भारत सरकार

GOVERNMENT OF INDIA

केंद्रीय लोक निर्माण विभाग

CENTRAL PUBLIC WORKS DEPARTMENT

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DIRECTORATE GENERAL, CPWD, NIRMAN BHAWAN, NEW DELHI 110011

CPWD GENERAL SPECIFICATIONS FOR HVAC 2024

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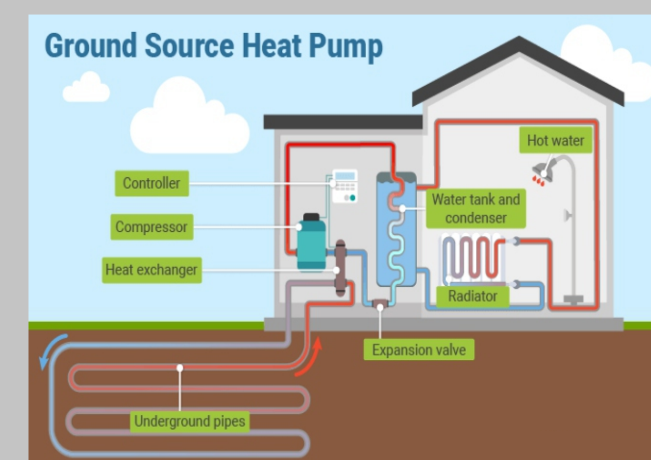
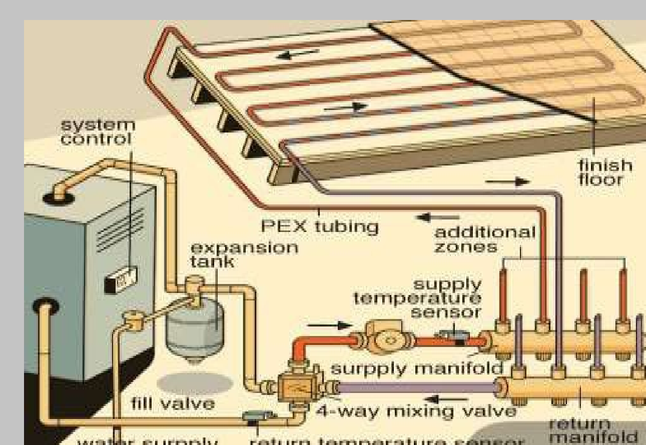
तापन, संवात और वातानुकूलन (एच वी ए सी) कार्यों के लिए समान्य विनिर्देश 2024

GENERAL SPECIFICATIONS for HEATING, VENTILATION & AIR- CONDITIONING (HVAC) WORKS 2024





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GOVERNMENT OF INDIA
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GENERAL SPECIFICATIONS FOR HEATING, VENTILATION AND AIRCONDITIONING WORKS
2024

PUBLISHED UNDER THE AUTHORITY
OF
DIRECTOR GENERAL, CPWD, NEW DELHI

DISCLAIMER

1. *Whereas every care has been taken to ensure that all relevant and essential provisions required for execution of Construction and Maintenance Works are incorporated in this Specification in a simplified and transparent manner, all executing entities referring to are requested to bring it to the notice of the Directorate, if any conflicting provisions/ discrepancies are noticed in the Specification.*

2. *This specification is prepared for the use of CPWD. However, this may be used by other government departments, PSUs, private bodies & other institutions or individuals at their own discretion only. CPWD shall not be responsible for any ambiguity, discrepancy, dispute or financial loss, arising directly or indirectly by using or following items in specification by such Government/ Private bodies or individuals.*

A GOVERNMENT OF INDIA PUBLICATION

Published by under the authority of
Director General
Central Public Works Department
Nirman Bhawan
New Delhi-110011

RAJESH KUMAR KAUSHAL
Director General

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FOREWORD

CPWD executing all types of air conditioning, heating and ventilation works right from system design to installation, commissioning, operation and maintenance in Govt. Buildings. This revised and enlarged edition of "CPWD General Specification for Heating, Ventilation & Air-Conditioning (HVAC) Works 2024 is of the need to update the long pending HVAC Specifications published in 2017 Since, then there have been changes in the field.

This updated specifications consist of technology based on sustainable development, energy efficiency and green building norms related to central air conditioning system, VRF System, Unitary System, air and water cooled chiller with centrifugal, screw, scroll and magnetic centrifugal type compressor etc. Chapters on Geo Thermal Space Heating and Cooling, indoor air quality, compliance to ECBC energy efficiency norms, etc. has been included. I wish that these specifications will be helpful to reduce the carbon footprint.

I acknowledge the hard work and sincere efforts put in towards this publication by Sh. Shatrughna Prasad Chaudhary, Spl. DG (Former Chairman of Drafting Committee), Sh. Ujjwal Mitra, ADG (T & R), Chairman of Drafting committee and other members Sh. Vikas Gupta CE (E), Sh. Vimal Kumar, CE (E), Sh. Vikash Rana, CE (E), Sh. Rajeev Kumar Sao, CE (E), Sh. Neeraj Kumar Bansal CE (E), Sh. R. R. Meena, CE (E), Sh. R.P. Gupta SE (E), Sh. Vivek Gupta, SE (E) toward reviewing and finalizing the CPWD General Specification for HVAC 2024.

I also acknowledge and appreciate the efforts by Sh. Naimuddin, ADG (Tech), Sh. R.R. Meena, CE CSQ (E), Shri R. P. Gupta, SE (E) TAS, Sh. Ashok Kumar Meena (E) TAS and entire CSQ(E) team towards revision and finalisation of General Specifications for HVAC 2024.

Place: New Delhi
Dated: 08.07.2024

(Rajesh Kumar Kaushal)
Director General, CPWD

Ujjwal Mitra
Additional Director General

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MESSAGE FROM CHAIRMAN DRAFTING COMMITTEE

CPWD General Specifications for HVAC works 2024 is the revised version of the earlier specifications released in 2017. There was a growing need to revise these specifications due to major technological changes over a period as well as concept of energy efficiency gaining momentum after introduction of ECBC 2017 and further amendments. Accordingly, changes have been effected in this revision.

Almost all the chapters have been modified to align them with the tried and trusted changes that have taken place in the field of air conditioning VRV/VRF System along with window type and split type AC have been included in this edition. Magnetic Bearing Variable Speed Centrifugal Water Chillers, chilled beams, radiant cooling system, Geo thermal based air cooling system, variable flow hydronic system and variable air volume boxes are some of the new technological additions which have found place in this edition. Similarly, inclusion of BEE Star Rating for Chillers and other equipment are some of the few useful tabular additions for all practicing HVAC engineers including designers of HVAC systems

I am indeed grateful to Shri Rajesh Kumar Kaushal, Director General, CPWD, for reposing trust in our team to undertake this work. I acknowledge the efforts put in by former Chairman of drafting committee Sh. Shatrughna Prasad Chaudhary, Spl. DG and members of the specification committee Sh. Vikas Gupta CE (E), Sh. Vimal Kumar, CE (E), Sh. Vikash Rana, CE (E), Sh. Rajeev Kumar Sao, CE (E), Sh. Neeraj Kumar Bansal CE (E), Sh. R. R. Meena, CE(E), Sh. R.P. Gupta SE(E),Sh. Vivek Gupta, SE (E) for their valuable contributions and inputs in drafting the present specification which is technically update, modern and user friendly.

I compliment Sh. Naimuddin, ADG (Tech), Sh. R. R. Meena CE CSQ(E), Sh. R. P. Gupta, SE (E) TAS, Sh. Ashok Kumar Meena, EE(E) TAS, Sh. Sandeep Kumar Das, AE(E) TAS, Sh. Harjeet Singh, AE (E) TLQA and other officials of CSQ (E) unit i/e CE (E)s Vimal Kumar & Vikas Rana for contribution during their tenure as CE CSQ (E) who made their sincere efforts to update the specifications and making the publication available in very short time.

Place: New Delhi
Dated: 8 .07.2024

(Er. Ujjwal Mitra)
Additional Director General, (T & R)
CPWD

Naimuddin
Additional Director General

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PREFACE

CPWD envisages a lead role for itself in the execution, maintenance and standardization of the built environment in India, while continuing to play the role of a government department in facilitating the implementation of policies for sustainable development and transparency in governance along with assimilation of knowledge and experience. CPWD strives to educate its clients to aspire for green buildings and develops norms for the same. Its vision is to create and maintain a sustainable and inclusive built environment within the available resources while ensuring world class quality.

The Central Public Works Department (CPWD) is a 170 years old institution and is the principal agency of the Government of India responsible for creating assets and providing comprehensive services including planning, designing, construction and maintenance of office and residential buildings as well as other infrastructures of various ministries, departments of Government of India, autonomous bodies and public sector enterprises. Its activities are spread throughout the country.

The following is the sequence of various editions of CPWD General Specifications for HVAC Works.

- 1977
- 2004
- 2017
- 2017 (Amendments)
- 2024 (Present edition)

CPWD General Specifications for HVAC works 2024 is the revised version of the earlier specifications released in 2017. There was a growing need to revise these specifications due to major technological changes over a period of more than six years as well as concept of energy efficiency gaining momentum after introduction of ECBC 2017. Accordingly, changes have been effected in this revision.

Almost all the chapters have been modified to align them with the tried and trusted changes that have taken place in the field of air conditioning VRV/VRF System, window type and split type AC, screw, scroll, centrifugal and magnetic bearing variable speed centrifugal air cool and water cool chillers, radiant cooling system Geo thermal based air cooling system. Ground source thermal heating and cooling system, heat pumps etc. are some new technologies based on green and sustainable energy source included in this edition and will reduce huge amount of carbon emission in future. Smoke exhaust and pressurisation system, area ventilation are also included. Similarly, the List of CFC and HCFC free Refrigerant along with their ODP. GWP and application, minimum efficiency requirement for VRF air conditioning and air-cooled chiller for ECBC and ECBC+ building are also included in this edition. Automatic tube cleaning system, fire safety related to AHU, duct work, smoke control, recommended rate of air circulation, pressurisation of stair case and lift lobby, are also included in this edition.

- Addition of following new items.
    - Geo Thermal space conditioning.
    - Adiabatic cooling
    - Indoor Air quality.
    - Filter and air cleaning devices.
    - Parameters for Air cool and water cool chillers for ECBC, ECBC+ and ECBC super building.
    - Automatic tube cleaning system, fire safety related to AHU, duct work, smoke control.
    - Pressurization of stair case and lift lobby.
    - List of CFC and HFC free refrigerant from in their ODP and GWP and application.
    - Important Indian standards are also updated.

I am grateful to Shri Rajesh Kumar Kaushal, Director General, CPWD, for reposing trust in our team to undertake this work. I acknowledge the efforts put in by Chairman and members of the specification committee in drafting the present specification which is technically update, modern and user friendly. I express my deep appreciation for Sh. Shatrughna Prasad Chaudhary, Spl. DG (Former Chairman of Drafting Committee), Sh. Ujjwal Mitra, ADG (Training & Research) Chairman of the Drafting committee and members Sh. Vikas Gupta CE (E), Sh. Rajeev Kumar Sao, CE (E), Sh. Neeraj Kumar Bansal CE (E), Sh. R.R. Meena, CE CSQ (E), Sh. R.P. Gupta, SE (E) TAS, Sh. Vivek Gupta, SE (E) for their valuable contributions and inputs.

I compliment Sh. R. R. Meena CE CSQ(E), Sh. R. P. Gupta, SE (E) TAS, Sh. Ashok Kumar Meena, EE(E) TAS, Sh. Sandeep Kumar Das, AE(E) TAS, Sh. Harjeet Singh, AE (E) TLQA and other officials of CSQ (E) unit i/e CE (E)s Vimal Kumar & Vikas Rana for contribution during their tenure as CE CSQ (E) who made their sincere efforts to update the specifications and making the publication available in very short time.

Errors or omissions, and suggestions for improvement, if any, may kindly be brought to the notice of the Superintending Engineer (E) TAS, in the Office of Chief Engineer (E) CSQ, CPWD, New Delhi-110011(Tel No. 01123061418, email: delseetas.cpwd@nic.in

Place: New Delhi
Dated: 8 .07.2024

(Er. Naimuddin)
Additional Director General, (Tech)
CPWD

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APPENDIX

INDEX OF TABLES

CHAPTER-1
GENERAL

1.1 INTRODUCTION

1.1.1 Scope

1.1.1.1 These specifications cover the following types of Air-conditioning, Heating and Ventilation Works:

(i) Window AC, Split AC.
(ii) VRV/ VRF type Air-conditioning System.
(iii) Central air-conditioning system.
(iv) Central heating system.
(v) Mechanical ventilation system :
(a) General Ventilation
(b) Basement, Parking & Area ventilation
(c) Smoke exhaust and pressurization systems.
(vi) Ground Source Thermal Heating and Cooling System.
(vii) Solar Heating and Cooling System.
(viii) Heat Pumps
(ix) Package type Air conditioning Plant
(x) Cold Room
(xi) Evaporative Air Conditioning

1.1.1.2 Central air-conditioning system included in these specifications is by means of Scroll or centrifugal or screw type compressors. Therefore, only vapour compression type refrigeration equipments are covered herein.

1.1.1.3 While these Specifications serve as general guidelines, appropriate technical sanctioning authority/ NIT Authority can depart from such guidelines to meet the particular requirements of any work or for other technical reasons with recorded justification.

1.1.1.4 These General Specifications cover the equipments and materials for the system, their testing and/ or inspection as may be necessary before their dispatch from their respective factory, their delivery at site, all preparatory works, assembling, installation and adjustments, commissioning, final Testing, Adjusting & Balancing putting into operation, equipment capacity computation and handing over of the complete system.

1.1.1.5 These General Specifications are subject to revision from time to time.

1.1.1.6 Each air-conditioning work has its own particular requirements. These General Specifications shall be supplemented with tender specifications as may be required for a particular work. The tender specifications, wherever they differ from these General Specifications, shall have over- riding value and shall be followed for that particular work. However, the deviation of tender specification with this specification shall be duly justified and recorded by NIT/TS Authority.

1.1.2 Related Documents

These General Specifications shall be read in conjunction with the National Building Code of India (NBC) 2016 as amended up to date and Energy Conservation Building Code of India 2017 (ECBC 2017) as amended up to date, BEE Star labelling.

1.1.3 **Terminology**

The definition of terms used in these specifications shall be in accordance with IS: 3615- “Glossary of terms used in refrigeration and air-conditioning”. Some of the commonly used terms are defined in Appendix ‘A’.

1.1.4 **Site Information**

The tenderer should, in his own interest, visit the site and familiarize himself with the site conditions before tendering. For any clarification, tenderer may discuss with the Engineer-in-Charge.

1.1.5 **Heat Load Calculations, Equipment Selection**

(i) The successful bidder/ contractor should give detailed heat load calculations as per Appendix ‘D’ separately for all the seasons in which, the specified conditions are to be maintained along with various coefficients considered and the calculation of U values, R values of Roof assemblies, Walls, Windows, Doors, Fenestration etc. (in compliance to values as mentioned in chapter-3 of this specifications) and other required detail immediately after award of work.

(ii) The successful Bidder/Contractor should also give the above heat load calculations wherever required separately for the areas served by each AHU in a central air conditioning/ heating system.

(iii) The equipment selection and duct design shall be made on the basis of the above heat load calculations.

(iv) The Contractor can refer and utilize the design done by the department/ consultants for the department, however, there shall be no commitment to provide the same to the contractor, nor the contractor shall be absolved of the responsibility of correct design and performance of the air-conditioning system provided by him/her siting the design proposed by the department/consultant for the department.

1.2 CONFORMITY WITH STATUTORY ACTS, RULES, STANDARDS AND CODES

(i) All components shall conform to relevant Bureau of Indian Standard Specifications, wherever existing, amended up to date and Energy Conservation Act 2001 as amended up to date, Energy Conservation Rule 2018 as amended up to date and Energy Conservation Building code 2017 of India as amended up to date, BEE star labeling. A non- comprehensive list of such standards is appended in Appendix ‘B’.

(ii) All works shall conform to relevant Bureau of Indian Standard Specifications, National Building code 2016 as amended up to date, Energy Conservation Act 2001 as amended upto date, Energy Conservation Rule 2018 as amended up to date and Energy Conservation Building code 2017 of India as amended up to date, National Electric Code 2023 as amended up to date, as well as relevant BIS codes, BEE star Labeling. All codes and Standards shall mean upto date updated the latest edition as on last date of submission or last extended date of submission of tender.

(iii) All electrical works shall be carried out in accordance with the provisions of Indian Electricity Act, 2003 and Indian Electricity Rules, 1956 amended to date, National Electrical Code of India 2023 as amended upto date. They shall also conform to CPWD General Specifications for Electrical works, Part-I: Internal, 2023 as amended/revised upto date and Part-II: External, 2023 as amended/revised upto date and Part IV (Sub-station), 2013, as amended/revised upto date.

(iv) In the case of discrepancy between the schedule of Quantities, the Specifications and/ or the Drawings, the following order of preference shall be observed:
(a) Description of Schedule of Quantities, if any
(b) Particular Specification and Special Condition, if any.
(c) Drawings.
(d) CPWD Specifications.
(e) Bureau of Indian Standard Specifications
(f) ECBC 2017,
(g) National building code 2016,
All above mentioned documents amended up to date are applicable.

1.3 SAFETY CODES AND LABOUR REGULATIONS

(i) All the safety procedures outlined in the safety codes listed in Appendix 'C' shall be complied with.

(ii) In respect of all labour employed directly or indirectly on the work for the performance of the air conditioning contractor's part of work, the contractor at his own expense, will arrange for the safety provisions as per the statutory provisions, B.I.S recommendations, factory act, workman's compensation act, CPWD code and instructions issued from time to time. Failure to provide such safety requirements would make the tenderer liable for penalty as provided in the labour laws/ GCC for each violation. In addition the Engineer-in-charge, shall be at liberty to make arrangements and provide facilities as aforesaid and recover the cost from the contractor.

(iii) The contractor shall provide necessary barriers, warning signals and other safety measures while laying pipelines, ducts cables etc. or wherever necessary so as to avoid accident. He shall also indemnify CPWD against claims for compensation arising out of negligence in this respect. Contractor shall be liable, in accordance with the Indian Law and Regulations for any accident occurring due to any cause. The department shall not be responsible for any accident occurred or damage incurred or claims arising there from during the execution of work. The contractor shall also provide all insurance including third party insurance as may be necessary to cover the risk. No extra payment would be made to the contractor due to the above provisions thereof.

1.4 WORKS TO BE DONE BY THE CONTRACTOR

Unless otherwise mentioned in the tender documents, the following works shall be done by the contractor and therefore, their cost shall be deemed to be included in their tendered cost whether specifically indicated in the schedule of work/ tender or not: -

(i) Foundations for equipments including foundation bolts and vibration isolation spring/ pads,
(ii) Support columns and beams for cooling towers,
(iii) Suspenders, brackets and floor/ wall/Ceiling supports for suspending/ supporting ducts and pipes,
(iv) Suspenders and/ or cable trays for laying the cables,
(v) Excavation and refilling of trenches in soil wherever the pipes are to be laid directly in ground, including necessary base treatment and supports,
(vi) Sealing of all floor slab/ wall openings provided by the Department or contractor for pipes and cables, from fire safety point of view, after laying of the same,
(vii) Painting of all exposed metal surfaces of equipments and components with appropriate colour as per Para 1.13.

(viii) Making openings in the walls/ floors/ slabs or modification in the existing openings wherever provided for carrying pipe line, ducts, cables etc. In case of new construction work the opening shall be made in slab casting/ wall construction.

(ix) Providing wooden/ metallic frames for fixing grills/diffusers.

(x) Making good all damages caused to the structure during installation and restoring the same to their original finish.

(xi) Balancing of all HVAC systems in accordance with generally accepted engineering standards. A written balance report shall be provided (wherever asked for) to the Engineer-in-Charge or his representative for HVAC systems as per chapter 17 requirement.

(xii) A set of three copies of operations manual shall be provided to the Engineer-in-Charge or his representative containing following information at a minimum-

  (a) HVAC equipment capacity,
  (b) Equipment operation and maintenance manuals,
  (c) HVAC system control maintenance and calibration information, including wiring diagrams, schedules, and control sequence descriptions,
  (d) A complete written narrative of how each system is intended to operate.

(xiii) In case of new construction work (EPC as well as Non EPC) involving civil work, HVAC work and other E&M services having working plant tonnage 200 & above, the Contractor shall associate the Energy modeller and carried out the energy modelling of complete building & Energy Performance Index modeling i/c all services and other active/passive factors i/c Core & shell as involved in the complete design. The cost of this energy modelling deemed to include in the tendered cost and nothing extra will be paid on this account.

1.5 POWER SUPPLY, WATER SUPPLY AND DRAINAGE:

1.5.1 In case of Standalone work of HVAC in the existing building, the following below given will be applicable.

Unless and otherwise specified in the tender, the Power, Electricity and drainage shall be provided by the Contractor for successful and satisfactory completion of work.

1.5.2 In case of EPC contracts the Contractor has to arrange Power, Water i/c water Softening plant, Drainage, Tube cleaner system etc. by own resources at free of Cost, until otherwise specified in the tender.

1.6 MACHINERY FOR ERECTION

All tools and tackles, heavy machinery handling equipment, etc. required for unloading/ handling of equipments and materials at site, their assembly, erection, testing and commissioning shall be the responsibility of the contractor.

1.7 COMPLETENESS OF THE TENDER, SUBMISSION OF PROGRAMME, APPROVAL OF DRAWINGS AND COMMENCEMENT OF WORK

(i) **Completeness of the tender**

All sundry equipments, fittings, assemblies, accessories, hardware items, gaskets, masonry platforms/ foundation for Chilling Units, pumps, Cooling Towers etc., supports for pipes foundation bolts, supports, termination lugs for electrical connections, cable glands, junction boxes and all other items which are useful and necessary for proper assembly and efficient working of the various equipments and components of the work shall be deemed to have been included in the tender, irrespective of the fact whether such items are specifically mentioned in the tender or not.

(ii) **Submission of programme**

Within fifteen days from the date of receipt of the letter of acceptance until otherwise mentioned in NIT, the successful tenderer shall submit his programme for submission of Design Calculation, drawings, Heat Load Calculation, Documents to be submit to Local Bodies, Air and water distribution layout and drawings, Selection of Equipment, supply of equipment, installation, testing, commissioning, getting approval from Local body. Any other activities as required in NIT and handing over of the installation to the Engineer-in-Charge. This programme shall be framed keeping in view the milestones stipulated in the contract, building progress. Items like ducting, piping etc. that directly affect the building progress shall be given priority.

(iii) **Submission of Drawings**

The contractor shall submit the drawings to the Engineer-in-Charge as per para 1.17.2 for approval before start of work.

(iv) **Commencement of Work**

The contractor shall commence work as soon as the drawings submitted by him are approved.

1.8 DISPATCH OF MATERIALS TO SITE AND THEIR SAFE CUSTODY

The contractor shall dispatch materials to site in consultation with the Engineer-in-Charge. Programme of dispatch of material shall be framed keeping in view the building progress. Safe custody of all machinery and equipment supplied by the contractor shall be the responsibility of the contractor till final taking over by the department.

1.9 CO-ORDINATION WITH OTHER AGENCIES

The contractor shall co-ordinate with all other agencies involved in the work so that the work of other agencies is not hampered due to delay in his work. Ducting, piping, cabling or any other work, which directly affect the progress of building work, shall be given priority.

1.10 QUALITY OF MATERIALS AND WORKMANSHIP

(i) The components of the installation shall be of such design so as to satisfactorily function under all conditions of operation.

(ii) The entire work of manufacture/ fabrication, assembly and installation shall conform to sound engineering practice. The entire installation shall be such as to cause minimum transmission of noise and vibration to the building structure.

(iii) All equipments and materials to be used in work shall be manufactured in factories of good repute having excellent track record of quality manufacturing, performance and proper after sales service.

(iv) None of the equipment/ machines supplied shall be more than Six months old from date of supply at site, Copy of Excise Gate Pass/ Invoice/ Shipment /Custom Clearance certificate/ details (in case of Imported equipment)/GST Bills shall be submitted to prove the date of manufacture & genuineness of the equipment/machines supplied. In case of whereas per NIT condition specialized agency is associated by main contractor as per agreement terms & conditions, all materials to be procured by associate specialized agency and all bills shall be in the name of associate agency in such cases.

(v) The all material dispatch shall also accompanied with the acceptance test/ quality tests/performance test certificate as carried out by the Manufacture and by third party.

1.11 CARE OF THE BUILDING

Care shall be taken by the contractor during execution of the work to avoid damage to the building. He shall be responsible for repairing all such damages and restoring the same to the original finish at his cost. He shall also remove all unwanted and waste materials arising out of the installation from the site of work from time to time.

1.12 COLOUR SCHEME FOR THE EQUIPMENTS AND COMPONENTS

(i) Colour scheme for equipment like chilling unit, pumps, AHUs, cooling tower etc. shall be as per manufacturer's standard colour scheme.

(ii) The scheme of colour code painting of pipe work services for air conditioning installation shall be as per National building code and is indicated below:

Description	Ground colour	Lettering colour	First colour band
Condenser water piping	Sea Green	Black	French Blue
Chilled water piping	Sea Green	Black	Black
Central heating piping Below 60 deg C	Sea Green	Black	Canary Yellow
Central heating piping 60 deg C to 100 deg C	Sea Green	Black	Dark Violet
Drain pipe	Black	White	
Vents	White	Black	
Valves and pipe line fittings	White with black handles	Black	
Belt guard	Black & Yellow diagonal strips		
Machine Bases, Inertia Bases and Plinth	Charcoal Grey		

(iii) Colour bands shall be 150 mm wide, superimposed on ground colour to distinguish type and condition of fluids. The spacing of band shall not exceed 4.0m.

(iv) In addition to the colour bands specified above all pipe work shall be legibly marked with black or white letters to indicate the type of service and the direction of flow identified as follows:-

High temperature Hot water : HTHW
Medium temperature Hot water : MTHW
Low temperature Hot water : LTHW
Chilled water : CHW
Condenser water : CDW
Steam : ST
Condensate : C

1.13 INSPECTION AND TESTING

1.13.1 Initial Inspection & testing

(i) Initial inspection of materials & equipment e.g. chiller, AHU, FCU, Cooling tower, Pumps, VRF units shall be carried out by Engineer-in-charge or his authorized representative in factory. For items requiring assembly at site the inspection shall be for the components to be assembled. The Engineer-in-charge can ask for factory inspection of other items also and the same shall also be deemed to be included in tender cost. The all main material equipment etc. as required in inspection & testing is deemed to be included in tender cost. For item/ equipment requiring initial inspection at manufacturer's works, the contractor will intimate the date of testing of equipment at the manufacturer's works before dispatch. The contractor shall give sufficient advance notice regarding the dates proposed for such tests to the department's representative(s) to facilitate his presence during testing. The Engineer-in-charge at his discretion may witness such testing. Equipment will be inspected at the manufacturer/ authorized dealer's premises, before dispatch to the site by the contractor. For equipment sourced from abroad, the contractor shall include in his bid the costs of journey & stay, other costs if any, for sending his technically competent representative to witness the performance and pre-dispatch tests at the manufacturer's works. Evidence to this effect by way of travel documents etc. shall be produced before the payment against delivery is released. The Engineer-in-charge, at his discretion, may also witness such testing subject to Government Orders at that time.

(ii) The department also reserves the right to inspect the fabrication job at factory and the successful tenderer has to make arrangements for the same.

(iii) The materials duly inspected by Engineer-in-Charge or his authorized representative shall be dispatched to site by the contractor.

(iv) No additional payment shall be made to the contractor for initial inspection /testing at the manufacturer's works by the representative of the Engineer-in-Charge. However, the department will bear the expenses of its representative deputed for carrying out initial inspection/testing.

(v) Factory testing of VRF having aggregate capacity more than 100 HP at NABL Certified Test Bed in India. Factory testing of Chillers shall be as per BIS/ BEE/ ARI.

1.13.2 Final Inspection & Testing

Final Inspection & testing will be done by the Engineer-in-Charge or his representative as per details indicated in Chapter 17.

1.13.3 Safety measures

All equipment shall incorporate suitable safety provisions to ensure safety of the operating personnel at all times. The initial and final inspection reports shall bring out explicitly the safety provisions incorporated in each equipment.

1.14 RUNNING IN PERIOD & DATE OF ACCEPTANCE

(i) After the installation work has been completed by the contractor, he will conduct tests and make adjustments as per chapter 17 and further as may be necessary to satisfy himself that the plant including low side equipment is capable of continuous running. There after he will offer to the department a running-in period of 7 days subject to a minimum aggregate of 120 hrs at his cost. The duty cycle of the plant during this running in period shall be same as that specified in the tender documents. In case of multiple compressor installations, all the compressors should be run by rotation. The plant will be operated and a log of all parameters will be maintained during this period. The contractor will be free to carry out necessary adjustments etc. during this period without stopping the plant. Record of inside conditions will be made during this period to check that the same are as per NIT requirements. The plant will be said to have successfully completed the running-in-period, if no break down or abnormal/ unsatisfactory operation of any machinery occurs during this period. After this the plant will be made available for beneficial use. After the plant has operated without any major break down/ trouble and inside conditions are maintained as per NIT requirements for the above specified running in period, it shall be taken over by the department subject to guarantee clause mentioned below. This date of taking over of plant after trouble free operation during the running in period shall be the date of acceptance.

(ii) Any loss of refrigerant or oil during the running in period shall be made good by the contractor free of charge.

(iii) Capacity test of the chilling unit & other major equipment shall be carried out as and when conditions become stabilized as per details given under Appendix 'G'.

(iv) Seasonal testing may be carried out as & when outside conditions become suitable for the Major Season Test.

1.15 GUARANTEE

(i) The contractor shall guarantee the complete system to maintain the specified conditions under all conditions of ambience and internal loads subject to the condition that designed outside conditions & designed internal loads are not exceeded. Also the inlet/ outlet temperatures at the specified flow of water in the chiller unit shall be guaranteed.

(ii) All equipment shall be guaranteed for a period of 12 months from the date of acceptance and taking over of the installation by the Department or greater period as mentioned in the NIT against unsatisfactory performance and/or breakdown due to defective design, material, manufacture, workmanship or installation. The equipment or component or any part thereof so found defective during the guarantee period shall be repaired or replaced free of cost to the satisfaction of the Engineer-in-Charge. In case it is felt by the department that undue delay is being caused by the contractor in doing this, the same will be got done by the department at the risk & cost of the contractor. The decision of Engineer-in-Charge in this regard shall be final.

(iii) Any leakage of refrigerant and/or oil due to defective design, manufacture, workmanship or installation during the guarantee period shall be made good by the contractor free of charge.

1.16 PAYMENT TERMS

1.16.1 The following percentage of contract rates shall be payable against the stages of work shown herein:

	Stage of work	
I	After initial inspection (wherever specified) & delivery at site in good condition on pro-rata basis	70%
II	On completion of pro-rata installation	15 %
III	On commissioning and completion of successful running in period	10 %
IV	On completion of major seasonal test	5 %

1.16.2 When the major seasonal test cannot be carried out on commissioning of the installation due to any reason not attributable to the contractor, the installation will he handed over to the Department for beneficial use after completion of successful running in test of 7 days subject to a minimum aggregate of 120 hours as per para 1.15 above. The balance payment shall be released to the contractor on his furnishing a bank guarantee in the specified format from a scheduled bank for an equivalent amount. The bank guarantee shall be valid for a period of 6 months. However, it will be extended till the successful completion of the major seasonal test. This bank guarantee shall be independent of the one furnished for performance guarantee.

1.16.3 The following shall be considered major seasonal test for the purpose of the above payment terms: -

a)	Air-conditioning system	:	Summer or monsoon
b)	Central heating system	:	Winter
c)	ETAC	:	Summer
d)	Cold room/ Walk in cooler	:	Summer

1.17 TENDER DRAWINGS, DRAWINGS FOR APPROVAL & COMPLETION DRAWINGS

1.17.1 Tender Drawings

(a) **EPC Mode-III:** The drawings appended/ uploaded with the tender documents are intended to show the areas to be conditioned, space allotted for various equipment, tentative duct, cable and pipe routes. The equipment offered shall be suitable for installation in the spaces shown in these drawings. In case of applicability of BIM model as per NIT, these drawing shall be abstracted from BIM.

(b) **EPC Mode I and II:** As mentioned in the NIT the contractor shall develop all Drawings for HVAC work including Equipment layout, Ducting, Piping, Foundation Support, Automation etc. In case of applicability of BIM model as per NIT, these drawing shall be abstracted from BIM.

1.17.2 Drawings for approval on award of the work (Not applicable in case of Window and Split AC)

The contractor shall prepare & submit three sets of hard copy & one Digital/ soft copy in AutoCAD format of following drawings (2D/3D) and get them approved from the Engineer-in-Charge before the start of the work. The approval of drawings however does not absolve the responsibility of contractor to supply the equipments/ materials as per agreement, if there is any contradiction between the approved drawings and agreement. In case of applicability of BIM modeling as per NIT then all drawings and data’s shall be develop and extracted from BIM platform.

(i) Lay out drawings of the equipments to be installed in various rooms such as plant room, AHU rooms, hot water generator room, cooling tower and other equipments.

(ii) Drawings including section, showing the details of erection of entire equipments including their foundations, water basin for the cooling towers / air washers, etc.

(iii) Plumbing drawings showing the layout of entire piping, dia & length of pipes, valves and isometric drawings showing connections to various equipment.

(iv) Ducting drawings showing sizes, locations of dampers, grilles & diffusers.

(v) Electrical wiring diagrams for all electrical equipments and controls including the sizes and capacities of the various cables and equipments,

(vi) Dimensioned drawings of all electrical and control panels,

(vii) Drawings showing the details of all insulations and vapour barrier works,

(viii) Drawings showing details of supports for pipes, cable trays, ducts etc.

(ix) Any other drawings relevant to the work.

The department shall, at its discretion, use the soft copy of such drawings to prepare and examine the integrated services layout, resolve conflicts, and advise the contractor to modify the execution drawings suiting & adjusting to all the services requirements. The contractor shall be bound to modify & execute accordingly.

1.17.3 Completion Drawings (Not applicable in case of Window and Split AC)

One set of Digital/ soft Copy and three sets of the following laminated drawings shall be submitted by the contractor while handing over the installation to the Department. Out of this one of the sets shall be laminated on a hard base for display in the A.C. plant room. In addition one set will be given on compact disc.

(i) Plant installation drawings giving complete details of all the equipment, including their foundations,

(ii) AHU room installation drawings,

(iii) Plumbing layout drawings including insulation giving sizes and lengths of all the pipes and the sizes and locations of all types of valves, and including isometric drawings for the entire piping including the pipe connections to the various equipment and insulation details wherever required,

(iv) Duct layout drawings with their sizes and locations, and sizes and locations of all dampers, grills & diffusers,

(v) Line diagram and layout of all electrical control panels giving switchgear ratings and their disposition, cable feeder sizes and their layout,

(vi) Control wiring drawings with all control components and sequence of operations to explain the operation of control circuits,

(vii) BMS drawings (wherever applicable)

(viii) Electrical cabling layout

(ix) Mechanical Ventilation layouts.

1.18 AFTER SALES SERVICES

The contractor shall ensure adequate and prompt after sales service in the form of maintenance, spares and personnel as and when required and shall minimize the breakdown period. In case of equipment supplied by manufacturer, other than the contractor, the firm shall also furnish a guarantee from the manufacturer for the same before the plant is taken over.

1.19 DOCUMENTS TO BE FURNISHED ON COMPLETION OF INSTALLATION

Three sets of the following documents shall be furnished to the department by the contractor on completion of work:-

(a) Completion drawings as per para 1.17.3.

(b) Three set in Digital form and 03 set in printed form of manufacturer’s technical catalogues of all equipment and accessories,

(c) 02 sets of digital and hard copy of Operation and maintenance manual of all major equipment, detailing all adjustments, operation and maintenance procedure.

(d) The Licenses for all softwares and technologies as applicable.

(e) In case of applicability of BIM modeling as per NIT then all drawings and data’s shall be develop and extracted from BIM platform.

1.20 RATES :

1.20.1 The work shall be treated as on works contract basis and the rates tendered shall be for complete items of work (except the materials, if any, stipulated for supply by the department) inclusive of all taxes, GST (including works contract tax, if any), duties, and levies etc. and all charges for items contingent to the work, such as, packing, forwarding, insurance, freight and delivery at site for the materials to the supplied by the contractor, watch and ward of all materials (including those, if any, supplied by the department) for the work at site etc.

1.20.2 Prices quoted shall be firm. Price adjustments shall however be governed by Clause 10C, 10CC the Conditions of Contract given in form CPWD 7or 8 of the tender documents, for works executed under these forms, as applicable. All relevant documents shall be produced by the contractor to the Engineer-in-charge, whenever called upon by him to do so, for working out such adjustments in rates.

1.21 TAXES AND DUTIES :

1.21.1 Being an indivisible works contract, GST, custom duty, import duty, Octroi and any other taxes and duties etc. are not payable separately.

1.21.2 The works contract tax shall be deducted from the bills of the contractor as applicable in the State in which the work is carried out, at the time of payments.

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CHAPTER-2
SYSTEMS AND SYSTEM REQUIREMENTS

2.1 AIR-CONDITIONING SYSTEM

An air-conditioning system is a means of cooling/heating, dehumidification/ humidification, filtration and its distribution to the various conditioned spaces, maintaining indoor air quality, energy efficiency and other resources. Various types of air-conditioning systems commonly used are:-

(a) Unit type equipments, which may be a window type room air-conditioner or a split type air-conditioner.

(b) VRV/ VRF system

(c) Central plants (Water Cooled / Air Cooled), which are of two types :-

(i) Central DX-Plants with AHUs etc.

(ii) Central chilled water plants with AHUs, Fan Coil Units, Chilled Beams, Embedded chilled water pipes in slabs & walls, etc.

For each application there will specifically be only one system, which will be just right for it.

(d) Heat Pumps/ Ground Source Heat Pumps.

(e) Adiabatic Cooling / Heating.

2.2 DESIGN PARAMETERS

2.2.1 Outdoor Design Conditions

Outdoor design conditions (where the air conditioning is to be installed) shall be accordance with Table 2.1. For cities not included in this table, it is recommended that extrapolation may be done, from the data of the nearby listed city, but keeping into consideration the specific topographical and climatic conditions of the concerned location. 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. 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.

Maximum dry bulb temperature and co-incident wet bulb temperature shall be considered for design.

2.2.2 **Indoor design conditions**

2.2.2.1 **Indoor Design Temperature**

Indoor design temperature for different type of buildings shall be as given below, however These are not applicable for outdoor running mean temperatures below 15°C.

(a) **For naturally ventilated (NV) buildings**

Indoor operative temperature (in degree Celsius) = (0.54 × 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**

In Mixed-mode buildings, the HVAC is operated only during extreme outdoor conditions.

Indoor operative temperature (in Degree Celsius) = (0.28 × 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**

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 (Va), air temperature (Ta), radiant temperature (Tr), outdoor temperature (Tout), clothing insulation (Clo) and activity rate (MET).

(i) **Air temperature based approach**

Indoor operative temperature in Degree C = (0.078 × 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.

(ii) **Standard effective temperature based approach**

Standard effective temperature = (0.014 × outdoor temperature) + 24.53

Where standard effective 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.

2.2.2.2 **Indoor Relative Humidity requirement**

For design purposes RH of 55% shall be considered for Comfort air conditioning.

2.2.2.3 **Minimum ventilation rate**

The minimum supply rates of outdoor air required for acceptable indoor air quality for comfort air-conditioning shall be as prescribed in the Table 2.2. For the hospital and other specialised application the ventilation requirement shall be decided by the NIT Authority in consultation with Client and relevant standard requirements. 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.

2.2.2.4 **Indoor Air Quality (IAQ)**

It shall be as per chapter 22 of this specification.

2.3 Equipment Design Parameters

2.3.1 **CHILLING UNIT**

(i)	Centrifugal chilling unit	:	CFC and HCFC free refrigerant
(ii)	Suction temperature	:	As per manufacturer standard
(iii)	Condensing temperature	:	design to suit duty of Water Chilling Unit
(iv)	**Condenser**		
(a)	Water temperature IN	:	32.2 deg C
(b)	Water temperature OUT	:	36.4 deg C
(c)	Temperature rise	:	4.2 deg C
(d)	Fouling factor	:	0.001 (British unit)
(e)	Maximum permissible 10 m of water- pressure drop	:	head
(v)	**Chiller**		
(a)	Water temperature IN	:	12.2 deg C
(b)	Water temperature OUT	:	6.67 deg C
(c)	Temperature drop	:	5.5 deg C
(d)	Fouling factor	:	0.0005 (British unit)
(e)	Maximum permissible 10 m of water- pressure drop	:	head

2.3.2 **PIPING**

(i)	Maximum flow velocity	:	2.5 m/s
(ii)	Maximum friction	:	5 m/100 m run

2.3.3 **AIR HANDLING UNIT**

(i)	Maximum face velocity across cooling coil	:	155 m/min
(ii)	Maximum outlet air velocity	:	610 m/min
(iii)	Maximum velocity across filters		
(a)	Ordinary filters	:	155 m/min
(b)	Micro-vee filters	:	155 m/min
(c)	HEPA filters	:	155 m/min
(iv)	Minimum spray density for humidification	:	10 lpm/sq.m

2.3.4 **DUCTING FOR AIRCONDITIONING (office Building)**

		Main Duct	Branch duct
(i)	Maximum flow velocity	400 m/min	250 m/min

(ii) Maximum velocity at supply air grilles/ diffusers 150 m/min
(iii) Maximum friction in duct 1cm WG/100 m run

2.3.5 **DUCTING FOR AUDITORIUM, CONFERENCE HALL, OT's**

Value of all above parameters be kept as three fourth of values specified at para 2.3.4 above.

2.3.6 **DUCTING FOR ETAC system and VENTILATION System (normal operation) in Basement** :

Value of all above parameters be kept as 1.5 times of values specified at para 2.3.4 above.

2.4 RECOMMENDED COOLING DEMAND DENSITIES

Following table from ASHRAE GRP 158, Load Calculation Manual (Heating & Cooling), provides the recommended cooling demand densities (m^2 /TR) for different building types using air conditioning systems. The requirements given in the table may be used for preliminary calculations **only**. However, final sizing shall be based on the actual heat load calculations.

Example of Building air conditioning load (TR) for preliminary calculation using the table given below.

To estimate the cooling demand (air conditioning load TR) of an office building having air conditioned area of 1,000 m^2

Using the *Lo values (m^2/TR) given below in the table for office category building, the estimated total air conditioning load (TR) of the building will be

Preliminary estimated air conditioning load (TR)

= area (m^2)/ Cooling demand density (m^2t/TR)

= 1000/36

Notes:

‡ Refrigeration loads are for entire application

Air quantities for heavy manufacturing areas are based on supplementary means to remove excessive heat.

* Air quantities for hospital patient rooms and office buildings (except internal areas) are based on induction (air-water) system.

Refrigeration and air quantities for applications listed in this table of cooling load check figures are based on all-air system and normal outdoor air quantities for ventilation except as noted.

Cooling Demand Densities				
		Refrigeration		
		m^2/Ton‡		
Classifications		Lo*	Av*	Hi*
Apartment, High rise		45	40	35
Auditoriums, Churches, Theatres		40	25	9
Educational Facilities		24	18.5	15

Schools, College, Universities				
Factories	Assembly Areas	24	15	9
	Light Manufacturing	20	15	10
	Heavy Manufacturing#	10	8	6
Hospitals	Patient Rooms*	27.5	22	16.5
	Public Areas	17.5	14	11
Hotels, Motels, Dormitories		35	30	22
Libraries and Museums		34	28	20
Office Buildings*		36	28	19
Private Offices*		-	-	-
Stenographic Department		-	-	-
Residential	Large	60	50	38
	Medium	70	55	40
	Large	13.5	10	8
	Medium	15	12	10
Shopping Centres, Department Stores and Specialty Shops				
Department Stores	Basement	34	28.5	22.5
	Main Floors	35	24.5	15
	Upper Floors	40	34	28
Dress Shops		34.5	28	18.5
Drug Stores		18	13.5	11
Shoe Stores		30	22	15
Malls		36.5	23	16
Refrigeration for Central Heating and Cooling Plant				
Urban Districts		47.5	38	28.5
College Campuses		40	32	24
Commercial Centres		33	26.5	20
Residential Centres		62.5	50	37.5

Source: ASHRAE GRP 158, Load Calculation Manual (Heating & Cooling), Table A1.1- Cooling load Check figures

* **Hi values of cooling demand density may be used for existing buildings where building envelope cannot be improved**

* **Av values may be used for unitary (WT or Split type) units and for AC areas surrounded by non AC area else**

* **Lo values may be used for new buildings.**

2.5 Selection of the System

Selection of an appropriate air conditioning system for a particular application will need consideration of the following factors:

(i) Temperature and its acceptable variation,

(ii) Humidity and its acceptable variation,
(iii) Air movement,
(iv) Air purity or quality,
(v) Air changes per hour,
(vi) Air and/or water velocity requirements,
(vii) Local climate,
(viii) Space pressure requirements,
(ix) Capacity requirements as per load calculation analysis,
(x) Redundancy,
(xi) Spatial requirements,
(xii) Fire safety and security concerns,
(xiii) Initial cost,
(xiv) Operating cost, including energy and power costs,
(xv) Maintenance cost,
(xvi) Reliability,
(xvii) Flexibility,
(xviii) Controllability,
(xix) Life-cycle analysis,
(xx) Sustainability characteristics,
(xxi) Acoustics and vibration, and
(xxii) Mold and mildew prevention.
(xxiii) Peak cooling/heating load
(xxiv) Minimum load which system has to cater to at any time.
(xxv) System redundancy and reliability
(xxvi) Availability of cooling water in adequate quantity and quality
(xxvii) Energy and water Conservation.
(xxviii) Availability of Space for installation of Central Plant/ cooling Towers be added.

A comparison of various systems is given in the Table 2.3. However this is for general guidance and justification for choosing a particular system hall be evaluated by the technical Sanctioning Authority.

As a general guideline WTAC, Splits and Ducted Splits shall be used where the Cumulative load in proximity is less than 100 TR and VRF Systems shall be limited where the cumulative load does not exceed 500 TR. Other considerations listed in 2.5 shall override this general guidance. VRF Systems have been found to be beneficial where multiple indoor units are required and some or most of them may not be operational concurrent with the rest of the system. Decision on system selection in such cases shall be clearly documented.

Both EPC/Non EPC NIT’s the NIT approving authority shall clearly mention in NIT the provision of particular type of HVAC system.

2.6 WINDOW TYPE A.C. (Unitary)

2.6.1 **APPLICATIONS**:

These are provided where-

(i) Window for fixing the AC is available or necessary opening in wall is provided for the purpose.

(ii) Sound level of up to 50 dB inside the room is acceptable.

(iii) BEE star rated WTACs are available. As far as possible 5 star rated A.C. may be provided in all new installation for conserving electrical energy.

(iv) As far as possible the use of Window AC shall be avoided.

2.6.2 **INSTALLATION**

(i) While installing the A.C care be take that WTAC is not provided at back of sitting/ chair in room.

(ii) Standard A.C are provided with control plate and wire at right side of A.C (as seen from front) hence power outlet points should be provide at right side of window etc.

(iii) Standard installation procedures, as given by the manufacturers, may be followed.

(iv) Removal of condensate drain to be planned.

2.7 SPLIT TYPE A.C. (Unitary)

It comprises of an indoor unit and an outdoor unit. The indoor unit may be mounted on floor or on wall, or at ceiling. The outdoor unit consists of compressor, heat exchanger, fan and motor; installed in a separate independent cabinet. The indoor unit is an air handling system, 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. The split AC shall be Five Star BEE rated and variable speed compressor.

2.7.1 **APPLICATIONS:**

(i) Where window for installation of WTAC is not available, Split Type AC are planned.

(ii) Almost Silent (Low dB level) operation of A.C is important, considering VIP rooms, conference rooms, etc.

Various types of split air conditioners may be categorized based on type of compressor for outdoor unit and air-distribution for indoor unit, as below:

(a) Outdoor unit with variable speed compressor : It is also called an inverter AC or variable speed AC, which works on part load depending on the demand for the conditioned space. This uses a variable-

(b) Frequency drive to control the frequency and thereby the speed of the compressor motor.

(c) Free-blow indoor unit : It could be high wall mounted, ceiling suspended cassette (exposed type), or floor-mounted.

(d) Furred-in indoor unit (ceiling suspended) : It is mounted in the ceiling and provided with a duct collar and grille.

(e) Ducted indoor unit : It requires ducting for air distribution.

2.7.2 **INSTALLATION**

(i) Wherever split A.C. are planned in the new buildings, necessary openings in wall may be provided by with use of 75 mm PVC pipe sleeves at suitable locations for taking refrigerant pipes and cable to outdoor unit, so as to avoid unnecessary cutting/ damage to walls at a later stage. The slope of sleeve of PVC pipe should be towards exterior to avoid seepage of water into the room. This opening should be sealed properly after installation to avoid entry of vermin and rain water.

(ii) For condensate drain, 40 mm PVC/ HDPE pipe be also provided and taken to nearest drain or up to the stack for collection & disposal of condensate. The slope of such pipe also should be downwards. As far as possible, joints should be avoided in this pipe.

(iii) The length of connecting refrigerant pipes between outdoor and indoor unit be kept to minimum feasible at site. However it should not exceed 9 m, as the efficiency of the unit gets severely affected on increase of distance. The refrigerant pipes should be taken along the walls/ columns etc. duly clamped to their surface by saddles. If walls etc. are not available, tray be used to support the refrigerant pipes. Where bending of refrigerant pipes is required, proper pipe bending tool should be used to avoid pinching of pipes.

(iv) The refrigerant pipes should be properly insulated as per the recommendations of the manufacturer of split type AC units. The insulation over refrigerant pipes be examined once in a year and in case of any deficiency/ defect the same may be replaced.

(v) Wall mounted unit and similar exposed indoor unit are provided with installation plate for ease in installation. Care shall be taken to ensure that enough clearance space is available below the ceiling in order to have free intake of return air.

(vi) Outdoor unit is mounted on an epoxy-coated steel frame with rubber gourmet to minimise vibrations 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 also available to the outdoor air cooled condenser. Also precaution should be taken that hot air from any one outdoor unit does not mix with the outdoor air intake of any other air cooled condenser.

(vii) The location of the Outdoor unit shall be shown in the drawing and shall be ensured that the outdoor unit shall be easily approachable for maintenance activities.

2.7.3 **Limitations :**

Split air conditioner is generally not recommended for,

(i) Where distance between indoor unit exceeds beyond the maximum of 30 m (or higher as per the recommendation of the manufacturer) from the outdoor unit for units up to 17500W (5 TR). The horizontal distance between the indoor unit and outdoor unit should not exceed 10 m for reciprocating compressor, nor for scroll compressor. The vertical distance between the indoor unit and the outdoor unit should not exceed 10 m for units with reciprocating compressor, and 25 m for unit with rotary/scroll compressor.

(ii) Area requiring close control of both the indoor temperature and relative humidity.

(iii) Sound recording rooms where criteria for acoustics are stringent.

(iv) Special applications like sterile rooms for hospitals and clean room applications where

(v) High filtration efficiency is desired.

(vi) Large multi-storeyed buildings where multiplicity of compressors may entail

(vii) Subsequent maintenance problems.

2.8 VRV/ VRF SYSTEM:

In a generalising definition, Variable refrigerant flow (VRF) can be explained as a multiple Split Air-conditioning system using principle of control of flow/ quantity of refrigerant through the Indoor Unit to control the cooling/ heating effect. VRF system uses refrigerant as the cooling and heating medium. This refrigerant is compressed and liquefied by a single outdoor condensing unit (ODU), and is circulated within the building through copper refrigerant pipes to multiple fan-coil units (FCUs) called the IDUs (Indoor Units).

VRF ODUs are typically provided with rectifier-inverter power system, which provided a Variable Voltage & Variable Frequency (V3F) supply to compressor motor, in order to support variable speed. This in turn provides variable refrigerant flow through the refrigerant lines meeting the demand of cooling/ heating. The speed of the motor is controlled through a feedback system sensing the refrigeration demand from the IDUs. VRFs come in two system format, two pipe and three pipe systems. In a 2 pipe system all of the zones must either be all in cooling or all in heating. A three pipe Heat Recovery (HR) systems has the ability to heat certain zones while others require cooling. In this case the heat extracted from the zone requiring cooling is put to use in the zone requiring heating. This is made possible because the heating units are functioning as a condenser. In order to cater to fresh air needs, VRF system outdoor unit should be connected with TFA-AHU. A control box equipped with electronic expansion device and communication printed circuit board (PCB) is needed for TFA-AHU so that it can communicate seamlessly with the VRF system outdoor unit.
VRF system is available with air cooled or water cooled condenser. The water cooled system are more efficient than air cooled system .The NIT authority shall mentioned the type of system water/air cooled in NIT.

2.8.1 APPLICATIONS:

These systems are basically extensions of split type A.C's and are much less efficient as compared to central A.C. plant hence should not be provided except in following cases-

(a) In the existing building, requiring central AC but the space for providing AC plant, height of ceiling for ducting, water supply for chilled water based AC plant, is not available.

(b) It is not possible to provide central A.C. plant and run the chilled water lines up to cool the rooms with fan coil units to cool the rooms.

Such system is normally provided where high diversity in demand is available i.e. small Guest houses, small hotels, small offices, Art Galleries, etc.

A comparison of the VRF/ VRV systems with the Central Chilled water system was got done. Also recommendations of BEE were taken in case of a large building AC requirement. It is added below for making decision.

<u>Comparison between VRF/VRV System with Central Chilled Water System:</u>

S.No.	Variable Refrigerant Flow (VRF) system	Chiller based Air conditioners
1.	Power consumption in VRF system ranges up to 1.6 KW/TR of refrigeration.	Power consumption in this system range up to 1.0 KW/TR of refrigeration.
2.	Most of the VRF units are designed at an ambient temperature of 36°C, and so its use would not be suitable if the system is used in places with hotter temperature.	Customization in design of the Chiller system can be done with respect to higher ambient temperature.
3.	If the system is used at hotter place, then system de-rates.	This is not the case in chiller based system.
4.	It requires more space for its outdoor unit as maximum size of outdoor unit available is 60 hp, so a	It can be managed by a single plant room.

	large no. of outdoor units would be required to fulfill the requirement of 3500-4000 TR	
5.	Design is very complex. Requires whole building to have refrigerant piping, cabling and control from individual rooms. In case refrigerant pipe leaks, whole gas is leaked involving huge cost. Also leaking gas is a fire and health hazard.	Design is very simple. Handles only chilled water after plant room and only air after AHU. Can be easily centrally controlled through BMS.
6.	Its CoP (Coefficient of Performance) varies from 3 to 4.2; a higher CoP implies greater efficiency	Its CoP varies from 5.4 (for 750 TR chiller) to 6.3 (for 1000 TR chiller)
7.	Its part load efficiency is good if used at more than 50 % rated capacity	Its part load efficiency is good even at one – third of the rated capacity.
8.	Air Quality of conditioned space: RH, CO2, Bacteria, Dust, pollutants control, air changes, air distribution Controls are very limited and inefficient	Air Quality can be control.
9.	Fire safety: Refrigerant in system goes to all areas of the building and is combustible at high temperatures releasing toxic products of combustion	Only water in the AHUs and Air in rooms through ducts. Refrigerant is limited to only within chilling units. Hence very safe.
10.	Electrical Logistics: Out door units in large number are located on the terrace far away from the substation. All the FCs require power cabling. Power distribution logistics and cost is very high.	The Plant Room is adjacent to the Substation. Interconnection cost is low. In the building power supply is required only to AHUs.

Source: Information by Bureau of Energy Efficiency while designing A.C. system of one of the largest CPWD Projects.

In respect of VRF System, the air quantity handled by the indoor units shall determine the number of units that will be required in each space. Once the indoor units of various types and capacities are selected, the cumulative total of the capacities of all the indoor units shall be computed and the outdoor unit/s shall be selected for 80% of the cumulative indoor unit capacity. In case, standby capacity is desired, additional indoor/outdoor units will need to be provided.

2.9 CENTRAL PLANTS

For capacities larger than 100 TR, it is generally economical to go in for central plants.

2.9.1 System components

A central air-conditioning system may comprise of following basic components.

(i) Refrigeration unit (Central plant) comprising of compressor, condenser, expansion valve, evaporator & interconnecting refrigerant piping.
(ii) Hot water generators.
(iii) Cooling towers.
(iv) Condenser water pumps
(v) Chilled / Hot water pumps (Primary and Secondary System as applicable).
(vi) Chilled / Hot water piping (required in central chilled water system).
(vii) Condenser water piping including pressurised make up water tank.
(viii) Air handling units (AHUs) comprising of supply air blower, cooling coil and/ or heating coil, humidification system (wherever specified), & filters (the room in which AHU is installed is called weather maker room).
(ix) Air distribution system comprising of ducting, variable air volume (VAV) valves, fire control dampers, grilles & diffusers.
(x) Treated fresh air system (TFA), Free Cooling System,
(xi) Demand Control Ventilation System.
(xii) Heat Recovery Wheel / Heat recovery pipe/any other measure for energy conservation for areas, requiring high fresh air intake.
(xiii) Electric power supply & distribution.
(xiv) Controls & control wiring.

Depending upon the application and design requirements, which the air-conditioning system must meet, some of above components shall have to be arranged in certain sequence to condition the air.

2.9.2 **Type of Central plants**

Refrigeration unit (Central plants) as mentioned under para 2.9.1 (i) above may be of DX type or chilled water type as per following details:-

2.9.2.1 **DX (Direct Expansion) type central plant**

(i) While these are functionally same as a split type AC unit, in these units a condensing unit (Compressor + Condenser) is connected to a Direct Expansion type cooling coil located in a floor or ceiling mounted air handling unit. The air handler can be floor or loft mounted or ceiling suspended. If need be, the same condensing unit can be connected to multiple air handlers. Distance from location of the condensing unit to air handler/s is a constrained and from energy considerations shall be limited to 20 m of running pipe length.
(ii) In this type of central plant the evaporator(s) component of the central plant is located in the air handling unit(s) & works there as DX-type cooling coil. The components-chiller, chilled water pumps & chilled water piping are, therefore, not required in this type of plant.
(iii) This type of plant is commonly installed under following circumstances-
 (a) When the air conditioning load is not very large say up to 100 TR & space for plant room is available adjacent to AHU room(s).
 (b) When the temperature to be maintained in air conditioning space is below $21^{o}C$, the use of DX type plant becomes technically essential due to the limiting factors of evaporation temperature of the refrigerant & the temperature difference between the primary & secondary cooling medium.
(iv) Capacity of the DX System is determined by the cumulative load of the air handling units connected to the system. In this case, diversity shall not be considered. If standby unit is required, an identical capacity unit shall be provided.

2.9.2.2 **Chilled water type central plant**

(i) The chilled water type central plant becomes necessary when a number of smaller zones require air-conditioning. In this case, the chilled water is generated in a centrally located plant room and is piped to various AHUs, which in turn are individually located near the space they air-condition. The chilled water so circulated shall be fed to multiple air handling units, fan coil unis radiant panels or thermally active structures serving various areas in the building. In thermally active structures, chilled water is circulated through an array of pipes laid on the floor or in the ceiling.

(ii) The BHP per ton of refrigeration in the case of chilled water system is high compared to the direct expansion system.

2.9.2.3 **Depending upon the type of compressor used, Central air conditioning plants are of two types.**

(i) Screw type central air conditioning plant
These plants use screw type compressors. These are generally used in capacities ranging from **80 TR and up to 400 TR at present**. The capacity of the compressor may be modulated down to 20 percent of full load capacity.

(ii) Centrifugal type central air conditioning plant
These plants use centrifugal compressors. Centrifugal compressors are not suitable for circulating and expanding the liquid refrigerant in remote heat exchange surface. They are, therefore, used only to chilled water/ brine for circulation through remote heat exchanger surface (AHU coils).

2.9.2.4 **System Design & plant selection**

(i) The system design shall be done after detailed heat load calculations considering the outside and inside design conditions, ventilation requirements and internal loads. The plant selection shall be made on the basis of the calculated peak load, load diversity, partial load requirements and standby capacity. Normally the size of chillers is so chosen that at least two chillers, each of 50% of full load requirement are provided. In case of very large requirements, sometimes the architectural & structural limitations may dictate the compulsions to limit the size of individual chillers to smaller capacity. The standby capacity in turn will depend upon the number of hours of operation of the plant per day, relative importance of the installation and functional requirements. Normally for 12 hrs operation of plant one number additional unit of the same capacity as standby may be provided. For 24 hrs operation of plant, 100% standby may be provided.

(ii) The type, capacity and quantities of the various components of the system shall then have to be worked out and specified.

(iii) It is also a good practice to simulate cost of operation of the plant by considering different capacity of chillers for the type of applications. It is established that by properly selecting the chiller size we can save up to 10 % in operational cost.

(iv) The various components of the system shall be so selected as to match each other under operating conditions of full load as well as anticipated partial loads.

(v) Having selecting the size of chillers it may be decided whether single circuit or dual circuit chiller be provided.

(vi) The overall dimensions of various equipments in the system shall be suitable for installation in the available space. The permissible loading of the building structure, acceptable noise level and aesthetics should also be considered.

(vii) Areas with different requirements of fresh air, degree of filtration and/ or operating hours shall need different and independent AHUs.

(viii) From the fire safety point of view, storage areas of combustible articles such as film stores and explosives shall not be served by the AHUs, which are serving other areas. Other fire precautions as per National Building Code, local municipal byelaws and other statutory requirements shall be complied with.

(ix) For 24 hrs A/C areas & where the secondary chilled water pumps are provided, to save energy, the secondary pumps may be provided with variable speed drive (VFD) to regulate water flow as per load requirement.

(x) For 100% (Fresh air) AHUs requiring 24 hrs. operation, variable speed drive (VFD) may be provided to regulate the flow of dehumidified air as per load requirement.

(xi) In case the cooling is done by positioning fan coil units (FCUs) within the conditioned spaces and circulated chilled water through them, it should also be supplemented by circulating conditioned air through 100 % FA AHU (Treated Fresh Air AHU) by a network of ducting, grills and diffusers to the conditioned spaces for better comfort conditions in terms of ventilation, ~~&~~ humidity control and Oxygen requirements.

(xii) For areas like operation theatre, animal house and where specifically required functionally, AHUs with 100% fresh air shall be used. The return/ used air in such cases shall be exhausted to atmosphere by installing a suitable exhaust air system. This exhaust air system shall consist of single skin blower section and a filter section. This exhaust air system may be ceiling suspended/ floor mounted as per the site availability.

(xiii) In 100% fresh air areas and areas having high occupancy such as lecture theatres, auditoria, etc., requiring high volume of fresh air, pre-cooling of fresh air be done by providing Heat Recovery Wheel.

(xiv) In addition to controlling the inside temperature it is necessary to control the concentration limit of various pollutants as per Chapter 22 (Table 22.1). This is done by providing Demand Control Ventilation System using sensors for detecting the concentration and varying the Fresh Air Supply through motorised dampers.

2.10 CENTRAL HEATING SYSTEM

2.10.1 A central heating system is a means of heating the air in a conditioned space with or without humidification. While the efficiency of a heating equipment can never be more than 100 percentage, a refrigeration system for heating usage can have the coefficient of performance (COP) of more than 4.5. Therefore, compared to electrical heating or thermal heating through boiler, preference should be for the systems working on refrigeration principle. The Various methods used for central heating are:-

(i) The most common method of heating is with the help of a hot water generator. This is achieved by circulating the hot water so generated either through: -

(a) Heat convectors or radiators positioned in the conditioned spaces, or

(b) Heating coils of AHUs and circulating the heated air through the conditioned spaces, analogous to the central chilled water air conditioning system.

(ii) Reverse cycle by providing changeover valves in the chilled and condenser water piping.

(iii) Solar water heating

(iv) Heat pump/ Ground source heat pump

Use of Strip Heaters is now discontinued due to fire hazard.

2.10.2 Central Heating through Hot Water Generators

(i) General Description of System

The hot water generator can be electrically operated. The use of Non-conventional energy sources e.g. Solar energy (solar water heating system) etc. shall also be used. Heat pumps which make use of the refrigeration cycle to generate hot water is an energy efficient method to generate hot water. Hot water can be generated in an auxiliary condenser/desuperheater where hot gas leaving the compressor gives up its superheat before going to the main condenser.

Coal & Oil fired hot water generators are now not in use due to very low energy efficiency and pollution considerations. The hot water so generated is piped through either heat convectors/ radiators or AHUs, depending upon the system followed. Heat convectors/ radiators are used where no humidity control is required. In order to provide better comfort conditions, this type of heating can be supplemented with preheated fresh air circulated through AHUs and ducts. The central heating scheme can also be designed along with the central chilled water air-conditioning scheme where cooling during summer and heating during winter are required in one of following manners:

(a) Laying separate pipe lines for chilled and hot water flow from A.C. plant room to AHUs. Here AHUs will have separate cooling and heating coils. For humidity control in monsoon re-heat coils in the main initial section of S.A. duct shall be provided.
(b) In case of space constraints in respect to laying of separate pipe lines & cooling, heating coils, same water lines and heat transfer coils may be designed to carry chilled water during summer/ monsoon for cooling and hot water during winter for heating. In this case however humidity control by reheat shall not be possible, as strip heaters used earlier are not allowed due to Fire Protection consideration.

(ii) System Component :

A complete central heating system may include the following components :

(a) Hot water generator,
(b) Hot water pump,
(c) Hot water piping,
(d) Convector/ radiator
(e) Heat transfer units (AHUs), variable air volume (VAV) valves, fire control dampers, grills & diffusers
(f) Treated fresh air system (TFA),
(g) Demand Control Ventilation System.
(h) Heat Recover Wheel.
(i) Air filters,
(j) Air distribution system,
(k) Controls and control wiring and,
(l) Power supply control and distribution arrangement.

Some or all of the above components shall have to be arranged in a proper sequence to condition the air.

(iii) System Design and plant selection:

It shall be done as per para 2.9.2.4 above.

2.10.3 Central Heating through electric strip heaters :

Strip heaters used earlier are not allowed due to Fire Protection consideration.

2.10.4 Central Heating through Reverse Cycle :

(i) **General Description**

(a) The chilled water air-conditioning system which is used for cooling in summer can also be used for heating in winter by providing additional valves & piping for interchanging the condenser water & chilled water flow circuits.

(b) During summer when cooling is required, the chilled water plant is operated as a conventional system with the chilled water being circulated through the cooling coils of the AHUs and FCUs to cool and dehumidify areas and condenser water being circulated through the cooling tower.

(c) During winter, when heating is required, the condenser water is circulated through the cooling coils of AHUs and FCUs. The warm condenser water heats the air passing over AHU/ FCU cooling coils and gets cooled in the process. The cooled condenser water is then circulated through the condenser to condense the refrigerant vapour and it gets heated up in the process. The cooling coils thus perform the function of the cooling tower. The chilled water from the chiller is circulated through the cooling tower. The temperature of chilled water being lower than the ambient air, the chilled water gets heated by the ambient air. The chilled water from the cooling tower is then circulated through the chiller to evaporate the refrigerant & it gets cooled in the process. The cooled water is then circulated through the cooling tower. The cooling tower performs the function of the cooling coil. This winter heating is known as reverse cycle heating and can be accomplished by interconnection of chilled water and condenser water supply and return headers through change over valves.

(d) **This system can be used in places where winter ambient temperature is more than 7.2^{0}C (W.B) & Quality of water shall have hardness less than 60 PPM.**

(ii) **Limitations**

(a) The reverse cycle heating cannot be resorted to when the outside wet bulb temperature drops below 7.2^{0}C.

(b) Further, if the quality of condenser water is bad, circulation of condenser water through the cooling coils may foul the tubes of the cooling coil and may also lead to scale formation inside the tubes of the cooling coils. Hence this system is used where hardness of water is less than 60 PPM.

2.10.5 **Central Heating through Heat Pumps and Ground Source Heat Pumps**

A heat pump is an electrical device that extracts heat from one place and transfers it to another. Air sourced heat pumps draw heat from the outside air during the winter heating season, and rejects 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 heating, in the winter season, the heat pump takes heat from the outside air and then transfers it to the water in the hydronic distribution system. During cooling, in the summer season, the process is reversed: heat pump extracts heat from water in the home distribution system and pumps it outside to cool.

Ground source heat pump uses the earth, or ground water, or both as the source 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. For year round air conditioning, the process is reversed during summer months, heat is taken from indoor air and transferred to the earth, by the ground water.

2.11 Mechanical Ventilation (For Non Air Conditioned Areas)

2.11.1 Ventilation

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

(a) Oxygen Content — Prevent depletion of the oxygen content of the air;
(b) Carbon dioxide and Moisture — Prevent undue accumulation;
(c) Contaminants — Prevent undue rise in concentration of body odours and other contaminants such as tobacco smoke;
(d) Bacteria — Oxidize colonies of bacteria and fungus to prevent their proliferation.
(e) Heat — Remove body heat, heat generated by electrical & mechanical equipment, solar heat gains through walls & glass, etc.

Mechanical ventilation is one of several forms of ventilation options available. It usually consists of fans, filters, ducts, air diffusers and outlets for air distribution within the building. It may include either mechanical exhaust system or exhaust can occur through natural means.

Natural ventilation and natural exhaust are also options. The scope of this section is therefore restricted to mechanical ventilation.

2.11.2 **Design Considerations**

Following considerations provide details regarding the various parameters that affect the type of ventilation system selected for a particular application, and the sizing of the ventilation plant:

2.11.2.1 The rate of ventilation for various general areas in normal conditions shall be as given in table 2.4 below

CMM required for ventilation system is thus calculated Based on the volume of the room and from the above table as-

$$CMM = \frac{\text{(no. of air changes/ hour) X (volume in cu. m of space to be ventilated)}}{60}$$

2.11.2.2 The Ventilation design consideration for some of specific areas/Applications:

(1) lifts lobby, lift shaft, stair case shaft pressurization:

Pressurization is a method adopted for protecting the exits from ingress of smoke, especially in high-rise buildings. In pressurization, air is injected into the staircases, lobbies, etc. as applicable, to raise their pressure slightly above the pressure in adjacent parts of the building. As a result, ingress of smoke or toxic gases into the exits will be prevented. The pressurization of staircases and lift lobbies shall be adopted as given in Table 2.5.

The Required minimum Pressure difference between staires case, Lobbies, Lift lobbies and adjacent area shall be as given below:

(i) The pressure difference for staircases and lift shaft shall be 50 Pa.
(ii) Pressure differences for lobbies (or corridors) shall be between 25 Pa and 30 Pa.
(iii) Further, the pressure differential for enclosed staircase adjacent to such lobby (or corridors) shall be 50 Pa.
(iv) For enclosed staircases adjacent to non-pressurized lobby (or corridors), the pressure differential shall be 50 Pa.

Fresh air intake for pressurization shall be away (at least 4 m) from any of the exhaust outlets/grille.

Contractor shall furnish calculations for fan and duct sizing to the Engineer-in -Charge and obtain approval before work is taken up. For Stairwell pressurization and lift lobby pressurization calculations shall be based on two doors open condition. While the Stairwell and lift shaft shall be pressurized for all floors at the same time, lift lobby shall be pressurized only on the floor under fire and the two adjacent floors. To achieve this automatic dampers actuated by the intelligent fire alarm system shall be provided

(2) Basement Parking Ventilation

(i) Divide the basement in zones of area not exceeding 3000 sqm. in case sprinkler system is provided in basement, if not, then not exceeding 750 sqm.

(ii) For each zone separate set of supply air fans and exhaust air fans shall be provided. Supply air fans shall not be required in areas in zone near Ramps or zone with natural ventilation, however sufficiency may be examined. A system of impulse fans (Jet Fans) shall be used for proper distribution of air in case basement area is in excess of 3000 Sq. m. Supply and exhaust fans shall be centrifugal fans or Axial flow fans located in fan rooms in the basement.

(iii) Minimum 06 air changes/hrs. are required for normal operation and 12 air changes per hours in case of fire to be provided.

(iv) Calculate the CMM required for each Zone based on air changes required as mentioned Point (iii) above.

(v) The recommended ventilation rate will ensure that the CO level will maintained within 29 mg/m³ for 8 hour exposure and 40 mg/m3 for 01 hour exposure. Therefore to Keep CO level with in limit the ventilation rate shall be calculated as given below

$$Q = \frac{0.25\ N\ x\ E\ x\ T_m}{26.7x60}$$

Where

Q = Ventilation rate in CMM

N = number of cars in peak usage;

E = average CO emission per car, in g/h; and

Tm = average time a car remains operating in the car park, in Seconds.

(vi) The higher among ventilation rate as per (iv) and (v) above shall be adopted for design.

(vii) In order to save energy consumption, the fan motors shall have VFD.

(viii) CO sensors shall be provided for basement car park spaces with total car park space greater than or equal to 600 m2 duly integrated for automatic operation of fans in case of increase of CO level, greater than required.

(ix) In the case of basement floor parking areas, a push-pull arrangement of ventilation can be used.

(x) The contractor shall do a detailed computation of the ventilation requirement with the aid of Computational Fluid Dynamics (CFD) and shall submit it for the approval of the Engineer-in-Charge before carrying out the works.

(xi) Demand Control Ventilation shall be employed by linking CO sensors with both supply and exhaust fans as well as Jet Fans. Normally the ventilation fans shall provide 6 to 8 air changes but CO sensors shall monitor the air quality on a continuous basis and shall modulate fan speed during lean hours when movement of cars in the basement is minimum. CO Sensors shall be grouped according to the zone covered by the exhaust fan.

(xii) The system used for ventilation of the basement shall also be used for smoke ventilation during fire emergencies. Smoke exhaust shall be designed as per relevant section of NBC 2016.This shall be achieved by employing dual speed fans. Fans used for smoke exhaust shall be suitably fire rated.

(xiii) CO Sensors shall ideally be located between 0.9 m and 1.8 m above floor level. However, for practical reasons (in order to protect from vandalism), the sensors may be installed at just above 1.8 m height from floor.

(3) 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.

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.

The minimum hood exhaust flow rates for different types of cooking equipment and exhaust hoods per linear metre of hood length should be as per Table 2. 6.

If more than one duty category appliance is 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 litres per second per linear metre of hood length for oven hoods, and 460 to 770 litres per second for condensate hoods.

The recommended kitchen exhaust fan should consist of a backward type impeller curved.

Oil and Grease problems can be greatly reduced through the use of proper filtration device in the hood exhaust system.

The air exhausted through a kitchen hood shall be replaced/make up 100 percent with clean outside air. The makeup air can be supplied untreated, or treated in an air washer so that slight negative pressure is maintained in the kitchen to prevent exfiltration of the pollutants to the public areas. This is achieved by exhausting approximately 10% more air than the supply air quantity. Kitchen room pressure shall be maintained at slightly (20 Pa) lower pressure than adjacent areas to prevent heat and odors spreading to adjacent areas.

For kitchens adjacent to a building exterior wall, the kitchen pressure should be slightly higher than the ambient to prevent ingress of dust, heat and insects.

Exhaust and supply air flow rates should be controlled by installing variable frequency drives (VFD) on the fan motors.

Air curtains can also be used at entry / exit points of the kitchen to prevent the kitchen pollutants from going into the public areas.

The following general guidelines should be followed in design of Kitchen exhaust duct design, installation and maintenance:

(i) Minimum sheet gauge should be 16 gauge mild steel Galvanised or 18 gauge stainless steel.

(ii) All joints and seams shall be fully welded and made grease tight.

(iii) Ductwork shall lead directly to building exterior and should not be interconnected with any other type of building ductwork.

(iv) Horizontal duct runs should be minimised and 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. A grease drain outlet shall be provided in form of a leg under a vertical riser.

(v) Maximum velocities are limited by pressure drop and noise and should normally not exceed 12.5 m/s.

(vi) The minimum air velocity for exhaust ducts should be 2.5 m/s.

(vii) For new single speed fan system, a design duct velocity of 7.5 m/s to 9 m/s is appropriate.

(viii) Access doors duly nut bolted with lead/fire rated gasket shall be provided for scavenging/ grease removal during maintenance.

(ix) The entire hood casing shall be welded and rendered air tight. An all-round grease gutter shall be provided with necessary slope towards valved drains.

(x) Grease filters shall be impingement, preferably change-of direction type made of 1mm thick Stainless Steel 304 with non-clogging continuous draining baffles. Filter shall be light in weight and easily removable for cleaning. Filter surface shall exhibit low flammability from licks of flame and the depth of filter shall be a minimum of 50 mm. A continuous filter frame of Stainless Steel 304 shall hold the bank of filters and the velocity across the grease filters shall not exceed 1.25 mps. Filters shall be placed according to the equipment under the hood. Blanks shall be placed over work tables and spreaders.

(xi) Each exhaust hood should be protected by a 2 hours rated fire damper set for not more than 80 deg. C.

(xii) Sprinklers shall be provided inside the hood over the equipment. Sprinklers shall be water mist type 163°C rated. Sprinkler header shall be brought out of the hood and terminated in a ball type brass valve.

(xiii) All wiring inside shall be through 90 deg. C rated wires in galvanized steel conduit brought out in galvanized steel junction box over the hood with a suitably rated EL MCB.

(xiv) Kitchen exhaust ducting shall be rectangular/round fabricated out of CRCA sheets conforming to IS 4030 – 1973 /SS Sheet conforming to IS: 4030. The fabricated duct shall be degreased and applied with one coat of primer and 2 coat of fire retardant paint.

(xv) Upright sprinklers shall be provided inside the duct at every 3.2m till the vertical riser. All sprinklers shall be water mist 260°C rated.

(xvi) Replacement air in air-conditioned or spot cooled kitchens shall be supplied as close to the hood as possible. This shall be achieved by use of Compensating Exhaust Hoods with supply air forming integral part of the hood.

(4) Designated Smoking Rooms

To curb any movement of contaminated air from the smoking zone to non-smoking areas, it should be ensured that the smoking zone operates at a negative pressure in comparison with the surrounding non-smoking areas.

Ventilation system of the smoking zone should be separate from that of the non-smoking areas. To maintain the required indoor air quality standards in the smoking zones, the smoking zones should have higher ventilation rates than non-smoking areas and should be designed for at least 60 cubic feet per minute per person.

The contaminated air from the smoking zone should be exhausted directly to the outdoors. It should be ensured that there is no recirculation of this air contaminated with tobacco smoke, to the non-smoking zones of the building.

If the smoking zone is mechanically ventilated, it should have an air circulation rate of not less than 30 air changes per hour.

(5) Mechanical Plant Rooms ventilation

In the case of air conditioning plant rooms, generator rooms, substation, boiler room, Firefighting room,

etc., located in the building basement, a push-pull arrangement of ventilation may be used. For plant rooms both supply and exhaust shall be provided and a 5 pa positive pressure shall be maintained to prevent ingress of dust from surroundings.

Air volume calculations shall be based on heat dissipation by the equipment in the room and permissible temperature rise that shall be allowed. Contractor shall furnish detailed calculations to Engineer-in – Charge and obtain approval before commencing work.

(6) Toilets Ventilation

Where the toilets are scattered and located at different places, a local exhaust system with propeller type exhaust fans mounted on the toilet walls exposed to the atmosphere is recommended. However, In multistoried buildings, where toilets are located one over the other, a centralized exhaust system with all toilets connected to common ducting with centrifugal fan mounted on the top of the terrace shall be made use of. In ducted exhaust systems, care shall be taken to ensure that the duct is under negative pressure when the fan is in operation. This will prevent foul air escaping from the duct at in-between floors.

(7) Calculation of Fan Static-

Pressurization system for lifts lobby, lift shaft, stair case shaft -.

As per NBC part – 5 fire and light safety the following pressure are to be maintained for various shafts in high-rise building more than 25 mtr. in height-

Building Height	**Pressure Difference**	
	Reduce Operation (Stage 1 of a 2 Stage system)(Pa)	**Emergency operation (Stage 2 of a 2 stage or single stage system)(Pa)**
Less than 15 m	8	50
15 m or above	15	50

(i) If possible the same levels shall be used for lobbies and corridors, but level slightly lower may be used for these spaces if desired. The difference in pressurization levels between staircase and lobbies (for corridors) shall not be greater than 5 Pa.

(ii) For Basement Parking Ventilation the static can be calculated by duct friction method using a ductolator.

(iii) Mechanical Plant Rooms:
In the case of air conditioning plant rooms, generator rooms, substation, boiler room etc., located in the building basement, a push-pull arrangement of ventilation may be used.

(iv) Designated Smoking Rooms
To curb any movement of contaminated air from the smoking zone to non-smoking areas, it should be ensured that the smoking zone operates at a negative pressure in comparison with the surrounding non-smoking areas.

(v) Toilets
Where the toilets are scattered and located at different places, a local exhaust system with propeller type exhaust fans mounted on the toilet walls exposed to the atmosphere is recommended. However, in multi-storied buildings, where the toilets are generally located one above the other in the various floors, the toilet shaft can be used for exhausting the air through sheet metal ducts with a centrifugal fan installed on the rooftop.

2.11.3 **Selection & Installation of Fans :**

Fan total efficiency is defined as under:

$$\text{Fan total efficiency} = \frac{\text{Flow rate m}^3\text{/s x Fan total pressure (Pa)}}{\text{Fanshaft power (W)}}$$

For axial fans requiring a shaft power of 2.5 kW or more, the fan efficiency grade shall be FEG 60 or more and FEI index equal to or greater than 1 & for centrifugal fans requiring a shaft power of 2.5 kW or more, the fan efficiency grade shall be FEG 71 or more and FEI index equal to or greater than 1. The minimum operating total efficiency of the selected fan at the desired point of operation for a given application shall be within 10 percentage points of its peak total efficiency value.

Having defined the fan CMM & static to be developed, the fan is selected on basis of following criterion-

(i) Pressurization system for lifts lobby, lift shaft, stair case shaft :
(a) Fans are normally installed at terrace and are to be enclosed in GI housing.
(b) Some duct work is required for connecting up to the shaft.
(c) These fans shall be operated automatically in case of fire on signal from IBMS or directly from Fire Control Panel of AFAS. Panels for these fans can be provided in lifts machine rooms. Auto manual switch is required to be provided to facilitate local testing.

(ii) Basement car parking ventilation :
(a) Normally centrifugal fan are provided in fan room in basement. In case fan room is not available, ceiling mounted axial fans may be provide.
(b) All exhaust fan provided for the scheme, shall be fire rated for 250°C for 2 hrs.
(c) Normal ventilation fans for min. 06 air change/ hrs are kept on during working hours. However, CO2 sensor may be provided which will continuously monitor the air quality and operate the normal fans only when required and there by conserve energy.
(d) For each zone, zonal electrical panel is required to be provided which shall get the signal from fire alarm panel to activate the fans in case of fire to achieve 12 air changes per hr.

(e) While selecting the fans noise level of fans may be kept under consideration to make sure that the noise level is kept below 80 decimal at all times except in case of fire.

(f) Selection of Fan type for Ventilation System

2.12 fire Safety for HVAC Work

2.12.1 Compartmentation

(a) All floors of the building shall be compartmented/zoned with area of each compartment being not more than 750 m^2. The maximum size of the compartment shall be as follows, in case of sprinklered basement/building:

Sr No	Use	Compartmentation Area m^2
(1)	Basement car parking	3000
(2)	Basements (other than car parking)	2000
(3)	Institutional buildings: Subdivision C-1	1800
(4)	Institutional buildings: Subdivision C-2 and C-3	1125
(5)	Mercantile and assembly buildings	2000
(6)	Business buildings	3000
(7)	All other buildings (Excluding low hazard and moderate hazard industrial buildings and storage buildings)*	750

*Compartmentation for low hazard and moderate hazard industrial buildings and storage buildings shall be done in consultation with local fire department.

(b) In addition, there shall be requirement of a minimum of two compartments if the floor plate size is equal or less than the areas mentioned above. However, such requirement of minimum two compartments shall not be required, if the floor plate is less than 750 m^2. Compartmentation shall be achieved by means of fire barrier having fire resistance rating of 120 min.

2.12.2 Fire safety requirement related to AHU :

(i) Separate air handling units (AHU) for each floor shall be provided so as to avoid the hazards arising from spread of fire and smoke through the air conditioning ducts. The air ducts shall be separate from each AHU to its floor and in no way shall interconnect with the duct of any other floor. Within a floor it would be desirable to have separate air handling unit provided for each compartment.

(ii) It would be desirable to have separate air handling unit provided for each compartment within a floor.

(iii) The air filters of the air handling units shall be made of non-combustible materials.

2.12.3 **Fire Safety requirement related to Duct work:**

(i) Air ducts serving main floor areas, corridors, etc, shall not pass through the exits/exit passageway/ exit enclosure. Exits and lift lobbies, etc, shall not be used as return air passage.

(ii) As far as possible, metallic ducts shall be used even for the return air instead of space above the false ceiling.

(iii) Fire or fire/smoke dampers shall be located at least in supply air ducts, fresh air and return air ducts/ passages at the following points :

(a) At the fire separation wall,

(b) Where ducts/passages enter the vertical shaft,

(c) Where the ducts pass through floors, and

(d) At the inlet of supply air duct and the return air duct of each compartment maintain, test and also replace, if so required.

(iv) Fire Damper shall be integrated with Fire Alarm Panel and it shall also manually operated. Fire Damper shall be of motorized type/fusible link type.

(v) The ducting within compartment would require minimum fire resistance rating of 30 min.

If such duct crosses adjacent compartment/floor and not having fire dampers in such compartment/floor, it would require fire resistance duct work rating of 120 min.

(vi) The materials used for insulating the duct system (inside or outside) shall be of non-combustible type.

2.12.4 **Smoke control**

2.12.4.1 **Smoke Control of Area above Ground and above**

(i) Smoke exhaust system consist of make-up air and exhaust air system or alternatively pressurization system with supply air system.

(ii) All mechanical pressurization system shall be automatic in action with manual controls in addition.

(iii) The smoke exhaust fans in the mechanical ventilation system shall be fire rated, that is, 250°C for 120 min.

(iv) Smoke exhaust system where provided, for above areas and occupancies shall have a minimum of 12 air changes per hour smoke exhaust mechanism.

(v) Power supply panels for the fans shall be located in fire safe zone to ensure continuity of power supply.

(vi) Power supply cabling shall meet circuit integrity requirement.

2.12.4.2 **Smoke Control of Area below Ground :**

Each basement shall be separately ventilated. Vents with cross-sectional area (aggregate) not less than 2.5 percent of the floor area spread evenly round the perimeter of the basement shall be provided in the form of grills, or breakable stall board lights or pavement lights or by way of shafts.

Alternatively, a system of mechanical ventilation system may be provided with following requirements:

(a) Mechanical ventilation system shall be designed to permit 12 air changes per hour in case of fire or distress call.

(b) In Multi-storeyed building All supply air and exhaust air fans on respective levels shall be installed in fire resisting room of 120 min. Exhaust fans at the respective levels shall be provided with back draft damper connection to the common smoke exhaust shaft ensuring complete isolation and compartmentation of floor isolation to eliminate spread of fire and smoke to the other compartments/floors.

(c) Inlets and extracts may be terminated at ground level with stall board or pavement lights as before. Stall board and pavement lights should be in positions easily accessible to the fire brigade and clearly marked 'AIR INLET' or 'SMOKE OUTLET with an indication of area served at or near the opening.
(d) The smoke exhaust fans in the mechanical ventilation system shall be fire rated, that is, 250°C for 120 min.
(e) Power supply panels for the fans shall be located in fire safe zone to ensure continuity of power supply.
(f) Power supply cabling shall meet circuit integrity requirement.
(g) No system relating to smoke ventilation shall be allowed to interface or cross the transformer area, electrical switchboard, electrical rooms or exits.
(h) Smoke exhaust system having make-up air and exhaust air system for areas other than car parking shall be required for common areas and exit access corridor in
(i) Basements/underground structures and shall be completely separate and independent of car parking areas and other mechanical areas.

2.13 Minimum Space Conditioning Equipment Efficiency :

The efficiency of the space conditioning equipments shall be minimum as per Mandatory requirement of Energy Conservation Building Code of India 2017 as amended upto date/ BEE star labeling / BIS whichever is higher.

The required minimum efficiency of some of the space conditioning equipments are to be as given in Table 2.7 to 2.9.

2.14 Controls :

The HVAC Systems shall have minimum following below given controls in addition to control as mention in Chapter 12.

2.14.1 **ECBC Building:**

2.14.1.1 **Time clock**

Mechanical cooling and heating systems in Universities and Training Institutions of all sizes and all Shopping Complexes with built up area greater than 20,000 m^2 shall be controlled by time locks that:

(a) Can start and stop the system under different schedules for at least three different day-types per week,
(b) Are capable of retaining programming and time setting during loss of power for a period of at least 10 hours, and
(c) Include an accessible manual override that allows temporary operation of the system for up to 2 hours.

Exceptions to this :

(i) Cooling systems less than 17.5 kWr
(ii) Heating systems less than 5.0 kWr
(iii) Unitary systems of all capacities

2.14.1.2 **Temperature Controls**

Mechanical cooling and heating equipment in all buildings shall be installed with controls to manage the temperature inside the conditioned zones. Each floor or a building block shall be installed with at least one control to manage the temperature. These controls should meet the following requirements:

(a) Where a unit provides both heating and cooling, controls shall be capable of providing a temperature dead band of 3.0°C within which the supply of heating and cooling energy to the zone is shut off or reduced to a minimum.
(b) Where separate heating and cooling equipment serve the same temperature zone, temperature controls shall be interlocked to prevent simultaneous heating and cooling.
(c) Separate thermost at control shall be installed in each
  (i) guest room of Resort and Star Hotel,
  (ii) room less than 30 m2 in Business,
  (iii) air-conditioned classroom, lecture room, and computer room of Educational,
  (iv) in-patient and out-patient room of Healthcare

2.14.1.3 **Occupancy Controls**

Occupancy controls shall be installed to de-energize or to throttle to minimum the ventilation and/or air conditioning systems when there are no occupants in:
(a) Each guest room in a Resort and Star Hotel
(b) Each public toilet in a Star Hotel or Business with built up area more than 20,000 m^2
(c) Each conference and meeting room in a Star Hotel or Business
(d) Each room of size more than 30 m2 in Educational buildings

2.14.1.4 **Fan Controls**

Cooling towers in buildings with built up area greater than 20,000 m^2, shall have fan controls based on wet bulb logic, with either:
(a) Two speed motors, pony motors, or variable speed drives controlling the fans, or
(b) Controls capable of reducing the fan speed to at least two third of installed fan power

2.14.1.5 **Dampers**

All air supply and exhaust equipment, having a Variable Frequency Drive (VFD), shall have dampers that automatically close upon:
(a) Fan shutdown, or,
(b) When spaces served are not in use
(c) Backdraft gravity damper is acceptable in the system with design outdoor air of the system is less than 150 liters per second in all climatic zones except cold climate, provided backdraft dampers for ventilation air intakes are protected from direct exposure to wind.
(d) Dampers are not required in ventilation or exhaust systems serving naturally conditioned spaces.
(e) Dampers are not required in exhaust systems serving kitchen exhaust hoods.

2.14.2 **Controls for ECBC+ and Super ECBC Buildings**

The ECBC+ and Super ECBC buildings shall have control as given in clause 2.14.1, chapter-12 and also following below given controls.

2.14.2.1 **Centralized Demand Shed Controls**

ECBC+ and Super ECBC Buildings with built up area greater than 20,000 m^2 shall have a building management system. All mechanical cooling and heating systems in ECBC+ and Super ECBC Buildings with any programmable logic controller (PLC) to the zone level shall have the following control capabilities to manage centralized demand shed in non-critical zones:
(a) Automatic demand shed controls that can implement a centralized demand shed in non-critical zones during the demand response period on a demand response signal.

(b) Controls that can remotely decrease or increase the operating temperature set points by four degrees or more in all noncritical zones on signal from a centralized control point Controls that can provide an adjustable rate of change for the temperature setup and reset

(c) The centralized demand shed controls shall have additional capabilities to

(i) Be disabled by facility operators

(ii) Be manually controlled from a central point by facility operators to manage heating and cooling set points

2.14.2.2 **Supply Air Temperature Reset**

Multi zone mechanical cooling and heating systems in ECBC+ and Super ECBC Buildings shall have controls that automatically reset the supply-air temperature in response to building loads or to outdoor air temperature. Controls shall reset the supply air temperature to at least 25% of the difference between the design supply air temperature and the design room air temperature. However this control is not compulsory warm humid climate zone

2.14.2.3 **Chilled Water Temperature Reset**

Chilled water systems with a design capacity exceeding 350 kWr supplying chilled water to comfort conditioning systems in ECBC+ and Super ECBC Buildings shall have controls that automatically reset supply water temperatures by representative building loads (including return water temperature) or by outdoor air temperature. However, Controls to automatically reset chilled water temperature shall not be required where the supply temperature reset controls causes improper operation of equipment.

2.14.2.4 **Variable Air Volume Fan Control**

Fans in Variable Air Volume (VAV) systems in Super ECBC Buildings shall have controls or devices that will result in fan motor demand of no more than 30% of their design wattage at 50% of design airflow based on manufacturer's certified fan data.

2.15 **Services Identification :**

2.15.1 **Pipe Work Services Identification:**

The scheme of colour code for painting of pipe work services for air conditioning installation shall be as indicated in Table 2.10.

2.15.2 **Duct Work Services Identification :**

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 in length. 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/re-circulated air	:	Grey
Foul air	:	Brown
Dual duct system hot supply air	:	Red
Cold supply air	:	Blue

2.15.3 **Valve Labels and Charts :**

Each valve shall be provided with a label indicating the service being controlled by it, together with a reference number corresponding with that shown on the valve charts and on the as-built drawings. The labels shall be made from 3-ply (black/white/black) trifoliate material showing white letters and figures on a black background. Labels shall be tied to each valve with chromium plated linked chain.

2.16 Refrigerant :

Refrigerants are classified into two classes based on their toxicity, namely Class A (Permissible Exposure Limit > 400 ppm) having lower chronic toxicity and Class B (Permissible Exposure Limit <400 ppm) having higher chronic toxicity.

They are further classified into four classes based on their flammability, namely, Class 1 (no flame propagation), Class 2L (lower flammability), Class 2 (flammable) and Class 3 (higher flammability).

Flammability	**Toxicity**	
	Low Toxicity	**High Toxicity**
No flame propagation	A1	B1
Lower flammability	A2L	B2L
Flammable	A2	B2
Higher Flammable	A3	B3

Ozone depletion potential (ODP) of the refrigerant should be zero and shall be as permitted under The Ozone Depleting Substances (Regulation and Control) Amendment Rules, 2014 as amended from time to time up to date. The ODP of F11 refrigerant is 1.0.

Global warming potential (GWP) of the refrigerant should preferably be low to reduce greenhouse gas (GHG) emissions. The GWP of CO_2 is 1.0.

The ODP and GWP values and safety group of different common refrigerants are given in Table 2.11

The manufacturing of all HVAC equipment with HCFC will be banned in the India from 01 January 2025 in accordance with The Ozone Depleting Substances (Regulation and Control) Amendment Rules, 2014. Therefore HVAC system/ equipment based on HCFC refrigerant shall not be used.

Therefore the NIT approving Authority shall decide for selection of equipment/systems with refrigerant with high energy efficiency, least negative impacts on health, safety and environment as per the latest developments and Government of India Guidelines.

2.17 Packaged type Units

2.17.1 Application

These are best suited for air conditioning of areas up to about 450 sqm (about 30 TR A/C load) located adjacent to each other. Beyond this central plant is generally more economical. These are generally available in 5 TR, 7.5 TR, 10 TR, 15 TR and 20 TR capacities. The components are housed in a vertical cabinet. These units can be used singly or in multiples of two/ three units.

2.17.2 Type: A packaged unit can be either water cooled or air cooled.

2.17.3 System components

(i) A water cooled packaged type unit includes the following basic components:

(a) Refrigeration compressor
(b) Condenser (water cooled)
(c) Evaporator
(d) Expansion Valve
(e) Refrigerant piping along with controls
(f) Supply air blower
(g) Filters

Condenser in this system is cooled by a system of cooling tower(s), condenser water pumps & connecting condenser water piping.

(ii) An air-cooled packaged unit is in two portions-Indoor unit and outdoor unit. Compressor, Evaporator, Expansion Valve, SA blower & filters are in indoor unit & condenser along with condenser fan is in outdoor unit. Here condenser is cooled by a propeller fan.

2.18 ETAC Plants

A mechanical ventilation system is a means to dispense of unwanted odours, fumes and heat content to maintain freshness in the ventilated space.

When this is supplemented with an air washer for lowering dry bulb temperature and providing better comfort conditions in dry climates, the system is known as Evaporative Type Air Cooling (ETAC).

2.18.1 **Design Considerations**

(i) The climatic zone in which the building is located is a major consideration. An important distinction that must be made is between hot dry and warm-moist conditions. Hot-dry work situations occur around furnaces, forges, metal-extruding and rolling mills, glass forming machines, and so forth.

(ii) Typical warm-moist operations are found in textile mills, laundries, dye houses, and deep mines where water is used extensively for dust control. Warm-moist conditions are more hazardous than the hot-dry conditions.

(iii) Siting (and orientation) of the building is also an important factor. Solar heat gain and high outside temperature increase the load significantly. How significantly depends, on the magnitude of these gains particularly in relation to other gains for example the internal load.

(iv) The comfort level required is another consideration. In many cases, comfort levels (as understood in the context of Residential Buildings, Commercial Blocks, Office Establishments) cannot be achieved at all and therefore, what is often aimed at will be ‘acceptable working conditions’ rather than ‘comfort’.

(v) 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.

(vi) In locating the units, care should be taken to ensure that their noise level will not be objectionable to the neighbours. Appropriate acoustic treatment should be considered, if the noise levels cannot be kept down to permissible limits.

(vii) Exhaust air devices, preferably to leeward and overhead side may be provided for effective movement of air.

(viii) In the case of large installations it is advisable to have a separate isolated equipment room if possible.

(ix) 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.

(x) 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.

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

(xii) 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.

(xiii) In the case of large and multi-storied buildings, independent Ventilation/ Air Washer Units should be provided for each floor. The area to be served by the air-handling unit should be decided depending upon the provision of fire protection measures adopted. The Units should preferably be located vertically one above the other to simplify location of pipe shafts, cable shafts, drainers.

2.18.2 **General Description of System**

(i) The air in the ventilated space is exhausted into the atmosphere. This air is made up by injecting fresh air from outside. In a simple ventilation system, this fresh air (makeup air) is supplied untreated with the help of blower and duct network. However, in ETAC system, most suitable in a dry climate, this fresh air (make up air) is treated in an air washer before its supply to the ventilated space for providing better comfort conditions.

(ii) The air washer is basically a spray chamber where the air and the cooling medium are brought into contact with each other. The air is drawn through the spray chamber by means of a fan and water is sprayed by means of a water pump & piping network. Such a spray chamber, complete with water collecting tank, eliminator plates, inlet louvers and other auxiliary equipments are known as air washers. During the course of flow through the air washer, the air may get cooled & humidified or cooled & dehumidified or heated & humidified depending on the temperature of spray water as is given hereunder:-

(a) When the water used in the spray is simply re-circulated, the air passing through air washer will get cooled & humidified.

(b) When the water used in the spray is chilled (by some external devise) & its temperature is higher than the dew point temperature of entering air, the air on passing through air washer will get cooled & humidified.

(c) When the water used in the spray is chilled (by some external devise) & its temperature is lower than the dew point temperature of entering air, the air on passing through air washer will get cooled & dehumidified.

(d) When the water used in the spray is heated (by some external devise), the air on passing through air washer will get heated & humidified.

The air washers are usually constructed in two different lengths of 2.75 mtrs long and 4.25 mtrs long. The 2.75 mtrs long air washers are equipped with two banks of spray opposing each other. These air washers are used for humidification or dehumidification purpose. The 4.25 mtrs long air washers are usually with three banks of sprays. These air washers are generally used for certain special applications where high percentage of saturation of air is required.

(iii) Where ex-filtration of air from the ventilated space is to be prevented from reaching the other areas, a slight negative pressure is to be maintained in the ventilated space. This can be achieved by keeping the exhaust air quantity slightly higher than supply air (make up air) quantity. This is especially necessary where odours and fumes are required to be prevented from reaching other areas.

2.18.3 **System Components**

(i) A complete mechanical ventilation system with air washers includes the following components: -

(a) Means of exhausting and / or injecting the air,
(b) Air filters,
(c) Air distribution,
(d) Air washer,
(e) Water spray pump, nozzles & piping network,
(f) Controls and control wiring, and
(g) Power supply and distribution arrangement.

(ii) Depending upon the application and design requirements, which the mechanical ventilation / ETAC system must meet, some or all of the above components shall have to be arranged in a certain sequence to condition the air.

2.18.4 **System Design**

(i) The system design shall be done by first deciding upon the number of air changes per hour required to be maintained in the space. The capacity of the exhausting and/or the injecting equipments can then be worked out on the basis of the volume of the space and the number of air changes required per hour.

(ii) The recommended number of air changes per hour for various applications are as given at table 2.4

(iii) The other requirements shall be as given under paras 2.18.1 to 2.18.3

(iv) A brief system design for some of the applications is given below:

(a) Kitchens

The exhaust system should take care of all the heat, smoke and odours produced during the cooking process and also maintain a hygienic atmosphere within the kitchen. The exhaust of air should be done through hoods equipped with grease filters, duct network and a exhaust blower. The hood should be of such a size as to capture, as nearly as possible, all the above pollutants produced in the cooking process and to contain them until the fan can exhaust them. Grease filters are used with the hood to protect the exhaust system. The exhaust air is made up by using fresh air from outside with the help of a blower and a duct network. The makeup air can be supplied untreated, or treated in an air washer so that slight negative pressure is maintained in the kitchen to prevent exfiltration of the pollutants to the public areas. This is achieved by exhausting approximately 10% more air than the supply air quantity. Air curtains can also be used at entry / exit points of the kitchen to prevent the kitchen pollutants from going into the public areas.

(b) Toilets

Where the toilets are scattered and located at different places, a local exhaust system with propeller type exhaust fans mounted on the toilet walls exposed to the atmosphere is recommended. However, in multi-storied buildings, where the toilets are generally located one above the other in the various floors, the toilet shaft can be used for exhausting the air through sheet metal ducts with a centrifugal fan installed on the rooftop.

(c) Car Parks

In the case of basement floor parking areas, a push-pull arrangement of ventilation can be used. One set of axial flow fans can push fresh air into the basement area and another similar set can evacuate the fume-laden air.

(d) Mechanical Plant Rooms

In the case of air conditioning plant rooms, generator rooms, substation, boiler room etc., located in the building basement, a push-pull arrangement of ventilation as mentioned at (c) above may be used.

(e) Designated Smoking Rooms

To curb any movement of contaminated air from the smoking zone to non-smoking areas, it should be ensured that the smoking zone operates at a negative pressure in comparison with the surrounding non-smoking areas.

Ventilation system of the smoking zone should be separate from that of the non-smoking areas. To maintain the required indoor air quality standards in the smoking zones, the smoking zones should have higher ventilation rates than non-smoking areas and should be designed for at least 60 cubic feet per minute per person.

The contaminated air from the smoking zone should be exhausted directly to the outdoors. It should be ensured that there is no recirculation of this air contaminated with tobacco smoke, to the non-smoking zones of the building.

If the smoking zone is mechanically ventilated, it should have an air circulation rate of not less than 30 air changes per hour.

2.19 COLD ROOMS

A cold storage system is a means of achieving and maintaining low temperature conditions, with or without humidity control, in an enclosed space. For smaller capacities these can be of factory assembled units such as deep freezers, bottle coolers and walk-in-coolers. For larger capacities and to meet the specific requirements, site assembled or built up cold storage systems are resorted to. These General Specifications only cover the latter type, viz., built up cold storage systems.

2.19.1 General Description of the System

(i) A cold storage system involves refrigeration equipment, with or without humidity control equipment depending upon the application. Where humidity control is required, dehumidifiers or driers as are more commonly called, are used, especially in very low temperature applications. In normal cases, it should be possible to achieve the required humidity conditions with the normal refrigeration cycle.

(ii) The conventional method is to provide a product cooler, which is nothing but an evaporator in the refrigeration cycle, within the cold room. Alternatively, conditioned air through AHUs can also be fed to the cold room.

(iii) The cold room has to be properly insulated to reduce the refrigeration load and to maintain the desired inside conditions.

2.19.2 System Components

A built up cold storage system shall include the following components: -

(i) Refrigeration unit comprising of compressor, condenser, expansion valve, evaporator & refrigerant piping,

(ii) Cooling Tower,

(iii) Product Cooler/ AHU,
(iv) Air filtration and distribution,
(v) Piping systems which include refrigerant piping, condenser water piping, hot water/steam piping for defrosting,
(vi) Controls and control wiring,
(vii) Power supply control and distribution arrangement.
(viii) Dehumidifier

Depending upon the application and design requirements, which the cold storage system must meet, some of the above components shall have to be arranged in a certain sequence to give the required conditions.

2.19.3 **System Design**

(i) The system design shall be done as per para 2.3.
In addition, provision for automatic defrosts and disposal of collected water should be made. The selection of the type of defrosting shall be appropriate to the inside conditions.

(ii) Provision shall also be kept for safety alarm bell with high intensity blinking LED to assist any one trapped in the cold room.

(iii) Standby product cooler shall be provided as required.

Table 2.1
Summary for Outdoor Design Conditions
(Clause 2.2.1)

S.No.	Location Name	Cooling DB/MCWB						Evaporation WB/MCDB						Heating DB	
		0.4 Percent		1.0 Percent		2.0 Percent		0.4 Percent		1.0 Percent		2.0 Percent		99.6 Percent	99.0 Percent
		DB	MC WB	DB	MC WB	DB	MC WB	WB	MC DB	WB	MC DB	WB	MCDB		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
1	Ahmedabad	42.1	23.0	41.0	22.8	39.9	22.9	28.5	33.7	28.0	32.7	27.5	32.1	11.0	12.3
2	Akola	43.2	22.0	42.0	21.7	40.9	21.5	26.8	34.3	26.2	32.1	25.7	31.0	12.9	14.1
3	Allahabad	43.7	23.4	42.2	23.5	40.8	22.7	28.8	33.0	28.4	32.8	28.0	32.6	7.9	9.1
4	Amritsar	42.2	23.8	40.9	23.6	39.2	23.5	29.1	33.9	28.7	33.6	28.3	33.2	2.0	3.2
5	Aurangabad	40.2	22.6	39.2	22.7	38.2	22.4	26.6	35.2	25.7	33.1	25.1	31.7	10.6	12.0
6	Barmer	43.1	24.2	42.0	23.6	41.0	23.3	28.5	37.9	27.8	35.3	27.2	33.3	9.5	10.7
7	Belgaun	36.4	19.2	35.4	19.3	34.4	19.4	24.0	29.3	23.6	28.4	23.2	27.6	13.3	14.5
8	Bengaluru	34.2	19.8	33.4	19.8	32.6	19.8	23.6	28.9	23.1	28.3	22.7	27.7	15.2	15.9
9	Bhagalpur	42.4	26.8	40.7	27.4	38.9	25.6	30.0	37.1	29.6	36.4	29.2	35.2	11.4	12.6
10	Bhopal-Bairagarh	41.8	21.6	40.6	21.4	39.4	21.3	26.2	31.5	25.8	30.7	25.4	30.0	10.0	11.2
11	Bhubaneshwar	38.6	26.6	37.3	26.6	36.2	26.5	29.4	34.1	29.0	33.6	28.6	32.9	14.0	15.1
12	Bhuj	41.0	23.9	39.7	23.8	38.5	23.9	28.8	34.8	28.3	33.8	27.8	32.9	8.0	9.8
13	Bikaner	44.2	21.3	42.9	22.0	41.6	22.3	28.2	34.4	27.6	33.8	27.1	33.4	5.6	7.0
14	Chennai-Minambakkam	38.7	25.9	37.0	25.8	36.2	25.8	28.4	33.1	28.0	32.3	27.6	31.9	19.9	20.8
15	Chitradurga	36.2	20.8	35.4	20.8	34.6	20.9	25.5	31.4	24.7	30.4	24.1	29.5	15.8	17.0
16	Dehradun	37.7	21.6	36.2	21.3	34.7	21.4	26.8	30.3	26.4	29.9	26.0	29.5	5.3	6.4
17	Dibrugarh	34.0	27.0	33.2	26.8	32.3	26.7	28.3	32.6	27.8	31.8	27.4	31.3	7.5	8.7
18	Gorakhpur	41.4	26.2	40.3	26.0	39.1	26.4	29.9	35.2	29.7	35.5	29.4	34.7	7.9	9.0
19	Guwahati	34.5	26.5	33.6	26.5	32.8	26.5	28.7	32.7	28.2	31.9	27.9	31.3	10.8	11.8
20	Gwalior	43.7	22.0	42.6	22.3	41.3	22.2	28.2	32.9	27.8	32.2	27.4	31.7	6.0	7.1
21	Hissar	44.6	23.8	43.2	23.9	41.7	24.0	29.1	35.7	28.7	35.2	28.2	34.5	6.1	7.2
22	Hyderabad	40.2	21.8	39.1	21.7	38.0	21.8	25.7	31.5	25.1	30.8	24.7	30.2	13.9	15.1
23	Imphal	31.1	23.3	30.2	23.5	29.6	22.9	25.0	29.5	24.6	28.6	24.3	28.3	3.9	5.0
24	Indore	40.8	19.7	39.6	19.8	38.4	19.7	25.6	30.3	29.6	25.1	24.7	29.0	9.1	10.4
25	Jabalpur	42.4	20.7	41.1	20.7	39.7	21.0	26.7	31.4	26.2	30.4	25.7	29.6	8.4	9.6
26	Jagdalpur	39.3	22.5	38.0	22.6	36.8	22.5	26.3	31.5	25.7	30.5	25.4	29.9	9.9	11.2
27	Jaipur-Sanganer	42.5	21.3	41.2	21.3	40.0	21.3	27.5	31.2	27.0	30.9	26.6	30.5	7.2	8.6
28	Jaisalmer	43.5	23.9	42.3	23.8	41.1	23.8	28.0	35.3	27.5	34.8	27.1	34.4	8.4	9.7
29	Jamnagar	37.1	24.4	36.1	25.6	35.3	25.1	29.2	33.0	28.4	32.5	27.9	32.0	10.0	11.7
30	Jodhpur	42.7	21.2	41.4	21.6	40.2	21.8	27.5	32.4	27.1	32.1	26.7	31.8	8.8	10.1
31	Jorhat	34.4	28.2	33.6	27.7	32.9	27.3	28.7	32.7	28.3	32.7	28.0	31.8	9.6	10.6
32	Kolkata- Dum-Dum	37.4	27.0	36.3	27.0	35.4	26.8	29.6	34.5	29.1	33.8	28.7	33.0	11.5	12.7

33	Kota	43.5	23.0	42.4	22.6	41.2	22.6	27.3	35.2	26.8	33.0	26.5	31.8	9.9	10.8
34	Kurnool	41.5	23.0	40.5	23.1	39.4	22.9	26.2	33.7	25.8	32.9	25.4	32.2	17.0	18.0
35	Lucknow-Amausi	42.1	22.8	40.8	22.5	39.2	23.5	29.2	33.8	28.8	33.2	28.4	32.5	6.9	8.1
36	Mangalore	34.3	24.9	33.8	24.9	33.2	24.7	27.1	31.3	26.7	30.8	26.5	30.5	20.6	21.4
37	Mumbai-Santacruz	35.9	22.7	34.9	23.1	33.9	23.4	27.7	31.2	27.4	30.9	27.1	30.6	16.8	18.0
38	Nagpur-Sonegaon	43.9	22.5	42.8	22.4	41.4	22.2	27.4	32.3	26.8	31.6	26.4	31.0	11.8	13.0
39	Nellore	40.7	26.8	39.2	27.1	38.0	26.9	29.0	35.8	28.5	34.9	28.1	34.1	20.4	21.1
40	New-Delhi-Safdarjung	42.2	22.7	40.7	22.9	39.4	23.1	28.7	34.0	28.2	33.4	27.9	32.9	6.2	7.2
41	Panjim	34.1	25.6	33.5	25.6	33.0	25.5	28.2	31.9	27.7	31.3	27.4	30.9	19.7	20.4
42	Patna	41.0	23.4	39.5	23.4	37.9	23.8	28.9	33.7	28.6	33.0	28.2	32.3	8.2	9.3
43	Pune	38.1	19.7	37.1	19.6	36.0	19.7	24.6	29.8	24.2	29.0	23.7	28.3	9.7	10.9
44	Raipur	43.6	23.3	42.2	23.3	40.8	23.0	27.1	31.8	26.8	32.0	26.5	31.2	11.3	12.6
45	Rajkot	41.1	22.2	40.0	22.0	38.9	22.6	27.9	33.4	27.4	32.2	27.0	31.3	11.9	13.4
46	Ramagundam	43.4	25.6	42.2	25.1	40.7	25.8	28.3	37.3	27.9	35.6	27.4	34.4	12.5	13.7
47	Ranchi	38.9	22.1	37.7	21.8	36.4	21.5	26.2	31.7	25.6	30.4	25.2	29.2	9.1	10.4
48	Ratnagiri	34.1	22.8	33.3	23.2	32.7	23.5	27.2	30.6	27.0	30.3	26.7	29.9	18.2	19.2
49	Raxaul	38.6	23.1	36.9	24.5	35.5	24.6	28.9	33.0	28.4	32.0	28.1	31.8	7.5	8.5
50	Saharanpur	41.3	23.8	39.6	24.6	38.1	24.0	28.5	33.6	28.1	32.9	27.8	32.5	1.7	3.0
51	Shillong	24.2	19.7	23.5	19.4	22.8	18.9	20.7	23.3	20.3	22.7	19.9	22.2	-1.0	0.1
52	Sholapur	41.1	22.2	40.1	22.5	39.0	22.3	26.6	33.1	25.9	32.1	25.4	31.4	15.9	17.1
53	Surat	37.8	22.5	36.4	22.9	35.2	23.1	28.1	31.9	27.7	31.4	27.4	31.1	14.4	16.6
54	Sundernagar	36.1	19.1	34.6	19.6	33.1	19.4	25.2	30.1	24.8	29.2	24.4	28.0	1.8	2.8
55	Tezpur	34.2	27.4	33.3	26.5	32.5	27.1	28.9	32.8	28.4	31.8	28.0	31.4	10.5	11.4
56	Thiruvananthapuram	33.8	25.8	33.2	25.7	32.8	25.6	27.6	31.7	27.2	31.2	26.9	30.8	22.1	22.7
57	Tiruchchirapalli	39.0	25.8	38.1	25.7	37.3	25.5	27.8	35.0	27.2	34.1	26.7	33.5	20.0	20.8
58	Varanasi	43.0	22.5	41.8	22.7	40.1	23.2	28.9	33.8	28.6	33.2	28.2	32.6	7.8	8.9
59	Veraval	34.8	23.6	33.7	25.5	33.0	26.3	29.3	32.1	29.0	31.7	28.6	31.3	15.0	16.2
60	Visakhapatnam	33.7	27.0	32.9	27.5	32.3	27.3	29.1	32.0	28.7	31.6	28.3	31.2	20.1	20.8

NOTE -	**Abbreviations used:**
	DB- — Dry-bulb temperature.
	WB —-Wet-bulb temperature.
	MCDB —-Mean coincidental dry-bulb temperature.
	MCWB— -Mean coincidental wet-bulb temperature.

Table 2.2

Minimum Ventilation Rates in Breathing Zone (See Notes 1 to 5)

(This table is not valid in isolation; it shall be used in conjunction with the accompanying notes)
(Clause 2.2.2.3)

Sl No.	**Occupancy Category**	**People Outdoor Air Rate, R_p**		**Area Outdoor Air Rate, R_a**		**Notes**	**Default values**			**Air[1)] Class**
		Cfm/ person	I/s. Person	Cfm/ ft^2	I/s. m^2		Occupant Density (see Note 4)	Combined Outdoor Air Rate (See Note 4)		
							Persons per 1000 ft2 or per 100 m2	Cfm/person	I/s. Person	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
i)	**Correctional facilities:**									
a)	Cell	5	2.5	0.12	0.6		25	10	4.9	2
b)	Dayroom	5	2.5	0.06	0.3		30	7	3.5	1
c)	Guard Station	7.5	2.5	0.06	0.3		15	9	4.5	1
d)	Booking/waiting	10	3.8	0.06	0.3		50	9	4.4	2
ii)	**Educational Facilities:**									2
a)	Daycare (through age 4)	10	5	0.18	0.9		25	17	8.6	3
b)	Daycare sickroom	10	5	0.18	0.9		25	17	8.6	1
c)	Classrooms (age 5-8)	7.5	5	0.12	0.6		25	15	7.4	1
d)	Classrooms (age 9 Plus)	7.5	5	0.12	0.6		35	13	67	1
e)	Lecture classroom	10	5	0.06	0.3		65	8	4.3	1
f)	Lecture hall (fixed scats)	10	3.8	0.06	0.3		150	8	4.0	2
g)	Art classroom	10	3.8	0.18	0.9		20	19	9.5	2
h)	Science laboratories	10	5	0.18	0.9		25	17	8.6	2
i)	University/college laboratories	10	5	0.18	0.9		25	17	8.6	1
j)	Wood/metal shop	10	5	0.18	0.6		20	19	9.5	1
k)	Computer lab	10	5	0.12	0.6		25	15	7.4	1
l)	Media centre	10	5	0.12	0.3	See note 6	25	15	7.4	1
m)	Music/theatre/dance	10	5	0.06	0.3		35	12	5.9	1
n)	Multi-use assembly	7.5	5	0.06	0.3		100	8	4.1	1
iii)	**Food and beverage service:**									

a)	Restaurant dining rooms	7.5	3.8	0.18	0.9		70	10	5.1	2
b)	Cafeteria/fast-food dining	7.5	3.8	0.18	0.9		100	9	4.7	2
c)	Bars, cocktail lounges	7.5	3.8	0.18	0.9		100	9	4.7	2
iv)	**General:**									
a)	Break rooms	5	2.5	0.06	0.3		25	10	5.1	1
b)	Coffee stations	5	2.5	0.06	0.3		50	11	5.5	1
c)	Conference/meeting	5	2.5	0.06	0.3		50	6	3.1	1
d)	Corridors	-	-	0.06	0.3		-	-	-	1
e)	Storage rooms	-	-	0.12	0.6	See note 7	-	-	-	1
v)	**Hotels, motels ,resorts, dormitories:**									
a)	Bedroom/ living room	5	2.5	0.06	0.3		10	11	5.5	1
b)	Barracks sleeping areas	5	2.5	0.06	0.3		20	8	4.0	1
c)	Laundry rooms, central	5	2.5	0.06	0.6		10	17	8.5	2
d)	Laundry rooms with in dwelling units	5	2.5	0.12	0.6		10	17	8.5	1
e)	Lobbies/ Prefunction	7.5	3.8	0.12	0.3		30	10	4.8	1
f)	Multipurpose assembly	5	2.5	0.06	0.3		120	6	2.8	1
vi)	**Office buildings:**									
a)	Office space	5	2.5	0.06	0.3		5	17	8.5	1
b)	Reception areas	5	2.5	0.06	0.3		30	7	3.5	1
c)	Telephone/data entry	5	2.5	0.06	0.3		60	6	3.0	1
d)	Main entry lobbies	5	2.5	0.06	0.3		10	11	55	1
vii)	**Miscellaneous spaces:**									
a)	Bank vaults/ safe deposit	5	2.5	0.06	0.3		5	17	8.5	2
b)	Computer(not printing	5	2.5	0.06	0.3		4	20	10.0	1
c)	Electrical equipment rooms	-	-	0.06	0.3	See Note 7	-	-	-	1
d)	Elevator machine rooms	-	-	0.12	0.6	See Note 7	-	-	-	1
e)	Pharmacy (preparation area)	5	2.5	0.18	0.9		10	23	11.5	2
f)	Photostudios	5	2.5	0.12	0.6		10	17	8.5	1
g)	Shipping/receiving	-	-	0.12	0.6	See Note 7	-	-	--	1
h)	Telephone closets	-	-	0.00	0.0		-	-	-	1
i)	Transportation waiting	7.5	3.8	0.06	0.3		100	8	4.1	1

j)	warehouses	-	-	0.06	0.3	See Note 7	-	-	-	2
viii)	**Public assembly spaces:**									
a)	Auditorium seating area	5	2.5	0.06	0.3		150	5	2.7	1
b)	Places of religious worship	5	2.5	0.06	0.3		120	6	2.8	1
c)	Courtrooms	5	2.5	0.06	0.3		70	6	2.9	1
d)	Legislative chambers	5	2.5	0.06	0.3		50	6	3.1	1
e)	Libraries	5	2.5	0.12	0.6		10	17	8.5	1
f)	Lobbies	5	2.5	0.06	0.3		150	5	2.7	1
g)	Museums (children's)	7.5	3.8	0.12	0.6		40	11	5.3	1
h)	Museums/galleries	7.5	3.8	0.06	0.3		40	9	4.6	1
ix)	**Residential:**									
a)	Dwelling unit	5	2.5	0.06	0.3	See Note 8 and 9	See Note 8	-	-	1
b)	Common corridors	-	-	0.06	0.3		-	-	-	1
x)	**Retail:**									
a)	Sales (except as below)	7.5	3.8	0.12	0.6		15	16	7.8	2
b)	Mall common areas	7.5	3.8	0.06	0.3		40	9	4.6	1
c)	Barbershop	7.5	3.8	0.06	0.3		25	10	5.0	2
d)	Beauty and nail salons	20	10	0.12	0.6		25	25	12.4	2
e)	Pet shops (animal areas)	7.5	3.8	0.18	0.9		10	26	12.8	2
f)	Supermarket	7.5	3.8	0.06	0.3		8	15	7.6	1
g)	Coin-operated laundries	7.5	3.8	0.06	0.3		20	11	5.3	2
xi)	**Sports and entertainment:**									
a)	Sports arena (play area) .	-	-	0.30	1.5	See Note 10	-	-	-	1
b)	Gym, stadium (play area	-	-	0.30	1.5		30	-	-	2
c)	Spectator areas	7.5	3.8	0.06	0.3		150	8	4.0	1
d)	Swimming (pool and deck)	-	-	0.48	2.4	See Note 11	-	-	-	2
e)	Disco/dance floors	20	10	0.06	0.3		100	21	10.3	1

f)	Health club/aerobics room	20	10	0.06	0.		40	22	10.8	2
g)	Health club/weight rooms	20	10	0.06	0.3		10	26	13.0	2
h)	Bowling alley (seating)	10	5	0.12	0.6		40	13	6.5	1
j)	Gambling casinos	7.5	3.8	0.18	0.9		120	9	4.6	1
k)	Game arcades	7.5	3.8	0.18	0.9		20	17	8.3	1
m)	Stages, studios	10	5	0.06	0.3	See Note 12	70	11	5.4	1

Air Class **Characteristic**

1. Air with low contaminant concentration, low sensory-irritation intensity, and inoffensive odour.
2. Air with moderate contaminant concentration, mild sensory-irritation intensity, or mildly offensive odours. Class air also includes air that is not necessarily harmful or objectionable but that is inappropriate for transfer or recirculation to spaces used for different purposes.
3. Air with significant contaminant concentration, significant sensory-irritation intensity, or offensive odour.
4. Air with highly objectionable fumes or gases or with potentially dangerous particles, bio aerosols, or gases, concentrations high enough to be considered harmful.

NOTES

1. The rates in this table are based on all other applicable requirements being met.
2. This table applies to no-smoking areas only. Rates for smoking-permitted spaces shall be determined using other methods.
3. Volumetric airflow rates are based on an air density of 1.2 kgDA/m', which corresponds to dry air at a barometric pressure of 1 atm (101.3 kPa) and an air temperature of 21°C. Rates may be adjusted for actual density but such adjustment is not required for compliance with this standard.
4. Actual occupant density should be considered, the default occupant density shall be used only when actual occupant density is not known. Default combined outdoor air (per person) rate is based on the default occupant density.
5. If the occupancy category for a proposed space or zone is not listed, the requirements for the listed occupancy category that is most similar in terms of occupant density, activities and building construction shall be used.
6. For high school and college libraries, use values shown for public assembly spaces-libraries.
7. The prescribed value may not be sufficient when stored materials include those having potentially harmful emissions.
8. Default occupancy for dwelling units shall be two persons for studio and one-bedroom units, with one additional person for each additional bedroom.
9. Air from one residential dwelling shall not be recirculated or transferred to any other space outside of that dwelling.

10. When combustion equipment is intended to be used on the playing surface, additional dilution ventilation and/or source control shall be provided.
11. The prescribed value does not allow for humidity control. Additional ventilation or dehumidification may be required to remove moisture.
12. The prescribed value does not include special exhaust for stage effects, for example, dry ice vapours, smoke.

Table 2.3
HVAC System Analysis and Selection Matrix
(Clause 2.5)

SI No.	**System Characteristic**	**Fixed Speed Unitary Systems (window ACs/Split ACs/Package**	**Variable Speed/Flow/Frequency/Capacity Unitary Systems (Inverter Split ACs /Package ACs)**	**Variable Speed Multi or Modular Systems(VRF)**	**Central Systems**
(1)	(2)	(3)	(4)	(5)	(6)
i)	Temperature	No uniform and effective control possible	Minimal uniform and effective control possible	Reasonably uniform and effective control possible	Uniform and effective control possible
ii)	Relative Humidity	Effective control not possible	Effective control not possible	Effective control not possible	Effective control possible
iii)	Space pressure	Effective control not possible	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, no diversity	Capacity to suit zone peak, limited diversity can be considered	Allows the design engineer to consider HVAC load diversity factors, accordingly 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	It has the benefit of partial back-up or standby equipment	Back-up or standby equipment can easily be accommodated
vi)	Facility management	Allows minimal provision to maximize performance using good facility management techniques in operation	Allows minimal provision to maximize performance using good facility management techniques in operation	Limited possibilities to maximize performance using good facility management techniques in operation	Allows to maximize performance using good facility management techniques in operation
vii)	Spatial requirements	No plant/ equipment room required compromises building elevation	No plant/ equipment room required compromises building elevation	No plant/ equipment room required. Outside units can be located on roof or on	Equipment room/spaces and accessible shaft required for chilled water piping

				adjacent ground. Very small shaft desirable for refrigerant piping	
viii)	Electric Supply	Distributed electric supply required	Distributed electric supply required	Zone-wise distributed electric supply required	Minimal distribution cost by centralized supply near the substation
ix)	Initial cost	Minimum Initial cost	Initial cost marginally higher than fixed speed system	Moderate Initial cost but marginally higher than variable speed unitary product	Even with HVAC diversity, a central system may not be less costly than decentralized HVAC Systems
x)	Operating cost	Higher operating cost, strategic scheduling of multiple pieces of equipment can save marginal operating cost, but equipment is less efficient	Strategic scheduling of multiple pieces of equipment can save reasonable operating cost, but higher peak energy requirement	Strategic scheduling of equipment can save operating cost better than unitary product, but 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	Maintenance cost marginally higher than fixed speed	Maintenance cost higher than both fixed and variable speed unitary system but less than central system	Comparatively higher since centralized equipment room requires operator with no access to occupant workspace, but with fewer pieces of HVAC equipment to service
xii)	Reliability	Reliable equipment but low service life	Reliable equipment but low service life	Reliable equipment but moderate service life	Reliable equipment with much longer service life

xiii)	Flexibility	Has to be placed at fixed locations	Has to be placed at fixed locations	Can be placed at distributed locations	Flexibility available in terms of alternative locations
xiv)	Level of control	Limited control level available	Limited control level available	Moderate control level available	close control level available
xv)	Noise and vibration	Noise and vibration within/adjacent to occupied spaces for unitary window type air conditioners which is substantially reduced in case of split system	It is generally available in split system only for which noise and vibration is substantially reduced in occupied and adjacent spaces as compared to a window type air conditioner	Noise and vibration on roof terrace or ground, away from occupied spaces; however the same can be reduced with good installation practices	Noise and vibration away from occupied spaces
xvi)	Constructability	Multiple and similar-in-size equipment makes standardization a construction feature	Multiple and similar-in-size equipment makes standardization a construction feature	Multiple and similar-in-size equipment makes standardization a construction feature	Require more coordinated installation with added benefit of consolidated primary equipment in central location

Table 2.4
Recommended Rate of Air Circulation for Different Areas
(Clause 2.11.2.1)

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)	Cafes and coffee bars	10-12
8)	Canteens	8-12
9)	Cellars	3-10
10)	Changing rooms	6-10
11)	Churches	1-3
12)	Cinemas and theatres	10-15
13)	Club rooms	12, Min
14)	Compressor rooms	10-12
15)	Conference rooms	8-12
16)	Corridors	5-10
17)	Dairies	8-12
18)	Dance halls	12, Min
19)	Dye works	20-30
20)	Electroplating shops	10-12
21)	Entrance halls	3-5
22)	Factories and work shops	8-10
23)	Foundries	15-30
24)	Garages	6-8
25)	Glass houses	25-60
26)	Gymnasium	6, Min
27)	Hair dressing saloon	10-15
28)	Hospitals-sterilising	15-25
29)	Hospital-wards	6-8
30)	Hospital domestic	15-20
31)	Laboratories	6-15
32)	Launderettes	10-15
33)	Laundries	10-30
34)	Lavatories	6 -15
35)	Lecture theatres	5-8
36)	Libraries	3-5
37)	Lift cars	20, Min
38)	Living rooms	3-6
39)	Mushroom houses	6-10

40)	Offices	6-10
41)	Paint shops(not cellulose)	10-20
42)	Photo and X-ray dark room	10-15
43)	Public house bars	12, Min
44)	Recording control rooms	15-25
45)	Recording studios	10-12
46)	Restaurants	8-12
47)	Schoolrooms	5-7
48)	Shops and supermarkets	8-15
49)	Shower baths	15-20
50)	Stores and warehouses	3-6
51)	STP rooms	30, Min
52)	Squash courts	4, Min
53)	Swimming baths	10-15
54)	Toilets	6-10
55)	Underground vehicle parking	6, Min
56)	Utility rooms	15-30
57)	Welding shops	15-30

Table 2.5
Pressurization of Staircases and Lift Lobbies
(Clause 2.11.2.2)

Sl No.	**Component**	**Height of Building**		
(1)	**(2)**	**Less than 15 m (3)**	**15 m to 30 m (4)**	**More than 30 m (5)**
(i)	Internal staircase not with external wall	Pressurized except for residential buildings (A-2 and A-4)	Pressurized	Pressurized
(ii)	Internal staircase with external wall	Pressurized except for residential buildings (A-2 and A-4) or Naturally ventilated	Naturally ventilated or Pressurized	Cross-ventilated or Pressurized
(iii)	Lift lobby	Not required at ground and above. However lift lobby segregation and pressurization is required for lift commuting from ground to basement	Naturally ventilated or Pressurized (*)	Cross-ventilated or Pressurized(*)

NOTES

1 The natural ventilation requirement of the staircase shall be, achieved through opening at each landing, of an area 0.5 m^2 in the external wall. A cross ventilated staircase shall have 2 such openings in opposite/adjacent walls or the same shall be cross-ventilated through the corridor.

2 Enclosed staircase leading to more than one basement shall be pressurized.

(*) Lift lobby with fire doors (120 min) at all levels with pressurization of 25-30 Pa is required. However, if lift lobby cannot be provided at any of the levels in air conditioned buildings or in internal spaces where funnel/flue effect may be created, lift hoistway shall be pressurized at 50 Pa. For building greater than 30 m, multiple point injection air inlets to maintain desired pressurization level shall be provided. If the lift lobby, lift and staircase are part of firefighting shaft, lift lobby necessarily has to be pressurized in such case, unless naturally ventilated.

Table 2.6
Appliance Category and their Recommended Hood Exhaust Flow Rates
(Clause 2.11.2.2(3))

Sl No. (1)	**Appliance Category Surface Temperature °C (2)**	**→ Light → 200°C (3)**	**Medium 200°C (4)**	**Heavy 315°C (5)**	**Extra Heavy 370°C (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 ranges b) Griddles c) Fryers d) Pasta cookers e) Conveyor ovens f) Grill g) Rotisseries	a) Open burner ranges b) Broiler 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
iii)	Hood type	Hood exhaust flow rates per linear metre of hood length litre per second			
a)	Wall mounted canopy	309	463	618	850
b)	Single island	618	772	927	1080
c)	Double island (per side)	386	463	618	850
d)	Back shelf	463	463	618	-

Table 2.7 (as per BEE Star leveling program
Minimum Requirements for Unitary, Split, Packaged Air Conditioners
(Clause 2.13) (Minimum 5 star)

Capacity	ISSER
For all capacities	5

Table 2.8
Minimum Efficiency Requirements for VRF Air conditioners
(Clause 2.13)

	ISEER
For < 40kWr	6.4
For $\geq$ 40kWr and <70kWr	6.5
For $\geq$ 70kWr	6.6

Table 2.9
Minimum Efficiency Requirements for Computer Room Air Conditioners
(Clause 2.13)

Sl.No.	Equipment type	Net Sensible Cooling Capacity[a]	Minimum SCOP-127[b]	
			Down flow	Upflow
1	All types of computer room ACs Air/Water/Glycol	All Capacity	2.5	2.5

Note:
a. Net Sensible cooling capacity = Total gross cooling capacity - latent cooling capacity – Fan power
b. Sensible Coefficient of Performance (SCOP-127): A ratio calculated by dividing the net sensible cooling capacity in watts by the total power input in watts (excluding reheater and dehumidifier) at conditions defined in ASHRAE Standard 127-2012 Method of Testing for Rating Computer and Data Processing Room Unitary Air Conditioners)

Table 2.10
Scheme of Colour Code of Pipe Work
Services for Air Conditioning Installation
(Clause 2.15.1)

Sl No. (1)	**Description (2)**	**Ground Colour (3)**	**Lettering Colouring (4)**	**First Colour Band (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		

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, as identified below:

Hot water	:	HW
Chilled water	:	CHW
Condenser water	:	CDW
Steam	:	ST
Condensate drain	:	CN

Table 2.11

ODP and GWP Values (100 year values) and safety group of different refrigerant types

(Clause 2.16)

S No	REFRIGERANT		ODP	GWP	Safety Group {see accepted standard [8-3(2)]}
	Refrigerant Number	Composition Designating Prefix			
(1)	(2)	(3)	(4)	(5)	(6)
i)	Hydrofluorocarbons (HFC) and their blends:				
a)	R-32	HFC	0	677	A2L
b)	R-134a	HFC	0	1430	A1
c)	R-245fa	HFC	0	858	B1
d)	R-404A	HFC	0	3922	A1
e)	R-407C	HFC	0	1774	A1
f)	R-407F	HFC	0	1825	A1
g)	R-410A	HFC	0	2088	A1
h)	R-507A	HFC	0	3985	A1
i)	R-448A	HFC	0	1386	A1
ii) Hydrofluoroolefins (HFO):					
a)	R-1233zd (E)	HFO	~0	1	A1
b)	R-1234ze(E)	HFO	0	0.97	A2L
c)	R-1234yf	HFO	0	0.31	A2L
d)	R-1336mzz(Z)	HFO	0	2.0	A1
e)	R-154A	HFO	0	1.75	B1
iii)	Hydrofluoroolefins (HFO)/ Hydrofluorocarbons (HFC)				
a)	R-452A	HFO and HFC blend	0	2141	A1
b)	R-452B	HFO and HFC blend	0	675	A2L
c)	R-513A	HFO and HFC blend	0	573	A1
iv)	Natural refrigerants:				
a)	R-718 (Water)	-	0	0	A1
b)	R-744 (Carbon dioxide)	-	0	1	A1
c)	R-717 (Ammonia)	-	0	0	B2L
d)	R-290 (propane)	HC	0	3.3	A3

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CHAPTER-3
ARCHITECTURAL AND STRUCTURAL REQUIRMENTS

3.1 SCOPE

This chapter outlines the general guidelines for planning space requirements, equipment location, floor loading & other structural requirements for various types of HVAC systems.

3.2 Packaged Type Plant

3.2.1 Space Requirements

(i) The floor area requirement for installation of the packaged type plant room shall be as under:

(a) Single Unit : 3 m X 2.5 m

(b) Double Units : 3 m X 4 m

(c) Triple Units : 3 m X 5 m

(ii) Dimensions indicated are clear space requirements. The minimum clear height of the packaged unit room shall be same as that of the space to be air-conditioned to facilitate laying of ducts.

(iii) The Space requirement shall be fine-tuned during detailed engineering based on manufacturer's recommendations.

3.2.2 Equipment Location

The packaged type plant room shall be adjacent to the space to be air- conditioned.

3.2.3 Floor loading & other structural requirements

(i) Floor loading of the packaged type unit plant room shall not be less than 1200 Kg/ sqm

(ii) The plant room shall have a fresh air intake point, fresh water connection and drain point for draining out condensate.

3.3 CENTRAL AIR CONDITIONING PLANT

3.3.1 Space requirements

(i) Space requirement for central air conditioning plant shall be worked out on following basis:

Chilling unit

(a) Centrifugal/ screw - 40-50 sq.m. per unit

(b) Centrifugal pump - 8-10 sq.m each pump

(c) Electrical panel - 20-25 sq.m per chilling unit

(d) Control panel - 20-25 sq.m

(ii) Additional space for circulation shall be taken as 20-25% of the above total space.

(iii) Provision shall also be kept for anticipated future requirements.

(iv) The minimum clear height of the plant room shall be 4.5 m below soffit of beam for chillers of capacity upto 500 TR and 5.5 m below soffit of beam for chillers of capacity greater than 500 TR.

(v) The entrance to A.C. plant room for centrifugal / screw type units shall be through rolling shutter/ suitable door shutters of steel or strong material to take self load having minimum width of 3 m & height not less than 4 m for centrifugal/ screw type units .

3.3.2 **Equipment location**

The plant room shall have easy accessibility for moving in and out of equipments and shall be well ventilated. The location of the plant room shall also take into consideration the routing of the chilled water and condenser water lines from the plant room. As far as possible the plant room should be in close proximity to the electrical substation, since AC plant is main power load. The plant room shall be preferably located in a separate service building along with the substation. Basements shall be avoided from the fire safety point of view.

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.

Plant machinery in the plant room shall be placed on levelled plain/reinforced cement concrete foundation block and provided with anti-vibratory supports.

Appropriate sound insulation and noise control measures shall be taken in plant room space as per Part 8, Building Services, Section 4 Acoustics, Sound Insulation and Noise Control of the NBC 2016.

Floor drain channels or dedicated drain pipes in slope shall be provided within plant room space for effective disposal of waste water, if necessary by automatic level controlled sump pumps. Fresh water connection may also be provided in the air conditioning plant room.

Level of Cooling Towers shall be above the condenser water header. Cooling Tower level shall be at least 100-120 Cm above the terrace level for connection of out let, drain pipes etc.

3.3.3 **Floor loading and other structural requirements**

(i) The floor loading of the AC plant shall be calculated however it shall not be less than as mentioned in the part 6 structural design Section 1 Loads, Forces and Effects of the NBC 2016. However as rough guide it can be considered as 2000 Kg/sq mtr.

(ii) The Plant room should have a fresh water connection & drain trap.

3.4 Weather Maker / AHU Rooms

3.4.1 Space requirements

(i) Floor area requirement for the AHU room shall be as under:

(a) For AHUs upto 340 CMM : 4.5 m X 4 m

(b) For AHUs between 340 CMM & 680 CMM : 5.5 m X 5 m

(ii) The minimum clear height of the AHU room shall be the same as that of the air-conditioned space to facilitate laying of ducts.

3.4.2 **Equipment Location :**

AHU rooms should be contiguous to the respective areas to be air-conditioned by them. Their location should also take into consideration the feasibility of routing the ducts as well as provision of chilled water lines, water connections for the humidification equipments, fresh air inlet point and drain outlets. In multistoried constructions, the AHUs should be located in a vertical configuration to facilitate laying of chilled water lines. Individual AHUs shall not serve more than one floor from the fire safety point of view. Similarly each fire compartment shall have a separate AHU. Where the AHUs are located in the basement or in any floor below the air-conditioned floors, individual shafts shall be provided for each AHU from the AHU room for the supply and return air, from the fire safety point of view.

3.4.3 **Floor loading and other structural requirements :**

(i) The floor loading of AHU room shall be 800 Kg/ sq m

(ii) The doors of the AHU rooms shall be single leaf, air tight having a minimum width of 1.2 m and openable outside. The floor of the AHU room shall slope towards the drain point. For clean room applications and other special requirements the internal finish of the AHU room shall be suitable for these special applications.

(iii) All cutouts in the floor for the pipelines and cable shall be effectively sealed from the fire safety point of view.

(iv) The clear height required to be maintained under the false ceiling shall take into consideration the ducting design and after allowing for the depth of the beams, thickness of the false ceiling including its frame work, recessed light fittings, etc.

(v) The cutouts required in the floor slabs for installing the pipes, ducts and / or cables shall be decided at the initial planning stage and marked in the architectural drawings.

(vi) Requirements for fresh air openings, water and drain in the AHU rooms as well as insulation of exposed roof slabs of conditioned areas as well as AHU room shall also be detailed in the initial planning stage.

(vii) The beams in the ceiling of AHU rooms shall be of low depth to facilitate installing of supply air duct and return air duct.

(viii) All air handling rooms should have floor drains and if possible, water supply connection. The trap in floor drain shall provide a water seal between the air conditioned space and the drain line.

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

(x) Appropriate sound insulation and noise control measures shall be taken in air handling unit rooms, if located in close proximity to occupied areas, as per Part 8 'Building Services, Section 4 Acoustics, Sound Insulation and Noise Control' of the NBC 2016 as amended up to date.

(xi) The door shall be fire resistant (see Part 4 'Fire and Life Safety' of the Code) and fire/ smoke dampers shall be provided in supply/return air duct at air handling unit room wall crossings. Annular space between the duct and the wall should be fire- sealed using appropriate fire resistance rated material.

3.5 Cooling Towers

3.5.1 **The recommended floor area requirement for various types of cooling tower is as given below:**

(i) Natural draft cooling tower : 0.15 to 0.20 m^2/TR

(ii) Mechanical draft cooling tower : 0.07 to 0.10 m^2/TR

The Structural loading requirement shall be decided by the NIT approving authority as per actual requirement based on information from manufacturer and Codal requirement.

3.5.2 **Equipment location :**

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 Architect. In case the cooling towers are located on the terrace of the building, the structural loading of the terrace shall be considered. For this respective columns are to be raised by two feet at the terrace. Cooling towers shall be installed in such a way that their load is transferred directly to the columns for which necessary Mild steel-I sections shall be provided by Air- conditioning contractor. The cooling towers shall be rested on Mild Steel-I sections & not on terrace slab. Sufficient free space shall be left all around for efficient operation of the cooling tower.

3.6 Central Heating System

3.6.1 Space Requirements :

(i) The space requirement shall depend upon the type and capacity of the hot water generator chosen for the work and its overall dimensions.

(ii) Sufficient space shall be left all around the hot water generator for maintenance and operation purpose.

(iii) Space shall also be provided for the auxiliary equipments such as hot water circulating pumps and electrical control panels.

(iv) The minimum clear height of hot water generator room shall be 4.5 m.

(v) Sufficient space should also be provided for the storage of fuel in case of oil fired hot water generator. Though the daily service tank shall be provided within the room, bulk storage tank may be provided outside the buildings, either above or below ground level.

(vi) Use of HSD/ LDO oil fired hot water generator has been discontinued due to pollution & fire safety considerations.

The space requirement to be planned based on capacity of the system/manufacturer's requirement.

3.6.2 Equipment Location

(i) The hot water generator room shall preferably be located in a separate service building from the fire safety point of view. The room shall have easy accessibility for moving in and out the equipment.

(ii) Electrically operated hot water generator shall preferably be located in close proximity to the electrical substation, especially in the case of large capacity hot water generator.

3.6.3 Structural Requirements

(i) The floor loading of the hot water generator room shall be 2000 Kg/sq m.

(ii) The loading of the equipment to be based on the capacity of the system/manufacturer's requirement.

3.7 Mechanical ventilation/ Evaporative Cooling System

3.7.1 Space Requirement

(i) The space requirement for the equipment, air washers etc., shall be as per the manufacturer's recommendations.

(ii) Space shall also be provided as required for the installation of the pumps along with the air washers.

(iii) The minimum clear height of the equipment and air washer rooms shall be 3.6 m. The actual height required would depend upon the capacity of the equipment and manufacturer's recommendation.

3.7.2 Equipment Location

(i) The plant room shall be located contiguous to the space to be ventilated to reduce the pressure drop in the system.

(ii) Where air washers are also to be installed the room shall be treated with waterproof treatment and shall be located adjacent to the blower room.

(iii) The plant room shall be so located that it is conveniently possible to exhaust or inject the air to / from the ambient.

3.7.3 Floor loading & other Structural Requirements

(i) The floor loading of the plant room and air washer room shall be 2000 kg/sqm.

(ii) The doors of the plant room and air washer room shall be single leaf, air tight and open able outside. The floor and walls of the air washer room shall be properly treated, preferably with tiles to prevent seepage of water to the adjoining areas. The floor of the air washer room shall be properly sloped towards the drain point.

(iii) The air washer room shall be provided with water and drain points.

(iv) Fresh air opening along with masonry louvers, fresh water connection and drain outlet shall be provided in the plant room / air washer room.

3.8 Cold Rooms

3.8.1 Space Requirements

(i) The space requirement shall have to be worked out in individual cases depending upon the system selected.

(ii) Sufficient space should be kept around the equipment for operation and maintenance purposes.

(iii) Normal room height in the building should be adequate for the equipment room as well as the cold room.

3.8.2 Equipment Location

(i) Plant Room

The plant room shall have to be necessarily adjacent to the cold room where DX system is used. The plant room shall have easy accessibility for men and materials and shall be well ventilated. In an air-cooled system, the condenser shall have to be located in a well-ventilated space and preferably within the equipment room.

(ii) AHU's Rooms and Cooling Towers

These shall be located as specified under 3.4.2 & 3.5

3.8.3 Floor loading and other Structural Requirements

(a) The floor loading for the equipment room shall be 2000 kg /sq. m.

(b) The floor loading/ weight of the equipment for AHU rooms and cooling towers shall be as specified under 3.3.3 & 3.5.

(c) Where the cold rooms are located in the uppermost floor, the roof slab shall be provided with effective water proofing treatment to avoid any damage to the insulation of the cold room. For the same reason, the cold rooms shall be located away from the wet areas such as toilets.

(d) Where the cold rooms are located on the ground floor, the flooring shall be effectively treated to prevent any seepage of water from the ground into the cold room.
(e) Suitable insulation along with vapor barrier shall be provided on all the sides of the cold room including the roof and flooring, especially in low humidity applications.

3.9 GENERAL STRUCTURAL REQUIREMENTS

The Building shall meet the Mandatory provisions under Section 4.2 and the prescriptive Criteria under Section 4.3 of ECBC 2017.

3.9.1 Rated Fenestration :

(i) U-factors shall be determined for the overall fenestration product (including the sash and frame) in accordance with ISO-15099 by an accredited independent laboratory, and labelled or certified by the manufacturer. U-factors for sloped glazing and skylights shall be determined at a slope of 20 degrees above the horizontal.

(ii) SHGC shall be determined for the overall single or multi glazed fenestration product (including the sash and frame) in accordance with ISO-15099 by an accredited independent laboratory, and labelled or certified by the manufacturer.

(iii) Visible light transmittance (VLT) shall be determined for the fenestration product in accordance with ISO-15099 by an accredited independent laboratory, and labelled or certified by the manufacturer. For unrated products, VLT of the glass alone shall be de-rate by 10% for demonstrating compliance with the VLT requirements for the overall fenestration product.

(iv) For all climatic zones, vertical fenestration (Certified/rated) shall meet the following requirements, for all three energy efficiency levels, i.e. ECBC, ECBC+, and Super ECBC, as given below :
(a) Maximum allowable Window Wall Ratio **(WWR)** : 40%
(b) Minimum allowable Visible light transmittance **(VLT)** : 0.27
(c) Vertical fenestration shall comply meet the requirement of maximum Solar Heat Gain Coefficient (SHGC) and U-factor requirements as given below:

Table 3.1

Rated/ Certified Vertical Fenestration Assembly U-factor and SHGC Requirements for ECBC Buildings

	Composite	Hot and dry	Warm and humid	Temperate	Cold
Maximum U-factor (W/m² K)	3.00	3.00	3.00	3.00	3.00
Maximum SHGC Non-North	0.27	0.27	0.27	0.27	0.62
Maximum SHGC North for latitude < 15°N	0.27	0.27	0.27	0.27	0.62
Maximum SHGC North	0.50	0.50	0.50	0.50	0.62

Table 3.2

Rated/ Certified Vertical Fenestration U-factor and SHGC Requirements for ECBC+ buildings and SuperECBC building

	Composite	Hot and dry	Warm and humid	Temperate	Cold
Maximum U-factor ($W/m^2.K$)	2.20	2.20	2.20	3.00	1.80
Maximum SHGC Non-North	0.25	0.25	0.25	0.25	0.62
Maximum SHGC North for latitude < 15°N	0.50	0.50	0.50	0.50	0.62
Maximum SHGC North	0.25	0.25	0.25	0.25	0.62

3.9.2 Unrated Vertical Fenestration:

(i) For unrated vertical fenestration, both operable and fixed, the glass VLT reported by Manufacturer must meet or exceed 0.37.

(ii) The SHGC values of unrated vertical fenestration must meet or exceed the requirements as given above (in compliance to ECBC 2017 as amended up to date).

(iii) U-factors for unrated vertical fenestration, both operable and fixed, shall be as given below (in compliance to ECBC 2017 as amended up to date):

Table 3.3

Defaults for Unrated Fenestration (Overall Assembly including the Sash and Frame)

Frame Type	Glazing Type	U-Factor ($W/m^2.K$)
All frame types	Single Glazing	7.1
Wood, vinyl, or fiberglass frame or metal frame with thermal break	Double Glazing(COG U value >1.6 $W/m^2.K$)	3.4
Wood, vinyl, or fiberglass frame or metal frame with thermal break	Double Glazing(COG U value <1.6 $W/m^2.K$)	3.0
Metal and other frame type	Double Glazing	5.1

3.9.3 Roof :

If the building is air conditioned, the roof of the air conditioned areas & W.M. room shall have insulation on the roof (preferably over deck insulation wherever possible) and insulation in the walls. U-factors shall be calculated for the opaque construction in accordance with ISO-6946. Testing shall be done in accordance with approved ISO Standard for respective insulation type by an accredited independent laboratory, and labelled or certified by the manufacturer.

The Insulation to roof shall be applied externally as a part of roof assembly and not as part of false ceiling. The U-value for roof shall be minimum as given below (in compliance to ECBC 2017 as amended up to date):

Table 3.4
Roof Assembly U-factor (W/m^2.K) Requirements for ECBC Compliant Building

	Composite	Hot and dry	Warm and humid	Temperate	Cold
All building types, except below	0.33	0.33	0.33	0.33	0.28
School <10,000 m^2 AGA	0.47	0.47	0.47	0.47	0.33
Hospitality > 10,000 m^2 AGA	0.20	0.20	0.20	0.20	0.20

Table 3.5
Roof Assembly U-factor (W/m^2.K) Requirements for ECBC+ Compliant Building

	Composite	Hot and dry	Warm and humid	Temperate	Cold
Hospitality, Healthcare Assembly	0.20	0.20	0.20	0.20	0.20
Business Educational Shopping Complex	0.26	0.26	0.26	0.26	0.20

Table 3.6
Roof Assembly U-factor (W/m^2.K) Requirements for SuperECBC Building

	Composite	Hot and dry	Warm and humid	Temperate	Cold
All buildings types	0.20	0.20	0.20	0.20	0.20

3.9.4 Opaque Wall :

Opaque above grade external wall shall have minimum U values as given below: (In compliance to ECBC 2017 as amended up to date):

Table 3.7
Opaque Assembly Maximum U-factor (W/m^2.K) Requirements for a ECBC compliant Building

	Composite	Hot and dry	Warm and humid	Temperate	Cold
All building types, except below	0.40	0.40	0.40	0.55	0.34
No Star Hotel < 10,000 m^2 AGA	0.63	0.63	0.63	0.63	0.40

Business < 10,000 m^2 AGA	0.63	0.63	0.63	0.63	0.40
School <10,000 m^2 AGA	0.85	0.85	0.85	1.00	0.40

Table 3.8

Opaque Assembly Maximum U-factor (W/m2.K) Requirements for ECBC+ Compliant Building

	Composite	Hot and dry	Warm and humid	Temperate	Cold
All building types, except below	0.34	0.34	0.34	0.55	0.22
No Star Hotel < 10,000 m^2 AGA	0.44	0.44	0.44	0.44	0.34
Business < 10,000 m^2 AGA	0.44	0.44	0.44	0.55	0.34
School <10,000 m^2 AGA	0.63	0.63	0.63	0.75	0.44

Table 3.9

Opaque Assembly Maximum U-factor (W/m2.K) Requirements for SuperECBC Building

	Composite	Hot and dry	Warm and humid	Temperate	Cold
All buildings types	0.22	0.22	0.22	0.22	0.22

3.9.5 Skylights :

Skylight roof ratio (SRR), defined as the ratio of the total skylight area of the roof, measured to the outside of the frame, to the gross exterior roof area, is limited to a maximum of 5% for ECBC Building, ECBC+ Building, and Super ECBC Building.

Skylights shall have the maximum U-factor and maximum SHGC as given below (in compliance to ECBC 2017 as amended up to date)

Table 3.10

Skylight U-factor (W/m2.K) and SHGC Requirements

Climate	Maximum U-factor	Maximum SHGC
All climatic zones	4.25	0.35

3.10 Check List for Space Provisions for Central Air Conditioning Works

(i) A.C Plant room
(ii) AC plant room water connection & drainage
(iii) Cooling tower location
(iv) AHU room
(v) AHU room water connection & drainage
(vi) Shaft for carrying chilled water pipes
(vii) False ceiling co-ordination

(viii) Ceiling height to accommodate ducting
(ix) Water requirement
(x) Routes of piping/ cable
(xi) Thermal/ acoustic insulation
(xii) Air tightness of windows/ doors
(xiii) Insulation for AC areas on top floors.

Some of the good practice for spacing of various component of central plant are as given below:-

(a) Plant Room adjacent to Electric Substation to reduce connectivity cost and to accommodate Chillers, pumps primary/secondary, Electrical Panel, BMS, Piping and Valves. See enclosed layout sketch for plant room and ESS.
(b) Cooling Towers on the Ground floor/ terrace of the Plant Building, including structural arrangement for erection of cooling towers and staircase approach to the terrace.
(c) AHUs in Vertical alignment so that chiller pipes from the plant can be taken inside AHU without passing through corridors.
(d) Suitable cuts in the AHU floor to take Wet Riser Pipes/ and Rising Mains to feed AHUs.
(e) Adequate corridor width and height for AC Ducting.
(f) Structural provision and Route for entry of chiller pipes and cables from plant room to AHUs.
(g) AHU Room: fresh air opening, water connection, Drainage arrangement, Acoustic lining,
(h) Insulation of wall/ceiling between AC non-AC areas.

3.11 Some of the good practice for spacing of various component of central plant are as given below:-

(i) All the doors/ windows of air-conditioned areas shall be made airtight.
(ii) Air leakage for glazed swinging entrance doors and revolving doors shall not exceed 5.0 l/s m^2.
(iii) Air leakage for other fenestration and doors shall not exceed 2.0 l/s m^2.

(iv) The following areas of the enclosed building envelopes shall be sealed, caulked, gasketed or weather stripped to minimize air leakage:
(a) Joints around fenestration and door frames
(b) Openings between walls and foundation and between walls and roof and wall panels.
(c) Opening at penetrations of utility services through roof, walls, and floors
(d) Site-built fenestration and doors
(e) Building assemblies used as ducts and plenums
(f) All other openings in the building envelope
(g) For air conditioning areas, where the return air is collected/ carried back to AHU rooms above false ceiling, the false ceiling shall be airtight.
(v) Plant Room adjacent to Electric Substation to reduce connectivity cost and to accommodate Chillers, pumps primary/secondary, Electrical Panel, BMS, Piping and Valves. See enclosed layout sketch for plant room and ESS.
(vi) Cooling Towers on the Ground floor/ terrace of the Plant Building, including structural arrangement for erection of cooling towers and staircase approach to the terrace.
(vii) AHUs in Vertical alignment so that chiller pipes from the plant can be taken inside AHU without passing through corridors.
(viii) Suitable cuts in the AHU floor to take Wet Riser Pipes/ and Rising Mains to feed AHUs.
(ix) Adequate corridor width and height for AC Ducting.

(x) Structural provision and Route for entry of chiller pipes and cables from plant room to AHUs.

(xi) AHU Room: fresh air opening, water connection, Drainage arrangement, Acoustic lining,

(xii) Insulation of wall/ceiling between AC non-AC areas.

3.12 Water Requirement for Air Conditioning

Total water requirements of air conditioning plant shall be assessed @ 15 litre/TR/Hr of plant operation. For 24 hour operation, the number of operating hours shall be considered as 16. For small central plants (up to 120 TR) a makeup water tank of one day's capacity shall be provided along the cooling towers. The bottom of this make up tank shall be at least 0.75 m above the sump level of cooling tower. For large size central plants an underground tank of one day's water requirement capacity shall have to be provided near the A.C. Plant room and a makeup water tank of 4 hours water requirement shall be provided near the cooling towers.

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CHAPTER-4
PACKAGED TYPE AIR CONDITIONING PLANTS AND VARIBALE REFRIGERANT FLOW/ VOLUME SYSTEM

4.1 WATER COOLED PACKAGED TYPE PLANTS

4.1.1 Scope

This chapter covers the requirements of packaged type air-conditioning plants with water-cooled condensers of 5, 7.5, 10, 15 and 20 TR capacities.

4.1.2 General Construction

(i) The packaged type plants shall be self-contained units generally conforming to **IS:** 8148: 2018 (Reaffirmed 2022) (packaged air- conditioner). The plant may have a single or multi refrigeration circuit as per design of respective manufacturers. Each compressor, however, shall have a independent condenser, evaporator & refrigerant circuit.

(ii) The packaged unit shall be constructed with adequate strength and rigidity to withstand handling, transportation and usage.

(iii) The unit shall be fabricated so as to be free from undue noise and vibration. All valves and refrigerant piping shall be suitably clamped.

(iv) The internal components of the unit shall be located so as to be easily accessible for inspection and maintenance. All parts which are accident hazard shall be effectively guarded.

(v) Due care shall be taken in the use of materials likely to come in contact with water, namely, condensate tray, etc. by the use of corrosion resistant material, or by treatment with corrosion resistant coating.

(vi) The unit shall be completely factory assembled.

4.1.3 Cabinet

(i) The cabinet will have a frame work of either M.S. angles or formed M.S. sheet sections in order to provide structural rigidity. Properly formed close fittings and easily removable sheet metal panels shall be provided all around this frame work to make a closed & streamlined cabinet. The sheet used shall be of minimum 1.25 mm thickness.

(ii) Inside and outside surfaces shall be finished with polyester epoxy powder coating.

(iii) The fan section and coil section of cabinet shall be insulated with at least 25mm resin bonded fibre glass lining on the inside duly finished with minimum 0.5mm thick aluminum sheet.

(iv) An insulated condensate tray shall be provided beneath the cooling coil so as to avoid dripping over the equipment installed in the lower portion of the cabinet. The drip tray should have a drain connection for leading away the condensate.

(v) A conditioned air outlet from the cabinet should be provided with suitable flanges in order to connect it to the canvas of the supply air ducting at the cabinet top.

(vi) A return grill of streamlined design shall be provided in the elevation in front of the filter section. This grill should be easily removable for inspection / maintenance of filter.

4.1.4 Compressor

(i) Compressor shall be scroll hermetic or semi hermetic type suitable for CFC/HCFC free refrigerant.

(ii) It shall be fitted with suction and discharge stop valves, permitting full servicing facilities, built in safety controls, filters, release valves, control valve and other standard accessories.
(iii) The compressor shall be installed on vibration isolating resilient material, so as to ensure operation with the minimum noise and vibrations.
(iv) Each compressor shall be provided with protection against high refrigerant pressure and low refrigerant pressure, anti-cycle timer, indication lamps, fault alarm etc. through microprocessor controller.
(v) Compressor shall be designed for 4.4 deg C suction temperature and 43.3 deg C discharge temperature.

4.1.5 Compressor Drive

(i) The compressor motor shall be squirrel cage induction motor capable of continuous operation at 415 V $\pm$ 10% , 50 Hz, 3 phase AC supply.
(ii) The motor shall be suction cooled, in case of sealed semi-hermetic type units.
(iii) The starter shall be as per para 13.9 and shall be provided on the packaged unit itself.

4.1.6 Condenser

(i) Condenser shall be of horizontal shell and tube construction with M.S. shell and integrally finned copper tubes. Thickness of tube shall be minimum 1.0 mm before finning.
(ii) The end covers shall be removable type and suitable provision shall be made in the unit cabinet, enabling easy cleaning of condenser tubes.
(iii) The condenser shall serve as liquid receiver for the refrigerant circuit & shall be complete with following: -
(a) Inlet and outlet refrigerant connections.
(b) Inlet and outlet water connections.
(c) Relief / purge valve and connections.
(d) Drain valve, air vent, test cock connection, facility with valves for descaling of tubes etc.

4.1.7 Cooling Coil

(i) Cooling coil shall be 3 or 4 rows deep, as per manufacturer's standards, made of copper tubes of minimum 0.5 mm thickness and aluminium fins of minimum 0.15 mm thickness, mechanically bonded to the coils.
(ii) No of fins per cm of tube shall be 4 to 5.
(iii) Coil shall be fitted with equalizing copper distributor to ensure that each coil circuit receives equal amount of refrigerant.
(iv) The coil shall be designed for a face velocity of not more than 155 m/min. Coil shall be thoroughly evacuated, dried and pressure tested to 21 Kg /sq.cm (300 psi).

4.1.8 Refrigerant Plumbing

(i) The unit shall be complete with refrigerant plumbing using copper tubes.
(ii) The refrigerant circuit shall include thermo-static expansion valve and suction gas strainer.
(iii) The work shall include provision of suction line insulation as per manufacturer standards.

4.1.9 Fan and Drive

(i) Fan shall be statically and dynamically balanced single/double inlet centrifugal type, designed for quiet operation. The fan wheel shall be constructed of aluminium or galvanised steel. Self-oiling bearing easily accessible for maintenance, with thrust collar shall be provided. Preferably, the bearings shall be life lubricated sealed type, mounted on vibration absorbing resilient supports.

(ii) The fan shall be belt driven through adjustable pulley permitting air quantity to be varied by adjusting the fan speed. Suitable fan belt tension adjusting arrangement shall be provided.

(iii) The fan motor shall be mounted within the cabinet. This shall be of TEFC enclosure, squirrel cage, induction motor of suitable HP for the duty involved. This shall be located with proper alignment with fan pulley for the belt drive.

(iv) Starter (DOL) and independent SPP shall be provided.

(v) The CMH and static pressure of the fan shall be as specified in the schedule of work.

4.1.10 Interlocking

The compressor motor shall be interlocked with the following:

(i) Air flow switch in the evaporator fan discharge

(ii) Differential pressure switch in the condenser water line

(iii) Condenser water pump

(iv) Cooling tower fan motor

4.1.11 Filters

(i) Cleanable aluminum wire mesh/ synthetic media type air filters, at least 25 mm thick, shall be provided, swung fit to prevent air by pass.

(ii) Face velocity across the filters shall not exceed 100 m/min.

4.1.12 Humidification

Where close control of RH is required provision of pan type humidifier shall be made as per para 6.2.3.5.

4.1.13 Micro process controller

Each packaged units shall be equipped with a micro-processor controller having all operating & safety controls.

4.1.14 Insulation

Insulation of packaged units shall be as per para 4.1.3 (iii) & Chapter 11 of these specification.

4.1.15 Power Consumption Rating for Packaged Air Conditioner under test conditions

Cooling Capacity		Maximum Power Consumption in Watts	
Watts	**Tons of Refrigeration**	**Water Cooled**	**Air Cooled**
10,000	3	3,750	4,750
17,500	5	6,000	7,000
26,250	7.5	9,000	10,000
35,000	10	11,500	13,500
52,000	15	17,000	20,000

4.2 AIR COOLED PACKAGED TYPE PLANTS

4.2.1 Scope

This chapter covers the requirements of packaged type air-conditioning plants with air-cooled condensers of 5, 7.5, 10, 15 and 20 TR capacities.

4.2.2 General Construction

(i) The air-cooled package unit shall be supplied in two portions –outdoor portion made up of the condenser & condenser fan and indoor unit made up of the evaporator & evaporator fan. The compressor can be provided along with the condenser or the evaporator depending upon the manufacturer's practice or the required application at site.

(ii) The two portions shall be piped together at site.

(iii) General construction shall be as per 4.1.2.

4.2.3 Cabinet

The cabinet shall be provided separately for the two portions as shown per para 4.1.3.

4.2.4 Compressor and Compressor Drive

These shall be as per 4.1.4 and 4.1.5

4.2.5 Condenser

The condenser shall be air-cooled and shall be in general conforming to para 5.5.4

4.2.6 Cooling Coil

This shall be as per 4.1.7

4.2.7 Refrigerant Piping

This shall be as per 4.1.8.

4.2.8 Fan and Drive

(i) These shall be as per 4.1.9.

(ii) Separate fans along with their drives shall be provided for the condenser and evaporator portions.

4.2.9 The compressor motor shall be interlocked with the following:

(i) Air flow switch in the evaporator fan discharge.

(ii) Air flow switch in the condenser fan discharge.

4.2.10 Filters

These shall be as per 4.1.11

4.2.11 Humidification

Where specified, this shall be provided as per 4.1.12

4.2.12 Insulation

Insulation of packaged units shall be as per para 4.1.3 (iii) & Chapter 11 of these specification.

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4.3 VARIBALE REFRIGERANT VOLUME/ FLOW SYSTEM

The system selected is a modular system, with number of indoors connected to centrally located outdoor units. The outdoor units for all the system shall be air cooled type.

4.3.1 General Description

All the VRF air conditioners shall be fully factory assembled, wired, internally piped & tested. The outdoor unit shall be pre-charged with first charge of refrigerant. Additional charge shall be added as per refrigerant piping at site. All the units shall be suitable for operation with 415 V **+/-** 10%, 50 Hz + 3%, 3 Phase supply for outdoor units; & 220 V **+/-** 10%, 50 Hz +/- 3%, 1 Phase supply for indoor units.

4.3.2 Specifications of Outdoor units :

(i) Outdoors units of the VRV system shall be compact air cooled type.

(ii) The outdoor unit should comprise of Inverter controlled Twin Rotary Compressor / Scroll Compressor

(iii) Each module of outdoor unit must have at least 100 % of Variable compressor which can work on Part load Suitable to operate at heat load proportional to indoor requirement. Multi compressors to be provided beyond **10 HP** Capacity.

(iv) The ODU must deliver COP of minimum 3.5 at full load at AHRI conditions and minimum IEER shall be as per Table 2.8. The ODU shall be tested and rated for capacity and efficiency for outside air Temperature of 42 Degree Celsius for cooling and 1 degree Celsius for heating unless otherwise mentioned in NIT.

(v) The outdoor units must be suitable for up to 180 m refrigerant piping between outdoor unit & the farthest indoor units. Allowable level difference between outdoor unit & indoor units shall be 50 m in case of outdoor unit on top & 40 m in case of outdoor unit at bottom.

(vi) Allowable level difference between various indoor units connected to one out door unit shall be up to 15 m.

(vii) The outdoor units shall be suitable to operate within an ambient temperature range of 5 Deg C to 51 Deg C in cooling mode; & -20 Deg C to 15 Deg C in heating mode.

(viii) The entire operation of outdoor units shall be through independent remotes of indoor units. No separate Start/ Stop function shall be required.

(ix) Starter for the Outdoor Unit compressor shall be “Direct on Line” type. Inverter compressor of the unit shall start first & at the minimum frequency, to reduce the inrush current during starting.

(x) Complete refrigerant circuit, oil balancing/ equalizing circuit shall be factory assembled & tested.

(xi) When outside temperature is more than 44^{o}C then the performance of VRF system degraded therefore in such scenario chiller based central plant system shall be preferred over VRF.

(xii) Multi compressors to be provided beyond 10 HP Capacity (Single ODU).

4.3.3 Specifications of Indoor units :

The units include pre-filter, fan section and DX coil section. The housing of units shall be light weight powder coated galvanized steel. Units shall have external casing of ABS Plastic for supply and return air.

(i) 4 Way/360 Degree airflow Cassette type indoor units

(a) These units shall be installed between the bottom of finished slab & top of false ceiling.

(b) Unit shall have provision of connecting fresh air without any special chamber & without increasing the total height of the unit (320 mm maximum).

(c) The unit must have in built drain pump, suitable for vertical lift of 750 mm.
(d) Unit must be insulated with sound absorbing thermal insulation material, Polyurethane foam. The sound pressure level of unit at the highest operating level shall not exceed 46 dB (A).
(e) The unit must have drain pump kit if. The drain pump must be suitable to lift drain up to 1000 mm from the bottom of the unit.

(ii) 4 Way/360 Degree airflow Compact Cassette type indoor units

(a) The compact cassette unit should perfectly fit into ceilings and match the standard architectural modules, without the need to cut ceiling tiles.
(b) The flaps fold tightly against the ceiling when operation stops so that the ceiling is affected only slightly even if air conditioning is installed.
(c) Designed for simple & easy installation and maintenance. It should be slim in design only 268 mm in height even when an electrical box is located inside the unit.
(d) The unit must have drain pump kit if. The drain pump must be suitable to lift drain up to 1000 mm from the bottom of the unit.

(iii) Concealed duct type units

(a) These units shall be ceiling suspended with suitable supports to take care of operating weight of the unit, without causing any excessive vibration & noise.
(b) The cold air supplied by these units will be supplied to the area to be air conditioned, through duct system specified in the tender.
(c) Each indoor unit must have electronic expansion valve operated by microprocessor thermostat based temperature control to deliver cooling/ heating as per the heat load of the room
(d) The Sound Pressure level of unit at the highest operating level shall not exceed 38 dB (A), at a vertical distance of 1.5 m below the units with duct connected to the unit.
(e) The unit must have provision of adding drain pump kit if required & specified. The drain pump must be suitable to lift drain up to 1000 mm from the bottom of the unit.

(iv) Wall Mounted Units

(a) Wall mounted units must be compact & stylish design that does not detract from the décor of the room.
(b) Each indoor unit must have electronic expansion valve operated by microprocessor thermostat based temperature control to deliver cooling/ heating as per the heat load of the room.
(c) The unit must have provision of adding drain pump kit if required & specified. The drain pump must be suitable to lift drain up to 1000 mm from the bottom of the unit.
(d) The sound pressure level of unit at the highest operating level shall not exceed 46 dB(A).
(e) Refrigerant control in the indoor unit shall be through Electronic Expansion Valve.

(v) Installation

(a) The units shall be mounted on ribbed rubber pads for vibration isolation. The contractor shall supply the required charge of refrigerant, lubricant and other consumables, for commissioning and testing of the equipment.
(b) All the equipment shall be thoroughly tested and checked for leaks. All safety controls shall be suitably set and a record of all setting shall be furnished to the project supervisor.

(c) Providing and fixing M.S. structural support for condensing unit with vibration isolator pad in-between support and structure and vibration isolation suspender and pads for evaporating units shall be in scope of contractor.

(d) OEM of VRF units or authorized vendor of the OEM shall verify, validate and certify the installation and testing/commissioning of copper piping system.

(vi) Painting

Shop coats of paint that have become marred during transportation or erection shall be cleaned off with mineral spirits, wire brushed and spot primed over the affected areas, then coated with enamel paint to match the finish over the adjoining shop- painted surfaces.

(vii) Condensate Drain Piping

All pipes to be used for condensate drain shall be PVC pipe conforming to IS: 4985 - Class I & all joints should be Gluing or solvent cementing as per manufacturer recommendation.

(viii) Refrigerant Piping

(a) All refrigerant pipes and fittings shall be soft drawn/ half hard/hard drawn copper tubes and wrought copper fitting suitable for connection with silver solder. Soft Drawn copper pipes shall be used only up to pipe size of 15.86 mm. The thickness of wall of copper tubes shall be 1.2 mm for tube size from 6.4 mm to 28.6 mm and 1.62 mm thickness for tube size above 31.8 mm up to 54 mm.

(b)

(i) The Copper Piping & Piping Circuit should be with Minimum Number of joints to avoid the leakage probability, which shall be attained by :

  (a) Using preferably less joint piping system e.g. One End Expanded Tubes.

  (b) Bending the tubes instead of using elbow joints wherever 90 degree bending is required.

(ii) Piping should be routed at site in such a manner, that brazed joints in the refrigeration piping are kept to a minimum.

(iii) The makes of tube fittings shall be same as that of tubes

(iv) The thickness of fittings used shall be same as that of the pipe.

(c) All joints in copper piping shall be swaged joints using low temperature brazing and/ or silver solder. Before jointing any copper pipe or fittings, its interior shall be thoroughly cleaned be passing a clean cloth via wire or cable through its entire length. The piping shall be continuously kept clean of dirt etc. The nitrogen gas must be purged for protecting copper pipe during brazing operation. After brazing allow it for natural cooling.

(d) Refrigerant lines shall be sized to limit pressure drop between evaporator and condensing unit to less than 0.2 kg per Sq.cm.

(e) After the refrigerant piping installation has been completed the refrigerant piping system shall be pressure tested using, Freon mixed with nitrogen at a pressure of 20 Kg per Sq. cm. (High side) and 10 Kg per Sq. cm (Low side). Pressure shall be maintained on the system for 24 hours.

(f) The system shall then be evacuated to a minimum vacuum of 70 cm. of mercury and held for 24 hours, during which time; change in vacuum shall not exceed 12 cm of mercury.

(g) All refrigerant piping shall be installed strictly as per the instructions and recommendations of air conditioning equipment manufacturers.

(h) The refrigerant copper tubes shall be comply with ASTM B280 (Standard specification for seem less copper tube for air conditioning and refrigeration).

(i) The refrigerant Copper tube fittings shall conform to ASME B16.18/B16.22/ B16.26/ B16.50. However, copper tube fitting used for brazed connections in air conditioning and refrigeration system shall comply with ASME standard B16.22. The refrigerant copper tube fitting shall be of same manufacturers as of copper tubes. The thickness of all copper tubes fitting shall be equal to or greater than thickness of copper tubes.

(j) All pipes must be tested for defects using Eddy Current Testing and other test as per ASTM B280-16.

(k) Joints in refrigerant piping should be kept as minimum as possible. The use of elbows, sockets, bends etc. shall be avoided and as per requirement the copper tubes shall be suitably bend with automatic bending machine.

(l) Each copper tube shall be marked (embossed) with manufacturer name, OD in mm, wall thickness in mm, lot number, month & year of manufacturer and conforming standard (as applicable).

(m) The copper tube fitting shall be marked (embossed) with manufacturer name, OD in mm and wall thickness in mm.

CHAPTER–5
CENTRAL AIR CONDITIONING PLANT

5.1 SCOPE

This chapter describes central Air-conditioning plant with factory assembled & tested chilling units comprising of scroll/ centrifugal/ screw compressor, as the case may be, direct driven with electric motor, water/ air-cooled condenser, chiller, connecting refrigerant plumbing, microprocessor based safeties and controls including first charge of refrigerant & compressor oil.

5.2 SCROLL COMPRESSORS:

(a) Compressors: Shall be hermetic, scroll-type, including:

(i) Compliant design for axial and radial sealing.

(ii) Refrigerant flow through the compressor with 100% suction cooled motor.

(iii) Large suction side free volume and oil sump to provide liquid handling capability.

(iv) Compressor crankcase heaters to provide extra liquid migration protection.

(v) Annular discharge check valve and reverse vent assembly to provide low-pressure drop, silent shutdown and reverse rotation protection.

(vi) Initial oil charge.

(vii) Oil level sight glass.

(viii) Vibration isolator mounts for compressors.

(ix) Brazed-type/ shell and tube connections for fully hermetic refrigerant circuits.

(x) Compressor Motor overload protection capable of monitoring compressor motor current. Provides extra protection against compressor reverse rotation, phase-loss and phase-imbalance.

(xi) Variable Speed Drive (VSD/VFD)/ Fixed Speed Drive - As per NIT requirement.

(xii) Journal bearings.

(xiii) Motor Starters: Motor starters shall be zero electrical inrush current (Variable Frequency Drives) or reduced inrush type (Closed transition Star-Delta or Solid State) for minimum electrical inrush. Open transition Star-Delta and Across the Line type starters will not be acceptable.

Chiller power consumption values shall be not more than for 4 Star chiller as per BEE star labeling norms.

5.3 CENTRIFUGAL COMPRESSORS

5.3.1 Type- Centrifugal compressor shall be single or multi stage open/ semi-hermetic sealed/ totally hermetic sealed type. It shall be working on **refrigerants having lowest toxicity & no flame propagation as per A-1 category given in ASHRE standard 34 classifications of refrigerants with zero ODP**. The impeller shall be of shrouded design and made of cast aluminum alloy of high strength and protected against corrosion. This shall be statically and dynamically balanced and over speed tested so as to ensure vibration free operation. The impeller shaft or drive end of the gear shaft, as the case may be, shall be connected with the motor through a flexible coupling in case of open design and rotor shaft in case of hermetic design. The compressor casing shall be of high strength ductile casting and of such design that servicing can be carried out without disturbing connections.

5.3.2 Drive gear

(i) The centrifugal compressor shall be variable speed.

(ii) The variable speed compressor shall have compressor/ chiller manufacturer's factory matched variable speed drive.

(iii) Where the impeller is designed for operation at speed higher than the drive motor, necessary speed increasing gear shall be connected to the impeller shaft in a self aligning and balanced way. The gears and pinion shall be pressure lubricated.

(iv) Variable speed drive shall be installed with appropriate controls in accordance with para 5.3.11.

5.3.3 Bearings

The compressor shall incorporate the necessary design features to take both axial and radial thrusts. The bearings shall be of self aligning type. The bearing shall be pressure lubricated during operation and shall be completely sequenced and interlocked with the start up of the machine in such a way that oil pump should start earlier than the machine and the machine should start after some time, provided the required oil temperature and pressure is maintained during the start up period.

5.3.4 Shaft seal

The compressor shaft seal (in case of open type machines) shall be as per manufacturer's standard design.

The seal should have small face area and low rubbing speed. It should provide an efficient seal under both vacuum and pressure lubricated during compressor operation. The seal must effectively prevent the leakage of refrigerant along the shaft during shut down periods. During operation an oil film should prevent outward leakage of refrigerant or ingress of moisture.

5.3.5 Lubrication system

Lubrication system must ensure complete forced and speed lubrication (at a pressure and controlled temperature) to all bearing surfaces under any speed conditions, at start up, at shut down and during operation at various loads. Adequate arrangement shall be provided to take care of lubrication during failure of power or abnormal shutdown. Full lubrication must be available to the machine during acceleration and deceleration periods through an automatic auxiliary motor driven pump. The lubrication system should include the following:

(i) Oil pump, Pressure control valve, Fil**ter mesh.**

(ii) **Pressure gauge, thermometer,** Oil level indicator, pressure sensor, temperature sensor.

(iii) Oil coolers and oil heaters (with built-in thermostat to aid maintaining constant temperature).

5.3.6 The compressor shall be complete with all accessories such as drive arrangement (for open drive machines), capacity control, safety controls.

5.3.7 Capacity Control

Capacity Control with VFD :

The centrifugal compressor shall be equipped for modulating capacity from 100% to 25% at constant condenser entering water temperature through variable frequency drive with appropriate controls.

5.3.8 Safety Control

Safety controls shall be provided as per details given under para 12.2 "Equipment Safety controls."

5.3.9 Inter locking

The compressor motor shall be interlocked with the following: -

(i) Differential pressure switch in the chilled water line(s) in case of chilled water system, and air flow switch in the evaporator fan discharge in the case of direct expansion system.

(ii) Differential pressure switch in the condenser water line(s) in case of water cooled condenser and air flow switch in the condenser fan discharge in the case of air cooled condenser.

(iii) Anti-freeze thermostat in case of chiller.

(iv) Condenser water pump in case of water cooled condenser and condenser fan in case of air cooled condenser.

(v) Chilled water pump in case of chilled water system and evaporator fan in case of direct expansion system.

The interlocks shall be provided with indicating lamps or flags in the control panel in the refrigeration plant room.

5.3.10 Drive motor

(i) The drive motor shall be an independent and coupler type or semi-hermetic/ hermetic type depending on the design adopted by the manufacturer.

(ii) The electric motor shall be of squirrel cage induction type motor, class 'F' insulation and shall be suitable for operation on 400/415 V $\pm$ 10%, 3 phase, 50 Hz, AC supply. **All Compressor motors in Centrifugal chillers with variable speed compressors shall be provided with VFD and shall also be suitably designed for use with Variable Frequency Drive having THD less than 5%.** The variable speed drive shall be supplied by chiller OEM and tested at the manufacturer's work.

(iii) Synchronous speed of the motor shall not exceed 3000 RPM.

(iv) Continuous BHP rating of the motor shall not be less than the maximum power requirement of the compressor and drive under specified design conditions. For open type compressor, the continuous B.H.P. rating of the motor shall be at least 110% of the maximum power requirement of compressor and drive under specified design conditions.

(v) The motor shall be TEFC/TERC/TEAC or SPDP as per installation requirement for open type chiller unit and Totally Enclosed refrigerant cooled for hermatic / semi hermatic type chiller unit. **For outdoor (exposed to atmosphere) chiller applications, TEFC/TERC/TEAC motor shall be used. Motor protection shall be minimum IP 54.**

(vi) Motor protection during over current shall be provided through winding temperature sensor in case of refrigerant cooled motors/ current sensing in each phase through microprocessor in case of open type air cooled motors.

(vii) Power factor correction capacitors as required to maintain a displacement power factor of 95% at all load conditions shall be provided for VFD Motor.

5.3.11 Motor starter

(i) For variable speed compressor:

(a) In Case of VSD starter, it will vary the compressor motor speed by controlling the frequency and voltage of the electrical power to the motor. The adaptive capacity control logic shall automatically adjust motor speed and compressor pre-rotation vane position independently for maximum part-load efficiency by analyzing information fed to it by sensors located throughout the chiller.

(b) To Limit Harmonic generation from VSD, Active Harmonic Filters as per IEEE 519 must be used at the source itself.

(c) Drive will be PWM type utilizing IGBT's with a power factor of 0.95 or better at all loads and speeds.

(d) Make of VSD shall be exactly same as per global catalogue / practice of OEM. The variable speed drive shall be with all power and control wiring between the drive and chiller factory installed, including power to the chiller oil pump.

(e) Field power wiring shall be a single point connection and electrical lugs for incoming power wiring will be provided.

(ii) The following features will be provided:

(a) Door interlocked circuit breaker capable of being padlocked.

(b) ground fault protection.

(c) Over voltage and under voltage protection.

(d) 3-phase sensing motor over current protection.

(e) Single phase protection.

(f) Insensitive to phase rotation.

(g) Over temperature protection.

Digital readout at the chiller unit control panel of output frequency, output voltage, 3-phase output current, input Kilowatts and Kilowatt-hours, self-diagnostic service parameters. Separate meters for this information will not be acceptable.

5.4 SCREW TYPE COMPRESSOR

5.4.1 The screw compressor shall have a rotary mono/ twin screw, and may be of open/ Semi-sealed / totally (hermetic) sealed type. It shall be using refrigerants **having lowest toxicity & no flame propagation as per A-1 category given in ASHRE standard 34 classifications of refrigerants with zero ODP.**

5.4.2 **The screw compressor shall be variable speed. T**he variable speed compressor shall have factory mounted variable speed drive.

The mono/ twin rotary screw shall be manufactured from forged steel. The profile of screws shall permit safe operation upto a speed of 3000 RPM for 50 Hz operation.

The compressor shall unload from fully loaded to the minimum capacity by means of **VFD.**

5.4.3 The compressor housing shall be of high grade cast iron, machined with precision, to provide a very close tolerance between the rotor(s) and the housing.

5.4.4 The rotor(s) shall be mounted on antifriction bearings designed to reduce friction and power input. There shall be multiple cylindrical bearings to handle the radial and axial loads.

5.4.5 There shall be built in oil reservoir to ensure full supply of lubricants to all bearings and a check valve to prevent backspin during shut down.

5.4.6 There shall be oil pump or other means of differential pressure inside the compressor for forced lubrication of all parts during startup, running and during shut down. An oil sump heater shall be provided in the casing.

5.4.7 The open type compressor shall also have a suitable shaft seal, to prevent leakage of refrigerant.

5.4.8 The units shall be complete with automatic capacity control mechanism, to permit modulation between 25% to 100% of capacity range.

5.4.9 Interlocking

It shall be as per details given in para 5.3.9.

5.4.10 The driving motor shall be double squirrel cage type or suitable hermetic/ Semi hermetic/ open type as required, protected against damage by means of built in protection devices. Motor protection shall be minimum IP 54.

5.4.11 Compressor motor and starters

These shall be as per details given under para 5.3.10, a**ll compressor motors in screw chillers shall be provided with VFD having THD less than 5% and VFD shall be factory fitted.**

(i) Continuous BHP rating shall be as per para 5.3.10(iv)

(ii) Motor Starters: Motor starters shall be zero electrical inrush current (Variable Frequency Drives).

(iii) Power factor correction capacitors as required to maintain a displacement power factor of 95% at all load conditions shall be provided.

5.5 MAGNETIC BEARING VARIABLE SPEED CENTRIFUGAL WATER CHILLERS

5.5.1 General Description

(i) Packaged centrifugal chiller including the following: evaporator, motor and compressor, capacity control device, condenser with integral sub cooler, refrigerant metering device, lubrication system, motor starter, control panel with user interface, and – if required – a refrigerant purge system.

(ii) Chiller shall be utilizing an CFC and HCFC free refrigerant that has an Ozone Depletion Potential (ODP) of ZERO, and that has no refrigerant production phase-out date and no phase out date for equipment that uses that refrigerant.

(iii) Refrigerant isolation valves: two butterfly valves, one on the compressor discharge line and one on the liquid line.

5.5.2 Refrigerant flow control

(i) Variable orifice or electronic expansion valve. Refrigerant level control: Through electronic expansion valve.

(ii) Refrigerant level sensing: Monitor refrigerant level in the condenser or in cooler; report refrigerant level back to unit control panel and control chiller accordingly.

5.5.3 Compressor

(i) Single stage or multi stage Semi/ hermetic sealed

(ii) Fully accessible housing with vertical circular joints.

(iii) Direct driven

(iv) Magnetic bearings

(a) Levitated shaft position shall be actively controlled and monitored by an X-, Y-, and Z-axis digital position sensor.

(b) The compressor shall be capable of coming to a controlled, safe stop in the event of a power failure by diverting stored power from the DC bus to the magnetic bearing control system.

(c) **Magnetic bearing control shall be equipped with auto vibration reduction and balancing systems.**

(v) Pre-rotation guide vanes positioned by solid rod linkage and connected to an easily serviceable, externally mounted electric actuator.

(vi) Mechanical linkage system that continuously monitors compressor-discharge gas characteristics and optimizes diffuser spacing to minimize impeller gas-flow disruptions.

(vii) The driveline (compressor and motor) and chiller starter shall be individual unit assemblies or integrated allowing for independent inspection, service, and repair/replacement. If an integrated driveline and starter package is utilized which is not fully field repairable, the supplier must provide one spare package with the unit.

(viii) The chiller shall utilize a single compressor that delivers the specified performance at all load and lift conditions.

5.5.4 Motor

(i) Semi-hermetic permanent magnet motor / BLDC.

(ii) Electrical connection: Steel terminal box with gasketed front access cover; overload and overcurrent transformers.

5.5.5 Compressor Motor Starter: Variable Speed Drive

(i) General: Variable Speed Drive (VSD) compressor motor starter to start motor and control motor speed be controlling the frequency and voltage of the electrical power supplied to the motor.

(ii) Drive type: Pulse width modulated (PWM) utilizing insulated gate bipolar transistors (IGBTs).

(iii) Control Logic: Independently control motor speed and pre rotation vane (PRV) position for optimum efficiency and operational stability. Base motor speed and PRV position on a minimum of 4 inputs: leaving chilled water temperature, return chilled water temperature, evaporator refrigerant pressure, condenser refrigerant pressure; Verify motor speed and PRV position and also use as inputs to the control logic.

(iv) Power Factor: At all loads and speeds, provide a minimum of a 0.95 power factor.

(v) Enclosure: IP42 or higher type with hinged access door with door interlock, lock and keys, and padlockable

(vi) Cooling: Cool drive pole assembly components and internal ambient air via fluid-cooled, closed loop; all starter components accessible for service and replacement without opening the chiller’s main refrigerant circuit.

(vii) Harmonic Distortion: Provide a drive and chiller system with an integrated active harmonic filter mounted inside the starter cabinet. System must generate harmonic distortion levels less than the following, measured at the input side of the drive:
Current: 5% maximum current total demand distortion

(viii) Inrush amperage: Limited to the design full load amperage of the chiller.

(ix) Protective devices:

(a) Electronic current-sensing overloads (1 per phase) – with indicating message on the control panel and reset button; shut down chiller upon detection of operating current exceeding 105% full load amperage.

(b) High instantaneous current overload – with indicating message on the control panel and reset button; shut down chiller upon detection of starting current exceeding 115% of design inrush starting current for 1 second.
(c) Phase rotation insensitivity
(d) Single phase failure protection circuit with indicating light – shut unit down if power loss occurs in any phase at startup.
(e) High temperature safety protection system on IGBTs with indicating light and reset button; via thermistors embedded on IGBT heat sinks – shut unit down if IGBT temperature exceeds acceptable limits.
(f) Power fault protection for momentary power interruptions – interrupt power to the compressor motor within 4 line cycles upon detection of power interruptions longer than ¾ of a line cycle.
(g) High and low line voltage protection.

5.6 CONDENSER

5.6.1 Scope

This chapter covers the requirements of condensers suitable for screw, Scroll and centrifugal types of refrigeration machines for central air-conditioning and cold room applications.

5.6.2 Type

This section covers the following types of condensers: -
(i) Water cooled condensers, and
(ii) Air cooled condensers.
Evaporative condensers are excluded from the scope of these specifications.

5.6.3 Water Cooled Condensers

5.6.3.1 Rating

(i) Where a package condensing or water chilling unit is required, the condenser capacity shall match the compressor capacity specified in the tender specifications. The condenser shall be selected for 4.2 degree C temperature rise of water through the condenser unless otherwise specified in the tender specifications.
(ii) The condenser shall be designed for a fouling factor of 0.0002 hr. sq.m. degree C difference / K.Cal unless otherwise specified in the tender specifications.

5.6.3.2 Material and Construction

(i) The condenser shall be horizontal, shell and tube type, designed, constructed and tested for the refrigerant specified in the tender specifications.
(ii) The shell of the condenser shall be made of MS of thickness not less than 8mm, with electric fusion welded seams. The shell capacity shall be such as to hold 1.25 times the refrigerant charge in the machine of which the condenser is a part, under pumped down conditions.
(iii) The end plates of condenser shall be made of MS of thickness not less than 25mm.
(iv) The condenser shall be designed for a working pressure on the refrigerant side suitable for the refrigerant offered, and on the water side for 10 kg./sq.cm. gauge.
(v) The tubes shall be of seamless hard drawn copper and finned, unless otherwise specified. The minimum wall thickness shall be 1.0 mm with root thickness of 0.63 mm below the fins.

(vi) Intermediate tube supports of steel shall be provided at not more than 1250 mm intervals to prevent sagging and vibration of the tubes. The condensers shall have water boxes designed for multi pass flow.

(vii) The tubes may be provided with special tabulating arrangement to improve heat transfer where such an arrangement is a standard design of the manufacturer.

(viii) The condensers shall be provided with removable heads on either side made of cast iron or steel with neatly machined surface for effective jointing with the shell for easy accessibility for cleaning/replacement of the tubes. Suitable baffles shall be incorporated to achieve the required number of passes. It should be possible to descale the tubes without disconnecting the water line connections, wherever marine water boxes have been specified in the tender documents.

(ix) The condenser shall be provided with baffle arrangement for preventing direct impingement of hot gas over the tubes and to enable even distribution of the gas over the tube bundles.

(x) The condenser shall include necessary provision for sub-cooling of the refrigerant where the refrigerating machine is selected with such sub-cooling requirement. The arrangement shall be such that the cold water entering the condenser first cools the liquid refrigerant in the sub-cooler.

(xi) The condenser shall be sand blasted from both inside & outside.

5.6.3.3 Connections and Accessories

The condenser shall be provided with the following connections and accessories and conforming to Section "Refrigerant Piping" where applicable: -

(a) Hot gas inlet and liquid outlet connections. The liquid line connections shall be provided with isolating valves.

(b) Water inlet and outlet connections

(c) Pressure relief device,

(d) Drain connection with valve for water side.

(e) Differential flow switch/ pressure switch/ flow switch / flow sensor in the water line(s).

5.6.3.4 Pressure Testing

(a) The condenser shall be tested at the works to 1.5 times the maximum working pressure for the refrigerant or as specified in the tender specifications.

(b) The water side of the condenser shall also be tested to a hydraulic pressure of 10 kg./sq.cm in the works.

(c) Pressure test certificates shall be produced in respect of each condenser.

5.6.3.5 Treated Water for Condensers

All high-rise buildings using centralized cooling water system shall use soft water for the condenser and chilled water system.

5.6.4 Air Cooled Condensers

5.6.4.1 Material and Construction

(i) The condenser coil shall be fabricated of seamless hard drawn copper tubes and aluminium fins of 0.18 mm minimum thickness, fins spacing ranging from 3 to 5 fins per cm. The minimum wall thickness of tubes shall be 1.0 mm.

(ii) The coil shall normally be 3/4 rows deep unless otherwise specified.

(iii) The condenser shall be designed so as to hold 1.25 times the refrigerant charge in the system during the idle periods.

(iv) Suitable number and capacity of propeller type fans shall be provided for moving the air through the entire condenser coils. For more uniform flow over the condenser coil, the condenser shall be designed on the draw through principle. The air velocity over the condenser coil shall be maintained upto 200 mpm maximum.

5.6.4.2 Connections and Accessories

The following connections and accessories shall be provided on the condenser and conforming to Section "Refrigeration Piping" where applicable: -

(a) Hot gas inlet and liquid outlet connections. The liquid outlet connections shall be provided with isolating valves,

(b) Pressure relief device,

5.6.4.3 Pressure Testing

The pressure testing shall be done at 31 kg/sq.cm on refrigerant side.

5.6.4.4 Condenser Locations

Care shall be exercised in locating the condensers in such a manner that the heat sink is free of interference from heat discharge by devices located in adjoining spaces and also does not interfere with such other systems installed nearby.

Condensers should be located in such a manner that there is no restriction to the air flow around the condenser coils, there is no short-circuiting of discharge air to the intake side, and the heat discharge of other adjacent equipment is not anywhere the air intake of the condenser.

5.7 CHILLER

5.7.1 Scope

This chapter covers the requirements of chillers suitable for centrifugal, scroll and screw types of refrigerating machines for air-conditioning.

5.7.2 Types

This section covers the shell and tube type water chillers. These may be again of the following types: -

(a) For centrifugal type units the chiller shall be of flooded type or falling film type.

(b) For screw type units the chiller shall be of Direct expansion (DX) type or Flooded type or falling film type.

(c) For scroll type units chiller shall be shell and tube type or brazed plated type.

5.7.3 Shell and Tube Type Water Chillers

5.7.3.1 Rating:

(i) In a package water chilling machine, the chiller shall match the compressor capacity specified in the tender specifications. The chiller shall be selected for 4.4 degree C temperature drop of water through the chiller for scroll compressor & 5.5 deg C for centrifugal & screw type compressors.

(ii) The fouling factor shall be 0.0001 hr. sq.mtr. degree C temperature difference/K. Cal. unless otherwise specified in the tender specifications.

5.7.3.2 Material and Construction

(i) The water chiller shall be horizontal, shell and tube type, designed, constructed and tested for the refrigerant specified in the tender specifications.

(ii) The chiller shall be designed for a working pressure on the refrigerant side suitable for the refrigerant offered, and on the water side for 10 kg./sq.cm. gauge.
(iii) The end plates of chiller shall be made of MS of thickness not less than 25mm.
(iv) The shell of the chiller shall be made of MS of thickness not less than 8mm with electric fusion welded seams.
(v) The tubes shall be of seamless, hard drawn copper with a minimum tube wall thickness of 0.71 mm for plain tubes & minimum 0.63mm at the root of fins.
(vi) The tubes shall be plain for DX type chillers and may be either plain or internally finned for flooded type chillers as per manufacturer's design.
(vii) The tubes shall be rolled into grooves in the tube sheets and flared at ends.
(viii) Intermediate tube supports of steel or polypropylene shall be provided at spacing not less than 1250 mm for flooded type chiller and 500mm for DX type chiller to prevent sagging / vibration of tubes.
(ix) The flooded chillers shall have water boxes designed for multipass flow. The DX type chillers shall be provided with adequate number of properly spaced baffles so that the water passes through the tube bundle many times.
(x) The chiller shall be smooth finished with one coat of zinc chromate primer before the insulation is applied.
(xi) The chiller shall be sand blasted from both inside (before insertion of tubes) & outside.

5.7.3.3 Connections and Accessories

(a) For DX Type Chiller

The DX type chiller shall be provided with the following connections and accessories and conforming to the Section "Refrigeration Piping" where applicable: -

(i) Refrigerant inlet and outlet connections
(ii) Thermostatic / Electronic type expansion valve(s) with adjustable superheat control and external equalizer part,
(iii) Line solenoid valve, or pilot solenoid valves as required.
(iv) Water inlet and water outlet connections
(v) Drain connection with stop valve for water side only.
(vi) Vent connection with valve.
(vii) Flow switch in water line.

(b) For Flooded Type Chiller

The flooded type chiller shall be provided with the following connections and accessories and conforming to section "Refrigeration Piping" where applicable:

(i) Refrigeration inlet and outlet connections.
(ii) Liquid refrigerant float for level control/ expansion valve/ fixed or variable orifice.
(iii) Pressure relief device.
(iv) Charging connection with valve.
(v) Eliminator plate.
(vi) Drain and vent connections with valves
(vii) Water inlet and outlet connections
(viii) Proper oil return system.
(ix) Flow switch/pressure switch/differential flow switch/ flow sensor in the water line (s).

5.7.3.4 Pressure Testing

(a) The chiller shall be tested in the works to 1.5 times the maximum
(b) working pressure for the refrigerant or as specified in the tender specifications, or 21 kg./sq.cm. (Pneumatic), whichever is higher.

(c) The water side of the chiller shall also be tested to a hydraulic pressure of 10 kg./sq.cm at the works.

(d) Pressure test certificates shall be produced in respect of each chiller.

5.7.3.5 Insulation

The insulation shall be done as per chapter 11.

5.7.4 Minimum Efficiency of Chillers :

Chillers shall be AHRI certified. Cooling equipment shall meet or exceed the minimum efficiency requirements and other performance requirements of BEE 4 Star Label chillers and IS 16590 (as valid applicable for last date of submission of bid or last date of extended date of submission of bid).

Table 5.1

Minimum Efficiency for Water cooled Chiller

kW of cooling	ISEER
<260	6.10
>=260 & <530	6.80
>=530 & <1050	7.40
>=1050 & <1580	7.90
>=1580	8.20

Table 5.2

Minimum Efficiency for Air cooled Chiller

kW of cooling	ISEER
<260	4.00
>=260	4.30

5.8 CHILLER PLANT OPTIMIZER

Chiller Plant Optimizer shall be provided in the plant room for Chilling Unit (s), Chilled Water Pumps /Primary Chilled Water Pumps, Condenser Water Pumps. AHUs/FCUs and Cooling Towers. The Chiller Plant Optimizer shall be of the same manufacturer/ OEM as that of the Chilling Unit.

Optimization is to be done by monitoring and controlling of equipments like chillers, pumps, cooling towers and AHUs in association with control system. It also includes monitoring of ambient temperature and RH, temperature and RH of air-conditioned rooms, chilled water flow, temperature across chiller, pressure in and out across chiller, condenser water flow, temperature across condenser, pressure in and out across condenser, conductivity and PH of water in chilled water and cooling water, temperature and relative humidity at inlet of cooling tower, air velocity at cooling tower fan, temperature and pressure across AHUs and FCUs, flow across AHUs and FCUs, power of all the major power consuming equipments.

Then, control system builds all the coordination which enable access to chillers internal data. This data is used as input data to design efficient chiller control program.

5.9 REFRIGERANT PLUMBING

5.9.1 Design aspects of Refrigerant Plumbing

(i) **Refrigerant piping shall be designed and installed so as to**

(a) ensure circulation of adequate refrigerant at all loads.

(b) ensure oil return to crank case of compressor positively and continuously.

(c) keep pressure losses within limits, especially in suction lines.

(d) prevent oil/liquid refrigerant from entering the compressor when the compressor is working as well as when it has stopped.

(e) prevent trapping of oil in evaporator or suction lines, which may return to the compressor in the form of slug.

(ii) **Hot gas lines**

Oil shall be entrained and carried by hot gas under all load conditions likely to be encountered in normal operation.

(iii) **Liquid Lines**

(a) Liquid lines shall be designed to ensure that flashing of liquid refrigerant does not occur by minimising the pressure drop suitably, by avoiding long vertical risers, and appropriate sub cooling.

(b) Each liquid line shall be provided with a permanently installed refrigerant drier of throw away or rechargeable type. The drier shall be installed in a valved line.

(c) Flow indicator (moisture indicating type) shall be installed on all liquid lines.

(iv) **Suction Lines**

(a) Oil shall be entrained and carried by the suction gas under all conditions of load likely to be encountered in normal operation.

(b) Piping shall be designed for a suitable velocity of refrigerant (similar to hot gas line) to ensure that oil will not separate from the gas and drain to the compressor in slugs.

(c) The refrigeration system shall be equipped with controls for pump down system so that the evaporator and suction line are emptied before the compressor shuts off, thus preventing liquid refrigerant and oil from entering the compressor when restarted.

(d) Refrigerant lines shall be sized to limit pressure drop between evaporator and condensing unit to less than 0.2 kg. per sq.cm. (3 psi).

(v) Isolating valve shall be provided to enable isolation of each compressor in case of multiple compressor units (as built in valves), strainer, drier and any other components as may be required for proper operation and maintenance.

(vi) Thermostatic / Electronic type expansion valve/ float valve shall be provided in refrigerant circuit of DX system/ flooded system.

5.9.2 Material

(i) Refrigerant plumbing shall be with copper tubes, with tube thickness conforming to L type to ATM standards. The tubes shall be bright annealed copper upto and including 15 mm size. The tube shall be suitable for the duty involved.

(ii) Fittings like bends, tees, sockets etc. shall be of wrought copper or forged brass and shall be suitable for the duty involved. Flare type compression fittings of forged brass shall be allowed upto 15 mm piping size. Tubes upto and including 15 mm size may be bent to form 90 degree bends with inside radius not less than 3 tube diameters. For bigger sizes, bend fittings as mentioned above must be used.

(iii) Where specified in the tender specification, mild steel may be provided for refrigeration piping, with seamless MS tubes and fittings of heavy class conforming to IS: 1239. All liquid lines and instruments lines shall however be of copper only.

(iv) Valves shall be of the packed, back-seating type for both copper and MS refrigerant plumbing work, and these shall be of forged or cast brass construction.

5.9.3 Pressure Testing

(i) **After completion of the piping installation, the entire chilling unit shall be pressure tested with dry nitrogen or any other inert gas.**

This test shall be carried out as follows: -

(a) The system shall be charged with nitrogen or inert gas to 1.0 Kg./sq.cm. gauge and all joints shall be checked for leakage with a mixture of four part water, one part liquid soap and a small amount of glycerin. Leaks shall be marked, pressure released and repairs done. Brazed joints, which leak, shall be opened and redone. These shall not be repaired by addition of brazing alloy to the joints.

(b) The system shall now be charged with nitrogen or the inert gas to the pressure specified in the above table and the process of locating leaks and repairs shall be repeated.

(ii) **Final pressure test**

After all the leaks have been repaired, the system shall be retested with the test pressure maintained for a period of not less than 8 hours. No measurable drop in pressure should be detected after the pressure readings are adjusted for temperature changes.

Pressure gauges, controls and compressors may be valved off during pressure testing.

5.10 AUTOMATIC TUBE CLEANING SYSTEM (ATCS)

Automatic tube cleaning system with common injection cum collection pump or separate pumps for injection and collection shall be microprocessor controlled injection system which pushes an external cleaning agent such as soft balls or stars through the condenser tubes of the water cooled chiller. Frequency of injection shall be adjustable from micro processor based control panel.

Control valves for reversing directions of cleaning agents shall be provided and shall be operated from chiller control panel. Frequency of injection shall be settable from the microprocessor control panel.

Pumps shall have Y strainer on suction side and NRV on discharge side.

It is advisable for providing common ATCS system for all component requirements.

5.11 MICROPROCESSOR CONTROLLER

5.11.1 Each chilling unit shall be complete with a microprocessor based interactive control console in a locked enclosure factory mounted (directly on the unit), prewired with all operating and safety controls and tested.

5.11.2 It will provide start, stop, safety, interlock, capacity control and indications for operation of the chiller units through a alphanumeric / graphical display.

5.11.3 Controls shall provide to view and change digital programmable essential set points, cause of shutdown and type of restart required.

(a) Leaving chilled water temperature,

(b) Percent current limit.

(c) Remote reset temperature range.

(d) Reset of current limit.

5.11.4 All safety and cycling shutdowns shall be enunciated through the alphanumeric/ graphical display and consist of of system status, system details, day, time, cause of shutdown and type of restart required.

5.11.5 Cycling shutdown shall include low leaving chilled water temperature, chiller/ condenser water flow interruption, power fault, internal time clock and anti-recycle.

5.11.6 Safety shutdowns to be indicated through display and shall consist

5.11.7 The default display screen shall indicate the following minimum information

(i) date and time
(ii) return and leaving chilled water temperatures
(iii) return and leaving condenser water temperatures
(iv) differential oil pressure
(v) percent motor rated current
(vi) evaporator & condenser refrigerant saturation temperatures
(vii) chiller operating hours (hour run) and
(viii) number of compressor starts
(ix) oil sump temperature
(x) status message

5.11.8 The chiller control panel shall also provide:

(1) System operating information including:

(i) return and leaving chilled water temperature
(ii) return and leaving condenser water temperature
(iii) differential oil pressure
(iv) percentage motor current
(v) evaporator and condenser refrigerant temperature
(vi) compressor discharge temperature/pressure
(vii) oil reservoir temperature
(viii) compressor thrust bearing positioning and oil temperature
(ix) operating hours/Date & Time
(x) number of compressor starts
(xi) Chiller and condenser water flow rate
(xii) lubricating oil pump pressure
(xiii) bearing temperature
(xiv) VFD status

(2) Digital programming of set points through the universal keypad including:

(i) leaving chilled water temperature
(ii) percentage current limit
(iii) pull-down demand limiting
(iv) weekly schedule for starting and stopping the chiller, pumps and tower
(v) remote reset temperature range

(3) Status messages indicating:

(i) system ready to start
(ii) system running
(iii) system shutdown

(iv) system safety shutdown-manual restart
(v) system cycling shutdown-auto restart
(vi) start inhibit

(4) The text displayed within the system status and system details field shall be displayed as a color coded message to indicate severity:
Red for safety fault, orange for cycling faults, yellow for warnings, and green for normal messages.

5.11.9 Security access shall be provided to prevent unauthorized change of set points, to allow local or remote control of the chiller and to allow manual operation of the pre rotation vanes and oil pump.

5.11.10 The chiller shall be provided with ports compatible with **open protocol** building management system offered, to output all system operating information, shutdown/ cycling message and a record of last four cycling or safety shutdowns to a remote printer (option). The control centre shall be programmable to provide data logs to the printer at a set time interval.

5.11.11 Control center shall be able to interface with third party BMS.

5.11.12 On initiation of start, the microprocessor control system shall check all pre-start safeties to verify that all prestart safeties are within limits. (If one is not, an indication of the fault will be displayed and the start aborted).

5.12 INSTALLATION

The complete chilling unit shall be installed over a RCC foundation and shall be adequately isolated against transmission of vibrations to the building structure. Special attention shall be paid to the alignment of the driving and driven shaft. Final alignment shall be checked at site in presence of the Engineer-in-charge using a dial indicator. Necessary foundation bolts, nuts, leveling screws etc wherever required for mounting the unit shall be provided by the contractor.

5.13 PAINTING

The equipment shall be supplied as per manufacturer’s standard finish painting.

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CHAPTER- 6
FACTORY BUILT AIR HANDLING UNIT (AHU), FAN COIL UNIT (FCU) AND OTHER AIR DISTRIBUTION SYSTEMS

6.1 SCOPE

This chapter covers the detailed requirements of factory built double skin air handling unit (AHU), single skin fan coil unit (FCU) and other air distribution systems like chilled beam, floor radiant cooling, and variable air volume systems for central air-conditioning system as well as for central heating systems.

6.2 FACTORY BUILT AIR HANDLING UNIT (AHU)

6.2.1 Type

The air handling unit shall be of double skin construction, draw through type in sectionalized construction consisting of blower section, coil section, Drive Motor with starter and Isolator, humidification section (where specified), filter section, Ultra Violet Germicidal Irridation system and insulated drain pan. Unless otherwise specified, the unit shall be horizontal type.

Vertical type units are generally used whenever there is a space constraint.

The use of Ceiling Suspended AHUs should be discouraged due to maintenance problems.

6.2.2 Rating

(a) The capacity of the cooling/heating coil, the air quantity from the blower fan and static pressure of blower fan shall be as laid down in the tender documents. Where these parameters as calculated by the tenderer exceed the specified values, the coils and the blower fan shall satisfy these calculated values.

(b) The coil shall be designed for a face velocity of air not exceeding 155 m/min.

(c) The requisite static pressure demanded by the air circuit shall be developed by the fan at the selected operating speed. The static pressure value shall not in any case be less than 40 mm water gauge in normal cases, not less than 65 mm water gauge where microvee filters are also used and not less than 100 mm water gauge where absolute filters are also used. The fan motor HP shall be suitable to satisfy these requirements and the drive losses.

(d) The air outlet velocity from the blower fan shall not exceed 610 m/min.

(e) Noise level at a distance of 2M from AHU shall not exceed 70 dBA. However, when requirement of noise level is more stringent than as mentioned above than the requirement shall be mentioned in NIT.

(f) All AHU shall be AHRI / Eurovent certified.

(g) All fans shall be certified by Air Movement and Control Association (AMCA) also.

6.2.3 Material and Construction

6.2.3.1 Housing/ Casing

(i) The housing/ casing of the air handling unit shall be of double skin construction. The housing shall be so made that it can be delivered at site in total/ semi knocked down conditions depending upon the requirements. The main framework shall be of extruded aluminium hollow structural sections. The entire framework shall be assembled using mechanical joints to make a sturdy and strong framework for various sections. For 100%

fresh air application or for unit with mixing box framework shall be made of thermal break hollow extruded aluminium profile.

(ii) Double skin panels shall be minimum 25mm thick for units upto 20,000 CFM and for units capacity above 20,000 CFM panel thickness shall be 40 mm, made of minimum 0.8mm pre-plasticized and pre-painted with PVC guard, GSS sheet on outside and minimum 0.8mm galvanized sheet with minimum 275 GSM zinc coating inside with Polyurethane foam insulation of density not less than 38 kg/cu. m injected in between by injection moulding machine. These panels shall be bolted from inside/ screwed from outside on to the framework with soft rubber gasket in between to make the joints airtight. The gaskets shall be inserted within groove in extruded aluminium profile of the framework. For units installed outdoor, the thickness of double skin panels shall be minimum 40 mm and shall be provided with canopy. All GI components provided shall have minimum 275 GSM zinc coating.

(iii) Frame work for each section shall also be bolted together with soft rubber gasket in between to make the joints air tight. Suitable doors with nylon handles, aluminium die-cast powder coated hinges & latches shall be provided for access to various panels for maintenance. However, AHU in the form of complete single unit shall also be acceptable with access door(s) for maintenance to various sections. The entire housing shall be mounted on galvanised steel channel frame work made out of G.I. sheet of thickness not less than 2mm. For higher capacity above 30000 CFM AHUs hot dip galvanized steel channel framework made of minimum 3 mm thick G.S. sheet shall be used. All GI components provided shall have minimum 275 GSM zinc coating.

6.2.3.2 Drain Pan

Drain pan shall be made out of minimum 1.25 mm **stainless steel grade SS 304** sheet externally insulated with minimum10mm thick closed cell Polyethylene foam insulation **or nitrile rubber or PUF** with necessary dual slope to facilitate fast removal of condensate. Necessary supports will be provided to slide the coil in the drain pan. For stacked coil, additional drip pan or intermediate drain pan fabricated from same material as main drain pan will be installed at back between two coils.

6.2.3.3 Cooling / Heating coil

(i) The coil shall be made from seamless solid drawn copper tubes ASTME -75. The minimum thickness of tube shall be 0.5 mm for cooling / heating / heating-cum-cooling coils. AHUs shall be selected for a maximum face velocity of 500 FPM (2.54 MPS) for cooling coils. The Coil Casing shall be of SS-304 & fins shall be hydrophilic coated type.

(ii) The depth of the coil shall be such as to suit the requirements, viz. re-circulated air applications, or 100 % fresh air applications and the bypass factor required shall be specified in the tender specifications. The coil shall be 4 or 6 rows deep for normal re-circulated air application and 8 rows deep for all outdoor air application, unless otherwise specified in the tender specifications. In case of 8 rows deep coils, it shall be made of 2x4 rows deep coils with a spacing of 200mm between the two coils, access door and independent drain pan.

(iii) U bends shall be of copper, jointed to the tubes by brazing, soft soldering shall not be used.

(iv) Each section of the coil shall be fitted with flow and return headers to feed all the passes of the coil properly. The headers shall be of copper and shall be complete with water in/out connections, vent plug on top and drain at the bottom. The coil shall be designed to provide water velocity between 0.6 to 1.8 m/s in the tubes.

(v) The fins shall be of aluminium. The minimum thickness of the fins shall be 0.15 mm nominal. The no. of fins shall not be less than 12 Nos per inch length of coil. Fins may be of either spiral, Sinewave, corrugated or plate type. The tubes shall be mechanically expanded to ensure proper thermal contact between fins and tubes. The fins shall be evenly spaced and upright. The fins bent during installation shall be carefully realigned. For coastal areas complete coil i/c fins shall be treated with Anticorosive Coating and for 100% F.A. application fins shall be hydrophilic type.

(vi) The coil shall be suitable for use with the refrigerant specified or with water as the case may be. Refrigerating coils shall be designed for the maximum working pressure under the operating conditions. Water coils shall be designed for a maximum working pressure of 10 kg./sq.cm.

(vii) Shut off and regulating valves at the inlet and outlet of water shall be provided. In the case of DX coils, solenoid valve and expansion valves shall be provided at the inlet of coil.

(viii) Chilled water/ Hot water coils shall be (AHRI Certified).

6.2.3.4 Supply Air Fan and Drive

(i) The supply air fan shall be AMCA certified centrifugal type with DIDW forward/ DIDW Aerofoil backward curved/Plug Fan/Plenum fan / EC fan motor blades double inlet double width(DIDW) type. For static pressure upto 50mm forward curved blades shall be used and for higher sizes backward curved blades shall be used. Minimum efficiency of forward curved fans shall be 60%, for backward curved fans shall be 74%, & for EC-Fan motor, system efficiency shall be minimum 68% or above. The fan housing of Galvanised sheet steel and the impellers shall be fabricated from heavy gauge steel sheet as per approved manufacturers standard. The side plates shall be die formed for efficient, smooth airflow and minimum losses. Fan impeller shall be mounted on solid shaft supported to housing using heavy duty ball bearings (self aligning type) Inlet cone must be Spun GSS.. Fan housing and motor shall be mounted on a common extruded aluminium base mounted inside the fan section on anti-vibration spring mounts or cushy- foot mount. The fan outlet shall be connected to casing with the help of fire retardant fabric. The spring or rubber isolator is mounted between the fan compartment and the rest of the AHU to prevent the transmission of noise and vibration into panels.

(ii) The fan impeller assembly shall be statically and dynamically balanced.

(iii) In case of belt driven system, The fan shall be fitted with vee belt drive arrangement consisting of not less than two evenly matched belts. Belts shall be of oil resistant type. Adequate adjustments shall be provided to facilitate belt installation and subsequent belt tensioning by movement of the motor on the slide rails. A readily removable door guard shall be provided.

(iv) The fan motor shall be totally enclosed fan cooled squirrel cage induction motor with IP-55 protection & selected for quiet running. The motor shall be suitable for operation on 415 $\pm$ 10%V, 3 phase, 50 Hz., A.C. supply. The fan motor shall be premium efficiency IE3 class, as per IS 12615. Motors shall be selected considering 10 % over the maximum possible power absorbed by the fan operating at a maximum face velocity of 3.25 mps. The natural frequency of the fan assembly shall not fall with in 30% of its operating speed. For 24 Hour operating systems, there shall be an extended shaft with two drive systems and two motors The motor shall be suitably designed for use with variable frequency drive.

(v) AHU fan motors shall be provided with variable frequency drive with Inbuilt Harmonics filters where VAVs (Variable Air Volume control) are provided in the ducts.

(vi) For energy efficiency of system, where VAVs (Variable Air Volume control) are provided in the ducts, VFD, in place of starter shall be provided in Air Handling Units. VFD with harmonics filters should be specified. Whenever VFD is fitted, direct shaft driven motors are normally used.

(vii) Where VFD is provides an alternative starting arrangement with DOL/Star Delta shall be provided as an alternative.

6.2.3.5 Humidification Arrangement

Wherever specified in the tender specifications, humidification arrangements shall be provided with the AHUs. This shall consist of one of the following arrangements. The particular arrangement to be followed shall be specified in the tender specifications.

(a) Pan type humidification arrangement

Pan type humidifier shall be complete with stainless steel sheet (minimum 2mm thick) tank duly insulated, steam outlet nozzle, top open able with stainless steel bolts, immersion heaters, low level cut out, humidistat, thermostat; safety stat, float value & sight glass etc. The tank shall be insulated with 50mm thick expanded polystyrene (TF quality) slabs & finished with 0.5mm thick G.I. sheet.

(b) Ultrasonic humidification arrangement

These humidifiers consume leser energy as compared to Pan type humidifiers. Use of this type may be done where the cost is comparable to other types.

An ultrasonic humidifier uses a metal diaphragm vibrating at an ultrasonic frequency to create water droplets that silently exit the humidifier in the form of a cool fog. Ultrasonic humidifiers use a piezoelectric transducer to create a high frequency mechanical oscillation in a film of water. This forms an extremely fine mist of droplets about one micron in diameter, which is quickly evaporated into the air flow. Unlike the humidifiers that boil water, these water droplets will contain any impurities that are in the reservoir, including minerals from hard water (which then forms a difficult-to-remove sticky white dust on nearby objects and furniture). Any pathogens growing in the stagnant tank will also be dispersed in the air. Ultrasonic humidifiers should be cleaned regularly to prevent bacterial contamination from being spread throughout the air.

The amount of minerals and other materials can be greatly reduced by using distilled water, though no water is absolutely pure. Special disposable demineralization cartridges may also reduce the amount of airborne material,

6.2.4 Instruments and Valves

The following instruments shall be provided at the specified locations in the AHUs for the chilled water / hot water system: -

(i) Pressure gauges at the inlet and outlet of the coil with tubing and gauge cock.

(ii) Stem type thermometers at the inlet & outlet of coil with tubing & gauge cock.

(iii) Butterfly valve at the inlet and outlet of coil.

(iv) Balancing valve at the outlet of coil.

(v) Y-strainer at the inlet of coil.

(vi) Motorized- 2/3 ways (to be specified in NIT) diverting/ mixing valve along with proportionate thermostat.

(vii) BMS ready connectivity

(viii) On-Off timer

(ix) Air Filter pressure drop alarm with choking indicator.

6.2.5 Controls

These shall be as per details given under chapter 12 ‘Controls’.

6.2.6 Insulation

The insulation of casing shall be as per para 6.2.3.1 (ii) & that of drain pan shall be as per 6.2.3.2.

6.2.7 Installation

The air handling unit shall be so installed as to transmit minimum amount of vibration to the building structure. Adequate vibration isolation shall be provided by use of rubber/ neoprene pads and/or vibration isolation spring mountings.

6.3 FAN COIL UNITS

6.3.1 General

The fan coil units shall be floor/ wall/ ceiling mounted draw through type complete with finned coil, fan with motor, insulated drain pan, cleanable air filters and fan speed regulator and other controls as described. Performance of the complete FCU shall be certified as per AHRI Standard.

6.3.2 Casing

All sheets used for casing panels shall be with 1.25 mm thick pre painted precoated/powder coated GI sheet.

6.3.3 Cooling coil

Coils shall be made of 10mm or larger copper tube with plain aluminum fins expanded on to the tube. Number of fins shall not be less than 10-12 fins per inch. Coils shall be tested to 20 bar working pressure. Supply and return connections shall be 16mm O.D copper arranged either right or left handed as required. Automatic air vents shall be provided on the return headers with a flexible pipe discharging into the drain pan. End connections shall have supply, return and control solenoid valves (on the return side). Coil design shall be such that the coil could be disconnected and removed from the unit for cleaning and maintenance. The coil circuit should be sized for adequate water velocity but not exceeding 1.8 m/s. The air velocity across the coil shall not exceed 155 m/min.

6.3.4 Fan

This shall consist of two lightweight aluminum impellers of forward curved type, both statically and dynamically balanced, along with properly designed GI sheet casings.

Fans shall be slow-speed direct driven. Fans shall have three speeds (100%, 70% & 50%) and shall be quiet in operation. The maximum sound power level of the unit shall not exceed NC 35.

Fan motors shall be single phase 220V 50Hz or 3 phase 400V with built in thermal overload protection and shall be capable of reliable starting and vibration free operation upto 90% of the rated voltage. Motor shall be mounted on Heavy Gauge motor mounting plate, minimum 3 mm thick and capable of being removed easily.

The 3-speed type Brushless Direct Current type (BLDC) motor can also be used as it has high torque, high PFC value, longer life cycle, and reduced noise pollution levels, while generating up to 140% more instant air volume and shall be factory wired to a terminal block mounted within the fan section. Motors shall be having extended shaft on both sides.

6.3.5 Drain Pan :

A full size double skin drain pan shall be fabricated of 1.00 mm stainless steel grade SS304. 25mm polystyrene or polyurethane shall be sandwiched or foamed-in. The two skins shall not be interconnected at any point. Pan shall be large enough to contain the unit and the coil connection, shut-off valves, control valves etc. Units shall be mounted on the pan with rubber bushes. Inside of pan shall be finished smooth and pitched towards a 25mm drain connection located on the same side as the coil connections. Drain shall be connected to the drain pipe with flexible connection and a PVC trap of 40mm water seal and with inbuilt cleaning plug.

6.3.6 Air Filter

The filter shall be cleanable type 15mm thick with 90% efficiency down to 10 micron of dry cleanable synthetic type to be mounted behind the return air grill in the unit casing.

6.3.7 Speed control

A sturdy switch shall be provided with the unit complete with wiring, for ON/OFF operation and with minimum three speed control of the fan.

6.3.8 Automatic controls

Unit should be provided with factory fitted valves package. Unit control package shall consist of two way or three way solenoid or motorized water valve and two shut-off valve. The valve shall be fixed at a convenient location. The thermostat shall be mounted along with the speed control switch on a common plate. The plate shall clearly indicate the fan positions.

The water valves on inlet line shall be of gun metal ball type with internal water strainers, having BSP female pipe thread inlet and flare type male pipe thread outlet connection. The valves on return line shall be as above, but without the water strainer.

A wall mounted control panel shall consist of:

(a) ON-OFF room thermostat having digital display with adjustable set point.
(b) Control switch with ON-OFF and High, Medium & Low Fan speeds (upto 1000cfm)
(c) On-line starter with a 3PN MCB/MCCB.
(d) Potential free contacts for integration.

6.3.9 Water Connections

The water lines shall be finally connected to the coil of the fan coil unit, by at least 300mm long, type `L' seamless solid drawn copper tubing, with flare fittings and connections.

6.4 INSULATION

The drain pan shall be insulated as per para 6.3.5.

6.5 PAINTING

All equipment shall be supplied as per manufacturer's standard finish painting.

6.6 CHILLED BEAMS

6.6.1 System description

Chilled beam system is an air conditioning system for cooling, heating and ventilation in spaces for good indoor climate and individual space control. The chilled beam system is an air/water system that utilizes the heat transfer properties of water and provides comfortable indoor climate energy efficiently.

6.6.2 System mounting

The Chilled Beams shall be ceiling mounted and consisting of a heat exchanger, a number of nozzles and a plenum in which dehumidified air is supplied.

6.6.3 System operation

Chilled beam systems are designed to use the dry cooling principle operating with conditions in which condensation is prevented by control applications.

(a) Ventilation

Ventilation using active chilled beams is an efficient mixing ventilation application that results in uniform air quality. Supply air is diffused from linear slots on either both sides or on only one side of the chilled beam. Ventilation in passive chilled beam systems is typically arranged using mixing ventilation with ceiling or wall diffusers. Alternatively, floor diffusers can be used.

(b) Cooling

Active chilled beams use the primary air to induce and recirculate the room air through the heat exchanger of the unit, resulting in high cooling capacities and excellent thermal conditions in the space. Passive beam operation is based on free convection in the heat exchanger and supply air distribution is realized with separate diffusers.

(c) Heating

Integration of heating into chilled beams is recommended when heating capacity is low enough (200-300 W/m) and the U-value of the windows prevent a down-draught under the window.

6.6.4 Typical input values and operation range

(i) Room temperature: 23-25 °C
(ii) Supply air temperature: 16-19 °C
(iii) Water inlet temperature: 14-16 °C
(iv) Target duct pressure level: 70 -120 Pa
(v) Target water flow rate: 0.02-0.08 kg/s
(vi) Sound pressure level < 35 db (A)
(vii) Outdoor airflow rate/ floor area: 1.5-2.5 (6) l/s/m^2
(viii) Outdoor airflow rate/ effective length: 5-12 l/s/m
(ix) Cooling capacity / floor area: 120 (200) W/m^2
(x) Cooling capacity / beam effective length: 350 (500) W/m
(xi) Heating capacity / floor area: 60 (80) W /m^2
(xii) Heating capacity / beam effective length: 200 (300) W/m

6.6.5 Technical specifications

(i) The active chilled beam shall have an integral recirculation air path through the perforated front panel. The induced room air flow rate shall be manually adjustable via three setting positions without influencing the primary air supply flow rate. The airflow rate of the chilled beam shall be adjustable without plugging or changing the nozzles.

(ii) The primary air flow rate shall be adjustable over a wide range via a supply air unit integrated into the chilled beam.

(iii) Outdoor air flow rate control shall not have any effect on coil cooling and heating capacities.

(iv) The beam with adjustable air flow rate shall have only one duct connection. The appearance of the chilled beams with constant air flow and variable air flow rate shall be the same.

(v) The front panel shall be openable from either side in order to allow general maintenance and cleaning. The front panel shall be removable without any special tools.

(vi) The air supply to the room space shall be either unidirectional or bi-directional.

(vii) The position of the duct connection shall be changeable without the use of any special tools.

(viii) The frame, front, and side panels shall be made of galvanized steel plate.

(ix) All visible parts shall be white/ painted to match the ceiling colour.

(x) All pipes shall be manufactured from copper, and connection pipes with a wall thickness of 0.9-1.0 mm.

(xi) The fins shall be manufactured from aluminium.

(xii) Optionally, heating shall be incorporated within the heat exchanger by means of two 10-mm pipes, connected in series.

(xiii) All joints shall be soldered and factory pressure-tested.

(xiv) The pipework's operation pressure should be 1.0 MPa.

(xv) The active chilled beam shall have an air flow adjustment damper as an option and a measurement tap to allow air flow measurement.

(xvi) As an option, an exhaust valve shall be integrated into the chilled beam.

(xvii) In tropical countries like India, The chilled beam should have drain pan and pump to collect and dispose-off the condensate.

6.7 Variable Air Volume Terminals

The Variable air volume system uses Variable speed drives for fan volume control providing a great deal of flexibility for multiple zones in temperature control and efficiency, good control of ventilation air quantities, and opportunity for higher levels of filtration.

The modules shall vary the supply air volume to provide both VAV heating and VAV cooling in individual rooms controlled through a room temperature sensing thermostat in each room. It shall sense room temperature and vary the supply air.

6.7.1 The VAV unit assembly shall be pressure independent and shall reset to any air flow between zero and the maximum catalogued air volume. At an inlet velocity of 10mps, the differential static pressure for any unit shall not exceed 2.5mm WG. Sound rating of air distribution assemblies shall not exceed NC 35 at 50mm WG pressure.

6.7.2 The air flow sensor shall be of cross configuration located at the inlet of assembly and shall have multiple pick up points, designed to average the flow across the inlet of assembly. The air flow sensor shall amplify the sensed air flow signal.

6.7.3 The terminal unit controller shall be a dedicated, microprocessor based, pressure independent VAV controller complete with electronic flow transducer. The controller shall be capable of stand alone operation and have the capability to network with a building automation system, personal computer or portable operator interface device.

6.7.4 The actuator shall be bi-directional and direct coupled to the damper shaft. The actuator must be capable of operating in the stalled position without overheating or mechanical damage.

6.7.5 Terminal controller, flow transducers and electric actuator shall be factory wired, calibrated and pretested to ensure full functional unit. The zone sensor shall be furnished by the terminal unit manufacturer and shall include temperature set point adjustment and access for connection of a hand held operator terminal. The DDC control package shall be calibrated and factory set for maximum and minimum flow rates as shown on the drawings.

6.7.6 The air terminal unit shall be installed and field adjusted to maintain controlled pressure independent airflow. The units shall be provided with a minimum of four duct diameters of straight inlet duct, same size as the inlet, between the inlet and any takeoff, transition or fitting. To facilitate field measurements terminal unit manufacturer shall furnish a portable hand held operator interface. The operator interface shall have capability of changing all inputs, set points and operating parameters of the VAV controllers by connection to the zone sensor.

6.7.7 All control components should be mounted inside a protective metal shroud. All VAV terminals shall be connected to the grille or diffuser through an insulated flexible duct and grille/diffuser.

BLANK

CHAPTER-7
COOLING TOWERS

7.1 SCOPE

This chapter covers the general requirements of cooling towers for packaged units, central air-conditioning plants and cold rooms.

7.2 TYPE

The cooling tower shall be of Mechanical draft type having fiber glass re-enforced plastic (FRP) construction with PVC fill and FRP basin. Fan on Mechanical draft towers may be on the inlet air side or exit air side. In case of former it is called forced draft type and in case of later it is called Induced draft type. On the basis of direction of air flow and water flow, Mechanical draft cooling tower can be counter flow or cross flow type as per the manufacturer design.

In the counter flow induced draft design, hot water enters at the top, while the air is introduced at the bottom and exits at the top. Both forced and induced draft fans are used. In cross flow induced draft towers, the water enters at the top and passes over the fill. The air, however, is introduced at the side either on one side (single-flow tower) or opposite sides (double-flow tower). An induced draft fan draws the air across the wetted fill and expels it through the top of the structure.

7.3 DESIGN

(i) **Rating**

The cooling tower shall be rated for the heat rejection capacity specified in the tender specifications. All cooling towers shall be certified by CTI (Cooling Tower Institute).

(ii) **Range**

The Cooling tower shall be designed to cool the requisite quantity of water through 5.00 degree C or as specified in the tender specifications, against the prevailing wet bulb temperature.

(iii) **Wet Bulb approach**

The cooling tower shall be selected for a wet bulb approach of not more than 2.77 degree C.

(iv) **Outlet temperature**

The cold water temperature from the cooling tower shall match the entering temperature for which the condenser selection is made.

(v) **Flow rate**

The water flow rate through the cooling tower shall match that through the condenser.

(vi) **Multi cell design**

The induced draft cooling tower shall be of one or more cells.

(vii) **Drive Motor**

The fan motor shall be premium efficiency IE3 class, as per IS 12615, class ‘F’ insulation.

(viii) The drift loss shall be less than 0.003%.

7.4 MATERIAL AND CONSTRUCTION

Fibreglass Reinforced Plastic (FRP) Cooling tower

(i) The structural framework of the cooling tower including all members shall be designed for the load encountered during the normal operation of the cooling tower and its maintenance. The structure shall be rugged and rigid to prevent distortion and shall include tie arrangements as may be necessary.

(ii) The cooling tower shall be induced draft type, with FRP casing in square/ rectangular/ octagonal/ circular shape, and with an FRP basin to match the shape of the casing. The casing may be in one or in sections bolted together with sealing gasket to make a leak proof joint.

The air intake shall be from openings all along the circumference of the casing near its base in case of circular shape. Air Intake shall be along the sides in case of square or octagonal/ rectangular cooling tower. These openings shall be covered with hot dip galvanized expanded metal mesh screens.

(iii) The basin shall have a holding capacity adequate for operation for atleast 30 minutes without addition of make-up water to the basin. The construction should be such as to eliminate the danger of drawing air into the pump when operating with minimum water in the basin.

(iv) The basin fittings shall include the following: -

(a) Bottom /side outlet,
(b) Drain connection with valve,
(c) Ball type automatic make-up connection with valve,
(d) Overflow connection,
(e) Bleed off with valve, from inlet header to overflow pipe.

(v) The supporting framework for the tower casing and the water basin shall be made of hot dip galvanised steel and it shall be further protected with epoxy painting.

(vi) The fill shall be of film PVC. Thickness of PVC fills shall not be less than 0.3mm. These shall be of such construction as to provide low air resistance, large wetted surface for a high heat transfer efficiency, and easy replace ability. Fill shall be fire retardant and chemically inert to atmospheric impurities. Film fill, because it offers greater heat transfer efficiency, is the fill of choice for applications where the circulating water is generally free of debris that could plug the fill passageways.

(a) The water distribution may be either through self-rotating or fixed type sprinklers or through balancing, sub balancing and spreader troughs (unpressurised system) "open gravity type with polypropylene nozzle", ensuring uniform water loading and distribution of water over the fill. All pipes and fittings shall be of PVC. The sprinklers shall operate from the residual velocity head at the headers. Due care shall be taken with regard to corrosive effects and maintainability in the design of the water distribution system. In case of multiple towers, an external valved equalizer of size not less than 150% of the suction connection shall be provided.

(b) Drift eliminators of PVC shall be provided for maximum removal of entrained water droplets. The spacers and tie rods used shall be of plastic material.

(c) The fan shall be multi-blade axial flow type, made of aluminium alloy or FRP. The fan assembly shall be statically and dynamically balanced. For forced draft cooling towers, centrifugal fans shall be used.

(d) The fan drive shall be from a three phase TEFC squirrel cage induction motor **of efficiency class IE3 as per IS 12615**, either direct or through a spiral gear work. The entire drive arrangement shall be designed for a minimum noise with VFD having THD less than 5% and it shall be rigidly supported to the tower structure.

(e) Motor shall be located outside the humid interior of cooling tower.

(f) The motor starter shall be in accordance with para 13.9.

(g) To ensure safety of personnel at the time of working on cooling tower a steel ladder shall be provided in such a manner and location as necessary to give safe and complete access to all the parts of the cooling tower requiring inspection or adjustments. The ladder shall be bolted to the tower at the top and grouted in masonry at the bottom end.

(h) Cooling tower noise shall not exceed the value specified in the tender specifications. Tower shall be mounted on suitable vibration mounts.

7.5 CLOSED CIRCUIT INDUCED DRAFT CROSS FLOW COOLING TOWER

Closed circuit cooling tower consists of two separate fluid circuits: (a) an external circuit, in which spray water circulates over the heat exchange coil and mixes with the outside air and (b) an internal circuit, in which the process fluid to be cooled circulates inside the heat exchange coil. During the operation, heat is transferred from the warm fluid in the coil to the spray water, and then to the atmosphere as a portion of the water evaporates. It can be of parallel flow or counter flow or cross flow type.

In addition to chiller applications and industrial process cooling, closed circuit cooling towers are often used with heat pump systems, where closed loop cooling is required.

A closed circuit cooling tower can provide the following advantages over an open cooling tower:

- Lower volume of re-circulating water to treat
- Process loop requires minimal treatment
- During periods of dry operation, the need for make-up water is eliminated
- Keeps the system clean and contamination free.

MATERIAL & CONSTRUCTION

(a) **Cold Water Basin:**

Constructed with a heavy-gauge galvanized steel or 304 stainless steel with access doors at both ends of tower to air plenum. All factory seams in the cold water basin will be welded to ensure watertight assembly and welded seams will be warranted against leaks. Sloped with depressed section with drain/clean-out connection. Corrosion resistant PVC make-up valve with plastic float for easy adjustment of operating water level.

(b) **Water Distribution System:**

(i) Water will be distributed evenly over the coil at a flow rate sufficient to ensure complete wetting of the coil at all times.

(ii) Spray Water Pump(s): The closed circuit cooling tower will include an appropriate number of close coupled, centrifugal pump(s) and IE3 motor(s) assemblies equipped with mechanical seal, and piped from the suction connection to the water distribution system. The pump motor(s) will be the totally enclosed fan cooled (TEFC) type. The system shall include a metering valve and bleed line to control the bleed rate from the pump discharge to the overflow connection.

(c) **Casing Panels and Framework:**

Casing panels and framework will be constructed of galvanized steel or 304 stainless steel.

(d) **Air Inlet Louvers :**

Louver sections will be individually removable sections with PVC inlet shields. The combined inlet shields will be UV resistant PVC, installed on the air inlet face to minimize air resistance, prevent water splash out. A removable galvanized steel/stainless steel wire mesh air intake screen.

Fans: Multi blade, axial type.
Motors & Drive: Three phase TEFC squirrel cage induction motor of efficiency Class IE3 as per IS 12615 with VFD having THD less than 5%.
Heat Transfer Coils: Galvanized Steel or 304 stainless steel
Fill & Drift Eliminator: The fill and integral drift eliminators will be formed from self-extinguishing polyvinyl chloride (PVC) or chlorinated polyvinyl chloride (CPVC).

7.6 OPEN CIRCUIT FORCED DRAFT COUNTER FLOW COOLING TOWER:

In forced draft cooling towers, air is pushed through the tower from an inlet to an exhaust. A forced draft mechanical draft tower is a blow-through arrangement, where a blower type fan at the intake forces air through the tower. The forced draft benefit is its ability to work with high static pressure. They can be installed in more confined spaces and critical layout situations. These can be used for indoor applications and ducted to outside of the building.

MATERIAL & CONSTRUCTION

(i) **Cold Water Basin**

Constructed with heavy-gauge galvanized steel with all edges given a protective coating of zinc-rich compound. Basin shall include large area lift out strainers with perforated openings sized smaller than the water distribution system nozzles and an anti-votexing device to prevent air entrainment.

(ii) **Casing Panels and Framework**

Casing panels and framework will be constructed of galvanized steel. Panels will utilize double-brake flanges for maximum strength and rigidity and reliable sealing of watertight joints.

(iii) **Fans**

Centrifugal type mounted on steel shaft with belt drive, bearings.

(iv) **Motors and Drives**

Three phase TEFC squirrel cage induction motor of efficiency Class IE3 as per IS 12615 with VFD having THD less than 5%

(v) **Distribution Section**

Polyvinyl chloride piping header and branches with non-clog ABS plastic spray nozzles.

(vi) **Fill & Drift Eliminator**

The fill and integral drift eliminators will be formed from Polyvinyl chloride plastic.

7.7 INSTALLATION

The cooling tower shall be installed on M.S. girders fixed in masonry foundations with cement concrete footing. Second class brick work and cement mortar having one part cement & six parts sand shall be used for the masonry work. 12mm sand cement plaster shall be provided over the brickwork.

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 Architect. In case the cooling towers are located on the terrace of the building, the structural loading of the terrace shall be considered. For this respective columns are to be raised by two feet at the terrace. Cooling towers shall be installed in such a way that their load is transferred directly to the columns for which necessary Mild steel-I sections shall be provided by the air- conditioning contractor. The cooling towers shall be rested on Mild Steel-I sections & not on terrace slab. Sufficient free space shall be left all around for efficient operation of the cooling tower.

Cooling tower shall be not less than 75cm above the ground/ floor level unless otherwise stated in the tender specifications. 6mm neoprene pads shall be placed between the tower and the girder for vibration isolation whereas directed by the Engineer-in-charge. Guy-wires of suitable sized shall be used to secure firmly to its base wherever necessary.

7.8 PAINTING

The cooling towers shall be supplied with the manufacturer's standard finish painting.

7.9 TESTING

The All Cooling towers shall be CTI (Cooling Technology Institute) certified and tested.

7.10 Treatment of Water for Cooling Tower

The water used in cooling tower serving treated and water quality shall be maintained in conformity to IS 8188 : 1999 (Reaffirmed Year : 2020) as updated up to date. The cost of water treatment plant and accessories shall be deemed to be included in to tender cost until otherwise specify in NIT.

7.11 The important parameters, related to cooling towers, are

(i) "Range" is the difference between the cooling tower water inlet and outlet temperature.

(ii) "Approach" is the difference between the cooling tower outlet cold water temperature and ambient wet bulb temperature. Although, both range and approach should be monitored, the 'Approach' is a better indicator of cooling tower performance.

(iii) Cooling tower effectiveness (in percentage) is the ratio of range, to the ideal range, i.e., difference between cooling water inlet temperature and ambient wet bulb temperature, or in other words it is = Range / (Range + Approach).

(iv) Cooling capacity is the heat rejected in kCal/hr or TR, given as product of mass flow rate of water, specific heat and temperature difference.

(v) Evaporation loss is the water quantity evaporated for cooling duty and, theoretically, for every 10,00,000 kCal heat rejected, evaporation quantity works out to 1.8 m3

An empirical relation used often is:

*Evaporation Loss (m3 /hr) = 0.00085 x 1.8 x circulation rate (m3 /hr) x (T1-T2)

T1-T2 = Temp. difference between inlet and outlet water.

(vi) Cycles of concentration (C.O.C) is the ratio of dissolved solids in circulating water to the dissolved solids in make up water.

(vii) Blow down losses depend upon cycles of concentration and the evaporation losses and is given by relation:
Blow Down = Evaporation Loss / (C.O.C. – 1).

(viii) Liquid/Gas (L/G) ratio, of a cooling tower is the ratio between the water and the air mass flow rates. Against design values, seasonal variations require adjustment and tuning of water and air flow rates to get the best cooling tower effectiveness through measures like water box loading changes, blade angle adjustments.
Thermodynamics also dictate that the heat removed from the water must be equal to the heat absorbed by the surrounding air:
where:
$L(T1 - T2) = G(h2 - h1)$
$L/G = (h2 - h1) / (T1 - T2)$

L/G = liquid to gas mass flow ratio (kg/kg)
T1 = hot water temperature (°C)
T2 = cold water temperature (°C)
h2 = enthalpy of air-water vapor mixture at exhaust wet-bulb temperature (same units as above)
h1 = enthalpy of air-water vapor mixture at inlet wet-bulb temperature (same units as above)

7.12 Minimum in Built provisions i/c Instrumentation for measuring of the of the following parameters shall be provided

(a) Wind velocity
(b) Wet bulb temperature (for both intake and exhaust air)
(c) Dry bulb temperature (for both intake and exhaust air)
(d) Hot water temperature (cooling water IN temperature)
(e) Re-cooled water temperature (cooling water OUT temperature)
(f) Circulating water flow
(g) Make-up water quantity and temperature
(h) Purge water quantity and temperature
(i) CT fan motor amps, volts, kW
(j) TDS of cooling water

7.13 **Energy Saving Opportunities in Cooling Towers**

The some of the typical measures by which energy can be saved in cooling towers.

(a) Follow manufacturer's recommended clearances around cooling towers and relocate or modify structures that interfere with the air intake or exhaust.
(b) Optimise cooling tower fan blade angle on a seasonal and/or load basis.
(c) Correct excessive and/or uneven fan blade tip clearance and poor fan balance.
(d) On old counter-flow cooling towers, replace old spray type nozzles with new square spray ABS practically non-clogging nozzles.
(e) Replace splash bars with self-extinguishing PVC cellular film fill.
(f) Install new nozzles to obtain a more uniform water pattern.
(g) Periodically clean plugged cooling tower distribution nozzles.
(h) Balance flow to cooling tower hot water basins.
(i) Cover hot water basins to minimise algae growth that contributes to fouling
(j) Optimise blow down flow rate, as per COC limit.
(k) Replace slat type drift eliminators with low pressure drop, self extinguishing, PVC cellular units.

(l) Restrict flows through large loads to design values.

(m) Segregate high heat loads like furnaces, air compressors, DG sets, and isolate cooling towers for sensitive applications like A/C plants, condensers of captive power plant etc. A 1°C cooling water temperature increase may increase A/C compressor kW by 2.7%. A 1°C drop in cooling water temperature can give a heat rate saving of kCal/kWh in a thermal power plant.

(n) Monitor L/G ratio, CW flow rates w.r.t. design as well as seasonal variations. It would help to increase water load during summer and times when approach is high and increase air flow during monsoon times and when approach is narrow.

(o) Monitor approach, effectiveness and cooling capacity for continuous optimisation efforts, as per seasonal variations as well as load side variations.

(p) Consider COC improvement measures for water savings.

(q) Consider energy efficient FRP blade adoption for fan energy savings.

(r) Consider possible improvements on CW pumps w.r.t. efficiency improvement.

(s) Control cooling tower fans based on leaving water temperatures especially in case of small units.

(t) Optimise process CW flow requirements, to save on pumping energy, cooling load, evaporation losses (directly proportional to circulation rate) and blow down losses.

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CHAPTER-8
CIRCULATING WATER PUMPS

8.1 Scope

This chapter covers the general requirements of water circulating pumps for central air-conditioning, central heating, etac and cold room applications. This section does not cover either humidification pumps or spray pumps for spray over coils.

8.2 Type

The pumps shall be centrifugal type direct driven with a 3 phase, 415 $\pm$ 10%volts, 50 hz., a.c. Motor. The motor for chilled water pumps shall be suitable for use with variable frequency drive. The motor starter for condenser water pump shall be in accordance para 13.9. The motor shall be screen protected drip proof (SPDP) or fan cooled or totally enclosed fan cooled (TEFC) type. The efficiency class of motors shall be i.e. 3 class (IE 3) or better as per IS:12615 with class 'F' insulation. The pumps may be either of horizontal split casing (HSC) type or vertical split casing end suction type with operating speed not exceeding 1500 rpm, or solid casing, mono block type with operating speed not exceeding 3000 rpm as specified in the tender documents.

The pump motor shall be TEFC squirrel cage induction motor having efficiency class IE3 (as per IEC 60034) with class 'F' insulation, 1500 RPM synchronous speed, operating on 415 V +/- 10%, 3 phase, 50 Hz AC supply. The motor shall be non-overloading type. Performance characteristics of pumps shall be part of technical submissions.

The pump and motor shall be mounted on a common base plate. All external and exposed cast iron parts of pumps should have an epoxy-based coating . Chilled water pump set shall be complete with thermal insulation with, aluminum cladding at suction and discharge, necessary anti vibration pads, MS base plate, and all other accessories complete as required.

8.3 Rating

The pumps shall be suitable for continuous operation in the system. The head and discharge requirements shall be as specified in the tender documents. The discharge rating shall not be less than the flow rate requirement of the respective equipments through which the water is pumped. The head shall be suitable for the system and shall take into consideration the pressure drops across the various equipments and components in the water circuit as well as the frictional losses. Pump motors greater than or equal to 3.7 kW (5 hp) shall be controlled by variable speed drives wherever specified in the BOQ. Efficiency of the pumps at selection should be 70% or above.

8.4 MATERIAL AND CONSTRUCTION

(i) The centrifugal pumps shall conform to IS 1620. The motor for chilled water pumps shall be suitable for use with variable frequency drive. The motor starter for condenser water pump shall be in accordance with para 13.9. The motor shall be screen protected drip proof (SPDP) fan cooled or TEFC type. The efficiency class of motor shall be IE 3 or better.

(ii) The pump casing shall be of heavy section close grained cast iron. The casing shall be provided with air release cock, drain plug and shaft seal arrangement as well as flanges for suction and delivery pipe connections as required.

(iii) The impeller shall be of bronze or gunmetal. This shall be shrouded type with machined collars. Wear rings, where fitted to the impeller, shall be of the same material as the impeller. The impeller surface shall be smooth finished for minimum frictional loss. The impeller shall be secured to the shaft by a key.

(iv) The shaft shall be of stainless steel and shall be accurately machined. The shaft shall be balanced to avoid vibrations at any speed within the operating range of the pump.

(v) The shaft sleeve shall be of bronze or gunmetal. This shall extend over the full length of the stuffing box or seal housing. The sleeve shall be machined all over and ground on the outside.

(vi) The bearings shall be ball or roller type suitable for the duty involved. These shall be grease lubricated and shall be provided with grease nipples/cups. The bearings shall be effectively sealed against leakage of lubricant.

(vii) The shaft seal shall be a mechanical seal stuffing box type unless otherwise specified, so as to allow minimum leakage compatible with the operation of the seal. In case, stuffing box type is used, it shall be of adequate length and shall be packed with graphite asbestos or any other suitable material for the operating temperature. A drip well shall be provided beneath the seal.

(viii) In the case of HSC pumps, the same shall be directly coupled to the motor shaft through, a flexible coupling protected by a coupling guard. In case of mono block pumps with solid casing, the motor and pumps shall be on a common shaft.

(ix) The pump and motor shall be mounted on a common base plate either of cast iron or fabricated from rolled steel section. The base plate shall have rigid, flat and true surfaces to receive the pump and motor mounting feet.

8.5 ACCESSORIES

Each pump shall be provided with the following accessories: -

(i) Pressure gauges at suction and discharge sides complete with syphon and gauge cock in SS construction.

(ii) Butterfly valves on suction and discharge, and

(iii) Reducers, as may be required to match the sizes of the connected pipe work.

(iv) Non-return valve at the discharge.

(v) Y-Strainer on suction side of pump.

(vi) Strainers with perforated SS screen – perforations not larger than 3 mm.

(vii) Double Arch flexible bellows or metallic flexible bellows on suction and discharge lines complete with control guide rod assembly.

8.6 INSULATION

The thermal insulation of the pump casing for hot/chilled water circulating pumps shall be of the same type and thickness as provided for the connected pipe work and is discussed in Chapter 11.

8.7 INSTALLATION

(i) The pump and motor assembly shall be mounted and arranged for ease of maintenance and to prevent transmission of vibration and noise to the building structure or excess vibration to the pipe work.

(ii) More than one pump and motor assembly shall not be installed on a single base or cement concrete block. The mass of the inertia block shall not be less than the combined mass of the pump and motor assembly. The inertia block shall be vibration isolated from the plant room floor by 25 mm. neoprene or any other equivalent vibration isolation fittings. Where spring mountings are used for vibration isolation, these shall be complete with leveling screws and lock nuts and shall be placed over a concrete plinth for distribution of the mass of the assembly over the plant room floor. The pump motor sets shall be properly aligned to the satisfaction of the Engineer-in-charge.

8.8 PAINTING

The pumps shall be supplied with the manufacturer's standard finish painting.

8.9 Chilled/Hot water schemes

A chilled water scheme is one by which chilled/Hot water is produced and circulated throughout the building or through cooling coils in air handling units (AHU) to provide space cooling. It basically consists of a primary loop (production) and a secondary loops (distribution).

(a) **Primary pumping system :** The main objective of the primary pump is to circulate chilled water within the production loop. This pump is typically located anywhere (either upstream or downstream of the chiller), provided the pump satisfies the following conditions:

- It maintains the minimum dynamic pressure head (inlet pressure) at the heat exchangers (evaporator coil) at the chiller.
- It accommodates the total pressure (static plus dynamic head) on system components such as the chiller's evaporator and valves.
- It meets the minimum net positive suction head requirements. This means system inlet pressure at the pump must be positive and high enough for the pump to operate properly.

(b) **Secondary pumping system** : The main objective here is to distribute the chilled water to the various cooling coils overcoming the frictional resistance offered by the pipes, valves and bends in the entire network. The distribution system may contain other components such as expansion tanks, control valves, balancing valves, check valves and air separators. These pumps are usually configured in header fashion for system redundancy.

8.10 VARIABLE FLOW HYDRONIC SYSTEMS

8.10.1 Variable Fluid Flow in Chilled or Hot Water System

Primary variable or secondary variable chilled or hot-water systems shall be designed for variable fluid flow and shall be capable of reducing pump flow rates to no more than the larger of:

(a) 50% of the design flow rate, or the minimum flow required by the equipment manufacturer for proper operation of the chillers, or boilers.

(b) THD less than 5%.

8.10.2 Automatic Isolation Valves

Water cooled air-conditioning or heat pump units with a circulation pump motor greater than or equal to 3.7 kW (5 hp) shall have two-way automatic isolation valves on each water cooled air-conditioning or heat pump unit that are interlocked with the compressor to shut off condenser water flow when the compressor is not operating.

8.10.3 By pass starter to be provided with VFD.

8.10.4 Variable Primary Chilled water or hot water pumping system

Wherever specified in the BOQ the chilled water or hot water pumps circulating the water should be without secondary pumping set. This means the chilled water pumps will be one set only for circulating water through chillers. Similarly, for hot water circulation also there will be 1 set of pumps for circulating water through hot water generators and the heating coils. The cooling and heating coils will be provided with pressure independent balancing cum control valves (PIBC Valves). These valves will modulate the flow of water through cooling coil/heating coils based on the requirement of cooling or heating. If the requirement of water flow reduces in the circuit, then a pressure differential switch will signal the controller of variable speed pumping system (VSPS System). The controller will then signal the VFD's of pumps to ramp down or ramp up the speed of pumps as per the flow requirement in the circuit. In order to maintain a minimum flow in the circuit a bypass line between the supply and the return water pipes should be installed towards the end of circuit. This bypass line should have modulating valve controlled by flow sensor. When the speed of the pump is reduced to the minimum permissible limit and if still the water requirement is lower than these modulating valves should gradually open to maintain the minimum flow in the circuit.

8.10.5 Primary-secondary

A primary-secondary pumping scheme divides the chilled water system into two distinct circuits that are hydraulically separated by a de-coupler (neutral bridge). In primary-secondary systems, chilled water flows through the chiller primary loop at a constant flow rate, whereas in the secondary loop, flow rate is varied according to the load. The hydraulic independence of each loop prevents variable flow in the secondary loop from influencing the constant flow in the primary loop. The speeds of the secondary pumps are determined by the controller measuring differential pressure (DP) across the supply and return mains of the chilled water loop or across the most critical load in the pipe network. Primary-secondary variable flow systems are more efficient than constant flow systems, since unnecessary pumping is avoided in the distribution loop, resulting in better energy efficiency.

During part-load conditions, the two-way valves begin to close, causing an increase in system differential pressure which is detected by a DP (differential pressure) sensor. Subsequently, the secondary pump control panel reduces the pump speed and flow of the secondary pump to match the load requirement.

The decrease in flow from the secondary loop means the chilled water will flow from the supply side to the return side to maintain constant volume through the chillers. This happens since the production loop (primary side) flow is greater than the distribution loop (secondary side) flow. Similarly, when the load increases at the space area, zone temperature increases, which makes the two-way valves open more. This reduces differential pressure across the cooling loads, causing the secondary chilled water pumps to ramp up.

In these changing load patterns, a hydraulic de-coupler located between the suction headers of the secondary and primary pumps acts as a balancing line, allowing chilled water to flow in either direction, from supply to return and vice versa. Without this de-coupler line, both the primary and secondary pumps would be in series, making the system unbalanced and causing operational problems.

8.10.6 Primary-secondary-tertiary

When the buildings to be served are distributed over a larger area, such as a university campus, so-called “primary-secondary-tertiary” schemes help to reduce pump pressures in the system. By splitting the system head between the secondary and tertiary pumps, excessive pressurisation in zones which don’t need high pressure is reduced. In these systems, all cooling coils or building loops may be served by a third set of pumps – tertiary pumps. These distributed pumping systems are well suited for large, multiple zone buildings, or multiple building systems with central energy plants. These systems are actually a collection of smaller systems operating independently of each other, but all of them use the same distribution piping and the central chiller plant. Tertiary pumps are sized for requirements of the specific cooling coil alone. Pump head is also calculated only to overcome the frictional loss in the tertiary loop.

Each of the tertiary pumps has its own pump controller, responding quickly to any changes in loop pressure caused by fluctuating demand. These pumps are usually speed controlled and when used as part of a suitable building connection strategy, they work in coordination with speed controlled central plant distribution (secondary) pumps.

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CHAPTER–9
DUCTING

9.1 SCOPE

This chapter covers the general requirements for sheet metal air duct work for air distribution with associated items such as air outlets and inlets, fresh air intake and fire dampers. The air duct material and construction requirement shall be confirming to IS 655: 2006 (reaffirmed 2022) as updated up to date/SMNCA standard.

9.2 MATERIAL:

9.2.1 Ducts

(i) The ducts shall be fabricated from Galvanized Sheet Steel (GSS) conforming to class 4 of IS: 277 as amended up to date for Insulated Ducts and class-3 of IS 277 for un-insulated ducts or The Aluminum sheet shall conform to IS : 737 as amended up to date. The steel sheet shall be hot dip galvanized with Matte finish with coating of minimum 120gm/sqm (GSM) of zinc, GI Sheet shall be laid free, eco-friendly and RoHS compliant.

(ii) Stainless steel sheet shall conform to IS 6911 as amended up to date.

(iii) Steel products shall conform to IS 2062 as amended up to date.

(iv) All sheet metal connections, partitions and plenums required for flow of air through the filters, fans etc. shall be at least 1.25 mm thick galvanized steel sheets, in case of G.I. sheet ducting or 1.8 mm thick aluminum sheet, in case of aluminum sheet ducting and shall be stiffened with 25 mm x 25 mm x 3 mm angle iron braces.

(v) Aluminum ducting shall normally be used for clean room applications, hospitals works and wherever high cleanliness standards are functional requirements.

(vi) Hanger rods shall be of mild steel and of at least 10 mm dia for ducts up to 2250 mm size, and 12 mm dia for larger sizes.

(vii) All nuts, bolts and washers shall be zinc plated steel. All rivets shall be galvanized or shall be made of magnesium - aluminum alloy. Self-tapping screws shall not be used.

9.3 CONSTRUCTION

The Construction of Ducts shall be as per IS 655 “Specification for metal air ducts”/SMNCA standard until otherwise deviated in this specification.

The various accessories, assembly materials shall be conform to below given IS Code.

(i) The steel jointing flange shalt conform to IS: 2062 as amended up to date.

(ii) Hexagon head bolts and nuts shall conform to IS: 1363 (Part 1) as amended up to date and IS : 1363 (Part 3) as amended up to date respectively.

(iii) The steel rivets shall conform to IS: 2998 as amended up to date. When the duct material is stainless steel sheet or polyvinyl chloride lined steel sheet, the rivet shall be made of stainless steel or copper conforming to IS: 2907 as amended up to date.

(iv) The adhesive to be used for connection of glass wool duct shall conform to IS: 848 as amended up to date.

(v) Steel bars for the support material shall conform to IS : 2062 as amended up to date.

(vi) Steel flats for support material shall conform to IS : 2062 as amended up to date.

(vii) Steel tubes for support material shall conform to IS : 3601 as amended up to date.

9.3.1 **Rectangular Ducts :**

(i) Ducts shall be fabricated at site or factory fabricated and shall be generally as per IS: 655 "Specifications for metal air ducts", unless otherwise deviated in these General Specifications. The factory made Ducts shall be IS Marked as per IS: 655 as amended up to date.

(ii) The interior surfaces of the ducting shall be smooth.

(iii) All the ducts upto 600 mm longest side shall be cross broken between flanges by a single continuous breaking. Ducts of size 600 mm and above shall be cross broken by single continuous breaking between flanges and bracings. Alternatively, beading at 300 mm centres for ducts upto 600 mm longest side, and 300 mm centres for ducts above 600 mm size shall be provided for stiffening.

(iv) As far as possible, long radius elbows and gradual changes in shape shall be used to maintain uniform velocity accompanied by decreased turbulence, lower resistance and minimum noise. The ratio of the size of the duct to the radius of the elbow shall be normally not less than 1:1.5.

(v) Flanged joints shall be used at intervals not exceeding 2500 mm. Flanges shall be welded at corners first and then riveted to the duct.

(vi) Stiffening angles shall be fixed to the sides of the ducts by riveting at 1.25 meters from joints for ducts of size 600 mm to 1500 mm, and 0.6 mm from joints for ducts of size larger than 1500 mm. Bracings for ducts larger than 1500 mm can alternatively be by diagonal angles.

(vii) Plenums for filters shall be complete with suitable access door of size 450 mm x 450 mm.

(viii) All factory fabricated duct shall be supplied in L sections, the length of any piece shall not be more than 1800 mm for duct with longest side of cross section as 600 mm and above and 3000 mm for rest.

(ix) Dimensions of long side and short side of rectangular duct shall be as per given below Table:

TABLE 9.1
DIMENSIONS OF LONG SIDE AND SHORT SIDE OF RECTANGULAR DUCT

Long size (In mm / Short size (In mm)	100	150	200	250	300	350	400	450	500	550	600	650	700	750	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400	2500
100		o	o	o	o		o																									
150		o	o	o	o		o		o		o																					
200			o	o	o		o		o		o		o		o																	
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NOTES

3 The mark shows the standard size and inside of the thick line frame shows the recommended sizes.

4 The maximum value of the ratio of vertical dimension to lateral dimension in recommended sizes shall be 1:4.

5 The long side of duct by same sheet flange technique shall be 2200 mm at the maximum.

(x) Tolerance on both long side and short side -0, +4 mm.

(xi) The thickness of sheet of short side of rectangular duct shall be the same as that of long side. The thickness of sheet of rectangular duct, namely galvanized steel ducts, stainless steel ducts shall be as given below :

Table -9.2
Thickness of Sheet for Galvanized Steel Sheet Duct

Duct Dimension		Thickness of Sheet,(Min) In mm,
Long side of duct (L)	L ≤ 750 mm	0.63
	750 mm < L ≤ 1500 mm	0.8
	L > 1500mm ≤ 2250 mm	1.0
	L>2250 mm	1.25

Table- 9.3
Thickness of Sheet for Stainless Steel Sheet Duct

Duct Dimension		Thickness of Sheet,(Min) In mm,
Long side of duct (L)	L ≤ 750 mm	0.5
	750 mm < L ≤ 1500 mm	0.6
	L > 1500mm ≤ 2250 mm	0.8
	L>2250 mm	1.0

Note: Provision of table 9.2 & 9.3 are for low pressure duct. Therefore for medium and high pressure duct the provision of IS 655 will be applicable.

(xii) Reinforcement of Galvanized steel duct :

(a) Lateral Reinforcement shall be as given below:

Table-9.4
Lateral Reinforcement of Duct

Long Side of Duct (L) mm	Spacing Reinforcement			
	Minimum Size of Steel Angle Reinforcement mm	Maximum Spacing		
		Angle Flange Technique mm	Slide-on Flange Technique mm	Same Sheet Flange Technique mm
(1)	(2)	(3)	(4)	(5)
250 < L ≤ 750	25x25x3	925	925	925
750 < L,≤ 1200	30x30x3	925	925	925
1200 < L ≤ 2200	40x40x3	925	925 + Tie rod	925 + Tie rod

L>2200	40x40x5 (3)	925	925 + Tie rod	-

Note : The value given in parenthesis shows that when tie rods are also used.

(b) Longitudinal Reinforcement shall be as given below:

Table-9.5
Longitudinal Reinforcement of Duct

Long Side of Duct (L) mm (1)	Minimum Size of Steel Angle mm (2)	Position of Reinforcement (3)
1200 < L ≤ 2200	40x40x3	One point or more
L>2200	40x40x3	Two points or more

Note :

1. The value given in parenthesis shows that when tie rods are also used.
2. The mounting of steel angle shall be made by rivets of nominal diameter not less than 4.5 mm or electrical spot welding and the spacing between welding shall not exceed 100 mm.
3. For ducts not thermally insulated with a long side exceeding 450 mm diamond brake or reinforcement rib with a pitch not exceeding 300 mm shall be mounted.
4. The longitudinal reinforcement shall be evenly spaced on the side of duct so that the specified number of reinforcements is obtained.

Angle reinforcement may be outside or inside of the duct.

(xiii) Reinforcement of Stainless steel sheet Duct: it shall be same as for Galvanized steel duct except that the reinforcement section shall be stainless steel and rivet shall also be of SS.

(xiv) Joint of Galvanized Steel Sheet Duct and Stainless :

It shall be of following material as given below

Table-9.6
Materials for Joint of Ducts by Angle Flange Technique

Long Side of Duct (L) mm	Joint Flange		Flange Mounting Rivet		Connecting Bolt		
	Angle Minimum Size mm	Maximum Spacing mm	Minimum Nominal Diameter mm	Maximum Spacing of Rivets mm	Minimum Nominal Diameter mm	Maximum Spacing	
						Corner mm	Other Corner mm
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
L < 750	25X25X3	1820	4.5	65	M8	100	100
750 < L ≤ 1500	30X30X3	1820	4.5	65	M8	100	100

1500 < L ≤2200	40X40X3	1820	4.5	65	M8	100	100
L>2200	40X40X5	1820	4.5	65	M8	100	100

Notes :

1. The bolts shall be located symmetrically at the central portion of flange.
2. Electrical spot welding may be employed other than riveting. The spacing shall be within 100 mm
3. The diameter of connecting bolt shall not exceed a certain diameter which ensure enough edge distance.

9.3.2 **Circular Ducts:**

Ducts shall be fabricated at site or factory fabricated and shall be generally as per IS: 655 "Specifications for metal air ducts", unless otherwise deviated in these General Specifications.

(a) Internal diameters of circular ducts and circular spiral ducts shall be as given below 63, 80, 100, 125, 160, 200, 250, 315, 355, 400, 450, 500, 560, 630.
The Tolerances on size of circular ducts shall be as given below:

Table-9.7
Tolerances on External Diameters of Circular Duct, Circular Spiral Duct and Socket Joint

<table>
<tr><th rowspan="2">Internal Diameter of Duct Mm
(1)</th><th colspan="2">Dimensional Tolerances of Duct mm</th><th colspan="2">Tolerances on External Diameter of Socket Joint mm</th></tr>
<tr><th>Min
(2)</th><th>Max
(3)</th><th>Min
(4)</th><th>Max
(5)</th></tr>
<tr><td>63</td><td rowspan="20">0</td><td rowspan="4">+0.5</td><td rowspan="4">-1.2</td><td rowspan="20">-0.7</td></tr>
<tr><td>80</td></tr>
<tr><td>100</td></tr>
<tr><td>125</td></tr>
<tr><td>160</td><td>+0.6</td><td>-1.3</td></tr>
<tr><td>200</td><td>+0.7</td><td>-1.4</td></tr>
<tr><td>250</td><td>+0.8</td><td>-1.5</td></tr>
<tr><td>315</td><td>+0.9</td><td>-1.6</td></tr>
<tr><td>355</td><td rowspan="2">+1</td><td>-1.7</td></tr>
<tr><td>400</td><td rowspan="3">-1.8</td></tr>
<tr><td>450</td><td rowspan="2">+1.1</td></tr>
<tr><td>500</td></tr>
<tr><td>560</td><td rowspan="2">+1.2</td><td rowspan="2">-1.9</td></tr>
<tr><td>630</td></tr>
<tr><td>710</td><td rowspan="2">+1.6</td><td rowspan="2">-2</td></tr>
<tr><td>800</td></tr>
<tr><td>900</td><td rowspan="2">+2</td><td rowspan="2">-2.1</td></tr>
<tr><td>1000</td></tr>
<tr><td>1120</td><td rowspan="2">+2.5</td><td rowspan="2">-2.2</td></tr>
<tr><td>1250</td></tr>
</table>

NOTE – Dimensional tolerances on cross –section of circular glass wool duct shall be ±3 mm.

(b) The thickness of sheet for galvanized steel sheet duct and for stainless steel sheet circular and circular spiral duct shall be as given below

Table – 9.8
Thickness of Sheet for Galvanized Steel Sheet Duct and Stainless Steel Sheet Duct

Duct dimension		**Thickness of Sheet, Min, mm**
Internal diameter of duct (d), mm	$d \leq 450$	0.8
	$450 < d \leq 630$	1.0

Table – 9.9
Thickness of Sheet for Circular Spiral Galvanized Steel Sheet Duct

Duct dimension		**Thickness of Sheet, Min, mm**
Internal diameter of duct (d), mm	$d < 200$	0.5
	$200 < d \leq 560$	0.6
	$560 < d \leq 1000$	0.8
	$800 < d \leq 1000$	1.0
	$d > 1000$	1.2

(c) Reinforcement of Circular Galvanized sheet or Stainless steel sheet Ducts:
It shall be as given below:

Table-9.10
Reinforcement of Circular Galvanized Steel Sheet or Stainless Steel Sheet Duct

Thickness of Sheet mm	**Minimum size of steel angle mm**	**Maximum Spacing mm**	**Mounting Rivet**	
			Minimum Nominal Diameter mm	**Maximum Spacing of Rivet mm**
(1)	(2)	(3)	(4)	(5)
0.6	25x25x3	2400	4.5	100
0.8	30x30x3	1800	4.5	100
1.0	40x40x3	1800	4.5	100
2.0	40x40x5	1200	4.5	100

iv) Joints of Circular Duct ad Circular Spiral Duct:
The connecting materials, the number of flange bolts, and dimensional positioning of flange bolt holes shall be as given below:

Table-9.11
Connecting Materials for Flange Joint

Internal Diameter of Duct (d) mm	Joint Flange		Flange Mounting Rivet		Connecting Bolt	
	Minimum Size of Angle mm	Maximum Spacing mm	Minimum Nominal Diameter mm	Maximum Spacing mm	Minimum Nominal Diameter mm	Maximum Spacing mm
(1)	(2)	(3)	(4)	(5)	(6)	(7)
d < 700	25x25x3	1820	4.5	65	M8	100
710 < d ≤ 1000	30x30x3	1820	4.5	65	M8	100
1000 < d ≤ 1260	40x40x3	1820	4.5	65	M8	100

Note : The diameter of connecting bolt shall not exceed a certain diameter which ensures enough edge distance of flange.

9.3.3 **Air Outlet and Inlets (Supply and Return)**

(i) All air outlets and intakes shall be made of extruded aluminum sections & shall present a neat appearance and shall be rigid with mechanical joints.

(ii) Square and rectangular wall outlets shall have a flanged frame of extruded aluminium section with the outside edges returned or curved 5 to 7 mm and fitted with a suitable flexible gasket between the concealed face of the flanges and the finished wall face. The core of supply air register shall have adjustable front louvers parallel to the longer side to give up to 22.5 degrees vertical deflection and adjustable back louvers parallel to the shorter side to achieve a horizontal spread air pattern to at least 45 degrees. Return air grilles shall have only front louvers. The outer framework of the grilles shall be made of not less than 1.6 mm thick aluminum sheet. The louvers shall be of aero foil design of extruded aluminum section with minimum thickness of 0.8mm at front and shall be made of 0.8mm thick aluminum sheet. Louvers may be spaced 18 mm apart. Louvers shall be in modular panel form for ease of handling. These shall be free from waves and buckles. Vertical blades shall be truly vertical and horizontal blades shall be truly horizontal. Butt joints in blades shall not be accepted.

Additional intermediate equally spaced supports and stiffeners shall be provided to prevent sagging/ vibrating of the louvers, at not more than 750mm centers where the louver's length is longer than 750mm. A bird wire screen made of 12 mm mesh in 1.6 mm steel wire held in angle or channel frame shall be fixed to the rear face of the louver frame by screens.

(iii) Square and rectangular ceiling outlets/intakes shall have a flange flush with the ceiling into which it is fitted or shall be of anti-smudge type. The outlets shall comprise an outer shell with duct collar and removable diffusing assembly. These shall be suitable for discharge in one or more directions as required. The outer shell shall not be less than 1.6 mm thick extruded section aluminum sheet. The diffuser assembly shall not be less than 0.80 mm thick extruded aluminum section.

(iv) Circular ceiling outlets/intakes shall have either flush or anti smudge outer cone as specified in the tender specifications. Flush outer cones shall have the lower edge of the cone not more than 5 mm below the underside of the finished ceiling into which it is fitted. Anti-smudge cones shall have the outer cone profile designed to reduce dirt deposit on the ceiling adjacent to the air outlet. The metal sheet used for construction of these shall be minimum 1.6 mm thick extruded aluminum sheet.

(v) Linear diffusers shall have a flanged frame with the outside edges returned 3.5 mm and shall have one to four slots as required. The air quantity through each slot shall be adjustable. The metal sheet used for the construction of these shall be minimum 1.6 mm thick extruded aluminum sheet.

(vi) Grilles and diffusers constructed of extruded aluminum sections shall have grille bars set straight, or deflected as required. These shall be assembled by mechanical interlocking of components to prevent distortion. These grilles and diffusers shall have a rear set of adjustable blades, perpendicular to the face blades for deflection purposes.

(vii) All supply air outlets shall be fitted with a volume control device, made of extruded aluminum gate section. The blades of the device shall be mill finish/ block shade pivoted on nylon brushes to avoid rusting & rattling noise, which shall be located immediately behind the outlet and shall be fully adjustable from within the occupied space without removing any access panel. The volume control device for circular outlets shall be opposed blade radial /shutter type dampers, or two or more butterfly dampers in conjunction with equalizing grid. Opposed blade dampers shall be used for square and rectangular ceiling/wall outlets and intakes. Each volume control damper shall be AMCA (Air Movement and Control Association) certified for Air leakage (Class I) & Air Performance. Pressure drop shall not exceed 5 Pa when tested at 300 m/min face velocity on a 600x600 mm size damper.

(viii) All the products supplied by contractor should supplement in performance by selection curves of product ratings from the manufacturer.

(ix) Laminar supply air diffusers shall be made of 2 mm thick powder coated aluminum sheet duly insulated with 5mm thick closed cell polyethylene foam insulation having factory laminated aluminum foil and joints covered with self-adhesive aluminum tape and having holes 2/3 mm dia including frame work.

9.3.4 **Fresh Air Intakes**

(i) Fresh air intake grills shall be made of extruded aluminum sections.

(ii) A flanged frame using RS sections shall be provided on front face to conceal the gap between the louvers and the adjoining wall face. Corners of frame shall be welded. The frame shall be made structurally rigid.

(iii) Louvers made from extruded aluminium section shall be in modular panel form for ease of handling. These shall be free from waves and buckles. Vertical blades shall be truly vertical and horizontal blades shall be truly horizontal. Butt joints in blades shall not be accepted.

(iv) Additional intermediate equally spaced supports and stiffeners shall be provided to prevent sagging/ vibrating of the louvers as required.

(v) A bird wire screen made of 12 mm mesh in 1.6 mm steel wire held in angle or channel frame shall be fixed to the rear face of the louver frame by screens.

9.4 FIRE CUM SMOKE DAMPERS:

(i) Fire dampers shall be provided in all the supply air ducts and return air ducts (where provided), return air passage in the air-handling unit room and at all floor crossings. Access door will be provided in the duct before each set of fire dampers.

(ii) Fire dampers shall be multi blade louvers type. The blade should remain in the air stream in open position & shall allow maximum free area to reduce pressure drop & noise in the air passage. The blades and frame shall be constructed with minimum 1.6mm thick galvanized sheet & shall be factory fitted in a sleeve made out of 1.6mm galvanized sheet of minimum 400mm long. It shall be complete with locking device, motorized actuator & control panel.

(iii) Fire dampers shall be motorized smoke & fire dampers type. It shall be supplied with spring loaded UL stamped fusible link (certified according to UL 33) to close fire damper in the event of rise in duct temperature. Fire damper shall also close on receipt of fire alarm signal to cut off air supply instantaneously. An electric limit switch shall also be operated by the closing of fire damper, which in turn shall switch off power supply to AHU blower motor as well as strip heaters. Fire cum smoke damper shall operate based on heat as well smoke detection.

(iv) Fire dampers shall be tested and certified with dynamic fire damper requirements of UL standard 555 and with smoke damper requirements of UL standard 555S. Fire cum smoke damper shall be tested and/or certified with requirement of UL standard 555 and UL standard 555S. Fire Ceiling Damper shall be tested and certified with requirement of UL Standard 555C.

(v) The Fire damper shall also meet requirements with:

(a) NFPA 80, 90A, 92, 101 and 105 (latest edition)

(b) National Building Code of India 2016

(vi) Fire dampers shall be certified for 90 minutes rating against collapse & flame penetration as per UL 555.

(vii) Fire dampers shall be compatible with the fire detection system of building & shall be capable of operating automatically through an electric motor on receiving signal from fire alarm panel.

(viii) Necessary wiring from fire alarm panel up to AHU electric panel shall be provided by the department & further from AHU electric panel to fire damper shall be provided by air conditioning contractor.

(ix) Damper shall have a UL standard 555 fire resistance ratings of 3 hours and damper shall have a UL standard 555S elevated temperature rating of 2500C.

(x) Dampers shall have a UL standard 555S leakage rating of leakage class I (8 cfm/ft2 at 4 in. WG (101.6 mmWG), velocity rating of 4000 fpm and differential pressure rating of 4 in. WG (minimum).

(xi) Electric actuator shall be external mounting type with 230 V AC, 2 position or modulating. An access door shall be provided as per NFPA 80 & 105 requirement.

(xii) The Fire Damper shall be installed such that the fire integrity of the partition is maintained. Sleeves, if any, used for mounting the damper shall be designed for the rated fire resistance and the opening in the partition fire sealed with an appropriate and approved sealant.

9.5 Turning vanes :

Air turning devices shall be provided at least for first four outlet collars after every elbow and at all non-split branch take offs. Turning blades shall be fabricated out of 0.8 mm (22G) thick G.S sheets and equally spaced on side runner to be riveted/bolted to duct sheets. All vanes shall be of double thickness.

9.6 Splitter dampers :

Splitter dampers shall be installed in branches wherever split takes place. Splitter dampers shall consist of double thickness air foil blades hinged at the down streams edge. The operation rod shall terminate outside of the duct and insulation, and an air tight hub and locking set screw shall be provided. Damper blade thickness shall be the same as the duct in which it is installed but not less than 1.5 mm. Entire splitter damper shall be enclosed in a sheet steel ducting with flanges at both ends aligning with main run of ducting. The enclosure shall be made of sheets one size larger than the upstream duct.

9.7 Louvre dampers :

Louvres dampers shall be provided in all branches. Any duct feeding more than four outlets shall be regarded as a branch and louver dampers provided whether shown or not. Louvre dampers shall be multi-blade type with opposed blades or parallel blades of air foil construction rotating in permanently lubricated ball/ roller bearings. Blades shall be 1200 x 250 maximum mounted in a channel frame. Blades shall be connected with suitable linkage for gang operation by an operating rod extending beyond the frame and insulation if any and terminating in a locking quadrant with damper position indicator. Damper larger than 1200 mm in width shall be furnished in multiple sections. Dampers shall be enclosed in a sheet steel box with flanges at both ends. Thickness shall be one size larger than the upstream duct**.**

9.8 VARIABLE AIR VOLUME (VAV) BOXES

(i) These shall of the low velocity variable air volume boxes without re-heat coils, and shall be of open protocol as marketed by a firm specializing in this field. The contractor shall supply and install units to the quantity and locations as specified.

(ii) The unit shall be complete with damper, airflow ring, and solid-state electronic controls to provide accurate room temperature control. The damper shall be aero foil type construction with bearings.

(iii) Boxes shall be supplied with all internal attenuation treatment and acoustical damped casing necessary to achieve the required noise criteria. Casing shall be of 22G GSS minimum fitted with a completely sealed, easily removable means of access to all internal parts. Access to all boxes must be from the underside only.

(iv) The actuator shall be of 24V AC Bi-directional, direct coupled to the damper shaft. The required transformer to step down of the voltage range from 230V to 24V shall be part of the unit. The power point with an isolator near the VAV will be provided by other agencies.

(v) The unit shall be complete with transformer, access panel and other accessories as per the standard.

(vi) The noise level shall be less than 35dbA.

(vii) Maximum allowable static pressure to the boxes for its satisfactory operation shall not exceed 0.10WG, otherwise fan and motor selections may be affected.

(viii) Boxes shall be able to reset any air flow between 10% and the maximum air quantity that the boxes can handle without changing orifices or other parts. Air quantity limiters will not be accepted.

(ix) A suitable device shall be provided for the field adjustment of minimum airflow. All boxes shall be initially factory set at minimum air quantity of 10% and maximum quantity of 110%of the design requirements.

(x) Under shut-off conditions, all boxes shall not have air leakage more than 2% of the maximum air quantity at 75mm static pressure.

(xi) The VAVs shall be used in standalone mode complete with its own temperature sensor and controller and shall perform the function of maintaining the temperature and airflow.

(xii) Where ever specified, the VAVs shall be BMS compatible to enable to network the VAVs to a Network Control Unit and onto BMS. In this mode all VAV data shall be available at the BMS workstation and it shall be possible to change set points and flow settings from the BMS workstation. All such controllers used for the control of VAV boxes shall be compliant with BACnet/ MODBUS protocol and be freely communicable to third party BACnet/ MODBUS IP controllers.

(xiii) All boxes shall be electrically controlled. The boxes shall be pressure independent.

(xiv) VAV Box shall have provision to support from floor/ wall/ ceiling and in vertical/ horizontal condition.

9.9 ACOUSTIC LINING AND INSULATION

This shall be done as per details given in Chapter 11.

9.10 FLEXIBLE DUCTING

9.10.1 Application

Flexible Duct is a round, flexible light weight duct and is preliminary used for

(i) Speedy completion of project
(ii) Offers a high degree of flexibility, which allows it to be easily connected to any desired position.
(iii) A quick and economical means of correcting misalignment between system components.
(iv) Allows ducting around obstacles where fabricated and fitted ducts would be difficult and costly to install.

9.10.2 Material

(i) An un-insulated flexible duct shall be made of double lamination of metalized polyester film permanently bonded to a coated spring steel wire helix. Duct shall be in tear & puncture resistant construction.
(ii) For insulated flexible duct where specified, inner core for the same should be made of double lamination of metalized polyester film permanently bonded to a coated spring steel wire helix. Fiberglass insulation of minimum 14 kg/cu.m density, 25 mm thickness shall be wrapped over the inner core & covered with strong outer jacket cum vapour barrier made of fibre glass reinforced metalized polyester film laminate.
(iii) Care must be taken to install all the flexible duct in fully extended position & bends made with adequate radius as per manufacturer recommended practices.
(iv) Length of flexible duct shall be limited to less than 1000 mm.

9.11 INSTALLATION OF METALLIC DUCT

9.11.1 Ducting

(i) The fabrication and installation shall be in a workmanlike manner. Duct work shall be rigid and straight without kinks.
(ii) All exposed ducts within the conditioned space shall have slip joints. Flanged joints shall not be used.
(iii) All joints shall be airtight.
(iv) Ducts shall be supported independently from the building structure and adequately, to keep the ducts true to shape. The support spacing shall be not more than 2 m. where ducts cannot be suspended from ceiling, wall brackets or other suitable arrangements, as approved by the Engineer-in-charge shall be adopted. Neoprene or other vibration isolation packing of minimum 6 mm thickness shall be provided between the ducts and the angle iron supports/brackets. Vertical duct work shall be suitably supported at each floor by steel structural members.
(v) Where metal ducts or sleeves terminate in woodwork, tight joints shall be made by means of closely fitting heavy flanged collars. Where ducts pass through brick or masonry openings, Suitable provision shall be made for safety of the duct & fire spread and the crossing ducts shall be provided with heavy flanged collars on either side of the wooden frame work, so that duct crossing is made leak-proof.
(vi) Duct connections to the air-handling unit shall be made by inserting a double canvas sleeve fire rated as per NBC 100 mm long. The sleeve shall be securely bonded and bolted to the duct and unit casing.
(vii) Dampers shall be provided in branch duct connections for proper volume control and balancing the air quantities in the system, whether indicated in the drawings or not. Suitable links, levers and quadrants shall be provided for proper operation, control and setting of the dampers. Every damper shall have an indicating device clearly showing the

position of the dampers at all times. In case of false ceiling the indication device shall be below the false ceiling.

(viii) Where electrical heaters are mounted in the duct, these shall be of low temperature totally enclosed type fitted with radiation fins. A removable panel for access to the heaters shall be provided in the duct. Any hole in the duct for electrical wiring must be provided with suitable bushes to avoid leakage along with suitable lining. A manually reset thermostatic safety switch shall be provided near the duct section having heaters. In addition, the heaters must be interlocked with the connected fan motor of the AHU.

9.11.2 **Air Outlets and Inlets**

(i) The locations of the air outlets and intakes shall be shown in the tender drawings and necessary openings and the wooden framework for fixing the grilles shall be provided by the air conditioning contractor. The location of these outlets/ inlets is subject to change and the approval of the Engineer-in-Charge shall be obtained before finally fixing the grilles/diffusers in position.

(ii) In installing fresh air intakes, no fixing device shall be visible from the face of the frame. Where louvers are to be fixed in masonry or concrete, fixing shall be with either expanding plugs or raw plugs. Where the louvers are to be fixed in steel or wood, non-ferrous screws or bolts shall be used.

(iii) Supply air outlets and return air intakes shall be anodized/ powder coated aluminium to the desired colour to match the surroundings wall/ceiling. The fresh air intakes shall be anodized/ powder coated aluminium as approved by the Engineer-in-Charge. The paint colour shall be approved by the Engineer-in-Charge.

(iv) All damages to the finish of the structure during the installation work shall be made good by the air-conditioning contractor before handing over the installation to the Department.

9.11.3 **Duct supports :**

Duct supports and suspenders shall be galvanized steel and meet the following requirements:

Duct Width (mm)	Support	Hangar Rod (mm)	Location
Upto 1200	40 x 40 x 3 mm angle	10mm	At Transverse Joints OR Support length not exceeding 2500mm
Over 1200 - 1800	- Do -	10mm	- Do -
Over 1800 to 2500	40 x 40 x 6 mm steel MS	12mm	At Transverse Joints OR Limiting Support length not exceeding 2500mm
Over 2500	50 x 50 x 6 mm MS angle	12mm	At Transverse Joints OR Limiting support length not exceeding 1200mm

As an alternative slotted galvanized brackets attached to the top two bolts of the four bolt duct jointing system may be used.

Additional supports wherever considered necessary by the Engineer-in-charge shall be provided.

All duct supports, flanges, hangers shall be hot-dip galvanized.

9.11.4 **Duct connectors**

Ducts connected to air-moving apparatus shall have flexible connectors. Flexible connectors shall be preassembled factory made units with minimum 150mm in width with 50mm galvanized steel rims on both sides. Connectors shall be mildew resistant and shall have fire retardant materials. Flexible Duct connector shall be tested and certified in accordance with BS 476 part 7 for class 1 and NFPA -701 from NABL accredited lab.

9.12 BALANCING

Air systems shall be balanced in a manner to minimize throttling losses. The entire air distribution system shall be balanced with the help of an anemometer. The measured air quantities at fan discharge and at the various outlets shall be within ± 5 percent of those specified/quoted. For fans greater than 0.75 KW (1.0 HP), fans must then be adjusted to meet design flow conditions. Branch duct adjustments shall be permanently marked after the air balancing is completed so that these can be restored to their correct position if disturbed at any time.

The entire air distribution shall be adjusted and balanced for delivery of design air quantities or as required for achieving design space conditions. Tests shall be carried out for each fan or AHU section. After all adjustments are made, the air readings shall be recorded on the drawings vis-à-vis the space conditions. All dampers after adjustment shall be set and locked in position. The provision related to balancing as mentioned in Chapter 17 shall be complied.

9.13 MEASUREMENT

(i) Duct measurements (for insulated ducts) shall be taken before application of insulation.

(ii) Duct work shall be measured section wise on the basis of external surface area by multiplying the axial length from flange face to flange face for each section by the corresponding duct perimeter in the centre of that section length.

(iii) Uniformly tapering straight sections shall also be measured as in (ii) above. However, for special pieces like tees, bends etc. area computations for surface areas shall be done as per the shape of such pieces.

(iv) The quoted unit rate for external surfaces of ducts shall include all wastage allowances, flanges, gaskets for joints, vibration isolators, bracings, hangers and supports, inspection chambers/access panels, splitter dampers with quadrants and levers for position indication, turning vanes, straightening vanes, and all other accessories required to complete the duct installation as per the specifications. These accessories shall not be separately measured.

(v) Grilles and diffusers (except linear diffusers) shall be measured by the cross sectional areas, perpendicular to the airflow, and excluding the flanges. Volume control dampers, where provided shall not be separately accounted for.

(vi) Linear diffusers shall be measured by linear measurements only, and not by cross-sectional areas, and shall exclude flanges for mounting of the linear diffusers. The supply air plenum for linear diffusers shall be measured as described above for ducting.

(vii) Fire dampers shall be measured by their cross sectional area perpendicular to the direction of the airflow. Quoted rates shall include the necessary collars and flanges for mounting, inspection pieces with access door, fusible link/solenoid with wiring, but excluding the fire detectors, etc.

CHAPTER-10

WATER PLUMBING WORK

10.1 SCOPE

This chapter covers the requirements of plumbing work in chilled water, hot water, water in condenser circuit and drains, to be executed as part of heating, ventilating and air conditioning.

10.2 PLUMBING DESIGN

Pipe sizes shown in tender documents are purely for contractor's guidance. The contractor shall be responsible for selection of sizes as per detailed engineering to be done by him. Plumbing design to be done by the Air-conditioning contractor shall conform to the following: -

(i) Water velocity in pipes shall not exceed 2.5 m/sec.

(ii) Butterfly/ Ball valves shall be provided at

(a) suction and delivery sides of pumps.

(b) inlet and outlet of each condenser, chiller, cooling tower, hot water generator.

(c) all drain connections from equipments.

(d) Inlet & outlet of every heat exchanger coil, namely for AHU's, FCUs's, convector etc.

(iii) Non return valve shall be provided at the delivery of each pump. This shall be of swing type.

(iv) Balancing valve shall be provided at the outlet side of chiller, condenser, heating and cooling coils to regulate the maximum flow rate upto value preset as desired.

(v) Balancing valves shall be provided, where specified, for AHU's to regulate the maximum flow rate upto a value preset as desired. A mercury manometer shall be supplied with every 10 nos. or part thereof of balancing valves, whether or not specifically indicated in the tender specifications.

(vi) Air valves shall be provided at all high points in the piping system for venting with a size of 25 mm for pipes upto 100 mm and 40 mm for larger pipes.

(vii) Plumbing drawings showing the sizes of valves, layout and other details shall be prepared and shall be got approved from the Engineer-in-Charge before the execution of the plumbing work.

10.3 PIPE MATERIALS

Pipes shall be of the following materials.

(i) Mild steel C-class (Black steel) tube conforming to IS: 1239 for sizes upto 150 mm.

(ii) Welded black steel pipe, heavy duty, conforming to IS: 3589, for sizes greater than 150 mm. These pipes shall be factory rolled & fabricated from minimum 6mm thick M.S. Sheet for pipes upto 350mm dia & from minimum 7mm thick M.S. sheet for pipes of 400mm dia & above.

10.4 PIPE JOINTS

Seismic considerations shall be taken into account while planning joint details. Joints in black steel pipes shall be of any of the following types.

(i) Screwed joints and union joints screwed to pipes, upto 25 mm size.

(ii) Butt welded joints for pipe sizes above 25mm. Electric welding shall be used for sizes 100mm and above.

(iii) Flanges joints with flanges as per IS: 6392 for all sizes. Flanges may be steel welded neck type or slip on type welded to pipe, or alternatively screwed type. The item of flanges shall be measured and paid separately.

(iv) Flexible coupling V groove joints.

(v) Flexible connections shall be provided at the pumps, and other machine where requires as per following specifications-

(a) The Flexible connections shall be flanged type expansion joint. Flanges shall be non-compressible and mechanically strong type and the Neoprene rubber shall be provided in between the flange ends.

(b) The connections shall work for a temperature range of minus 10°C to 70°C.

(c) The length and working pressure of bellows shall be as follows:

Nominal Bore (mm)	Length (mm)	Pressure (Bar)
20-25	125	15
32-200	150	15
250-350	200	10

(d) Connections shall be provided with control rods to control the excessive elongation or compression of piping systems.

(e) these shall be capable to withstand torsional movement upto 3^o without damage.

10.5 INSULATED CHILLED WATER PIPES

(i) The pipe shall be MS ERW as specified in the Piping Section.

(ii) The pipe insulation shall be polyurethane foam with minimum density of 36 kg/cu m, 90% minimum closed cell content, minimum compressive strength of $2.7kg/cm^{2,}$ and initial thermal conductivity of 0.02W/mK. The insulation shall completely fill the annular space between the service pipe and jacket and shall be bonded to both, the service pipe & jacket.

(iii) The cladding shall be spirally wounded of G.I. or Aluminium as specified in tender documents for pipes installed on surface.

(iv) For pipes installed on surface The insulation (PUF) shall be provided to the thickness with thickness of cladding as below:

S.No.	Dia. of MS Pipe	Minimum Thickness of PUF in (mm)	Minimum Thickness of G.I. Cladding	Minimum Thickness of Al. Cladding
1.	20 mm	33	0.457mm	0.559mm
2.	25 mm	32	0.457mm	0.559mm
3.	32 mm	33	0.457mm	0.559mm
4.	40 mm	30	0.457mm	0.559mm
5.	50 mm	31	0.457mm	0.559mm
6.	65 mm	36	0.457mm	0.559mm
7.	80 mm	42	0.457mm	0.559mm
8.	100 mm	42	0.457mm	0.559mm
9.	125mm	41	0.457mm	0.559mm
10.	150 mm	41	0.457mm	0.559mm
11.	200 mm	52	0.457mm	0.559mm
12.	250 mm	62	0.457mm	0.559mm
13.	300 mm	51	0.457mm	0.559mm
14.	350 mm	46	0.457mm	0.559mm
15.	400 mm	46	0.457mm	0.559mm

16.	450mm	45	0.457mm	0.559mm
17.	500mm	57	0.559mm	0.711mm
18.	550mm	57	0.559mm	0.711mm
19.	600mm	57	0.559mm	0.711mm
20.	650mm	56	0.559mm	0.711mm
21.	700mm	56	0.559mm	0.711mm
22.	750mm	55	0.559mm	0.711mm
23.	800mm	55	0.559mm	0.711mm

(v) Underground systems shall be buried in a trench of not less than 600 mm deeper than the top of the pipe & not less than 450mm wider than the combined OD of all piping systems. A minimum thickness of 600mm of compacted backfill over the top of the pipe is desirable.

(iv) Trench bottom shall have a minimum of 150mm of sand, pea gravel or specified backfill material, consolidated to suit operating weight & to act as a cushion for the piping.

(v) For pipes buried in ground outer protective insulation jacket shall be seamless, extruded, black, UV resistant, high-density polyethylene (HDPE).

(vi) For leak identification purpose 2 wire dignostic wiring shall also be provided.

(vii) Fitting can be fabricated at site over the carrier pipe and correct quantity of PUF shall be poured manually.

(viii) Field joints insulation shall consist of **PUF** poured manually in a site-fabricated GI cladding fixed around the joint

(ix) For pipes buried in ground minimum thickness of the **HDPE** jacket and PUF shall be as follows:

S.No.	**MS Pipe dia. (mm)**	**PUF Thickness (mm)**	**Thickness of HDPE Cladding (mm)**
1.	20 mm	30	3.0
2.	25 mm	40	23.0
3.	32 mm	30	3.0
4.	40 mm	40	3.0
5.	50 mm	40	3.0
6.	65 mm	40	3.0
7.	80 mm	40	3.0
8.	100 mm	40	3..0
9.	125mm	40	3.0
10.	150 mm	55	5.0
11.	200 mm	65	5.0
12.	250 mm	60	6.3
13.	300 mm	60	7.0
14.	350 mm	65	7.8
15.	400 mm	70	8.8
16.	450mm	75	9.8
17.	500mm	50	11.1
18.	550mm	65	11.1
19.	600mm	85	12.5
20.	650mm	60	12.5
21.	700mm	80	13.0
22.	750mm	105	15.0
23.	800mm	80	15.0

10.6 VALVES

(i) The material of butter fly valves shall be as under:
Body- Cast iron
Disc- Cast Bronze or Stainless Steel
Seat- Either integral or Nitrile rubber
O-ring-Nitrile/ Silicon

(ii) Balancing valve shall be of cast iron flanged construction with EPDM/ SG iron with epoxy coated disc with built in pressure drop measuring facility (pressure test cocks) to compute flow rate across the valve. The test cocks shall be long enough to protrude out of pipe insulation.

(iii) Non return valves shall be of gun metal construction upto 65 mm, the metal conforming to class 2 of IS: 778. For 75 mm and above, the valve shall be of bronze or gun metal, body being of cast iron. While screwed or flanged ends may be provided upto 65 mm, flanged ends shall be provided for larger sizes.

(iv) Air valves shall be of gunmetal body.

10.7 STRAINERS

(i) Strainers shall be of 'Y" type or pot type as specified.

(ii) 'Y' strainers shall be provided on the inlet side of each air-handling unit and pump in chilled water and condenser water circuit.

(iii) Pot strainers, where specified, shall be provided in return water headers, for chilled water and condenser water if enough floor area is available in the refrigeration plant room, as an alternate to individual Y type strainers with pumps.

(iv) The strainers shall be designed to the test pressure specified for the gate valves.

(v) Filtration area of Y-strainer shall be minimum four times the connecting pipe size.

(vi) Strainers shall have a removable bronze/ stainless steel minimum 1mm thick screen with 3 mm perforations and permanent magnet.

(vii) Strainers shall be provided with flanges or threaded sockets as required. They shall be designed so as to enable blowing out accumulated dirt and facilitate removal and replacement of screen without disconnection of the main pipe.

(viii) Strainers shall be provided with equal size isolating gate valves on either side so that the strainers may be cleaned without draining the system.

(ix) Pot strainer shall be fabricated out of MS sheet and the sizes shall be as under: -

Pipe sizes (mm)	**Pot dia (mm)**	**Pot Height (mm)**	**Basket dia (mm)**	**Basket Height (mm)**
50	300	400	200	240
80	350	450	250	250
100	450	500	300	280
125	500	600	330	340
150	540	700	360	390
200	610	815	400	470
250	800	955	550	510
300	1000	1105	750	580
350	1190	1300	895	678
400	1350	1500	1020	785
450	1518	1700	1060	890
500	1690	1800	1100	900

10.8 Pressure Independent Balancing cum Control Valves (PIBCV)

Each PICV is an automatic temperature control valve, an automatic flow - regulating valve and a flow-limiting valve packaged into one body. The PICV regulates and maintains a constant flow to the coil, irrespective of differential pressure variations, and is used in heating and cooling systems for both air handling units and fan coil units.

(i) In case specified in NIT, each Air handling unit / Fan Coil / DOAS / TFA unit shall be provided with a 2-way pressure independent balancing and control valves with Actuator unit. The control shall be modulating type for AHUs / DOAS / TFA and On/OFF type for FCUs. The PIBCV shall be a self-balancing, pressure independent, 2-way control valve with 100% authority on the control valve.

(ii) The pressure drop across the PIBCV should not exceed 20kPa for FCUs and 30kPa for the AHUs.

(iii) The differential pressure controller should maintain a constant differential pressure across the control valve, irrespective of fluctuations in the system pressure. Each valve should have a precisely adjustable maximum flow limitation as per designed flow rate of coils which is capable of being field adjusted. All valves should have testing ports for verifying the flow by measuring the differential pressure.

(iv) The valve and actuator must be capable for both Logarithmic control characteristics and linear control characteristics to ensure compatibility for both water/air and water/water exchanger. The actuator shall be electrical gear motor type. The response time should not be more than 7.5 s/Nm of stroke length.

(v) Flow setting of the valves should be simple and capable of being reset on site.

10.9 BTU / Water Flow Meter :

(i) Ultrasonic flow sensor shall be especially designed for heating, cooling or combined heating/cooling application shall be used in conjunction with type approved heating/cooling energy calculator to from combined heating/cooling energy meter for larger applications. Flow sensor for remote or compact system, accuracy class 2, carbon steel flow sensor, transmitter, operating instruction and calibration report. Remote system shall include also 4 transducer coaxial cables and mounting kit with bracket and terminal box.

(ii) Flow sensor shall use ultrasonic measuring technology with measuring frequency of 15Hz with mains supply and 0.5 Hz with battery supply. The flow sensor shall be able to measure water flow and shall offer long term stability and no pressure drop.

(iii) Protection class IP67 according to EN 60529 and DIN 40050.

(iv) Temperature range for compact version 2 to 120°C and for remote 2 to 200°C

(v) Operating pressure 16/25/40 bars

(vi) Battery lifetime up to 6 years

10.10 INSTRUMENTS

(i) Pressure gauge of appropriate range and 150 mm. dial size shall be provided at the following locations.

(a) Supply and return of all heat exchange equipments.

(b) Suction and discharge of all pump sets.

The pressure gauge shall be duly calibrated before installation and shall be complete with shut off cocks.

(ii) Direct reading industrial type thermometer of appropriate range shall be provided at the inlet and outlet of all heat exchange equipments. The thermometers shall be installed in separate wells.

(iii) Appropriate number of additional sockets shall be provided for the installation of pressure & temperature transducers for BMS.

10.11 EXPANSION TANKS

(i) Expansion tanks for chilled water and hot water shall be of M.S. construction and of adequate capacity, to contain 200% of the maximum expansion likely to take place in the system. The tank shall be insulated and be complete with float valve, gauge glass, drain, overflow and make up connections, with gate valves and vent piping wherever required.

(ii) The piping shall be enlarged at the connection to the expansion tank to permit entrained air to separate and to be vented through the tank. The expansion tank should be located at the pump suction side at the highest point of the system.

(iii) Valves, strainers and traps must be omitted from the expansion line since these may be accidentally turned off or become plugged.

(iv) Pressurized expansion tank with air separator, can be used where the conventional type expansion tank is not feasible to be provided.

10.12 INSTALLATION

(i) The installation work shall be carried out in accordance with the detailed drawings prepared by the Air-conditioning Contractor and approved by the Engineer-in-charge.

(ii) Air-conditioning contractor shall utilize the structural provisions for Air-conditioning services wherever provided by the Department in the building and make his own arrangements for additional changes.

(iii) Expansion loops or joints shall be provided to take care of expansion or contraction of pipes due to temperature changes.

(iv) Tee-off connections shall be through equal or reducing tees, otherwise ferrules welded to the main pipe shall be used. Drilling and tapping of the walls of the main pipe shall not be resorted to.

(v) Wherever reducers are to be made in horizontal runs, eccentric reducers shall be used if the piping is to drain freely, in other locations, concentric reducers may be used.

(vi) Open ends of piping shall be blocked as soon as the pipe is installed to avoid entrance of foreign matter.

(vii) All pipes using screwed fittings shall be accurately cut to the required size and threaded in accordance with IS: 554 and burs removed before laying.

(viii) Piping installation shall be supported on or suspended from structure adequately. The Air-conditioning contractor shall design all brackets, saddles, clamps, hangers etc. and shall be responsible for their structure integrity.

(ix) Pipe supports, preferably floor mounted shall be of steel, adjustable for height and prime-coated with zinc chromate paint and finish-coated gray. Spacing of pipe supports shall not be more than that specified below: -

Nominal Pipe size (mm)	Spacing (Metres)
12 and 15	1.25
20 and 25	2.00
32, 40, 50 and 65	2.50
80, 100 and 125	2.50
150 and above	3.00

(x) Extra supports shall be provided at the bends and at heavy fittings like valves to avoid undue stress on the pipes. Pipe hangers shall be fixed on walls and ceiling by means of metallic or rawl plugs or approved shear fasteners.

(xi) Insulated piping shall be supported in such a manner as not to put undue pressure on the insulation.

(xii) Anti-vibration pads, springs or liners of resilient and non-deteriorating, material shall be provided at each support, so as to prevent transmission of vibration through the supports.

(xiii) Pipe sleeves of diameter larger than the pipe by least 50 mm shall be provided wherever pipes pass through walls and the annular spaces shall be filled with felt and finished with retaining rings.

Space	Sleeve dia (mm)	Sleeve Projection (mm)	Sleeve Material	Sleeve packing and Closure
Floors	D + 50	50 AFF	1.25 mm GSS OR Light duty galvanized tube	32 Kg/cum Resin bonded fibre glass/rock wool with 8 mm thick polysulphide or Silicon sealant
Walls i) Internal	D + 50	Flush with Finish	- do -	32 Kg/cum Resin bonded fibre glass /rock wool closed on both sides with 1.0 mm GSS split flange
ii) External	D + 50	- do -	- do -	Caulked with lead wool and oakum & closed on both sides with 1.25mm GSS split flanges with brass screws

D = Outside diameter of pipe with insulation
GSS = Galvanised sheet steel
AFF = Above finished floor

(xiv) Vertical risers shall be parallel to walls and column lines and shall be straight and plumb. Risers passing from floor to floor shall be supported at each floor by clamps or collars attached to pipe with a 12 mm thick rubber pad or any other resilient material as approved by the Engineer-in-charge.

(xv) The space in the floor cut outs around the pipe work (after insulation work where applicable) shall be closed using cement concrete (1:2:4 mix) or steel sheet, from the fire safety considerations, taking care to see that a small annular space is left around the pipes to prevent transmission of vibration to the structure.

(xvi) Riser shall have suitable supports at the lowest point.

(xvii) Where pipes are to be buried under ground, the top of the pipes shall be not less than 75 cms. from the ground level. Where this is not practicable, permission of the Engineer-in-charge shall be obtained for burying the pipes at lesser depth. The pipes shall be surrounded on all sides by sand cushion of not less than 15 cms. After the pipes have been laid and top sand cushion provided, the trench shall be refilled with the excavated soil and any extra soil shall be removed from the site of work by the Air conditioning contractors.

(xviii) Where pipes are directly buried in ground, the pipes shall have “Pypcote” wrapping or as specified in IS 10221.

(xix) All pipes and their steel supports shall be thoroughly cleaned and given one primer coat of Zinc chromate before being installed.

(xx) After all the water piping has been installed, pressure tested in accordance with clause 10.10, all exposed piping in the plant room shall be given two finish coats of paint, approved by the Engineer-in-Charge. Similar painting work shall be done over insulated pipe work, valves etc. The direction of flow of fluid in the pipes shall be indicated with identifying arrows.

(xxi) 3 mm gasket shall be used for flanged joints.

(xxii) Cut-outs in floor slabs shall be sealed with cement concrete or steel plate after the plumbing work is done, from the fire safety point of view.

10.13 PRESSURE TESTING

(i) All piping shall be tested to hydrostatic test pressure of at least one and a half times the maximum operating pressure, but not less than 10 kg./sq.cm. for a period not less than 24 hours. All leaks and defects in joints revealed during the testing shall be rectified to the satisfaction of the Engineer-in-Charge.

(ii) Piping repaired subsequent to the above pressure test shall be re-tested in the same manner.

(iii) System may be tested in sections and such sections shall be securely capped.

(iv) It shall be made sure that proper noiseless circulation is achieved through all the coils and other heat exchange equipments in the system. If proper circulation is not achieved due to air-bound connections, the contractor shall rectify the defective connections. He shall bear all the expenses for carrying out the above rectification, including the tearing up and refinishing of floors, walls, etc. as required.

(v) Insulation shall be applied to piping only after the completion of the pressure testing to the satisfaction of the Engineer-in-charge.

(vi) Pressure gauges may be capped off during pressure testing of the installation.

(vii) The contractor shall provide all materials, tools, equipments, instruments, services and labour required to perform the tests and to remove water resulting from cleaning after testing.

10.14 BALANCING

(i) After completion of the installation, all water system shall be adjusted and balanced to first minimize throttling losses; then the pump impeller shall be trimmed or pump speed shall be adjusted to meet design flow conditions.

Exceptions to above:

(a) Where Variable frequency Drives are used as starter &capacity control.

(b) Impellers need not to be trimmed nor pump speed adjusted for pumps with pump motors of 7.5 kW (10 hp) or less,

(c) Impellers need not to be trimmed when throttling results in no greater than 5% of the nameplate horsepower draw, or 2.2 kW (3hp), whichever is greater.

(ii) Automatic control valves (Pressure Independent Balancing cum Control Valve) and three way diverting valves shall be set for full flow condition during balancing procedure. Water circuit shall be adjusted by balancing cocks provided for balancing. These shall be permanently marked after the balancing is completed so that they can be restored to their correct positions, if disturbed.

(iii) The other provision regarding balancing as mentioned in Chapter 17 shall also be complied.

10.15 MEASUREMENT

Measurements of plumbing work shall be on following basis: -

(i) Piping shall be measured along the centre line of installed pipes including all pipe fittings and accessories but excluding valves and other items for which quantities are specifically indicated in the schedule of work. No separate payment shall be made for fittings and accessories.

(ii) The rates for piping work shall include all wastage allowances, pipe supports, hangers, nuts and check nuts, vibration isolators, suspension where specified or required, and any other item required to complete the piping installation. None of these items will be separately measured nor paid for.

(iii) Piping measurement shall be taken before application of the insulation in the case of insulated pipe work.

10.16 INSULATION

The insulation of pipes carrying hot or chilled water shall be carried out as per Chapter-11.

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CHAPTER–11
INSULATION WORK

11.1 SCOPE

This chapter covers the requirements of thermal insulation for chilled water / hot water piping, pumps and tanks, duct work, and acoustic lining in duct work and weather maker rooms. This does not cover exposed roof insulation and under deck insulation work.

11.2 MATERIAL TYPES

The insulation material to be used for various applications shall be any of the following, as required:

(i) For insulation of water piping, pumps and tanks: -

(a) Expanded polystyrene (T. F. Quality)
(b) Resin bonded glass wool
(c) Polyvinyl Nitrile (Closed cell rubber foam)
(d) XLPE (Closed cell cross linked polyolefin foam)
(e) Cross linked closed cell Oxide acetate insulation foam- CFC/HCFC free

However, all shall need to be covered with vapor barrier and cladding with aluminum sheet.

(ii) For Insulation of duct work: -

(a) Resin bonded glass wool.
(b) Polyvinyl Nitrile (Closed cell rubber foam)
(c) Crosslinked closed cell Oxide acetate insulation foam- CFC/HCFC free
(d) XLPE (Closed cell cross linked polyolefin foam)

(iii) For acoustic lining of duct work and AHU rooms: -

(a) Resin bonded glass wool.
(b) Resin bonded mineral wool.
(c) Oxide Acetate open cell Foam- CFC/HCFC free
(d) XLPE (Open cell cross linked polyolefin foam)

(iv) For suction line**, Chilled water pipe** and Chiller insulation: -

(a) Expanded Polysterene (T.F.Quality)
(b) Polyvinyl Nitrile (Closed cell rubber foam)
(c) Crosslinked closed cell Oxide acetate insulation foam- CFC/HCFC free
(d) XLPE (Closed cell cross linked polyolefin foam)

(v) For double skin AHUs:

(a) Polyurethane foam (PUF insulation)

11.3 MATERIAL SPECIFICATIONS

The insulation material shall satisfy the following requirements: -

(i) For thermal application on pipes.

Material	Minimum Density (Kg/cu.m)	Maximum Thermal conductivity (K.cal/ hr. degree C/m at 0 Deg C mean temp.)
Resin bonded glass wool	32	0.031
Expanded polystyrene	20	0.035

(TF)		
Polyvinyl Nitrile foam	55	0.034
Crosslinked Closed cell Oxide acetate foam - CFC/HCFC free	30	0.032

(ii) For thermal insulation of ducts:

Material	Minimum Density(Kg / cu.m)
Resin bonded glass wool	24
Polyvinyl Nitrile foam	40
Crosslinked Closed cell Oxide acetate insulation foam-	30

Fibre Glass Insulation used for duct insulation shall be factory faced with aluminium foil on one side reinforced with kraft paper & fused to the insulation material.

Polyvinyl Nitrile foam Insulation used for duct insulation shall be factory faced with aluminium foil on one side.

Crosslinked Closed cell Oxide acetate insulation Foam used for duct insulation shall be factory faced with aluminium foil on one side.

(iii) For acoustic lining:

Application	**Thickness**	**Material**	**Minimum Density (Kg./Cu.M)**
Duct	25 mm	Resin bonded glass wool	32
AHU room	50 mm	Resin bonded glass wool/ Mineral wool	32/ 48
Duct	15 mm	Oxide acetate foam	40
AHU room	25 mm	Oxide acetate foam	50

(iv) The specification for resin bonded glass wool insulation & resin bonded mineral wool insulation shall conform to IS 8183 as amended up to date. The specification for expanded polystyrene shall conform to IS-4671 as amended up to date.

(v) The insulation material for all applications shall have following properties also:-

(a) CFC/HCFC free,
(b) fire rating class O and class 1,
(c) anti-fungal, anti-mold and anti-bacterial
(d) RoHS free

(vi) Expansion tank Insulation
Expanded polystyrene insulation of density not less than 20kg per cu.m. shall be used.

11.4 INSULATION THICKNESS

The thickness of insulation shall be as indicated below unless specified otherwise in the tender specifications.

(vii) For pipe insulation (for chilled water as well as hot water application

Pipe Size (mm)	**Material**	**Thickness (mm)**
150 & below	Glass fibre /Exp. Polystyrene	50
Above 150	Glass fibre /Exp. Polystyrene	75
150 & below	Oxide acetate foam- CFC/HCFC free	32
Above 150	Oxide acetate foam- CFC/HCFc free	45

(viii) For Duct insulation

Application	Material	Thickness (mm)
Thermal for AC area	Fiber Glass	12.5
Thermal for Non AC area	Fiber Glass	25
Acoustic	Fiber Glass	25
Thermal for AC area	Oxide acetate foam CFC/HCFc free	9
Thermal for Non AC area	Oxide acetate foam CFC/HCFc free	19
Acoustic	Oxide acetate foam CFC/HCFc free	10

(ix) For room acoustic lining

Resin bonded glass wool 50 mm

Resin bonded mineral wool 50 mm

Oxide acetate open cell acco isolate foam 25mm

(x) For pumps :

Expanded polystyrene TF quality 50 mm

(xi) Chiller Insulation

Thickness of polyvinyl rubber insulation used for chiller insulation shall not be less than 19mm.

(xii) Expansion tank

Thickness of expanded polystyrene (TF quality) insulation used shall not be less than 50mm.

11.5 APPLICATION OF INSULATION ON PIPES (including suction line insulation)

(i) The surface to be insulated shall be first cleaned and a coat of zinc chromate primer shall be given. The insulation shall be fixed tightly to the surface with cold setting adhesive CPRX compound. All joints shall be staggered and sealed. The second layer of insulation wherever required shall be similarly applied over the first layer.

(ii) Pipes shall be preferably pre insulated at factory, meeting the requirement or the insulation shall be finished at site as under:

(a) For pipes laid inside the building, the insulation over the pipe work shall be finished with 0.63 mm thick aluminium sheet cladding over a vapour barrier of 120 gm/ sq.m. polythene sheet with 50 mm overlap and tied down with lacing wire and complete with type 3, grade-I roofing felt strip (as per IS 1322 as amended upto date) at the joints..

(b) For pipes outside the building laid above ground the finishing over the pipe insulation shall be finished with 0.63 mm G S sheet cladding over a vapour barrier of 120 gm/sq.m polythene sheet with 50mm overlap and tied down with lacing wire and complete with type 3 grade I roofing felt strip applied by means of cold setting CPRX compound.

(c) For pipes outside the building laid underground the insulation shall be covered with 500 gauge polythene faced hessian, (the polythene facing outwards), with 50 mm overlap. All joints shall be sealed with bitumen. A layer of 0.50 mm x 20 mm G.I. wire mesh netting shall be provided over it butting all joints and it shall be laced down with GI wire, sand cement plaster (1:4) 20 mm. thick shall be provided in 2 layers of each 10mm and shall be water proofed by applying hot bitumen & fixing tar felt over the plaster. It shall be finally finished with a coat of hot bitumen.) In case of factory pre insulated pipes, buried underground, a water leakage sensing wire shall also be provided, to detect the location of water leakage at later date.

(d) In case of factory pre insulated pipes, all joints shall be properly insulated at site as per recommendation of manufacturer

(iii) 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.

11.6 APPLICATION OF INSULATION ON PUMPS

Expanded polystyrene (TF quality) 50 mm thicknesses shall be sandwiched between two aluminum sheets of 0.5mm thickness and properly clamped to pump in two semicircular sections.

11.7 APPLICATION OF INSULATION ON EXPANSION TANK

Insulation of expansion tank shall be expanded polystyrene (T. F. Quality) of thickness not less than 50mm. It shall be applied as under

(i) Surface shall be thoroughly cleaned with wire brush and rendered free from all dust & grease.

(ii) The two layers of hot bitumen shall be applied.

(iii) The insulation slabs will then be fixed in one layer and joints shall be sealed with hot bitumen.

(iv) The insulation slab then shall be covered with 0.63 mm x 19mm G.I. wire mesh netting which shall be fixed to insulation with brass / G.I. nails.

(v) The insulation shall then finally be finished with aluminum cladding of thickness not less than 0.5mm.

11.8 APPLICATION OF INSULATION (THERMAL) ON DUCT

(i) The surface of duct 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.

(ii) Two coats of cold compound adhesive (CPRX compound) shall be applied over the duct. (Any other adhesive recommended by the manufacturers may also be used with the approval of the Engineer-in-charge).

11.9 APPLICATION OF DUCT LINING (ACOUSTIC INSULATION)

Where specified in the tender specifications, ducts shall be lined internally with acoustic insulation as detailed below:

(i) 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.

(ii) Then 25 x 25 sq.mm section of minimum 1.25 mm thick G.I. sheet shall be fixed on both ends of the duct piece.

(iii) The insulation slabs shall then be fixed between these section of ducts using CPRX adhesive compound and stickpins.

(iv) The insulation shall then be covered with Reinforced plastic/ fibre glass tissue **with proper overlap**, sealing all joints so that no fibre is visible.

(v) The insulation shall finally be covered with minimum 0.5 mm thick perforated aluminum sheet having perforations between 20-40%.

11.10 APPLICATION OF ACOUSTIC LINING IN AHU ROOMS

(i) The wall/ roof surface should be thoroughly cleaned with wire brush.

(ii) A 610x610 mm frame work of 25mm x50mm x50mm x50mm x25mm shape channel made of 0.6mm thick G.S.S. shall be fixed to walls leaving 610mm from floor by means of raw plugs in walls and dash fasteners in ceiling. Similar frame work shall also be fixed on ceiling by means of dash fasteners.

(iii) Resin bonded glass wool/ mineral wool as specified cut to size will be friction fitted in the frame work and covered with tissue paper.

(iv) Aluminum perforated sheet having perforation between 20-40%of thickness not less than 0.8mm shall be fixed over the entire surface neatly without causing sag/ depression in between and held with screws. Sheet joints should overlap minimum 10mm.

(v) Aluminum beading of 25mm wide and thickness not less than 1.00 mm shall be fixed on all horizontal/ vertical joints by means of screws.

11.11 MEASUREMENT OF INSULATION

(i) Pipe insulation shall be measured in units of length along the center line of the insulated pipe. The linear measurements shall be taken before the application of the insulation. For piping measurements, all valves, orifice plates and strainers shall be considered strictly by linear measurement along the center line of the pipes, and no special rate shall be applicable for insulation of any accessories, fixtures or fittings whatsoever.

(ii) Duct insulation and acoustic lining shall be measured on the basis of surface area along the outer surface (ref IS14164 of 2008) of insulation thickness. Thus the surface area of externally thermal insulated or acoustically lined duct shall be based on the perimeter at the center of thickness of insulation, multiplied by the center-line length of ducting including tapered pieces, bends, tees, branches etc. as measured for bare ducting. In the case of tapering pieces, their average perimeter shall be considered.

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CHAPTER-12
CONTROLS

12.1 SCOPE

This chapter covers the requirements of equipment safety controls, refrigerant flow controls, system controls, and variable speed drive (VSD). For chilling units all the controls shall be microprocessor based.

12.2 EQUIPMENT SAFETY CONTROLS

12.2.1 Compressor

(a) Compressor shall be provided with the following safety controls: -

(i) High discharge pressure (HP) safety (cut out) to stop the compressor automatically, in case discharge pressure exceeds a pre-set safe value. This safety shall operate when discharge head pressure exceeds the set point. Only manual resetting shall be provided for this safety.

(ii) Low suction pressure (LP) safety (cut-out) to stop the compressor automatically, in case suction pressure falls below a pre-set value. This safety shall operate when the suction pressure falls below the set point. Automatic resetting shall be provided for this safety, with adjustable cut-in and cut-out pressures. This safety shall be used for pumping down the system for shutting off the refrigeration plant.

(iii) Oil pressure (O.P) safety (cut-outs) to stop the compressor, in case lubricating oil pressure falls below a safe set value. A time delay mechanism shall also be provided, so as to permit running of the compressor upto a maximum period of 90 seconds, with the oil pressure differential below the set value and allow it to continue normal operation if the pressure differential builds up to the set value within that time, or otherwise shut-down the compressor. Only manual resetting shall be provided for this safety.

(iv) High bearing oil temperature cut-out (for centrifugal compressor only). This shall be provided with a manual reset only.

(v) High lubricating oil temperature cut-out (for centrifugal compressor only). This shall be provided with a manual reset only.

(vi) Time delay mechanism on the starting gear to limit short cycling regardless of mal-functioning of controls.

The cut-outs (i) to (v) mentioned above shall operate when the respective controlled variable crosses the set point to trip the compressor. Audio visual alarm shall be provided to indicate such operations. A manual reset shall be provided for them.

(b) Safeties mentioned above shall operate when the respective controlled variable crosses the set point to trip the compressor.

(c) Audio visual alarm shall also be provided to indicate such operations.

12.2.2 Condenser

The safety control for a condenser shall comprise a safety pressure relief valve on the shell. This shall operate to relieve the pressure at the set point without prior leakage. For small condensers, a fusible plug may be provided to melt at a predetermined temperature.

12.2.3 Chiller

(i) Antifreeze shall be provided with water chiller, set at a few degrees above the freezing point. This shall operate, when the temperature of water in the chiller falls below the set point to trip the compressor motor. The reset provided for the safety shall be manual.

(ii) Flooded type of chiller in addition, shall be provided with safety pressure relief valve.

12.2.4 Refrigeration Plant

(i) In addition to the safety controls as above for the individual components of a refrigeration plant, the following safety controls shall also be provided for the plant.

(a) Compressor motor over current cut-out.

(b) Condenser water flow switch.

(c) Chilled water flow switch.

(d) Condenser air flow switch in the condenser fan discharge (in case of air-cooled condensers).

(e) Air flow switch in the evaporator fan discharge in case of direct expansion coils.

(ii) The above controls, on operation, shall trip the compressor motor, and these shall be provided with manual reset arrangement.

(iii) The compressor motor shall also be interlocked electrically with,

(a) Condenser water pump in case of water cooled condenser, and condenser fan with air cooled condensers,

(b) Chilled water pumps in case of chilled water system and evaporator fan in case of direct expansion system, and

(c) Antifreeze thermostat in case of chillers.

(iv) Indicating lamps shall also be provided on the control panel for indicating operation of the safeties and interlocks.

12.3 REFRIGERANT FLOW CONTROLS

A refrigeration plant shall be provided with controls, necessary for starting, stopping and modulating the flow of refrigerant in the plant so as to satisfy the load requirements. These comprise solenoid valve, thermostatic/ Electronic type expansion valve, float valve, compressor capacity controls etc. and other special controls if specified in a particular work.

12.3.1 Solenoid Valve

(a) Screw type compressors liquid line solenoid valve shall be provided in the liquid line of the system, ahead of the expansion valve, to allow or to stop the flow of liquid refrigerant to an evaporator, or a section of sectionalized evaporator. This shall be operated by snap-acting thermostat and it shall also be provided with a test switch to enable manual energizing.

(b) Discharge gas valves shall be provided in the following applications as required: -

(i) Hot gas defrosting: Normally this solenoid valve shall remain closed, but it shall open up to feed the evaporator with hot gas for defrosting when required, especially in cold storage applications.

(ii) Compressor capacity control for compressor and for cylinder unloading during starting.

(b) Solenoid valves shall be direct acting in smaller sizes and pilot operated for larger sizes, as required. The size of the valves shall be determined by the desired flow rate of refrigerant through them and the pressure drop across the same (and not by the size of the refrigerant line).

12.3.2 Thermostatic / Electronic type Expansion Valve

Thermostatic/ Electronic type expansion valve shall be provided in DX type refrigeration plant to modulate the flow rate of liquid refrigerant entering the evaporator in response to the extent of superheat of refrigerant gas leaving the evaporator, so that only a metered flow is ensured matching the load.

The number of expansion valve shall be such that the specified accuracy of temperature control of the system can be achieved and that no valve is expected to operate below 35% of its rated capacity. The sizes shall be selected suitably so as to avoid hunting. Adjustable super heat control and external equalizer port shall be provided for each valve. Each expansion valve shall be easily removable for cleaning and adjusting.

12.3.3 **Float Valve**

Float valve shall be provided in refrigeration plant with flooded type chiller for maintaining the liquid level in chiller under all conditions of load at a rate commensurate with the rate of vaporization. This can be provided either on low pressure side or on high pressure side. When provided as low side float valve, this shall be located as a part of the chiller or accumulator.

12.3.4 **Compressor Capacity Control**

The capacity control arrangement shall be in accordance with 5.2.7 for compressor, and 5.3.7 for centrifugal type compressor & 5.4.8 for screw type compressor.

12.4 SYSTEM CONTROLS

(i) The requirements for maintaining the inside design conditions as specified in the tender specifications for the work shall be met by appropriate system controls and control elements. The system shall satisfy the requirements of both full load and partial load conditions. Details of complete control elements shall be indicated by the tenderer in the tender.

(ii) For cooling applications in plants other than package type AC (PTAC) units, control shall be effected by 3 way diverting valve in chilled water coil. For heating using hot water coils, flow control through them shall also be achieved by using 3 way valves.

(iii) In the case of PTAC type units, the control of the units is affected through snap acting room thermostat.

(iv) The size of 3 way diverting valves shall be selected so as to match the coil wherein the flow is to be regulated. The make and size shall be indicated in the Technical particulars in the tender.

(v) Operation of the modulating motor of 3 way diverting valve shall be controlled by proportional type thermostat.

(vi) One snap acting humidistat shall be provided for each humidifier.

(vii) Where strip heaters are specified, maximum size of each heater bank shall not exceed 9 KW, distributed in three phases of 3 KW per phase.

(viii) Every bank of strip heaters shall be controlled by a snap acting thermostat in case of temperature control requirement and by a snap acting humidistat for reheat control to maintain the specified RH condition.

(ix) Where more than one bank of heaters is required to be provided for one AHU, thermostat shall be provided in each bank shall suitable for operation in stages.

(x) A safety thermostat (safety stat) shall be provided as high limit safety for each bank of heaters.

(xi) The heater banks intended for reheating during monsoon shall form part of heaters required for winter heating (where winter heating is specified). Necessary change-over switch shall be provided as part of the system wiring to change their control by thermostats or humidistat as required.

12.5 OPERATIONAL CONTROLS AND INTERLOCKS

(i) The operation of refrigeration plant shall be either manual or automatic, as specified. The plant shall be started by an ON/OFF switch. Additionally, in the case of an automatic plant, an auto/manual switch shall also be provided.

(ii) The automatic operation shall be effected through the monitoring of return chilled water temperature, or the room conditions, as the case may be. In multi unit installations, one unit shall be arranged to be loaded fully before the next unit is switched on automatically.

A similar operation system shall be followed in shutting off of the unit. Change over from one operating unit to another shall be possible through the status switch of the plant to be shut down by change to manual position and thus overriding its anti-cycle timer. It should be possible to introduce the changed unit by running it to speed and changing over the status switch to "auto" position.

(iii) Pump down shut down shall be provided through low pressure (LP) safety irrespective of the status switch position, auto/manual.

(iv) It should be possible to start the compressor motor only after the cooling tower fan motor (where provided), chilled water (where provided) and condenser water pumps are operated.

(v) The compressor motor shall be able to be started or run, only after all the safeties as per para 12.2 are satisfied.

(vi) The blower motor shall be interlocked with strip heaters (where provided) such that power supply to strip heaters will become ON, only after the blower has been started and run to full (designed) speed.

(vii) Where only the blower motor and not heaters is connected to standby generating set in any particular application, a timer shall be provided, such that the heaters may get energised, only after a period of time, after the blower is run.

(viii) In the event of signal from high limit safety of heaters the power supply to the blower motor and the heater bank shall automatically and instantly be switched off.

(ix) The power supply to AHU shall be cut off on receipt of a signal from the Fire Alarm System.

12.6 REQUIREMENTS OF CONTROL ELEMENTS

The system control elements comprise controlling elements such as thermostats, humidistat, three way valves, heaters, humidifiers, dehumidifier etc as required for individual applications.

12.6.1 Thermostats

Thermostats shall be electric fixed differential type as indicated below, with sensing element located in the return air stream. All thermostats shall be supplied with the standard mounting boxes as recommended by the manufacturer. The profile, mounting arrangement and exact location of the thermostat shall be such as to suit the site.

(i) Proportional control thermostats shall be provided for actuating the three way modulating valve at each air handling unit. Thermostat shall provide manual switching (heat-off-cool-in heating-cooling system).

(ii) Snap-acting fixed differential type thermostat for actuating the three-way diverting valve at each fan coil unit.

(iii) Thermostat shall have temperature adjustments WARM-NORMAL-COOL settings and fan switch. Switching off must break fan circuit.

(iv) Snap-acting fixed differential heating thermostat for electric winter heating and reheat applications for putting on/off power supply to electric heating or reheat coils in air handling units.

(v) Safety thermostat shall be provided for electric winter heating and reheat application for cutting off power supply to strip heaters in case air flow across strip heater is not established.

(vi) Air-stat shall be provided within air handling unit containing electric heating or reheat coils to prevent heaters from energizing unless the air flow is established.

12.6.2 Humidistat

Humidistat shall be provided with air handling unit for areas, which require humidity control. One humidistat shall activate the reheat coils in case the space humidity rises beyond the preset limit. Another humidistat shall energize the humidifier when the humidity falls below the preset limit. These humidistat shall also de-energize these devices when the desired humidity is reached.

Humidistat shall be snap-acting type having humidifier/dehumidifier control from 20-80 percent relative humidity, with differential of 5 percent. Humidistat shall have nylon element with three bobbins, and removable knob to prevent tempering of set point.

12.6.3 **Three-way modulating valves (for AHUs)**

These shall be provided in chilled/hot water lines as diverting valves at each air-handling unit and shall be actuated by a space thermostat. Space conditions shall be maintained by continuous proportional modulation of the chilled/hot water through the coil. The valve shall revert to fully bypass position when fan is shut off. Maximum pressure drop across valve shall not exceed 0.85 kg/ sq.cm. Where VSD (to control chilled water flow) is provided, the AHUs shall be provided with 2 way diverting valve.

12.6.4 **Three-way diverting valves for FCUs**

This shall be provided as 2 position diverting valves in chilled/hot water lines at each fan coil unit and shall be actuated by a space thermostat. Space conditions shall be maintained by allowing all of chilled/hot water to either pass through the coil or bypass the coil and mix with the chilled/hot water return. The valves shall revert to fully bypass position when fan is shut off. Pressure drop across the valve shall not exceed 0.14 kg/ sq.cm. Valve shall have the facility to replace motor actuator without removing the valve body.

12.6.5 Spray humidifiers, where specified, shall be as per details given under para 6.2.3.5(b).

12.6.6 Pan humidifiers where provided shall be as per para 6.2.3.5(a).

12.6.7 Strip heaters shall be of finned type construction with a surface temperature not exceeding 45 deg. C. The same shall be suitable for 230 V, AC supply. The heaters shall be adequately insulated electrically from their mountings unit/ casing.

12.6.8 Dehumidifiers, where provided shall use adsorption type desiccants. The desiccant used shall be non-toxic, non-corrosive having a life of about 5 years with constant employment in regeneration cycle.

12.7 SPECIAL REQUIREMENTS FOR COLD STORAGES

Automatic defrosting arrangement shall be provided in cold storages. The arrangement shall comprise stopping of the refrigeration system and providing defrosting using warm air or water as specified. Hot gas defrosting arrangement shall be provided where specified in particular applications.

12.8 VARIABLE SPEED DRIVE (VSD)

12.8.1 **Air quantity flow control**

The VSD System shall function to supply variable air quantity in the air-conditioned area in response to the load variations including that due to variations in ambient conditions and filter cleanliness conditions, to maintain the inside designed temperature, RH and pressure conditions in conjunction with the humidifier and re-heaters. During the day hours, as per the time interval selected, the VSD System shall regulate the speed of the AHU to maintain the temperature within maximum designed temperature and positive air pressure inside the air-conditioned area. The positive air pressure shall be maintained by keeping a difference of minimum 15% in the airflow between the supply and exhaust air. However, under any circumstances during the day hours, the air flow rate will not fall below the 60% of the rated CFM of the AHU or 15 air changes, whichever is higher. During the rest of the night hours, the Programmable timer shall give a signal to the VSD to run the AHU at a pre-determined reduced speed so as to provide only 25% of the normal CFM or the minimum CFM achievable closest to 25% but not below 25% of the normal CFM. Due to the clogging of the air filter if the inside temperature conditions are not achieved even at 100% AHU speed then the VSD will close an N.O. contacts to activate an alarm. The VSD shall have the provision to switch over to the manual mode as and when required. The system shall comprise of dedicated Variable Speed Drives (VSDs) designed for HVAC applications to accept 2 feedback signals (from temperature sensor installed in the AC area and programmable timer controller) and have 2 programmable set points (inside temperature conditions, and 60% of the normal CFM condition as stated above) using HVAC terminology, to regulate the speed of the AHU motors in response to the variations in load and filter cleanliness conditions to maintain temperature and Air flow differential in supply and exhaust conditions. In case, any additional sensor (s) including wiring etc are required to meet the system requirements the cost of that shall be deemed to be included in the cost of the VSD. The VSD control shall have:

(a) RFI (Radio frequency interference) Filters for EMC (Electromagnetic compatibility) compliance.
(b) Voltage Vector Control technology to generate advanced sinusoidal output voltage, 100% true RMS value of the fundamental voltage at rated speed and nominal torque, cause no motor de-ration and keep motor temperature limits within permissible class B limits.
(c) Displays in user’s friendly Alpha Numeric Characters for all operating parameters, programming parameters and faults.
(d) Built in energy meter.
(e) Built in run time counter.
(f) Local control panel (key pad)

The system shall also comprise a suitable programmable timer & PLC with required electronic components, to allow 2 feedback signals (Temperature & Minimum CFM) to be passed on to the VSD during the day hours. In the night hours only one signal from the programmable timer shall go to the VSD to run it at pre-determined reduced speed. The room/ space air temperature and air flow shall be sensed by a temperature and air flow transmitters, which shall generate suitable DC signal to provide feedback to the VSD, which in turn shall regulate the speed of the AHU fan to maintain the designed conditions as described above.

VSD shall be designed, with built-in PID controller, control panel (keypads & display), IP 20 enclosure for use on standard centrifugal fans. The VSDs should not cause any de-ration of the connected motors and must ensure that class B temperature levels of the connected motors are never exceeded. The display should be in alpha-numeric characters and programming facility should be in user-friendly HVAC terminology. The VSDs should be able to accept up to 2 feedback signal from temperature & air flow transmitter simultaneously and to program 2 set points in it.

The system shall also have following features incorporated:

(i) Heat sink over temperature protection
(ii) Under voltage protection
(iii) Over voltage protection
(iv) Alpha-numeric display facilities
(v) ON indication
(vi) Trip indication
(vii) Selectable display of various parameters line voltage, frequency, speed, power, torque, motor temperature percentage, VSD temperature percentage, KWH.
(viii) Raise and lower speed push button in local mode.

(ix) Frequency range variation from 0 to 50 Hz.
(x) Remote start and stop facility including indications there of with necessary hardware and terminal blocks, including toggle switch etc. to over ride remote start & stop at the time of maintenance/ repairs.
(xi) Off delay facility through timer or PLC with 30 sec to 120 sec. time delay, to be connected to air flow switch.
(xii) Safeguard facility against single phasing.
(xiii) Tripping of AHU blower motors in response to the fire alarm signal from AFAS.
(xiv) Inter locking of Exhaust and AHU blowers such that power supply gets fed to exhaust blower only when the supply air flow is there.

12.8.2 **Chilled water flow control**

Variable Speed Drive (VSDs) for controlling the chilled water flow rate in the secondary circuit may be provided when AHUs operation is for 24 hours and where the secondary chilled water system has been provided. Requirement and Specifications of VSD system shall be as follows:

The VSD System shall function to supply variable chilled water flow in the secondary circuit of air-conditioning system in response to the load variations including that due to variations in ambient conditions to maintain the inside designed temperature conditions. However, under any circumstances, the secondary chilled water pump speed shall not fall below the 30% of the nominal speed or any other suitable minimum speed as per the system requirement. The VSD shall have the provision to switch over to the manual mode as and when required and facility for the manual speed variation from VSD itself. The system shall comprise of dedicated Variable Speed Drives (VSDs) designed for HVAC applications to accept two feedback signals (from differential pressure transmitters installed across the two farthest, most significant AHUs of the zone to select either maximum of the two or average of the two (as selected by the user) feedback signals using HVAC terminology, to regulate the speed of the secondary chilled water pump motors in response to the load variations. In case, any additional sensor (s) including wiring etc. if required to meet the system requirements the cost of that shall be deemed to be included in the cost of the VSD. The VSD shall have:

(a) RFI (Radio frequency interference) Filters for EMC (Electro magnetic compatibility) compliance.
(b) Voltage Vector Control technology to generate advanced sinusoidal output voltage, 100% true RMS value of the fundamental voltage at rated speed and nominal torque, cause no motor de-ration, and keep motor temperature limits within permissible class B limits.
(c) The VSDs shall have D.C. link reactors/ harmonic filters integrated to minimise power line harmonics. There shall be reactors in both the positive and negative rails.
(d) An automatic energy optimisation feature shall be provided as standard in the frequency converter. This feature shall reduce output voltage, further to quadratic V/f characteristics, when the motor is lightly loaded and minimise the motor losses.
(e) The VSD shall be able to provide full rated output current continuously, 110% of rated current for 60 seconds and 160% torque for upto 5 seconds (for high inertic and high friction load).
(f) The VSD shall include Automatic Motor Adaptation (AMA) to optimize motor performance, improve start capabilities and compensate for motor cable variances. The AMA shall be carried out at motor stand still with no need for detaching the pump from motor.
(g) Unlimited output power circuit switching must be possible without the need for central circuit interlocking and without causing damage to the VSD.

(h) Auto-derating of maximum drive current shall be incorporated in VSD to allow continued operation at reduced speed in case of VSD over temperature phase loss or mains imbalance without damaging the VSD.
(i) Displays in user's friendly Alpha Numeric Characters for all operating parameters, programming parameters, faults,
(j) Built in energy meter.
(k) in run time counter.
(l) Local control panel (key pad)
The system shall also comprise a suitable PLC if required, with electronic components.
VSD shall be designed, with built-in PID controller, control panel (keypads & display), IP 20 enclosure for use on standard centrifugal pumps. The VSDs should not cause any de-ration of the connected motors and must ensure that class B temperature levels of the connected motors are never exceeded. The display should be in alpha-numeric characters and programming facility should be in user-friendly HVAC terminology. The VSDs shall be able to accept up to two feedback signals from differential Pressure transmitters simultaneously and to program set points in it.
The system shall have following features incorporated:-
(i) Heat sink over temperature protection
(ii) Under voltage protection
(iii) Over voltage protection
(iv) Protections against input transients, loss of A.C. line phase, short circuit, ground fault, frequency converter over temperature.
(v) Alpha-numeric display facilities
(vi) ON indication
(vii) Trip indication
(viii) Selectable display of various parameters like output line voltage, output frequency, speed, power, motor temperature percentage, heat sink temperature, VSD temperature percentage, KWH, hours run, differential pressure.
(ix) Raise and lower speed push button in local mode.
(x) Frequency range variation from 0 to 50 Hz.
(xi) Remote start and stop facility including indications thereof with necessary hardware and terminal blocks, including toggle switch etc. for override of remote start & stop of at the time of maintenance/ repairs.
(xii) Safeguard facility against single phasing.

12.8.3 Where both building management system and air quantity flow control / chilled water flow control through VFD are provided for same application, control panel for sequencing of VFD shall not be required.

12.9 ECONOMIZER

12.9.1 **Air- Side Economizers (Ambient Cooling)**
Each individual cooling fan system that has a design supply capacity over 72 CMM (2,500 cfm) and a total mechanical cooling capacity over 22 kW (6.3 tons) shall include either:
(i) An air economizer capable of modulating outside-air and return-air dampers to supply 100% of the design supply air quantity as outside-air; or
(ii) A water economizer capable of providing 100% of the expected system cooling load at outside air temperatures of 10°C (50°F) dry-bulb/7.2°C (45°F) wet-bulb and below
Exceptions to above are:
(a) Projects in the hot-dry and warm-humid climate zones are exempt
(b) Individual ceiling mounted fan systems < 192CMM (6,500 cfm) are exempt

12.9.2 **Partial Cooling**

Building's intrinsic thermal mass can be used to reduce peak cooling loads by circulating cool night-time air to pre-cool the building prior to daily occupancy in the cooling season. The building control system can operate ventilation fans in the economizer mode on a scheduled basis. Care should be taken to prevent excessive fan operation that would offset cooling energy savings. It should also be ensured that night humidity does not preclude the use of this strategy.

Economizers shall be capable of providing partial cooling even when additional mechanical cooling is required to meet the cooling load.

12.9.3 **Testing of Air-Side Economizer**

Air-side economizers shall be tested in the field following the requirements in Appendix K to ensure proper operation.

Exception to above:

Air economizers installed by the HVAC system equipment manufacturer and certified to the building department as being factory calibrated and tested per the procedures in Appendix K

12.10 ENERGY RECOVERY WHEEL

12.10.1 **System features**

(i) It shall have minimum recovery/ removal of 75 % - 80 % of total heat, that is both sensible and latent (each being 75 % - 80 %). The recovery of sensible and latent shall be equal.

(ii) The wheel shall be made of pure aluminum foil coated with molecular sieve desiccant with pore diameter of 3^{o}A.

(iii) The cross contamination between the two air streams shall be nil and leakage less than 0.04%.

(iv) The vertical and radial run of the wheel shall be less than 1 mm per meter of diameter.

(v) The wheels shall have non-contact labyrinth seals for effective sealing between the two air streams.

12.10.2 **Specifications**

(a) Substrate

The substrate or wheel matrix should be only of pure aluminum foil so as to allow:

(i) Quick and efficient uptake of thermal energy.

(ii) Sufficient mass for optimum heat transfer

(iii) Maximum sensible heat recovery at a relatively low rotational speed of 20 to 25 rpm.

Nonmetallic substrates made from paper, plastic, synthetic or glass fibre media, will therefore, not be acceptable.

The substrate shall not be made from any material which is combustible or supports combustion like synthetic fibrous media.

The rotor depth shall be minimum 270 mm to maximize recovery efficiency ratio.

(b) Pressure drop

The pressure drop across the rotary heat exchanger shall not exceed 2.5mm for every 0.5mps face velocity, or part thereof, for the minimum stated/ required latent recoveries / efficiencies.

(c) Desiccant

(i) The desiccant shall be water molecule selective and non-migratory.

(ii) The desiccant shall be of molecular sieve 3Å so as to keep the cross contamination to absolute minimum and also ensure the exclusion of contaminants from the air streams, while transferring the water vapor molecules.

(iii) The desiccant, of sufficient mass which shall not be less than 5 kg per 1000 CFM of air, shall be coated with non-masking porous binder adhesive on the aluminum substrate so as to allow quick and easy uptake and release of water vapor.

(iv) The rotor/wheel matrix shall have equal sensible and latent recovery.

(v) The weight of desiccant coating and the mass of aluminum foil shall be in a ratio so as to ensure equal recovery of both sensible and latent heat over the operating range.

(d) Rotor

(i) With optimum heat and mass through matrix formed by desiccant, of sufficient mass, coated on an aluminum foil, the rotor should rotate at lower than 20 to 25 RPM, thereby also ensuring long life of belts and reduced wear and tear of seals.

(ii) The rotor shall be made of alternate flat and corrugated aluminum foil of uniform width.

(iii) The rotor honeycomb matrix foil should be so wound and adhered as to make a structurally very strong and rigid media which shall not get cracked, deformed etc. due to change of temperature or humidity.

(iv) The rotor having a diameter upto 2800 mm shall have spokes to reinforce the matrix.

(v) From 2000 mm diameter upwards, the option of a special wing structure, to prevent the rotors from wobbling or deforming due to the successive pressure differentials, will be available.

(vi) Sectioned wheels, with pie segments, capable of being assembled in the field, shall be available as an option, above 2000 mm in diameter.

(vii) The surface of the wheel/rotor shall be highly polished to ensure that the vertical run out does not exceed + 1 mm for every 1 metre diameter, thereby ensuring, negligible leakage, if labyrinth non contact seals are provided, and minimal drag, if contact wiper seals are provided.

(viii) The radial run out also shall not exceed + 1 mm for every 1 meter diameter, thereby minimizing the leakage/drag on the radial seals, and minimize the fluctuation in the tension of the drive belt.

(ix) The rotor shall be a non clogging aluminum media, having a multitude of narrow aluminum foil channels, thus ensuring a laminar flow, and will allow particles upto 800 microns to pass through it.

(x) The media shall be cleanable with compressed air, or low pressure steam or light detergent, without degrading the latent recovery.

(e) Cassette/Casing

The recovery wheel cassette/casing shall be manufactured from tubular / sheet metal structure to provide a self-supporting rigid structure, complete with access panels, purge sector, rotor, bearings, seals, drive mechanism complete with belt.

The rotor/wheel should have a field adjustable purge mechanism to provide definite separation of airflow minimizing the carryover of bacteria, dust and other pollutants, from the exhaust air to the supply air. It shall be possible, with proper adjustment, to limit cross contamination to less than 0.04% of that of the exhaust air concentration.

12.10.3 **Passive desiccant wheel system**

System features

(i) The desiccant honeycomb rotor media shall be adsorbent, non toxic, non flammable, fully water washable.

(ii) The substrate of the rotor shall not be made from asbestos or any synthetic material, and shall not have any toxic desiccants impregnated like lithium chloride, etc.

(iii) The desiccant media shall have in-situ synthesized metal silicate desiccant on an inert inorganic fibre substrate. The synthetic media shall not be acceptable.

(iv) The usable desiccant mass shall be at least 80% of the media weight, so as to ensure high performance and minimal heat carry over.

(v) The net organics in the honeycomb media shall not exceed 2%.

(vi) The desiccant rotor shall have integral long life bearings supported by a simple fixed shaft design to allow a simple slide out of the rotor/bed.

(vii) The desiccant media shall have a perimeter flange which should encircle the entire perimeter so as to allow greater durability and to roll the rotor on the ground, without damage. The perimeter flange should be smooth and consistent to serve as a perimeter seal surface, thus ensuring long life for the perimeter seal, without being cut, torn or otherwise damaged.

(viii) The desiccant media shall not fracture due to repeated temperature and moisture cycling and all the materials of construction shall be non toxic.

(ix) The surface of the media shall have a special edge hardening so as to ensure a smooth surface and long life of both the media and the seal contacting it.

(x) The desiccant media shall not use any organic burn off process, as this shall weaken the media structure.

12.10.4 TIMECLOCK CONTROL

All mechanical cooling and heating systems shall be controlled by a timeclock that:

(i) Can start and stop the system under different schedules for three different day-types per week.

(ii) Is capable of retaining programming and time setting during loss of power for a period of at least 10 hours

(iii) Includes an accessible manual override that allows temporary operation of the system for up to 2 hours

Exceptions to the above are:

(a) Cooling systems < 28 kW (8 tons)

(b) Heating systems < 7 kW (2 tons)

12.10.5 TEMPERTAURE CONTROL

All heating and cooling equipment shall be temperature controlled. Where a unit provides both heating and cooling, controls shall be capable of providing a temperature dead band of 3° C (5° F) within which the supply of heating and cooling energy to the zone is shut off or reduced to a minimum Where separate heating and cooling equipment serve the same temperature zone, thermostats shall be interlocked to prevent simultaneous heating and cooling.

12.10.6 DEMAND BASED CONTROL

Conventional HVAC controls employ pressure -or temperature-set point control to isolate (or decouple) one system element from another. In any air conditioning plant, the cooling towers, chillers, distribution pumps, and supply fans are controlled independently with temperature or pressure set points that ensure the surrounding equipment also can operate independently over a wide range of loading requirements.

Although a network-capable direct-digital-control (DDC) system may be employed for control, the network typically is used only to collect information for operations. In many systems, additional isolation is provided with primary -secondary pumping, bypasses, decoupling lines, and valves or dampers that have large pressure drops.

This focus on independent equipment selection wastes a lot of energy. In this system, normally the chiller will operate at a fixed chilled water temperature. At low load conditions, the chiller compressor would operate at a higher than needed head to provide colder water than required which the chilled water pump will distribute at a higher pressure than what is required. All these bring inefficiency into the system though the individual controls are provided to control them.

Demand-based control is a method of applying direct-coupled network control. It is based on the idea that a building HVAC system is a single system the energy efficiency and comfort performance of which are optimize d when the operation of all the components is coordinated to meet actual needs in the spaces served.

Demand based control is intended to fill the vacuum created by development of variable frequency drive for HVAC equipment.

Demand based control ties the operation of all the equipment to end use requirements- actual space requirement in single building HVAC applications but this does not mean that chillers and cooling towers operate directly from the room temperature sensor. Rather in this control, all the components of air conditioning plant are directly coupled and work as a single system.

With variable-speed equipment and network capabilities, the long standing dictum that equipment must be decoupled to operate effectively has been re versed. Direct coupling leads to simpler, more-efficient operation. It is intuitive that coordinating the operation of a chiller plant and chilled-water distribution network is required to achieve the highest overall cooling system efficiency. When cooling needs to adjust in response to space conditions, demand based control coordinates the operation of all elements to provide cooling where it is needed according to predefined efficiency relationship.

Equal marginal performance principle is applied to optimize the pumps operation under all loading conditions. A circuit consisting of cooling towers, chiller pumps, and conditioning fans with VSD could be optimize in this manner. These components could be directly coupled and controlled using demand-based control to operate the circuit as a single system and provide the cooling capacity required. Thus, with demand-based control, equipment is coordinated to operate according to power (kilowatt) set points, which is s impeller, more stable, and much more efficient than the use of temperature or pressure set points is.

CHAPTER-13
ELECTRICAL WORK

13.1 SCOPE

This chapter covers the requirements for the electrical works associated with heating, air conditioning, ventilation and cold room applications, namely, switch boards, power cabling, control wiring, earthing, p.f. capacitors and remote control-cum-indicating panels. Electric motors are not covered here, as these are covered as part of the respective equipment specifications.

13.2 GENERAL

(i) Unless otherwise specified in the tender specifications, all equipments and materials for electrical works shall be suitable for continuous operations on 415 V / 240 V $\pm$ 10%(3 phase/single phase), 50 Hz. AC system. Where the use of high voltage equipments is specified in particular works, all the respective equipments shall be suitable for continuous operation on such specified high voltage.

(ii) All electrical works shall be carried out complying with the Indian Electricity Rules, 1956 as amended to date.

(iii) All parts of electrical works shall be carried out as per appropriate CPWD General specifications for Electrical works, namely, Part I (Internal) 2023, Part II (External) 2023work, and Part IV (Sub-station), 2013 all as amended to date, National Electrical Code of India 2023 and National Building Code of India 2016.

(iv) All materials and components used shall conform to the relevant IS specifications amended to date.

13.3 SWITCH BOARDS

(i) The main switch board in the A.C. plant room shall be floor mounted, free standing cubical type and shall be factory built fabricated by one of the reputed switch board manufacturer. It shall be suitable for termination of the incoming cable(s)/ bus trunking from top/ bottom. The switchboards in air handling unit (AHU) rooms shall be wall mounted, or floor mounted as feasible at site and as approved by the Engineer-in-charge, but they shall be cubical design, unless otherwise specified and open able from front.

(ii) The capacity of switch gear, starters etc. shall be suitable for the requirements of loads fed/controlled. Starting currents shall be duly considered in case of motor loads.

(iii) The starter and SPP shall be located adjacent to the controlling switch gear.

(iv) ACBs, MCCBs and MCBs shall be used. For rating 630 A and above ACBs shall be used. In Main Panels MCBs shall not be used.

(v) One volt meter with selector switch, a set of indicating lamps and fuses for voltmeter and lamps shall be provided at each switchboard. One ammeter with CTS, and selector switch shall be provided with each motor starter. Instruments shall be flush mounted with the panel and have a glass index not higher than 1.5. The instruments and accessories shall be provided whether or not specifically indicated in the tender specifications.

(vi) The fabrication of switchboard shall be taken up only after the drawings for the fabrication of the same are approved by the Engineer-in-charge.

(vii) Switchboards shall be fabricated as per specifications indicated in sub-para above.

(viii) The layout of bus bars and cable alleys shall be designed for convenient connections and inter-connections with the various switchgear. Connections from individual compartments to cable alleys shall be such as not to shut down healthy circuits in the event of maintenance work becoming necessary on a defective circuit.

(ix) Care shall be taken to provide adequate clearances between phase bus bars as well as between phase bus bars, neutral and earth.

(x) Where terminations are done on the bus bars by drilling holes therein, extra cross section shall be provided for the bus bars. Alternatively, terminations may be made by clamping.

(xi) Provision shall be made for proper termination of cables at the switchboards such that there is no strain either on the cables, or on the terminators. Cables connected to the upper tiers shall be duly clamped within the switchboard.

(xii) Identification labels shall be provided against each switchgear and starter compartment, using plastic engraved labels.

(xiii) Metallic danger board conforming to relevant IS shall be fixed on each electrical switchboard.

(xiv) Switchboard housing only isolators near cooling towers shall be housed in weather proof enclosure. The mounting arrangement shall be as approved by the Engineer-in-Charge to suit the site conditions.

(xv) All the AHUs shall be in preferably vertical alignment. A rising main starting from Ground floor with tap off at each floor will feed power to the AHU. The AHU Panel shall be cubicle type, wall mounted/floor mounted as required.

(xvi) All the AHUs are on emergency supply so that in case the power supply is off, all the AHU motors continue to supply air to the indoor areas.

13.4 POWER CABLING

(i) Unless otherwise specified, the power cables shall be XLPE insulated, PVC FRLS inner & Outer sheathed, upto 16 sq mm the conductor shall be copper and above 16 sq mm conductor shall be copper/aluminium, armored cables rated for 1100 V grade. The power cables shall be of 2 core for single phase, 4 core for sizes up to and including 25 sq.mm, 3-1/2 core for sizes higher than 25 sq.mm for 3 phase. Where high voltage equipment's are to be fed, the cables shall be rated for continuous operation at the voltages to suit the same. Fire Survival cables for Life safety systems as per Internal Electrical Specifications-2023. Termination with lugs/thimbles and cable glands on both sides.

(ii) Power cables shall be of sizes as indicated in the tender specifications. In all other cases, the sizes shall be as approved by the Engineer-in-Charge, after taking into consideration the load, the length of cabling and the type of load.

(iii) Cables shall be laid in suitable metallic trays suspended from ceiling, or mounted on walls, or laid directly in ground or clamped on structures, as may be required. Cable ducts shall not be provided in plant rooms. Cable trays shall be fabricated from slotted angle/solid angles to make ladder type cable tray, designed with adequate dimensions for proper heat dissipation and also access to the cables. Alternatively, cable trays may be of steel sheet with adequate structural strength and rigidity, with necessary ventilation holes therein. In both the cases, necessary supports and suspenders shall be provided by the Air-conditioning Contractor as required.

(iv) Cable laying work shall be carried out in accordance with 13.4 (iii) above. The scope of work for the Air-conditioning Contractor shall include making trenches in ground and refilling as required, but excludes any masonry trenches for the cable work.

13.5 CONTROL WIRING

(i) Control wiring in the plant rooms and AHU rooms shall be done using ISI marked FRLS PVC insulated and FRLS PVC sheathed, 1.5 sq.mm copper conductor, 250 V grade, cables drawn in ISI marked steel or PVC conduits. Alternatively, armoured multi-core copper conductor cables may also be used for the purpose. The control cables interconnecting the plant room and the AHU rooms shall be of multi-core armoured type only, and suitable for laying direct in ground.

(ii) The number and size of the control cables shall be such as to suit the control system design adopted by the Air-conditioning Contractor.

(iii) ISI marked steel conduit pipes, wherever used, shall be of gauge not less than 1.6 mm thick for conduits upto 32 mm dia and not less than 2.0 mm thick for higher sizes. All conduit accessories shall be threaded type with substantial wall thickness.
(iv) Control cables shall be of adequate cross section to restrict the voltage drop.
(v) In the case of control wires drawn through steel conduits, the wire drawing capacity of conduits as specified under the CPWD General Specifications for Electrical Works (Part I) 2023 shall not be exceeded.
(vi) Runs of control wires within the switchboard shall be neatly bunched and suitably supported/clamped. Means shall be provided for easy identification of the control wires.
(vii) Control wiring shall correspond to the circuitry/sequence of operations and interlocks approved by Engineer-in-Charge.
(viii) In cold storage involving temperatures below zero deg. C, polythene cables shall be used instead of PVC cables.

13.6 EARTHING

(i) Provision of earth electrodes and the type of earthing shall be as specified in the tender specifications.
(ii) The earth work shall be carried out in conformity with CPWD Specifications for Electrical works (Part-I), Internal 2023.
(iii) Metallic body of all medium voltage equipment's and switch boards shall be connected by separate and distinct earth conductors to the earth stations of the installations; looping of such body earth conductors is acceptable from one equipment, or switch board to another.
(iv) Armoring of cables shall be connected to the body of the equipment's/switch board at both the ends. Compression type glands shall be used for all such terminations in the case of PVC cables.

13.7 POWER FACTOR CAPACITORS

(i) PF capacitors shall be provided for all motor loads of 5 HP and above. PF capacitors can be for individual motor or it can be provided in centralized panel. These capacitors shall come into circuit when the respective motor load is switched on. For this purpose, necessary interconnections between the capacitors and the motors/starters shall be included in the scope of work of the Air-conditioning Contractor.
(ii) The power capacitors shall be of such value as to improve the PF to 0.90 lagging when the motor is running at full load. In the case of large size motors, the capacitors may be made in suitable banks so that the required bank(s) of capacitors may be switched under partial load conditions. Such operations of individual banks shall be automatic.
(iii) Where the PF capacitors are provided in banks, each bank shall be controlled by suitably rated switch gear with MCB's.
(iv) The capacitor banks and the controlling switchgear may be fabricated in independent cubical or may form part of the switchboard in the installations. In the latter case, the capacitors are permitted to be mounted on the switchboard, if so desired.

13.8 REMOTE CONTROL CUM INDICATING PANEL

(i) The remote control cum indicating panel shall be provided in the plant room. This panel shall have necessary push buttons for on and off controls and status indication of all electric motors except for small motors as of humidifiers of AHUs and FCUs. **However, if BMS system is provided, remote control-cum- indicating panel shall not be required.**
(ii) In view of (i) above, push buttons need not be provided as part of the starters in the switch boards, except of the AHU blower motors. In the case of the AHU blower motors, push buttons shall be provided as part of the starters for local on and off operations.

(iii) Back indication to show the status of operation of all the motors (except small motors as in humidifiers of AHUs and FCUs) and also of the electric strip heaters (AHU wise) shall be provided.

(iv) Panel shall be fabricated from 1.6 mm thick steel sheet. This shall be of freestanding floor mounting type design. This shall be complete with necessary termination arrangements, multicore cables, tag blocks, control transformer, designation plastic labels, double earth studs etc. as required.

13.9 MOTOR STARTER

(i) The motor starter shall conform to IS: 1822 "Motor starters of voltage not exceeding 1000 volts" and shall be air insulated and suitable for 415 volts, $\pm$ 10%, 50 Hz., 3 phase AC supply. Enclosures shall have protection of IP 42 for Indoor applications and IP 55 for outdoor applications.

(ii) Starter for the motor shall be direct on line (D.O.L) for motors up to and including 7.5 H.P. rating and automatic star-delta close transition type for motors of higher ratings unless otherwise specified in the tender specifications. Starters shall be rated for intermittent duty. Starting current should not exceed two times the full load current.

(iii) Chiller shall be fitted with part winding starter and housed in chiller panel.

(iv) The starter shall be mounted on the main electrical control panel/ unit mounted/ self mounted as specified.

(v) Each starter shall be provided with the following protections: -

(a) Thermal overload on all the three phases with adjustable settings,

(b) Under voltage protection, and

(c) Independent single phasing preventor. (current sensing type)

(vi) Adequate number of extra NO/ NC contacts for interlocks, indicating lamps etc. shall be provided on the starter/ contactor.

13.10 PAINTING

All panels shall be supplied with the manufacturer's standard finish painting or as indicated in the Schedule of Work.

13.11 MOTOR EFFICIENCY

(i) All permanently wired poly-phase motors of 0.375 kW or more serving the building and expected to operate more than 1500 hours per year and all permanently wired poly phase motors of 50 kW or more serving the building and expected to operate more than 500 hours per year shall have a minimum acceptable nominal full load motor efficiency not less than IE3 class as per IS 12615 for Energy Efficient motors.

(ii) Motor horsepower ratings shall not exceed 20% of the calculated maximum load.

(iii) Motor nameplates shall list the nominal full load motor efficiencies and the full load power factor.

(iv) Motor users should insist on proper rewinding practices for rewound motors. If the proper rewinding practices cannot be assured, the damaged motor should be replaced with a new, efficient one rather than suffer the significant efficiency penalty associated with typical rewind practices.

(v) Certificates shall be obtained and kept on record indicating the motor efficiency. Whenever a motor is rewound, appropriate measures shall be taken so that the core characteristic s of the motor is not lost due to thermal and mechanical stress during removal of damaged parts .After rewinding, a new efficiency test shall be performed and similar records shall be maintained.

(vi) Motors should be installed with soft start energy savers and Variable Speed drives based on the application required.

13.12 Variable Frequency Drives :

(i) VFD shall comply with recognized, international standards, and the manufacture must be carried out in accordance with ISO 9001 and BS 5750, parts 1 and 2. The VFD shall comply with EMC and RFI requirements according to EN 55011 (VDE 0875), and the supplier shall issue a certificate of such compliance. By Pass Starters shall also be provided with VFDs.

(ii) Mechanical Protection :
The VFD shall have a metal enclosure which will meet the requirements of IP54 unless specified otherwise in the schedule of work to ensure that an extra enclosure is not necessary and have integrated fans as required. The supplier shall provide information on heat dissipation. All VFDs to be with factory supplied back plate to facilitate air flow across the heat sink so as to enable free standing installation of VFD.

(iii) The VFD shall be able to operate under the following conditions:
(a) Rated input voltage 400V +/- 10%, 3 phase, 50 Hz +/- 2 Hz
(b) Ambient temperature as specified.
(c) The VFD shall be suitable for manual as well as remote control.

(iv) The VFD shall be able to supply the motor with a sine shaped supply and fully circular magnetic flux to obtain full motor torque at rated frequency, without the motor becoming warmer than in normal mains operations.

(v) The VFD shall be able to vary the output frequency from 0 to 100 percentage and output voltage from 10% to full mains voltage even at -10% of full mains voltage. The VFD shall regulate the output to continuously adapt as the case may be to the current load on the pump or the fan so as to minimize energy consumption.

(vi) The VFD shall be able to work as a Stand-Alone unit, where all safety requirements have been fulfilled, or as part of a larger BMS system , where the control is centralized and operated via serial communication using integrated RS 485 ports.

(vii) The control panel shall be detachable and be able to function in a central control panel, if used.

(viii) The VFD shall be able to regulate all types of motors without load reduction and without the motor temperature becoming higher than under normal mains operation.

(ix) The VFD shall be able to control motors of different sizes connected in parallel, and it must be possible to stop a machine during operation without the risk of tripping. The VFD shall be able to run without the motor being connected, for the purpose of servicing. Servicing must not require access from the back of the VFD.

(x) The following features should be incorporated in the VFD.
(a) Alphanumeric display
(b) “ON.” and “ALARM” indications.
(c) Choice of different displays, eg. of output current, voltage, frequency, speed, output, torque, motor temp., energy kwh.

(xi) The VFD shall be able to avoid at least 4 bypass frequencies with adjustable bandwidth to avoid mechanical resonance.

(xii) The VFD shall have filters in the intermediate circuit to ensure that the 5th harmonic transmitted to the mains supply is limited to approx. 30%.

(xiii) The current limiting function shall be quick enough for the VFD to resist short-term earthing and short circuiting on the output terminals without any damage to the components.

(xiv) The VFD shall have integrated protection against the mains transients in accordance with VDE 0160, single phasing, in the mains or motor, or short-circuiting of motor phases. If the speed reference is lost, it shall be a programming option to either maintain the motor speed or regulate to stop.

(xv) The VFD shall be able to give off a warning or stop the motor if the motor is overheated. This function must form an integral part of the VFD.

(xvi) The output circuit shall ensure the possibility of unlimited switching between VFD and motor regardless of load and speed, without any damage to the VFD, and without extra equipment being required.

(xvii) The VFD shall have an override function which in the case of overloads during operation and starting reduces the motor current to prevent damage.

(xviii) The VFD shall have a power factor of 1 on the supply side (AC) at all loads and speeds; extra AC coils for stable operation shall not be required.

(xix) Protection features

The following protection shall be provided:

(a) Inverter trip at 75°C on the heat sink.
(b) Protection against under voltage
(c) Protection against overvoltage
(d) A lock to prevent unintended programming of the VFD.

CHAPTER-14
CENTRAL HEATING SYSTEM

14.1 SCOPE

This chapter covers the requirements for all heating and reheat systems for Air Conditioning applications .Heating shall be required to maintain inside design conditions when the ambient temperature is low. Heating in the form of reheat shall be required where RH has to be maintained at specified levels for which the dehumidified air needs to be cooled down to a lower temperature than space requirements and then reheated to specified levels.

A central heating system includes hot water generator and associated works like Factory built air handling units, Fan coil units, VAVs, Convector/grill/diffuser, radiators, treated fresh Air units, Heat recovery wheels, air filters, water treatment system i/c plant, Air filter and air distribution system, Fire Control and safety, Water circulating pumps, Ducting, Water plumbing work, insulation work, controls & control wiring & electrical works. Specifications for all associated works are same as for air-conditioning works covered from chapter 6 to 13. For system design refer Chapter 2 and chapter 5 may be referred.

14.2 Types of Systems. :

14.2.1 A heating/reheat system is a means of heating the air in a conditioned space with or without humidification. Heating can be through a hot water generator or by the hot refrigerant gas.

14.2.2 Hot water generators shall either be electrically heated type or can be operated on the refrigeration cycle as a Heat Pump. Electrical heating or heating using fuels such as coal or oil shall be discouraged since these methods are inefficient and consumes energy. Only exception to this are situations where steam or hot water is available as a by product such as in a factory, hotel or hospital. In all other cases Heat Pumps shall be the source of hot water.

14.2.3 The hot water generated shall be circulated through :

(a) Heat convectors or radiators positioned in the conditioned spaces, or

(b) Heating coils of AHUs and circulating the heated air through the conditioned spaces, analogous to the central chilled water air conditioning system.

14.2.4 Heating of the space shall also be achieved by employing reverse cycle ie, by providing changeover valves in the chilled and condenser water piping.

14.2.5 Reheat can also be provided by using heat pipes in the AHU or HRU.

14.2.6 Duct mounted heater either strip or tubular shall not be used because of the fire hazard.

14.3 ELECTRICALLY OPERATED HOT WATER GENERATOR

(i) The hot water generator shall be cylindrical in shape, fabricated out of MS sheet of 10 mm thickness in robust welded construction. It shall be complete with necessary supports for free standing on floor, such that the bottom of the shell is 300 mm above the finished floor level.

(ii) Shell shall be complete with necessary lifting lugs, and provisions for inlet and outlet connections, drain connections, and heating elements.

(iii) Shell shall be insulated with non-setting, non-corrosive glass wool insulation blanket. This shall be covered with 2 mm thick aluminium sheet, or 1.25 mm thick MS sheet, painted with heat resistant paint. The surface temperature of the cladding shall not be exceeding 45 deg. C.

(iv) Electric heating elements shall be replaceable, immersion type having solid copper facing designed for low heat concentration, not exceeding 70 W/ 1000 sq.mm. The elements shall be located near the bottom of the shell. The number as well as wattage of the elements shall be clearly indicated in the technical particulars by the Air-conditioning Contractor so as to guarantee production of hot water at the specified rate.

(v) The elements shall be connected to suitable terminal box with hinged cover and shall be complete with provision for termination of electric supply cables, as required. The elements shall be distributed in 3 phase equally for balanced loading, and shall be brought out in the terminal box for switching in stages as required. The number of stages shall be indicated by the Air-conditioning Contractor.

(vi) Suitably rated contactors shall be housed in the control box mounted on or near the hot water generator for the switching of the heater elements in the desired stages. This shall be complete with necessary interconnecting wiring/cabling between the control box and terminal box.

(vii) Hot water generator shall be provided with but not restricted to the following accessories.
- (i) Safety valve,
- (ii) Drain valve,
- (iii) Pressure release valve,
- (iv) Vent cock,
- (v) Thermometer,
- (vi) Pressure gauge
- (vii) Electrically operated pressure switch

14.4 HEAT PUMP based hot water generator :

(i) System description

(ii) Heat Pump Extent of Work

(iii) The heat pump shall be complete with all ancillaries as feed water lines, hot and cold water piping between the unit and the storage tanks(as per clause 14.2) . MCC, Storage tanks, controls, instrumentation, safety interlocks, circulation pumps, all the power cabling and control cabling for the heat pump and the circulation pumps from terrace, electrical works etc.

14.4.1 Each Heat pump shall comprise of the following:

(A) Compressor

(i) The Heat pump shall be provided with Single-Stage direct connected Positive Displacement Semi-Hermetic Rotary Screw or Scroll Compressor of the Oil injected type driven a two pole Motor.

(ii) The Screw Compressor shall be of Single/multi-screw type, with the Provision of each compressor operating in isolation.

(iii) All the moving parts in the Compressor shall be dynamically balanced to minimize the operating noise, vibration and ensure longer life of the Compressor.

(iv) The Pure Rotary Motion of the compressor shall ensure uniform flow of gas, even torque and positive displacement. The intake and Discharge Cycles shall overlap.

(v) The load of each rotor shall be evenly distributed through the use of Anti-Friction Roller Bearings.

(vi) Each Compressor shall include an integral Oil Separation system, Oil Sump and Oil filter.

(vii) The oil temperature shall be controlled during operation throughout the lubrication system.

(viii) Each Compressor shall have a suction check valve, suction filter, suction service valve and discharge check valve. Isolation valves shall be provided on all connection to the compressor to allow condenser to be used as a pump down receiver.

(B) Compressor Motor

(i) The driving motor shall be TERC squirrel cage type or suitable hermetic as required, protected against damage by means of built in protection devices.
(ii) The compressors and Motors shall be fully protected against abnormal operating conditions by high and low pressure switches, thermal relays, overload relays and safety controls and Phase failure protection.
(iii) The compressors shall be fitted with gauge connections for reading oil, suction and discharge pressure, and shall be fitted with sight glass, internal motor protection.
(iv) The motor shall have solid state protection to prevent the motor from operating at unsafe operating temperatures.
(v) The profile of Screws shall permit safe operation up to a speed of 2900 RPM for 50 Hz operation.
(vi) The starter type shall be DOL up to 7.5 HP and Star Delta for above 7.5 HP for reduced starting currents.

(C) Microprocessor based control

(i) It should be possible to set the Leaving hot water temperature by inputting the same via the Chiller Control Panel. Microprocessor control shall be provided for the Chiller Unit to monitor.
(ii) Analog and Digital inputs to the Chiller and to control the operational and protective function of the unit.
(iii) The Control Panel shall have a display panel. It shall be possible to display the following parameters without an experienced operator:

- Discharge Pressure
- Discharge Temperature
- Compressor Status

The Following Automatic Protection Controls shall be provided to insure system reliability:

(i) Low Suction Pressure
(ii) High Discharge Pressure
(iii) High Oil Temperature
(iv) Freeze Protection
(v) High Motor Temperature
(vi) Power Loss
(vii) Chilled water Flow Loss
(viii) Phase Unbalance
(ix) The supplier shall provide the Motor Electrical Data and the Part Load Performance curves for the Chiller being offered.
(x) The design, manufacture and performance of refrigerant Compressor shall comply with
(xi) all currently applicable statutes, regulations and safety codes in the locality where the
(xii) equipment will be installed. The equipment performance shall also conform to the latest
(xiii) applicable AHRI/ Eurovent Standards. Nothing in this specification shall be constructed to relieve supplier of his responsibility.
(xiv) The compressor shall be in accordance with the specification prescribed in the attached
(xv) Data Sheet. The type of accessories, controls and instrumentation shall be as indicated in the data sheets. The motor, included in Supplier’s scope of supply shall comply with the Motor
(xvi) Specification indicated in the Data Sheet or the latest prevalent standards.

(xvii) The Equipment shall be packed on metallic skids to permit easy installation.

(xviii) Hydrostatic and refrigerant leak tests shall be carried out at the manufacturer's works before the dispatch of the Chiller.

(D) Condenser

(i) The condenser shall be Single/Multi pass.

(ii) The Condenser vessels shall be cleanable shell and tube type with integral finned copper tubes mechanically expanded into heavy fixed steel tube sheets Evaporator

(iii) The Dry Expansion/flooded Evaporator shall be cleanable shell and tube with seamless

(iv) carbon steel shell, with grooved copper tubes mechanically fixed into heavy fixed steel tube sheets. OD of tubes should be minimum 19 mm & with thickness of 0.63 mm.

(v) The dry expansion evaporator/flooded shall have complete accessories i.e. Electronic expansion valve, filter drier, necessary temperature sensor and connections for drain and vent.

(vi) The dry expansion evaporator/flooded shall have a built in distributer for feeding refrigerant evenly under the tube bundle to produce a uniform boiling action and baffle plates shall ensure vapour separation.

(vii) The water heads shall be of carbon steel and designed for easy removal for mechanical tube cleaning and/ or tube removal. It shall be designed for multiple pass arrangement for optimum water velocity through tubes for efficient heat transfer and lower pressure drop.

14.5 Electrical control board which is made up from following accessories

Main isolating switch and fuse protection of auxiliary and power circuit.

(i) Compressor remote control

(ii) Fan reverse regulator for condensation control

(iii) Pump relay or motor overload protection and remote control

(iv) Main alarm on/ off contacts.

(v) Re-circulation pump controls.

14.6 Microprocessor for the control of the following function

(i) Regulation of the water temperature with inlet control;

(ii) Anti-freeze protection;

(iii) Compressor timing;

(iv) High pressure pre-alarm management (to prevent unit block)

(v) Enabling of summer/winter changeover

(vi) Automatic defrosting;

(vii) Alarm signals;

(viii) Alarms reset;

(ix) Self-adaptable regulation to allow optimal functioning in the case of low water content inthe plant

(x) Digital input for summer/winter remote changeover

14.7 Display, with following facility

Outlet water temperature

(i) Condensation temperature;

(ii) Set temperature and differentials set

(iii) Description of the alarms 400V/3N~/50Hz power supply for heat pump.

14.8 Controls and safety devices:

Each Heat pump shall be provided with followings:

(i) Utility water temperature control probe (situated at entry of heat pump);

(ii) Anti-freeze probe that activates the anti-freeze alarm (with automatic re-arm at limited intervals)
(iii) High pressure gauge (with manual re-arm);
(iv) Low pressure gauge (with automatic re-arm at limited interventions);
(v) Mechanical flow switch supplied as standard
(vi) Condensation pressure control by means of rev. regulator for functioning with low external temperatures
(vii) High pressure safety valve
(viii) Compressor internal over-temperature protection
(ix) Compressor external over-temperature protection
(x) Single Phasing & Reverse Phasing protection
(xi) Automatic Defrost System
(xii) Compressor / Fan / Circulation Pump – Shut Down & Re start Sequencing all the necessary control cables between the heat pump and hot water storage tank is included in the scope of work.

14.9 Testing

Following listed tests shall be conducted after installation of the heat pumps:

(a) Capacity test to confirm heat output for Heat pump
(b) All controls and safety tests.
(c) Efficiency test.
(d) Safety valve flow test.
(e) Hydraulic test.

All necessary equipment or instruments required for conducting above tests shall be arranged by the contractor. Heat pump will be accepted subject to clearance of above tests.

14.10 Drawings

Contractor shall furnish following drawings in triplicate within one month from the date of order to the consultants.

(a) Foundation details of Heat pump and storage tanks.
(b) Dimension detail of Heat pump and storage tanks and Piping arrangement.
(c) Heat pump electrical wiring diagram.
(d) Heat pump operation manual.
(e) P & I diagram.
(f) General arrangement & Terminal point details.

14.11 Pre-commissioning

On completion of the entire erection of equipment, piping, connection to the pipe system and electrical system, contractor shall fill the entire system with cold water and test for leakage and other erection defects. All such defects shall be removed. All motors shall be tested and shown for its operation as per the parameters of the OEM and as approved by the NU.

14.12 Commissioning & testing

On completion of all procedures at pre-commissioning stage, Heat pump shall be tested by the respective supplier and all adjustments shall be carried out in valves and other accessories for the related equipment's. Heat pump shall be allowed to run till the desired temperature in the system is obtained. Any defect noted shall be rectified immediately.

14.13 PAINTING

All equipment shall be supplied with the manufacturer's standard finished painting.

CHAPTER–15
MECHANICAL VENTILATION SYSTEM AND ETAC PLANTS

15.1 SCOPE

This chapter includes supply air fan, exhaust air fan and evaporative type air cooling plant. Specification for all associated works such as ducting, plumbing, electrical works etc. are same as for air-conditioning works covered under chapter 9, 10 and 13. For system design refer chapter-2.

15.2 General

All types of fans having motor capacity equal to or more than 5 HP shall have VFD drive.

15.3 CENTRIFUGAL FANS

(i) All centrifugal fans shall be complete with access door, squirrel-cage induction motor, V-belt drive, belt guard or Direct driven type etc. Since belt drives may entail significant transmission losses, centrifugal fans shall be supplied in direct driven configuration unless otherwise specified. All direct driven fans shall be installed with a variable frequency drive (VFD) of suitable rating to adjust fan speed.

(ii) Housing shall be of heavy gauge Galvanized sheet steel or hot dipped galvanized in welded / locked formed /bolted construction, thickness as per OEM. It shall be rigidly reinforced and supported by structural angles. However, neoprene/ asbestos packing shall be provided throughout split joints to make it airtight. 1.2 mm galvanized wire mesh inlet guard, of 5 cms sleeves shall be provided on both inlets. Housing shall be provided with access door with quick locking tension handles and neoprene gasket. Rotation arrow shall be clearly marked on the housing.

(iii) Fan wheel shall be of GSS and backward curved non-overloading type unless otherwise specified. Fan wheel and housing shall be statically and dynamically balanced. Fan outlet velocity shall not exceed 610 meters per minute for DIDW / Plug Fans and 960 meters per minute for SISW Fans (Kitchen / Laundry / Smoke / STP). Fan housing and motor shall be mounted on a common extruded aluminium / galvanised steel / MS powder coated base mounted inside, the fan section on anti- vibration spring mounts or cushy-foot mount. The fan outlet shall be connected to casing with the help of fire-retardant fabric. Fan housing and motor shall be mounted on a common extruded aluminium base mounted inside the fan section on anti- vibration spring mounts or cushy- foot mount. The fan outlet shall be connected to casing with the help of fire retardant fabric.

(iv) The fan impeller assembly shall be statically and dynamically balanced.

(v) Shaft shall be constructed of steel, turned, ground and polished.

(vi) Bearings shall be of the sleeve/ball bearing type mounted directly on the fan housing. Bearing shall be self-aligned, oil grease packed, pillow block type.

(vii) Drive to fan shall be provided from 3 phase electric motor Direct Driven type until otherwise mention in NIT. with adjustable motor sheave and belt guard. Belt shall be of the oil resistant type. The number of belts shall be not less than two. However until otherwise specify in NIT drive to fan shall be direct driven type 3 phase electric motor with VFD.

(viii) Drive motor shall be in accordance with para 6.2.3.4(v). Motors should be in conformity to IS:12615 of Bureau of Indian Standards and shall have BIS / ISI mark. Motor name plate shall bear the BIS license number

(ix) Motor starter shall be in accordance with para 13.9.

(x) Fan shall confirm to AMCA standard 211 and 311. The fan must be tested in accordance with ANSI/AMCA standards 210-99 and AMCA standard 300-96 in an AMCA accredited lab. Fans shall be certified to bear the AMCA label for air & sound performance.

15.4 AXIAL FLOW FANS

(i) Casing shall be constructed of heavy gauge sheet steel with minimum 220 GSM zinc coating. Casing shall be provided with hinged door enabling easy replacement of wheel, shaft and bearings. A small inspection door with handle and neoprene gasket shall also be provided. Casing shall have flanged connection on both ends for ducted applications. Support brackets for ceiling suspension shall be welded to the casing for connection to hanger bolts.

(ii) Straightening vanes shall be aerodynamically designed for maximum efficiency by converting velocity pressure to static pressure potential and minimizing turbulence. Casing shall be de-rusted, cleaned, primed and finish coated with enamel paint.

(iii) Rotor hub and blades shall be of cast aluminium, or cast steel construction. Blades shall be die-formed aero foil shaped for maximum efficiency and shall vary in twist and width from hub to tip to effect equal air distribution along the blade length. Fan blade mounting on the hub shall be statically and dynamically balanced. Extended grease leads for external lubrication shall be provided. The fan pitch control maybe manually readjusts able at site, upon installation, for obtaining actual airflow values, as specified.

(iv) Motor shall be of 3 phase squirrel-cage totally enclosed, fan cooled type suitable for 415±10% volts, 50 cycles, 3 phase AC power supply, provided with class ‘F’ or class ‘H’ insulation. Motor and starter shall be in accordance. Motors should be in conformity to IS:12615 of Bureau of Indian Standards and shall have BIS / ISI mark. Motor name plate shall bear the BIS marked. The fan speed shall be as per OEM best selection ensuring compliance to key critical parameters like airflow, Static pressure, noise level & fan total efficiency as required in the NIT and this specification.

(a) Drive :

For Duct/Wall Mounted Fan:

For duct/wall mounted fans the impeller shall be mounted directly on the motor. Drive unit and impeller shall be totally enclosed inside the duct.

For Floor/Ceiling Mounted Fan:

For floor/ceiling mounted fans the impeller shall be mounted directly on the motor. Drive unit and impeller shall be totally enclosed inside the duct.

(b) **Vibration Isolation**

Base shall be provided for each fan. Base for both fan and motor shall be built as an integral part and shall be mounted on a concrete foundation through cushy foot vibration isolators. The concrete foundations shall be at least 15 cm above the finished floor level and shall be further isolated from the structural floor through 5 cm. Thick layers of sand all around, topped with bitumen. In case ceiling hung fan within the ceiling shall be provided Vibration Isolation Suspension (VIS) shall be provided in each of string.

(v) Axial Flow Fan shall be AMCA certified for Air and Sound performance in accordance with AMCA 210 and AMCA 300. Fan shall be suitable for both indoor and outdoor application with all accessories.

(vi) All High temperature axial fans complete with IS 12615 licensed motor & the complete fan assembly should be certified for a temperature rating for at least 250 deg C for 2 hours, either CE certified as per EN 12101-3: 2015 from an independent accredited European laboratory or UL listed for “Power Ventilators for Smoke Control”. Fans should be UL or CE labeled. Motor make shall be the same as mentioned on the fire certificate.

15.5 PROPELLER FANS

(i) Propeller fans shall be direct-driven, three or four blade type, mounted on a steel mounting plate with orifice ring.

(ii) Mounting plate shall be of heavy gauge sheet steel/galvanized steel construction, streamlined venture inlet (reversed) for supply applications. The size shall suit the fan size.

(iii) Fan blades shall be constructed of aluminium or steel. Fan hub/blade shall be of heavy welded/fabricated or bolted steel construction with blades bolted to the hub. Fan blades and hub assembly shall be statically and dynamically balanced at the factory.

(iv) Motor shall be standard (easily replaceable) single phase, permanent split capacitor or shaded pole for small sizes, totally enclosed with pre-lubricated sleeves or ball bearings, designed for quiet operation with a maximum speed of 1000 RPM for fans of 3 cm. dia or larger and 1440 rpm for fans of 31 cm. dia and smaller. Motors for larger fans shall be suitable for 415 $\pm$10% volts, 50 cycles, 3 phase, power supply. Motors shall be suitable for either horizontal or vertical services, as indicated in drawing/schedule of quantities.

(v) The following accessories may be required and provided with propeller fans, as indicated in the tender specifications.

(a) Wire guard on inlet side and bird screen at the outlet.
(b) Gravity operated louver shutters built into a steel frame.
(c) Regulators for controlling fan speed for single phase fan motors.

(vi) Fan shall be AMCA certified for Air and Sound performance in accordance with AMCA 210 and AMCA 300.

(vii) Motors should be in conformity to IS:12615 of Bureau of Indian Standards and shall have BIS / ISI mark. Motor name plate shall bear the BIS marked. The fan speed shall be as per OEM best selection ensuring compliance to key critical parameters like airflow, Static pressure, noise level & fan total efficiency as required in the NIT and this specification.

15.6 ROOF MOUNTED FANS

(i) Roof mounted fans shall be centrifugal fans, direct driven complete with motor drive and housing with weather-proof cowl or butterfly damper.

(ii) Housing shall be constructed of heavy gauge steel sheet or GSS or hot dip galvanized. The housing shall have a low silhouette. For belt driven units, motor shall be installed in ventilated water proof housing outside the air stream. The discharge cowl shall be hinged along one edge for easy access to motor and drive for inspection and maintenance. The entire assembly shall be weatherproof and raised from the roof terrace sufficiently to prevent down flow of rain water accumulated on the terrace. Galvanized steel mesh bird screen shall be provided on all discharge cowls around the outlet areas.

(iii) Fans shall be backwardly inclined centrifugal wheel or propeller type as required, designed for maximum efficiency, minimum turbulence and quiet operation. Fan shall be statically and dynamically balanced.

(iv) Single phase motor shall be shaded pole with permanently lubricated sleeve bearing, or split capacitor type with permanently lubricated sleeve or ball bearings, designed for quiet operation. Motors should be licensed under IS: 12615 of Bureau of Indian Standards and shall have BIS / ISI mark. Motor name plate shall bear the license number. Bearing shall be designed for vertical mounting. Motor name plate horsepower shall be such that the motor shall not be overloaded in the entire range of rated speed. Motor and fan assembly shall be easily removable. Motor's power supply characteristic and maximum speed shall be as specified for propeller fans.

(v) Fan bearings shall be heavy duty, self-aligning sleeve/ball bearing designed for thrust load and sealed for grease retention.

(vi) Backdraft damper shall be provided where specified. Roof mounted fan shall be equipped with rattle-free backdraft damper to prevent air from re-entering the fan when fan is not in operation, thus sealing completely in closed position. Damper shall be shatterproof.

(vii) Motors should be in conformity to IS:12615 of Bureau of Indian Standards and shall have BIS / ISI mark. Motor name plate shall bear the BIS marked. The fan speed shall be as per OEM best selection ensuring compliance to key critical parameters like airflow, Static pressure, noise level & fan total efficiency as required in the NIT and this specification.

(viii) Fan shall be AMCA certified for Air and Sound performance in accordance with AMCA 210 and AMCA 300.

15.7 Cabinet Type Fans

(i) Fan cabinet shall be similar to single skin Air Handling Units in rectangular cabinet with interchangeable panels so the direction of fan discharge can be customized at least having a casing thickness of 0.8mm, fabricated out of mild / galvanized steel angles and galvanized sheet steel with bracing or beading for structural rigidity.

(ii) Fans shall be forward / backward curve / aero foil centrifugal double inlet multiple blade type, enclosed inside the unit casing as specified above and together with the drive/s, unless stated otherwise.

(iii) Drive motor shall be mounted on adjustable motor base capable of a minimum adjustment of 100mm. Wherever 24 hours operation with two drive motors are specified the fan shaft shall be extended on both sides with the drive pulleys. Motor ratings shall exceed the maximum power absorbed by the fan at all operating conditions.

(iv) Fan shall be AMCA certified for Air and Sound performance in accordance with AMCA 210 and AMCA 300.

15.8 High Temperature Fans

Fan with accessories shall be certified for high temperature rating for 2 hours at 250^{o}C and should be CE labeled. BS EN12101-3 or UL Listed for “Power Ventilators for Smoke Control”. Type certificate shall be provided for each fan, clearly mentioning model number of fan, motor and origin, type of fan, details of testing factory. Motor shall have IP 55 & class H insulation. Fan shall be AMCA certified for Air and Sound performance in accordance with AMCA 210 and AMCA 300.

15.9 Plug Fans With EC Motor

(i) SISW Backward PLUG/Plenum fans shall be coupled with electronic commutation (EC) motor.

(ii) Fans shall be dynamically trim (Two stage) balanced to ISO1940 and AMCA 204/3 - G2.5 quality grade after assembly. A computer printout with vibration spectrum analysis shall be submitted.

(iii) Fan Impeller shall be made of High Grade Aluminium Sheet / Hot Rolled Sheet / Steel Cold Rolled sheet steel with polyester powder coating. Impeller shall be directly coupled on motor shaft to avoid any maintenance and to save drive transmission losses.

(iv) Inlet Cone shall be Spun GSS. For spark resistance arrangement, Inlet cone shall be of Copper/brass. Plastic / FRP inlet cone shall not be acceptable for normal / spark resistance construction.

(v) Fan shall be AMCA certified for Air and Sound performance in accordance with AMCA 210 and AMCA 300.

Table 15.1

DIFFERENCES BETWEEN FANS, BLOWER AND COMPRESSOR

Equipment	Specific Ratio	Pressure rise (mmWg)
Fans	Up to 1.11	1136
Blowers	1.11 to 1.20	1136 – 2066

Compressors	more than 1.20	–

TABLE 15.2
FAN EFFICIENCIES

Type of fan	Peak Efficiency Range
Centrifugal Fans	
Airfoil, backward curved/inclined	72-79
Modified radial	72–79
Radial	69–75
Pressure blower	58–68
Forward curved	60–65
Axial fan	
Vane axial	78–85
Tube axial	67–72
Propeller	45–50

TABLE 15.3
TYPES OF FANS, CHARACTERISTICS, AND TYPICAL APPLICATIONS

Centrifugal Fans			Axial-flow Fans		
Type	**Characteristics**	**Typical Applications**	**Type**	**Characteristics**	**Typical Applications**
Radial	High pressure, medium flow, efficiency close to tube-axial fans, power increases continuously	Various industrial applications suitable for dust laden moist air/gases.	Propeller	Low pressure, high flow, low efficiency peak efficiency close to point of free air delivery (zero static pressure)	Air-circulation, ventilation, exhaust.
Forward curved blades	Medium pressure high flow, dip in pressure curve, efficiency higher than radial fans, power rises continuously	Low pressure HVAC, packaged units, suitable for clean and dust laden air /gases.	Tube-axial	Medium pressure, high flow, higher efficiency than propeller type, dip in pressure-flow curve before peak pressure point.	HVAC, drying ovens, exhaust systems
Backward curved blades	High pressure, high flow, high efficiency, power reduces as flow increases beyond point of highest efficiency	HVAC, various industrial applications forced draft fans, etc.	Vane-axial	High pressure, medium flow, dip in pressure-flow curve, use of guide vanes improves efficiency exhausts	High pressure applications including HVAC systems,
Airfoil type	Same as backward	Same as backward			

	curved type, highest efficiency	curved, but for clean air applications			

15.10 EVAPORATIVE TYPE AIR COOLING (ETAC)

(i) The ETAC unit shall be of double skin construction draw-through type comprising of various sections such as filter section, cellulose deck bed section and supply air fan section.

(ii) Housing of air handling unit shall be of double skin construction. The frame work shall be of extruded aluminium hollow section. All the frames shall be assembled using pressure dye cast aluminium joints of various sections, strong and self-supporting frame work of various sections. The double skin panels shall be 25mm thick and shall be made of 0.8mm pre-painted GSS sheet on outside and 0.63mm pre-painted GSS sheet on inside with 25mm thick PUF insulation injected in between by injection moulding machine. These panels shall be screwed on to the frame work with soft rubber gasket in between to make the joints air-tight. Suitable air-tight access doors with hinges and locks shall be provided for access to various sections for maintenance. The entire housing shall be mounted on extruded aluminium channel frame work having pressure dye cast aluminium joints.

(iii) Fan: The fan shall be backward curved double inlet, double width type. The wheel and housing shall be fabricated from heavy gauge galvanised steel. The fan impeller shall be mounted on a solid shaft supported to housing with angle iron frame work and pillow block heavy duty ball bearing. The impeller and fan shall be statically and dynamically balanced. The fan shall be selected for a speed not exceeding 1000 RPM. Frame housing with motor shall be mounted on a common extruded aluminium base mounted inside the housing on anti-vibration mounds. Fan outlet shall be connected to casing with the help of fire retardant fabric acting as flexible connection for anti-vibration. The manual dampers shall be installed at the outlet of the unit. The damper should be air-tight and should be in a position to prevent back flow.

(iv) Wet Deck humidifier: The humidifier pads shall be of cellulose paper minimum 200mm deep which shall be housed in a galvanised steel case complete with water distribution header and interconnecting heavy duty PVC pipe between pump and distribution header. The water circulation pump shall be vertical type. The suction portion shall be at the bottom with proper sealing arrangement to directly pick up water from the tank. The pump shall be suitable for the operation on 3-phase 415 ± 10% volt A.C. supply.

(v) The tank shall be of stainless steel sheet of thickness not less than 1.6mm, having necessary arrangement for inlet water with float valve over flow and drain arrangement.

(vi) Filter section : The unit shall be provided with factory assembled filter section containing washable air filter having bounded expanded aluminium media with frame. The filter media and frame shall be rust proof and corrosion resistant. The filter shall be fitted so as to prevent by-pass and it shall be possible to remove the filters easily.

(vii) Motor & Drive: The fan motor shall be suitable for 415 ± 10% volts 50 cycle 3 phase squirrel case totally enclosed fan cooled with IP 55 protection. The motor speed shall not exceed 1450 rpm. The drive to the fan shall be provided through belt arrangement.

15.11 EXHAUST UNIT

The construction of the exhaust unit shall be identical with that of the air washer unit except that the exhaust unit will not have filters and humidifiers.

15.12 TWO STAGE EVAPORATIVE COOLERS

Evaporative coolers are cooling systems that use only water and a blower to circulate air. In the system, warm, dry air is pulled through a water-soaked pad. As the water evaporates, a cooling effect on the surrounding air occurs. Evaporative coolers use only a fraction of the energy of traditional air conditioning systems. Unfortunately, except for in very dry climates, they may increase humidity to a level that makes occupants uncomfortable. Two-stage evaporative coolers do not produce humidity levels as high as that produced by traditional single-stage evaporative coolers.

15.12.1 Features

(i) In the first stage of a two-stage cooler, warm air is pre-cooled indirectly without adding humidity (by passing inside a heat exchanger that is cooled by evaporation on the outside).

(ii) In the direct stage, the precooled air passes through a water-soaked pad and picks up humidity as it cools. Because the air supply to the second stage evaporator is pre-cooled, less humidity is added to the air (because cooler air can't hold as much moisture as warmer air).

(iii) This result in a cool air with a relative humidity between 50 and 70 percent, depending on the climate, compared to a traditional system that produces about 80 percent relative humidity air.

(iv) An advanced two-stage evaporative cooler uses 100 percent outdoor air and a variable speed blower to circulate cool air.

15.12.2 Benefits

(i) Two-stage evaporative coolers can reduce energy consumption by 60 to 75 percent over conventional air conditioning systems.

(ii) This relative improvement depends on location and application. Evaporative coolers work best in very dry climates.

15.13 PACKAGE TYPE AIR WASHERS:

The packaged type air washer shall be complete in all respect and shall generally comply with the following specifications given below.

15.13.1AIR WASHERS

The packaged air washer shall be of GI sheet metal sectionalized construction and shall include fan section, cooling pad section, motor drive etc.

(i) **Fan Section:**

The impellers of the fan or fan shall be of GI sheets, double inlet backward curved centrifugal design, both statically and dynamically balanced. The fan housing shall be of sturdy construction made from double skinned GSS casing having 0.6mm precoated GI sheet outside and plain 0.6mm thick GI sheet inside with 25 mm thick puff insulation with smooth air inlets. The fan shall be mounted on properly aligned shaft and mounted on self-aligning bearing blocks. The casing of the cab section shall be made of 16 G (1.6mm) GI sheets suitably reinforced to provide rigidity. The frame work shall either be folded G.I. sheets or of hot dipped galvanized iron.

The fan section shall be complete with V belt drive, belt guard and motor mounting base.

(ii) **Cooling Pad:**

The cooling pads shall be of honey comb design to provide extended and sufficient wetted surface to give a water absorbing efficiency of at least 80% at an air velocity of 3.0 m/sec. The cooling pads shall be made of either acetate paper or high impact PVC. The cross section and depth shall be sufficient for specified efficiency. The cooling pad section shall be of 16 G (1.6mm) G.I. sheet similar to fan section. It shall be complete with galvanized supports for mounting the pads and a water distribution through the uniform supply of water over the entire surface.

(iii) **Water Sump:**

The water sump below the pad section shall be of minimum 1mm SS 304. The tank shall be complete with makeup, overflow and drain connections. A float valve shall be provided for makeup water line.

The pump set shall be of construction, with end suction and top discharge with flanged connections, bronze impeller and casing all mounted directly on a squirrel cage, drip proof induction motor of suitable capacity.

15.13.2 MOTORS:

The motor for each blower shall be totally enclosed, fan cooled, squirrel cage induction type and conform to specifications, class F insulation with IP 55 protection.

15.13.3 MISCELLANEOUS:

Necessary accessories shall be provided wherever necessarily required for proper operation and shall also include:

(i) Necessary GI piping for water circulation
(ii) Vibration isolations pads for the blowers and pumps
(iii) Canvass connections at the outlet of each fan
(iv) Nuts, bolts, shims etc. as required for the grouting of the equipment
(v) Float valves in the air washer tank, along with quick fill connection

15.13.4 LIMITATIONS:

The air velocity limits are as follows:

(i) Average velocity across air washer filters shall not exceed 2.5 m/sec (500 FPM)
(ii) Velocity at blower outlet shall not exceed 10 m/sec (2000 FPM)

15.14 Wet SCRUBBER

15.14.1 GENERAL:

The kitchen Scrubber will be self-contained and will consist of the following component parts listed in the following paragraph. The entire unit shall be weather proofed and corrosion protected as herein after specified. The unit shall be factory fabricated and will include:

15.14.2 BLOWER SECTION:

The blower section shall be constructed out of 16G GI sheet in folded construction and shall include Centrifugal backward curved DIDW fan wheel of totally GI construction with inlet cones and shall be complete with individual motor and drive and shall be mounted C Channel frame and Cushy Foot or Spring Mounts. The fan shall have a capacity not less than the one specified in the catalogues and shall be constructed and rated based on delivery against the rated static pressure with the media and filters in place. The fan will be of riveted construction and made with GI sheet of required thickness. The fan wheel will be of the multi-blade type and mounted on two self-aligning pillow block bearings of the requisite size. The fan shall be run with the help of groove drives as per the recommendation of the drive supplier. The blower housing will of the Pittsburgh joint construction and the drive will be provided by a motor of adequate capacity. The motor plate will be constructed out of 6mm MS or heavier metal with slotted holes, which permit belt adjustment in both the direction. The outlet velocity of the blowers will be kept low.

15.14.3 EVAPORATIVE/ SCRUBBER SECTION:

The wet section will have 16G GI tank and body with folded construction with the bolted openable sides also in 18G SS sheet/FRP. The wet section will contain 50 mm thick rigid media to act as the first stage of scrubber to be sprayed by water through WIDE ANGLE

NOZZLES to wet, scrub and clean the media installed at the inlet. These nozzles will be provided on a pipe grid such that the total face of the first bank of rigid media is kept fully wet and also gets pressure cleaning.

The wet section will have a also have another subsequent layer of 150 mm thick rigid media which will act as the cleaning media for the smoke and smell, these media banks will be designed @ 2.5 m/s to give 90% adiabatic efficiency. For the second bank 2 mm thick FRP specially fabricated header will be provided for the water distribution using perforated PVC piping 15 mm brass bleed off cock along with 20 mm heavy duty brass float. PVC drain/overflow and bleed off outlet are to be provided on all wet sections.

15.14.4 FILTER SECTION:

All wet sections will include 5 layer 30 micron aluminium wire mesh filters of 50 mm thickness including the mounting channels in SS 304 1.6mm GI for ease of removal and renewal of filter cells. The filters to be designed at 2.5 m/s to give 90% efficiency down to 30 microns.

15.14.5 PUMPS

The unit will have a horizontal single phase 220 Volts + 6% 50 c/s single phase power supply mono block self-priming pump assembly to provide re-circulated tank water and a pressurized flow via a piping system for proper pad and media water distribution. The pump capacity will be such that it can take care of the bank of nozzles provided for cleaning the first bank and also feed water to wet the second bank.

15.14.6 CABINET FANS

The construction of the cabinet fans shall be identical with that of the air washer unit except that the cabinet fans will not have filters and humidifiers .

15.15 Electronic Cleaners (Dry Scrubbers)

Electronic Air Cleaners (or dry scrubbers) shall be suitable for kitchen ventilation system handling grease laden particulates. Units shall operate from 380V 3 Ph / 220 V / 1Ph AC supply with power consumption not exceeding 1W per cmh of throughput. Face velocity should not be more than 1.5 mps and ozone discharge in the output should not exceed 0.12 ppm. Unit shall have a distribution plate or a set of suitable prefilters to effect uniform distribution and shall also be made such that periodic cleaning is easy.

15.16 PAINTING

All equipment shall be supplied with the manufacturer’s standard finished painting.

BLANK

CHAPTER - 16
COLD ROOMS

16.1 SCOPE

This chapter describes cold rooms with factory assembled Dx-type refrigeration unit, product cooler and defrosting & reheat arrangement required for cold room work.

16.2 COMPRESSOR

The compressor shall be multicylinder, reciprocating/ Scroll open/ hermetic/ semi hermetic type. The compressor shall be complete with crank case heaters, forced feed lubrication system, isolation valves strainer, safety controls, interlocking, instruments etc. as are required for efficient and safe operation of the unit.

16.3 DRIVE ARRANGEMENT

The Compressor shall be direct driven. It shall be complete with a guard. The motor HP shall be at least 110% of the maximum power requirement of the compressor. The motor shall be provided with bank of capacitors for power factor improvement with motors of 5 HP & above.

16.4 MOTOR

The electric motor driving the compressor for open type unit shall be squirrel cage fan cooled, induction motor having drip proof enclosure and class `B' insulation where as for sealed units, it shall be totally enclosed type.

The motor shall be suitable for operation on 415 volts 3 phase 50 Hz supply. The motor HP shall be at least 110% of the maximum power requirement of the compressor. The motor shall be provided with bank of capacitors for power factor improvement with motors of 5 HP & above. The motor starter shall be as per para 13.9.

16.5 CONDENSER

The condenser shall be shell & tube type, water cooled and shall match the compressor capacity. The condenser shall be selected for 4.2 deg C temperature rise of water (water in 32.2 deg C and water out 36.4. deg C). The condensing temperature shall not exceed 40 deg C. The total heat rejection shall be calculated based on evaporator temperature and condensing temperature. The condenser shall be designed for fouling factor of 0.0002 (metric). The condenser shall have integrally finned copper tubes and thickness at the root of fins shall not be less than 0.63mm. The minimum tube thickness of copper tubes shall be not less than 1.0mm. The water velocity in tube shall not exceed 3 m/s and pressure drop in condenser shall not exceed 8 m of water.

The condenser shall be complete with all connections, isolating valves, water inlet & outlet connections with thermometers & pressure gauges, globe valve on water out let, flow switch in water line. Liquid receiver of adequate capacity along with Suction accumulator and oil receiver shall be provided. The entire unit shall be mounted on a steel galvanized/powder coated base frame with mounting arrangements necessary.

16.6 PRODUCT COOLER

The product cooler shall be factory assembled ceiling/ wall mounted and shall consist of direct expansion cooling coil, hot water coil for defrosting, hot water coil for reheat (if required), propeller fan with motor. Defrosting shall be used for Cold Room Temperature below 4 Deg C. Above 4 Deg C Room temperature air defrost (Timer based) method can be used. .The cabinet shall be of 1.6 mm G.I. sheet on rigid frame. The drain pan shall be insulated and large enough to prevent any dripping of the condensate. The drain pan shall have adequate slope to ensure efficient drainage of defrosted condensate. The drain pan & drain pipe shall be provided with insulated heating element to prevent frosting.

The cooling coil shall be with copper tubes & copper fins. The tube thickness shall not be less than 0.5mm. The hot water coils for defrosting and re-heating shall also be with copper tubes and copper fins. The tubes & interconnecting pipe shall be designed in such a manner that water does not remain trapped inside the cold rooms when water circulation is stopped. Suitable manual heating arrangement may also be provided to clear the tubes of any accidental frosting inside.

The fan shall be statically and dynamically balanced, medium speed preferably direct driven by a suitable HP TEFC squirrel cage induction motor complete with starter. The motor shall be specially insulated to withstand saturated conditions and suitable for operation on specified inside temperatures.

16.7 REFRIGERATION PIPING:

The compressor, condenser & product cooler shall be interconnected with `L'. Type copper refrigerant pipe of suitable size. Isolation, valves shall be provided with compressor, condenser & product cooler etc. Interconnection of refrigerant lines of both the systems shall also be provided. In case of the cold room atmosphere being corrosive, the connecting piping shall also be used of non-corrosive material.

Suitable number of expansion valves shall be provided for achieving temperature, control. The refrigerant line shall be complete including liquid flow indicator/ drier with bypass arrangement etc. Suction line shall be suitably insulated.

16.8 DEFROSTING & REHEAT ARRANGEMENT

Common hot water generator shall be provided in the equipment room for supplying hot water to the hot water coils in product coolers for defrosting of the D.-X. coil and reheat for dehumidification purpose. Insulated pipe line along with pump, control valves etc. shall be provided for each product cooler separately. In place of plaster aluminium foil cladding shall be provided over insulation. The hot water generator shall be capable to meet the maximum requirement of hot water of both the cold rooms simultaneously. All valves/ controls for the same should be provided outside the cold rooms. Arrangement for makeup water in the hot water generator with the help of level controller shall be made. The heating element shall also be interlocked with the level in the hot water generator. Thermostat, shall be provided to maintain the hot water temperature within limits. Safety provisions shall be as per para 2.12.

16.9 Drain Piping

Drain piping shall be provided from the product cooler (Air Cooling Unit) upto the nearest available drain point or outside the chamber in consultation with the Engineer-in- charge with a U trap provided outside the chamber. The material for drain piping shall be heavy duty PVC piping or GI piping with pipe sizing similar to the outlet of the product cooler. The minimum size of any drain line should be 25 mm NB.

16.10 Insulation for walls, ceiling and floor including sandwich type panels and insulated doors shall comply with the specifications provided in Chapter 11.

16.11 PAINTING

All equipment shall be supplied with the manufacturer's standard finished painting.

CHAPTER-17
INSPECTION, TESTING, ADJUSTING, BALANCING AND COMMISSIONING

17.1 SCOPE

This chapter covers initial inspection and testing of compressor, condenser, chiller & AHUs at manufacturer's works, initial inspection of other equipment/ materials on receipt at site, final inspection testing , Adjusting, Balancing & commissioning of all equipment and systems at site & description of testing, Adjusting , balancing and requirements & procedure.

17.2 INITIAL INSPECTION AT MANUFACTURER'S WORKS

17.2.1 Centrifugal / Screw Compressor/Scroll :

(i) Salient features such as model, capacity control, type of lubrication etc. shall be verified against the requirements visually without opening the compressors.

(ii) Manufacturer's internal test certificates shall be scrutinized to check compliance with the requirements as specified in the contract.

(iii) Free running test shall be carried out at the speed for which the motor is available with manufacturer but the speed shall not be less than that specified in contract. This test shall be carried out for 30 minutes in open space. During this running test following operations are to be noted :

(iv) Manual operation of capacity control

(v) Lubrication oil pressure

(vi) (a) Pneumatic test pressure test at 21 Kgf/sq.cm for casing of compressor.

(b) Vacuum test for the compressor for 0.5mm of Hg.

17.2.2 Compressor

(i) Salient features such as model, No. of cylinders, capacity control, provision of crank case heaters, type of lubrication etc. shall be verified against the requirements visually without opening the compressors.

(ii) Manufacturer's internal test certificates shall be scrutinized to check compliance with the requirements as specified in the order.

(iii) Rate of leak test shall be checked by developing 7kg/sq.cm (gauge) pressure on HP side and 1 kg/ sq.cm on LP side using dry Nitrogen air or carbon dioxide. The leakage through the valves, shaft seal, cylinder heat gasket etc. should not be more than 0.3 kg/sq.cm per cylinder in 4 minutes time. Alternatively this may be demonstrated through vacuum.

(iv) Pneumatic pressure test shall be carried out at 22 kg/ sq.cm and by submerging the compressor in water for 1 hour & there shall be no leakage.

(v) Free running test shall be carried out at the rated speed specified in contract. This test shall be carried out for 30 minutes in open space. During this running test following operations are to be noted :

(a) Manual loading / unloading of capacity control

(b) Lubrication oil pressure

(c) Safety valve operation

(vi) Vacuum test for the compressor for 0.5mm Hg.

17.2.3 Condenser

(i) Salient features like number of tubes, inside diameter of tubes (from which the gauge of the tube can be verified), no. of passes, material of fins, length of condenser, provision of fittings like safety valve, water, gas connection shall be verified during stage inspection. The tube thickness shall be checked.

(ii) Manufacturer's internal test certificates shall be furnished and it shall be verified against contract requirements.

(iii) Pneumatic pressure test at twice the normal condensing pressure for gas side of condenser shall be carried out.

(iv) Hydraulic test at 10 Kgf/ sq.cm. for water side of the condenser shall be carried out.

17.2.4 Chiller

(i) Salient features like type of chiller, number and inside diameter of tubes (from which gauge of the tubes can be verified), material of tubes, type, material and the number of fins, wherever applicable, diameter and length of chiller and provision of fittings be verified against requirements specified in the contract during stage inspection. Tube thickness shall be checked.

(ii) Manufacturer's internal test certificate shall be furnished and same shall be checked as per contract requirements.

(iii) Pneumatic pressure test at twice the normal condensing pressure for gas side of condenser shall be carried out.

(iv) Hydraulic test at 10 Kgf/sq.cm. for the water side of chiller shall be carried out.

17.2.5 Chilling unit (Water cooled only)

Full load test shall be carried out to verify the capacity and IKW / Ton. (For air cooled chilling units this test shall be carried out at site)

Note: In case of imported centrifugal chilling machine, initial inspection shall be carried out at site before installation in respect of items needing physical inspection and verification. The test certificates for all the specified tests shall be produced which shall be accepted if found in order.

Factory Testing:

The complete unit shall be factory tested at 25%, 50%, 75% and 100% capacity at constant condenser water temperature and witnessed by Representatives of the Department or as given in bid document for performance at the rated conditions by simulating the actual design conditions. One unit of each capacity shall be tested.

All controls and switchgear shall be tested for proper functioning and set of design values.

The capacity in TR / kcal/hr shall be calculated from measurements of temperature difference and flow rate of water, in condenser and chiller. The power consumption shall be checked from current measurement of the motor. All calculated and checked results shall match the specified data within tolerances as stipulated by ARI.

All instruments and personnel for tests shall be provided by the contractor. Contractor shall inform the client about the chiller testing schedule min. 10 to 15 days before the chiller is ready for factory testing.

17.2.6 Air Handling Units

(i) Salient features such as model, size, physical dimensions, and other details of various sections, fan motor details, fan dia, static pressure etc. shall be verified against the contract requirements.

(ii) Manufacturer's internal test certificates for the motor and air handling unit shall be furnished and scrutinized as per contract requirements.

(iii) Test certificate for static and dynamic balancing of the fan/ blower should be furnished. Fan balancing may be witnessed by Engineer-in-Charge or his authorised representative.

(iv) Salient features like, type, material, no. and gauge of fins and tubes and no. of rows of cooling coil shall be furnished and verified with reference to contract requirements during stage inspection.

(v) Hydraulic pressure to the extent of 10 Kgf/sq.cm or pneumatic pressure of 21 kgf/ sq.cm shall be applied to cooling coil and this pressure should be maintained for 1 hour and no drop should be observed indicating any leaks.

17.3 INITIAL INSPECTION AT SITE

17.3.1 Ducting

(i) The sheet used for ducting shall be checked for physical test at site. The physical test should include the sheet thickness and bend test as per relevant IS specifications.

(ii) Zinc coating of GSS sheet as mentioned in the tender documents may be got tested from a laboratory to verify that same meets the contract requirements.

17.3.2 Pumps

(i) Salient features such as model and make shall be checked as per contract requirements.

(ii) The manufacturer’s test certificates with Sr. No., head, discharge will be furnished and verified against contract requirements.

17.3.3 Cooling tower

(i) Salient features such as make, model, dimensions, materials used, constructional details, number and size of nozzles, headers, size of tank, etc. should be verified against the requirements. Inspection of cooling tower in knocked down condition would be carried out at the site.

(ii) Manufacturer’s test certificate certifying the capacity of cooling tower and static balancing of fan should be furnished.

17.3.4 Switch Gear, Control Gear, and Measuring Instruments

These should be of specified make. For air circuit breaker manufacturer’s test certificate shall be furnished by contractor and the same shall be verified as per contract requirements.

17.3.5 Electric Motors

Electric motors should be of specified make, manufacturer’s test certificate for electric motor shall be furnished.

17.3.5 Pipes and Valves

(i) It should be checked that the same is as per makes specified in contract.

(ii) Dimensions including weight shall be checked for pipes against the requirements of contract.

(iii) **Manufacturer’s test certificates for valves for testing of pressure withstand.**

17.3.6 Insulation and acoustic lining

(i) Physical verification for thickness and make should be made as per contract before application of insulation.

(ii) Manufacturer’s test certificate for density, **thermal conductivity, sound absorption and class of fire retardation wherever applicable** should be furnished**.**
Note: Accuracy of testing instruments shall be as mentioned in the final inspection procedure.

17.4 FINAL INSPECTION

(i) After completion of the entire installation as per specification in all respects, the AC contractor shall demonstrate trouble free running of the AC equipments and installation for a period of minimum 120 hours of running as detailed under para 1.15.

(ii) After the trial run as in para 1.15 above, the AC contractor shall offer the plant for the seasonal test, namely test for summer or monsoon season whichever occurs earlier. The test results as per Appendix G shall be furnished.

(iii) The equipment capacity computations as per para 'B' under notes of the Annexure 'G' shall be carried out.

(iv) The Input KW of the unit / TR at full load shall also be checked against contract requirements, if any.

(v) Pressure drops across chiller and condenser at specified flow rates shall be checked against the contract requirements.

(vi) All instruments for testing shall be provided by the AC contractor. These shall be as per Note `A' of Appendix G. The accuracy of the instruments shall be as follows:

(a) Temperature: Liquid in glass thermometer having accuracy $\pm$ 1 deg. C as per IS: 4825.

(b) Wet bulb Temperature: Sling psychrometer conforming to IS:6017.
Scale Error:
For less than 0 deg. C : 0.3 deg C $\pm$ 0.2 deg. C.
For over 0 deg. C : 0.2 deg. C $\pm$ 0.1 deg. C.

(c) Pressure Gauge: With the accuracy of $\pm$ 1% for maximum scale value from 10 to 90%, and $\pm$ 1.9% for maximum scale value for rest of the scale conforming to IS: 3695.

(d) Water flow meter : Water flow shall be measured using the arrangement installed as per schedule of work.
In case the tendering firms do not have testing instruments of the accuracy mentioned above, they should specify the accuracy of the instrument available with them for testing at the tender stage.

(vii) The Testing, Adjusting and Balancing (TAB) shall be carried out during execution of work as well as at the stage of final inspection and commissioning for aggregate system capacity 100 TR and above.

17.5 TESTING, Adjusting and Balancing (TAB)

17.5.1 The Testing, Adjusting and Balancing of air distribution system, Hydronics System, HVAC equipment (Chillers, Pumps, Cooling Towers , AHU/FCU, Heat exchangers, Heat recovery wheels, Heat pumps, Humidifiers, VAV boxes etc.), Sound levels, Vibrations etc of HVAC installation shall be carried out as per" Test & Balance Procedure" by Associated Air Balance Council, USA, or National Environment Balancing Bureau USA, or SMACNA or ASHRAE or ISHRE or BIS codes guidelines and provisions of this Specifications.

17.5.2 **Testing, adjusting, and balancing (TAB)** is the process of checking and adjusting all HVAC systems in a building to produce the design objectives.
This process includes:

(i) balancing air and water Hydronic balancing,
(ii) adjusting the total system and Equipments
(iii) Measuring electrical performance of HVAC equipments,
(iv) establishing quantitative performance of all equipment,
(v) verifying automatic control system operation and sequences of operation, and
(vi) sound and vibration measurement
(vii) Measurement of duct leakages etc.

These procedures are accomplished by checking installations for conformity to design, measuring and establishing the fluid quantities of the system as required to meet design specifications, and recording and reporting the results.

Report forms. : Test data sheets arranged in logical order for submission and review. They should also form the permanent record to be used as the basis for any future TAB work.

All tests, Adjusting and balancing shall be carried out in the presence of Engineer-in-charge or his.

The instrument shall be capable of storing data and then down loading into a Computer. The HVAC contractor shall provide a minimum but not limited to the following instruments:

(i) Microprocessor based calculation meter to measure DB and WB temperature, RH and Dew point
(ii) Velo meter to measure air volume and air velocity
(iii) Pitot tube
(iv) Electronic rotary vane Anemometer
(v) Accubalance flow measuring hood
(vi) Manometer
(vii) Techo meter
(viii) Anemometer
(ix) Sound level meter
(x) Vibration analyzer
(xi) Hygrometers
(xii) Air differential pressure gauges
(xiii) Hydronic Differential pressure gauges
(xiv) Bourdon tube gauges
(xv) Psychometers
(xvi) Flow meters
(xvii) Duct leakage test kit

The contractor shall be responsible to provide necessary sockets and connections for fixing of the testing instruments, probes etc.

The all equipments, materials, labour, Technicians and skilled man power, T&P, testing point, testing arrangements and other requirement for TAB is to be arrange by the contractor and it is included in the scope of work of the contractor.

17.5.3 Air Systems

(A) Preliminary Procedure for Air Balancing

(i) Before balancing, all pressure tests (duct leakage) of duct and piping systems must be complete and acceptable.
(ii) Obtain as-built design drawings and specifications, and become thoroughly acquainted with the design intent.
(iii) Obtain copies of approved shop drawings of all air-handling equipment, outlets (supply, return, and exhaust), and temperature control diagrams, including performance curves. Compare design requirements with shop drawing capacities.
(iv) Compare design to installed equipment and field installation.
(v) Walk the system from air-handling equipment to terminal units to determine variations of installation from design.
(vi) Check dampers (both volume and fire) for correct and locked position and temperature control for completeness of installation before starting fans.

(vii) Prepare report test sheets for both fans and outlets. Obtain manufacturer's outlet factors and recommended test procedure. A summation of required outlet volumes allows cross-checking with required fan volumes.
(viii) Determine the best locations in the main and branch ductwork for the most accurate duct traverses.
(ix) Place all outlet dampers i/c fire dampers in full open position.
(x) Prepare schematic diagrams of system as-built ductwork and piping layouts to facilitate reporting.
(xi) Check filters for cleanliness and proper installation (no air bypass). If specifications require, establish procedure to simulate dirty filters.
(xii) For variable-volume systems, develop a plan to simulate diversity (if required).
(xiii) Providing operation and maintenance manuals. Manual contents are defined as the manufacturers' data on the HVAC equipment installed and must include the following:

- The manufacturers' method for adjusting and setting components for correct operation under actual load conditions;
- The manufacturers' recommended tolerance for maximum and minimum operating conditions;
- The recommended correction, or A_k factors, to allow adjustment of flow, rpm, etc.;
- A list of spare ports, identification numbers, and diagrams of their proper locations; and
- Pressure drops for air and hydronic flows through the component or unit at design flow rate.

(xiv) Clean interior of all plenums, casings and ducts and install all filters before starting systems.
(xv) Make sure all controls systems are calibrated and functioning properly.

(B) Systems are to be balanced by first adjusting the total flow at the fan, then by adjusting main dampers and branch dampers. Only final minor adjustments are to be made with register and diffuser dampers. Balancing of the air system shall be accomplished without causing objectionable air noise. Baffles and orifice plates required for proper air balance shall be furnished and installed by the contractor. the following are some of the tests, Balancing and adjustments however the testing , balancing and adjustment shall be carried as standards mentioned in clause 17.5.1.

(i) Test all fan systems to provide proper cfm/ cmh.
(ii) Adjust fresh air, return air and exhaust dampers to provide proper air quantities in all modes of control.
(iii) Test and record fresh air, return air and mixed air temperature at all air handling units. Test and record data at all coils after air and hydronic systems are balanced. Measure wet and dry bulb temperature both entering and leaving on cooling coils.
(iv) Make point tube transverse at all main supply and return ducts to set proper air quantities. Adjust all zone and branch dampers to proper cfm/cmh.
(v) Test and adjust each register, grills, diffuser or other terminals equipment to within 5% of design air quantity. Each opening shall be defined on the test report by size, manufacturer's model, room location, design cfm and actual cfm. Outlets shall be adjusted to minimize objectionable drafts.
(vi) Test and record static pressure drop across all filters and major coils.
(vii) High velocity duct systems shall be tested for leakage. If excessive or audible leakage is detected, the defect shall be repaired by the contractor. Sufficient static pressure readings shall be taken from the air handling units to the terminal units to establish system static pressure.
(viii) Test and record system static pressures, suction discharge and total.
(ix) Test and adjust system for design outside air.

(x) Each grille, diffuser, register shall be identified as to location and area.

(xi) Size, type and manufacturer of diffusers, grilles, registers, and all tested equipment shall be identified and listed. Manufacturer's ratings on all equipment shall be used to make required calculations.

17.5.4 Water System

Minimally, preparation before balancing water system should include collecting the following:

(A) Collection of documents:

(i) Pump submittal data; pump curves, motor data, etc.

(ii) Starter sizes and overload protection information

(iii) Control valve Cv ratings and temperature control diagrams

(iv) Chiller, boiler, and heat exchanger information; flow and head loss

(v) Terminal unit information; flow and head loss data.

(vi) Pressure relief and reducing valve setting

(vii) Flowmeter calibration curves

(viii) Other pertinent data

(B) Inspect the system completely to ensure that

(i) It has been flushed out, it is clean, and all air is removed;

(ii) All manual valves are open or in operating position;

(iii) All automatic valves are in their proper positions and operative; and

(iv) The expansion tank is properly charged.

(C) Place controls in position for design flow.

(D) Examine flow diagram and piping for obvious short circuits; check flow and adjust the balance valve.

(E) Take pump suction, discharge, and differential pressure readings at both full and no flow. For larger pumps, a no-flow condition may not be safe. In any event, valves should be closed slowly.

(F) Read pump motor amperage and voltage, and determine approximate power.

(G) Establish a pump curve, and determine approximate flow rate.

(H) If a total flow station exists, determine the flow and compare with pump curve flow.

(I) If possible, set total flow about 10% high using the total flow station first and the pump differential pressure second; then maintain pumped flow at a constant value as balance proceeds by adjusting the pump throttle valve.

(J) Any branch main flow stations should be tested and set, starting by setting the shortest runs low as balancing proceeds to the longer branch runs.

(K) With primary and secondary pumping circuits, a reasonable balance must be obtained in the primary loop before the secondary loop can be considered. The secondary pumps must be running and terminal units must be open to flow when the primary loop is being balanced, unless the secondary loop is decoupled.

(L) Open all valves to full open position, including coil stop valves, bypass valves, and return line balance.ng cocks.

(M) Examine water in system and ensure water has been treated and is cleaned.

(N) Check expansion tanks to determine they are not air bound and the system is completely full of water.

(O) Check all air vents at high points of water systems and determine all are installed and operated freely. Bleed any air out of systems.

(P) Check operation of all automatic valves.

(Q) Check and set operating temperatures of chillers to design requirements.

(R) Check all air vents at high points of water systems and determine all are installed and operated freely. Bleed any air out of systems.

(S) Check and set operating temperatures of chillers to design requirements.

(T) Systems are to be balanced by opening all valves, closing all by-pass and setting all mixing valves to full coil flow. Water systems shall be cleared of air. Verify that the system has been properly cleaned, flushed and treated before testing. Basically, the following tests and adjustments are required.

(i) Test and adjust all pumps to deliver the proper gpm. Record rpm, motor amperage, discharge and suction pressure. Pumps shall operate without objectionable noise or cavitation. Plot actual pump and system performance points on manufacturer’s pump curves.

(ii) Check all expansion tanks for proper filling pressurization. Verify operation of automatic fill and relief valves.

(iii) Check the operation of all automatic valves.

(iv) Test and adjust correct water flow through chiller, major items of equipment and main water circuits. The balancing valves, provided on the equipment shall be used for adjustment.

(v) Check capacity output of chillers and set water flow rate for proper data.

(vi) Check and adjust each coil to provide proper gpm. Record water and air temperature changes and water pressure drop.

(vii) Set pressure drops across coil by-pass to match coil full-flow pressure drop.

(viii) Check and set operating temperatures of chillers to design requirements.

(ix) Record and check the following items also at each cooling elements: Flow Rate, Inlet Water Temperature, Leaving Water Temperature, Pressure drop of each coil, Pressure drop across by pass valve, Pump operating suction and discharge pressures and final total discharge head, List of all mechanical specifications of pumps Rated and actual running amperage and KW of Pump Motor.

(U) Water side measurements Instruments :

(i) Ultrasonic flow meter

(ii) Mercury Thermometer

(iii) Calibrated Pressure Gauge

(iv) Fluid System Digital Electronic Differential Pressure Meters

17.5.5 Unit capacity in Tons Refrigeration shall be computed from the temperature readings, pressure readings and water/ brine flow measurements. Flow measurements shall be preferably through flow meters. Pumps shall be tested for the discharge head, flow and BHP. Where it is not possible to measure the flow, atleast the discharge head and BHP (on the input side) shall be field tested.

17.5.6 Balancing Tolerance

Systems shall be balanced within the following tolerances :

(i) Duct leakage Rates (at operating pressures) :

Low pressure ducts (0 to 0.5 kPa)	5% of full flow
Medium Pressure Ducts (0.5 to 3 kPa)	1% of full flow
High Pressure Ducts (Greater than 3 kPa)	1% of full flow

(ii) Air flow rates :

Under 70 L/S	10% of flow
Over/ at 70 L/S	5% of flow

(iii)	Water flow rates :	
	Chilled Water	2% of flow
	Other	5% of flow
(iv)	Heat flow rates :	
	Heat exchangers	5% of design capacity

17.5.7 **Procedure**

Review all pertinent plans, specifications, shop drawings and other documentation to become fully familiar with the systems and their specified and intended performance.

Furnish equipment and instruct sheet metal trade on proper use for conducting duct leakage tests. Conduct first test as a way of instructing the above trades in the presence of the Department's representative.

Test relative barometric pressures in various building area, as deemed necessary by the Department's representative and at least in all areas served by different systems.

Test performance and continuously record on a 24 hour basis, temperature and humidity levels where control equipment is provided for that purpose in certain critical areas.

Before commissioning of the equipment, the entire electrical installation shall be tested in accordance with relevant BIS codes and test report shall be furnished by a qualified and authorized person. All electrical work shall be inconformity with CPWD General Specification for Electrical Works Part-I Internal 2023 and Part-II External 2023, Substation Specification 2013.

17.5.8 **Training**

The contractor shall provide training including all equipments, man power, aids, and other requirements as required for training of man power of the Department and the Client department as directed by the Engineer in charge and this is included in the scope of work. Training shall minimum the following, however this is only indicative list and the contractor has to give training for other aspect as directed by Engineer-in-charge.

(i) Purpose of the systems
(ii) O & M Manuals
(iii) Control drawings and schematics.
(iv) Start up and operation parameters.
(v) Interaction with other systems
(vi) Optimization for energy conservation.
(vii) Health and safety.
(viii) Special maintenance and replacement.
(ix) Occupant interaction.
(x) System response to different operating conditions.
(xi) Emergency situations.

All training shall be videotaped for future reference and for facilitating subsequent training modules.

17.5.9 Reports

Provide 3 copies of the complete Testing, Adjusting and balancing reports to the department(both hard and soft copies). Report shall be neatly typed and bound suitable for a permanent record.

17.5.10 Final documentation

The contractor shall leave the system operating in complete balance with water and air quantities as shown on drawings. Set stops on all balancing valves and lock all damper quadrants in proper position. Secure all automatic damper and valve linkages in proper positions to provide correct operating ranges. Proper damper positions shall be marked on ducts with permanent indication. Notify the department of any areas marginal or unacceptable system performance.

The above tests and procedures are mentioned herein, for general guidance and information only, but not by way of lamination to the provisions of conditions of contract and design/ performance criteria.

Upon commissioning and final handover of the installation, the HVAC contractor shall submit (within 4 weeks) to the engineer-in-charge/ department 6 (six) portfolios of the following indexed and bound together in hard cover ring binder (300 x 450 mm) in addition to the completion drawings as per para 1.17.3.

(i) Comprehensive operation and maintenance manual
(ii) Test certificates, consolidated control diagram and technical literature on all controls.
(iii) Equipment warranties from manufacturers.
(iv) Commissioning and testing reports
(v) Rating charts for all equipment
(vi) Log books as per equipment manufacturers standard format
(vii) List of recommended spares and consumables
(viii) Any special tools required for the operation or the maintenance of the plant shall be supplied free with the plant.

At the close of the work and before issue of final certificate of completion by the Engineer-in-charge, the contractor shall furnish a written guarantee indemnifying the department against defective materials and workmanship for the Defects liability period. The contractor shall hold himself fully responsible for reinstallation or replace free of cost to the department.

(i) Any defective material or equipment supplied by the contractor
(ii) Any material or equipment supplied by the department which is proved to be damaged or destroyed as a result of defective workmanship by the contractor.

17.5.11 MISCELLANEOUS

(i) The above tests are mentioned herein for general guidance and information only but not by way of limitation to the provisions of conditions of Contract and Specification.
(ii) The date of commencement of all tests listed above shall be subject to the approval of the Engineer in charge and in accordance with the requirements of this specification.
(iii) The contractor shall supply the Commissioning Engineer and all necessary instruments and carry out any test of any kind on a piece of equipment, apparatus, part of system or on a complete system if the Engineer in charge requests such a test for determining specified or guaranteed data as given in the Specification or on the Drawings.
(iv) Any damage resulting from the tests shall be repaired and/or damaged material replaced to the satisfaction of the Engineer in charge.
(v) In the event of any repair or any adjustment having to be made, other than normal running adjustment, the tests shall be void and shall be recommended after the adjustment or repairs have been completed.

(vi) The Contractor must inform the Engineer in charge when such tests are to be made, giving sufficient notice, in order that the Engineer in charge or his nominated representative may be present.

(vii) Complete records of all tests must be kept and 3 copies of these and location drawings must be furnished to the Engineer in charge.

(viii) The Contractor may be required to repeat the test as required, should the ambient conditions at the time not given, in the opinion of the Engineer in charge, sufficient and suitable indication of the effect and performance of the installation as a whole or of any part, as required.

(ix) For Testing, Adjusting, Balancing & commissioning the third party specialized agency having sufficient experience and competency for above work shall be associated by the agency and the credential for the same shall be submitted to Engineer-in-Charge for approval. The specialized agency shall be engaged only after approval of credential by Engineer-in-Charge.

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CHAPTER 18
BUILDING MANAGEMENT SYSTEM

18.1 Scope

18.1.1 Scope of work shall comprise the supply, installation, testing and commissioning of the Building Management System (BMS) performing the following general functions:

(i) Building Management and Control with recording of Energy Data

(ii) Monitoring and Control of Controllers, Remote Devices and Programmable Logic Controllers and Energy Data Analysis

(iii) Hardwired and Hand-held Operator Interface

(iv) Video display integration

(v) Data collection, Data Storage , Alarm Management & Trending

(vi) Report Generation

(vii) Network Integration

(viii) Data exchange and integration with a diverse range of other computing and facilities systems using industry standard techniques.

(ix) Collection and storage of Weather and Outdoor IAQ Data.

NOTE: The scope of BMS here is for Air-conditioning applications only. It shall be expandable to include other building services at the option of Engineer-in Charge. The BMS software and supervising shall therefore have the capability to expand the system to minimum 125% of the present capability.

18.1.2 The systems shall be complete with all components, controls, equipment and devices as specified in SOR.

18.1.3 Scope of work shall include commissioning of the BMS in line with ISHRAE Standard 10003-2020.

18.1.4 Standards and Codes

Applicable standards and codes are listed in Appendix C.

18.1.5 Technical Submissions

Documentation as specified in the SOR along with manufacturer's catalogue shall be submitted for the approval of Engineer-in-charge.

18.1.6 All systems, sub systems, equipment, controls and devices offered shall have maintenance facility in India and details of vendor's/ distributor's service facility nearest to the place of installation shall be furnished with the offer.

18.1.7 There are different open protocols like BACnet, LON works, MODBUS etc. available for control and / or monitoring the connected equipment of the BMS. Any particular protocol shall be utilized for the work depending on the protocols available in the equipment to be controlled / monitored. Being one of the most widely used protocol, the requirements of hardware and software components to meet the BACnet protocol are given in various section of these Specifications with a heading labelled "BACnet specific:". Similar, if not exact, functionality shall be provided in case protocols other than BACnet are proposed to be utilized in which case the Contractor shall submit specifications of the proposed protocol, meeting the intent of these specifications, for approval of the Engineer-in-charge. The decision as to what protocol is to be deployed on the work shall rest solely with the Engineer-in-charge.

18.2 BMS System provided shall be of three levels architecture–Management Level, Application level and field level.

18.2.1 Management Level

The software shall enable the operation of the entire installation and shall perform tasks such as process visualization and monitoring, installation control, message and alarm processing, logging, subordinate management and optimization functions, unlimited data storage and centralized archiving. It shall be 100% web-based for use as well as configuration. Access to the operating system of the server must not be necessary in any case. For example, the creation of a new project, the creation of new users, the configuration of user groups or even restarting Windows services must be possible entirely via the web interface intended for this purpose. The use of HTML5 technology shall allow access from everywhere and at any time. The web interface should not require a plug-in in order to be displayed and must be compatible with all types of latest-generation web browsers (standard or mobile). The creation and modification of the entire picture area, as well as the project navigation, must be performed via a separate and independent tool in order to avoid interfering with the use of the project during its development. This tool shall enable the programming of sub-stations, and it must be possible to use the configuration and the various visualization systems. The software shall support system generated alarms with statistics of alarm types, notification via email, SMS, etc. System shall be suitable for integration with SAP S/4HANA ERP (E-NIRMIT software of CPWD) Also, the system shall be able to exchange data over internet on real time basis and shall be equipped to accept REST-API requests and push the data to E-NIRMIT ERP) BACnet specific software shall be certified and complying to BACnet Cross-Domain Advanced Operator Workstation (BXAWS) and BACnet Protocol revision version 18.0 or later as per ASHRAE BACnet Standards and the Addendums released as of date.

18.2.2 The field buses shall be connected via a network (LAN/WAN). The architecture shall allow the hardware resources (clustering) used by the software to be modulated and optimized. The application shall include only services (SaaS) that start up with the operating system and that do not require a Windows session to be opened. The operating system must be Windows 10 or later versions.

18.2.3 The historical data, alarms and user logbooks shall be saved in an MS SQL 2016 database or higher. The architecture is to enable modules to be added as required and without any particular restrictions, in order to expand the capacity and options of the system.

The following functionalities are required in the WS Software:

(i) Web user interface
(ii) All operation and configuration actions must be carried out via a group- or user-specific interface.
(iii) Each module (data point list, alarm list, user action logbook, charts, reports) can be adjusted to the user’s needs (position and selection of information displayed, colour, duration) without the need to involve a specialist.
(iv) At least the following views must be available:
(v) Data point list
(vi) Historical trends
(vii) Real-time trends
(viii) Comparative trends (the same data points in different time periods)
(ix) Alarm list
(x) User action logbook
(xi) Reports

18.2.4 It must be possible to completely personalize the views (colors, columns displayed, information displayed etc.) without the user having access to changing the configuration for the respective view. The interface must be intuitive and user-friendly with regard to its speed and its logical structure.

18.2.5 The following modules must be accessible without having to change the interface or the web application:

(i) Dashboard
(ii) Picture module
(iii) Energy management module
(iv) Data point list module
(v) BACnet browser
(vi) Trend module
(vii) User action logbook module
(viii) User and group administration module
(ix) Data point creation module
(x) Alarm creation module
(xi) Alarm list module
(xii) Report module
(xiii) Automated export module
(xiv) Notification management module
(xv) Module for the configuration of the entire topology and the communication buses
(xvi) Global configuration module
(xvii) Module for managing the time and calendar programs

Every user is to have the option to define documents as favorites. This configuration shall not affect the other users' favorites.

To be able to work as efficiently as possible, the user shall be able to define a document that opens as standard when a module is opened.

A clear navigation structure for displaying all project pictures and available documents must be available in every module so that every page can be found quickly. Also standard tree structure shall be available for graphics creating.

End user shall easily be able to create trends and alarms of any parameters without having to get the BMS vendor to visit the site and with a minimum training.

Along with the alarms, the software shall have capability to add relevant video files to be linked to guide the end user carry out the relevant maintenance function. Also the software shall capability to store relevant vendor/service provider information required for periodic maintenance activities.

Graphics of the equipment shall incorporate the actual location of the field devices as per site conditions which will help the end user to identify the relevant field device.

All documents shall be in the same tree as the navigation within the corresponding sub-menus or directly below a picture via the web interface and during the creation of documents, it must be possible to create document templates so that new documents can be created.

All templates and documents must be exportable via the web interface in order to make creating new projects easier.

The display of the individual elements, such as pictures, operating elements, navigation and the arrangement of same shall be automatically adjusted to the size of the browser window.

The following settings are required for the picture display:

- Full-screen with automatic adjustment to the size of the browser window and automatic transition to the horizontal and vertical "scroll mode" for very small windows.
- For the display with a navigation tree, up to a specified display size the same mechanisms are used as with a full-screen display.

18.2.6 Managing the user rights

It must be possible to assign rights to persons or groups. There must not be any restriction on the number of groups or persons. Unsuccessful connection attempts must lead to the user being blocked. The user shall be automatically reactivated after a definable time period.

The user rights shall be assigned easily. It shall be possible to define the business department and the location.

The rights relating to the data points shall be assigned via the navigation so that this operation shall be structured as efficiently as possible.

The system must enable stronger password security. It must be possible to define password rules:

(i) The password strength shall be defined, i.e. a minimum number of special characters, upper-/lower-case characters and total number of characters can be specified.

(ii) The history of the password must be checked so that no passwords can be used multiple times, nor the same password reused.

18.2.7 Communication protocols

(a) PICS documents must be available. A native BACnet driver must be integrated into the solution. BACnet driver must be based on a BACnet stack from Comatrix of version 6.4d or higher. The BACnet driver must support the following functions

(i) BBMD

(ii) FD

(iii) BACnet routing

It must be possible to scan the BACnet network using the engineering tool and select the objects to be imported.

It must be possible to import the BACnet objects into the engineering tool using EDE files. When importing sub-stations it must be possible to update them with a single click. They shall be scanned via the BACnet network.

(b) The following object types must be supported without restrictions

(i) Analog Input

(ii) Analog Output

(iii) Analog Value

(iv) Binary Input

(v) Binary Output

(vi) Binary Value

(vii) Multi-state Input

(viii) Multi-state Output

(ix) Multi-state Value

(x) Scheduler

(xi) Command

(xii) Calendar
(xiii) Loop
(xiv) Proprietary objects

With the BACnet Web Services protocol, it shall be possible to scan DDC in order to download the available data points, pictures and navigation into the higher-level management system and display them. An OPC UA client driver must be available.

It must be possible to convert the OPC UA client to DA 3.x using an integrated OPC gateway. The engineering software must enable the scanning of the different OPC UA or DA servers in order to import the data points quickly.

Using a tab showing the topology of the project, it must be possible to display on one page the number of connected bus systems and the number of data points for each bus. This topology page must be accessible via the web interface.

It must also be possible to use the view of the page showing the topology of the project to configure the advanced parameters of each bus, and to define specific functions for each sub-station via the web interface without any restrictions. It must be possible to parameterize the advanced configurations of the different drivers entirely via the web interface.

18.2.8 Online help

Online help shall be provided which shall be called up directly from the program. The language of the online help shall automatically match the selected user language.
An overview page shall be available showing the individual chapters of the online operating instructions.
Within the program, the corresponding chapters shall be accessed directly via buttons (context-based online help).

(i) File export & import functions
(ii) File exports in CSV format can be configured.
(iii) File imports in CSV format can be configured (time stamp and value).
(iv) Objects can be selected via a filter mechanism.
(v) Number formats, date formats and separator formats can be configured.
(vi) API – application programming interface

The interface shall be used for the optional integration of the building management system into the IT application structure of the customer or company. The API shall be used to create connections to external programs and thus use data in higher-level or more advanced systems.

18.2.9 Dynamic pictures of the installation showing the data points

The software shall have a library of graphics of all MEP equipment and systems in use. The programming engineer shall be able to use that resource to create graphics page. Also, during the DLP period, if there is any update on the graphics library with new features, same shall be used and updated at site free of cost by the vendor.

(c) The pictures shall consist of the following elements

(i) Numerical values that are updated based on events.
(ii) Sliders allowing analogue, binary or multi-state values to be changed and displayed.
(iii) Texts

(iv) Drop-down menu allowing multi-state or binary values to be displayed and changed. The drop-down menu will, as standard, use the descriptions of states in the displayed list and not the actual value of the data point.

(d) Dynamic pictures depending on the status of a data point. These can be animated in various ways

(i) Display a fixed picture depending on the value of a data point or the state of an alarm
(ii) Display a sequence of pictures with a time interval that can be managed depending on the value of a data point or the state of an alarm.
(iii) Static pictures
(iv) Input of analogue values via an alphanumeric keyboard
(v) Input and display of the binary and multi-state values due to their respective status texts
(vi) Modification of analogue values using numerical increment/decrement buttons
(vii) The pictures can consist of dynamic 3D elements for optimum display of the different installations.

(e) The dynamic 3D elements enable the following types of installations to be drawn

(i) Ventilation systems
(ii) Heating systems
(iii) Air-conditioning systems
(iv) Hydraulic circuits for heating and air-conditioning
(v) Domestic hot water systems
(vi) IRC (end device management)
(vii) Air Distribution Systems

(f) The main properties of the various BACnet objects shall be displayed in the picture. For each data point, it shall be possible to display various icons or satellite buttons which enable the following actions

(i) Display the object priority active at this moment
(ii) Button for resetting the BACnet 8 priority (automatic mode)
(iii) Icon displaying the current status flag of the object
(iv) Links to a quick chart
(v) Links to the schedule of the data point
(vi) Acknowledgement of alarms

All pictures shall be displayed on any internet browser (standard or mobile) during operation without the need to install a plug-in. All pictures shall be visualized in full-screen mode or in the display area intended for this purpose.

If a picture is displayed in full-screen mode and the user clicks on a link leading to another picture, the subsequent picture must also be displayed in full-screen mode. It must be possible for all pictures, and without any further development steps, to display the list of the data points, used in the picture shown, with just one click.

18.2.10 Alarms

(a) It must be possible to process the following alarm types:
(i) System alarms generated by the supervisor.
(ii) Alarms generated by the different auxiliary modules such as the energy management module.
(iii) Alarms generated by the sub-stations connected to the field buses.
(iv) Alarms with programmable conditions generated by the supervisor that are connected to the data point values.

(b) It must be possible to personalize the alarm filters completely and easily without requiring the intervention of a technician. It must be possible to define these filters using the following filter types

(i) Filter by alarm type (system, module, bus etc.)
(ii) Filter by alarm priority
(iii) Filter by BACnet notification class
(iv) Filter by BACnet object or data point of every other connected bus
(v) Intelligent, automatic filters depending on variable, dynamic parameters
Automatic filter by image - This makes it possible to create an alarm list for a department or building in just a few clicks.

(c) For each alarm it must be possible, either individually or based on filters, to generate the following actions at the start/end of the alarm

(i) Sending a parametrizable e-mail with alarm information
(ii) Sending parametrizable text messages with alarm information via e-mail
(iii) Sending parametrizable text messages with alarm information via an SMS modem
(iv) Sending predefined reports without any restrictions, so that information is available not only on the consequences of alarms, but also on the causes.
(v) Continuous printout of various alarms on continuous stationery printer
It must be possible to personalize completely each of the aforementioned alarm-based actions for each user so that they have the information they require in the way that they want it.

(d) It must also be possible to manage all alarm-based actions depending on a calendar. All alarm lists must automatically be able to display the following data without any further development steps

(i) Historical data for the selected filter
(ii) Statistical data linked to the alarm events (top 5, frequency) with the display of the data for the selected filter as a table or chart
(iii) It must be possible to activate the following functions from all alarm lists based on the rights of each user (these functions are available with just one click)
(iv) Acknowledge all types of status changes if necessary
(v) Add comments
(vi) Display the alarm details (different depending on the bus or the alarm type)
(vii) Display the historical data of a single alarm
(viii) Display the statistics for a specific alarm
(ix) Display a menu listing all the documents or pictures displaying this alarm. These documents and pictures must be accessible with one click via this menu.
(x) For alarms issued by field buses, display a window with all the properties of the object affected by the alarm.
(xi) Download a help document for this alarm allowing the operator to quickly see how to correct the problem.
(xii) Display a quick chart of the data point affected by the alarm in order to use a curve to quickly detect why, and for how long, the data point has been affected by the alarm.
(xiii) A link allowing the end of an alarm to be forced manually.
(xiv) Display all remaining bus or project objects linked to the object affected by the alarm.
It must be possible for every user to personalize all alarm lists without this affecting either the filter, the configuration of the list or the display of this list for the other users.

(e) The user-specific personalization of the list must enable the following parameters to be configured

(i) The colors used for each alarm type

(ii) The columns displayed to allow each user to display the information that interests them without being able to modify the list filter.

(iii) The arrangement of the columns

(iv) It should be possible to lock the alarms individually. A list view of the locked alarms must be available.

18.2.11 List of interactive data points

The lists of data points must be dynamic so that the updated values are displayed automatically. Binary and multi-state data points must allow the values to be displayed as states. Starting from these data point lists, it must be possible to open the historical curve of one of the data points in the relevant list with one click even if no chart has been created beforehand. This option must allow multiple data points to be shown in the same chart. These charts to be exported in different formats, such as jpg, png or pdf files, with just one click.

For each data point in these lists, it must be possible to open a dynamic window listing all documents and pictures relating to the relevant data point, and to open these documents and pictures with one click.

With regard to all set points, the manual control in overwrite mode and the return to automatic mode must be possible via these lists for all points for which a write operation is possible, presuming that the user has all the corresponding rights.

It must be possible for every user to personalize all data point lists without affecting either the filter, the configuration of the list or the display of this list for the other users.

(a) The user-specific personalization of the list must enable the following parameters to be configured

(i) The colours used for each type of data point

(ii) The columns displayed to allow each user to display the information that interests them without being able to modify the list filter.

(iii) The arrangement of the columns

(iv) In order to find quickly one or more data points, it must be possible to group the data points in accordance with the user’s requirements by simply moving one or more columns.

(v) The selection of data points from a list must be permitted using a static or dynamic filter.

(vi) Chart / trend curve

(b) The charts must be able to have the following forms

(i) Real-time charts displaying the current values. This function is also available if the data point does not have any history stored in the supervisor.

(ii) Historical charts displaying historical values in the database.

(iii) Comparative charts displaying one and the same data point or data points on different time axes.

(iv) The maximum number of curves that can be displayed in a chart must be definable by the user to allow the available system resources to be used as optimally as possible.

(v) For clarity purposes, it must be possible to display and separate the different curves in 4 different charts within a view. However, for a visualization in table form, the values must be in the same table so that they can be compared better.

(vi) Each curve can be displayed using bars or lines, as required.

(vii) For every curve, markers can be defined as required.

It must be possible to completely parameterize the x and y axes according to the user's choice in order to provide the maximum amount of information. Consolidated values must be displayed for binary and multi-state values.

(c) All charts shall be exported with one click in the following formats

(i) PDF report format containing not only the different charts but also all the values displayed in table form.

(ii) CSV format containing all the values and different information on the data points, including the time stamp.

(iii) Picture format (png, jpg and vectorial) includes only the selected chart.

(iv) E-mail format including the aforementioned PDF export.

All charts shall be used in two different views without any additional configuration. One of these is the standard chart view and the other is a table view of all the values with a time stamp, as well as information about the data points that can be selected by the user.

(d) It must be possible to access the following functions for every point displayed with one click via a chart

(i) A dynamic window listing all documents and pictures relating to the relevant data point. It must be possible to open these documents and pictures with one click.

(ii) A dynamic window with the option to navigate the historical values of a data point.

(iii) BACnet specific A dynamic window showing all the properties of the data point, with the option to change the adjustable BACnet object properties.

(iv) BACnet specific A dynamic window for analyzing or changing the configuration of the Trend Log object for the BACnet data points connected to such an object.

(v) A dynamic window with the option to navigate in the historical values of a data point.

BACnet specific When a BACnet object is connected to a BACnet object Trend Log, the history of the Trend Log must be stored in the database automatically. When a Trend Log object is used as a history storage method, it must be downloaded to the sub-station automatically and transparently when a chart that displays this BACnet object is opened. This function must be transparent for the user and must not slow down the system usage. When a chart is being used, it must be possible to change the values represented by the curves on the screen with one click, in order to improve the response time of the system when displaying longer time periods.

(e) The following values shall be displayed at the minimum

(i) Actual values

(ii) Hourly values

(iii) Daily values

(iv) Weekly values

(v) Monthly values

(vi) Yearly values

(f) When displaying curves showing values other than actual values, it must be possible to display multiple aggregations for the same curve depending on the user selection. The following calculation methods must be available at the minimum

(i) Average value

(ii) Minimum

(iii) Maximum

(iv) Energy Management aggregation (calculation method for the energy management)

(g) It must be easy to select the time periods for the curves without changing the view. It must be possible to change the time period displayed with one click using predefined dynamic time periods or using a calendar for the start and end dates. At the minimum, the following predefined dynamic time periods must be available

(i) Last month
(ii) This month
(iii) Last week
(iv) This week
(v) Yesterday
(vi) Today

(h) When creating a chart, it must be possible to define a fixed or dynamic standard time period that is always used when the chart is opened. Each user must be able to personalise all charts without this affecting the filter, the standard configuration or the display of the chart for the other users. The user must be able to define the following parameters during the user-specific personalization

(i) The colour used for each curve
(ii) Information on the data points in a table view or chart
(iii) The number of charts per view
(iv) The default time period when the chart is opened
(v) The default aggregation used when the document is opened
(vi) The configuration of the x and y axes
(vii) The markers used

In all modules it shall be possible to display the data graphically ad hoc (quick chart) without having to configure charts. Historical data shall be used automatically for the display, and if this is not available, the current data shall be used automatically and what is known as a "live chart" (real-time chart) is displayed.

18.2.12 Simplified creation of reports

Reports - Customized reports for events and alarm with Graphic screen shots. Report facility shall be inbuilt in software.

(i) Reports can be generated as follows

(i) Manually
(ii) Automatically in conjunction with a calendar
(iii) At the start or end of an alarm

(j) During the creation of reports, the following shall be possible

(i) Print the report out on a printer connected to the system at the time it is generated
(ii) Send the report via e-mail to people designated in advance
(iii) Constant availability via the web interface for downloading
(iv) When reports are downloaded, it must be possible to select one or more reports simultaneously, which are then downloaded in a single ZIP package.
(v) To ensure that creating the report is as efficient and easy as possible, it shall suffice to select existing documents.
(vi) All documents in the system shall be selected as part of a report.
(vii) It must be possible to define common dynamic time periods for all documents that are part of the report, or to leave the period predefined in the different documents. This time period shall be used to generate the export with the defined values.
(viii) The different parts of the documents selected for the report can be activated, or not activated, in order to generate a report that contains only relevant information and provides a quick overview of the problems or proper functioning of the system.

(ix) The reports exported by e-mail or saved in the system memory are non-editable PDF documents.

(x) In the reports generated, the first page must be reserved for general export information. For example, information stating the user who made the export, or which page is being displayed out of how many pages.

18.2.13 Time functions and calendar

BACnet specific The BACnet schedule and calendar objects must be read, changed and then written to the BACnet stations again.

In addition to the BACnet schedule, there shall be a higher-level schedule within the management software that controls additional objects. This is used to manage OPC objects or BACnet stations that do not support any calendar or scheduler objects.

Complex scenarios shall be activated via special command objects in the management software. There should be a consolidated view of the various schedules for each object. Priorities shall be assigned when multiple schedules are being used.

(i) It must be possible to use exceptions of the date, time period or day types.

(ii) The interface must enable a quick, easy switch to a chart or list view.

(iii) The interface must enable exceptions to be displayed in chart and list views.

(iv) BACnet specific For BACnet schedules, the "Relinquish Default" values must be displayed in the chart and list views.

(v) BACnet specific For BACnet schedules, it must be possible to change all the basic configurations in connection with the schedule object, such as Relinquish Default or the write priority.

(vi) For adding or deleting a command, this must be easy and must be adjusted to the relevant data point type. For example, if a command is being added for a multi-state or binary object, a drop-down menu displaying the descriptions of the states must appear.

(vii) It must also be possible to add a command once for multiple days, hours, minutes or seconds.

18.2.14 Personalization

It shall be possible for each user to personalize the look and feel of the information displayed and available in each document. Each user shall be able to select the background colors and the text colors in these documents without any change to the original document or to the display of the document for the other users.

The position and selection of the columns displayed in the tables shall also be personalized for each user without affecting the display of the documents for the other users. Each user shall be able to define the position of the quick actions for which they are authorized.

The personalization shall enable each user to define their environment so that they can work as efficiently as possible. Every user shall be able to create their own directory and navigation structures and use Drag Drop to include documents and pictures in the relevant structure.

18.2.15 Extension of the system

The system used must be flexible and allow various extensions to be added. At least the following extensions must be possible:

The number of licensed points shall be extended based on client / project requirement

Additional modules shall be added in future as extension without restrictions and without impacting the stability of the product.

18.2.15.1 Energy monitoring module

(k) The system will allow easy communication with an energy monitoring module. This module will have the following functions:

(i) Meter points
(ii) Calculated data points
(iii) Unit conversion
(iv) Fully-definable additional attributes
(v) Alarm calculation that can generate a report sent by e-mail and printed out
(vi) Display of comparative diagrams for definable periods

(l) Various compression functions (aggregation modes):

(i) Sum
(ii) Time for which an object lies within a specific value range.
(iii) Integral of the values within a time range
(iv) Sum of hourly average-values
(v) Positive and negative difference between start and stop values
(vi) Use of the last value available
(vii) Calendar view of the charts / values with an option to easily change the type of display (lines, bars, circle, values).

The calendar views shall be switched between the weekly, monthly and yearly views.

18.3 Application level:

The application level shall have the following capabilities:

The Integrator shall have 2-port Ethernet switch and WLAN interface. It should have BTL label (BACnet communications passed the BTL test) and consisting of Dual microprocessor with Storage capacity of 1 GByte RAM. It should support Real Time clock with backup of up to 7 Days and shall have option for external battery if required. It should Support of the major communication protocols: BACnet/IP, BACnet MS/TP, Modbus IP and Modbus RTU up to 500 points. Modbus-RTU communication should have inbuilt short circuit protection. Cyber security protection with BACnet Secure Connect communication as BACnet/SC node protocol.

(i) Necessary routers or system network controllers shall be provided between the field level DDC Controllers and the BMS Workstation.

(ii) Also, the bridge/gateway/supervisory controller shall have the capability to connect with all the 3rd Party devices/equipment as per equipment summary sheet, IO Point summary and BOQ.

(iii) BMS vendor to ensure seamless integration of the Energy Meters, VFD, UPS systems, CPM, Chemical Dosing, STP, Water Meters, DG Sets, Fire Alarm System, Diesel Fuel Meter, Basement Ventilation System, BTU Meters, through Modbus/BACnet /M BUS protocols so that all the parameters of the equipment are to be made available at the BMS workstation.

(iv) All the BMS functionalities shall be resident in the network controllers.

(v) They shall communicate over BACnet over Ethernet/IP. They shall also be capable of future integration for applications through 3rd party BACnet /Modbus/M-BUS devices and protocols.

(vi) Contractor shall specify the number of field level DDCs/modules that can be connected to the system controller.

18.4 Field Level

18.4.1 Direct Digital Controller (DDC) shall be as specified with capacity to accommodate input/ output (I/O) points required for the application plus spare points specified.

Each DDC shall be a truly standalone controller with its own Input-Output capacity, control logic capability, time programming and energy management capabilities. All field equipment including the sensing element (inputs) and control elements (outputs) shall be wired to the respective DDC. It shall be possible to hook up a DDC to a Portable Operator Terminal (POT) to enable monitoring and control of the DDC.

DDC shall be designed for complex DDC and energy management applications, true peer-to-peer communications with other DDC and with the Central Operator Stations. The DDC shall be networked on a truly distributed intelligence concept where each DDC shall be a self-sustained intelligent device capable of all its functionalities without dependence on other devices

EDGE Controller Smart sensors and wireless actuators providing all functional requirements shall form part of the system where specified.

18.4.2 Digital Control Processors (DDC) shall be a 32 bit minimum 400 mHz microprocessor types with flash memory for all data file and control programs (DDC Programs) and using RAM only for operating data. Each DDC have at least 1 RS485 port. DDC have IT security like TLS 1.3, IEEE 802.1x, IEEE 802.11 for wifi etc.

18.4.3 Each DDC shall have Lithium battery to support complete operation of the RAM for unto 30 days in the event of a power failure to the DDC. A low battery voltage status shall generate an alarm condition.

18.4.4 Each DDC have communication protocol BacNet IP and Future cloud connectivity ready with communication protocol MQTT, Rest API.

18.4.5 DDC shall have internal real-time clock with minimum 30-day battery backup power. All time-based controls (time scheduling, integrations and other real-time based controls) shall be performed with this real-time resident clock. Clock synchronization of the DDC on the whole bus shall be automatic

18.4.6 DDC using clocks generated by software or timers for clocking shall not be accepted.

18.4.7 The battery backup power shall support the real-time clock. Upon power restoration all clocks shall synchronize automatically.

18.4.8 The DDC's shall be capable of supporting 8 to 48 I/Os preferably in a combination of 8 AI (Analog input), 2 DI(Digital input), 4 AO(Analog output), 2 DO(Digital output) with minimum of 10% spares of each type per DDC.

18.4.9 The DDC shall be dedicated standalone in nature and would be placed near the instrument they are controlling to reduce the installation and wiring cost.

18.4.10 Analogue input support of the following minimum types shall be provided:

(i) 0/4-20mA
(ii) 0-10 volts
(iii) 0-5 volts 0/2-10 volts

(iv) Resistance signals (Pt3000, Pt1000, Pt100, Ni1000)

18.4.11 Digital Inputs shall be, but not limited to the following types:

(i) Normally open discrete contacts

(ii) Normally closed discrete contacts

Microcontrollers confirming to proven Industry Standard meeting Functional requirements and Data Transfer facility shall be used where specified.

18.4.12 DDC POT functionality shall be as follows:

(i) There will be an electric socket/port in every DDC for accessing the data points and real time information via a portable plug-in type Portable Operator Terminal (POT).

(a) The POT shall not have any EEPROM and shall not require any programming.

(b) The POT will plug into the DDC for its power and data. The POT which are not plugged in to the DDC but are hard wired from the Interface unit, PC station or any other device shall not be acceptable.

(ii) The connection of the POT to a controller shall not affect normal operation of the controller or the bus communication in any way.

(iii) The connection of the POT to any controller on a bus shall provide display access to all controllers on the bus. Each DDC shall have provision for plugging of the POT.

(iv) It shall be possible for the POT to be connected to any controller on the bus to view and control any point on any other controller on the bus under password protected menus. POTs in which only a predefined number and set of points are available shall not be accepted.

(v) A failure of any DDC on the bus, Interface unit or Central PC station or any other device of the system shall not affect the operation of the POT.

Systems in which the POT is connected to only a single interface master port and hard wired to other controllers shall not be accepted.

(vi) Use of a POT at DDC shall allow the user to display software information and via password control, modify DDC software.

(vii) All displays on the POT shall be in English language text and data points shall have customized descriptions as per application requirement.

(viii) The POT shall be equipped with multiple lines (with minimum of 4 lines of 20 characters each) backlit alphanumeric LCD display and a control keypad. The keypad would include Command keys, data entry keys and cursor control keys. Alternately, touchpad displays shall be provided.

(ix) Access shall be through self-prompting menus with cursor controls for moving through the menus. Menu selection shall be with arrow key controls for moving to next/previous menu and to step forward backward within a menu

18.4.13 Controllers shall be responsible for monitoring and controlling directly connected HVAC/MEP equipment such as AHUs, VAV Terminals, FCU Terminals, Pump Systems, Electrical Breakers and/or other building automation systems as required. DDCs shall be Programmable Controllers.

The automation station / controller shall be a modular unit used for autonomous control, regulation, monitoring and optimization in building automation technology as per EN ISO 16484 (BACnet) or any other suitable alternative.

The controller shall support Parallel, independent processes with definable, varyingly short cycle times shall make it possible to solve fast control tasks. The automation station shall contain all modules and interfaces required for operation, connection of plant devices and communication with devices, plant and room automation as well as with the management level.

The I/O mix of the physical inputs/outputs of the automation station shall be extended with I/O modules. Integrated communication interfaces and additional communication modules shall extend the integration capability via field bus protocols to sensors and actuators. The I/O and communication modules shall be connected directly to the automation station without additional wiring. I/O and communication modules shall also be remotely controlled via any IP network. Remote operation via IP networks shall be possible in the local network (LAN) and in the IT (WAN) network also via Internet. Communication via IT networks (WAN) and communication with the cloud shall be encrypted.

The automation station shall have network port for IP Connectivity.

The integrated Bluetooth interface shall enable the configuration and commissioning of the station as well as the operation of the individual inputs/outputs via an app on mobile end devices.

BACnet specific The automation station shall support communication via the standardized BACnet/IP communication protocol as per EN ISO 16484-5 without additional measures (native). The BACnet scope of functions shall comprise the BACnet B-BC profile (BACnet Building Controller). As a BACnet server, the automation station shall provide all the objects required for the building automation applications, as well as the related properties and necessary services. Analogue, binary and meter signals to be uniquely represented by the corresponding standard BACnet objects. Time and calendar functionalities shall be implemented according to the BACnet standard as Schedule and Calendar objects. Events (alarms) need to be monitored and transmitted with intrinsic and/or algorithmic BACnet standard mechanisms and recorded using Event Log objects. Data acquisition shall be time-controlled with the Trend Log object and implemented via value changes or triggered.

The station shall have web server integrated and shall provide a secure user interface for configuration during local commissioning as well as visualization and use during operation.

An integrated, configurable user administration enables role-dependent access management. User activities shall be seamlessly logged in an audit trail.

The communication with the web server of the automation station must be encrypted via TLS 1.2 (https).

BACnet specific

The web server shall support the visualization and operation of the BACnet objects parameterized in the station. The plant shall be automatically displayed in a hierarchical tree structure. The visualization shall also be extended with dynamic plant schematics. The web visualization shall be responsive for operation via mobile end devices and PC operating stations.

(a) The following shall be displayed

(i) Dynamic plant schematics

(ii) Data point lists (BACnet objects)

(iii) Subordinate plant sections
(iv) Time programs and special calendars
(v) Diagrams
(vi) Text documents
(vii) Websites

(b) The alarms and events generated by the automation shall be visualized as intuitive symbols (normal/alarm/fault)
(i) Alarm lists
(ii) Dynamic images
(iii) Data point lists
(iv) The alarm lists shall be shown as:
(v) Current and historical alarms
(vi) Can be sorted and filtered
(vii) Flat event lists
(viii) Grouped lists summarizing all the events of an object

Alarm notification shall be set up according to priority, system, user and system section. Authorized users shall acknowledge the alarm and event entries via the interface. Alarms and faults shall be sent by email or text message.

Historical data from own Trend Log objects shall be displayed in combined diagrams with up to six data rows. The diagram rows shall be selected and deselected. Configurable recording intervals (polling) or a recording in case of value change according to BACnet COV shall be set up. The display shall be switched between raw values and a compressed display via the interface.

The diagrams shall have an infinitely variable and zoomable time range. Alternatively, defined time intervals (last hour, last day, last week) shall be selected directly. The uncompressed historical data shall be permanently stored on the internal SD card The data shall be compressed for fast data transmission. Recorded data shall be exported as a csv text file.

BACnet specific
There shall be a clear graphical user interface for the operation of own BACnet Schedule time programs and the special-day calendars (BACnet calendar). A standardized interface shall provide a summary of the weekly program calendar and the prioritized special-day calendar.

The automation station shall be able to manage a minimum of four independent application program parts. The application program parts can have different cycle times. If a program is changed on an application part, the other sub-programs shall continue to run without interruption.

The station must be able to obtain current, region-specific weather forecast data (temperature (min, max), duration of sunshine, global radiation, amount of precipitation, relative humidity, wind speed and direction) for energy-efficiency, without additional components as an IoT functionality via a standing Internet connection and must be able to include these in the control strategy.

Based on IEC 62443-3-3, there shall be security mechanisms and technologies such as data encryption, zone segmentation via integrated network separation, user- and user role-specific authorizations, or switching interfaces on/off.

(c) Performance features

(i) Automation station for plant automation in building automation as per EN ISO 16484.
(ii) Integrated Ethernet interfaces
(iii) Primary communication protocol BACnet/IP and support BACnet/SC
(iv) Integrated web server based on HTML5 for commissioning, visualization and operation.
(v) Modularly expandable
(vi) Software function modules for
(vii) HVAC function modules
(viii) Standard control algorithms (P, PI, PID)
(ix) Guidance and selection modules
(x) Restricting and limit value modules
(xi) Timer and switching modules
(xii) Calculation modules
(xiii) Clock functions
(xiv) Extended function modules, such as:
(xv) Energy requirement with basic daily value
(xvi) Primary energy plus CO2 with basic daily value
(xvii) FC fan or damper control with air quality sensor
(xviii) Ventilation systems (FC/4-speed fan) for outdoor air cooling
(xix) BACnet device profile B-BC
(xx) Web server features
(xxi) Protocols
(xxii) Automation level:
(xxiii) BACnet/IP Rev. 16 or later.
(xxiv) Web access
(xxv) HTTPS, HTTP
(xxvi) Email and text messaging
(xxvii) SMTP, SMPP
(xxviii) Time synchronization
(xxix) BACnet/IP

(d) Energy Management Applications: The controller shall have the ability to perform any or all of the following energy management routines

(i) Time of Day Scheduling
(ii) Calendar Based Scheduling
(iii) Holiday Scheduling
(iv) Exception Scheduling
(v) Temporary Schedule Overrides
(vi) Optimal Start
(vii) Optimal Stop
(viii) Night Setback Control
(ix) Enthalpy Switchover (Economizer)
(x) Peak Demand Limiting, Load Shed
(xi) Temperature Compensated Duty Cycling
(xii) CFM Tracking
(xiii) Chilled Water Reset
(xiv) Condenser Water Reset
(xv) Chiller Sequencing

(xvi) Demand Ventilation

18.4.14 Firmware Upgrades

The controller firmware shall be upgradeable for updates as future enhancements and expanded functionality.

18.4.15 Hardware Platform Features

(a) Processor: The controller shall employ at minimum a 32-bit microprocessor with a min clock speed of 600MHz

(b) Memory: The operating system and the application programs for the controller shall be stored in non-volatile FLASH memory. The controller shall have a minimum of 128 MB of flash memory. In the case of a power failure, the controller shall first try to restart from the RAM memory. If that memory is corrupted or unusable, then the controller shall restart itself from its application program stored in its FLASH memory.

(c) Inputs: The controller shall have on-board universal inputs with a minimum of 16-bit analog to digital conversion. Each universal input shall have over-voltage protection. Universal inputs shall have the following integrated, software selectable terminations: 0-10 VDC, 4-20mA. Each universal input shall be software selectable as analog or binary.

(d) Outputs: The controller shall have on-board universal outputs with a 16-bit digital to analog conversion.

(e) Real Time Clock (RTC): Each controller shall have an integrated real-time clock, for time programs Date, time and time zone shall be set in the DDC when the user data is loaded. Where BACnet protocol is used, the BACnet services shall be used to synchronize the time and date automatically if the correct BACnet time server data is specified. The DDC shall also be used as a BACnet time server.

(f) Terminal Block Connectors: The controller shall have removable screw terminal blocks that can accommodate wire sizes of 1.5 Sq.mm and 2.5 Sq.mm copper wire. Terminals shall be color coded: black terminals for power, green terminals for input and outputs, and grey terminals for twisted-shielded-pair communication.

(g) Power Supply: The power supply for the controller shall be 230VAC / 24 volts AC (-15%, +20%) power. Voltage below the operating range of the system shall be considered an outage. Department shall provide 230 V AC 50Hz supply voltage. The contractor shall make his own arrangements to convert/rectify to any other voltage.

(h) Mounting: The controller shall be able to be mounted on standard DIN rail or to a panel using integrated mounting holes on 1” centers. Inputs/Outputs: to follow the BOQ for optimum selection of IO modules with the spare IOs.

(i) Modular Expandability: The controller shall allow expansion of the device Input and Output capacity via Expansion Modules, making it possible to add I/O as desired to meet the requirements for individual control applications.
The controller shall support up to four expansion I/O modules. Total point count with expansion modules shall be 100 points.

18.5 Field devices, Sensors and cabling

18.5.1 Electronic Data Inputs and Outputs

Input/output sensors and devices shall be matched to the requirements of the respective connected controller panel for accurate, noise-free signal input/ output. Control input response shall be high sensitivity and matched to the loop gain requirements for precise and responsive control.

(a) Temperature sensors shall be Resistance Temperature Detector types of Pt3000, Pt1000, Pt100 or Ni1000. These shall be two wire type sensors and shall conform to following:
Space temperature sensors shall be wall/surface mounted and shall be provided with blank commercial type looking covers Duct temperature sensors shall be rigid stem or averaging type as specified and shall be suitable for duct installation Immersion temperature sensors shall be provided with matching Stainless steel thermo- well of lengths as specified.
Outdoor air temperature sensors shall have weatherproof enclosures and shall be directly wall/surface mounted Outside air, return air, discharge air, return air, space and well sensors shall have ± 0.55 degrees C accuracy between 0 degree and 100 degree C.

(b) Relative humidity sensors shall be capacitance type with an effective sensing range of 10% to 90% .Accuracy shall be +/-5% or better.
Duct mounted humidity sensors shall be provided with a sampling chamber. Wall mounted sensors shall be provided with covers identical to temperature sensors. Sensor housing shall plug into the base such that the same can be easily removed without disturbing the wiring.

(c) **Differential and Static Pressure Switches**

(i) **Differential pressure switches- Air**
They shall have field adjustable set-point capability for the specified range. They shall provide a built-in switching differential at the set-point over the specified range. Switches shall be piped to fan discharge except where fans operate at less than 25mm WC(water column), they shall be piped across the fan. Maximum pressure rating shall be at least 300 mm WC. The electrical contacts shall provide dry contacts as specified and shall be rated for at least 300V A pilot duty @ 240V AC

(ii) **Differential pressure switches-Water**
Switches shall be adjustable differential pressure type as specified in the sequence of operation or data point summary. Devices shall be 10 kg/ sq.cm rated except chilled water flow switches shall be provided with totally sealed vapor tight switch enclosure on 20 kg/sq.cm body .Differential pressure switches shall have valved manifold for servicing. The electrical contacts shall provide dry contacts as specified and shall be rated for at least 300V A pilot duty @ 240V AC.

(iii) **Differential Pressure Sensors**
Air flow and duct static pressure analog sensors shall be high accuracy suitable for the low pressures to be encountered, be selected for approximately 50% over range, and have a 4 to 20 ma/ 0-10 VDC output.
Air flow measuring station sensors shall be with valved lines for testing and calibration, and shall have adjustments for zero and span.
Water flow analog sensors shall be provided complete with flow element and shall be an all solid state precision industrial type with stainless-steel body, maximum error of not more than 0.5% of span.
Sensor shall be rated for 17 kg/sq.cm minimum and installed in strict accordance to the manufacturer's instructions complete with three- valve manifold for calibration and maintenance.

(d) **Water Hardness Analyzer**

Water hardness analyzer shall be on-line conductivity type and shall provide analog output proportional to specified range.

Control relays and analog output transducers shall be compatible with controller output signals. Relays shall be suitable for the loads encountered. Analog output transducers shall be designed for precision closed loop control with pneumatic repeatability error no greater than *2%.*

(e) **Level Measurement**

Level switches shall be directly vessel mounted type either top mounted or side mounted as required. These shall be float type unless specified. Process connection shall be flanged. Wetted parts shall be made of stainless steel (SS316).

Level sensors shall be capacitance probe type. It shall be possible to mount the transmitter unit integral to the probe on the vessel or field mounted away from the probe. Unless specified probe insulation shall be of PTFE and probe rod material SS316. Process connection shall be flanged or BSP connections as specified.

18.5.2 Automatic Control Valves

Automatic control valves up to 50mm and smaller shall be screwed type, and valves of 65 mm and larger shall be flanged type.

Valves shall be ANSI-rated to withstand the pressures and temperatures encountered. Valves shall have stainless-steel stems and spring loaded Teflon packaging with replaceable discs.

All modulating straight-through water valves shall be provided with equal-percentage contoured throttling plugs. All three-way valves shall be provided with linear throttling plugs such that the total flow through the valve shall remain constant regardless of the valve's position. Valves shall be sized as specified for a pressure drop equal to the coil they serve but not to exceed 0.2 kg/ sq.cm.

All modulating steam valves shall have linear characteristic for 90% of the closing stroke and equal-percentage for the final 10%. Valves shall be sized for 0.68kg/ sq.cm entering steam and 0.2 kg/ sq.cm pressure drop through valves.

All automatic control valves shall be actuated by a directly coupled proportional electric actuator. Eccentric linkages are not acceptable.

18.5.3 Electric Actuators for Valves and Dampers

Unless specified otherwise, the electric actuator shall accept proportional input signal of 0/2- 10VDC or 0/4-20mA. Unless specified actuators shall provide modulating control. Actuators shall be powered 24VAC or 240VAC as specified.

The actuators shall be designed to deliver the required torque and have close off pressure ratings as required by the specified process data. The actuator shall incorporate magnetic coupling to ensure torque limitation which shall be independent of voltage supply. Unless specified, in case of power failure the actuator shaft position will remain stay-put at the last position just before power off. It shall be possible to replace the actuator / remove the actuator / dismantle it from the valve body without having to remove the valve body. The actuator shall have a built in electronic switch to enable switch- over of direct / reverse action of valve/damper. It shall be possible to change the direct/reverse action of valve without having to remove the actuator from valve body or change linkage assemblies.

18.5.4 Differential Pressure Switch

The differential pressure switch shall monitor the difference in pressure between 2 points and shall activate a NO/NC contact. The construction shall be diaphragm type with an adjustable set point and a set point range to suit the application. It shall have IP55 protection. Differential pressure switch range should be selected to suit the required specific application. These are used for installation across the filters on the air side and also for determining the run status of the fans. DPS shall include necessary mounting accessories such as flange with tubes.

18.5.5 Immersion Temperature Sensor

Immersion type temperature sensors shall be used to measure the temperature in a water pipe and shall be provided with matching thermo well. The thermo well shall be fitted onto a coupling that is welded onto the pipe and in no circumstance; it shall directly be fixed on the pipe.

The enclosure shall be IP 55 rated.
The enclosure shall be designed for all industrial and commercial immersion temperature sensing applications.
It shall be rust proof, hermetically sealed and with fast response time.
Sensor shall be 10K Type2 Thermistor with operating temperature -40°C to 100°C.
The accuracy of the sensor shall be ±0.2°C.
Probe shall be made of 304 stainless steel.

18.5.6 Duct T & RH Sensor

The humidity sensor shall provide a standard signal of 0-10V.
Overall accuracy shall be of ±3% RH from 0 to 100 % RH.
Sensing element for the humidity should be capacitive polymer.
It shall be suitable for duct mounting facilities and conduit fittings.
Degree of protection should be IP55 for indoor applications.
The temperature sensing element shall be of NTC type 10K/20K thermistor.
Accuracy for all BMS monitored duct type temperature sensors shall be ±0.2°C and shall be suitable for duct mounting.
Degree of protection should be IP55 and have a temperature range of 0 to 70°C.
The sensor should be able to be calibrated on site.
Sensor Response Time within 15 sec.
Duct mounted humidity sensors shall be provided with a sampling chamber.
Humidity sensor's drift shall not exceed 0.5% of full scale per year.

18.5.7 Water Level Transmitter - Ultrasonic Type Level Sensor

The level transmitter shall UL / CE listed and shall meet the following requirements:

Type	: Float Type/Capacitance type/Conductivity type
Mounting	: To suit application.
Connection	: Flanged ANSI 150 lbs RF Carbon steel
Float material	: 316 SS
Stem Material	: 316 SS
Output	: 4 – 20 mA
Enclosure	: IP 68
Accuracy	: +/- 0.5% FS
Temperature	: -20 deg C to 100 deg C

18.5.8 Level Switch (Hi-Med-Lo)

Type	: Magnetic Level Switch
Mounting	: To suit application.
Connection	: Flanged ANSI 150 lbs RF Carbon steel
Float material	: 316 SS
Stem Material	: 316 SS
Output	: NO/NC switching outputs
Enclosure	: IP 68

18.5.9 Water Pressure Transducer

Sensors shall be UL / CE listed and have linear output signals.
Zero and span shall be field-adjustable.
Sensor sensing elements shall withstand continuous operating conditions +/- 50% greater than calibrated span without damage to the components.
Water pressure sensor shall have SS316 diaphragm construction with SS316 body, proof pressure of 2 times the design and burst pressure of 5 times the Minimum.
Sensor shall be complete with 4-20 mA output, with over voltage protection.
The accuracy shall be ±0.25% or better.
The total error band shall be ±0.5% or better
IP protection should be IP65.
Pressure Transmitter's drift shall not exceed 0.1% of full scale per year.
Electric Connector for the same shall be DIN or mini DIN Connector.
Internal Snubber to protect from Vibration
Range shall be 0-250 psig. (Vendor to check and order appropriate range)

18.5.10 Duct type Static pressure transmitter

Duct mounted static pressure sensors shall have an accuracy of ±0.5% and the range shall be between 0 to 1000 Pa. Degree of protection should be IP55 and operating voltage should be 24Vac. It should output an analogue signal of 0-10V or 4-20mA.

Stability	: ±1% FS/year.
Temperature Limits	: 32 to 122°F (0 to 50°C).
Pressure Limits	: 2 psi (13.8 kPa).
Output Signal	: 4 to 20 mA or unit with field selectable 0 to 10 & 0 to 5 volt.

18.6 All field devices shall be installed by the controls supplier. BMS vendor shall submit their system architecture schematic with necessary cabling drawings for the specific project with the data sheets of the individual components that has been taken into account in the design. The system shall be supplied and installed by competent vendor. The vendor shall confirm to the Engineer-in -Charge that they have service set up to extend programming and services for the entire BMS system for 15 years from the date of recorded completion of work.

18.7 BMS vendor shall submit working drawings for all their works at site including cable layouts, cable schedule and DDC panel details; contractor shall also submit all data sheets, graphics layout of the screen for approval. Submittal shall be approved by the Engineer-in-Charge before any work is carried out at site.

18.8 It shall be the responsibility of the BMS vendor, to coordinate with all the MEP Contractors and vendors for soft integration of all equipment's and devices as per SOR to ensure successful integration. Handover of the System shall not be deemed complete without all integrations successfully completed and verified by the Engineer-in -Charge.

18.9 **Programming, testing and commissioning**

The entire system shall be programmed, tested and commissioned by the BMS supplier using qualified and trained personnel with necessary service tools/software that has been provided by the manufacturer. They shall co-ordinate as necessary with the other equipment suppliers wherever 3rd party integrations are required to successfully bring their data to the BMS Platform.

18.10 Training

Necessary training shall be conducted by the BMS contractor and shall utilise IOM manuals, data sheets and as-built drawings and necessary documentation; Operator training shall be carried out for a minimum period of eight hours including a site familiarization of the facility, various critical functioning of the BMS, data recovery, transfer and storage, text editing and graphics, review of sequence of operation, preparation of reports and modifying the same for presentation to management, trouble shooting of various important functions, password control. The training shall be done immediately upon system completion and before handing over.Unless this training is conducted and verified by the Engineer-in – Charge the BMS system shall not be deemed to be complete.

Operator training shall include multiple sessions encompassing:

(i) Selection of all displays and reports
(ii) Use of all specified OS functions
(iii) Use of portable operators terminals
(iv) Trouble shooting of sensors (determining bad sensors)
(v) Password assignment and modification

18.11 O & M Manual

One copy of the draft O & M manual shall be submitted for review and shall have all the necessary data sheets and drawings immediately upon the commissioning of the project.

After approval of the draft manual by the Engineer-in – Charge documentation as specified in Chapter 26 shall be furnished. 5 copies of O&M manual shall be submitted after review and finalization with all the necessary data sheets of the equipment and components supplied and installed with as-built drawings and commissioning data sheets.

Operator training shall include total multiple sessions encompassing:

(i) Selection of all displays and reports
(ii) Use of all specified OS functions
(iii) Use of portable operator’s terminals
(iv) Trouble shooting of sensors (determining bad sensors)
(v) Password assignment and modification

The training shall be under taken in two phases. One training session shall be conducted at system completion, and the other shall be conducted within forty-five days of system completion.

18.12.1 Chiller Plant Manager (CPM)

In case specified in the SOR, the contractor shall provide a chiller plant control system to perform chiller plant control, automation, and energy management functions. The chiller plant control system shall have the capability to monitor and control chillers and primary chilled water pumps and monitor the various parameters of the secondary pumps and provide the chiller plant operator with control, monitoring, and management information. The Chiller Plant Manager shall have the capability of communicating over owner's TCP/IP compatible network or over a dedicated Ethernet network. CPM shall be provided with a modem card and connected to a telephone line remote monitoring. The system shall be capable of being dialed up and the chiller & system parameters shall be accessible from a remote location.

18.12.2 System Hardware

The chiller plant control system shall consist of the following hardware:

(i) Factory - installed microprocessor - based controller mounted on each chiller (supplied with chillers); also, the chillers shall have hardwired points for start/stop, run and fault status; also the chiller have software communication capability of communicating chiller parameters through BACnet/ModBus protocols;

(ii) Field - mounted microprocessor - based chiller plant controller and DDC Controllers for connecting to Chilled Water Primary Pumps, CDWP, CTs and Motorized Isolation Valves.

18.12.3 System Applications

Chiller control system shall provide following applications:

(i) Chiller control system shall provide control of system leaving water temperature by adding chillers as the building cooling load increases. It should also be able to calculate chilled water set point sent to each chiller.

(ii) It shall be able to optimize energy use by subtracting chillers when the cooling load does not require them to be enabled.

(iii) Provide runtime equalization and wear on each chiller by using different rotation schemes.

(iv) Control System condenser and chilled water pumps and associated equipment attached to it.

(v) Add additional chiller based on
(a) System chilled water set point
(b) System chilled water supply temperature

(vi) The temperature subtract algorithm based on:
(a) Actual system delta T
(b) System design delta T
(c) Total available operating capacity (tonnage)
(d) The capacity available after next chiller is subtracted
(e) Allow operator to force an add or subtract request from the screen.

(vii) Specify chiller rotation type as (based on different capacities of the chillers):
(a) Normal
(b) Peak (last on- first off)
(c) Base (first on - last off)
(d) Swing (unevenly sized units)

(viii) Allow automatic rotation of sequence.

(ix) Control soft loading when system supply temperature is far from set point.

(x) Provide text description to assist the operator in understanding current chiller plant control operation and help to anticipate the next chiller plant control decision.

(xi) Alarm Processing. Any object in the system shall be configurable to alarm in and out of normal state. The operator shall be able to configure the alarm limits, warning limits, states, and reactions for each object in the system.

(xii) Trend Logs. The operator shall be able to define a custom trend log for any data in the system. This definition shall include interval, start-time, and stop-time. Trend intervals of 1, 5, 15, 30, and 60 minutes as well as once a shift (8 hours), once a day, once a week, and once a month shall be selectable.

(xiii) Alarm and Event Log. The operator shall be able to view all logged system alarms and events from any location in the system.

(xiv) Reports and Logs. Provide a reporting package that allows the operator to select, modify, or create reports. Each report shall be definable as to data content, format, interval, and date. Report data shall be archived on the hard disk for historical reporting. Provide the ability for the operator to obtain real time logs of designated lists of objects
(a) Custom Reports: Provide the capability for the operator to easily define any system data into a daily, weekly, monthly, or annual report.
(b) Standard Reports: These reports shall be readily customized to the project by the owner.

(xv) Scheduling. Provide the capability to schedule each object or group of objects in the system. Each schedule shall consist of the following:
(a) Weekly Schedule. Provide separate schedules for each day of the week.
(b) Exception Schedules. Provide the ability for the operator to designate any day of the year as an exception schedule.
(c) Holiday Schedules. Provide the capability for the operator to define up to [99] special or holiday schedules. These schedules may be placed on the scheduling calendar and will be repeated each year. The operator shall be able to define the length of each holiday period.
(d) Optimal Start/Stop. The scheduling application outlined above shall support an optimal start/stop algorithm.

(xvi) Maintenance Management. The system shall monitor equipment status and generate maintenance messages based upon user designated run time, starts, and/or calendar date limits.

(xvii) Chiller Sequencing: Provide applications software to properly sequence the chiller plant to minimize energy use. This application shall perform the following functions:
(a) The chiller plant control application shall have the ability to control a combination of chillers of any type including centrifugal, screw and scroll chillers of various capacities;
(b) This application shall be able to control both constant and variable flow systems as well as parallel, series and decoupled piping configurations.
(c) The chiller plant control application shall be able to control multiple chiller plants per site.

(d) Alarm Indications - The chiller plant control status screens shall display chiller plant and individual chiller alarm messages.

(xviii) PID Control. A PID (proportional-integral-derivative) algorithm shall calculate a time-varying analog value used to position an output or stage a series of outputs.

(xix) Staggered Start. This application shall prevent all controlled equipment from simultaneously restarting after a power outage. The order in which equipment (or groups of equipment) is started; along with the time delay between starts shall be user-selectable.

(xx) Anti-Short Cycling. All binary output points shall be protected from short cycling. This feature shall allow minimum on-time and off-time to be selected.

CHAPTER 19
FILTERS AND AIR CLEANING DEVICES

19.1 Scope

(i) Scope of work shall comprise the supply, installation, testing and commissioning of various kinds of Air Filters in the air circulation and fresh air intake systems. It also includes electronic air cleaning devices as well as Ultra Violet Germicidal Irradiation systems.

(ii) The system shall be complete with all components, controls and equipment and Devices.

(iii) Scope of work shall include commissioning of the filters/systems in line with ISHRAE Standard 10003-2020.

(iv) The filter shall be as per ASHRAE 52.1, ASHRAE 52.2, ISO 16890, EN 779, EN 1822.

19.2 Air Filters – Filter Types

(i) **PREFILTERS**

Prefilter for VOC and particles removal: High efficiency particle filtration for deodorisation and removal of VOC pollutants

(a) **CLEANABLE TYPE**

Coarse filters can be cleanable panel type (or made of multiple layers of fine HDP mesh preferably with a fibrous non-woven material sandwiched between the HDP mesh layers stitched or crimped together and arranged in a pleated formation inside the frame such a fashion so as to give the desired filtration rating and airflow. These filters shall have fractional efficiency of 90% for 10 micron particle size and conforming to G3 or MERV 5 grade. Suitable pleat retaining mechanism shall be provided to maintain during service. The filter media shall be sealed to the frame using a suitable adhesive. Thickness of frame shall be 1.25 mm and the overall thickness of the filter panel shall be 50 mm. Filter panels shall be rendered fire retardant. Filter face area and filtration media area shall be as specified. Filters shall be rendered fire retardant. Face velocity across these filters shall not exceed 155 MPM.

(b) **REPLACEMENT TYPE**

Filters should be ISO ePM Coarse with PM efficiency 65% minimum as per IS-17570: 2021/ ISO16890: 2016 and Light duty VOC as per ISO10121-3. Each unit shall be provided with ISO 9001: 2015 factory assembled filter section containing 50mm thick disposable air filters. Should be made up of Synthetic fibre and broad-spectrum carbon, Initial Pressure Drop (IPD) </=140 Pa wg (+/-10%) and recommended Final Pressure drop at clogged condition (FPD) >/=250 Pa wg (+/-10%) with 1.5m² media area. Filter should minimum 50% removal efficiency for Ozone. Filter should be maintenance free. Filter banks shall be easily accessible and designed for easy withdrawal and renewal of filter cells. Face velocity across these filters shall not exceed 500 FPM. Filters shall carry certificate from manufacturer for the IS17570: 2021/ ISO16890: 2016 and ISO10121-3. Conformity and a sample test report. The filter area shall be made up of panels of size convenient for handling. The filter testing method shall be as per IS17570:2021/ISO16890: 2016 latest edition. Filters shall be changed once reaches on its final pressure drop and disposed as per State Pollution Control Board norms.

(ii) **FINE FILTERS**

(a) **CLEANABLE TYPE**

Microvee Filters shall be cleanable panel type and media shall be random fiber mats (non-woven) stitched with a HDP mesh covering on both sides, suitably arranged in a pleated formation inside the frame so as to give the desired filtration rating and airflow. These filters shall have fractional efficiency of 99% for 5 micron particle size and conforming to MERV 11 or 12 grades. The thickness of the aluminium frame shall be 1.25 mm minimum. Filter panel thickness and size shall be as specified Filters shall be rendered fire retardant.

(b) **REPLACEMENT TYPE**

The filter shall have minimum ePM1 80% rating (conforming to IS 17570: 2021/ISO16890:2016). Each unit shall be provided with a factory assembled filter of Panel type less than or equal to 300mm depth glass fiber media type air filters having Recyclable ABS frames. Filter Media should be Glass Fiber separated with Holt met glue. Initial Pressure Drop (IPD 85 Pa wg (+/- 10%)), and recommended Final Pressure drop at clogged condition (FPD) >/=300 Pa wg (+/- 10%). The Dust holding capacity of the filter should be 650 gms @30 mmwg. Filter should be energy efficient and should not consume energy more than 200 watts (W) per hour.Filters should be Maintenance free. Filter banks shall be easily accessible and designed for easy withdrawal and renewal of filter cells. Filter framework shall be fully sealed. Face velocity across these filters shall not exceed 500fpm. Filters shall carry certificate from manufacturer for the IS 17570: 2021/ISO 16890 : 2016 Conformity and a sample test report. The filter area shall be made up of panels of size convenient for handling. Filters shall be changed once reaches on its final pressure drop and disposed as per State Pollution Control Board norms.

(iii) **HEPA FILTERS**

HEPA filter media shall be waterproof, high strength microfiber glass paper. Corrugated aluminum separators should be provided to ensure uniform media utilization. These filters shall have efficiency of 99.97% up to 0.3 micron particle size and shall conform to H13 grade as per EN1822/ISO29463:2019 and shall be used for applications like operation theatre, micro-labs, ICU, HDU etc. The casing shall be aluminum 1.6 mm thickness with leak free installation and dimensional stability. Neoprene (non particle shedding) gasket shall be fitted to the frame on both sides to ensure leak tight installation. The filter media shall be fitted to the filter frame with a suitable adhesive compound providing rigid construction. These are also provided in the AHU after fan section or at terminal point and always must be backed by Pre filters & Fine filters as per above mentioned specifications.

These filter after they become dirty, cannot be reused and have to be thrown away. The filters should be Maintenance free.

Face velocity across these filters shall not exceed 500 fpm.

Filter should be in deep pleated construction with Aluminium separators. Media should be glass fibre to achieve H13 class. Initial Pressure Drop (IPD 450 Pa wg (+/- 15%)), and recommended Final Pressure drop at clogged condition (FPD) >/=750 Pa wg (+/- 10%). Each filter shall be accompanied by a test report. Filters shall be disposed as per State Pollution Control Board norms.

(iv) **Chemical Filters**

(a) General

Air filters shall be compact 12” deep adsorbed with granules type media with combination of sorbent / particulate removal media, impact-resistant plastic end caps, plastic vertical support channels, and a nominal 1” header for front or side-access applications.

(i) Sizes shall be as noted on drawings or other supporting materials.

(ii) Manufacturer shall provide evidence of facility certification to ISO 9001:2008

(b) Construction

(i) Filter media shall be specifically manufactured for the removal of molecular and particulate contaminants. Sorbent shall be broad spectrum grade of carbon incorporating Rapid Adsorption Dynamics (RAD) designed for the removal of a wide range of odours and VOC’s.

(ii) Total media area shall be at least 0.038 square feet per rated cfm of filter.

(iii) The media shall be formed into uniform pleats using hot-melt separators, assembled into multi-media packs and bonded into a high impact resistant plastic frame to prevent air bypass.

(c) Molecular Performance Testing

(i) A full size, 24” x 24” filter, shall be tested as per Global test standard for molecular filters in IAQ application ISO10121-3.

(ii) At a minimum the initial removal efficiency and test concentration shall be provided for:

- Ozone
- Nitrogen dioxide
- Sulphur dioxide
- Toluene

(d) Initial Resistance Performance

Initial resistance to airflow shall not exceed 0.37 inches w.g.(+/-10%) at 500 feet per minute velocity

(v) **Installation of filters**

(a) The filters shall be installed in the frames in such a manner that no air by pass takes place. Filters shall be easily inserted from the sides. Rigidity and sealing effectiveness of the frame are of utmost importance. HEPA filters shall be handled and installed with extreme care. Filters shall be installed such that the free area is at right angles to airflow to the extent possible and eddy currents shall be avoided and air shall be distributed uniformly over the entire filter surface. Sufficient space shall be provided in front as well as behind the filter to make it accessible for service and access doors of convenient size shall be provided to the filter service areas.

(b) All doors on the clean airside shall be gasketed to prevent infiltration of unclean air and all connections and screws of the ducting shall be airtight. Filter bank shall be caulked to prevent bypass in the case of HEPA filters. The filters shall be installed only after ensuring complete cleanliness of the system.

(vi) All filters shall be type tested for their efficiency and dust-holding capacity. Each type filter shall have a prototype test certificate and where specified in SOR, the contractor should get the filters tested in an approved test facility.

(vii) After installation, all filters shall be tested for leakage in an approved manner.

19.3 Electronic Air Cleaning (EAC) System

(i) Air Handling Units, Ceiling suspended AHU/Ductable, fan coil units, split indoor units of all types & covering the entire range of air delivery units, Be it recirculating or fresh air type units, shall be fitted with an electronic air cleaner system if so specified. The system shall be complete with washable pre-filter, charging section and collector section and shall be installed before the cooling coils. Other forms of air filtration systems such as charged media filters, dielectric media filters, or ionizers (which do not have second stage collector cells) shall not be accepted. The electronic air cleaner (EAC) shall be capable of removing ultra-fine particulates of size as small as 0.01 microns including microscopic haze particles, smoke, dust and other biological forms like Virus, mold spores, fungi and bacteria etc. System must have been tested on anti-microbial capability to Trap & Kill airborne infectious diseases.

(ii) The EAC must be UL 867 certified in line with US OSHA safety standards implemented through NRTL accredited labs such as Intertek, Underwriters Limited, etc. certified international labs only. Product to comply and tested as per globally accepted IS-17570:2021 / ISO 16890:2016 & ASHRAE 52.2 - 2017 of particles performance set standards in line with general ventilation & Indoor Air Quality (IAQ) standard with no consumable media filter.

The EAC must be tested for its anti-microbial capability on E. coli (ATCC 15597), Corona Virus & other microbial species as per ASTM E2149 & FDA GLP Regulations (40 CFR Part 160) in FDA accredited global labs only.

The EAC shall have valid test reports to ensure that it meets the following safety criteria with reference to UL 867 and IS-17570:2021/ ISO 16890:2016 for all air purification modules.Ozone level of EACs provided shall be within acceptable limit of 50 ppb as per UL 867 safety standard on complete systems and not just components.

Performance Testing

- EMC compatibility
- LVD (low voltage) test

The vendor/contractor shall submit a design analysis conditional qualification test report to confirm that tests have been conducted based on the above criteria and that the EAC has passed these tests.

(iii) Safety Provisions

(a) Each EAC cell shall have their automatic interlock switch which disconnects power and discharges the cell when the access door is opened. In addition, the EAC shall be capable of interlocking when disconnecting the power to each individual EAC unit, or when the AHU fan is not running.

(b) To ensure complete safety & security no arching, popping noise should occur during the dust test with no residual charge to avoid any shock risks.

(c) A high voltage test button shall be provided for each individual high tension power supply unit to indicate the presence of high voltage on the electronic cells. An overall test button for a group of power supply units to provide a general indication of high tension voltage shall not be accepted.

(iv) Performance / Reliability Requirements

The number of EAC shall be chosen in such a way as to match the AHU airflow, air velocity and performance criteria.

The EAC filtration shall be certified with a minimum rating of MERV 14 or above tested as per ASHRAE 52.2-2017 standard from a global accredited laboratory.

The Ionizer and Collector shall operate on high voltage DC power controlled by an electric panel integrally fitted on each module of the EAC .They shall be of one single high voltage or of dual voltage for the Ionizers and Collectors as per manufacturer’s design.

For the EAC to perform effectively against PM1, PM 2.5 pollutants, the EAC shall have a fractional efficiency test report from a third-party ASHRAE test compliant laboratory to confirm CME (Composite Minimum Efficiency) of the following:

Particle Size	CME *
0.3-0.4µm	90
1.0- 3.0µm	94
3.0-10 µm	95

* Manufacturer to specify.

The entire Filtration system shall be washable and reusable without need for replacements. Electrostatic media filters that collect particles on disposable media pads shall not be acceptable.

The average initial pressure differential drop across the entire filtration system shall not exceed 60 pa tested at 2.5 m/s airflow. It shall be washable for repeated use.

The EAC shall be complete with hot- dipped galvanized or coated with non-corrosive polyester based material cabinets to protect against rust, heavy duty commercial use electronic cells, solid state power supply, protective screen and prefilter .

The EAC shall have the capability for the optional addition of high performance granular activated carbon (Charcoal) filter. The activated carbon filter shall be able to reside into the EAC cabinet as and when necessary without the need for any modification, no foam or charcoal coated media will be accepted.

(v) Diagnostics / Interfacing to Building Management System

The EAC shall have the optional capability to interface with the building management system through a Solid-State Performance Indicator. The following status shall be allowed for remote monitoring by the building management system.

(a) Normal operation of solid state power supply (ON).

(b) Any malfunction of the system that shall cause an alarm activation.

(c) Excessive dirt accumulation in the collector cells that could result in the reduction of the EAC performance.

The EAC shall have local LEDs at each individual unit to indicate the operation status and it shall be able to provide in addition a signal to link-up with the building management system for monitoring.

(vi) Submission of Compliance Documentation

Vendor/contractor shall provide full documentation/technical literature/data sheets/reports to confirm compliance to specifications.

19.4 Ultraviolet (UV) lamp systems

(i) Installation of UV in AHUs

(a) The UV emitters shall be installed upstream/downstream of AHU between the coil Section & filters/ coil & fan section and if required in the supply air duct to provide surface disinfection of the cooling coil and air stream disinfection within the AHU wherever possible. If a clear space of 300 to 600 mm between the cooling coil and fan section is not available in the AHU, the coil surface disinfection shall be done in the AHU and air stream disinfection in the supply duct.

(b) The UV-C emitters shall be of high UV-C energy output type and shall be chosen to deliver adequate fluence (UVGI dose) in destroying pathogens (viruses, bacteria and fungi), allergens (bacteria & mold) and toxins (endotoxins & mycotoxins) under cold moving air conditions.

(c) The UVGI system shall be designed to irradiate the entire face area of the cooling coil. The face velocity of dehumidified air over the coil will be 500 FPM or lower. The UVGI system shall be designed with UVGI intensity to achieve minimum 2 log reduction of infection causing pathogens in the air stream. If a 300-600 mm gap is available between the coil and fan inlet section, which facilitates 0.25 to 0.4 second exposure time, air stream disinfection shall be done inside the AHU.UVGI dose of URV 10 and above shall be preferred. If adequate exposure time is not possible within the AHU, air stream disinfection shall be done in the supply air duct and only AHU coil surface disinfection shall be done within the AHU.
UVGI irradiation of minimum 100 uW/cm^2 on the coil shall be applicable only in case of 24x7 operation of UVGI. Else the irradiation intensity shall be suitably increased to for effective removal of biofilm on the coil surface.

(d) The UVGI system shall be suitable to operate with 230V, single phase A.C. supply, 6 Amp current. The UVGI system shall be suitable for installation in an AHU without any modification to the AHU. The UVGI system shall be installed in front of the cooling coil with lamp facing coil to cover the drain pan. The selection and placement of the UVGI system shall ensure full irradiation of the entire face area of the cooling coil and drain pan. The UVGI System shall be free standing and be mounted in such a manner that lamps are in perpendicular plane to air flow.

(e) Depending on the manufacturer's recommendation and IP rating of the ballast module,(electronic driver) it may be installed on the UVGI lamp mounting racks or outside the AHU.

(f) The entire framework and support inside AHU shall be fabricated out of Aluminum Alloy. All material used shall be UV resistant .The framework shall be free standing and suitable for quick assembly. All parts shall be corrosion resistant.

(g) Electronic ballasts with a high power factor of more than 0.95 shall be used. Ballast if mounted inside the AHU shall be in an IP 67 rated enclosure. The ballasts shall be constant current output ballast over input voltage range of 190 to 270 VAC (or better range), 1 phase, 6 Amp current to ensure effective lamp life. Microprocessor based control panel with the following (minimum) display shall be provided.

- Individual/System Lamp run hours for timely and easy replacement
- Individual lamp On/Off/Error Indicator
- Programmable (optional) Real time On/Off switching for system

(h) The panel shall be BMS compatible with NONC contact point. Panel shall be IP 42/ suitable rating. All power and control cables shall be FRLS (Fire retardant low smoke).

(ii) The vendor /contractor shall specify in detail a layout of the number of UV-C sources required and their respective position (distance from the coil and alignment on the coil).

(a) Safety interlock switches shall be installed on all access doors where UV intensity may be present. CAUTION Labels shall also be installed on these access doors.

(b) The UVC lamp shall be of pure fused quartz or of soft glass, properly doped with Titanium Oxide in order to filter out 99.99% of the 185 nm. Wavelength to avoid the production of ozone. UVGI lamps shall be preferably shatterproof i.e. the unbreakable so that the broken glass does not circulate through AHU & duct system.

(c) The distance of lamp location from the coil and the UVGI intensity it delivers shall be ascertained from the manufacturer's rating chart.

(d) Performance measurement shall be done using a radiometer at site to verify if the design intent of UVGI intensity is achieved.

(iii) The UV lamps shall meet following criteria:
Lamp shall be High Output (HO) Quartz or soft glass type. The lamp shall produce UVC @ 253.7 nm only. Lamp intensity measurements shall be verified at site. The lamp tube shall be 15 mm (T5) diameter .The lamp output shall not drop by more than 20% after 12000 hours of operation. UVGI lamps shall be UL 1995 & UL 2043 standards certified.

19.5 UV-C Lamp for air cleaning/disinfection in the ducting system.

(i) Whenever 0.25 to 0.4 sec exposure time of air stream to UVGI irradiation is not practically achievable in AHU, Air stream disinfection using UVGI in Supply Air plenum near AHU or in the Supply Air duct shall be opted for. Disinfection in Return air duct shall be attempted only in such cases where return air is ducted upto the AHU.

(ii) The low-pressure UV lamp specification shall remain the same as described in the AHU UVGI section above.

(iii) The UVGI shall be mounted in parallel or perpendicular to air flow direction. All the holes / gaps in the duct, created for installation of UVGI, shall be sealed off to avoid leakage of irradiation outside the duct.

(iv) The UV-C lamps shall be supported along its length, to avoid breakage due to cantilever action and exposure to high air velocity inside the supply air duct.

(v) The UV-C lamps shall be installed in such a way that service access for lamp replacement or any maintenance work could be easily performed at site.

(vi) The length of duct to be irradiated inside shall be calculated to achieve an exposure time of 0.4 sec of air stream. The UVGI fluence or dosage required shall be suitably calculated for the required 2-log or 3-log reduction of the pathogens.

(vii) All Air stream disinfections (either inside AHU or inside Supply Air duct) shall be designed with a design intent of disinfection in one-pass of the air stream only.

(viii) Shatterproof UV lamps with FEP sleeve shall avoid spilling of mercury and glass particles inside the AHU.

(ix) UVGI dose equivalent to URV12 or URV13 or URV14 may be chosen, when multiple pathogens are targeted to be disinfected in air stream to minimum 2-log reduction.

(x) Furthermore, for in-duct application, the OEM must have CSIR - India approved Corona inactivation test & designed with an authorization to use TOT agreement.

(xi) The duct section, where UVGI is installed inside, shall have a sticker cautioning that UVGI is installed inside.

(xii) All required precautions in accordance with Electrical safety codes shall be followed, in routing the power supply wires, adequate electrical insulation, mounting of UV-C lamp ballast and electrical control panel etc.

19.6 Performance Criteria :

(i) **Approximate Equivalent Ratings for Filters Tested Under ASHRAE Standards 52.2 (MERV) and ISO 16890 and European Union EN779 Class**

ASHRAE MERV * (Standard 52.2)	ISO 16890 Rating	European Union EN779 Class
1-6	ISO Coarse	

7-8	ISO Coarse > 95%	G (G1 equivalent to MERV 1, G2 equivalent to MERV 2 to MERV 4, G3 equivalent to MERV 5 to MERV 6, G4 equivalent to MERV 7 to MERV 8)
9-10	ePM_{10}	F5
11-12	$ePM_{2.5}$	F6
13-16	ePM_1	F (F7 equivalent to MERV 13, F8 equivalent to MERV 14 and F9 equivalent to MERV 15 & MERV 16)

(ii) **Type of filter (conforming to ASHRAE 52.1, 52.2), efficiency and their typical application**

Minimum Efficiency Reporting Values (MERV)	**Particle size range (as per ASHRAE 52.2)**			**Test (as per ASHRAE 52.1)**		**Particle size range, µm & typical contaminant**	**Typical air Filter/ cleaner type**
	3 to 10 µm	**1 to 3 µm**	**0.3 to 1 µm**	**Arrestance**	**Dust spot**		
	Filtration efficiency						
MERV 1	< 20%	—	—	< 65%	< 20%	>10 Pollen, Spanish moss, Dust mites, Sanding dust, Spray paint dust, Textile fibres, Carpet fibres, etc.	**Throwaway** Disposable fiberglass or synthetic panel filters. **Washable** Aluminum mesh, latex coated animal hair, or foam rubber panel filters. **Electrostatic** Self-charging (passive) woven polycarbonate panel filter.
MERV 2	< 20%	—	—	65–70%	< 20%		
MERV 3	< 20%	—	—	70–75%	< 20%		
MERV 4	< 20%	—	—	> 75%	< 20%		
MERV 5	20–35%	—	—	80–85%	< 20%	3.0–10 Mold, Spores, Hair Spray, Fabric Protector, Dusting aids, Cement Dust, Pudding mix, Snuff, Powdered milk, etc.	**Pleated Filters** Disposable, extended surface, 25 to 125 mm (1 to 5 in.) thick with cotton-polyester blend media, cardboard frame. **Cartridge Filters** Graded density viscous coated cube or pocket filters, synthetic media. **Throwaway** Disposable synthetic media panel filters.
MERV 6	35–50%	—	—	> 90%	< 20%		
MERV 7	50–70%	—	—	> 90%	20–25%		
MERV 8	> 70%	—	—	> 95%	25–30%		

MERV 9	> 85%	< 50%	—	> 95%	40–45%	1.0–3.0 Legionella, Humidifier dust, Lead dust, Milled flour, Coal dust, Auto emissions, Nebulizer drops, Welding fumes, etc.	**Bag Filters** Non-supported (flexible) micro fine fiberglass or synthetic media. 300 to 900 mm (12 to 36 in.) deep, 6 to 12 pockets. **Box Filters** Rigid style cartridge filters 150 to 300 mm (6 to 12 in.) deep may use lofted (air laid) or paper (wet laid) media.
MERV 10	> 85%	50–65%	—	> 95%	50–55%		
MERV 11	> 85%	65–80%	—	> 98%	60–65%		
MERV 12	> 90%	> 80%	—	> 98%	70–75%		
MERV 13	> 90%	> 90%	< 75%	> 98%	80–90%	0.3–1.0 All bacteria, Most tobacco, smoke, Droplet nuclei, (sneeze) Cooking oil, Most smoke, Insecticide dust, Copier toner, Most face powder, Most paint, pigments, etc.	**Bag Filters** Non-supported (flexible) micro fine fiberglass or synthetic media. 300 to 900 mm (12 to 36 in.) deep, 6 to 12 pockets. **Box Filters** Rigid style cartridge filters 150 to 300 mm (6 to 12 in.) deep may use lofted (air laid) or paper (wet laid) media.
MERV 14	> 90%	> 90%	75–85%	> 98%	90–95%		
MERV 15	> 90%	> 90%	85–95%	> 98%	~95%		
MERV 16	> 95%	> 95%	> 95%	> 98%	> 95%		
MERV 17	—	—	≥ 99.97%	—	—	<0.3 Virus (unattached), Carbon dust, Sea salt, All combustion, smoke, Radon Progany, etc.	
MERV 18	—	—	≥ 99.99%	—	—		
MERV 19	—	—	≥ 99.999%	—	—		
MERV 20	—	—	≥ 99.9999%	—	—		

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CHAPTER-20
GEOTHERMAL SPACE CONDITIONING

20.1 About

A Geothermal (or Geo-exchange) is a type of Space Conditioning system that can do heating, cooling and Domestic Hot water. The earth absorbs almost 50% of all solar energy and remains a nearly constant temperature depending on geographic location. Working with an underground loop system, a geothermal unit utilizes this constant and stable temperature to exchange energy between the building and the earth as needed for heating and cooling.

20.2 General Description of System

Geothermal is the most efficient Air-conditioning system because the ground temperature stays stable and has no impact due to the above the ground ambient temperature.

A geothermal heat pump simply takes advantage of this stable temperature energy source and pumps it up to a usable level to cool/heat the building.

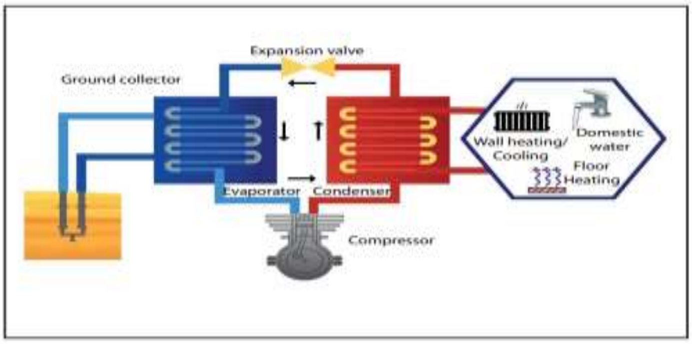
20.3 System Components

A geothermal system shall include the following components: -

(i) Ground source heat pump with refrigeration cycle comprising of compressor, condenser, expansionvalve, evaporator & refrigerant piping.(CARNOT CYCLE)
(ii) Ground loops to inject/extract heat.
(iii) Distribution circuits for chilled/hot water lines.
(iv) Buffer tanks for thermal storage.
(v) Air distribution via FCU/AHU/Radiant Under floor etc.
(vi) Domestic Hot water distribution line.
(vii) Controls and control wiring.
(viii) Power supply control and distribution arrangement.

20.4 Description

Geothermal Heat Pumps draw energy out of the ground which stays relatively constant year round. According to the Environmental Protection Agency, geothermal heat pumps can reduce energy consumption—and corresponding emissions—up to 45% compared to air source heat pumps and up to 72% compared to electric resistance heating with standard air-conditioning equipment. GHP systems have relatively few moving parts, and because those parts are sheltered inside a building, they are durable and highly reliable. The underground piping often carries warranties of 25–50 years, and the heat pumps often last 20 years or more.



20.5 Types of geothermal loops system

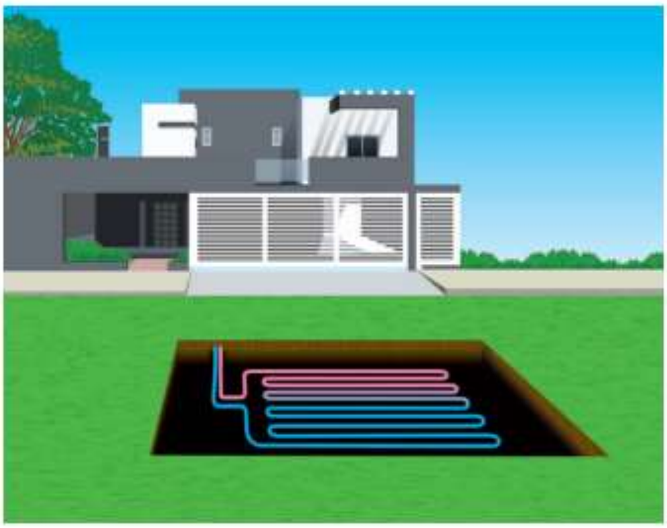
20.5.1 **Closed Loop Systems** - A closed loop is one in which both ends of the loop's piping are closed. The water or antifreeze fluid is recirculated over and over and no new water (make up water) is introduced to the loop. The heat is transferred thru the walls of the piping to or from the source, which could be ground, ground water, or surface water.

Types of closed loop systems;

20.5.2 **Vertical Loops** - Vertical loops utilize bore holes drilled to an average depth of 100-140 metres depending upon the exchange required. Once the loop pipe is inserted into the bore, it is grouted using a suitable mixture similar to the soil thermal conductivity. This mixture is determined after performing the TRT test (Thermal Response Test) for finding the soil conductivity.

20.5.3 Horizontal Loops - Horizontal loops utilize trenches dug to an average depth of four to six feet. As one of the more cost effective loops to install, horizontal loops are commonly found in open fields, parks or under parking lots.

These may work only in mild climates where exchange is small quantity. In harsh climates the horizontal loop is not effective.



20.5.4 **Water Body Loops -** Water loops utilize a "slinky" assembly of geothermal loop piping placed at the bottom of a pond, lake, or other large body of water. An extremely cost effective loop system, lake loops are an easy alternative if the option is available.

20.5.5 **Open Loop Systems** - Open loops pump natural water from a well or body of water (lake, river) into a heat exchanger inside the heat pump and then return the water back to the water source. The supply and return lines must be placed far enough apart to ensure thermal recharge of the source. Due to loss of water however these systems are very rare.

20.6 Benefits

(i) High Efficiency and Stable Capacity
(ii) Comfort and Air Quality
(iii) Simple controls and Equipment
(iv) Low Maintenance Cost
(v) Low Cost Water Heating
(vi) No Outdoor Equipment
(vii) Packaged Refrigeration Equipment
(viii) An earth-coupled heat pump can be applied practically anywhere for residential, commercial and industrial heating & cooling systems.
(ix) An earth-coupled heat pump system has the lowest operating cost of any space heating or cooling system.

20.7 Thermal response test

A thermal response test (TRT) is used to determine the thermal properties of the ground. The TRT is vital for designing ground exchange requirement.

A TRT is a measurement method which is the most correct way to determine precise thermal properties. A simple arrangement in which heat at constant power is injected into (or extracted from) a borehole while the borehole mean temperature is measured. A full power TRT rig is used for this purpose with heat injection capacity of 9 KW. The test is performed for 36-48 hrs without any stoppage. If stoppage happens then the test is considered void and its repeated

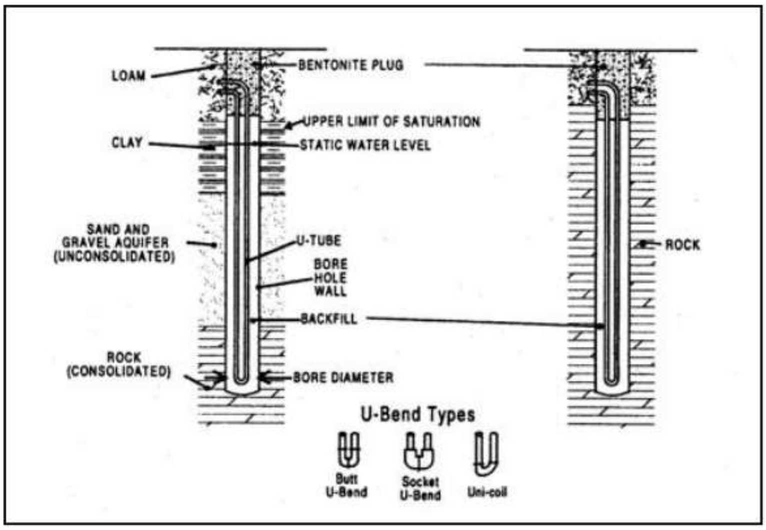
The system consists of a borehole, pipe system, circulation pump, ~~a chiller or~~ heater with constant power rate, and continuous logging of the inlet and outlet temperatures of the flow. The equipment is normally contained within a single unit for ease of transport and efficient use.

The thermal response data (i.e. temperature development in the borehole at a certain energy injection/extraction) allows estimation of the effective thermal conductivity of the ground and the thermal resistance of the borehole.
This data is then transported to suitable software with specialized loop exchange design capabilities.
This data is not to read in absolute or in excel pattern.

The guiding parameters for TRT is attached in the annexure.

20.8 Typical Vertical loop installation

The ground loop is a heat exchanger that is similar to a cooling coil or an evaporator in a chiller. The goal is to transfer energy from the heat pump loop fluid to/from the ground.



At steady-state conditions, there is heat transfer from the heat pump fluid to the ground. The temperature difference between the ground and the fluid in the loop provides the impetus for the energy to move.

20.9 Borehole Thermal Resistance

Many factors affect the thermal resistance of the ground loop. These include the pipe properties, flow rate, backfill and grout properties, soil properties and fluid properties.

Hence the Software design must be able to take into considerations all these factors and determine the design of the loop system.

20.10 Soil Properties

The thermal conductivity of the soil at the site is required to estimate the ground loop performance and thus design. For large (over 50 tons) projects, the soil should be tested by proper TRT rigs and test as per norms as mentioned.. The advantage to testing is that more accurate soil data will allow the designer to minimize the safety factor and optimize the number of holes. The savings from the reduced number of holes should more than pay for the test.

20.11 Effects of ground water

Ground water movement through the bore hole field can have a large impact on its performance. Ground water recharge (vertical flow) and ground water movement (horizontal flow) can all carry away large amounts of energy. Evaporation can also cool the surface soil and improve horizontal loop performance.

20.12 Ground Source Heat Pump

Geothermal heat pumps Inverter technology, package suitable for HFC 410a or any green refrigerant.

All geothermal pumps must be, Brine to Water heat pumps with inverter based scroll compressor electronic expansion valve control, plates heat exchanger, group of security, ability to be cascaded up to 6 drives and ability to manage up to 6 groups of drive unit.

The unit shall be suitable to operate at 415 Volts + 10 %, 3 phase, 50 Hz A.C. supply .The unit shall be filled with first charge of the refrigerant R-410a of not more than 10 Kgs per 100 KW.

Performance: All the pumps must be capable of heating and cooling and DHW (Domestic Hot Water) as the building intends to run the system in heating and cooling mode depending upon the outdoor conditions.

International Standard to Follow: EN 14511, (All Geothermal Heat Pumps must be A++ Energy Label)

<u>Power Range</u>
Heating power- B0W35 (As per EN 14511) = 21.1 to 86.7 kW,

Active cooling power, B35W7 (As per EN 14511) = 22.3 to 90.3 kW,
Max. DHW temperature without support = 60 Deg C

<u>Consumption Range</u>
Maximum consumption, B0W35= 20.3kW / 31.8 A As per EN 14511, including circulation pumps and Inverter.

Maximum consumption, B0W55= 29.6kW / 45.1 A As per EN 14511, including circulation pumps and Inverter.

Range of performance for Heat Pumps –
Heating COP: Brine 0 / W 35: 4.5,
Cooling EER: Brine 35 / W 7: 4.6
Either data curve or modulation curve needs to be provided. (Mandatory)

20.13 Circulating Pumps

The pump is **canned-rotor type** design. This also means that pump and motor form an integral unit without shaft seal and with only two gaskets for sealing. The bearings are lubricated by the pumped, single-phase pump and characterised by having the controller and control display integrated in the control box. The pump also has a built-in differential-pressure and temperature sensor.

Circulator Pump DN 40 or 65 Flanged Connection, Multiple settings for Constant Speed, Constant Pressure and Proportional Pressure, capable of handling System Pressure of 6/10/16 BAR,

Liquid Temperature (-10Deg C up to +110 Deg C), complete with TFT Control, working Voltage 230 Volts AC having Three digital inputs, Two output relays & One analog Input for External Sensor.

Pumped liquid: Water / Brine, Liquid temperature range: (-)10 to 110 °C, Density: 983.2 kg/m³, Pump housing: Cast iron (EN-GJL-250 / ASTM A48 -250B / equivalent),

Impeller: Glass Fiber reinforced Polyether Sulfone (PES 30% GF), Range of ambient temperature: 0 to 40 °C Maximum operating pressure: 10 Bar, Flange standard: DIN,

Pipe connection: DN 40 or 65, Pressure rating: PN6/10/16 (@): 340 mm, Power rating: 15 to 800 W (Approx.), Mains frequency: 50 Hz, Rated voltage: 1 x 230 V,

Pumps shall be suitable to operate at 220 ± 10% volts, 50 Hz, single phase AC supply, connections of three digital inputs, two output relays & one analog Input for external Sensor and TFT display for monitoring.

No separate BMS (Building Management System need to be planned, but Energy manager & Supervisor must be planned in the cascade)

20.14 Buffer Tanks

Single or double Coil tanks Volume (l) to be designed as per building requirement.

Max. Working Pressure (bar) 8, Manufactured in Stainless steel, thermally insulated with rigid, injected, HCFC-free polyurethane foam.

Outer finishing semi-rigid PVC in AISI 316 stainless steel designed with Flexible corrugated spiral coil with optimum contact surface and better heat transfer.

Thermal insulation in rigid foam of HCFC-free injected polyurethane and exterior finish in semi-rigid PVC. Heat Transfer Surface area based on capacity.

20.15 Drilling Vertical Borehole & Trenching

Borehole drilling by double head machine with simultaneous intubation or by rotation and direct circulation or by ODEX- 155-170 mm dia.
Casing or Guiding Pipes shall be 150mm
Shank spacing should be around 120-132mm
Trench for Horizontal Piping: trench of 1 meter in width and 1.2 meter in depth or as per design (depending on Frost line depth in cold climates) for HDPE pipe laying is required to be provided.

The critical item here is to ensure the surface pipework is encased in sand or round pea gravel **or ensure that there is no damage to pipes laid horizontally.**

Ideally 100mm below and 100mm above the pipework as a minimum. This is to ensure no damage during the backfill process. When backfilling is important that sharp material (broken stones or other) is avoided in close proximity to the pipework. If the sand/gavel bed thicker this is best. Once the pipe is in the sand bed, the material excavated for the trench can be used again for filling in.

20.16 Antifreeze

Propylene glycol Food Grade with water to complete brine circuit in the system. Freezing point shall be demonstrated with a Refractometer for the brine and design parameters based on climate.
Due to environmental reasons Ethylene glycol shall not be permitted as Antifreeze.

Circulation System must be able to handle the density/viscosity. The System must be able to maintain “flow and Return” under the freezing conditions. The Pipes must not “burst”.

20.17 Chilled/Hot Water Piping

All piping for Hot / chilled water shall be of PPR pipes. They are used for connections and they can be used in any type of transitions.
There are fittings with metal parts for connections with the threaded pieces on the line.

20.18 Testing & Balancing

(i) All piping shall be tested to hydrostatic pressure of at least 2.5 times the maximum operating pressure, but not less than 3-4 kg/sq. cm for a minimum period of 24 hours.

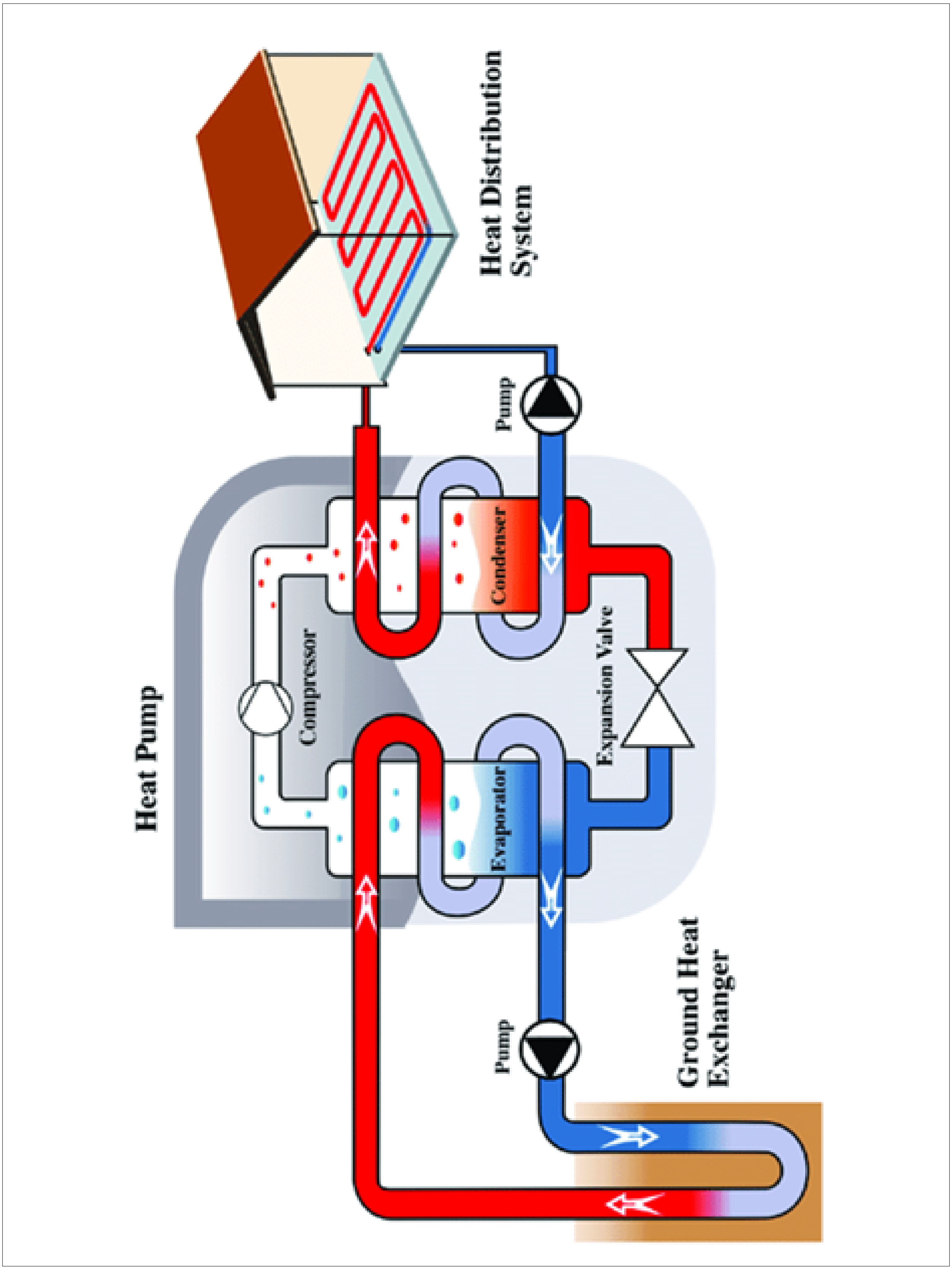
(ii) All leaks and defects in joints revealed during the testing shall be rectified and gotten approved at site.

(iii) Piping repaired subsequent to the above pressure test shall be re-tested in the same manner.

(iv) The Contractor shall make sure that proper noiseless circulation of fluid is achieved through all coils and other heat exchange equipment in the system concerned. If proper circulation is not achieved due to air bound connection, the Contractor shall rectify the defective connections.

(v) A test run for at least 24 – 48 hours after completion of installation has to be performed to check any leaks in the system.

Ground Source Heat Pumps



CHAPTER-21

ADIABATIC COOLING SYSTEM

21.1 About

Adiabatic cooling systems remove heat by evaporating water in a stream of warm, dry (low humidity) air. In the process of going from a liquid to a gas, the evaporated water simultaneously humidifies and cools the air stream to within a few degrees of the wet bulb temperature.

21.2 Skid with Pumps & Valves:

The Skid should have pipe and necessary fittings to connect the 5 Level of Water Treatment & Purification System (ie. Side Screen Filer with Automatic Backwash Control Technology, Bio Filter, Water Filter, Inline Scale Preventer Device & Water Sterilizer) inbuilt in the system to ensure mist nozzle does not get choked. The valves used shall be of actuator/solenoid type with minimum IP54 protection & NEMA –II protection. The valve should be suitable to work in high humid environment up to 95% (Non-condensing) RH. All fasteners shall be of high-tension grade 9.8, 10.9, 12.9. Pumps shall be imputed to boost water upto 150 Bars. The proposed system should be manufactured and complied with ISO 14001:2015, ISO 9001:2015. The system must be CE + RoHS compliant and in accordance with UL standards.

21.3 Control Panel:

The Control Panel should be PLC based with LCD Display. The touch display should show circuit wise running along with pump running and off condition. The alarms and faults shall be indicated on the screen in case of any issue in operation. Display must be 7” Touch type, graphical presentation, and with multi-level security passwords with defined functional authorities. The Controller shall have Adaptive Algorithm Control Logic for Multimode operation by sensing Ambient Temperatures & RH. The Display shall have Service/Preventive Maintenance Alerts. The System shall Controls Water Supply and Reduces the water wastage. The water consumption should not be more than 1.4 L/TRH.

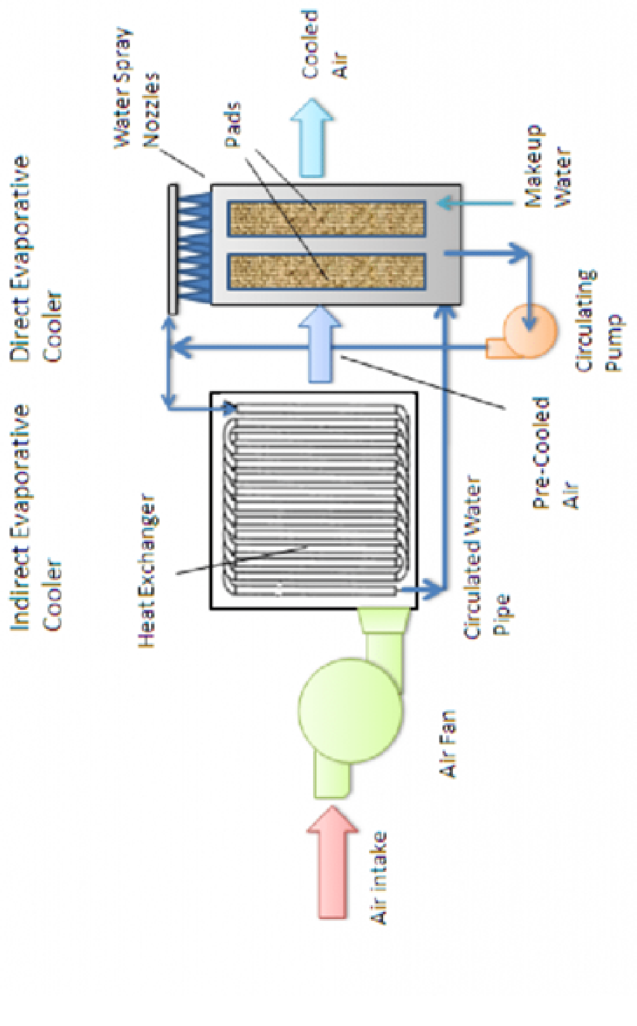
21.4 Air Screen Filter:

Chiller protection is one of the most important elements. Air Screen Filter should provide full condenser protection from limescale (calcium and mineral deposit) formation, rust and direct sunlight. It also protects cooling equipment condensers and compressors from overheating. It also enables the operation of cooling equipment in extreme environments, where ambient air temperatures reach as high as 54ºC. It should not have pressure drop more than 20 Pa max

21.5 Panel & Nozzle:

Panels with misting nozzles shall be mounted externally in front of a condenser. Micro nozzles should create a mist wall. The mist should be sprayed in front of the condenser, the mist should come into contact with hot air and shall evaporate instantly. Water that has not instantly evaporated should settle on the air screen filter and should continue to evaporate. When the water evaporates, the temperature of the condenser intake air is should be lowered as per the system design. The cooled air should then be fed into the condenser.

Adiabatic Cooling



CHAPTER-22
INDOOR AIR QUALITY

22.1 Indoor air quality (IAQ) refers to the types and concentrations of contaminants in indoor air that are known or suspected to affect people's comfort, well-being, health, learning outcomes and work performance. Primary classes of these contaminants include particulate matter (both biological, including allergens, potential pathogens, and non-biological), organic gases (e.g., volatile and semi-volatile organic compounds), and inorganic gases (e.g., carbon monoxide, ozone, and nitrogen oxides). Other factors contributing to IAQ include water vapor and odors. Indoor concentrations of contaminants are influenced by outdoor concentrations, ventilation and infiltration, indoor emissions, and a number of other contaminant-specific sources and sink mechanisms (e.g., deposition, chemical reactions, and air cleaning).

22.2 **Recommended Indoor Air Quality levels :**
The minimum indoor air quality para meters shall be as given below (as per WHO air quality guidelines 2021)

TABLE 22.1

Pollutant	**Average time**	**Air quality Level (minimum)**
$PM_{2.5}$, µg/m^3	Annual	5
	24- hour[a]	15
PM_{10}, µg/m^3	Annual	15
	24- hour[a]	45
O_3, µg/m^3	Peak season[b]	60
	8- hour[a]	100
NO_2, µg/m^3	Annual	10
	24- hour[a]	25
SO_2, µg/m^3	24- hour[a]	40
CO, mg/m^3	24- hour[a]	4
CO2 ppm	-	Ambient Plus 350
TVOC (equivalent to Isobutylene) µg/m^3	-	<200

[a] 99th percentile (i.e. 3-4 exceedance days per year)
[b] Average of daily maximum 8-hour mean O_3 concentration in the six consecutive months with the highest six-month running-average O^3 concentration.

22.3 **Testing Method of Indoor air quality parameters**
The sampling and testing of various indoor air quality parameter as defined in table above shall be carried out as per ISO: 16000 (Part 1 to 34) and ISO 13964 for ozone.

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CHAPTER 23
LIST OF APPENDIXES

APPENDIX –A TERMINOLOGY
(Clauses1.1.3)

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. **Air System Balancing :**
   Adjusting air flow rates through air distribution system devices, such as fans and diffusers, by manually adjusting the position of dampers, splitter vanes, extractors, etc, or by using automatic control devices, such as constant-air-volume or variable-air-volume (VAV) boxes.

3. **Atmospheric Pressure:**
   The pressure of air exerted on the surface of earth by the atmospheric column is called atmospheric pressure. At sea level, the atmospheric or barometric pressure is 760mm column of mercury (29.92 in Hg/ 406.8 inch water column/ 101.325 Kpa).

   Generally atmospheric pressure is used as a datum for indicating the system pressures in air-conditioning and accordingly, pressures are mentioned above the atmospheric pressure or below the atmospheric pressure considering the atmospheric pressure to be zoro. A `U' tube manometer will indicate zero pressure when atmospheric pressure is measured.

4. **Buildings Related Illnesses (BRI) :**
   BRI are attributed directly to the specific air-borne building contaminants like the outbreak of the legionnaire's disease after a convention and sensitivity pneumonitis with prolonged exposure to the indoor environment of the building.

5. **Building Energy Simulation :**
   Use of computer 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

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

7. **Building Management System (BMS) :**
   An energy management system relating to the overall operation of the building in which it is installed. It often has additional capabilities, such as equipment monitoring, protection of equipment against power failure, and building security. It may also be a direct digital control (DDC) system where the mode of control uses digital outputs to control processes or elements directly.

   NOTE — Mechanical and electrical equipment installed in the building, such as, air conditioning, ventilation, lighting, lifts, power, pumping stations, fire fighting systems, security systems are controlled and managed through BMS.

8. **Coefficient of Performance, Compressor, Heat Pump:**
   Ratio of the compressor heating effect (heat pump) to the rate of energy input to the shaft of the compressor, in consistent units, in a complete heat pump, under designated operating conditions

9. **Coefficient of Performance, Compressor, Refrigerating :**
   Ratio of the compressor refrigerating effect to the rate of energy input to the shaft of the compressor, in consistent units, in a complete refrigerating plant, under designated operating conditions.

10. **Coefficient of Performance (Heat Pump):**
    Ratio of the rate of heat delivered to the rate of energy input, in consistent units, for a complete operating heat pump plant or some specific portion of that plant, under designated operating conditions.

11. **Coefficient of Performance (Refrigerating):**
    Ratio of the rate of heat removal to the rate of energy input, in consistent units, for a complete refrigerating plant or some specific portion of that plant, under designated operating conditions.

12. **Cooling Load :**
    Amount of cooling per unit time required by the conditioned space or product; or heat that a cooling system shall remove from a controlled system over time.

13. **Cooling Tower :**
    An enclosed device, often tower like, for evaporative cooling water by contact with air.

14. **Dry-Bulb Temperature:**
    The temperature of air as registered by an ordinary thermometer.

15. **Dew point Temperature :**
    The temperature at which condensation of moisture begins when the air is cooled at same pressure.

16. **Duct system:**
    A continuous passageway for the transmission of air which in addition to the ducts, may include duct fittings, dampers, plenums and grilles & diffusers.

17. **Dedicated Outdoor Air System (DOAS) :**
    A unit that is used to separately condition outdoor airbrought into the building for ventilation or to replace air that is being exhausted.

18. **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.

19. **Design Pressure Difference:**
    The desired pressure difference between a given space and an adjacent space measured at the boundary of the given space under a specified set of conditions, such as, that required

in various spaces of hospital, clean rooms, protected space in case of smoke control operation, etc.

20. Evaporative air cooling :

The evaporative air-cooling application is the simultaneous removal of sensible heat and the addition of moisture to the air. The water temperature remains essentially constant at the wet-bulb temperature of the air. This is a process in which heat is not added or removed from the air.

21. Enthalphy :

A thermal property indicating the quantity of heat in the air above an arbitrary datum in kilo joules per kg of dry air (or in Btu per pound of dry air).

22. 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.

23. Economizer, Water :

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

24. 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.

25. Energy Efficiency Ratio (EER) :

Ratio of net cooling capacity in BTU/h to total rate of electric input in watts under designated operating conditions.

26. Energy Recovery Unit :

A heat exchanger assembly for transferring energy between two isolated fluid sources. The recovery system may be of air-to-air design or a closed loop hydronic system design. The system will include all necessary equipment, such as fans and pumps, associated ducts or piping and all controls (operating and safety), and other custom- designed features.

27. Fire cum Smoke Dampers :

A smoke damper is similar to fire damper. However, it closes automatically on sensing presence of smoke and heat in air distribution system or in conditioned space.

28. 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.

29. Fire separation wall :

The wall provides complete separation of one building from another or part of a building from another part of the same building to prevent any communication of fire of any access or heat transmission to wall itself which may cause or assist in the combustion of materials of the side opposite to that portion which may be on fire. . Fire dampers installed in assemblies having a fire-resistance rating of less than 3 hours shall have an hourly fire-protection rating of 1-1/2 hours. Fire dampers installed in assemblies having a fire-resistance rating of 3 hours or greater shall have an hourly fire-protection rating of 3 hours.

30. Global Warming Potential (GWP) :

Global Warming can make our planet and its climate less hospitable and more hostile to human life. It is, therefore, necessary to reduce emission of green house gases such as Co2, Sox, Nox and refrigerants. The potential of a refrigerant to contribute to Global Warming is called its GWP. Long atmospheric life time of refrigerants results in Global Warming unless the emissions are controlled.

31. Geothermal Heat Pump :

A heating and/or cooling system utilizes the earth's crust, as heat source (in the winter) or a heat sink (in the summer) by using fluid to be pumped into the earth and circulated in order to exchange heat for the purpose of heating or cooling applications.

32. Heating Load :

Heating rate required to replace heat loss from the space being controlled.

33. Heat Pump :

A thermodynamic heating/ refrigerating system to transfer heat. The condenser and evaporator may change roles to transfer heat in either direction. By receiving the flow of air or other fluid, a heat pump is used to cool or heat. Heat pumps may be the air source with heat transfer between the indoor air stream to outdoor air or water source with heat transferbetween the indoor air stream and a hydronic source (ground loop, evaporative cooler, cooling tower, or domestic water).

34. Heat Recovery :

Use of heat that would otherwise be wasted from a system or process, for example, heat-recovery chiller which uses hot waste gases as a heat source.

35. 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).

36. Hydronic Systems :

The water systems that transfer 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.

37. Humidity :

It is the amount of water vapour present in a certain volume of air.

38. Hydronic Systems :

Water systems that convey heat to or from a conditioned space or process with hot or chilled water are frequently called hydronic systems. 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.

39. Hydronic System Balancing :

Adjusting water flow rates through hydronic distribution system devices,such as pumps and coils, by manually adjusting the position valves or by using automatic control devices, such as automatic flow control valves.

40. Indirect-Direct Cooling :

The cooling which involves the following two stages:

(i) 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; and

(ii)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.

41. Infiltration/Exfiltration :

The phenomenon of air leaking into (infiltration) or leaking out (exfiltration) out of an air conditioned space

42. **Indoor Air Quality (IAQ)** :

Indoor air quality refers to the nature of conditioned air that circulates throughout the space/ area where one works or lives, i.e. the air we breath when we are indoors. IAQ refers not only to comfort which is affected by temperature, humidity and odours but also to harmful biological contaminants and chemicals present in the conditioned space.

Bad Indoor Air Quality can be a serious health hazard. Carbon dioxide (CO_2) has been recognized by ASHRAE as the surrogate ventilation index or the only measurable variable for the indoor air contaminants.

43. Latent Heat :

Change of enthalpy during a change of state, usually expressed in kcal/kg. With pure substances, latent heat is absorbed or rejected at constant temperature at any pressure.

44. Latent Heat Load :

Cooling load required to remove latent heat.

45. **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.

46. 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.

47. 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.

48. **Ozone Depletion Potential (ODP)** :

The potential of refrigerant or gasses to deplete the Ozone in the atmosphere is called ODP.

49. 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.

50. 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 by using natural ventilation, air cooling and shades.

51. 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.

52. Plenum :
An air compartment connected to one or more distributing ducts.

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

54. Psychrometric Chart :
A chart graphically representing the thermodynamic properties of moist air.

55. Psychrometry :
Psychrometry is the science involving thermo dynamic properties of moist air and the effect of atmospheric moisture on materials and human comfort. It also includes methods of controlling thermal properties of moist air.

56. Psychrometric Chart :
A Psychrometric chart graphically represents the thermodynamic properties of moist air. If two properties are known, all the other properties can be determined with the help of psychrometric chart.

57. Positive Ventilation :
The supply of outside air by means of a mechanical device, such as a fan. Plenum

An air compartment or chamber to which one or more ducts are connected and which forms part of an distribution system.

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

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

60. Relative Humidity :
Ratio of the actual water vapor in the air as compared to the maximum amount of water that may be contained at its dry bulb temperature. When the air is saturated, dry bulb, wet bulb and dewpoint temperatures are all equal.

61. Return Air :
The air that is collected from the conditioned space and returned to the conditioning equipment is termed as return air.

62. Re-Circulated Air :
The return air that has been passed through the conditioning apparatus before being re-supplied to the space is called re-circulated air.

63. Sick Building Syndrome (SBS) :
SBS is a term, which is used to describe the presence of acute non-specific symptoms in the majority of people caused by working in buildings with an adverse indoor environment. It could be a cluster of complex irritative symptoms like irritation of the eyes, blackened nose and throat, headaches, dizziness, lethargy, fatique irritation, wheezing, sinus, congestion, skin rash, sensory discomfort from odours, nausea, etc. These symptoms are usually short-termed and experienced immediately after exposure, and may disappear when one leaves the building.

64. Sensible Cooling :
The process of removing sensible heat (lowering the dry-bulb temperature) from the air passing through it under specified conditions of operation.

65. 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.

66. Smoke Management :
A smoke control methodthat utilizes natural or mechanical systems to maintain a tenable environment for the means of egress from a large-volume space or to control and reduce the migration of smoke between the area on fire and communicating spaces.

67. 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.

68. 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.

69. Shade factor :

The ratio of instantaneous heat gain through the shading device to that through a plain glass sheet of 3mm thickness.

70. Sensible heat factor (SHF) :

Sensible heat factor is the ratio of sensible heat to total heat, where total heat is the sum of sensible and latent heat.

71. Supply Air :

The air that has been passed through the conditioning apparatus and taken through the duct system and distributed in the conditioned space is termed as supply air.

72. **Supply and Return Air grilles & Diffusers** :

Grilles and diffusers are the devices fixed in the air-conditioned space for distribution of conditioned supply air and return of air collected from the conditioned space for re-circulation.

73. Smoke damper :

A smoke damper is similar to fire damper. However, it closes automatically on sensing presence of smoke in air distribution system or in conditioned space.

74. Thermal Transmittance :

Thermal transmission through unit area of the given building unit divided by the temperature difference between the air or some other fluid on either side of the building unit in `steady state' conditions.

75. Thermal Energy Storage :

Storage of `Cold Energy' sensible, latent or combination for use in central system for air-conditioning or refrigeration is called thermal energy storage. It uses a primary source of refrigeration for cooling and storing `Cold Energy' for reuse at peak demand or for backup as planned.

76. Terminal Devices :

Devices fixed in the air conditioned space for distribution of conditioned supply air and return of air such as, supply and return air grilles and diffusers.

77. **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.

78. Thermal Comfort :

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

79. Thermal Insulation Material :

A material used over the conducting material 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.

80. Velocity Pressure :

The pressure exerted by movement of air which makes the air to travel to longer

81. Variable Refrigerant Flow (VRF) System :

A heating and/or cooling system in which the flow of the refrigerant can be varied according to the load.

82. Water Treatment :

The treatment of water circulating in a hydronic system, so that it can be used without creating undue corrosion or scaling to the piping systems and other deleterious effects.

83. Water conditioning :

Water circulating in a hydronic system may require to be treated to make it suitable for air-conditioning system due to its effect on the economics of air-conditioning plant. Unconditioned water used in air-conditioning system may create problems with equipments such as scale formation, corrosion and organic growth.

84. Wet-Bulb temperature :

The temperature registered by a thermometer whose bulb is covered by a wetted wick and exposed to a current of rapidly moving air.

85. Indian Seasonal Energy Efficiency Ratio (ISEER) :

Ratio of the total amount of heat that equipment can remove when operated for cooling in active mode to the total amount of energy consumed by equipment during the same period.

APPENDIX –B LIST OF RELEVANT INDIAN STANDARDS (Clauses1.2)

Sl.No.	IS Code	Year	Reaffirmed Year /Reviewed	Description
1.	I.S. 3615	2020	-	Glossary of Terms Used in Refrigeration & Air Conditioning.
2.	I.S. 3624	1987	2018	Bourden Tube Pressure and Vacuum Gauges
3.	I.S. 7403	1974	2018	Code of practice for selection of standard worm and helical gear boxes
4.	I.S. 996	2009	2019	Single phase small A.C. and Universal motors
5.	I.S. 1239	2004	2014, 2019, 2021	Mild steel tubes, tubular and other wrought steel fittings
6.	I.S. 3589	2001	2022	Electrically welded steel pipes for water, gas and sewage
7.	I.S. 6392	2020	-	Steel pipe flanges
8.	I.S. 778	1984	2020	Copper Alloy gate, globe and check valves for general purpose
9.	I.S. 277	2018	2022	Galvanized steel sheets
10.	I.S. 737	2008	2018	Wrought aluminum and aluminum alloy sheet and strip for general engineering purposes.
11.	I.S. 655	2006	2022	Specification of Air ducts
12.	I.S. 732	2019	-	Code of Practice for Electrical Wiring Installations
13.	I.S. 900	2019	-	Code of Practice for Storage, Installation and Maintenance of Induction Motors
14.	I.S. 1248	2021	-	Direct acting indicating analogue electrical measuring instruments and their accessories.
15.	I.S. 1554 (Part-I)	1988	2020	PVC insulated (heavy duty) electric cables: Part 1 for working voltage upto and including 1100 volts
16.	I.S. 1554 (Part-II)	1988	2020	PVC Insulated (Heavy Duty) Electric Cables - Part 2 : for Working Voltages from 3"3 kV up to and Including 11 kV
17.	I.S. 8183	2024	-	Bonded Mineral Wool - Specification
18.	I.S. 4671	2018	-	Specification for expanded polystyrene for thermal insulation purposes.
19.	I.S. 11561	2018	2022	Code of practice for testing of Water cooling towers.
20.	I.S. 7896	2023	-	Air Conditioning Outdoor Design Conditions Data For Indian Cities.
21.	I.S. 8148	2018	2022	Ducted and Packages air conditioners
22.	I.S. 2370	2014	-	Walk-in Cold Rooms - Specification
23.	I.S. 5111 (ISO 917 : 1989)	1993	2022	Testing of refrigerant compressors
24.	I.S. 10594	2021	-	Thermostatic Expansion Valve

25.	IS 12615	2018	-	Line Operated Three Phase a.c. Motors (IE CODE) "Efficiency Classes and Performance Specification
26.	IS/ISO 817	1966	2019	Code of practice for training and testing of metal arc welders
27.	IS 8188	1999	2020	Reviewed in 2020) Code of practice for treatment of water for cooling towers
28.	IS 1391(Part 1)	2023	-	Specification for Room Air conditioners : Unitary air conditioners
29.	IS 1391 (part 2)	2023	-	Specification for Room Air conditioners: Split air conditioners
30.	IS 12976	2023	-	Code of practice for solar water heating systems.
31.	IS 3103	1975	2018	Code of practice for industrial ventilation.
32.	IS 4831	2019	-	Recommendation on units and symbols for refrigeration
33.	Is 2312	1967	2020	Specs for Propeller type AC ventilating fans
34.	IS 4736	1986	2021	Hot Dip Zinc coatings on Mild steel tubes
35.	IS 3588	1987	2014	Spec for electrical Axial flow fans
36.	IS 4894	1987	2019	Specification for centrifugal pumps
37.	IS: 5111/ ISO : 1999	1993	2022	Testing of refrigerant compressors
38.	IS 732	2019	-	Code of practice for electrical wiring installations
39.	IS 3043	2018	-	Code of practice for earthing
40.	IS 1255	1983	2016	Code of practice for installation and maintenance of power cables up to and including 33 kV rating
41.	IS 10773	1995	2021	Wrought copper tubes for refrigeration and air - Conditioning purposes - Specification
42.	IS 4759	1996	2021	Hot - Dip zinc coatings on structural steel and other allied products - Specification
43.	IS 2629	1985	2021	Recommended practice for hot-dip galvanizing of iron and steel
44.	SP 7	2016		National Building code of India – 2016
45.	ECBC 2017	2017		Energy Conservation Building Code of India
46.	SP 30	2023		National Electrical Code of India (NEC)
47.	CEA Authority (Measures relating to Safety and Electric Supply Regulations, 2022)	2023		Central Electricity Authority (Measures relating to Safety and Electric Supply Regulations, 2022)
48.	IS 3069	2020	-	Glossary of Terms, Symbols and units relating to thermal insulation Materials
49.	IS 661	2019	-	Thermal Insulation of Cold Storage — Code of Practice
50.	IS 14164	2008	2019	Industrial application and finishing's of thermal insulation materials at temperatures

				above -80°c and up to 750°c - code of practice
51.	IS 13095	2020	-	Butterfly valves for general purposes.
52.	IS : 5312	2004	2019	Swing Check Type Reflux (Non-Return] Valves for Water Works Purposes
53.	IS 3950	1979	2022	Specification for surface boxes for sluice valves.
54.	IS: 12992 (part - 1)	1993	2018	Safety relief valves, spring loaded design.
55.	IS : 3483	1965	2020	Code of practice for noise reduction in industrial buildings.
56.	IS: 8418	1999	2019	Specification for horizontal centrifugal self-priming pumps.
57.	IS 12615	2018	-	Line Operated Three Phase a.c. Motors (IE CODE) "Efficiency Classes and Performance Specification
58.	IS 966	2023	-	Desiccated Coconut – Specification
59.	IS 17570 (Part 1 to 4)	2021	-	Air Filter for general Ventilation
60.	ISO: 16000 (Part 1 to 34)	2021	-	Indoor Air Quality
61.	ISO 13964	1998	1998	Air quality — Determination of ozone in ambient air — Ultraviolet photometric method
62.	IS : 9842	2024	-	Preformed Fibrous Pipe Insulation - Specification
63.	IS/IEC 61439 (Part 1-7)	2020	-	Low voltage switchgear and control gear assemblies
64.	IS : 3961		2021	Recommended current rating of cables
65.	IS : 1079	2017	2022	Hot rolled carbon steel sheets
66.	IS : 513	2016	2021	Cold reduced low carbon sheet
67.	IS : 5504	1997	2018	Spirally welded pipes
68.	IS : 13114	1991	2022	Forged brass gate, globe and check valves
69.	IS : 10221	2008	2021	Code of practice for coating & wrapping of underground mild steel pipes
70.	IS : 10617	2018	2022	Hermetic compressors
71.	IS : 11329	2018	2022	Finned type heat exchangers for room ac
72.	IS : 16656 (ISO 817 : 2014)	2017	2001	Refrigerants - defenitions & safety classifications
73.	IS 16678 (Part 1 to 4) (ISO 5149 (part 1 to4) : 2014)	2018	2022	Refrigeration systems and heat pumps -safety and environmental requirements
74.	IS : 3315	2019	-	Specification for evaporative Air coolers (desert coolers)
75.	IS: 12976	2023	-	Code of practice for solar Water heating systems
76.	IS 16590	2023	-	Liquid chilling package units-specification
77.	IS 16590	2017	2022	Water cooled chilling packages using the vapour compression cycle — specification

78.	ASTM C 578			Standard Specification for Rigid, Cellular Polystyrene Thermal Insulation
79.	ASTM D 1248			Standard Specification for Polyethylene Plastics Extrusion Materials for Wire and Cable1
80.	NFPA 13			Standard for the installation of sprinkler systems
81.	NFPA 72			National fire alarm signaling code
82.	NFPA 90 A			Standard for the installation of air conditioning and ventilation systems
83.	NFPA 92			Standard for smoke control systems
84.	NFPA 92A			Standard for smoke control using barriers and pressure differences
85.	NFPA 96			Standard for ventilation control and fire protection of commercial cooking operations
86.	ASHRAE 52			Filter testing standard 52
87.	ASHRAE			Standards and handbooks
88.	ASHRAE 52.2			Method of cleaning general ventilation air cleaning devices for removal efficiency by particle size
89.	ASHRAE 62.1			Ventilation for acceptable indoor air quality
90.	ASHRAE 90.1			Energy standard for buildings
91.	ASHRAE 189.1			Standard for design of high performance buildings
92.	ASHRAE 170			Ventilation of health care facilities
93.	ASHRAE 55.1			Thermal environment conditions for human occupancy
94.	ISHRAE	2017		HVAC Data book
95.	IS: 13621	1998	2021	Sound power rating of air - Conditioning and air - Source heat pump equipment
96.	IS: 1475	2001	2022	Self - Contained drinking water coolers – Specification
97.	IS : 16753	2022	-	High Efficiency Filters and Filter Media for removing Particles from Air
98.	IS : 17584	2022	-	Refrigerant properties
99.	IS: 7872	2020	-	Deep Freezers- Specification

APPENDIX – C I.S. SAFETY CODES
(Clauses1.3, 18.1.4)

I.S. 660	Safety Code for Mechanical Refrigeration
I.S. 659	Safety Code for air conditioning
I.S. 3016	Code of Practice for Fire precautions in welding and cutting operations
I.S. 818	Code of practice for safety and health requirements in electrical and gas and cutting operations.
IS. 5216	Code for safety procedure and practice in electrical works
I.S. 3696	Safety code for scaffolds and ladders

APPENDIX –D HEAT LOAD CALCULATION PROFORMA (Clauses1.1.5)

Name Of Job ______________________ ____Location ____

Space used for						
Sizes X =		sq.ft X =		Cu Ft		
ITEM	ARE OR QUANTITY	SUN GAIN OR TEMP. DIEF.		FACTOR		BTU / HOUR
SOLAR GAIN – GLASS						
GLASS	Sq. FT	x		x		
GLASS	Sq. FT	X		X		
GLASS	Sq. FT	X		X		
GLASS	Sq. FT	X		X		
SKYLIGHT	Sq. FT	X		x		
SOLAR & TRANS. GAIN – WALLS & ROOF						
WALL	Sq. FT	X		X		
WALL	Sq. FT	X		X		
WALL	Sq. FT	X		X		
WALL	Sq. FT	X		X		
ROOF-SUN	Sq. FT	X		X		
ROOF-SHADED	Sq. FT	X		X		
TRANS. GAIN – EXCEPT WALLS & ROOF						
ALL GLASS	Sq. FT	X		X		
PARTITION	Sq. FT	X		X		
CEILING	Sq. FT	X		X		
FLOOR	Sq. FT	X		X		
INFILTRATION	CFM	X		X		
INTERNAL HEAT						
PEOPLE	PEOPLE			X		
POWER	HP OR KW			X		
LIGHTS	WATTS	X	3.4	X		
APPLIANCES ETC				X		
ADDITIONAL HEAT GAINS				X		
SUB TOTAL						
STORAGE	Sq. FT	X		X	(-)	
SUB TOTAL						
SAFETY		%				
ROOM SENSIBLE HEAT						
SUPPLY DUCT HEAT GAIN	SUPPLY DUCT %+LEAK LOSS	FAN %+H.P %				
OUTDOOR AIR	CFMX	FX	BFX 1.08			
EFFECTIVE ROOM SENSIBLE HEAT						
LATENT HEAT						
INFILTRATION	CFM	X	GR/LB X 0.68			
PEOPLE	PEOPLE	X				
STEAM	LB/ HR	X	1050			
APPLIANCES ETC						
ADDITIONAL HEAT GAINS						
VAPOR TRANS	SQ.FTX	1/100X	GR/LBX			
			SUB TOTAL			
SAFETY FACTOR	%					
			ROOM LATENT HEAT			
SUPPLY DUCT LEAKAGE LOSS	%					
OUTDOOR AIR	CFMX	GR/LBX	BFX 0.68			
			EFFECTIVE ROOM LATENT HEAT			
EFFECTIVE ROOM TOTAL HEAT						
OUTDOOR AIR HEAT						
SENSIBLE	CFMX	FX (1-	BF) X 1.08			
LATENT	CFMX	FX (1-	BF) X 0.68			
			SUB TOTAL			
RETURN DUCT HEAT GAIN	RETURN DUCT %+LEAK GAIN	HP %+ PUMP	DEHUM & %+PIPE LOSS %			
			GRAND TOTAL HEAT			

ESTIMATE FOR	LOCAL TIME SUN TIME		PEAK LOAD	LOCAL TIME SUN TIME		
HOURS OF OPERATION						
CONDITIONS	DB	WB	%RH	DP	GR/ LB	
OUTDOOR (OA)						
ROOM (RM)						
DIFFERENCE						
VENTI-LATION	PEOPLE	X		CFM/ PERSON	=	
	DOORS	X		CFM/ DOORS	=	
				CFM VENTILATION		
INFIL-TRAT-ION	SWINGING REVOLVING					
	DOORS	PEOPLE	X	CFM /PERSON	=	
	OPEN DOORS	DOORS	X	CFM/ DOORS	=	
	EXHAUST FAN					
	CRACK	FEET	X	CFM/ FT	=	
				CFM INFILTRATION		
	CFM OUTDOOR AIR THRU APPARATUS				CFM OA	
APPARATUS DEWPOINT						
ESHF	EFFECTIVE SENS HEAT FACTOR =	EFECTIVE ROOM SENSNHEAT / EFFECTIVE ROOM TOTAL HEAT =				
ADP	INDICATED ADP=______F	SELECTED ADP=	______________F			
DEHUMIDIFIED AIR QUANTITY						
TEMP. RISE	(1-________BF) X (Trm____ __F – Tadp_______F) =		___________F			
DEHUM CFM	EFFECTIVE ROOM SENS. HEAT = / 1.08 X ________F temp rise		__ __________ CFMda			
OUTLET TEMP. DIEF.	ROOM SENS. HEAT = / 1.08 X _____________ CFMda		________F (rm outlet air)			
SUPPLY AIR QUANTITY						
SUPPLY CFM	ROOM SENS. HEAT = / 1.08 x___________Fdesired diff		___________CFMsa			
BYPASS CFM	_______CFMsa - ____________CFMda=		___________CFMba			
RESULTING ENT & LVG CONDITIONS AT APPARATUS						
EDB	Trm____F + ___CFMda / CFM X (Toa___F – Trm____F)=		Tedb______F			
LDB	Tadp____F + ___BF X(Tedb____F – Tadp___F) =		Tldb ______F			
	FROM PSYCH. CHART: Tewb_____F,Tlwb_____F					
NOTES						

APPENDIX – E
PROFORMA FOR SCHEDULE OF TECHNICAL PARTICULARS

(A) COMPRESSOR :

1. Manufacturer

2. Model

(a) Overall dimensions (mm)
(b) Weight (kg)
(c) Size of foundation
(d) Refrigerant
(e) Test pressure (max.) (kg./sq.cm)
(f) Maximum revaluations per minute
(g) Minimum revolutions per minute for proper lubrication
(h) Type of capacity control
(i) No. of steps of capacity control
(j) Capacity of the m/c at suction & condensing temperatures specified in Tender specification.

(k) B.H.P. consumption

At conditions	As per tender Specification	As per system offered
at 100% load		
Part load step I		
Part load step II		
Part load Step III		

(l) Crank case heaters
(i) Whether provided
(ii) Power rating (w)
(m) Type of drive arrangement
(n) No.of belts in case of V-belt drive
(o) Whether oil pump is provided
(p) Type of oil pump

<u>For Centrifugal units</u>

1. Manufacture
2. Model

3. Type

4. (a) Refrigerant
   (b) Weight of refrigerant per unit

5. Operating speed (RPM)
6. Type of drive and speed ratio
7. No. of impellers/ No. of stages

8. Output in TR and input power consumption in KW, at the selected operating conditions

% of Load TR	Input KW at 0.0002 (metric)	Input KW at ARI fouling

fouling factor for condenser   factors for condenser
& 0.0001 (metric) fouling and chiller factor for chiller

100% load
75 % load
60% load
50% load
40% load
25% load

9. Type of capacity control
10. Capacity control range
11. Type of lubrication
12. Material of bearing
13. Operating weight (Kg.)
14. Overall dimensions of the machine

15. Compressor motor

i) Make
ii) Rated output
iii) Working voltage range
iv) Type of enclosure
v) Class of insulation
vi) Speed
vii) Full load current
viii) Starting current
ix) Efficiency
x) Power factor
xi) Temperature rise over ambient of 45 deg C.

16. **List of Safeties/protection provided in the chiller unit (Whether provided)**

i) Motor over current
ii) Over voltage
iii) Under voltage
iv) Single cycle dropout/ intermitent power loss
v) Baring oil high temperature
vi) Low evaporator refrigerant temperature
vii) High condenser refrigerant pressure
viii) High motor temperature (For sealed/ semi hermetic chiller units only)
ix) Prolonged surge in compressor
x) Compressor starter faults
xi) Star-to-start and stop-to-stop timers for motor protection against rapid recycling
xii) Low lubricating oil pressure

17. Details of all the functions of Microprocessor control system are to be enclosed. Whether enclosed- Yes/ No.

(B) CONDENSER

1. Manufacturer
2. Shell dia (mm)
3. Type of fins, if any, in tubes
4. No. of passes
5. Water flow (L.P.M.)

6. Water velocity (M.P.S.)
7. Pressure drop at above velocity (M. of water)
8. Condensing Temp (deg C)
9. Tube material
10. Tube outside diameter (mm)
11. Tube thickness (mm)
12. Tube length (mm)
13. No. of tubes
14. Tube surface, inside (sq.m.)
15. Tube surface, outside (sq.m.)
16. **Water temperature :**

(i) entering –deg C
(ii) leaving – deg C

(C) CHILLER

1. Manufacturer
2. Type
3. Shell dia (mm)
4. Tube length (mm)
5. No. of tubes
6. tube material
7. Tube diameter (mm)
8. Tube surface inside (sq.m.)
9. Tube surface outside (sq.m.)
10. Type of fin
11. Refrigerant temp. (deg C)
12. No. of passes
13. Water flow (LPM)
14. Water velocity (MPS)
15. Pressure drop (M. of water)
16. Temperature of water :

(i) entering –deg C
(ii) leaving – deg C

(D) REFRIGERANT PIPING

1. Material for pipes
2. Pipe wall thickness (mm)
3. Material of fittings
4. Material of valves
5. Make of TX valve if provided
6. Make of refrigerant float if provided

(E) AIR HANDLING UNIT

1. **General**

(i) Manufacturer
(ii) Type of unit
(iii) Overall diamensions (mm)
(iv) Operating weight (including wt. Of water/ refrigerant in circulation (kg)
(v) Noise level

2. Material and thickness of drain pan

3. Fan Section :

(i) Manufacturer
(ii) Type of fan
(iii) Fan speed (RPM)
(iv) No.of fans
(v) Fan wheel diameter (mm)

4. Drive arrangement
5. No.of belts in case of belt drive
6. Material and thickness of fan wheel and blades
7. Material and thickness of housing
8. Fan outlet area (sq. m.)
9. Outlet velocity (MPM)
10. Total air quantity (CuM./ Min.)
11. Static pressure at outlet (mm of water)
12. Whether statically and dynamically balanced
13. Type of bearings.

14. Cooling Coil :

(i) Manufacturer
(ii) Type
(iii) Material of tubes
(iv) Material of fins
(v) Tube diameter
(vi) Tube thickness
(vii) Fin thickness
(viii) Method of bonding of tube and fins
(ix) No. of fins/ cm.
(x) No. of row deep
(xi) Total tube surface, outside (sq. m.)
(xii) Test pressure
(xiii) Coil face area
(xiv) Flow rate of water/ refrigerant (kg./Min. or L.P.M.)
(xv) Vol. Of water/ refrigerant through tube (MPS)
(xvi) No. of circuits
(xvii) Pressure drop in coil (Kg/ Sq/ cm. Of M. of water)

15. Air filters :

(i) Manufacturer
(ii) Type of medium
(iii) Filter medium
(iv) Material of frame work and its thickness (mm)
(v) Face area (Sq.m)
(vi) Face velocity across filters (MPS)
(vii) Pressure drop across filters (mm. of water)

16. Humidification arrangement :

(i) Type
(ii) Spray water rate (LPM)
(iii) Rating of spray pump, if provided (FHP)

(iv) Make and size of solenoid valve where provided
(v) Material of nozzles
(vi) No. of nozzles

17. Spray arrangement : (For sprayed coils only)
(i) Pump casing
(ii) Rating of spray pump
(iii) Rate of spray (LPM/ SQ.M. of coil face area)
(iv) Spray density
(v) Material of nozzles
(vi) No. of nozzles

18. Electric strip heaters
(i) Manufacturer
(ii) Type
(iii) Material of sheath
(iv) Material of fins
(v) Power rating (KW)

(F) COOLING TOWER :
1. Manufacturer
2. Type
3. Model
4. Overall dimensions (mm)
5. Weight with water (kg.)
6. No. of fans
7. CMH per fan
8. Outlet velocity (Mts. Per min)
9. Tip speed (Mts per min)
10. Drift loss (LPH)
11. Total water loss (LPH)
12. Approach to the design wet bulb (deg C)

(G) CENTRIFUGAL PUMPS :
(Give separate particulars for each application)
1. Manufacturer
2. Type
3. Model
4. Overall dimensions
5. Weight (Kg)
6. Size of foundations (mm)
7. Material :
(i) Pump casing
(ii) Impeller
(iii) Shaft
(iv) Shaft sleeve
(v) Base plate

8. Type of bearings
9. Type & material of seal
10. Speed (rpm)

11. Discharge (LPM)
12. Head (Mtr.)
13. Efficiency
14. Performance curves (whether enclosed with the tender)

(H) WATER PIPING :

1. Material for pipes
2. Material for fittings
3. Pipe wall thickness
4. Material for valves
5. Pressure gauges:

(i) Make
(ii) Range
(iii) Dial size

6. Flow meter type and make
7. Size of flow meter

(I) ELECTRICAL

1. Motors (Give separate particulars for each application)

(i) Manufacturer
(ii) Type and frame reference
(iii) Rated output (KW)
(iv) Range of working voltage (V)
(v) No. of phases
(vi) Rated frequency
(vii) Rated speed (RPM)
(viii) Full load current (amps)
(ix) Class of insulation
(x) Efficiency and power factor at the following loadings 100%, 75%, 50% 25% of
(xi) Rated full load.
(xii) Type of bearings

2. Motor starters (Give separate particulars for each application):

(i) Manufacturer
(ii) Type
(iii) Rating
(iv) Whether the following protections are provided –
(a) Over load
(b) Under voltage
(c) Single phase prevention (for 3 phase motor starters)

3. Switch board :

(i) Manufacturer
(ii) Type

4. Circuit Breaker

(i) Manufacturer
(ii) Type
(iii) Rated normal current (amps)
(iv) Short circuit ratting (MVA)

(v) Whether following are provided –
(a) O/L trip
(b) E/F trip
(c) Under voltage trip

5. Measuring Instruments :
(i) Manufacturer
(ii) Range
(iii) Dial size
(iv) Glass Index

6. Iron clad switch gears :
(i) Manufacturer
(ii) Make of HRC fuse provided

(J) CONTROLS :
1. Make and type of thermostats
2. Make and type of humidistats
3. Make and type of damper motor
4. Make and type of other control components

(K) DUCTING
1. Material
2. Manufacturer
3. Whether ducting is as per IS: 655

(L) INSULATION (For each application)
1. Manufacturer
2. Material and density
3. `K' value at 10 deg C mean temperature
4. Thickness.

APPENDIX– F
PROFORMA FOR TEST RESULTS & NOTES ON TEST INSTRUMENTS AND CAPACITY COMPUTATIONS

Sl. No.	Item	Test Results	
1.	Ambient conditions	D.B. Temp W.B.Temp %RH	- deg C - deg C
2.	Compressors	R.P.M Suction pressure Discharge pressure Oil pressure	 - Kg/sq.cm -Kg/sq.cm -Kg/sq.cm
3.	Compressor Motors	R.P.M. Voltage Current (i)at 100% load (ii) at partial load (a) (b) (c)	 - Volts - amps - amps - amps - amps
4.	Water Chillers	Water flow rate Water temperature Entering Leaving Water pressure Entering Leaving	- LPM - deg C - deg C -Kg/sq.cm -Kg/sq.cm
5.	Condensers	Water flow rate Water temperature Entering Leaving Water pressure Entering Leaving	- LPM - deg C - deg C -Kg/sq.cm -Kg/sq.cm
6.	Pumps	R.P.M. Motor current Discharge pressure Suction pressure	 -amps -Kg/sq.cm -Kg/sq.cm
7.	Cooling Towers	Water temperature Entering Leaving Wet bulb approach Fan motor current Fan motor voltage Fan motor R.P.M	 - deg C - deg C - deg C - amps - volts
8.	Air handling units	Total air quantity across coil Coil face area Air temperature	 - cu.m / min - Sq.m.

		Entering (D.B.) Entering (W.B.) Leaving (D.B.) Leaving (W.B.) Water pressure Entering Leaving Water temperature Entering Leaving Water flow rate	- deg C - deg C - deg C - deg C -Kg/sq.m -Kg/Sq.m - deg C - deg C - LPM
9.	Fresh air intakes	Face area Air quantity	- Sq.m - Cu.m/ min
10.	Room conditions at the working plane (No. of readings shall be taken and averaged out)	Temperature D.B. W.B.	 - deg C - deg C
11.	Controls	Function of each control shall be tested and report furnished	

NOTES

A. Test Instruments

1. All instruments for testing shall be provided by the air conditioning contractor.
2. Thermometers used for measurement of temperature of water/ refrigerant shall have graduation of 0.1 deg C and shall be got calibrated from N.P.L. or any recognized test house beforehand.
3. Thermometers used in the psychomotor shall have graduations of 0.2 deg C and shall be calibrated as at (2) above.
4. Pressure gauges shall also be got calibrated beforehand from a recognized test house.
5. Orifice type of flow meters shall be used for measuring flow rate through the condensers and chillers.

B. CAPACITY CPMPUTATIONS

1. Condensing unit:
   The capacity shall be computed from the water temperatures and water flow rate measurements of the condenser water and the compressor motor current readings. A reference may be made, if necessary to the manufacturer’s motor performance characteristics for arriving at the B.H.P. consumption.
2. Water chilling unit:
   The capacity shall be computed from the water temperature and water flow rate measurements of the chiller. Heat rejection from the condenser shall be computed from the water temperature and water flow rate measurements at the condenser.
3. Cooling Tower:
   Water quantity measured at the condenser and the temperature of water at the cooling tower shall be recorded. Wet bulb approach shall be checked against design data recorded in the tender documents.

4. Air handling unit (chilled water type) :
   The capacity shall be computed from the water temperature and water flow rate measurement. A tolerance of $\pm$ 5% from the tender documents value shall be acceptable

in the capacity so computed. Air quantity shall be measured in the supply duct and checked with the quantity specified in the tender documents. a tolerance of ± 10% in the air quantity shall be acceptable. The enthalpy difference of air entering and leaving the coil shall be computed from air temperature and recorded.

5. Air handling unit (DX type) :
The capacity shall be computed from the air quantity measured in the supply air duct and the enthalpy difference between the air entering and leaving coil. Air quantity measured shall be checked with that recorded in the tender documents. A tolerance of ± 10% from the tender documents value shall be acceptable.

7. For the purpose of system capacity, the refrigeration tonnage obtained from the main refrigeration plant will be accepted.

8. If due to any reason, internal load mentioned in the tender specifications is not available psychometric computations for actual load conditions will be done and the plant, if found satisfactory will be accepted.

APPENDIX – G MAINTENANCE
(Clauses1.14, 17.4)

The section covers the maintenance schedule during warranty period and 5 yrs subsequent to the warranty period.

The maintenance provided during the warranty period shall be fully comprehensive and shall include but not limited to all equipments, labour part and emergency calls providing and site response within 24 hours. However during the maintenance period after the warranty is over, the materials shall be arranged by the department if any replacement is warranted. However consumable materials shall be arranged by the department during 6 yrs period including that of warranty period.

The maintenance shall also include a minimum of 12 monthly preventive maintenance visits by qualified personnel who are thoroughly familiar with the type of equipment and system provided for this project.

Chiller	Monthly Inspection and Service	1. Check refrigerant level, leak test with electronic Leak detector. If abnormal, trace and rectify as necessary, Inform department in writing on the rectification. 2. Inspect level and condition of oil. If abnormal, trace fault and rectify as necessary. Inform department in writing on the rectification. 3. Check the liquid line sight glasses for proper flow. 4. Check all operating pressure and temperature. 5. Inspect and adjust, if required, all operating safety controls. 6. Check capacity control, adjust if necessary. 7. Lubricate vane/ linkage/ bearings. 8. Visually inspect machine and associated components, and listen for unusual sound or noise for evidence of unusual conditions. 9. Check lock bolts and chiller spring mount. 10. Review daily operating log maintained by department's operating personnel. 11. Providing written report to Department, outlining services carried out, adjustment made, rectification carried out and if the deficiency is of a major nature, arrange with department for shut- down to rectify equipment.
Chiller	Annual Inspection Prior to expiry of warranty period	1. Perform all functions for monthly check 2. Check all flanges for tightness 3. Change oil in oil sump 4. Replace filter 5. Check oil temperature control 6. Check motor terminals 7. Check connections in starter Please note that oil filter gasket replacement shall deem to be included in the contract.

		8. Check motor earthing, meggar motor and connection wiring on each leg 9. Check motor temperature cut-out, tighten motor terminals. 10. Check starter contacts, arc shield, transformer. 11. Check dashpot oil, clean dashpot and replace oil when necessary 12. Test and calibrate overload setting. 13. Inspect, calibrate and adjust to original specifications all gauges, safety and operating controls including low temperature and high pressure cutout, oil pressure switch, load limit relay and electrical interlocks. 14. For water cooled condenser systems, inspect condenser tubes for fouling. If fouling exceeds original specifications, the contractor shall carry out cleaning of the tubes at his own expense. 15. For air-cooled condenser coils, dust should not be allowed to accommodate on the condenser coil surfaces. Cleaning should be as often as necessary (approximately every three months) to keep coil clean. Exercise care when cleaning the coil, so that the coil fins are not damaged. Under no circumstances this unit be cleaned with acid based cleaner.
Water pumps	Monthly Inspection	1. Inspect all water pumps 2. Check all seals, glands and pipelines for leaks and rectify as necessary. 3. Re-pack and adjust pump glands as Necessary. 4. Check all pump bearings and lubricate with oil or grease as necessary. 5. Check the alignment and condition of all rubber couplings between pumps and drive motors and rectify as necessary. 6. Check all bolts and nuts for tightness and tighten as necessary.
Water pumps	Annual Inspection prior to expiry of warranty period	1. Perform all function for monthly checks 2. Check motor earthing, meggar Motor and connection wiring on each leg. 3. Tighten motor terminals 4. Check starter contacts 5. Test and calibrate overload setting.
Expansion tank	Annual inspection prior to expiry of warranty period	3. Inspect expansion tank, Drain, clean and flush out tanks as necessary
Air handling units and fancoil units	Monthly inspection	1. Inspect all air handling and fan coil units. 2. Check all air filters and clean or change filters as necessary. 3. Check all water coils, seals and pipelines for leaks and rectify as necessary.

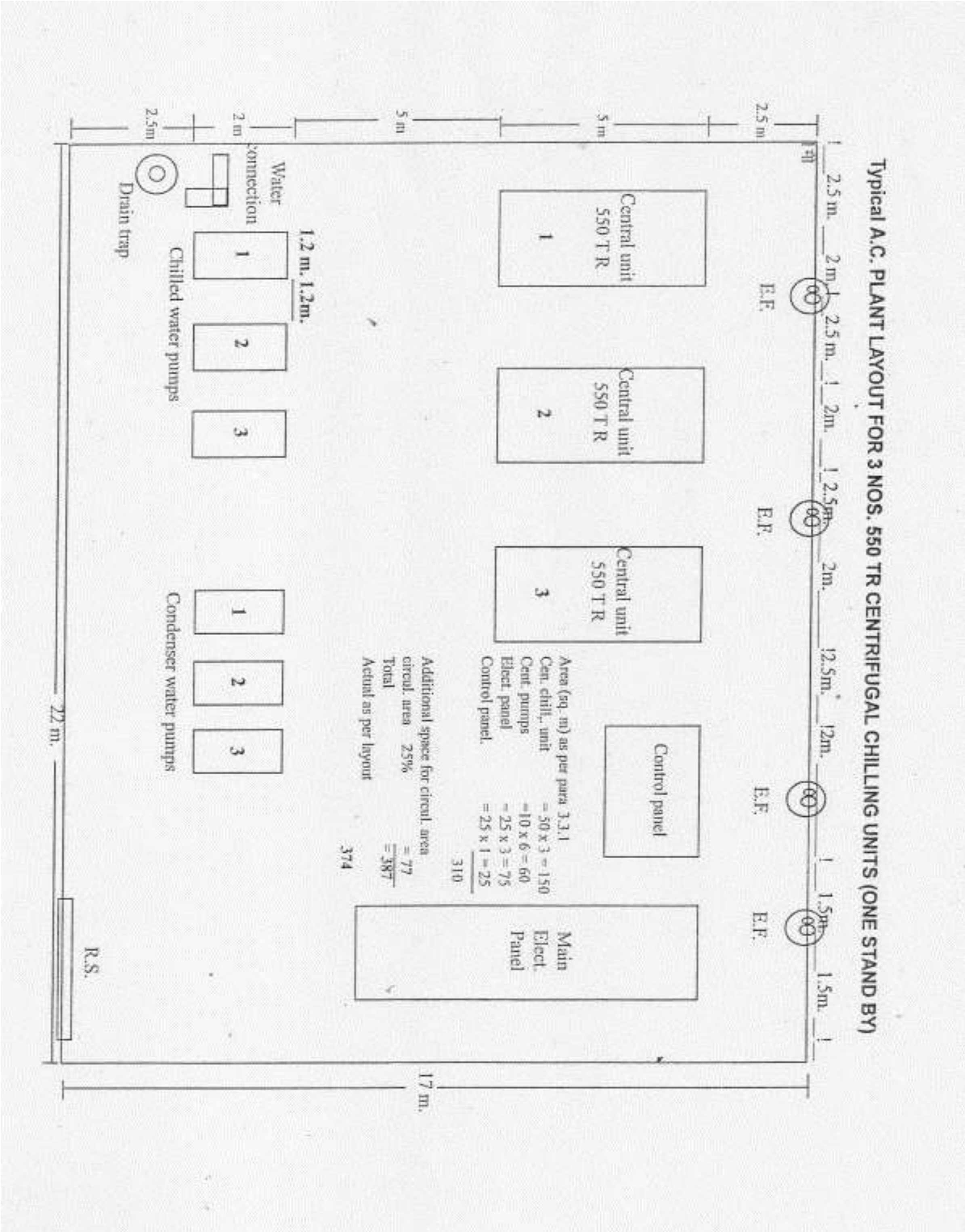
		4. Check and re-calibrate modulating valves and controls. Adjust and rectify as necessary to ensure compliance to the original specifications. 5. Purge air from all water coils. 6. Check all fan bearings and lubricate with grease as necessary. 7. Check the tension of all belt drives and adjust as necessary. 8. Check and clean all the condensate pans, trays and drains. 9. Check measure and re-calibrate all sensors if necessary. 10. Check, clean and service smoke detectors. Carry out a system test to ensure that the smoke detector will trip the AHU's. 11. Check spring vibration isolators for abnormal vibration. Rectify if necessary. 12. Coil to be cleaned by (a) spray of high-pressure clean water (not exceeding 30 psi (b) with chemical spray, if necessary.
Air handling units and fan coil units	Annual Inspection prior to expiry of warranty period	1. Perform all functions for monthly checks. 2. Tighten motor terminals 3. Check starter contacts. Test and calibrate overload settings.
Air cooled packaged units and precision-computer air-condition equipment	Monthly check	1. Check condenser fan motor load ampere. 2. Check fan and motor mounting brackets. 3. Check shafts and bearings. Lubricate with grease as necessary. 4. Check the tension of all belt drives and adjust as necessary. 5. Check for refrigerant leaks with electronic leak detector. 6. Check electrical terminals and contactors operation and connection for tightness. 7. Check compressor motor current. 8. Check refrigerant line driers and moisture indicators.
Air cooled packaged units and precision-ac equipment	Annual inspection prior to expiry of warranty period.	Perform all functions listed in the monthly checks.
Air distribution system	Monthly and annual inspection prior to expiry of warranty period	1. Check operation of all modulating and fixed dampers controlling air flow through unit. Lubricate all damper bearings and linkages as necessary. 2. Carry out space temperature checks on air-conditioned areas With thermo hydrograph. Balance air flow as necessary to

		Compliance with requirements of original specifications. These checks include the calibration of sensors, thermostat, etc. 3. Check noise level of discharged air from diffusers.
Ventilation	Monthly check and annual inspection prior to expiry of warranty period	1. Check adjusts as necessary the air flow of all fans is in compliance with the original specifications. 2. Check the tension of all belt drives and adjust as necessary. 3. Check and lubricate all fan bearings. 4. Tighten motor terminals. 5. Check starter contacts. 6. Test and calibrate overload settings. 7. A system check shall be carried out for all Mechanical ventilation (MV), Pressurization and Exhaust system to verity the performance of the systems.
Switch board	Six-monthly and annual inspection prior to the expiry of the warranty period	1. Clean and adjust all switch gear, contactors, relays and associated electrical equipment at intervals not exceeding six months. 2. Check and prove operation of thermal over load and protection devices. 3. Check and ensure tightness of all equipment fastenings and cable terminations within switch boards. 4. Vacuum clean all switch board cubicles.
Piping system	Monthly and annual inspection prior to expiry of warranty period	1. Check all piping system for leaks and repair these where they have occurred. 2. Check for damage & deterioration of insulation or sheathings. 3. Rectify as necessary
	Consumable materials	The department shall supply the following consumable materials as and when required :- 1. All oils and greases required for lubrication of compressors, fan bearings, motors bearings, pivots and other moving parts. 2. All refrigerant required for topping up. Refrigerant loss if due to manufacturing defect or due to negligence shall be made good by the contractor. 3. All consumable filter elements/ rolls.All chemicals for the correct chemical treatment of the cooling tower and chilled water system. 4. All carbon brushes required to replace worn brushes in electric motors. 5. All electric contact points required to replace worn electric contact points in switchgears, motor starter gears, electronic control gears and electric relays. 6. All electric fuses required to replace blown fuses. Just before the expiry of the warranty of the contract, the contractor shall carry out a complete system

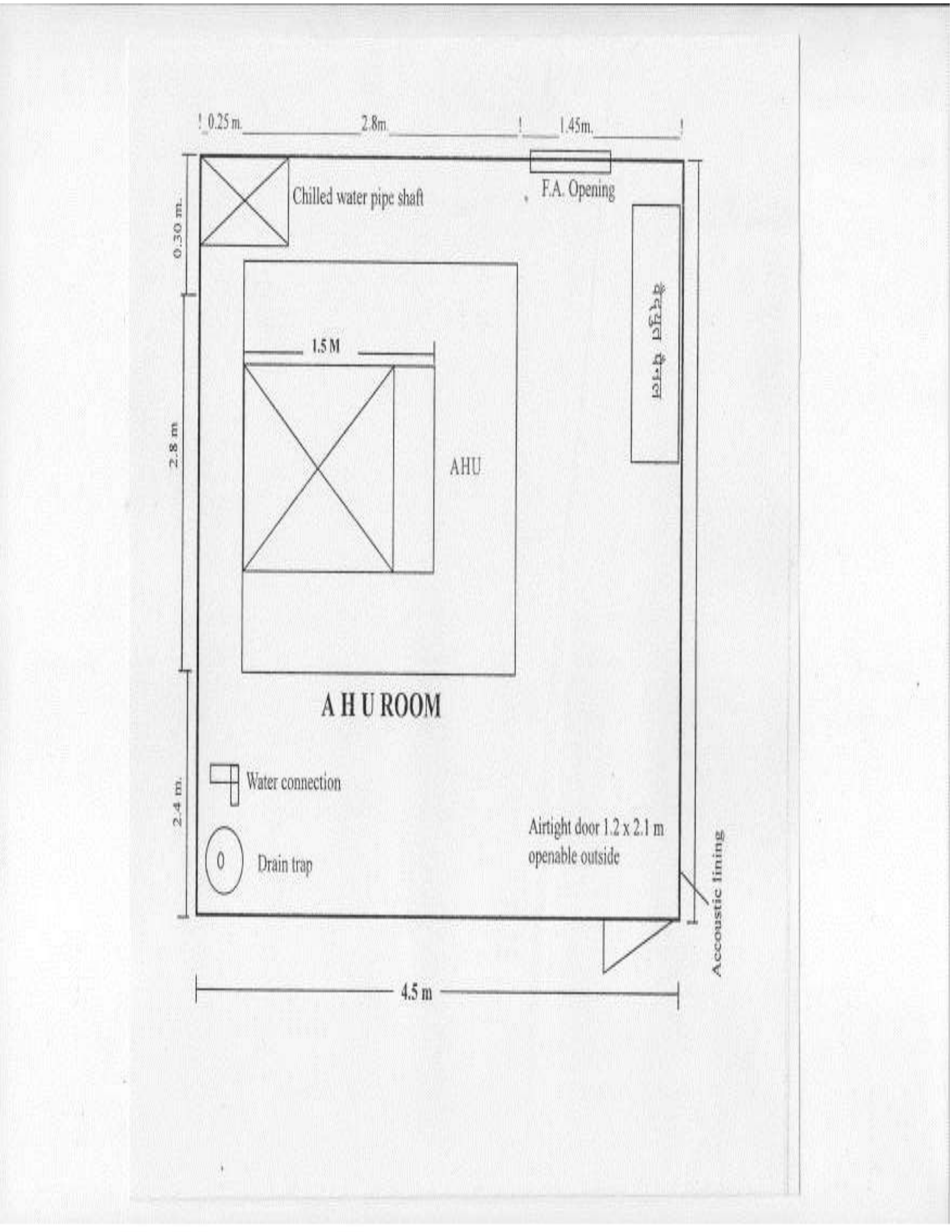
		operability test on all the systems or sub-systems as called for in the contract. 7. The purpose of the test is to verify that the performance of all the systems or sub-systems in the contract is in accordance to the specifications. All test shall be carried out in the presence of the Engineer-in-Charge or his representative. 8. The warranty period is deemed to be over if the department or his representative is completely satisfied with the system performance during the test.

APPENDIX - H

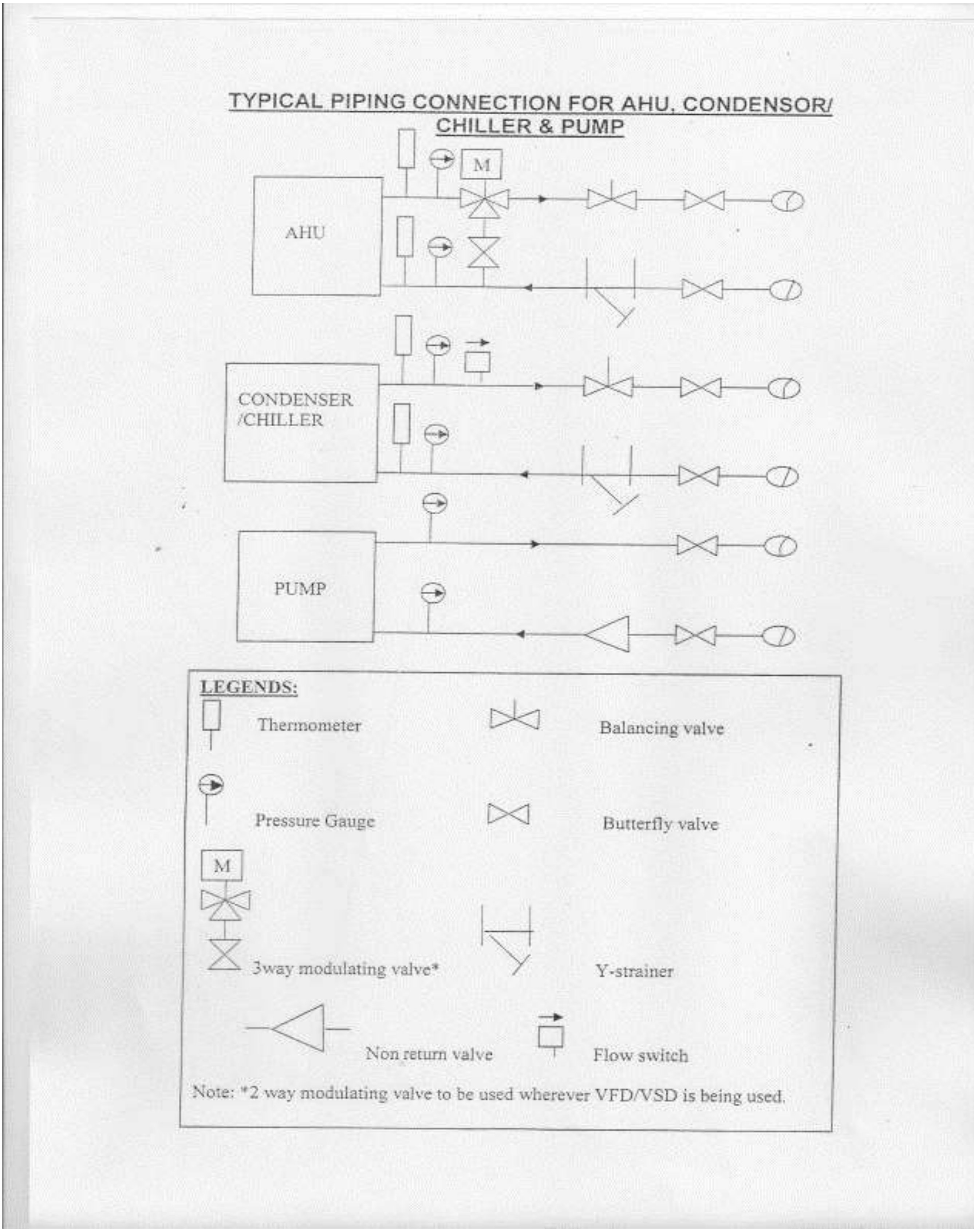
TYPICAL A.C. PLANT LAYOUT FOR 3 NOS. 550 TR CENTRIFUGAL CHILLING UNITS (ONE STAND BY)



APPENDIX -I
TYPICAL AHU ROOM LAYOUT FORM 680 CMM (24000 CFM) AHU



APPENDIX –J
TYPICAL PIPING CONNECTION FOR AAHU, CONDENSORS/CHILLER & PUMP



APPENDIX – K
AIR-SIDE ECONOMIZER ACCEPTANCE PROCEDURES
(Clauses12.9.3)

1.1 Construction Inspection

Prior to Performance Testing, verify and document the following:

(i) System controls are wired correctly to ensure economizer is fully integrated (i.e. economizer will operate when mechanical cooling is enabled)

(ii) Economizer lockout control sensor location is adequate (open to air but not exposed to direct sunlight nor in an enclosure; away from sources of building exhaust; at least 8 m [25 ft] away from cooling towers)

(iii) System is provided with barometric relief, relief fan or return fan to control building pressure

1.2 Equipment Testing

Step 7: Simulate a cooling load and enable the economizer by adjusting the lockout control set-point. Verify and document the following:

(i) Economizer damper modulates opens to 100% outside air

(ii) Return air damper modulates closed and is completely closed when economizer damper is 100% open

(iii) Economizer damper is 100% open before mechanical cooling is enabled

(iv) Relief fan or return fan (if applicable) is operating or barometric relief dampers freely swing open

Step 8: Continue from Step 1 and disable the economizer by adjusting the lockout control set-point. Verify and document the following:

(i) Economizer damper closes to minimum ventilation position

(ii) Return air damper opens to at or near 100%

(iii) Relief fan (if applicable) shuts off or barometric relief dampers close. Return fan (if applicable) may still operate even when economizer is disabled

APPENDIX- L
SUGGESTIVE CHECKLIST FOR AIR-CONDITIONING

This checklist is only suggestive and not exhaustive and it is for guidance purpose only. The NIT authority shall make suitable modification, addition /alteration in the provision in the NIT as per requirement.

1. for Architectural and Structural Coordination

(a) Plant Room, (preferably part of ESS Service Building) to accommodate chillers, pumps, Electrical Panel, BMS, Piping and Valves.
(b) Cooling Towers on the terrace of Plant Building, including structural arrangement for erection of cooling towers and staircase approach to the terrace.
(c) AHUs in vertical alignment (As per CPWD HVAC specifications) so that chiller pipes from the Plant can be taken inside AHU without passing through the corridors.
(d) Adequate corridor width/ height for AC Ducting.
(e) Structural provision for entry of chiller pipes and cables from plant room to AHU.
(f) Provision of air tight doors/windows. Double glazing windows with required U Value and SHGC Value
(g) Envelope/ ceiling insulation
(h) Orientation of the building to reduce heat ingress.
(i) Surrounding greenery planning.
(j) Structural loading for various equipments.
(k) AC Water Ground tank and make up water tank for cooling tower
(l) Air Curtains
(m) AHU Room: fresh air opening. Drainage arrangement, Acoustic Lining
(n) Insulation of wall/ ceiling between AC non-AC Areas.
(o) Entire building to be airtight. No connection with outside except through fresh air openings in AHU Room.

2. Check list for Documents from AC Consultant

(a) Based on Heat Load Calculation, peak load calculation for day and night.
(b) Selection of number and capacity of chillers.
(c) Chillers required on essential (DG) electric supply.
(d) Electrical Coordination: Capacity and number of transformers with voltage correction, APFC Panel, no and capacity of back up DG Sets. In coming supply ACB rating from substation LT Panels, Essential/Non-essential for termination into AC Main Panel.
(e) Space for future chillers.
(f) Provision for stand by chillers.
(g) Essential supply to Chillers and all AHUs provided.
(h) BMS for monitoring and control of the entire AC installation provided.
(i) Water requirement for AC Coordinated.
(j) Provision of Ground tank for AC water tank and make up water tank for each cooling tower.
(k) Water conditioning for water to be used for cooling tower.
(l) Water from STP for AC Plant?

(m) All AHUs in vertical alignment for entry of chilled water pipe and cables from Plant Room without passing through corridors.
(n) Chilled water pipe and cable route from plant room to the building coordinated.
(o) VF Drive for chillers, pumps, AHUs, C Tower included.
(p) AHU: fresh air opening.
(q) Envelope insulation, Roof insulation.
(r) Indoor Air Quality, automatic control included.
(s) Clients detailed functional requirements included.
(t) For all the areas, inside conditions to be maintained, specified.
(u) Winter heating provided?
(v) Space provision for plant room, terrace (for Cooling Towers), AHU Rooms, corridor width and height adequate.

3. Design related

(a) Heat Load Calculation
(b) Detailed Design Sheet
(c) Technical summary of steps taken to reduce Heat Ingress.
(d) Technical steps taken to reduce IKW/TR from 1 KW to lowest possible level. Specify the target IKW with summary of steps taken is.
(e) Plant equipment layout drawing with dimensions to include chillers, pumps, AC Electrical Panel, VFDs, Cabling, Piping, and Valves etc to ensure that space is adequate.
(f) Space for future chillers.
(g) Terrace layout drawing for cooling towers.
(h) Chiller pipe/ cable route from Plant to the Building.
(i) AHU Room: AHU layout with Panel, piping, valves.
(j) Ducting drawing from AHU to conditioned areas through corridors.
(k) AR for rates adapted
(l) BOQ for complete job with all associated works included.
(m) If any exclusion, Specify.
(n) Approved Makes of materials, equipments.
(o) Governing specifications.

REFERENCE TO AMENDMENTS

S. No.	Reference under which Issued	Item No.	Page No.	Remarks

REFERENCE TO AMENDMENTS

S. No.	Reference under which Issued	Item No.	Page No.	Remarks