भारतीय मानक ब्यूरो
BUREAU OF INDIAN STANDARDS

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व्यापक परिचालन मसौदा

हमारा संदर्भ : सीईडी 46/टी-16 **31 जुलाई 2015**

तकनीकी समिति :राष्ट्रीय भवन निर्माण संहिता विषय समिति, सीईडी 46

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प्राप्तकर्ता :

1 सिविल इंजीनियरी विभाग परिषद् के सभी सदस्य

2 राष्ट्रीय भवन निर्माण संहिता विषय समिति, सीईडी 46 व
वातानुकूलन एवं तापन के लिए पैनल, सीईडी 46:P14 के सभी सदस्य

3 रूचि रखने वाले अन्य निकाय ।

महोदय/महोदया,

निम्नलिखित मसौदा संलग्न है:

प्रलेख संख्या	शीर्षक
सीईडी 46(8016)WC	राष्ट्रीय भवन निर्माण संहिता का मसौदा: भाग 8 भवन सेवाएं, अनुभाग 3 वातानुकूलन, तापन एवं यांत्रिक वायुसंचालन [SP7(भाग 8/अनुभाग 3) का तीसरा पुनरीक्षण]

कृपया इस मसौदे का अवलोकन करें और अपनी सम्मतियाँ यह बताते हुए भेजें कि यदि यह मसौदा भारत की राष्ट्रीय भवन निर्माण संहिता के भाग के रूप में प्रकाशित हो तो इस पर अमल करने में आपके व्यवसाय अथवा कारोबार में क्या कठिनाइयाँ आ सकती हैं ।

सम्मतियाँ भेजने की अंतिम तिथि : **31 अगस्त 2015**।

यदि कोई सम्मति हो तो कृपया अधोहस्ताक्षरी को उपरिलिखित पते पर संलग्न फोर्मेट में भेजें । हो सके तो कृपया अपनी सम्मतियाँ ई-मेल द्वारा **sanjaypant@bis.org.in** पर भेजें ।

यदि कोई सम्मति प्राप्त नहीं होती है अथवा सम्मति में केवल भाषा सम्बन्धी त्रुटि हुई तो उपरोक्त प्रलेखों को यथावत अंतिम रूप दे दिया जाएगा । यदि सम्मति तकनीकी प्रकृति की हुई तो विषय समिति के अध्यक्ष के परामर्श से अथवा उनकी इच्छा पर आगे की कार्यवाही के लिए विषय समिति को भेजे जाने के बाद प्रलेख को अंतिम रूप दे दिया जाएगा ।

यह प्रलेख भारतीय मानक ब्यूरो की वैबसाइट **www.bis.org.in** पर भी उपलब्ध है ।

धन्यवाद ।

भवदीय,

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(बी.के. सिन्हा)
प्रमुख (सिविल इंजीनियरी)

संलग्न: उपरिलिखित

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DRAFT IN WIDE CIRCULATION

DOCUMENT DESPATCH ADVICE

Reference	Date
CED 46/T-16	31 July 2015

TECHNICAL COMMITTEE:
NATIONAL BUILDING CODE SECTIONAL COMMITTEE, CED 46

ADDRESSED TO:

1. All Members of Civil Engineering Division Council, CEDC
2. All Members of National Building Code Sectional Committee, CED 46 and its Panel for Air Conditioning and Heating, CED 46:P14
3. All other interests.

Dear Sir/Madam,

Please find enclosed the following draft:

Doc. No.	Title
CED 46 (8016)WC	**Draft National Building Code of India: Part 8 Building Services, Section 3 Air Conditioning, Heating and Mechanical Ventilation** **[*Third Revision of* SP 7(Part 8/Section 3)]**

Kindly examine the draft and forward your views stating any difficulties which you are likely to experience in your business or profession if this is finally adopted as part of the National Building Code of India.

Last Date for comments: **31 August 2015** .

Comments if any, may please be made in the format as attached, and mailed to the undersigned at the above address. You are requested to send your comments preferably through e-mail to **sanjaypant@bis.org.in**.

In case no comments are received or comments received are of editorial nature, you may kindly permit us to presume your approval for the above document as finalized. However, in case of comments of technical nature are received then it may be finalized either in consultation with the Chairman, Sectional Committee or referred to the Sectional Committee for further necessary action if so desired by the Chairman, Sectional Committee.

This document is also hosted on BIS website **www.bis.org.in**.

Thanking you,

Yours faithfully,

Sd/-

(B. K. Sinha)
Head (Civil Engg)

Encl: as above

FORMAT FOR SENDING COMMENTS ON THE DOCUMENT

[Please use A4 size sheet of paper only and type within fields indicated. Comments on each clause/sub-clause/ table/figure, etc, be stated on a fresh row. Information/comments should include reasons for comments, technical references and suggestions for modified wordings of the clause. **Comments through e-mail in MS WORD format to sanjaypant@bis.org.in shall be appreciated**.]

Doc. No.: CED 46(8016)WC **BIS Letter Ref**: CED 46/T-16 **Dated**: 31 July 2015

Title: Draft National Building Code of India: Part 8 Building Services, Section 3 Air Conditioning, Heating and Mechanical Ventilation [*Third Revision of* SP 7(Part 8/Section 3)]

Name of the Commentator/ Organization: ______________________________________

Clause No. with Para No. or Table No. or Figure No. commented *(as applicable)*	**Comments / Modified Wordings**	**Justification of Proposed Change**

Doc: CED 46 (8016)WC
July 2015

Draft NATIONAL BUILDING CODE OF INDIA

PART 8 BUILDING SERVICES

Section 3 Air Conditioning, Heating and Mechanical Ventilation

[*Third Revision of* SP 7(Part 8/Section 3)]

BUREAU OF INDIAN STANDARDS

CONTENTS

IMPORTANT EXPLANTORY NOTE FOR USERS OF THE CODE

In this Part/Section of the Code, where reference is made to 'good practice' in relation to design, constructional procedures or other related information, and where reference is made to 'accepted standard' in relation to material specification, testing, or other related information, the Indian Standards listed at the end of this Part/Section may be used as a guide to the interpretation.

At the time of publication, the editions indicated in the standards were valid. All standards are subject to revision and parties to agreements based on this Part/Section 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 this Section, the number appearing in the first column indicates the number of the reference in this Section. For example:

a) Accepted standard [8-3(2)] refers to the Indian Standard given at serial number (2) of the above list given at the end of this Section 3 of Part 8, that is IS 655 : 2006 'Air ducts - Specification (*second revision*)'

b) Good practice [8-3(8)] refers to the Indian Standard given at serial number (8) of the above list given at the end of this Part 11, that is IS 661 : 2000 'Thermal insulation of cold storage - Code of practice (*third revision*)'.

BUREAU OF INDIAN STANDARDS

DRAFT FOR COMMENTS ONLY

Draft NATIONAL BUILDING CODE OF INDIA

PART 8 BUILDING SERVICES

Section 3 Air Conditioning, Heating and Mechanical Ventilation

[*Third Revision of* SP 7(Part 8/Section 3)]

ICS: 01.120; 91.040.01

National Building Code Sectional Committee, CED 46	Last Date for Comments: **31 August 2015**

National Building Code Sectional Committee, CED 46

FOREWORD

This Section deals with the selection, design considerations, and installation of air conditioning, heating and mechanical ventilation systems for different types of building application and in towns and cities under all the climatic zones of India. It covers all aspects including the goals and objectives, basis of design, input parameters for design, guidelines for design of system, performance parameters, available system options, pre-planning considerations, range of equipment and system components, building management system, installation of the system, testing, commissioning and handing over and also operation and maintenance of the air conditioning, heating and mechanical ventilation system.

Indian construction industry is poised to add an-order-of-magnitude built foot-print in the coming years. With the advent of information technology and computers becoming part of our life-style, the requirement of air conditioning of built environment is being increasingly felt and met with. The challenge faced for this unprecedented development is the lack of material resources and natural resources like energy, water and clean air. Therefore, the selection of air conditioning and mechanical ventilation system optimally suited for the specific type of building application and its climatic zone becomes critical. It is necessary for the owner, designer, builder and developer to understand the provisions of this Section, and consult an air conditioning engineer at the pre-planning stage.

Sustainable buildings movement in the country has gained tremendous momentum. The Part 11 'Approach to Sustainability' of this Code, deals with all aspects of sustainable buildings, from selection of site, building design, energy and water efficient systems, use of recycled material resources, construction, third party commissioning, operation and maintenance of sustainable buildings. It is expected that by following the provisions of this Section in conjunction with those given in Part 11, India will adopt sustainable buildings as the way of life, as has been the practice for centuries, prior to the onslaught of industrial revolution in India.

Computerized weather data is now available, and has been included for around 60 locations across the country, covering all the five climatic zones. This data is based on the latest values obtained from India Metrological Department, Government of India. For any tier III city not included, it is recommended that extrapolation may be done, from the data of the nearby listed city, but keeping in mind the specific topographical and climatic conditions of the concerned location.

The first version of this Section was prepared in 1970 which was subsequently revised in 1983 and 2005. The major modifications made in 2005 version of the Code included 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 were included.

b) A new clause on design criterion was incorporated.

c) 'Indoor air quality' had 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 had been recommended for each floor.

e) Inside design conditions for various applications had been included; they replaced earlier Table 2 and Table 3.

f) The text on minimum outside fresh air had been revised in the light of currently accepted international norms. Recommended values for outside air requirements for ventilation purposes had been furnished for a wider variety and a larger number of applications.

g) New details had 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, had been given in more details.

j) A new clause on statutory regulation/safety considerations had been included.

k) Under the clause on design considerations, various system options available had been described.

m) The characteristics and application of options available in piping, water distribution systems and piping layout had been given prominently.

n) The text on air filters had been revised; giving focus 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 had 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 had been incorporated in this clause.

q) 'Automatic Controls' included in the 1983 version had been replaced by Building Management System, which addressed not only the control function, but also had 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 had been revised and elaborated.

s) The text on heating had been completely revised.

t) The text had been thoroughly revised and additional details had 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, had been given.

Since the last revision of the Code in 2005, there has seen tremendous emphasis on energy conservation to meet the challenges posed by the climatic change. Hence the building design practices, the system components and principal equipment have gone through major development. The current revision fully recognizes the latest developments in the field of air conditioning, heating and mechanical ventilation.

The significant modifications made in the current revision include amongst others, the following key changes:

a) Definitions of several new terms have been added relating to number of new concepts introduced in this revision.

b) Clause on refrigerants has been modified to include new refrigerants like HFC32 with zero ozone depletion potential and ultra-low global warming potential. These are now manufactured in India and are commercially available, or are in advanced stage of development in the R&D laboratories. Water, Ammonia, CO_2, and other natural refrigerants are making a comeback and are described with relevant details.

c) Planning considerations have been expanded to include the available options of variable refrigerant volume system; inverter technology, district cooling system, and hybrid central plant using chilled beams and radiant floor components. Planning clause also identifies the thrust on envelope optimization using energy modelling, day-lighting simulation, solar shade analysis and wind modulation software to optimize the air-conditioning load. Such buildings are thus designed to utilize the most energy efficient air conditioning system to bring the annual energy consumption to a minimum, which could be generated through renewable energy resources.

d) Outdoor design conditions for air conditioning load calculation and heating requirement, have been based on the latest weather data tabulated for around 60 cities, covering all the five climatic zones of India. These are derived from the latest weather data taken from India Metrological Department, Government of India.

e) Indoor design conditions for comfort air conditioning, heating, and mechanical ventilation have been based on adaptive comfort conditions for the specific climatic zone, as per the procedure described in this completely revised clause.

f) The central plant equipment clause has been revised to include active and passive chilled beams, radiant floor for cooling/heating of space, underfloor air distribution to minimize stratification, geo-thermal cooling and heating, and recently developed high-efficiency cooling towers with very low approach to ambient wet bulb temperature.

g) Clauses on unitary/distributed equipment have been expanded and also direct/indirect evaporative cooling units have been included.

h) Provisions for specialized applications have been further detailed where provisions have also been now included for data centres and underground metro stations.

j) Refrigeration is common for summer air conditioning and for cold stores. Cold storage is key to India’s food security by minimizing food wastage. Therefore, a new clause has been introduced in this revision, on refrigeration for cold stores, describing the latest state-of-the-art technologies locally adopted.

k) Heating is required for indoor comfort conditions during winter months in northern part of India. This clause now describes the most efficient strategies for winter heating, using reverse cycle operation, solar heating systems, electric heat pump, and ground source heat pump.

m) Ventilation has now taken the centre-stage for sustainability in design, construction and operation of buildings. Natural ventilation and passive architecture are dealt in Part 8 'Building Services', Section 1 'Lighting and Natural Ventilation' with further strategies for sustainable buildings covered in Part 11 'Approach to Sustainability'. However, modern system of mechanical ventilation for industries, commercial kitchen, underground car parking, and for open tunnels connecting underground metro stations, has been now covered in this Section. It also covers demand control ventilation, where fresh air input for the control of indoor air quality, varies in direct proportion to the occupancy. Newly developed axial flow fans with aerofoil profile blades and acoustic silencers, has also been covered including criteria for solution of most efficient fan for the specific application.

n) Installation practices for the air conditioning, heating and mechanical ventilation system have been modified to suite the vast options of components now available. The clause identifies the procedure and precautions to be taken for each major component of the central system; unitary/distributed systems; fan; ducting and piping support; and for insulation. Emphasis is laid on ease of maintenance/repair/replacement; for noise and vibration isolation, and for centralized monitoring and control through computerized building automation system.

p) Symbols, colour coding and identification of services clause has been modified to match with the international practices.

q) Measurement and verification of building performance is now widely practiced and has put strong emphasis on integrated building management system for modern building complexes. Therefore, the clause on building automation system has been upgraded to include the latest practices for web-based monitoring and control of performance parameters.

r) Testing, balancing, commissioning and handing over of the air-conditioning, heating and mechanical ventilation system clause has been extensively revised to include state-of-the-art procedures adopted.

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, water 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 codes 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*)
8148 : 2003	Specification for packaged air conditioners (*first revision*)

Assistance has also been derived from the following publications in preparation of this Section:

Guidelines, Standards and Handbooks of American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE)

Handbooks of Indian Society of Heating, Refrigerating and Air Conditioning Engineers (ISHRAE)

India Model for Adaptive Comfort, CEPT University, Ahmedabad

ISO 7730:2005 Ergonomics of the thermal environment -- Analytical determination and interpretation of thermal comfort using calculation of the PMV and PPD indices and local thermal comfort criteria

ISO 16484-1:2010 Building automation and control systems (BACS) - Part 1 - Project specification and implementation

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

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2:1960 `Rules for rounding off numerical values (revised)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this Section.

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Draft NATIONAL BUILDING CODE OF INDIA
PART 8 BUILDING SERVICES
Section 3 Air Conditioning, Heating and Mechanical Ventilation

[*Third Revision of* SP 7(Part 8/Section 3)]

ICS: 01.120; 91.040.01

National Building Code Sectional Committee, CED 46	Last Date for Comments: **31 August 2015**

1 SCOPE

1.1 This Section covers the planning, design considerations, installation, testing, commissioning and handing over and also operation and maintenance of air conditioning, heating and mechanical ventilation systems for buildings. It also covers refrigeration for cold storages.

1.2 The provisions of this Section aim to ensure a heating, ventilation and air conditioning system which can provide comfort by managing air temperature, humidity, indoor air quality and distribution of conditioned air for the specific use and occupancy of built space while giving due consideration to minimizing energy consumption and other resources.

1.3 The provisions on natural ventilation are covered in Part 8 'Building Services', Section 1 'Lighting and Ventilation'.

2 TERMINOLOGY

2.0 For the purpose of this Section the following definitions shall apply in addition to those given in the accepted standard [8-3(1)].

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 Air Side Balancing — A method employed to minimize throttling losses in air systems.

NOTE — Air system should be balanced in order to minimize throttling losses. For fans, its speed should be adjusted to meet design flow conditions, by creating correct air flow at fans and outlet system performance can be increased.

2.3 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).

NOTE — 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.

2.4 Building Management System (BMS) — A stand-alone computer based control system installed in buildings that controls and monitors the building’s mechanical and electrical equipment such as ventilation, lighting, power systems to meet their need. In addition, a modem is also connected to the system to allow remote access.

2.5 Building Energy Simulation — Use of computer simulation models for design and optimization of building's energy performance, to compare the cost-effectiveness of energy conservation measures in the design stage as well as assessing various performance optimization measures during the operational stage.

2.6 Building Integrated Renewable Energy — Integration of renewable energy application in parts of the building envelope such as the roof, skylights, or facades.

2.7 Buildings Related Illnesses (BRI) — The illness attributed directly to the specific air-borne building contaminants like the outbreak of the Legionnaire’s disease.

NOTE —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 are decreased productivity, absenteeism and the legal implications if occupants IAQ complaints are left unresolved.

2.8 Cooling Degree Day — The temperature above which a building needs to be cooled. It is the number of degrees that a day’s average temperature is above 23°C. One cooling degree day means that the temperature conditions outside the building were equivalent to being higher than a defined threshold comfort temperature inside the building by one degree for one day.

2.9 Demand Based Ventilation — Intelligent airflow management that adjusts outside ventilation air based on the number of occupants and the ventilation demands that those occupants create.

2.10 Design Pressure Difference — The desired pressure difference between the protected space and an adjacent space measured at the boundary of the protected space under a specified set of conditions with the smoke control system operating.

2.11 Dew Point Temperature — The temperature at which condensation of moisture begins when the air is cooled at same pressure.

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

2.13 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.

2.14 Economizer, Air — It consist of duct, damper and control system that allow outside air to cool the building when outside air is cooler than inside.

2.15 Economizer, Water — In this system the supply air of a cooling system is cooled indirectly with water that is itself cooled by heat or mass transfer to the environment without the use of mechanical cooling.

2.16 Effective Temperature — Combined effects of air temperature, humidity, air movement, mean radiant temperature, clothing and activity on the sensation of warmth or cold felt by the human body. Numerically equivalent to the temperature of still air producing similar thermal sensation as produced by combination of above six parameters of thermal comfort.

2.17 Evaporative Air Cooling — It is the process of evaporating part of a liquid by supplying the necessary latent heat from the sensible heat of the main bulb of the liquid which is thus cooled.

2.18 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.

2.19 Geothermal Heat Pump — The thermal energy within the earth's crust, by using ground source water to be pumped out and recirculated in order to convert the use of geothermal energy for the purpose of cooling or heating applications.

2.20 Global Warming Potential (GWP) — The relative measure of how much a given mass of a refrigerant contributes to global warming over a given time period compared to the same mass of carbon dioxide over the same period.

NOTE —The GWP value of carbon dioxide is taken to be 1.0. The GWP value of a refrigerant is calculated over a time horizon. The time horizon can greatly affect the numerical value of GWP. Usually the GWP values are reported over a 100 years' time horizon.

2.21 Heat Pump — A refrigerating system employed to transfer heat into a space or substance. The condenser provides the heat while the evaporator is arranged to pick up heat from air, water, etc. By shifting the flow of air or other fluid, a heat pump system may also be used to cool the space.

2.22 Heat Recovery Unit — An air to air heat exchanger for preconditioning of air used to minimize the building load. In the heat recovery unit, conditioned air going outside the building exchanges heat with incoming air in order to minimize load on the system.

2.23 Heating Degree Day — It indicates the temperature below which a building needs to be heated. It is the number of degrees that a day's average temperature is below 18°C. One heating degree day means that the temperature conditions outside the building were equivalent to being below a defined threshold comfort temperature inside the building by one degree for one day.

2.24 Hybrid Building — A building which contains both active and passive systems of heating or cooling. It requires small amount of non-renewable energy to maintain required amount of coefficient of performance (COP).

2.25 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.

2.26 Indirect-Direct Cooling — The cooling which involves two stages;

a) the first stage, in which the air is made to pass through heat exchanger for sensible cooling (no direct contact of air and water), whereby the leaving air dry-bulb temperature (DBT) as well as the wet-bulb temperature (WBT) are reduced;
b) the second stage, in which the air after the first stage is made to pass through the evaporative air-cooling (adiabatic cooling) application where water and air are in direct contact and there is simultaneous removal of sensible heat and the addition of moisture to the air giving lower DBT.

The resultant of this two stage cooling is that the leaving air DBT is lower than ambient WBT.

NOTE — The first stage cooling is through indirect cooling. In this method, air-dry bulb and wet-bulb temperature are reduced without direct contact of air with water and through heat exchange only.

2.27 Indoor Air Quality (IAQ) — Air quality that refers to the nature of unconditioned or conditioned air that circulates throughout the space/area where one works or lives, that is, the air one breathes when indoors.

2.28 Infiltration/Exfiltration — The phenomenon of outside air leaking into/out of an air conditioned space.

2.29 Mean Radiant Temperature — The uniform temperature of an imaginary enclosure in which the radiant heat transfer from the human body is equal to the radiant heat transfer in the actual non-uniform enclosure.

2.30 Mixed Mode Building — A hybrid approach to space conditioning that uses a combination of natural ventilation and mechanical systems. These buildings utilize mechanical cooling only when and where it is necessary to supplement the natural ventilation.

2.31 Naturally Conditioned Building — A building in which the ventilation system rely on opening and closing of window of the space to maintain the thermal comfort of the space rather than mechanical systems.

2.32 Operative Temperature —A uniform temperature of a radiantly black enclosure in which an occupant would exchange the same amount of heat by radiation plus convection as in the actual non-uniform environment. It is the combined effects of the mean radiant temperature and air temperature calculated as average of the two. It is also known as dry resultant temperature or resultant temperature.

2.33 Ozone Depletion Potential (ODP) — A relative capability of a refrigerant or a gas to degrade ozone in the atmosphere as compared to trichlorofluoromethane [R-11 or Clorofluorocarbon-11(CFC-11)]. The ODP of CFC-11 is taken to be 1.0.

2.34 Passive Cooling — A building design approach that focuses on heat gain control and heat dissipation in a building in order to improve the indoor thermal comfort with low or zero energy consumption with using natural ventilation, air cooling and shades etc.

2.35 Passive Heating — Passive heating uses the energy of natural source such as the sun, to keep the occupants of the building comfortable by design approach of building without the use of mechanical or electrical heating systems.

2.36 Plenum — An air compartment connected to one or more distributing ducts.

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

2.38 Psychrometric Chart — A chart graphically representing the thermodynamic properties of moist air.

2.39 Recirculated Air — The return air that has been passed through the conditioning apparatus before being re-supplied to the space.

2.40 Refrigerant — The fluid used for heat transfer in a refrigerating system, which absorbs heat at a low temperature and a low pressure of the fluid and rejects heat at a higher temperature and a higher pressure of the fluid, usually involving changes of state of the fluid.

2.41 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.

NOTE — When the air is saturated, dry-bulb, wet-bulb and dew point temperatures are all equal, and the relative humidity is 100 percent.

2.42 Return Air — Air returned from conditioned or refrigerated space.

2.43 Shade Factor — The ratio of instantaneous heat gain through the fenestration with shading device to that through the fenestration.

2.44 Sick Building Syndrome (SBS) — A term, 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.

2.45 Smoke Barrier — A continuous membrane, either vertical or horizontal, such as a wall, floor, or ceiling assembly, that is designed and constructed to restrict the movement of smoke in conjunction with a smoke control system.

2.46 Smoke Damper — A damper similar to fire damper, however, having positions to close automatically or sensing presence of smoke in air distribution system or in conditioned space.

2.47 Smoke Management — A smoke control method that utilizes natural or mechanical systems to maintain a tenable environment in the means of egress from a large-volume space or to control and reduce the migration of smoke between the fire area and communicating spaces.

2.48 Stack Effect — The vertical airflow within buildings caused by the temperature-created density differences between the building interior and exterior or between two interior spaces.

2.49 Static Pressure — The normal force per unit area that would be exerted by a moving fluid on a small body immersed in it if the body were carried along with the fluid. Practically, it is the normal force per unit area at a small hole in a wall of the duct through which the fluid flows (piezometer) or on the surface of a stationary tube at a point where the disturbances, created by inserting the tube, cancel. It is supposed that the thermodynamic properties of a moving fluid depend on static pressure in exactly the same manner as those of the same fluid at test depend upon its uniform hydrostatic pressure.

2.50 Supply Air — The air that has been passed through the conditioning apparatus and taken through the duct system and distributed in the conditioned space.

2.51 Supply and Return Air Grilles and Diffusers — 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.

2.52 Thermal Adaptation — The gradual diminution of the people's response to repeated environmental stimulation and subsumes all processes which building occupants undergo in order to improve the fit of the indoor climate.

2.53 Thermal Conductance (*C*) – The thermal transmission of a single layer structure per unit area divided by the temperature difference between the hot and cold faces. It is expressed in W/m^2 K (Watt per square meter-degree Kelvin).

NOTE – Thermal conductance is a measure of the thermal transmission per unit area through the total thickness of the structure under consideration. Thermal conductivity on the other hand refers to unit thickness of material. Further, this term applies only to a single layer of material and not to a composite insulation or to a structure made up of several layers of materials or medium.

2.54 Thermal Conductivity (*k*) – The quantity of heat in the steady state conditions flowing in unit time through a unit area of a slab of uniform material thickness of infinite extent and of unit thickness, when unit difference of temperature is established between its faces. Its unit is W/mK (Watt per meter-degree Kelvin).

NOTE – Thermal conductivity is a characteristic property of a material and its value may vary with a number of factors, including density, porosity, moisture content, fibre diameter, pore size, type of gas in the material, mean temperature and outside temperature range. The conductivity value varies from 0.03 W//mk for insulators to 400W//mk for metals. Materials with lower conductivity are preferred, as they are better insulators and reduce the external heat gains from the envelope or loss of internal heat to outside cold environment.

2.55 Thermal Comfort – That condition of mind which expresses satisfaction with the thermal environment and is assessed by subjective evaluation.

2.56 Thermal Insulation Material — A protective material used over the conducting materials to retard the flow of heat energy in the form of heat loss or gain to facilitate the temperature control as the process and prevent permeability of moist vapour and reduces condensation on cold surfaces.

2.57 Thermal Resistance (*R*) – The reciprocal of thermal conductance. For a structure having plane parallel faces, thermal resistance is equal to thickness (*L*) of the structure divided by thermal conductivity (*k*).

$$R = \frac{L}{k}$$

NOTE – The usefulness of the quantity is that when heat passes in succession through two or more components of the building units, the resistance may be added together to get the total resistance of the structure.

2.58 Thermal Resistivity (*1/k*) – The reciprocal of thermal conductivity. It is expressed in mk/W.

2.59 Thermal Transmittance (*U*) – **Thermal Transmittance (*U*)** – Thermal transmission through unit area of the given building unit divided by the temperature difference between the air or other fluid on either side of the building unit in steady state conditions. It is also called as *U*-value. Its unit is W/m^2K.

NOTE – Thermal transmittance differs from thermal conductance in so far as temperatures are measured on the two surfaces of a building unit in the latter case and in the surrounding air (or other fluid) of the material on the two sides, in the former case. Thermal conductance is a characteristic of the building unit whereas thermal transmittance depends on conductance and surface coefficients of the building unit under the conditions of use.

2.60 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.

2.61 Velocity Pressure — The pressure exerted by movement of air which makes the air to travel to longer distance in ducts. This pressure is always in the direction of flow.

2.62 Variable Refrigerant Flow (VRF) Cooling System — System in which the flow of the refrigerant can be varied according to the load.

2.63 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.

2.64 Water Hardness — The hardness in water represented by the sum of calcium and magnesium salts in water, which may also include aluminium, iron, manganese, zinc, etc.

2.65 Water Side Balancing — It is done by piping friction loss calculations, measure system pressure losses, measure flow at each terminal, which enables proportional balancing and, ultimately, matching pump head and flow to actual system requirements by trimming the pump impeller or reducing pump motor power.

2.66 Wet-Bulb Temperature — The temperature at which liquid or solid water, by evaporating into air, can bring the air to saturation adiabatically at the same temperature. Wet-bulb temperature (without qualification) is the temperature indicated by a wet-bulb psychrometer constructed and used according to specifications.

3 REFRIGERANTS

3.1 Manufacturers and designers shall adopt balanced approach considering environmental impact and human health, while selecting refrigerants. Some of the key criteria to be considered are as follows:

a) *Ozone depletion potential (ODP),* should be zero/lowest possible;
b) *Global warming potential (GWP),* should be as low as possible;
c) *Energy efficiency* (*part load, full load system)*, should be as high as possible;
d) *Flammability,* should be as low as possible and suitable risk mitigation process/ infrastructure needs to be opted to handle flammability; and
e) *Toxicity,* should be zero/lowest possible.

For ODP and GWP of different refrigerants, reference may be made to Table 1. As the industry is currently researching an ideal refrigerant, it is advised that project teams should make a conscious effort to select refrigerant with least negative impacts as per the latest findings.

Table 1 ODP and GWP Values of Different Refrigerant Types (100 Year Values)
(*Clause* 3.1)

Sl No.	**Refrigerant**	**ODP**	**GWP**
(1)	(2)	(3)	(4)
	Chlorofluorocarbons		
i)	CFC-11	1.000	4,680
ii)	CFC-12	1.000	10,720
iii)	CFC-114	0.940	9,800
iv)	CFC-500	0.605	7,900
v)	CFC-502	0.221	4,600
vi)	HCFC-22	0.040	1,780
vii)	HCFC-123	0.020	76
viii)	HFC-23	~0	12,240
ix)	HFC-134a	~0	1,320
x)	HFC-245Fa	~0	1,020
xi)	HFC-404a	~0	3,900
xii)	HFC-407c	~0	1,700
xiii)	HFC-410a	~0	1,890
xiv)	HFC-507a	~0	3,900
xv)	HFC-32	~0	675
	Natural Refrigerants		
xvi)	Carbon dioxide (CO_2)	0	1.0
xvii)	Ammonia (NH_3)	0	0
xviii)	Propane	0	3

4 PLANNING

4.1 Fundamental Requirements

4.1.1 The objective of installing air conditioning, heating and mechanical ventilation in buildings shall be to provide comfortable conditions without compromising on health and safety of occupants.

4.1.2 Ventilation and air conditioning installation shall aim at controlling and optimizing following factors in the building:

a) Air quality
b) Air movement,
c) Dry-bulb Temperature,
d) Relative humidity,
e) Noise and vibration,
f) Energy efficiency, and
g) Fire safety.

4.1.3 All plans, design drawings, 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').

4.1.4 The plans and design drawings 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) use of building;
d) orientation: north direction on plans and design drawings;
e) general plans: dimensions and height of all rooms;
f) intended use of internal spaces;
g) detail or description of wall construction, including insulation and finish;
h) detail or description of roof, ceiling and floor construction, including insulation and finish;
j) detail or description of windows and outside doors, including sizes, weather stripping, storm sash, sills, storm doors, etc;
k) internal equipment load, such as number of people, motor, heaters and lighting load;
m) layout showing the location, size and construction of the HVAC equipments being installed;
p) information regarding air distribution system;

q) information on air and water flow rates;
r) information regarding location and accessibility of shafts;
s) information regarding type and location of dampers (both volume control & fire/smoke dampers) used in air conditioning system, such as, whether motorized or manually operated;
t) location and grade of the required fire separations;
u) water softening arrangement; and
v) information on presence of any chemical fumes or gases.

4.2 Preplanning

4.2.1 *Design Considerations*

4.2.1.1 Cooling and heating load estimate shall be carried out prior to design and installation of comfort equipment. Calculation of cooling and heating load shall take into account the following factors:

a) Recommended indoor temperature, relative humidity, air velocity, mean radiant temperature, clothing and activity;
b) Outside design conditions as specified in **5** of this chapter;
c) Details of building construction and orientation of exposures of building components;
d) Fenestration area and shading factors;
e) *Occupancy* – Number of people and their activity;
f) *Ventilation* – Requirement for fresh air;
g) Infiltration, air leakage;
h) *Internal Load* – Lighting and other heat generating sources like computers, equipment and machinery;
i) Effective volume; and
j) Occupancy, lighting and equipment schedule.

4.2.1.2 The design of air conditioning, heating and mechanical ventilation system and its associated controls shall also take into account the following:

a) Nature of application,
b) Permissible control limits,
c) Fire safety
d) Opportunities for heat recovery,
e) Energy efficiency,
f) Filtration standard,
h) Hours of use,
j) Suitable diversity factor based on usage, and
k) Outdoor and indoor air quality.

4.2.1.3 Due consideration shall also be given to air conditioning load encountered during off-peak hours including night time and weekend/holidays.

4.2.1.4 Consideration shall be given to future permanent or temporal changes in building load and the system shall be so designed that maximum operational efficiency is maintained.

4.2.1.5 Special applications like hospitals/operating theatres, computer rooms, clean rooms, laboratories, libraries, museums/art galleries, sound recording studios, etc shall be handled differently.

4.2.1.6 Computer based hourly load calculation and energy simulation tools should be used for HVAC equipment sizing and to identify effect of various energy conservation measures on energy consumption.

4.2.2 *Equipment Room for Central Air Conditioning Plant*

4.2.2.1 This room shall be located as centrally as possible with respect to the area to be air conditioned, in close proximity to main electrical supply room and free from obstructing columns. The clear headroom below soffit of beam should be minimum 4.5 m for larger capacity chillers (500 TR and above) and minimum 3.6 m for smaller plants.

4.2.2.2 The floors of the equipment rooms should be finished smooth. For floor loading, the air conditioning engineer should be consulted (*see also* Part 6 'Structural Design', Section 1 'Loads, Forces and Effects').

4.2.2.3 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.

4.2.2.4 Equipment rooms, wherever necessary, shall have provision for mechanical ventilation. In hot climate, evaporative air-cooling or air-conditioning may also be considered.

4.2.2.5 Plant machinery in the plant room shall be placed on plain/reinforced cement concrete foundation and provided with anti-vibratory supports or alternatively on inertia bases. Supports for appliances shall be designed and constructed to sustain vertical and horizontal loads within the stress limitations specified in the Part 6 'Structural Design'. All foundations should be protected from damage by providing epoxy coated angle nosing. Seismic restraints requirement should also be considered.

4.2.2.6 Equipment room should preferably be located adjacent to external wall to facilitate equipment movement and ventilation.

4.2.2.7 Acoustic treatment should be provided in plant room space to prevent noise transmission to adjacent occupied areas.

4.2.2.8 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.

4.2.2.9 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.

4.2.2.10 *Thermal energy storage*

Thermal storage should be used for controlling peak electricity load, reducing chiller capacity, and to take advantage of high system efficiency during low ambient conditions.

In case of central plants, designed with thermal energy storage, its location shall be decided in consultation with the air conditioning engineer. 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.

4.2.3 *Equipment Room for Air Handling Units and Package Units*

4.2.3.1 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').

4.2.3.2 In the case of large and multi-storeyed 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.

4.2.3.3 Provision shall be made for the entry of outdoor ventilation air into air handling unit room. The outdoor air intake shall have louvers having rain protection profile, with volume control damper, pre-filter and bird screen. It is desirable to install airflow quantity measurement stations for modulation.

4.2.3.4 In all cases, outdoor 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.

4.2.3.5 Exterior openings for outdoor air intakes and exhaust outlets shall be shielded from weather and insects.

4.2.3.6 No exhaust air from any dwelling unit shall be circulated directly or indirectly to any other dwelling unit, public corridor or public stairway.

4.2.3.7 All air handling rooms should 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.

4.2.3.8 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.

4.2.3.9 Waterproofing of air handling unit rooms shall be carried out to prevent damage to floor below.

4.2.3.10 The floors should be finished smooth. For floor loading, the air conditioning engineer should be consulted (*see also* Part 6 'Structural Design', Section 1 'Loads, Forces and Effects').

4.2.3.11 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/smoke dampers at air handling unit room wall crossings.

4.2.3.12 The air handling unit rooms may be acoustically treated, if located in close proximity to occupied areas.

4.2.3.13 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.

4.2.3.14 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.

4.2.3.15 For all buildings, care should be taken for providing outdoor air intakes in air handling unit rooms. Fire isolation shall be provided for vertical fresh air duct, connecting several floors.

4.2.3.16 It is desirable that floor mounted air handling unit with fire barriers at fire separations or individual ceiling mounted air handling unit should be installed for each fire compartment.

4.2.4 *Pipe Shafts*

4.2.4.1 The shafts carrying chilled water pipes should be located adjacent to air handling unit room or within the room.

4.2.4.2 Shaft carrying condensing water pipes to cooling towers located on terrace should be vertically aligned.

4.2.4.3 All shafts shall be provided with fire barrier at floor crossings (*see* Part 4 'Fire and Life Safety').

4.2.4.4 Access to shaft shall be provided at every floor.

4.2.4.5 In case of tall buildings, care shall be taken for expansion/contraction of pipes while planning the supports.

4.2.5 *Supply Air Ducts and Return Air Ducts*

4.2.5.1 Duct supports, preferably in the form of fully threaded rods/angles of galvanized steel/aluminum construction using stud anchors shall be provided on the ceiling slab from the drilled hole. Alternately, duct supports may be fixed with internally threaded anchor fasteners and threaded rods without damaging the slabs or structural members.

4.2.5.2 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. Flexible ducts may be used for making the final connections.

4.2.5.3 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').

4.2.6 *Cooling Tower*

4.2.6.1 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 shall be installed at a place where free flow of atmospheric air is available.

4.2.6.2 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.

4.2.6.3 *Selection of cooling tower*

Following factors shall be considered for selection of cooling tower:

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.

4.2.6.5 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/TR
b) Mechanical draft cooling tower	0.07 to 0.10 m^2/TR

4.2.6.6 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.

4.2.6.7 Special care should be taken in design where noise to the adjoining building is to be avoided.

4.2.6.8 Certain amount of water is lost from circulating water in the cooling tower, as given below:

a) *Evaporation loss* – It is usually about 1 percent of the rate of water circulation.
b) *Drift loss* –The drift loss shall be below 0.1 percent of rate of water circulation.
c) *Blow-down/bleed-off* –The amount of blow-down shall be below 0.8 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.

4.2.6.9 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.

4.2.6.10 Make-up water having contaminants or hardness, which can adversely affect the refrigeration plant life, shall be treated. Treated water where hardness as ppm of $CaCO_3$ is reduced to 50 ppm or below is recommended for air conditioning applications. Water with *p*H value less than 5 shall also need to be treated.

4.2.6.11 Cooling tower should be so located as to eliminate nuisance from drift to adjoining structures.

4.2.7 *Building Envelope*

The envelope of the building including wall, roof and fenestration shall be planned as per Part 11 'Approach to Sustainability'. Designers shall aim for energy efficient building with the right blend of passive and active design strategies to minimize the energy use while keeping people comfortable as per adaptive thermal comfort requirement.

5 OUTDOOR DESIGN CONDITIONS

5.1 The outdoor design conditions shall be taken in accordance with Table 2. Values of ambient dry-bulb temperatures 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 h, 88 h and 175 h respectively 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 of 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.

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 conditions, values under 1.0 percent column should be used for cooling loads and 99 percent column for heating loads. For critical applications, values under 0.4 percent column should be used for cooling loads and 99.6 percent column for heating loads.

Table 2 Summary for Outdoor Design Conditions
(*Clause* 5.1)

Location	Heating DB		Cooling DB/MCWB						Evaporation WB/MCDB			
	99.60%	99.0%	0.40%		1.0%		2.0%		0.4%		1.0%	
			DB	MCWB	DB	MCWB	DB	MCWB	WB	MCDB	WB	MCDB
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Ahmedabad	11.0	12.3	42.1	23.0	41.0	22.8	39.9	22.9	28.5	33.7	28.0	32.7
Akola	12.9	14.1	43.2	22.0	42.0	21.7	40.9	21.5	26.8	34.3	26.2	32.1
Allahabad	7.9	9.1	43.7	23.4	42.2	23.5	40.8	22.7	28.8	33.0	28.4	32.8
Amritsar	2.0	3.2	42.2	23.8	40.9	23.6	39.2	23.5	29.1	33.9	28.7	33.6
Aurangabad	10.6	12.0	40.2	22.6	39.2	22.7	38.2	22.4	26.6	35.2	25.7	33.1
Barmer	9.5	10.7	43.1	24.2	42.0	23.6	41.0	23.3	28.5	37.9	27.8	35.3
Belgaum	13.3	14.5	36.4	19.2	35.4	19.3	34.4	19.4	24.0	29.3	23.6	28.4
Bangalore	15.2	15.9	34.2	19.8	33.4	19.8	32.6	19.8	23.6	28.9	23.1	28.3
Bhagalpur	11.4	12.6	42.4	26.8	40.7	27.4	38.9	25.6	30.0	37.1	29.6	36.4
Bhopal-Bairagarh	10.0	11.2	41.8	21.6	40.6	21.4	39.4	21.3	26.2	31.5	25.8	30.7
Bhubaneshwar	14.0	15.1	38.6	26.6	37.3	26.6	36.2	26.5	29.4	34.1	29.0	33.6
Bhuj	8.0	9.8	41.0	23.9	39.7	23.8	38.5	23.9	28.8	34.8	28.3	33.8
Bikaner	5.6	7.0	44.2	21.3	42.9	22.0	41.6	22.3	28.2	34.4	27.6	33.8
Madras-Minambakkam	19.9	20.8	38.7	25.9	37.2	25.8	36.2	25.8	28.4	33.1	28.0	32.3
Chitradurga	15.8	17.0	36.2	20.8	35.4	20.8	34.6	20.9	25.5	31.4	24.7	30.4
Dehradun	5.3	6.4	37.7	21.6	36.2	21.3	34.7	21.4	26.8	30.3	26.4	29.9
Dibrugarh	7.5	8.7	34.0	27.0	33.2	26.8	32.3	26.7	28.3	32.6	27.8	27.8
Gorakhpur	7.9	9.0	41.4	26.2	40.3	26.0	39.1	26.4	29.9	35.2	29.7	35.5
Guwahati	10.8	11.8	34.5	26.5	33.6	26.5	32.8	26.5	28.7	32.7	28.2	31.9
Gwalior	6.0	7.1	43.7	22.0	42.6	22.3	41.3	22.2	28.2	32.9	27.8	32.2
Hissar	6.1	7.2	44.6	23.8	43.2	23.9	41.7	24.0	29.1	35.7	28.7	35.2
Hyderabad-AP	13.9	15.1	40.2	21.8	39.1	21.7	38.0	21.8	25.7	31.5	25.1	30.8
Imphal	3.9	5.0	31.1	23.3	30.2	23.5	29.6	22.9	25.0	29.5	24.6	28.6
Indore	9.1	10.4	40.8	19.7	39.6	19.8	38.4	19.7	25.6	30.3	29.6	25.1
Jabalpur	8.4	9.6	42.4	20.7	41.1	20.7	39.7	21.0	26.7	31.4	26.2	30.4
Jagdelpur	9.9	11.2	39.3	22.5	38.0	22.6	36.8	22.5	26.3	31.5	25.7	30.5
Jaipur-Sanganer	7.2	8.6	42.5	21.3	41.2	21.3	40.0	21.3	27.5	31.2	27.0	30.9
Jaisalmer	8.4	9.7	43.5	23.9	42.3	23.8	41.1	23.8	28.0	35.3	27.5	34.8
Jamnagar	10.0	11.7	37.1	24.4	36.1	25.6	35.3	25.1	29.2	33.0	28.4	32.5
Jodhpur	8.8	10.1	42.7	21.2	41.4	21.6	40.2	21.8	27.5	32.4	27.1	32.1
Jorhat	9.6	10.6	34.4	28.2	33.6	27.7	32.9	27.3	28.7	32.7	28.3	32.7
Calcutta-Dum-Dum	11.5	12.7	37.4	27.0	36.3	27.0	35.4	26.8	29.6	34.5	29.1	33.8
Kota	9.9	10.8	43.5	23.0	42.4	22.6	41.2	22.6	27.3	35.2	26.8	33.0

Kurnool	17.0	18.0	41.5	23.0	40.5	23.1	39.4	22.9	26.2	33.7	25.8	32.9
Lucknow-Amausi	6.9	8.1	42.1	22.8	40.8	22.8	39.2	23.5	29.2	33.8	28.8	33.2
Mangalore	20.6	21.4	34.3	24.9	33.8	24.9	33.2	24.7	27.1	31.3	26.7	30.8
Bombay-Santa Cruz	16.8	18.0	35.9	22.7	34.9	23.1	33.9	23.4	27.7	31.2	27.4	30.9
Nagpur-Sonegaon	11.8	13.0	43.9	22.5	42.8	22.4	41.4	22.2	27.4	32.3	26.8	31.6
Nellore	20.4	21.1	40.7	26.8	39.2	27.1	38.0	26.9	29.0	35.8	28.5	34.9
New-Delhi-Safdarjung	6.2	7.2	42.2	22.7	40.7	22.9	39.4	23.1	28.7	34.0	28.2	33.4
Panjim	19.7	20.4	34.1	25.6	33.5	25.6	33.0	25.5	28.2	31.9	27.7	31.3
Patna	8.2	9.3	41.0	23.4	39.5	23.4	37.9	23.8	28.9	33.7	28.6	33.0
Pune	9.7	10.9	38.1	19.7	37.1	19.6	36.0	19.7	24.6	29.8	24.2	29.0
Raipur	11.3	12.6	43.6	23.3	42.2	23.3	40.8	23.0	27.1	31.8	26.8	32.0
Rajkot	11.9	13.4	41.1	22.2	40.0	22.0	38.9	22.6	27.9	33.4	27.4	32.2
Ramagundam	12.5	13.7	43.4	25.6	42.2	25.1	40.7	25.8	28.3	37.3	27.9	35.6
Ranchi	9.1	10.4	38.9	22.1	37.7	21.8	36.4	21.5	26.2	31.7	25.6	30.4
Ratnagiri	18.2	19.2	34.1	22.8	33.3	23.2	32.7	23.5	27.2	30.6	27.0	30.3
Raxaul	7.5	8.5	38.6	23.1	36.9	24.5	35.5	24.6	28.9	33.0	28.4	32.0
Saharanpur	1.7	3.0	41.3	23.8	39.6	24.6	38.1	24.0	28.5	33.6	28.1	32.9
Shillong	-1.0	0.1	24.2	19.7	23.5	19.4	22.8	18.9	20.7	23.3	20.3	22.7
Sholapur	15.9	17.1	41.1	22.2	40.1	22.5	39.0	22.3	26.6	33.1	25.9	32.1
Surat	14.4	15.6	37.8	22.5	36.4	22.9	35.2	23.1	28.1	31.9	27.7	31.4
Sundernagar	1.8	2.8	36.1	19.1	34.6	19.6	33.1	19.4	25.2	30.1	24.8	29.2
Tezpur	10.5	11.4	34.2	27.4	33.3	26.5	32.5	27.1	28.9	32.8	28.4	31.8
Thiruvanantha-puram	22.1	22.7	33.8	25.8	33.2	25.7	32.8	25.6	27.6	31.7	27.2	31.2
Tiruchchirapalli	20.0	20.8	39.0	25.8	38.1	25.7	37.3	25.5	27.8	35.0	27.2	34.1
Varanasi	7.8	8.9	43.0	22.5	41.8	22.7	40.1	23.2	28.9	33.8	28.6	33.2
Veraval	15.0	16.2	34.8	23.6	33.7	25.5	33.0	26.3	29.3	32.1	29.0	31.7
Visakhapatnam	20.1	20.8	33.7	27.0	32.9	27.5	32.3	27.3	29.1	32.0	28.7	31.6

NOTE — Abbreviations used:

DB — Dry-bulb temperature
WB — Wet-bulb temperature
MCDB — Mean coincidental dry-bulb temperature
MCWB — Mean coincidental wet-bulb temperature

6 INDOOR DESIGN CONDITIONS

6.1 Heating, ventilating and air conditioning systems (HVAC) is employed to achieve thermal comfort inside building, when means to achieve the same only through building design is limited. Following six primary factors should be addressed when defining indoor thermal comfort conditions:

a) Metabolic rate,
b) Clothing insulation,
c) Air temperature,
d) Radiant temperature,
e) Air speed, and
f) Humidity.

There are number of secondary parameters also which are important to define thermal comfort conditions such as, radiative temperature asymmetry, temperature gradient, and draught rate.

6.2 Design of Indoor Conditions as per Adaptive Thermal Comfort Model

Design based on an adaptive thermal comfort model can play a major role in reducing energy use whilst maintaining the comfort, productivity and well-being of occupants. This approach recognizes that people's thermal comfort needs depend on their past and present context and that these needs vary with the outdoor environmental conditions of their location. People living year-round in air-conditioned spaces are likely to develop high expectations for homogeneity and cool temperatures, and may become quite critical if thermal conditions deviate from the center of the comfort zone they have come to expect. In contrast, people who live or work in naturally ventilated buildings, are able to control their immediate interior spaces, get accustomed to variable indoor thermal conditions that reflect local patterns of daily and seasonal climate changes. Their thermal perceptions, preferences as well as tolerances are likely to extend over a wider range of temperatures. It allows buildings to operate within broader temperature bands. The specification of a broader comfort band suited to the Indian context has the potential to reduce the use of energy intensive space cooling for Indian buildings.

Theories deals with adaptive thermal comfort model which differentiate the thermal response of occupants in air conditioned and naturally ventilated buildings. It is imperative to specify indoor comfort conditions separately depending upon operation of building – air conditioned buildings as well as naturally ventilated buildings.

Operative temperature is more suitable index to measure thermal comfort in the building having low indoor air velocities, since the index also accounts for impact of building surface temperatures (radiant temperatures) on human comfort. Indoor operative temperature, for sedentary activities, can be approximated as an arithmetic mean of indoor air and radiant temperatures. For operating air conditioning system based on operative temperature, the prevalent conditions along with the historical outdoor trend can be used to derive suitable operative temperature limits. Statistically analyzed typical climatic conditions of various Indian locations is in public domain.

In case of buildings having higher indoor air velocity (more than 0.5 m/s), effective temperature based approach is recommended since in addition to all factors considered in operative temperature, it also takes into account heat dissipation from human body through convective heat transfer. High air velocity can give opportunity of keeping higher air temperature without compromising thermal comfort. However, it is also suggested to keep under consideration noise and other effect of high indoor air velocity. For reference, the comfort conditions range derived as per adaptive model for Indian cities may be seen. These are indicative simplified values using weather files. More accurate design conditions can be derived using following equations.

a) *For Naturally Ventilated* (NV) *Buildings*:

The following equation should be used for design and operation of naturally ventilated (NV) buildings. It indicates that occupants in NV buildings thermally adapt to the outdoor temperature of their location. It is based on the 30-day outdoor running mean temperature (in °C).

Indoor Operative Temperature = (0.54 x outdoor temperature) + 12.83

Where, indoor operative temperature (in °C) is neutral temperature, and outdoor temperature is the 30-day outdoor running mean air temperature (in °C).

The 90 percent acceptability range for the India specific adaptive models for naturally ventilated buildings is ± 2.38°C.

b) *For Mixed-Mode (*MM*) Buildings*:

Mixed-mode buildings, where HVAC is operated only during extreme outdoor conditions, are becoming prevalent in India. The occupants in mixed-mode buildings are more adaptive when compared to those in air conditioned buildings and somewhat less adaptive compared to occupants in naturally ventilated buildings.

Indoor Operative Temperature = (0.28 x outdoor temperature) + 17.87

Where indoor operative temperature (in °C) is neutral temperature and outdoor temperature is the 30-day outdoor running mean air temperature (in °C).

The 90 percent acceptability range for the India specific adaptive models for mixed-mode buildings is ± 3.46°C.

c) *For Air Conditioned (AC) Buildings*:

Studies shows that static Predictive Mean Vote (PMV) model over-predicts the sensation on the warmer side of the 7-point sensation scale in air conditioned buildings. One of the two methods should be adopted while determining indoor conditions of fully air-conditioned buildings. One of these methods is based on air temperature and the other is based on standard effective temperature (SET) which includes effect of body surface area, relative humidity (RH), air velocity

(V_a), air temperature (T_a), radiant temperature (T_r), outdoor temperature (T_{out}), clothing insulation (*Clo*) and activity rate (MET).

1) *Air temperature based approach*:

Indoor Operative Temperature = (0.078 x outdoor temperature) + 23.25

Where indoor operative temperature (in °C) is neutral temperature and outdoor temperature is the 30-day outdoor running mean air temperature (in °C).

The 90 percent acceptability range for the adaptive models for conditioned buildings is ±1.5°C.

2) *Standard Effective Temperature Based Approach*:

Indoor Operative Temperature = (0.014 x outdoor temperature) + 24.53

Where indoor operative temperature (in °C) is neutral temperature and outdoor temperature is the 30-day outdoor running mean air temperature (in °C).

The 90 percent acceptability range for the adaptive models for conditioned buildings is ±1.0°C.

Above equations are not applicable for outdoor running mean temperatures below 15°C.

3) *Minimum Outside Fresh Air*

The fresh air supply is required in fully air conditioned building to maintain an acceptably non-odorous atmosphere by diluting body odorous and tobacco smoke and to dilute the carbon dioxide exhaled. This quantity should be quoted per person and is related to the occupant density and activity within the space. Table 3 gives minimum fresh air supply rates for fully mechanically ventilated or air conditioned space. Naturally ventilated spaces and mixed mode spaces while getting operated in naturally ventilated mode will have to rely on outdoor air using fenestration systems. The quantity and distribution of introduced fresh air should take into account the natural infiltration of the building.

The proportion of fresh air introduced into air conditioned building may be varied to achieve economical and efficient operation. When the fresh air can provide a useful cooling effect the quantity shall be controlled through air side economizer 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.

Table 3 Outdoor Air Requirements for Ventilation[1)] for Air Conditioned Commercial spaces
[*Clause* 6.2(c)(3)]

Sl No.	Application	Outdoor Air Requirement		Remarks
		l/s/person	(l/s)/m^2	
(1)	(2)	(3)	(4)	(5)
i)	**Commercial dry cleaner**	15		
ii)	**Food and Beverage Service**			
	Dining rooms	10		
	Cafeteria, fast food	10		
	Bars, cocktail lounges	15		Supplementary smoke removal equipment may be required.
	Kitchen (cooking)	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	8		
	Conference rooms	10		
	Assemble rooms	8		
	Dormitory sleeping areas	8		*See also* food and beverage services, merchandising, barber and beauty shops, garages, offices.
	Office space	10		Some office equipment may require local exhaust.
	Reception areas	8		
	Telecommunication centres and data entry areas	10		
	Conference rooms	10		
iv)	**Public Spaces**			
	Corridors and utilities		0.25	
	Public restrooms, (in 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.
v)	**Retail stores, sales, floors, and show room floors**			
	Basement and street		1.50	
	Upper floors		1.00	
	Storage rooms		0.75	

	Dressing rooms		1.00	
	Malls and arcades		1.00	
	Shipping and receiving		0.75	
	Warehouses		0.25	
	Smoking lounge	30		Normally supplied by transfer air, local mechanical exhaust; exhaust with no re-circulation recommended.
vi)	**Specialty Shops**			
	Barber Shop	8		
	Beauty Parlour	13		
	Florists	8		Ventilation to optimize growth may dictate requirements.
	Clothiers, furniture		1.50	
	Hardware, drugs, fabric	8		
	Supermarkets	8		
	Pet shops		5.00	
vii)	**Sports and Amusement**			
	Spectator areas	8		When internal combustion engines are operated for maintenance of playing surfaces, increased ventilation rates may be required.
	Game rooms	13		
	Ice arenas (playing areas)		2.50	
	Swimming pools (pool and deck area)		2.50	Higher values may be required for humidity control.
	Playing floors (gymnasium)	10		
	Ballrooms and discos	13		
	Bowling alleys (seating area)	13		
viii)	**Theatre**			
	Ticket booths	10		
	Lobbies	10		
	Auditorium	8		
	Stages, studios	8		Special ventilation will be needed to eliminate special stage effects (for example, dry ice vapours, mists, etc.)
ix)	**Transportation**			
	Waiting rooms	8		Ventilation within vehicles may require special consideration.
	Platforms	8		
	Vehicles	8		
x)	**Workrooms**			
	Meat processing	8		Spaces maintained at low temperature at (-10^{o}F to + 50^{o}F or - 23^{o}C to + 10^{o}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	8		
	Darkrooms		2.50	

	Pharmacy	8		
	Bank vaults	8		
	Duplicating, printing		2.50	Installed equipment shall incorporate positive exhaust and control (as required) of undesirable contaminants (toxic and otherwise).
xi)	**Education**			
	Classrooms	8		
	Laboratories	10		Special contaminant control systems may be required for processes or functions including laboratory animal occupancy.
	Training shop	10		
	Music rooms	8		
	Libraries	8		
	Locker rooms		2.50	
	Corridors		0.50	
	Auditoriums	8		
xii)	**Hospital, Nurses and Convalescent Homes**			
	Patient rooms	13		Special requirements or codes provisions and pressure relationships may determine minimum ventilation rates and filter efficiency.
	Medical procedure	8		
	Operating rooms	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	8		
	Correctional Cells	10		
	Dining halls	8		
	Guard stations	8		
xiii)	**Smoking lounges**	30		Normally supplied by transfer air. Local mechanical exhaust with no recirculation recommended.

[1)] This table prescribes supply rates of acceptable outdoor air required for acceptable indoor air quality. These values have been prescribed to dilute human bio effluents and other contaminants with an adequate margin of safety and to account for health variations among people and varied activity levels.

6.3 Indoor Air Quality

Indoor air quality (IAQ) is the quality of air which affects our comfort and health. This is most directly related to health and may result in sick building syndrome (SBS). Poor indoor air quality will result in severe and recurring discomforts such as nausea, headaches, cold, dry mucous, inflamed membrane eye, nose and throat irritation, drowsiness, fatigue, dry skin and respiration problems.

6.3.1 *Measure of Indoor Air Quality*

Carbon dioxide is used as a surrogate ventilation index for diagnosing the ventilation efficiency in an air-conditioned area. The measurement of carbon dioxide inside a conditioned area is an indicator of IAQ.

Indoor carbon dioxide concentrations should be less than 700 ppm above the outdoor concentration, so that the comfort (odour) criteria with respect to human bio-effluents may be satisfied.

6.3.2 *Components of Acceptable IAQ*

Acceptable IAQ is typically not achieved by addressing any one specific building product, system or procedure. Rather, it is the result of careful attention to each of the following fundamental elements:

a) Containment source control;
b) Proper ventilation;
c) Humidity management; and
d) Adequate filtration.

Controlling the source of contaminants is fundamental to any IAQ strategy. Indoor contamination can also be in the form of particles or chemicals that may come from occupants and their activities. Contaminants from stationery local sources within the space should be controlled by collection as close to the source as practical and its removal from there itself. In some cases such as volatile organic compounds (VOCs), where collection close to sources is not possible, dilution with clean outdoor air should be adopted as the most practical and cost effective solution.

Microbial contamination (fungi and bacteria) can also be a major source of indoor contamination. When mold spores and other microbiological particles become airborne, occupants may experience allergic reactions and will result in offensive odours through the building. Proper design and selection of the air conditioning system should prevent the issues related to microbial contamination. Indoor humidity levels over 60 percent RH for periods as short as 24 h can support the growth of some forms of mold and fungi and should therefore be avoided.

6.3.3 *Subject to be Managed at Contamination Source*

These should be managed by separate management system, such as the following:

a) *Photocopying machines, ammonia-printing machines* — use local exhaust system to exhaust from such equipment.
b) *Fibrous insulating materials* — may be avoided.
c) *Formaldehyde from reconstituted wood and other lignocellulosic products* — use of alternative materials may be considered.

6.3.4 *Subject to be Managed at Operation and Maintenance Stage*

a) Ensure that the chilled water temperature is adequate or the refrigerant charge is adequate in the case of DX system. Avoid high humidity inside the conditioned area due to improper dehumidification.

b) Mildew and mold spores from the damp corners or on false ceiling, damp carpeting and office furniture where there is water leakage from the air-conditioning units: it shall be ensured that there is no leakage from the drain pan of the units or no condensation on the chilled water/refrigerant pipes and valves by properly insulating the same.

c) Generation of fumes inside the conditioned area: use ionizers.

d) The air handling unit rooms shall not be used as a storage space for storing files and waste materials.

e) *Dirty supply air ducts, dirty false ceiling and return air space, dirty filters, dirty water accumulation or standing water in the drain pans, dirty cooling coils, dirty water in the air coolers and evaporative cooling plants, virus, bacteria, fungus from the air handling unit and drain pan of the air handling units, etc* — Planned operation and preventive maintenance shall be implemented to avoid such issues.

6.3.5 *Pre-Occupancy Purge of Contamination*

Pre-occupancy purge shall be carried out to assure that contaminants that may build up during unoccupied periods are removed prior to occupancy.

7 DESIGN OF AIR CONDITIONING

7.1 General

Systems for air conditioning need to control temperature, humidity and air quality within predetermined limits throughout the year. Systems for air conditioning may be grouped as all-air type, air and water type, all water type or unitary type. Suitability of system type cannot be generalized, it needs to be building specific decision considering, initial cost, efficiency, maintenance, effect on building aesthetics, noise, service life and other factors. Lower operating costs and central maintenance and control are primary considerations. Designers may select centralized systems that comprise DX units or chillers and cooling towers (as applicable) away from occupied spaces. This mitigates noise impacts. The heating application may require heat pumps or boilers. These systems often require a greater first cost than distributed systems but often result in annual energy savings because additional benefits include the ability to reduce installed capacity by using load diversity. Centralized cooling systems usually prove to be more cost-effective when the total building load exceeds 100 TR, depending on climate and patterns of occupancy use. Central heating systems are desirable in heating applications in many building sizes since they can provide better close space control and can be used with many terminal unit types.

When low first cost and simplicity are primary concerns, designers may select zone-by-zone distributed systems incorporating either cooling or both heating and cooling capacity. This approach tends to be used for smaller buildings or larger buildings with sufficient roof area. Distributed equipments consists of fan, cooling coil, compressor and outdoor condenser. Examples of distributed systems include unitary air conditioners, packaged rooftop air conditioners, variable refrigerant flows (VRFs) and heat pumps as well as refrigerant-based split-system fan-coil units (single or multi-unit). Water-source heat pumps (WSHPs) are also distributed systems in that the compressor is located close to the occupied space, but they are served by a centralized water system with auxiliary heat rejection devices.

7.2 Design Considerations

7.2.1 *System Analysis and Selection*

For system selection for occupant comfort as defined in **6**, space cooling, heating and ventilation criteria shall be considered and should include the following:

a) Temperature,
b) Humidity,
c) Air motion,
d) Air purity or quality,
e) Air changes per hour,
f) Air and/or water velocity requirements,
g) Local climate,
h) Space pressure requirements,
j) Capacity requirements, from a load calculation analysis,
k) Redundancy,
m) Spatial requirements,
n) Fire safety and security concerns,
p) First cost,
q) Operating cost, including energy and power costs,
r) Maintenance cost,
s) Reliability,
t) Flexibility,
u) Controllability,
v) Life-cycle analysis,
w) Sustainability of design,
y) Acoustics and vibration, and
z) Mold and mildew prevention

7.2.1.1 *Types of systems*

HVAC system selection should be based on the criteria of selection such as close-tolerance, temperature and humidity control. Comparative advantages, disadvantages and constraints of each option should also be evaluated before zeroing down to final HVAC system selection. Table 4 lists out various system characteristics of different HVAC systems and may be used as a tool for system analysis and selection.

Table 4 HVAC System Analysis and Selection Matrix
(*Clause* 7.2.1.1)

Sl No.	System Characteristics	Unitary Systems (Window ACs/Split ACs/ Package ACs)	Unitary Systems (VRF)	Central Systems
(1)	(2)	(3)	(4)	(5)
i)	Temperature	No uniform and effective control	No uniform and effective control	Uniform and effective control possible
ii)	Humidity	Effective control not possible	Effective control not possible	Effective control possible
iii)	Space Pressure	Effective control not possible	Effective control not possible	Effective control possible
iv)	Capacity Requirements	Capacity to suit zone peak, No diversity	Capacity to suit zone peak, Limited diversity	Allows the design engineer to consider HVAC diversity factors that reduce installed equipment capacity
v)	Redundancy	Does not have the benefit of back-up or standby equipment	Does not have the benefit of back-up or standby equipment	Back-up or standby equipment can easily be accommodated
vi)	Facility Management	Does not allow maximize performance using good business/ facility management techniques in operation	Limited possibilities to maximize performance using good business/ facility management techniques in operation	Allows maximize performance using good business/ facility management techniques in operation
vii)	Spatial Requirements	No plant/equipment room required. Compromises building elevation	Outside units can be located on roof or on adjacent ground. Smaller shaft required	Equipment rooms/spaces and shafts required
viii)	Electric Supply	Distributed electric supply required	Zone-wise distributed electric supply required	Minimal distribution cost by centralized supply near to sub-station
ix)	First Cost	Minimum first cost	Medium first cost	Even with HVAC diversity, a central system may not be less costly than decentralized HVAC systems

x)	Operating Cost	Strategically scheduling of multiple pieces of equipment can save operating cost. But equipment is less efficient	Strategically scheduling of equipment can save operating cost. Higher peak energy requirement	More energy-efficient primary equipment and multiple pieces of HVAC equipment allow staging of operation to match building loads while maximizing operational efficiency
xi)	Maintenance Cost	Comparatively less maintenance cost	Comparatively less maintenance cost	Centralised equipment room requires operator with no access to occupant workspace and fewer pieces of HVAC equipment to service
xii)	Reliability	Reliable equipment but low service life	Reliable equipment but low service life	Reliable equipment with longer service life
xiii)	Flexibility	Can be placed at numerous locations	Can be placed at distributed locations	Flexibility available in terms of alternative or backup source
xiv)	Level of Control	Limited control level available	Low control level available	Close control level available
xv)	Noise and Vibration	Noise and vibration within/adjacent to occupied spaces	Noise and vibration on roof terrace or ground away from occupied spaces	Noise and vibration away from occupied spaces
xvi)	Constructability	Multiple and similar-in-size equipment makes standardization a construction feature	Multiple and similar equipment makes standardization a construction feature	Require more coordinated installation with added benefit of consolidated primary equipment in a central location.

When accurate temperature control is needed, constant volume systems shall be used. Dehumidification, return air bye-pass shall be included while designing constant volume system. When using high velocity system, dual ducting shall be provided.

7.2.2 The requirements for equipment/system are given in **7.2.3** to **7.2.15.**

7.2.3 *Chilled Water Optimization —Central Plants and Plant Room Spaces*

7.2.3.1 The equipment selection criteria shall be based on a comprehensive study to evaluate and define the lowest life-cycle cost performance of the chilled water system. The study shall address system components and parameters, such as, chilled water leaving temperature, inlet/outlet temperature differential, cooling water temperature, chilled/condenser water flow, pipe and pump sizes, etc.

While optimizing the chilled water system parameters, special consideration shall be given to spaces requirement.

Space for chillers, pumps, and towers should not only include installation footprints but should also account for adequate clearance to perform routine and major maintenance. A service clearance of 1.2 m or the manufacturer's minimum required clearance for the equipment, whichever is greater, shall be provided around equipment for operator maintenance and service. For chillers, one end of the chiller barrels should be provided with free space the length of the evaporator and condenser barrels, to allow for tube pull clearance. Designers may provide service bay roll-up doors or ventilation louvers to allow tube access. Overhead service height is also required, especially where chillers are installed. Provision for 5 m ceilings in a central plant is recommended, to accommodate piping and service clearance dimensions.

Where boiler installations as well as heating distribution equipment and appurtenances are required, the plant's physical size shall account for the type of boiler and required exhaust emissions treatment, if any.

The relationship between outdoor air intakes and loading docks, exhaust, and other contaminating sources should be considered during architectural planning. The final mechanical room size, orientation, and location shall be established after discussion with the architect and owner. The design engineer should keep the architect, owner, and facility engineer informed about the HVAC analysis and system selection.

All systems should be coordinated during the space-planning stage to safely and effectively operate and maintain the central cooling and heating plant.

For central plants, on-grade should be the first choice, followed by below grade. The designer shall always ensure access for maintenance and replacement.

Winter time cooling requirement in case required, shall also be evaluated before finalizing system/equipment design.

The choice of refrigerant shall be based on guidelines specified in **3**.

7.2.3.2 *Central chilled water plant sizing*

The refrigeration/cooling plant size shall be optimized considering block load of the project and the module selection shall be based on the optimal performance of chillers with ancillary equipment for the entire load profile of the project. The cooling load requirements for special applications where mandated dedicated chillers may be required, shall not be included.

7.2.3.3 *Standby chiller capacity*

For new construction and major renovation projects, the central chilled water plant shall comprise of number of chillers in operation to meet the total cooling demand and one installed standby chiller.

All plant components, chilled water pumps, condenser water pumps, cooling towers and controls shall be sized and selected to match the plant capacity including standby machine.

7.2.3.4 *Liquid chilling machines*

Liquid chilling systems may be based on cool water, brine, or other secondary coolant for air conditioning or refrigeration. The most frequent application is water chilling for air conditioning, although brine cooling for low temperature refrigeration and chilling fluids for thermal storage processes are also becoming common.

The basic components of a vapour-compression, liquid-chilling system include a compressor, liquid cooler (evaporator), condenser, compressor drive, liquid-refrigerant expansion or flow control device and control center; it may also include a receiver, economizer, expansion turbine and/or sub cooler. In addition, auxiliary components may be used, such as a lubricant cooler, lubricant separator, lubricant-return device, purge unit, lubricant pump, refrigerant transfer unit, refrigerant vents, and/or additional control valves. Liquid chilling units are also available incorporating an air cooled condenser.

7.2.3.5 *Vapour compression water chiller*

The unit shall be set down on to a solid foundation on resilient mountings. Pipe connections shall have flexible couplings; these should be considered in conjunction with the design of the pump mountings and the pipe supports.

Capacity control shall be capable 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 and plant optimization system is desirable 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 cooler.

Multiple chiller configuration, same or different size and types shall be used to achieve energy efficiency and system availability at all conditions. System COP shall be the basis for design and selection of equipment.

Power consumption should 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 water chilling packages are classified based on the type of compressor, as given below:

a) *Centrifugal compressors*

These compressors use impellers to impart pressure energy to the refrigerant. These can be modulated down to approaching 20 percent of full load capacity, with some control of the condensing pressure. However, part load operation of centrifugal compressor should be done while avoiding surging of compressor that may damage it if continues to occur.

In order to save energy, centrifugal compressors with variable speed drives should be preferred over fixed speed chillers. VFD's are used on chillers not only to enhance the part load performance but also to act as an alternate for starting the compressor smoothly.

Modern variable speed oil free centrifugal chillers have the shaft with impeller levitated during rotation using digitally-controlled magnetic bearings. This unique feature reduces the friction and heat caused by conventional bearings, adding to the overall high efficiency. It also eliminates the need for lubricating oil and the ancillary components required to support the lubricating oil system, which further improves efficiency.

c) *Screw compressors*

Screw compressors are available in open and semi-hermetic form 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.

Similar to centrifugal compressors, screw compressors with VFD's may be used as an effective way to enhance the part load performance and other benefits such as smooth start.

They are usually used in smaller capacities up to 200TR.

In 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.

d) *Scroll Compressors*

Scroll compressors may be used in residential and small/light commercial air-conditioning. Scroll chillers may be used in smaller sizes less than 120 TR.

e) *Reciprocating compressors*

Due to relatively lower efficiency, reciprocating compressors are nearly phasing out from the comfort air-conditioning application. However, for cold storage and other special purpose applications, they still have importance due to their capacity to offer high pressure ratio.

7.2.3.6 *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 applications where waste heat is readily available. Solar energy assisted air-conditioning/cooling systems also use such systems.

7.2.3.6.1 *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.

7.2.3.6.2 *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 for this; firstly capital costs are higher and secondly the danger to personnel in the event of leakage of the refrigerant.

Direct firing has the advantage that the losses in an indirect heating system are avoided, but in an air conditioning installation where a boiler system is installed to provide heating, the advantage is minimal.

7.2.3.7 *Chilled water system components*

7.2.3.7.1 *Chilled and condenser water pumps*

7.2.3.7.1.1 Radial flow centrifugal pumps are recommended for use in HVAC systems for circulation or transfer of water or water/glycol solutions. The choices available are single inlet/end suction or single inlet/double suction type pumps. Liquid enters through a single inlet with end suction to impeller in end suction pumps while in double suction pumps liquid enters on two sides of the impeller along the shaft. Double suction pumps are self-balancing with reduced impact on bearings, mechanical seal when fluid enters the pump and may be used for larger flows (> 63 lps) requirement. Some smaller end-suction pumps are direct-coupled: the impeller mounts directly on the shaft of a face-mounted motor. A third popular HVAC pump is the in-line centrifugal, in which inlet and discharge piping are in line. Direct coupled pump assemblies and inline pumps may be used for smaller flow applications. Higher flow rates requiring motor sizes above 7.5 kW pumps shall be coupled with high efficiency (Eff1) motors, until the time mono-block pumps up to 7.5 kW are available with motors having Eff1 efficiency.

The split case horizontal pump shall be used in larger applications. These pumps cost higher than other pumps, but are more efficient and the split case allows inspection and maintenance without disturbing the rotor, motor, or the connecting piping. End-suction pumps may be used in smaller applications.

Base-mounted, centrifugal (horizontal or vertical split-case or vertical turbine) pumps are to be provided for chilled water and condenser water applications. In-line pumps may also be used for certain sizes.

Cavitations shall be avoided by selecting suitable location of pump with respect to the cooling tower, meeting net positive suction head (NPSH) requirement of pump.

7.2.3.7.1.2 *Selection criteria*

Pump shall be selected to operate at lowest possible rpm to achieve energy efficiency. Select the operating point at or near the highest efficiency and to the left side of the maximum efficiency point but not more than 5 percent from the maximum efficiency curve. The pump motors shall be non-overloading over the entire range of their operation and compatible with variable speed drives, where such applications are used.

For water pumps, available net positive suction head (NPSH) shall exceed required NPSH to avoid pump cavitation.

7.2.3.7.1.3 *Types of Pumping System*

The possible chilled water recirculation systems are as given below:

a) Constant Speed Pumping System

b) Variable Speed Pumping System (VSPS)

   1) Parallel VSPS configuration
   2) Zoned VSPS configuration
   3) Primary Secondary Tertiary Pumping System (P-S-T)

c) Primary only Variable Speed Pumping System (PVF)

In order to improve energy efficiency of larger systems that, amounts to 5 percent to 9 percent of total energy consumption in a building, glass flake coatings for large size pumps shall be used as it reduces friction and improves efficiency based on life cycle cost assessment.

Chilled water circulation system having pump motor more than 3.7 kW shall be designed for variable fluid flow.

7.2.3.8 *Cooling towers*

7.2.3.8.1 Water is commonly used as a heat transfer medium to remove heat from refrigerant condensers. Cooling towers are used to dissipate heat from air-conditioning systems. The water consumption rate of a cooling tower system is only about 5 percent of that of a once-through system, making it the least expensive system to operate with purchased water supplies. Additionally, the amount of heated water discharged (blow down) is very small, so the ecological effect is greatly reduced. The cooling towers can cool water to within 2 to 3 K of the ambient wet-bulb temperature, which is always lower than the ambient dry-bulb, or approximately 20 K lower than air-cooled systems of reasonable size (in the 880 to 1250 kW range). This lower temperature improves the efficiency of the overall system, thereby reducing energy use significantly.

7.2.3.8.2 *Selection Criteria*

Location of the cooling tower is usually determined by one or more of the following:

a) structural support requirements,

b) rigging limitations,

c) cost of bringing auxiliary services to the cooling tower, and

d) architectural compatibility.

Sound, plume, and drift considerations are also best handled by proper site selection during the planning stage.

Minimum cooling tower efficiency shall be as follows:

1) 350 lpm/HP for 24/7 facilities, and
2) 300 lpm/HP for all others.

Cooling tower approach shall take care of the following requirements:

i) < 2.0°C approach for 24/7 plants, and
ii) < 3.0°C approach for all other applications.

The cooling tower accessories shall be project-specific and shall include such items as walking platform; stairs and ladder safety cage; tower loading and supporting structure; and variable speed drives fan motors.

Cooling tower installations shall include installation of conductivity controller, flow meter on the makeup water line, and overflow alarm.

7.2.3.8.3 *Scale control*

Water treatment is desirable to prevent scaling, corrosion, and biological fouling of the condenser and circulating system. Large systems shall be provided with fixed continuous-feeding chemical treatment systems in which chemicals, including acids for pH control, must be diluted and blended and then pumped into the condenser water system. Corrosion-resistant materials may be required for surfaces that come in contact with these chemicals. In piping system design, provisions for feeding the chemicals, blow downs, drains, and testing must be included. System design may incorporate main/side-stream filtration without/with separate pumping systems.

It is desirable that following methods to control scale formation be used:

a) Limit the concentration of scale-forming minerals by controlling cycles of concentration or by removing the minerals before they enter the system. A cycle of concentration is the ratio of makeup rate to the sum of blow down and drifts rates. The cycles of concentration can be monitored by calculating the ratio of chloride ion, which is highly soluble, in the system water to that in the makeup water. Make mechanical changes in the system to reduce the chances for scale formation. Increased water flow and exchangers with larger surface areas are examples.
b) Feed acid to keep the common scale forming minerals (e.g., calcium carbonate) dissolved.
c) Treat with chemicals designed to prevent scale.

7.2.3.9 *Air handling units*

All-air systems may be adapted to many applications for comfort or process work.

7.2.3.9.1 *Selection criteria*

The designer shall properly determine an air-handling unit's required supply air temperature and volume; outdoor air requirements; desired space pressures; heating and cooling coil capacities; humidification and dehumidification capacities; return, relief, and exhaust air volume requirements; filtration and required pressure capabilities of the fan(s).

The equipment shall be adequate, accessible for easy maintenance and not overly complex in its arrangement and control to provide the required conditions. Face velocity across filter and coil section shall be kept less than 2.0 m/s.

7.2.3.9.2 *Fans*

Fan selection should be based on efficiency and sound power level throughout the anticipated range of operation, as well as on the ability of the fan to provide the required flow at the anticipated static pressure.

7.2.3.9.3 *Cooling coils*

The cooling medium flowing through cooling coils can be either chilled water or refrigerant. In all finned coils, some air passes through without contacting the fins or tubes. The amount of this bypass can vary typically from 10 percent for a four-row coil at 2.0 m/s, to less than 2 percent for an eight-row coil at 1.5 m/s. The dew point of the air mixture leaving a four-row coil might satisfy a comfort installation with 25 percent or less outdoor air (10 percent for humid climates), a small internal latent load, and sensible temperature control only.

7.2.3.9.4 *Reheat coils*

Reheat coils are heating coils placed downstream of a cooling coil. Reheat systems are strongly discouraged, unless recovered energy is used. Positive humidity control is required to provide comfort conditions for most applications. Either reheat or desiccant is usually required to dehumidify outdoor air. Reheating is necessary for laboratory, health care, or similar applications where temperature and relative humidity must be controlled accurately. Heating coils located in the reheat position, are frequently used for warm-up, although a coil in the preheat position is preferable. Hot-water coils provide a very controllable source of reheat energy. Inner-distributing-tube coils are preferable for steam applications.

7.2.3.9.5 *Humidifiers*

Humidifiers shall be installed as part of the air-handling unit, where close humidity control of selected spaces is required. For comfort installations requiring humidity control, moisture can be added to the air by mechanical atomizers or point-of-use electric or ultrasonic humidifiers.

7.2.3.9.6 *Air to air energy recovery devices*

Energy recovery devises shall be used in locations where 50% or more supply air is outdoor air. Sensible heat recovery devices only exchange heat between the two streams of air, whereas enthalpy wheels or commonly called as energy recovery wheels, exchange heat as well as moisture. In cases of high latent loads, enthalpy wheel should be used to save energy.

7.2.3.9.7 *Fan coil units*

Basic components of fan-coil units are cooling coil, filter, fan, and temperature control device. The fan re-circulates air from the conditioned space through the coil, which then transfers heat to or from the air. The fan and motor assembly shall be arranged for quick removal for servicing. If the unit includes a cooling coil, it shall be equipped with an insulated drain pan. The casing shall be internally insulated for both thermal and acoustic considerations.

Fan motor control shall be provided for modulating air delivery and as additional control over cooling and dehumidification. The coil's water valve piping package shall include flow controls (manual or automatic), pressure-independent water valves, strainers, unions, pressure-temperature ports, air vents, flexible connections, drains, and balancing valves.

The hydronic heating and cooling coils may be separate or contained in a single fin pack.

7.2.4 *Chilled Beams/Chilled Slab*

7.2.4.1 *Chilled beams*

Two types of chilled beams, passive and active, are in use. Passive chilled beams consist of a chilled-water coil mounted inside a cabinet. Chilled water is piped to the convective coil at between 14 and 17°C. To ensure proper dehumidification and adequate fresh air delivery to the spaces, passive chilled beams require a separate ventilation system If more ventilation air is needed to meet the space requirements, the volume of air can be split by the active beams and high-induction diffusers. Care must be taken in selecting diffuser locations to coordinate well with the convective currents required by the chilled beams. Overcooling of chilled beams must be avoided during cooling seasons, to prevent discomfort, condensation and microbial growth in spaces.

Active chilled beams operate with induction nozzles that entrain room air and mix it with the primary or ventilation air that is ducted to the beam. Chilled water is piped to the coil at between 13 and 17°C. Primary air should be ducted to the beam at 13°C or lower to provide proper dehumidification. Active beams can have either a two- or four-pipe distribution system. The two-pipe system may be cooling only or two-pipe changeover. Active beams can be designed to heat and cool the occupied space. In all chilled beam installations, flow control valves and chilled water supply temperature reset is to be provided. Vertical chilled beams shall be provided with condensate drain.

7.2.4.2 *Chilled Slab/Ceiling and Radiant Floor*

Radiant cooling and heating systems provide an opportunity to achieve significant energy and peak demand savings compared to conventional all-air systems..

Radiant cooling systems can have circulation of water in pipes or tubes embedded in floor or ceiling or even on other surfaces such as walls. Tubes can also be fitted in raised floor or suspended ceiling, with proper condensate drain, flow and temperature control. Looping of tubes/pipes shall be done for switching on/off cooling in particular area/pocket of the space as per the usage pattern.

Some low-energy cooling strategies such as displacement or natural ventilation, thermal mass, night ventilation shall be combined with radiant cooling to make it more effective.

Since the radiant cooling can take care of only sensible loads, parallel schemes are required for latent loads. These methods may form part of the ventilation strategy such as dedicated outdoor air systems.

Operative temperature or effective temperature approach shall be used while designing these systems.

7.2.5 *Under-Floor Air Conditioning*

Under floor air distribution (UFAD) is an alternate to ceiling/side based overhead air distribution system. UFAD systems have several potential advantages over traditional overhead systems, including improved thermal comfort, improved indoor air quality, and reduced energy use due to delivery of conditioned air right at the occupant level.

Under floor systems are generally configured to have a relatively large number of smaller supply outlets, many in close proximity to the building occupants, as compared to a conventional overhead system. Outlets may be floor diffusers or particularly when part of a task/ambient conditioning (TAC) system, desktop or partition outlets equipped with individual control. Air is returned from the room at ceiling level.

7.2.6 *Piping and Water Distribution System*

7.2.6.1 *Materials*

Steel piping with welded or flanged joints should be used. Dielectric coupling shall be used to avoid corrosion when choosing material combinations.

7.2.6.2 *Design principles*

The system design should achieve the following main objectives.

a) A good distribution of water to the various heat exchangers/cooling coils at all conditions of load with matching temperature, humidity and pressure control strategy.

b) Adequate provision should be made for balancing, measuring flow rates and pressure differentials.

c) Pipe sizing shall be based on balance between operational and capital cost.

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

In a large system when multiple water-chilling packages have to be used, the control of the machines and the arrangement of the water circulation should be considered as an integrated whole

Expansion tank shall be provided to cater to volume changes due to temperature changes in the system. System connection to expansion tank shall never be shut off. To maintain positive pressure during pump off situation, the expansion tank shall be located at highest point. An inert gas pressurized expansion tank may be installed at a lower level. Air separator shall be provided in the chilled water system to improve the life and efficiency of chilled water piping and heat exchange equipment.

Soft water shall be shall be used for central chilled water air conditioning systems, as heat transfer medium to convey the heat from the air-handling units to the primary refrigerant in the evaporator. Special applications with temperature lower than 5 °C shall be provided with additives to depress the freezing point. Next generation fluids should be used to enhance heat exchange efficiency based on nanotechnology to reduce energy consumption.

7.2.6.3 *Piping design*

The water velocity shall be in the range 1m/s to 3m/s. Main headers in the plant room shall be designed for very low velocity around 1 m/s. Velocity in excess of 4m/s should be avoided for acoustic reasons and erosion control.

Friction factor in piping should not exceed 5 m of water for 100 m of pipe length. System design shall be with high temperature to reduce friction by low flow to reduce energy consumption.

7.2.6.4 *Layout considerations*

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

Air vents shall be provided at all high points in the system.

Piping system should be designed to permit proper cleaning and flushing and should include suitable strainers and drain points at appropriate locations.

7.2.7 *Thermal Insulation*

7.2.7.1 Air conditioning and water distribution systems carrying chilled or heated fluids/air shall be thermally insulated to prevent undue heat gain or loss and also to prevent internal and external condensation. Vapour seal shall be provided to avoid possibility of condensation.

7.2.7.2 The thermal insulation material shall be selected based on following physical characteristics:

a) Fire Properties: Insulating materials shall be noncombustible and, in a fire, shall not produce noxious smoke and toxic fumes. Materials and their finishes should inherently be proof against rotting, mould and fungal growth, and attack by vermin and should be non-hygroscopic.

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

c) 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.

d) It should have a low thermal conductivity throughout the entire working temperature range.

e) It should be non-flammable and should not support nor spread fire.

f) It should have good mechanical strength and rigidity otherwise it should be cladded for protection.

7.2.8 *Ductwork, Air Distribution and Fan-System Interface*

7.2.8.1 *Materials*

Ductwork is normally fabricated, erected and finished to the requirements in accordance with accepted standard [8-3(2)]. 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. Special applications may warrant use of stainless steel and mild steel. Wherever, aluminium sheet is used, the same shall conform to 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.

7.2.8.2 *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.

7.2.8.3 *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.

7.2.8.4 *Fan connection to duct system*

The performance of a fan when installed in a system can be adversely affected by the flow conditions at fan inlet and outlet. Manufacturers' fan performance ratings are mostly based on optimum arrangements of fan inlet and outlet connections to provide uniform straight flow condition.

7.2.8.4.1 *Outlet Ducts*

A system designer must closely examine the manufacturer's fan ratings to determine the conditions under which the fan has been tested. Fans intended for supply air applications are normally tested with an outlet duct. To achieve the rated performance for centrifugal fans, it is recommended to connect an outlet duct of one effective duct length (EDL) which is defined as a minimum of 2.5 equivalent duct diameters (EDD). Equivalent duct diameter for a rectangular duct is the diameter of a circular duct having the same cross sectional area as the fan outlet. For fan outlet velocity higher than 12.5 m/s, additional length of one EDD for each 5 m/s increment should be added. The absence of an outlet duct in case of a tube axial fan does not result in any additional pressure losses. However, for a vane axial fan, a minimum of 50 percent EDL is required for them to perform as per the ratings.

7.2.8.4.2 *Outlet duct elbows*

Pressure losses in duct elbows are minimum when air approaching the elbow has uniform velocity profiles. For centrifugal fans, elbows should be mounted after the outlet duct. In case of a tube-axial fan, outlet duct can be installed at fan outlet without causing additional losses. For vane-axial fans also, additional pressure losses can be made negligible by using a 4 pc. mitered elbow and placing it after a minimum of 12% EDL.

7.2.8.4.3 *Volume control dampers (VCDs)*

Manufacture's pressure drop ratings of wide open control dampers are usually based on uniform approach velocity profiles. To achieve these ratings, VCDs should be mounted after the outlet duct specified.

7.2.8.4.4 *Inlet ducts*

Non-uniform flow and swirl at fan inlets is the most common cause of deficient fan performance. The performance of a tube axial fan is severely compromised in the absence of an inlet duct. An inlet duct length equal to one impeller diameter, a bell mouth/conical inlet or a combination of the two is recommended to minimize pressure losses and substantially enhance fan performance.

7.2.8.4.5 *Inlet duct elbows*

Elbows connected at or close to fan inlets make the approach velocity profiles non-uniform. In addition they can cause pressure fluctuations, instability and excessive noise. It is strongly recommended that an inlet elbow be installed at least 3 inlet diameters away for an axial or centrifugal fan. The cross-sectional area of the inlet duct should be within -7.5 percent to +12.5 percent of the fan inlet area. 4 piece mitred elbows are preferred over 2 piece elbows.

7.2.8.5 *Cabinet effects*

Restricted fan inlets as in the case of inlets placed too close to a wall or inside a cabinet adversely impact fan performance. Fans inside plenums/cabinets or next to walls shall be placed so as to allow un-obstructed air flow into fan inlets. A minimum distance of 75 percent of inlet diameter shall be provided between fan inlet and the wall. In case of two or more double inlet double width (DIDW) centrifugal fans placed side by side, a minimum separation of one inlet diameter must be provided between two adjacent inlets. The position of cabinet inlet should be symmetrical with the fan inlet to avoid uneven inlet flow or inlet spin.

7.2.9 *Geothermal Energy*

These systems are largely based upon the fact that temperature inside earth remains almost constant throughout the year at annual mean temperature of that place. Such systems exchange het with ground or an aquifer inside the ground.

GSHP systems consist of three parts namely ground heat exchanger, heat pump unit and air delivery system that is similar to any conventional air-conditioning system.

The ground heat exchanger can be a closed loop laid horizontal, vertical, immersed in pond or lake or even sewer line.

Decision about heat exchanger type shall be taken considering load, soil conditions, available land area and the local installation costs. The same loop works for both heating and cooling

In cooling dominated climates, the depth of the horizontal pipe should be atleast 9 feet to reduce efficiency losses in the late summer due to drying soils. In heating-dominated areas, the depth may be reduced six feet. Antifreeze should be used in cold places. Antifreezes should be biodegradable and present no hazard to the environment. All pipes should have the minimum cell classification number imprinted on the pipe. To create closed-loop systems, pipe and fittings are connected by butt or socket fusion (heat fusion) or stab fittings. Barbed fittings and clamps should not be used as they result in potential leaks and joint failure when used with high density polyethylene pipe.

The pipes are to be pressure tested, then connected to the heat pump inside the building. The trenches are backfilled.

For a vertical ground loop system, multiple boreholes drilled 10 to 15 feet apart and 100 to 400 feet deep depending on the thermal conductivity test (TC Test). Two separate pipe lengths are connected with a U-bend to form a loop, then placed in each borehole and pressure tested. The borehole is backfilled with a grouting material and sealed off at the surface, Vertical loops are tied together with a system of horizontal piping laid in trenches, then connected to the heat pump in the building.

Pond/lake/sewer loops depend on the location of a pond or lake or sewer near the building.

Loop coils should not be placed in a river or a body of water where fluctuating water levels or flood stage conditions could damage the pipe. Pipe is coiled in a fairly large body of water, at least eight feet deep to prevent freezing in winter and exposing of tubes due to shortage of water in summer.

In an open-loop system, once it has circulated through the heat pump, the water is returned to the ground through one of several methods: a recharge well, a drain field or surface discharge.

This option should only be used where an adequate supply of water is available. About three gallons per minute for each ton of heating and cooling is required.

Thermal conductivity and thermal diffusivity tests should be conducted before designing GSHP systems:

a) *GHX TC test equipment* — Thermal conductivity test for vertical or horizontal borehole consists of:

   1) Determining the ambient deep earth ground temperature,
   2) Injecting heat into borehole at known rate (Btu/h or kW),
   3) Determining the ΔT between fluid entering and leaving the GHX, and
   4) Calculating thermal conductivity using the line source method.

b) *Thermal conductivity unit* — It shall consist of:

   1) Circulation pump,
   2) Electric elements,
   3) Entering and leaving water temperature sensors,
   4) Data logger, and
   5) Power supply for electric elements.

c) *Typical TC test results* — A typical TC Test report shows the entering and leaving water temperatures from the U-tube, as well as energy input. Data is typically logged in 1 to 5 minute intervals for the duration of the test. Standard method of testing shall be followed.

7.2.10 *District Cooling*

7.2.10.1 District cooling systems, comprises collective equipment to produce and distribute chilled water. Chilled water is produced by production plants and distributed by water pipes (the distribution network) to buildings equipped with energy transfer stations (sub-stations). The chilled water then supplies some of its cooling to the building's installations. Such cooling system operates in closed-circuit and always includes at least two water pipes; one of which carries the chilled water to the end-user, and the other which carries it back towards the production plant.

In such systems, the thermal energy produced at a central location is then distributed to a set of consumers in Commercial, Residential or Institutional buildings. This enables the consumer to air condition the building without having to install individual cooling (or heating) plants. Principle is similar to distribution of electricity to a number of consumers by an electrical distribution company.

Some of the advantages of district cooling system are as follows:

a) Chilled water could be produced at one dedicated place, using large, highly efficient chillers. User buildings need to provide minimal space for the tertiary equipment and metering.

b) Total installed capacity and peak load of the area covered due to air conditioning gets significantly reduced.

c) Problems of plant operation and maintenance are confined to a centralised location instead of distributing across the district.

d) Since air conditioning plants consume more than 40 percent of electricity in any building, power distribution systems would become lighter and cables sizes smaller.

e) The plant capacity can be substantially pruned, owning to large diversity in the cooling loads due to diverse building usage pattern in district.

f) Problems of noise and vibration are confined to a place where it need not be objectionable.

7.2.10.2 Distribution of insulated chilled water pipes shall follow dedicated routes for easy laying and maintenance. These distribution pipes need adequate space for laying and maintenance and need to be integrated in the district planning.

7.2.10.3 *Co-generation*

Cogeneration is the simultaneous production of electric power and thermal energy in a useful form such as steam, hot water and low temperature water, all from a single energy source such as coal, oil or gas. Such systems are found useful in an establishment where combined heat and power are simultaneously consumed e.g. a factory, a hotel or a hospital where heating by way of steam or hot water or cooling by chilled water is simultaneous with the electric power consumption. Cogeneration systems present a 50% to 70% more efficient utilization of the source energy (i.e) coal, oil or gas. These shall be used with district cooling systems.

7.2.11 *Window Air Conditioner*

7.2.11.1 According to function, unitary air conditioners shall be classified as follows:

a) cooling and dehumidification,
b) cooling and heating by heat pump, and
c) cooling and heating by electric heater.

7.2.11.2 *Suitability*

Unitary air conditioners are suitable for bedrooms, office cabins, general office area, hotel rooms and similar applications where normal comfort conditions are required up to a distance of 6 m from unitary air conditioner.

7.2.11.3 *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.

7.2.11.4 *Location*

Unitary air conditions 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.

Room air conditioners are not recommended in the situations where special applications like sterile rooms for hospitals and clean room applications where high filtration efficiency is desired or in case like operation theatres where 100 percent fresh air is needed and fire hazard exists depending on the type of anesthesia being used. These are also not suitable for areas that require close control of temperature and humidity.

7.2.11.5 For detailed information regarding constructional and performance requirements and methods for establishing ratings of room air conditioners, reference shall be made to the accepted standard [8-3 (4)].

7.2.12 *Split Air Conditioner*

7.2.12.1 It comprises of indoor unit and outdoor unit. The Indoor unit may be mounted on floor or wall or ceiling. The Indoor and Outdoor units consist of compressor, heat exchangers, fan motors and air handling system installed in two separate cabinets. It is designed primarily to provide conditioned air to an enclosed space, room or zone (conditioned space). It includes a prime source of refrigeration for cooling and dehumidification/heating and means for the circulation and filtering of air.

Various types of split air conditioners may be categorized based on type of compressor as below:

a) *Units with variable speed compressor* — These are also called as Inverter AC or Variable speed ACs, which works on part load depending on the demand for the conditioned space connected with or without ducting for air distribution or multiple indoor units connected. This uses a variable-frequency drive to control the speed of the motor and thus changing the frequency of the compressor.

b) Units with fixed speed compressor

Various split air conditioners available may be categorized based on indoor units as below:

a) Duct free indoor unit, which is high wall, cassettes, ceiling suspended exposed type and 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.

7.2.12.2 *Suitability*

Split Air conditioners are suitable for wide range of applications including residences, small offices, clubs, restaurants, showrooms, departmental stores, etc.

7.2.12.3 *Operating parameters*

In General, nominal capacity of all these air conditioners are de-rated due to high ambient temperatures in summer months in most of Indian cities. Also, generally a voltage stabilizer shall be installed to get stabilized rated voltage as per specifications defined by manufacturer. For 3 phase units it is recommended to use phase reversal protector.

7.2.12.4 *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 shall 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.

7.2.12.5 *Installation*

High Wall Indoor and similar structure units are provided with installation plates for ease in installation. Care shall be taken to ensure enough space from ceiling in order to have free intake of air.

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.

The service valves are to be provided for proper pressure testing of the system for leaks, evacuation for moisture and air from the system and to carry out predetermined gas quantity in to the system. Also in case of maintenance of any part, the valves can be isolated for storing the refrigerant within the outdoor unit by pumped down and save the gas.

7.2.12.6 *Limitations*

Split air conditioners are generally not recommended for:

a) Where distance between indoor type unit exceeds maximum of 30m (or higher as per recommendation by manufacturer) from the outdoor unit for units up to 17 500W (5 TR).
   The vertical distance between the indoor unit and the outdoor unit should not exceed 10 m for units with reciprocating compressors and 25 m for units with rotary/scroll compressors. The horizontal distance between the indoor unit and outdoor unit should not exceed 10 m for reciprocating compressors and should not exceed for scroll compressors.
b) Area requiring close control of temperature and relative humidity.
c) Sound recording rooms where criteria for acoustics are stringent.
d) Special applications like sterile rooms for hospitals and clean room applications where high filtration efficiency is desired.
e) Large multi-storey buildings where multiplicity of the compressors may entail subsequent maintenance problems.

7.2.12.7 For detailed information regarding constructional and performance requirements and methods for establishing ratings of split type room air conditioners, reference shall be made to the accepted standard [8-3(5)].

7.2.13 *Packaged Air Conditioner*

7.2.13.1 Packaged air conditioners are self-contained units 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. These machines are equipped with compressor, evaporator, expansion device and remote air cooled condenser or water-cooled condenser with interconnected copper refrigerant piping. It also includes fan driven by motor for circulation of air and filter.

The packaged unit can also be provided with winter heating package or humidification package.

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. The water-cooled condenser unit require cooling tower with necessary piping and pump sets for circulating condenser-cooling water.

Packaged units are generally available with vertical air discharge or horizontal air discharge. Vertical air discharge shll be preferred to avoid heat island effect.

7.2.13.2 *Suitability*

Packaged units are suitable for wide range of applications including offices, clubs and restaurants, showrooms and departmental stores, and banquet halls etc.

7.2.13.3 *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.

7.2.13.4 *Installation*

The packaged units are normally mounted on a resilient pad which prevents vibration of the unit from being transmitted to the building.

7.2.13.5 *Limitations*

Packaged air conditioners 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 approximately.30 m. However duct length provision depends upon external static pressure as specified by the manufacturer.

c) Where the vertical distance of air-cooled condenser from the packaged unit exceeds about 25 m. The sum of horizontal and vertical distances should be generally kept within 30 m.

d) Special applications like sterile rooms for hospitals and clean room applications where high filtration efficiency is desired.
For these applications, special packaged units can be designed with high micron and efficiency filters.

e) Operation theatres where 100 percent fresh air is needed and fire hazard exists depending on the type of anesthesia being used.

7.2.13.6 For detailed information regarding constructional and performance requirements and methods for establishing ratings of packaged air conditioners, reference shall be made to the accepted standard [8-3(6)].

7.2.14 *VRF System*

7.2.14.1 Variable refrigerant flow (VRF) System is direct expansion (DX) multi-split system with variable speed compressor capable of delivering capacity according to variable load requirement. By operating at variable speeds, VRF units delivers required capacity allowing for substantial energy savings at partial-load conditions. VRF system has outdoor unit connected with multiple number of indoor units via refrigerant piping. Some attributes that distinguish VRF system from other DX system are multiple indoor units connected to a common Outdoor unit, scalability, variable capacity, distributed temperature control and heating/cooling mode.

VRF system can have at least one or all variable speed compressor to cater to variable load requirements.

VRF systems achieve temperature control on a zone by zone basis primarily by using refrigerant side control.

As compared to DX systems, VRF Indoor unit has an additional electronic expansion device to control refrigerant flow passing through evaporator coil to control indoor temperature precisely based on instantaneous load requirement. In order to cater to fresh air needs & high air volume requirements, VRF System outdoor unit should be connected with air handling units. A control box equipped with electronic expansion device & communication PCB is needed to connect air handling unit so that it can communicate seamlessly with VRF outdoor unit.

VRF technology comes in two pipe or three pipe system. In a heat pump 2 pipe system, all of the zones must either be in cooling mode or in heating mode. Application requiring simultaneous heating and cooling should have 3 pipe system for enabling heat recovery.

7.2.14.2 *Configuration*

Generally in Air cooled VRF system, top discharge and side discharge outdoor units are available.

VRF system is available with air cooled or water cooled condensers.

7.2.14.3 *Suitability*

VRF system are suitable for wide range of applications including residences, apartments, Villas, small & big offices, clubs, restaurants, showrooms, departmental stores, healthcare facilities, hospitality, cultural facilities, educational facilities and Industrial facilities etc.

In VRF system, depending on application same or different types of indoor units can be connected to a single outdoor unit or multiple outdoor units.

VRF Indoor units & Air Handling Units for fresh air/ re-circulated air treatment can be connected to the same refrigerant line to facilitate more flexible system design in mid & large size applications. However, usage of bigger AHU in VRF systems may have evident effect on the part load energy efficiency advantage of the system. In VRF system line up, Treated Fresh Air (TFA) type indoor units can also available used to connect with VRF outdoor unit to meet fresh air requirement. However for bigger fresh air requirement air handling units are preferred.

Similar to Air handling units, VRF system TFAs can also be connected separately with VRF outdoor unit or may be connected to same refrigerant line in combination with other VRF indoor units.

7.2.14.4 *Controls*

VRF systems usually have factory packaged integral controls in each component that communicates through their system specific protocol to ensure that all system components operate collectively. VRF indoor and outdoor units include refrigerant and air side sensing and control devices which allow the system to optimize its output (compressor speed, discharge temperature, fan speed) based on inputs from controllers. Depending on the application and design, a VRF system is able to operate with many levels of controls. Different types of controllers are available to cater to various requirements which are defined as below:

a) individual/group controllers,
b) centralized controllers,
c) interface with building management system, and
d) remote system monitoring and control.

7.2.14.5 *Individual/group controllers*

VRF indoor units can be controlled individually with wired or wireless individual remote controllers. Control options include ON/OFF, temperature change, mode change, fan speed change etc. Applications such as big common area in which multiple indoor units are running simultaneously at same condition can be controlled by single remote controller by making as a group. All setting conditions remain same for all indoor units connected in a group. Each of the grouped indoor units may operate according to the sensed return air temperature.

7.2.14.6 *Centralized controller*

Centralized controller allows users to operate & monitor multiple indoor units centrally. Besides having all functions of individual remote controllers, additionally centralized controllers have facility of scheduling, energy saving by operation restrictions, web monitoring etc. In some applications, single outdoor unit is used by different tenants connected by different indoor units. In such cases, some of centralized controller offer facility of tenant billing software application depending on individual usage through power proportional distribution.

Some manufacturers offer smart phone application as it provides easy access and human interface to VRF system users. With the help of smart phone app user have the flexibility to operate and monitor the system remotely

7.2.14.7 *Interface with building management system*

VRF system should be integrated with building management system if available, with the use of different interface gateways that communicates with different protocols. With this interfacing it is easy to operate and monitor air conditioning with user’s building management system.

7.2.15 *Evaporative Cooling – Indirect Direct Cooling System*

7.2.15.1 The various components of the indirect-direct cooling system are as follows:

a) Filters;
b) Cooling coil/heat exchanger– for indirect cooling (sensible heat exchanger);
c) Cellulose pads – for evaporative (direct or adiabatic cooling);
d) Fan section with enclosure for fan, filter, heat exchanger, cellulose pads with piping, moisture eliminators and dampers);
e) Cooling tower;
f) Pumps for Heat exchanger and cellulose pads; and
g) Piping with valves and fittings.

7.2.15.2 The indirect cooling can be done by using following systems for dissipating the heat of heat exchanger:

a) through water in open cooling tower;
b) through liquid in closed loop Cooling tower;
c) through liquid in closed loop geothermal system;
d) through water in open loop – lake or pond geothermal system;
e) through specially designed plate type heat exchanger; and
f) through refrigerant circulating in heat exchanger (that is, cooling coil etc) of refrigeration system.

7.2.15.3 This system is more useful in areas having moderate ambient temperature and especially low wet bulb temperature. The system can be used using both stage of cooling during peak summer conditions giving outlet dry bulb lower than ambient wet bulb temperature. In monsoon, only indirect cooling can be used where the moisture is not added in the already moist ambient air

7.2.15.4 It is good practice to have 100 percent fresh air system where during summers in the dry climates, the lower outlet temperature can reduce the amount of air required to dissipate or remove the heat from the enclosed area especially in Industrial applications or applications where only comfortable temperature range is acceptable.

7.2.15.5 The air velocity across cooling surface is recommended between 2 and 2.5 m/s. The lower face velocity, the heat exchange is better while with higher face velocity, it is lower.

7.2.15.6 Saturation efficiency of these indirect/direct coolers are normally higher than 110 percent.

7.2.15.7 For detailed information regarding air capacity, constructional features, performance requirements and methods of testing of evaporative air coolers, reference shall be made to the accepted standard [8-3(7)].

7.3 Application Factors

The general guidance for the factors that usually influence the selection of the type, design and layout of the air conditioning or ventilating system to be used for various applications are covered in **7.3.1** to **7.3.7**.

7.3.1 *Commercial Applications*

The primary objective of the application described under this heading is provision of comfort conditions for occupants.

7.3.2 *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.

Each system or each zone within a system shall be provided with not less than one thermostat capable of being set from 15°C to 30°C and capable of operating the system's cooling and heating. The thermostat or control system, or both, shall have an adjustable dead band, the range of which includes a setting of 12°C between heating and cooling where automatic changeover is provided. Wall-mounted temperature controls shall be mounted on an inside wall.

7.3.3 *Hotel Guest Rooms*

Each guest room or each zone shall be provided with not less than one thermostat capable of being set from 15°C to 30°C and capable of operating the system's cooling and heating. The thermostat or control system, or both, shall have an adjustable dead band, the range of which includes a setting of 12°C between cooling and heating where automatic changeover is provided. Wall-mounted temperature controls shall be mounted on an inside wall.

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. 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.

7.3.4 *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.

7.3.5 *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.

7.3.6 *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.

Movie theatres design consideration shall be based upon timing of usage, low occupancy levels and low sensible loads. Special care must be taken to ensure proper relative humidity levels without overcooling the space. System design shall meet the required noise criteria. The lobby and exit passageways in a multiplex which are seldom densely occupied, although some light to moderate congestion can be expected for short times, shall be separately treated.

Stage in auditorium shall be specially treated because of heavy mobile lighting load and performance considerations.

7.3.7 *Educational Institutes*

Special attention for the design of the HVAC systems shall be paid to meet the needs of every age group. The equipment should be easy to operate and maintain and the design should provide no drafts. These facilities have two distinct occupant zones: (1) the floor level, where younger children play and (2) normal adult height, for the teachers. The administrative and teachers area shall be considered as a separate zone.

Special consideration shall be given to operating schedule for setback. Supply air outlets should be positioned to avoid drafts. Proper ventilation and exhaust shall be provided for controlling odours and to prevent the spread of diseases.

Universities and college campuses having large diversity in cooling/heating loads should be provided with large central utility plants or smaller mechanical rooms serving cluster of buildings. The central utility plants may supply chilled/hot water. The designer should consider site constraints, including geographic location. In addition to accommodating the mechanical and electrical equipment, central utility plants may also house engineering, operation and maintenance personnel. A central control room shall be provided for energy monitoring.

7.4 Buildings, in which the HVAC planning and design requirements vary from a normal comfort application and needs different treatment, such as, data centers, hospitals and underground metro stations, etc are covered in **8**.

8 SPECIALIZED APPLICATION

8.1 There are many buildings with application, like, data centers, hospitals and underground metro etc, where the HVAC requirement varies from a normal comfort application and hence they need to be treated differently. The requirements for such specialized applications have been given below:

a) *Health Care Facility/Hospital* — Hospitals have operation theatres which requires stringent conditions of temperature and Relative Humidity control with 100 percent fresh air. To maintain the desired conditions in operation theatre, low temperature is needed so that dehumidification can be done and at the same time other area can be fed with normal chiller water temperature. To cater to this diversified demand, different design philosophies are available.

b) *Data Centres* — The occupant load in data centres is nearly 1 or 2 percent maximum and else everything is server/equipment load. In these types of buildings, the majority of load is sensible load. It is critical to maintain the operating conditions of server/equipment for their safe and consistent operation at lowest operating cost. Design needs should be identified after working closely with architect, equipment/server manufacturer and HVAC consultant and therefater designed.

c) *Underground Metro-station* — There are two challenges to be dealt with at underground metro-station:
   1) Tunnel air temperature which increases due to the movement of metro train in tunnel.
   2) Comfort condition at platform and concourse due to sudden high passengers load and metro movement (equipment load).

   Both the above may be handled differently by different designers.

The methodology which may be adopted for addressing the specific requirements of above applications are given in **8.1.1** to **8.1.3**.

8.1.1 *Health Care Facility*

Patient therapy shall be the prime consideration while air conditioning or ventilating a health care facility. While planning the air conditioning and ventilation of the health care facility, the plan shall include the clinical services to be provided in each space, equipment to be used with in the space and requirement of temperature, humidity, air flow pattern and pressure gradient with respect to adjacent spaces.

Following are the parameters which shall be taken into consideration while designing HVAC system for health care facilities:

a) Temperature and humidity requirements of various spaces;
b) Ventilation and filtration requirements for contamination control;
c) Restriction on air movement between adjoining spaces;
d) Permitted tolerance on environmental conditions;
e) System reliability and maintainability; and
f) Adaptability of the system for fire emergency and for smoke management.

8.1.1.1 *Air distribution systems*

Air distribution systems in a health care facility shall provide ventilation to dilute and remove contaminants and assist in controlling transmission of air borne infections besides maintaining the desired temperature and humidity. Design of the air distribution system shall be such that air movement is from clean to less clean areas.

For critical care areas, constant volume systems shall be used to maintain proper pressure relations and ventilation. For patient rooms and non-critical areas, variable air volume system shall be considered for energy conservation. However when variable air volume systems are used, care should be taken to ensure that minimum ventilation requirements are not compromised and pressure balance is maintained even at minimum flow.

Active smoke control systems shall be used along with fire and smoke partitions to limit the spread of smoke in the event of fire. Smoke and fire management shall be done in accordance with Part 4 'Fire and Life Safety'. For health care facilities which provide ambulatory care to patients, safety from fire and smoke is a paramount design consideration and shall be provided in accordance with Part 4 'Fire and Life Safety' of the Code.

A separate exhaust system or vacuum system shall be provided for removal of anesthetic gases from the operation theatre.

Air handling devices shall be designed to prevent water intrusion and permit access for inspection and maintenance.

When humidifiers are provided, they shall be located with-in the air handling unit or duct work in such a way that moisture accumulation on downstream components do not take place .Evaporative pan type humidifiers shall not be used.

Fibrous acoustic insulating material shall not be used as duct lining for critical spaces unless downstream terminal filters are provided. Supply air ducts shall be externally insulated as required.

Multiple direct drive plenum fans may be used in air handling units serving critical areas. This provides redundancy and minimizes shut down of critical areas in case of single fan failure.

For critical areas, both supply air and return air shall be ducted. Ducts shall be sized for medium velocity and medium pressure drop (2 m/s and 4 mm for 10 m *max*).

Ultra violet germicidal irradiation is recommended for air handling units serving health care facilities. Lamps may be installed either upstream or downstream of the evaporator coil but away from the filter media.

8.1.1.2 *Air flow and filtration*

Outside air intakes shall be located at least 8 m away from exhaust stacks, cooling towers and such other areas. Bottom of an outside air intake shall not be located less than 2 m above ground level and 1 m above any roof level.

Exhaust outlets shall be located at a minimum height of 3 m away from ground level and away from doors, occupied areas and operable windows. Locating exhaust outlets above the roof projecting upwards is preferred.

While installing filters, care shall be taken to see that there is no scope for leakage between frame and filters and between filter segments.

Openings in ducting/diffusers shall be sealed to prevent infusion of dust and dirt.

Shaft openings shall be terminated in enclosed rooms and airflow systems shall be designed and balanced to create positive or negative air pressure with-in specified areas.

It is recommended that supply air outlets shall be located at or near the ceiling and exhaust is collected near the floor level. This is to ensure that clean air moves through breathing and working space to the floor area for exhaust.

For operating and procedure rooms where patients highly susceptible to infection are treated (such as orthopedic and cardiac operating theatres) laminar air flow systems shall be considered. A unidirectional air flow pattern at a velocity of 0.45 ± 0.10 m/s should be aimed for. A vertical laminar flow system which will wash the patient on the operating table and flow downwards, to be collected near floor level, shall be chosen for such rooms. The area of laminar flow grid shall extend by a minimum of 300 mm beyond the foot print of the operating table on all sides. If required, additional supply diffusers may be provided for achievement of required temperature and humidity. Exhaust grilles (minimum two) shall be provided at opposite corners of the room at approximately 200 mm above the floor level.

8.1.1.3 *Pressure differentials*

Operating rooms where highly infectious patients are treated and infectious isolation rooms shall be provided with an anteroom between the room and external area.

Anteroom shall be maintained at positive pressure with respect to both the room and the surrounding space.

All air from airborne infection isolation rooms shall be exhausted directly to outdoors and if this is not practical, the room shall be ventilated with re-circulated air supplied through high-efficiency particulate arrestance (HEPA) filters. Such rooms shall be maintained at a minimum negative pressure of 2.5 N/m^2 with respect to surrounding areas.

Protective environment rooms, such as bone marrow transplants, organ transplants etc, shall be maintained at a positive pressure of 2.5 N/m^2 with respect to surrounding spaces.

8.1.1.4 *Conditioning equipment*

Cooling equipment can be central or local chilled water systems, direct expansion type condensing units or variable refrigerant flow systems. Indirect cooling systems using chilled water are preferred and, if direct cooling systems are used, required safety measures should be adopted.

Heating equipment shall include heat pumps, boilers and heat exchangers.

Sizing and arrangement shall give adequate consideration to minimum loading and standby facility for critical areas. It shall be possible for the facility to operate even when one of the systems is under break down or maintenance.

Where specific areas are to be maintained at low temperature coupled with low humidity, an additional direct expansion coil may be introduced downstream of the regular evaporator coil. In such cases, the control strategy shall ensure that the DX coil is energized only after the main evaporator coil is at full load.

When variable refrigerant flow systems are used, care shall be taken to see that minimum air change and pressure differential considerations are not compromised.

8.1.1.5 *Installation and maintenance*

The air distribution system shall be provided with access panels to allow inspection and cleaning. Duct systems shall be cleaned of construction debris before commissioning.

Surfaces of air terminals shall be suitable for cleaning.

Access to equipment rooms shall be planned so as to avoid intrusion of maintenance personnel into critical care areas, operation theatres etc. Equipment room layout shall allow access to equipment for its operation and maintenance.

Operation and maintenance records shall include temperature and pressure requirements as well as permitted tolerances for all spaces. It shall also include standard operating procedures for emergencies such as power failure, equipment breakdown, fire situation, etc.

Pressure differentials of operating rooms, protective environment rooms, and air borne infection isolation rooms with respect to adjoining areas shall be verified and recorded semiannually.

HEPA filters shall be replaced periodically based on pressure drop. Filters of fan coil units and air handlers shall be cleaned to a regular maintenance schedule. AHU/ Fan Coil drain pans shall be cleaned monthly.

Supply and return air ducts for critical areas shall be tested for air leakage and after installation an air blow down process shall be undertaken before loading of filters. All areas served by the air handler shall be cleaned and mopped before the air handler is started. Filters shall be loaded in sequence. Pre filters shall be loaded first followed by Post filters and finally HEPA filters. Air handler shall be run with each set of filters for 24 h and the conditioned area shall be cleaned and mopped each time before the next set of filters is loaded.

After air balancing, and adjusting of air quantity, temperature, humidity, and pressure differentials, a validation process shall be carried out and recorded. For critical areas such as operating theatres, isolation rooms etc, validation process shall be repeated and recorded at least once every year.

8.1.2 *Data Centre*

8.1.2.1 Data center is a technological facility which houses electronic equipment used for data processing, storing and networking (datacom equipment). The design requirement for cooling of such technological facility differs from comfort air conditioners.

Such facility has a few or no requirement of occupancy as the facility becomes complete automatic barring interventions for maintenance. The major contributing heat is from electronic equipment which is sensible in nature and hence cooling equipment needs to be designed with a high sensible factor. Main focus is equipment cooling rather than comfort.

The facility generally works for all day and all night (continuously 24x7 h). High reliability and redundancy is an important criteria as any loss of data may contribute to huge financial loss. The components to be selected for cooling datacom equipment need to be highly reliable besides being energy efficient.

8.1.2.2 *Inside conditions/thermal guidelines*

Inside temperature within the facility may vary depending on whether it is on inlet side or exhaust side of the equipment. Presently the best practice of facility design for datacom equipment placement in the rack is based on hot and cold aisle air arrangement. In such configuration, front of the datacom equipment cabinet/rack should face cold aisle, where supply of cold air from cooling equipment is supplied either through floor grilles or overhead ducts.

The allowable envelope is where information technology (IT) manufactures test their equipment in order to verify that the equipment will function within these envelope boundaries.

Prolonged exposure of IT equipment to conditions outside its recommended range, especially approaching the extremes of the allowable environment, can result in decreased equipment reliability and longevity. Occasional short time excursions into the allowable envelope may be acceptable.

Facilities should be designed and operated to target the recommended range. The present recommended range is:

Low end temperature	*18°C (64.4°F)*
High end temperature	*27°C (80.6°F)*
Low end moisture	*5.5°CDP (41.9° FDP)*
High end moisture	*60 percent RH and 15°CDP (59° FDP)*

8.1.3 *Underground Metro-station*

The underground metro station is provided with environment control system (ECS). The ECS system shall serve following function:

a) Station public area and ancillary room air-conditioning,
b) Mechanical ventilation of plant rooms, and
c) Smoke management system.

8.1.3.1 *Station public area and ancillary room air-conditioning*

8.1.3.1.1 *Station air conditioning design philosophy*

The underground stations of the metro corridor are built in a confined space. A large number of passengers occupy concourse halls and the platforms, especially at the peak hours. It is therefore, essential to provide forced ventilation in the stations for the purpose of:

a) Supplying fresh air for the physiological needs of passengers and the authority’s staff;

b) Removing body heat, obnoxious odours and harmful gases like carbon dioxide exhaled during breathing;
c) Preventing concentration of moisture generated by body sweat and seepage of water in the sub-way; and
d) Removing large quantity of heat dissipated by the train equipment like traction motors, braking units, compressors mounted below the under-frame, lights and fans inside the coaches, air-conditioning units etc.

8.1.3.1.2 *Station heat load*

The station heat loads are a combination of the unsteady train heat loads, passenger heat load, lighting, equipment, miscellaneous equipment and fresh air loads.

a) *Unsteady heat load due to train movement*

   The major source of heat for the station is from the train air conditioning systems and the train traction and braking systems.

   The heat developed inside the tunnel during normal operation mixes with station air due to piston effect caused by train movement. This increases heat load of the station. This heat load is unsteady and needs special software for its estimation. These software model the complete metro network of tunnels and underground station and take train operation, rolling stock physical parameter, tunnel structure parameters, tunnel gradient and alignment, station architecture, etc, as input data. Such software takes into account the heat load of tunnel airflow generated by the train movement and the heat of trains dwelling at station as per the planned headway of train operation. These values do not include the fresh air heat loads or the steady heat loads from station, such as passengers, lighting, escalator and other equipment.

   The unsteady heat load is obtained in software at simultaneous and staggered headway for summer and monsoon condition and the system is designed for the highest heat load.

b) *Steady heat load*

   1) Passenger heat load- The passenger occupancy at station and tunnel section is taken from Peak Hour Peak Direction Traffic (PHPDT) data given in Detail Project Report (DPR).
      The passenger heat gains shall be adopted as per the available data.
   2) Lighting and miscellaneous equipment load- The lighting in public area and equipments like lifts, escalators, AFC Gates, etc, contributing to the heat load is calculated as per available area of respective station.
   3) Fresh air loads - Fresh air is supplied to the platform and concourse to meet the physiological requirements of the passengers. Fresh air load

is considered 10 percent of supply air or 0.005 m^3/s whichever is highest.

8.1.3.1.3 *Design criteria*

As the passengers stay in the stations only for short periods, a fair degree of comfort conditions, just short of discomfort are considered appropriate. Station air conditioning systems shall be designed to maintain specific design temperatures.

Station air conditioning system design conditions are:

Platform, Concourse	:	27°C at 55 percent relative humidity
Outdoor	:	Summer and monsoon condition as per location

8.1.3.1.4 *System description*

The station environment shall be centrally air-conditioned. Station shall have provision of fresh air intake and exhaust shaft. The station shall be supplied with conditioned air via ductwork from air handling unit (AHU) located in plant room. AHU shall be supplied with chilled water from water cooled chillers and its associated pumping system.

To extract the return air, Trackway Exhaust System shall be installed in the trainways of each station to capture both excessive tunnel airflows and the heat rejected by the vehicle propulsion/braking/air-conditioning systems as the train dwells in the station. An under platform exhaust (UPE) duct is often utilized to capture heat from the trains undercarriage heat sources. An overtrack exhaust duct is normally utilized to capture heat that is rejected from the above car area of dwelling trains. The overhead trackway exhaust (OTE) duct may be required if the railcars have rooftop mounted air-conditioning units. Openings in the OTE and UPE shall be located so as to be near the heat generating sources on the train.

8.1.3.1.5 *Modes of operation*

a) *Open mode operation*

In open mode, 100 percent outside air is circulated in the stations. It is the more economical mode of operation when the outside air temperatures are relatively low. AHU shall suck the air directly from outside via fresh air shaft and deliver the air at platform level and concourse level. Trackway exhaust fans (TEF) shall extract the air from OTE and UPE and discharge it outside directly via exhaust shaft. The water cooled chillers units shall remain shutdown in this mode. This mode is generally used during winter season.

b) *Closed mode operation*

In close mode, air is extracted from the public areas of the station and returned to the air handling units to be cooled and delivered back to the platform and concourse. Closed mode operation is proposed when the outside air temperature and humidity are high. In this operation, AHU shall recirculate the air of OTE and UPE with the addition of 10 percent fresh air with fresh air fans (FAF). The TEF will take the exhaust from OTE and UPE and deliver to return air plenum where 10 percent fresh air is also mixing with return air. This mode is generally used during summer and monsoon season.

8.1.3.2 *Ancillary area air conditioning*

Ancillary area, that are occupied by staff and non-travelling persons, who are going to stay in the rooms for considerable duration, air conditioning is to be done similar to that for normal buildings.

8.1.3.3 *Mechanical ventilation*

The backs of house area rooms are provided with ventilation supply, ventilation exhaust or both according to their use and particular requirements.

8.1.3.4 *Smoke management system*

The smoke extract fans (SEF) and trackway exhaust fans (TEF) are being used in the for concourse and platform smoke extraction respectively. The smoke extraction fans and other system components like duct, dampers, attenuators etc shall have suitable fire rating. Smoke extraction fans with related equipments shall be installed in the ECS plant rooms provided at concourse level at the each end of the stations. Where smoke extract ducting passes through protected areas it shall be rated to the same fire resistance as the walls of the compartments. Flow switches shall be provided for exhaust and the station smoke removal fans to provide a positive indication of the fan operation at the station control rooms (SCR) as well as operations control centres (OCC).

The fire of 1 MW in public area of platform and concourse is considered for smoke extraction system design. The smoke extraction system operates in various modes depending on the location of the fire.

8.1.3.5 *Staircase pressurization*

Pressurization of the firemen’s staircase and emergency staircase shall be done in accordance with Part 4 'Fire and Life Safety' of the Code so as to maintain tenable environment in the staircases.

9 REFRIGERATION FOR COLD STORES

Cold store plays a major and critical role in cold chain. Apart from required temperature and relative humidity management, better air movement around the produce, proper arrangement of stacking, inspecting for any defectives are also important to maintain the produce quality in cold storage. The two basic product groups on cold storage of perishable food stuffs are chilled food and frozen food. The material of the equipment/machineries used in cold stores should be corrosion proof and easily accessible for maintenance.

9.1 Key Elements and Components of Cold Room

9.1.1 *Product Quality*

Refrigeration cannot improve the quality of products. It does slow down the processes of microbial, chemical or enzymatic deterioration that occur in them. The more advanced these processes are, the more difficult it is to slow them down. Good results can, therefore be, expected only with clean, wholesome products which are free of any bruises, contamination or physiological disorders, and which have a normal microbial population for the products.

Storing products which do not have these qualities can harm those that do, when they are stored in the same room. They can also contaminate the rooms in which they are put together through odours, dispersal of mold spores, etc. It must be kept in mind that harmful micro-organism development can begin after a certain amount of time and then speed up considerably. It is often very useful to know exactly where the product has come from and its history in order to better evaluate its long-term keeping quality, from both a qualitative and a commercial point of view.

Cold treatment should come quickly; that is, it should be done as soon as possible after the raw products have been harvested. Any delay in storing a product reduces the amount of time it can be stored, either because it has already deteriorated or because it has already been transformed, and putting it into cold storage may not keep it from deteriorating further. Refrigeration should be continuous.

9.1.2 *Temperature*

During the entire storage period the temperature should remain as constant as possible. Some products are particularly sensitive to temperature variations, which can reduce the shelf life of some fruits.

One must avoid putting into a room a large amount of goods at a temperature too different from that of goods already in the room. The cold-production equipment should be checked to make sure it can handle this extra load. Within one room the temperature should be as uniform as possible, as this affects not just products that are sensitive to temperature variations, but also those with recommended temperatures near 0^oC. These optimum conditions must be able to be approached without risks of freezing.

Heat coming in through the floor and the walls can upset this uniformity of temperatures in a room and can be made uniform through forced air circulation. Dead zones and regular drafts must be avoided. The ranges of temperatures given in chilling are generally meant as acceptable tolerances for each food. Storage temperature must in any case be kept as constant as possible. Temperature sensors should be placed around the room on the basis of the accuracy, as indicated by the manufacturer, of the automatic devices. Cold store temperatures can be either recorded or read at regular intervals. Thermometers should be protected from impacts and yet easily accessible. Temperatures ought to be read at more than one location. Moreover, the temperature of the products themselves should be taken.

9.1.3 *Measurement of Temperature of Food*

A thermometer that can measure the internal temperature of food, like one with a probe that can be inserted into the food, is required as the surface temperature may be warmer or cooler than the temperature of the rest of the food. The thermometer shall be accurate to ± 1°C. This means that when the thermometer shows that the food is at a temperature of 5°C, the actual temperature of the food would be between 4°C and 6°C. To check that the thermometer is that accurate, its probe can be placed in a container of crushed ice that is just melting; the thermometer should then read 0°C within 1°C that is, between – 1°C and +1°C. If it does not, then it needs checking by the manufacturer. The thermometer should be cleaned and sanitized before inserting it into food. The probe should be washed in warm water and detergent, sanitized according to the sanitizer instructions or the instructions that thermometer accompanies, and the probe should be allowed to air dry or thoroughly dried with a disposable towel.

9.2 Typical Design Inputs for a Standard Cold Room

The criteria involved in designing a cold room are similar to any warehouse, that is, storage capacity, facilities for receiving and dispatching goods, interior operating space, location of cold room, selection and location of refrigeration units.

While designing cold room, the difference between room temperature and product temperature should be kept minimum.

9.3 Importance of Heat Loads

Refrigeration load includes:

a) Transmission load, which is heat transferred into the refrigerated space through its surface;
b) Product load, which is heat removed from and produced by products brought into and kept in the refrigerated space;

c) Internal load, which is heat produced by internal sources (for example, lights, electric motors, and people working in the space);
d) Infiltration air load, which is heat gain associated with air entering the refrigerated space; and
e) Equipment-related load.

The first four segments of load constitute the net heat load for which a refrigeration system is to be provided; the fifth segment consists of all heat gains created by the refrigerating equipment.

Thus, net heat load plus equipment heat load is the total refrigeration load for which a compressor must be selected.

While other loads are quite similar to loads in regular HVAC system design, the product load includes the primary refrigeration loads from products brought into and kept in the refrigerated space, which includes:

a) Heat that must be removed to bring products to storage temperature, and
b) Heat generated by products (mainly fruits and vegetables) in storage.

In addition, another new aspect in heat load is the heat from defrosting where the refrigeration coil operates at a temperature below freezing and must be defrosted periodically, regardless of the room temperature.

In order to avoid system oversizing due to load diversity, it is recommended to use the hour-by-hour load calculation or simulation method.

9.4 Considerations for Cold Room Selection

The conditions within a closed refrigerated chamber must be maintained to preserve the stored product. This refers particularly to seasonal, shelf life, and long-term storage.

The four principal concerns regarding product compatibility are temperature, moisture, ethylene, and odour.

Specific items for consideration include,

a) Uniform temperatures,
b) Length of air blow and impingement on stored product,
c) Effect of relative humidity,
d) Effect of air movement on employees,
e) Controlled ventilation, if necessary,
f) Product entering temperature,
g) Expected duration of storage,
h) Required product outlet temperature,
i) Traffic in and out of storage area,

j) Design of storage bins, and
k) Size of food product (*L* x *W* x *H*)/volume.

Rack systems are mostly related to retail store refrigeration and are not considered as part of building system.

9.5 Installation and Maintenance of Cold Room- Key Aspects

9.5.1 The conventional construction in cold stores is the insulation on walls and ceilings, and finishing with cement sand plaster. The latest trend is to use sheet metal cladding. The cladding materials are aluminium sheet or pre-coated galvanized steel sheet.

The development of pre-insulated panels has brought in a change in cold storage construction. Polyurethane foam (PUF) panels using polyurethane as insulation material foamed between two metal skins, are structurally strong and have a better insulation value as compared to expanded polystyrene (EPS) panels for a given thickness. All panels for thermal insulation of cold storage shall be selected and designed in accordance with the good practice [8-3(8)].

The highlights of prefab panel's construction are:

a) Greater flexibility and faster construction due to reduced site labour;
b) Better thermal efficiency due to better isolation between outside and inside;
c) Less moisture load due to good vapour barrier by PUF and sheet skin;
d) The panels serve as walls and ceilings, and therefore brick walls are eliminated thereby increasing the cold store volume on a given floor area;
e) Modular construction is feasible and offers advantages of addition or expansion as per requirement; and
f) Increased hygienic quality of the structures. Panels can have a finish as per user's specification and are easy to clean and maintain.

9.5.2 *Safety Aspects*

9.5.2.1 Refrigeration systems have to be built as per proper specification to ensure that refrigerant leakage does not occur. It is essential to have proper emergency measures in case of any accidental leaks. The building structure has to be designed with adequate safety factors and the thermal insulation has to be protected properly from any possible occurrence of fire. Emergency alarms should be provided in the cold store with switches in each chamber.

Safety is critical in the design, construction and operation of refrigeration systems for cold storage, especially with ammonia systems. Refrigeration system's safety standards shall meet requirements relating to safe design, construction, installation, and operation of refrigeration systems by establishing safeguards for life, limb, heath and property as per the applicable safety standards. This includes, but is not limited to, occupancy classification, restriction on refrigeration use, installation restrictions, design and construction of equipment and systems, and operation and testing. Consider equipment selection and its placement for safe accessible maintenance. A safety review of the engineered design and equipment layout is recommended with participation from the owner's site operations and maintenance (O&M) entities. The designer should perform a system safety plan and hazard analysis. Personnel safety measures are required as part of the facility design.

9.6 Cold Room Safety

The cold temperatures inside a low temperature cold room can cause increase in blood viscosity and risk to life unless proper precautions are taken. A hooter should be installed outside the cold room, powered through a UPS and the switch should be fixed prominently and within reach, inside the cold room. This will help any person trapped inside to alert those outside for help.

9.6.1 The following safety provisions should be kept/taken care of, at cold room site:

a) fire fighting equipment,
b) handling refrigerant leaks,
c) safety devices, controls and alarm systems,
d) emergency lighting in the cold chambers,
e) lightening arrestor,
f) first aid kit,
g) air filters/breathers,
h) emergency assembly points,
i) regular safety drills and training,
j) water shower in ammonia plants, and
k) avoid ramps since they are slippery when wet or frozen.

9.6.2 *Precautions Against Getting Trapped in Freezing Room*

To allow someone locked in a cold room to get out, emergency exits shall be provided which could be opened from inside, even when they are locked from the outside. In all cases, the following shall be installed in the freezing room:

a) Doors which can open manually both from the inside and the outside (for functioning during power shortages, etc). In case of rooms with large dimensions say more than 25 m, it is advisable to provide emergency doors with sign at other end of room for easy exit.

b) A signing system outside the rooms with a steady or blinking light, and a siren or buzzer activated from the inside by a lighted button. This button is also connected to the caretaker's apartment, where a monitoring board shows where the button was pressed. These visible and audible alarms ought to be connected to a self-contained electric-circuit, operated with a permanently charged battery, independent, battery-operated emergency lighting on the same circuit as above or a phosphorescent signaling system making the way to the nearest emergency exit.

c) Sliding doors, electric or pneumatic, able to be operated from outside and inside by push-button or pull-cords easily accessible to a driver from a fork-lift. Like all emergency exits, these doors should be electrically heated to keep them free from freezing.

9.6.3 *Precautions against Refrigerant Leaks*

Safety measures should be taken against leaks of liquid or gaseous refrigerant. Consideration should also be given to installing gas detectors, mainly in unmanned areas, with which the refrigerant supply can be cut long before the gas is concentrated enough to affect the stored products.

Self-contained breathing apparatuses and protective clothing are essential for entering a building with a concentration of ammonia greater than 50 ppm. Nearby doors and windows should be shut. Ammonia clouds can be neutralized with dry ice (CO_2) or transformed by fog nozzle, but there is then a risk of water pollution.

In refrigeration applications with ammonia, there is a risk of a high concentration accumulating in an enclosed room. With 15 to 28 percent by volume, and an ignition source (of 582 ^oC), it is possible to create a fast burning process which could be something like an explosion.

9.7 *Cold Room in Various Segments and Requirements*

The temperature ranges for various applications/product categories of modular cold rooms are given below:

Horticulture (fruits and vegetables)	*+2 to +8 ºC*
Floriculture	*+2 to +6 ºC*
Hotels, restaurants, fast food chains	*+2 to +6 ºC*
Pharmaceuticals	*+8 to -25ºC*
Dairy	*+8 to -25ºC*
Ice cream	*-20 to -25ºC*
Ripening	*+12 to +20ºC*
Controlled Atmosphere	*+1 to +3 ºC*

The above temperature ranges against the applications, are indicative only, and may tend to vary, based on specific application requirements and other conditions.

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. Electrical heating may be actively discouraged and instead heating through superheat of cooling unit, heat pump, reverse cycle operation of unitary system and solar hot water systems are highly encouraged which results in a greener environment and lower carbon foot print.

While the efficiency of a heating equipment can never be more than 100 percent, a refrigeration system for heating usage can have the efficiency [or coefficient of performance (COP)] more than 450 percent. So in comparison to electrical heating such as electrical heaters or thermal heating such as boilers, preference should be for the systems working on refrigeration principle such as heat pump or VEF system or unitary systems like air cooled package or split air conditioner (in reverse cycle mode) or even window air-conditioners (in reverse cycle mode) as the same can result in huge energy saving (and lesser carbon print).

10.2 The heating equipments/systems are described under **10.2.1** to **10.2.7**. 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 require~~d~~ 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 bus bars and connections and be capable of withdrawal from the casing, thus enabling the elements to be cleaned or repaired whilst the remainder is in operation. Each section should be capable of being isolated electrically before being withdrawn from the casing.

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

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

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

10.2.3 *Solar Water Heating* (*SWH*) *Systems*

SWH is the conversion of sunlight into renewable energy for water heating using a solar thermal collector. In a close-coupled SWH system the storage tank is horizontally mounted immediately above the solar collectors on the roof. No pumping is required as the hot water naturally rises into the tank through thermal siphon flow. In a pump-circulated system, the storage tank is ground or floor-mounted and is below the level of the collectors; a circulating pump moves water or heat transfer fluid between the tank and the collectors.

SWH systems are designed to deliver hot water for most of the year. However, in winter there sometimes may not be sufficient solar heat gain to deliver sufficient hot water. In this case a gas or electric booster is used to heat the water.

Residential solar thermal installations fall into two groups; passive systems (sometimes called compact) and active systems (sometimes called pumped). Both typically include an auxiliary energy source (electric heating element or connection to a gas or fuel oil central heating system) which is activated when the water in the tank falls below a minimum temperature setting such as 55°C. Hence, hot water is always available. The combination of solar water heating and using the back-up heat from boiler or electrical heaters to heat water can enable a hot water system to work all year round in cooler climates, without the supplemental heat requirement of a solar water heating system being met with fossil fuels or electricity.

The design, installation and performance evaluation of solar heating systems shall be in accordance with the good practice [8-3(9)].

10.2.4 *Heat Recovery Systems*

Heat recovery systems captures energy that would otherwise be wasted to the atmosphere and converts this energy into useful heat. It is possible to capture this heat-out from the condenser and use it to generate hot water. By capturing this heat that would otherwise be wasted, overall system efficiencies are improved very much.

An air-cooled chiller produces chilled water while simultaneously transferring significant quantities of heat to the outdoors through its air-cooled condenser. If this heat could be captured and re-directed to a water-cooled condenser, the system could produce not only a controlled source of chilled water but also a significant amount of useful heat to generate hot water. Air-cooled chillers with heat reclaim capabilities can produce chilled water controlled to the necessary temperature while generating hot water as a by-product of the chilled water system.

The heat recovery condenser can transfer 100 percent of the chiller's total heat of rejection to the hot water loop. The leaving water temperature can reach a maximum temperature of 55°C under steady state and constant hot water flow conditions. The allowable leaving hot water temperature range is 40°C to 55°C. Such systems should be used wherever there is heating requirement concurrent with cooling demand.

10.2.5 *Heat Pump*

Heat pump can provide year-round climate control by supplying heat in the winter and cooling it in the summer. Some types can also heat water. A heat pump is an electrical device that extracts heat from one place and transfers it to another. Air-source heat pumps draw heat from the outside air during the heating season and reject heat outside during the summer cooling season. There are two types of air-source heat pumps. The most common is the air-to-air heat pump. It extracts heat from the air and then transfers heat to either the inside or outside depending on the season. The other type is the air-to-water heat pump, which is used with hydronic heat distribution systems. During the heating season, the heat pump takes heat from the outside air and then transfers it to the water in the hydronic distribution system. If cooling is provided during the summer, the process is reversed: the heat pump extracts heat from the water in the home's distribution system and pumps it outside to cool. Efficiency of heat pump is significantly higher as compared to gas or electric heaters.

10.2.6 *Ground Source Heat Pump*

Ground source heat pump uses the earth or ground water or both as the sources of heat in the winter, and as the sink for heat removed from the conditioned areas in the summer. Heat is removed from the earth by using groundwater or an antifreeze solution; the liquid's temperature is raised by the heat pump; and the heat is transferred to indoor air. During winter months, the process is reversed, heat is taken from indoor air and transferred to the earth by the ground water or antifreeze solution.

11 MECHANICAL VENTILATION

11.1 Ventilation

Ventilation is the process of changing air in an enclosed space. A portion 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 and health, comfort and safety of building occupants. Ventilation is required to control the following:

a) *Oxygen Content* – Prevent depletion of the oxygen content of the air;
b) *Carbon di-oxide and Moisture* – To prevent undue accumulation;
c) *Other hazardous gases such as CO, NOx, SO_2 etc*;
d) *Odours and Contaminants* – To prevent undue rise in concentration of body and other odours and contaminants (chemical, VOCs, tobacco smoke etc);
e) *Bacteria* – To oxidize colonies of bacteria and fungi to prevent their proliferation.
f) *Heat* – To remove body heat and heat dissipated by electrical or mechanical equipment or solar heat gains.

Ventilation may include either mechanical exhaust system or exhaust can occur through natural means. Mechanical ventilation is the one of the forms of ventilation option available. It usually consists of fans, filters, ducts, air diffusers and outlets for air distribution within the building. Natural ventilation and natural exhaust, which are another option for ventilation, are covered in Part 8 Building Services, Section 1 Lighting and Ventilation. The scope of this Section is therefore restricted to Mechanical Ventilation.

Following considerations affect the type of ventilation system selected for a particular application and 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. In an industrial environment, hot-dry conditions 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 hot-dry conditions.

b) Siting (and orientation) of a building is also an important factor. Solar heat gain and high outside temperature can add significant heat load to internal heat gains from equipment and processes.

c) The comfort level required is another consideration. In many industrial applications, comfort levels as understood in the context of residential buildings, commercial blocks or office establishments cannot be achieved 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 - 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. For meeting heat stress standards, radiation shielding in addition to ventilation control measures described above may become necessary.

As a general rule, in complex and harsher environmental situations, mechanical systems should be the preferred alternative to achieve acceptable working conditions.

11.2 Industrial Ventilation

Industrial buildings form a major application of mechanical ventilation. Industrial processes may use chemical compounds and toxic substances which may cause particulates, gases and mists in the work zone air in concentrations that cross the prescribed safe limits. Thus in industrial buildings, ventilation is needed not only to provide oxygen rich fresh air normally required for health and hygiene and to mitigate against thermal loads due to equipment, people and building heat gains, but also to remove and maintain the hazardous industrial pollutants within safe limits.

11.2.1 *Basic Ventilation Strategies*

11.2.1.1 *Mechanical extract/natural supply*

This is the simplest form of extract strategy comprising one or more exhaust 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. This strategy creates negative pressurization in the building and is not suitable for dusty ambient environment or when dust free environment is to be maintained indoors.

11.2.1.2 *Mechanical supply/natural extract*

This strategy is similar in form to the extract strategy but arranged so that one or more fans supply fresh air into the enclosed space. Such a system necessitates the discharge of vitiated air by natural means through open doors, windows, other building openings and cracks. This ventilation strategy creates positive pressurization in the enclosed space which is essential to maintain a clean interior environment. For relatively closed spaces, positive pressurization levels can be controlled by providing balanced pressure relief dampers at selected discharge zones.

The points of delivery of fresh air supply can be controlled by incorporating a system of supply ducts and discharge diffusers. The desired level of air quality in the supply air can be maintained by providing suitable filters in the supply fan systems.

11.2.1.3 *Mechanical supply/mechanical extract*

This strategy is a combination of the two above and consists of two independent systems – a mechanical supply system and a mechanical extract system with or without their respective duct systems.

This strategy provides the best opportunities for control of ventilation parameters such as indoor air quality, air distribution, movement and pressurization, with rising system cost and complexity.

In the interest of efficient use of energy and comfort to the occupants, it is imperative that all ventilation strategies should be considered in relation to the thermal characteristics of the building, ambient environment and the nature of processes inside.

Reference shall be made to the good practice [8-3(10)] for basic requirements regarding safe design, installation, operation, testing and maintenance of ventilating systems with respect to general ventilation and wherever applicable dilution ventilation for industrial processes. Measures to reduce heat hazards due to industrial processes are also briefly described therein. The information contained in this section should be considered complimentary to the good practice and shall not supersede the provisions of the same.

11.2.2 *Ventilation for Heat Control*

Ventilation control measures normally include cooler replacement air, an evaporative or mechanically cooled source, velocity cooling method or combination thereof. The required ventilation flow rate should be calculated both for the sensible and latent heat load. The required ventilation rate is the larger of the two volumetric flows.

In majority of cases the sensible heat load far exceeds the latent heat load, so the design rate usually can be calculated on the basis of sensible heat alone. The sensible heat load includes solar heat gain, occupancy, lighting load, equipment load as well as other particular sources if any.

The ventilation flow rate can be calculated using the following equation:

$$Q_s = 3.462 \times \frac{H_s}{\Delta T}$$

Where H_s = sensible heat load in kcal/h;
Q_s = air volume flow rate in m^3/h; and
ΔT = allowable temperature rise in °C.

The allowable temperature-rise values are specified in Table 2 of the good practice [8-3(10)]. The ventilation should be designed to flow through the hot environment in a manner that will effectively control the excess heat.

11.2.3 *General* (*Dilution*) *Ventilation versus Local Exhaust Ventilation*

General exhaust ventilation (dilution ventilation) is appropriate when:

a) Emission sources contain materials of relatively low hazard;
   NOTE- The degree of hazard is related to toxicity, dose rate, and individual susceptibility.
b) Emission sources are primarily vapours or gases, or small, respirable size aerosols (those not likely to settle);
c) Emissions occur uniformly;
d) Emissions are widely dispersed;
e) Moderate climatic conditions prevail;
f) Heat is to be removed from the space by flushing it with outside air;
g) Concentrations of vapours are to be reduced in an enclosure; and
h) Portable or mobile emission sources are to be controlled.

Local exhaust ventilation is appropriate when:

a) Emission sources contain materials of relatively high hazard;
b) Emitted materials are primarily larger diameter particulates (likely to settle);
c) Emissions vary over time;
d) Emission sources consist of point sources;

e) Employees work in the immediate vicinity of the emission source;
f) The plant is located in a severe climate; and
g) Minimizing air turnover is necessary.

Local exhaust ventilation normally requires lower air flows than general (dilution) ventilation.

Dilution ventilation is used to reduce the concentration of vapours from a given liquid solvent in the air to a safe level known as the threshold limit value (TLV) of the solvent expressed in ppm (parts per million). For a given solvent, the volume of air required to dilute its vapour concentration to below TLV can be calculated by the following equation:

$$\text{Air volume in m}^3 \text{ per kg of evaporation } = \frac{\left(24 \times 10^{6} \times k\right)}{\left(m \times TLV\right)}$$

where, *k* = Constant varying from 3 to 10 depending on the solvent, uniformity of air air distribution, dilution of vapours in air and location of exhaust hood; and
m = Molecular weight of the solvent.

A local exhaust ventilation system normally consists of a hood, a duct system, air cleaner, a fan and an exhaust stack. Such a system captures the contaminants at the point of generation through a properly mounted exhaust hood. The exhaust flow rate is determined from the area of the hood openings and capture velocity sufficient to prevent outward escapement of the contaminant. Table 5 lists the recommended range of capture velocities for various types of industrial contaminants.

Table 5 Recommended Capture Velocities for Industrial Contaminants
(*Clause* 11.2.3)

Sl No.	**Condition of dispersion of contaminant**	**Process example**	**Recommended Capture Velocity** m/s
(1)	**(2)**	**(3)**	**(4)**
i)	Released with practically zero velocity into still air	Evaporation from pickling tank, degreasing tank	0.25 - 0.5
ii)	Released at low velocity into moderately still air	Spray booth, intermittent container filling, welding, plating, low speed conveyor transfer	0.5 - 1.0
iii)	Active generation into zone of rapid air motion	Spray painting in shallow booth, barrel filling, conveyor loading, crushers	1.0 - 2.5
iv)	Released at high initial velocities into zone of very rapid air motion	Grinding, abrasive blasting, tumbling	2.5 - 10

From the range of capture velocities shown in the above table, the proper choice of a value can be made based on the factors described in Table 6.

Table 6 Factors affecting the Choice of Capture Velocity within a Range
(*Clause* 11.2.3)

Sl No.	**Lower end of range**	**Upper end of range**
(1)	**(2)**	**(3)**
i)	Minimum air currents favourable to capture	High room air currents
ii)	Minimum toxicity of the contaminants	High toxic contaminant
iii)	Intermittent/low production	High production/heavy use
iv)	Large hood, large air mass in motion	Small hood, local control only

The sizing of the ducts shall be determined considering the volume of air required and minimum recommended duct velocities necessary to convey the contaminants with minimum possible pressure drop keeping in mind economics of installation and operation. Recommended duct velocities for exhaust ventilation systems are given in Table 7.

Table 7 Recommended Duct Velocities for Exhaust Ventilation Systems
(*Clause* 11.2.3)

Sl No.	**Nature of Contaminants**	**Examples**	**Recommended Duct Velocity** m/s
(1)	**(2)**	**(3)**	**(4)**
i)	Vapours, gases, smoke	All vapours, gases & smoke	5 - 10
ii)	Fumes	Welding	10 – 12.5
iii)	Air laden with very fine dusts	Litho powder, wood flour, cotton lint	12.5 - 15
iv)	Dry dust and powders	Fine rubber dust, moulding powder dust, cotton dust, jute lint, soap dust, leather shaving	15 - 20
v)	Average industrial dusts	Grinding dust, general material handling, clay dust, brick cutting, lime stone dust, asbestos dust in textile industry, dry buffing lint, granite dust, silica flour, shoe dust	17.5 - 20
vi)	Heavy dusts	Metal turnings, saw dust, sand blast dust, C.I. boring dust, lead dust, foundry tumbling barrels and shakeout	20 – 22.5
vii)	Heavy and moist dusts	Lead dust with small clips, moist cement dust, sticky buffing lint, quick lime dust	22.5 and above

The selection, installation and operation of fans should be in conformity to the nature of contaminants and should be capable of overcoming the total system pressure drop and deliver the required flow rate. For dust and other industrial contaminant laden air, the drive arrangements (motor, belts and pulleys) should be kept outside the air stream.

11.2.4 General Ventilation Rate for Non Air-Conditioned Areas

The rate of air circulation recommended for different general areas is as given in Table 8.

Table 8 Recommended Rate of Air Circulation for Different Areas

Sl No. (1)	**Application** (2)	**Air Change per Hour** (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.	Changing Rooms	6-10
12.	Churches	1-3
13.	Cinemas and theatres	10-15
14.	Club rooms	12, *Min*
15.	Compressor rooms	10-12
16.	Conference rooms	8-12
17.	Corridors	5-10
18.	Dairies	8-12
19.	Dance halls	12, *Min*
20.	Dye works	20-30
21.	Electroplating shops	10-12
22.	Enclosed underground vehicle parking	8, *Min*
23.	Engine rooms/DG Rooms/GG Rooms	15-30
24.	Entrance halls	3-5
25.	Factories and work shops	8-10
26.	Foundries	15-30
27.	Garages	6-8
28.	Glass houses	25-60
29.	Gymnasium	6, *Min*
30.	Hair dressing saloon	10-15

31.	Hospitals-sterilising	15-25
32.	Hospital-wards	6-8
33.	Hospital domestic	15-20
34.	Laboratories	6-15
35.	Launderettes	10-15
36.	Laundries	10-30
37.	Lavatories	6-15
38.	Lecture theatres	5-8
39.	Libraries	3-5
40.	Living rooms	3-6
41.	Mushroom houses	6-10
42.	Offices	6-10
43.	Paint shops (not cellulose)	10-20
44.	Photo and X-ray dark room	10-15
45.	Public house bars	12, *Min*
46.	Recording control rooms	15-25
47.	Recording studios	10-12
48.	Restaurants	8-12
49.	School rooms	5-7
50.	Shops and supermarkets	8-15
51.	Shower baths	15-20
52.	Stores and warehouses	3-6
53.	Squash courts	4, *Min*
54.	Swimming baths	10-15
55.	Toilets	6-10
56.	Utility rooms	15-20
57.	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.

11.2.5 *Humidification for Industrial Processes*

Evaporative cooling should generally be used where humidification is necessary to meet the requirements of manufacturing processes in factories, as for instance, in a cotton mill to keep the textile fibres pliable and strong, in rubber factories to prevent static electricity in processes using volatile and inflammable solvents or in painting and lithographic works to maintain accurately the size of the paper and other materials. Evaporative cooling shall be done in accordance with **7.2.15**.

11.2.6 *Commercial Kitchen Ventilation*

The basic purpose of a kitchen ventilation system (KVS) is to provide a comfortable environment in the kitchen and to ensure the safety of the people working in the kitchen and other building occupants by effective removal of effluents which may include gaseous, liquid and solid contaminants produced by the cooking process and products of fuel and food combustion.

Heat is the primary ingredient of kitchen effluents. 50 to 90 percent of the appliance energy input is released in the form of a rising convective thermal plume above the cooking surface. Balance is released into the surrounding space through radiation. The thermal plume also contains most of the food and fuel generated effluents. In the absence of cross drafts, the hot convective plume above a cooking surface rises vertically, entraining ambient air which enlarges the plume, cools it and slows it down. This hot plume can be conveniently captured by placing an exhaust hood over the cooking surface. The hood must be of sufficient size and placed at proper height to encompass the whole plume. The hood exhaust flow rate should be slightly higher than the plume flow rate. Extra exhaust capacity may be required to resist cross drafts.

From a system design perspective, grease is the most important constituent of effluent generation in a commercial kitchen. Grease generation is a function of both what is being cooked and on what type of appliance is it being cooked. The amount of grease in vapour phase is significant and varies from 30 percent to 90 percent by mass. This is an important factor in designing the grease removal system. Carbon monoxide (CO), carbon dioxide (CO_2) and oxides of nitrogen (NO_X) are present in combustion processes in gas appliances and not in electrical appliances.

11.2.6.1 *Hood exhaust flow rate*

Kitchen hoods have been classified as two types, Type I and Type II. Type I hoods are used to collect and remove grease, smoke, steam and heat. Type II hoods only remove steam and heat. Thus, Type I hoods are fitted with some kind of grease collection device such as grease filters, baffles and a fire suppression system but a Type II hood typically does not have these devices. Appliances such as cooking ranges, fryers, broilers and griddles require Type I hoods whereas ovens, steamers and dishwashers can work with Type II hoods.

The most commonly used Type I hoods are available in four basic styles:

a) wall canopy;
b) single island;
c) double island; and
d) back shelf or proximity.

The upward velocity of the effluent thermal currents over the hot cooking surface is mainly a function of the temperature of the cooking surface and varies from 0.08 m/s over steam equipment to 0.8 m/s over charcoal broilers. Higher the effluent velocity, higher will be the flow required. Thus for a particular hood style, the exhaust flow rate is primarily determined by the appliance surface temperature (type of appliance), in addition to an allowance for cross drafts.

Recommended hood exhaust flow rates (in ℓ/s) for different types of cooking equipment and exhaust hoods per linear meter of hood length should be as per Table 9.

Table 9 Recommended Hood Exhaust Flow Rates by Appliance Category
(*Clause* 11.2.6.1)

Sl No.	Appliance Category	Light	Medium	Heavy	Extra Heavy
	Surface Temperature °C	200 °C	200 °C	315 °C	370 °C
(1)	(2)	(3)	(4)	(5)	(6)
i)	Cooking equipment	a) Electric/gas ovens b) Electric/gas steamers c) Cheese melters d) Pizza ovens e) Food warmers	a) Hot Top/ Element b) Ranges c) Griddles d) Fryers e) Pasta Cookers f) Conveyor Ovens g) Grill h) Rotisseries	a) Open Burner Ranges b) Broilers c) Wok Ranges	Appliances using solid fuels for example, wood, charcoal briquettes.
ii)	Plume velocity (m/s)	0.25	0.43	0.75	0.93
	Hood type	Hood exhaust flow rates per linear meter of hood length l/s			
i)	Wall mounted canopy	309	463	618	850
ii)	Single island	618	772	927	1 080
iii)	Double island (per side)	386	463	618	850
iv)	Back shelf	463	463	618	-

If more than one duty category appliance are placed under one hood, the hood exhaust flow should be calculated on the basis of the heaviest duty appliance.

For Type II hoods, the recommended exhaust flow rates are from 150 to 460 l/s per linear meter of hood length for oven hoods and 460 to 770 l/s for condensate hoods.

11.2.6.2 *Good hood design and installation practices*

Following are good hood design and installation practices:

a) Increasing hood overhang increases capture volume which aids capture and prevents spillage. A minimum overhang of 150 mm on all open sides for all canopy hoods is recommended. Increasing front overhang and use of inclined side panels (instead of side overhang) significantly reduces capture flow rates.

b) Deployment of side panels improves hood performance significantly. Side panels prevent the plume from spilling at the side, prevent cross drafts and increase velocity at the hood front.
c) Under a wall canopy hood, pushing the appliance towards the back wall significantly improves hood performance in two ways, increased front overhang and reduction in gap between the appliance and the back wall.
d) When using multiple duty category appliances in line under a single hood, the lowest capture rates are achieved when light duty appliance are at the end of the line. Therefore, hood performance is best when heavy duty appliances are placed in the middle of the line.
e) Hood should be mounted at as low a height as practical above the appliance surface.

11.2.6.3 *Oil/grease removal*

The removal of oil/grease from the exhaust airflow is a very important part of commercial kitchen operation. In absence of proper filtration, grease will

a) collect in the exhaust plenum and ducts resulting in
   1) a fire hazard,
   2) an increase in the frequency of costly duct cleaning;
b) collect on the fan causing it to become unbalanced and lead to premature failure;
c) create odour in or near the restaurant;
d) collect on the rooftop creating safety/environmental hazard; and
e) collect on the rooftop equipment and cooling coils.

These problems can be greatly reduced through the use of proper filtration devices in the hood exhaust system. The design and selection of proper filtration device shall conform to the applicable pollution control norms.

11.2.6.4 *Recommended exhaust duct design, installation and maintenance practices*

Kitchen exhaust ductwork carries hot grease laden air. The following general guidelines should be followed in their design, installation and maintenance:

a) Ducts should be round or rectangular.
b) Ducts shall be grease tight and should be free of traps that can hold grease.
c) Minimum sheet gauge should be 16 g carbon steel or 18 g stainless steel.
d) All joints and seams shall be fully welded and liquid tight.
e) Ductwork shall lead directly to building exterior and shall not be interconnected with any other type of building ductwork.
f) Horizontal duct runs should pitch towards the hood or an approved reservoir for continuous drainage of liquid grease and condensate. The slope should be 2 percent for runs under 23 m. For horizontal runs greater than 23 m, 8 percent slope should be provided.

g) Maximum velocities are limited by pressure drop and noise and should normally not exceed 12.5 m/s.
h) The minimum air velocity for exhaust ducts should be 2.5 m/s.
j) For new single speed fan systems, a design duct velocity of 7.5 m/s to 9 m/s is appropriate.
k) Ducts shall conform to requirements given in Part 4 'Fire and Life Safety'.
m) Access doors shall be provided next to each extra duct component, for example, fire dampers. This should be marked/provided in drawings as well as in actual duct work, so that nothing is built to block access to them.
n) It is recommended that the grease film thickness inside ducts (measured with a wet film thickness gauge or equivalent device) should not exceed 180 microns.

11.2.6.5 *Fans for kitchen exhaust*

Kitchen exhaust consists of hot, grease laden air with some solid particulate matter also. Fan shall be capable of handling this air and the motor and the drive train (shaft, bearings, belts etc) shall be kept outside the air-stream. The recommended kitchen exhaust fan is a backward type centrifugal fan. A forward curved centrifugal fan is not recommended for kitchen exhaust.

11.2.6.6 *Terminations of kitchen exhaust systems*

Kitchen exhaust systems should be terminated so that:

a) Discharge direction should be such as to minimize re-entry into fresh air intake. This not only requires a minimum separation between exhaust and intakes but also knowledge of prevailing winds.
b) Grease should be collected and drained to a closed container (a fire safety precaution).
c) Rainwater should be kept out of the grease container.
d) Grease should not be allowed to drain down the side of the building.
e) Discharge not to be directed downward or towards pedestrian areas.

11.2.6.7 *Replacement (make-up) air considerations*

The air exhausted through a kitchen hood must be replaced 100 percent with clean outside air. Kitchen room pressure should be kept at a slight positive to the outside at all times. This can be accomplished by providing slightly more air than what is being exhausted. The dining room should be kept at an even greater positive pressure, which will allow a slight airflow from the dining area to contain heat and odours to the kitchen. Even though both dining area and kitchen are at positive pressure, the kitchen is at negative pressure when compared to the dining area.

Replacement air in air-conditioned kitchens should be supplied as close to the hood as possible and this can be best achieved by the use of compensating exhaust hoods with supply air forming an integral part of the hood.

11.2.6.8 *Energy management considerations*

Hood exhaust flows can result in twenty or more air changes per hour. Installing a variable volume system is the first step towards energy conservation to allow for the exhaust and supply units to ramp up and down depending on the cooking load. Varying both the exhaust and the supply will vary the amount of air that needs to be conditioned. In some cases, a variable system can reduce the costs associated with conditioning make-up air by up to 50 percent.

Exhaust and supply air flow rates should be controlled by installing variable frequency drives (VFD) on the fan motors. The VFDs are controlled by a temperature sensor mounted in duct collar. The control system varies the frequency of the motor drives and thus fan speed according to the temperature seen in the duct collar. The VFD system varies the flow continuously as per the cooking requirement as opposed to the high, medium and low speed settings on the motor controlled manually. The energy savings using VFDs result from the fact that the fan power, *W* is proportional to the third power of speed, *N*, that is, $\left(W \propto N^3\right)$.

11.3 Underground Car Park Ventilation

11.3.1 *Requirement*

Ventilation is essential in car parking areas to dilute the level of toxic gases such as carbon monoxide (CO), oxides of nitrogen (NOx), presence of petrol/diesel fumes and smoke from engine exhaust. CO is a colourless, odourless and highly poisonous gas. Even dilute concentrations of CO in air can cause nausea, headache and vertigo. The undesirable health and fire hazard of the above contaminants can be contained if their levels are maintained within permissible limits by ventilation.

The ventilation rate required to maintain the concentration of toxic gases within safe limits for an enclosed parking facility depends primarily on four factors:

a) *Numbers of cars in operation during peak usage* (*N*),

b) *Length of time of operation* - The length of time a car remains in operation in a parking garage (T_m), which further depends on the size and layout of the garage and the number of cars trying to enter or exit. The time taken can vary from 60 s to 600 s, but on average ranges from 60 s to 180 s.

c) *Car emission rate* - The operation of a car in a parking garage differs considerably as compared to the car on the road or even in a road tunnel, because most of the operation of the car in and around the garage takes place at low gear. A car entering the garage is at slow speed but the engine is usually hot. A car exiting the garage has a cold engine with rich fuel mixture. Emissions from a cold start are generally much higher, so the distinction between a hot and cold start plays a critical role in determining the ventilation rate. Typical CO emissions (*E*) within parking garages can vary from 113 g/h (grams/hour) in summers to 202 g/h in extreme winters with hot engines. With cold start engines, the rates go up to 220 gm/h in summers to as high as 1 130 g/h in winters. These rates are at an assumed vehicle speed of 8 km/h.

d) *Contaminant level criteria* - The recommended ventilation rate will ensure that the CO level is maintained within 29 mg/m^3 (25 ppm) with peak levels not to exceed 137 mg/m^3 (115 ppm).

For a parking garage of area, *A* (in m^2) and height, *H* (in m), the resulting air changes per hour (ACH) can be calculated as under:

$$ACH = \frac{Q}{(A \times H)}$$

11.3.2 *Ventilation Rate Requirement*

11.3.2.1 *Naturally ventilated car parks*

These have permanent wall openings on each level, which are equal to 5 percent of the plan area, arranged to provide cross ventilation.

11.3.2.2 *Mechanically ventilated car parks*

For enclosed underground car parks without provision for natural ventilation, a ventilation rate of 9 air changes per hour is considered adequate to keep contaminants within acceptable hygiene limits.

11.3.3 *System Requirement*

The ventilation system for normal CO ventilation in car parks should consist of supply fans, exhaust fans and a system of ducts or impulse fans for proper distribution of air in the car park.

When the fans and the ventilation system used for normal CO level ventilation are also to be used for smoke ventilation during a fire, the fans, ancillaries and the system should be rated for high temperature operation as per the requirements (*see also* Part 4 'Fire and Life Safety').

11.3.4 *Demand Control Ventilation Based on CO Level*

The ventilation air flow rate can be varied according to CO levels to conserve energy during off-peak hours when vehicular movements are much lower than during peak hours. Since the flow rate of a fan is directly proportional to its speed, this can be achieved with multiple fans in an ON/OFF mode, with dual speed motors or motors connected to variable speed drives (VFDs). In multilevel basements as well as in large single level structures, independent fan systems with individual control are required. This is to take care of fire compartmentation requirements (*see also* Part 4 'Fire and Life Safety').

Significant energy savings are possible with demand control ventilation (DCV), which varies the fan speed to regulate CO levels below the maximum permissible level. The power consumed by a fan is proportional to the third power of its speed $(W \propto N^3)$.This means that even if larger fans are installed to meet code requirements, power consumption will not necessarily increase as long as demand control ventilation is used.

11.3.4.1 *Location of sensors*

The sensors shall be placed in the following manner:

a) Maximum distance of any corner in the car park to the nearest sensor should be less than 25 m.
b) First 12 m from fresh air opening are considered as natural ventilation (NV) zone.
c) Sensors should be grouped according to the zones by the exhaust fans. The coverage area of each sensor should typically be 500 m^2.
d) Sensors should ideally be located between 0.9 m and 1.8m above floor level. However, for practical reasons (in order to avoid vandalism), the sensors can be installed at just above 1.8 m height from floor.

11.4 Tunnel Ventilation System

11.4.1 *General*

The tunnel ventilation system (TVS) at underground metro station or tunnels is intended to provide:

a) an acceptable environment in the tunnel and station trackway for the operation of trains,
b) pressure relief during normal operation,
c) Heat removal during congested/maintenance operation, and
d) an effective means of controlling smoke flows during emergency conditions.

11.4.2 *Operation Philosophies*

There are three design operating conditions for the tunnel ventilation system, normal, congested and emergency.

During normal operation, the main source of ventilation for the tunnels is piston-generated airflow produced by moving trains. In congested operation, the tunnel ventilation fans (TVFs) are activated for preventing the accumulation of warm tunnel air around idling trains in the affected ventilation zone. The tunnel ventilation design condition for congested train operations is maximum stratified tunnel air temperature of 46°C or 50°C (depends on the design of the rolling stock). In emergency operation, the TVS is set to operate to control the movement of smoke and provide a smoke-free path for evacuation of the passengers and for the fire fighting purposes. The ventilation system is operated in a 'push-pull' supply and exhaust mode with jet fans or nozzles driving tunnel flows such that the smoke is forced to move in one direction, enabling evacuation to take place in the opposite direction. Fig. 1 shows a typical ventilation system in tunnel during fire on a train.

11.4.3 *System Description*

The tunnel ventilation system (TVS) consists of tunnel ventilation fans (TVFs), trackway exhaust fans (TEFs), tunnel booster fans (TBFs), tunnel ventilation dampers (TVDs), nozzles and sound attenuators provided in the tunnel ventilation plant rooms at each end of the station and connected to both trackways and to atmosphere through the ventilation shafts.

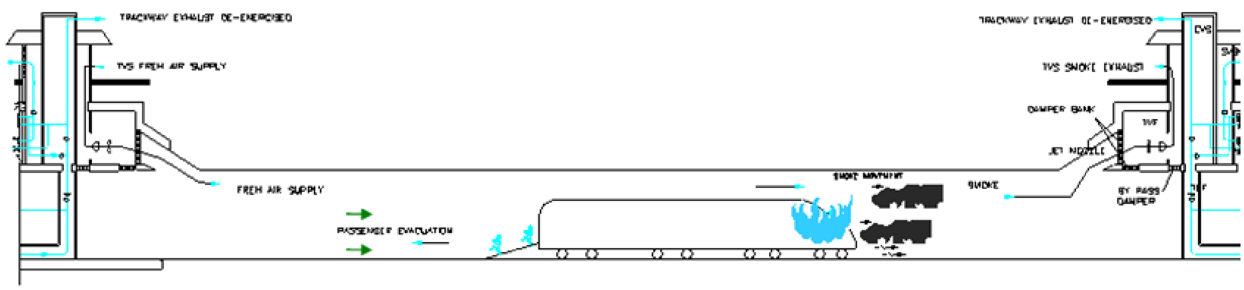


Fig. 1 Ventilation in tunnel during fire on a train

Each tunnel ventilation installation has two fully reversible tunnel ventilation fans with fan isolation dampers. These dampers are closed when the fan is not in operation. In addition, there is a bypass duct around the fan room, which acts as a pressure relief shaft when open during normal conditions, and enables the flow of air to bypass the TV fans (TVFs), allowing air exchange between tunnel with flows generated by train movements. Dampers are also used to close the connections to tunnels and nozzles when under different operating conditions. The tunnel booster fans are installed at the crossover locations to direct the flow in desired direction during congestion and emergency ventilation. The trackway exhaust fans are located in separate plant rooms at each end of the station and connected to station trackway through under platform exhaust and over track exhaust ducts and to the atmosphere through exhaust ventilation shafts to enable separate ventilation of station trackway. The specialized software tools are used to derive the TVF airflow rate, TBF thrust and location and operation philosophy to be adopted to meet the design criteria of above mentioned scenario. In addition to this 3D modelling tools are used to study the temperature stratification in congestion mode.

A typical schematic of the TVS system installed at Delhi Metro station at platform level is shown in Fig. 2:

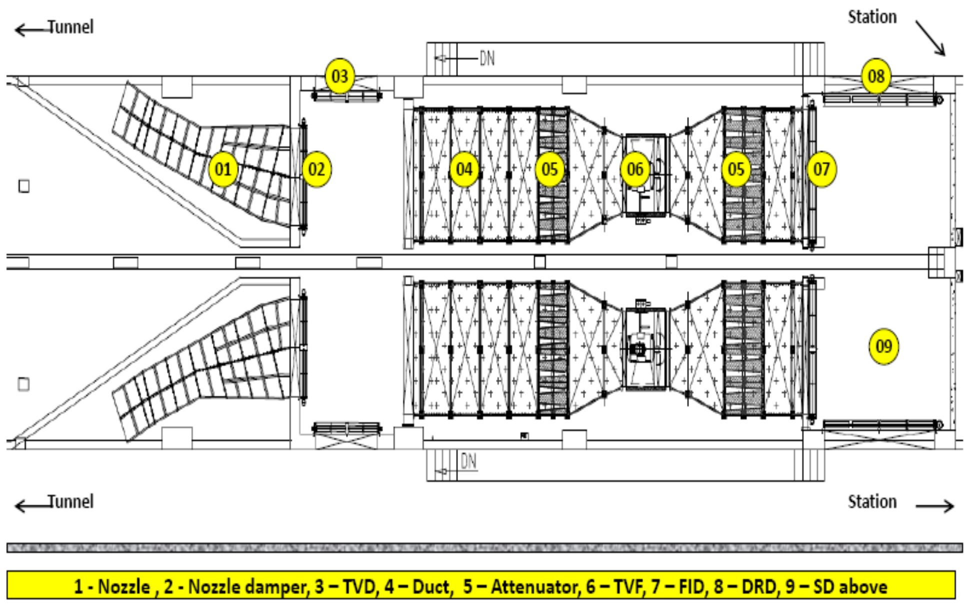


Fig. 2 Typical schematic of the TVS Plant Room at Platform Level

11.4.4 *Control and Monitoring of TVS*

The TVS system shall be equipped with provisions for automatic, manual, local and remote controls so that the fans and motors can be operated from a station control room (SCR) or from the operations control centre (OCC). At OCC, an integrated supervisory control and data acquisition system (SCADA), should be employed to control and monitor the TVS plant in each station, as the same are unattended locally.

11.5 Selection of Fans for Mechanical Ventilation

Fans consume most of the energy in a mechanical ventilation system. Various types of fans are available for ventilation applications, for example, forward and backward curved centrifugal fans, tube axial/vane axial fans, mixed flow fans, roof ventilators and in-line fans. Proper selection and application of fans for a given application results in the most economic and energy efficient operation.

The primary factors that govern the size and type of fan are the required flow, system pressure drop and acceptable noise levels. The size of the fan and its operating speed should be selected on the basis of the fan operating efficiency criterion. A fan should be selected so that its efficiency at the required point of operation is the highest possible from a range of selections. This will not only ensure minimum motor power and low energy cost but will also normally result in the quietest operation. This is because most fans emit minimum sound levels in the vicinity of the maximum efficiency operating point.

11.5.1 *Fan Efficiency Requirement*

Centrifugal fans tend to have higher operating efficiencies than tube axial fans. The air flow downstream of the impeller in a tube axial fan is highly turbulent and vortex like. This leads to excessive losses and noise. For this reason, tube axial fans are not recommended for supply air applications. The efficiency and flow performance of tube axial fans can be enhanced significantly by providing guide vanes on the downstream side. These fans are known as vane axial fans.

Fan total efficiency is defined as under:

$$Fan\ total\ efficiency\ (\text{in percent}) = \frac{Flow\ rate\ \left(\text{in m}^3/\text{s}\right) \times fan\ total\ pressure\ (\text{in Pa})}{Fan\ shaft\ power\ (\text{in W})}$$

Fans are classified under various efficiency grades (FEG) based on their peak efficiencies (*see* Fig. 3). The FEG grading is representative of the fact that larger size fans are inherently more efficient than geometrically similar smaller fans. The following selection criterion should be used to select fans for various types of mechanical ventilation applications for new buildings:

a) For tube axial fans requiring a shaft power of 2.5 kW or more, the fan efficiency grade shall be FEG 60 or more.

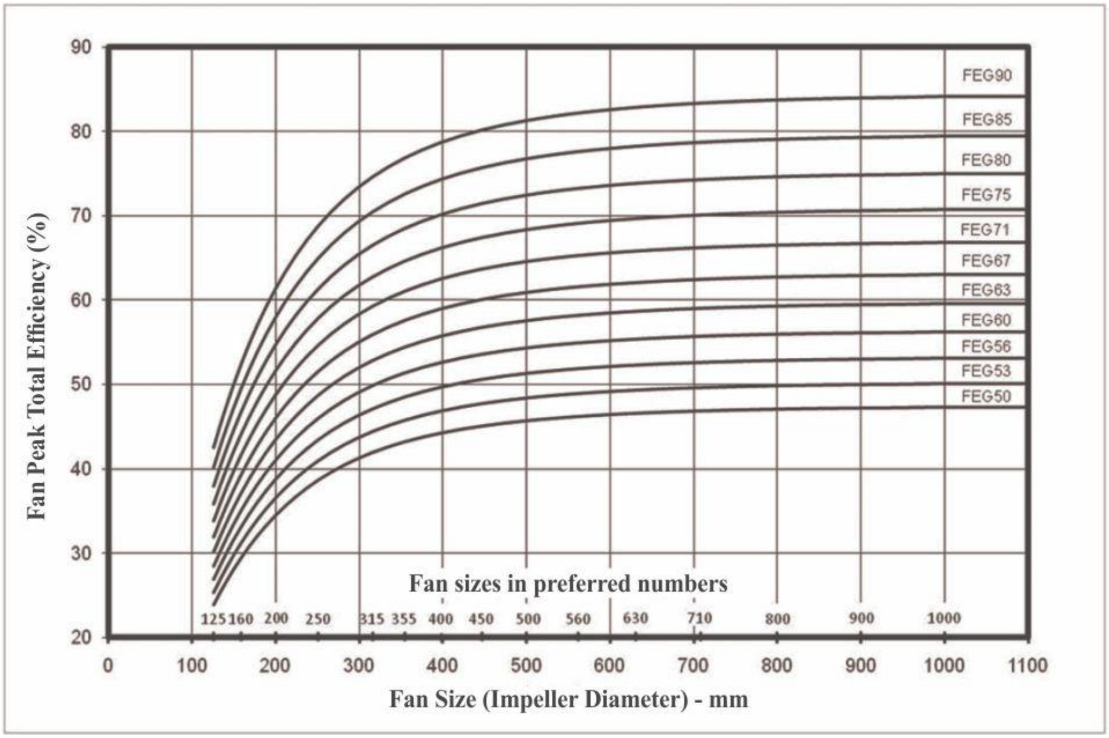
b) For centrifugal and vane axial fans requiring a shaft power of 2.5 kW or more, the fan efficiency grade shall be FEG 71 or more.

The operating total efficiency at the selected point of operation for a given application shall be within 10 percentage points of the peak value.

11.5.2 *Other Fan Selection Parameters*

In addition to the size and operating speed, the choice of a fan and its drive arrangements also depends on the nature of air to be handled and the type of application. If the fan has to handle dust laden or contaminated air, for example, industrial exhaust or kitchen exhaust, the fan drive arrangements (motor, pulleys, bearing and belts) must be kept outside the air stream. The same applies to the temperature of air to be handled. For higher than normal air temperatures, for example, smoke ventilation, the fans must be rated for high temperature applications.

Because belt drives incur additional transmission losses, consideration should also be given to direct driven fans in conjunction with variable speed drives (VFDs) to adjust fan speeds.



NOTE- Beyond 1 100 mm diameter size, the FEG lines are horizontal

Fig. 3 FEG Rating of Fans for Various Impeller Diameters

12 INSTALLATION OF HVAC SERVICES

12.1 Installation of Air Conditioning System

12.1.1 *Installation of Chiller*

The chiller shall be mounted on a reinforced cement concrete/structural foundation and shall be adequately isolated as per manufacturer's recommendations against transmission of vibration to the building structure.

For open type, special attention shall be paid to the alignment of the drive and driven shafts; final alignment shall be checked at site in presence of the contractor, using a dial indicator.

Compressor and motor sole plates, anchor bolts and sleeves and necessary vibration isolation pads shall be included.

All controls and switch gear shall be tested for proper functioning and set of design values and there should be enough space between the machine to move around and door of panels can be operated freely, if needed .

On completion of installation of works, the water chilling unit shall be tested for performance. The capacity in kcal/hr (tons) shall be calculated from measurements of temperature difference and flow rate of water in condenser and water in chiller. The power consumption shall be checked from current measurement of the motor. All calculated and checked results shall match the specified data.

12.1.2 *Installation of Pumps*

The pumps shall be mounted on concrete block which in turn is mounted on machinery isolation cork or any other equivalent isolation fitting. More than one pump set shall not be installed on a single base or cement concrete blocks.

Foundation bolts shall be embedded correctly. Before the bolts are grouted and the coupling bolted, the bed plate levels and alignment must be checked before proceeding with work.

The motor with driving equipment shall be mounted on foundation and connected to each other with flexible coupling if needed with guard in condenser and chilled water pumps.

On installation the capacity of the pumps shall be checked by measuring water flow, using the balancing valve in full open position, motor current and pressure difference at inlet and outlet. The readings shall be recorded to compare actual performance with the specified data.

After installation of the complete system and before testing, the pump shall be lubricated or painted in strict accordance with the manufacturer’s instructions.

The pumps shall be installed in a manner that would allow maintenance without causing damage to the insulation.

12.1.3 *Installation of Cooling Tower*

The cooling tower shall be mounted on a reinforced cement concrete pillar/structural foundation as per manufacturer's recommendations. Height of pillar to be decided as per space required to install pipe and valve for proper operation.

These may be located at a well-ventilated place either at ground level and contiguous to the plant room or on the terrace of the building in consultation with the structural consultant. In case the cooling towers are located on the terrace of the building, the structural loading of the terrace shall be considered accordingly. Cooling tower shall be installed in such a way that there load is transferred directly to the columns for which necessary mild steel I-section shall be provided. The cooling towers shall be rested on these mild steel I-section and sufficient space shall be left all around for efficient operation of the cooling tower.

Cooling tower shall not be less than 100 cm above the ground/floor level unless otherwise specified. Suitable thickness of vibration isolation pad shall be placed between the tower and guider to avoid the transfer of vibration towards the columns.

On completion of installation of works, the cooling tower shall be tested for performance. The capacity in kcal/hr (tons) shall be calculated from measurements of temperature difference, approach and flow rate of water in condenser. The power consumption shall be checked from current measurement of the motor. All calculated and checked results shall match the specified data.

12.1.4 *Installation of Air Handling Unit* (*AHU*)

Air handling unit shall be installed as below:

a) AHU locations shall be marked on the plinth as per approved drawings/manufacturers details. Co-ordination with contractors for civil works and other services shall be checked prior to installation. Installation of AHU shall be adequately isolated as per manufacturer's recommendations against transmission of vibration to the building structure.

b) Easy accesses and sufficient clearance shall be ensured for servicing and maintenance, that is, for cleaning of filters, maintenance of strainer/valve packages along with motors.

c) The slope should be in the direction of floor trap to avoid the accumulation of water in AHU room. Also the slope of the drain tray should be checked in the direction of drain pipe connection.

d) The drain piping shall be connected with U-trap to avoid odour.

e) The duct flexible connection shall be fixed on air outlet side of the AHUs to avoid vibration towards the duct.

f) The valve package and piping connections shall be completed as per approved drawings.

g) Installation of ceiling suspended unit shall be done with rod and fasteners as per the procedure stated above except the foundation required for floor mounted AHU.

h) On completion of installation works, the AHU shall be tested for performance.

12.1.5 *Installation of Air Washer*

Air washers shall be installed as below:

a) The air washer locations shall be marked on the plinth as per approved drawings/manufacturers details. Co-ordination with contractors for civil works and other services shall be checked prior to installation and shall be adequately isolated as per manufacturer's recommendations against transmission of vibration to the building structure.

b) Easy accesses and sufficient clearance shall be ensured for servicing and maintenance, that is, for cleaning of filters, maintenance of pump, motor and blower.

c) The slope should be ensured in the direction of floor trap to avoid the accumulation/spread of water in air washer room.

d) The duct flexible connection shall be fixed on air outlet side of the air washer units to avoid vibration towards the duct.

e) The plumbing piping connections shall be completed as per manufacturer's recommendation.

f) On completion of installation works, the air washer unit shall be tested for performance.

12.1.6 *Installation and Testing of Axial Fan*

12.1.6.1 *Installation of axial fan*

Installation of axial fans shall be complete with vibration isolation and mild steel structure of C-channel of size 100 mm x 50 mm x 5 mm welded with mild steel plate having 6 mm thickness with 2 coat of red oxide and one coat of enamel paint. The support rods shall be cut and trimmed after finalizing the levels. In case, fans are installed horizontally, extra length of 25 mm of support rods should be left for final adjustments. Burrs and sharp edges, if any should be removed.

The fan shall be installed in a manner that would allow maintenance freely.

All necessary accessories, as below shall be provided for proper installation:

a) vibration isolators for the axial fans;
b) double canvas connections at the outlets of each fan;
c) nuts, bolts etc, as required for the grouting of the equipment; and
d) bird screens for the protection, if needed.

12.1.6.2 *Testing of axial fan*

Capacity of all fans shall be measured by an anemometer. Measured airflow capacities shall conform to the specified capacities and ratings. Power consumption shall be computed from measurements of incoming voltage and input current and field balancing to be done, if required.

12.1.7 *Installation of Ducts*

The material and constructional requirements for ducts shall conform to the accepted standard [8-3(2)]. The installation of sheet metal duct work for air distribution and also its associated items, such as, air outlets and inlets, fresh air intake and fire dampers are covered in **12.1.7.1** to **12.1.7.3**.

12.1.7.1 *Ducts support and hangers*

Supporting details for low pressure system are given below:

Larger Side of Duct mm	Supporting Angle mm	Vertical Rod Diameter mm	Maximum Spacing between Supports mm
Up to 900	40 X 40 X 5	8	2 400
901 to 1 500	40 X 40 X 5	8	2 400
1 501 to 2 400	40 X 40 X 5	10	2 400
2 401 and above	65 X 65 X 5	12	2 400

Supporting details for higher pressure systems are given below:

Larger Side of Duct mm	Supporting Angle mm	Vertical Rod Diameter mm	Maximum Spacing between Supports mm
Up to 1 250	50 X 50 X 5	12	2 400
1 251 to 2 100	65 X 65 X 5	12	2 400
2 101 and above	75 X 75 X 5	15	2 400

12.1.7.2 *Dampers*

Volume control dampers must be provided at the junctions of each branch duct with main duct. Dampers shall be 2 gauge heavier than the gauge of large duct but should not be less than 20 gauge and shall be rigid in construction to the passage of air.

12.1.7.3 *Access door*

Access door shall be provided in duct before & after equipment installed in duct & at all fire damper locations. All access doors shall be fabricated of the same material as the duct work & shall have minimum two hinges. Hinges shall be zinc plated and pins shall be of brass. Access doors shall be of minimum of 305 mm x 305 mm size. At least two heavy solid fasteners and a brass handle are required for each door. A continuous neoprene rubber gasket shall be adhered to the opening frame with adhesive.

12.1.8 *Installation of Pipe*

Installation of chilled water/condenser water/drain water pipes, pipe fittings and valves etc shall be in accordance with **12.1.8.1**. All pipes, fittings and valves etc, shall conform to relevant Indian standards.

12.1.8.1 *Water piping*

Pipes and fittings shall be designed for system requirement pressure rating.

Chilled/condenser/hot water pipes shall be "heavy" class “C” mild steel black pipes up to 150 mm and mild steel ERW black pipes above 150 mm and it shall conform to the accepted standards [8-3(11)] or Grade 330 of the accepted standard [8-3(12)].

Piping shall be properly supported on, or suspended from, stands, clamps, springs, hangers, as required at site. Design of all the brackets, saddles, anchors, clamps and hangers shall be as per design requirement.

All pipes in HVAC plant room shall be supported with engineered support structures made of pipes and channels from floor only with necessary high density PUF/ wooden pipe supports.

CHILLED WATER PIPE SUPPORT STRUCTURE DETAIL					
Sl No.	**Pipe Size**	**Ceiling Support**	**Base Support mm**	**MS Plate Size mm**	**Fastener Size mm**
i)	Up to 50 mm	40 x 40 x 5 thick angle	40 x 40 x 5 thick angle	Cleat ISA 75 x 75 x 5	M10 x 2 numbers
ii)	65 mm to 125 mm	50 x 50 x 6 thick angle	75 x 40 MS channel	250 x 250 x 8 thick	M10 x 4 numbers
iii)	150 mm to 250 mm	75 x 40 MS channel	100 X 50 MS channel	250 x 250 x 8 thick	M10 x 4 numbers
iv)	300 mm to 350 mm	100 x 50 MS channel	150 X 75 MS channel	300 x 300 x 10 thick	M12 x 4 numbers
v)	400 mm to 500 mm	100 x 100 x 6 MS channel box	150 X 150 x 6 MS channel box	400 x 400 x 10 thick	M16 x 4 numbers
vi)	600 mm to 700 mm	150 x 150 x 6 MS channel box	150 x 150 x 6 MS channel box	400 x 400 x 12 thick	M16 x 4 numbers
SHAFT SUPPORT FOR CHILLED WATER PIPE					
vii)	65 mm to 125 mm	-	75 x 40 MS channel	250 x 250 x 8 thick	M10 x 4 numbers
viii)	150 mm to 250 mm	-	100 x 50 MS channel	250 x 250 x 8 thick	M10 x 4 numbers

All pipe supports shall be of steel, coated with two coats of anti-corrosive paint and finally finished with paint. Where pipe and clamps are of dissimilar materials, a gasket shall be provided in between.

Vertical pipes passing through floors shall be parallel to wall and should be straight to wall duly checked with plumb line.

Wherever pipes pass through the brick or masonry/slab openings, the gaps shall be properly sealed as per the provisions given in Part 4 'Fire and Life Safety'.

Wherever insulated pipes are running, it should be supported in such a way that no undue pressure is exerted on the insulated pipes.

Piping layout shall take due care for expansion and contraction in pipes and include expansion joints where required.

All pipes shall be accurately cut to the required size in accordance with relevant Indian Standards, edges beveled and burrs removed before laying. Open ends of the piping shall be closed as the pipe is installed to avoid entrance of foreign matter. Where reducers are to be made in horizontal runs, eccentric reducers shall be used for the piping to drain freely. In other locations, concentric reducers may be used.

Auto purge valves shall be provided at all highest points in the piping system for venting air. Air valves shall be 15 mm pipe size with screwed joints. Discharge from the air valves shall be piped through an equal sized mild steel or galvanized steel pipe to the nearest drain or sump. These pipes shall be pitched towards drain points.

Drain pipes shall be provided at all the lowest points in the system, as well as at equipments where leakage of water is likely to occur, or to remove condensate and water from pump glands. The drain pipe work can be carried out with threaded joints or simply welded.

12.1.9 *Installation of Insulation Works*

Fixing of thermal/acoustic insulation of ducts, pipes and equipment rooms with valves shall be done in accordance with **12.1.9.1** to **12.1.9.5**.

12.1.9.1 *Material*

Selection of material shall be as per design requirement, such as, fibre glass, nitrile rubber, expanded polystyrene (EPS), polyurethane foam (PUF) etc.

12.1.9.2 *Insulation of duct*

12.1.9.2.1 *Thermal insulation on duct*

a) Surface of, on which the external thermal insulation is to be provided, shall be thoroughly cleaned with wire brush and rendered free from all dust and grease.
b) The two coat of cold compound adhesive (environment friendly) shall be applied

over the duct.

c) The thermal insulation material shall then be wrapped to the duct with aluminium facing on outer side. Joints of insulation must be properly sealed with either same type of material or aluminium tape of 50 mm width on all longitudinal/ transverse joints.
d) Finally PVC straps shall be fixed at suitable interval to ensure that the insulation is properly fixed with the ducts.
e) The insulation shall then be covered with 0.63 mm x 19 mm galvanized iron (GI) wire mesh netting on the outside of a duct, if required to be done for specific material.
f) The ducts in areas exposed to the weather shall be additionally covered with one layer of tar-felt and to be stuck with suitable material.

12.1.9.2.2 *Acoustic lining of duct*

The material to be used for duct lining shall be 12/25 mm thick resin bonded fibre glass rigid board having a density of 48 kg/m³ and covered with 0.5 mm thick perforated aluminum sheet. The lining of initial length of the duct shall be done as per the requirement at site and shall be carried out as follows:

a) The inside surface of duct on which the acoustic lining is to be provided shall be thoroughly cleaned with wire brush and rendered free from all dust and grease.
b) Board of suitable thickness shall be fixed inside the duct using suitable adhesive and cover with fibre glass tissue paper.
c) The insulation board shall be covered with 0.5 mm thick perforated aluminum sheet with at least 20 to 40 percent perforation.
d) The insulation board and aluminum sheet shall be secured with cadmium coated bolts nuts and cup washers/steel screws.
e) Finally the ends shall be sealed completely, so that no lining material is exposed.

12.1.9.2.3 *Acoustic lining in equipment room*

The four walls and ceiling of equipment rooms shall be provided with acoustic lining of thermal insulation. The process shall be as below:

a) The wall/roof surface should be thoroughly cleaned with wire brush.
b) A 610 x 610 mm frame work of 25 x 50 x 50 x 50 x 25 mm ‘U’ shape channel made of 0.6 mm thick G.S.S. shall be fixed on to walls leaving 610 mm from floor by means of rawl plug in walls and dash fasteners in ceiling. Similar frame work shall also be fixed on ceiling by means of dash fasteners.
c) Resin bonded glass wool/ mineral wool as specified cut to size will be fitted in the frame work and covered with tissue paper.
d) Finally, finish it by covering the surface with 0.5 mm thick perforated aluminum sheet with brass screws having perforation 20 to 40 percent.
e) All horizontal and vertical joints shall be covered with at least 25 mm. wide, 1mm

aluminum strips held in position by steel or brass screws.

12.1.9.3 *Material and process of thermal insulation of CHW/HW pipes / ac equipments*

Pipe insulation material shall be EPS/PUF/nitrile/fibre glass as per requirement with suitable density and thickness. Adhesive used for setting the insulation shall be non-flammable, vapour proof, CPRX compound.

Procedure for pipe insulation and aluminum cladding shall be as given below:

a) The pipe to be insulated should be cleaned thoroughly with steel brush for removing dirt, rust and grease.
b) A coat of zinc chromate primer and two coats of cold setting adhesive CPRX compound shall be applied on pipes.
c) Insulation of specified thickness should be fixed tightly and all joints should be sealed with adhesive compound.

12.1.9.4 The insulation shall be finished as under:

a) *Inside the building* - Insulation over the pipe work shall be finished with specified thickness of aluminum sheet cladding over a vapour barrier with 50 mm overlap and tied down lacing wire.
b) *Outside the building* - Insulation over the pipe work shall be finished with specified thickness of aluminum/GSS sheet cladding over a vapour barrier with 50 mm overlap and tied down lacing wire. Otherwise over the vapour barrier, pipe to be insulated with 12 mm thick cement-sand plaster in two layers of 6 mm thick each followed by curing of minimum 48 h.
c) *Buried pipe insulation* - For pipes outside the building and laid underground, the insulation shall be covered with suitable gauge polythene faced hessian, (the polythene facing outward), with 50 mm overlap. All joints shall be sealed with bitumen. A layer of 0.50 mm x 20 mm GI wire mesh netting shall be provided over it butting all joint and it shall be laced down with GI wire. A 20 mm thick cement-sand plaster (1:4) shall be provided in 2 layers of 10 mm thickness each and shall be water proofed by applying hot bitumen and fixing tar-felt over the plaster. It shall be finally finished with a coat of hot bitumen.
d) *Pump insulation* - Chilled water pump shall be insulated to the same thickness as the pipe to which they are connected and application shall be same as above. Care shall be taken to apply insulation in a manner as to allow the dismantling of pumps without damaging the insulation.
e) *Insulation of valves and fittings in chilled water line* - All Valves, fittings, strainers etc shall be insulated to the same thickness and in the same manner as for the respective piping, taking care to allow operation of valves without damaging the insulation.

12.2 Installation of Mechanical Ventilation Systems

12.2.1 *General Planning and Installation Guidelines*

12.2.1.1 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.

NOTE- Proper location helps achieve satisfactory air distribution and also results in a less expensive installation.

12.2.1.2 Equipment room should preferably be located adjacent to external wall to facilitate equipment movement and ventilation. It should also be close to main electrical panel of the building, if possible, in order to avoid large cable lengths.

12.2.1.3 Location and dimensions of shafts and openings in walls, slabs, roof etc, for ducting, cables, pipes, air intakes and exhaust (if envisaged) should be planned at the virtual stages itself. Shafts 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 is not 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.

12.2.1.4 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).

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.

12.2.1.5 Supporting of pipe within equipment room~~s~~ 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 connection pipes, ducting cables/cable trays etc, shall be isolated from the structure to prevent transmission of vibrations.

12.2.1.6 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.

12.2.1.7 Wherever necessary, acoustic treatment should be provided in plant room space to prevent noise transmission to adjacent occupied areas.

12.2.1.8 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.

12.2.1.9 In the case of large and multistoried 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.

12.2.1.10 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.

12.2.1.11 Outdoor air intakes and exhaust outlets shall be effectively be shielded from weather and insects.

12.2.1.12 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.

12.2.1.13 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.

12.2.1.14 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.

12.2.1.15 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.

12.2.1.16 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.

12.2.2 *Energy Efficient Installation of Ventilation Fans*

The performance of a fan when installed in a system can be adversely affected by the flow conditions at fan inlet and outlet. Manufacturer's fan performance ratings are mostly based on optimum arrangements of fan inlet and outlet connections to provide uniform straight flow condition. Any deviation from this will result in deficient performance. The amount of pressure loss associated with a given type of inlet/outlet condition is termed System Effect Factor (SEF) and its units are mm or inches of water column. The SEF is a function of air velocity and is proportional to its square, that is, doubling the velocity will increase SEF to 4 times. The air velocity is the velocity at the point of interest, that is, inlet or outlet. All SEFs must be added to the design system pressure drop to accurately reflect the actual system pressure drop.

12.2.2.1 *Outlet ducts*

A system designer must closely examine the manufacturer's fan ratings to determine the conditions under which the fan has been tested. Fans intended for supply air applications are normally tested with an outlet duct. To achieve the rated performance, it is necessary to connect an outlet duct of a certain length. However, due to space constraints or reasons of economy, fans in many cases are installed without an outlet duct.

Effective duct length (EDL) is a minimum of 2.5 equivalent duct diameters. For outlet velocities higher than 12.5 m/s, one duct diameter for each additional 5 m/s is added. Equivalent duct diameter for a rectangular duct is the diameter of a circular duct having the same cross sectional area as the fan outlet.

Typical air velocity profiles at fan outlets are given in Fig. 4.

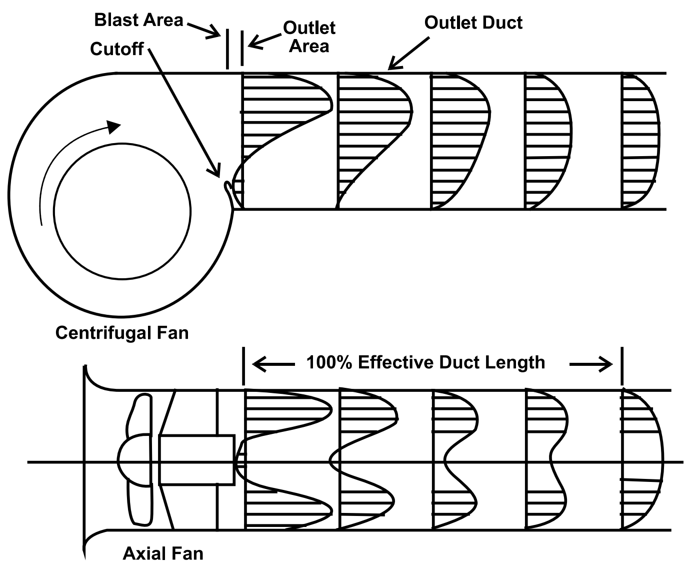


Fig. 4 Air Velocity Profiles at Fan Outlets

a) *Axial flow fans* - The absence of an outlet duct in case of a tube axial fan does not result in any additional pressure losses. However, for a vane axial fan, a minimum of 50 percent EDL is required for them to perform as per the ratings.

b) *Centrifugal fans* - In centrifugal fans, air leaves the blast area (normally 60 to 70 percent of the outlet area) at a much higher velocity and gradually expands and slows down to fill the outlet duct. In manufacturer's fan ratings with an outlet duct, it is normally assumed that the higher velocity pressure associated with the blast at fan outlet (difference in velocity pressure corresponding to blast velocity and outlet velocity) is fully converted into useful static pressure. Thus in actual installation, the manufacturer's fan ratings can be achieved only if the fan is installed with a 100 percent EDL. The pressure losses associated with less than optimum outlet duct length are given below:

	No duct	*Effective duct length*			
		12 percent	*25 percent*	*50 percent*	*100 percent*
Pressure recovery in centrifugal fans by placing an outlet duct (Blast velocity to outlet velocity), in percent	*0*	*50*	*80*	*90*	*100*

Pressure losses in duct elbows are minimum when air approaching the elbow has uniform velocity profiles. Elbows mounted at fan outlets will encounter non-uniform velocity profiles depending on the length of the outlet duct and orientation of the elbow with respect to wheel rotation and fan inlet in case of centrifugal fans. The non-uniform velocity profiles will create additional SEFs (pressure losses) in the elbow.

In case of a tube-axial fan, it is found that the SEFs associated with outlet duct elbows are negligible. For vane-axial fans also, the SEFs can be made negligible by using a 4 piece mitered elbow, instead of a 2 piece and placing it after a minimum of 12 percent EDL (*see* Fig. 5).

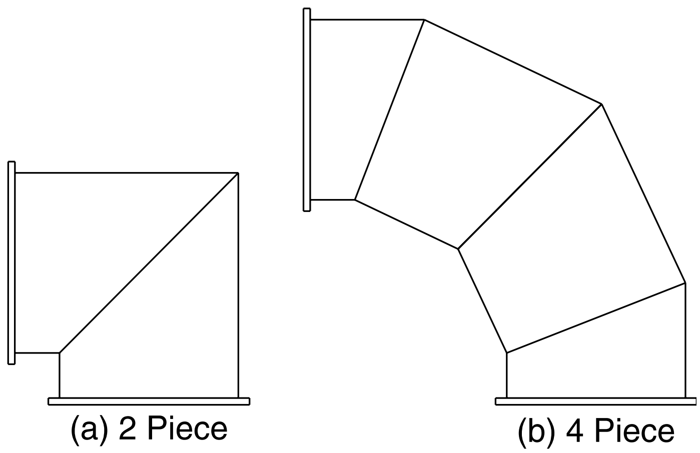


Fig. 5 Round 90°Mitered Elbow

For centrifugal fans, the SEFs are a function of the position of the elbow with respect to wheel rotation and fan inlet. Fig. 6 shows four such positions marked A, B, C and D for an single inlet single width (SISW) fan.

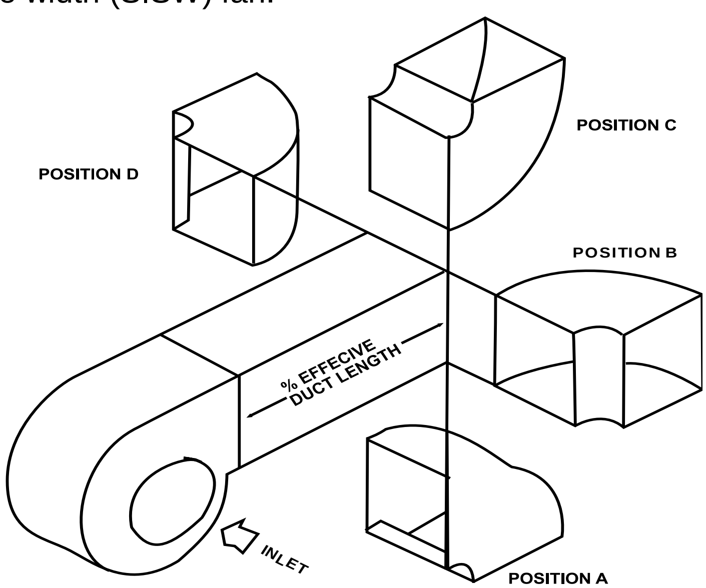


Fig. 6 Positions of Outlet Duct Elbow in SISW Centrifugal Fans

The SEFs for both single inlet single width (SISW) and double inlet double width (DIDW) centrifugal fans with a blast to outlet area ratio of 60 percent at a typical duct velocity of 10 m/s is as given below:

Type of Fan	*Elbow Position*	*SEFs for Outlet Duct Elbow Positions in Centrifugal Fans for in mm*				
		No Duct	*Effective duct length*			
			12 percent	*25 percent*	*50 percent*	*100 percent*
SISW Fans	*A*	*10*	*8*	*5*	*2.5*	*-*
	B	*12*	*10*	*7.5*	*3*	*-*
	C	*18*	*15*	*10*	*5*	*-*
	D	*18*	*15*	*10*	*5*	*-*
DIDW Fans	*A*	*10*	*8*	*5*	*2*	*-*
	B	*15*	*12.5*	*9*	*4*	*-*
	C	*18*	*15*	*10*	*5*	*-*
	D	*15*	*12.5*	*9*	*4*	*-*

For other values of duct velocity, the SEFs vary as square of the duct velocity.

12.2.2.2 *Volume control dampers (VCDs)*

Manufacturer's pressure drop ratings of wide open control dampers are usually based on uniform approach velocity profiles. In case a damper is placed very close to fan outlet, these profiles are non-uniform and much greater pressure losses can be expected. In case of centrifugal fans, for the normal blast area/outlet area ratio of about 0.63, the rated pressure drop must be multiplied by 3 to get the actual pressure drop for dampers mounted on fan discharge.

12.2.2.3 *Inlet conditions*

Non-uniform flow and swirl at fan inlets is the most common cause of deficient fan performance. Restricted fan inlets as in the case of inlets placed too close to a wall or inside a cabinet will also adversely impact fan performance.

The performance of a tube axial fan is severely compromised in the absence of an inlet duct. An inlet duct length equal to one impeller diameter, a bell mouth/conical inlet or a combination of the two can substantially enhance fan performance. The absence of an inlet duct or a bell mouth severely reduces fan inlet area, a phenomenon called vena contracta and compromises fan performance.

12.2.2.3.1 *Inlet duct elbows*

Elbows connected at or close to fan inlets make the approach velocity profiles non-uniform. In addition they can cause pressure fluctuations, instability and excessive noise. It is strongly recommended that an inlet elbow be installed at least 3 inlet diameters away from an axial or centrifugal fan. The cross-sectional area of the inlet duct should be within -7.5 percent to +12.5 percent of the fan inlet area.
The SEFs for tube axial and vane axial fans which have a 2 piece mitered round inlet duct elbow for an inlet velocity of 12.5 m/s are shown below. The SEFs for a 4 piece elbow are much lower.

Type of Fan	*90° Elbow*	*SEFs for Inlet Duct Elbows for Axial Fans for*		
		Inlet duct length in mm		
		No duct	*1 x D*	*3 x D*
Tube axial fan	*2 piece*	*4*	*-*	*-*
	4 piece	*-*	*-*	*-*
Vane axial fan	*2 piece*	*13*	*7*	*4*
	4 piece	*-*	*10*	*-*

The SEFs for a square inlet duct and elbow connected to an SISW centrifugal fan at inlet velocity of 12.5 m/s is as given below. SEFs shown are for elbows with no turning vanes. Properly designed turning vanes in the elbows can reduce the SEFs considerably.

Type of Fan	*90° Elbow*	*SEFs for Inlet Duct Elbows for Centrifugal Fans for*		
		Inlet duct length in mm		
		No duct	*1 x D*	*3 x D*
Tube axial fan	*2 piece*	*4*	*-*	*-*
	4 piece	*-*	*-*	*-*
Vane axial fan	*2 piece*	*13*	*7*	*4*
	4 piece	*-*	*10*	*-*

SEFs for Inlet Duct Elbows for Centrifugal Fans

R/D	*No duct*	*2D Duct*	*5D Duct*
0.5	*24 mm*	*15 mm*	*8 mm*
0.75	*19 mm*	*12 mm*	*6 mm*
1.0	*12 mm*	*6 mm*	*3 mm*
R = Mean Elbow Radius *D = Equivalent Inlet Collar Diameter*			

12.2.2.4 *Cabinet effects*

Fans inside plenums/cabinets or next to walls should be placed so as to allow un-obstructed air flow into fan inlets. Fan performance is impaired if the inlet is placed too close to cabinet walls. A minimum distance of one half inlet diameter shall be provided between fan inlet and the wall (*see* Fig. 7). In case of two or more DIDW centrifugal fans placed inside a cabinet, a minimum separation of one inlet diameter must be provided between two adjacent inlets. Fig. 7 also shows that the cabinet inlet should be symmetrical with the fan inlet to avoid uneven inlet flow or inlet spin.

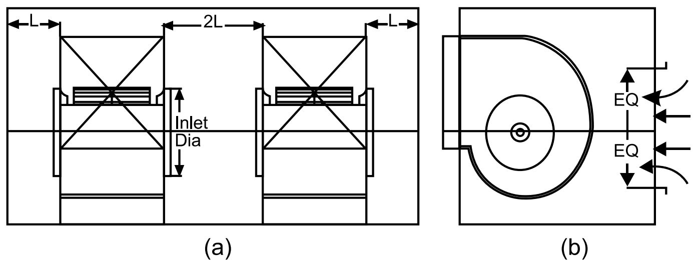


Fig. 7 Fans placed in Cabinets

The SEFs for various inlet to wall distances for a typical inlet velocity of 12.5 m/s are given below:

SEFs for Fans placed in Cabinets

Inlet to Wall Distance	*System Effect Factor*
0.75 x inlet diameter	*2 mm*
0.5 x inlet diameter	*4 mm*
0.3 x inlet diameter	*8 mm*

12.3 Fire Control

The requirements for smoke control systems are with the objective to accomplish one or more of the following:

a) Inhibit smoke from entering stairwells, means of egress, smoke refuge areas, elevator shafts, or similar areas.
b) Maintain a tenable environment in smoke refuge areas and means of egress during the time required for evacuation.
c) Inhibit the migration of smoke from the smoke zone.
d) Provide conditions outside the smoke zone that enable emergency response personnel to conduct search and rescue operations and to locate and control the fire.
e) Contribute to the protection of life and to the reduction of property loss.

The smoke control systems shall meet the requirements of Part 4 'Fire and Life Safety'.

12.4 Vibration Isolation

The use of isolation is primarily for reducing the effect of the dynamic forces generated by moving parts in a machine into the surrounding structure.

This is accomplished by incorporating a truly resilient material, which when subjected to a static load, deflects and by so doing establishes the natural frequency of the isolation system. The disturbing frequency f_d of a machine can be readily determined either by measurement or by the known operating characteristics of the equipment. Generally the lowest r.p.m. in the system is used as the disturbing frequency.

The natural frequency f_n of a machine set on resilient material is a function of the static deflection of the resilient material under the imposed load. For practical purposes the natural frequency f_n is described by the formula:

$$f_n = \frac{187.8}{\sqrt{d}}$$

where

d = static deflection, in inches.

The ratio (f_d/ f_n) establishes the efficiency of the isolation from the following formula:

$$E = 100.1 - \frac{1}{\left(\frac{f_d}{f_n}\right)^2 - 1}$$

where,

E = Percentage of vibration isolated;
f_d = Disturbing frequency of the isolated machine; and
f_n = Natural frequency of the isolated machine.

The percentage of isolation efficiency attained as a measure of the amount of reduction in the amplitude of the transmitted mechanical vibration. Reference may be made to Fig. 8 to readily select the static deflection required to attain desired isolation efficiency.

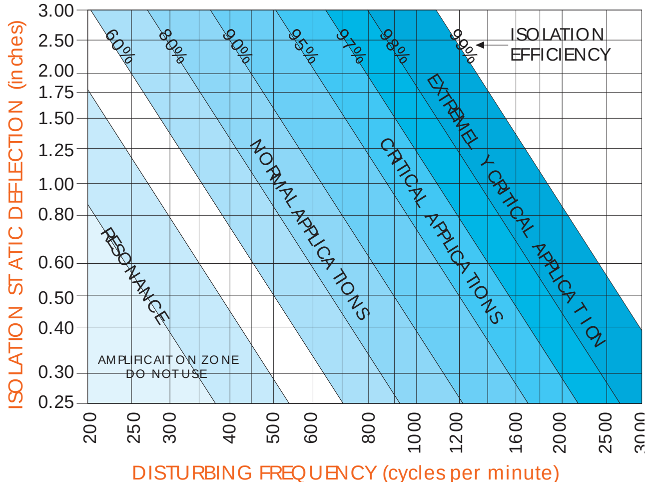


Fig. 8 Static Deflection required for Desired Isolation Efficiency

To determine the percent of isolation efficiency from Fig. 8, read from the graph at the intersection of vibration (disturbing) frequency and static deflection.

12.4.1 *Vibration Transmission and Noise*

Noise and vibration are intrinsic components of several activities in which machinery with moving parts are used. The positioning of anti-vibration devices between the machinery and their support structures acts as isolation, without any intervention on the balancing of the machine itself.

12.4.2 *Vibration Isolation of Mechanical Equipment*

Three principle factors control the selection of an isolator for a particular machine. The first is the weight to be supported, the second is the disturbing frequency of the machine and the third is the rigidity of the structure supporting the machine.

The normal method to isolate the vibration from building services plant is to support on resilient supports or isolators e.g. helical steel springs; rubber blocks or pads. These resilient supports or isolators, otherwise known in the building services industry as anti-vibration mounts (AVMs), must be selected and positioned carefully, as incorrect specification and use can equally worsen the vibration problem as isolate it. These anti-vibration devices can elastomer based, elastomer/metal bonded, springs or fluid based.

12.4.3 *Selection of Suitable Anti-vibration Mounts*

The following introductory pages aim to provide a brief guide to the selection, positioning and calculation of loads for building services pipe-work and plant.

a) *Estimating the force or load on each mounting point* – The weight distribution at each mounting point is dependent on the position of that point relative to the center of gravity of the total mass. The equipment manufacturer will provide the equipment weight and the center of gravity. The load on each mounting point can be calculated by taking moments about each mounting point. These calculations can be performed manually if there are 4 mounting points, each at the corner of a rectangular base. However, if there are more than 4 points, or the base is not rectangular, then the calculations are more complex and computer programs should be used; our technical department can assist with this.

b) *Selecting the type of anti vibration mount* – Once the load on each mounting point has been calculated, or if the information was given directly by the manufacturer, thought can be given to which type of mount is best suited to the type of equipment being supported, operating speed (speed of rotation), the supporting building structure, environmental conditions (for example, wind loadings) and space availability. The Table 10 is a brief guide to which type of AVM to use relative to the building structure.

The mathematical model used for the selection of the anti vibration mounts is a simple spring/mass arrangement based on the supporting mass being very large compared with the equipment mass. In practice, if the equipment is placed on suspended supports of increasing span, then these act as further "springs" in the model which require a higher performance from the anti vibration mount. This usually means higher deflection in the case of a spring mount, although the amount of damping offered by the anti vibration mount may also need to be increased when faced with lightweight structures and "live" steel frameworks.

c) *Selecting the size or load rating of the anti vibration mount* – Having established the equipment load and type of mount, the next step is to determine the load rating of the mount. The selection will depend upon the load, the speed of rotation (usually the lowest) and the isolation efficiency required. The charts below enable prediction of the isolation efficiency based upon the speed of rotation and the percentage loading of the spring. When selecting rubber mounts, the charts will only give an approximate indication of the isolation efficiency because rubber has high inherent damping properties that reduce the maximum efficiency attainable.

For each of the load points in turn, look on the selected anti vibration mount data sheet and find the next highest load rating. Divide the actual load by the mount load rating to obtain the percentage loading.

12.4.4 *Equipment Wise General Guidelines*

a) *Chillers and Cooling Towers* – Vibration isolators shall be free standing, unhoused, laterally stable springs wound from high strength spring steel of approved make. Springs shall have a lateral stiffness greater than 0.8 times the rated vertical stiffness and shall be designed to provide up to 50% overload capacity. Springs shall be selected to provide operating & static deflections shown on the Vibration Isolation Schedule or as indicated on the project documents. Springs shall be color coded or otherwise identified to indicate load capacity. Springs shall be assembled between a top and bottom steel load plate. The upper load plate shall be provided with a steel leveling bolt lock nut and washer for attachment to the supported equipment. The lower load plate shall have a non-skid noise isolation pad bonded to the bottom and have provisions for bolting the isolator to the supporting structure and provide stability. Equipment should to be installed using flexible connections.

b) *Air Handling Units* – Fan housing with motor shall be mounted on a common steel base mounted inside the air handling unit on anti-vibration spring mounts. The fan inlet and outlet should connected using flexible connections to avoid transmission of vibration. The air handling unit should installed using spring hangers/rubber sandwich or waffle pads.

c) *Fan Coils Units* – To ensure vibration free operation, each fan coil unit is to be installed using spring isolators/hangers and flexible rubber twin sphere flexible connectors/ss braided flexible connectors. The fan outlet should be connected to the casing using flexible connections with flanges/frame on both sides.

d) *Pumps* – To ensure optimal performance, Pumps shall be installed with neoprene flexible connections at suction and discharge and on concrete Inertia Bases and spring isolators. The Bases shall be constructed of concrete cast into a prefabricated inertia base frame assembly. Depth shall be equal to 1/12 the longest dimension of the base, but shall not be less than 6” or exceed 12” unless recommended by the base manufacturer. Height saving vibration isolation brackets shall be used. Design calculations should be performed to ensure that the inertia base is engineered to support the mechanical equipment.

Frame members shall be welded to form a structurally integral assembly, complete with primer-painted steel perimeter members, welded and tied reinforcing rods, recessed isolator brackets and equipment anchoring bolts. Bases shall be shipped ready for pouring of concrete fill in the field. Contractor is required to submit the inertia base calculation report to ensure compliance to required specifications.

Concrete Inertia Bases (Pumps)- The inertia base and the spring isolators will be supplied as a single unit along with the design calculations. As an indication of the standards required, minimum thickness of the inertia base shall generally comply to the following table or be 1/12th of the longest dimension of the base, whichever is the larger:

Motor Size kW	Minimum Thickness mm
3.7-11	150
15-37	200
45-55	250
75-185	300

Unless otherwise specified, concrete inertia bases shall weigh from 2 to 3 times the combined weight of the equipment to be installed thereon.

e) *Fans and Blowers* – The equipment has to be installed on enclosed spring type vibration isolators. The isolation efficiency should not be less than 80 percent. The fan outlet should be connected to the casing using suitable flexible connections with extruded flange/frame on both sides of approve make.

f) *Flexible U Connectors (For Expansion Joints)* – Flexible expansion loop (thermal applications): Provide flexible expansion loops of size and type noted on drawings of approved make. Flexible loops shall consist of two flexible sections of hose and braid, two 90ƒ elbows, and an 180ƒ return assembled in such a way that the piping does not change direction, but maintains its course along a single axis. Flexible loops shall impart no thrust loads to system support anchors or building structure.

Loops shall be installed in a neutral, pre-compressed or pre-extended condition as required for the application. For steam service, loops must be installed with flexible legs horizontal to prevent condensate buildup. Install and guide per manufacturer's recommendations. Materials of construction and end fitting type shall be consistent with pipe material and equipment/ pipe connection fittings.

g) *Piping* – All pipes should be installed using steel supports and hangers. Piping shall be properly supported by MS clamps/hangers/supports as specified and required. All pipes in the HVAC plant room shall be supported on polyurethane pipe supports or PUF supports. To prevent the insulation from being crushed, pre molded polyurethane pipe supports sections of 1400 kg/m^3 density and thermal conductivity of 0.16 w/m℃ between the pipe and pipe support.

h) *Building Settlement and Subsidence* – Flexible piping connections should be used accommodate differential movement between buildings or between floors, at the interface between piping and equipment, or to accommodate for thermal expansion. At expansion and seismic separation joints, the distribution system must be able to accommodate the displacements between structures. Since the structures can move independently in any direction (towards each other, away from each other, etc.), the minimum and maximum displacements must be determined. Distribution systems crossing at expansion and seismic separations joints must accommodate movements that compress, extend, and shear the system crossing the joint.

12.4.5 *Seismic Isolation on Non-Structural Components*

In addition to the structural framing and the floor and roof systems, buildings include many components and systems that are not structural in nature but that can be damaged by earthquake effects. These include;

a) Mechanical components and systems including air conditioning equipment, ducts, elevators, escalators, pumps, and emergency generators;
b) Electrical components including transformers, switchgear, motor control centers, lighting, and raceways;
c) Fire protection systems including piping and tanks; and
d) Plumbing systems and components including piping, fixtures, and equipment.

The design and installation requirements should ensure;

a) That most of these components are adequately attached to the supporting structure so that earthquake shaking does not cause them to topple or fall, injuring building occupants or obstructing exit paths.
b) For those pieces of equipment and components that must function to provide for the safety of building occupants (e.g., emergency lighting and fire suppression systems), the installation criteria should ensure that these systems and components will function after an earthquake.
c) The design and installation criteria should ensure that non-structural components critical to the operability of essential facilities such as hospitals, airports can operate following strong earthquake shaking. These buildings include:

    1) Hospitals,
    2) Airports,
    3) Emergency Response Centers,
    4) Data Centers,
    5) Buildings Vital to National Defence, and
    6) High Rise Buildings.

The design shall conform to the available standard and literature. The performance objecives and compliance method and expections are given in Table 10 and Table 11.

Table 10 Non-structural Seismic Performance Objectives

Performance Objective	Design Objective Description
Position retention	Maintain positive retention of non-structural position, under design-level earthquake demands, without consideration of frictional resistance produced by the effects of gravity. This includes position retention of non-structural anchorage, attachments and the force resisting skeleton.
Systems interaction avoidance	Account for unwanted interaction, under design-level earthquake demands, between non-structural systems and anything else that might be located in the immediate vicinity of the non-structural installation, so that failure of one system or contact between systems does not cause Consequential Damage of an essential system. The "anything else" could be building elements or other installed non-structural systems.
Active operation	Maintain active operation functionality of mechanical and electrical equipment and distribution systems following (i.e., not during) application of design-level earthquake demands.

Table 11 Non-structural Seismic Compliance Methods and Expectations

Performance Objective	Validation Method	Compliance Expectation
Position retention	Analysis	Seismic Calculation & Analysis can be used to validate that non-structural anchorage, force resisting skeleton and attachments have position retention capacity equal to or greater than the project-specific design level demand for the application installation location. Both strength design and allowable stress design approaches are accepted.
	Experience data	The use of earthquake experience data, based upon nationally recognized procedures, can be used to establish nonstructural position retention capacity provided that the substantiated seismic capacities equal or exceed the project specific design-level demand for the application installation location.
	Testing	The use of seismic simulation testing, based upon a internationally recognized testing standard procedure, such as ICC-ES AC156, can be used to establish nonstructural position retention capacity provided that the seismic capacities equal or exceed the project-specific design-level demand for the application installation location.
Systems interaction avoidance	Inspection	Visual inspection of the nonstructural installation is performed to validate that no unwanted system interactions may result under the project-specific design-level earthquake demands.

Active operation	Experience Data	The use of earthquake experience data, based upon nationally recognized procedures, can be used to establish nonstructural active operation capacity provided that the substantiated seismic capacities equal or exceed the project specific design-level demand for the application installation location.
	Testing	The use of seismic simulation testing, based upon a internationally recognized testing standard procedure, such as ICC-ES AC156, can be used to establish nonstructural active operation capacity provided that the seismic capacities equal or exceed the project-specific design-level demand for the application installation location.
	Combined testing and analysis	The use of combined seismic calculations and seismic simulation testing can be used to establish nonstructural active operation capacity for physically massive systems (i.e., large-class) that are impractical to test as complete systems. The testing aspects need to conform with nationally recognized testing standard procedures, such as ICC-ES AC156. The established active operation capacity, using combined testing and analysis, is to equal or exceed the project-specific design level demand for the application installation location.

13 SYMBOLS, UNITS, COLOUR CODE AND IDENTIFICATION OF SERVICES

13.1 Units and symbols to be used in air conditioning, ventilation and refrigeration system shall be in accordance with good practice [8-3(12)].

13.2 Colour code is required for identification for various items in air conditioning installations for easy interpretation and identification. 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(13)].

13.3 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.

13.4 Further identification may also be carried out using lettering and marking direction of flow.

13.5 Services Identification

13.5.1 *Pipe Work Services*

13.5.1.1 The scheme of colour code for painting of pipe work services for air conditioning installation shall be as indicated in Table 12.

13.5.1.2 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 :

Hot Water	HW
Chilled Water	CHW
Condenser Water	CDW
Steam	ST
Condensate Drain	CN

Table 12 Scheme of Colour Code of Pipe Work Services for Air Conditioning Installation
(*Clause* 13.5.1.1)

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	Sky Blue	Black	Black
iii)	Central heating	Dark Blue	Black	Canary yellow
iv)	Condensate Drain pipe	Black	White	
v)	Vents	White	Black	
vi)	Valves and pipe line fittings	White with black handles	Black	
vii)	Belt guard	Black yellow diagonal strips		
viii)	Machine bases, inertia bases and plinth	Charcoal grey		

13.5.2 *Duct Work Services*

13.5.2.1 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	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

13.5.3 *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'/'as built' 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.

14 BUILDING AUTOMATION SYSTEM FOR HVAC CONTROL, MONITORING AND VERIFICATION

14.1 General

The energy use of buildings is affected by several factors that change with time. Be it usage patterns, properties of the structure, installed equipment or weather outside – all of them affect the energy consumption of the building significantly. The evaluation of energy savings due to improvements in a building thus becomes a difficult task. Technology is now available that can quantify the factors affecting consumption in more detail than just logging data at the meter.

14.1.1 *Role of Building Automation System (BAS) in HVAC Operation and Maintenance*

The core functionality of BAS is to keep the building indoor environmental conditions (for example, temperature, humidity, lighting, indoor air) within a specified range, monitor system performance and device failures and provide malfunction alarms. It typically consists of:

a) *HVAC controls* – consisting of sensors, thermostats, controllers, actuators, communications, control panels, and user interfaces associated with building climate control systems;
b) *Lighting controls* – specifically focused on integrated and networked lighting controls;
c) *Fire and life safety controls* – including sensors, controllers, master panels, actuators, and communications for fire detection and control, but excluding actual fire suppression components; and
d) *Security and access controls* – including sensors, access controllers and readers, cameras, user interfaces and panels, and IT hardware.

Some of the BAS functions for HVAC include, monitoring status of sensors and controlled devices, scheduling equipment on and off, scheduling set points and setbacks, and trending equipment status.

Some of the BAS functions for lighting include scheduling lights to turn on and off, maintain fixed illuminance levels, integrating daylighting with electrical lighting, etc.

Installing a BAS helps in controlling the energy consumed by HVAC, lighting etc. However it is important to note that BAS should be installed only in case of large complex HVAC systems for optimum usage and is not required for smaller equipment like split ACs.

14.2 BAS Design Requirements

The BAS design shall take into account the following:

a) *General considerations*

1) Building structure, for example, metal frame, concrete, size, thermally active building components, historical construction (listed objects);
2) Type of building(s), for example, high rise, single storey, open campus, tunnel;
3) Building usage type and profile, for example, hospital, single/multi tenant, industrial, commercial, residential, etc;
4) Space usage profile, for example, occupation schemes, diverse usage of space, continuous operation;
5) System integrity including off-site considerations, for example, communication infrastructure and topology, availability, reliability, response time, safety and security, redundancy;
6) Intended organization of operation and technical services, for example, third party, caretaker, trade segregation, user account levels;
7) Energy supply requirements, for example, alternative energy systems, load shedding, energy monitoring;
8) Safety and security systems integration with BAS and mutual interaction, for example, fire system, access control system, interoperability area and integration depth;
9) Implementation of the project by phases, for example, timescales for each phase, constraints on plant shutdowns, impact on continuous operation;
10) Budget, for example, change contingency, overtime work;
11) Future usage, for example, spare capacity, flexibility, future intended extensions; and
12) Application of the commissioning process.

b) *Integration requirements*

1) Deployment of special system integration consultants;
2) Allocation of responsibilities, for example, for subsystem functionality and interfaces, for delivery of integration of subsystems;
3) Vendor and manufacturer independence, for example, standardized protocols, profiles and interfaces;
4) Enhanced energy performance, for example, interdisciplinary operations of HVAC, blinds and lighting controls;

5) Compatibility, for example, software/hardware versions of subsystems, protocol versions, proprietary protocols;
6) Interoperability, for example, data sharing, event and alarm management, scheduling, trend and event logging, device and network management;
7) Functional interaction, for example, fans disabled by fire conditions;
8) Single seat operation, for example, shared computer, consolidated user information and alarms;
9) Infrastructure sharing, for example, ethernet structured cabling, shared computer;
10) Commissioning, for example, availability and interaction of subsystems; and
11) Interoperability diagnostics, for example, event recording, device and object binding integrity, protocol analyzing.

c) *Physical requirements*

1) New equipment and its ability to be monitored and controlled, for example, adding monitoring and control;
2) Existing equipment and its ability to be monitored and controlled, for example, reuse, adding functionality;
3) Existing controls or BAS, for example, integrate, migrate, replace;
4) Space, for example, for cabinets, wall mountings, human system interface (HSI);
5) Human system interface, for example, local display, operator workstation;
6) Local conditions, for example, environmental, temperature, humidity, seismic risk, extreme weather;
7) Cabling, for example, topology, media type, size, rating, environment;
8) Power supply, for example, frequency, voltage, emergency power supply, UPS.

d) *Occupational requirements*

1) Priorities for operation of the building, for example, emergency situations, normal conditions, overrides;
2) Occupancy profile, for example, schedules/calendar, set points, operating modes, daylight saving, energy use;
3) Energy performance, for example, energy usage, energy savings;
4) Comfort conditions, for example, thermal, visual, acoustic, air quality;
5) Human system interfaces, for example, local override/indication devices, operator and monitoring units or panels, operator work stations including visual display units, internet browser on different types of platforms.

e) *System requirements*

1) Priorities for operation, for example, safety of personnel, protection of equipment, occupancy profile, comfort, energy savings, cost savings, reliability, indoor air quality;

2) Control strategies;
3) Management functions;
4) Data storage, data retrieval;
5) Maintenance management requirements, for example, condition-based monitoring, local/remote reporting;
6) Energy management requirements;
7) Alarm strategy, for example, categories, priorities, delivery, routing;
8) Human system interface, for example, localization, multi language, graphics quality, types, functionality;
9) System support, for example, remote access, technical support;
10) System performance, for example, accuracy, response time, display response;
11) System reliability, for example, availability, redundancy; and
12) Documentation, for example, format and media, content, quantity, compliance certificates.

f) *Site and client-specific requirements*

1) Installation, for example, electrical, mechanical, controls;
2) Commissioning and handover requirements, for example, witness testing, process for uncompleted actions, summer/ winter operation, phased delivery, documentation of the results;
3) Training, for example, instructions for use, operation and maintenance, system/product training;
4) Documentation, for example, language, content, media, certificates, software licenses and backup;
5) Post completion, for example, warranty/guarantee requirements, spare parts requirement, maintenance;
6) Requirements and software updates; and
7) Application of the commissioning process, for example, required qualification and role of commissioning authority.

14.3 BAS for New *versus* Existing Constructions

Installation of building automation technology is split between new building construction and existing building retrofits. Each of them has different factors influencing the BAS specifications and purchasing decisions. BAS are expected to last at least 10 to 20 years, so market access to a building for new systems is severely limited once construction of that building is complete. The manufacturer's market for new automation systems has thus been driven primarily by new commercial building construction.

For existing buildings with BAS in place and in need of replacement/upgrade, an assessment of the current system is necessary. Some aspects to be kept in mind during this assessment may include:

a) Identification of the full capabilities of the current system and extent of use thereof.
b) Status of current system in terms of its currency or obsolesce technologically and also scope of its up-gradation.
c) Any problem with the system and its attribution to lack of maintenance or service.
d) Status of currency of software, firmware, and hardware revisions and the extent of up-gradation thereof required.
e) Any need of replacement or up-gradation of controlled equipment.
f) Reasons for excessive number of trouble or comfort calls attributable to existing BAS.

While assessing the above aspects, the owner should consider not only the current facility needs for energy management but predicted future needs as well. In addition to clearly defining a building's BAS needs, an owner or facility manager shall also evaluate the state of the current system. Determining whether an existing system can and should be upgraded is even more complex than the specification of a new system and requires an honest and complete analysis of the current system. It is also important to determine whether the BAS vendor has an upgrade path for the existing BAS. If he does, it is necessary to compare the cost to system replacement and review the relative benefits of an upgrade versus a replacement.

An existing building automation system should be upgraded if:

a) It can be upgraded to the current vendor product line.
b) It performs the functions the owner thinks necessary.
c) The shortcomings of the existing system will be corrected in the upgrade.

An existing building automation system should be replaced if:

a) The control system is primarily pneumatic.
b) The BAS cannot be upgraded to current technology. Changing vendors should be considered in this case as the system is considered an "orphan" system.
c) The BAS does not have functions required to implement the desired types of energy management strategies, or it will not interface with VAV boxes that will be upgraded.
d) The system is overly complex and arduous to use, so that its features are under-utilized, or it is one or more software/firmware revisions behind.
e) There are significant comfort problems/occupant complaints that a new system would resolve.
f) The potential return on investment of the proposed replacement meets capital project criteria, or utility rebates or local/state/federal tax credits (or rebates) are available.
g) Enhanced use of advanced energy management strategies is anticipated. Full use of these advanced capacities can bring a rapid return on investment.[5]

14.4 BAS for Monitoring

A BAS is designed to monitor and control the HVAC, lighting, mechanical, security, fire and flood safety, and humidity control and ventilation systems in a building. Its primary function is to keep the building indoor environmental conditions (for example, temperature, humidity, lighting, indoor air) within a specified range, monitor performance and device failures in all systems and provide malfunction alarms to building maintenance staff. It provides the information and the tools that building managers need both to understand the energy usage of their buildings and to control and improve their buildings' energy performance.

To provide data necessary to improve building systems operation, monitoring should be considered for boilers, chillers, cooling towers, heat pumps, air-handling unit fans, large fan-coil units, major exhaust fans, major pumps, comfort cooling compressors, lighting panels, electric heaters, receptacle panels, substations, motor control centers, major feeders, service water heaters, process loads, and computer rooms. For overall success of the system, it is critical for the BAS to have the capability to allow building staff to measure electrical values, such as voltage, current, power, energy, power factor and other power quality parameters for proper performance monitoring. It also calculates, and records system status, water use, energy use at the main meter or of particular end-use systems, demand, and hours of operation, as well as start and stop building systems, control lighting, and print alarms when systems do not operate within specified limits.

All the measured values shall be aggregated and trended in both instantaneous and time-based numbers for chillers, boilers, air-handling units and pumps. The data can be made accessible through a web browser. A graphical user interface must offer trending, scheduling, downloading memory to field devices, real-time graphic programs, parameter changes of properties, set point adjustments, alarm/event information, confirmation of operators, and execution of global commands. This concise representation makes interpretation of collected data robust and more user-friendly. A floor manager is able to precisely monitor all aspects using an effective and dynamic system like the BAS.

BAS Monitoring can be broadly broken down to two aspects – Energy Monitoring and Indoor Environment Monitoring. We have already discussed above the parameters to be measured for energy monitoring. Let's now discuss the Indoor Environment Monitoring in more detail. Indoor Environmental Quality (IEQ) encompasses the conditions inside a building—air quality, lighting, thermal conditions, ergonomics—and their effects on occupants or residents. Strategies for addressing IEQ include those that protect human health, improve quality of life, and reduce stress and potential injuries. Hence it is necessary to monitor indoor environment in both real-time and long-term manner. But manually managing it is an impossible task and hence the use of a BAS is tailormade to address this specific need. HVAC systems consist of mechanical parts which should provide air to building occupants at a comfortable temperature and humidity that is free of harmful concentrations of air pollutants. Also, building ventilation is an important factor affecting the relationship between airborne transmission of respiratory infections and the health and productivity of workers. Improper operation and maintenance of HVAC systems is one of the most common problems that impact workplace IEQ. As discussed in the earlier sections, HVAC systems include all of the equipment used to ventilate, heat, and cool the building; to move the air around the building (ductwork); and to filter and clean the air. These systems can have a significant impact on how pollutants are distributed and removed. Maintaining good IEQ requires constant attention to the building's HVAC system, which includes the design, layout and pollutant source management or air filtration.

14.5 BAS for Measurement and Verification

Analyzing the energy consumption pattern of a building can be a difficult exercise considering that numerous factors such as building envelope and local climate in addition to Lighting and HVAC systems can also have a significant impact on building's energy consumption. To simplify this, a process called measurement and verification is used to analyze the energy savings obtained through design and operation of efficient buildings. The process of determining the actual savings produced within a facility upon implementation of an energy efficiency program is called Measurement and Verification. To measure savings in energy, a comparison is done between the energy usage measured before and after the implementation of the project. But this is not enough since energy usage is also dependant on building conditions and hence measurement may require adjustments in the analysis of measured data. Weather and occupancy are examples of factors that often change. To assess the effectiveness of the retrofit alone, the influence of these confounding factors must be eliminated through a process of normalization and adjustments. Relationships must be found between energy use and these factors to remove the influence of the factors from the energy savings measurement. These relationships are usually determined through data analysis. Upon analyzing the data, modifications are made to the building to conserve energy or manage demand. These modifications are called Energy Conservation Measures (ECM). ECMs can be of different types – changes to the equipments in the building, operation and maintenance procedures, software, training to staff and employees etc.

A typical M&V process may include the following activities:

a) Installation of metering devices,
b) Gathering and screening of data,
c) Development of a computation method with acceptable accuracy,
d) Computation of measured data,
e) Reporting on analysis and conclusions, and
f) Third party verification.

For efficient measurement and verification, it is important to develop an M&V Plan which is specific to a project or site and is a result of the deliberations and negotiations between the project stakeholders (implementer, owner, investor, regulator etc.) which limits its applicability to the specific project for which it has been developed. It captures the project and individual energy conservation measure boundary, assumptions, engineering calculations/equations, metering infrastructure to be deployed, parameters to be monitored and measured or stipulated along with their frequency or basis, and agreed upon by the two parties.

Most facility managers use building automation systems for monitoring and maintenance though it has applications in control as well. The BAS stores and analyzes building data to produce reports and dashboards that help facility managers keep track of their energy consumption and other operational data points. The live data stream provided by the BAS is also used to reduce or prevent unwanted events in the future. The real value of data from BAS is in its ability to provide information to anyone – right from an energy auditors or facility managers to the top management – thereby enabling proactive management of building operations.

15 TESTING, COMMISSIONING AND PERFORMANCE VALIDATION

15.1 Commissioning shall mean putting the equipment or system into active service for the use intended by the customer.

15.1.1 For a room (window) air conditioner or split air conditioner, this shall involve connecting the unit (after installation) to a suitably sized power socket, switching it on and recording the temperature in various parts of the room. The process will also involve checking whether the unit’s promised features such as auto-swing etc, are working properly and also whether the compressor switches off after the desired temperature is achieved. The air flow from the unit shall be measured using an anemometer and compared with the catalogue. The sound level at a distance of 1 m away from the unit shall be measured and recorded.

15.1.2 For a central air-conditioning plant or a ventilation system the process shall involve a systematic procedure to ensure that the plant performs as per the design parameters and shall include instructing the owner’s personnel in proper operation of the plant. Hand over procedure shall include compiling operation manuals for the equipment, service schedule, spare parts list, recommended log recording sheet and regular operation and maintenance procedures which shall all be made available to the owner.

15.1.2.1 Commissioning engineer shall be involved right from the design stage and his/her inputs shall be taken while designing and laying out the plant as well as while choosing the control and monitoring systems including measurement and verification points.

15.1.2.2 In cases, where commissioning by third party is specified in the agreement, a commissioning agency distinct from the designer and the contractor shall be appointed by the owner. Third party commissioning shall help the owner to obtain an independent validation of the plant performance with respect to design.

15.2 Inspection of Materials and Equipment

15.2.1 All materials and equipment delivered to site shall be compared with specified and approved specifications and shall be found acceptable to the owner.

15.2.2 Physical properties such as thickness, malleability, test pressure etc shall be verified from manufacturer's test certificates. Where test certificates by independent test houses are specified, they shall be produced for acceptance. Agreed lot sizes shall be inspected before use at site.

15.2.3 Testing of equipment shall be done at the (manufacturer's) factory by factory personnel and shall be witnessed by owner's representative if desired by the owner and agreed by the contractor/manufacturer.

15.2.4 Equipment test certificates for pressure tests, capacity tests or any other specified tests shall also be produced and accepted by the owner before the said equipment is taken up for erection/installation.

15.2.5 Agreed method of inspection shall be properly recorded and results of the inspection shall be preserved by the contractor as a record during currency of the contract.

15.2.6 All metering/measuring instruments used for commissioning and testing shall be calibrated and certificate of calibration shall be on record.

15.3 Cleaning and Stage-wise Inspection of Work

15.3.1 All equipment, ancillaries, pipes, ducts, insulation materials etc shall be cleaned prior to use. Cleaning of piping systems, duct work etc shall be done by an approved and trained agency and the method of cleaning shall be submitted for approval before work is carried out.

15.3.2 Tests on ducts and pipes shall be done in sections as per approved schematics. Test pressures and applicable standards shall be proposed by the contractor and approved by owner. Once the approval is received, contractor shall prepare and submit testing schedules indicating the sections or circuits where testing is proposed. Contractor shall depute competent staff to supervise testing and arrange for the owner or his representative to witness the testing.

15.3.3 Testing of duct work shall be carried out in manageable sections and entire duct layout shall be tested complete with all air outlets in place. For testing, it is recommended to isolate the ductwork at branch damper locations. Contractor shall refer to the commissioning authority and provide adequate number of test points at appropriate locations, as required.

15.3.4 Pipe work shall be tested in parts, floor by floor or zone by zone and by risers which can be isolated by valves.

15.3.5 Cabling and control wiring shall be tested as one complete unit.

15.4 Readiness for Commissioning

15.4.1 Final pressure testing and leak testing of all piping and ducting systems shall be done and it shall be ensured that any blank offs introduced have been removed.

15.4.2 All equipment shall be made ready to run. All fan and pump shipping bolts shall be removed and each equipment shall be made ready to start.

15.4.3 For all major equipment such as chillers, VRV units, cooling towers, air handlers, pumps, ventilation fans etc, manufacturer or his authorised representative shall certify that the equipment is ready to start.

15.5 Pre-Commissioning Inspection

15.5.1 Commissioning and performance validation shall be attempted only after completion of staged tests as well as part pressure tests and results shall be recorded and certified by the contractor.

15.6 Scope of Commissioning Activity

15.6.1 Commissioning activity shall include the following:

a) testing, adjusting, and balancing of air side systems;
b) testing, adjusting, and balancing of chilled water and piping systems;
c) measurement of final operating parameters of HVAC systems;
d) sound measurement of equipment where specified;
e) vibration measurement of equipment where specified; and
f) testing, adjusting and balancing of smoke control systems, exhaust, and fresh air or pressurization systems.

15.6.2 The testing, commissioning, and performance validation activities shall be carried out by qualified personnel. The services shall be performed by a third party commissioning agent (independent of the HVAC designer and HVAC works contractor), where so specified.

Necessary documents, drawings and data shall be provided to the commissioning team and cooperation shall be provided by the contractor.

15.6.3 Commissioning shall be a systematic process confirming that building systems have been installed, properly started, and consistently operated in strict accordance with the contract documents. A documented proof that all systems are complete and functioning in accordance with the contract documents shall be provided to owner's operating personnel. Commissioning shall include seasonal tests, if specified and approved by the owner.

15.6.4 The commissioning engineer shall prepare a documented plan which shall be approved by the owner. The structure, schedule, and co-ordination plan of the commissioning process from the construction phase through the warranty period must satisfy the owner’s requirements.

15.6.5 Static inspections of material or component tests that verify proper installation of equipment (for example, belt tension, oil levels, labels affixed, gauges in place, sensors calibrated, etc) shall be approved as complete and shall be submitted with the request for start-up.

15.6.6 The activities where equipment is initially energized, tested, and operated shall be completed prior to functional performance tests (FPT).

15.6.7 Functional performance test shall mean testing of dynamic functions and operation of equipment and systems. System shall be tested under various modes such as low cooling loads, high loads, varying ambient conditions, power failure, life safety conditions, etc as specified. Functional performance tests shall establish that the system is performing as designed under these conditions.

15.6.8 Test of dynamic interactive functions and operation of multiple systems under various modes, such as fire alarm and emergency situations, life safety conditions, power failure, etc shall be carried out as specified. Systems shall be integrally operated through all specified sequences of operation. Components shall be verified to be responding in accordance with contract documents. Integrated system tests shall provide verification that the integrated systems will properly function according to the contract documents, under all situations, and shall comply with the relevant fire and safety requirements.

15.6.9 Integrated system test procedures and commissioning protocols and instructions fully describing system configurations and steps required to determine if the interacting systems are performing and functioning properly shall be provided by the commissioning engineer. HVAC contractor shall prepare these procedures to document integrated system tests.

15.6.10 Functional performance or integrated system performance tests may be deferred due to partial occupancy, partial equipment loads, seasonal requirements, or other site conditions that prohibit the test from being performed prior to acceptance. Such deferment shall record owner’s confirmation and shall also indicate the tentative dates when the tests will be carried out.

15.6.11 Deficiency shall mean a condition of a component, piece of equipment or system that is not in compliance with contract documents.

15.7 Following is an example of the various steps in the commissioning process of a vapour compression type air conditioning system.

a) Check and confirm that working pressures and temperatures are in line with those specified in design.
b) Check compressor oil level. Oil should not be foaming.
c) Check compressor body temperature.
d) Check for liquid flood back.
e) Check air and water flow through condenser and evaporator.
f) Check motor current and body temperature.
g) Check refrigerant change.
h) Clean/Replace liquid and suction strainers till they remain clean after usage.
j) Check superheat at expansion valve.
k) Set the safety controls and confirm their operation.
m) Check the piping for any excessive vibration.
n) Ensure that current drawn by all motors is within motor ratings.
p) Check air distribution system, do air balancing and ensure uniform temperature in air conditioned space.
q) Verify and balance chilled water flow through various sections of the system.
r) Check the cooling tower operation and make sure wet bulb approach is with in design limits.
s) Ensure guards are provided on all rotating parts.
t) Initiate regular 'log' readings.
u) Operating and maintenance (O&M) information as per requirements of the technical specifications and requirements shall be made available to the owner by the contractor. The contractor shall ensure that the O&M manual content, as built drawings and specifications, component submittal drawings, and other pertinent documents are available to the owner for review.

15.8 Performance validation involves verification that the system performs as per design parameters. The design parameters may include:

a) Temperature and relative humidity;
b) Chilled water or brine temperature and flow rate;
c) Maximum ambient dry-bulb and wet-bulb temperature;
d) Occupancy in conditioned area;
e) Pressure drop across condenser/cooler;
f) Water flow rate through condenser/cooler;
g) Entering and leaving water temperature for condenser/cooler;
h) Chilled water flow rate across cooling coils in AHU;
j) Pressure drop across cooling coils;
k) Compressor speed;
m) Evaporating/condensing temperature/pressure;
n) Current drawn by motors;
p) Air flow rate across cooling coil of AHU;
q) Fresh air quantity;

r) Apparatus dew point;
s) DB/WB temp of air entering/leaving the cooling coil;
t) WB approach of cooling tower; and
u) Power consumption in KWH.

NOTE - The above is not a comprehensive list. Depending on type of plant and application, the parameters will vary. The parameters to be recorded should be as per design data for the particular plant and as agreed between the owner and the contractor.

15.9 For individual components of an HVAC system following are the critical parameters.

a) *Water cooled condenser*
   1) Water flow rate as established by pressure drop across the condenser;
   2) Temperature rise; and
   3) Condensing temperature and pressure (leaving temperature difference).

b) *Air cooled condenser*
   1) Air flow rate across the condenser; and
   2) Condensing temperature and pressure (leaving temperature difference).

c) *Chiller (cooler)*
   1) Water or brine flow rate; and
   2) Temperature drop.

d) *Pumps for condenser/chilled water*
   1) Water flow rate as established from pump curves based on suction/ discharge pressure; and
   2) Pump motor current.

e) Air handling unit
   1) Pressure drop through cooling coils;
   2) Water flow through the cooling coil; and
   3) DB/WB temperature of entering/leaving air.

f) *Cooling tower*
   1) Wet bulb approach.

g) *Compressor*
   1) Oil pressure; and
   2) Suction/discharge pressures.

h) *Air distribution systems*
   1) Room conditioners at various places in the room. Temperature rise from AHU units to tail end of duct;
   2) Draft in occupied zones (between 15 m/min to 30 m/min); and
   3) Noise level.

15.10 Objectives of performance validation shall be to:

a) verify design conformity;
b) establish fluid flow rates, operating temperatures and pressures;
c) test all electrical installations for earthing continuity and earth resistance;
d) verify electrical consumption for each motor and for the plant as a whole;
e) establish operating sound levels;
f) check for abnormal vibration;
g) adjust and balance all parameters to design levels; and
h) record and report results in a specified format.

15.11 Controls and Safety Cut Outs

Operation of all controls and safety cut outs should be demonstrated during the commissioning process and results should be recorded.

15.12 Calibration of Instruments

All measuring instruments used during the commissioning process should be calibrated either by an independent calibration agency or in comparison with a calibrated gauge and calibration certificates of all instruments should be available on record.

15.13 Third Party Commissioning

The objective of third party commissioning shall be to verify and ensure that the building's equipment and systems are commissioned to achieve performance as envisaged during the design stage.

The third party commissioning authority shall be an agency which is not involved in the design, operation, and maintenance of the building. It shall directly report to the owner of the building. It shall be the individual designated to organize, lead and review the completion of commissioning process activities. The commissioning authority shall facilitate communication among the owner, designer, and contractor to ensure that complex systems are installed and function in accordance with the owner's project requirements.

The commissioning authority shall:

a) have a minimum of 3 years prior experience in commissioning equipments and systems.
b) document in brief, owner's requirements in terms of performance expectations from the equipments and systems.
c) submit a plan to show how the building would be audited for its performance after occupancy, with regard to the following:

1) HVAC systems - Chiller, VRV systems, primary and secondary water pumps, cooling tower, AHU fans, fresh air fans and exhaust fans, fresh air treatment units, heat recovery wheel and VFDs;
2) Unitary air conditioners;
3) Temperature and RH measurements in individual spaces;
4) Pumps and motors;
5) CO_2 monitoring system;
6) Energy and water metering;
7) Building management system;
8) Report specific observations and variations identified by commissioning authority to the project owner, for each equipment and system, with respect to commissioning plan and how they were addressed;
9) Submit measurement and verification plan for yearly reporting; and
10) Submit post-occupancy survey to verify occupant comfort (temperature, relative humidity, noise levels, etc).

The third party commissioning authority shall report on the following:

a) Equipment specifications;
b) Test results with specific comments from the Commissioning Authority, at the time of commissioning;
c) Key monitoring aspects to sustain performance;
d) Estimated energy and water consumption; and
e) Scope for performance enhancement in future, and savings thereof.

15.14 Handover Procedure

15.14.1 Handover documentation should include all information that the user will need to operate the equipment efficiently and economically. It should include recorded reading of all factory and site testing including the calibration certificates of measuring instruments as well as details of all control settings.

15.14.2 The following are the requirements of handover documentation (as applicable from case to case):

a) Description of the installation, schedule of equipment;
b) Heat load calculations and equipment selection details;
c) Schematic drawings for chilled water/condenser water;
d) Schematic drawings for exhaust and pressurization systems;
e) As-built drawings including air distribution layouts;
f) Operations and maintenance manuals for all equipments/controls/ instrumentation;
g) Manufacturer’s spare parts list and ordering instructions;
h) Test certificates/test results, as required;
i) Commissioning readings countersigned by commissioning authority;
j) Guarantee certificate and service escalation matrix; and

k) List of all accessories, tools, spares handed over with the plant.

15.15 Operation and Maintenance

Operation of the plant shall include a continuous vigilance on the performance of the system and day-to-day routine maintenance.

The operating procedures shall be as given in **15.15.1** to **15.15.5**. The maintenance procedures shall be as laid down in **15.15.6**.

15.15.1 Before starting the plant, the operator shall ensure that:

a) All the valves in the refrigeration system, condenser water lines and chilled water lines are open, except those of the standby items of equipments.
b) There is sufficient water supply to the cooling tower and the make-up water system is working satisfactorily.
c) The make-up water system to the expansion tank of the chilled water circuit is working and there is a regular water supply. Water is lost from the chilled water system through pump gland drips. If the level in the expansion tank is not maintained, air can enter the chilled water system, affecting the system performance substantially. It can even lead to freeze up of the chiller.
d) All the air filters and water strainers are clean. The dirty filters and the blocked strainers shall be cleaned.
e) All doors and windows of the air conditioned/refrigerated area are closed.
f) The crankcase of the compressor is warm (to the physical touch). If it is not warm, check for defects in the crankcase heater and/or circuit. Do not start the compressor until the defect is rectified and the crankcase warms up. Otherwise poor lubrication will result, thereby substantially reducing the life of the bearings of the compressor.
g) The supply voltage is within permissible limits. The windings of the motors can get affected if run on low voltage conditions.

15.15.2 The starting sequence shall be as under:

a) Switch ON the mains. Observe the voltage. If it is less than the permissible level, do not start the plant.
b) Start air-handling unit motors (all the dampers has to be checked based on application).
c) Start condenser water pumps. Check that sufficient water pressure is obtained.
d) Start cooling tower fans.
e) Start chilled water pumps and check the pressure.
f) Switch ON the compressor control switch.
g) Start the compressor motor.

15.15.3 The following aspects require special attention:

a) In the compressors with oil pumps, the compressor oil pressure should build up as the compressor is started. Check that correct net oil pressure is built-up.
b) Check the oil level in the oil sight glass of the compressor. The oil level should be about 40 to 50 percent of the sight glass. In operation, certain amount of oil gets entrained in the refrigerant vapour in the compressor and is carried away to the system along with the refrigerant.
c) After the plant operation has stabilized, check all the pressures and temperatures and ensure that the plant is working satisfactorily.
d) Record periodically the readings of temperature, pressures, current and other required data in the log sheet.
e) Check for any unusual noise/vibration in the plant. If something unusual is noticed, trace out the reason for it and rectify the cause.
f) During the operation of the plant, if it stops suddenly, try to trace out its reason, before starting the plant again.

15.15.1.4 The stopping sequence of the plant shall be as under:

a) Switch off the compressor on the low pressure switch, as the system gets pumped down.
b) Switch off the power supply to compressor.
c) Check that the crankcase electric heater comes on as soon as compressor stops and ensure that the heater is working.
d) Stop chilled water pumps.
e) Stop air-handling units.
f) Stop condenser water pumps and cooling tower fans.

15.15.5 Following are standard operating instructions which the operator shall follow.

a) In case stand-by plants, pumps etc are provided, systematically change-over the plants periodically. This will ensure uniform wear and tear of the plants. Further, this also helps in ensuring that all the plants are in good shape and the stand-by is in good condition.
b) Do not switch off the main switch on the main electrical board or switch off any component of the system, when the plant is in operation.
c) All the water valves in the system shall be kept open and need not be closed unless specifically instructed by designer. But it is essential to close and open each valve periodically to ensure that the valves work and are not stuck by scale formation or dirt accumulation.
d) Keep the plant room clean. Do not use the plant room, particularly the air-handling unit rooms for storage.

15.15.6 The following are the important day-to-day maintenance work which shall be attended to:

a) *Clean the air filters* - A dirty air filter reduces the plant capacity. If not cleaned regularly the filter gets saturated with dirt and thereafter dirt can pass on to the cooling coil fans. In dusty environs, it may be necessary to clean the air filters more often. The filters shall be replaced when cleaning is no longer effective.

b) *Leak testing for refrigerant leak* - Even a minute leak can cause poor oil return, heating of the compressor and ultimately leading to poor refrigeration.

c) *Water pump (packed) glands* - Certain amount of water drip through the gland is necessary to keep the gland cool. But if the drip develops into a regular flow, it is an indication that the gland is not holding. The gland nuts may be tightened to reduce the leak. If this does not improve the situation, the gland packing should be replaced.

d) *Clean the water strainers* - A clogged strainer reduces the water flow rate and thus affect the plant performance.

e) *Belt tension of belt drives* - Check the tension of belts and tighten whenever found loose. A loose belt reduces transmission efficiency.

f) *Check the spray of the cooling tower nozzles.*

g) *Drain, clean and refill the cooling tower sump* - Cooling towers, being in the open, collect a lot of dust and muck. Hence, the tower shall be cleaned at least once in a week.

h) It is the pressure gauges and thermometers which give the correct indication of the plant performance and condition. Therefore, it should be ensured that they are in good order and are periodically calibrated.

j) Analyze the pressure and temperature readings of the plant from the log book and ensure that they conform to design parameters. Corrective action should be promptly taken when the readings show even a minor discrepancy.

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.

(1)	IS 3615:2007	Glossary of terms used in refrigeration and air conditioning (*first revision*)
(2)	IS 655:2006	Air ducts — Specification (*second revision*)
(3)	IS 737:1986	Specification for wrought aluminium alloy sheet and strip for general engineering purpose (*third revision*)
(4)	IS 1391 (Part 1):1992	Specification for room air conditioners : Part 1 Unitary air conditioners (*second revision*)
(5)	IS 1391 (Part 2):1992	Specification for room air conditioners : Part 2 Split air conditioners (*second revision*)
(6)	IS 8148:2003	Specification for packaged air conditioners (*first revision*)
(7)	IS 3315:1994	Specification for evaporative air coolers (desert coolers) (second revision)
(8)	IS 661:2000	Thermal insulation of cold storage - Code of practice (*third revision*)
(9)	IS 12976:1990	Solar water heating systems - Code of practice
(10)	IS 3103:1975	Code of practice for industrial ventilation (*first revision*)
(11)	IS 1239 (Part 1):2004	Steel tubes, tubulars and other wrought steel fittings — Specification: Part 1 Steel tubes (*sixth revision*)
(12)	IS 3589:2001	Steel pipes for water and sewage (168.3 to 2 540 mm outside diameter) — Specification (*third revision*)
(13)	IS 4831:1968	Recommendation on units and symbols for refrigeration
(14)	IS 5:1994	Specification for colours for ready mixed paints and enamels (*fourth revision*)

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