzer is turned off after this return drive.

b) *Fireman's service (Phase 2):*

   The phase 2 operation of the lift shall be as defined below.

   1) The phase 2 is started after phase 1, if the switch is "ON".
   2) The lift does not respond to landing calls but registers car calls. All heat and smoke sensitive door reopening devices are rendered inoperative.
   3) When the car call button is pressed the doors start closing. If the button is released before the doors are fully closed, they re-open. The car call is registered only when the doors are fully closed.
   4) After registering a car call the lift starts driving to the call. If more than one car call is registered, only the nearest call is answered and the remaining calls will be cancelled at the first stop.
   5) At the floor the doors are opened by pushing the door open button. If the button is released before the doors are fully open, they re-close.
   6) The lift returns to normal service when it stands at the evacuation floor with doors open and the switch is "OFF".

**6.9 Supply Cables and Switches**

Each lift should be provided with a main switch or circuit breaker of a capacity determined by the lift manufacturer and the incoming supply cable should terminate in this switch. For a single lift, this switch should be fixed adjacent to the machine room entrance inside the machine room. In a machine room common to more than one lift, each main switch should be conveniently situated with respect to the lift it controls. Switches and fuses (which may form part of a distribution switch-board) should be provided for isolating the supply cables to the machine room.

**6.10** The detailed design considerations for different types and selection of the lifts shall be done in accordance with good practice [8-5(5)].

## 7 POWER AND CONTROL SYSTEMS

### 7.1 Features Associated with Power Systems

**7.1.1** *Industrial Switchgear*

Switchgear for controlling lift power systems is characterized by its high duty cycle and its high rupturing capacity. Switchgear must be robust enough and shall be so designed as to withstand the high duty cycle and high rupturing capacity introduced during the operation of the lifts.

**7.1.2** *Levelling Accuracy*

The levelling tolerances in accordance with good practice [8-5(4)] are those which can be reasonably expected between no load and full load in either direction.

Where greater levelling accuracy is required, careful examination should be made to see whether such increased precision is justified or practical. Advice should also be obtained, as additional apparatus and cost may be involved, and in some cases the requirement may not be practicable.

**7.1.3** *Corrective Levelling*

This should only be used when it is impossible otherwise to achieve the required levelling tolerances or on long travel lifts to maintain the required levelling tolerances during loading and unloading.

**7.1.4** *Levelling with Variable Voltage*

A variable voltage system is one using continuous regulation which minimizes speed differences due to load variation. Therefore, the actual levelling speed is of less importance than the general refinement of its regulation control. In fact no levelling speed as such may be identifiable.

**7.1.5** *Overload Tests*

A lift is designed to operate and transport the contract load at the required duty cycle, and should not by intention or habitually be used to carry overloads. During test as a safeguard to cover variable supply and temperature conditions a lift is checked for the car to complete one round trip with contract load plus 10 percent at nominal supply voltage and nominal ambient temperature. There is also a static test with contract load plus 25 percent to check that the brake will sustain the car.

It is unnecessary to specify and additional overload test or capacity and in fact it is detrimental to the normal running efficiency and safety of the lift to do so.

**7.1.6** *Occasional Extra Load*

It is not good practice to request that a lift should be designed to carry an occasional extra load. It is tantamount to specifying an excessive overload test which is detrimental to the normal running efficiency and safety of the lift.

### 7.2 Description of Operation Systems

**7.2.1** *Methods of Control Systems*

The methods of control systems are as follows:

a) Attendant and dual control (*see* **7.2.2**), and
b) Automatic push button operation (*see* **7.2.2**).

**7.2.1.1** *Types of control systems*

a) Collective control (*see* **7.2.3**),
b) Single push button collective control (*see* **7.2.4**),
c) Down collective control (*see* **7.2.5**),
d) Directional collective control for one car (*see* **7.2.6**),
e) Directional collective control for two or three cars (*see* **7.2.7**), and
f) Group supervisory control (*see* **7.2.8**).

Features of control systems are described in **7.3**.

**7.2.2** *Automatic Push Button Operation*

Automatic control is a method of operation by which a momentary pressure on a push button sets the car in motion and causes it to stop automatically at any required lift landing. This is the simplest control system and it is sometimes referred to as push button control.

A car answers a landing or car call whichever is actuated first by momentary pressure provided the lift is not in use. Momentary pressure of a car push button will send the car to the designated floor. The car always responds to a car push button in preference to a landing push button.

With this type of control, a RED landing signal light or direction arrow indicates that the car is in use that is the lift is travelling.

This type of control is recommended for the following applications.

a) A single passenger lift serving up to 4 floors.

b) Goods lifts serving any number of floors where it is usually the most suitable form of control.

For special purposes, the following two systems may be considered:

a) Despatch from landings as an additional feature for a goods lift with manually operated doors. The call is registered by pressing the car push button and when the doors are closed the car will travel to the designated floor.

b) Automatic with attendant control as an additional feature on goods lifts with a key operated switch in the car to transfer the control from normal automatic to attendant operation. There is also a visual call indicator with buzzer in the car to indicate to the attendant the landing floors at which push buttons have been pressed when the car is under attendant control.

**7.2.3** *Collective Control*

Collective control is a generic term for those methods of automatic operation by which calls made by pressing push buttons in the car and at lift landings are registered and answered by the car stopping in floor sequence at each lift landing for which calls have been registered irrespective of the order in which the calls have been made, and until all calls have had attention.

Collective control of any form is usually not suitable for goods lifts except where loading is not expected to fill the car and additional loads can be taken at other stops.

**7.2.4** *Single Push Button Collective Control*

Single push button collective control has a single push button at each landing. It is not recommended, as the direction in which it is desired to travel cannot be registered by the intending passenger.

**7.2.5** *Down Collective Control*

Down collective is a control system where landing calls are registered from a single push button, irrespective of the car being in motion or the landing door being open and calls are stored until answered. Any number of car calls can be registered and the car will stop in sequence in the down direction at each of the designated floors. The car will travel in the up direction to the highest call registered stopping only in response to car calls. It will then travel downwards answering calls in floor sequence. If only one call has been registered the car travels to the floor of call.

This system is suitable where there is traffic between the ground and upper floors only and no interfloor traffic. Two or three car banks have interconnected control.

With this type of control the following signals are included:

a) A landing signal light indicates that the call has been registered and will be answered.

b) Illuminated car position indicator above car entrance.

**7.2.6** *Directional Collective Control for One Car*

Directional collective control for one car is a control system having UP and DOWN push buttons at intermediate landings whereby the call is registered for the intended direction of travel. Calls from the car or landing push buttons are registered and stored until answered. The car will answer calls in floor sequence in one direction of travel. Calls for the opposite direction of travel are answered when the direction of travel is reversed.

This system is suitable for single lifts serving 4 or more floors with interfloor traffic, such as small office blocks, hotels and blocks of flats.

With this type of control the following signals are included:

a) A landing signal light for each landing push button indicates that the call has been registered and will be answered.

b) Illuminated car position indicator above the entrance in the car.

c) Arrow shaped signal lights in the back of the car or on the landing to indicate to the entering person in which direction the car is going to depart.

**7.2.7** *Directional Collective Control for Two or Three Cars*

Directional collective control for two or three cars is a system covering a control in which the two or three cars in a bank are interconnected. One push button unit with UP and DOWN push buttons or floor buttons (in case of car control from floor) are required at each landing and the call system is common to all lifts. If for architectural balance, in the case of a three car bank, extra push button units are required, these should be specified. Each landing call is automatically allocated to the best placed car. The control is designed so that cars are effectively spaced and thus give even service. When a car reaches the highest floor to which there is a call its direction of travel is automatically reversed when it next starts. One or more cars will return to the parking floor.

Automatically bypassing of landing calls when a car is fully loaded is an essential feature for three-car banks. It is also necessary for two-car banks in offices. Other cars will continue to provide service to all floors.

When three-car banks serve 7 or 8 floors and over, some form of automatic supervisory control (*see* **7.2.8**) is generally necessary in the interest of efficiency.

With this type of control the following signals are included:

a) A landing signal light for each landing push button to indicate that the call has been registered and will be answered.
b) Illuminated car position indicator above the entrance in the car.
c) Arrow shaped signal lights in conjunction with an audible single stroke gong or an indication on the landing call push button station above each landing entrance to indicate to the waiting person(s) which car is going to stop and in which direction it will continue its course.

**7.2.8** *Group Supervisory Control*

A bank or group of intensive traffic passengers lifts requires a supervisory system to co-ordinate the operation of individual lifts which are all on collective control and are interconnected.

The very nature of intensive service calls for a sophisticated automatic supervisory control system so as to match the speed capacity of these lifts.

The supervisory system regulates the despatching of individual cars and provides service to all floors as different traffic conditions arise minimizing such unproductive factors as idle cars, uneven service and excessive waiting time. The system will respond automatically to traffic conditions such as UP and DOWN peaks, balanced or light traffic and provides for other specialized features.

If desired, a master station can be provided in the lift lobby which gives by indicators, visual information regarding the pattern under which the system is operating. Where the system is based on a definite programme, control means are provided for altering the type of traffic programme. There are other facilities, such as the removal of any lift from service.

**7.3 Features of Operation Systems**

**7.3.1** *Car Preference*

Sometimes it is necessary to give a special personal service or a house service. When this service is required and for whatever purpose, it should be specified as 'car preference' is by a key operated switch in the car. The operation is then from the car only and the doors remain open until a car call is registered for a floor destination. All landing calls are bypassed and car position indicators on the landing for this lift are not illuminated. The removal of the key when the special operation is completed restores the control to normal service.

**7.3.2** *Landing Call Automatic Bypass*

For collective operation, automatic bypassing of landing calls can be provided. This device will bypass landing calls when a car is fully loaded but the calls are not cancelled.

**7.3.3** *Motor Generator Shut Down*

Lifts controlled by variable voltage system automatically shutdown when subject to an over-riding control which puts them out of service under certain conditions; for example, no demand for lift service. They are automatically put back into service as required.

**7.3.4** *Basement Service*

For lifts with collective control when service is required below the main parking floor, which is usually the ground floor, to a basement and/or a sub-basement, the lift maker should be informed of the type of service required, as special technical considerations are then usually necessary.

**7.3.5** *Hospital Service*

Lifts for carrying beds and stretchers require a car preference switch so than an attendant can have complete control of the car when required. This requirement should be specified as 'car preference' and it will function as described in **7.3.1**. Otherwise such lifts can have the same control systems as for normal passenger lifts, the choice depending on the number of floors served, the service required and the number of lifts.

**7.3.6** *Manually Operated Doors (Without Closers)*

A 'door open' alarm should be provided to draw attention to a car or landing door which has been left open.

**7.3.7** *Automatically Power Closed Doors*

For passenger operation when the car arrives at a landing the doors will automatically open and then close after lapse of a time interval. This time interval can be overruled by the pressure of a push button in the car to give instant door closing.

An 'open door' push button is provided in the car to reverse closing motion of the doors or hold them open.

**7.3.8** *Controlled Power Closed Doors*

When there are conditions that particularly affect the safety of passengers or damage to vehicles or trucks, the closing of the doors should only be made by the continuous pressure of push buttons in the car or on landings.

A 'door open' alarm should be provided to draw attention to a car or landing door which has been left open. This means of operation is required for some forms of goods lifts.

**7.3.9** *Safe Operation of Doors*

The safety of passengers passing through lift entrances is fully covered by the provision of good practice [8-5(9)]. No modification of these provisions should be specified.

**7.3.10** *Director Service*

There are many forms of giving special service for individuals, but they should always be avoided. They range from key operated switches at preferred landings to the complete segregation of one out of a bank of lifts. It is obvious that any preferential treatment of this nature can seriously jeopardize the efficiency of the service as a whole. When a bank of say three lifts is installed to meet the anticipated traffic requirements and then, when the building is occupies, one lift is detached permanently for directors' service, the traffic handling can be reduced by a half rather than a third.

When preferential service is imperative, then the car preference feature should be available (*see* **7.3.1**).

**7.3.11** *Indication of Car Arrival*

As all lift cars are illuminated when available (in service). It is recommended that this illumination be used to signal the arrival of a car at a landing in preference to special signals such as LIFT HERE signs since signal lamps can fail when the lift is still operating satisfactorily.

The following is the practice adopted for vision panels in doors:

a) For lifts with manually operated car and landing doors, vision panels are provided in all doors;
b) For lifts with power operated car doors and manually operated landing doors, vision panels are provided in the landing doors only;
c) For lifts with automatically opened car and landing doors, no vision panels are required; and
d) When vision panels are provided they should comply with the requirements of good practice [8-5(4)].

**7.3.12** *Service Switches*

When switches are provided to take cars out of service, that is because the remaining cars in the group can cater for the required passenger traffic, it is essential that such switches should not stop the fireman's control from being operative in the event of the lift being designated as a fireman's lift. Service switches should not be confused with maintenance switches which are only used when it is dangerous to attempt to operate the lift because maintenance work is actually in progress. A control station fitted on top of the car is regarded as a maintenance switch.

**7.3.13** *Fire Switch*

When required by the fire authority a fire switch has to be provided, the function of which is to enable the fire authority to take over the complete control of one or more lifts in an installation {*see* good practice [8-5(4)]}.

**7.3.14** *Push Buttons and Signals*

It is most important that the purpose of every push button and signal should be clearly understood by all passengers.

**7.3.15** In public places where blind persons are expected to use the lifts it is recommended to provide Brailey buttons.

**7.4 Electrical Installation Requirements**

**7.4.1** *General*

The good practices [8-5(4)] states the requirements for main switches and wiring with reference to relevant regulations. The lift maker should specify, on a schedule, particulars of full load current, starting current, maximum permissible voltage drop, size of switches and other details to suit requirements. For multiple lifts a diversity factor may be used to determine the cable size and should be stated by the lift manufacturer.

It is important that the switches at the intake and in the machine room which are provided by the electrical contractor are the correct size, so that correctly rated HRC fuses can be fitted. No form of 'NO VOLT' trip relay should be included anywhere in the power supply of the lift.

a) *Power supply mains* — The lift sub-circuit from the intake room should be separate from other building service.

   Each lift should be capable of being isolated from the mains supply. This means of isolation should be lockable.
b) For banks of interconnected lifts, a separate sub-circuit is required for the common supervisory system, in order that any car may be shut down without isolating the supervisory control of the remainder.

c) *Lighting* — Machine rooms and all other rooms containing lift equipment should be provided with adequate illumination and with a switch fixed adjacent to the entrance. At least one socket outlet, suitable for lamps or tools, should be provided in each room.

The supply to the car light should be from a separate circuit, and controlled by a switch in the machine room. For multiple lifts with a common machine room a separate supply should be provided for each car. The car lighting supply should be independent of the power supply mains. Plug should be provided with a light, the switch for which should be in the lift well, and accessible from the lower terminal floor entrance.

When the alarm system is connected to a transformer or trickle charger, the supply should be taken from the machine room lighting.

**7.4.2** *Electric Wiring and Apparatus*

**7.4.2.1** All electrical supply lines and apparatus in connection with the lift installation shall be so constructed and shall be so installed, protected, worked and maintained that there may be no danger to persons therefrom.

**7.4.2.2** All metal casings or metallic coverings containing or protecting any electric supply lines of apparatus shall be efficiently earthed.

**7.4.2.3** No bare conductor shall be used in any lift car as may cause danger to persons.

**7.4.2.4** All cables and other wiring in connection with the lift installation shall be of suitable grade for the voltage at which these are intended to be worked and if metallic covering is used it shall be efficiently earthed.

**7.4.2.5** Suitable caution notice shall be affixed near every motor or other apparatus in which energy is used at a pressure exceeding 250 V.

**7.4.2.6** Circuits which supply current to the motor shall not be included in any twin or multicore trailing cable used in connection with the control and safety devices.

**7.4.2.7** A single trailing cable for lighting control and signal circuit shall be permitted, if all the conductors of this trailing cable are insulated for maximum voltage running through any one conductor of this cable.

**7.4.3** *Emergency Signal or Telephone*

It is recommendatory that lift car be provided either with an emergency signal that is operative from the lift car and audible outside the lift well or with a telephone.

When an alarm bell is to be provided each car is fitted with an alarm push which is wired to a terminal box in the lift well at the ground floor by the lift maker. This alarm bell, to be supplied by the lift maker (with indicator for more than one lift) should be fixed in an agreed position and wired to the lift well. The supply may be from a battery (or transformer) fixed in the machine room or, when available, from the building fire alarm supply.

When a telephone is to be provided in the lift car the lift maker should fit the cabinet in the car and provided wiring from the car to a terminal box adjacent to the lift well.

The type of telephone should be stated in the enquiry.

**7.4.4** *Earthing*

**7.4.4.1** The terminal for the earthing of the frame of the motor, the winding machine, the frame of the control panel, the cases and covers of the tappet switch and similar electric appliances which normally carry the main current shall be at least equivalent to a 5 mm diameter bolt, stud or screw. The cross-sectional area of copper earthing conductor shall be not smaller than half that of the largest current-carrying conductor subject to an upper limit of 65 $mm^2$ {*see also* good practice [8-5(10)]}.

**7.4.4.2** The terminal for the earthing of the metallic cases and covers of door interlocks, door contacts, call and control buttons, stop buttons, car switches, limit switches, junction boxes and similar electrical fittings which normally carry only the control current (such terminal being one specially provided for this purpose), and the earth conductor should be appropriately sized in accordance with good practice [8-5(10)].

The size of earthing conductor shall be in accordance with Part 8 'Building Services, Section 2 Electrical and Allied Installations'.

**7.4.4.3** The earthing conductor shall be secured to earthing terminal in accordance with the recommendations made in good practice [8-5(10)] and also in conformity with the latest provisions of *Electricity Act*, 2003 and Rules framed thereunder from time to time.

**7.4.4.4** The exposed metal parts of electrical apparatus installed on a lift car shall be sufficiently bonded and eartherd.

**7.4.4.5** Where screwed conduit screws into electric fittings carrying control current making the case and cover electrically continuous with the conduit, the earthing of the conduit may be considered to earth the fitting. Where flexible conduit is used for leading into a fitting, the fitting and such length of flexible conduit shall be effectively earthed.

**7.4.4.6** One side of the secondary winding of bell transformers and their cases shall be earthed.

**7.4.4.7** Where there are more than one lift in a building, there should be a separate earth pit for the lifts.

**7.5 Building Management Systems — Interface for Lifts**

**7.5.1** Where more than three lifts are provided in a building and especially when these are provided at different locations in the building a form of central monitoring may be provided. Such central monitoring may be through a Building Management Systems, if provided in the building or through a display panel.

**7.5.2** The following signals should be given to the building management interface from each lift.

a) Alarm button in car,
b) Door Zone or floor level information,
c) Lift moving information,
d) Power on information, and
e) Lift position information.

**7.5.3** Each of these signals shall be provided through a potential free contact located in the lift machine room. The contacts shall be rated for 230 V ac/1A or 24 V dc/1A. A pair of wires should be used for each potential contact.

**7.5.4** The wiring between lift machine room to Building Management Systems shall be planned and carried out by the builder along with other wiring in the building.

**7.5.5** The building management system should ensure that any position information is read only when the lift is not moving (lift moving information) or is capable of reading several times to detect a stable state.

In addition to the signals above the following signals may be added if required for the benefit of monitoring the lift performance.

a) A summary fault output to indicate a lift in fault condition, which prevents the lift from providing service. This summary fault condition shall include the most common faults such as safety circuit open.
b) Service or inspection mode.
c) Attendant mode.
d) Fire mode.
e) Doors opening.
f) Doors closing.
g) Lift moving up.
(In combination with lift moving and lift moving up information, lift moving down information can be sensed by the Building Management Systems).
h) Door Reopen Request (Summary of Door Open, Light Curtain, Photocell, Safety Edge Signals).

**7.5.6** Where it is desired that it should be possible to control the lift from Building Management Systems, the following control signals can be provided.

a) Normal to service/inspection mode change over
b) Fault Accept/Rest Input
(Using this input, the lift controller may be allowed to clear an existing fault if this is other wise safe. It will be decided by the Lift manufacturer as to what faults can be cleared)
c) Car call to top most floor and bottom most floor of each lift.

Where such control inputs are provided, it should be with a pass word and login feature that allows one to determine who has used these inputs and at what time. Always such inputs should be through authorized person only. The Building Management Systems should make all changeovers effective only when lift is not moving.

**7.5.7** Control inputs from Building Management Systems should be through a potential free contact capable of carrying 24 V dc/1A or 230 V ac/1A. The wiring should be terminated in each lift machine room.

## 8 CONDITIONS FOR OPTIMUM PRACTICE

### 8.1 Lift Entrance Operation

**8.1.1** *General*

Every lift journey involves two horizontal movements, in and out of the car, to one vertical movement. The type of door, and the operation of the doors, play a main part in the service given, and should receive careful consideration.

**8.1.2** *Goods Traffic*

Most types of goods traffic require relatively longer loading and unloading times and manual doors are frequently used for economy and simplicity.

Power operation can be applied, especially for large entrances, to give automatic opening: the doors then always open fully, reducing the risk of damage. For many types of goods traffic, it is preferable for closing though powered, to be controlled by continuous pressure button, rather than being automatically initiated {*see* good practice [8-5(4)]}.

For heavy duty lifts, a power operated vertically sliding door preferred, this can be made extremely robust, and is capable of extension to very large entrances.

### 8.2 Painting at Works and on Site

Lift equipment with normally receive a protective coat of paint at works before despatch to site. Further painting of lift equipment may be necessary and is normally in the form of a finishing coat and can take place on site. Alternatively, the further painting of the equipment may be carried out at works as a finishing coat with normal touching up after site erection as may be necessary.

Any additional painting, due to site conditions during erection and/or final operating conditions in the premises, is subject to negotiation between the lift maker and the purchaser.

Decorative finishes are a subject for separate negotiation.

### 8.3 Special Environments

Standard equipment is suitable for use inside normal residential, commercial and industrial buildings but when unusual environments are likely to be encountered, the advice of the lift maker should be sought at the earliest possible stage to enable the most economic satisfactory solution to be found. Special mechanical protection and or electrical enclosures may be necessary as well as compliance with statutory or other regulations and with the purchaser's particular requirements, which should be fully considered at the time of enquiry.

Examples of situations which necessitate special consideration are:

a) Exposure to weather, for example, car parks.
b) Low temperatures, for example, cold stores.
c) High temperatures, for example, boiler plant.
d) Hosing-down for example, for hygiene or decontamination.
e) Corrosive atmosphere, for example, chemical works.
f) Dusty atmospheres, for example, gas plant.
g) Explosive and inflammable atmosphere, for example gas plants, and petroleum and polyester industries.

### 8.4 Ventilation of Machine Rooms

Machine rooms shall be ventilated. They shall be such that the motors and equipment as well as electric cables etc, are protected as far as possible from dust, harmful dusts and humidity. The ambient temperature in the machine room shall be maintained between 5°C and 40°C.

### 8.5 Lighting and Treatment of Walls, Floors, Etc

**8.5.1** All machine rooms should be considered as plant space, and conditions provided to permit reliable operation of electrical switchgear and rotating machinery, and be conducive to good maintenance.

Lighting should be provided to give at least 200 lux around the controller and machine. The machine room walls, ceiling and floor should be faced in dust-resisting materials, tiles, etc, or painted as a minimum to stop dust circulation which otherwise could damage rotating machinery and cause failure of switchgear. Machine rooms should also be weatherproof and if ventilation louvers are provided they should be designed and sited to prevent snow being driven through or to the apparatus.

**8.5.2** Lift wells should be constructed to be weatherproof and of a dust free surface material or should be painted to minimize dust circulation on to moving apparatus and from being pumped by the car movement into machine rooms or on to landings.

Sufficient number of light points should be provided in the lift shaft for proper illumination.

**8.5.3** Should a lift entrance open out into an area expected to the weather the entrance should be protected by a suitable canopy and the ground level slope up to the entrance to prevent during rain or surface drainage from entering the lift well through the clearances around the landing doors. Any push buttons so enclosed should be of weatherproof type.

### 8.6 Stairwell Enclosures

The location of lifts in stairwells is not recommended.

The use of stair stringers for fixing of guides normally involves extensive site measurement in order to fabricate purpose-made brackets. The resulting attachments are often unreliable and lacking in robustness. For stairwells of normal width, the span required for the lift machine support beams is excessive and unless uneconomic sections are used the deflections under varying load adversely affect the motor of the lift.

The necessary provision of suitable continuous enclosures can be very expensive.

### 8.7 Handwinding Release Procedure and Indication

The release procedure by handwinding should only be carried out in an emergency and by authorized persons who have received the necessary instruction because it is dangerous for any other persons to attempt to do so.

Before attempting to move the car, it is imperative that any person in the car be warned of the intention to move the car and that they do not attempt to leave the car until they are advised that it is safe to do so. Any failure to carry out this precaution may render the person concerned guilty of negligence should an accident occur.

Before attempting to handwind the lift machine, it is vital that the supply is switched off at the main switch.

It is usually necessary to have two persons in the machine room: one to operate the brake release and the other to carry out the handwinding. The exceptions are small lift machines where the handwinding and be easily controlled by one man and larger machines which need two men to operate the handwinding alone with an additional man to control the brake release.

If the car is stuck in the lift well and cannot be moved when an attempt is made to move it in a downward direction, then no attempt at handwinding should be made because the car safety gear may have set. Any further procedure should be carried out under the instruction of a qualified lift mechanic.

Provided the car is free to be moved in the downward direction, then it should be hand wound to the nearest floor. There is a preference to move the car in a downward direction. However, this may not always be practical owing to the distance involved and the time taken to complete the movement. In addition the amount of out of balance load on the counterweight side, due to the size of car and the small number of persons inside it, may make it necessary to wind the car upwards. In the case of higher speed lifts the direction of handwinding will usually be governed by the effort required to move the car because of the absence of a large gear reduction ratio.

It is essential that all detail operations be carried out according to the manufacturer's instructions for the lift concerned and these should be clearly stated and permanently displayed in the form of a notice in the machine room.

## 9 RUNNING AND MAINTENANCE

**9.1** The lift installation should receive regular cleaning, lubrication, adjustment and adequate servicing by authorized competent persons at such intervals as the type of equipment and frequency of service demand. In order that the lift installation is maintained at all times in a safe condition, a proper maintenance schedule shall be drawn up in consultation with the lift manufacturer and rigidly followed. The provision of a log book to record all items relating to general servicing and inspection is recommended for all lifts. It is essential that the electrical circuit diagram of the lift with the sequence of operation of different components and parts should be kept readily available for the persons responsible for the maintenance and replacement where necessary.

**9.2** Particular attention may be directed for thorough periodical examination of wire ropes when in service. Attention should also be directed to the thorough examination of the groove of drums, sheaves and pulleys when installing a new rope. A groove deepened by rope wear is liable to lead to early failure of a new rope unless the groove is returned.

**9.3** Any accident arising out of operation of maintenance of the lifts should be duly reported to the Authority in accordance with the rules laid down. A notice may be put in the machine room to this effect.

## 10 LIFT ENQUIRY OR INVITATION TO TENDER

### 10.1 General

A period of four weeks is normally sufficient for return of tenders. This should be extended if large numbers of lifts or special requirements are involved.

The enquiry documents should be kept to the essential minimum, and should be strictly confined to material relevant to the lift work and to the particular project concerned

When enquiring for and ordering an electrical lift in accordance with this Section, the particulars given below shall be furnished:

**PARTICULARS OF LIFTS**

1) Type of lift (Passenger, goods, service or dumb waiter)……………………
2) Number of lifts required…………………
3) Load: number of persons……………kg……
4) Rated speed…………………m/s
5) Travel…………………………m
6) Serving…………floors……entrances…….
7) Number of floors served…………………
8) Method of control………………(*see* **7.2**)
9) Position of machine room………………
10) Sizes of lift well(s)…………………
11) Position of counterweight………………
12) Internal size of lift car…………………
13) Construction, design and finish of car bodywork…………………………
14) Car entrances:
    a) Number, size and type of doors
    b) Power or manual operation
15) Car light…………………………
16) Call indicator……………position indicator in car……………………

17) Lift Landing Entrance:
    a) Number, size and type of doors or gates or shutters (for goods lifts)
    b) Location of landing entrances in different floors, if the car has more than one opening.
18) Electric Supply:
    Power………………volts ac/dc……………
    phase………………
    Cycles…………, wire system………………
19) Whether neutral wire available for control circuit?
20) Lighting……………volts ac/dc…………… cycles………………
21) Are premises subject to Lifts Act/Rules?
22) Proposed date for commencement on site……………………
23) Proposed date for completion………………
24) Additional items, if required………………..
25) Booklet giving complete details of maintenance schedule and circuit diagram where so specified……………………

**10.2 Additional Items**

The enquiry should state any additional items required beyond those specified in good practice [8-5(4)], such as fireman's control, radio interference suppression and dismantling of existing lift, etc.

Lifts to be installed in adverse conditions, such as chemical works, lifts used with power trucks, and similar specialized applications, required individual consideration according to the circumstances.

**10.3 Finishes**

Finishes should be specified at the enquiry stage or provisional sums should be included for them.

Finishes to be considered may include car body work, ceiling, floor, light fitting, ventilation, trims, car and landing doors, including vision panels if required, landing architrave push and indicator fittings, car and landings.

**10.4 Inclusions and Exclusions**

A number of peripheral items are associated with a lift installation, of which some should always be provided by the builder, and some are best included by the lift maker. The requirements vary to some extent with the type of installation.

It is important that the limits of responsibility are clearly understood, and the enquiry documents should be specific in this respect.

The lift maker should include such items as:

a) Guide brackets and wall inserts;
b) Buffers and any associated steelworks;
c) Pit screen to counterweight;
d) Steel beams of raft for machine and pulleys;
e) Sound insulation to machine where this is required;
f) Doors;
g) Door tracks;
h) Supporting steelworks for horizontal sliding doors and frames for hinged doors;
j) Wiring materials for the lift itself starting from the supplies furnished by the purchaser;
k) Over current protection (type to be specified) (*see* **7.4.1**);
m) Alarm push and bell or telephone (*see* **7.4.3**);
n) Alarm push and bell or telephone (*see* **7.4.3**);
p) Lifting tackle and small electric tools for use during the actual installation;
q) Services of erection staff to install and wire;
r) Services of testing engineer and provision of the necessary instruments and test weights; and
s) Guarantee of equipment.

The lift maker should exclude the supply and fixing of the items as the following:

a) Builders' work, such as forming lift well, pit and machine room and building in wall inserts;
b) Machine room floor including any reinforcement necessary for load bearing;
c) Lifting beams in machine room where necessary;
d) Steel surrounds for vertical bi-parting sliding doors;
e) Any necessary tanking, lining or reinforcement of the pit;
f) Dividing beams for multiple wells, and interwell pit screens;
g) Temporary guarding of openings;
h) Scaffolding, planks and ladders;
j) Off-loading and storage of materials;
k) Cutting away and making good;
m) Site painting of steel work, etc;
n) Working lights, temporary and permanent electricity supplies, etc; and
p) Mess rooms, sanitary accommodation and welfare facilities.

For more detailed discussion of the requirements for site preparation and work by other trades, reference should be made to good practice [8-5(2)], and to other clauses **5**, **7.4** and **12**.

Apart from the items referred to in the preceding clauses, which are common to almost all lift installations, the following shall apply:

a) Sill support members with toe guards are included as part of the complete doors entrance except for general purpose goods lifts, for which the builder should supply the sill support; and
b) Architrave, or finish surrounds to doors: if of metal, these should be provided by the lift maker, with back filling by the general contractor and if of timber by the joinery contractor.

As referred to in **11.5**, facilities for the use of the main contractor's crane should be provided to assist in installing heavy equipment. In addition to other unloading facilities on site in the course of erection. The main contractor should be instructed to include these facilities in his own quantities.

Where the lift maker agrees to use mobile platforms in place of lift well scaffolding, the general contractor should provide 400/440 V 3-phase and 200/220 V single-phase supply in the lift shaft to operate such equipment, the supply to terminate at the position in the lift well required by the lift maker.

These mobile platforms are limited in use for erection personnel and the transportation of light equipment only, but use of crane will also be necessary to assist in the installation of the heavy machinery and also in the initial installation of the mobile platform equipment.

### 10.5 Site Programme

The enquiry should indicate as accurately as possible the contract programme as it affects the lift maker, in particular the target date for lift completion, and the date when the lift site will be prepared and the availability of a crane.

## 11 ACCEPTANCE OF TENDER AND SUBSEQUENT PROCEDURE

### 11.1 General

The procedure indicated below particularly relates to the most usual case, where the lift maker is a sub-contractor.

### 11.2 Order

The main contractor is instructed to place an order with the selected lift maker. If alternative schemes have been offered, the order should clearly indicate which has been accepted.

### 11.3 Programme

As noted in **10.5** the programme should have been indicated as accurately as possible at the time of enquiry. At the time of order, the programme for manufacture and installation of the lift should be agreed.

The programme should cover each lift separately, including dates such as:

a) The order date,
b) The date when the lift site will be ready,
c) The date for provision of lift electricity supplies, and
d) The lift completion date.

The period between order and delivery of material falls into two stages: first the finalizing of details and secondly the actual production of the equipment when depends on the first stage. Within the first stage, other dates may need to be considered, such as:

a) All relevant building information available,
b) Submission of lift maker's drawings,
c) Approval of drawings, and
d) Final selection of finishes.

Information relevant to programming the site work can be found in other clauses of this Section, such as in **12** and **13**.

### 11.4 Drawings

Following order, the lift maker should supply drawings showing builder's work required, together with point loadings. To enable these to be prepared, the purchaser's representative should furnish the relevant detail building drawings.

### 11.5 Approval of Drawings

The purchaser's representative should give written approval of the drawings (after modification if necessary), at the same time asking for such additional copies (up to five of each drawing) as he requires for distribution to other parties concerned.

### 11.6 Selection of Finishes

Where the contact provides for the purchaser's choice of decorative finishes, colours, etc, the decisions should be communicated by the purchaser's representative as early as possible, and preferably not later than the time of approval of drawings.

### 11.7 Electricity Supplies to Lift

Operation of the machine under power is required from a comparatively early stage of installation for the most efficient working, and supplies should be furnished accordingly. Whilst temporary supplies may be sufficient for erection purposes, final testing and setting up can only be carried out with the permanent supplies connected. For this reason the timely provision of the permanent supplies is important.

## 12 CO-ORDINATION OF SITE WORK

### 12.1 Preparatory Work on Site

It is customary for the lift maker to make periodic visits to the site before his starting date to check progress on the lift well construction and discuss relevant matters with the contractor. The lift maker should assure himself that all building work has been completed in accordance with his requirements.

Immediately, before the time for lift erection to commence the lift maker should check that site conditions are fit to permit erection to proceed.

Building work to be completed before lift erection starts includes the following:

a) Pit lift well and machine room complete and weather tight. Pit dry and watertight including tanking if necessary and clear of rubbish.

   NOTE — In certain systems building and buildings of over 10 floors, it may be necessary by prior agreement to start erection before the top portion of the lift well has been constructed, in which case the general contractor should temporarily deck out and waterproof.

b) Preparation for lift fixings in pit, lift well and machine room complete. If built-in wall inserts are used, these should be placed accurately and slots cleared of any seepage of concrete.

c) Steelwork items finally grouted or otherwise fixed in position after checking for correct position by the lift maker (for example lift well trimmers and machine beams).

d) Scaffolding in position, as arranged with the lift maker, lift well etc. properly fenced and guarded in accordance with current regulation.

e) Entrance preparations completed, including preparations for door frames, push boxes and indicators. In many cases, progress can be facilitated by omitting the front walls of the lift well until the lift car, doors, etc. are installed.

f) Datum line (in elevation) established at each floor to enable the lift maker to set metal sills and frames in relation to finished floor levels.

### 12.2 Delivery of Material

The lift maker should advise the contractor when equipment is ready for despatch, so that the contractor can make arrangements on site to receive and unload with appropriate hoisting tackle, slings and supports, as near as possible to the lift well.

### 12.3 Storage

Adequate provision should be made by the building contractor for storing, protecting and preserving against loss, deterioration or damage, all material on the site. Attention is drawn to the adverse affect of damp conditions on electrical equipment and on steel wire ropes.

### 12.4 Site Meetings

For the successful progress of the work, full co-operation among all parties is essential. In large sites, regular meetings of such parties are beneficial. Programmes for the constructional work in that part of the building containing the lift should be made in consultation among all parties concerned.

### 12.5 Service of Other Trades

The lift erector will require the services of joiners, bricklayers and other trades as the work proceeds, and it is essential that the lift erector should give due notice to the building contractor of the demands to be made on other trades, so that he can plan accordingly.

### 12.6 Scaffolding, Fencing Etc

Scaffolding timbers, rollers and similar items required for the unloading and erection of the lift, and also for the proper guarding and close fencing of the lift well should be provided, erected and maintained by the building contractor.

The lift well should not be used as a means of disposal for rubbish from the upper floors. Such practice is dangerous.

The lift well should be handed over to the lift contractor complete, and no other trades should be allowed to work above or below during the whole time of erection of the lift, except by arrangement with the lift contractor.

### 12.7 System Building Sites

If the building programme allows insufficient time for lift erection in conventional fashion after the well is completely built special procedures are needed. This applies particularly to industrialized and multi-storey buildings.

Methods differ in detail. In most cases however the building contractor's crane is used to lower and position pre-assembled batches of lift equipment into the progressively rising top of the lift well.

The building contractor should provide a suitable portable cover to the completed portion of the lift well in order to protect the lift erectors working below against the weather and falling objects.

When the top of the well has been reached it is normal to cap it immediately with a precase load bearing floor slab on to which is lowered the pre-assembled machine room equipment. It then remains for the building contractor to complete and weatherproof the machine room as swiftly as possible.

On all such projects as these the closest co-operation between the building contractor and the lift maker is essential.

### 12.8 Connecting to Power Supply

The lift maker should give prior warning to the building contractor of the date the power supply to the lift is required, so that suitable arrangements for connection can be made.

## 13 PROCEDURE FOLLOWING TEST, INCLUDING INSPECTION AND MAINTENANCE

### 13.1 Acceptance

The purchaser should make timely arrangements for accepting the lift on completion of test, and for insurance cover. Special arrangements (*see* **13.4**) are necessary if there is to be at interval before the lift goes into normal service.

### 13.2 Guarantee and Servicing

Any guarantee provided by the lift maker should be conditional upon the lift receiving regular and adequate servicing, and should cover the free replacement of parts which prove defective through reasons of fault, materials or workmanship in the guarantee period, which is generally twelve months.

To ensure the continuance of satisfactory and safe operation, the purchaser (or building occupier) should arrange for the completed lift to receive regular servicing by competent persons at such intervals as the type of equipment and intensity of operation demand. Such service can be secured under a service contract. It is desirable and normal for the lift maker to be entrusted with the servicing during the guarantee period of a new lift.

The scope of a service contract may be extended to cover not only regular servicing, but also intermediate service calls, repairs and replacement of worn parts.

The building owner should co-operate with the service engineer, and should ensure that the equipment is properly used, and that unauthorized persons are not permitted to enter the lift well or machine rooms.

Particular attention should be paid to methods of ensuring that lifts are not overloaded when they are used in connection with furniture and equipment removals, and internal redecoration and other similar activities, which may be undertaken within the building.

### 13.3 Statutory Examinations

Lifts in certain premises are required by statutory regulations to be examined at intervals, as specified by the Lift Act, by a competent person, who is required to report on a prescribed form. Such reports should normally be kept in a register.

Statutory examinations are not a substitute for servicing, the provision of statutory reports may be specially included in a service contract or may be arranged separately.

### 13.4 Lift not in Immediate Use (Shut Down Maintenance)

When conditions do not permit a lift to be taken to normal service immediately following completion and acceptance, it should be immobilized. The main contractor should take effective precautions against damage especially to finishes, or damage to equipment from dampness and builder's debris, until such time as the lift is required.

A separate service contract should be made with the lift maker to make regular visits during this period, to inspect, lubricate and report on the condition of the lift.

A date should also be agreed with the lift maker from which his guarantee period will commence.

### 13.5 Temporary Use of Lifts

If the purchaser intends to permit temporary use of a lift by some other party, such as the building contractor, before taking it into normal service, so that it is not immobilized, then the responsibilities of those concerned should be clearly defined and agreed. In addition to the precautions noted in **13.4**, temporary insurance cover should be arranged.

If temporary use of lifts is envisaged, it should preferably be given consideration at an early stage, having regard to the conditions under which it is likely to take place.

### 13.6 Cleaning Down

Acceptance following test should include checking the condition of decorative finishes, before the lift maker leaves the site.

After a shut down (or temporary service) period, the lift may require a further general cleaning down immediately before taking into normal service. The lift maker should be instructed accordingly to undertake this work and if any accidental damage has occurred to repair this at the same time. Both these items should be the subject of extra costs.

## 14 ESCALATORS

**14.1** Escalators are deemed essential where the movement of people, in large numbers at a controlled rate in the minimum of space, is involved, for example, railway stations, airports, etc. In exhibitions, big departmental stores and the like, escalators encourage people to circulate freely and conveniently.

**14.1.1** As the escalators operate at a constant speed, serve only two levels and have a known maximum capacity, the traffic study is rather easy. Provided the population to be handled in a given time is known, it is easy to predict the rate at which the population can be handled.

**14.1.2** For normal peak periods, the recommended handling capacities for design purposes should be taken as 3 200 to 6 400 persons per hour depending upon the width of the escalator.

The number of persons that may be theoretically carried by the escalator in 1 h can be calculated as follows:

a) For determination of theoretical capacity it is assumed that one step with an average depth of 0.4 m can carry 1 person for a step width of 0.6 m, 1.5 persons for a step width of 0.8 m and 2 persons for a step width of 1.0 m.

b) The theoretical capacity then is:

$$3\,600 \times (\text{rated speed in m/s} \times k)/0.4$$

where

$k$ = 1, 1.5, or 2 for 0.6, 0.8 and 1.0 m step widths.

c) Some values calculated as per the above are:

| *Step Width* | *Theoretical Capacity in Persons/hour* | | |
|---|---|---|---|
| | 0.5 m/s speed | 0.65 m/s speed | 0.75 m/s speed |
| 0.6 m | 4 500 | 5 850 | 6 750 |
| 0.8 m | 6 750 | 8 775 | 10 125 |
| 1.0 m | 9 000 | 11 700 | 13 500 |

### 14.2 Essential Requirements

**14.2.1** Angle of inclination of an escalator from the horizontal shall not exceed 30°, but for rises not exceeding 6 m and rated speed not exceeding 0.5 m/s the angle of inclination is permitted to be increased up to 35°.

**14.2.1.1** The rated speed of the escalator shall not exceed 0.75 m/s for an angle of inclination up to 30° and 0.5 m/s for an escalator with an angle of inclination of more than 30° but within 35°.

**14.2.2** The horizontal distance (measured at right angles to the direction of travel) between the balustrade interior panellings at lower points shall be equal to or less than the horizontal distance measured at points higher up. The maximum distance between the balustrade interior panelling at any point shall be smaller than the distance between handrails.

**14.2.3** The parts of the balustrade facing the steps shall be smooth. Covers or strips not in the direction of travel shall not project more than 3 mm. They shall be sufficiently rigid and have rounded or bevelled edges. Covers or strips of such nature are not permitted at the skirting.

Cover joints in the direction of travel (in particular between the skirting and balustrade interior panelling) shall be arranged and formed in such a manner that the risk of trapping is reduced to a minimum.

Gaps between interior panels of the balustrade shall not be wider than 4 mm. The edges shall be rounded off or bevelled. The balustrade interior paneling shall have adequate mechanical strength and rigidity. When a force of 500 N is applied at any point of the paneling at right angles on a area of 2 500 mm$^2$. There shall be no gap greater than 4 mm and no permanent deformation (setting tolerances are permitted).

The use of glass for balustrade interior panelling is permitted with the approval of the Authority; further, provided it is splinter free one layer safety (tempered) glass and has sufficient mechanical strength and rigidity. The thickness of the glass shall not be less than 6 mm.

**14.2.3.1** There shall be no abrupt changes in the width between the balustrades on the two sides of the escalator. Where a change in width is unavoidable, such change shall not exceed 8 percent of the greatest width. In changing the direction of the balustrades resulting from a reduction in width the maximum allowable angle of change in balustrades shall not exceed 15° from the line of the escalator travel.

**14.2.3.2** Where the skirting of the escalator is placed beside the steps the horizontal clearance shall not exceed 4 mm at either side and 7 mm for the sum of the clearances measured at both sides at two directly opposite points.

**14.2.3.3** Where the building obstacles can cause injuries appropriate preventive measures shall be taken. In particular, at floor intersections and on criss-cross escalators, a vertical obstruction of not less than 0.3 m in height (not presenting any sharp cutting edge, for example as an imperforate triangle) shall be placed above the balustrade decking. It is not necessary to comply with this requirement when the distance between the centreline of the handrail and any obstacle is equal to or greater than 0.5 m.

For escalators arranged adjacent to one another either parallel or criss-cross the distance between the edges of the handrails shall not be less than 120 mm.

**14.2.4** *Handrails*

**14.2.4.1** Each balustrade shall be provided with a handrail moving in the same direction and at substantially the same speed as the steps.

**14.2.4.2** Each moving handrail shall extend at normal handrail height not less than 300 mm beyond the line of points of combplate teeth at the upper and lower landings.

**14.2.4.3** Hand or finger guards shall be provided at the points where the handrails enters the balustrade.

**14.2.4.4** The width of the handrail shall be between 70 mm and 120 mm. The distance between the handrail and the edge of the balustrade shall not exceed 50 mm. The distance between centreline of handrails shall not exceed the distance between the skirtings by more than 0.45 m.

**14.2.5** *Step Treads*

**14.2.5.1** The step depth in the direction of travel shall not be less than 0.38 m.

**14.2.5.2** The surface of the step treads shall have grooves in the direction of movement, with which the teeth of the combs mesh. They shall be sensibly horizontal in the usable area of the escalator.

The width of the grooves shall be at least 5 mm and not exceed 7 mm. The depth of the grooves shall not be less than 10 mm. The web width shall be at least 2.5 mm and not exceed 5 mm.

**14.2.6** *Landing*

The landing area of escalators shall have a surface that provides a secure foot hold for a minimum distance of 0.85 m measured from the root of the comb teeth. Exempted from this are the combs.

**14.2.7** *Combplates*

There shall be a combplate at the entrance and at the exit of every escalator. The combplate teeth shall be meshed with and set into the slots in the tread surface so that the points of the teeth are always below the upper surface of the treads. Combplates shall be adjustable vertically.

**14.2.8** *Trusses or Girders*

The truss or girder shall be designed to safety sustain the steps and running gear in operation. In the event of failure of the track system it shall retain the running gear in its guides.

**14.2.9** *Step Wheel Tracks*

This shall be designed to prevent displacement of steps and running gear if a step chain breaks.

**14.2.10** *Driving Machine, Motor and Brake*

**14.2.10.1** The driving machine shall be connected to the main drive shaft by toothed gearing, a coupling, or a chain.

**14.2.10.2** An electric motor shall not drive more than one escalator.

**14.2.10.3** Each lift shall be provided with an electrically released, mechanically applied brake capable of stopping the up or down travelling escalator with any load up to rated load. This brake shall be located either on the driving machine or on the main drive shaft.

Where a chain is used to connect the driving machine to the main drive shaft, a brake shall be provided on this shalt, it is not required that this brake be of the electrically released type if an electrically released brake is provided on the driving machine.

**14.2.10.4** *Speed governor*

Escalators shall be equipped in such a way that they stop automatically before the speed exceeds 1.2 times the rated speed. Where speed control devices are used for this purpose they shall have switched off the escalator before the speed exceeds 1.2 times the rated speed. It is permissible to disregard this requirement in case of a.c. motors with a non-friction connection with the drive for the steps and whose slip does not exceed 10 percent if thereby overspeed is prevented.

**14.2.10.5** For operation and safety devices, electrical work, precautions and tests, reference may be made to good practice [8-5(11)].

## LIST OF STANDARDS

The following list records those standards which are acceptable as 'good practice' and 'accepted standards' in the fulfillment of the requirements of the Code. The latest version of a standard shall be adopted at the time of enforcement of the code. The standards listed may be used by the Authority as a guide in conformance with the requirements of the referred clauses in the Code.

| *IS No.* | *Title* |
|---|---|
| (1) 14671 : 1999 | Code of practice for installation and maintenance of hyraulic lifts |
| (2) 14665 | Electric traction lifts: |
| (Part 1) : 2000 | Guidelines for outline dimensions of passenger, goods, service and hospital lifts |
| (Part 3/Sec 1 & 2) : 2000 | Safety rules, Section 1 Passenger and goods lifts, Section 2 Service lifts |
| (Part 4/Sec 1 to 9) : 2001 | Components, Section 1 Lift Buffers, Section 2 Lift guide rails and guide shoes, Section 3 Lift carframe, car, counterweight and suspension, Section 4 Lift safety gears and governors, Section 5 Lift retiring cam, Section 6 Lift doors and locking devices and contacts, Section 7 Lift machines and brakes, Section 8 Lift wire ropes, Section 9 Controller and operating devices |
| (3) 14665 (Part 4/ Sec 1 to 9) : 2001 | Electric traction lifts: Components, Section 1 Lift buffers, Section 2 Lift guide rails and guide shoes, Section 3 Lift carframe, car, counterweight and suspension, Section 4 Lift safety gears and governors, Section 5 Lift retiring cam, Section 6 Lift doors and locking devices and contacts, Section 7 Lift machines and brakes, Section 8 Lift wire ropes, Section 9 Controller and operating devices |
| (4) 14665 (Part 3/ Sec 1 & 2) : 2000 | Electric traction lifts: Part 3 Safety rules, Section 1 Passenger and goods lifts, Section 2 service lifts |
| (5) 14665 (Part 2/ Sec 1 & 2) : 2000 | Electric traction lifts: Part 2 Code of practice for installation, operation and maintenance, Section 1 Passenger and goods lifts, Section 2 Service lifts |
| (6) 962 : 1989 | Code of practice for architectural and building drawings (*second revision*) |
| (7) 2309 : 1989 | Code of practice for the protection of buildings and allied structures against lightning (*second revision*) |
| (8) 1950 : 1962 | Code of practice for sound insulation of non-industrial buildings |
| (9) 14665 (Part 3/ Sec 1 & 2) : 2000 | Electric traction lifts: Part 3 Safety rules — Section 1 Passenger and goods lifts, Section 2 Service lifts |
| (10) 3043 : 1987 | Code of practice for earthing |
| (11) 4591 : 1968 | Code of practice for installation and maintenance of escalators |