HVAC Installation Guidebook

First Edition - 2026

Shankar Sapaliga and **Ajaj Kazi**

ISHRAE

Indian Society of Heating, Refrigerating and Air Conditioning Engineers

COVER 2

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Disclaimer: This book is a compilation of data from various open sources.

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Foreword

It is with great pride and enthusiasm that we present the ISHRAE Installation Guidebook, a comprehensive guide that aims to elevate the standards of HVAC (Heating, Ventilation, and Air Conditioning) installations across the industry.

The Indian Society of Heating, Refrigerating and Air Conditioning Engineers (ISHRAE) has long been a beacon of knowledge, expertise, and innovation in the HVAC sector. This edition of the Installation Guidebook reflects the Society's commitment to providing essential resources that support the growth and development of professionals in this critical field. Whether it is the smallest split AC or a large chiller plant, this Guidebook is designed to be an invaluable tool for engineers, contractors, and technicians involved in the installation of HVAC systems, offering them practical guidance, best practices, and essential technical insights.

As HVAC technology continues to evolve rapidly, ensuring that installations are carried out with the highest degree of accuracy and efficiency is paramount. This Guidebook not only outlines the core principles of effective HVAC system installation but also emphasizes the importance of sustainability, energy efficiency, and safety — core values that are fundamental to the future of the industry. Whether you are a seasoned professional or just starting in the field, this guide will prove to be a reference point, offering a structured approach to solving common challenges faced during installations.

The expertise and knowledge contained within these pages have been drawn from decades of experience, research, and collaboration within the ISHRAE community. We sincerely hope this handbook book serves as an indispensable resource for all involved in HVAC installations, enabling them to enhance their skills, adhere to industry standards, and contribute to building a more sustainable and comfortable built environment.

I would like to extend my gratitude to all the contributors who have made this publication possible. Their dedication, hard work, and passion for excellence in HVAC installation have truly shaped this document.

As you delve into the contents of this handbook, we encourage you to embrace the knowledge within and apply it diligently. The future of HVAC installation is in your hands, and through the adoption of best practices outlined in this guide, we can ensure that the systems we create are not only efficient and reliable but also contribute positively to the world around us.

Nishant Gupta
Chair, ISHRAE Technical Committee

Preface

"Air conditioning was a most important invention for us, perhaps one of the signal inventions of history. It changed the nature of civilization by making development possible in the tropics. Without air-conditioning, you can work only in the cool early morning hours or at dusk. The first thing I did on becoming Prime Minister was to install air conditioners in buildings where the civil service worked. This was key to public efficiency "

These are the words of Lee Kuan Yew (1923-2015) founder of modern Singapore.

For us in India it took, perhaps, half a century after independence to realize this and the industry was shackled by penal taxation. However, in the last 30 years, the importance of air conditioning has come to be recognized, not only for essential applications such as health care, hospitality, software development and manufacturing, but also for personal comfort. The proliferation of domestic refrigerators we saw in the 1980s in middle class households, is now being witnessed in the room or split air conditioner market.

Industry shows an astonishing growth rate of 15% year on year in the foreseeable future. Though comfort air conditioning is the primary driver of growth, the role of sophisticated applications such as clean rooms, data centers, pharma and electronics is equally significant.

It is with this background that ISHRAE is attempting to put before you this volume on good installation practices. While, there is a proliferation of books on HVAC&R, almost all of them deal with theory and/or application engineering and there is hardly any reference book for the technician and engineer who are entrusted with installation of equipment and systems. They have to mostly depend on manufacturers' instruction leaflets and even these are not easily made available in the field.

It was precisely to take care of this knowledge gap that way back in 2009, ISHRAE Bangalore Chapter brought out an Installation Guide. ISHRAE is grateful to the pioneers who worked behind this volume.

Technology, equipment, applications and most importantly customer requirement and expectations have undergone a sea change during the last 16 years. This book not only takes care of such changes but also covers many more topics which have become all important to modern HVAC&R.

Like all efforts of ISHRAE, this book is also the result of the selfless, voluntary and collaborative contributions of several experts in respective fields. ISHRAE gratefully acknowledges all such contributions and a list of persons who collaborated is given in the list below (in alphabetical order).

A special mention needs to be made of the substantial contribution of Mr. Shankar Sapaliga who collected a lot of material from various sources, and Mr. Ajaj Kazi who spent several hours editing, collating and putting together this volume.

This book is expected to be an invaluable companion to the site engineer/technician and following these guidelines will result in systems which are energy efficient, sustainable, easy to maintain and service, delivering highest levels of Thermal Comfort, Indoor Environment Quality and optimum Life Cycle Cost.

Extreme care has gone into production of this volume but we cannot completely rule out errors. Also, experienced readers could be aware of more efficient and simpler practices and methods than those described herein. ISHRAE welcomes any and all suggestions for improving this book which may please be sent to tgsupport@ishraehq.in and these would be considered for inclusion in future editions.

ISHRAE has put together this book with love and care and our sincere hope is that this will help elevate the standards of installation, safety and quality of HVAC&R installations..

K. Ramachandran
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Basics of Refrigeration, Air Conditioning and Ventilation

1.0 Introduction

Air Conditioning and Refrigeration industry in India has been consistently growing at a CAGR of more than 15 % over the last few years. This growth throws up tremendous opportunities to practitioners of this industry.

Reasons for such growth, briefly, are:

- Comfort air conditioning, especially in the residential sector, which was deemed to be a luxury affordable only to the affluent few has now become universal due to general improvement in standard of living of a majority of citizens.
- For offices and other public spaces, comfort air conditioning is now increasingly recognized as a necessity.
- Applications such as healthcare, hospitality, electronics and several areas of manufacturing and service are now dependent on air conditioning.
- Possibilities afforded by refrigeration, besides improving marketing opportunities for the farmer, are playing a major role in cutting down food wastage.

This growth, while presenting opportunities, is also bringing into focus the needs for skilling of personnel. An air conditioning system, whether it is a room or split air conditioner serving a bed room right up to the most complex central chilled water-based system serving a criti-care hospital needs skill and knowledge to obtain a proper and trouble-free installation.

The purpose of this book (Published by ISHRAE originally in 2009 and updated in 2025) is to be a practical guide to the installation/service engineer. This book covers most of the range of air conditioning and refrigeration systems (operating on the vapor compression cycle), its sub systems, equipment, controls and instrumentation. The book is specifically targeted to installers in India.

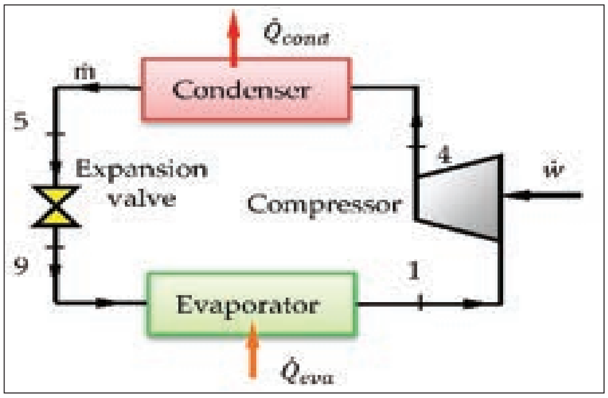
While the book does not offer insights into design and selection of systems, it has tried to provide basic information on sound installation practices. Reader seeking more knowledge on design, selection as well as in-depth knowledge on system components is advised to refer to the range of publications from ISHRAE, ASHRAE and REHVA on the subject.

2.0 Basics

We will review the basics of Refrigeration and Air Conditioning and become familiar with the system components, the correct installation practices for which are detailed in subsequent chapters.

2.1 Refrigeration is the process of removing heat from a substance and rejecting it to atmosphere which is at a higher temperature. For this reverse heat flow, we need external energy and a substance as the carrier of heat. This substance, which is called the refrigerant, initially needs to be at a temperature lower than that of the substance to be cooled so that heat flows from the substance to the refrigerant. By compressing this refrigerant (in gaseous form) in a refrigeration compressor its pressure and consequently temperature is raised and heat is rejected either to water or air before the liquid refrigerant once again is cooled below the temperature of the substance so that it can once again absorb heat from the substance to be cooled. A simple vapor compression refrigeration cycle where heat is rejected in an air-cooled condenser is shown at *Figure 1.1*. Please refer *Figure 1.2* for chiller plant room installation.

2.2 Air conditioning is the process of treating or conditioning of air to alter its temperature and moisture content to suit specific requirements. This is generally done with the help of refrigeration. It is also possible to evaporatively cool the air without using refrigeration. In cold climates, it may be required to heat the air. The process of air conditioning may also involve filtering the air to remove dust particles as well as treating the air to remove microbes, bacteria and viruses. The treated air has to be transported to spaces which need to be conditioned through ducting and has to be distributed through registers. Air from the conditioned space has to be brought back to the air handler either through return ducting or ceiling voids and the process gets repeated.



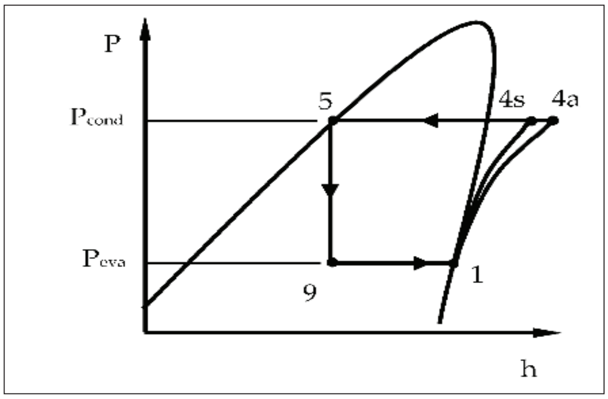


Figure 1.1: Vapor compression refrigeration cycle.

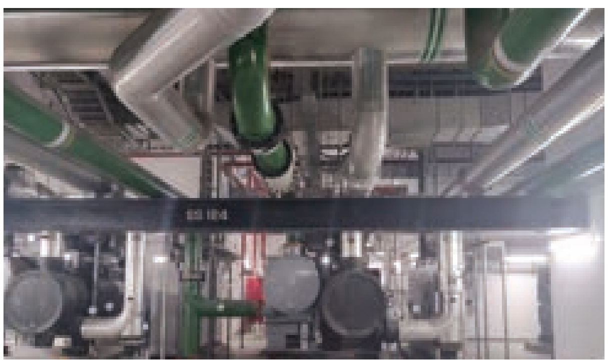


Figure 1.2: Chiller plant room

2.3 Ventilation is the process of suppling fresh outdoor air to air-conditioned spaces in order to limit the content of carbon dioxide as well as other impurities, and Volatile Organic Compounds (VOCs) in the breathing spaces. There are Standards which specify the ventilation requirements (Refer ISHRAE IEQ Standard 10001-2016). For specific applications such as healthcare there are stringent ventilation standards to be maintained. (Refer National Building Code). Generally, ventilation air is drawn through a fresh air opening in the AHU room which is regulated through a volume control damper. For certain systems treated outdoor air supply is necessary to be provided.

Ventilation systems are also used for toilet exhaust as well as for smoke exhaust, pressurization of stair cases etc. in the event of a fire emergency. Ventilation of parking basements is another major application. In certain manufacturing and health care applications, ventilation systems are employed to maintain pressure gradients between adjacent spaces.

3.0 System Components

Major components of a refrigeration machine operating on the vapor compression cycle are the compressor, the condenser, expansion device and the evaporator.

3.1 Compressor in the air conditioning system may be one of several types such as rotary, scroll, reciprocating, screw or centrifugal and the capacity can range from small compressors driven by fractional HP motors to large centrifugal machines driven by high tension motors. Condensers can be air cooled or water cooled. Expansion devices range from capillary tubes used in room air conditioners to thermostatic or electronic expansion valves as well as float valves used in flooded chiller installations. Evaporator can be a cooling coil used in the room / split air conditioner or the evaporator coil in a DX AH unit. It can also be a DX or flooded type cooler (chiller).

3.2 Previously, there was a practice of bringing various components of a condensing unit or chiller to the site and assemble it on site with required refrigerant piping. However, currently chillers as well as condensing units come factory assembled and duly tested. Details for installation of chillers are explained in Chapter 5.

3.3 While the chillers come fully assembled with interconnecting refrigerant piping, in respect of split units and VRF systems refrigerant piping from the condensing unit (ODU) to the evaporator unit (IDU) and return has to be done in the field. Particulars of refrigerant piping are given in Chapter 12 and insulation of the same is covered in Chapter 13.

3.4 Installation of unitary systems such as room (window) air conditioner, split air conditioning units and packaged air conditioners are covered under Chapter 3. Some of the larger units require ducting to transfer conditioned air from the unit to the space to be conditioned. Ducting and air distribution is covered under Chapter 11 and both thermal and acoustic insulation of ducts are covered under Chapter 13.

3.5 Variable refrigerant flow (VRF) systems have become very popular due to their flexibility, energy efficiency as well as ease of installation. Currently, most of the VRF systems installed in the country are air cooled systems but it is also possible to have VRF systems in the water-cooled configuration. A separate chapter – Chapter 4 – has been dedicated to installation of VRF Systems.

3.6 Cooling tower is a very important component of water-cooled systems. Heat removed from the substance or space to be cooled is rejected to the atmosphere in the cooling tower. Location of the tower, its selection and installation are very important from noise considerations. Also cooling towers can generate a drift of water particles which is not welcome in public areas. Location and installation of cooling towers is covered in Chapter 6.

3.7 In Direct expansion (DX) systems such as window, split, VRF and DX Condensing units, the refrigerant itself is circulated to the space to be cooled. However, this is not possible in large installations such as multi-storeyed buildings where a secondary refrigerant which is usually chilled water (and in certain applications, a brine solution) is circulated from a central chiller plant to various air handling units (AHUs) or fan coil units (FCUs) located at various places in the building. This involves pumping of chilled water from the plant room to various units as well as the return of this water to the plant room. Usually, the chilled water flow through the chiller is controlled by a primary pumping system and the flow through the load is controlled by a secondary pumping system. Exceptions to this are also there and systems are there where the same pumps circulate water through the chiller as well as through load.

In water cooled systems, pumps are used to push cooling water through the water-cooled condenser as well as the cooling tower.

There can be more pumps in the system such as for feeding make up water to the chilled water system through an expansion tank as well as for distributed pumping loops in a tertiary chilled water system.

Installation of pumps and pumping systems is covered under Chapter 7.

3.8 Fans in an air conditioning system are used to cool the circulating air by passing it through a cooling coil (which may be part of an IDU, AHU or FCU and thereafter deliver the conditioned air to the space to be cooled either through a ducting system or even directly. Fans find other applications also in HVAC system such as the fan installed in a cooling tower and also fans which provide ventilation to various places in the building. Exhaust fans are used to remove stale contaminated air from spaces such as toilets, kitchens and laundry. Fans are also necessary to pressurize (or depressurize) certain areas for fire safety, smoke exhaust and for providing a pressure gradient between adjacent spaces to prevent cross contamination. Thus, fans find universal application in HVAC systems. Installation of fans is covered in Chapter 8.

3.9 AHUs and FCUs may also be categorized as fans but they have in addition a cooling or evaporator coil through which the primary or secondary refrigerant flows. A separate chapter – Chapter 9 – is dedicated to such units.

3.10 Chapter 10 covers filters and other air cleaning mechanisms such as ultra violet germicidal irradiation (UVGI) and photo catalytic oxidation (PCO) as well as ionization systems which are in use for cleaning the air as well as for disinfecting it to desired extent by removing organisms such as mold, bacteria and viruses.

3.11 Ducting and other air distribution system components such as constant airflow regulator and variable air volume (VAV) units are covered in Chapter 11.

3.12 Piping work and its proper installation is very important for proper functioning of HVAC Systems. Refrigerant piping, water and chilled water piping as well as drain piping are all covered in Chapter 12.

3.13 Thermal as well as acoustic insulation of ducts, pipes and plant and other equipment rooms is covered in Chapter 13. Insulation plays a major role in reducing transmission of outside heat into the building (in hot climates) and also for transmission of heat from inside to outside (in cold climates). Such transmission can have a major impact on the cooling or heating loads to be taken care by the HVAC system. Therefore, building insulation (walls and roof) assumes a lot of importance. Insulation is vital for cold storages where food and other perishables are stored. All types of insulation commonly used are covered in Chapter 13.

3.14 Heat recovery systems can range from a simple side arm condenser mounted on a chiller which produces hot water for use in the building from waste heat to complex systems involving air to air, air to water or water to air systems. Since the mandatory ventilation air taken from the ambient atmosphere forms a significant part of the cooling load, pre cooling this air by passing it through a heat recovery unit can save a lot of energy. Installation guidelines for various types of heat recovery systems are detailed in Chapter 14.

3.15 Load on the electrical grid feeding to the building is not constant. It varies significantly according to the time of day posing a big challenge to the utility company to manage varying demand on the grid. In order to balance the load somewhat, most power supply companies offer time of day tariffs which can be significantly low in off peak hours and high in peak hours. This provides an opportunity to generate the buildings cooling requirement during off peak hours (say from 11 pm to 8 am) and use the cooling so generated and stored when the building needs it (say from 9 am to 6 pm). A thermal storage system which can store the energy either in chilled brine or in the form of ice makes this possible. There are also applications such as high load data centers which cannot allow disruption of cooling even for a few minutes (time taken by a chiller to start and bring up to load after a power break) where thermal storage provides a good solution. Installation of different kinds of thermal storage systems is covered in Chapter 15.

3.16 Chapter 16 focuses on specific installation requirements for a few of the special applications of the HVAC system such as health care, hospitality, data centers, cold storages, pharma and clean rooms.

3.17 Generally, all the systems described in this volume works on electric power; bringing in the power, protections needed, its distribution and regulation assume great importance. Electrical installations, motors and drives are detailed in Chapter 17.

3.18 Controls which were electro mechanical as well as pneumatic a few years ago are increasingly getting replaced by electronic and digital controls. Installation details of various types of controls as well as instrumentation is covered in Chapter 18. This chapter also covers installation techniques for building management systems as well as IOT and wireless communication for control systems.

3.19 Noise as well as vibration has been the bane of HVAC systems for a long time. Since the system uses reciprocating as well as rotating equipment, fans, pumps, cooling towers etc. which generate and transmit vibration and objectionable noise and since these can be carried through piping, ducting, pipe and duct supports to occupied area, abatement of noise and vibration assumes a lot of importance. Apart from the noise generated by equipment, even the noise generated by air moving at high velocity through duct systems and discharged into the room through registers and outlets can be a source of unacceptable noise. Proper and careful installation can go a long way to remedy the objectionable noise and vibration. Chapter 19 deals with this important topic.

3.20 The importance of safety in any occupation/activity cannot be over-emphasized, more so in installation of air conditioning, refrigeration and ventilation system. Installation involves working at heights with different tools, dealing with rotating equipment, electrical installations as well as refrigerants which can be toxic and flammable. Safety aspects shall follow National and local codes as well as rules and regulations formulated by Authorities Having Jurisdiction (AHJs).

Only those aspects of safety which are specific to installation of HVAC systems are detailed in Chapter 21. Section dealing with refrigerant safety needs special attention.

3.20 Aspects of painting, protection and labelling are covered in Chapter 20.

3.21 Commissioning of the HVAC system is a critical activity. However, much is spent on selecting the best and most energy efficient equipment, other materials and installation practices; unless the system is properly commissioned, the owner or end user will not be able to derive the advantages he/she has paid for. Commissioning activity which comes at the last stage of the project is mostly neglected and once the system is switched on and gives the cooling no more attention is given to this. It should be clearly understood that commissioning should be a structured process right from the inception of the project and shall go through various stages such as design, selection, procurement, installation, start up and testing and shall continue through the life of the plant by way of 'ongoing commissioning'. ISHRAE has brought out a Commissioning Guidebook as well as a Commissioning Standard (HVAC Commissioning Process Standard No 10003-2020), and all practitioners are sincerely advised to strictly implement the process in projects where they are involved. An overview of the commissioning process is available in Chapter 22.

Disclaimer

While all care is exercised while formulating various sections of this book, it is possible that practices different from those described here have been successfully used by industry practitioners. It also cannot be ruled out that some of the processes described herein have been updated and modified. Since this is an industry which is continuously evolving, newer and better practices will keep on getting introduced. ISHRAE will consider it a great favor if the readers and users of this book point out any corrections or changes they would like to suggest by sending a mail to *tgsupport@ishraehq.in.*

Chapter 2:

General Installation Guidelines

1.0 General

HVAC system involves various equipment, materials to be integrated. This integration is critical for proper functioning of the system. HVAC system is a major consumer of energy and hence it is critical that installation is done effectively. The following are the primary objectives to be achieved for effective installation of HVAC system.

1. Energy Efficiency: Equipment and systems installed as per manufacturers guidelines and good industry practices can help in getting the energy efficiency of the system as per design.

2. Quality: Installation of system following correct quality guidelines can result in achieving good installation with better reliability and durability.

3. Safety: Safety is the most important aspect in installation activities. The installation must follow right safety protocols to ensure zero harm to people and property.

4.Speed: The speed of installation must match the project and stakeholder's requirement. Innovative techniques can help in reducing the time of installation.

5.Cost: With increased productivity, less rework due to quality, adhering to safety guidelines and achieving energy efficiency can help in reduction of overall life cycle cost.

6. Noise and Vibration: Care shall be taken to ensure that the noise generated during installation process and thereafter during operation phase is not objectionable to neighbors. It shall also be ensured that equipment noise and vibration is strictly within acceptable limits for user/occupant of the premises.

Let us look some of the important factors in installation of HVAC system

2.0 Equipment Location

2.1 Equipment location shall be selected with care. There shall be adequate space to mount the equipment, make required service connections and operate and maintain the equipment without compromising safety. In case of large installations, a separate utility block may be considered.

2.2 Routing of services such as electric as well as control and data cabling and earthing, Cooling water, chilled water shall be thought through.

2.3 While it is always advantageous to house the equipment as close to the point of use, exceptions need to be provided for.

2.4 Adequate ventilation and natural lighting are very important while planning the installation.

2.5 Location should be such that it shall be possible to move in and move out equipment installed not only during the installation period but also during operation phase of the building when replacement becomes necessary. This aspect is especially important for basement installations where ramps or service hatches will be required.

2.6 It should be possible, if required, to contain noise generated by the equipment so that noise does not become objectionable to surrounding spaces as well as to building occupants. Care shall be taken that any vibration generated is not transmitted to building structure.

2.7 Location shall be clean and free of dust.

2.8 While mounting heat rejecting equipment such as cooling towers and air-cooled condensers, care should be taken to ensure that there are no obstructions to heat rejection. Good ventilation and adequate top and side clearances shall be provided specially when multiple units are mounted in close proximity.

2.9 Equipment load shall be properly transferred to the structure and it is advisable to have this cleared by a structural engineer.

2.10 Where drainage is required, adequate provisions shall be made to remove it. In case of pumped drainage, alarm shall be provided in case water level rises beyond pre-determined level. Possibility of re-using condensate water shall be explored.

2.11 Service shafts and wall openings shall be planned in advance so that breakages are avoided. Shafts shall be closed at all levels so that fire safety is not compromised. Openings in structural elements shall not be made without the approval of structural engineer.

2.12 Pipes, ducts, cable trays etc. shall be supported from either the floor or the ceiling in such a way that vibrations are not transferred to building structure.

2.13 Equipment foundations shall be adequately designed and inertia blocks and seismic restraints shall be provided where necessary.

2.14 Fresh air intakes shall be planned keeping required distance from exhaust outlets as well as any sources of possible contamination. Where the intakes or exhausts open outside the building, they shall be protected with wire mesh bird screen and louvres/cowl piece for rain protection.

2.15 Access to equipment rooms shall be through double leaf doors or rolling shutters of adequate width and height. Doors of fan rooms shall be air tight. Doors shall open to outside. A sill shall be provided to prevent water ingress.

2.16 Source of power and water as well as drainage points have to be planned out in advance. Power supply with adequate protection needs to be terminated as close to the equipment as possible with an isolating switch. All electrical systems shall be adequately grounded and protections such as surge protectors and circuit breakers shall be provided as per approved electrical drawings.

3.0 Receipt, Storage of Material and Inspection/Testing

3.1 Heavy and bulky equipment may be received at site only after its installation location is fully ready with foundations etc. so that multiple shifting is avoided. Receipt of equipment, its unloading, shifting to interim storage or final place of installation shall be done only with proper tools and tackle. This requires advance planning.

3.2 All equipment and materials shall be cleaned prior to use. Ducts and pipes shall be stored with their ends closed to prevent dirt ingress. After and during installation, pipes and ducts shall be kept closed. All equipment either in temporary storage or as installed and waiting for commissioning shall be kept covered with tarpaulin or canvas cloth. Shafts of rotating equipment, especially electric motors, if stored for more than 10 days, shall be rotated by hand once in 10 days. This is to prevent the grease applied to shaft from solidifying. Before commissioning all duct and pipe work shall be thoroughly cleaned as per an approved SOP.

3.3 Materials and equipment received at site shall be compared with approved specifications and found correct before same is accepted. Where required, test certificates shall be sought. Where independent third-party inspection is specified, same should be complied with. Where factory inspection is specified in contract, accepted factory test certificates shall be produced by vendor before equipment is accepted at site.

3.4 Agreed Quality Assurance Plan (QAP) shall be available with site in-charge and shall be strictly followed. Agreed lot sizes shall be inspected and approved before use. Test results shall be recorded in proper formats. All instruments and gauges used shall be calibrated ones and valid calibration certificates shall be available.

3.5 Testing of sub systems shall be carried out in sections as per approved drawings. All test parameters including test duration, applicable standards and test pressures shall have owner's approval. Tests need to be planned in advance and intimated to all concerned so that they can be witnessed by authorized personnel where desired. Qualification and experience of vendor's personnel involved in testing shall be prior intimated to owner. Number of test points for duct and pipe work shall be pre-agreed between owner and vendor. Once section wise testing is successfully completed, system shall be tested as a whole. Electric power, control and data cabling shall be tested as one lot.

4.0 Installation Guidelines for Specific Equipment

4.1 Unitary, Packaged Units and VRF: The location of outdoor units as well as for cooling tower (in respect of water-cooled systems) must be open and with effective ventilation. The location must be dust free to avoid soiling of condenser coils and basin of cooling tower. The location must be non-sensitive to avoid transfer of vibration and noise. The location must have proper access for maintenance. The location of indoors units to be decided considering the effective coverage area of cooling. The packaged type plant room should be adjacent to the space to be air conditioned. The location must be selected such that there are no direct drafts. The same must be coordinated with interior layouts.

4.2 Chillers: The location for air-cooled chillers must be open and there should not be any obstacle for air flow. The recirculation of hot air must be avoided. The location must be dust free to avoid soiling of condenser coils. The enclosed space with proper ventilation with required air changes should be provided for water cooled chillers. The location must be selected so as not to be close to any sensitive area which can have direct impact of vibration and noise.

4.3 Cooling Tower: The location of cooling tower must be well-ventilated to avoid any starvation of fresh air. The location preferably can be on building terrace ensuring the load transfer is directly on structural beams. 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 resting on mild steel-I sections and not on terrace slab. Sufficient free space shall be left all around for efficient operation of the cooling tower. The location of cooling tower shall avoid the transfer of noise and vibration to nearby areas.

Figure 2.1: Typical lifting of chillers with crane

4.4 Pumps: The location of pumps need to be near chillers or cooling tower. The pumps also transmit vibration and hence care must be taken to avoid the direct transfer of vibrations and use of vibration eliminators and/or inertia blocks is recommended.

4.5 Air Handling Units: 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 equipment, 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. However, if this is unavoidable, proper fire/ damper arrangements need to be provided to avid transfer of fire and smoke from one floor to another. It is advisable to have a separate AHU for each fire compartment. 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.

The location of ceiling suspended units should be away from sensitive areas. The location should not be above electrical rooms, IT rooms where chances of water leakage can have huge impact. The location should have proper access for maintenance. Mechanical noise as well as air noise produced by AHU needs to be considered while planning and adequate sound attenuation as well as acoustic lining needs to be planned.

4.6 Fan Coil Units: The fan coil units are ceiling suspended and location must be such that proper access is available. The water leakage is one of the issues of FCUs. The location of FCUs should not be above electrical installations.

4.7 Fans: There are various types of fans and they differ with respect to type and application. The approved drawings and manufacturer's guidelines must be considered for proper location. The location of fans must be away from sensitive areas to avoid the impact of vibration and noise.

4.8 Electrical Panel: The location must be as per approved drawings and close to the related equipment. The electrical panels are to be located in ventilated spaces and raised above the floor levels to avoid possible water ingress.

5.0 Space Planning, Access and Floor Loading

5.1 Unitary Products

(i) While installing an air conditioner, care should be taken that draft of cold air does not inconvenience the user.

(ii) Window (room) air conditioners are normally provided with control plate and electric connection at right side of the unit (as seen from front) hence power outlet points should be provided at right side of window unit.

(iii) The indoor units to be planned to avoid direct draft on occupants.

(iv) Drain piping to be planned, routed properly and connected to the main drain.

(v) Access to outdoor units must be given for safe installation and maintenance.

5.2 Packaged and Ductable Units

(i) The loading of indoor units and outdoor units to be considered with respect to capacity of equipment. Floor loading capacity of the packaged type unit plant room shall not be less than 400 kg/m^2.

(ii) Space for indoor units to be planned considering piping, ducting, electrical cabling and drain piping. The space planning must include access and maintenance requirements. The acoustic insulation to space where indoor units are installed is recommended. The routing of connection must be planned considering safety aspects both during installation and maintenance.

iii) The floor area for installation of the packaged type plant room shall be spacious enough to take return air from the conditioned place.

iv) 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.

v) The space requirement to be fine-tuned during detailed engineering based on manufacturer's recommendations.

vi) Drain piping to be planned, routed properly and connected to the main drain. Floor drain to be provided for packaged units.

vii) Lighting arrangement in room and above ceiling (for ceiling suspended units) to be provided.

vii) Water supply points inside the packaged unit room are preferred for filter cleaning.

viii) Proper access for ceiling suspended units and its connection to be provided.

ix) Isolator to be provided near the units if the control panel is away from the unit.

x) Access to outdoor units must be given for safe installation and maintenance.

xi) In case of water-cooled units, cooling tower location with routing of piping, electrical cabling to be planned.

5.3 VRF / VRV

(i) Space planning for ODUs for effective heat transfer, refrigerant piping and maintenance to be provided.

(ii) The loading of equipment to be considered for structure design and floor loading.

(iii) The refrigerant piping, control and power cabling to be considered for space planning.

(iv) It is recommended to cover the exposed piping.

(v) The space planning based on its type to be planned taking reference to manufacturers' guidelines.

(vi) The space for installation and maintenance to be planned for indoor units.

(vii) Drain piping to be planned, routed properly and connected to the main drain.

(viii) The refrigerant and drain piping shall be properly designed and provided at regular intervals and should be mentioned in the layout drawing clearly.

5.4 Chillers and Condensing Units

(i) Chiller/ condensing unit loading, its point load, vibration and sound details to be considered for loading details and structural / foundation design.

(ii) The floor loading of the AC plant shall be 2000 kg/m^2. The detailed working to be done based on the capacity and dimensions of the unit.

(iii) Space planning for chiller piping connections, electrical panels and cabling, maintenance to be done.

(iv) Space requirement for central air conditioning plant shall be worked out considering sufficient space for movement of equipment during installation, operation and maintenance.

Note: Space requirement to be fine-tuned during detailed engineering based on manufacturer's recommendations.

- Additional space for circulation shall be taken as 20-25% of the above total space.
- Provision shall also be kept for standby / anticipated future requirements.
- The entrance to plant room shall be through double leaf doors or rolling shutters of steel or strong material to take self-load having minimum width of 3.5 m and height not less than 4 m. The door size shall be based on manufacturer's detailed dimensions of chillers.
- For air-cooled chillers open space to be identified with proper air circulation for effective heat transfer. The foundation/ structure to install these chillers to be designed by competent structural engineer.

(v) In case of auto tube cleaning system, additional space to be planned.

(vi) Minimum of 2 meter distance to be kept from the adjacent wall and between chillers or as per manufactures' guidelines to be kept for better air circulation and heat transfer.

(vii) Space for platform for maintenance to be considered.

(viii) Access to electrical panels, valves, key and critical components of chillers to be considered.

(ix) Floor drain and water supply point to be considered.

(x) Utmost care has to be taken to provide proper ventilation system in the plant room in addition to lighting.

5.5 Cooling Tower

(i) Cooling tower loading, its point load, vibration and sound details to be considered for loading details and structural / foundation design as per manufacturer's design parameters.

(ii) Space planning for cooling tower piping connections, electrical panels and cabling, maintenance to be done.

(iii) Space for proper air circulation should be considered.

(iv) Access to electrical panels, valves, key and critical components of cooling towers to be considered.

(v) The uninterrupted water supply to be planned to avoid air lock of cooing tower. Make up water connection with float valve should be provided.

(vi) Isolators to be planned near cooling tower if the control panels are away from cooling tower.

(vii) Cooling tower foundation on the terrace should be designed in such a way that cooling tower sump bottom level should be at least one meter above the condenser pump inlet.

(viii) Floor drain to be considered near towers.

5.6 Pumps

- Pump weight, vibration and sound details to be considered for loading details and structural / foundation design.
- The space planning for pump piping connections, electrical panels and cabling, maintenance to be done.
- Sufficient distance between pumps as per manufacture's guideline to be kept for maintenance and movement of parts / removal of pump in case of maintenance.
- Floor drain to be considered in space planning
- Space for access to valves, strainers, isolators to be considered.
- Pumps shall be isolated from the piping through flexible connections. Where specified, pumps shall be mounted on Inertia blocks to prevent transfer of vibration.

5.7 Air handling Unit (AHU)

(i) Weight, its point load, vibration and sound details to be considered for loading details and structural / foundation design.

(ii) Loading details

- The floor loading of AHU room shall be 600 kg/m^2.
- 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.
- All cutouts in the floor for the pipelines and cable shall be effectively sealed from the fire safety point of view.

(iii) The space planning for AHU piping connections, ducting and dampers electrical panels and cabling, maintenance to be done.

(iv) Space Requirement.

- The AHU room should be designed in such a way that there should be sufficient space for return air circulation, movement of AHU parts in case of repair, maintenance.
- The minimum clear height of the AHU room shall be the same as that of the air-conditioned space to facilitate laying of ducts.
- Never allow the vacant space in the AHU room for storing materials. A written notice to be pasted in the room in this connection

Note: Space requirement to be fine-tuned during detailed engineering based on manufacturer's recommendations.

(v) 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.

(vi) 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.

(vii) 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 at the initial planning stage.

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

(ix) Trap door size (in case of ceiling suspended units) to be 450 mm extra over the dimensions of unit. Additional access for valves, connections to be considered.

(x) Drain slope to be considered while space planning.

5.8 Fan Coil Units (FCU)

(i) Weight, its point load, vibration and sound details to be considered for loading details and structural / foundation design.

(ii) Space planning for FCU piping connections, ducting, drain, electrical points and cabling, maintenance to be done.

(iii) Trap door size (in case of ceiling suspended units) to be 300 mm extra over the dimensions of unit.

5.9 Fans

(i) Weight, its point load, vibration and sound details to be considered for loading details and structural / foundation design.

(ii) Space planning for ducting and dampers, electrical panels and cabling,and maintenance to be done.

(iii) Trap door size (in case of ceiling suspended units) to be 450 mm extra over the dimensions of unit.

Chapter 3:

Split, Window and Packaged Unit Installation

1.0 General

The window air conditioner is a compact unit where all the components of the air conditioner are assembled in one box and the machine is assembled and tested at the factory. The unit when received at the site is removed from the packing and fitted in the wooden frame already installed in the room window or wall.

In case of split air conditioner, the outdoor unit (ODU) (consisting of compressor, condenser and the controls and the IDU (indoor unit) comprising of evaporator, supply air fan and capillary tube comes to site in two different boxes. The service technician will install the IDU and OUD as per the site plan and connect both by means of copper piping. Once piping is done, non-condensable gas is removed from the piping through vacuum test and refrigerant gas is charged thereafter.

Packaged air conditioners (PAC) sizes vary from 4.00 TR up to 22 TR and installed in multiples for the higher capacity. PACs are manufactured either as air cooled or water cooled. PACs are manufactured and tested in the factory like split units and delivered to the site. In case of water-cooled PACs, there will be cooling tower and condenser water pumps connected to the PAC. Both cooling tower and water pumps are designed and delivered to the project site as per the design to match capacity of PACs. Please refer installation guidelines in the chapters on Cooling Tower and Pumps.

In order to ensure proper functioning of above units, the installation has to be done perfectly as per the installation guidelines failing which the machine will fail or consume more power without achieving desired cooling. It is therefore very essential to follow the installation guidelines in order to get the best of comfort and energy saving.

2.0 Packing, Dispatch, Receiving at Site, Lifting and Storage

The units are generally packed in cartons with thermocole packing inside to protect any damages during the transport. The units are delivered with their manufacture's installation, commissioning and maintenance manual. The same needs to be followed for correct installation, commissioning, trouble shooting and maintenance. It is important to check the transit damage if any while receiving the unit and report accordingly. Following parameter needs to be checked while accepting the units:

1. Manufacture
2. Types of AC system delivered is same as per requirement (capacity, model, etc.)
3. The packing has been properly made and there are no damages to the product
4. The accessories should also be with the product (filters, installation accessories, remote control unit)
5. Rated cooling capacity
6. Rated heating capacity
7. All wiring and piping connections have been made at factory
8. Installation manual is included in the box
9. Test and warranty certificates
10. Pipe connections are correct in size

The units must be stored in protected place and shifted to location before installation.

3.0 Pre-Installation and Installation Checks

3.1 AC units /relevant location of the units as specified in the construction drawings are completed and free of construction debris.

3.2 All glazing works are completed and all windows closed.

3.3 Temporary/ permanent lighting shall be in place at the specified location of the equipment.

3.4 The installation location of indoor units is free from obstacles and necessary space is available for maintenance. The room of packaged unit is as per drawing and necessary spaces for connections and maintenance is available.

3.5 The power arrangement is made available as per electrical standards.

3.6 The location for ODU is clear and ventilation is sufficient for proper heat transfer. The structure is safe to mount the units.

3.7 In case of multiple outdoor installations, the minimum space between unit is maintained for proper heat transfer. Refer manufacturer's guidelines.

3.8 The arrangement for condensate drain connection is available. Necessary slope is available for drain piping.

3.9 The route for copper piping is clear and within the limit as recommended by manufacturer.

4.0 Installation Procedure

4.1 Window (Room) Air Conditioners

4.1.1 Window units are installed in the cutouts provided in the wall or window with a proper frame as per required size. Before installation, unpack the unit and install the outer section by fastening it on to the frame. Install the unit within the frame and ensure the stability of the unit. The slope of the unit should be to the outside.

Figure 3.1: Window AC installation

4.2 Split Air Conditioners

4.2.1 *Figure 3.3* illustrates the placement of Indoor Unit (IDU) and Outdoor Unit (ODU) with respect to the room to be air conditioned.

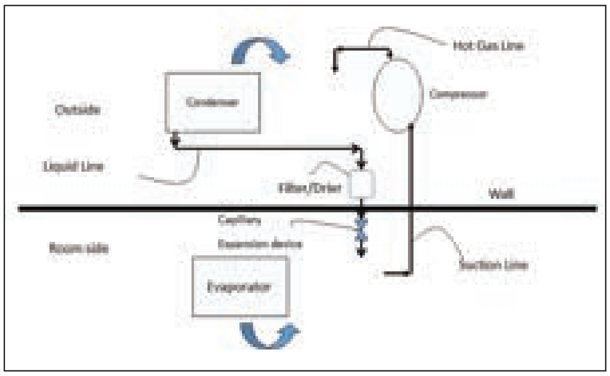


Figure 3. 2: Layout of a split AC

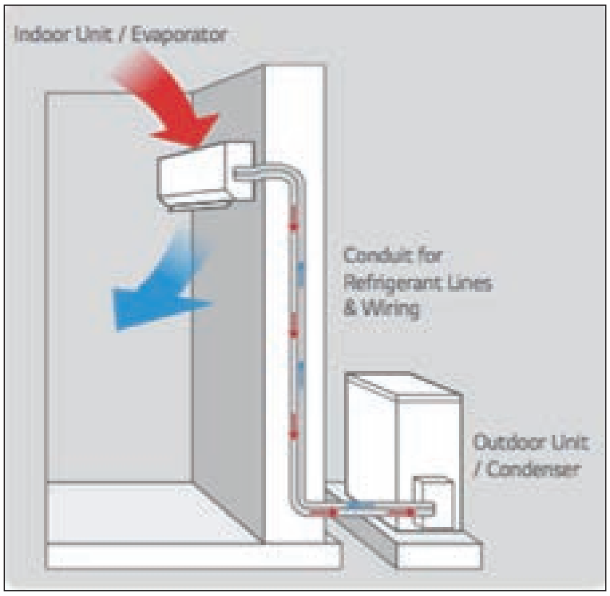


Figure 3.3: Split air conditioner with placement of IDU and ODU

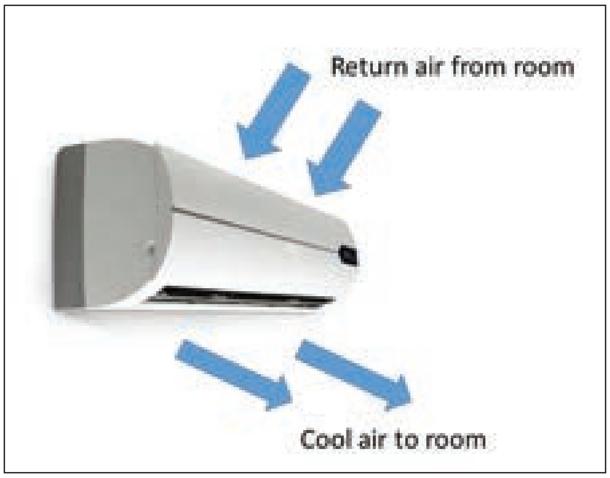


Figure 3.4: Indoor unit

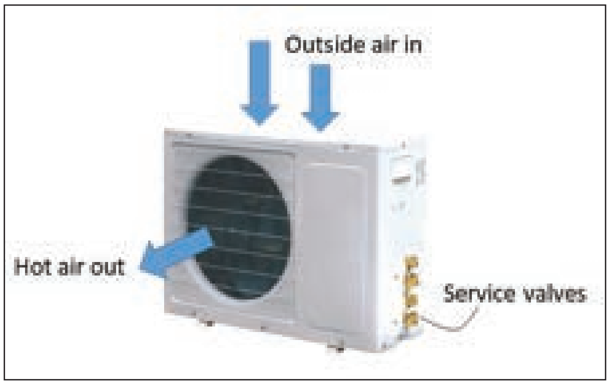


Figure 3.5: Outdoor unit

4.2.2 A filter drier *(Figure 3.7)* is an essential component in the refrigerant circuit. It has two essential functions: a) to adsorb system contaminants, such as water, which can create acids, and b) to provide physical filtration. The filter drier is to be chosen depending on the line size used. It needs to be replaced whenever the system is being re-charged.

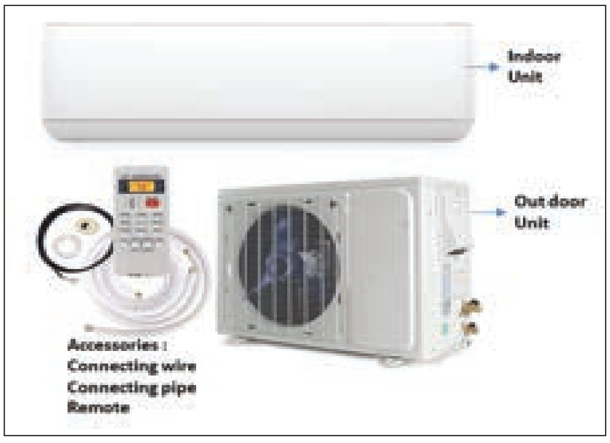


Figure 3.6: Split unit with accessories

Figure 3.7: Filter/driers

The remote control is supplied along with the unit.

4.2.3 The ODU and IDU for split ACs comes in the two packages from the factory and both have to be installed at site by a qualified and experienced technician as per the laid down procedure The step-by-step procedure for installation is given below:

(i) Placement of the IDU inside the conditioned room away from any obstacles in properly sized frame work.

(ii) Placement of ODU at the place outside the conditioned room keeping enough place around the unit for air movement and maintenance purpose,

(iii) Connect both IDU and ODU by properly laid copper pipping and with proper clamps to avoid vibration.

(iv) Remove the non-combustible gases from the piping by flushing and vacuumizing.

(v) Top up with refrigerant as per the required quantity.

(vi) Check the suction, discharge pressure and the current drawn by the unit which should match the design parameters.

Placement of IDU

i) The IDU should be easily accessible by standing on a small stool so that filters can be cleaned easily.

ii) The IDU comes with a wall hook bracket. It is an aluminum template with all the necessary holes. The technician needs to make holes in the wall as defined by template. A spirit level is to be used to check if the template is horizontal.

Figure 3.8: Template for marking drilled holes for fixing indoor unit

iii) During the process of air conditioning, the moisture in the air will condense on the cooling coil (evaporator) and provision has to be made for this water to flow out of the room. The hole in the wall should be made lower than the IDU so that the collected water can flow out easily through the drain pipe. Test that water flows easily by pouring water into drip tray.

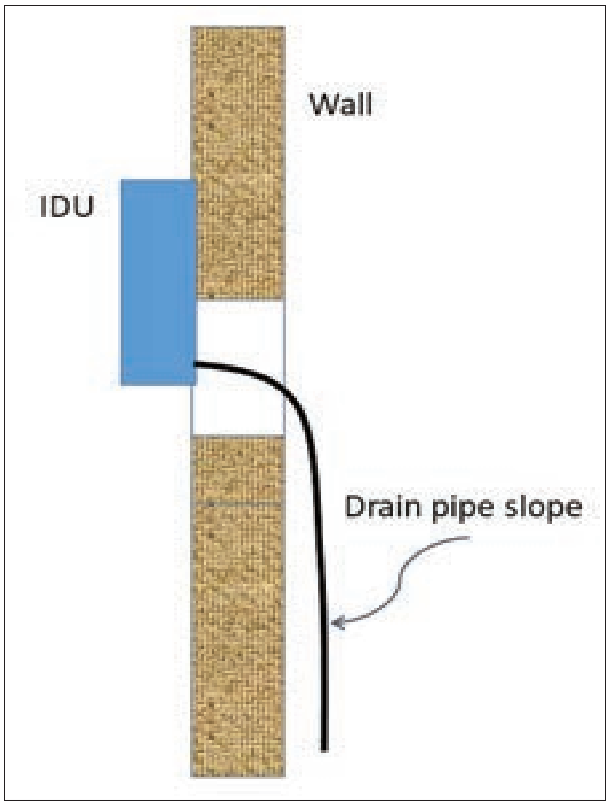


Figure 3.9: Drain pipe for condensate

iv) A hole of about 75 mm in diameter has to be made in the wall and near the bracket. This opening will carry the (a) copper tubing that brings the refrigerant in liquid form into the room and the copper tubing carrying the refrigerant in vapor form back to the compressor that is placed outside the room. These tubing are insulated; hence they need hole of suitable diameter, (b) The drain pipe though which the condensed water is drained, (c) The power supply cable giving power to the compressor.

v) It is important that a PVC sleeve is used in the hole and after all the lines are passed through the hole, the remaining space is to be filled up by caulking material (putty). The filling is to be done neatly so that the appearance is good.

Placement of ODU

i) It is very important that the ODU has to be placed on a firm surface using vibration isolators (rubber pads) to prevent vibration.

ii) The ODU needs to be placed such that cool air flows over the unit. The cooler the air the better is the performance of the air conditioner. Best place is the shaded terrace but if the terrace is not available it can be kept on the awning (*chhajja*) above the window or it can be hung on the external wall supported by angles.

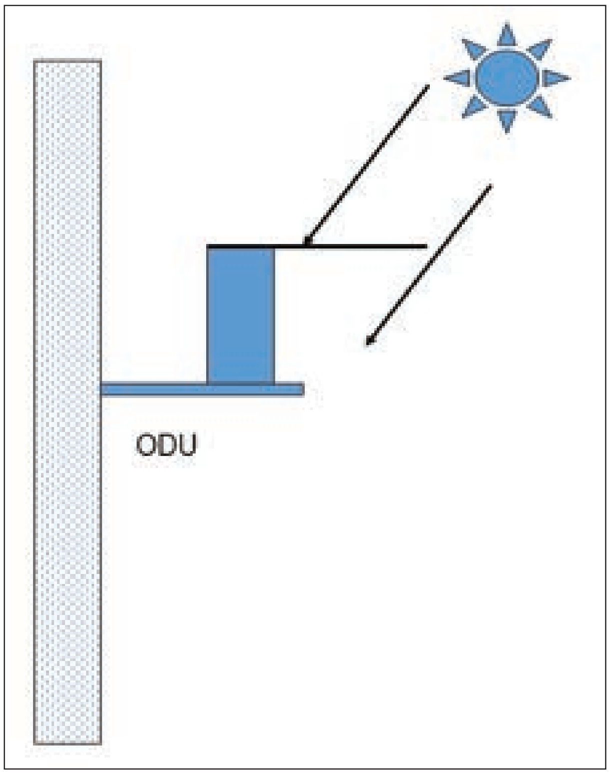


Figure 3.10: ODU on sunshade

iii) As far as possible the ODU should not be exposed directly to the sun, however, if this cannot be avoided, a sunshade should be made to protect it from direct sunlight. This is a very important matter since direct sunlight will affect the ability of the condenser to reject heat and the performance of the system gets affected.

iv) But remember at the same time, the ODU needs to be accessible for repair, gas charging and cleaning.

v) In case of installation of multiple units, one ODU should not face another ODU or be located close by because the hot air from one will disturb the performance of the other. Please see *Figure 3.11.*

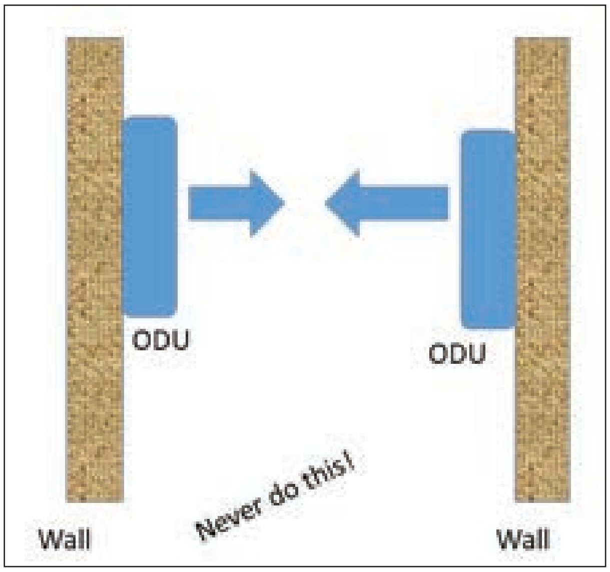


Figure 3.11: Never let ODUs face each other

vi) The distance between the indoor and the outdoor unit should be kept as minimum as possible to reduce the loss of the cooling effect. The maximum distance between the indoor and the outdoor units can be about 15 meters or as specified by manufacturer but try your best to keep to minimum.

vii) The height difference between IDU and ODU should not exceed 5 meters.

Refrigerant Piping Layout and Routing to Connect IDU and ODU

i) Once the IDU and ODU are installed, the very important task of connecting with copper tubing remains. The copper tubes of the correct sizes are supplied with the indoor unit. The smaller size pipe carries the liquid refrigerant and the larger one carries the vapor back to compressor.

While routing the copper pipe,

- The number of bends should not exceed 15,
- Radius of each bend should be more than 10 cm.

Connecting IDU and ODU in pre-charged systems

In modern day split air conditioners, the gas is pre-charged under pressure in the ODU

This gas has to be released to the whole system including the refrigerant tubing and the indoor unit. Thus, in the new split unit there is no actual gas charging in real sense, it is only distributing the gas compressed in the outdoor unit to the whole air conditioning system.

Once the IDU and ODU are properly placed, the distance between them is measured and two copper tubing of correct size are cut and laid properly along the wall by clamping to make it neat and tight.

Oil is constantly pumped out of all compressors and circulated with the refrigerant. The oil must be returned to the compressor for proper lubrication of bearings and contact surfaces. Suction and vapor lines must be sized carefully to eliminate oil management problems.

The pipes should not touch the building structure to prevent vibration transmission. Pipes need to be clamped to the walls at periodic intervals and soft material between pipe and clamp shall be inserted to prevent erosion due to different metal surfaces touching each other.

For systems with ODU above IDU, one trap must be installed at the bottom of the suction riser as shown in *Figure 3.12.*

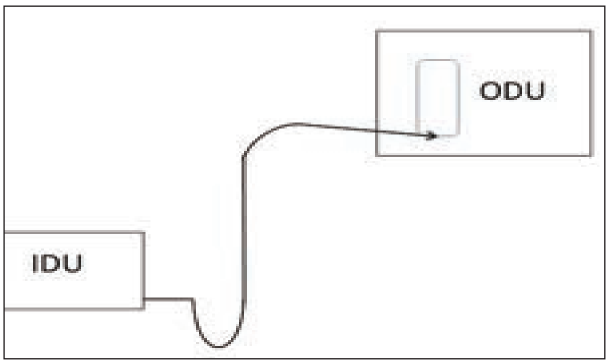


Figure 3.12: Suction piping with U trap placement

Though it is recommended that the ODU be placed above the IDU, it may not be always possible. In such cases, the arrangement shown in *Figure 3.13* can be used for the piping. When an evaporator is located above or on the same level as the condensing unit, the suction line must rise to the top of the evaporator. This helps prevent liquid from migrating to the compressor during the off cycle. Traps should also be installed at the bottom of all vertical risers. Horizontal suction lines should be level or slightly sloped toward the condensing unit.

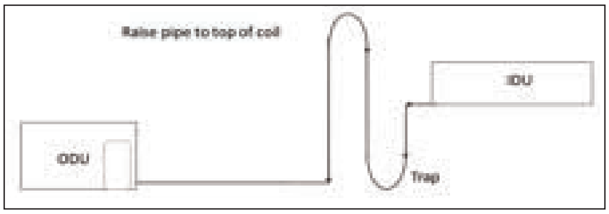


Figure 3.13: Suction piping when ODU is below IDU

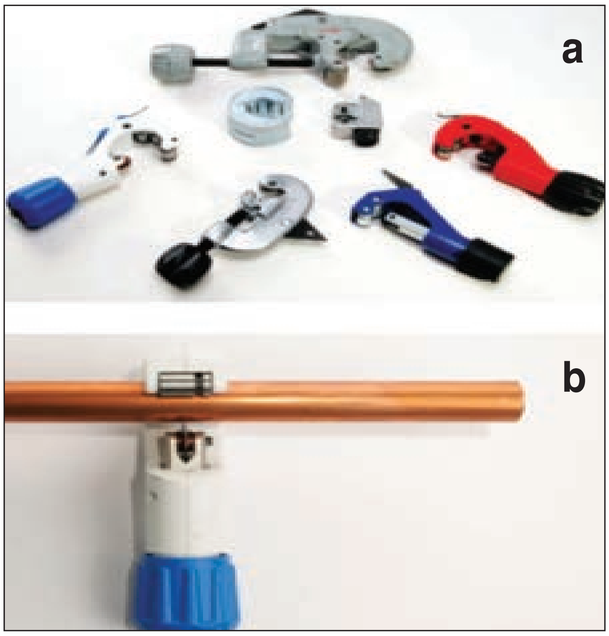


Figure 3.14: (a) Tube cutters (b) Cutter position for square cut, perpendicular to run of tube

Care needs to be taken that there should not be too much extra length of tube since it leads to extra pressure drop.

The two-copper tubing are passed through the hole made in the wall. On one of the ends of these two tubing flaring connections are made for connecting onto the flare nut already available on the tubing emerging from the indoor unit.

The other end is to be joined to the ODU. While taking the tubing outside the building, it is important to provide support and clamping for these tubing to the wall by using brackets so that they won't keep vibrating when the refrigerant flows through them. This is to avoid the breakage of connections due to vibrations resulting in leakage of the refrigerant.

Before connecting the refrigerant tubing to the outdoor unit, it should be covered with the insulation material, which is usually the foam tube.

It is important that the tubing be fixed to the exterior wall in a symmetric and aesthetic manner and not spoil the show of the exterior.

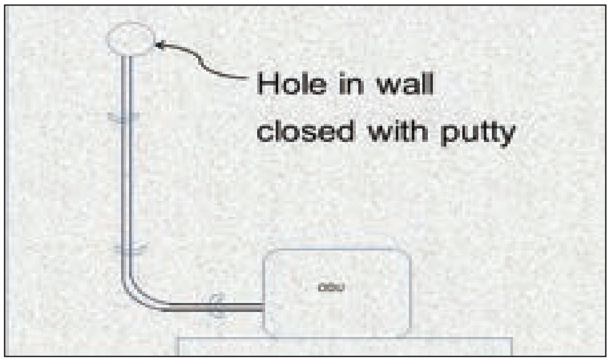


Figure 3.15: Neat arrangement of pipes on exterior of building

The two free ends are to be now connected to the ODU. Flare connections are made at the two free ends of the two-tubing using flaring tool taking care to first insert the female flare nut. Put some seal oil to cover the joint and flare.

Figure 3.16: (a) Lowering the flaring cone into the tube end (b) Completed flared tube

The flare nuts on each of the tubing are connected to the connector provided outside the outdoor unit and the connection tightened.

The indoor and outdoor units are now connected by the refrigerant tubing. The two units can now be connected together by the electric wiring as per instructions in manual and which is finally connected to the main supply.

4.3 Electrical Points/Power Requirement

The quality of power available needs to be checked properly. Very often the cause of fire is due to faulty electrical connections.

The following are to be specially noted and care taken:

1. Voltage other than specified can damage the unit. Rated voltage ±10% should be available. If not, proper stabilizer is to be used.
2. A circuit breaker needs to be installed to protect the air conditioner from over-current.

Figure 3.17: Miniature circuit breaker (MCB)

Figure 3.18: Power socket for air conditioner

3. Proper earthing/grounding is to be provided. Take care that the earth line is not near water or gas or telephone line. Voltmeter reading between Neutral and Earth should be less than 3V.
4. Supply between Line and Earth must be the rated voltage ±10%. Supply between Line and Neutral should be ±10%. Technician should carry multimeter/ clamp-on meter to check.
5. No extensions are to be made to the power cord and the power plug should be firmly in the socket; there should not be a loose connection.
6. No other device is to be connected to the power source.

5.0 Packaged Air Conditioners

Packaged air conditioners (PAC) are normally available from 4.0 TR in the range of 5.0, 6.0, 7.5, 11.0 and 22 TR capacity and for higher plant capacity are installed in multiples of these sizes. The packaged units are either air-cooled or water-cooled type. The installation, site activities such as refrigerant piping layout, pressure testing, vacuumizing, gas charging Do's and Don'ts are similar to split air conditioners.

Water-cooled packaged air conditioners will have pumping system, cooling tower and water piping between condenser and cooling tower. The details on cooling tower and pumping system are covered separately under cooling tower and pumping sections.

5.1 Placement of ODU

Select a suitable place on the terrace or awning (chhajja) outside the room. The ODU has to be placed on a firm surface using vibration isolators (rubber pads) to prevent vibration. It can be hung on the external wall supported by the angles. When it is directly exposed to sun a sunshade should be provided to protect it from direct sunlight. The ODU needs to be accessible for repair, gas charging and cleaning. One ODU should not face another ODU and shall be placed in such a manner that the hot air from one will not disturb the performance of the other. The placement and its foundation purely depend upon the site layout and conditions.

5.2 Laying of Refrigerant Piping

Once the IDU and ODU are installed at the correct location, the very important task is to connect both ODU and IDU with copper tubing. The copper tube of correct size is supplied along with the IDU.

a) While routing the copper tube the number of bends should not exceed 15 and radius of each bend should be more than 10 cm.
b) The maximum distance between the indoor and the outdoor units should be about 10 meters or as specified by manufacturer. The height difference between IDU and ODU should not exceed 5 meters. In case the distance between the IDU and ODU, the height difference between IDU and ODU exceeds the recommended limits, the OEM should be consulted to decide on the size of pipe and the additional gas charge required for proper functioning of the machine.
c) While the machine is operation, the oil is constantly pumped out of the compressor and circulated with the refrigerant. The oil must be returned to the compressor for

proper lubrication of bearings and contact surface.

d) When an evaporator is located above or on the same level as the condenser, the suction line must rise to the top of the evaporator. This will help prevent liquid from migrating to the compressor during the off cycle. Oil trap also shall be installed at the bottom of vertical riser. The horizontal suction lines should be level or slightly sloped towards the ODU.

e) The pipes shall not touch the building structure to prevent vibration transmission. Pipes need to be clamped to the walls at periodic intervals and soft material between pipe and clamp to prevent erosion due to bi-metallic corrosion.

f) Where the ODU is installed above the level of IDU, one trap must be installed at the bottom of suction riser immediately after the evaporator.

5.3 Tube Straightening and Cutting

Before laying copper tubing between IDU and ODU care should be taken to straighten the piping properly. Support the coil upright with one hand and holding the free end of the tubing stationary on a flat surface with the other hand. The tubing should be marked at one end and the required length of tube is measured at the other end. Once the correct marking is done the tube shall be cut using tube cutter only.

5.4 Cleaning and Polishing

The coper tubes used for the refrigerant piping must be free from moisture, dirt, oil and kept clean using abrasives like emery paper, wire brush etc. When two pieces of piping are used for joining, the surfaces of both the ends should be dry without any oil or liquid traces, polished by emery paper.

5.5 Tube Cutting

The cutting of soft copper tubing should be done using a tube cutter which makes an accurate 90°. It should be at a right angle to the axis of tube and smooth. Do not use hacksaw or any other tool to cut soft copper tubing. After cutting off the desired length, place the cap or plug on the end of the coil to prevent contamination.

5.6 Flaring

Flare connection is a mechanical joint without any gasket in between and used to connect tubing to fittings such as valves or to join the copper tube with male threaded flare fitting. The flaring operation should be done only on the tube which is cut by the tube cutter and after removing the burrs. The end of the soft copper tube is flared at 45° angle. For flaring operation, a flaring block and a flaring yoke are required. The soft copper flare takes the shape of the fittings and seals properly. The flared joint must be done so carefully that the flare joint should withstand the test pressure of refrigerant line to avoid any leakage of refrigerants. The flared end of tubing rests against the male portion of the fitting being connected. Inspection of the flaring must be done after removing the tubing from the flaring tool. If the tube end has split, the flared portion to be cut and repeat the process.

5.7 Tightening Torque Required for Different Size Flare Nuts

The torque required for tightening different tube sizes varies according to the diameter of the tube. Apply torque that is just right for flare nuts, over tightening shears the tubes, ultimately resulting into a leak. If a flare joint leaks even after tightening to the required torque, the reason for leakage may be due to bad flare, burrs on tube and wrong size flare. Then cut the tube and make the new flare.

5.8 Brazing

Tubing used in refrigeration and air-conditioning (RAC) is made of copper. Brazing is a process for joining two metal or alloy pipes in RAC. Brazing is a hot non-attachable process using flame, and safety precaution while doing brazing should be ensured.

Brazing shall be done between copper to copper, copper to aluminum, copper to brass and copper to steel tubes to make a leak proof connection which will also withstand vibrations and shocks. To perform the brazing process, brazing rods or filler material, and an acetylene-oxygen cylinder and torch with different sizes of nozzles are required

The temperature required for brazing will depend on the size and thickness of the material being brazed. For air-conditioning application normally heat source should produce temperature above 450°C. The brazing rod should melt on contact with the heated copper tubes and should never be heated directly by the torch flame and melted. The filler rod that has melted on contacting the heated base metals flows into the clearance between the overlapping copper tubes that have to be joined, by capillary action. This capillary action will take place only when the clearances are maintained within certain limits and the movement of flame across and around the joint.

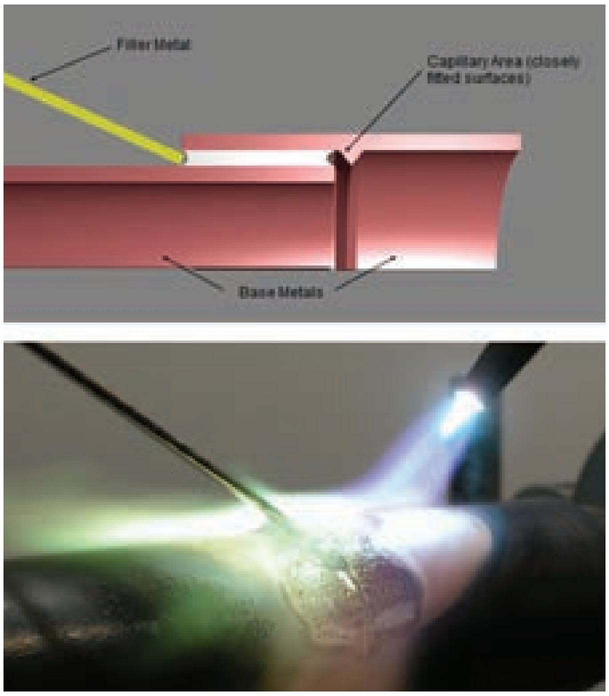


Figure 3.19: Capillary action during brazing

Introduction of Nitrogen as protective gas with a very low flow rate inside the tube assembly during the brazing process is a good method to avoid oxidation. Service valves should be protected with wet rags or heat sink material while doing brazing. Use only recommended fillers for various joints.

Note: When flammable refrigerant is used in air-conditioner, it is advisable to avoid flare connections inside the room and join the tubes by brazing only

5.9 Air Purging

The flare nuts at the IDU end can be loosened for a few seconds to purge the air present in the copper tubing.

5.10 Leak Testing

The joints of the refrigerant tubing have to be checked for leakages. There are four joints in the split air conditioner: two at the indoor unit and two at the outdoor unit, connecting the refrigerant tubing and the indoor and the outdoor units. Since the gas is now present in the air-conditioning system, it is at high pressure and to check for the leakages, soap solution is applied to the joints. If there are any leakages, bubbles will be seen forming at the joints.

Leak testing is an important activity since the amount of gas is small and leakage will end up in compressor burn-out since in domestic units the compressor is a hermetic one where the compressor motor is cooled by the refrigerant gas itself.

If there is some gas leakage the connections have to be tightened. If the leakage does not stop, the leakage point may have to be dismantled and reinstalled.

5.11 Pressure Testing

Any air conditioning system will be charged with refrigerant under pressure. If there is a leak anywhere in the system, it can cause leakage of refrigerant and affect the working of the system. Especially in domestic appliances which have hermetic compressors which depends on the refrigerant for cooling the motor.

The method of ensuring that there are no leaks in the system is called pressure testing.

The operating pressure of an air conditioning system denotes the condensing pressure and suction pressure. Compressor discharge shut off valve to inlet of expansion valve is called the high-pressure area (condensing pressure – high pressure side). Outlet of expansion valve to the suction service shut off valve on the compressor is low-pressure area (suction pressure – low pressure side).

Normally the factory that manufactures split air conditioners, pressure tests them before being dispatched to the field. The pressures to which they are tested are also indicated therein. In the field what is tested is only the refrigerant piping and connections to ensure that they are leak proof (of course the components also go through the test)

5.12 Important Points to Note While Pressure Testing

1. Standard bone-dry nitrogen is used to put the system under pressure.
2. Extra alertness is required that only nitrogen is used for this purpose.
3. Many accidents have taken place due to untrained persons using oxygen to do pressure testing. Double-check the cylinder at all times.
4. It is essential that pressure regulating valve should be fitted on the nitrogen cylinder.
5. Domestic refrigerators and air conditioners have very limited internal volume and

pressure buildup can be very rapid if pressure regulating valve is absent and serious fatal accidents can happen.

6. High side has to be tested for high pressure (1.5 times condenser pressure – maximum). Low side has to be tested for low pressure (1.5 times evaporator pressure / suction pressure / standing pressure).
7. First test the entire system to low pressure and make sure that there are no leaks (all the valves are kept open).
8. Shut off the discharge service shut off valve and the liquid line service valves.
9. Apply high pressure to the high side only and test the systems for leak.

It is very important to take care of the following points while pressure testing:

1. Have total patience while carrying out pressure testing. Do not hurry up.
2. Educate the client the need to have a proper pressure testing.
3. Do not rely on the work of an untrained person.
4. Do not use oxygen for pressure testing.
5. Do not use the gas cylinder without proper pressure regulating valve.
6. Do not test the system for a pressure higher than the desired pressure.
7. Do not start the system while pressure testing is in progress even by chance.
8. Whenever the manufacturer specifies the pressure limit, never exceed the same.
9. The purpose of the leak testing is to detect leak and not to assume there is no leak.
10. A leak in the system not detected and rectified at the correct time, can lead to costly and time-consuming work after the plant is put to operation

5.13 Leak Detection

Use of soap solution is an easy and cheap way of doing this. Smear soap solution over every joint / pipe seams.

Observe formation of bubbles and stop the leak.

Pressure test again till it is sure that there are no more leaks.

5.14 Vacuumizing

Ensuring that the system is without moisture and air at the time of charging oil and refrigerant is called vacuumizing

Why does the system need to be put under vacuum?

Air inside the system will:

1. Prevent the system from being fully charged with refrigerant.
2. Remain as a non-condensable inside the condenser and reduce condenser capacity and thus reduces the cooling effect.
3. Increase condensing temperature, temperature of parts inside the compressor.
4. Reduce the effective use of electric power consumed – lower efficiency.

Moisture inside the system will result in:

1. Formation of acids inside the compressor due to heat, oil, gas and moisture.
2. Acids acting on the motor winding in case of hermetic / semi-hermetic compressor.
3. Acids will act on the part of the compressor resulting in corrosion.
4. Breakdown of compressor either electrical or mechanical or both.
5. Blocking of expansion device by formation of ice.

5.15 How Much Vacuum is Needed?

Unit of measurement of vacuum in HVAC industry is ‘micron’. One micron is one millionth part of a meter. One micron is 1/1000 mm, that is, 0.001 mm. The limit specified should be acceptable and practicable.

When a system is under vacuum of, say, 759.9 mm, it means the air and moisture exerts a pressure of 760-759.9 i.e. 0.1 mm, that is, 100 microns.

For small hermetic systems a vacuum of anything less than 1000 microns is recommended in order to have a better system for hermetic / semi hermetic compressor system.

Procedures adopted while vacuumizing

A good vacuum pump is needed that can draw the required vacuum within a reasonable time.

In a rotary pump there is no clearance volume and hence deep vacuum is possible. A two-stage pump is more desirable to make sure that the discharge air is at a pressure higher than the atmospheric pressure.

Air ballast facility with the vacuum pump is beneficial to make the operation faster. The air ballast is a manually operated valve which allows a certain amount of atmospheric air into the compression side of the rotor and this air becomes hot while passing through the body of the vacuum pump and carries away the moisture to the atmosphere.

Do not use the system compressor for drawing the vacuum as the compressor cannot draw the required vacuum, the compression ratio will become very high and will heat up the parts badly.

System should not have leaks, as that will prevent us from drawing a good desired vacuum.

Vacuum pump should have oil of proper quality and changing the oil periodically is desired as the oil will be absorbing moisture while in operation.

The vacuum is measured with a compound gauge.

5.16 Vacuum Standing Test

Once the desired vacuum is drawn using a good quality vacuum pump, note down the date, time, and temperature of the surrounding and quantum of vacuum reached. The vacuum pump is connected to system through the manifold gauge set.

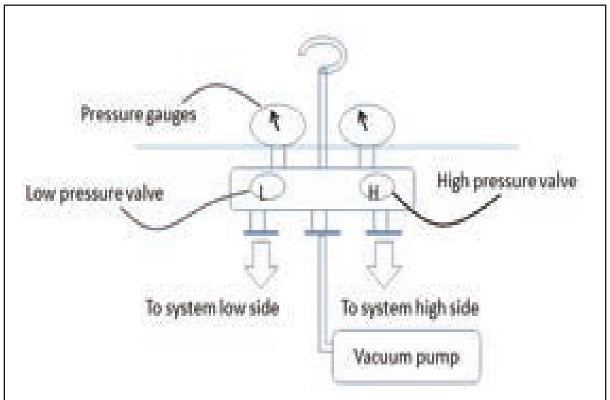


Figure 3.19 Manifold gauge during vacuuming

Close the valves of vacuum pump.

On the next day and at the same time (after 24 hours) observe the vacuum in the system and temperature of surrounding air. Subject to slight variation in ambient temperature, vacuum should remain the same. If not, then there is leak, which is to be detected and arrested.

5.17 Oil Charging

Do's:

a. Calculate the quantity of oil to be charged and charge only the required quantity of oil.
b. Get the oil certified for suitability of the quality of oil for the specific application.
c. Charge oil after vacuumizing is over.

Don'ts:

a. Use any oil available in store – the result could be disastrous.
b. Top up the system with oil before making sure of the location of the oil already charged. Excess oil in system will reduce refrigeration.

5.18 Refrigerant Charging

Do's:

Check the quality of refrigerant before charging as a rule. Be sure to charge only adequate quantity of refrigerant.

It is advisable to use a large size drier in the charging line, which will eliminate or reduce the moisture content.

Keep the cylinder vertical while charging into suction line (or as recommended by manufacturer).

5.19 Gas Charging from the Outdoor Unit

There are two valves located at the lower end of the outdoor unit, one for supplying the compressed gas from the outdoor unit to the indoor unit and other one for receiving the return gas from the indoor unit. Initially, both the valves are closed. During gas charging both the valves are opened slowly by using a key. With this the refrigerant gets distributed in the whole air conditioning system including the indoor unit, the outdoor unit and the refrigerant tubing.

If the refrigerant piping is more than 7 meter in length, an additional amount of gas at the rate of 15 gm/excess meter is to be added to the system, i.e. 15 gm is to be added if the length is 8 m, 30 gm for 9 m and 45 gm if length is 10 m, etc.

5.20 Start Up

Once the above steps are completed, the following checks need to be done.

1. Measure the resistance between the power cord and the ground. It should be greater than 30 mega ohms.
2. Ensure conditioned room is clean and doors windows are closed and no outside materials dirt etc. is present in the room.
3. Start the fan of Indoor unit and check if the vanes are moving in the correct direction and air flow is felt in the room. Check the sound level and note is there is any unwanted sounds and vibration. A handheld decibel meter can be used for sound measurement.
4. Take readings of air velocity and temperatures and record.
5. Next check if there is any obstruction to the

air flow around the outdoor unit. Now start the unit and again check for unwanted sound and vibration of the outdoor unit. Record the outside temperature.
6. Run the system for some time and record inside temperature of room.
7. Please follow the procedure for Commissioning as detailed in Chapter 21.

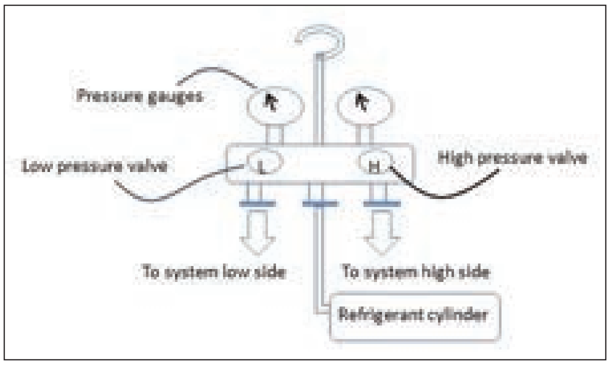


Figure 3.20: Manifold gauge during refrigerant charging

While charging refrigerant, keep a watch on the current drawn by the compressor (should not exceed full load current), suction pressure, discharge pressure, level of liquid in the condenser.

Don'ts:

1. Do not charge in a hurry. Haste invites danger and accidents.
2. Refrigerant charging needs to be entrusted only to experienced technician.
3. Do not bypass the safety controls.

Before starting the system, the following steps are to be followed:

1. Check and ensure that the units are installed correctly with vibration isolating rubber pads.
2. Check and ensure correct refrigerant piping connected to ODU and IDU.
3. Check and ensure correct supports are provided for refrigerant pipes.
4. Check and ensure clearance around the condenser for adequate air circulation.
5. Check and ensure correct size cables are used for motors, compressors etc.
6. Check and ensure correct termination of power and control cables.
7. Check and ensure the cleanliness in the conditioned space
8. Check and ensure filters are installed in the system.
9. Check and ensure correct size fuses are installed.
10. Check and ensure correct incoming voltage.
11. Check and ensure correct direction of rotation of evaporator fan motor and condenser fan motors.
12. Check and ensure design air quantities of the unit.
13. Check and ensure operation of system safety controls.
14. Check and record conditioned area temperatures.
15. Check and ensure correct operation of thermostats.

5.21 Safety

Safety of the personnel involved in installation and service of HVAC equipment is of utmost importance. Following the correct practices and use of the correct tools can eliminate accidents.

Correct practices have been given in Chapter 19 but to highlight they are repeated here.

1. Check the cylinders for its content before using.
2. While pressure testing, check that its nitrogen gas going to be used. Never use oxygen.
3. Disconnect power lines when system is under pressure and keep a large board that says system is under pressure.
4. Check that the nitrogen cylinder has a pressure regulating valve.
5. Be doubly sure that the correct gas is being charged into the system.
6. Different refrigerants have different operating pressures; check the values before gas charging.

6.0 Packaged Air Conditioners – Water Cooled

Water cooled PACs are assembled and refrigerant charged during manufacturing and no assembling is required at site. On installation at the pre-decided location, piping work will commence from the condenser to the cooling tower. Electrical panel will be provided near the PAC and connection to motors carried out as per the design.

Generally, in case of PACs, both air cooled and water cooled, supply air is delivered through properly designed ducting system. Based on the layout, supply and return air ducts/passages are carried out and insulated where ever required. Chapter 11 may be referred to for ducting and air distribution and Chapter 13 may be referred to for insulation.

Chapter 4:

VRF Installation

1.0 General

Variable refrigerant flow (VRF) is a type of heating and cooling system for residential or commercial applications. Most heating and cooling systems fall within two broad categories: ducted split systems, or ductless mini-split systems. The VRF system relies on refrigerant alone instead of a water-based cooling system. Without chillers or coils, a VRF system is quick, responsive, and adaptive to outdoor conditions. VRF systems mostly use inverter compressors. This allows the compressor motor to run at variable speeds to save energy.

A VRF system allows for multiple air handlers within the same system. Different rooms or spaces are equipped with a wall or ceiling mounted indoor unit to distribute air. This lets users make more specific heating and cooling decisions based on the room or space.

With up to 64 indoor air conditioning units connected to one outdoor unit, the VRF system operates similar to a multi-split system. Each individual indoor unit determines the capacity it needs based on the current indoor temperature and requested temperature from the remote control (set point).

The total demand among all indoor units will determine how the outdoor unit adjusts the refrigerant volume and temperature. By only supplying the cooling or heating that is needed, the inverter compressor continues to save a large amount of energy during VRF operation.

2.0 Material Receipt and Storage at Site

Transport the indoor units to the installation location in the original packing. In case the site is not ready, shift the materials to already allotted safe storage space in original packed condition When receiving the products, be sure to check for any blemishes or dents.

Make sure the outdoor unit is in its original packaging to avoid damage during local transport.

- Handle the outdoor unit with care. Keep the outdoor unit upright to avoid damaging inside components.
- If a forklift is used to transport the outdoor unit, the forklift arms should pass through the openings at the bottom.
- If a crane is to suspend the outdoor unit, it is recommended that two ropes at least 7 m in length be used. Necessary crane safety to be followed.
- Pass the ropes under the unit. Pass the rope through the two forklift slots each at the front and rear of the outdoor unit.

Similarly arrange to store the components, copper piping, and fittings to the allotted space and stack them properly. The heavy materials and machines should be shifted though crane / fork lift depending on the capacity and size of the material.

If any damages to the material or components are found while receiving, the matter should be reported in writing to the supplier / manufacturer and necessary report for insurance claim should be initiated.

Protective storage space for the equipment, piping, insulation materials, spares, refrigerant and oil, consumables, tools and tackles and workshop facilities such as carpentry, plumbing, rigging and crane facilities are to be planned and arranged before installation can be taken up.

3.0 Installation of Units

3.1 Choosing Installation Site for Indoor Units

Based on the layout drawing consider following points and proceed with the installation of indoor units. Choose a location that fully complies with the following conditions and user requirements to install the air conditioning unit.

There shall be adequate space for the free movement of airflow. Wall/partition/ceiling shall be strong enough to bear the weight of the indoor unit.

There shall be sufficient space for repair and maintenance work to be carried out.

The length of the piping between the indoor and outdoor units should be within the permitted range (refer to the manufacturer's manual on installation of the outdoor unit). Mounting height is 2.5 ~ 3.5 meters. Based on the shape of the room, determine the airflow directions for the installation location.

3.2 Before Installation

Determine the route to move the unit to the installation site.

First unseal and unpack the unit. Then, hold the seats of the hanger (4 pieces) to move the unit. Refrain from exerting force on other parts of the unit, especially the refrigerant piping, water discharge piping, and the plastic parts.

3.3 Installation Sequence for New Ceiling Units

1. Arrange the hooks in the ceiling, and make sure that they are strong enough to bear the weight of the indoor unit, and that the unit will not become loose when the concrete shrinks.
2. Once the unit is lifted and mounted in the ceiling, use M 6x12 fasteners to secure the installation board on the unit body. Make sure the size and positions of the opening in the ceiling is correct and ceiling is in level position. The necessary gap for installation of grill is maintained.

3.4 Indoor Unit Installation

1. Install indoor units based on the design plan, ensuring proper spacing and accessibility for maintenance.
2. Connect refrigerant piping, communication wiring, and power supply according to the manufacturer's specifications. Check for proper drainage and insulate refrigerant pipes to prevent condensation.
3. Confirm the space required for servicing and installation. Mark the center of the indoor unit with chalk lines, using the base point lines drawn on the floor as a guide.

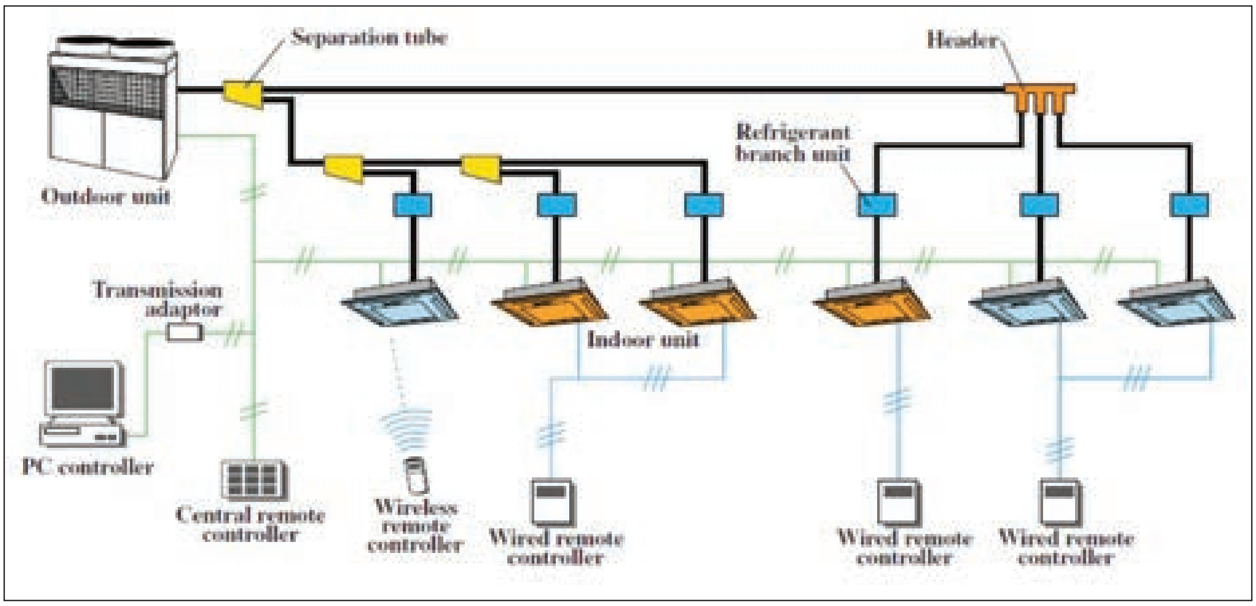


Figure 4.1: Typical VRF layout

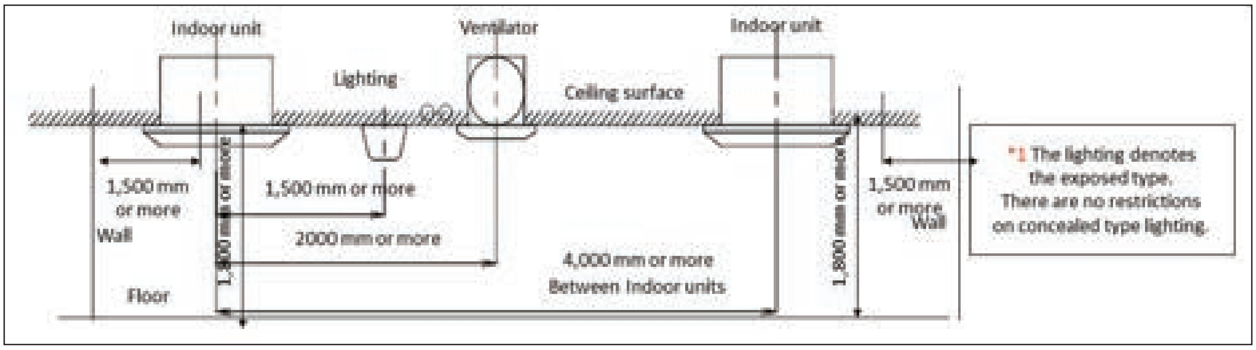


Figure 4.2: Indoor cassette type indoor unit installation with grid ceiling

4. Using upper packing material, mark the suspension locations on the floor based on the center of unit.

3.4.1 Determination of Installation Location

Before installing, place the two nuts (locally procured) and 2 washers (accessory) on the suspension bolt. (Double nut on the lower side of the bolt.)

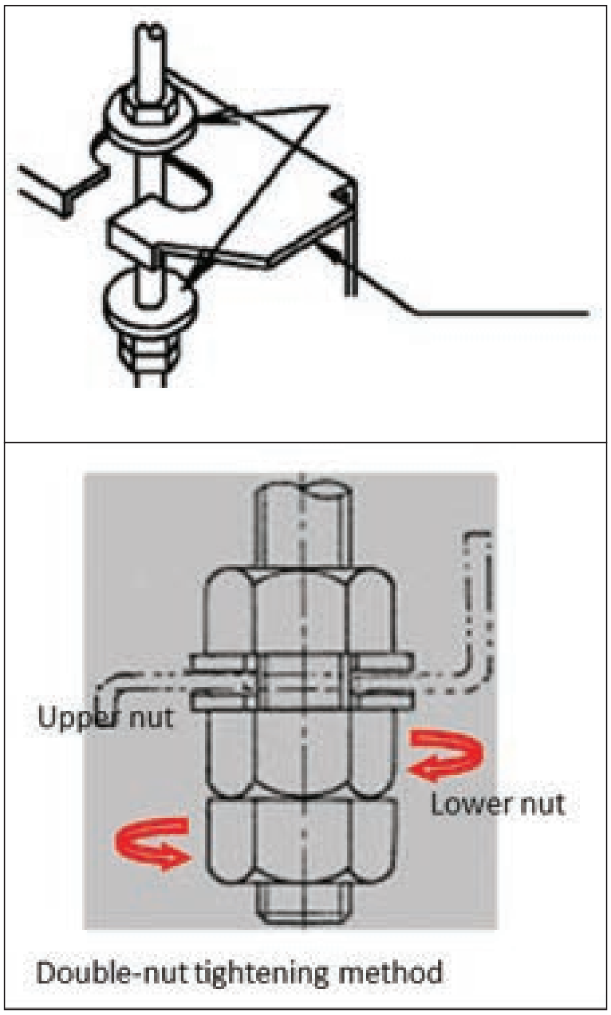


Figure 4.3: Double nut arrangement

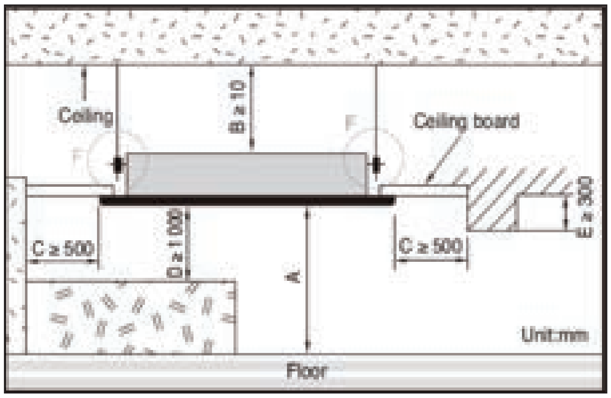


Figure 4.4: Clearances needed for indoor cassette installation

Note: Ensure the correct grid is given by the interior team before installation of unit.

3.5 Outdoor Unit Installation

1. Install outdoor units in a location with sufficient ventilation and clearance as per the manufacturer's guidelines.
2. Connect refrigerant piping, ensuring proper insulation and leak prevention.
3. Connect communication wiring and power supply, following the wiring diagram provided in the installation manual.

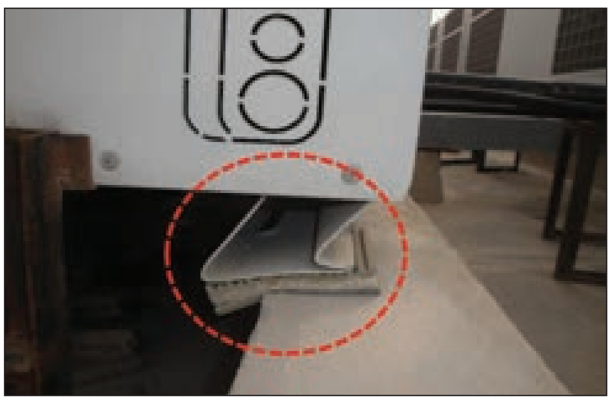


Figure 4.5: Outdoor unit installation – wrong practice

3.5.1 Outdoor Unit Location

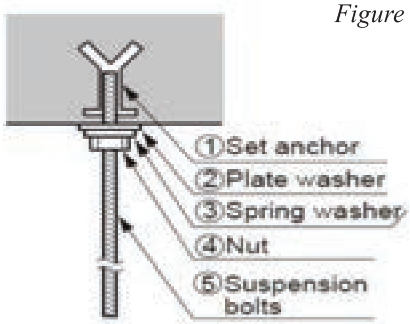
Select a location for installing the outdoor unit that will meet the following general conditions:

- A location strong enough to bear the weight of the outdoor unit.
- A location that allows for optimum air flow and is easily accessible for inspection, maintenance, and service.
- Where piping between the outdoor unit and indoor unit(s), are within allowable limits.
- Include space for drainage to ensure condensate flows properly out of the unit when it is in heating mode. Avoid placing the outdoor unit in a low-lying area where water could accumulate as well as away from areas where steam discharges from boiler stacks, chimneys, steam relief ports, kitchen vents, plumbing vents etc. High-frequency electrical noise / electromagnetic waves may affect operation.
- Where operating sound from the unit will not disturb inhabitants of surrounding buildings.

3.5.2 Anchoring the Outdoor Unit

- Tightly anchor the outdoor unit with a bolt and nut to a concrete or rigid platform.
- When installing on a wall (with field-supplied brackets), roof, or rooftop, securely anchor the mounting platform with nails, taking into consideration the possibility of strong winds or earthquakes.
- If there is a possibility of vibration from the outdoor unit transmitting to the building, add an anti-vibration material to the platform.

Figure 4.6 (a)



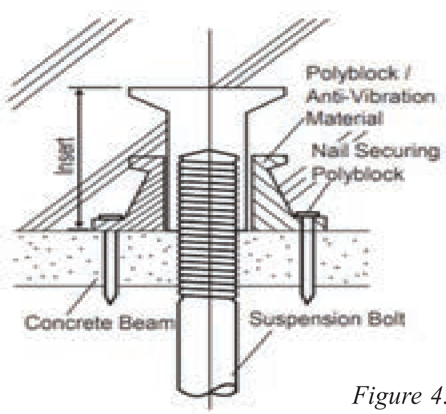
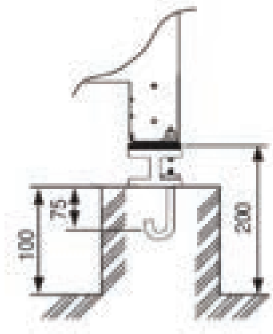


Figure 4.6 (b)



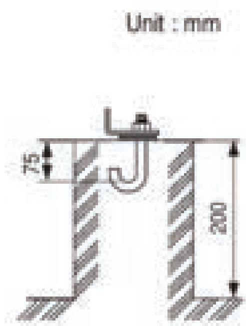


Figure 4.6 (c) *Figure 4.6 (d)*

Figure 4.6: Anchoring of outdoor unit

3.5.3 Outdoor Unit Location to Avoid Strong Winds from Sea

If the outdoor unit must be placed in a location in close proximity to the sea where it would be subjected to direct and strong sea breeze, install a concrete windbreaker strong enough to block strong wind. Windbreaker height and width should be more than 150% of the outdoor unit, and be installed at least 700 mm away from the outdoor unit to all.

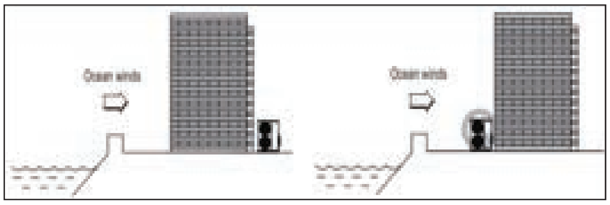


Figure:4.7: Outdoor unit location near ocean

3.5.4 Oceanside Installation Precautions

- Avoid installing the outdoor unit where it would be directly exposed to ocean winds.
- Install the outdoor unit on the side of the building opposite from direct ocean winds.
- Select a location with good drainage.
- Periodically clean dust or salt particles off of the heat exchanger with water.

3.5.5 When Outdoor Unit is Installed Below Indoor Unit

1. Wrap the vinyl tape around the separately insulated refrigerant piping, the drain hose, and the communications cable / power wiring together from the bottom to top.
2. Secure the bundle along the outside wall

using saddles or a similar type of piping support.

3. Seal any openings in the wall.
4. A trap is required to prevent water from entering the outdoor unit electrical control box. Use plastic band insulation and tape drain hose piping connecting cables power supply cord. Seal the small opening around the piping.

3.5.6 When Outdoor Unit is Installed Above Indoor Unit

1. Wrap the vinyl tape around the separately insulated refrigerant piping, the drain hose, and the communications cable / power wiring together from the bottom to top.
2. Secure a portion of the bundle along the outside wall using saddles or a similar type of piping support.
3. At the appropriate location, form a trap with the bundle to prevent water from entering interior spaces or the electrical control box of the outdoor unit.
4. Secure the rest of the bundle along the outside wall using saddles or a similar type of piping support.
5. Seal any openings in the wall.

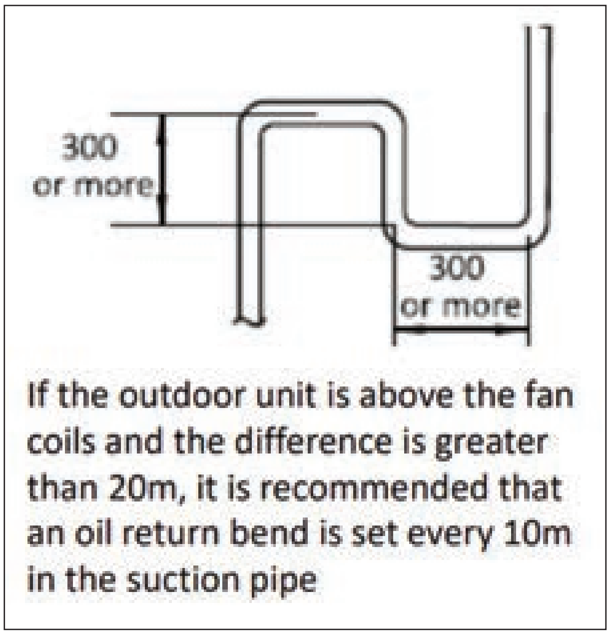


Figure 4.8: Detail of oil return bend

3.5.7 Installation Location – Protection against Corrosion

1. Install the units at least 3 meters away from equipment that generates electromagnetic waves and away from interfering sources, such as radio, computer, and stereo equipment.
2. Also, away from people living / working nearby so that hot discharge air or noise do not disturb them. Away from inflammable materials.
3. Ensure that condensate water generated by the outdoor unit can drain smoothly away from the unit (for heating systems).

Install the power and communication cables in a separately installed enclosure.

Avoid installing the outdoor unit where corrosive gases, such as sulphur oxides, ammonia, and sulphurous gas, are produced. If unavoidable, consult with an installation specialist about using a corrosion-proof or anti-rust additive to protect the unit coils

Apply corrosion protection and any other protective coatings to the unit as per recommendation of the manufacturer.

4.0 Refrigerant Piping

Follow the manufacturer's guidelines for refrigerant piping installation, including sizing, insulation, and proper bending.

Ensure that the refrigerant piping is free from kinks and bends that may restrict the flow. Following are important points which need attention.

- Piping support
- Working points
- Support of horizontal pipes
- Prevention of sagging due to their own weight
- Prevention of spot overloading due to pipe expansion and contraction

Figure 4.9 Types of pipe clamps

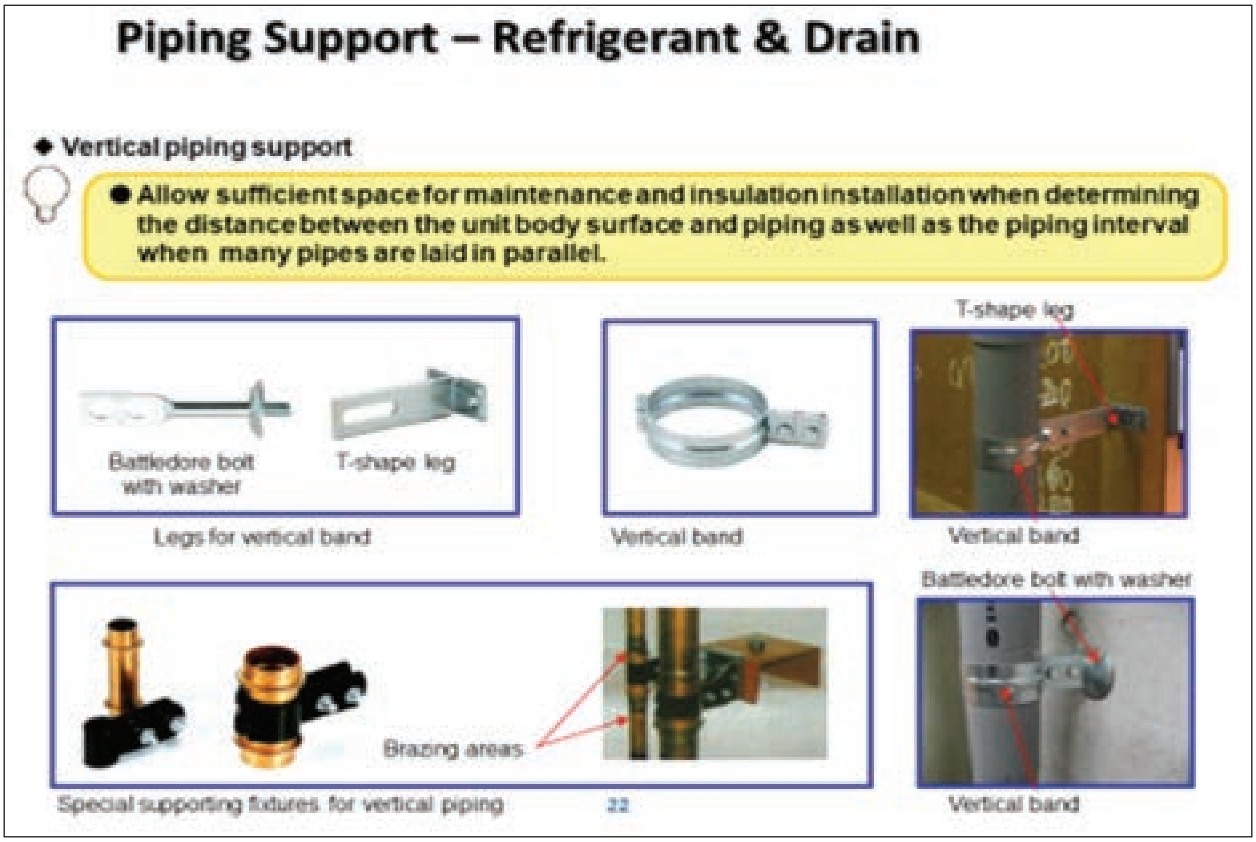


Figure 4.10: Vertical piping support (refrigerant and drain)

4.1 Outdoor Unit Pipe Connections

1. Do not use kinked pipe caused by excessive bending in one specific area on its length.
2. Braze the pipes to the service valve pipe stub of the outdoor unit.
3. After brazing, check for refrigerant gas leaks.

4.2 Creating a Flare Fitting

One of the main causes of refrigerant leaks is defective flared connections. Create flared connections using the procedure below.

4.3 Cutting the Pipe to Length

- Measure the distance between the indoor unit and the outdoor unit.
- Cut the pipes a little longer than measured distance.
- Completely remove all burrs from pipe ends.
- When removing burrs, point the end of the copper pipe down to avoid introducing foreign materials in the pipe.
- Remove the flare nuts attached to the indoor and outdoor units. Slide the flare nut onto the copper tube.

4.4 Flared Connection

While flaring the pipe end: use the proper size flaring tool to finish flared connections.

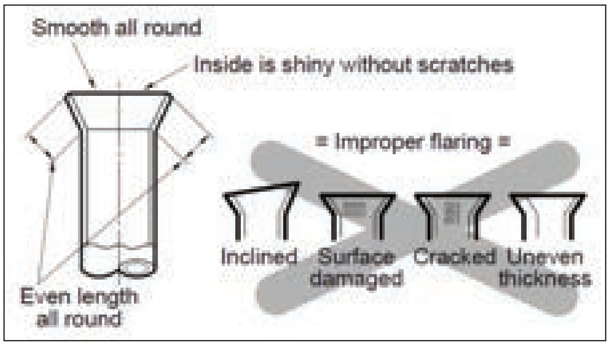


Figure. 4.11: Flare connection details

4.5 Piping Material and Size.

Select and purchase copper pipes that correspond to the design and site conditions such as length and size calculated for the selected model in the installation manual of the manufacturer of the outdoor unit and actual project requirements.

4.6 Piping Layout

1. Seal the two ends of the piping properly before you connect the indoor and outdoor piping. Once unsealed, connect the piping of the indoor and outdoor units as quickly as possible to prevent dust or other debris from

entering the piping system via the unsealed ends, as this may cause the system to malfunction.

2. If the piping needs to go through walls, drill the opening in the wall, and place accessories like casings and covers for the opening properly.
3. Place the refrigerant connecting piping and the communication wiring for the indoor and outdoor units together, and bundle them tightly to make sure air does not enter and condensate to form water that may leak from the system.
4. Insert the bundled piping and wiring from outside the room through the wall opening into the room. Be careful when you lay out the piping not to damage the piping.
5. Sleeve should be installed with proper space for refrigerant pipe, drain pipe and cable to pass through the wall.

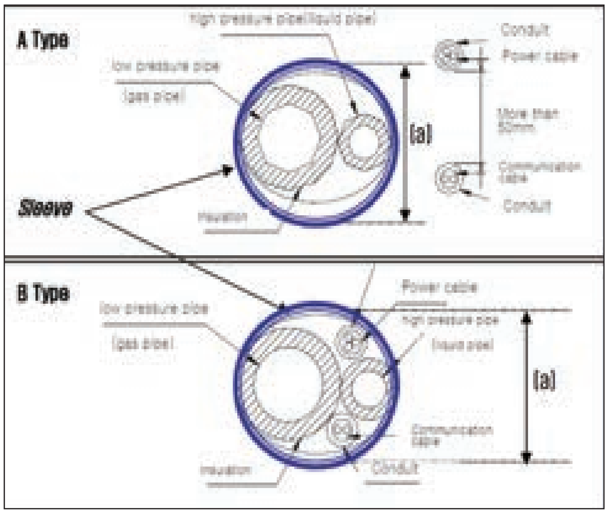


Figure 4.12: Refrigerant piping located within sleeve

4.7 Precautions While Welding Refrigerant Pipes

- Before you weld the refrigerant pipes, fill the pipes with nitrogen first to discharge the air in the pipes. If no nitrogen is filled during welding, a large amount of oxide film will form inside the piping which may cause the air conditioning system to malfunction.
- Welding can be carried out on the refrigerant pipes when the nitrogen gas has been replaced or refilled.
- When the pipe is filled with nitrogen during welding, the nitrogen must be reduced to 0.02 MPa using the pressure release valve. See *Figure 4.13*.

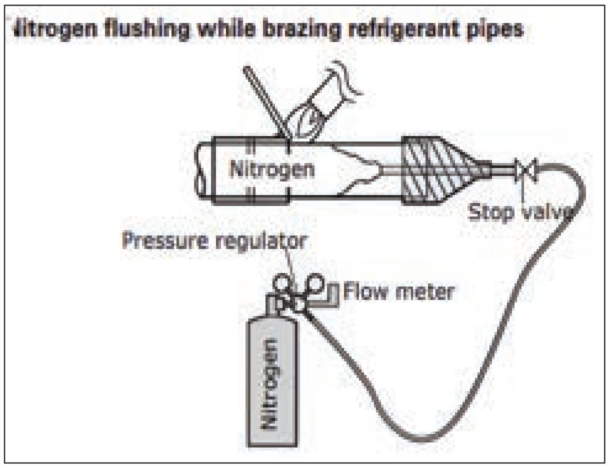


Figure 4.13: Nitrogen flushing of refrigerant piping

4.8 Heat Insulation Treatment for Gas-Liquid Piping Connections for Indoor Unit

The heat insulation treatment is carried out on the piping at the gas and liquid sides of the indoor unit respectively.

a. The piping on the gas side must use heat insulation material that can withstand temperatures of 120°C and more.
b. For the piping connections of the indoor unit, use the insulation casing for copper pipes (accessory protection sleeve for refrigerant piping) to carry out the insulation treatment, and close all gaps.

Figure 4.14: Refrigerant joint

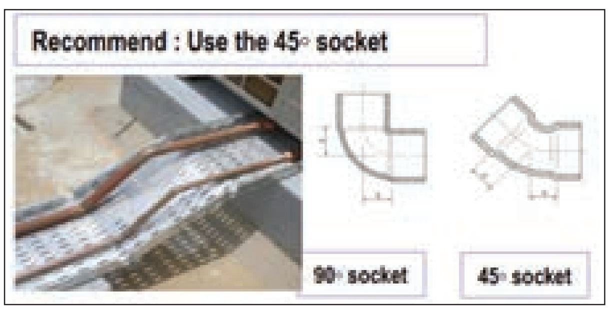


Figure 4.15: Use of sockets in piping

4.9 Brazing Practices

All joints are brazed in the field. The system operation and performance of the VRF system depends on using best practices in brazing copper pipes and utmost care while assembling the piping system.

- While brazing, use a dry nitrogen purge operating at a minimum pressure of three psig and maintain a steady flow.
- Blow clean all pipe sections with dry nitrogen prior to assembly.
- Use a tubing cutter. De-burr and clean all cuts before assembly.
- Use adapters to assemble different sizes of pipe. Use a 15% silver phosphorous copper brazing alloy to avoid overheating and produce good flow.
- Protect isolation valves, electronic expansion valves, and other heat-sensitive control components from excessive heat with a wet rag or a heat barrier spray product.

Figure 4.16: Brazing of copper pipes

4.10 Piping Materials and Handling

Pipes used for the refrigerant piping system must have the specified thickness, and the interior must be clean as recommended by the manufacturer.

- Annealed tempered (soft) ACR copper tubing is available in sizes 1/4 through 2-1/8 inches (ASTM B 280, clean, dry, and capped). Tube wall thickness should meet local code requirements and be approved for an operating pressure for refrigerants used (R 410A, R 32, R 407A). Be sure no traps or sags are present when rolling out soft copper tubing coils.

4.10.1 Copper Expansion and Contraction

Under normal operating conditions, the vapor pipe temperature varies during operation. Designer must consider pipe expansion and contraction to avoid pipe and fitting fatigue failures. Refrigerant pipe, along with the insulation jacket, form a cohesive unit that expands and contracts together. During system operation, heat transfer occurs between the pipe and the surrounding insulation. If the pipe is mounted in free air space, no natural restriction to movement is present if mounting clamps are properly spaced and installed. When the refrigerant pipe is mounted underground in a utility duct stacked among other pipes, natural restriction to linear movement is present. In extreme cases, the restrictive force of surface friction between insulating jackets could become so great that natural expansion ceases and the pipe is 'fixed' in place. In this situation, opposing force caused by change in refrigerant fluid/vapor temperature can lead to pipe/fitting stress failure.

4.10.2 Refrigerant Pipe Support

The pipe support must be engineered to allow free expansion to occur. When a segment of pipe is mounted between two fixed points, provisions must be kept to allow pipe expansion to naturally occur. The most common method is the inclusion of expansion loop or U-bends mounted in the horizontal plane. When expansion loops are placed in a vertical riser, the loop is to be formed in a horizontal fashion resulting in a torsional movement during expansion and contraction. Each segment of pipe has a natural fixed point where no movement occurs. This fixed point is located at the center point of the segment assuming the entire pipe is insulated in a similar fashion. The natural fixed point of the pipe segment is typically where the expansion loop or U-bend should be.

4.10.3 Liquid Line

Although the liquid temperature remains the same, the direction of flow will reverse. Therefore, no significant change in length of the liquid line is anticipated. When creating an expansion joint, the joint depth should be a minimum of two times the joint width. Use soft copper with long radius bends on longer runs or long radius elbows for shorter pipe segments.

5.0 Flushing of Refrigerant Piping

Flushing is a method of cleaning the refrigerant piping using pressurized nitrogen gas.

1. Removes oxidation bubbles that may have formed inside the copper piping if nitrogen replacement was insufficient during soldering.
2. Removes foreign material and moisture from piping if the piping was not stored properly.

5.1 Refrigerant Piping Flushing Procedure

1. Attach a pressure regulator on a nitrogen cylinder.
2. Connect the charge hose from the pressure regulator to the outdoor unit liquid piping side service port before its connection to the indoor or outdoor unit piping.
3. Open the main valve on the nitrogen cylinder and set the pressure regulator to 0.5 MPa (72.5 psi).
4. Verify that the nitrogen is flowing through the piping correctly.
5. When flushing, block the open end of the piping with a wood insulation block. When the pressure becomes too high, quickly remove the block.
6. Repeat steps 4 and 5 until the piping is completely flushed and clean.
7. Connect the charge hose from the pressure regulator to the outdoor unit gas piping side service port before its connection to the indoor unit piping.
8. Each piping run should be flushed individually before connecting the indoor units (follow steps 3, 4, 5, and 6).

6.0 Leak Test Procedure

Before performing the test run, refrigerant piping and the piping connections to the outdoor unit, the indoor units must be evacuated to remove any non-condensable gases and moisture that may be present in the system, and checked for leaks. Air and moisture that is left in the piping can lead to undesirable results and can cause damage to the working unit. It is important to go through a complete air purging cycle to be sure that the lines are cleared out. Note that this process may have to be repeated should any air or moisture be found to remain in the piping. After air purging and evacuating the lines, be sure to take a leak test for all piping and tubing.

If any air and moisture remain in the refrigerant system:

1. Pressure in the system rises.
2. Operating current rises.
3. Cooling or heating efficiency drops.
4. Moisture in the refrigerant circuit may freeze and block capillary tubing.
5. Water may corrode parts of the refrigeration system.

6.1 Before the Leak Test

6.1.1. Check that all refrigerant piping, the drain pipe, and power wiring / communications cables are properly connected.

6.1.2. Remove the caps from both the gas and the liquid service valves on the outdoor unit. Verify that both service valves are closed.

6.1.3. Connect the manifold valve (which includes the pressure gauges), along with the dry nitrogen gas cylinder, to the service valves using the charge hoses. Use a manifold valve for leak testing. The high side manifold valve must always be kept closed.

6.2 Leak Test Procedure

6.2.1 Pressurize the system to maximum 550 psig with the dry nitrogen gas. Inert gas (nitrogen) should be used when checking leaks, cleaning or repairs of pipes, etc.

- To avoid nitrogen entering the refrigerant system in a liquid state, the top of the cylinder must be higher than its bottom when the system is pressurized. i.e., the cylinder should be used in a vertical standing position.

6.2.2 Close the cylinder valve when the gauge reading reaches 550 psig, and then test for leaks using the liquid soap method.

6.2.3 While running the nitrogen gas tank hookup, apply a soap water or a liquid neutral detergent to all indoor, outdoor unit connection(s), and all refrigerant piping joints with a soft brush. Also test for leaks at both the gas and liquid side service valves. Perform the leak test by pressurizing nitrogen gas to 550 psi on both the liquid and gas pipes. Test with the piping service valves closed.

If the pressure does not drop for twenty-four hours, the system passes the test. If the pressure drops, there is a nitrogen leak in the system. Find the leak, repair, and then test again.

While operating the pressure gauge system, observe the connections for any leaks. If bubbles appear at any of the connections (indoor and outdoor units) or refrigerant piping joints, a leak is present.

6.2.4 Make a note of where the leaks are, and remove the soap with a clean cloth.

6.2.5 Disengage the nitrogen pressure by loosening the charge hose connector at the nitrogen cylinder. After the system pressure is back to normal range, disconnect hose from the cylinder. Repair the connections and piping where bubbles / leaks were observed. When finished, repeat leak testing using the liquid soap method and nitrogen cylinder.

6.2.6 After system is leak free, depressurize by loosening the charge hose connector at the nitrogen cylinder. When system pressure returns to normal, disconnect the hose from the cylinder.

6.3 Essential Points for Leak Testing

The key to successful testing is strict adherence to the leak testing procedure.

The liquid and gas piping in each refrigerant system should be pressurized with nitrogen gas in accordance with the steps listed below.

Step 1: Pressurize to 44 psi for three minutes or more. (This will identify if major leaks are present in the system.)

Step 2: Pressurize to 220 psi for three minutes or more. (This will identify if major leaks are present in the system.)

Step 3: Pressurize to 550 psi for approximate twenty-four hours. (Will identify if minor leaks are present in the system.) Pressurizing the system to 550 psi does not guarantee the identification of minor leaks if the pressure is maintained for only a short time. It is recommended that the system remain pressurized for at least 24 hours.

Check for pressure drop. If there is no drop in pressure, the test is successful. If the pressure drops, there is a leak in the piping system. If, however, there was a change in the ambient temperature between when pressure was initialized and when pressure drop is checked, pressure correction for variation in temperature needs to be considered.

Refrigerant systems and circuits shall be pressure tested for 24 hours with nitrogen gas to test pressures as indicated below:

Refrigerant	High Side Test Pressure kPa	Low Side Test Pressure kPa
R 134a (Air Cooled)	2080	1190
R 134a (Water Cooled)	1270	880
R 717 (Air Cooled)	3230	1820
R 717 (Water Cooled)	1940	1340
Others	*	*

* In performing pressure tests for refrigerant systems and circuits containing blend refrigerants (e.g. R407C and R410A), manufacturer's recommended procedures and test pressures shall be followed.

7.0 Vacuum Procedure

Vacuum drying should be performed from the service port provided on the outdoor unit's service valve to the vacuum pump commonly used for liquid pipe and the vapor pipe. Vacuum of the pipe and the indoor units should be made from the port of the outdoor unit's service valve with the service valve closed.

- Never perform air purging using refrigerant; it will damage the outdoor unit.
- Use a vacuum pump that can evacuate to 500 microns.

1. Evacuate the system from the liquid and vapor pipes with a vacuum pump for over two hours and bring the system to 500 microns.
2. Maintain system under that condition for over one hour; if the vacuum gauge rises, the system may contain moisture or a leak.
3. If there is a possibility of moisture in the piping (rain water may have entered the piping if work was performed during a rainy season or over an extended period), then:
   - Evacuate the system for two hours to 7.3 psi (vacuum break) with nitrogen gas.
   - Evacuate it again with the vacuum pump for one hour to 500 microns (vacuum drying).
4. If the system cannot be evacuated to 500 microns, repeat the steps of vacuum break and drying.
5. Finally, after maintaining the system in vacuum for one hour, check if the vacuum gauge rises or not.
   - If the primary refrigerant charge is not performed in a reasonable time after the vacuum procedure is complete, wet air may infiltrate the system.
   - Do not perform refrigerant charge while the compressor is operating, otherwise, liquid may leak and subsequently damage the compressor.
   - Use a micron gauge to measure vacuum.
   - Obtain the precise amount of refrigerant needed using calculations outlined in the following pages. Too much or too little refrigerant may cause the system to malfunction.

Refrigerant charge the system with refrigerant according to the instructions in the installation manual.

8.0 Drainage of Condensate

8.1 In order to prevent the back-flow of water into the interior of the air conditioner when the operation stops, the water discharge pipe should slope downwards towards the outside (drainage side) at a slope of more than 1/100. Make sure that the water discharge pipe does not swell or store water; otherwise, it will cause strange noises.

8.2 When connecting to a long water discharge pipe, the connections must be covered with the insulation casing to prevent the long pipe from coming loose.

8.3 When the outlet of the water discharge pipe is higher than the pipe connection for water suction, try to keep the water discharge pipe as vertical as possible, and the water outlet connecting fittings will bend so that the height of the water discharge pipe should be within 1000 mm away from the base of the water pan. Otherwise, there will be excessive water flow when the operation stops.

8.4 When connecting the water discharge piping, do not use force to pull the pipes to prevent the water suction pipe connections from coming loose. At the same time, set a supporting point at every 0.8~1 m to prevent the water discharge pipes from bending.

8.5 Drainage system design requirements.

- Level difference between the highest point and the base of the ceiling: $h \leq 700$ mm.
- Length of sloping section: L mm.
- Inner diameter: d mm (wrap insulation material around pipeline to prevent condensation $L*d*d \leq 65{,}0000$ (L and d are in millimeters).

That is, the volume inside the water pipe in the slope section shall not be more than 500 ml.

Excessive accumulated water in the piping on the slope will lead to problems like poor drainage, backflow, and water leakage. Installation works for the water pipes must be based on the requirements. We recommend to use a pipe with an inner diameter of 25 mm, and the length of the sloping section not more than 1 m.

9.0 Charging the Refrigerant

9.1. Determine the refrigerant that is needed, applying the necessary formulae as per manufacturer's recommendation.

9.2 Connect the charging cylinder to the charge hose on the manifold valve.

9.3. Purge air from the charge hose by opening the valve at the bottom of the cylinder, and press the check valve on the manifold valve.

9.4. If the required amount of refrigerant cannot be charged all at once, the refrigerant can be charged a little at a time while the system operates in cooling. This procedure must be repeated until the entire amount of refrigerant gets charged into the system.

9.5. Immediately disconnect the charge hose from the service port on the three-way valve. Stopping halfway allows the refrigerant to discharge.

- If the system has been charged with liquid refrigerant while it operates, turn the system off before disconnecting the hose.

9.6. Mount the valve stem nuts and the service port nut. Use torque wrench to tighten the service port nut to a torque of 1.8 kg.m and check for leaks.

10.0 Water Discharge Test

Before the test, make sure that the water discharge pipeline is smooth, and check that each connection is sealed properly.

Conduct the water discharge test in the new room before the ceiling is paved.

1. Connect the power supply, and set the air conditioner to operate in the cool mode. Check the running sound of the drainage pump.
2. Remove the test water cap to connect to the test water outlet to inject water into the water pan, and at the same time, observe if there is any water discharged from the drainage outlet. Make sure water is discharged normally from the water drainage outlet.
3. Stop the air conditioner. Wait for three minutes, and then check if there is anything unusual. If the water discharge piping layout is not correct, the excessive water flow can be noticed. There may even be water overflowing from the water pan.
4. Continue to add water until the alarm for excessive water level is triggered. Check if the drainage pump drains water immediately. After three minutes, if the water level does not fall below the warning level, the unit will shut down. At this time, you need to turn

off the power supply, and drain away the accumulated water before you can turn on the unit normally.

5. Turn off the power supply, remove the water manually using the drainage plug, and put the test cap back to the original place.

10.1 Water Discharge Piping Installation for Indoor Unit

1. Use PVC pipes for the water discharge pipes

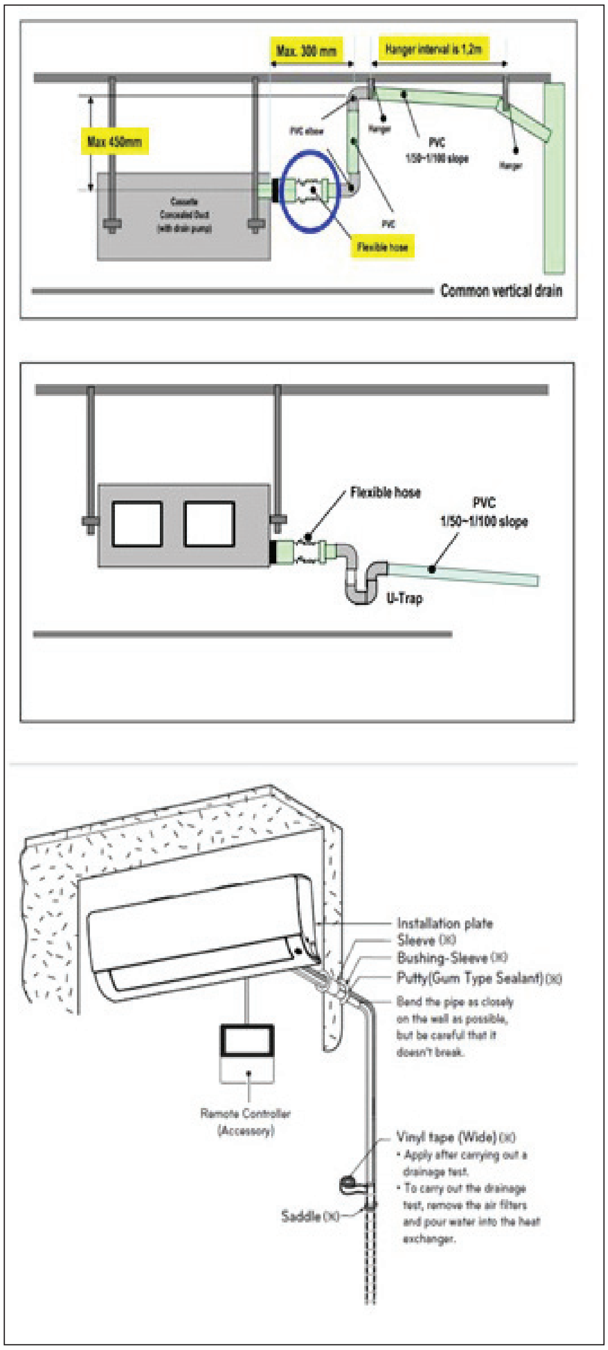


Figure 4.17: Typical drain connection from the indoor unit

(outer diameter: 37~39 mm, inner diameter: 32 mm).

2. Insert the water discharge pipe into the end of the water suction connecting pipe of the unit body, and use the ring clamp (accessory Ring clamp) to clamp the water discharge pipes with the insulation casing for the water outlet piping securely.
3. Use the insulation casing for water discharge piping (accessory Insulation casing for piping) to bundle the water suction and discharge pipes of the indoor unit (especially the indoor portion),

10.2 Piping Installation

Refer to the installation manual of OEM. All gas and liquid piping must be properly insulated in order to avoid condensate water falling on the floor and damaging the items kept in the room.

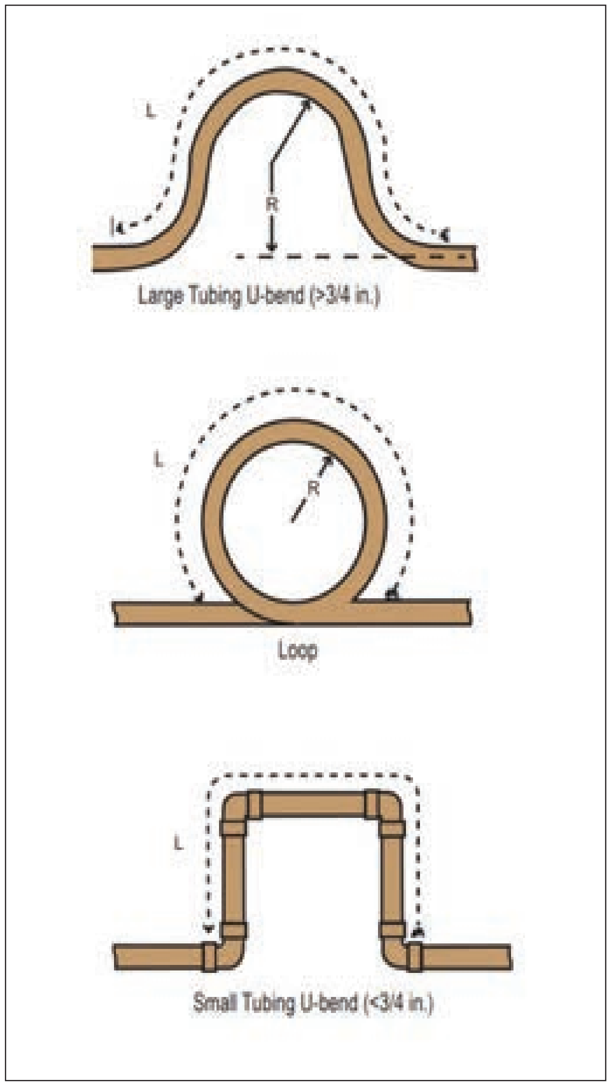


Figure 4.18: Copper piping loops

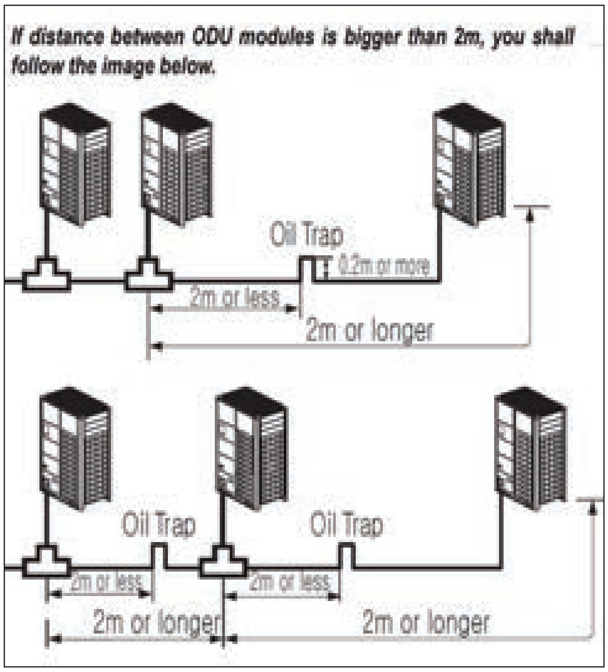
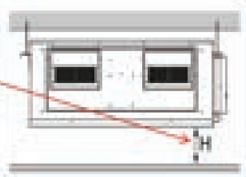


Figure 4.19: Layout of multiple units

[Inspection Hole Standard]

Number of inspection hole	Distance between False ceiling & actual ceiling	Remarks
1	More than 100cm	Sufficient space in the ceiling for servicing
2	20cm to 100cm	Insufficient space Difficult for servicing
Hole size should be [illegible] than the size of IDU	Less than 20cm	Minimum height for motor replacement



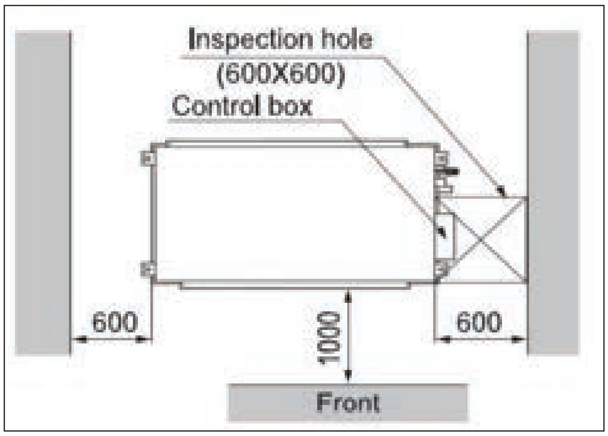


Figure 4.20: Inspection openings for indoor units

11.0 Power and Control Cabling

- It is important to choose the proper conduits according to the installation conditions

Condition	Conduit	
	Power Cable	Communication cable
Outdoor	Metal Conduit	Metal Conduit / Hard PVC
Riser	Metal Conduit	Metal Conduit / Hard PVC
Indoor	PVC Conduit	PVC Conduit
Reclaimed in the earth	Metal Conduit	Metal Conduit

- Use a waterproof flexible conduit at a special place such as substations, etc.
- Comply with the electric facilities law.
- Distance between power and transmission cable must be more than 50mm.

12.0 Insulating Piping Joints

1. Push the EPDM insulation from the straight piping surrounding the joint (elbow, outdoor unit to indoor unit piping connection point, etc.) as close together as possible.
2. Cut a piece of insulation to fit the joint, overlapping the insulation on the surrounding piping by at least 25 mm.
3. Apply adhesive to bond all the ends.
4. Secure by completely wrapping narrow vinyl tape around the insulation / joint so that there are no gaps.
5. Tape should be sufficient to cover the piping so it can fit into the rear piping housing area at the back of the indoor unit.
6. Pipe insulation should be done separately for both pipes.

Figure 4.21: Insulation of refrigerant piping

11.0 Power and Control Wiring (contd.)

Connect the electrical wiring according to the wiring diagram provided by the manufacturer.

Check voltage, current, and phase to ensure they meet the system requirements.

11.1 Electrical Wiring

Ensure that all the parts, materials and electrical works must comply with local regulations as well as Indian Electricity Act and Rules.

- Use only copper wires.
- Use a dedicated power supply for the air-conditioners. The voltage must be in line with the rated voltage.
- The electrical wiring works must be carried out by a professional technician, and must

comply with the labels stated in the circuit diagram.

- Before the electrical connection works are carried out, turn off the power supply to prevent injuries caused by electric shock.
- The incoming power supply for the air conditioner must include an earthing connection.
- Leakage protective devices must be configured according to the local standards and requirements for electrical and electronic devices.
- The distance between the power cord and signaling line must be at least 300 mm to prevent the occurrences of electrical interference, malfunction or damage to low voltage components.
- Connection to the main power supply to be made only after all the wiring and connection works have been completed. Use a dedicated power supply for the indoor unit that is different from the power supply for the outdoor unit.
- Do not connect two power cords with different diameters to the same power supply terminal.

Maximum allowable voltage range variation between phases is 2%.

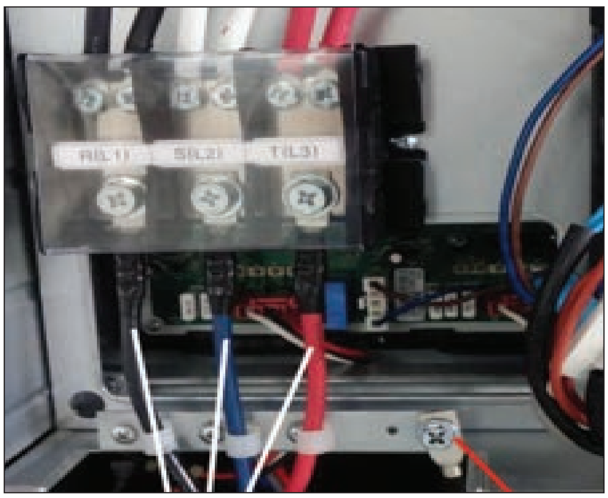


Figure 4.22: Electrical control box (typical)

11.2 Power Wiring and Communication Cable

- Be sure that main power to the unit is completely off before proceeding. Follow all safety and warning information as per manufacturer.
- Undersized wiring may lead to unacceptable voltage at the unit and may become a fire hazard, causing bodily injury or death.
- Install appropriately sized breakers / fuses / overcurrent protection switches and wiring in accordance with local, state, and National Electrical Code regulations related to electrical equipment and wiring. Using an oversized breaker or fuse may result in electric shock, physical injury or death.

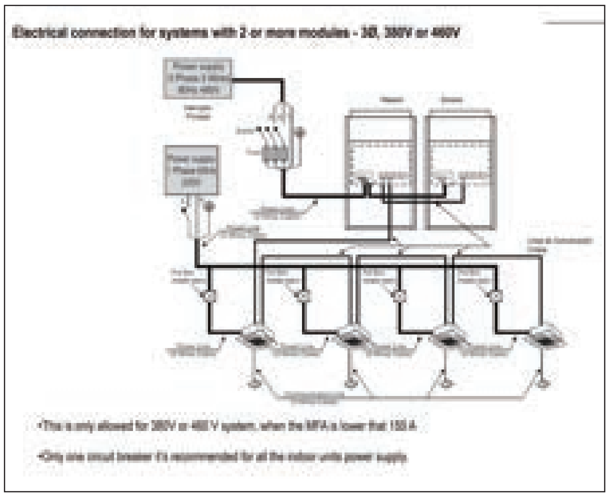


Figure 4.23: Typical electrical wiring diagram

13.0 Commissioning

- Commissioning of the system shall be carried out as per ISHRAE Standard 10003-2020.
- Conduct a thorough commissioning process, including refrigerant charging, system testing, and performance verification.
- Verify communication between indoor and outdoor units.
- Adjust refrigerant charge and airflow to achieve optimal system performance.

13.1 Charging the Refrigerant

1. Determine the refrigerant that is needed as per manufacturer's recommendation.
2. Connect the charging cylinder to the charge hose on the manifold.
3. Purge air from the charge hose by opening the valve at the bottom of the cylinder, and press the check valve on the manifold valve.

Refrigerant pipe installed underground should be routed inside a vapor tight protective sleeve to prevent insulation deterioration and water infiltration. Refrigerant pipe installed inside underground casing must be continuous without any joints. Underground refrigerant pipe must be located at a level below the frost line.

13.2 Test Run

Things to note before test run:

- Indoor and outdoor units are properly installed;
- Piping and wiring are correct;
- No leakage from the refrigerant piping system;
- Water discharge is smooth;
- Insulation is complete;
- Grounding line has been properly connected;
- Piping length, and amount of refrigerant filled have been recorded;
- The voltage of the power supply is the same as the rated voltage of the air conditioner;
- No obstacles at the air inlet and outlet of the indoor and outdoor.

14.0 Controls and User Interface

Set up and configure the control system according to the user's requirements.

Provide user training on how to operate and maintain the VRF system.

15.0 Documentation

Keep detailed records of the installation process, including system specifications, piping diagrams, and commissioning data.

Adhere to documentation requirements as stipulated in ISHRAE Standard 10003-2020.

16.0 Precautions While Installing/ Maintaining the System

- Do not use the unit in locations where flammable gas may exist. If flammable gas comes into contact with the unit, a fire may occur which could result in serious injury or death.
- If unit exhibits any abnormal behavior (such as emitting smoke) there is a danger of serious injury. Disconnect the power supply and find out the cause and take corrective action immediately.
- If unit is used in the same room as a cooker, stove, or burner, ventilation for sufficient fresh air must be ensured, otherwise the oxygen concentration will fall, which may cause injury.
- The unit should only be serviced and maintained or relocated by a professional air conditioning service engineer. Incorrect servicing or maintenance can cause electric shocks, fire or water leaks.
- Do not allow this unit or its remote controller to come into contact with water.
- Turn off the unit before cleaning it to avoid electric shocks.
- To avoid electric shocks and fires, install an earth leakage detector.
- Do not open or remove the unit's panel when the unit is powered on. Touching the unit's internal components while the unit is powered on can lead to electric shocks or injuries caused by moving parts such as the unit's fan.
- Ensure that the power supply is disconnected before any servicing or maintenance is carried out.
- Do not touch the unit or its remote controller with wet hands, as doing so can lead to electric shocks.
- Do not allow children to play near the unit.
- Do not spray any liquids onto the unit or allow any liquids to drip onto the unit.
- Do not remove the remote controller's front or back overs and do not touch the remote controller's internal components to avoid injury.
- Ensure that the unit is properly grounded and suitable surge protectors and circuit breakers are properly installed.
- Do not start the unit until the qualified technician in preset at the location.
- The fins on the unit's heat exchanger are sharp and can cause injury if touched. To prevent injury, when the unit is being serviced, gloves should be worn or the heat exchanger should be covered.
- Do not place items which might be damaged by moisture under the unit. When the humidity is greater than 80% or if the drain pipe is blocked or the air filter is dirty, water could drip from the unit and damage objects placed under the unit.
- Ensure that the drain pipe functions properly. If the drain pipe is blocked by dirt or dust, water leaks may occur when the unit is running in cooling mode.
- When fumigating a room with insecticide or other chemicals, cover the unit well and do not run it. Failure to observe this could lead to chemicals getting deposited inside

the unit and later emitted from the unit when it running, endangering the health of occupants.

- Do not dispose of this product as unsorted waste. It must be separately collected and processed.
- Do not place appliances that have naked flames under or near the unit, as heat from the appliance can damage the unit.
- Do not place the unit's remote controller in direct sunlight. Direct sunlight can damage the remote controller's display.
- Do not use strong chemical cleaners to clean the unit, as doing so can damage the unit's display or other surfaces. If the unit is dirty or dusty, use a slightly damp cloth with very diluted and mild detergent to wipe the unit. Then, dry it with a dry cloth.
- The refrigerant in this unit is safe and should not leak if the system is designed and installed properly. However, if a large amount of refrigerant leaks into a room, the oxygen concentration will decrease rapidly, which can cause serious injury or death. The refrigerant used in this unit is heavier than air, so the danger is greater in basements or other underground spaces. In the event of a refrigerant leak, turn off any devices that produce a naked flame and any heating devices, ventilate the room, before attending to the unit.
- Toxic fumes may be produced if the refrigerant in this unit comes into contact with naked flames (such as from a heater, gas stove/ burners, or electric appliances).
- Dispose of this unit's packaging carefully, so children cannot play with it. Packaging, especially plastic packaging, can be dangerous, can cause serious injury or death. Screws, staples and other metal packaging components can be sharp and should be disposed of carefully to avoid injury.
- Do not use paint, varnish, hair spray, other flammable sprays or other liquids that may give off flammable fumes/vapor near this unit, as doing so can cause fires.
- When replacing a fuse, ensure that the new fuse to be installed completely complies with requirements.

Chapter 5:

Chiller Installation

1.0 General

Various types and capacity of chillers are manufactured in India or imported from Asea, Europe or America. Majority of these chillers are factory assembled and tested at factory. The assembled and tested chillers are transported to the site through sea and road transport.

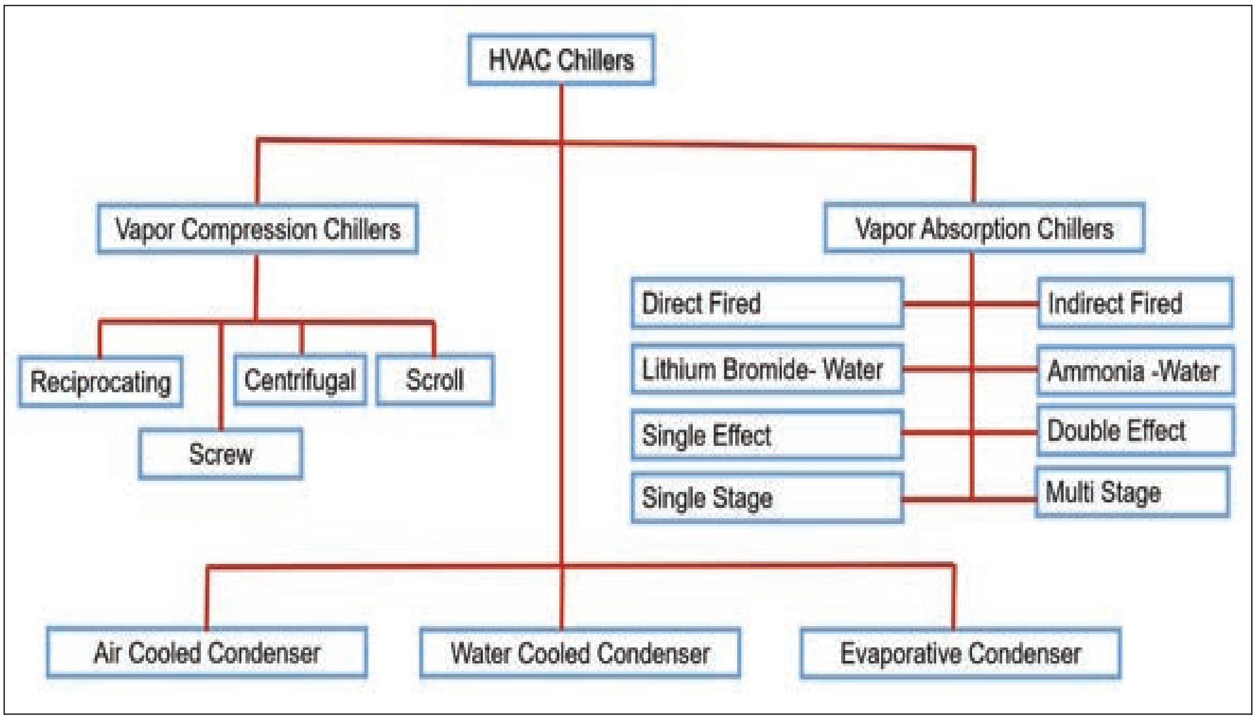
1.1 Types of Chillers

The following table gives details about various types of chillers:

1.2 Pre-Installation Activities

Prior to delivery of the chillers, a number of activities needs to be planned at site. These activities include the approval of shop drawings (plant room) with chiller locations, and providing necessary details to civil or structural team with respect to dimensions, weight etc. to prepare the foundation or structure for placement of chillers. It is important to ensure and check the foundations are ready and correct. The site activities start from unloading, storage, shifting to the

Table 5.1: Types of chillers



actual installation site. The vibration isolators need to be installed to reduce the transfer of vibration. All the site activities are carried out in line with the installation instruction manual provided by the manufacturer. The chillers once installed are connected with chilled water and condenser water piping, electrical cabling, Control and communication cabling for BMS or Chiller Plant Manager (CPM).

For proper selection of chillers for the application concerned, please refer to ISHRAE Chiller Standard ISH001TRLC.

Performance of any type of chillers is greatly influenced by the way its installation and commissioning is carried out. Detailed below is the correct way of installing and commissioning of chillers right from the time they leave the manufacturers works till they are put to beneficial use.

1.3 Installation Location

Care must be taken while selecting location for air cooled chillers. Select space for installation air-cooled unit, which will meet the following conditions:

- Foundation / structure which bears operating weight of the unit.
- Clear moving space for service / maintenance work.
- Do not install chillers near or above any sensitive areas where noise and vibration can create problems.
- The floor of the machine room must be water proof.
- Ensure there are no obstacles for free movement of air for air cooled chillers.
- The area should be dust free to reduce soiling on condenser coils of air-cooled chillers.

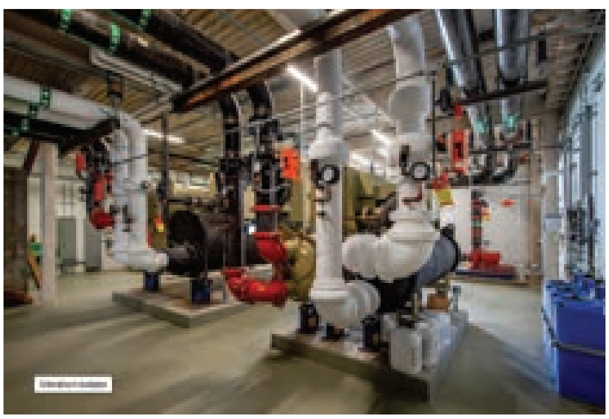


Figure 5.1: Water cooled chiller with vibration isolator

Figure 5.2: Air cooled chiller – multiple units with spacing

1.4 Inspection, Packing, Dispatch, Receiving at Site, Lifting and Storage

All Chillers including the components provided in the chiller package like electrical controls are inspected at the factory before shipment to assure unit is received at site in good condition with all components. Inspect the chiller thoroughly upon arrival at the installation site. Chillers are packed to avoid any damages. The packaging differs from manufacturer to manufacturer as well as based on the type of the chiller.

The rigging hooks or points are provided by the OEM and the same should be used for rigging and shifting. Upon the receipt of the chillers, it is important to check the chillers with respect to specifications and approved technical submittals. Following minimum checks are expected:

1. Manufacturer
2. Chiller Model No.
3. Evaporator Model No. if not included in chiller no.
4. Condenser Model No. if not included in chiller no.
5. Chiller compressor type (centrifugal, screw, reciprocating, scroll)
6. Condenser type (water or air cooled)
7. Compressor motor voltage
8. Locked Rotor Amps (LRA): current under starting conditions
9. Rated Loads Amps (RLA): maximum current under any operating condition
10. All accessories as specified
11. Pipe connections are correct in size
12. Refrigerant type
13. Manufacturer's efficiency rating (kW/ton) in standard conditions and IEER
14. Test and warranty certificates
15. Unit checked for exterior damages

1.5 Chiller Shifting and Positioning

Chiller shifting and its positioning is one of the critical activities. The same needs to be planned and supervised thoroughly. The entire process should be carried out by following all safety protocols to avid damage to property and to the people.

Following points must be checked prior to delivery of chillers at site:

1. The foundation of chillers is ready and as per drawings.
2. Access to place of installation is clear and without any hurdles.
3. Site survey is done by the competent crane/ equipment operator and the place of location of crane/equipment is finalized.
4. The place of location of crane/equipment is proper and with required strength.
5. All the required local permissions are obtained.
6. The access to location of crane is clear and proper.
7. All the lifting tools and tackles are inspected.
8. The correct crane/equipment is selected for lifting the chillers.
   a. It is not the crane capacity which matters; it is the capacity of the crane to lift the chillers of a specific weight at specific height from a distance of the property (angle of boom of crane).

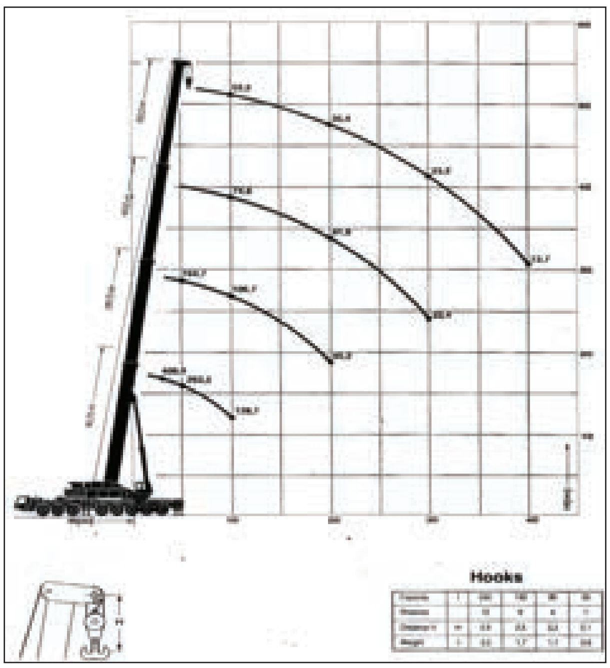


Figure 5.3: Typical crane selection chart

Figure: 5.4 Sample hoist inspection format

   b. The crane charts need to be verified before its selection.
   c. Prior inspection of crane is done with respect to its condition, hook, ropes, jacks etc.
   d. A competent crane operator and its signal man is available.

2.1 Pre-Installation Guidelines

Air-cooled chillers are designed for outdoor installation and can be installed at ground level or on a suitable rooftop location. In order to achieve good operation, performance and trouble-free service, it is essential that the proposed installation location meets the following requirements:

- The most important consideration while deciding upon the location of air-cooled chillers is the provision for supply of adequate ambient air to the condenser and removal of heated discharge air from the condenser. This is accomplished by maintaining sufficient clearances which have been specified around the units and avoiding obstructions in the condenser air discharge area to prevent the possibility of warm air circulation.
- Further, the condenser fans are propeller type and are not recommended for use with ductwork or other hindrances in the condenser air stream. Where these requirements are not complied, the supply or discharge airflow restrictions or warm air recirculation will cause higher condensing temperatures resulting in poor unit operation, higher power

consumption and possible eventual failure of equipment.

- The unit's longitudinal axis should be parallel to the prevailing wind direction in order to ensure a balanced air flow through the condenser coils. Consideration should also be given to the possibility of down-drafts caused by adjacent buildings, which may cause recirculation or uneven unit airflow. For locations where significant cross winds are expected, an enclosure of solid or louver type is recommended to prevent wind turbulence interfering with the unit airflow. When units are installed in an enclosure, the enclosure height should not exceed the height of the unit.
- The location should be selected for minimum sun exposure and away from hot air sources, steam, exhaust vents and sources of airborne chemicals that could attack the condenser coils and steel parts of the unit. Avoid locations where the sound output and air discharge from the units may be objectionable.
- If the location is an area which is accessible to unauthorized persons, steps must be taken to prevent access to the unit by means of a protective fence. This will help to prevent the possibility of vandalism, accidental damage or possible harm caused by unauthorized removal of panels or protective guards exposing rotating or high voltage components.
- The clearance requirements prescribed by the manufacturer are necessary to maintain good airflow and provide access for unit operation and maintenance. However, it is also necessary to consider access requirements based on practical considerations for servicing, cleaning and replacing large components.
- The unit must be installed on a one-piece, flat and levelled {within ½" (13 mm)} over its length and width} concrete base that extends fully to support the unit. The carrying or supporting structure should be capable of handling complete operating weight of the unit.
- For ground level installations, it must be ensured that the concrete base is stable and does not settle or dislocate upon installation of the unit which can strain the refrigerant lines resulting in leaks and may also cause compressor oil return problems. It is recommended that the concrete slab is provided with appropriate footings. The slab should not be connected to the main building foundation to avoid noise and vibration transmission.
- For rooftop installations, choose a place with adequate structural strength to safely support the entire operating weight of the unit. The unit shall be mounted on a concrete slab similar to ground installations. The roof must be reinforced for supporting the individual point loads at the mounting isolator locations. It must be checked and ensured that the concrete base is perfectly horizontal and levelled, especially if the roof has been pitched to aid in water removal. It should be determined prior to installation if any special treatment is required to assure a levelled installation else it could lead to the above-mentioned problems.

2.2 Installation and Service Connections Guidelines

The chillers need to be installed and positioned as per approved drawings. One of the important aspects while installation of chillers is vibration isolation. The correct vibration isolators need to be placed below each of the positioning or loading point of chiller. Most times, wrong isolators are placed below load points as they may look similar externally. This mistake cannot help in reducing the transfer of vibration to the building elements. This can also result in rework. Hence, the supervisor must pay attention to ensure the correct isolators are installed during the positioning of chillers. There are additional items such as snubbers which are used to avoid the toppling of chillers during seismic conditions. These snubbers are designed and their installation positions are also marked. It is necessary to install the same during positioning and installation of chillers.

2.2.1 Piping Connections

Piping to be connected to chiller and condenser with flange connections of grooved fittings.

Chilled water piping to be connected with flexible connection at the inlet and outlet, of suitable pressure rating.

Suitable provisions for probes required for gauges and sensors to be made in the piping.

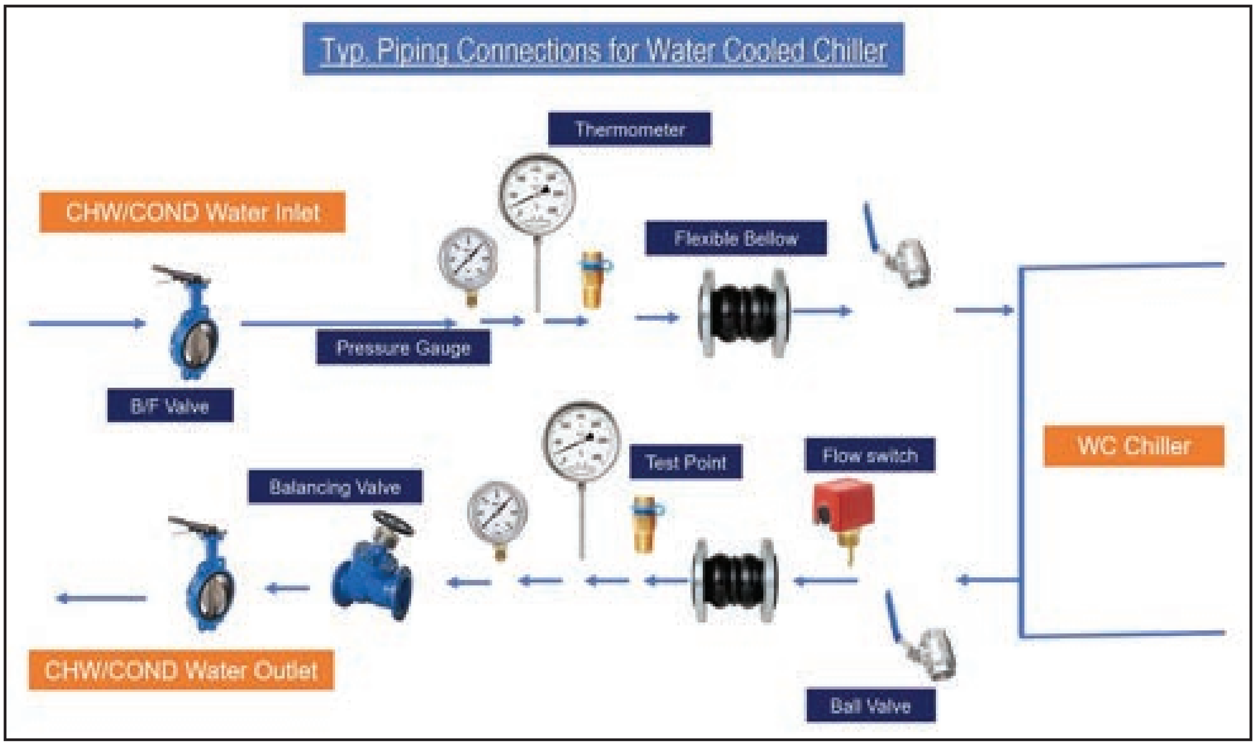


Figure 5.5 Typical water connections to chiller

Flushing bypass to be provided to avoid the entry of initial water during the flushing.

Proper supporting to be provided at the connections.

All the isolation valves, balancing valves etc. as per approved drawings and specifications to be provided.

2.3 Quality of Water Used for Chilled and Condenser Water

When the fluid to be cooled is water, the water quality can affect the performance and corrosion resistance of the system if proper corrective action is not taken. Minerals in the water can cause a scale build up on the surface of the heat transfer surface. If this fouling is not removed from the plates, the required leaving water temperature cannot be obtained. Free chlorine is released from the water as it is discharged from the distribution header. As the chlorine level of the water increases or if the water is super chlorinated, the free chlorine level can concentrate and cause corrosion of even stainless-steel surfaces that are not wetted during operation. These surfaces include the chiller frame, parts of the water distribution pan, exterior panel surfaces, and refrigerant headers. The free chlorine must be vented to reduce the concentration level. Venting can be obtained by installing optional vents or typically by weekly cleaning procedures to remove the stagnant water that collects on the non-wetted surfaces and vent free chlorine. Opening the cabinet door releases trapped chlorine. If followed by a fresh water wash down of all the surfaces on a weekly basis, the system will typically remain in a passive state and corrosion free. Weekly cleaning also eliminates scale build that requires more aggressive cleaning methods to remove.

2.3.1 Quality of Water, Treatment and Filtration

Optional make-up water strainers are available to remove solids and material large enough to plug openings in the water distribution system.

Table 5.2 Recommended water quality standards

Recommended Water Quality Standards

Test items	Chilled Water Quality	Cooling Tower Water Quality	Makeup Water Quality
pH	7.2 - 8.5	7.2 - 8.5	6.0 - 8.0
Total hardness ($CaCo_3$) ppm	Max. 80	Less than 200	Max. 50
Total alkalinity ($CaCo_3$) ppm	Less than 100	Less than 100	Less than 80
Chloride ion (ppm)	Less than 50	Less than 200	Less than 50
Total Ion (Fe) ppm	Less than 0.3	Less than 1.0	Less than 0.3
Silica (SiO_2) ppm	Less than 30	Less than 50	Less than 30
Ammonium ion ppm	Less than 0.2	Less than 1.0	Less than 0.2

Consult a local water treatment company to determine if additional water treatment or filtration is required to produce the desired water quality and reduce maintenance of the water distribution system.

2.3.2 Make-up Water Connection Lines

Properly size the water piping to the make-up water connection and cooling tower to deliver the specified flow and pressure. Standard design parameters for chillers use minimum 5 psig city water pressure or water pumped from storage at the inlet to the chiller. The maximum water pressure is 100 psig. Systems with water pressures over 100 psig should be equipped with pressure reducing valves in the lines to the chiller. Expansion tanks may be required on some systems with high water pressure to prevent water hammer.

2.3.3 Water Temperature

Entering water temperatures on typical chiller installations can range from 90°F down to 35°F. For entering water temperatures over 90°F, the manufacturer of chiller should be consulted. The fluid to be cooled is brought into the chiller through the water inlets located at the top of the chiller. Entering fluid is discharged from the PVC fluid distribution system located inside the chiller into the stainless-steel water distribution pan to ensure optimum distribution to all plates in the system.

2.4 Electrical Connections

2.4.1 Electrical wiring design and installation on the unit are based on factory standard practice. All installation and management activities must be carried out by qualified personnel and shall ensure compliance with relevant local laws and regulations.

Refer to the specific wiring diagram and electrical component manual before electrical installation. Site contractor shall do termination at site for wiring connection between components that are located at different sections and delivered separately.

2.4.2 The electric supply to the motor must correspond to the rated voltage stated in motor nameplate and be in conformance with the National and Local Electric Code and Regulations.

2.4.3 The electrical cables and earthing should be laid in cable tray and routed properly. It is necessary to avoid electrical installations below any of the piping.

2.4.4 Sufficient ventilation to be provided for safe working of electrical and electronic components.

2.4.5 Care to be taken for outside electrical installation. The selection and correction installation of IP rated electrical items to be ensured.

2.4.6 Signage of ‘Danger’, ‘Electrical’ to be placed wherever required.

3.0 Start up and Commissioning

Requirements specified in ISHRAE Standard 20003-2020 shall be followed.

3.1 Following pre commissioning checks to be done prior to startup and commissioning of chillers:

1. Delivery checks of chiller are completed.
2. Correct chiller is installed and located as per drawing.
3. Unit is correctly levelled.
4. All pipe connections are completed.
5. Clear access to all required components.
6. Factory start-up sheet completed and attached.
7. Test and balance report is reviewed for chiller system flows.
8. All accessories (e.g. pressure gauges and thermometers) are in place.
9. Expansion valve bulbs and any other temperature or pressure sensing bulbs are correctly located with capillary tubes free from damage or distortion.
10. Pipeline trappings (with fixed or test gauges) for pressure and temperature measurements are available on chilled water and condenser water circuits.
11. Chiller and surrounding areas are clean.
12. No visible water or oil leaks.
13. No unusual noise or vibration.
14. Vibration isolators are in place.
15. Appropriate safety warning signs in place.
16. Refrigerant fill is sufficient and refrigerant is clean from dirt and moisture.
17. Electric control wiring is completed.
18. Confirm power availability for duration of commissioning.
19. BMS data is available during the commissioning.
20. Chiller system is in operation before the test procedures are started.

3.2 Following is the process for start-up of chillers:

1. Chiller pre-commissioning checks are completed.
2. Electrical test sheets are completed and available from electrical contractor.
3. All chiller accessories (high- and low-pressure limits, freezing limit, liquid receiver, filter drier, refrigerant sight glass, liquid solenoid valve, hot gas by-pass valve, water make-up solenoid valve, evaporator flow switch, etc.) are performing properly.
4. Ensure that there are no water or bubbles in the refrigerant.

Table 5.3: Chiller operating data sheet

Chiller Operation Data Collection Sheet							
Project:			**Chiller name:**				
Contractor:			**Chiller ID #:**				
Sl. No.	**System Parameter**	**Unit**	**Designed**	**Measured**	**Difference**	**Make**	**Break**
1	Outdoor air temperature						
2	Evaporator water temperature in						
3	Evaporator water temperature out						
4	Condenser water temperature in						
5	Chilled water temperature during 2 h period min						
6	Chilled water temperature during 2 h period max						
7	Condenser water temperature out						
8	Evaporator water flow rate						
9	Condenser water flow rate						
10	Air cooled compressor: air temperature in						
11	Air cooled compressor: air temperature out						
12	High pressure						
13	Low pressure						
14	Number of trips per hour						
15	Chiller control valve / balancing valve position						
16	Condenser control valve / balancing valve position						
17	Locked Rotor Amps (LRA): current under starting conditions						
18	Rated Loads Amps (RLA): maximum current under any operating condition						
19	Voltage - phase I						
20	Current - phase I						
21	Speed - phase I						
22	Voltage - phase II						
23	Current - phase II						
24	Speed - phase II						
25	Voltage - phase III						
26	Current - phase III						
27	Speed - phase III						
28	Voltage imbalance (<2%)						
29	Chiller noise level (at 1 m apart)						

5. Chiller operates without unusual number of trips.
6. Outside air temperature lockout functions properly.
7. Controlling independent variable is set correctly for chilled water temperature reset.
8. Chilled water temperature follows reset schedule.
9. Ensure that chiller maintains chilled water temperature set-point ±1ºC over a 2-hour operating period.
10. Measure all chiller operation parameters (temperatures, pressures, flow rates, electrical parameters).
11. Remove the chiller load and verify the chiller and accessory shutdown sequence.
12. Add load and verify the chiller and accessory start-up sequence.
13. Carry out running-in procedures and related inspections afterwards.
14. Shutdown and start-up sequences stage multiple chillers and accessories properly.
15. Chiller control algorithm operates as specified in Sequence of Operations (SOO).
16. Chiller control and operation algorithms are correctly configured in BMS.
17. Chiller appears to meet load.

3.3 Once all pre-commissioning checks are completed and start-up is done, parameters in *Table 5.3* to be noted on a regular basis.

4.0 Integration with Building Management System

- BMS helps to monitor and improve energy performance of the building and can highlight any problems that may come up so that corrective action can be taken and downtime and expensive repairs can be avoided.
- Chillers consume a significant part of energy in an HVAC system and directly affect performance of the entire system. Therefore, their central monitoring and control becomes important.
- As a first step, BMS allows monitoring of the system without changing any control parameters. Chiller run status, air flow, power consumption, water and air temperatures etc. as well as any abnormalities can be noticed by the system.
- Going forward, it is also possible to control the system parameters.
- For details regarding installation aspects of BMS and CPM kindly refer to Chapter 18.

Chapter 6:

Installation of Cooling Tower

1.0 General

A cooling tower is a heat rejection device. It works by bringing air and water into contact to cool the water both by sensible heat transfer with the air as well as through evaporation of a small part of the water by rejecting heat to the air passing over it. The heat so rejected goes into the atmosphere. Cooling towers are also useful in industrial processes because some industrial processes tend to generate tremendous amounts of heat. Facilities need reliable ways to dissipate that heat to keep their working environments cool and reduce the risk of breakdowns and fire.

Cooling towers come in a variety of sizes, with some as small as a few square meters and some several hundred square meters large. The different sizes enable different load configurations. Cooling towers also come in different shapes and designs, which we shall discuss in more detail below.

All cooling towers perform the same primary function — to increase the surface area over which air and water interact. A larger surface area means more efficient evaporation, and more efficient evaporation means faster and better cooling.

The water flows through the cooling tower, losing heat along the way, until it reaches the sump at the bottom. The sump sends most of the cold water back to cool the hot machinery. When heat transfer from the equipment heats the water again, the water flows back to the cooling tower, and the process repeats.

Cooling towers are specialized heat exchangers, but instead of the usual conduction-convection heat transfer of shell and tube heat exchangers, it generates cooling by bringing water and air into contact for evaporative cooling.

There are different types of cooling towers depending on their air flow generation, air-to-water flow, heat transfer method, and construction. Each of these types has its own set of advantages and disadvantages.

2.0 Types of Cooling Tower

Cooling towers come in a few unique designs that use different technologies to cool process water. Below are some of the different cooling tower types.

A single cooling tower may fall into more than one of the categories listed below — like a counterflow induced draft cooling tower or a crossflow forced draft cooling tower.

2. 1 Crossflow Cooling Tower

Crossflow cooling towers get their name because the air they use cuts perpendicularly across the flow of water. Crossflow towers use splash fills that allow incoming air to flow horizontally through the cooling tower. At the same time, gravity sends hot water flowing down from distribution basins at the top of the tower.

Crossflow cooling towers offer the advantage of great height, and they are some of the simplest models to maintain. Because they use gravity to aid air-to-water contact, they can use smaller pumps, so they are cost-effective and easy to maintain — even while in use. And because their spray is non-pressurized, they allow for more variable water flow.

They are more prone to freezing than counterflow towers, though, and they can be more inefficient. Their design also makes their fill more likely to become clogged with dirt or debris, especially in windy, sandy and dusty regions.

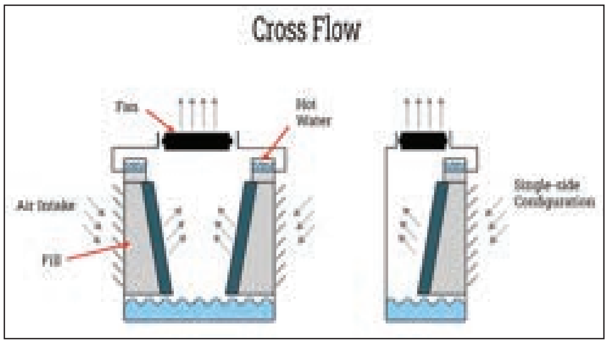


Figure 6.1: Crossflow cooling tower

2. 2 Counterflow Tower

In a counterflow cooling tower, as in a crossflow tower, water flows down from the top of the tower. In this case, though, the air also moves vertically across the splash fill, from the bottom of the tower to the top. Because the airflow is upward, counterflow towers cannot use gravity-flow basins, so these towers use pressurized spray nozzles to distribute the water over the splash fill.

Counterflow towers are more modest in size than crossflow towers, which means they can sometimes provide greater efficiency. And because of their spray distribution, they offer more resistance to freezing than crossflow towers. The extensive surface area of the large volume of spray they produce also makes heat transfer more efficient.

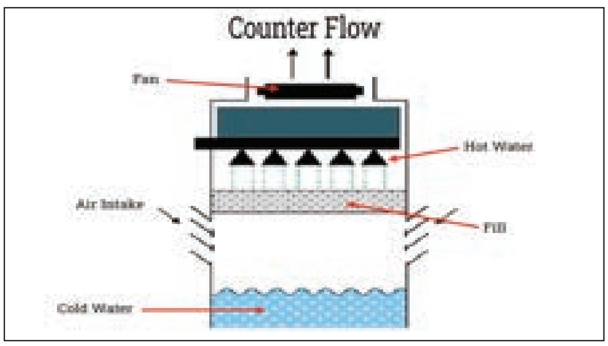


Figure 6.2: Counterflow cooling tower

2. 3 Natural Draft Cooling Tower

Unlike mechanical cooling towers such as induced and forced draft models, natural draft or passive draft cooling towers use natural convection. Air flows naturally through the tower, and differences in air density create specific patterns of movement.

The cold, dry air flowing into the tower is less dense than the warm, moist air flowing out after contact with the hot water, so the warm air naturally rises while the cold air falls. These movements create a stable, constant pattern of air circulation that helps cool incoming water and release heat.

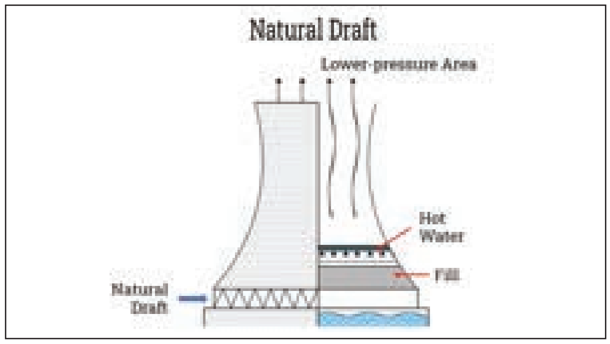


Figure 6.3 Natural draft cooling tower

2. 4 Induced Draft Cooling Tower

An induced draft tower typically has fans located at the top of the air outlet. These fans pull cool air through the tower. One of the benefits of an induced draft cooling tower is that the force of the induction means the air is moving at a high velocity when it exits the tower. That high velocity sends the air far enough away to prevent unwanted recirculation.

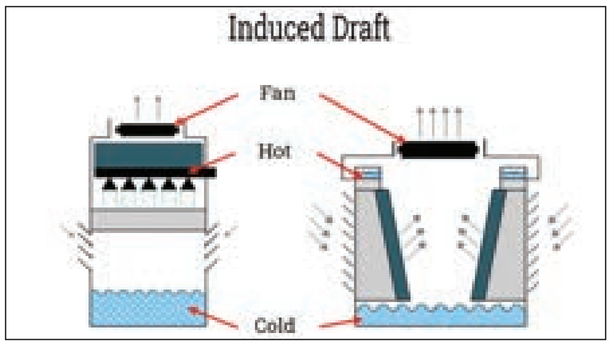


Figure 6.4: Induced draft cooling tower

2. 5 Forced Draft Cooling Tower

A forced draft tower typically has fans located in the air intake rather than the air outlet. These fans, located on the sides or at the base of the tower, push air directly into the tower instead of pulling it.

Forced draft cooling towers take air in at a high velocity, but they tend to discharge it as a lower velocity, since friction slows the air as it passes through the tower. This lower velocity means forced draft towers are more susceptible to undesirable air recirculation. However, forced draft cooling towers are particularly useful

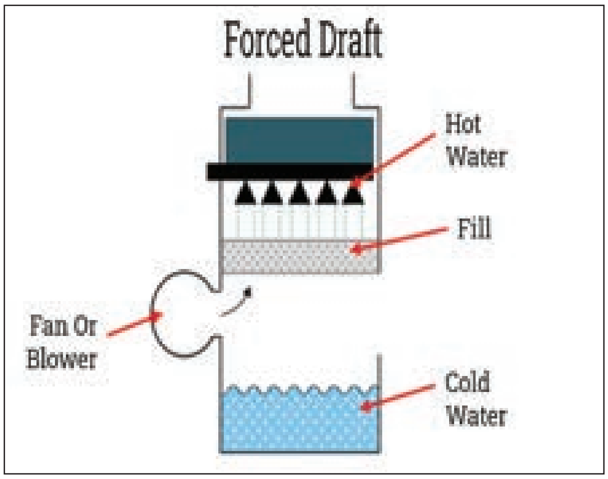


Figure 6.5: Forced draft cooling tower

in indoor facilities because they handle high pressure exceptionally well. This ability makes them well suited to smaller indoor spaces.

3.0 Essential Components of Cooling Towers

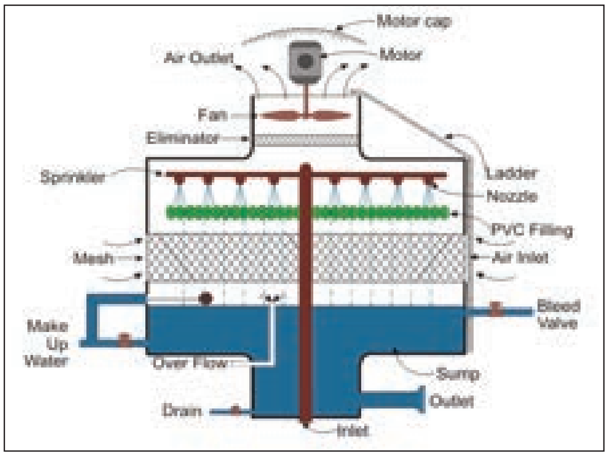


Figure 6.6: Cooling tower components (typical)

3.1 Fans

A cooling tower may contain large fans that circulate significant volumes of air. Though not all cooling towers require fans, many models use them to create and direct airflow through the tower. They may push or pull air through the tower, and they may be axial or centrifugal depending on the specific needs of the application. Axial fans are more efficient, whereas centrifugal fans are quieter and can deal with higher levels of static pressure.

3.2 Fill

Fill, also called wet deck or surface, typically consists of textured polyvinyl chloride (PVC) that is integral to the cooling tower function. It usually features ridges with open spaces for the air and water to travel through. Its purpose is to allow water to collect on it, thereby maximizing the surface area of the water and facilitating heat transfer between the water and the air. Fill can come in a couple of different types. Film-type fill increases the water's surface area by spreading it into a thin film. Splash-type fill increases the water's surface area by breaking a falling stream of water into smaller droplets.

3.3 Spray Nozzles

Spray nozzles in the cooling tower can also be useful in increasing the surface area of the water. In some types of cooling towers like counterflow towers, spray nozzles disperse small droplets of water into the air. The spray helps ensure a uniform distribution of the water over the fill, and the droplets provide a large surface area for air contact.

3.4 Distribution Basin

The distribution basin, or hot water basin, is often used in crossflow cooling towers. A distribution basin takes the place of the spray nozzles by distributing the hot water evenly throughout the tower. It sits atop the tower and typically consists of a pan with holes or nozzles along its base. Hot water flows in through the top of the tower, and the holes or nozzles release it evenly over the fill material below.

3.5 Collection Basin

The collection basin, or cold-water basin, sits at the bottom of the tower to collect the water after it has cooled. In field-built models, these basins are often built of concrete to support the tremendous weight of the water coming down the tower.

3.6 Inlets and Outlets

Inlets and outlets in the cooling tower take in cool air from the environment and release the warm air after it has absorbed the water's heat.

3.7 Drift Eliminators

Drift, or water loss, in a cooling tower is undesirable, but it sometimes occurs when droplets of water escape into the outlet and flow out with the exiting air. Drift eliminators help keep the water secure in the tower. They point the airflow in multiple directions to prevent it from whisking water away.

4.0 Terminology

4.1 Cooling Range

This is the difference between the water temperature at the entry and exit from the cooling tower.

4.2 Cooling Load

The rate at which heat is removed from the water.

4.3 Make-up

The quantity of fresh water which must be supplied to the water system to replace the same amount of water that evaporated.

4.4 Drift

The air droplets that become entrained or carried by the air stream coming into contact with water.

4.5 Plume

The effluent mixture of heated air and water vapor discharged from a cooling tower.

4.6 Approach

The difference between the temperature of water leaving the tower and the wet bulb temperature of the air entering.

4.7 Wet Bulb Temperature

The ambient air temperature at 100% relative humidity. This is measured by a psychrometer where a thin film of moisture covers the bulb of the thermometer which is then exposed to flowing air. The resulting measurement is usually cooler as compared to the measurement from an ordinary thermometer depending on the relative humidity.

Figure 6.7: Sling psychrometer

4.8 Blowdown

Water that is deliberately removed from the system in order to remove parts of the accumulated solids due to the continuous water evaporation, and sludge due to impurities and bacterial growth.

4.9 Recirculation

Occurs when the discharge air re-enters the system by mixing with fresh air. This lowers the efficiency of the cooling tower.

4.10 Starvation

Occurs when the availability of fresh air is insufficient which can result in lower efficiency of cooling tower.

5.0 Dry Cooling Towers

This cooling system has the same principle of operation as automobile radiators. Hot air passes through finned tubes or coils exposed to ambient air. Heat is mainly removed by sensible heat transfer.

For detailed information on cooling towers, please refer to ISHRAE Publication

'All About Cooling Towers (ISHICTH)'.

6.0 Packing, Dispatch, Receiving at Site, Lifting and Storage

Cooling towers, if not packed properly, are susceptible to transit and handling damage. Cooling towers are generally dispatched in knockdown conditions. Hence, it is necessary to check the delivery of all components of cooling towers. It is recommended to shift the pump at the place of installation to avoid multiple handling at site. Upon receipt of the Cooling Tower, visual inspection to be done to check for any damage and also for the correctness of cooling tower with respect to approved technical submittal or specifications. Any damage must be notified to manufacturer and transporter. It is also essential to check the number of parts of the Cooling Tower against a packing list. Following are the major parameters which can be checked upon the receipt with respect to approved technical submittal.

1. Manufacturer
2. Model no.
3. Cooling tower type (open circuit / closed circuit)
4. Number of fans
5. Fan type
6. Drift eliminator in place
7. Fill is as specified
8. Pipe connections are correct in size
9. Test and warranty certificates
10. Unit checked for exterior damages

7.0 Pre-Installation and Installation Checks

7.1 The delivery must be planned as per site requirement and site readiness.

7.2 The drawings must be studied and planning to be done for shifting of the cooling tower to location safely. The necessary shifting equipment's like crane, fork lifts, trolleys to be identified and planned.

7.3 The approach to cooling tower location must be free and proper.

7.4 The location must be surveyed for its suitability. The location must be open and conducive for free air movement. The location is generally determined by one or more of the following.

7.5 Architectural compatibility.

7.6 Rigging limitations.

7.7 Noise, vibrations and drift.

7.8 Structural requirements.

7.9 Maintainability: the location must be as per approved drawing.

7.10 The foundation drawings to be shared with civil/ structural team for its readiness.

7.11 The foundation must be checked and verified for its suitability. Any problems observed must be communicated to the client/ consultant/ PMC.

7.12 The dimensions of foundations must be checked thoroughly.

7.13 The piping layout to be checked and all the connections like piping, electrical, make up water to be planned.

7.14 The water proofing below the cooling tower must be done prior to installation.

7.15 A method statement for installation must be approved before starting the execution.

Figure 6.8: Large cooling tower located close to residential building (not acceptable)

8.0 Installation of Cooling Tower

8.1 Following points to be checked for correct installation of cooling towers.

8.2 Ensure the installation of cooling tower is done by competent team members.

8.3 The safety induction and hazard identification and risk analysis (HIRA) to be done prior to start of installation.

8.4 The dimensions and levelling of foundations to be checked.

8.5 The components must be assembled as per the manufacturer's guidelines.

8.6 Check for any damages to components before start of installation.

8.7 Ensure the area where the cooling tower in installed is open and with free air movement; there is no starvation of air.

8.8 Ensure area where cooling tower is installed is non sensitive with respect to noise and vibrations.

8.9 Maintain sufficient distance between the adjacent wall; sufficient as per manufacturer's guidelines.

8.10 Ensure the adjacent wall is not above the top of cooling tower fans. In such cases, use of cowl piece (check the static of fans) is necessary. This can avoid air recirculation and reduction in efficiency of cooling towers.

8.11 Maintain sufficient distance between cooling tower in case of multiple cooling tower application. Refer manufacturer's guidelines for the same.

8.12 Ensure there is no dust around the cooling towers which can get inside the fills.

8.13 Installation of proper vibration isolators below the fans / tower to reduce the vibration.

8.14 Installation of noise barriers, acoustic enclosures as per approved specification and drawing.

8.15 Ensure drift eliminator is installed.

8.16 Ensure the basin is free of dust.

8.17 Ensure the piping connections as per approved drawings.

8.18 Ensure the make-up water and quick fill connection is done.

8.19 Ensure uninterrupted water supply is available.

8.20 Ensure the bypass loops are installed in piping for flushing of the system.

8.21 Ensure equalizer piping is done in case of multiple cooling towers.

8.22 Ensure adequate space is available for maintenance of the cooling tower, its components and its connections like valves, gauges, etc.

8.23 Identification and tagging of cooling tower are done after installation is completed.

8.24 The leakage testing of basin is done by holding the water for 2 hours duration. The leaks must be identified and rectified.

The following Checklist can be used to check the correctness of installation and signed off.

Table 6.1: Installation check list

Installation Check List for Cooling Towers				
Client Name				
Project		Inspection Report No:		
Location		Date		
Check List for Installation of Cooling Tower		Location		
Sr. No.	**Check List**		**Verification**	
			Yes	**No**
1	Ensure Drawing used for installation are current and approved for construction (Drg Ref:………………………..)			
2	Report any transit damage			
3	Material Inspection is done and MIR is signed			
4	Foundations are checked for its dimensions and suitability			
5	Work carried out as per installation procedure given by manufacturer			
6	The vibration isolators are installed			
7	Acoustic louvers/ cowl pieces are installed if applicable			
8	Location is open and dust free. There is no blockage for air movement			
9	The levelling of basin is checked			
10	The connections are done as per approved drawing			
11	The distances between adjacent wall and between tower is correct			
12	Check and ensure pump / motor name plates are as per approved submittals			
13	Check adequate space is available around tower for installation and maintenance of equipment as per manufacturers recommendations			
14	Check all nuts, bolts, screws, etc. are tightened			
15	Verify that flexible connectors are provided for pipe connections as per approved drawing			
16	Check that location and provision of control sensors are as per approved control schematics			
17	Check and ensure that drain connection of the base frame of pump to be connected to nearest drain			
18	Check that identification labels / tags are provided as per requirement			
19	Check that identification labels / tags are provided as per requirement			
Comments:		(Attach separate sheet if required)		
Checked By		Approved By		
Signature		Signature		
Name		Name		
Date		Date		

9.0 Piping Connections

9.1 The piping to be connected to cooling with flange connections.

9.2 The piping to be connected with the flexible connection at the inlet and outlet of suitable pressure rating.

9.3 Suitable provisions for probes required for gauges and sensors to be made in the piping.

9.4 The flushing bypass to be provided to avoid the entry of initial water during the flushing.

9.5 Equalizer line to be provided in case of multiple cooling towers with a common header.

9.6 The proper supporting to be provided at the connections.

9.7 All the isolation valves, balancing valves, etc. as per approved drawings and specifications to be provided.

10.0 Electrical Connections

10.1 Electrical wiring design and installation on the unit are based on factory standard practice. All installation and management activities must be carried out by qualified personnel and shall ensure compliance with relevant local laws and regulations.

10.2 Refer to the specific wiring diagram and ensure electrical component manual attached with the product before electrical installation. Site contractor shall do termination at site for wiring connection between components that located at different sections and delivered separately.

10.3 The electric supply to the motor must correspond to the rated voltage stated in motor nameplate and be in conformance with the National and Local Electric Code and Regulations.

10.4 The electrical cables and earthing to be laid in cable tray and routed properly. It is necessary to avoid electrical installations below any of the piping.

Figure 6.9: Maintenance walkways make the tower serviceable

10.5 Care to be taken for outside electrical installation. The selection and correction installation of IP rated electrical items to be ensured.

10.6 Signage of 'Danger', 'Electrical' to be placed wherever required.

11.0 Start Up and Commissioning

Commissioning of the cooling tower shall follow the process as detailed in ISHRAE Standard 10003-2020

Following pre commissioning checks to be done prior to startup and commissioning of cooling towers.

11.1 Delivery checks of cooling tower are completed

11.2 Correct cooling tower is installed and located as per drawing

11.3 All pipe connections are completed

11.4 Clear access to all required components

11.5 The water-circulating system serving the cooling tower is cleaned

11.6 That interior filling of cooling tower is clean and free of foreign materials such as scale, algae and tar

11.7 Fill is fixed properly and clean

11.8 Drift is fixed properly and clean

11.9 The cooling tower fans are free to rotate and the tower basin is clean

11.10 There is no abnormal noise or vibration

11.11 Vibration isolators are in place

11.12 Fans are fixed properly

11.13 Drive alignment and belt tension have been checked

11.14 Bearings and lubrication have been checked

11.15 Drainage and fall

11.16 Strainer is clean

11.17 Ball valve function

11.18 Water level in the tower basin is maintained at the proper level

11.19 Water treatment equipment

11.20 Water make-up solenoid

11.21 Electrical supply connections

11.22 Earth bonding

11.23 Confirm power availability for duration of commissioning

11.24 BMS data is available during the commissioning

11.25 Cooling tower is in operation before the test procedures are started

Following is the process for startup of cooling towers:

1. Cooling tower pre-commissioning checks are completed.
2. Electrical test sheets are completed and available from electrical contractor.
3. Verify that the minimum speed settings on VSDs have been coordinated with the requirements of the cooling tower drive train.
4. Ensure, that centrifugal action during full flow does not cause any entrainment of air which may cause pump cavitation.
5. All valves except balancing valves in the water system are in fully open position.
6. Verify the sensor that the control system used to sequence the fans and bypass valve is located downstream of the point where the bypass water mixes with the water coming from the tower basins.
7. Verify all safety interlocks work properly.
8. Verify system and control loop performance and stability at all load conditions (cool and dry, hot and humid) and flow conditions (min and max air and water flow rate).
9. Verify that basin heaters and heaters systems are shut down when the temperatures rise above freezing.
10. Verify that seismic restraints have been properly installed and adjusted.
11. Verify that start-up screens have been removed from the strainers and replaced with gravel screens.
12. Shutdown and start-up sequences stage multiple cooling towers perform properly.
13. Use entering and leaving wet bulb temperatures to determine the tower performance.
14. Use entering and leaving wet and dry bulb temperatures to determine the rate of evaporation.
15. Cooling tower water sample has been taken and analyzed.
16. Cooling tower water quality is acceptable.
17. Cooling tower control algorithm operates as specified in Sequence of Operations (SOO).
18. Cooling tower operates as per design.

Once all pre-commissioning checks are completed and start up is done, following parameters should be noted on a regular basis.

Table 6.2: Cooling tower operation checklist

Cooling Tower Operation Data Collection Sheet					
Project:			Name:		
Contractor:			ID #:		
Sl. No.	**System Parameter**	**Unit**	**Designed**	**Measured**	**Difference**
1	Ambient air dry bulb temperature				
2	Ambient air wet bulb temperature				
3	Entering air dry bulb temperature				
4	Entering air wet bulb temperature				
5	Leaving air dry bulb temperature				
6	Leaving air wet bulb temperature				
7	Cooling water flow rate				
8	Cooling water entering temperature				
9	Cooling water leaving temperature				
10	Make up water flow rate				
11	Constant bleed water flow rate				
12	Fan air flow rate				
13	Fan power				
14	Fan pressure				
15	Supply voltage				
16	Motor starting current				
17	Motor running current				
18	Motor speed				
19	Fan speed				

12.0 Water Treatment

Because of the continuous evaporation of water, several problems arise, such as scaling and biological fouling. Common water treatment methods are water blowdown, filtration, water softening, and chemical addition.

As the water evaporates, impurities dissolve in the water and become more concentrated. Make-up water is added, which will later evaporate and leave behind more impurities. These are dissolved minerals that will later build scale to the parts of the cooling tower in-contact with water. Not only is the cooling tower affected, but also, down the line equipment such as heat exchangers and condensers.

Aside from scale build-up, biological fouling tends to form on surfaces. Evaporative cooling towers are particularly prone to biological fouling where an air stream carrying microbes is scrubbed by the water. Concentrated minerals present in the water due to evaporation provide a favorable environment for these microbes to grow.

Depending on the application and water parameters, methods of water treatment largely vary. There are proprietary water treatment chemicals and filtrations systems being sold on the market targeting a range of problems. The following are some common cooling water treatment methods.

- Blowdown and additional make-up water;
- Filtration;
- Water softening;
- Chemical treatment (corrosion inhibitors, pH control, biocides).

13.0 Integration with Building Management System

- BMS helps to monitor and improve energy performance of the building and can highlight any problems that may come up so that corrective action can be taken and downtime and expensive repairs can be avoided.
- Cooling Towers consume a significant part of energy in an HVAC system and directly affect performance of the entire system. Therefore, their central monitoring and control becomes important.
- As a first step, BMS allows monitoring of the system without changing any control parameters. chiller run status, air flow, power consumption, water and air temperatures etc. as well as any abnormalities can be noticed by the system.
- Going forward, it is also possible to control the system parameters.
- Kindly refer to Chapter 18 for details of BMS integration for cooling towers.

Chapter 7:

Installation of Pumps

1.0 General

Pumps are used in HVAC systems for circulation of water through condensers, cooling towers, chillers, AHUs, FCUs and other type of heat exchangers. Pumps are also used for condensate drainage, for feeding water to expansion tank, etc. There are various types of pumps used depending upon the capacity, head, efficiency, space availability, etc. Pumps are connected with piping to the equipment they feed. Pumps are generally driven by electric motors which need power connections. Pumps are also connected to BMS for operation and control. Sensors and transmitters are used for measurements which are connected to BMS or Chiller Plant Management System. Site work shall involve installation of pumps with proper foundation with vibration isolators, piping connections, electrical, and control system including BMS.

Performance of any type of the pump is greatly influenced by the way its design (proper selection of pumps), installation and commissioning is carried out. Detailed below is the correct way of installing and commissioning of the pumps right from the time they leave the manufacturer's works till they are put to beneficial use.

2.0 Packing, Dispatch, Receiving at Site, Lifting and Storage

2.1 Pumps, if not packed properly, are susceptible to transit and handling damage. Depending upon the type and capacity of the pumps, the weight of the pump varies. Pumps are generally bolted to wooden pallets and covered in a wooden box. The right arrangement must be made to unload and shift the pump to avoid any damage. It is recommended to shift the pump, on receipt at site, to the place of installation to avoid multiple handling at site. Upon receipt of the pump, visual inspection to be done to check for any damage and also for the correctness of pump with respect to approved technical submittal and specifications. Any damage must be notified to manufacturer and transporter. It is also essential to check the number of parts of the pump against a packing list. Following are the major parameters which can be checked upon receipt with respect to approved technical submittal.

a. Rated motor power
b. Minimum circulation required
c. Type of flow control system installed
d. Vibration eliminator
e. Test and Warranty certificates
f. Pipe connections are correct in size

2.2 Lifting of the pump in an improper manner can damage the casing of pump and motor, shaft etc. Pump shall be rigged and moved by the lifting brackets provided or by the skid when a fork-lift is used. Manufacturer's instructions must be strictly followed for lifting and handling of the pump.

2.3 For external storage prior to installation, the units must be protected from dust, rain, constant sun exposure and rodents. Pump should be further protected by tarpaulin or similar covering. It is important to manage the delivery of pumps upon the readiness of foundations so that the pumps are directly shifted on the foundation. The suction and delivery ends of the pumps need to be protected to avoid entry of foreign particles which can damage the impeller. The motors should be protected properly to avoid exposure to the humid conditions.

3.0 Pre-Installation and Installation Checks

3.1 Refer to the pump manufacturer for guidelines for installation and minimum service clearances. The foundations and mounting arrangement shall be ready prior to installation.

3.2 The foundation should be able to absorb any kind of vibration and form a permanent and rigid support for the pumps.

3.3 The weight of the foundation should be 1.5 times the weight of the pump. Where inertia blocks are specified, they shall be used.

3.4 Provide a flat and substantial concrete foundation in order to prevent strain and distortion when one tightens the foundation bolt.

3.5 The foundation should be of sufficient depth to accommodate the J bolts provided by the manufacturer.

3.6 The provision of pockets needs to be kept while casting the concrete foundations.

3.7 Allow enough bolt length for grout, shims, lower baseplate flange, nuts, and washers.

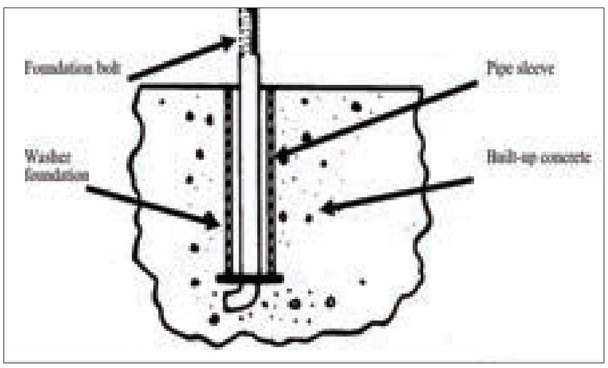


Figure 7.1: Details of typical pump foundation

3.8 Isolation pads to be installed between the main slab and foundation.

3.9 Chemical fastener can be used instead of J bolts with proper design.

3.10 Inertia base foundations are used to minimize the transfer of vibration to the structure.

3.11 Proper selection of inertia base foundation is a must. Inertia base allows the foundation above the mother slab and the weight of the pump to be transferred through a number of vibration isolators as shown below.

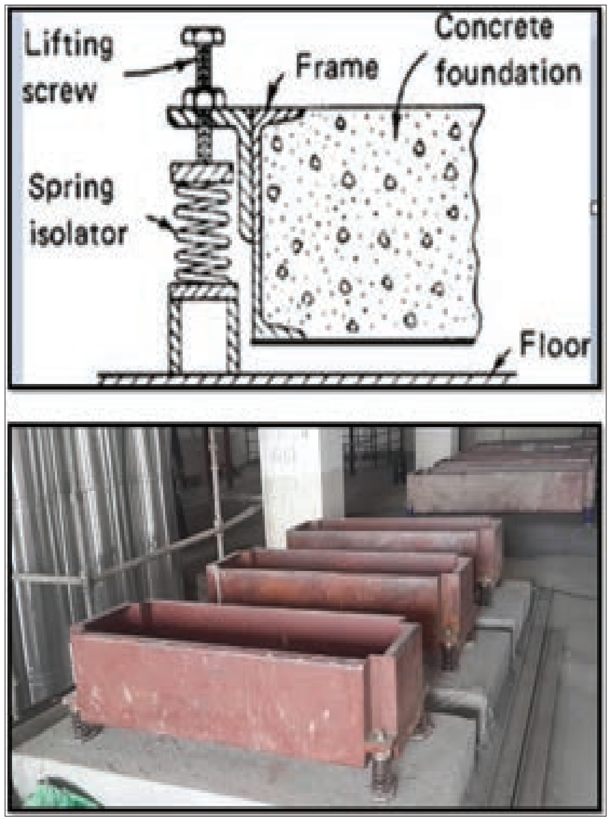


Figure 7.2 Typical pump foundation details

3.12 Correct vibration isolators to be provided to minimize the vibration.

3.13 The provision of seismic snubbers to avoid the toppling of the pumps in case of earthquake.

3.14 Do not install pumps near or above any sensitive area.

3.15 Make sure there is enough space around the pumps.

3.16 Make sure the lifting arrangement/hoist above the pumps to lift the pump in case of any maintenance.

3.17 The area where pumps are installed needs to be effectively ventilated.

3.18 Once the pump is placed on foundation, place 1'' thick steel shims or wedges on the both side of each anchor bolt in order to support the pump. This also provides a means for levelling the base.

3.19 Grouting the baseplate is essential. A non-oil based cleaner and non-shrink grout is required. Following is the process which can be adopted for base plate grouting:

a. Clean all the areas of base plate which can come in contact with grout.
b. Build a dam around the foundation.

c. Wet the area of foundation that can come in contact with the grout.
d. Pour the grout into baseplate up to the base rails.
e. Locate shims to allow removal after the grouting.
f. Remove the air bubbles by using vibrator.
g. Allow the grout to set.

3.20 The pumps are generally factory aligned. However, due to transport and shifting the alignment can get impacted and hence it is recommended to align the pumps at site.

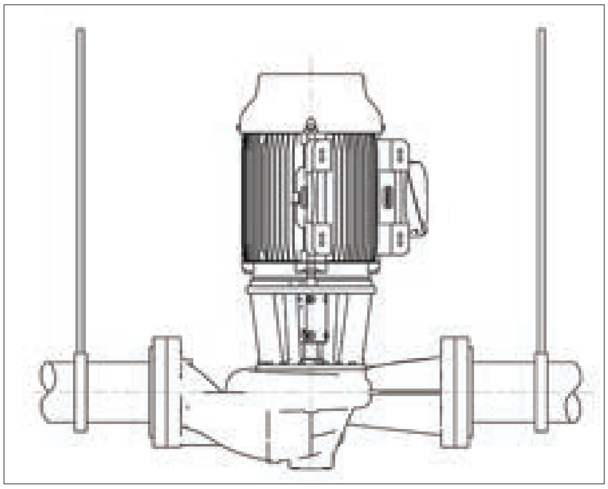


Figure 7.3: Inline pump installation

3.21 Inline pumps can be installed directly in the piping with pipe hangers adequate to carry the loads from the pump and piping.

3.22 In many installations, the piping is installed near the ceiling with the pump located close to the floor for ease of maintenance. Pumps with up to 100 mm nozzles and up to 286 NEMA (180 IEC) frame motors can be installed in this configuration with pipe hangers adequate to carry the loads from the pump, piping and piping accessories. Larger pumps can be installed in this configuration but require flange supports or a floor support under the discharge elbow and an adjustable support leg.

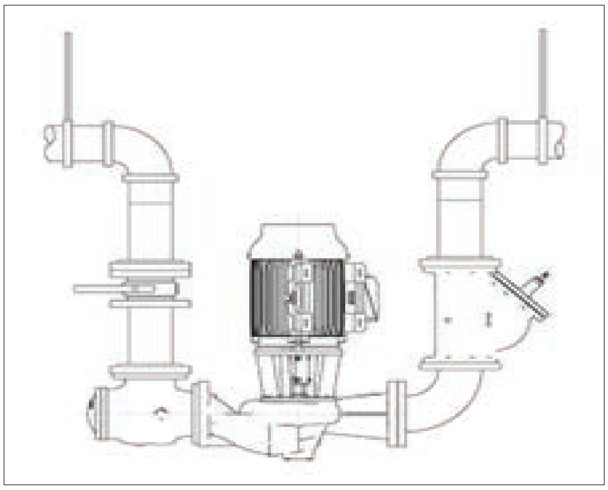


Figure 7.4: Ceiling support for in-line pumps

Pumps can be installed in the piping with floor mounted saddles adequate to carry the loads of the pump and piping.

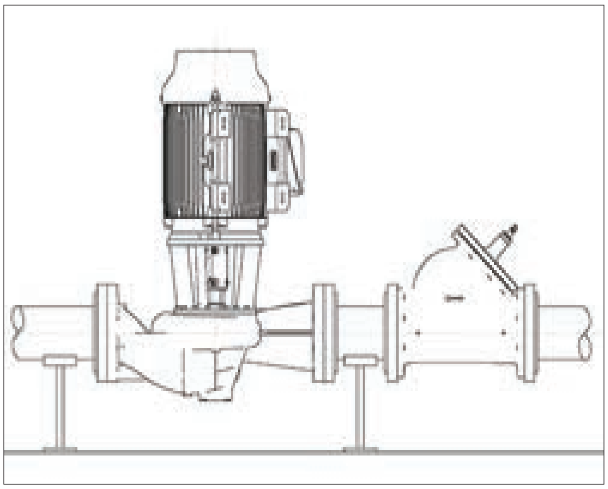


Figure 7.5: Typical flange support for pumps

3.23 Optional flange supports can be used when rigid pump support to the floor or isolation base is required. The supports are installed on the back side of the pump flanges and have tapped holes to accept the flange bolting and have mounting holes in their bases for anchor bolts. Pipe supports (not shown) are required such that the pump flanges are not supporting the piping.

Alternately with the optional flange supports, isolation pads can be used between the support and the floor.

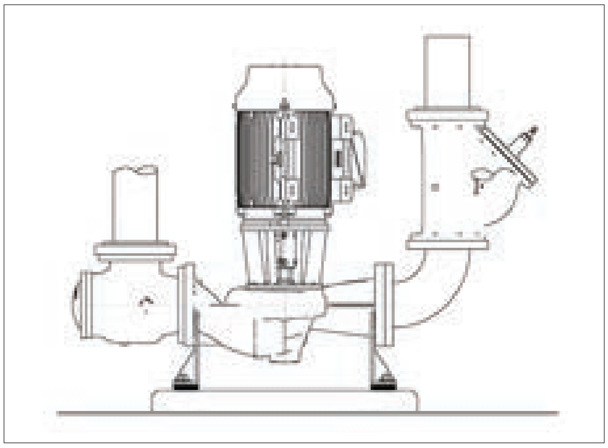


Figure 7.6: Flange support with isolation pad

3.24 Pumps have a four-bolt circle on the bottom of the volute to accept an ANSI/ ASME flange that can be used with a connected pipe as a temporary pump support while the permanent pump piping or pump supports are being fitted to the pump. This support can only be used to handle the pump weight as it is not suitable resist loads in other directions.

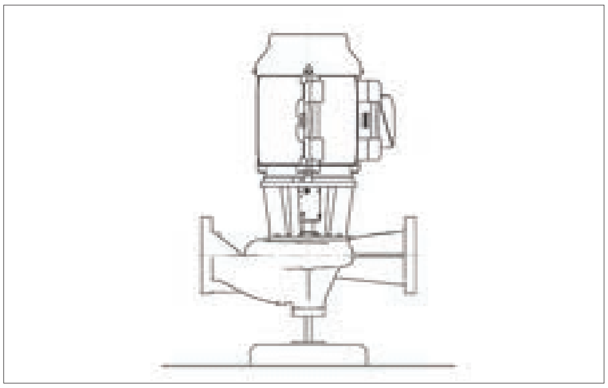


Figure 7.7: Temporary pump support

3.25 For installations in grooved piping systems when the pump is supported by the piping, flange locking type grooved piping connections are required to prevent the pump from rotating in the piping.

4.0 Piping Connections

4.1 Check that a section of straight pipe, with a length that is five times its diameter, is installed between the suction side of the pump and the first elbow. This reduces suction turbulence by straightening the flow of liquid before it enters the pump.

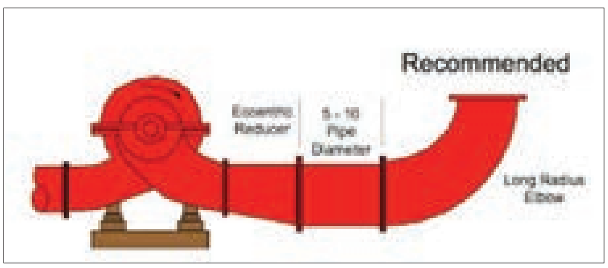


Figure 7.8: Example of straight length at suction

4.2 Check that the suction and discharge pipes are supported independently by use of pipe hangers near the pump. This eliminates pipe strain on the pump.

4.3 Check that there is a strong, rigid support for the suction and discharge lines.

4.4 Check that there is a strong, rigid support for the suction and discharge lines.

4.5 Check expansion bellows are provided at suction and discharge side of pumps.

4.6 Use eccentric reducers on the suction side of the pump when a pipe size transition is required. The flat portion is designed to discourage an air pocket from forming at the pump suction.

4.7 Isolation valves for suction and discharge lines, Y strainer at the suction side, NRV on discharge side are installed. The valves should be at operating levels. The valve tags are provided.

4.8 The provision of pressure gauges, transmitters, sensors are provided in the piping connections.

4.9 The drain valve is provided in the piping connections.

5.0 Electrical Connections

5.1 Electrical wiring, earthing design and installation on the unit are based on factory standard practice. All installation and management activities must be carried out by qualified personnel and shall ensure compliance with relevant local laws and regulations.

5.2 The electric supply to the motor must correspond to the rated voltage stated in motor nameplate and be in conformance with the National and Local Electric Code and Regulations.

5.3 Suitable electrical protection isolator should be installed to protect the motor and other electrical equipment.

6.0 Installation Checklist

6.1 Checklist as given below can be referred for final inspection and sign off:

6.2 A specific method statement for each project to be made.

7.0 Commissioning of Pumps

7.1 For complete guidelines for Commissioning of Pumps, please refer to ISHRAE Standard 10003-2020 – Commissioning Process Standard for HVAC Systems. The Standard includes, as Normative Annexures, Delivery, Installation, Start up and Operation Checklist for Pumps and Piping System. These should be carefully followed.

7.2 Before taking start up actions, one must ensure there is a clear access to pump.

Project		Inspection Report No:	
GO No		Date	
Check List for installtion of Pumps		Location	

Sr.No	**Check List**	**Verification**	
		Yes	No
1	Ensure Drawing used for installation are current & approved for construction (Dig Ref)		
2	Mock Up Approval wide Doc. No		
3	Work carried out as per installation procedure given by manufacturer		
4	Supporting Materail as per approved submittal ref....Jtender specs/typical installation drg ref		
6	Inspect & ensure equipment and other associated material used is in new and undamaged		
7	Report any transit damage 8 Check and ensure pump / motor name plates are as per approved submittals		
9	Ensure adequate space is available around Pump for installation & maintanance of equipment as per manufacturers recommendations		
10	Check all dimension of pump base frame and inertia base as per approved details		
11	Check and ensure that base frame of the pump is bolted properly on inertia base as per approved installation details		
12	Check that inertia base with spring isolators are provided		
13	Check all nuts, bolts .screws etc. are tightened		
14	Verify that flexible connectors are provided for pipe connection on suction & discharge side as per approved drawing		
15	Check that location & provison of control sensors are as per approved control schematics.		
16	Check and ensure that drain connection of the base frame of pump to be connected to nearest drain		
17	Check that identification labels / tags are provided as per requirment. Comments: (Attach separate Sheet if required) Checked By 'Approved By		

Pump Operation Data Collection Sheet					
Project:			Pump name:		
Contractor			Model ID #:		
SI.No	**System Parameter**	**Unit**	**Designed**	**Measured**	**Difference**
1	Water flow rate				
2	Pump suction head				
3	Pump discharge head				
4	Pump speed (rpm) with maximum water flow rate				
5	Pump motor voltage with maximum water flow rate				
6	Pump motor current with maximum water flow rate				
7	Pump noise level				
8	Supply voltage				
9	Starting current				
10	Running current				
11	Overload Setting				
12	Tripping Time of Starter Overload				

7.3 All electrical connections are tight and correctly wired.

7.4 Motors and pumps are aligned properly.

7.5 Impeller is free to rotate when decoupled and should not make unusual noise when rotated by hand.

7.6 Bearings are clean and lubricated and drive guards are fitted.

7.7 Pressure test points are provided at the suction and discharge of pump.

7.8 Flow measurement devices are installed as per approved shop drawing.

7.9 System has been flushed and cleaned.

7.10 Pump strainer is cleaned after flushing.

7.11 Pump drain is connected to main drain.

7.12 Ensure system is free of foreign matter which could damage the pump.

7.13 Power is available during commissioning.

7.14 All the provisions for sensors and gauges are available. The required gauges and sensors are installed and calibrated.

7.15 Once all pre commissioning checks are completed, performance parameters to be recorded as per the Data Collection Sheet given on page 61.

8.0 Integration with Building Management System

8.1 BMS helps to monitor and improve energy performance of the building and can highlight any problems that may come up so that corrective action can be taken and downtime and expensive repairs can be avoided.

8.2 Pumps consume a significant part of energy in an HVAC system and directly affect performance of the entire system. Therefore, their central monitoring and control becomes important.

8.3 As a first step, BMS allows monitoring of the system without changing any control parameters. Pump run status, water pressures, power consumption etc. as well as any abnormalities can be noticed by the system.

8.4 Going forward, it is also possible to control the system parameters.

8.5 The interlocking of pumps with other equipment like chiller, cooling towers to be checked as per system operation.

8.6 For details of installation/integration with BMS systems, please refer to Chapter 18.

Chapter 8:

Installation of Fans

1.0 General

The fans used in HVAC systems are for supply air, return air, exhaust air and for many other applications such as staircase, lift well pressurization and smoke management.

The ventilation system will have single or multiple supply, return or exhaust air fans connected with or without ducting. The fans are factory made, tested and accepted before they are delivered at project sites. Site work shall involve installation of fans with proper foundation (for floor mounted fans) or mounting arrangement for wall or ceiling mounted fans, ducting with canvas connection, mechanical, electrical, structural work and control system including BMS.

For proper selection of fans for the application concerned, please refer to ISHRAE Fan Guidebook (ISH001HFG).

Performance of any type of fan is greatly influenced by the way its installation and commissioning are carried out. Detailed below is the correct way of installing and commissioning of fans right from the time they leave the manufacturer's works till they are put to beneficial use.

1.1 Packing, Dispatch, Receiving at Site, Lifting and Storage

1.1.1 Fans, if not packed properly, are susceptible to transit and handling damage. Depending upon the type and size of the fans, the weight of the fans varies. The right arrangement must be made to unload and shift the fans to avoid any damage. Upon receipt of the fans, visual inspection to be done to check for any damage and also for the correctness of fans with respect to approved technical submittal or specifications. Any damage must be notified to manufacturer and transporter. It is also essential to check the number of parts of the fans against a packing list.

1.1.2 Lifting of the fan assembly in an improper manner can damage the fine alignment and can damage the casing or impeller. In respect of heavy and bulky fans, they shall be rigged and moved by the lifting brackets provided or by the skid when a fork-lift is used. Manufacturer's instructions must be strictly followed for lifting and handling of the fan assembly. Fans should not be lifted by the motor shaft, housing, motor or belt-guard.

1.1.3 Fans should be stored at site in a clean and dry location. Storage location has to be carefully selected so that multiple shifting is avoided. If the fan is stored for an extended period, the propeller/impeller should be rotated by hand once a month to ensure that bearings remain lubricated and the lubricant does not solidify around them. Fan motors should be energized once in 3 months while they are in storage.

For extended storage, fans are recommended to be stored approximately 100 mm above the floor on wooden blocks and shall be covered with moisture proof paper or polyethylene sheathing. Before use, excessive grease in the bearings shall be purged and wiped off. Before lifting the fan from storage for installation, make sure that all shipping materials have been removed.

1.2 Pre-Installation Checks

1.2.1 Before taking up installation works, it is necessary remove transit blocks. The area of installation shall be clear for installation and proper space for service shall be available. Refer to the fan manufacturer for guidelines for installation and minimum service clearances. The foundations, mounting arrangement shall be ready prior to installation.

1.2.2 Correct vibration isolators to be provided to minimize the vibration.

1.2.3 The direction of fans with respect to air flow shall be checked.

1.2.4 Electric power and control wiring as well as earthing shall be carried out as per approved drawings and as per manufacturers' recommendations.

1.2.5 All fasteners, set screws, locking collars on the fan wheel, bearings, drum, motor block and accessories should be checked for tightness with a torque wrench. Fan wheel should be slowly rotated by hand to ensure that there are no rubbing parts. Bearing alignment and proper lubrication of bearings should be checked. Ensure the fan guards are securely attached and will not interfere with the moving parts. Fan housing and ductwork should be checked for any obstructions.

1.2.6 In case of ceiling suspended fans, the selection of correct structure, mounting, anchor fasteners to be done. It is recommended to use additional fastener if in case one fails.

1.2.7 The ducting connections to be done with canvass connection at the fan inlet and outlet. Electrical isolator or push button near the fan is required.

Figure 8.1: Axial fan installation (ceiling suspended)

1.3 Ducting Connection of Fans

1.3.1 The performance of the fan when installed in a system can be adversely impacted by the flow conditions at inlet and outlet. Pressure loss associated with a given type of inlet/outlet condition expressed in millimeters or inches of water column is termed as System Effect. For calculating System Effect for various types of fans please refer to ISHRAE Fan Guidebook, Chapter 8.

1.3.2 For non-ducted installations, the fan inlet being too close to a wall or any other obstruction can result in reduced performance. It is recommended to have a gap equal to one wheel diameter between the obstruction and the fan

1.3.3 If a fan is mounted in a box or is connected to a plenum, the box/plenum should be symmetrical about the fan inlet axis to avoid swirl or spinning of air.

1.3.4 In case of belt driven fans, fan pulley, belt guard or drive motor which are in the air flow path can affect the performance due to system effect and this element must be considered while selecting the fan.

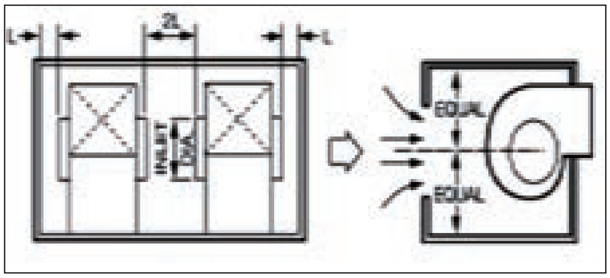


Figure 8. 2: Fan mounting in a box

1.3.5 In case of kitchen exhaust system, the motor of the fan should not be in the part of air stream.

1.3.6 Air approaching fan inlets should have smooth entry. Use of properly designed bell mouth inlet cones reduce pressure loss and noise. Cones should be symmetrically aligned to the impeller inlet axis.

1.3.7 Two or more fans operating in parallel shall have separation of one inlet diameter at fan inlets to avoid erratic flow.

1.3.8 Forward curved fans have electrical overloading characteristic. Hence, in such cases, the fan motor may be oversized to take care of possible overloading.

1.3.9 The ducting connections of fans can have impact on fan performance. In *Figure 3* and *4*, correct and incorrect ducting connections are given for centrifugal and axial fans respectively.

1.4 Mounting of Fans

1.4.1 In respect of floor mounted fans (such as a SISW or DIDW centrifugal fan) a strong and level foundation is a must. A reinforced cement

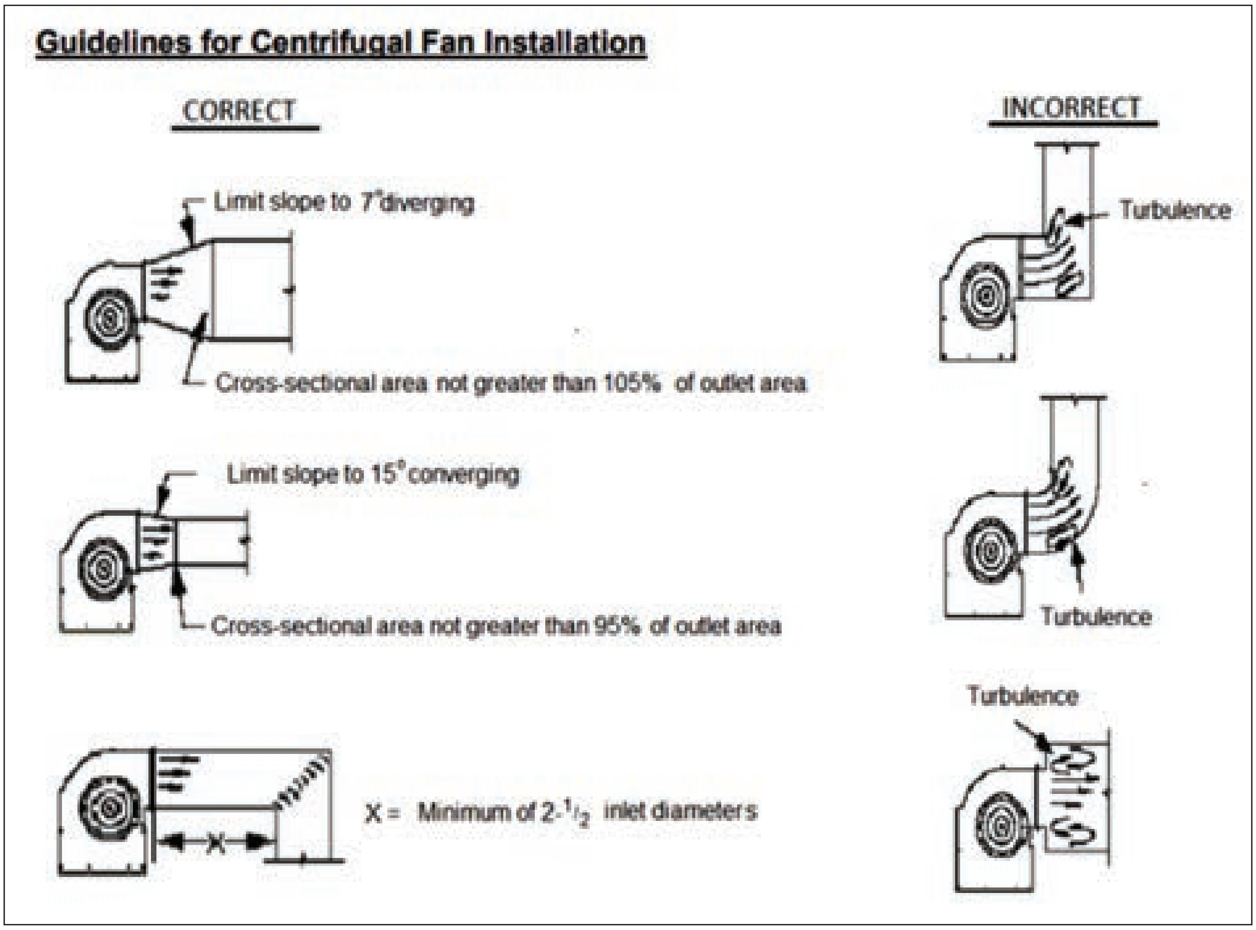


Figure 8.3: Guidelines for centrifugal fans

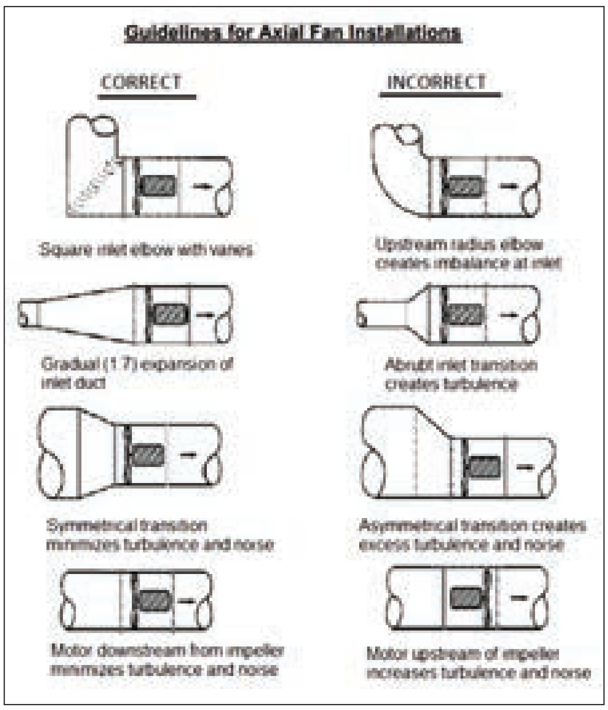


Figure 8.4: Guidelines for axial fans

concrete block with a steel base or an inertia base will provide an adequate foundation.

Vibration isolators should be used. Isolators are to be installed between the fan base and the foundation. After installing the isolators, the fan should be levelled. For doing this, level should be kept on the fan base and not on the fan shaft. Additionally, the motor and fan shafts must be level and parallel to each other.

1.4.2 Centrifugal In-Line fans can be mounted horizontally, vertically or at an angle. Fan should be attached to suitable mounting brackets provided by the fan supplier. Vibration isolators are recommended to be used. Access panels are to be provided on both sides.

1.4.3 Axial flow fans can be flange- mounted within ducts with air flow vertically in upward, downward direction or they can be mounted horizontally. Fan along with the duct should be adequately supported with firmly bolted mounting rods and with vibration isolators where support is taken from the ceiling.

Axial flow fans can also be supported independent of duct from ceiling or wall with airflow in either vertical or horizontal direction. Here again, when ceiling supports are used, vibration isolation is recommended to avoid transmittal of vibration to the building structure.

1.4.4 Propeller fans are mounted with horizontal discharge either on wall openings or on collars or housings attached to the wall. It should be noted that wall opening required will be different for both the cases. The distance from the propeller to the damper is critical to avoid turbulence and damper flutter. Manufacturer's guidelines should be followed.

1.5 Belts, Drives and Alignment

1.5.1 In respect of belt driven fans, fan and motor pulley sheaves should be aligned with a straight edge. Pulleys should be located close to bearings. Correct number and size of belts should be used. This depends on motor power and size of the smaller pulley. Belt tension should be adjusted and the unit should be run for a few minutes to allow the belts to set in. Belt tension shall be proper. When pressed with one finger, the deflection of the belt shall be 10 to 20 mm.

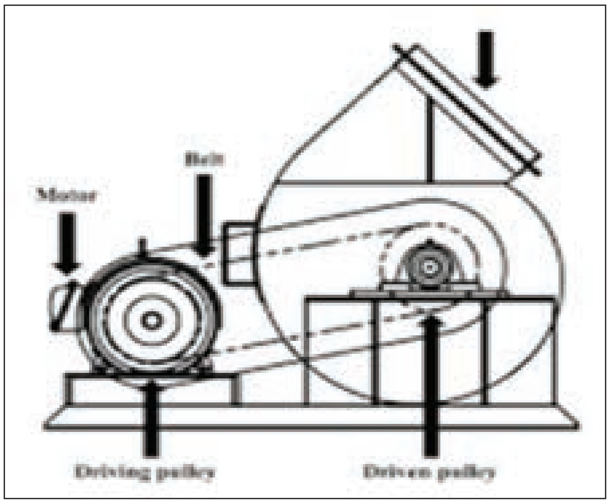


Figure 8.5: Mounting of motor and fan pulleys.

Figure 8.6: Centrifugal fan

1.5.2 Pulleys and belts should be checked for proper alignment to avoid unnecessary belt wear, noise, and vibration. Motor and drive shafts must be parallel and pulleys should be in line.

1.6 Fan Location

1.6.1 To the extent possible, fans should be located away from occupied areas where its noise can be disturbing. For large fans, an acoustically treated room is preferred. Flexible connections to the fan can be designed with acoustical properties to reduce fan noise emitting from the inlet or outlet.

1.6.2 Inlet and outlet orientation of the fan should be verified with respect to the approved drawing.

1.6.3 Once the fan is correctly located in position, identification labels and airflow directions should be clearly marked.

1.6.4 In case a delay is expected between installation of fan and its commissioning as part of a system, the fan should be kept suitably protected from damage and dust.

1.7 Vibration and Isolation

1.7.1 Unbalance or out of balance of the rotating wheel or impeller as well as unbalance or misalignment in other parts of the fan such as shaft, coupling, pulley, belts can cause vibration. Fan need to be tested at the factory to acceptable Balance-Vibration grade for the specific application.

1.7.2 Besides these factors, installation factors and mass and stiffness of the supporting system can influence vibration level of the installed unit.

1.7.3 In respect of floor mounted fan, this can be tackled by mounting the fan and drive train on a rigid base frame which in turn is supported on suitably rated vibration isolators mounted on a foundation or structure. The fan should be secured to a concrete foundation of suitable mass. The foundation should be 3 to 6 times the mass of the fan and motor assembly. Fan should be properly levelled and secured. A flexible neoprene or other suitable flexible pad may be introduced between the full contact surface of the fan base and the contact foundation. The resilient mounts are designed to prevent transmission of vibration through the structure. For selecting

Table 8.1: Checklist for fan installation

Project		Inspection Report No:		
GO No		Date		
Check List for installtion of Fans		Location		
Sr.No	**Check List**		**Verification**	
			Yes	**No**
1	Check that location of fan is correct as per shop Drawing No			
2	Supporting detail are as per approve submittal ref/tender specs/ typical installation drg			
3	For floor mounted fans precast foundation are provided			
4	Check that fan is properly supported / installed			
5	Check that easy acess is available for maintenance all around the fan			
6	Check that direction of air flow is as per requirment			
7	Check that anti vibration rubber groumet pads are provided for the fans.			
Comments:		(Attach separate Sheet if required)		
Checked By		Approved By		

the appropriate vibration mount and for field balancing of the fan, manufacturer's guidelines shall be followed.

1.7.4 Duct should be connected to fan outlet and inlet through canvas or other clean flexible material. Access should be provided in the connection for periodic removal of dirt and any accumulated dust etc.

1.7.5 After Installation, inspection can be done as per the checklist and signed off. A sample checklist is given in *Table 8.1.*

1.8 Commissioning of Fans

1.8.1 For complete guidelines for Commissioning of Fans and Fan Systems, please refer to ISHRAE Standard 10003-2020 – Commissioning Process Standard for HVAC Systems. The Standard includes, as Normative Annexures, Delivery, Installation, Start-up and Operation Checklist for Fans (Table HA-9) and also for Air Distribution System Basement Ventilation System, Kitchen Ventilation System, Exhaust System and Pressurization System (HB 6 to HB 10). These should be carefully followed.

1.8.2 Before taking up start-up, it should be ensured that the fan/ assembly is adequately supported and vibration isolators and flexible connections as specified have been provided.

1.8.3 In case back draft dampers are specified, their correct installation needs to be verified.

1.8.4 All dampers and sensors should be accessible. Testing locations should be available.

1.8.5 Ducting as well as the area from where fan will suck the air should be clean and free of dust.

1.8.6 In case inlet guide vanes are provided, they should be partially closed at start-up.

1.8.7 Electrical isolation should be available close to the fan and should be easily accessible. Adequacy of earthing must be checked. At start-up all the dampers should be in fully open position. Control sequence and BMS connectivity (if provided) should be verified.

1.8.8 Once all pre commissioning checks are completed, performance parameters to be recorded as per *Table 8.2*. The fan operating point based on the recorded readings shall be marked on the fan curve. If any damper adjustments are

Table 8.2: Operating parameters checklist

System Parameter	Unit	Designed	Measured	Difference
Supply air flow rate				
Pressure generation of fan with maximum air flow rate				
Fan RPM with maximum air flow rate				
Fan motor RPM with maximum air flow rate				
Fan motor voltage with maximum air flow rate				
Fan motor current with maximum air flow rate				
Noise level of fan				
Center-to-center distance of the motor base travel				

required to be done to match the air quantity with respect to design value, they should be carried out and VCD positions shall be marked. Method of measuring air flow as well as air pressure in duct connected to the fan are detailed in ISHRAE Standard 10003-2020.

1.9 Integration with Building Management System

1.9.1 BMS helps to monitor and improve energy performance of the building and can highlight any problems that may come up so that corrective action can be taken and downtime and expensive repairs can be avoided.

1.9.2 Fans consume a significant part of energy in an HVAC system and directly affect performance of the entire system. Therefore, their central monitoring and control becomes important.

1.9.3 As a first step, BMS allows monitoring of the system without changing any control parameters. Fan run status, air flow, power consumption as well as any abnormalities can be noticed by the system.

1.9.4 Going forward, it is also possible to control the system parameters by increasing or decreasing fan speed, opening or closing of inlet guide vanes or dampers provided in the system.

1.9.5 For all life safety related fans, it is necessary to integrate the fans with fire alarm system. The integration to be checked to ascertain the correct logic of operation of fans in case of emergency.

For installation details for BMS and control systems, please refer to Chapter 18.

Chapter 9

Installation of Air Handlers

1.0 General

The AHUs used in HVAC systems are for supplying treated air to the space which is to be air conditioned. There are single skin and double skin type of units. The single skin type units are getting obsolete now. Based on the mounting, there are two types i.e., (i) Ceiling Suspended AHU and (ii) Floor Mounted AHU. AHUs are connected with chilled water piping to its coils, electrical power to its blower motors and with the ducting to supply the treated air to the spaces to be air conditioned and also in certain cases to take the return air back for recirculation. They are also connected to BMS for operation and control. Recently, Smart AHUs are being introduced for its precise control and connectivity. AHUs are certified by various Certification bodies across the globe. Site work shall involve installation of AHUs with proper foundation (for floor mounted AHUs) or mounting arrangement for wall or ceiling mounted AHUs, ducting with canvas connection, mechanical, electrical, structural work and control system including BMS.

For proper selection of AHU for the application concerned, please refer to ISHRAE AHU Standard 20002-2020.Performance of any type of AHUs is greatly influenced by the way its installation and commissioning are carried out. Detailed below is the correct way of installing and commissioning of AHUs right from the time they leave the manufacturer's works till they are put to beneficial use.

2.0 Packing, Dispatch, Receiving at Site, Lifting and Storage

AHUs, if not packed properly, are susceptible to transit and handling damage. Depending upon the type and size of the fans, the weight of the AHUs varies. The smaller units are generally delivered in assembled conditions and large units in CKD (dismantled) condition. The right arrangement must be made to unload and shift the AHUs to avoid any damage. Upon receipt of the AHUs, visual inspection to be done to check for any damage and also for the correctness of AHUs with respect to approved technical submittal or specifications. Any damage must be notified to manufacturer and transporter. It is also essential to check the number of parts of the AHUs against the packing list.

2.1 Lifting of the AHU assembly in an improper manner can damage the fine fan alignment and

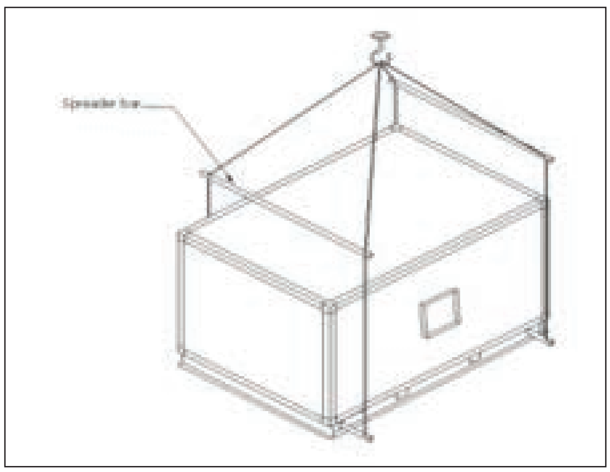


Figure 9.1: Lifting of assembled units

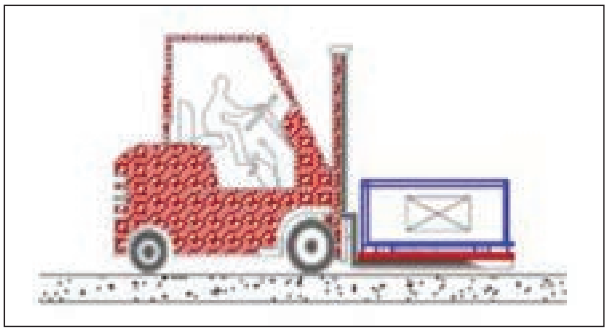


Figure 9.2: Use of forklift to lift AHU

can damage the casing or impeller. In respect of heavy and bulky AHU, they shall be rigged and moved by the lifting brackets provided or by the skid when a fork-lift is used. Manufacturer's instructions must be strictly followed for lifting and handling of the fan assembly.

2.2 For external storage prior to installation, the units must be protected from dust, rain, constant sun exposure and rodents. Although covered in shrink-wrapped plastic sheeting, this is not intended for long-term storage and should be removed as soon as it is offloaded. Unit therefore should be protected by tarpaulin or similar covering. Avoid exposing the units for coil connection damages by transient load. The fan impeller or motor drive must be rotated once every month. Should the units be stored for a period of exceeding 6 months, then it is recommended that the drive belts be removed and stored separately. The factory protection of various parts, specifically the coils should not be removed.

3.0 Pre-Installation and Installation Checks

3.1 Refer to the manufacturer for guidelines for installation and minimum service clearances. The foundations and mounting arrangement shall be ready prior to installation. The units are not designed to be weatherproof (unless equipped with canopy) and therefore should not be installed outdoors. Flexible connections should be used on the outlet and inlet duct connections for all units. A minimal amount of air leakage is normal on the cabinet and it will not affect unit performance. The air handling units are not designed to be suspended from the top of the unit. Therefore, when the unit is ceiling hung, make sure unit is supported with a base rail of channel.

3.2 Correct vibration isolators to be provided to minimize the vibration.

3.3 The direction of rotation of fans with respect to air flow shall be checked.

3.4 Electric power and control wiring as well as earthing shall be carried out as per approved drawings and as per manufacturers' recommendations.

3.5 All fasteners, set screws, locking collars on the fan wheel, bearings, drum, motor block and accessories should be checked for tightness with a torque wrench. Fan wheel should be slowly rotated by hand to ensure that there are no rubbing parts. Bearing alignment and proper lubrication of bearings should be checked. Ensure the fan guards are securely attached and will not interfere with the moving parts. Fan housing and ductwork should be checked for any obstructions.

3.6 In case of ceiling suspended AHUs, the selection of correct structure, mounting, anchor fasteners to be done. It is recommended to use additional fastener if in case one fails.

3.7 The piping connections to be done with flexible bellows of rated pressure along with the provision of gauges and sensors required to measure the performance of the AHUs. The piping connections to be supported adequately. The condensate drain piping to be laid with proper slope and with U trap.

3.8 The ducting connections to be done with canvass connection at the fan inlet and outlet.

3.9 Electrical isolator or push button near the unit is required.

3.10 Space for return air and filter removal is required.

3.11 Lighting arrangement inside AHU room and above false ceiling for ceiling suspended units.

3.12 A weather proof lamp inside the unit to be provided.

3.13 Limit switch for AHU doors to be provided and operational.

3.14 Sight glass must be provided on the door of AHUs.

3.15 Belt guard to be provided for all belt driven units.

3.16 Access doors for the units and its connections to be provided for maintenance.

3.17 Water source near to the unit to be provided for filter cleaning.

3.18 Installation of ceiling suspended units over an electrical installation must be avoided.

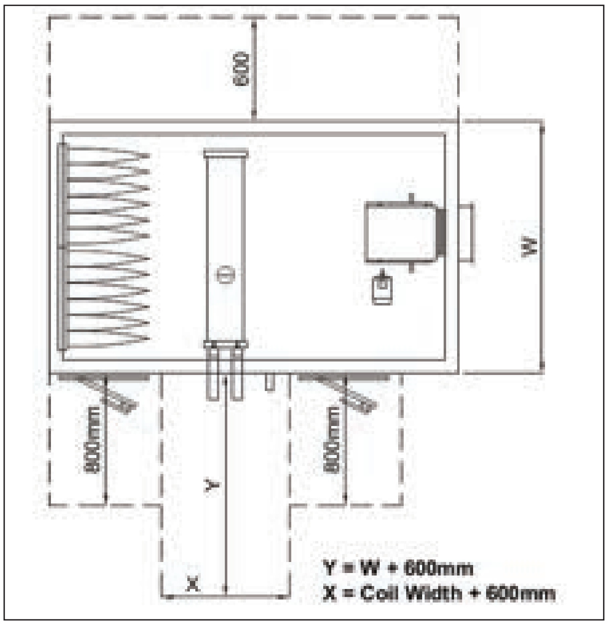


Figure 9.3: Minimum clearance required

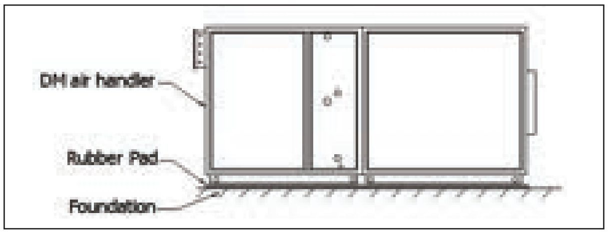


Figure 9.4: Floor mounted AHU installation

Figure 9.5: Floor mounted AHU

4.0 Fan Installation

4.1 The performance of the fan when installed in a system can be adversely impacted by the flow conditions at inlet and outlet. Pressure loss associated with a given type of inlet/outlet condition expressed in millimeters or inches of water column is termed as System Effect. (Please refer to ISHRAE Fan Guidebook for more details).

4.2 The duct connection to the unit must be smooth and without any sharp bends or tapers at the outlet of the unit. Provision of probes to be made at the outlet of the unit to measure the air performance in terms of air quantity and temperature.

4.3 In case of use of ducting plenum, proper design to be done and implemented.

4.4 Based on the noise level requirement the ducting acoustic to be done. It is recommended to do acoustic treatment for initial 3 meters of ducting from the outlet of the unit.

4.5 The ducting must be connected with fire retardant canvas connection.

4.6 Volume control damper to be provide at the inlet (return and fresh air) and at the outlet.

4.7 Ducting or plenum to be adequately supported.

4.8 If a fan is mounted in a box or is connected to a plenum, the box/plenum should be symmetrical about the fan inlet axis to avoid swirl or spinning of air.

5.0 Piping Connections

5.1 The chilled water piping to be connected with di-electric coupling (MS to copper connection).

5.2 The chilled water piping to be connected with the flexible connection at the inlet and outlet of suitable pressure rating.

5.3 Suitable provisions for probes required for gauges and sensors to be made in the piping.

5.4 Flushing bypass to be provided to avoid the entry of initial water during the flushing.

5.5 The condensate drain piping to connected with U trap and with proper slope.

6.0 Electrical Connections

6.1 Electrical wiring design and installation on the unit shall be as per Manufacturer's instructions. All installation and management activities must be carried out by qualified personnel and shall ensure compliance with relevant local laws and regulations.

Refer to the specific wiring diagram and electrical component manual supplied with the product before electrical installation. Site contractor shall do termination at site for wiring connection between components that located at different AHU sections and delivered separately.

6.2 The electric supply to the motor must correspond to the rated voltage stated in motor nameplate and be in conformance with the National and Local Electric Code and Regulations.

6.3 The fan section metal frame must be grounded. Suitable electrical protection isolator should be installed to protect the motor and other electrical equipment.

6.4 Flexible conduit must be used when wiring up fan motors to allow the fan motor to move freely on its anti-vibration mounts.

6.5 Cables passing through panels must be made with gland or grommet.

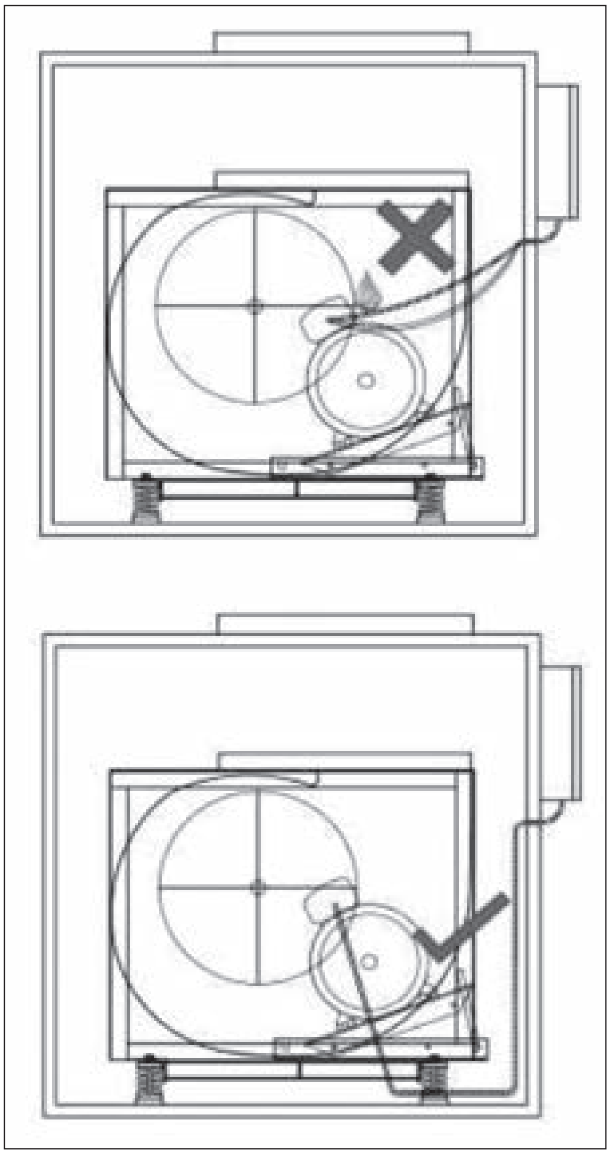


Figure 9.6: Right and wrong methods of drawing electrical cable

6.6 Motor wiring must go downward from motor terminal box to prevent condensation water flowing into motor and lead to a failure.

7.0 Mounting of Fans

7.1 In respect of floor mounted AHUs a strong and level foundation is a must. A reinforced cement concrete block with a steel base or an inertia base will provide an adequate foundation.

Vibration isolators should be used. Isolators are to be installed between the AHU base and the foundation. After installing the isolators, the AHU should be levelled. For doing this, level should be kept on the fan base and not on the fan shaft. Additionally, the motor and fan shafts must be level and parallel to each other.

7.2 In case of ceiling suspended units, a proper selection of structure, threaded rods, supporting base channel, anchor fasteners are must. Manufacturer's guidelines should be followed. AHU should not be placed on electrical installations or on top of any sensitive areas. Maintainability of the unit should be of prime importance before selection and installation of unit. Extreme care to be taken to ensure the installation is done correctly and inspected before the start up is taken up.

8.0 Belts, Drives and Alignment

8.1 Improper sheave alignment and belt tension can cause excessive vibration, premature failure of belts and bearings. Pulleys and belts should be checked for proper alignment to avoid unnecessary belt wear, noise, and vibration. Motor and drive shafts must be parallel and pulleys should be in line.

8.2 Tensioning of the drive belt is achieved by moving the motor in relation to the fan (see *Figure 9.8*). When inserting new belts, do not force belts over grooves, Loosen the adjusting screw at motor base until belt can slide smoothly over the grooves. When all belts are in position, proceed to adjust belt tension using the adjusting screw and nuts on the motor base.

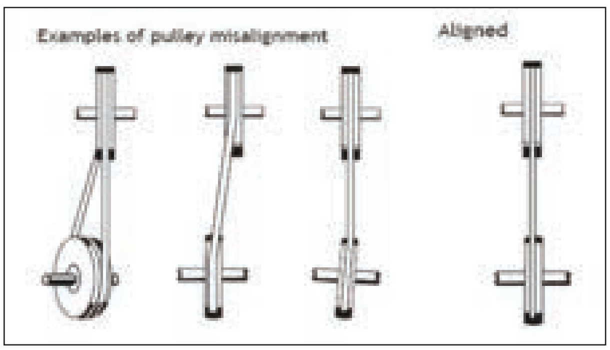


Figure 9.7: Alignment of pulley

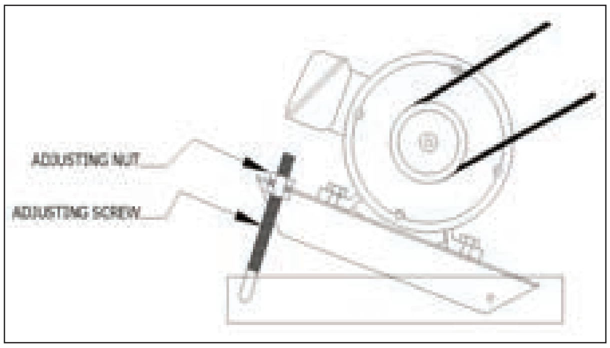


Figure 9.8: Belt tensioning

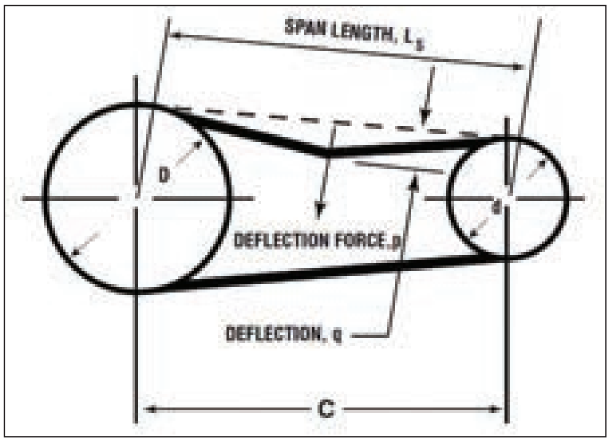


Figure 9.9: Belt deflection distance

8.3 Use recognized belt tension gauge to check the belt tension by apply a force large enough at the center of the belt to deflect the belt by 16 mm per meter (See *Figure 9.10*). The deflection force of factory setting is based on 'Initial Fitting', re-tensioning as 'Re-tension' after the unit has run for 24 hours.

Note: Refer to factory specifications for tension values

9.0 AHU Location

9.1 To the extent possible, AHU should be located away from occupied areas where its noise can be disturbing. An acoustically treated room is preferred. Flexible connections to the fan can be designed with acoustical properties to reduce fan noise emitting from the inlet or outlet. Sound attenuator can be incorporated to minimize the sound levels.

9.2 Inlet and outlet orientation of the AHU should be verified with respect to approved drawing.

9.3 Once the AHU is correctly located in position, identification labels and airflow directions and its positions (return, fresh and supply air) should be clearly marked.

9.4 In case a delay is expected between installation of AHU and its commissioning as part of a system, the outlet of the units should be kept suitably protected from damage and dust.

10.0 Vibration and Isolation

10.1 Unbalance or out of balance of the rotating wheel or impeller as well as unbalance or misalignment in other parts of the fan such as shaft, coupling, pulley, belts can cause vibration.

10.2 Besides these factors, installation factors and mass and stiffness of the supporting system can influence vibration level of the installed unit.

10.3 In respect of floor mounted units, this can be tackled by mounting the fan and drive train on a rigid base frame which in turn is supported on suitably rated vibration isolators mounted on a foundation or structure. The unit should be secured to a concrete foundation of suitable mass. The foundation should be 3 to 6 times the mass of the AHU. Unit should be properly levelled and secured. A flexible neoprene or other suitable flexible pad may be introduced between the full contact surface of the fan base and the contact foundation. The resilient mounts are designed to prevent transmission of vibration through the structure. For selecting the appropriate vibration mount and for field balancing of the fan, manufacturer's guidelines shall be followed.

10.4 For ceiling suspended units, the correct vibration isolators to be selected and installed. The vibration isolators can be placed vertically if threaded rods are used to hang the units or between the AHU base frame and structure if the structure is used to install the units.

10.5 Duct should be connected to fan outlet and inlet through canvas or other clean flexible material. Access should be provided in the connection for periodic removal of dirt and any accumulated dust, etc.

10.6 Piping connections to be done with flexible bellows at the inlet and outlet connections of the AHU.

10.7 After Installation. Inspection can be done as per the checklist and signed off. The sample checklist is given in *Table 9.1*.

Fan coil units are smaller capacity version of air handling units, mostly installed above ceiling. These are commonly used for small cabins, guest rooms of hotels and hospitals, etc. Commonly

Table 9.1: Checklist for AHU installation

Project		Inspeclion Report No:	
GO No		Date	
Check List for installtion of AHU		Location	
Sr.No	**Check List**	**Verification**	
		Yes	**No**
1	Ensure Drawing used for installation are current & approved for construction (Drg Ref. ....)		
2	Mock Up Approval wide Doc.		
3	Supporting Materail as per approved submittal ref		
4	For floor mounted Al-Ills check foundation provided or not		
5	Inspect & ensure equipment and other associated material used Is in new and unclamaged		
6	Report any transit damage		
7	Check the panels of AHU are not damaged and Joints a r sealed with sealants		
8	Ensure adequate space is available around AHU for installation & maintanance of equipment as per manufacturers recommendations.		
9	Check all dimension including height		
10	Check all nuts. bolts, screws etc. are tightened		
11	Check for the provision of drain connection, seal and slope of drain pan for free flow of conclensta.a drain water		
12	Verify that flexible connectors are provided for final duct connections on fan mouth of AHU		
13	No cable tray shall be laid on floor around AHU		
14	Check rubber pads are kept below the AHU		
15	Check the valve package is installed as per the approved drawing and spcae for pipe connection is adequate		
16	Check and ensure the Ai-IU interiors are cleaned arid free from dust & foreign material		
17	Check the cooling coil is clean 8, free from debris. Combing to be done on the coil if required		
18	Check that location a. proviso n for inserting a changing of control sensors are as per approved control schematics		
19	Check that spring isolators under fan motor are provided		
20	Check and ensure Installation of AHU is done as per specification & requimients		
21	Check that IdentificatIon labels / tags are provided as per requirrnent.		
Cmments:		Attach separate Sheet if required	
Checked By		Approved By	
Signature		Signature	
Name		Name	
Date		Date	
Checks 1)* Wite relevant ref no 2) Checks not al p licable mark NA			

used fan coil units are with draw type blower. Since majority of installation is above the false ceiling, the care needs to be taken for proper installation of the same. Some of the correct installation actions are given below:

- Proper selection and layout for location is very important for fan coil unit.
- The space for installation of fan coil units needs to be checked before installation.
- While ordering the units the left and right piping connection details to be provided to manufacturer.
- The unit to be installed with full threaded rods, structure with proper vibration isolators.
- The correct access door for maintenance of the unit, its electrical and piping connections to be provided.
- Piping connection to done properly. Refer Chapter 12 for Piping.
- It is recommended to go for factory fitted valve package (include ball valve with and without strainer, control valve, copper piping).
- The provision for additional drain tray is recommended to avoid slippage of water.
- The drain piping to be laid properly with U trap and slope.
- The correct wiring connection for power and thermostat/ BMS control to be made. The wiring to be laid in conduits.
- The integration of control valve and thermostat needs to be checked prior to installation.
- The lighting arrangement to be made near the unit for ease of maintenance.
- It is recommended to have commissioning filters during the startup of the unit.
- The area around the unit after the installation needs to be cleaned effectively.
- Fesh air duct provision to be made right up to the supply air grills of the unit.

11.0 Commissioning of AHU

11.1 For complete guidelines for Commissioning of AHU, please refer to ISHRAE Standard 10003-2020 – Commissioning Process Standard for HVAC Systems. The Standard includes, as Normative Annexures, Delivery, Installation, Start

Table 9.2: AHU operation checklist

System Parameter	Unit	Designed	Measured	Difference
Supply air flow rate				
Pressure generation of fan with maximum air flow rate				
Pressure difference across all filters				
Pressure difference across cooling coil				
Pressure difference across Energy Recovery Wheel				
Pressure difference across volume control dampers				
Supply air flow rate with all VAV dampers in min position (each VAV damper measurement separately)				
VFD / fan motor frequency with maximum air flow rate				
VFD frequency with minimum air flow rate				
Fan RPM with maximum air flow rate				
Fan motor RPM with maximum air flow rate				
Fan motor voltage with maximum air flow rate				
Fan motor current with maximum air flow rate				
Center-to-center distance of the motor base travel				
Supply air volume control damper (VCD) position				
Fresh air flow rate				
Fresh air VCD damper position				
Return air flow rate				
Return air VCD damper position				
Supply air temperature				
Inlet water temperature of cooling coil				
Return water temperature of cooling coil				
Water flow rate of cooling coil				
Noise level @ Distance…..				

up and Operation Checklist for AHUs and also for Air Distribution System. These should be carefully followed.

11.2 Before taking up start up, it should be ensured that the AHU is adequately supported and vibration isolators and flexible connections as specified have been provided.

11.3 In case back draft dampers are specified, their correct installation needs to be verified.

11.4 All dampers and sensors should be accessible. Testing locations should be available.

11.5 Ducting as well as the area from where fan will suck the air should be clean and free of dust.

11.6 The piping connections are done with flushing loop. The flushing is carried out before charging the water to the AHUs.

11.7 Electrical isolation should be available close to the fan and should be easily accessible. Adequacy of earthing must be checked. At start up all the dampers should be in fully open position. Control sequence and BMS Connectivity (if provided) should be verified.

11.8 All the provisions for sensors and gauges are available. The required gauges and sensors are installed and calibrated.

11.9 The units are free of dust. The coils fins are combed and free from dust. The required gaps are blanked off around the coil.

11.10 Once all pre commissioning checks are completed, performance parameters to be recorded as per *Table 9.2.*

12.0 Integration with Building Management System

12.1 BMS helps to monitor and improve energy performance of the building and can highlight any problems that may come up so that corrective action can be taken and downtime and expensive repairs can be avoided.

12.2 AHU consume a significant part of energy in an HVAC system and directly affect performance of the entire system. Therefore, their central monitoring and control becomes important.

12.3 As a first step, BMS allows monitoring of the system without changing any control Parameters. AHU run status, air flow, power consumption, water and air temperatures, etc. as well as any abnormalities can be noticed by the system.

12.4 Going forward, it is also possible to control the system parameters.

12.5 It is also necessary to integrate the AHU with Fire Alarm System to stop the unit in case of fire.

12.6 For BMS and control details, please refer to Chapter 18.

Chapter 10

Installation of Ducting and Air Distribution Systems

1.0 General

1.1 In an air conditioning or ventilation system ducts are used to transfer air from one point to another as per air distribution requirements. Proper selection of ducting, its material, leak tightness, adequate supporting and proper installation are important requirements.

1.2 Ducts in HVAC Systems are made of:

Sheet metal: galvanized iron, stainless steel or aluminum.

Pre-insulated aluminum backed.

Pre-insulated nonmetallic.

Flexible ducting.

Fabric ducting.

Designer shall specify the material of ducts, appropriate standard to be followed, maximum permitted velocity of air in the duct and the required pressure class. Sheet metal ducting is generally made of galvanized iron while aluminum and stainless steel are used for special applications. In some cases, building materials such as brick or concrete are used for construction of air passages, in which case the interior shall be made fire resistant, smooth, straight and not susceptible to erosion.

1.3 Ducts can be rectangular, oval or round in shape. While round or elliptical ducting is the most efficient in terms of material use as well as pressure drop considerations, the space available to install the ducts dictates the use of rectangular or oval ducts. Due to aerodynamic considerations, it is recommended that the aspect ratio (height to width ratio) shall be kept within 1:3.

1.4 *Figure10.1* can give clarity on types of ducting.

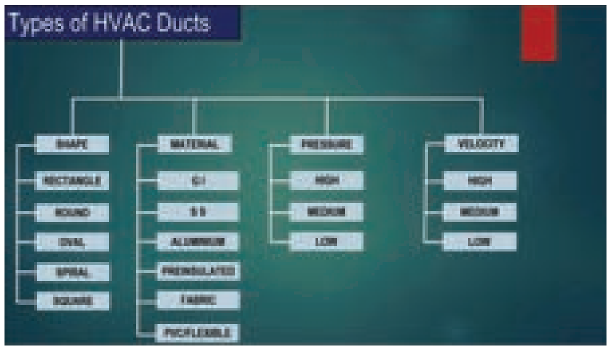


Figure 10.1: Types of ducting

2.0 Packing, Dispatch, Receiving at Site, Lifting and Storage

2.1 Depending on the material of constructions, the packing of the ducting is decided. Metal ducting is delivered in prefabricated pieces of 1.20 m from factory. It is important to avoid any external damages to the ducts. Careful packing and handling are required for non-metallic ducts where the chances of damages are high.

2.2 Some of the suit-to-site pieces of ducting are fabricated at site. Hence, the sheets are delivered at site from which the pieces are manually fabricated. Thickness and zinc coating are some of the important criteria to be checked after the receipt of the material at site.

2.3 Once the ducting is received at site, it is important to store at designated area at site. The area should be clean and clear to keep the ducts. The ducts are then shifted to the area of installation based on clearances.

3.0 Installation of Ducting

3.1 Installation methods of ducting depend on type of the ducting. Fabrication specification, applicable standards and supporting details must be understood and must be made available with relevant stakeholders before installation is taken up. ISHRAE Ducting Standard may please be referred to for details of duct fabrication. Normative Appendix A to the Standard gives details of duct design, and Normative Appendix B to the Standard gives details of duct accessories and construction practices.

3.2 Following are the steps and actions involved in ducting installation:

3.2.1 Fabrication of the duct to the required sizes (this can be done at site or at factory). The ducts are fabricated in shapes as per requirement.

3.2.2 Assembly of the ducts with necessary flanges, stiffeners and accessories.

3.2.3 Marking of the duct supports as per the drawing.

3.2.4 Hanging of the ducts with supports.

3.2.5 It is very important to have grid work so that the collars can be terminated effectively. No branches or collars are to be terminated without grid work.

3.2.6 It is very important to see that droppers / branches are terminated right up to the edge of ceiling thus avoiding air leakages.

3.2.7 Installation of vanes in elbows is important.

3.2.8 Check the ducting for possibilities of gaps in joints that may cause leakages. Sealants must be used to seal these joints.

3.2.9 Where duct penetrates brickwork or masonry openings, wooden framework shall be provided within the opening and crossing ducts shall be provided with heavy flanged collars on either side of the wooden frame so that duct crossing is made leakproof. Alternatively, the duct section passing through the structure may be suitably wrapped so that vibration is not transmitted to the structure. Where duct passes through a fire compartment partition, the annular space around the duct shall be sealed with a fire sealant to prevent fire/smoke transmission.

3.2.10 Provision for commissioning, testing and balancing to be made in the ducting as per commissioning requirement.

3.2.11 The open ends of the ducting to be protected after installation to avoid entry of dust and other materials inside.

3.2.12 The ducting needs to be identified with proper identification labels. Please refer to *Figure 10.2* for identification of ducts.

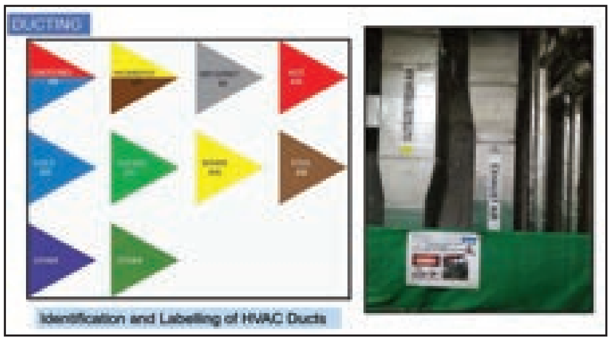


Figure 10.2: Suggested duct labelling

3.2.13 Manufacturer's guidelines to be followed for pre insulated and fabric ducting.

3.2.14 Neoprene or other vibration isolation material of minimum 6 mm thickness shall be inserted between the ducts and the angle iron supports/brackets. Vertical ductwork shall be supported at each floor by suitable structural steel members.

3.2.15 Safey aspects with respect to shifting of ducts – injury due to sharp edges, working at heights and inside the shafts needs to be take care during installation of ducting.

3.2.16 Use of automated tools to be promoted to get better quality of work with greater speed and safety.

3.2.17 When fans feed into a duct system, uniform straight flow conditions shall be ensured. Fan manufacturer's recommendation in regard to straight length of connecting duct both at inlet and outlet of the fan to obtain optimum fan performance shall be followed. Pressure loss in a duct elbow or a volume control damper is minimum when air approaching the elbow/damper has a uniform velocity profile and positioning the elbow/damper after an adequate straight piece of duct is recommended.

3.2.18 Duct supports shall be designed to handle the load without bulging or buckling. Where seismic considerations are specified, they shall be followed. Support material shall be galvanized/coated steel or aluminum angle sections, threaded rods and wire supports using stud anchors provided in ceiling slab or by threaded fasteners. Care shall be taken to ensure that the slab or structural members are not damaged. Where false ceiling is provided, supports for ducting and false ceiling shall be independent.

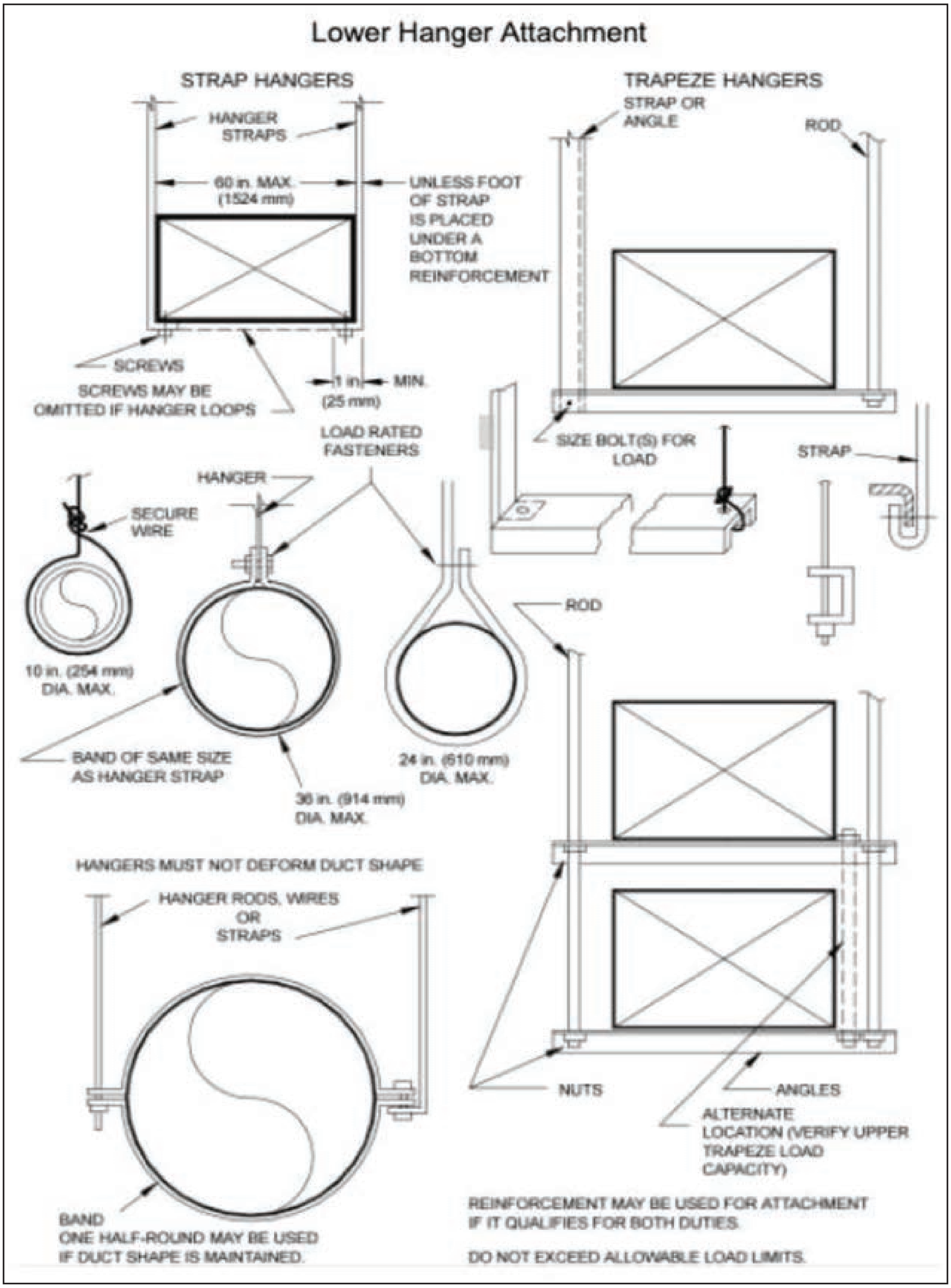


Figure 10.3: Typical duct supports

4.0 Duct System Components

4.1 Turning Vanes

They shall be provided at supply air outlet collars and at branch take-offs. Similarly, all elbows shall have adequate number of turning/guide vanes to ensure uniform air flow over the entire cross-section. Blades of the vanes shall be minimum 1 mm GI sheet. They shall be equally spaced on the runner side and the runner shall be rivetted to the duct.

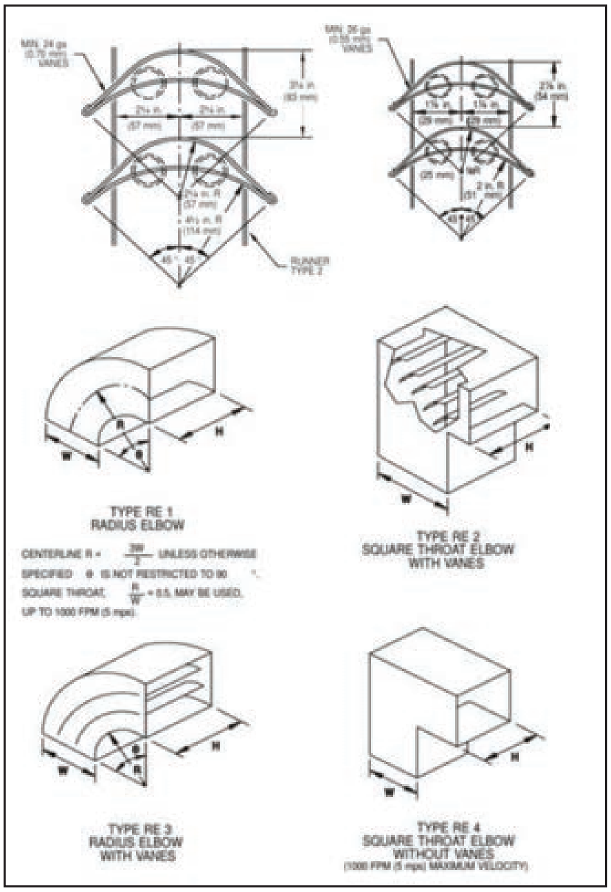


Figure 10.4: Elbows and turning vanes

4.2.1 Take Offs

They allow air from main duct to be diverted to branch ducts; take offs are fitted into circular or rectangular openings cut into the wall of the main duct, and small metal tabs cut at the start of the take-off are bent to connect the take off to main duct. Alternatively, a snap-in attachment with an adhesive foam gasket can be used. Outlet of the take-off connects to branch duct.

4.2.2 Dampers

Dampers in a duct system allow control of airflow to different sections and are necessary to balance air flows in the system. Dampers shall

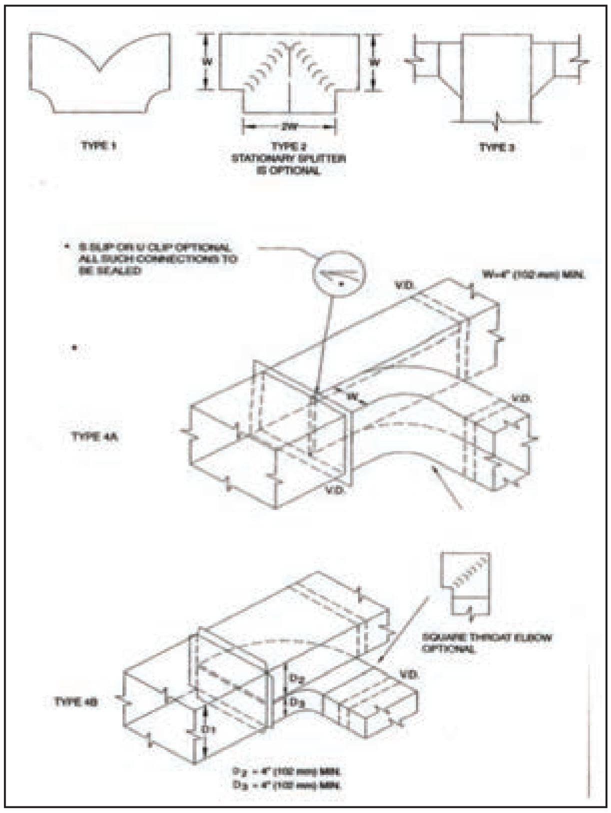


Figure 10.5: Branches and take offs

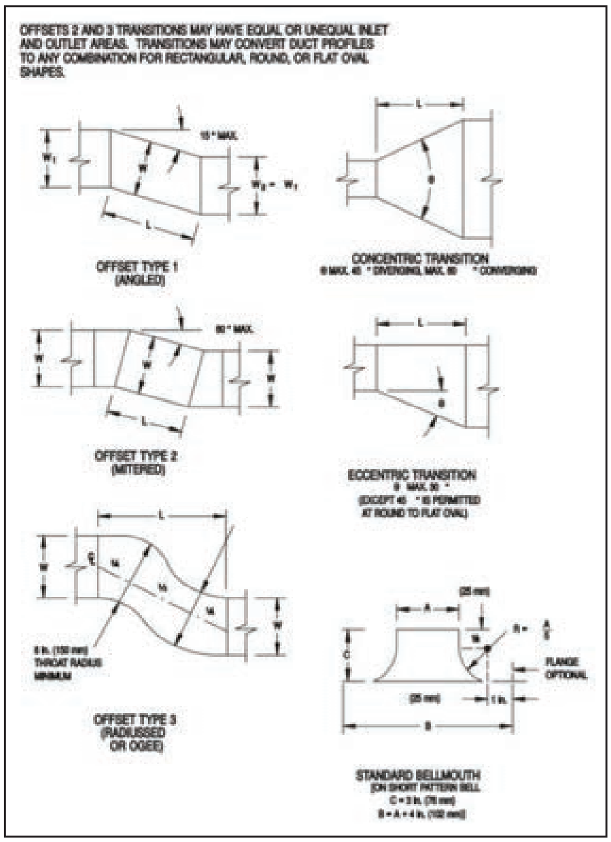


Figure 10.6: Offsets

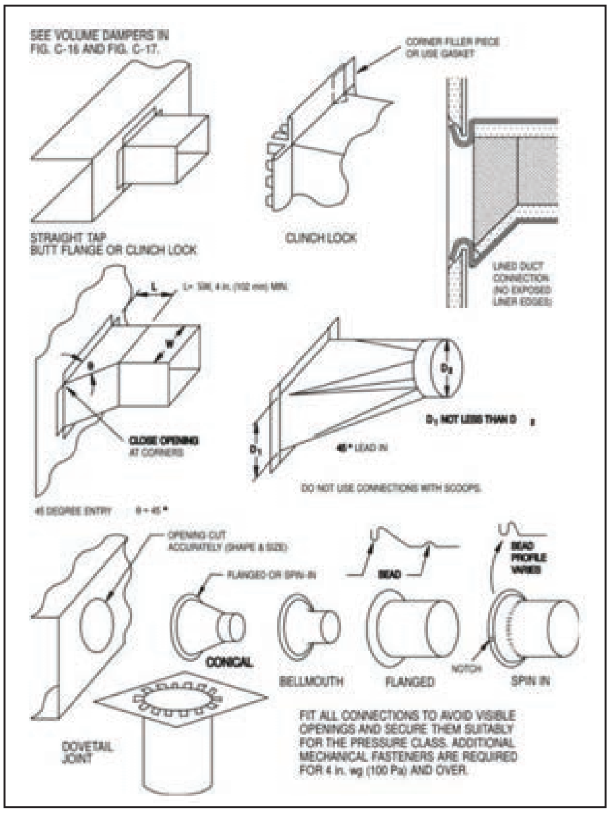


Figure 10.7: Branch connections

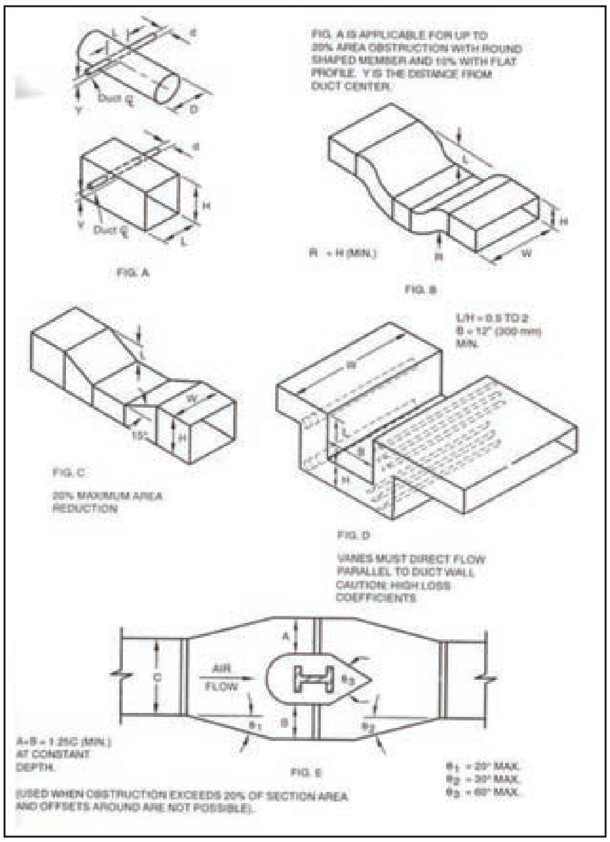


Figure 10.8: Obstructions

be manually controlled or automatic. Dampers shall be rated for operation against 1.5 times the rated pressure class of ducting. Links, levers and quadrants shall be provided for proper operation, control and setting of the dampers. Linkages shall be blade to blade and concealed in a jamb out of the airstream. Every damper shall have an indicating device showing the damper position and a locking device. Where dampers are operated via an external gear train, these are to be constructed out of engineering polymers with self-lubricating properties, and, located out of the air stream. Leak resistant access doors next to the dampers will not only facilitate attending to the dampers but also duct cleaning. Dampers shall be manual or motorized as specified and actuators shall be rated for operation against static pressure of 650 Pa unless specified otherwise.

4.3.1 Splitter Dampers

In branches where split takes place, splitter dampers shall be provided. These dampers are hinged at their downstream edge. Device for operating the damper shall project outside the duct and insulation (if provided). It shall be possible to lock the damper in position. Blade thickness shall be minimum 1.5 mm. Double thickness aero foil blades are recommended. The splitter damper assembly shall be a separate unit with flanges at both ends aligning with the main duct. Enclosure shall be made of sheet thickness one size higher than the upstream duct.

4.3.2 Louvre Dampers

Louvre dampers shall be provided in all branches. Any duct feeding more than four outlets shall be regarded as a branch and louver dampers provided.

Louvre dampers shall be multi-blade type with opposed blades or parallel blades of aero 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. Dampers 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.

4.3.3 Balancing and Control Dampers/ Shut off Dampers

Balancing dampers are used to modify airflow rate. Shut off dampers, allow closure of the airflow. Damper blades shall be 1.5 mm galvanized steel 3V type with three longitudinal grooves for reinforcement. Blades shall be completely symmetrical relative to their axle pivot point, presenting identical resistance to airflow and operation in either direction through the damper. Blade seals shall be TPE. Linkage shall be blade-to-blade concealed in jamb (out of the airstream), to protect linkage and reduce pressure drop and noise.

Single blade dampers shall consist of a single pivoted blade adjustable through 90º by means of a quadrant. Spindle of the quadrant may be extended to connect to a power actuator. Single skin blades may be used for a maximum duct width of 300 mm and double skin single blade dampers may be used for a maximum duct width of 1250 mm, in both cases the maximum duct height being 300 mm.

Multiblade dampers shall be either parallel or opposed blade and single skin or double skin. They shall consist of a number of pivoted blades contained in a casing and operable through 90º. There is no restriction on size of duct but when damper blade length exceeds 1250 mm, suitable reinforcement or support shall be provided. Damper blade width shall not exceed 200 mm.

4.3.4 Backdraft Dampers

Backdraft dampers are air pressure actuated or gravity actuated and are uni-directional. Such dampers shall be used in horizontal ducts or in vertical ducts where the flow is upwards. For downward flow in vertical ducts, calibrated spring assisted gravity louvres may be used. Backdraft dampers may also be used for pressure relief duty in which case; the louvres shall be provided with adjustable counterbalance weights or with tension adjustable springs.

4. 3.5 Fire Dampers/ Combination Fire and Smoke Dampers

Fire dampers shall be provided in all the supply air ducts and return air passages and at all floor crossings and fire compartment crossings. Access door shall be provided in the duct for each set of fire dampers.

Fire dampers shall be multi blade louver type. The blade should remain in the air stream in open position and shall allow maximum free area to reduce pressure drop and noise in the air passage. The blades and frame shall be constructed with minimum 1.6 mm thick galvanized sheet and shall be factory fitted in a sleeve made out of 1.6 mm galvanized sheet minimum 400 mm long. It shall be complete with locking device, motorized actuator and control panel. Where specified, fusible links may be used in place of motorized actuator. In respect of motorized actuator, an electric signal shall cut off air supply immediately on receipt of fire alarm signal. Where the operation is through fusible link, 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. Electric actuator shall be external mounting type with 230 V AC, 2 position or modulating. An access door shall be provided.

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.

All fire, smoke and combination fire and smoke dampers shall be suitable to be installed either in horizontal or vertical direction. Damper assemblies shall include built-in clearance frames to allow for expansion of the casing in the event of fire. Integrity of fire barrier shall be maintained either by metal-to-metal contact or by fire resistant packing.

4.4 Electrical Heaters

Electrical heaters, either tubular or strip, shall not be mounted inside ducts except in locations clearly identified and approved.

4.5 Variable Air Volume

VAV boxes shall be installed at specified locations. They may be supported from floor, wall

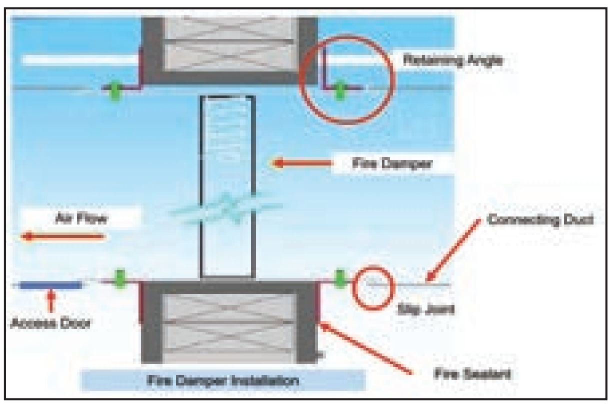


Figure 10.9: Typical fire damper installation

or ceiling as specified and may be mounted in vertical or horizontal direction. VAV shall be factory set for minimum airflow of 10% and maximum airflow of 110% of design flow. Access to the box shall be from below and shall be completely sealed but easily removable. Power point with an isolator shall be provided and stepdown transformer shall be part of the unit. Following are the important points for installation of VAVs.

a) VAV shall be mounted in a clean environment free of dust and contaminants.
b) VAV shall be kept away from high voltage as well as high vibration equipment.
c) There shall be no electromagnetic interference or flammable vapors near the unit.
d) Follow manufacturer's instructions for installing the VAV in the duct branch.
e) Power connection to the VAV shall be strictly as per manufacturer's instructions.
f) Select and install the right controller for the number of VAVs installed in the system.
g) All communication wiring shall be with shielded cables. A daisy chain configuration can be used to connect a number of controllers.

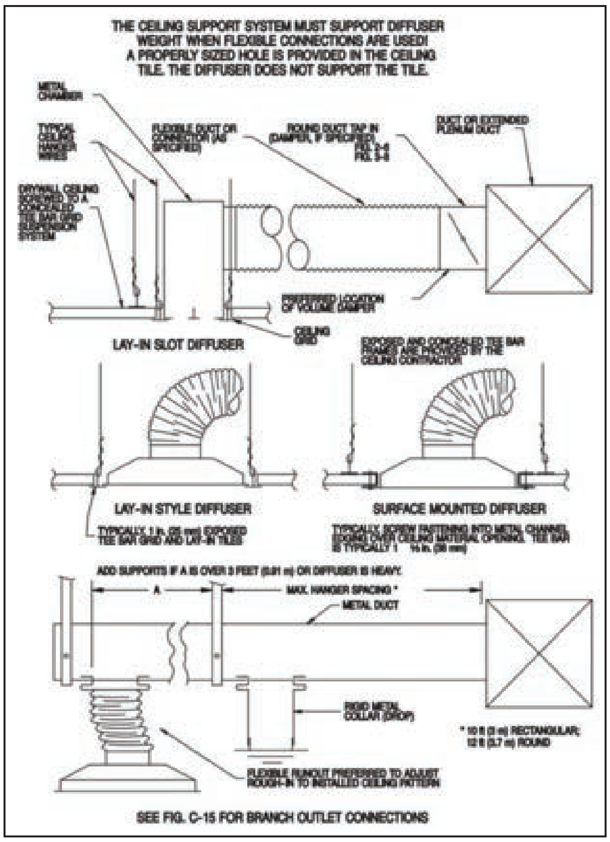


Figure 10.10: Typical diffuser tap off and diffuser connections

h) Mount the room sensor as per manufacturer's instruction.
i) Duct sensor shall be mounted upstream from the VAV unit in a straight section of the branch duct.

4.6 Grilles, Diffusers and Registers

They act as terminal units for supplying air from the duct system to the room or for collecting back air from the room either to exhaust or for return to AHU/fan. Terminal units may be fitted with air filters. Square or rectangular wall outlets shall have a flanged frame. Outer edge of the frame shall be curved to a radius of 5 to 10 mm. A flexible gasket shall be fitted between the wall and the frame. Supply air registers shall have front louvres in the horizontal direction and back louvres in the vertical direction. Horizontal front louvres shall allow a deflection of up to 25 degrees (to the vertical) and vertical louvres shall allow a deflection of up to 45 degrees (to the horizontal)

4. 6.1 Same as wall outlets, ceiling outlets shall also have a flexible gasket between the flange and the ceiling. Core assembly shall be removable. Inner as well as outer rings shall be minimum 1.1 mm thick and diffuser assembly shall be 0.8 mm thick extruded aluminum section. Circular ceiling

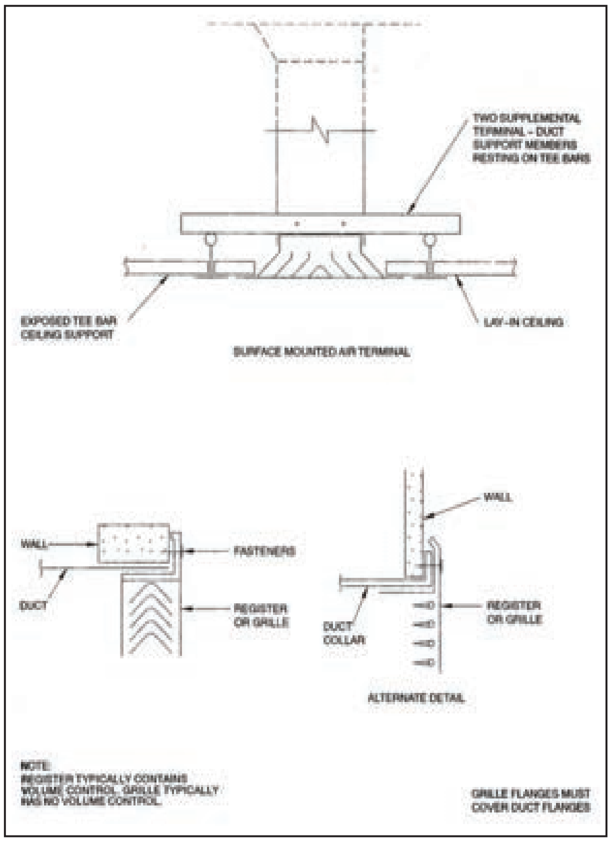


Figure 10.11: Typical grille and diffuser connections

outlets shall have the option to have an outer cone in which case the lower edge of the cone shall not be more than 5 mm below the finished ceiling. Dirt deposit on the ceiling adjacent to the outlet/inlet is a common problem and care should be taken in design to avoid this.

4.6.2 Linear diffusers shall have a flanged frame with the outer edge turned 3.5 mm and shall have 1 to 8 slots as specified in design. These shall be constructed out of 1.6 mm thick extruded aluminum sheet. All supply air outlets shall have volume control device made of extruded aluminum.

4.6.3 All air outlets and inlets shall be as reflected in drawings.

4.7 Sealing Gaskets

Gaskets are needed to seal transverse joints of ducts. Gaskets of various materials and in various forms are available. Unless otherwise specified gaskets 3 mm thick may be used. Gasket material shall be soft and pliant so that after being located, they expand in the flanging gaps to arrest leakages. However, they should not be overly soft to get compressed and leave gaps when the flange joint is tightened. Gasket material shall not be porous nor shall it be of closed cell composition. It is suggested that the joints in which gasket is inserted be either inclined or of tongue and groove type. Gaskets, while applying, shall have as few joints as possible and shall not be stretched while applying. Since some amount of shredding over time cannot be avoided, use of food grade material is recommended.

4.8 Constant Airflow Regulator

Constant Airflow Regulators (CAR) automatically regulate airflows in ductwork to constant levels. Operation is completely passive and no electric or pneumatic sensors are needed. The active element of the CAR is a flexible silicone bulb which will inflate and deflate in response to the static pressure difference to maintain the airflow.

4.8.1 The CAR's sub-assembly consisting of the silicone bulb and its housing shall be mounted on a rolled galvanized steel sleeve. The total assembly shall be designed to fit inside standard rigid round ducting as well as duty fittings such as tees, etc. A seal shall be provided around the circumference to ensure a tight fit.

4.9 Access Panels and Inspection Covers

4.9.1 Access panels shall be provided adjacent to in-line equipment requiring intermittent access. Openings shall be 450x450 mm and shall provide hand or arm access only. Inspection openings shall be provided next to in-line equipment that need only visual inspection from outside. It shall be 100 mm square or round.

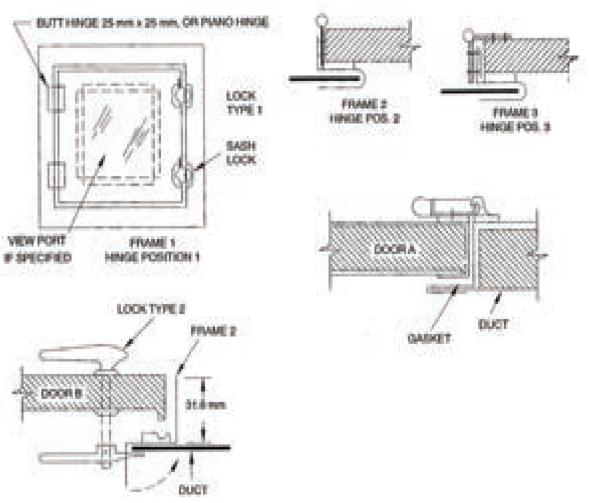
Access panels next to fire dampers shall provide access to both blades as well as actuator/ fusible link. Panels next to filters, coils, fans shall be located upstream of device.

Inspection covers shall be provided next to regulating dampers where the control linkage is mounted within the duct.

Handholes to permit proper joining of duct sections, if provided, shall be sealed and securely fastened after use.

Test holes 15 mm dia with a removable seal shall be provided at the outlet of fans and before and after cooling/ heating coils. These may be provided at site during commissioning activity. Test probes shall be of heavy-duty zinc alloy casting. Expansion plugs shall be neoprene and capable to withstand 80ºC and 300 kPa pressure.

Access doors for internal cleaning of ductwork may be provided as directed by the specialized cleaning contractor. It is a good practice to have access doors at 10 m intervals.



	Door Size (mm)	No. Hinges	No. Locks	Metal Thickness (mm)		
				Frame	Door	Back
500 Pa Static and Less	305 x 305	2	1-S	0.70	0.55	0.55
	406 x 508	2	2-S	0.85	0.70	0.55
	610 x 610	3	2-S	0.85	0.85	0.55
750 Pa Static	305 x 305	2	1-S	0.85	0.85	0.55
	406 x 508	2	1-S,1-T,1-B	1.00	1.00	0.55
	610 x 610	3	2-S,1-T,1-B	1.00	1.00	0.70
1000 Pa to 2500 Pa	305 x 305	2	1-S,1-T,1-B	1.00	1.00	0.55
	406 x 508	3	2-S,1-T,1-B	1.00	1.31	0.70
	610 x 610	3	2-S,2-T,2-B	1.31	1.31	0.70

S = Side opposite hinges, T = Top, B = Bottom

Figure 10.12: Access door arrangements

Opening in the ductwork as well as access doors shall be adequately reinforced to prevent distortion. Suitable sealing gasket shall be provided along with sufficient clamping type latches to ensure an airtight seal between the duct and access door.

4.10 Air Outlets and Inlets

4.10.1 Fixing devices 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 Rawl plugs. Where the louvers are to be fixed in steel or wood, non-ferrous screws or bolts shall be used. The fresh air intakes and exhaust outlets shall be anodized/ powder coated aluminum. Fresh air intake grills shall be made of extruded aluminum sections.

4.10.2 A flanged frame using rolled steel 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. Louvers made from extruded aluminum section shall be in modular panel form for ease of handling. These shall be free from waves and buckles. 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 no more than 750 mm centers where the louver's length is longer than 750 mm.

4.10.3 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. Unless specified otherwise, louvers shall be made of 3 mm thick 100 mm wide extruded aluminum sections fixed in an extruded aluminum frame. Louvers shall be fixed at 45o to vertical and provide 60% minimum net opening.

4.10.4 The entire assembly shall be fitted into the clear opening in the wall and the edges sealed with a polysulphide or silicone sealant. All frames and clamps used shall be hot dip galvanized or extruded aluminum.

4.11 Flexible Ducts

4.11.1 Flexible duct connections shall be used to connect ducting to equipment such as fan coils and to terminal units such as grills/diffusers. Flexible ducts shall be of metal or fabric.

These ducts shall be mechanically fastened at both ends maintaining air tightness of the system.

4.11.2 Non-metallic flexible ducts may be of PVC/polyester laminate encasing a high tensile steel wire helix. They shall be securely fastened at each end by a suitable band assuring the required airtightness.

4.11.3 Flexible ducts length shall be kept to a minimum and shall be supported in such a way that excessive sagging and kinking is avoided. It is not advisable to have test holes in flexible ducts and these shall be restricted to regular metal ducts.

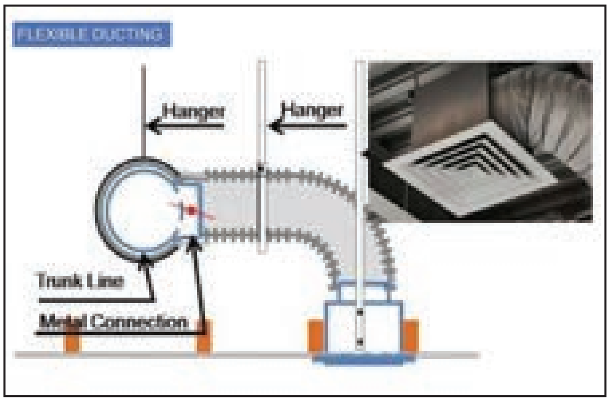


Figure 10.13: Typical collar connection with flexible duct

5.0 Kitchen Exhaust

Kitchen exhaust ducting shall be of 16 G MS CRCA sheets and shall be of welded construction. Access doors shall be provided at 3 m intervals and the duct shall have a mild slope towards the kitchen hood. Laundry and dish washer extract ducts shall be of air and watertight construction and shall be of aluminum sheets in accordance with BS 1470.

6.0 Air Leakage Duct Sealing and Leakage Testing

6.1 Duct leakage

Duct Leakage refers to the unintended escape of air from the ductwork of an air distribution system. This leakage can occur at various points such as joints, seams, and penetrations. The presence of duct leakage gives rise to two main issues:

6.1.1 Inadequate air flow: The leakage can result in certain areas at the end of the duct run receiving insufficient airflow, leading to compromised comfort levels or reduced performance of the HVAC system.

6.1.2 Increased energy consumption: Duct leakage also impacts the energy efficiency of the system. The fan, which is responsible for circulating the air, needs to compensate for the lost air due to leakage. The energy required by the fan increases exponentially with the amount of air leakage.

6.2 Leakage in Unsealed Ducts

This can vary significantly depending on factors such as the type of fabricating machinery used, assembly methods, and the quality of installation workmanship. Sealed ducts offer a range of sealing methods and products to minimize leakage.

6.3 Air Leakage within Installed Ductwork

This predominantly takes place at the longitudinal seams and cross joints. These areas, especially the corners and the points where the seams and cross joints intersect, are the primary locations where air leakage occurs.

6.4 Duct Sealing

6.4.1 There are seven pressure classes available (125,250,500,750,1000,1500 and 2500 Pa). In cases where the pressure class is not specified, 250 Pa may be assumed for normal ducting and 500 Pa for ducting upstream of VAV boxes.

6.4.2 It is important to note that certain sealants may adversely affect the function of breakaway connections to fire dampers. Therefore, it is advisable to consult the damper manufacturer for any installation restrictions or guidelines.

6.4.3 Duct sealing involves the application of approved materials or sealants at specific locations prone to air leakages. These locations typically include the supply and return plenums, starting collars where ducts connect to the plenums, fittings within the duct runs, splices along the ducts, and terminations where the ducts connect to the supply registers. Proper sealing at these points helps minimize air leakage and ensure the optimal performance of the HVAC system.

6.5 Approved Sealants

To ensure effective duct sealing, it is recommended to use sealants that meet certain criteria. The sealants should be UL 181 listed, which ensures their compliance with industry standards. They should also be water-based, non-toxic, and have water-resistant properties. It is preferable for the sealants to have a high solids content.

Approved sealants for duct sealing include flexible gaskets, fiber-reinforced mastic, and mastic used in combination with mesh tape. Duct systems that are sealed with mastics generally demonstrate lower levels of leakage.

It is important to note that certain types of tapes, such as foil tapes, cloth-backed duct tapes, or pressure-sensitive tapes, are not suitable for duct sealing purposes. These tapes may not provide the necessary durability and longevity required for effective sealing. Similarly, oil-based caulking and glazing compounds should be avoided as they are not designed for duct sealing applications and may not provide reliable and long-lasting seals.

Table A.14: Ductwork seal classes

Seal Level	Sealing Requirements
Seal Class A	All transverse joints and longitudinal seams, and duct wall penetrations. Pressure-sensitive tape shall not be used as the primary sealant.
Seal Class B	All transverse joints and longitudinal seams. Pressure-sensitive tape shall not be used as the primary sealant.
Seal Class C	All transverse joints only

- Seal Class A: This class permits 2 to 5 percent total system leakage, which includes leakage from transverse joints, longitudinal seams, and duct penetrations.
- Seal Class B: Class B allows for 3 to 10 percent total system leakage, covering leakage from transverse joints and longitudinal seams.
- Seal Class C: Class C specifies 5 to 20 percent total system leakage, which includes leakage from transverse joints.
- Unsealed: The unsealed category indicates a higher level of leakage, allowing for 10 to 40 percent total system leakage.

6.6 Leakage Testing of Ducts

6.6.1 Verification of leakage control through field testing is unnecessary when proper assembly and sealing methods are employed. Conducting leakage tests adds extra expenses to the installation process. It is generally not cost-effective to test duct systems constructed to a 750 Pa class or lower. For duct systems constructed to a 1000 Pa class or higher, the designer should evaluate the need for testing and clearly specify the portions of the system to be tested and the appropriate test methods.

6.6.2 Discrepancies of approximately ten percent between fan delivery and airflow measurements at terminals do not necessarily indicate poor sealing or excessive leakage. Potential inaccuracies in flow measurements should be considered, as open access doors, incomplete connections, missing end caps, or other oversights can contribute to such discrepancies. When air terminals are located far from fans (over 150 m), more effective sealing may be required to prevent compromised system performance.

6.6.3 Contractors should carefully choose construction details that align with sealing requirements, air pressure direction, and adequate sealing methods. The cost of rectifying systems that have not been properly sealed can far exceed the modest expense of applying proper sealing. Contractors utilizing slip and drive connection systems shall ensure control over connector length and notch depth on rectangular duct ends to facilitate effective sealing.

6.6.4 Duct system leakage test, if specified, shall be carried out as per SMACNA System Air Leakage Test Standard – 2020.

7.0 Pre-Commissioning Checks

Following are the pre-commissioning checks for ducting.

7.1 There are no sharp edges inside the duct-work

7.2 All joints are sealed

7.3 All flanges are properly made and gasket has been used in joints to ensure air tight installation

7.4 Duct is sufficiently supported (type, distance, etc.)

7.5 There are no dents or other damages in ducts

7.6 Confirm duct-work runs are correctly located and have adequate clearance from other services

7.7 Duct-work leakage test (as specified in design documents) was completed before insulation

7.8 All volume control dampers (VCD), VAV dampers and static pressure dampers are correctly installed (location, safety distance, direction, access to actuator)

7.9 Fire dampers, smoke dampers, and access doors are installed as designed

7.10 Fire insulation/sealant around duct is sufficient and fire/smoke tight as per fire rating, where specified

7.11 All dampers, motors and sensors are reachable

7.12 As-built drawings have been submitted

8.0 Start-up Procedure

Following are important points of start up for ducting.

8.1 Ensure that all pre-commissioning checks has been made

8.2 Leakage testing of duct-work was carried out before insulation

8.3 The duct-work leakage test reports are available

8.4 Ensure that all ducts are clean inside, if not, carry out the duct-work cleaning

8.5 Ensure that all VCD and VAV dampers are in fully open position before starting the duct-work balancing

8.6 Adjust air diffusion in the space if it generates too high velocity in the occupied zone

8.7 Measure all air flow rates and calculate the ratios between measured and designed air flow rates in each diffuser/grille and VCD damper

8.8 Carry out the proportional balancing of each diffuser/grille damper, sub- and main- branch VCD dampers and in the end reduce the fan speed to achieve the designed air flow rate

8.9 Measure all air flow rates (each diffuser / grille, VCD dampers) and record them as a final balancing document together with the records of each damper position

8.10 Ensure that there is not too much noise generated by the ventilation system

8.11 Measure the air flow rate of each VAV damper with maximum and minimum position after balancing work is done.

9.0 Air System Balancing

9.1 Air distribution system shall be balanced so that air quantity measured at the fan discharge and the total of the air quantities at various outlets shall be within +/-5% of the design airflow. Branch duct adjustments shall be permanently marked after the balancing is complete. Throttling losses in the system shall be minimum. Tests shall be carried out for each fan and AHU. All dampers after adjustment shall be set and locked in position. All air and static pressure measurements shall be done with probe type meters. After balancing the fan speed shall be suitably adjusted.

9.2 For complete procedure of commissioning the ducting system, please refer to ISHRAE Standard 10003-2020 for Commissioning Process of HVAC Systems.

Chapter 11

Filters and Other Air Cleaning Devices

1.0 General

Filters for general use have the filtering media made of synthetic material in the form of a mesh stitched and formed into deep folds and housed in mild steel or aluminum frame. Such filters are used in comfort air conditioning as well as pre filters for clean rooms. They can arrest particles of 10 to 20 microns with about 90% efficiency. They offer pressure drop ranging from 6 mm to 15 mm depending on 'clean' to 'congested' status.

Fine filters have the capacity to filter down to 5 microns have microlayers of fiberglass and have efficiency up to 99.9% and pressure drop ranges from 6 to 15 mm depending on cleanliness level.

Absolute filters or High Efficiency Particulate Air (HEPA) filters are used where dust has to be arrested down to 0.3 microns up to 99.97 % efficiency and the filtering media is a sheet of extremely fine fiberglass interwoven in different directions and mixed with resins. Media is accordion pleated for increasing surface area. Corrugated spacers are inserted in each fold. Direction of channels of the spacers ensure a parallel pattern of airflow and ensures uniform velocity of air at filter exit. These filters offer pressure drop ranging from 25 mm to 50 mm and when the pressure drop reaches 50 mm, these filters need to be replaced. HEPA filters shall not be cleaned and reused. Life of HEPA filters depend on amount of particulate matter filtered through them as well as the degree of pre-filtering employed. Pre-filters (both coarse and fine) shall be maintained well to extend life of HEPA filters.

1.1 Please refer to ISHRAE Publication on Air Filters for HVAC for more information on filters.

Figure 11.1: Pre filter, fine filter and HEPA filter

2.0 Filters

Filters play a major role in maintaining Indoor Air Quality (IAQ) and unless correctly installed and maintained, will not serve the intended purpose.

2.1. Before commencing installation of air filters in a HVAC site, the design layout drawings shall be reviewed and filter locations such as fresh air intakes, rooftop fresh air or ventilation units, floor-mounted recirculation AHUs, ceiling suspended AHU, etc. shall be reviewed and properly understood by the installation crew.

2.2 Filters are generally available in standard dimensions and thickness, to facilitate maintenance and replacement. Some of the common dimensions are

610 x 610 x 25/50 mm	595 x 595 x 25/50 mm
595 x 295 x 25/50 mm	495 x 495 x 25/50 mm
295 x 295 x 25/50 mm	610 x 610 x 150/300 mm HEPA
610 x 610 x 200/400/600/800 mm pocket filters	

2.3. As per the site drawings and OEM recommendation, allocate correct size filters for each equipment.

2.4. Filters are generally designed for 2.5 meters per second face velocity. Though the filters will have some additional safety factor considered in design, they will get damaged at higher face velocity. Hence face velocity of air across filters shall be guided by manufacturer's recommendation.

2.5. The face area of filters shall be perpendicular to the air flow and there shall be sufficient distance for air flow to stabilize before they enter into the filer sections uniformly. Avoid eddy currents and dead-air space on filters. Air shall be uniformly distributed over filter section using baffles, louvers etc.

2.6. Filter Frames need to be air-tight, regardless of material of construction like aluminum, GI or cardboard. Pay attention to their rigidity, caulking and sealing.

2.7. Filters shall be suitable for the duty they are intended for – like type of dust, amount of dust, required cleanliness, allowable pressure drop, temperature, etc. and be made of right media like HDPE, synthetic fiber, polypropylene, synthetic welded media, etc.

2.8. Keep service space on the front side as well as back side of filters with necessary access doors. This allows convenient access to filters.

2.9. Filters installed near outdoor air intake shall be protected with suitable overhead hoods, so that rain water shall not drip over filters. In case of rainy environments, use a moisture separator upstream of filters with suitable 'water drain tracks'.

2.10. In any dusty environment (such as roof top AHUs), consider pre-filters before fine filters.

2.11. Filters shall have permanent pressure gauges installed like nanometers or McLeod gauges or electronic type (piezo measurement) pressure sensors, which can be integrated to BMS alarm systems. They allow timely detection of filter clogging to allow cleaning or replacement.

2.12. On receipt, inspect air filters for any signs of damage, debris and the filter frame for tight sealing and gaskets. This is very important since are shipment damage to the filter frame or filter media can render the filters useless for the application.

2.13 It is a normal practice to keep the filters in their original packing till the units are ready for a test-run. After installing filter systems, they shall be tested to ensure there are no leaks around filters.

2.14 As per the norms laid out in the project document, run the system for stated no of hours. Then replace the used-filters with a fresh set of filters.

2.15. Once air filters are installed, a comprehensive maintenance schedule shall be planned and established.

2.16 HEPA filters may require to be tested for proper installation, using certain prescribed test procedures, involving certified professionals. These shall be followed as specified.

2.17 If ceiling suspended units (CSUs) are mounted above false ceiling, ensure that adequate lighting is provided above the false ceiling for service purposes. The entire false ceiling needs to be cleaned up, before doing the first run test of units, to avoid unnecessary filter choke.

2.18 If filter media is combustible, install a fire-extinguisher handy nearby. For hazardous material, consider Box-in Box-out (BI/BO) filter housing for convenient disposal of used filter.

2.19 Air filters collect bio-aerosols and if the air entering filters have moisture content, it becomes a breeding ground for microorganisms and becomes a health hazard. Change and clean filters regularly. Use face mask, hand gloves and safety goggles while handling filters.

3.0 Filters in Healthcare Applications

3.1 Use filters with PAO / DPP certifications to ensure integrity after the installation.

3.2 Where specified use filters with moisture resistance and chemical stability.

3.3 For critical area such as operation theatres and ICU, replace the filters every 6-12 months, as per OEM recommendations.

4.0 Modifications and Changes to Existing Filter Installations

If at all any modification or change of filtration system is required, the checklist shall include (1) AHU OEM recommendations, (2) size, (3) media construction and area, (4) air flow rate, (5) initial and final pressure drops, (6) filter frame, (7) filter hardware, (8) fastening devices, (9) gaskets and (10) caulking.

4.1 Service technicians shall be familiar with safety precautions and lock-out procedures to be followed at site.

5.0 Electrostatic Filters

5.1 Air stream to be filtered passes through an electrostatic field strong enough to charge the particles in the air stream. When this air is passed between two parallel plates, which are charged positive and negative (grounded), the positively charged particles in the air stream get attracted to the negative charged plate and are held on to this plate. Particles in the air stream which are not charged, get attracted to the positive plate. Once the charged particles come in contact with the negative plate, they lose the charge and can fall off. Electrostatic charge of the plates is created by stepping up the line voltage through a power pack to a very high order of DC static voltage (12 to 13 kV).

5.2 The ESP filters are located upstream of AHU cooling coils. These are effective in controlling $PM^2.5$ outdoor air pollutants from entering space. ESP filters, if used in new installations, will take place of conventional air filters and do not require any filters upstream or down stream of it. ESP filters if used in retrofit projects will replace existing filters.

5.3. The ESP filters carry high voltage DC and shall have safety certifications both for human electrical shock and ozone generation safety.

5.4. They are generally available in 610 mm (H) x 305 mm (W) or 610 mm (H) x 610 mm (W) configurations as individual grid elements. Before installation, a mounting grid plan shall be prepared, deciding how to place the total no of ESP filters in front of the cooling coil – by either modifying existing filter bracket or by replacing it with a new frame structure.

5.5 ESP individual grids are to be inserted – similar to the way we insert or slide the standard 610 x 610 filter brackets. Each grid has its power supply cable. Connect them to power source, using correct size cable as per electrical wiring diagram provided.

5.5 In running condition, the ESP filter bank needs to remain energized (power ON) for it to ionize and clean the air stream. Voltage to the plates need to be checked periodically since inadequately charged plates will not function properly. Great care has to be exercised while installing or servicing ESPs. Power supply must be switched off before attending to the ESPs and earth connection shall be checked periodically.

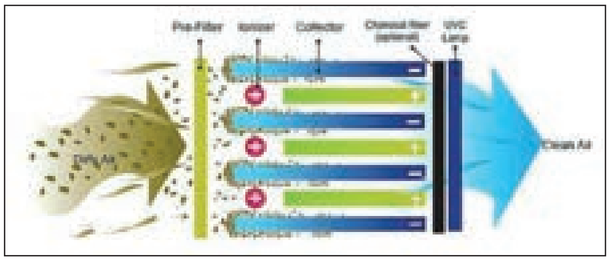


Figure 11.2: Electrostatic filter

5.6 It is a good practice to use IAQ sensors to monitor the air stream parameters. ESP filters upstream and 254 nm UVGI downstream of the cooling coil (which have ozone absorbing characteristics), is an energy efficient combination for good IAQ.

5.7 Ionization of air stream may lead to ozone generation. ESP manufacturers have to adopt appropriate designs to keep the ozone generation level to a safe limit for humans. The products have to be tested and certified under UL 867 for safe ozone emission levels.

5.8 The ESP filters are to be installed with safety interlocks to avoid electrical shocks and to stop the power module in case of less air flow.

6.0 UVGI Installation

6.1 The best location for UVGI lamps is downstream of the cooling coil, i.e. the space between the cooling coil and the fan inlet, inside of the AHU.

6.2 While installing UVGI lamps, please study the engineering drawings fully well and prepare an installation plan. Make a plan of which AHU has to be fitted with which model UVGI lamps, how many in numbers and in what configuration.

6.3 It is not necessary that all lamps are mounted horizontally. Depending on design calculations few lamps may be in vertical positions as well.

6.4 It is recommended to use UVGI lamps of 360º design intended for both surface disinfection and air-stream disinfection. They do not come with a reflector, which are used only for surface disinfection.

6.5 Mounting frames are usually provided by lamp manufacturers with suitable clamps or holders for the lamps. Else these frames have to be fabricated at site.

6.6 The distance of lamps' frames from the cooling coil is a critical design element, as this determines the UVGI energy flux impinged on the coil surface area. Mark out this distance inside the AHU appropriately.

6.7 Other than the lamps and mounting frames, the third element of UVGI system is the 'power assembly' or the 'ballast' to power up the lamps.

6.8 Few manufacturers accommodate the power assembly in the mounting frame itself. These are fully enclosed. In case the power assembly is not installed in the mounting frame, the power assembly along with any other electrical components like MCB, a time clock for 'total use count', etc. shall be mounted just outside the AHU panel.

6.9 Follow the UVGI lamp manufacture's recommendations strictly.

6.10 UVGI lamps shall be installed on the frames only in the last minute before trial runs.

- This helps to avoid unnecessary damage to lamps when the other AHU parts' installation or verifications are still in progress.

6.11 Unless specifically notified, the maintenance and operating team may not know that the AHUs are fitted with UVGI lamps. Accessing and coming across UVGI unknowingly and in an unprepared manner is a 'safety risk'. This calls for notifying everyone that UVGI lamps have been installed in the AHUs.

> UVGI stickers have to be positively fixed at 'noticeable places' on AHU.

> AHU 'asset record' should be updated with UVGI information:

- Make, model, type (standard / high output, etc.), length, quantity used, design intensity at End-of-Life, etc.

6.12 Dust on UVGI could be wiped with a soft cloth (wetted in alcohol) – without touching with fingers. Finger prints will affect the irradiation intensity. Adjust dust wiping frequency, with periodical observation.

6.13 UVGI rays cannot penetrate sheet metals and UVGI radiation leakage into the AHU room from the lamps installed inside the AHU is just not possible.

6.14 While installing UVGI in supply air ducts and while installing upper zone irradiation UVGI in clinics and public places, after installation of units, a compulsory measurement of UV-C intensity using appropriate Radiometer is a MUST. The measured intensity shall not be more than 0.2 μw/cm^2.

6.15 For more information on UVGI and other non-filter air cleaning devices, kindly refer to ISHRAE Position Paper on the subject.

Figure 11.3: Duct mounted UVGI

Figure 11.4: UVGI in AHU

Chapter 12

Installation of Piping and Accessories

1. General

The piping work shall be carried out in accordance with the specifications and good engineering practice by qualified and experienced personnel. The work procedure shall be documented and records prepared and updated for proper execution in accordance. Since the piping work is carried out at site, the equipment location and the pipe routing is decided and document / layout drawing prepared only after which the installation shall commence. The piping used for HVAC system should be capable of operating between the maximum and minimum service temperatures. Adequate allowances shall ensure that no excessive residual stresses remain in the piping prior to or after start-up of plant operations. Where excessive expansion is expected, adequate flexibility shall be allowed. Piping is recommended to be suitably anchored in accordance with the standard drawings. Anchoring plastic pipes by clamping with saddles or U-bolts is not right. U-bolt guides with two lock nuts are recommended to be loosely clamped to allow free movement of the pipe during expansion and contraction.

Based on the approved location of equipment and piping routing, adequate covered workshop facilities shall be made available at a convenient location close to the installation. The space for storage of piping and other materials, workshop tools, machining, testing facilities shall be clearly identified with enough movement space, electrical power supply, lighting, proper ventilation, first aid kit and water supply.

In medium and large projects where piping is taken to a number of AHUs, piping spool, blank offs, pipe bends / elbows as required shall be made available.

Electrical power connection with adequate capacity to run the welding machine, drilling and cutting machines shall be made available at the space allotted for the workshop facility.

2. Types of Piping

In HVAC&R systems the following types of piping are used:

- Condenser Water Piping
- Chilled Water/ Brine Piping
- Hot Water /Steam Piping
- Refrigerant Piping

2.1. Water Piping

2.1.1 Chilled water piping: The piping used to circulate chilled water from the chiller to various air handling units and fan coil units and back to the chiller via chilled water pumps.

2.1.2. Condenser water piping: The piping used to circulate water from the condenser to the cooling tower for heat rejection and back to the condenser making the circuit complete.

2.1.3 Drain piping: The piping used to collect the drain water from equipment such as chiller, condenser, pump, AHU, FCU, cooling tower.

2.1.4. Make up water piping: Piping used to deliver make up water to cooling tower and chiller.

2.1.5 Hot water piping: Piping used to carry the hot water from condenser and hot water generator to AHU, FCU for heating or reheat purposes.

2.1.6. Brine piping: Piping used to circulate the brine from the chiller to the process and back to the chiller.

2.1.7 Steam piping: Piping used for steam from the boiler for heating or reheat.

2.1.8 Refrigerant piping: Piping used to circulate refrigerant from compressor to condenser, expansion device and evaporator and back to compressor.

3. Piping Material

Design and selection of pipe size, thickness and material is dependent on the fluid expected to flow in it, flow velocity, pressure, structural support, etc. It is therefore necessary to carry out inspection of pipe material, thicknesses and size before installation at site.

The material used for various applications in HVAC&R applications is given below:

3.1. Mild Steel: MS pipes are used for drinking water supply, fire protection, and HVAC&R. Mild steel does not corrode as its surface is coated with paint, varnish which makes it durable and can work in very harsh conditions. In addition, mild steel pipes can withstand variation in temperature. Steel piping as per ANSI schedule 40 is generally used in HVAC application.

MS seamless pipes are also used for refrigeration system (suction, hot gas and liquid lines) of 20 mm and above sizes.

3.2. Stainless Steel: Special precautions are recommended to be taken during SS piping erection. No direct contact between stainless steel and carbon steel should be permitted. Carbon steel blinds, spades and caps shall not be used for stainless steel pipe and components. Stainless steel clamps and U-bolts are recommended to be used for supporting stainless steel piping.

3.3. Galvanized Iron: GI pipe and fittings as per DN 50 and below are recommended to be supplied with galvanized screwed ends. Pipe as per DN 80 and larger is recommended to be shop fabricated and hot dipped galvanized in accordance with AS1650.

If any modifications are required to galvanized spool DN 80 and over during installation, the spool is recommended to be modified and hot dip galvanized again. For minor modifications and repairs, the spool may be cold galvanized.

3.4. Plastic Piping: The installation and testing of plastic piping is recommended to be in accordance with the following standards:

Polyethylene (PE) pipe for pressure applications to AS2033, AS4130.

UPVC piping to AS2032.

FRP/GRP piping to AS2634.

Polyethylene pipe connections are recommended to be made using compression fittings or butt weld fittings or using mechanical joint fittings. Backing rings is recommended to be installed when plastic (PE). pipe flanges are connected to valves. PE spacers are recommended to be used when wafer type butterfly valves are used, to ensure free movement of the disc.

Note: PVC and CPVC are the two types of plastic piping commonly used. They cannot withstand as wide a range of temperatures as metal pipes. However, PPR pipes which are now available can be used with fluctuating temperatures.

3.5. Polyurethane and PTFE Lining: Flanged spools are recommended to be fabricated and lined in accordance with the relevant Codes and Supplier's recommendations. The lining shall cover the face of the flange. Rubber lining shall cover full face of flange and polyurethane lining shall extend up to the inside of bolt holes. Bends and elbows shall have flanged ends. Flanged spools are recommended to be transported to the work site and erected in accordance with the Supplier's recommendations and relevant codes.

Make up pieces are recommended to be site measured, fabricated, lined and then erected at site ensuring that no external loadings are exerted on the equipment or mating flanges.

For rubber lined flanged joints, gaskets should not be used. However, for frequently dismantled joints, 1 mm PTFE full-face gaskets is recommended to be used to prevent bonding of rubber. Bolt torque for flanged joints is recommended to be in accordance with the Supplier's recommendations.

Repairs to damaged lining are recommended to be done by cutting the affected area to the base metal and relining the affected area in accordance with the procedure employed for the original lining.

3.6. Underground Piping: Underground pipes need to have cathodic protection to prevent corrosion from dirt. The flanges used are per ANSI B16.1. Cast iron or steel is used for screwed pipe and forged steel welding necks are used for welded line sizes.

The external surfaces of underground steel pipe and fittings to be coated and wrapped, are to be clean, dry and free of any oil and grease. Wrapping material is recommended to be polyvinyl chloride pressure sensitive tape or approved equivalent 0.5 mm thick. Width is recommended to be 50 mm for pipe diameter up to 50 mm; 100 mm for pipe diameter up to 200 mm and 150 mm for pipe diameter 250 mm and larger.

Tape is recommended to be spirally wrapped on the steel pipe and fittings starting on the mill coating 80 mm from the edge using 12 mm overlap and extending 80 mm over the adjacent mill coating.

Underground pipework is recommended to be laid in trenches of suitable width and generally 300 mm deep except at vehicle traffic locations where the trench is recommended to be 600 mm deep. Pipe is recommended to be laid on a sand bed and backfilled with suitable back filling material as recommended in the project specifications.

When repairing damaged coatings, the wrapping in the defective area shall first be removed and the pipe re-wrapped in accordance with the coating and wrapping procedure.

After inspection (visual and electronic) and testing are complete, the trench is to be back filled and compacted in accordance with the project specifications.

Recommended voltage for the leak detector is recommended to be approximately 400 volts for each 100 microns thickness. Cathodic protection, if required, is recommended to be provided in accordance with AS2832.1.

3.7 Please refer to ISHRAE Databook for details of piping materials as well as other details (Section 3 for water/brine piping and Section 4 for refrigerant piping).

4. Storage and Handling

4.1. Storage: All piping components are recommended to be stored in a clean area and away from the fabrication and construction activities and handled in such a way that neither damage nor mixing of materials occurs. Hooks or chains shall not be used for lifting. Pipes shall not be rolled off transport vehicle, dropped on to the ground or dragged over the ground.

4.1.1. Valves and flanges: Valves are recommended to be stored with spindles in vertical position. Relief valves shall be stored upright in cleaned and protected area. The threaded ends are Flange facings are to be protected from damage, covers are to be securely fastened to flange facings during handling, transportation and storage at site.

Partly installed piping components and spools are to be protected at all times from ingress of moisture or foreign materials by covering and taping.

A ledger should be maintained for all the materials stored with identification number; the ledger shall be up-dated as and when material is removed from the location

4.1.2. Stainless steel: SS and other materials shall be stored on pallets and end caps are provided on all materials. Stainless steel piping and components are to be stored in separate areas away from storage areas for carbon steel and other materials to avoid direct contact between carbon steel and stainless steel

4.1.3. Copper pipe storage: Store materials in a cool, dry (well ventilated) location to prevent moisture build up on the material. The protective film must not be exposed to prolonged sunlight or overheating. Ensure that the pipe ends are provided with caps in order to ensure dust, foreign materials or moisture does not enter the pipe.

4.1.4. Lined steel piping: Storage and handling of lined steel pipes require special arrangements and is recommended to be as follows:

- Pipes and piping components are recommended to be handled in such a way that the lining and other materials are not damaged.
- Lined pipe is recommended to be stored under cover to protect it from high atmospheric temperatures (40ºC and higher).
- Provide 20 mm bolted plywood flange covers.

4.1.5. Insulated piping: For pre-insulated piping or piping with shop applied insulation every precaution is to be taken that insulated parts remain weather protected at all times during storage, handling and erection to prevent moisture from entering behind or into the insulation materials.

4.2. Handling: Partly installed piping components and spools are to be protected at all times from ingress of moisture or foreign matter, by covering and taping. Steel wire slings shall not be used for handling and transportation of stainless steel pipes. Canvas or nylon slings are preferably to be used. Special care should be taken while handling and storing of stainless materials.

4.3. Inspection and Testing: All fabrication has to be inspected in accordance with given specification. Inspection and Test Plan (ITP) shall be submitted for written approval of the owner/ project in-charge. Inspection shall include 100% visual examination and any other additional examination necessary to ensure compliance with this specification. Inspection and testing are to be carried out before any painting or coating is applied.

Non-destructive test of welds shall be carried out after any final heat treatment is completed. Tolerances specified for fabrication and for Installation work are recommended to be complied with.

4.4. Transit Damage: Any damage or missing components shall be reported to the transport authority and report prepared, signed and handed over to the agency for replacement or insurance claim.

5. Pipe Connections

5.1 Pipe Connection to Equipment: Piping to the pumps is to be installed up to a break point between the nearest pipe support and the equipment. The connecting piping is to be fabricated at site after the pump alignment is done and properly fitted and alignment rechecked. It is essential that this is done accurately in order to avoid pump alignment getting disturbed.

Piping is to be disconnected from the equipment after installation to demonstrate that no stress has been transferred from piping to equipment, and then reinstalled.

Recheck the coupling alignment during the bolting and tensioning of the pipe flanges to the equipment flanges. The bolting up and tensioning of the flanges shall not affect the coupling alignment between the driver and driven equipment.

5.2. Threaded Connection: Inside ends of threaded pipes is to be deburred by reaming. All threaded connections should be gauge-checked or chased after galvanizing. Threaded connections shall not be seal welded. Threaded joints in piping system shall be made up using PTFE pipe tape or thread seal compound installed on the male thread.

5.3. Flanged Connection: When bolting gasketed flanged connections, the gasket should be uniformly compressed to the minimum torque (Ref. *Table 1*).

Table 1: Recommended bolting torque

Recommended Bolting Torques		
Bolt Size inch	**Bolt Size mm**	**Nm**
1/2	M12	55
5/8	M16	109
3/4	M20	190
7/8	M24	300
1	M27	450
1-1/8	M30	640
1-1/4	M33	910
1-3/8	M36	1180
1-1/2	M39	1560
1-5/8	M42	1900
1-3/4	M45	2440
1-7/8	M48	2850
2	M52	3660

> Unless otherwise indicated on the drawings, the bolt holes of all flanges shall offset to vertical and horizontal center lines. The maximum angular deviation of bolt holes shall not exceed 1.5 mm measured across the bolt pitch circle.

> Flanged connections shall be tightened sequentially diagonally opposite in a clockwise or anticlockwise order so that an even gasket seating results.

> Flanged spools mating with equipment flanges shall be site fitted for correct alignments to ensure that no stress or load is placed on the equipment and the spool flange shall then be fully welded in accordance with the requisite welding procedure.

> The surface of flange gasket face shall be free from rust, weld spatter, scars, paint, dents, arc strikes, and corrosion pitting and other imperfections.

> All flange connections shall be made using fully threaded stud bolts and nuts. A minimum of one and a maximum of three complete threads shall protrude from the nut after completion of tightening.

> Insulating gaskets is recommended to be installed when shown on the piping drawings. Care is recommended to be taken not to damage the bolt sleeve and gaskets when installing insulation gaskets. > Bolts and nuts shall be protected by an anti-seize compound.

5.3.1 Slip-on flanges: Slip-on flanges are recommended to be positioned so that the end of the pipe is recessed from the flange, a distance equal to the pipe wall thickness plus 1.5 mm, or 6.4 mm, whichever is the lesser. Seal welding for slip on flange is recommended to be carefully applied in order to avoid re-facing the flange. Pipes for insertion in slip-on flanges shall be cut square, within 0. 5mm (Ref. *Figure 1*).

5.3.2 Weld neck flange: The welding neck flange consists of a tapered hub which is secured to the pipe by a full penetration butt weld. Because of the additional reinforcement area available in the hub of weld neck flange and due to its installation by welding, the hub becomes an integral part of the pipe. Since weld neck flanges are secured to pipe by butt-welding, the internal diameter of the hub end should match the internal diameter of the pipe end (Ref. *Figure 2*).

5.3.3 Socket weld flange: A socket weld flange consists of a socket in which a pipe is secured by a fillet weld at the hub on the outside. As per ASME B31.3 an approximate gap of 1.5 to 2 mm is to be present before welding, including tack welding (Ref. *Figure 3*).

Figure 1: Slip-on flange

Figure 2: Weld neck flange

Figure 3: Socket weld flange

Figure 4: Blind flange

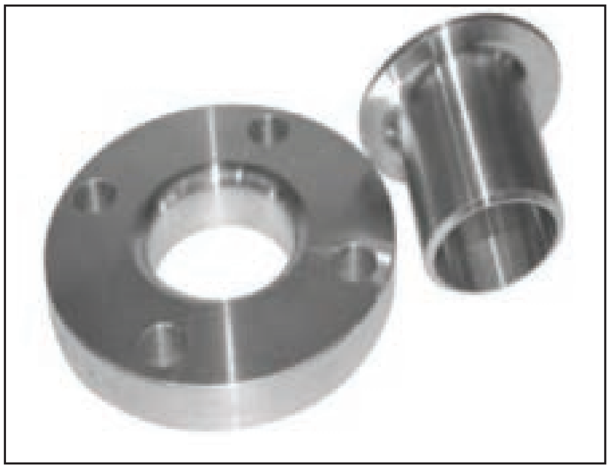


Figure 5: Lap joint flange

5.3.4 Blind flange: A blind flange is installed at the end of a piping system either on a header or branch connection or on a valve and functions as a means for positive isolation of the piping system. On drain systems blind flanges serve as important rodding points or can be dismantled for easy inspection (Ref. *Figure 4*).

5.3.5 Lap joint flange: A lap joint flange is a two-component assembly comprising of a stub end and a backing lap-joint ring flange. The stub end face acts as a raised face of the flange as its outside diameter corresponds to the dimensions of the raised face portion of a flange The cost of corrosion resistant stub end with carbon steel backing lap-joint flange is less than a complete slip-on flange in corrosion resistant material (Ref. *Figure 5*).

5.3.6. Flanged joint bolt torque: Stud bolts of diameter 20 mm and larger are recommended to be tightened by torque wrenches or other tightening methods which result in uniform tightening of the flange. Bolt torques for valves and lined piping shall be in accordance with the Supplier's recommendation.

Before flanged pipe spools are connected to pressure vessels, heat exchangers and flanged equipment, inspection is recommended to be carried out by loosening up to 10% of flanged or union joints to the equipment to ascertain that no stress is placed on equipment due to misalignment.

The surface of flange gasket face is recommended to be free from rust, weld spatter, scars, paint, dents, arc strikes, and corrosion pitting and other imperfections.

5.4. Victaulic Grooved Pipe Connection: The pipe groove is made by forming or machining an actual groove into the ends of two pipes. A gasket wraps around and on top of the pipe ends, the housings wrap around the gasket and sit in the pipe grooves, and the bolts and nuts are tightened with a wrench to hold it all together (Ref. *Figure 6a and 6b*).

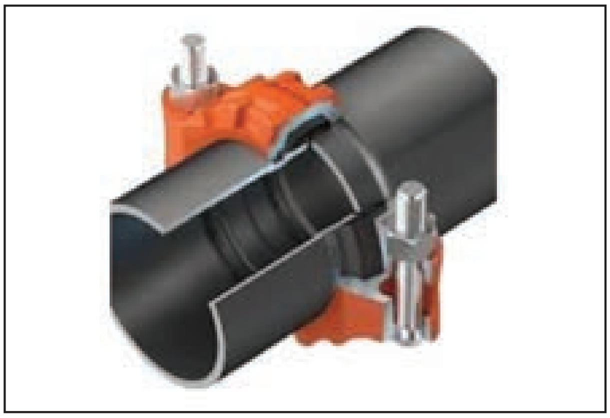


Figure 6a: Victaulic pipe connection

Figure 6b: Victaulic joint

5.5 Flare Connection: Refer Refrigerant Piping.

5.6 Branch Connections: Branch connection requirements are recommended to be in accordance with given specification. Branch reinforcement material is required to be made from the same pipe material as specified by the relevant piping class and subject to the same specification requirements. All cuts are recommended to be carefully beveled and accurately matched to form a suitable preparation for welding and to permit full penetration of welds between the branch and the run pipe at all points. All reinforcement pads for pressure openings, or each segment of built-up type reinforcement pads for pressure openings, are recommended to be provided with 6 mm NPT threaded hole for testing and venting. The vent hole is recommended to be sealed after completion of the pressure test with grease or silicon sealant to prevent ingress of moisture.

Branch connections, vent nozzles, true unions and other attachments including reinforcing pads shall not be welded over or near longitudinal or circumferential welds in the piping. The minimum distance from a longitudinal or circumferential weld to the next weld is recommended to be 50 mm measured between the heat affected zones.

For the relative sizes of main and branch pipes refer *Table 2.*

Table 2: Relative sizes of branches and mains

S. No.	Size of Main, mm	Number and Size of Branches Main Can Supply
1	12	Two x 10 mm
2	19	Two x12 mm
3	25	Two x 19 mm
4	32	Two x 25 mm OR One x 25 mm and Two x 19 mm

5	38	Two x 32 mm OR One x 32 and Two x 19mm
6	50	Two x38 mm OR One x 38 and Two x 32 mm
7	63	Two x 38mm and Two x 32 mm OR One x50mm and Two x32 mm
8	76	One x63 and One x50 mm OR Two x50 and Two x 38 mm
9	90	Two x 63 mm OR One x 76 and One x50 mm OR Four x 50 mm
10	102	One x 90 and One x 63 mm OR Two x 76 mm OR Three x63 and One x 50 mm OR Six x50 mm

6. Installation of Piping (other than Refrigerant Piping)

6.1 General Requirements: All piping is recommended to be installed in accordance with the drawings. Flanges or unions are recommended to be installed to allow installation, removal or maintenance of equipment or valves.

6.2 Modifications to pipe routing may be necessary at site to avoid interference. These modifications are required to be recorded for the purpose of as-built drawings. Proper care is recommended to be taken to prevent ingress of moisture or dirt into the expansion joint during erection.

A straight run of pipe shall contain the minimum number of welds. The use of off-cuts in straight piping runs is recommended to be avoided. Piping butt welds are recommended to be spaced a minimum of 50 mm or four times the thinnest wall thickness measuring between the heat affected zones, whichever is greater.

6.3 Misalignment beyond acceptable tolerances in straight pipe runs is not recommended. Seam orientation of welded straight pipe and pipe to fittings is recommended to be such that at circumferential welds, the longitudinal welds is recommended to be staggered over the top of the center line, preferable 30º left and 30º right of the center line. The minimum distance between the staggered joints is recommended to be 50 mm or six times the thinnest pipe wall thickness measured between heat affected zones, whichever is greater. Care is recommended to

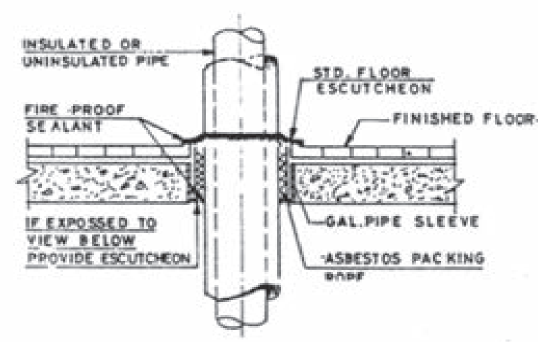


Figure 7a: Floor penetration details at dry location

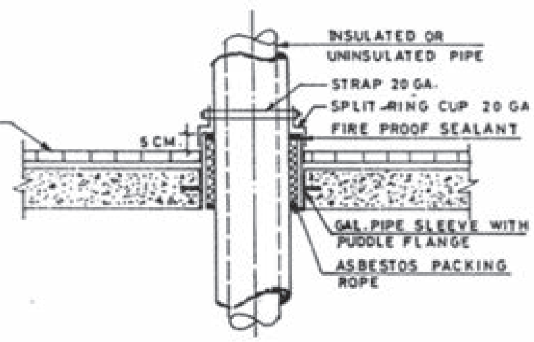


Figure 7b: Floor penetration details in wet areas

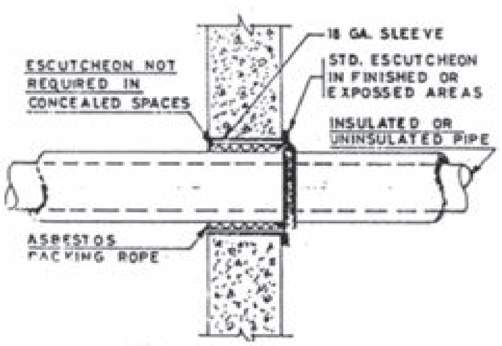


Figure 7c: Wall penetration

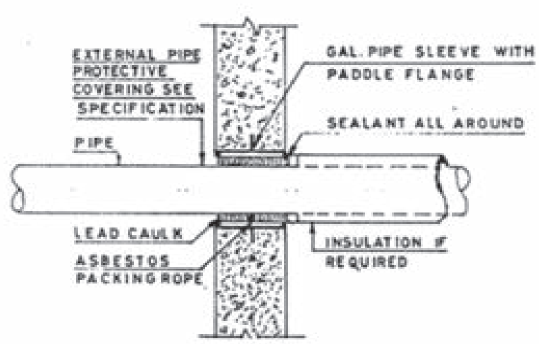


Figure 7d: Wall penetration (external wall above or below grade)

be taken to ensure that longitudinal welds clear branch connections.

6.4 Pipes passing through concrete walls or floors shall not be cast in. Pipe is recommended to be passed through cast in sleeves or standard weight pipe having an internal diameter large enough to give 12 mm radial clearance to the passing flange, including its lagging, where applicable, and shall have a light infill if air passage is to be restricted. Refer *Figure 7a, 7b, 7c* and *7d* for floor and wall penetration details.

6.5 Where pipework passes through floor plate floors and grid mesh, a 75 mm high collar having an internal diameter large enough to give minimum 25 mm clearance to passing flange is recommended to be welded to the floor plate/mesh to prevent chaffing and promote safety.

Erection of pipework using Victaulic couplings or similar is recommended to be in accordance with the Supplier's recommendations.

6.6 A method statement is recommended to be provided for site fabrication and installation of piping before installation work is taken up.

6.7 While taking branch connection or diversion make a proper Tee joint as per *Figure 8.*

6.8. Installation of Valves: Valves are recommended to be installed with stems orientated properly and to be indicated on piping drawings. Hand wheels and levers are recommended to be easily accessible for operation from grade or platform. Valves shall not be installed with their stems projecting into walkways. All valves located underground or in trenches are recommended to be provided with valve boxes and extension stems & to be shown on drawings. Refer *Table 3* for Applications of Pipes, Fittings and Valves.

Table 3: Applications of pipes, fittings and valves

S. No.	Application	Pipe Material	Thickness	Joint Type	FITTING CLASS	FITTING MATERIAL	SYSTEM TEMP, ºC	SYSTEM MAXIMUM PRESSURE AT TEMP, BAR
1	Recirculating Water	Steel (CW)	Standard	Thread	125	Cast Iron	120	8.6
	63 to 300 mm	Hard Copper	Braze or Silver Solder			Wrought Copper	120	10.3
		PVC	Sch 80	Solvent	Sch 80	PVC	24	
		CPVC	Sch 80	Solvent	Sch 80	CPVC	65	
		PB	SDR-II	Heat Fusion		PB	70	
		A 53 BERW Steel	Standard	Weld	Standard	Wrought Steel	120	27.6
				Flange	150	Wrought Steel	120	17.2
				Flange	125	Cast Iron	120	12
				Flange	250	Cast Iron	250	27.6
				Groove		MI or Ductile Iron	110	20.6
		PB	SDR-II	Heat Fusion		PB	75	
2	Steam and Condensate	Steel (CW)	Standard	Thread	125	Cast Iron		6.2
	50 mm and smaller			Thread	150	Malleable Iron		6.2
			XS	Thread	250	Cast Iron		13.8
				Thread	300	Malleable Iron		17.2

3	Steam and Condensate	Steel	Standard	Weld	Standard	Wrought Steel		17.3
	63 to 300 mm			Flange	150	Wrought Steel		13.8
				Flange	125	Cast Iron		6.9
		A 53 ERW Steel	XS	Weld	XS	Wrought Steel		48.2
				Flange	300	Wrought Steel		34.5
				Flange	250			13.8
4	Refrigerant	Hard Copper	Type L or K	Braze		Wrought Copper		
		A 53, B SML Steel	Standard	Weld		Wrought Steel		

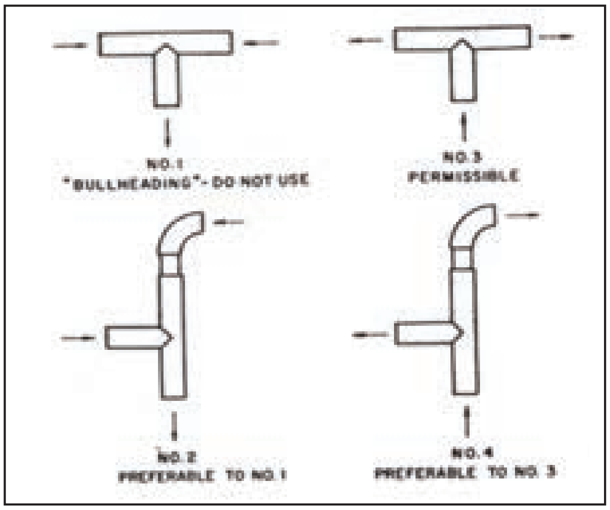


Figure 8: Connecting tee joints

Note 1: In this table Maximum working pressures have been derated. Higher system pressures can be used for lower temperatures and smaller pipe sizes. Pipes, fittings, joints and valves must all be considered.

Note 2: Lead and Antimony based solders shall not be used for potable water systems. Brazing and Silver solders shall be used.

Note 3: Extra strong pipe is recommended for all threaded condensate piping to allow for corrosion.

6.9 Relief valves are recommended to be installed in an upright position and accessible from a platform or grade. Relief valves or scour valves discharging hazardous liquids or gases, is recommended to be piped to a safe and environmentally acceptable location.

Chain wheel operators are shall be provided for valves with hand wheels more than 2,050 mm above the operating level. Chains shall clear operating floors by 900 mm and shall not hang in access areas.

6.10 Piping for Rotating Equipment: Pump and AHU piping is recommended to be installed up to a break point between the nearest pipe support and the equipment. The remainder of the piping is recommended to be site measured, fabricated and properly fitted between the equipment nozzle and its break point. It is essential that this is done accurately in order to avoid any external loadings on the equipment connections.

6.11 Piping is recommended to be disconnected from the equipment after installation to demonstrate that no stress has been transferred from piping to equipment, and then reinstalled.

6.11.1 The following procedure is recommended to be applied for the alignment of flanges to rotating equipment:

>Install, bolt down on shims and grout rotating equipment level on the foundation. Driver to equipment alignment to be set within manufacturer's tolerances.

>Align pipework to equipment flanges to within the Supplier's tolerance and in accordance with this specification.

>Recheck the coupling alignment during the bolting and tensioning of the pipe flanges to the equipment flanges. The bolting up and tensioning of the flanges shall not affect the coupling alignment between the driver and driven equipment.

6.12. Insulated piping: While installing the piping that will be insulated (Chilled water line or hot water lines) enough spacing is to be provided between two pipes (Ref *Figure 9*). Also, refer *Table 4* for distance between pipes.

Table 4: Distance between pipes (see also Figure 9)

“-------DIMENSION A													-------”	DIMENSION B
S No	**Pipe Size, mm**	**50**	**75**	**100**	**150**	**200**	**250**	**300**	**350**	**400**	**460**	**510**	**610**	
1	50	130	130	150	180	200	230	250	280	305	330	360	400	**100**
2	75	130	150	150	200	230	250	280	280	305	330	360	400	**100**
3	100	150	150	180	200	230	250	280	305	330	360	380	430	**130**
4	150	180	200	200	230	250	280	305	330	360	380	405	460	**160**
5	200	200	230	230	250	280	305	330	360	380	405	430	480	**180**
6	250	230	250	250	280	305	330	360	360	405	430	460	500	**200**
7	300	250	280	280	305	330	360	380	405	430	460	480	530	**230**
8	350	280	280	305	330	360	380	380	405	430	460	480	530	**230**
9	400	305	305	330	360	380	405	430	430	460	480	500	560	**250**
10	460	330	330	360	380	405	430	460	460	480	500	530	590	**280**
11	510	360	360	380	405	430	460	480	480	500	530	560	610	**305**
12	610	405	405	430	460	480	500	530	530	560	590	610	660	**360**
Note: Insulation thickness to be added to Dimension “A “ where applicable.														
All Dimensions in mm.														

>The following are key points for the proper installation of pipe works, ensuring alignment, sealing, support, and compliance with safety:

>It shall be verified that pipes of correct specifications such as pipe class, length, thickness, straightness and surface finish are received at the project site. Pipe routing as per ‘Good for Construction’ drawing shall be verified at site and pipes may be cut to required lengths.

> Edges of pipes shall be beveled by grinding to make a ‘butt’ joint. Fabrication of supports shall be as per site requirements and specifications. Spacing between supports shall be as specified.

> Overhead piping may be supported on walls/columns with appropriately sized brackets or may be suspended from ceiling/roof truss with MS suspension rods or hangars. Anchor fasteners of adequate sizes shall be used for pipe supports. Vertical risers shall be supported by horizontal supports mounted at regular intervals.

> Vertical pipes passing through floors shall be parallel to the wall and shall be straight (as verified with a plumb line).

> Where pipes pass through floor slab or walls, gaps between the pipe and floor/wall opening shall be sealed (Ref. *Figure 7a, b, c* and *d*).

> Chilled water piping shall be supported on PUF or wooden gutties. Single gutties shall be used for horizontal runs and double gutties for vertical risers. While installing insulated pipes, care shall be taken that insulation is not unduly compressed.

> Condenser water piping shall be placed on serrated rubber pads at each support and held in place by U clamps.

> Piping shall have expansion joints as required. Fittings, valves and instruments shall be as per approved drawings. Drain points and air vents shall be provided as required. Auto purge valves shall be provided at the highest point in each pipe loop with discharge piped out to nearest drain or sump. While T connections shall be permitted on suction side of pump, shoe connections shall be provided on the discharge side. Elbows / bends shall be minimum and reducers shall be eccentric type. Welding scale shall be removed before

applying red oxide primer. Readymade fittings to specifications are recommended. Welder shall be competent and hydraulic pressure testing with 1.5 times the working pressure shall be done for 24 hours.

Flanges shall be provided near each equipment connection and all flanges shall be with gaskets.

6 .13 Pipe Connections to Equipment

6.13.1 Pumps: After installing the pumps make sure that flexible connections and isolation valves are installed on both suction and discharge sides of the pump (Ref. *Figure 9*).

In case where pumps are used for high temperature application, expansion joints are used (*Figure 10*).

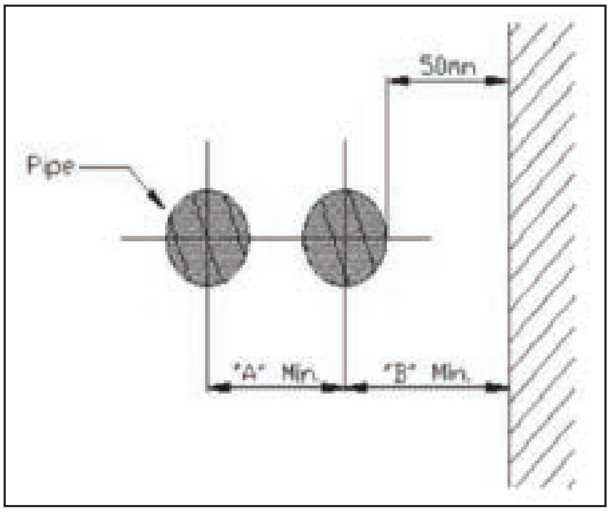


Figure 9: Spacing between insulated piping

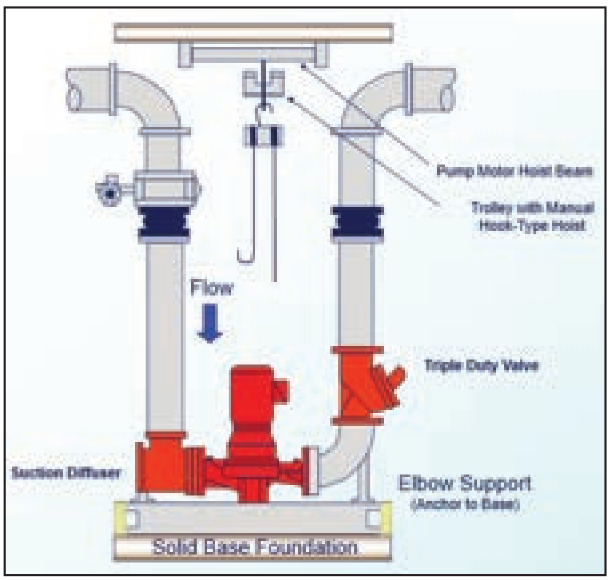


Figure 10 (a): Pipe connection to pump

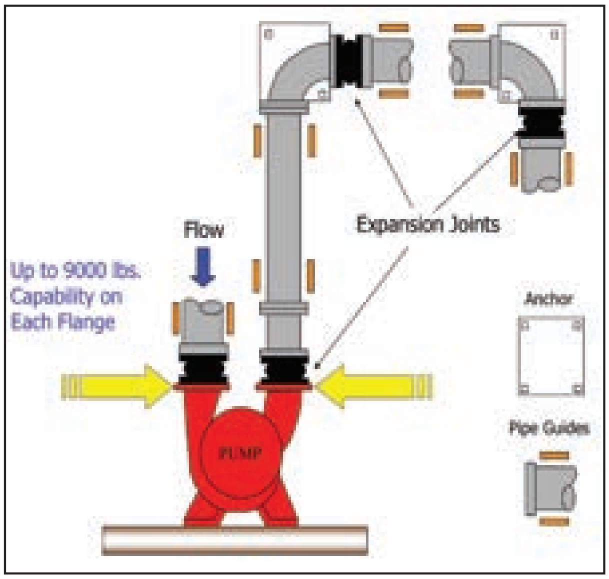


Figure 10 (b): Pipe connection with expansion joint

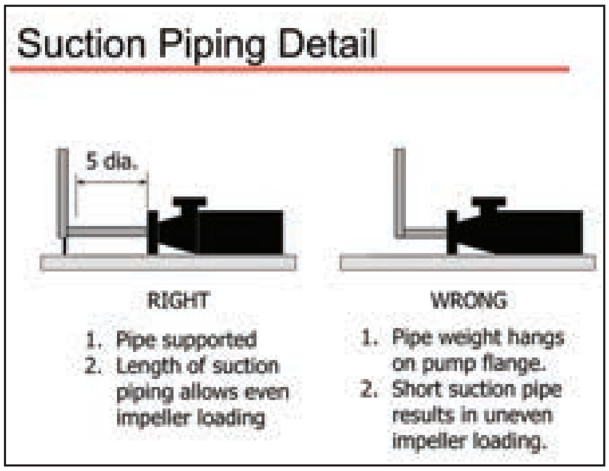


Figure 11: Pipe support and gap between elbow and pump

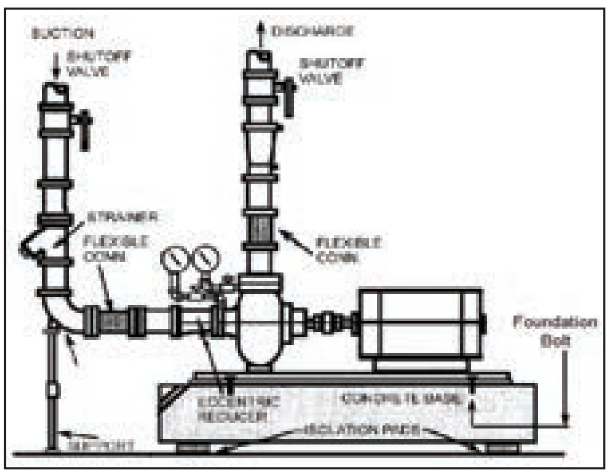


Figure 12: Pump connection with flexibles and pressure gauges

The straight length of pipe should be five times its diameter, when installed between the suction side of the pump and the first elbow (Ref. *Figure 11*).

6.13.2 If welding is to be performed on the mechanical or flange connections remove the solid-state temperature sensor and thermostat bulbs from the wells to prevent damage to those components.

6.13.3 Water pressure gauge connection taps and gauges could be provided in the field piping at the inlet and outlet connections of both vessels for measuring the water pressure drops (Ref. *Figure 12*).

6.14 Be sure that water inlet and outlet connections match certified drawings and stenciled nozzle markings. The condenser shall be connected with the cold water entering at the bottom to maximize subcooling.

6.15 The piping must be supported to eliminate weight and strain on the fittings and connections.

6.16 To avoid tube damages on heat exchangers tubes, cleanable water strainer shall be installed in both water inlet lines. Strainer mesh size has to be 1 mm.

6.17 Slope of the drain pan connection shall also be towards the drain pipe connection. Chilled water piping to AHU shall have a manual air vent at the top most point in the coil circuit and a drain plug at the bottom of the coil.

6.18 Typical pipe schematics are shown in *Figure 13, 14, 15, 16, 17, 18* and *19* just as an illustration. In all cases, please follow approved design drawings.

7. Pipe Fabrication

7.1 Cold Bending: Pipes DN 40 and smaller are recommended to be bent only where cold bending is indicated on the piping drawings. In all other cases, butt weld, socket weld or screwed elbows is recommended to be used depending on the piping class. Cold bending is recommended to be carried out using pipe bending machines, or presses provided that dies are employed to prevent flattening.

Unless otherwise noted, the center line radius of bends is recommended to be five nominal pipe diameters. Butt welds in the arcs of bends or for the addition of pulling legs shall not be permitted.

Bending shall not reduce the pipe wall thickness below the minimum wall thickness required

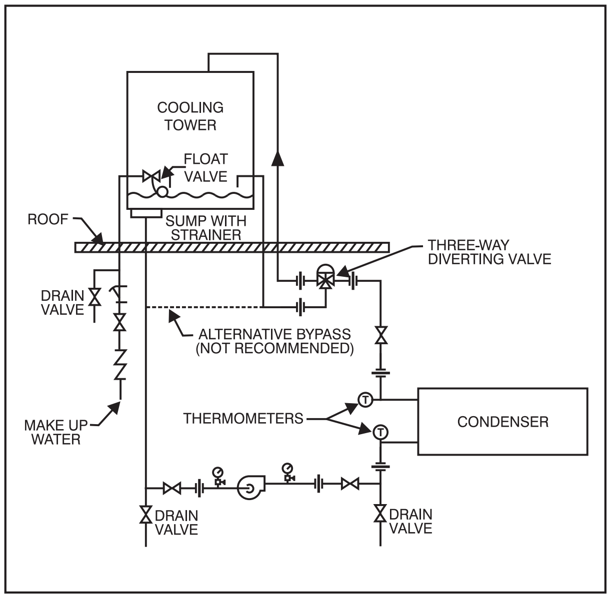


Figure 13: Schematic cooling tower piping

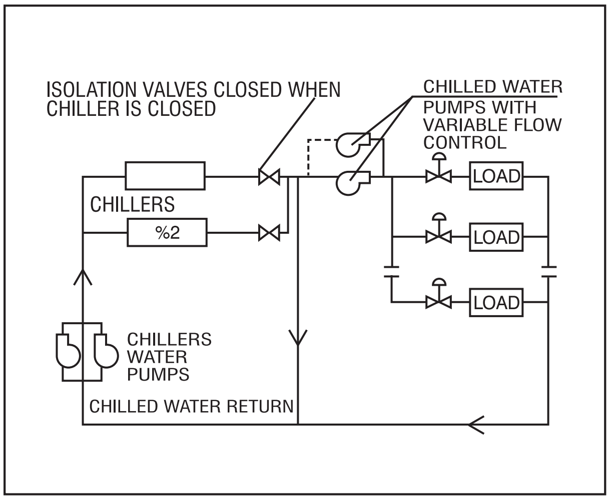


Figure 14: Primary-secondary chilled water system

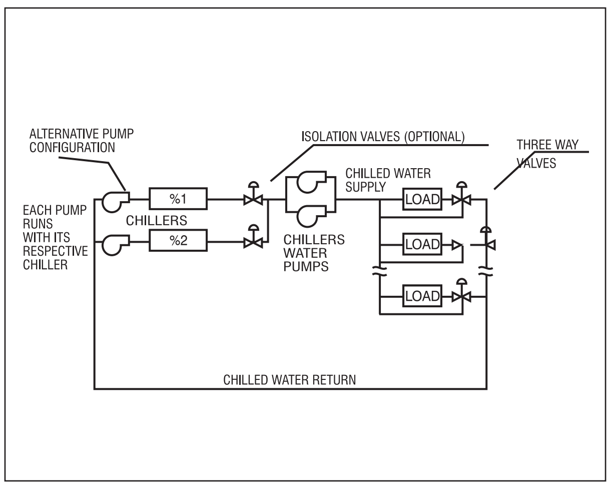


Figure 15: Variable flow chilled water system

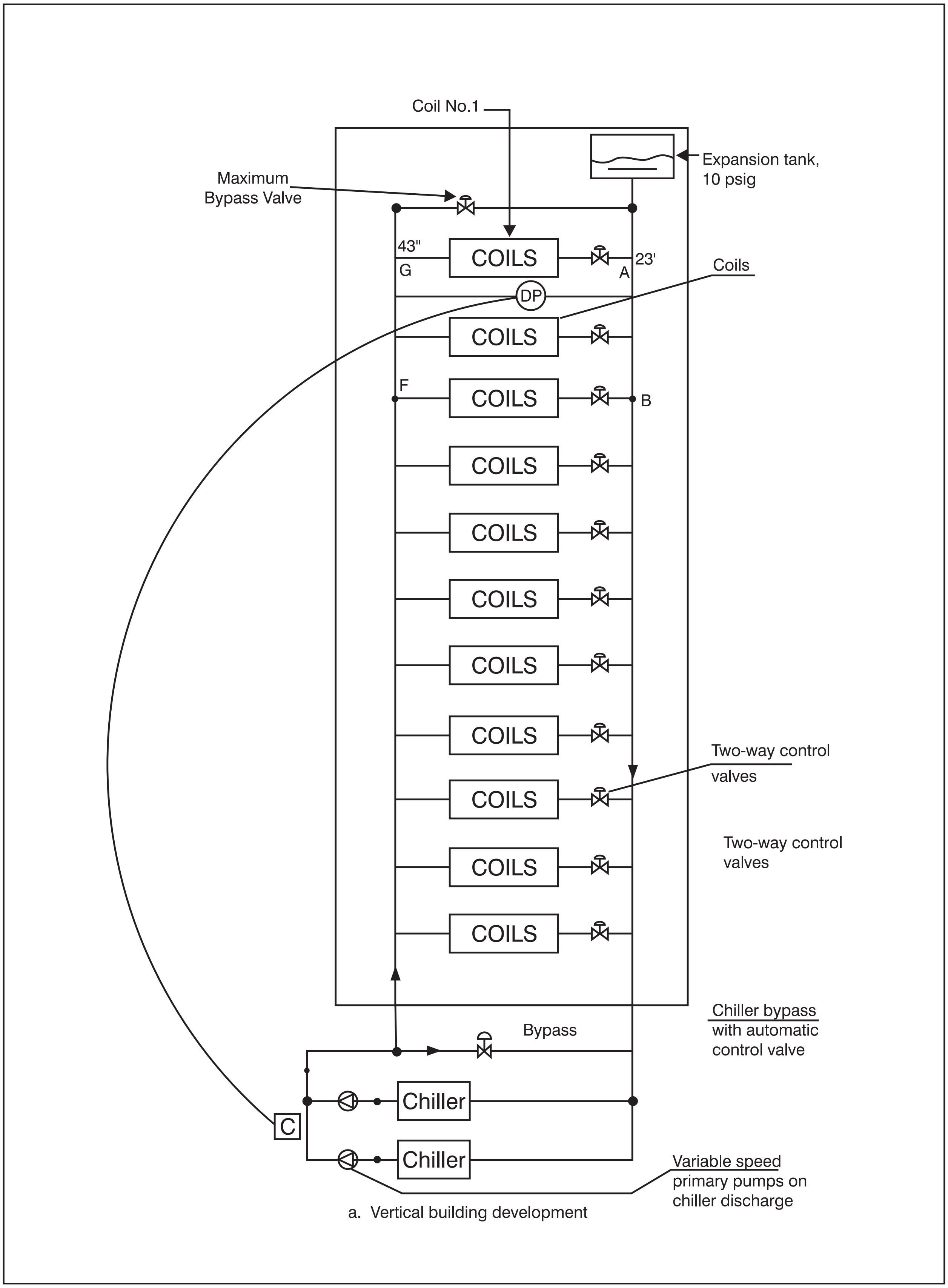


Figure 16: Typical multi-storey building chilled water system

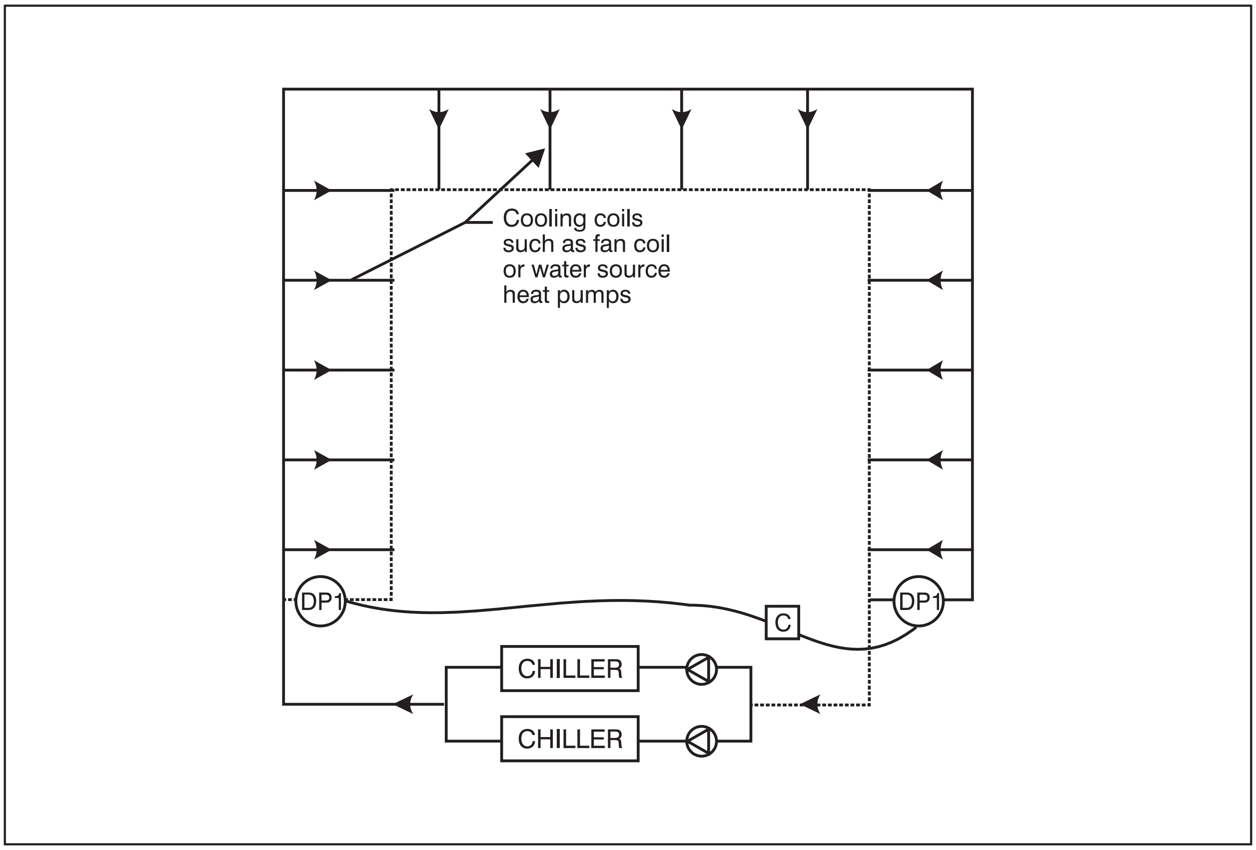


Figure 17: Reverse return system

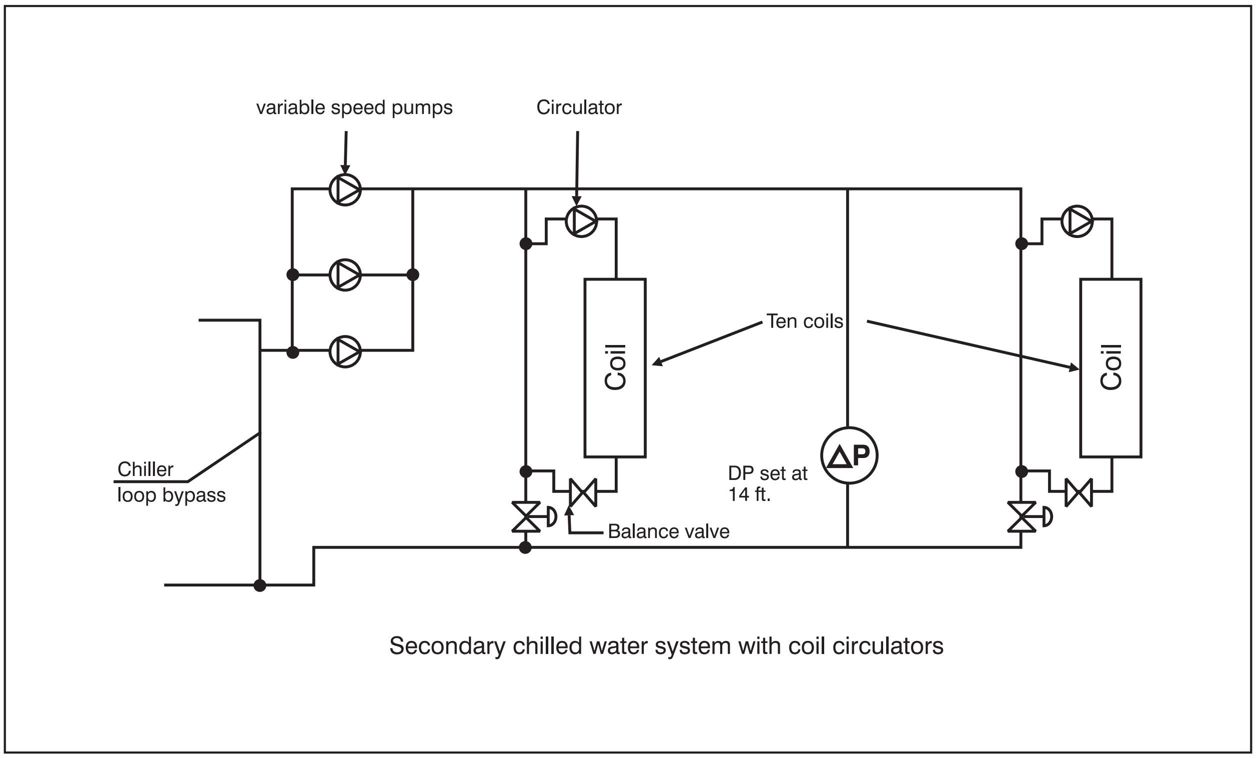


Figure 18: Secondary chilled water system with coil separators

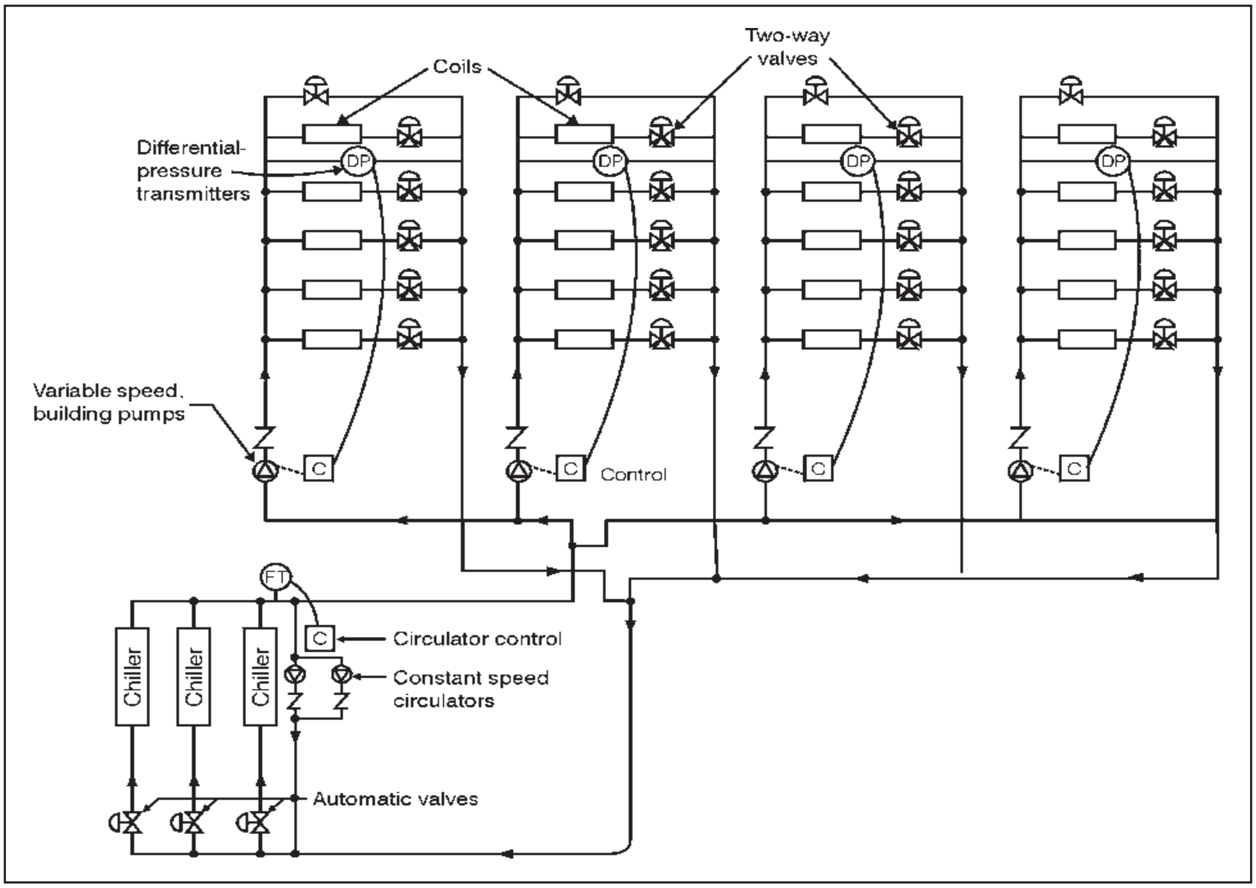


Figure 19: Distributed pumping for chilled water

NOTE : All VFD Driver Motors are required to run at a minimum speed for proper Motor Cooling.

Source : HVAC Pump Handbook

for the design temperature and pressure plus any corrosion allowance. All bends are recommended to be smooth, free from cracks and surface defects, without buckles and they are recommended to be within tolerance limits allowed by given specification.

7.2. Mitre Bends: Segmented bends are recommended to be manufactured by butt welding together segments of pipe, shaped to produce the required bend. Wherever possible, the segments are recommended to be taken from the same length of pipe. However, the use of segmented bends is to be limited to applications detailed on the piping drawing. The change of centerline at butt welds in segmented bends shall not exceed 30º.

8. Pipe Supports

8.1 Piping is recommended to be supported, guided and anchored, as per the piping and support detail drawings. Temporary supports are permitted to facilitate piping installation provided they are recommended to be completely removed upon completion.

8.2 Piping shoes and sliding pipe support attachments is recommended to be centered over the concrete or steel support beams before any field welding or bolting to the pipe is carried out.

8.3 Install all pipe supports, anchors, guides and other support attachments in accordance with the details on the drawings

8.4 Welding preparations for the pipe to pipe supports are recommended to be in accordance with the given specifications. Structural steel welding for pipe supports is recommended to be in accordance with AS1554.

8.5 All pipe supports are to be individually identified by number and this number is to be marked on the piping layout plans. Please refer to *Table 5* for suggested hangar spacing and rod size for straight horizontal pipe runs.

Table 5: Suggested hangar spacing and rod size for straight horizontal pipe runs

S No	Pipe OD, mm	Standard Steel Pipe Metre		Copper Tube Metre	Rod Size, mm
		Water	Steam		
1	12	2.2	2.4	1.5	6
2	19	2.2	2.7	1.5	6
3	25	2.2	2.7	1.8	6
4	38	2.7	3.6	2.4	10
5	50	3	4	2.4	10
6	65	3.4	4.3	2.7	10
7	75	3.6	4.6	3	10
8	100	4.3	5.2	3.7	12
9	150	5.2	7.3	4.3	12
10	200	5.8	7.9	4.8	16
11	250	6.1	7.9	5.5	19
12	300	7	9.8	5.8	22
13	350	7.6	9.8		25
14	400	8.2	10.7		25
15	450	8.5	11.3		32
16	500	9.1	11.9		32

Note: Spacing indicated above does not apply where concentrated loads such as valves, flanges etc are placed between supports

8.6 All pipe supports and attachment welds to the pipe should to be welded in accordance with the same welding procedure as used for the piping class. Temporary supports are recommended to be used during pipework installation to prevent overstressing the pipe work. These temporary supports are to be removed from site after completion of installation.

9. Testing of Piping Works

9.1. Preparation for Test: All joints in a test section is to be accessible during tests and shall not be painted, insulated, backfilled or otherwise covered until satisfactory completion of testing in accordance with this specification. All vents and other connections which can serve as vents are to be open during filling so that all air is vented prior to testing.

9.2 For hydrostatic testing piping systems of austenitic stainless steel test medium is recommended to be demineralized water with a chloride content of maximum 1ppm and pH between 6 and 7. Water is recommended to be drained immediately after completion of hydrostatic testing and the system dried out to avoid concentration of chlorides. For hydrostatic testing of piping systems with high nickel content, the water used is recommended to be checked for possibility of generation of hydrogen sulphide (H2S) during the test.

9.2.1 A report on water analysis including the chloride content and pH value of the water is recommended to be attached to the test report at all times when austenitic stainless-steel systems are hydrotested. Saline water can be used for testing of PE or UPVC pipework.

9.2.2 Pressure in the system is recommended to be introduced gradually until the pressure is the lesser of one-half of the test pressure or 170 kPa gauge. Maintain pressure for 10 minutes and then gradually increase pressure in steps of one tenth of the test pressure until the test pressure is attained.

9.2.3 Pressure testing: The test pressures is recommended to be 1.5 times the normal working pressures which are designated for the class of piping.

9.2.4 Open-ended vent, drain and similar piping systems operating at atmospheric pressure are not considered as pressure piping and shall not be pressure tested but is recommended to be leak tested by filling the lines with water. Piping systems to be tested are recommended to be divided into sections referred to as 'test sections.

9.2.5 Test sections' documentation shall contain isometrics or relevant sections of pipework related to the section of piping system that is being tested and shall include the following information.

Limit of test as illustrated on the P&IDs:

- Location and thickness of test spades
- Test medium
- Test pressure
- Location of vents and drains
- Requirements for isolation or removal of in-line equipment and instruments.

9.2.6 Testing procedure is recommended to be submitted as per the Project specification for approval. Reinforcing pads is recommended to be tested with air at 34 kPa gauge (5 psig). All weld surfaces on the inside and outside are recommended to be swabbed with a leak testing solution. After testing is complete, the vent hole is recommended to be plugged with grease or silicon sealant. A record of all reinforcing pad tests is recommended to be maintained.

Short pieces of pressure piping which must be removed to permit installation of test blinds are recommended to be tested separately.

9.2.7 Flanged connections at points where blinds are used during pressure tests do not require separate tests after test blinds have been removed. Screwed and socket weld connections is recommended to be inspected thoroughly after make-up to assure tightness.

Re-testing of any 'cut-in' or repair work into a line already tested, shall generally be carried out to the same procedure and test pressure as the original test.

Testing is recommended to be carried out in the person designated for the purpose by owner/ project manager. Records of all pressure tests are recommended to be maintained.

Ensure that the insides of all pipes, valves, fittings and other associated equipment are clean and free from loose foreign matter prior to commencement of the pressure test.

9.2.8 Normally, equipment is recommended to be isolated from the test section. However, where equipment which could be damaged by foreign debris is included in a test section, temporary in-line strainers are recommended to be installed.

9.3. For hydrostatic testing of carbon steel piping systems, test medium is recommended to be potable water at ambient temperature with pH value between 6 and 7.

For hydrostatic testing piping systems of austenitic stainless steel test medium is recommended to be demineralized water with a chloride content of maximum 1 ppm and pH between 6 and 7. Water is recommended to be drained immediately after completion of hydrostatic testing and the system dried out to avoid concentration of chlorides. For hydrostatic testing of piping systems with high nickel content, the water used is recommended to be checked for possibility of generation of hydrogen sulphide (H2S) during the test.

9.4 A report on water analysis including the chloride content and pH value of the water is recommended to be attached to the test report at all times when austenitic stainless-steel systems are hydrotested.

Saline water can be used for testing of PE or UPVC pipework.

9.5 Pneumatic Testing: Pneumatic testing of a piping system is generally not recommended unless specifically required for the project. Pneumatic test is recommended to be performed in accordance with given specification and the additional requirements of this specification.

- Test medium: Dry nitrogen or clean and dry oil free air.
- Area of test to be roped off and access into the area to be limited.
- The minimum metal temperature during a pneumatic test of piping shall not be less than the temperature required by the engineering design.
- Piping system to be tested is recommended to be protected by a relief valve. Set pressure of relief valve: test pressure plus the lesser of 70 kPa or 7% of the test pressure.
- Weak soapy water is recommended to be used for testing leaks in the joints.

9.6 Test Equipment: Equipment to be used during testing shall have suitable capacity for the range of test pressures required. All pressure gauges and chart recorders shall have been calibrated within 60 days prior to testing and shall have current calibration certificates. The gauges are recommended to be of a minimum face size of 150mm in diameter and ranged to approximately twice the test pressure.

A minimum of two gauges are recommended to be provided for each test system. One gauge is recommended to be located at the highest point and the other at the pump or at grade.

9.7 Test Duration: Unless otherwise specified, test pressure is recommended to be held for a minimum period of one hour to enable thorough inspection of the piping system of piping components for leaks.

Holding pins should not be removed from spring supports until testing is completed and the system is drained.

Pressure in the system is recommended to be introduced gradually until the pressure is the lesser of one-half of the test pressure or 170 kPa gauge. Maintain pressure for 10 minutes and then gradually increase pressure in steps of one tenth of the test pressure until the test pressure is attained.

9.8 Test Equipment: Equipment to be used during testing shall have suitable capacity for the range of test pressures required. All pressure gauges and chart recorders shall have been calibrated within 60 days prior to testing and shall have current calibration certificates. The gauges are recommended to be of a minimum face size of 150 mm in diameter and ranged to approximately twice the test pressure.

A minimum of two gauges are recommended to be provided for each test system. One gauge is recommended to be located at the highest point and the other at the pump or at grade.

9.9 Completion of Testing: Pressure test is recommended to be considered complete when:

All defective welds, defective materials, flange leaks, valve gland leaks or other such defects have been corrected and accepted as per the Project specification.

Sealing materials shall not be used to correct leaks at joints. Valve glands shall not be tightened to the extent that the valve cannot be operated. If necessary, valves are recommended to be repacked.

After hydrostatic testing of the system is complete and approved as per the Project specification, all lines and equipment are recommended to be completely drained of the test fluid. Piping systems vents is recommended to be opened while draining to avoid a vacuum. Care is recommended to be taken when draining the test fluid to avoid damage to other items of equipment. Special attention is recommended to be given to points where water may be trapped, such as in valve bodies or low points.

- All documentation and 'test section' information is complete and accepted as per the project specification.
- All temporary test blinds or spades and strainers have been removed, new gaskets installed and the piping system reinstated.

9.10 Test Record: Records for piping which require that pressure be held for a specified period of time shall include any corrections of test pressure due to temperature variations between the start and finish of the test.

Records of all tests carried out and approved as per the Project specification is recommended to be retained in the job records.

9.11 Repairs to Defects: Repairs to welded joints, defective or damaged pipe and fittings or any other pressure part shall be carried out with due recordings.

Repair procedures are recommended to be approved by the project specification prior to commencement of work.

9.12 If repairs or modifications are carried out after heat treatment has been completed, the areas affected by the repair or modification are recommended to be heat treated again.

10. Commissioning of the System with Pumps

10.1 Flushing and Cleaning of Pipe Work: When pipes are stored for longer duration, it is necessary to clean the piping before installation. Hammer, brush and scrub with soapy rags to loosen sand, dirt, or scale. Blow with air, or flush with clean water. Hammering shall not be used on cast iron, fiberglass-reinforced plastic, or plastic pipe.

10.2 Pipe work shall be cleaned and flushed before commissioning. Flushing of system shall be done bypassing sensitive parts such as chiller and heat exchanger tubes. Before filling up the system with clean water, all shut off and control valves shall be kept fully open. Continuous air venting shall be done. Pump shall be started only after filling up and air venting is completed. Additional flushing pumps may be used over and above system pumps and the primary pump strainer basket mesh shall not be less than 3 mm when flushing starts. Flushing velocity from 1.0 m/s to 1.25 m/s is recommended. Pressure drop across pumps shall be monitored during the process so that pump cavitation is avoided.

10.3 Dynamic flushing in several steps is recommended. First the primary ring main may be flushed, thereafter the main pipes and lastly the horizontal mains in each floor. After each round of flushing, the strainer basket shall be changed. Each loop needs to be flushed till the water is clean and the strainer basket does not collect sediments. Flushing of horizontal main pipes shall start at the topmost floor and finish at the lowest floor. After flushing in sections is completed, full system flushing shall be carried out. After flushing is complete, the water sample shall be analyzed to determine successful flushing.

10.4. Flushing the System: Prior to flushing remove orifice plates, traps, strainer elements, flow control valves, etc. Remove instruments which might be damaged by cleaning procedures. All such items shall be replaced with spool pieces, plugs, or blind flanges. A list shall be prepared mentioning where blinds have been installed for cleaning and shall be verified after cleaning is complete to that all blinds have been removed.

Items removed from piping system shall be cleaned separately.

New gaskets, thread lubricants, etc. shall be used when removed items are reinstalled after cleaning.

10.5. Special care to be taken with polyvinyl chloride (PVC) and fiberglass-reinforced plastic (FRP) piping that after initial filling of long pipe runs to determine that pipe is in contact with hangers and supports.

Install high point vents and low point drains required to remove trapped air and to drain flushing liquid.

10.6 Water Filling / Starting the Pumps: Properly size the water piping to the make-up water connection and cooling tower to deliver the specified flow and pressure. Standard design parameters for chillers use minimum 35 kPa city water pressure or water pumped from storage at the inlet to the chiller. The maximum water pressure shall be 700 kPa. Systems with water pressures over 700 kPa shall be equipped with pressure reducing valves in the lines to the chiller.

10.7 Water System Balancing: Water balancing (of chilled water/brine) shall be done as under:

> Keep all balancing, control and isolating valves in fully open position.

>Measure the water flow across each balancing valve and compare it with design flow.

>Identify the index value (lowest flow ratio) in each branch.

>Keep index valve fully open.

>Throttle the farthest valve to the same ratio and after that every valve in the branch starting from the lowest ratio.

>Monitor index valve percentage after throttling each valve gradually. By the time the last valve is completed, the flow is balanced at all valves including the index valve.

>Record the reading at all valves.

10.7.1 Where Pressure Independent Balancing and Control Valves (PIBCV) are used, the proportional balancing described above is not required. Each valve may be set to correct water flow rate as per manufacturer's instructions.

11. Quality of Water Used in HVAC System

Table 6: Recommended water quality

Rcommended Water Quality Standards

Test items	Chilled Water Quality	Cooling Tower Water Quality	Makeup Water Quality
pH	7.2 - 8.5	7.2 - 8.5	6.0 - 8.0
Total hardness ($CaCo_3$) ppm	Max. 80	Less than 200	Max. 50
Total alkalinity ($CaCo_3$) ppm	Less than 100	Less than 100	Less than 80
Chloride ion (ppm)	Less than 50	Less than 200	Less than 50
Total Ion (Fe) ppm	Less than 0.3	Less than 1.0	Less than 0.3
Silica (SiO_2)	Less than 30	Less than 50	Less than 30
Ammonium ion ppm	Less than 0.2	Less than 1.0	Less than 0.2

12. Refrigerant Piping (Copper)

12.1 Piping Material: Shall be wrought copper tubes for Refrigeration and Air Conditioning Purposes – IS 10773.

12.2 Pipes used for the refrigerant piping system shall have the specified thickness, and the interior shall be clean as recommended by the manufacturer.

12.3 Annealed temper (soft) ACR copper tubing is available in sizes 6 mm through 56 mm. (ASTM B 280, clean, dry, and capped). Tube wall thickness shall meet with local code requirements and shall be approved for an operating pressure for refrigerants used (R 410A, R 32, R 407A, etc.).

12.4 Laying of Pipes: Before laying copper tubing between IDU and ODU care should be taken to straighten the pipes properly. Support the coil upright with one hand and holding the free end of the tubing stationary on a flat surface with the other hand. The tubing shall be marked at one end and the required length of tube is measured at the other end. Once the correct marking is done the tube shall be cut using tube cutter (*Figure 20*).

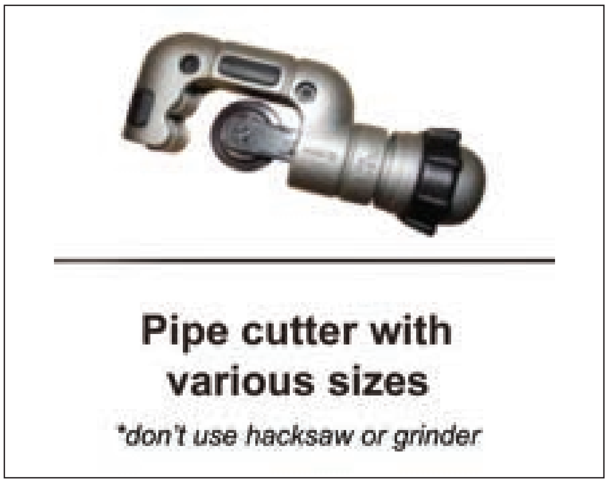


Figure 20: Tube cutter

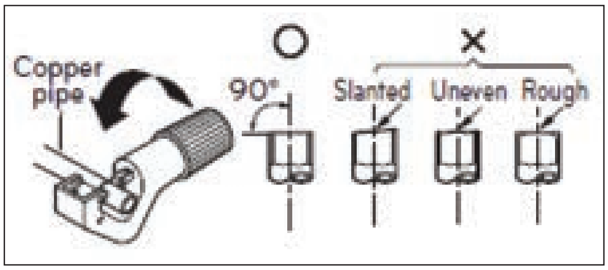


Figure 21: Tube cutting – angle

12.5. Cleaning and Polishing: The copper tubes used for the refrigerant piping must be free from moisture, dirt, oil and kept clean using abrasives like emery paper, and wire brush. When two pieces of piping are used for joining, the surfaces of both the ends should be dry without any oil or liquid tracing, polished by emery paper.

12.6 Flare connection is a mechanical joint without any gasket in between, which is used to connect tubing to fittings such as valves or to join the copper tube with male threaded flare fitting. The flaring operation shall be done only on a tube which is cut by the tube cutter and after removing the burrs. The end of the soft copper tube is flared at 45° angle. For flaring operation, a flaring block and a flaring yoke are required. The soft copper flare takes the shape of the fittings and seals properly. The flared joint shall be done very carefully that the flare joint shall withstand the test pressure of refrigerant line to avoid any leakage of refrigerants. The flared end of tubing rests against the male portion of the fitting being connected. Inspection of the flaring shall be done after removing the tubing from the flaring tool. If the tube end has split, the flared portion shall be cut and the process shall be repeated.

12.7 The torque required for tightening of different tube sizes varies according to the diameter of the tube.

Apply torque which is just right for flare nuts. Over-tightening shears the tubes ultimately resulting in a leak. If a flare joint leaks even after tightening to the required torque, the reason for leakage may be due to bad flare or burrs on tube or wrong size of flare, then cut the tube and make the new flare.

13. Brazing of Copper Pipes

Brazing is a hot process using flame, and safety precaution shall be taken during the process.

Brazing shall be done between copper to copper or copper to aluminum or copper to brass or copper to steel tubes, to make a leak proof connection which will also withstand vibration and shock. To perform the brazing process, brazing rods or filler material, acetylene-oxygen cylinder and torch with different sizes of nozzles are required.

The temperature required for brazing depends on the size and thickness of the material being brazed. For air conditioning application, normally heat source produces temperature above 450°C. The brazing rod shall melt on contact with the heated copper tubes and shall not be heated directly by the torch flame. The filler rod which has melted on contacting the heated base metals flows into the clearance between the overlapping copper tubes which are joined, by capillary action. This capillary action will take place only when the clearances are maintained within certain limits and the movement of flame is across and around the joint.

Introduction of nitrogen as protective gas with a very low flow rate inside the tube assembly during the brazing process is a good method to avoid oxidation. Service valves shall be protected with wet rags or heat sink material while doing brazing. Use only recommended fillers for various joints.

13.1. Brazing Joint Preparation: Before the start of the brazing process, ensure that the surface of tubes to be joined are cleaned thoroughly using emery or wire brush. This will ensure removal of all dirt, greases, oils and other impurities so that the brazing joint is perfect. In case of joining the same sizes of tubes, first swage one end of tube, insert the other tube in it and complete brazing. In the case of joining the two different sizes, insert the smaller diameter end into larger diameter end after proper cleaning and aligning. The length of the joint shall at least be equivalent to 1.5 times diameter of the smaller tube.

13.2. Brazing Filler Material: Brazing filler material in liquid state, distributes between two or more close fitting parts to be joined, by capillary action. Filler material interacts with a thin layer of the base metal (known as wetting) and when cooled, it forms a sealed/leak-proof joint as a single component. The brazed joint is stronger than the filler metals used because of the geometry of the joint and the metallurgical bonding that occurs. For brazing steel base metal with copper, filler material normally used is silver which is 35 to 43%. Fluxes made of sodium, potassium, lithium & borax is added as a paste, powder to brazed metal to remove oxides. At least 2% silver alloy shall be used as filler material for copper-to-copper joint.

13.3 Following shall be taken care of during brazing:

>Confirm that there is no explosive or flammable object around the work place.

>Wear regulated work clothes and equipment before starting brazing work.

>Remove scales and solder from brazing part.

>If objects such as dust, oil, scales, etc. are attached to a part to be brazed, wipe them off with cloth and polish it with sand paper. If a gap is too small to be brazed, file it.

>During the work, open both ends of a pipe and supply nitrogen gas in such a degree that its flow is noticed by hand. (Nitrogen gas prevents oxidation film from being created inside pipe due to brazing.)

>If other parts (such as valves, flexible tubes, etc.) are in close proximity, wrap them with cloth wetted with water.

14. Refrigerant Piping Support

The pipe support shall be engineered to allow free expansion to occur. When a segment of pipe is mounted between two fixed points, provisions must be provided to allow pipe expansion to naturally occur. The most common method is the inclusion of expansion loop or U-bends mounted in the horizontal plane. When expansion loops are placed in a vertical riser, the loop is to be formed in a horizontal fashion resulting in a torsional movement during expansion and contraction. Each segment of pipe has a natural fixed point where no movement occurs. This fixed point is located at the center point of the segment assuming the entire pipe is insulated in a similar fashion. Ref. *Table 7* for selecting correct spacing of pipe supports.

Table 7: Recommended support spacing for copper tubes

S No	Tube OD, mm	Distance Between Supports, meters
1	16	1.8
2	22 to 30	2.4
3	32 to 58	3
4	60 to 130	3.6
5	132 to 206	4.3

15. Leak Testing

Leak testing shall be done to check proper installation of pipes and components. Procedure for leak testing is similar for HCFC, HFC and propane refrigerants. Keep the system under pressure as recommended by the manufacturer based on the refrigerant used for 15 minutes and observe for any drop in pressure. If there is any drop in pressure, identify the leak and rectify it. Use of soap solution for leak testing is permitted when the system is under positive pressure. Apply soap solution on each joint with the help of a brush and look for leakage, if any.

15.1 Test Pressure – High Side and Low Side:

>High Side: The area from compressor discharge shut off valve to the inlet of expansion valve. High side has to be tested to the high test pressure which is 1.5 times the maximum condensing temperature of the refrigerant used.

>Low Side: The area from the outlet of expansion valve to the suction service shut off valve on compressor. Low side has to be tested to the lower pressure which is 1.5 times the maximum suction pressure / standing pressure corresponding to the maximum ambient temperature.

15.2 Suction Lines: Horizontal suction lines shall slope away from the evaporator toward the compressor at the rate of 1 in 50 for good oil return. When multiple evaporators are connected in series using a common suction line, the branch suction lines must enter the top of the common suction line. For dual or multiple evaporator systems, the branch lines to each evaporator should be sized for the evaporator capacity. The main common line shall be sized for the total system capacity. All suction lines must be insulated by recommended insulation material of proper thickness as per design.

15.3 Suction Line Risers: Prefabricated wrought copper traps are available, or a trap can be made locally. The suction trap must be the same size as the suction line. For long vertical risers, additional traps may be necessary. Generally, one trap is recommended for each length of pipe (approximately 600 mm) to insure proper oil movement.

A suction line trap (Ref. *Figure 22 a*) shall be installed at the point where piping changes the direction of refrigerant flow from any horizontal run to an upward vertical run.

15.4 Liquid Lines: Liquid lines shall be sized for minimum pressure drop to prevent 'flashing'. Flashing in the liquid lines would create additional pressure drop and poor expansion valve operation. If a system requires long liquid lines from the receiver to the evaporator or if the liquid has to rise vertically upward any distance, the losses should be calculated to determine whether or not a heat exchanger is required. The use of a suction to liquid heat exchanger may be used to sub cool the liquid to prevent flashing. This method of sub cooling will normally provide no more than 12ºC sub-cooling on high pressure systems.

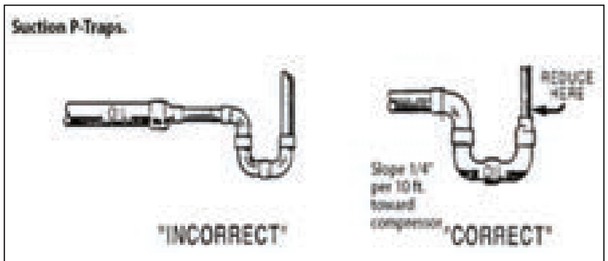


Figure 22 a: Use correct U trap in suction line

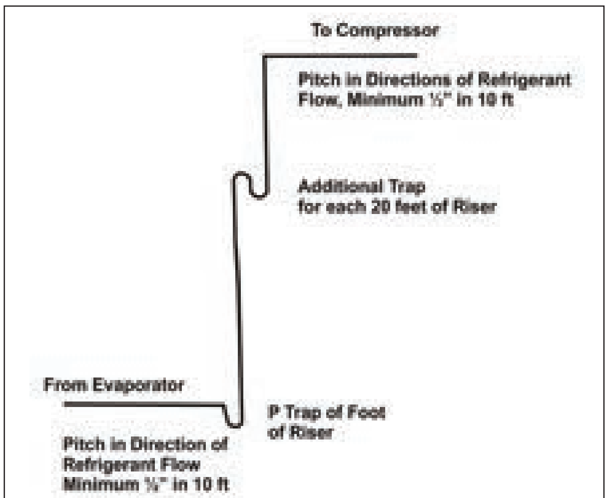


Figure 22 b: Typical suction line riser

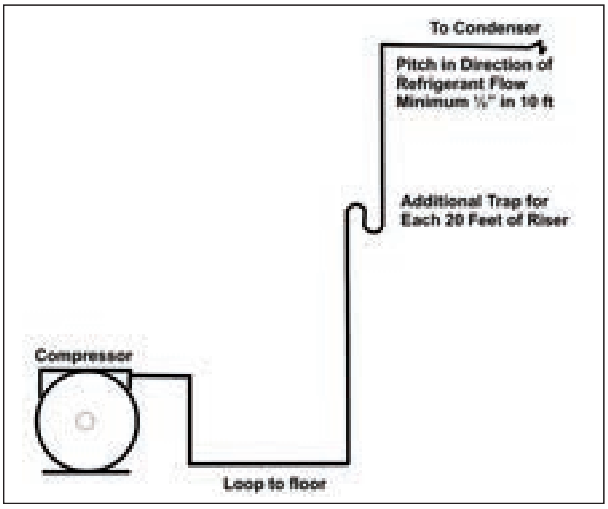
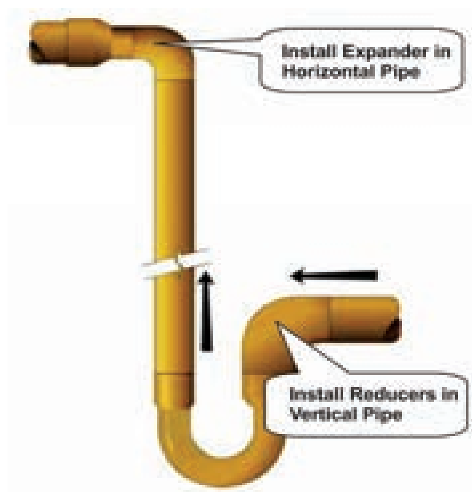
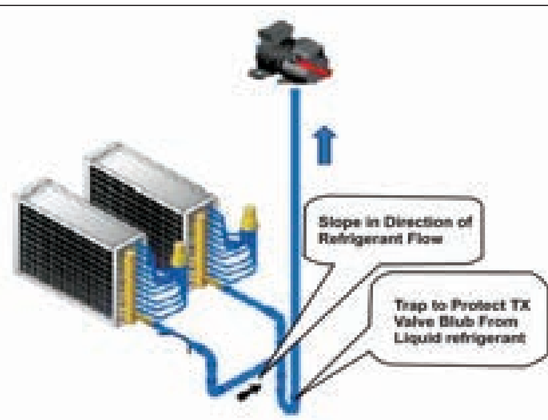


Figure 23: Typical discharge line riser



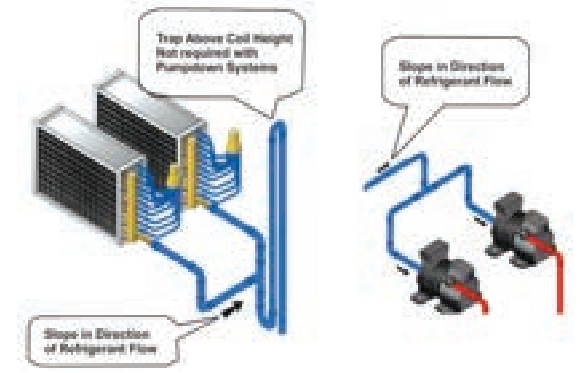
Source: McQuay Refrigerant Piping Design Guide

Figure 24: Method of reducing pipe dia. for suction and discharge risers



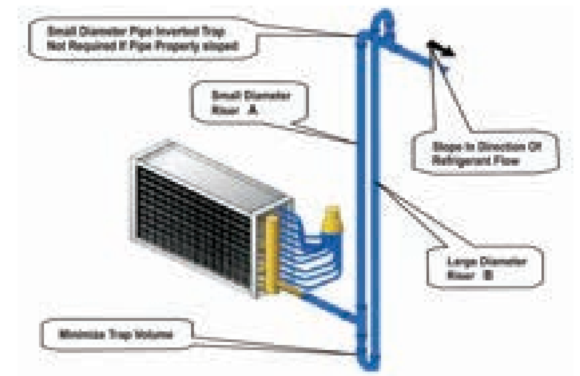
Source: McQuay Refrigerant Piping Design Guide

Figure 25: Typical refrigerant line when compressor is above evaporator



Source: McQuay Refrigerant Piping Design Guide

Figure 26: Typical refrigerant line when compressor is below evaporator



Source: McQuay Refrigerant Piping Design Guide

Figure 27: Double Suction Riser

15.5 Hot Gas Line: Hot gas line from the compressor discharge to the condenser (highest point) with minimum bends and size to deliver the designed capacity.

Following schematic diagrams are provided for illustration purposes. Please follow site issued approved drawings in all cases.

15.6 Flushing of Refrigerant Piping

>Attach a pressure regulator on a nitrogen cylinder.

>Connect the charge hose from the pressure regulator to the outdoor unit liquid piping side service port before its connection to the indoor or outdoor unit piping.

>Open the main valve on the nitrogen cylinder and set the pressure regulator to 0.5 MPa (72.5 psi).

>Verify that the nitrogen is flowing through the piping correctly.

> When flushing, block the open end of the piping with a wood insulation block. When the pressure becomes too high, quickly remove the block.

15.7 Pressure Testing of Refrigerant Piping

>First test the entire system to the low pressure and make sure that there are no leaks. Keep all the valves in the system open.

>Shut off the discharge service shut off valve/s and liquid line service valve/s.

> Apply high pressure to the high side only and test the system for leaks.

15.7.1 Methods adopted for pressure testing:

- ➢ Use soap solution to detect leaks: Air leaking from a joint turns the soap solution film to visible bubble and thus the leaky spot is identified.
- ➢ Apply into the system the desired test pressure using nitrogen. Avoid using carbon dioxide if nitrogen is not available, as much as possible.
- ➢ Smear soap solution of proper concentration over every joint and over the pipe seams totally.
- ➢ Observe formation of bubbles if any.
- ➢ Stop the leaks without pressure inside preferably.
- ➢ Pressure test again till you are sure that there are no more leaks.

15.8 Halide Leak Detector: A burning flame which is generally blue in color will turn green when any of the halogen gases (fluorine, chlorine, bromine or iodine) come near the flame.

Note: This method is not suitable for AMMONIA systems or for any system using a fluid other than a halogen gas.

- ➢ Apply a pressure up to 5 lb into the system using R 22 / 410A/ R32. Increase the test pressure to the desired level using Nitrogen or Carbon-di-oxide.
- ➢ Go over each and every joint / seam with the open end of the feeler tube.
- ➢ Observe for change in color of the flame and thus locate the leak.
- ➢ Stop the leaks without pressure inside preferably.
- ➢ Pressure test again till you are sure that there are no more leaks.

15.9. Electronic Leak Detector: Electronic instruments are available to detect presence of halogen gases in the vicinity of the instrument. The instrument can be adjusted to monitor leaks of different magnitudes, leaks such as one ounce per year per leaky joint.

16. Evacuation

The system shall be free from air, moisture, and non-condensable gases to ensure proper and efficient operation of the unit. Therefore, it is important to evacuate the IDU during installation of the air conditioner. For deep vacuum, a suitable two stage rotary vane vacuum pump shall be deployed (100-120 L/m and blank-off 20 microns). The evacuation shall reach 500 or lower level. In the absence of any micron vacuum gauge, the vacuum pump shall be run for at least about 15 minutes after the Bourdon type vacuum gauge reading shows minus 760 mm/zero millibar (at sea level).

16.1 Vacuum Standing Test

> Using a good quality vacuum pump, draw the desired vacuum within the entire system.

> Note down the data, i.e. time, temperature of surrounding air and the quantum of vacuum reached.

> Close the valves leading to the vacuum pump.

> On the next day at the same time (i.e., after 24 hours), observe the vacuum in the system and the temperature of air surrounding the system.

16.2 Extent of Vacuum Required: The limit specified should be acceptable and practicable. To remove moisture to the maximum extent in the field, we can examine the boiling point of water being 32ºF at 0.18 inch of mercury i.e., 4.5 mm i.e., a vacuum of 29.74 inches (755 mm of mercury) or 4500 microns. This limit is very practical in the field.

> Aim at 30 inches (760 mm) in order to have a better system for hermetic / semi-hermetic compressor systems.

17. Expansion Tank and Air Separator

17.1 An expansion tank is used in a chilled water system to accomplish three main tasks, (1) accommodate thermal expansion of the chilled water, (2) maintain positive pressure in the system at all times and (3) maintain net positive suction head at the chilled water pump(s). The expansion tank system shall be connected to air separator in the chilled water system for its proper functioning. The three types of expansion tanks are (1) open, (2) closed and (3) diaphragm.

17.2 Expansion tanks are closed containers supplied as pressure vessels that incorporate an internal bladder and gas charge. They are designed to allow the gradual ingress/egress of liquid from the attached system in order to prevent over-pressure or vacuum conditions if the volume of the liquid in the system changes due to temperature, or some other reason.

17.3 The air separator shell is at least 3 times the inlet and outlet pipe diameter. This assures maximum velocity reduction in order to develop the highest possible air separation efficiency. The separated air is easily directed upwards through the tube and vented in air elimination systems or returned to the compression tank in air control systems.

17.4 Typically this type of vessel is designed to allow the ingress and egress of liquids at a much lower rate than might be typical for a surge vessel. Expansion tanks are normally provided with an internal bladder, or membrane to separate the process liquid from the gas charge. Bladders, or membranes are used because they separate the liquid from the gas and prevent absorption of the gas by the liquid. They also prevent escape of the gas charge from the vessel when the system is depressurized.

Internal bladders will be supplied in Butyl, Nitrile or Viton rubbers, depending on the compatibility of the process liquid with the rubber as well as the operating conditions in which the tank will work.

Sizing of the vessel will depend upon the demands of the system, as well as the working pressure range and temperature.

17.4.1 The shell of an expansion tank should be ASME certified and should also be capable of withstanding the pressures within the system. Typically, the shell is rated for 1000 kPa and most shells are steel.

17.4.2 The diaphragm/bladder shall be suitable to withstand the corrosiveness of the air/water or glycol. The material of the diaphragm/bladder is typically a plastic like polypropylene or a rubber like butyl.

17.4.3 A shut off valve shall be provided on the system connection between the chilled water system and the expansion tank. The shut-off valve allows to disconnect the expansion tank so it can be repaired or replaced.

17.4.4 In order to repair the tank, the water must be drained from the expansion tank. The drain valve shall be at the lowest point of the tank and shall be in-between the shut off valve and the expansion tank.

17.4.5 An air valve is used to charge the bladder/ diaphragm with compressed air.

17.4.6 The expansion tank shall be supported by either hanging it from the ceiling or wall or floor. The expansion tank shall not be supported by the piping.

17.5 Expansion Tank Location

17.5.1. When locating the tank at the CHW Pump suction, near the lowest point in the system, the minimum and maximum pressures will be higher than the tank at the highest point. This is because the lowest point will have the pressure from the elevation acting upon this point, it is assumed that the minimum temperature is 4ºC and the maximum temperature is 40ºC. The benefit of locating the tank at the CHWP suction is that the expansion tank is typically easier to maintain near the pumps and chillers.

17.5.2 The tank location is a point of constant pressure when the pump is turned on and off, assuming temperature remains constant. Thus, the tank is typically not located on the discharge side of the pump because this means that regardless of when the pump is turned on or off, the discharge of the pump will have the same pressure.

17.5.3 When the tank is located at the highest point, the maximum and minimum pressures will be lower. Locating the tank at the highest point with the lower pressures will result in a smaller tank. The disadvantage is the maintenance issues with repairing and replacing a tank at the highest point in the chilled water system.

17.5.4 Bladder style expansion tanks are used in 'air elimination' systems. An automatic air vent is to be installed in the connection at the top of the automatic vents can also be installed at other high points in the system to assure an air free system.

17.5.5 Insulation of expansion tank shall be expanded polystyrene (T.F. quality) of thickness not less than 50 mm, polyurethane foam / polyisocyanurate foam not less than 40 mm. It shall be applied as under:

- ➢ Surface shall be thoroughly cleaned with wire brush and rendered free from all dust and grease.
- ➢ Two layers of hot bitumen or cold adhesive CPRX or quick setting fire resistive mastic compound shall be applied.
- ➢ The insulation slabs will then be fixed in one layer and joints shall be sealed with hot bitumen or CPRX or cold adhesive quick setting fire resistive mastic compound.
- ➢ The insulation slab then shall be covered with 0.63 mm x 19 mm G.I. wire mesh netting which shall be fixed to insulation with brass / G.I. nails.
- ➢ The insulation shall then finally be finished with aluminum cladding of thickness not less than 0.5 mm and lined with 40 mil Polysurlyn coating on inner side.

18. Air Separator

18.1 The standard air separator is constructed to meet ASME code and is stamped for design pressure and temperature ratings of 125 psig (862 kPa) and 350°F (177°C).

18.2 The ideal place to locate an air separator in a hydronic system is where the water temperature

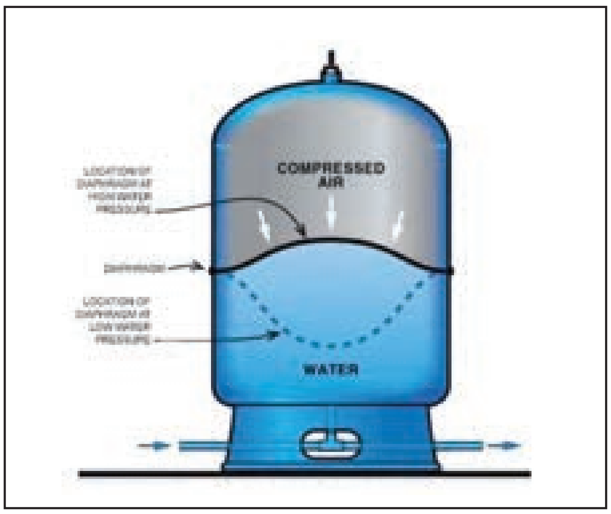


Figure 28: Expansion tank

Figure 29: Air separator

is high and the pressure is low. The solubility of the dissolved gases in the water is lowest at these conditions. In a heating system, the ideal location is at the outlet of the heat source. For chilled water systems, locate the separator at the return to the chiller.

18.3. The baffle is a barrier between the air-free water and the separated air. It assures that only air-free water is transferred to the outlet connection while separated air is directed to the collector tube.

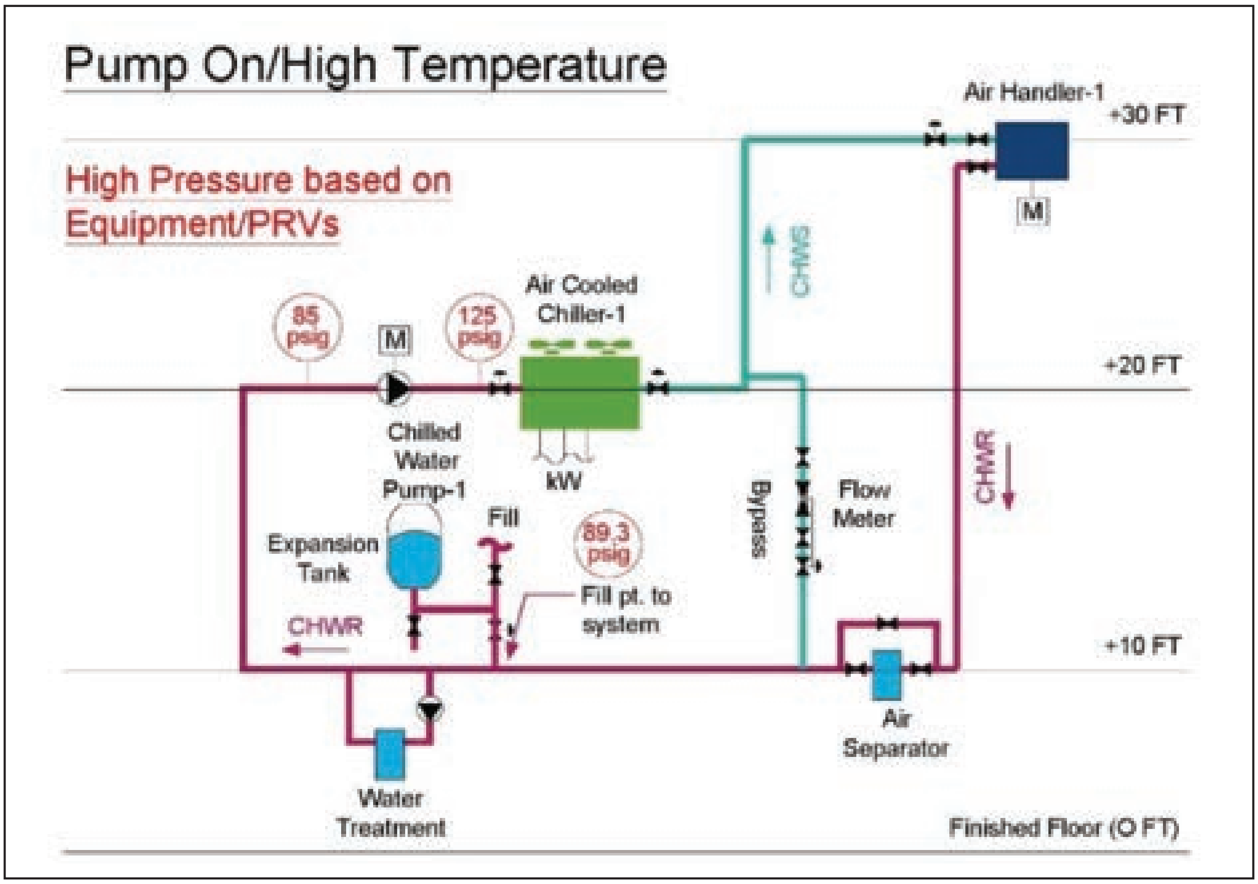


Figure 30: Typical arrangement of expansion tank with air separator in chilled water system

Chapter 13

Thermal and Acoustic Insulation

1.0 Insulation Material

1.1 Insulation of Water Piping, Pumps and Tanks

- Expanded polystyrene (T.F. quality)
- Resin bonded glass wool, Rockwool non-combustible grade
- Polyvinyl nitrile rubber (closed cell foam), Class O rated
- XLPE (closed cell cross linked polyolefin foam), Class O rated
- Polyurethane foam Class 1 rated
- Polyisocyanurate foam Class O rated

Expanded polystyrene (T.F. quality) shall be used for pipe insulation inside the A.C. plant room, exposed to outside or buried in ground. In the case of expanded polystyrene (TF quality), resin bonded glass wool or Rockwool the pipe insulation should be in rigid sections in two halves and pre-formed to fit snugly on to pipes (up to pipe sizes for which the pre-formed sections are manufactured). For higher pipe sizes, insulation slabs shall be used.

Polyvinyl nitrile (closed cell rubber foam) available in tube shapes for sliding on to the small dia. pipes can be used provided it is certified for fire retardant properties.

Polyurethane foam and polyisocyanurate foam, closed cell insulation pipe sections shall be used for pipes (up to pipe sizes for which the preformed sections are manufactured) for higher pipe size, insulation slabs or beveled logs should be used.

However, all these shall need to be covered with vapor barrier and cladding with aluminum sheet.

1.2 For Insulation of Duct Work

- Resin bonded glass wool, Rockwool non-combustible grade
- Polyvinyl Nitrile (Closed cell rubber foam), Class 0 rated
- Polyisocyanurate Foam, Class 0 rated

1.3 For Acoustic Lining of Duct Work and AHU Rooms

- Resin bonded glass wool, non-combustible grade
- Resin bonded Rock wool, non-combustible grade

1.4 For Suction Line, Chilled Water Pipe and Chiller Insulation

- Expanded polystyrene (T.F. quality)
- Polyvinyl nitrile (closed cell rubber foam) Class 0 rated
- Resin bonded glass wool, Rockwool non-combustible grade
- Polyurethane foam, Class 1 rated
- Polyisocyanurate Foam, Class 0 rated

1.5 For Double Skin AHUs

- Polyurethane foam (PUF insulation), Class 1 rated
- Polyisocyanurate Foam (PIC Insulation), Class 0 rated
- Open cell Nitryl Foam class 0 rated

1.6 Pre-insulated Ducts

- Polyisocyanurate foam insulation, Class 0 rated

1.7 Pre-insulated Pipes

- Polyurethane foam insulation, Class 1 rated

2.0 Material Specifications

2.1 For Thermal Application on Pipes

Please refer *Table 13.1*.

Table 13.1: Material specifications for thermal application on pipes

Material	Minimum **Density (kg/m³)**	Maximum Thermal Conductivity **(W/m.K at 10ºC mean temp.)**
Resin bonded glass wool / Rockwool	80 / 144	0.031
Expanded polystyrene (TF)	20	0.035
Polyvinyl nitrile foam	55	0.034
Polyurethane foam	36	0.021
Polyisocyanurate foam	32	0.021
Cross linked polyethylene	25	0.034

2.2 For Thermal Insulation of Ducts

Please refer *Table 13.2.*

Table 13.2: Material specifications for thermal insulation on ducts

Material	Minimum Density (kg/m³)
Resin bonded glass wool	24
Polyvinyl nitrile foam	55
Resin bonded Rockwool	48
Polyisocyanurate foam	32
Cross linked polyethylene	25

Glass wool, Rockwool Insulation used for duct insulation shall be factory faced with aluminum foil on one side reinforced with kraft paper and fused to the insulation material.

Polyvinyl nitrile foam Insulation used for duct insulation shall be factory faced with aluminum foil on one side.

2.3 For Acoustic Lining

Please refer *Table 13.3.*

Table 13.3: Material specifications for acoustic lining

Application	Material	Minimum Density (kg/m³)
Duct	Resin bonded glass wool / Rockwool	32 / 48
AHU room	Resin bonded glass wool/ Rockwool	32 / 48
	Open cell nitryl foam	140-200

2.4 Resin bonded glass wool insulation and resin bonded Rockwool insulation shall conform to IS 8183 for slabs and IS 9842 for pipe sections. The specification for expanded polystyrene shall conform to IS-4671. The specification for polyurethane foam and polyisocyanurate foam shall conform to IS 12436. The specification for nitryl foam shall conform to EN 14304 / DIN EN 8497.

2.5 Expansion Tank Insulation

Expanded polystyrene insulation of density not less than 20 kg/m³ shall be used.

Polyurethane foam insulation of density not less than 36 kg/m³ shall be used.

Polyisocyanurate foam insulation of density not less than 32 kg/m³ shall be used.

3.0 Insulation Thickness

The thickness of insulation shall be as indicated below unless specified otherwise in the tender specifications.

3.1 For Pipe Insulation (Chilled Water as Well as Hot Water Application)

Please refer *Table 13.4.*

Table 13.4: Insulation thickness for pipe insulation

Pipe Size (mm)	Glass Wool / Rockwool / Expanded Polystyrene (mm)	Polyurethane / Polyisocyanurate Foam (mm)	Nitryl Foam (mm)
150 and below	50	30-40	19-25
Above 150	75	50-60	32

3.2 For Duct Insulation

Please refer *Table 13.5.*

Table 13.5: Insulation thickness for pipe insulation

Application	Glass Wool / Rockwool / (mm)	Nitryl Foam / Cross-linked Polyethylene (mm)	Polyisocyanurate Foam (mm)
Thermal for AC area	30-40	19	25
Thermal for Non-AC area	50	25	40
Acoustic	50	25	

3.3 For Room Acoustic Lining

Resin bonded glass wool	50 mm
Resin bonded Rockwool	50 mm

3.4 For Pumps

Expanded polystyrene TF quality	50 mm
Polyurethane / polyisocyanurate foam	40 mm
Open cell nitryl foam	25 mm

3.5 Chiller Insulation

Polyvinyl rubber insulation 19 mm

Polyurethane / polyisocyanurate foam insulation 40 mm

Cross linked polyethylene foam 19-25 mm

3.6 Expansion Tank

Expanded Polystyrene (TF quality) insulation 50 mm

Polyurethane / Polyisocyanurate foam Insulation 40 mm

3.7 Pre-insulated Ducts

- Pre-insulated ductwork made of polyisocyanurate sandwich panels, comprising of polyisocyanurate rigid foam board faced on both sides by embossed aluminum foil.
- Physical characteristics of the panels shall be as in *Table 13.6.*

Table 13.6: Physical characteristics of pre-insulated duct panels

Thickness of Panels	Air-conditioned Areas		Plant Rooms		Exposed to Weather	
	20	mm	30	mm	30	mm
Thickness of aluminum foil	80/80	microns	80/200	microns	80/200	microns
Density of the foam	45	kg/m³	45	kg/m³	45	kg/m³
Finishing of aluminum	Embossed	Embossed	Embossed	Embossed	Embossed	Embossed

Close cell rigid expanded polyisocyanurate (PIR) foam, CFC free, density 45 kg/m³, chemically inert and insoluble, vermin, proof, fungus proof, non-metabolizable, conforming to IS 12436.

Thermal conductivity: 0.021 W/m.K or better. Water absorption shall be less than 0.5% by 24 hours immersion test.

Shall be tested by NABL approved laboratories in India for fire propagation properties conforming to BS 476 Part 6 and 7 for Class O.

The aluminum foil covering the panel to be maintained intact after installation to ensure vapor barrier continuity.

3.7.1 Duct Construction from Pre-insulated Panels

The ducting shall be fabricated from factory supplied standard pre-insulated panels. The thickness of the panels for rectangular ducts shall be as per *Table 13.7.*

Table 13.7: Panel thickness for rectangular ducts fabricated from pre-insulated panels

Maximum Size of the Duct in mm	Thickness in mm	Internal Supports *
Up to 750 mm	20 mm	Not Required
751 to 1200 mm	20 mm	Required
1201 to 1800 mm	30 mm	Required
1801 and above	30 mm	Required

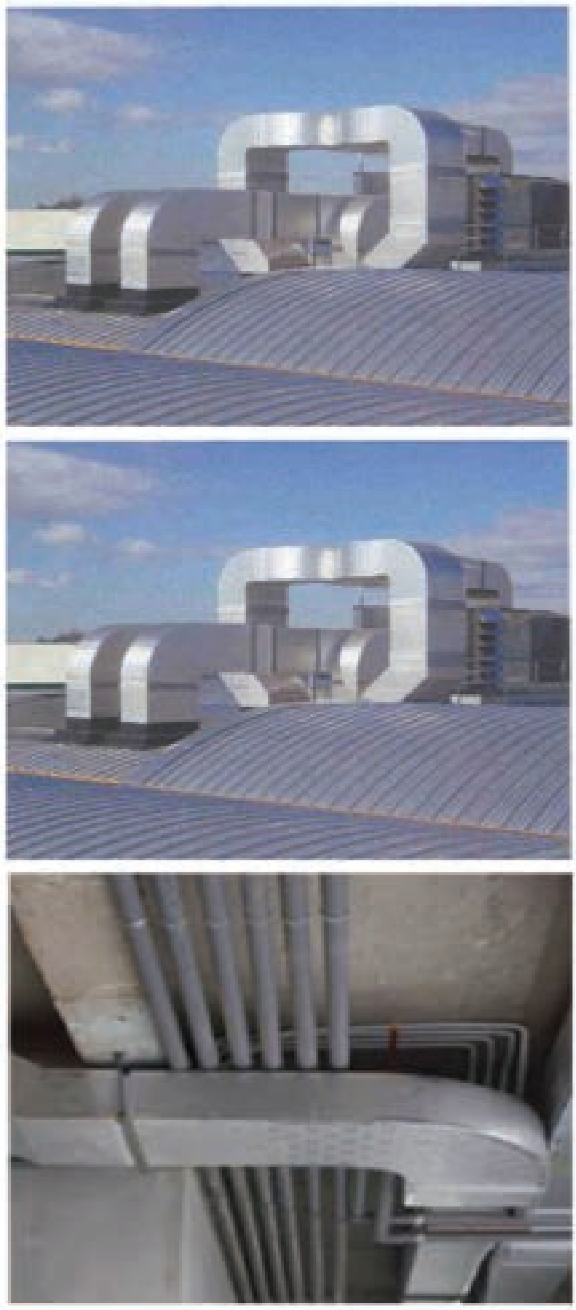


Figure 13.1 a, b, c: Pre-insulated ducts

Internal supports shall be in the form of 12 mm dia. aluminum/polymer stiffeners secured with polymer/aluminum discs and the support intervals to be given in a table by manufacturers.

3.7.2 Joint System

The joints between the ducts shall be with tongue and groove connectors or male-female connection system for small sizes up to 500 mm and for bigger sizes more than 500 mm aluminum / polymer invisible flanges and slide-in-channel to be used and to be connected by special cover corners, having a holding pin, which goes inside the flange and the insulation, to avoid any field connection and to give the system more strength.

Ductwork shall be installed, using supports, as described in construction drawings and according to manufacturer's requirements.

3.8 Acoustic Insulation

The panels shall ensure a sound attenuation (tentatively 14 dBA) and hence the thickness of insulation required shall be as mentioned in *Table 13.8.*

Table 13.8: Insulation thickness for sound attenuation

Item	Description	Thickness of Insulation – Length
Rockwool 48 kg/m³	12 mm	Initial – 3 m
Glass wool 24 kg/m³	12 mm	Initial – 3 m
Open cell nitrile rubber	10 mm	Initial – 3 m

3.9 Pre-insulated Pipes

i) The pipe shall be MS ERW or PVC as per specification.

ii) The pipe insulation shall be polyurethane foam with minimum density of 36 kg/m³, 90% minimum closed cell content, minimum compressive strength of 2.7 kg/cm², and thermal conductivity of 0.023 W/m.K. The insulation shall completely fill the annular space between the service pipe and jacket and shall be bonded to both the service pipe and the jacket.

iii) The cladding shall be spirally wound or plain G.I. or aluminum sheet as specified in SOR for pipes installed on surface.

iv) For pipes installed on surface the insulation (PUF) shall be provided to the insulation thickness and cladding thickness as in *Table 13.8.*

Table 13.9: PUF insulation and cladding thickness for pipes installed on surface

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	30	0.457 mm (26g)	0.559 mm (24g)
2	25 mm	30	0.457 mm (26g)	0.559 mm (24g)
3	32 mm	30	0.457 mm (26g)	0.559 mm (24g)
4	40 mm	30	0.457 mm (26g)	0.559 mm (24g)
5	50 mm	30	0.457 mm (26g)	0.559 mm (24g)
6	65 mm	40	0.457 mm (26g)	0.559 mm (24g)
7	80 mm	40	0.457 mm (26g)	0.559 mm (24g)
8	100 mm	40	0.457 mm (26g)	0.559 mm (24g)
9	125 mm	40	0.457 mm (26g)	0.559 mm (24g)
10	150 mm	40	0.457 mm (26g)	0.559 mm (24g)
11	200 mm	50	0.457 mm (26g)	0.559 mm (24g)
12	250 mm	60	0.457 mm (26g)	0.559 mm (24g)
13	300 mm	50	0.457 mm (26g)	0.559 mm (24g)
14	350 mm	50	0.457 mm (26g)	0.559 mm (24g)
15	400 mm	50	0.457 mm (26g)	0.559 mm (24g)
16	450 mm	50	0.457 mm (26g)	0.559 mm (24g)
17	500 mm	60	0.559 mm (24g)	0.711 mm (22g)
18	550 mm	60	0.559 mm (24g)	0.711 mm (22g)
19	600 mm	60	0.559 mm (24g)	0.711 mm (22g)
20	650 mm	60	0.559 mm (24g)	0.711 mm (22g)
21	700 mm	60	0.559 mm (24g)	0.711 mm (22g)
22	750 mm	60	0.559 mm (24g)	0.711 mm (22g)
23	800 mm	60	0.559 mm (24g)	0.711 mm (22g)

v) Underground systems shall be buried in a trench not less than 600 mm deeper than the top of the pipe and not less than 450 mm wider than the combined OD of all piping systems. A minimum thickness of 600 mm of compacted backfill over the top of the pipe shall be provided.

vi) Trench bottom shall have a minimum of 150 mm of sand, pea gravel or specified backfill material, consolidated to suit operating weight and to act as a cushion for the piping.

vii) For pipes buried in ground outer protective insulation jacket shall be seamless sheets or extruded, black, UV resistant, high-density polyethylene (HDPE).

viii) For leak identification (optional) purpose, two-wire diagnostic wiring shall be provided.

ix) Fittings shall be fabricated at site over the carrier pipe and correct quantity of PUF shall be poured manually.

x) Field joints insulation shall consist of PUF poured manually in a site-fabricated GI / aluminum or HDPE cladding fixed around the joint.

xi) For pipes buried in ground, minimum thickness of the HDPE jacket and PUF shall be as in *Table 13.10.*

Table 13.10: Minimum thickness of HDPE jacket and PUF for pipes buried in ground

S. No.	MS Pipe Dia. (mm)	PUF Thickness (mm) (minimum)	Thickness of HDPE Cladding (mm) (minimum)
1	20 mm	30	3
2	25 mm	40	3
3	32 mm	30	3
4	40 mm	40	3
5	50 mm	40	3
6	65 mm	40	3
7	80 mm	40	3
8	100 mm	40	3
9	125 mm	40	3
10	150 mm	55	5
11	200 mm	65	5
12	250 mm	65	5
13	300 mm	65	5
14	350 mm	65	5
15	400 mm	75	5
16	450 mm	75	5
17	500 mm	75	5
18	550 mm	75	5
19	600 mm	85	5
20	650 mm	85	5
21	700 mm	85	5
22	750 mm	105	5
23	800 mm	105	5

4.0 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 or quick setting fire resistive mastic compound. All joints shall be staggered and sealed. The second layer of insulation wherever required shall be similarly applied over the first layer with application of cold adhesive on top of first layer and inner side of second layer insulation.

(ii) Pipes shall be pre insulated at factory or at a workshop at site.

4.1 For pipes laid inside the building, the insulation over the pipe work shall be finished with 0.63 mm thick aluminum sheet cladding having Insulation on inner side over a vapor barrier of 120 g/m^2 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 up to date) at the joints or quick setting fire resistive mastic compounds to be applied between joints. The aluminum sheet joints to be grooved with grooving machine (both straight and longitudinal joints). Vapor barriers comprising of cold quick setting fire resistive mastic compound in 2 layers with glass cloth embedded in between shall also be acceptable. Additionally, 50 mm wide aluminum tape can be applied ones the joints.

4.2 For pipes outside the building laid above ground the finishing over the pipe insulation shall be finished with 0.63 mm G I sheet cladding or aluminum sheet cladding with 40 mil Polysurlin lining on inner side over a vapor barrier of 120 g/m^2 polythene sheet with 50 mm overlap and tied down with lacing wire and complete with type 3 grade I roofing felt strip applied by means or cold quick setting fire resistive Mastic compounds to be applied between joints. The aluminum sheet joints to be grooved with grooving machine (both straight and longitudinal joints). Vapor barriers comprising of cold quick setting fire resistive mastic compound in two layers with glass cloth embedded in between shall also be acceptable. Additionally, 50 mm wide aluminum tape can be applied ones the joints.

4.3 For pipes outside the building laid underground the insulation shall be covered with 500-gauge polythene faced hessian (polythene facing outwards), with 50 mm overlap. All joints shall be sealed with cold adhesive. 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 two layers of each 10 mm and shall be water proofed by applying hot bitumen and fixing tar felt over the plaster. It shall be finally finished with a coat of hot bitumen.)

Alternatively, 3-5 mm HDPE sheet cladding combined with hot air welding and sealing of the joints. In case of pre insulated pipes, buried underground, a water leakage sensing wire (optional) shall also be provided, to detect the location of water leakage at later date.

(a) In case of factory pre insulated pipes, all joints shall be properly insulated at site as per recommendation of manufacturer.

(b) Factory made pipe sections can be with aluminum foil lamination, 0.5 mm thickness, which will act as a vapor barrier and finish material in place of cladding where pipes are inside building. Otherwise, GI and aluminum cladding to be provided having 40 mil Polysurlyn coating on inner side. After application with adhesives, the joints will be sealed with aluminum tape.

Figure 13.2: Pre insulated pipe with HDPE cladding

4.4 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.

4.5 Pre-insulated valves with polyurethane foam insulation and HDPE sheet cladding with foam density of 55-70 kg/m^3 and with 3-5 mm thick HDPE sheet of density 940-950 kg/m^3 shall be accepted. Similarly, pre-insulated flanges are also acceptable.

Figure 13.3: Pre-insulated valve

Check list 13.1: Checklist for pipe insulation

Check List for Pipe Insulation				
Project:		**Location:**		
Sr. No.	**Check List**	**Verification**		
		Yes	**No**	
1	Ensure drawing used for installation are current and approved for construction (Drg Ref:………………………..)			
2	Mock up approval vide Doc. No*____________________			
3	Work carried out as per Method Statement No*__________/ approved submittals/tender specs			
4	Insulation thickness and material as per approved submittals ref:……./ tender specs			
5	Pressure testing completed Report No.*			
6	Pipe is cleaned and required primer application is done over pipes.			
7	Uniform application of adhesive			

8	Insulation application is uniform		
9	Check joints are sealed properly		
10	Vapor barrier is applied and no wrinkles /holes are visible on the same		
11	Finishing of sand cement plaster by application of chicken wire mesh and 12 mm thick sand cement plaster.		
12	Application of sand cement plaster is smooth and uniform without any cracks		
13	Finishing with aluminum / GI cladding with require thickness		
14	There are no wrinkles/ dents in cladding and application is smooth and uniform		
15	Check sleeves are provided for insulated pipe is passing through walls		
16	Painting / identification of pipes with specific color code and arrows		
17	PUF Support Blocks are applied at support locations		
18	Check insulation is done properly at terminations and sealed		

Comments:	
Checked By	Approved By
Signature	Signature
Name	Name
Date	Date
Checks 1) * Write relevant ref no. 2) Checks not applicable mark NA	

Figure 13.4 a, b, c: Pipe insulation with and without foil backing

Figure 13.5: PUF pipe sections

Figure 13.6: Piping with insulation finished with aluminum cladding

5.0 Application of Insulation on Pumps

Expanded polystyrene (TF quality) 50 mm thickness or polyurethane foam / polyisocyanurate foam of 40 mm shall be sandwiched between two aluminum sheets of 0.5 mm thickness and properly clamped to pump in two semicircular sections.

6.0 Application of Insulation on Expansion Tank

Insulation of expansion tank shall be expanded polystyrene (T.F. quality) of thickness not less than 50 mm, polyurethane foam / polyisocyanurate foam of 40 mm. It shall be applied as under:

- Surface shall be thoroughly cleaned with wire brush and rendered free from all dust and grease.
- Two layers of hot bitumen or cold adhesive CPRX or quick setting fire resistive mastic compound shall be applied.

- The insulation slabs will then be fixed in one layer and joints shall be sealed with hot bitumen or CPRX or cold adhesive quick setting fire resistive mastic compound.
- The insulation slab then shall be covered with 0.63 mm x 19 mm G.I. wire mesh netting which shall be fixed to insulation with brass / G.I. nails.
- The insulation shall then finally be finished with aluminum cladding of thickness not less than 0.5 mm and lined with 40 mil Polysurlyn coating on inner side.

7.0 Application of Thermal Insulation on Duct

7.1 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.

7.2 Two coats of cold adhesive CPRX or quick setting fire resistive mastic compound shall be applied over the duct.

7.3 GI stick pins to be used in case of glass wool and rockwool Insulation.

Check list 13.2: Checklist for duct insulation

Check List for Duct Insulation			
	Location		
Sr. No.	**Check List**	**Verification**	
		Yes	**No**
1	Ensure Drawing used for installation are current and approved for construction (Drg Ref:……………………….)		
2	Mock up approval vide Doc. No*___________________		
3	Insulation thickness and material as per approved submittal ref/ tender specs		
4	Method statement is approved wide Doc No.*		
5	Duct surface is cleaned before application		
6	Duct joints are sealed properly before application.		
7	Check application of adhesive and stick pins is proper		
8	Joints are sealed properly		
9	Finishing is as per approved submittal ref……/tender specs		
10	Sleeves are provided for insulated duct passing through walls		
11	No damage to the insulation material after application		
12	Collars and droppers have been taken before the insulation		
13	All flange joints are adequately insulated by providing insulation castable		
14	PUF/ rubber sheet is installed between insulation and support or at the edges		
15	Check insulation at termination points is done properly and sealed		
16	Identification of duct is done		

Comments:	(Attach separate Sheet, if required)
Checked By	Approved By
Signature	Signature
Name	Name
Date Date	
Checks 1) * Write relevant ref no 2) Checks not applicable mark NA	

Figure 13.7 a, b: Duct insulation with Rockwool/glass wool

Figure 13.8: Duct insulation with nitrile rubber

8.0 Application of Acoustic Duct Lining

Where specified in Drawings, ducts shall be lined internally with acoustic insulation as detailed below:

8.1 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.

8.2 Then 25 x 25 mm² section of minimum 1.25 mm thick G.I. sheet shall be fixed on both ends of the duct piece.

8.3 The insulation slabs shall then be fixed between these sections of ducts using CPRX adhesive or quick setting fire resistive mastic compound and stickpins.

8.4 The insulation shall then be covered with reinforced plastic/ fiberglass tissue with proper overlap, sealing all joints so that no fiber is visible.

8.5 The insulation shall finally be covered with minimum 0.5 mm thick perforated aluminum sheet having perforations between 20-40%. The aluminum sheet shall have 40 mil Polysurlyn lining on inner side.

Checklist 13.3: Check list for acoustic duct lining

Check List for Duct Acoustic Lining			
	Location		
Sr. No	Check List	Verification	
		Yes	No
1	Ensure Drawing used for installation are current and approved for construction (Drg Ref:……………………….)		
2	Mock up approval vide Doc. No*___________________		
3	Insulation thickness and material as per approved submittal ref…./tender specs		
4	Method statement is approved wide Doc No.*		
5	Duct surface is cleaned before application		
6	GI channels to hold insulation with nut bolts		
7	Adhesive application evenly on duct surface. If required used stick pins to hold the material.		
8	Application is proper.		
9	Finish with RP tissue over the insulation; no loose insulation to be visible		
10	Perforated mesh of required thickness. Use of nut bolts for proper holding		
11	No damage to the insulation material after application		
12	Collars and droppers have been taken before the insulation		

Comments:	(Attach separate Sheet, if required)
Checked By	Approved By
Signature	Signature
Name	Name
Date	Date

Checks
1) * Write relevant ref no
2) Checks not applicable mark NA

Figure 13.9: Duct acoustic insulation with glass wool

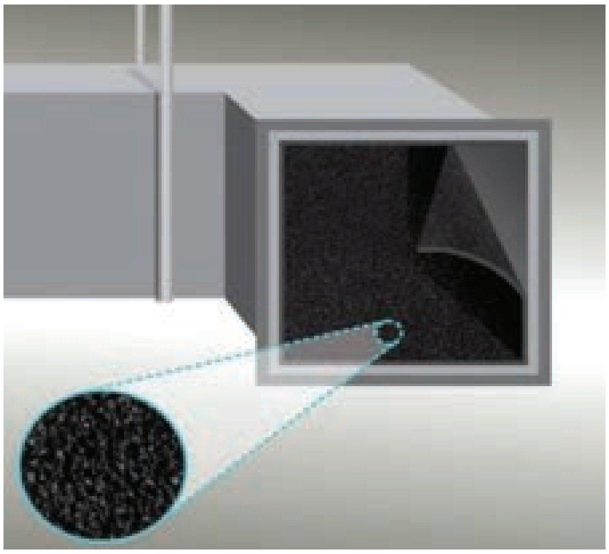


Figure 13.10: Duct acoustic insulation with open cell nitrile rubber

9.0 Application of Acoustic Lining in AHU Rooms

9.1 The wall/ roof surface should be thoroughly cleaned with wire brush.

9.2 A 610 x 610 mm frame work of 25 mm x 50 mm x 50 mm x 50 mm x 25 mm shape channel made of 0.6 mm thick GI shall be fixed to walls leaving 610 mm from floor by means of raw plugs in walls and dash fasteners. Similar frame work shall also be fixed on ceiling by means of dash fasteners.

9.3 Resin bonded glass wool / Rockwool as specified cut to size will be friction fitted in the frame work and covered with tissue paper.

9.4 Aluminum perforated sheet having perforation between 20-40% of thickness not less than 0.8 mm shall be fixed over the entire surface neatly without causing sag/ depression in between and held with screws. Sheet joints should overlap minimum 10 mm. Aluminum sheet shall have 40 mil Polysurlyn lining on inner side.

Figure 13.11: Plant/AHU room acoustic lining

9.5 Aluminum beading of 25 mm width and thickness not less than 1.00 mm shall be fixed on all horizontal/ vertical joints by means of screws.

Checklist 13.4: Check list for plant/AHU room acoustic lining

Check List for Plant Acoustic Lining			
	Location		
Sr. No.	Check List	Verification	
		Yes	No
1	Ensure drawings used for installation are current and approved for construction (Drg Ref:……………………….)		
2	Mock up approval vide Doc. No*___________________		
3	Insulation thickness and material as per approved submittal ref…../tender specs		
4	Method statement is approved wide Doc No.*		
5	GI Framework with 50 mm GI channels and 600 x 600 mm grid		
6	Wall surface is clean		
8	Application is proper; insulation is inserted properly		
9	Finish with RP tissue over the insulation; no loose glass wool		
10	Perforated mesh of required thickness.		
11	No damage to the insulation material after application		
12	Insulation at termination points is proper and sealed properly		

Comments:	(Attach separate Sheet if required)
Checked By	Approved By
Signature	Signature
Name	Name
Date	Date
Checks 1) * Write relevant ref no. 2) Checks not applicable mark NA	

10.0 Hot Insulation

10.1 Hot pipe insulation shall be as in *Table 13.11.*

Table 13.11: Minimum thickness of hot pipe insulation

	Application	Thickness (mm) (minimum)	Pipe (mm dia.)	Material
a)	Hot water pipe not exceeding 80ºC	9 / 25	12- 20	Nitrile rubber/ resin bonded rock wool/glass wool
		13 / 25	25	
		25	50 and above	-do-
b)	Steam piping for saturated	25	12-40	Resin bonded glass
	steam at less than 1 kg/cm^2	40	50-150	Wool / Rockwool
c)	Steam piping for saturated	50	12-75	Resin bonded glass
	Steam at 3 kg/cm^2	75	100 and over	Wool / Rockwool
	(145ºC)			
d)	Steam piping for saturated	75	All sizes	Resin bonded glass
	steam at 10 kg/cm^2			Wool / Rockwool
	(185ºC)			
e)	Thermic fluid at 250ºC	75	All sizes	Resin bonded glass
				Wool / Rockwool
f)	Condensate piping	25	12 – 40	Resin bonded Glass
		40	50 – 150	Wool/ Rock wool or expanded polystyrene or polyiso-cyanurate or phenolic foam

All insulation shall be in single layer.

10.2 Insulation shall be in pipe sections with reinforced aluminum foil face. The pipe shall be thoroughly cleaned with wire brush and the surface rendered free from rust. The cleaned surface shall be painted with one coat of suitable paint and the insulation applied with staggered joints. The insulation joints shall be sealed with aluminum adhesive tape and held in position with 1.0 mm wire at 600 centers and finished with aluminum cladding having 40 mil Polysurlyn lining on inner side.

10.3 Foam insulation shall be applied over the cleaned pipe surface and finished with aluminum cladding.

10.4 Pipe insulation shall be cladded with 0.5 mm aluminum sheet having 40 mil Polysurlyn lining on inner side with 50 mm overlapping joints. Cladding shall be tightly bonded to the insulated pipes with necessary grooves and held in position with metal screws.

10.5 Insulation of pumps for hot application shall be the same as for connected pipes and application similar to cold application. The insulation shall be held in position with wire netting as above but shall not be covered with hot bitumen. aluminum cladding having 40 mil Polysurlyn lining on inner side shall be done over the insulation.

11.0 Pipe Supports

The Insulation material to be used for pipe support of chilled water pipelines at various locations shall be polyurethane foam of high density 120 kg/m^3 and thickness equivalent to pipe insulation and width depending on pipe dia. The support should have inner circular shape of diameter same as the chilled water pipe. The shape of the pipe support and dimensions to be decided by the specifiers and manufacturers.

Figure 13.12: Pre-insulated pipe supports

12.0 Pipe Bends

12.1 The insulation material shall be cut into beveled lags and applied over the bends with suitable adhesive of CPRX or quick setting fire resistive mastic compound and all joints sealed with insulation cut pieces and adhesives. Finally, application of vapor barriers similar to the one applied on the pipelines.

Finally, aluminum sheet cladding having 40 mil Polysurlyn lamination on the inner side or GI sheet to be applied in thickness same as the pipe line cladding. The joints of the cladding to be grooved joints fixed with screws and sealed with mastic compound or aluminum tape. Alternatively, Factory fabricated 'L' shaped foam type insulation sections in two halves to be applied over the pipes with adhesive and tied with lacing wire.

Figure 13.13: Pipe bends

13.0 Under-deck Roof Insulation

13.1 Under-deck insulation shall be carried out using phenotherm 35kg/m³ or polyisocyanurate foam 32 kg/m³ or 48 kg/m³ resin bonded glass wool / resin bonded Rockwool rigid boards so that the R-value of the insulation should be not less than R 3.5m².ºC/w.

13.2 The surface shall be thoroughly cleaned with wire brush. 50 x 50 x 0.8 mm or 75 x 75 x 0.8 mm channel runners shall be provided at 600 mm center-to-center spacing. Apply cold adhesive CPRX or quick setting fire resistive mastic compound at 1.5 kg/m² and stick the slabs between the runners. Hold the slabs in position with 20 x 0.63 mm galvanized wire netting. Finish the insulation neatly with 10 mm gypsum or cement particle boards and fix with screws.

13.3 Apply suitable paint.

14.0 Over-deck Roof Insulation

Over-deck insultation with extruded polystyrene or polyurethane foam shall be applied as follows:

i) The R-value of the insulation shall not be less than R 3.5m².ºC/w and thickness to be calculated (R = thickness of Insulation / thermal conductivity).

ii) Clean the surface of the roof slab thoroughly.

iii) Spread blown grade bitumen 85/25 conforming to IS 702-1961 uniformly on the concrete surface at the rate of 2.5 kg/m² or cold adhesive CPRX or quick setting fire resistive mastic compound at the rate of 1.5 kg/m².

iv) Press heavy density (32 kg/m³) extruded polystyrene slabs or polyurethane foam (36 kg/m³) slab over the adhesive.

   Extruded polystyrene shall have conductivity of not more than 0.028 W/m.K and polyurethane foam not more than 0.021W/m.K at 10ºC mean temperature. Thickness to be calculated with the formula R = insulation thickness / thermal conductivity value.

v) Seal all the joints between adjacent slabs with bitumen or cold adhesive and cover the surface with bituminous kraft paper and geo textile cloth (3-6 mm).

vi) Lay minimum 20 mm thick sand cement plaster (ratio 1:4) over 22-gauge 20 mm galvanized wire mesh.

vii) Build cement mortar fillet all round at the junction of the roof slab and the parapet walls. This is done by constructing a fillet of cement plaster at the junction of roof slab and parapet walls. Smooth trowel over the entire roof. Cement plaster min 20 mm (ratio 1:4).

15.0 Over Deck Insulation (Sprayed)

Overdeck insulation with sprayed polyurethane foam as per IS 12432 of density 40-45 kg/m³ having thermal conductivity value of 0.023 W/m.K at 10ºC mean temperature.

R value shall be 3.5 m².ºC/w

Polyurethane foam will be sprayed over the RCC in multiple layers to form a jointless homogenous surface.

To provide geo-textile cloth over the insulation followed by plaster minimum 20 mm (ratio 1:4) over 22-gauge 20 mm galvanized wire mesh.

16.0 Wall Insulation

16.1 Wall Insulation shall be carried out using resin bonded glass wool or Rockwool non-combustible grade boards having density min 48 kg/m^3 or polyurethane foam / polyisocyanurate foam / extruded polystyrene foam boards of density 36 / 32 48 kg/m^3 so that the R value should not be less than R 2.5 $m^2.^{\circ}C/w$.

16.2 Internal Application

Surface to be cleaned with wire brush and then a coat of cement plaster to be applied on the wall to make it smooth and apply a coat of water based polymerized adhesive. Apply coat of water based polymerized cement adhesive on the polythene foam / polyisocyanurate foam / extruded polystyrene and press it over the wall. After approximately 2-3 hours, apply two coats of polymerized plaster over the Insulation boards to achieve thickness of min 12 mm interposing a synthetic non-metallic wire mesh in between. Upon drying of the plaster, apply paint coat.

16.3 External Application

The wall surface to be plastered smooth and then spraying polyurethane foam insulation in multiple passes to achieve the required thickness. The density shall be 40-45 kg/m^3 and thermal conductivity of 0.023 W/m.K at 10ºC mean temperature. Subsequently, apply minimum 12 mm thick polymerized plaster interposing a synthetic non-metallic wire mesh in between. Upon drying of the plaster, apply paint coat.

17.0 Exhaust Duct Insulation

Kitchen exhaust ducts to be insulated with 40-50 mm thick ceramic fiber blankets encased in aluminum foil conforming to IS 15402 and wrapped around the duct surfaces and held in position by tying with SS bands of thickness 0.6 mm. The ceramic fiber blanket insulation of density 128 kg/m^3 in roll form shall be covered with aluminum foil 0.1 mm thickness on all sides and laminated roll to be fabricated.

18.0 Tube Insulation

Pipes in the form of tube inserted through walls in hotels, hospitals or geyser pipes and DG exhaust pipes are to be insulated with ceramic fiber breaded rope of density 300 kg/m^3. The thickness of the rope shall be 18-25 mm and breaded on the outer side with SS W/N. The rope to be tightly wrapped over the pipe surface. In case of exposed DG exhaust pipes, the pipe to be further wrapped with aluminum tape for water protection.

19.0 Insulation Gaskets

Ceramic fiber gaskets of density 240 kg/m^3 and thickness 4-5 mm to be applied at the flange joint of GI sheet ducts. Ceramic fiber gaskets will be placed between the flange joints before mechanically tightening of GI sheets.

Chapter 14

Heat Recovery Systems

1.0 Water-to-Water Heat Recovery with De-superheater

1.1 Hot gas discharged from the compressor is passed through an auxiliary condenser (called a de-superheater) which is mounted in series with the main condenser. Generally, only de-superheating takes place in the auxiliary condenser and actual condensation does not take place. Both the inlet and outlet of the auxiliary condenser have to be liberally sized for hot gas to minimize its pressure drop. In case, condensation takes place in auxiliary condenser, the liquid so formed should drain freely into the main condenser by gravity. For this purpose, the auxiliary condenser shall be mounted at a higher level than the main condenser and the outlet shall be without traps and shall be as straight as possible.

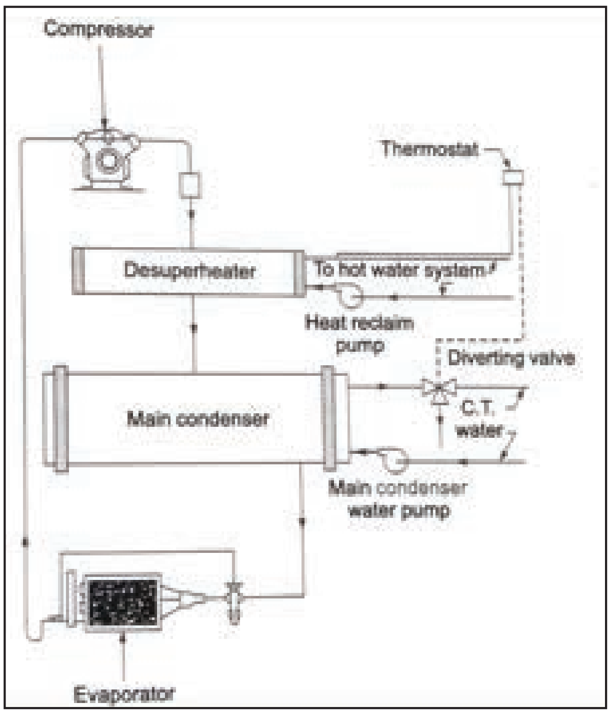


Figure 1: Heat recovery through auxiliary condenser

Please refer to schematic piping diagram (*Figure 1*).

1.2 A separate pump and water circuit is provided for the auxiliary condenser to prevent the hot water getting contaminated in the cooling tower. A three-way diverting valve controlled by a proportionating thermostat which senses the water temperature at the inlet of the auxiliary condenser. This three-way valve shall be mounted at the outlet of the main condenser and when the reclaim temperature falls the diverting valve bypasses some of the main condenser outlet water to the inlet thus increasing condensing temperature and consequently the reclaim temperature. When heat reclaim is not required, the water pump of the heat recovery circuit is stopped and the heat recovery condenser acts as part of the hot gas line.

It shall be noted that when the condensing temperature rises as a result of the action of the three-way valve, the refrigeration capacity drops and power consumption per unit refrigeration produced increases.

2.0 Air to Air Heat Recovery in Enthalpy Wheel

2.1 Heat recovery wheels are designed to be fitted with HVAC ductwork or in customized air-handling units.

2.1.1 Vertical Configuration

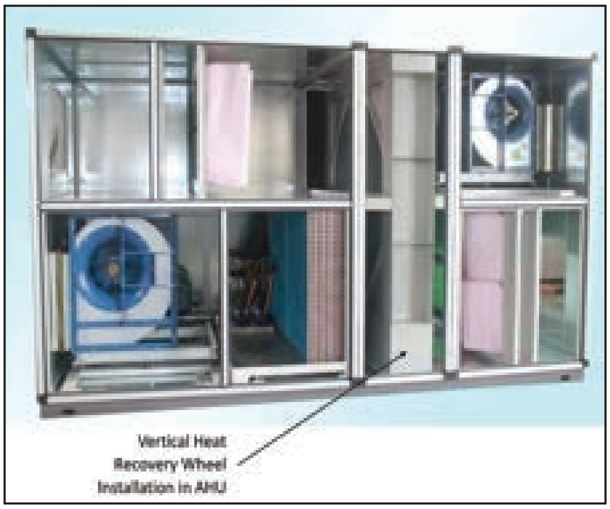


Figure 2: Enthalpy wheel mounted vertically in AHU

2.1.2 Enthalpy Wheel Mounted Horizontally

Horizontal unit must be installed with a supporting center beam. The maximum permissible deflection for the center beam (which bears all wheel load) and all other components is 1 mm. The supporting detail is shown in *Figure 3*.

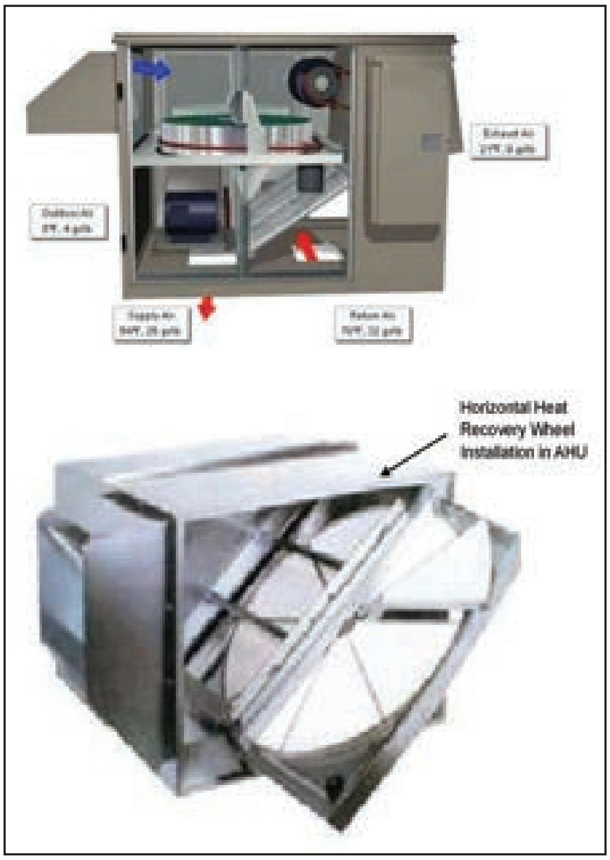


Figure 3: Horizontal enthalpy wheel installation

2.2 Typical Installation Steps

2.2.1 Cassette Inserted into Casing/Housing

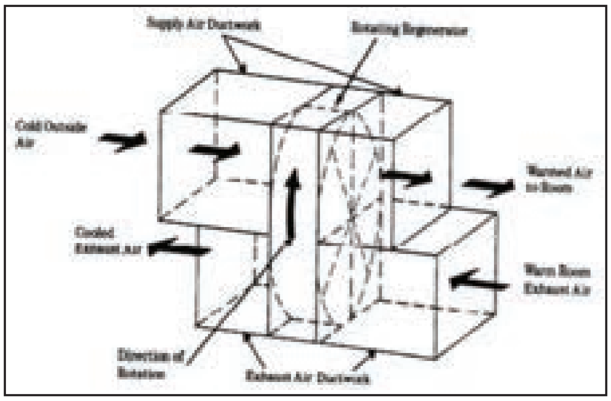


Figure 4: Cassette inserted into casing/housing

2.2.2 Connected to Ductwork

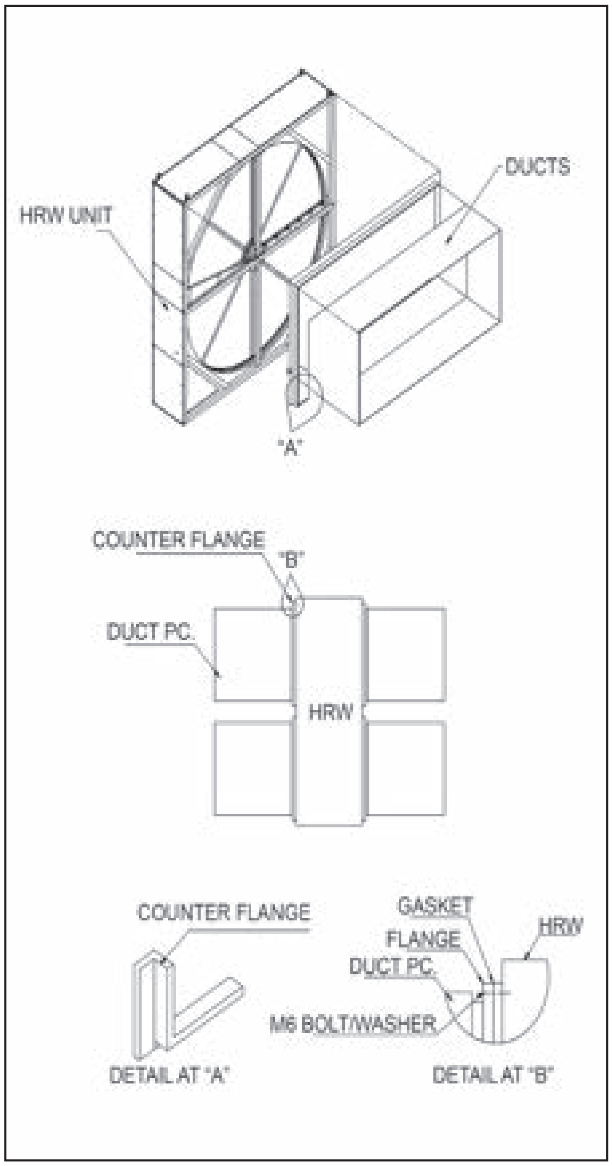


Figure 5: Duct fixing detail

2.2.3 Fixing in Air Handling Unit

Figure 6: Fixing the wheel inside the air handling unit

2.2.4 Check the proper unit orientation. Top and bottom airflow shall have labyrinth seal located horizontally across the unit, while side by side airflow requires labyrinth seal be located vertically across the unit.

2.2.5 Install the unit so the purge sector is always towards supply Air leaving. This is the side where return air enters and supply leaves the unit.

2.2.6 Rotation of the wheel shall be such that any spot on the media in the return air section would rotate towards purge sector without passing into the supply air stream.

2.3 Pre-commissioning Checks and Commissioning

2.3.1 Verify that all-shipping braces and brackets have been removed.

2.3.2 Verify that the installation is in accordance with the previous sections of this chapter as well as manufacturer's instructions.

2.3.3 Check rotor alignment at the top, bottom, left and right sides. There should be equal spacing from one location to the next. There should be a minimum of 6 mm spacing from any metal part of the wheel. This will allow for smooth and trouble-free operation.

2.3.4 Check all bearing collars and motor mounting screws. The bolts, which hold the bearings onto the support beam, should be checked for tightness. Also check the setscrews on the bearing mounting collars for tightness.

2.3.5 Check wheel flatness. Heat wheels are designed to maintain flatness to tolerances of less than 2 mm run out (+/-1 mm) per meter diameter.

2.3.6 Check seal clearance. Relieve the belt tension; this will make it much easier to move the wheel as you are adjusting the seals.

2.3.7 Seals of heat recovery wheel are designed to work at clearance of 1.5 to 2.5 mm. Locate the high side of the wheel and with a piece of 16-gauge GI Sheet metal formed in the shape of angle (see *Figure 7*), check and adjust the labyrinth seal clearance. The metal piece will act as a feeler gauge and ensure proper seal clearance. Due to the fact that the wheel will deflect under normal operation, it may be necessary to perform a final adjustment with airflow over the wheel. After the seals are finally adjusted, reinstall the belt over sheaves.

2.3.8 Verify the rotation of the wheel. In general, the rotation of the wheel is noted on the casing/housing. The rotation can be always verified by simple rule that the wheel always rotates from dirty air stream through the purge into clean air stream.

2.3.9 Check that no external objects, which may damage the end surfaces of the rotor, have been left in the supply and exhaust air ducts.

2.3.10 Power should be applied to drive motor for the first time with the wheel belt free from sheave/

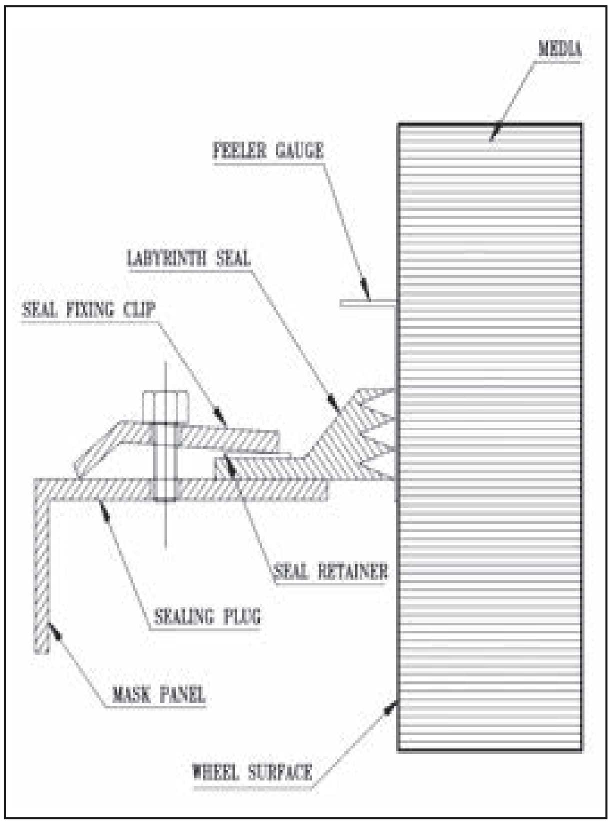


Figure 7: The seals in cross section

pulley. Once the rotation of drive sheave/pulley is established, the motor connection should be made such that the proper rotation is achieved.

2.3.11 Verify the purge angle. An adjustable purge section is provided in the heat recovery wheel. In order to provide air balance and keep cross contamination to a minimum level, the purge angle must be adjusted. Once airflow is established over the unit and preliminary air balancing reading taken, verify the purge pressure. If this value is significantly different from the designed value, then adjustment in the purge section will be required.

To adjust the purge section, simply unscrew the bolt on the wiper portion of the purge section and rotate it into the proper position, hold it and re-tighten. Seal the wiper with silicone sealant.

The purge section and labyrinth sealing system combine to limit cross contamination. Providing for a blow though supply fan and a draw though exhaust fan may limit cross contamination even further, and is recommended for critical applications involving airborne contaminants (refer *Figure 8*).

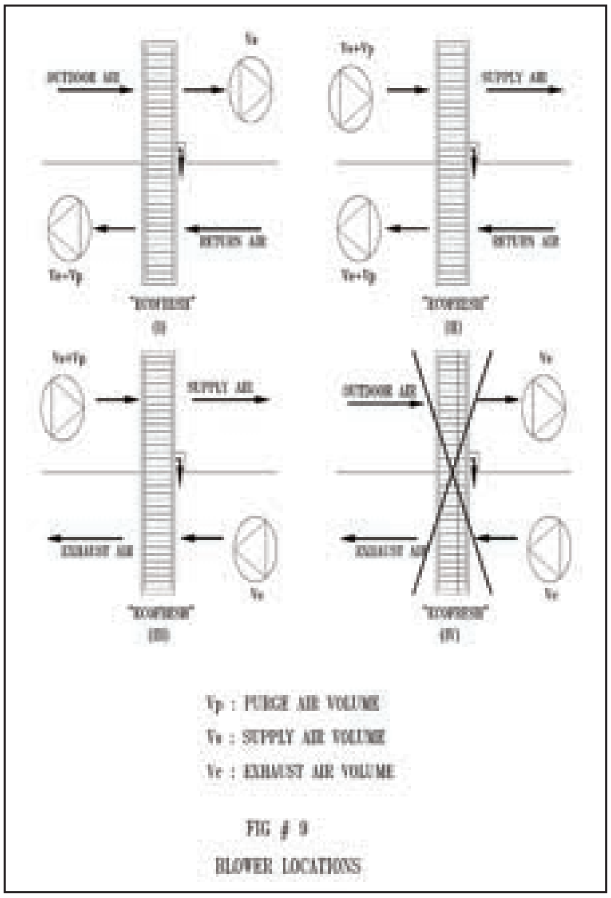


Figure 8: Blower locations

2.3.12 Check all sheaves/pulleys for tightness. All sheaves must be tight fit for smooth operation of the unit. Check and ensure that the screws into the sheaves are tight. Check belt tension.

3.0 Heat Pipe

3.1 This type of heat recovery system utilizes the refrigerant phase change property. It consists of two coils connected to each other by independent circuit; each circuit filled with a refrigerant.

3.2 Two main functions can be done using this system; it can be used for dehumidification or for heat recovery, according to the arrangement of the heat pipe coils with respect to other components.

3.3 Heat pipes for dehumidification function will have two sections: Pre-cool and reheat. The first section is located in the incoming air stream. When warm air passes over the heat pipes, the refrigerant vaporizes, carrying heat to the second section of heat pipes, placed downstream. Because some heat has been removed from the air before encountering the evaporator coil, the incoming air stream section is called the pre-cool heat pipe. Air passing through the evaporator coil is cooled to a lower temperature, resulting in greater condensate removal. The cooled air is then reheated to a comfortable temperature by the reheat pipe section using the heat transferred from the pre-cool heat pipe. This entire process of pre-cooling and reheating is accomplished with no additional energy use. The result is an air conditioning system with superior ability to remove moisture.

3.4 For Heat recovery function also, the heat pipe shall have two sections, each of them installed in an air steam, side by side or stacked one above the other depending on the unit arrangement. When warm air passes over the heat pipes, the refrigerant vaporizes; carrying heat to the second section and the warm air will be cooled down while the relatively cold air in the cold air

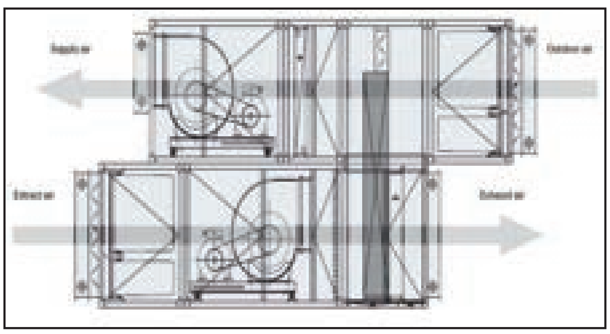


Figure 9: Heat pipe type recovery system

stream will condense the refrigerant which will return back to the first part by gravity. The cycle is repeated.

3.5 Horizontal/Vertical Heat Pipe Type Heat Recovery

This is a typical pipe / fin exchanger that is composed of two sections filled with refrigerant that operate as a condenser and an evaporator. Air from which heat is to be extracted, is taken through the evaporator side and its heat is transferred to the refrigerant. Vaporized refrigerant transfers it's heat to the cold air passing outside of the exchanger on the condenser side which is placed higher, and thus heat is transferred to the cold air and heat recovery is ensured. Only sensible heat is transferred in such arrangement.

Figure 10: Horizontal and vertical configurations

3.6 Wrap Around or Horse Shoe Heat Pipes

3.6.1 Horse shoe type heat recovery exchangers are heat pipes that are used for dehumidification operations in air conditioning systems. It performs pre-cooling of the air that shall be dehumidified and reheating of this air with the same energy. Thus, energy consumption is not required for both processes.

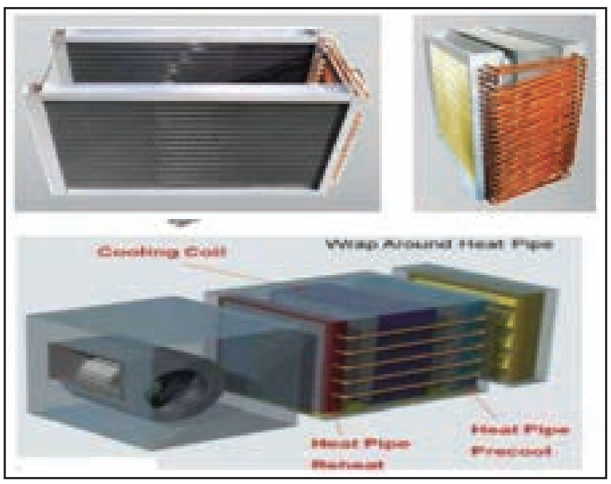


Figure 11: Horse shoe type heat pipes

4.0 Plate Type Heat Exchanger

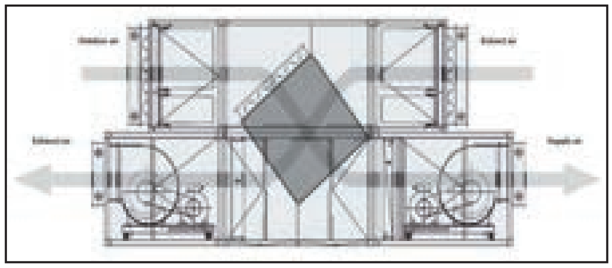


Figure 12: Plate type heat exchanger (schematic)

4.1 In this arrangement, a heat exchanger is situated to allow direct transfer of heat from one flow to the other. Heat is transferred from outdoor air coming into the unit to the cold air leaving it. The aim is to boost the removal of latent heat by decreasing the need to remove sensible heat. To a limited extent, the exchanger itself will remove latent heat by condensing moisture on the entering air side. Outdoor air is introduced into one side of the heat exchanger, and is partially cooled. It then flows over the cold refrigeration coil for moisture removal and additional sensible cooling. The cold, saturated air then passes through the other side of the exchanger for warming before being introduced to the air handler or the space. Cross flow type heat recovery provides up to 80% efficiency. While waste heat exchanger plates are typically manufactured in aluminum, special epoxy coatings or stainless steel plates are also common.

Figure 13: Plate type heat exchanger

Chapter 15

Installation of Thermal Storage Systems

1.0 General

1.1 Types of thermal storage systems are based on the type of thermal storage medium, and the way the storage medium is used. Storage media include chilled water, ice, and phase-change materials. These media differ in their heat-storage capacities, the temperatures at which cooling is stored, and the physical requirements of storing energy in the media.

Types of systems include chilled water storage, ice harvesting, internal melt and external melt ice-on-coil, encapsulated ice, ice slurry, and phase change material systems. Each of these storage types is described briefly below.

1.2 Ice thermal storage makes use of the latent heat of fusion of water, the heat required to change water from a solid state to a liquid state. Ice thermal storage stores cooling in the form of ice at its freezing point, 32°F (0°C). Refrigeration equipment for ice storage must operate at temperatures well below the normal operating range for air conditioning applications. Depending on the ice storage technology, either special ice-making equipment is used, or standard production chillers are configured for low temperature duty.

1.3 Chilled water storage makes use of the sensible heat capacity of water to store cooling. Sensible heat refers to the energy that produces a measurable change in the temperature of the thermal medium. Chilled water is most often generated and stored at temperatures between 4.5 and 6.5°C. These temperatures are directly compatible with conventional water chillers and distribution systems. Effective chilled water storage requires that some form of separation be maintained between the stored cold water and the warm return water. In the past, various physical methods have been used to create the separation, such as membranes, internal weirs and labyrinths, and multiple tanks. Natural stratification has emerged as the preferred method for chilled water storage, because of its low cost and superior performance. This method utilizes the phenomenon of stratification or temperature layering that can take place in a mass of still water. Specially designed diffusers introduce water into the storage tank at a low velocity to minimize mixing. Colder, denser water remains at the bottom of the tank, and warmer, lighter water remains at the top, with the separation maintained by a relatively stable 'thermocline' or boundary zone. The advantage of chilled water storage is its compatibility with conventional water chillers and distribution systems. Storage can be added without extensive modification of existing equipment, and a net reduction in energy use can often easily be achieved. There relatively large storage tank that is required may make this option unsuitable for certain sites where space is limited.

1.4 External melt ice-on-coil-Ice is formed on the outer surface of submerged pipes or tubes through which a refrigerant or secondary coolant is circulated. Cooling is discharged by circulating warm return water through the tank, melting the ice from the outside.

1.5 Ice is formed inside submerged pipes or tubes, similar to the external melt system. Cooling is discharged by circulating warm coolant through the pipes, melting the ice from the inside.

2.0 Thermal Energy Storage Tanks.

All thermal energy storage systems require tanks which is the single largest part of the system. These tanks can be installed over the ground or under the ground. They can be single or can be multiple. They can be horizontal or vertical. All needs to be insulated as per the manufacturer's recommendations. Some manufacturers supply pre-insulated-tanks, while others require site insulation. In both the cases insulation plays as much a role as the capacity of the tank as loss due to conduction is a direct loss in storage.

Following precautions needs to be taken:

> Ensure that the manufacturer's recommendations are followed.

> On receipt of the material at site, ensure that the bill of lading/ transporters copy matches with the crates which are received.

> Report any damages or shortages immediately, and ensure that the same is mentioned in the transporter's receipts.

> Care should be taken while unloading and placing the tanks at safe locations. Since the space occupied by them is fairly large, prior site planning of location of receipt and storage before installation is recommended.

> In case of single large horizontal tanks ensure that the ground is fairly leveled to minimize undue stresses in the tank joints.

> Before installation, ensure that the tanks are installed with a firm structural base. In case of plastic tanks, ensure that the entire base is flat and leveled to have full contact with the tank base.

> In case of multiple tanks, ensure that all tanks are leveled properly.

> If multiple vertical tanks, ensure that the top 25% of the tank remains above ground. Space the tanks properly for proper load distribution

> Connect the piping as recommended by the manufacturer ensure that inlet and outlet along with the control valves locations are exactly as per the design and manufacturer's requirements. Improper pressure balancing may divert the water in reverse directions than desired, which may lead to ineffective storage tanks.

> Ensure that the pressure and temperature gauges are installed in the piping network with proper angle of inclination and reverse to the direction of flow. Ensure that the operating ranges of the thermometers are as per requirement.

> Once the tanks are insulated and installed and piping connected, pressure testing of the system can be done. Hold and release the pressure as recommended by the manufacturer from one side to the other in sequence.

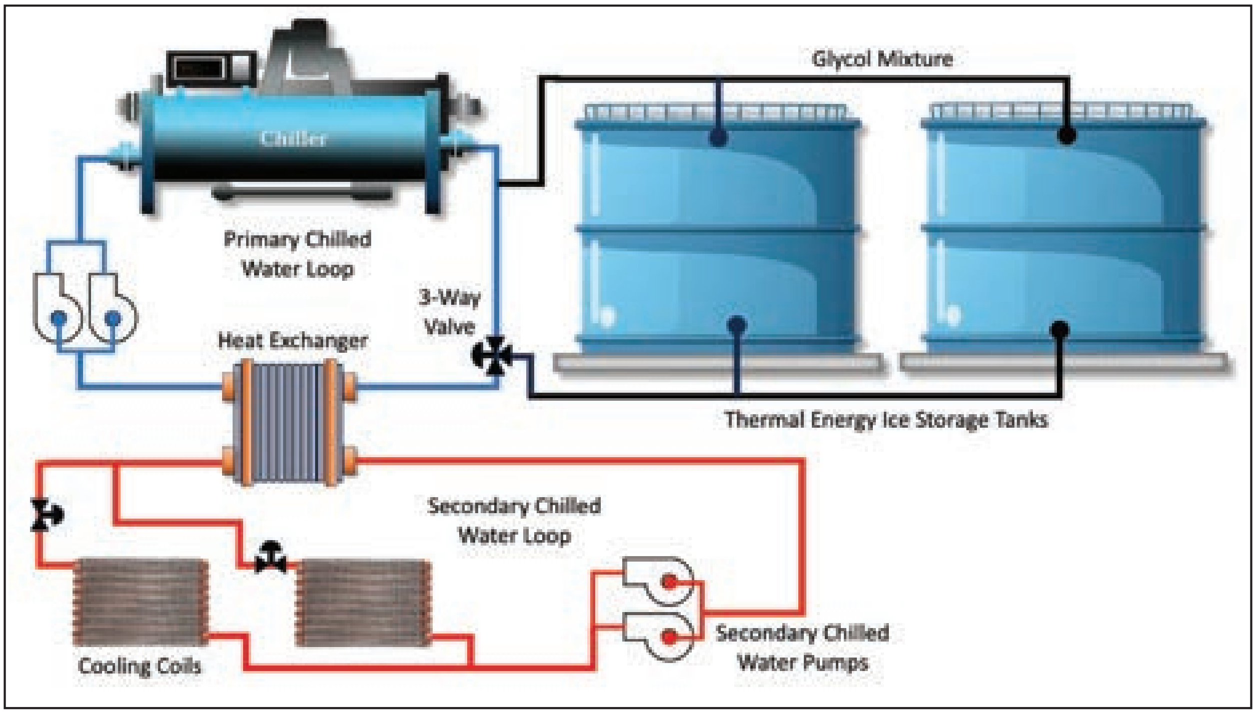


Figure15.1 (a): Ice based thermal storage tanks

Figure15.1 (b): Ice based thermal storage tanks

> Ensure that at least minimum 900 mm of space is clear above the tanks for inspection. In case, at a later date, the tanks need to be removed and replaced, this height will be required to install any pulley block hooking arrangements.

3.0 Pre-commissioning Checks

3.1 All the valves, header pipes and fittings shall be installed properly and independently of the tank.

3.2 The tank shall be filled with water covering the top of heat exchanger tubes.

3.3 An ice inventory meter shall be installed at the specified location and initial adjustments shall be done to read zero.

3.4 All system piping shall be insulated and checked for system leakage.

3.5 Electrical connections to the ice inventory meter should be done as per the specification provided in the catalog.

4.0 Stratified Chilled Water Storage System

4.1 A stratified water tank takes advantage of a natural stratification process requiring no added energy or harmful chemicals. The less-dense, warm water in the tank rises, and denser chilled water naturally accumulates near the bottom of the tank. A stratified water tank stores chilled water generated during off-peak periods; often using otherwise wasted cooling energy to recharge the tank with chilled water. This stored cooling energy is then available to augment that generated by the direct cooling system during peak demand. The TES tanks are to be placed on the rooftop or ground level as per the plantroom design. The tanks are to be positioned on the concrete platform created for the TES tanks.

A graph indicating a peak day operation facility cooling load vs chiller output may be seen in *Figure 15.1.* Few typical piping arrangements are shown in Figure 15.2 and 15.3. For more information, please refer to ISHRAE Data Book.

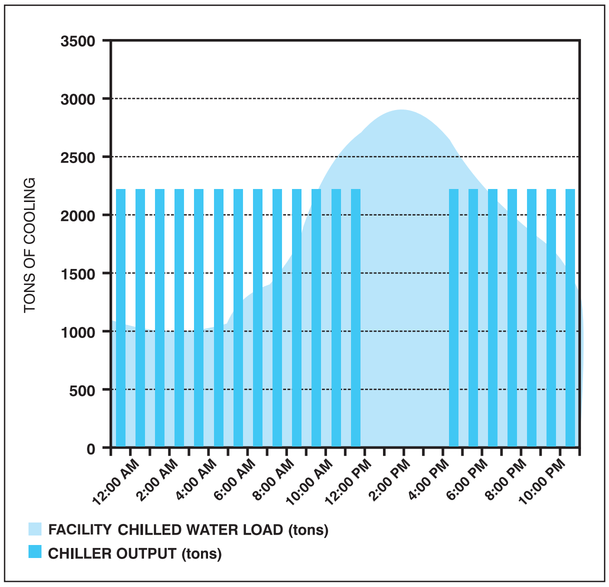


Figure 15.2 – Full storage TES Tank Full day operation facility – Cooling load Vs Chiller output

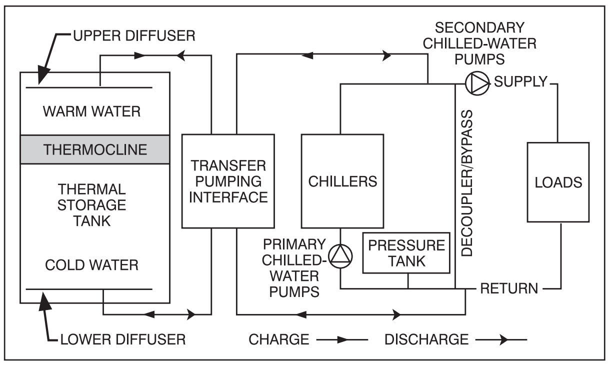


Figure 15.3- Typical Sensible storage connection scheme

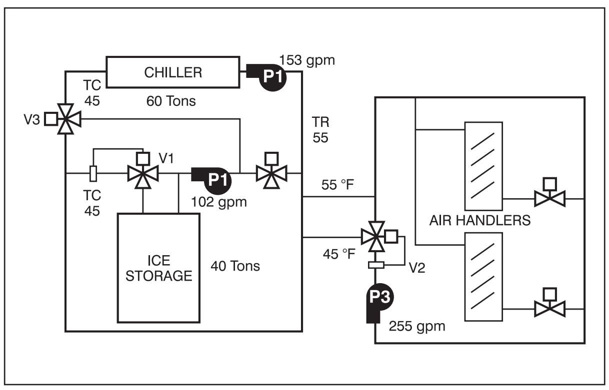


Figure 15.4 – Piping arrangement indicating parallel flow for Chiller and Storage

4.2 Benefits of Stratified Storage

> Instant discharge to the load when used for emergency chilled water supply in mission critical facilities.

> Easy retrofitting expansion to an existing HVAC system.

> Chilled Water TES utilizes normal evaporator temperatures.

> High and quick response to the cooling load due to common fluid throughout the circuit.

> Full thermal stratification maintains chilled water temperature differential, maintaining chiller loading and efficiencies.

> Easy and simple configuration and controls

4.3 Accessories to be Installed

> Temperature sensors with thermowell: one in CHWS pipe to nozzle before the isolation valve, one in the CHWR pipe from nozzle before the isolation valve.

> Temperature sensors on the tank shell.

> Pressure gauge in the nozzle provided on the shell of the tank.

> 5.3 Pressure safety valve on the top dish of the tank in nozzle.

> 5.4 Air vent ball valve on the top dish of the tank in nozzle.

> Drain ball valve on the bottom dish of the tank in nozzle.

4.4 Installation of Storage Tanks

It is important to ensure that the tank's inlet/outlet pipes are brought to the correct orientation exactly as shown in the layout plan. Tanks shall be placed in vertical alignment with the foundation and in horizontal alignment with inlet/outlet pipe connection.

4.4.1 The tanks are required to be grouted to the foundation which involves the following steps:

- Marking of holes on the foundation across base plate holes.
- Drilling of holes as per design depth in the foundation base.
- Cleaning the holes of any dust.
- Inserting bolts into the hole.

4.4.2 Levelling of TES tanks is of great importance for optimum performance. The purpose of levelling is to ensure that top and bottom diffusers which are already welded inside the tank, are parallel to the water surface inside the tank. Any tilt in the diffuser orientation can affect the uniformity of flow in radial direction inwards or outwards of the diffusers. Use water filled flexible pipe to level the tank and check the same at four locations 90 degrees apart.

4.4.3 Once the levelling of the tanks is done and the tanks are in perfect position, pour the grouting chemical in the bolt holes. After drying of the chemical, insert washer and tighten with two nuts.

4.4.4 On one pipe spool which is to be connected to the inlet/outlet nozzle of the tank, drill a hole suitable to the socket diameter. Tack the socket on the pipe and weld it.

4.4.5 Clean the bevel edges of the pipe and tack it to the flange. Ensure that the pipe is perpendicular to the face of the flange. Perform welding. Similarly weld the second flange on the other edge of the pipe.

4.4.6 Place the valve between two pipe spools and ensure it is in center of the pipe/flange. Insert the bolts across the two flanges and tighten the nuts. Ensure that the nuts are tightened diagonally in sequence.

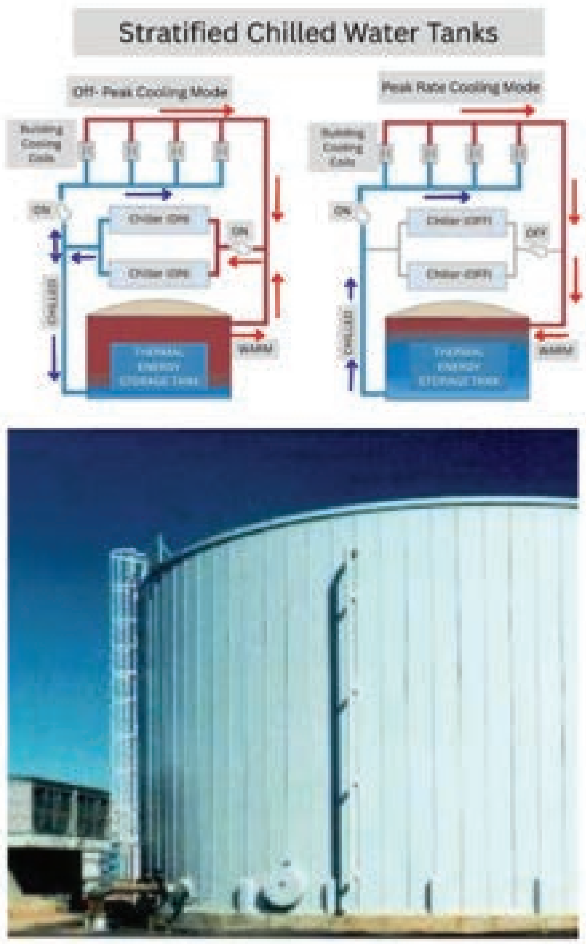


Figure15.5: Chiller water storage tank

4.4.7 Place the assembled valve with pipe spools on the face of the tank flange, insert a gasket in-between the two flanges. Insert bolts and tighten them.

4.4.8 Apply PTFE tape on the outside thread of the thermowell and tighten it in the designated nozzle. Apply PTFE tape on the outside of the temperature sensor probe threading and tighten this into the thermowell.

4.4.9 Apply PTFE tape on the thread of the accessory and tighten it on the designated nozzle.

Chapter 16

HVAC Installation Guidelines for Special Applications

For certain applications of HVAC Systems, special attention may have to be paid to some of the installation aspects. In this chapter, we shall see some of the specific requirements for these special applications.

1.0 Hospitals and Healthcare Facilities

1.1 Given below is an overview of installation guidelines for HVAC systems for healthcare environments. The content addresses critical elements that significantly impact performance, reliability, and patient safety in such sensitive settings.

Key areas covered include:

- Air handling unit (AHU) installation,
- Ducting for air distribution,
- HEPA Filters,
- Sound and vibration control measures, and
- Fan systems with considerations for emergency power integration.

1.2 Air Handling Units

1.2.1 AHUs shall be located in secured, accessible areas; avoid ceiling voids above occupied spaces.

1.2.2 Roof-mounted units shall be installed ensuring safe access and fall protection for personnel and equipment during maintenance.

1.2.3 Units located at ground level shall be within secure compounds to prevent unauthorized access and vehicle barriers shall be provided to avoid exhaust fumes entering air intakes.

1.2.4 Access to all internal components shall be provided for deep cleaning and easy replacement of fans, coils, and other components shall be possible.

1.2.5 If placed against a wall or back-to-back, front-only access must be ensured and units wider than one meter shall have dual-side access or large enough access doors.

1.2.6 Surrounding area shall be waterproofed and well-drained to prevent leaks.

1.2.7 AHU location should allow for proper drainage installation for cooling coils, humidifiers, and heat recovery units.

1.2.8 Materials used shall not support microbial growth and shall not be combustible or contribute to fire spread.

1.2.9 Units shall be airtight. Double-skin construction with insulation between metal layers is preferred.

1.2.10 Provide viewing ports at convenient heights and in stacked units, place ports at the bottom of upper unit doors to avoid ladders.

1.2.11 Provide internal illumination with IP55-rated fittings. Position lights for both general visibility and task lighting. All lights should be operated from a single switch.

1.2.12 Provide fixed ladders and platforms to access AHUs, filters, and coils safely.

1.2.13 Drain trays shall be made of corrosion-resistant material (preferably stainless steel) and shall be fully drainable, with 1:20 slope towards the outlet in all directions. Drain trays shall be either fully accessible or removable for small units to allow inspection and cleaning.

1.2.14 A properly sized U-trap shall be installed at the drain outlet to prevent air bypass or foul air ingress Trap depth shall match the static pressure differential (e.g., 25 mm of depth per 250 pascals).

1.2.15 Use corrosion-resistant piping (e.g., UPVC, stainless steel) and ensure a continuous downward slope with no sags or inverted sections to prevent water stagnation. Drain line should be independently supported at regular intervals and clean-out ports shall be provided at appropriate locations for maintenance access.

1.2.16 Drain shall discharge into a floor drain or designated condensate collection point and always maintain an air gap between the drain outlet and the receiving drain to prevent backflow contamination.

1.2.17 Where direct connection is necessary, include a proper backflow prevention device.

1.2.18 In critical care areas, provide a secondary (emergency) drain pan with its own outlet and piping.

1.2.19 Drain sensors or float switches to detect clogs or overflow and trigger system alarms is recommended.

1.2.20 The entire condensate drainage system shall be checked during commissioning to ensure proper flow and trapping.

1.2.21 In health care facilities, vibration/noise can raise serious issues for patient care and comfort.

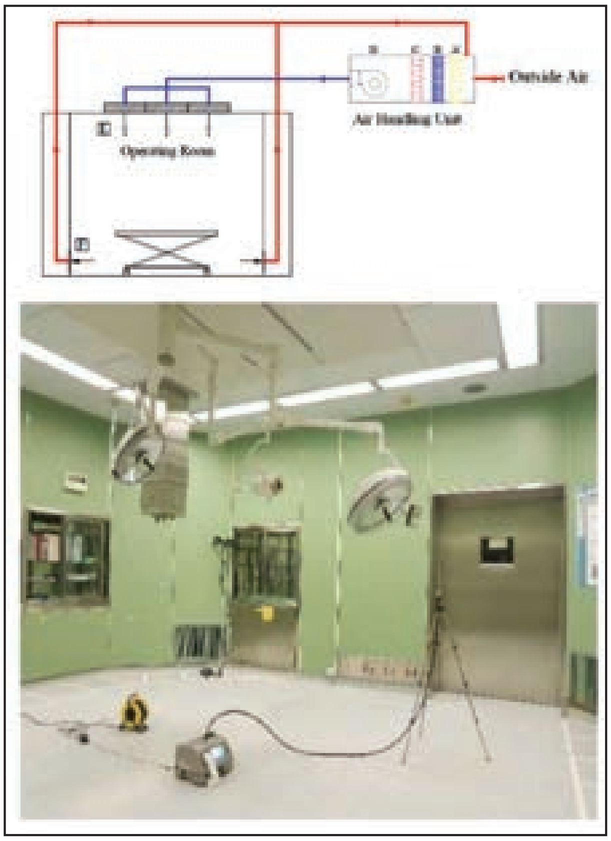


Figure 16.1: Operation theatre AHU and air distribution

Therefore, select low-vibration AHUs and mount them on appropriate anti-vibration isolators. Use flexible connectors in piping and ductwork—preferably in two perpendicular planes—placed close to the source. Consider anti-vibration hangers and supports for all connected services.

1.3 Air Distribution System

1.3.1 Use low-velocity air distribution systems for healthcare applications to ensure quieter, more stable airflow.

1.3.2 Route main distribution ducts away from patient sleeping areas. If unavoidable, ensure enhanced acoustic insulation is provided. Install auxiliary equipment like fans, filters, and terminal devices with independent supports and appropriate drainage. Use flexible connectors to isolate vibration.

1.3.3 Return air path above false ceiling is not suitable for healthcare facilities, particularly for critical areas such as isolation rooms, operating theatres, intensive care units (ICUs), and other sensitive spaces. The use of open return air paths through ceiling plenums in such environments poses serious hygiene and operational risks. Without dedicated return ducting, return air from multiple spaces can mix within the common plenum. In clinical settings, this increases the risk of airborne cross-contamination between rooms, especially when infectious or immunocompromised patients are involved. The return plenum operates under negative pressure. If the ceiling cavity is not perfectly sealed, it may draw in unconditioned and humid air from external sources or adjacent unconditioned spaces. This can lead to condensation and microbial growth above the ceiling. Contaminated air passing through such spaces can carry spores and pathogens back to the AHU, compromising air hygiene throughout the system.

1.3.4 For healthcare applications, return air from critical areas must be routed through dedicated return air ducting, properly sized, sealed, and accessible for inspection and cleaning. This not only supports infection control protocols but also ensures reliable HVAC system performance and patient safety.

1.3.5 Exhaust fans shall be positioned outside the building to ensure negative pressure within internal ductwork. If internal placement is necessary, fans shall be close to the exterior with minimal discharge ducting, which will be under positive pressure and must be sealed—no test ports or inspection hatches should penetrate this section.

1.3.6 In areas with high moisture or corrosive air, use aluminum or stainless steel. Stainless steel is required for high-temperature ducts. Provide drainage at low points in ducts to prevent water accumulation, especially in fresh air inlets and exhaust systems. Avoid flexible ducting for primary distribution in healthcare settings; use only for final terminal connections.

1.3.7 If phenolic-board (pre insulated) ducts are used, ensure they are well-fabricated, properly supported, and comply with the manufacturer's installation standards.

1.3.8 Internal surfaces of ducts should be smooth and free of projections. Use flanged, gasketed joints wherever possible.

1.3.9 Avoid lining the internal duct surface downstream of final filters in supply air systems to prevent particle contamination. All acoustic materials used in health care facilities shall be non-shedding type.

1.3.10 For critical healthcare areas, use pre-engineered attenuator units filled with acoustically-absorbing material, protected by a perforated metal casing and sealed with a non-permeable membrane to block moisture and fiber release. In case attenuator unit is installed downstream of final filters, it shall have access doors for cleaning at both ends of the attenuator unit

1.3.11 All components shall remain sealed and protected during on-site storage before installation. Open ends of ductwork and ventilation elements shall be sealed immediately after placement to prevent dust ingress during construction. Dampers shall be kept covered throughout the construction phase to prevent contamination. Before connecting ductwork, ensure damper blades are cleaned thoroughly.

1.3.12 Concrete or brick plenum ducts or shafts must have a smooth internal finish and be surface-sealed to prevent dust release. Drainage system shall be provided unless the design ensures self-draining functionality.

1.3.13 Take all precautions to avoid contamination of the internal surfaces of the ventilation system during construction, as post-contamination cleaning is difficult and often incomplete. Do not operate extract or recirculation fans until the area is very clean (i.e., all surfaces swept and wet-mopped).

1.3.14 Maintain the surroundings of the supply air intake area free from vegetation, litter, construction debris, and any potential contaminants.

1.4 Terminally Mounted High-Efficiency Filters – HEPA

1.4.1 HEPA filter installation shall allow for on-site validation, using:

1.4.2 DOP/POA testing with upstream injection and downstream measurement, or particle-counting methods

1.4.3 HEPA filters in extract systems (handling hazardous substances or pathogens) shall allow for safe maintenance and disposal through:

- o Pre-sealing of contaminants in the filter
- o Fumigation systems to neutralize biological risks
- o Safe-change (Bag-in-Bag-Out) housings that allow filter removal without direct contact

1.5 Fans in Healthcare HVAC Systems

1.5.1 Failure of the system — even briefly — can compromise infection control, patient safety, and the functioning of critical spaces. Fans shall be connected to emergency power to prevent pressure loss during power failure.

1.5.2 Fans used in operating theatres shall be of low-noise, high-efficiency type and suitable for continuous operation. Both supply and exhaust fans for OTs must be on essential power supply to avoid any break in airflow, which can compromise sterility. Critical fans shall be monitored via Building Management System (BMS) with real-time status, fault, and performance data. Alarms shall be raised in case of failure, power loss, or deviation from expected operating conditions.

1.6 Installation Work at Operating Health Care Facilities

Health and safety of installation personnel is a major concern. Personal protective equipment, adequate enforcement mechanisms and complete awareness of health and safety measures shall be ensured. Site supervisors shall be sensitized with occupational health and safety.

1.6.1 While doing installation work at any operating health care facility, the area has to be kept under Negative pressure. All partitions shall be air tight so that dust does not enter the patient areas and cause infection

1.6.2 Project Engineers shall seek to minimize the possibility of unplanned service interruptions during the renovation. Engineers should be well acquainted with the existing system.

1.6.3 Pre-design testing, adjusting and balancing (TAB) of newly installed equipment is advisable.

1.7 Infection Control Risk Assessment (ICRA)

1.7.1 Matrix of Precautions for Construction and Renovation

Project ________________________________,

Location ______________, Date ____________

Step 1. Using *Table 16.1*, identify the type of construction project activity (Type A – D).

Table 16.1: Types of construction project activity

TYPE A	Inspection and non-invasive activities Includes, but is not limited to, the following: • Removal of ceiling tiles for visual inspection only (for example, limited to one tile per 50 square feet) • Painting (but not sanding) • Wall covering, electrical trim work, minor plumbing, and activities that do not generate dust or require cutting of walls or accessing ceilings other than for visual inspection
TYPE B	Small-scale, short-duration activities that create minimal dust Includes, but is not limited to, the following: • Installation of telephone and computer cabling • Access to chase spaces • Cutting of walls or ceilings where dust migration can be controlled
TYPE C	Work that generates a moderate to high level of dust or requires demolition or removal of any fixed building components or assemblies Includes, but is not limited to, the following: • Sanding of walls for painting or wall covering • Removal of floor coverings, ceiling tiles and casework • New wall construction • Minor duct work or electrical work above ceilings • Major cabling activities • Any activity that cannot be completed within a single work shift
TYPE D	Major demolition and construction projects Includes, but is not limited to, the following: • Activities that require consecutive work shifts • Activities that require heavy demolition or removal of a complete cabling system • New construction

Step 2. Using *Table 16.2*, identify the Patient Risk Groups that will be affected. If more than one risk group will be affected, select the higher risk group.

Table 16.2: Patient risk groups

Low Risk	Medium Risk	High Risk	Highest Risk
• Office areas	• Cardiology • Echo-cardiography • Endoscopy • Nuclear medicine • Physical therapy • Radiology/MRI • Respiratory therapy	• Critical care unit • Emergency room • Labor and delivery • Laboratories (specimen) • Medical units • Newborn nursery • Outpatient surgery • Pediatrics • Pharmacy • Post-anesthesia care unit (PACU) • Surgical units	• Any area caring for immuno-compromised patients • Burn unit • Cardiac cath lab • Central sterile supply • Intensive care unit • Negative pressure isolation rooms • Oncology • Operating rooms, including C-section rooms

Step 3. Match the Patient Risk Group (Low, Medium, High, Highest) with the planned Construction Project Type (A, B, C, D) in *Table 16.3*, to find the Class of Precautions (I, II, III or IV) or level of infection control activities required.

Table 16.3: Class of precautions: construction project by patient risk

	Construction Project Type			
Patient Risk Group	**TYPE A**	**TYPE B**	**TYPE C**	**TYPE D**
LOW Risk Group	I	II	II	III/IV
MEDIUM Risk Group	I	II	III	IV
HIGH Risk Group	I	II	III/IV	IV
HIGHEST Risk Group	II	III/IV	III/IV	IV

Note: Infection Prevention and Control approval will be required when the Construction Project Type and Patient Risk Group indicate that Class III or Class IV control procedures are necessary.

Step 4: Plan all activities during the construction stage and upon completion as indicated in *Table 16.4.*

Table 16.4: Activities for various Classes of projects

	During Construction Project	**Upon Completion of Project**
CLASS I	1. Execute work using methods to minimize raising dust from construction operations. 2. Immediately replace a ceiling tile displaced for visual inspection.	1. Clean work area upon completion of the task.
CLASS II	1. Provide active means to prevent airborne dust from dispersing into the atmosphere. 2. Water mist work surfaces to control dust while cutting. 3. Seal unused doors with duct tape. 4. Block off and seal air vents. 5. Place dust mat at entrance and exit of work area. 6. Remove or isolate the heating, ventilation, and air conditioning (HVAC) system in areas where work is being performed.	1. Wipe work surfaces with cleaner/disinfectant. 2. Contain construction waste before transport in tightly covered containers. 3. Wet mop and/or vacuum with high-efficiency particulate air (HEPA) filtered vacuum before leaving work area. 4. Upon completion, restore HVAC system where work was performed.
CLASS III	1. Remove or isolate HVAC system in areas where work is being done to prevent contamination of duct system. 2. Complete all critical barriers (that is, sheetrock, plywood, plastic) to seal work area from non-work area or implement control cube method (cart with plastic covering and sealed connection to work site with HEPA vacuum for vacuuming prior to exit) before construction begins. 3. Maintain negative air pressure within work site, utilizing HEAP-equipped air filtration units. 4. Contain construction waste before transport in tightly covered containers. 5. Cover transport receptacles or carts. Tape covering unless lid is solid.	1. Do not remove barriers from work area until completed project is inspected by the owner's safety department and infection prevention and control department and thoroughly cleaned by the owner's environmental services department. 2. Remove barrier materials carefully to minimize spreading of dirt and debris associated with construction. 3. Vacuum work area with HEPA-filtered vacuums. 4. Wet mop area with cleaner/disinfectant. 5. Upon completion, restore HVAC system where work was performed.

CLASS IV	1. Isolate HVAC system in area where work is being done to prevent contamination of duct system. 2. Complete all critical barriers (that is, sheetrock, plywood, plastic) to seal work area from non-work area or implement control cube method (cart with plastic covering and sealed connection to work site with HEPA vacuum for vacuuming prior to exit) before construction begins. 3. Maintain negative air pressure within work site utilizing HEAP-equipped air filtration units. 4. Seal holes, pipes, conduits, and punctures appropriately. 5. Construct anteroom and require all personnel to pass through this room so they can be vacuumed using a HEPA vacuum cleaner before leaving work site or they can wear cloth or paper coveralls that are removed each time they leave the work site. 6. All personnel entering work site are required to wear shoe covers. Shoe covers must be changed each time the worker exits the work area.	1. Do not remove barriers from work area until completed project is inspected by the owner's safety department and infection prevention and control department and thoroughly cleaned by the owner's environmental services department. 2. Remove barrier material carefully to minimize spreading of dirt and debris associated with construction. 3. Contain construction waste before transport in tightly covered containers. 4. Cover transport receptacles or carts. Tape covering unless lid is solid. 5. Vacuum work area with HEPA-filtered vacuums. 6. Wet mop area with cleaner/disinfectant. 7. Upon completion, restore HVAC system where work was performed.

Step 5. Identify the areas surrounding the project area, assessing potential impact.

Unit Below	Unit Above	Lateral	Lateral	Behind	Front
Risk Group	Risk Group	Risk Group	Risk Group	Risk Group	Risk Group

Step 6. Identify specific site of activity, for example, patient rooms, medication room, and so on.

Step 7. Identify issues related to: ventilation, plumbing, and electrical in terms of the occurrence of probable outages.

Step 8. Identify containment measures, using prior assessment. What types of barriers (for example, solids walls)? Will HEPA filtration be required?

Note: Renovation/construction area shall be isolated from the occupied areas during construction and shall be maintained at negative pressure with respect to surrounding areas.

Step 9. Consider potential risk of water damage. Is there a risk due to compromising structural integrity (for example, wall, ceiling, roof)?

Step 10. Work hours: Can or will the work be done during non-patient-care hours?

Step 11. Do the plans allow for the required number and type of hand-washing sinks?

Step 12. Does the infection prevention and control staff agree with the minimum number of sinks for this project? (Verify against Facility Guidelines Institute (FGI) design and construction guidelines for types and area.)

Step 13. Does the infection prevention and control staff agree with the plans relative to clean and soiled utility rooms?

Step 14. Plan to discuss the following containment issues with the project team, for example, traffic flow, housekeeping, debris removal (how and when).

Step 15. Identify and communicate the responsibility for project monitoring that includes infection prevention and control concerns and risks. The ICRA may be modified throughout the project. Revisions must be communicated to the project manager.

Project Engineer ________________________

Infection Control Committee Member __________

G. M. Engineering: - ______________________

1.8 Risk Level Planning and Monitoring for Special Areas

Table 16.5: Risk level planning and monitoring for special areas

Area	Equipment	Planning	Monitoring
Bone Marrow Transplant	Air Handling Units • Filtration • Air changes • Positive pressure • Emergency power • Redundant equipment	• Preventive maintenance • Air quality certification • Emergency planning • Training • Outage notification • Bearings	• Air Changes per Hour • Pressure differential • Filtration analysis • Vibration check • Fan belts
Operation Theatres	Air Handling Units • Filtration • Air changes • Positive pressure • Emergency power	• Preventive maintenance • Air quality certification • Emergency planning • Training • Outage notification	• Air changes per hour • Pressure differential • Filtration analysis • Vibration check • Fan belts
Airborne Infection Isolation Rooms (all rooms)	Air handling unit systems • Negative pressure • Emergency power • Exhaust systems	• Preventive maintenance • Training • Outage notification	• Air changes per hour • Pressure differential • Filtration analysis • -Fan belts

Note: During unoccupied period air change rates may be allowed to be reduced to 25% of the occupied period rates, provided continuous directional control and room pressurization is maintained at all times and system to restore full air change rates can be re-established at any time.

1.8 Indoor Air Quality Maintenance Checklist

Table 16.6: IAQ maintenance checklist

Question	Yes / No	Not Applicable	Remarks
Is unit casing air tight and clean?			
Are all panels secured?			
Are outdoor air lovers free of obstructions?			
Are mixing box dampers operating properly?			
Are all filters in place?			
Do all filters sit in their place tightly?			
Are filters free of any signs of mold?			
Is cooling/heating coil finned surfaces free of debris?			
Are there any signs of condensate carryover?			
Are drain pans clean?			
Do condensate drain pans retain condensate water?			
Are biocides in place in the condensate drain pan?			
Are fan blades clean?			
Is fan running smoothly?			
Is belt secured without any evident slipping?			
Is duct work free of contaminants such as dust and mold?			
Are all sensors operating and calibrated?			
Is the control system adhering to designed sequence of operation?			
Are terminal units such as re-heaters and VAVs free of water stains or contaminants?			
Are all exhaust fans working properly and interlocked as designed?			

2.0 Hospitality Sector – Hotels

Figure16.2: Typical hotel room

2.1 Customer experience as well as energy efficiency are the two factors which govern HVAC&R installations for the hospitality sector. Indoor Environment Quality (IEQ) in terms of thermal comfort, air quality, noise and vibration all are critical factors. Simultaneously, since the hotels operate on an extremely competitive environment and energy costs, where HVAC&R is a major contributor to operating costs, it becomes very important to own and operate systems utmost efficiently.

2.2 Cooling Equipment

In Hotels where abundant waste water is available, which can be treated and recycled for use in cooling tower, water cooled chilled water system may be the most energy efficient option with chillers located in the basement. Please refer to Chapter 5 for points related to installation of chillers.

In case air cooled chillers are selected and they are located on building terrace, sufficient care should be taken to ensure that noise/ vibration is not transmitted to the guest floor below. It is recommended to provide an acoustic barrier around the air-cooled chiller located on terrace.

VRF systems as well as split AC units can also be used for guest room cooling.

2.3 Fresh Air to Guest Rooms

In all cases, treated fresh air shall be supplied to the guest rooms by a dedicated system and it is a good idea to keep the treated fresh air supply on even when the room is not occupied. Besides retaining the room freshness when the guest checks in, this will prevent mold formation on carpets and furnishings when rooms are not occupied for long periods.

To reduce load on the plant, heat recovery systems are used to recover thermal energy from exhaust to fresh air. Please refer to Chapter 14 for points related to installation of heat recovery systems.

2.4 Avoid locating AHUs near guest rooms, banquet halls, meeting rooms and other guest interactive areas. AHUs shall ideally be located on dedicated service floors or on terrace. If unavoidable, AHUs may be located on occupied floors but within enclosed AHU rooms with adequate vibration and sound isolation. AHU room floors shall be water proofed and adequate floor drain with U/P trap shall be provided.

2.5 Fan coil or split in door units shall be located away from the bed head to avoid draft on the bed. FCU valve package shall be fully insulated and the insulated drain pan shall be extended to cover the valve package. Spillage of condensate to be avoided at all cost. Trap door, sufficiently large, shall be provided to provide maintenance access to entire FCU, filter and valve package.

2.6 It is recommended that fresh air supply is connected to a dedicated part of the FCU grill itself. Fresh air flow to guest room shall be controlled through a volume control damper or a constant volume regulator.

2.7 Main ducts shall be routed away from guest rooms, meeting rooms and lobby area to avoid noise issues.

2.8 Constant air volume regulators are recommended for all toilet exhaust outlets. It is a good idea to provide some supply of cold conditioned air to toilets either through dedicated supply outlets or through door grills.

2.9 Kitchen exhaust ducts shall be of CRCA sheets and in welded construction. Grease filters shall be provided at kitchen hood connection to exhaust duct. Kitchen exhaust duct dampers shall be fire rated ones. Exhaust discharge shall be terminated at least 5 m horizontally and 2 m vertically from any fresh air intake. Pressure in the kitchen should be maintained slightly negative to prevent cooking smell spreading to adjacent area. It is recommended to used balancing type kitchen hoods which have fresh air supply provision in-built. Kitchen exhaust duct shall be laid at a slight slope so that accumulated grease can get collected at few points from where it can be removed. Sprinklers shall be provided on hoods as well as on exhaust ducts. Exhaust ducts which can come in contact with people as well as which pass through conditioned area shall be insulated.

2.10 It is recommended that spaces which require continuous exhaust such as garbage rooms, stores, locker rooms be provided dedicated exhaust systems.

2.11 Laundry area should have exhaust system of adequate capacity to remove both heat and humidity. Ducts are recommended to be coated on the inside with epoxy paint. Lint filters shall be provided on all laundry exhaust outlets with maintenance trap doors.

2.12 All plant rooms such as chiller room, boiler room etc. shall be well ventilated (supply as well as exhaust).

2.13 Hot water tanks and distribution lines shall be insulated. Drain points shall be provided for leakage as well as blow down discharge. Hot water return lines may be provided with non-return valves.

2.14 To prevent legionella growth, store hot water at 60ºC and sully at >50ºC. Provide strainers and flushing valves at low points.

2.15 For sauna and spa, keep exhaust system independent of general exhaust. Ensure that there is no recirculation from pool, sauna and spa to other areas.

3.0 Clean Rooms

This section presents an overview of installation guidelines for HVAC systems for clean room environments. The objective is to support HVAC professionals, contractors, and facility engineers in delivering systems that meet the rigorous demands of clean room operations, ensuring thermal comfort, indoor air quality, infection control, and operational continuity.

3.1 This guide should be read alongside applicable codes, standards, and infection control protocols relevant to healthcare infrastructure.

3.2 Air handling units need to be with thermal break profiles for its penta-post structure. The ventilation units may have profiles without the thermal break.

3.2.1 While assembling the AHU, particular attention shall be provided to the gaskets provided between the penta-post structure and the panels, panels and the dampers or collars for duct connection. The gaskets shall preferably be without any breaks in width or height. Care shall be taken to ensure that there are no gaps in the gaskets at the corners. The gasketing material used should preferably be of food grade quality.

3.2.2 Post gasketing and prior to fixing the panels, dampers or collars, a thin bead of RTV silicone sealant should be applied in the center to ensure adequate sealing. This bead should be straight without any break.

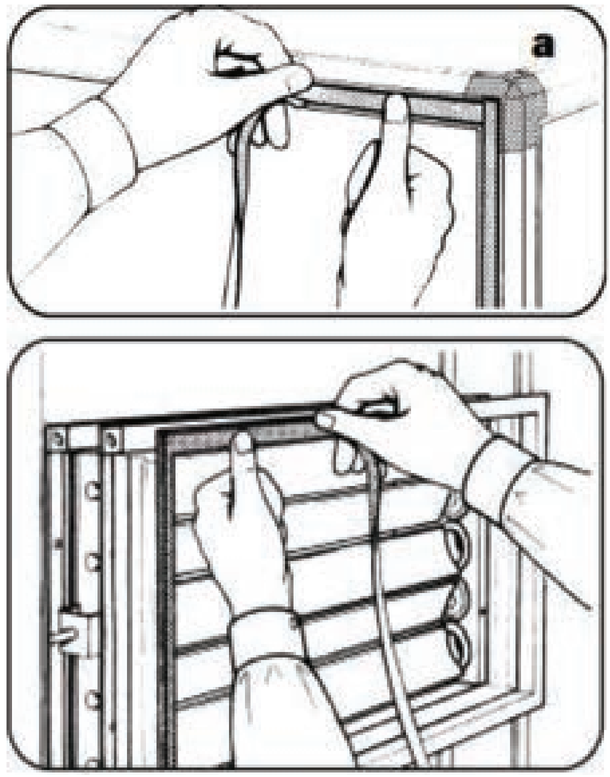


Figure 16.3: Gaskets between AHU panels

3.2.3 Once the penta-post structure along with the panels is installed, the unit must be checked for its true horizontal installation using spirit level both along the width and the length of the unit. It is suggested that a spirit level with minimum 300 mm length be used. Provide shims under the base for proper alignment if required.

3.2.4 The drain tray of the AHU is installed at the bottom of the unit. The drain tray material should be of anti-corrosive material, preferably SS-304 or better. Prior to installation of cooling/heating coils, water must be poured in the drain tray to ensure that no water gets retained within the drain tray. The distance between the two coils shall be maintained as minimum 200 mm with a removable panel to access this gap between the two coils to facilitate cleaning.

3.2.5 During coil installation, the protective layer of expanded polystyrene provided by the manufacturer must remain in position. The chilled water coil must be installed on the upstream edge of the drain tray to avoid air bypass below the coil. Similarly, if hot water coil is used for the reheating, it must be placed at the downstream edge of the drain tray to ensure no air bypass is allowed below the coil.

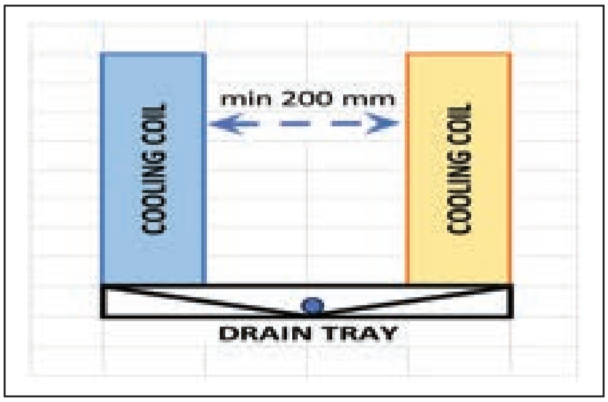


Figure 16.4: Drain tray

3.2.6 It is ideal to have the cooling and heating coils manufactured with SS-304 or better coil casing. Cooling coils should preferably have fins coated with hydrophilic compound.

3.2.7 The cooling and heating coils may be connected to their service headers using manifolds of adequate size. It is suggested that these manifolds may be connected to the coils using the flexible pipe connectors.

3.2.8 The drain trays must be connected to the U loops which need to be properly sized. The sizing depends on the AHU configuration, either blow through or draw through. Following figures indicate their sizing.

3.2.9 The fan installation is critical. The fan must be installed on properly selected vibration isolators. In case spring isolators are used, they are shipped from the manufacturer in clamped down condition. These clamps must be removed.

3.2.10 In case of direct driven fans, the fan and motor assembly must be aligned to ensure that the fan and motor shaft are truly horizontal, using a spirit level. This avoids the axial thrust on the fan and motor bearings, leading to their longer life.

3.2.11 The fans must be isolated for vibrations using a fire-retardant flexible connector between the fan inlet and the AHU casing for the plenum fans and between the fan outlet and the casing in the case of SISW/DIDW fans.

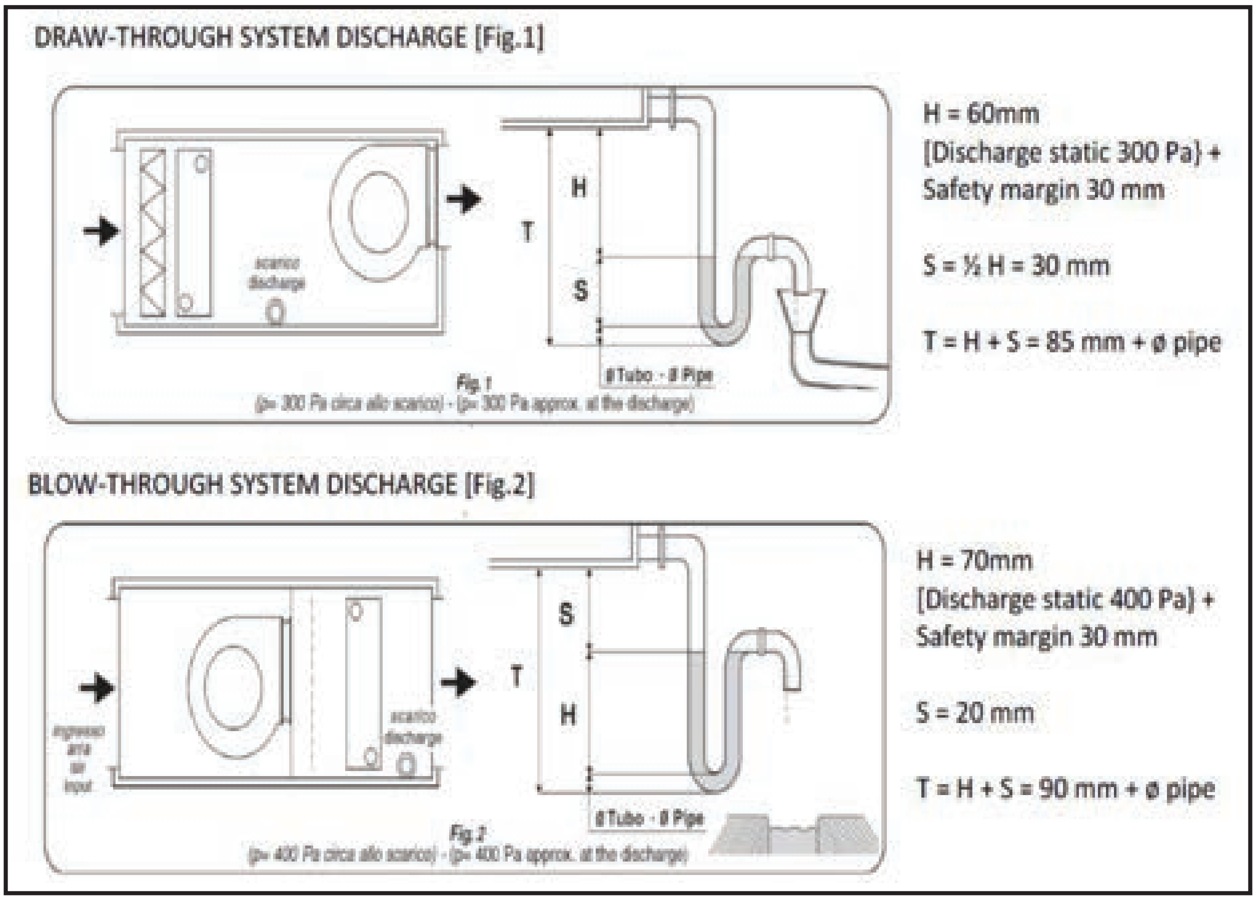


Figure 16.5: Draw through and blow through system discharge

3.2.12 In case of belt driven fans, both fan and the motor shafts must be truly horizontal. In addition, both the pulleys must be aligned radially as well as axially. It is preferred to use laser alignment tool for this purpose. The belts must be installed and their tension adjusted using the belt tension gauge.

Figure 16.6: Belt alignment

3.2.13 An IP-55 rated marine lamps with bulkhead should be installed in the fan compartment. The limit switch installed at the fan compartment door shall switch off the fan when the door is opened and at the same time will switch on the marine lamp. In addition, an on/off switch should be installed near the door so that the marine lamp can be switched on even when the door is closed so that fan running condition can be observed through the view glass on the fan compartment door.

3.2.14 It is recommended that till final handing over AHUs be provided with the commissioning filters. However, these commissioning filters may be of disposable frame and media as they need to be discarded at the time of handing over. The dimensions of the commissioning filters must match the dimensions of the final filters.

3.2.15 To facilitate the cable entries inside the AHU, a proper sleeve must be installed, where the cable punctures the panel. The cables must be clamped inside the AHU using cable clamps.

3.2.16 Since the environment within the AHU is likely to be highly humid, it is recommended that a double compression gland be used for the cable terminations to the motor and limit switches.

3.2.17 All the electrical components within the AHU, mainly motor, limit switch and the marine lamp should be provided with the adequate earthing having two independent paths. In addition, it is suggested that the AHU casing to be provided with the double earthing.

3.3. Dehumidifiers

Dehumidifiers must be installed as guided by the manufacturer. Most of the practices listed above for the AHU installation will apply. However, the following points must be borne in mind:

3.3.1 The drain tray post cooling coil will always remain dry and hence will not have any air seal. It is recommended that a solenoid valve be installed in the drain the post cooling coil. This solenoid valve shall be wired in such a way that when the system is operational the valve will remain closed. This valve will remain open when the system is shut down.

3.3.2 When the steam is used for the regeneration, the condensate drain may be recycled. In such cases, inverted bucket steam traps rated for adequate back pressure should be installed.

3.4 Ductwork for Air Distribution

3.4.1 In clean rooms both supply and return air systems shall be ducted. It is important to ensure duct leakages are minimum and within the acceptable limits. In clean rooms there would be equipment or dust collection systems, that exhaust the room air. While the supply and return air ducts are low velocity ducts and may be circular or rectangular, the dust collector ducting is necessarily high velocity ducts and in circular shape. The supply ducts have terminally mounted High Efficiency Particulate Air filter (HEPA filters) at the end of the ducts which have high pressure drops and also the pressure drops increasingly vary with time. Therefore, supply air ducts shall be designed for higher duct pressure class, typically 750 Pa and above. The return air ducts usually are not impacted by high and variable pressure drop and as such may be designed and installed for lower pressures, typically 250 pascals to 500 pascals. Following are the typical installation practices for the ductwork in clean rooms.

3.4.2 The preferred longitudinal joint for the duct is Pittsburgh lock, though button punch snap lock also may be used up to 1000 pascal duct pressure. Suggested Pittsburgh lock pocket depth is 16 mm.

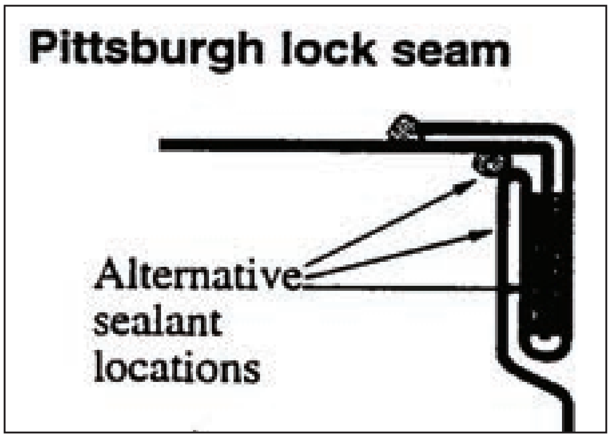


Figure 16.7: Pittsburgh joint in ducting

3.4.2.1 The longitudinal joint needs to be sealed. The preferred sealing location is inside seam joint as it provides larger shoulder for sealant application, other sealing locations may also be used. The typical sealants used is food grade room temperature vulcanizing (RTV) silicone, other sealing materials may also be used provided they are of food grade quality.

3.4.2.2 For transverse joints M.S. angle iron flanges are preferred, though transverse duct flanges (TDF) may also be used provided proper joint reinforcement as well as mid panel reinforcement is provided.

3.4.2.3 When angle iron flanges are used, the minimum upturn over the flange of 6 mm. is recommended. The riveting distances for the angle iron flange shall not exceed 150 mm, though 100 mm center to center is preferred. Similarly, the flanges shall be nut-bolted at an interval not exceeding 200 mm, though 125 mm is preferred center to center distance.

3.4.2.4 Minimum 3 mm thick gasket of food grade material must be used. The gasket should not have any joints along the width or heights. The corners shall be taken care of to ensure no gaps are left at the corners.

3.4.2.5 The transverse joint needs to be sealed at the following locations:

- Along the flange perimeter between the duct wall and edge of the flange.
- Each penetration of rivet used for flange fixing.
- Each corner of the duct section from inside the duct.
- Where a branch or take-off is taken from the duct wall, the joint must be sealed at the penetration.

3.4.2.6 The ducts must be adequately supported as indicated in standards such as SMACNA, DW-144 or ISHRAE. Irrespective of the interval distances, the ducts must be additionally supported at the following locations:

- Immediately before or after the bend.
- Immediately before and after the vertical offset.
- Immediately after a branch or take-off is taken from the duct wall.

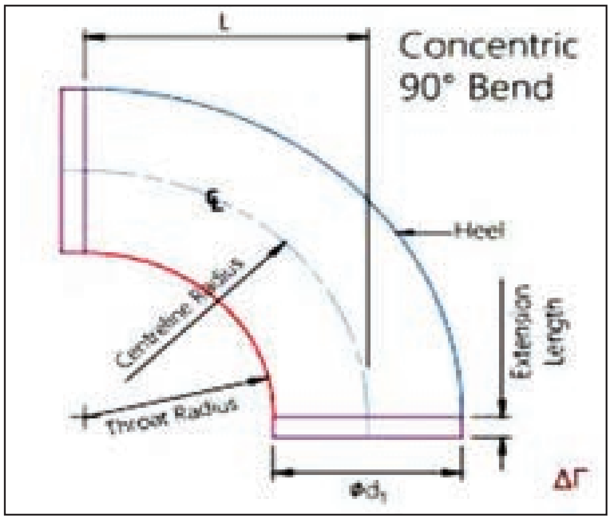


Figure 16.8: Concentric 90º bend

3.4.2.7 The ductwork post installation but prior to insulation should be pressure tested either as per SMACNA standards or as per DW-143 standard. Leakage classes recommended for SMACNA are Class 6 for circular ducts and class 12 for rectangular ducts as minimum. The ducts may be pressure tested as per medium duct pressure class when using DW-143.

3.4.3 Many times, flexible ducts are used for the final connection to the terminal filters. In such cases, it is suggested that the length of such duct should be restricted to 1500 mm to 2000 mm. Further, such ducts need to be installed as much in a straight line as possible. In case a bend becomes essential, the turning throat radius must be maintained at more than or equal to the duct diameter. Further, such ducts must be supported at every 1500 mm and also at both ends of the bend.

3.5 Filters

Clean room uses many grades of filters starting from G-3 onwards till H-14 and sometimes higher. The filters up to F-9 grade are normally either flanged or panel type, though flanged filters are preferred as their fixing arrangement has lower filter bypass. These filters are normally installed within the AHUs or the return air risers within the room. H-11 onwards are either gasketed panel type filters or gel sealed panel type filters and are normally used as terminal filters at the room inlet, though sometimes they also may be installed within the AHUs. When installed within the AHUs they are flanged.

For installation of filters up to F-9 grade, following steps are suggested:

- Ensure that filter flange has gasket which is undamaged. If found damaged, replace the gasket.
- Place the filter on its frame and insert all the bolts and tighten with them with fingers.
- Once they are hand tightened, tighten the bolts further in steps and sequence. Each step should be half a turn and sequence should be diagonally opposite.
- Once tightened check for any gaps in the seating. If any gaps are found, the same may be sealed with food grade RTV silicone sealant. It is suggested that F-9 grade filters may be sealed in any case.

Figure 16.9: Data centers and typical cooling arrangement

3.5.1 When filters of grades higher than F-9 are used in the flanged construction, use the above procedure as applicable to F-9 grade filters.

4.0 Data Centers

4.1 For the HVAC system serving a data center, reliability is the most important requirement. This is ensured by proper design, selection of equipment and systems as well as the right installation/commissioning practices.

4.2 Equipment redundancy, based on availability requirement is an important factor. The configuration of equipment shall be either N+1, N+2 or 2 N where N is the actual requirement. Redundant chilled water distribution path either supply/ return ring main or dual supply / return for concurrent maintainability or fault tolerant infrastructure. This allows meeting the requirement of mission critical facilities without shutdown during maintenance or failure condition. All components can be taken out for maintenance without shutdown.

4.3 Thermal storage is provided for high density of rack to prevent temperature exceeding the recommended level during power changeover from grid to emergency DG set operation.

4.4 Generally, all equipment is provided with dual power supply through ATS from two power sources to improve availability.

4.5 Chilled water pumps recirculating chilled water through cooling equipment shall be on UPS. Similarly, indoor cooling equipment needs to be on UPS for continuous cooling during power failure/ changeover from grid to emergency DG operation and vice versa.

BMS / chiller plant manager and all controls need to be on UPS power supply. The plant should continue operation even when BMS/ chiller plant manager is down.

4.6 Air cooled chillers are preferred for water neutral design and for quick start requirement. All chillers are required to be selected with quick start and quick recovery provision. Controllers for chillers are provided power from UPS or are provided with ultra capacitor. Chiller should be suitable for high chilled water leaving temperature.

4.7 Controller for all cooling equipment should have provision of operation in team mode.

4.8 Generally welding is not allowed inside data center premises to reduce server failure. Instead, grooved joint is preferred. Alternatively prefabricated chilled water piping can be adopted.

4.9 For liquid cooled servers, stainless steel chilled water piping with tri clamp is recommended.

4.10 All piping / ducting supports shall be seismically resistant for the particular zone and preferably one zone higher.

4.11 All battery rooms should have hydrogen sensor actuated ventilation system to prevent hydrogen accumulation and resulting fire.

4.12 It is recommended that a CFD analysis for server hall as well as external area is carried out before installation is taken up. A detailed site logistics plan for delivering, storing and protecting equipment shall be prepared. All equipment installation shall be as per approved method statement / installation manual from OEM. Power cabling shall be properly segregated from chilled water piping, extra low voltage cabling and data cabling and shall be in separate shafts with fire rated doors. Installation drawings shall be on BIM/Revit with LOD 350/400 detailing.

4.13 Commissioning process is critical for a data center. A third-party commissioning agent shall be engaged from the project initiation stage till project closure and handover. The testing process is the heart and soul of the commissioning process. The following defines the testing strategy during the commissioning.

4.14 A detailed commissioning plan as per ASHRAE covering L1 to L5, from factory testing to integrated testing at site, Battery/ chilled water storage back up test, black out test needs to be implemented. The primary objective for test procedures is to verify the component and system operational requirement have been achieved through a full range of operating modes and scenarios.

4.15 BMS system should be ready before L4 Functional performance testing.

4.16 The following documents are necessary for L2 to L 5 tests.

- Construction check lists.
- Factory test reports.
- Pre-start-up check list.
- Start-up check lists.
- Functional test reports.
- System test procedures.
- Integrated system test.

4.17 Third party commissioning agent shall be involved at every stage from start-up tests, functional, each system test and integrated system test. Please refer to ISHRAE Commissioning Standard 10003-2020 which needs to be closely followed at all stages of the Data Centre project.

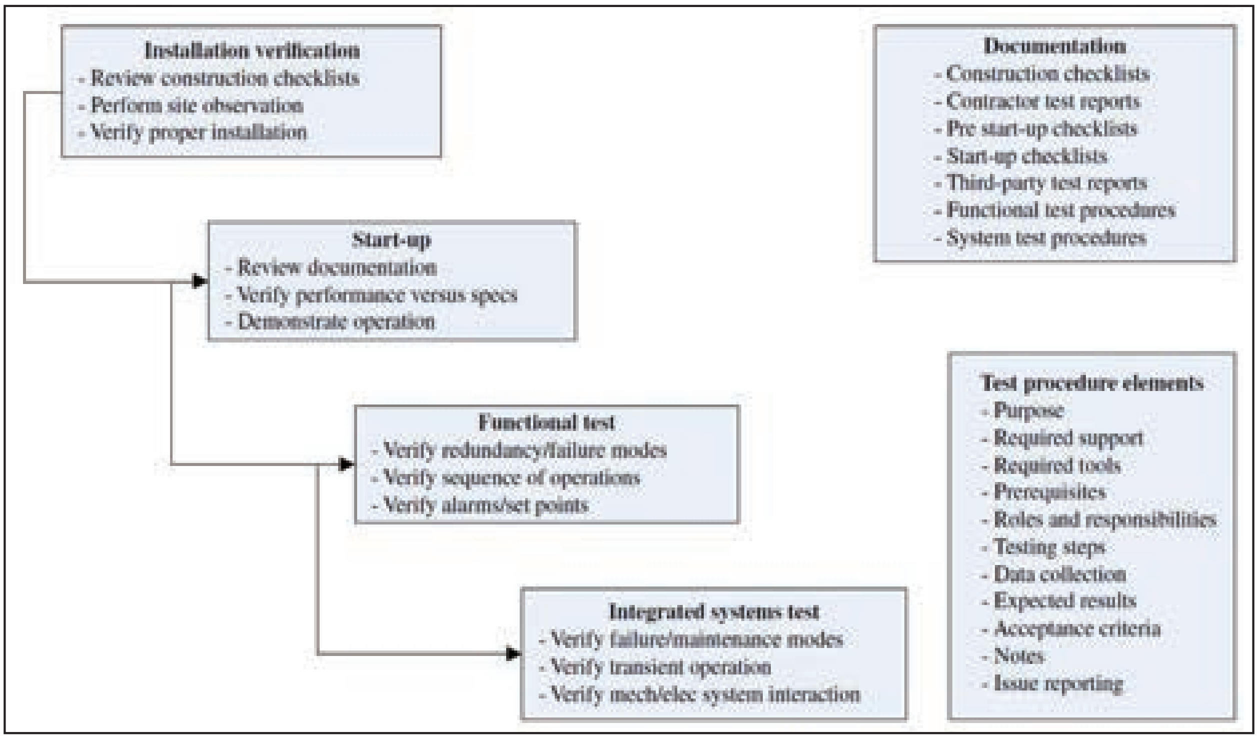


Figure 16.10: Testing strategy during commissioning

4.18 *Figure 16.11* shows the test procedure approval chart.

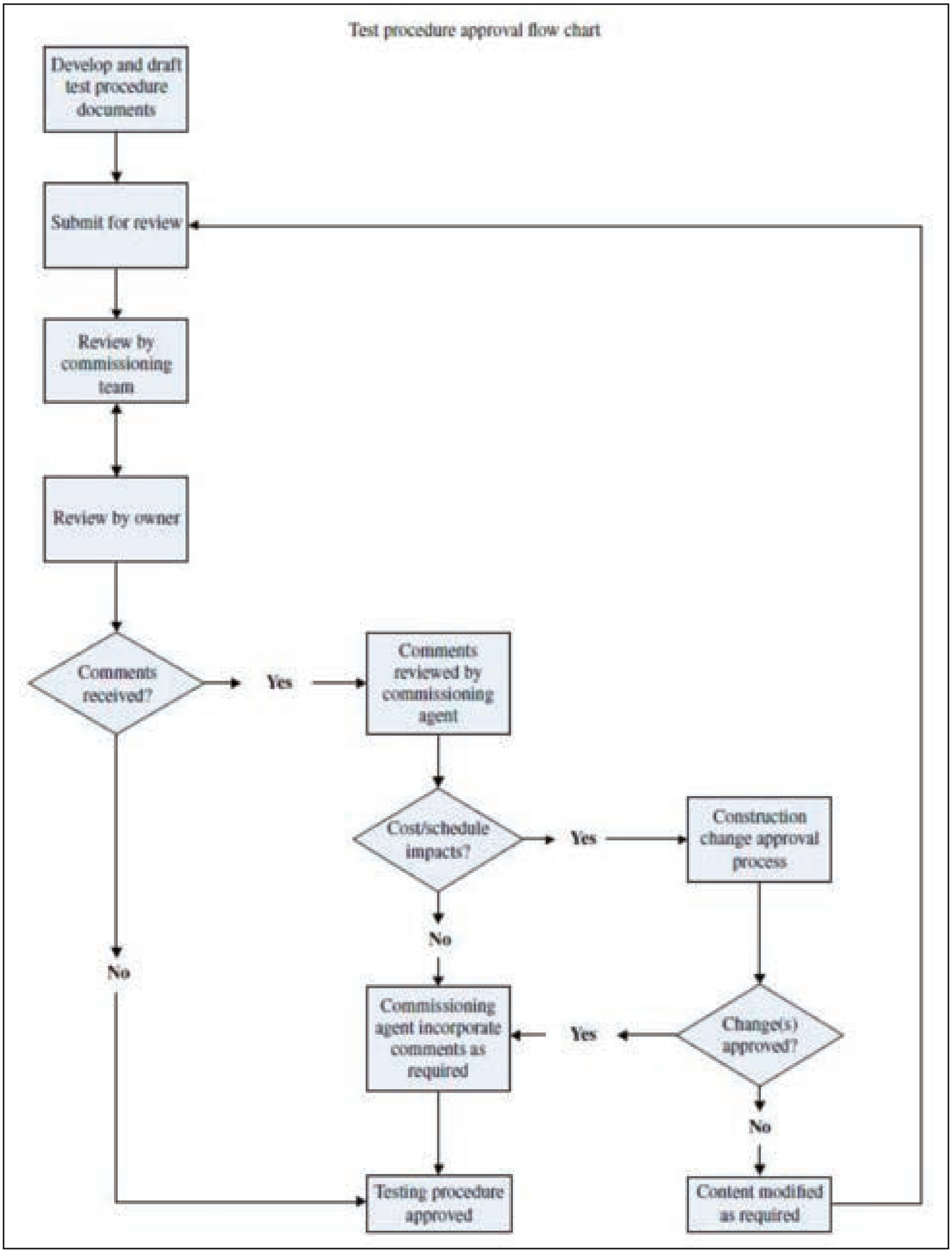


Figure 16.11: Test procedure approval chart

4.18 Factory performance test is a critical requirement for tier-III (rated-3) and Tier-IV (rated-4). Functional performance tests and IST verification process are two absolute musts when it comes to data center commissioning.

4.19 As built drawings (LOD 500), operation/ maintenance manual, lessons learnt and staff training are essential before project closure. It is a must for the engineering and operation/ maintenance department to have the complete set of operation and maintenance manual before taking over. The commissioning agent shall review the complete set of documents before taking over by operation.

5.0 Cold Rooms

Figure 16.12: Cold room

5.1 General

This document provides guidelines for the installation and maintenance of Freon-based refrigeration systems in cold storage facilities. The chapter also talks about some key pointers on installation and commissioning of thermal insulation, doors, and electrical / PLC systems in cold rooms. There is also information given on incorporating industry best practices, risk classification, regulatory protocols, and technical recommendations, with the aim to ensure optimal safety, energy efficiency, and compliance with relevant standards. Systems using ammonia as refrigerant are excluded from the scope of this section.

5.2 Risk Assessment and Storage Categories

Categorize cold storage zones by sensitivity and inventory type to plan work and mitigation strategies:

Low Risk	Medium Risk	High Risk	Highest Risk
Dry/non-perishable storage	Chilled produce	Vaccines/ medicines	Biopharmaceuticals, blood storage

5.3 Work Area Classification and Control

Apply control measures based on the disruption level and storage risk:

Class	During Works	Upon Completion
CLASS I	Limit dust, prompt cleanup, no refrigeration interruption	Clean-up work area
CLASS II	Seal entry/exit, use dust mats, isolate area, temporary covers for exposed goods	Damp mop, sanitize, inspect before resuming operations
CLASS III	Full area isolation, negative air pressure with scrubbers, critical barriers (plastic sheeting)	Deep clean, validate system integrity, documented inspection
CLASS IV	Total isolation, potential system shutdown, enhanced PPE, HEPA filtration, strict contamination control	Remove barriers only after owner and safety signoff, validate tightness, thorough cleaning, restoration records

5.4 Refrigeration System for Cold Rooms

- Install refrigerant lines (suction, discharge, liquid) as per drawings, minimizing bends and avoiding heat sources or mechanical damage.
- Use pipe hangers/supports at proper intervals to prevent sag and vibration.
- Use approved methods (brazing, welding, flare fittings) for pipe joining; ensure joints are free from burrs, moisture, or contamination.
- Apply the correct thickness of closed-cell insulation on all cold lines; seal all joints and terminations.
- Before insulation, pressure-test the piping system with dry nitrogen per code/standards, checking for leaks.
- After testing, evacuate all air and moisture with a vacuum pump to below 500 microns (absolute pressure).
- Install expansion/control valves, pressure regulators, driers, sight glasses, pressure switches, and sensors per design and manufacturer instructions.
- Connect drain lines to evaporators using correct slope; ensure no water stagnation occurs.

Install fixed refrigerant leak detectors as required.

- Install electrical panels and PLCs ensuring safe and compliant power/control wiring.
- Re-inspect the entire system for cleanliness, dryness, and tightness of all connections.
- Deep vacuum the system again if required.
- Charge the system with the specified Freon refrigerant type and quantity as per manufacturer guidelines.
- Use electronic detectors or soap solution to check all connections after charging.
- Power up ancillary equipment (fans, pumps, controllers) and then refrigeration circuits under manufacturer supervision.
- Program and calibrate all sensors, controllers, and PLCs for correct sequence operation.
- Operate the system under load, verifying operating pressures, temperatures, superheat/subcooling, compressor cycling, sound/vibration, and defrost operation.
- Simulate faults/emergencies to check proper alarm activation, emergency shutoff, fail-safe operation, and communication to remote systems (BMS/SCADA).
- Prepare as-built drawings, system manuals, warranties, and equipment/password logs.
- Train owner/operator staff in normal and emergency operation, routine maintenance, alarm response, and documentation.
- Submit all testing, balancing, and commissioning reports.
- Clean work area, remove debris, and restore facility readiness for occupancy or product storage.

5.5 Recommended Instrument Readings and Setpoints

Notes: Refer to the specific refrigerant data sheets (R22, R134a, R404A, R507, etc.) and all OEM documents for precise values.

Parameter	Typical Value/Range	Notes
Suction Pressure (Low Side)	1.5-4.0 bar (22–58 psi), varies by type	Depends on refrigerant and room temperature
Discharge Pressure (High Side)	9-18 bar (130–260 psi), varies by type	Monitor for abnormal rise/drop
Room Temp: Cold Storage	1-8°C	As per product requirement
Room Temp: Freezer	–22 to –18°C	As per product requirement
Evaporator Superheat	5–8K (Kelvin)	For efficient operation, prevent flooding
Condenser Subcooling	3–5K	Ensures adequate liquid to expansion valve
Compressor Oil Pressure	Per manufacturer's recommendation	Usually 1-2 bar above suction pressure
Insulation Resistance (Elec)	>1 MΩ @ 500V DC	For all major motors, per IEC/IS/NEC specs
Voltage Supply (Main Panel)	400 V ±5% (three phase), 230 V ±5% (single phase)	Adjust as per region (India/Europe/US)
Refrigerant Leak Detectors	Alarm at 50-75% of TLV-TWA	As per ASHRAE or national standard

5.6 Installation Checklist for Cold Rooms

Question	Yes/ No	N/A	Remarks
Piping and joints leak-free?			
Electrical wiring up to code?			
All panels/covers secured and clean?			
All refrigerant lines insulated without gaps?			
Defrost system operating?			
Drains clear and unobstructed?			
Pressure controls calibrated?			
Refrigerant detector(s) tested?			
Door gaskets and closures intact?			
Monitoring and alarms functional?			

5.7 Commissioning of Cold Rooms

Refer to ISHRAE Commissioning Standard 10003-2020 and follow the commissioning process specified therein. Also, follow ISO 817, ASHRAE 15 and 34, and all local/national codes for refrigerant classification, installation, and operation.

- Perform commissioning with system performance tests and control verification.
- Install and test refrigerant leak detection and mechanical ventilation to meet the TLV-TWA of each refrigerant.
- Only permit certified and trained technicians to work on refrigeration system.
- Compressor and machinery rooms are preferred with at least three external walls and one-hour fire-rated construction.
- Avoid installing refrigeration equipment in basements or sharing fire compartments with combustible devices.
- Use corrosion-resistant materials suited for humid areas.
- All refrigerant piping must be clean and clear of debris prior to installation.
- Use ASTM-rated, non-slit insulation for pipes; seal seams thoroughly to prevent thermal bridges and moisture ingress.
- Design insulation thickness based on application (typically 10 cm for above-freezing, 15 cm for below-freezing environments).
- Install drain sensors or float switches to detect clogs or overflow; integrate with the Building Management System (BMS) for instant alarms.
- Routinely inspect and clean drain pans/traps to avoid microbial growth and flooding.
- Monitor vibrations and noise using loggers or routine inspections to limit equipment wear and preserve product quality.

5.8 Leak Detection Best Practices

Use a robust mix of detection approaches:

- Visual inspections for oil residue.
- Soap bubble (or equivalent) tests for pinpointing leaks.
- Electronic gas detectors and fixed leak detection systems.
- UV dye tracing or pressure decay methods for ongoing monitoring.
- Strictly maintain and calibrate all detection devices as specified by manufacturers.
- Train staff for rapid leak containment, reporting, and safe evacuation, if required.

5.9 Thermal Insulation for Cold Rooms

Proper installation of sandwich panels ensures structural stability, thermal performance, and durability.

5.9.1 Pre-installation Checks

- Verify panel specifications (type, thickness, core material, facing sheet grade/coating) against approved drawings.
- Inspect panels for transport/storage damage (dents, delamination, moisture ingress at edges).
- Ensure sub-structure alignment (purlins, girts, wall supports) as per tolerance limits.
- Confirm that all accessories (fasteners, sealants, flashings, trims) are available and as specified.

5.9.2 Installation Checks

- Use spreader beams, suction lifters, or nylon slings to avoid panel damage.
- Position panels as per layout drawings; ensure correct orientation (lapping side and joint direction).
- Use self-drilling/self-tapping screws with neoprene washers.
- Maintain recommended spacing for roof and wall fasteners.
- Do not overtighten – avoid crushing of facings.
- Apply approved sealant or gasket in panel joints for weather-tightness.
- Use cold-cutting tools (not gas/plasma cutters) to prevent coating damage.
- Provide allowance for thermal expansion, especially in long panels.

5.9.3 Commissioning and Final Checks

- Ensure panels are straight, plumb, and level, with uniform joint lines.
- Check all joints, flashing, and sealant applications for continuity and no visible gaps.
- Verify that all fasteners are properly seated and capped; replace any damaged screws/washers.
- Remove cutting swarf, sealant smears, and debris from panel surfaces.
- Ensure roof slopes, gutters, and downpipes are clear and functional.
- Touch up scratches with approved paint; avoid exposure of core material.

5.9.4 Hand-over and Documentation

- Provide as-built drawings, maintenance instructions, and warranty documents.
- Record and hand over inspection checklists with any punch-list items resolved.

5.10 Installation of Insulated Cold Room Doors

Proper installation of insulated doors ensures thermal efficiency, hygiene, and durability of cold storage facilities. The following points must be verified during installation and commissioning:

5.10.1 Pre-installation Checks

- Confirm door type, size, thickness, and insulation (PUF/PIR/mineral wool) as per approved drawings.
- Inspect door leaf, frame, gaskets, and hardware for transport or handling damage.
- Verify that the opening dimensions are accurate and square, with level flooring and plumb wall surfaces.
- Ensure that floor insulation and vapor barriers are correctly installed before fixing the frame.

5.10.2 Frame and Leaf Installation

- Position and anchor the door frame firmly into the insulated panel/wall opening, ensuring correct alignment.
- Apply approved PUF/PIR sealant or vapor-tight seal between frame and wall/panel to prevent thermal bridging and condensation.
- Hang the door leaf and check uniform clearance on all sides.
- Ensure hinges, tracks (for sliding doors), and hardware are properly aligned and lubricated.

5.10.3. Sealing and Accessories

- Verify that gaskets are continuous, undamaged, and properly compressed when the door is closed.
- Check heater wires (if applicable, for freezer doors) around the frame/threshold to prevent condensation and ice buildup.
- Install handles, locks, panic release devices, and vision panels (if specified).
- For sliding doors, confirm smooth and effortless movement along the track with no obstructions.

5.10.4. Commissioning and Final Checks

- Close the door and check for light leaks or air gaps along the perimeter.
- Ensure smooth opening/closing without excessive force; auto-closing (if provided) must function correctly.
- Verify panic release (inside opening), door heaters, and limit switches for functionality.
- Confirm heater circuits and vapor seals are functional in low-temperature applications.
- Remove protective films, debris, and ensure surfaces are free from scratches or sealant smears.

5.10.5 Hand-over and Documentation

- Provide operation and maintenance manual, including cleaning procedures and lubrication schedule.
- Record commissioning checks for door heaters, gaskets, and hardware.
- Hand over warranty documents and spare part list (gaskets, heater wire, fasteners).

5.11 Electrical Systems and PLC in Cold Rooms

Electrical systems and PLC-based automation ensure safe operation, temperature control, and energy efficiency of cold rooms. The following points must be checked during installation and commissioning:

5.11.1 Pre-installation Checks

- Verify electrical design documents (single-line diagrams, control schematics, panel layouts) against approved drawings.
- Confirm supply capacity (voltage, phase, frequency, load rating) as per equipment specifications.
- Inspect electrical panels, switchgear, PLC modules, and wiring for any transport damage.
- Ensure earthing pits and grounding systems are installed and tested as per IS 3043.
- Confirm availability of UPS/backup power (DG/ATS) for critical loads.

5.11.2. Electrical System Installation

- Install main distribution panels (MDP), sub-panels, and control panels in accessible, moisture-protected locations.
- Route cables in proper trays/conduits; maintain separation of power, control, and communication lines.
- Use cables with correct insulation, size, and fire-retardant properties (FRLS/halogen-free).
- Ensure proper earthing and bonding of panels, compressors, evaporators, condensers, and lighting systems.
- Install circuit protection (MCBs/MCCBs, RCCBs, fuses) as per load requirements.
- Fit emergency lighting and exit signage with battery backup in compliance with safety standards.

5.11.3 PLC and Control System Installation

- Mount PLC and I/O modules in dust- and moisture-protected enclosures with adequate ventilation.
- Ensure proper wiring of sensors (temperature,

humidity, door contacts), actuators (valves, fans), and safety interlocks.

- Verify correct termination of communication cables (Ethernet/RS485/Modbus) for remote monitoring.
- Load and configure PLC software as per control logic (set points, alarms, interlocks).
- Ensure provision for manual override in case of automation failure.

5.11.4 Commissioning Checks

- Power System:
  - o Insulation resistance test of cables.
  - o Verify phase sequence, voltage levels, and earthing continuity.
  - o Check breaker/fuse ratings against equipment load.
- Panel:
  - o Tightness of connections and torque settings.
  - o Functionality of indicators, meters, and switches.
  - o Verification of protective relays (overload, short-circuit, earth fault).
- PLC and Automation:
  - o Verify sensor calibration and correct mapping to PLC inputs.
  - o Test setpoint-based operation (cooling start/stop, defrost cycles, door interlocks).
  - o Check alarm annunciation for high/low temperature, power failure, and door open.
  - o Validate data logging, SCADA/HMI display, and remote access (if applicable).
- Safety Systems:
  - o Emergency stop switches functional and accessible.
  - o Door trap alarms/panic release connected to power and PLC.
  - o Battery backup and auto-restart after power failure tested.

5.11.5 Hand-over and Documentation

- Submit as-built drawings, panel wiring diagrams, and PLC program backups.
- Provide test certificates (earthing, insulation resistance, panel FAT/SAT reports).
- Handover O&M manuals for electrical panels, PLC systems, and sensors.
- Train operating staff on setpoint adjustment, alarm acknowledgement, and basic troubleshooting.
- Provide list of spares (fuses, relays, PLC modules, sensors).

Chapter 17

Electrical Equipment and Systems

1.0 General

Proper and correct installation of electrical systems and equipment is of utmost importance not only from their application point of view but also from safety point of view both during their installation as also during operation phase.

Safety of the people handling, erecting, commissioning and operating the systems is of the highest importance. Instructions must be followed both in letter and spirit. All access and control points shall be provided with safety/isolating switches. Equipment and cables/wires need to be adequately sized. Proper marking and labelling at all open and accessible locations is a must.

Failure to follow correct Lockout Tagout (LOTO) procedure, removal of grounding pins, use of defective/unsafe power tools, use of tools or equipment close to energized parts can all contribute to electrical hazards.

Please refer to Chapter 19 on Safety as well as to ISHRAE publication on Safety for a comprehensive understanding of Electrical Safety.

Electrical installations are covered under Indian Electricity Act and the rules framed thereunder. Also, guidelines in this regard are often framed by Authority Having Jurisdiction (AHJ). These have to be complied with.

2.0 Power Supply and Distribution

- Electrical panels applicable to LV distribution panels, MCCs, PCCs etc.
- Main power cable feeds power from the supply mains or source.
- Earthing/grounding system.

2.1 Installation, Testing and Commissioning of Electrical panels

2.1.1 Electrical panels act as the nodal point in an electrical distribution network. The main functions of a typical electrical panel are to receive incoming power and distribute it to various loads and sub-panels while protecting all the components involved in this activity. Main components in an electrical panel are its incoming section, busbars, outgoing feeders and protection devices.

Power distribution to various equipment in an air-conditioning system is being handled by a Motor Control Centre (MCC). It is an electrical panel that houses motor starters, protection devices and control equipment for starting, protecting and controlling electric motors.

2.1.2 Pre-Installation Checks

- Document verification: This includes scrutiny of panel GA drawings, single-line diagrams (SLDs), control wiring diagrams, and material specifications. It is essential that the entire panel assembly is thoroughly verified for adherence to the approved GA drawings.
- Delivery inspection: Panels need to be checked for any possible physical damage, moisture ingress, or missing components. The nameplate details of the panels also need to be verified.
- Site readiness: Civil works shall be completed, including flooring, wall openings, cable trenches, access clearances etc. before the panel is brought to site. Choosing an accessible, well-ventilated, and dry location, away from heat sources, moisture, or flammable materials is very important.

Confirm that maintenance and access clearances comply with applicable electrical code.

2.1.3 Installation of Electrical Panels

- Positioning and fixing of panel: Proper mounting of electrical panels is crucial for stability and safety. Panels shall be securely fastened to the wall, foundation frame, or plinth to prevent movement or dislodging, which may cause electrical faults or safety hazards. Vertical and horizontal alignment must be ensured before fixing the panel to the base frame.
- If the panel is modular in construction, join multiple sections using the manufacturer-provided bolts and gaskets.
- Clear space not less than 1 meter shall be provided in front of the panel. If there is any attachment at the back of the panel clear space behind the panel shall be either less than 200 mm or more than 750 mm from the farthest outstanding part of the switchgear. If the space behind the panel exceeds 750 mm, there shall be a passageway from either end clear to a height of 1.8 m.
- All disconnect switches shall be clearly identified and labelled indicating the source of the circuit and the equipment/circuit it is feeding.
- Insulation mat conforming to IS 15652 of proper grade shall be used in front of panels of 415 volts and above.
- All panel doors shall be lockable and shall be made vermin proof by sealing all entry holes.
- Busbar connection: Busbar joints are usually bolted to facilitate maintenance. Correct phase sequence and proper tightening with a torque wrench, as per the manufacturer's guidelines, must be ensured during busbar connection. Busbar surfaces shall be smooth, clean, and free from oxide layers. A thin coat of contact grease, petroleum jelly, or conductive paste shall be applied to prevent oxidation. When multiple panel segments are joined, busbar links or expansion joints shall be used.
- Bus coupler panel and its cubicle shall be installed with utmost care. Bus coupler, adaptor panel and tie feeder panel shall be painted red on all sides for easy identification.
- Incoming barrier for power supply and phase barrier inside the switchgear panel shall be maintained.
- Cable entry preparation: Mark the cable entry points (top or bottom) as per the design. Ensure that the entry points are properly aligned with the cable trenches and trays.
- Gland plate preparation and cable glanding: Panels are typically provided with removable gland plates for cable entry. The correct type of cable gland (e.g., single compression, double compression, flameproof, weatherproof, plastic, etc.) must be selected based on the cable type and environmental conditions. Holes shall be drilled or punched on the gland plates to match the sizes of the selected glands. Cable glands for incoming and outgoing cables must be tightened with the recommended torque specified by the manufacturer. During this activity, ensure both earth continuity and the required degree of IP protection.
- Sealing: Maintaining the required Ingress Protection (IP) rating is critical for panels. Appropriate sealing compounds, gaskets, or brushes shall be used to ensure IP compliance. For outdoor panels, cable entries must be properly waterproofed. In hazardous areas, flameproof or explosion-proof glands shall be provided. Suitable cable supports and clamps shall be installed inside the panel to minimize strain on the terminations.
- Segregation and routing: Power cables, control cables, and communication cables shall be routed in separate ducts or trays to ensure proper segregation. Ferrules and markers shall be provided for clear cable identification.
- Cable termination: Cable termination inside an electrical panel is critical, as poor termination may cause hot spots and arcing. This will be further detailed in cables section.
- Panel earthing: A proper earthing system ensures personnel safety, equipment protection, effective fault current dissipation, and EMC compliance. The main component of panel earthing is the panel earth busbar. All non-current-carrying metallic parts, including the panel body, cable glands, and equipment installed inside the panel, shall be connected to the earth bus. The earthing conductor shall be sized as per IS 3043 / IEC 60364 to withstand the rated fault current and limit temperature rise. At least two independent earth connections from the panel to the earth grid shall be provided.

All doors shall be earthed using flexible copper braids or straps to ensure continuity even when the door is open.

Figure 17.1: Electrical panel installation

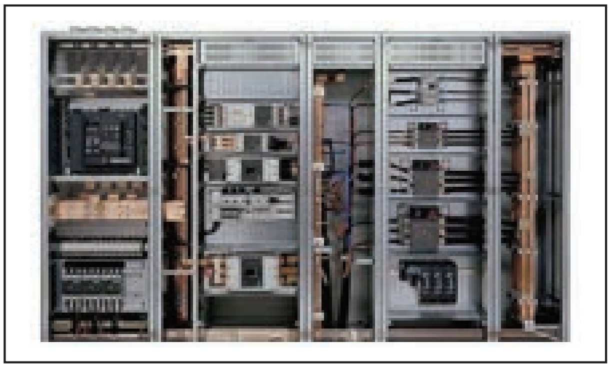


Figure 17.2: Open view of electrical panel

2.1.4 Pre-commissioning of Electrical Panels

Pre-commissioning of electrical panels involves activities carried out after installation but before energization, to ensure that the panel is mechanically, electrically, and functionally ready for safe operation. The key pre-commissioning activities are listed below:

- Mechanical checks and visual inspection. Key check lists:

1) Inspect for physical damage or defects, including the quality of paint work. Check for signs of corrosion and ensure no parts are missing.
2) Inspect panel alignment, proper coupling between sections, and secure anchoring to the foundation.
3) Verify the circuit layout for conformance with the approved GA drawing.
4) Verify that each circuit breaker has the correct rating as per the design drawings.
5) Check the tightness of all bolted connections.
6) Verify that phase separators, insulation sleeves, and shrouds are correctly installed and in place.
7) Verify that all front panel-mounted devices like meters, selector switches, push buttons, timers, indication lamps, etc. are installed as per the layout drawing and are correctly labelled.
8) Check for proper grounding connection.
9) Ensure that ventilation louvers and filters are clean, unobstructed, and in good condition.
10) Ensure that all covers, doors, partitions, and shrouds are properly fixed.

- Electrical tests. Key check lists:

1) Insulation test of all buses and wiring.
2) Polarity and phase sequence check.
3) Functional check of breakers, power contactors etc.
4) Calibrate voltmeters, ammeters, watt meters and phase selector switches.
5) Functional check of various relays and alarms. Confirm relay wiring and auxiliary circuits match schematic.
6) Functional check of all auxiliary devices including individual, group and main circuit breaker alarms.
7) Continuity test of control wiring, protection circuits, and interlocks. Check interlock operation (mechanical and electrical).
8) Verify CT and PT connections, polarity marks, and shorting links.
9) Verify protection settings on relays are as per coordination study.
10) There shall be no loose wiring, exposed joints and open cover on distribution box or junction box. Any switch gear which has been kept disconnected for a period exceeding three months shall be energized only after testing.

- Earthing and bonding:

1) Confirm that at least two independent earth connections are provided from the panel to the earth grid.
2) Check continuity between the main earth bar and all non-current-carrying metallic parts.
3) Verify earthing of doors, covers, cable gland plates, CT/PT chambers, and other metallic enclosures.
4) Ensure that cable armors are earthed at the cable glands.

- Cable termination and glanding:

1) Check that correct glands are used.
2) Ensure that cable lugs are crimped properly and tightened to recommended torque.

3) Confirm phase segregation and proper ferruling of all cables and cores.

- Pre-commissioning tests.

1) Perform Insulation Resistance (IR) tests on busbars: phase-to-phase and phase-to-earth.
2) Perform IR test on control wiring.
3) Perform high-voltage withstand test as specified by the OEM and project requirements.
4) Conduct secondary injection tests on relays to verify correct operation and tripping characteristics.
5) Measure the contact resistance of busbars and circuit breakers to ensure values are within acceptable limits.
6) Perform functional tests of tripping circuits and alarm circuits to verify correct operation.
7) Ensure that space heaters, thermostats, and illumination lamps (if provided) are tested.

- Panel cleaning:

1) Remove all tools, debris, and temporary jumpers.
2) Clean busbars, insulators, and cubicles with dry lint-free cloth or vacuum.
3) Ensure that no foreign materials like nuts, washers, wires etc. are left inside the panel.
4) Ensure that all doors, covers, and compartments are closed.
5) Place updated as-built drawings and test reports inside panel pocket.

2.1.5 Commissioning Activities of Electrical Panel

Following successful installation and pre-commissioning activities, the commissioning and energization of the panels are carried out. This critical phase includes making the panel live, verifying protection schemes, and preparing it for handover to service. It is generally done in following sequence:

1) Initial energization: Close the incoming breaker with all outgoing feeders kept in OFF position. Then check parameters such as busbar voltage levels (phase–phase, phase–neutral), phase sequence, heating, noise etc. After keeping the panel energized for a short span, IR values to be measured to ensure that there is no insulation deterioration.
2) Functional verification: Switch ON outgoing feeders one by one in a logical sequence. Measure and record parameters such as voltage, current, PF, frequency and load balance. Check the temperature at connections and joints to ensure that there are no loose connections. Verify the correct functioning of various auxiliary components like indicating lamps, meters, CT/PT circuits, selector switches, push buttons, space heaters, thermostats, panel lights etc.
3) Protection and interlock testing: Following tests are generally conducted to ensure various protection arrangements.

a. Relay testing: Primary/secondary injection tests to verify correct trip settings. Confirm under-voltage, over-current, earth fault, differential, etc. operate correctly.
b. Breaker functional checks: Manual and electrical closing/tripping. Spring charging mechanisms. Interlocks (door, mechanical, racking, key interlocks).
c. Trip circuit supervision: Ensure alarms/ indications are functional.

4) Load trial and stabilization: During this activity, the panel will be gradually energized under actual load conditions. Record load profiles for a defined period and capture critical parameters such as load sharing between feeders, current balance across phases, and breaker/busbar temperature rise.
5) Documentation and handover: At this stage, the commissioning report, as-built drawings, and operation and maintenance manuals shall be furnished to the client. The panel shall then be formally handed over to the operation and maintenance team.

3.0 Installation, Testing and Commissioning of Cables

The primary function of power cables is to transmit electrical power — low, medium, or high voltage —from the source, such as a transformer, switchgear, or distribution panel, to various loads, including motors, lighting, machinery, or sub-panels. They are designed to ensure a continuous and reliable power supply with minimal losses. Hence, the appropriate selection of cables is crucial, considering factors such as insulation, mechanical protection, and the ability to withstand system and environmental stresses. While the above aspects are addressed during the design and planning stage, achieving the intended design requires proper installation, testing, and commissioning of cables.

The installation and commissioning of power cables must be done systematically to ensure safety, performance, and compliance with standards.

Figure 17.3: Termination of cables

3.1 Installation and Commissioning Procedure for Cables

3.1.1 Pre-Installation Checks

Following are the pre-installations checks to be conducted for cables:

i) Verification of cable datasheets and specifications to meet project design intent. Some of key parameters are voltage rating, conductor material and size, core configuration, insulation material, inner and outer sheath materials, armor type, thermal parameters, dimensional details, and fire resistance.
ii) Verification of test certificates.
iii) Designated cable route to be inspected at site to ensure the compliance with drawings, required safety clearance, unforeseen site obstacles etc. Required clearances from heat sources, steam lines, and fuel lines must be maintained. It is also important to ensure that space for necessary bending radius is available at site.
iv) Verification of the cable drum lot received at site for any potential damage

3.1.2 Cable Storage

To prevent damage during storage and handling, cable drums must be stored and managed with proper care. They should be kept upright on firm ground, away from heat sources, water, and chemicals. If stored outdoors, the drums shall be covered to avoid prolonged exposure to sunlight. Drums must be rolled only in the direction indicated on the flange.

3.1.3 Cable Routing and Cable Laying

While planning the cable routing, power, control, instrumentation, and communication cables shall be segregated and laid separately to prevent interference. If unavoidable, power and signal cables should cross at right angles. Grouping of cables must take into account derating factors for current-carrying capacity. Adequate spacing shall be maintained between high-voltage (HV), medium-voltage (MV), and low-voltage (LV) cables.

Before cable laying, proper route marking shall be done as per approved drawings. For underground cables, cable trench shall be excavated to the required depth as per the standards along with required sand bed at the trench base. Adequate drainage must be provided to avoid water logging in trenches. Further, necessary backfilling and protective covers shall be provided at the top of the trench.

When cables are laid on cable tray, it must be ensured that the trays are aligned properly and firmly supported. Earthing continuity of metallic trays must be ensured and sharp edges, weld burrs, protrusions etc. shall be removed to avoid sheath damage. Anti-corrosive coating shall be applied as necessary. Supports/clamps must be provided at regular intervals to avoid sagging.

Whenever cable is crossing wall/partition, necessary sleeves/ducts shall be provided. Similarly, whenever cable crosses fire partition, wall openings must be protected with approved and adequately rated fire-sealant compound.

Before cable laying, Insulation Resistance (IR) and continuity of the cable to be checked to rule out any possible damage. Cable drums to be positioned near the laying point and necessary cable pulling equipment like rollers, winches, pulling ropes, socks etc. shall be made available before the activity.

General precautions to be followed while cable laying:

- Maintain minimum bending radius as stipulated by the standards and manufacturer's guidelines. Avoid sharp bends.
- Avoid mechanical stress: Place the drum on a cable jack/roller so the cable unreels from the top, not the bottom.
- Use cable socks/grips for pulling and cable should be pulled gently and guided along rollers.
- Do not exceed manufacturer's specified maximum pulling tension.

3.1.4 Cable Termination

Cable jointing is a critical activity in electrical installation. Even if a cable is of good quality and correctly laid, poor jointing or termination can cause failures such as heating, arcing, or insulation breakdown. Various stages of cable termination activities are briefly mentioned below:

- Ensure correct type and rating of termination kits as per voltage level.
- Before starting the work, verify that the cables are properly tested for Insulation resistance and continuity.
- Work area must be clean and dry.
- Cable ends must be properly sealed until termination is done.
- Cable preparation includes removal of outer sheath, armor and insulation without damaging the conductor strands.
- Further, the conductor and insulation surface must be cleaned with recommended solvent to ensure that it is free of oxide, dirt, moisture and grease.
- Install heat-shrink or cold-shrink terminations as per kit design.
- Ensure proper earthing/shield connection.

3.1.5 Pre-commissioning Activities/Tests:

i) Visual and Physical Inspection involves:
- Verification of cable routing, supports and dressing.
- Ensuring that there are no sharp bends, installation of glands and termination are proper.
- Ensuring that protective covering and route markers are in place.
- Confirm earthing/bonding of metallic sheaths and armors.

ii) Continuity test shall be carried out using a multimeter or continuity tester to ensure that each conductor is continuous end-to-end without breaks.

iii) IR Test, using meggers, should be performed to check the insulation integrity between phases and phase-to-earth.

v) High voltage test / withstand test (Hi-Pot Test) should be conducted to check dielectric strength of the cable insulation.

vi) Earthing/bonding checks shall be carried out to confirm proper bonding of armor/sheath to earth at one or both ends.

3.1.6 Commissioning Activities/Tests

Step by step commissioning procedure is listed below:

Step 1: Visual Inspection

During the final inspection, all connections should be verified at panels, switchgear, motor terminals, etc. In addition, the polarity and phase sequence should be reconfirmed. Ensure that switchgear and protection devices of the appropriate rated capacity are installed and operational.

Step 2: Gradual Energization

Feeders shall be energized in a predefined, sequential, and controlled manner. For heavier loads, they should be brought online gradually, starting from no load to part load to full load. During system energization, observe the connected equipment for any abnormal heating, noise, vibration, or other irregularities.

Step 3: Monitoring the Parameters:

i) Measure current and voltage readings across all phases and check for balance.

ii) Ensure that the earth leakage current is within acceptable limits.

iii) Thermal Monitoring should be conducted using an IR thermometer/thermal camera to detect hotspots at terminations, joints, and gland points.

iv) Protection Scheme Verification should be ensured for various relays by aligning trip settings with coordination study.

3.1.7 Post-Commissioning Checks

Following are the key post-commissioning checks:

i) Re-measure insulation resistance after energization to ensure no degradation.

ii) Verify circuit labels, cable tags, and route markers. Confirm that all safety covers, trench lids, and fire-stopping measures have been properly reinstated.

iii) Record load test results (voltage drop, current profile under load).

iv) Obtain formal acceptance certificate from client/consultant.

3.1.8 Documentation and Handover

Handing over documents shall include:

i) Complete records of test conducted during the pre-commissioning and commissioning stages.

ii) Cable details such as size, length, type, route etc.

iii) Protective relay settings.

iv) Other observation, if any.

3.2 Installation, Testing and Commissioning of Control Cabling

3.2.1 Cable pulling: Pull cables carefully to avoid exceeding the maximum tensile strength and damaging the insulation. Use rollers and other guiding equipment, especially at bends, to prevent sharp kinks and abrasion. Lay cables through conduits/trays as per route approved. Avoid sharp bends and provide adequate supports and saddles at intervals. Use sleeves/glands at wall or panel entry points.

3.2.2 Power and control cable separation: Maintain physical separation between power and low-voltage control cables to prevent electromagnetic interference (EMI). Run them in separate cable trays or conduits, keeping a minimum distance 300 mm separation between low-voltage control cables and high-voltage (LV/HV) power cables, if run in parallel without shielding. If power and control cables cross, they should cross at 90°. Control and power cables should not share the same tray unless separated by earthed metallic partitions.

3.2.3 Cable management: Neatly arrange cables within trays and conduits using cable ties. Do not over-bundle cables, which can cause crushing and damage. Leave a service loop of extra cable at terminal points to allow for future maintenance and replacement.

3.2.4 Shielding: For analog signal cables, ensure that shielded twisted-pair cables are used and the shielding is properly terminated at the control panel to minimize noise interference.

3.2.5 Labelling: Label both ends of each cable clearly with permanent tags corresponding to the project wiring diagrams. This is crucial for troubleshooting and maintenance.

3.2.6 Termination: Terminate wires at all components — including controllers, actuators, sensors, and terminal blocks — according to the wiring diagrams. Use appropriately sized crimpers or ferrules to prevent loose connections. Use correct size lugs, ferrules, and shield grounding. Tighten screws with torque as per terminal manufacturer's recommendation.

3.2.7 Grounding: Verify that all control panels, equipment, cable trays, and conduit systems are properly bonded and connected to the main ground lug. Ensure shielding on sensitive control cables is grounded correctly.

3.2.8 Instrument calibration: Calibrate all sensors, including temperature, humidity, and pressure sensors, according to manufacturer specifications.

3.2.9 Point-to-point verification: Systematically check continuity and resistance for every control cable from the control panel to its endpoint device to ensure correct connections.

3.2.10 Post-Installation Checks: Conduct post installation checks like continuity test, insulation resistance test, polarity check, shield grounding check, loop verification etc.

3.2.11 Safety interlocks: Test all safety devices and interlocks, such as smoke detectors, freeze protection, and high/low pressure switches, to ensure they trigger the correct shutdown sequences.

3.2.12 Power-up: Energize the control panels and verify that all power supplies are correct, particularly the low-voltage control circuits.

3.2.13 Functional performance testing (FPT): Test the full sequence of operations for the HVAC system. Run end-to-end functional test to ensure that the system responds to commands, sequences operate correctly.

3.2.14 Inter-system communication: For integrated systems using a Building Management System (BMS), test the communication between all controllers and the central monitoring software.

4.0 Earthing/Grounding System

The main purpose of the earthing of electrical installations is:

i) Protective earthing to limit the potential of non-current carrying metal parts associated with equipment and appliance connected to the system.

ii) System earthing of to limit the potential of current carrying conductor forming part of the electrical system.

The earthing system in India is primarily based on the Terra-Neutral-Separate (TN-S) system for low-voltage consumers, regulated by the Central Electricity Authority (CEA) Regulations and the Bureau of Indian Standards. This system ensures safety by separating the neutral and protective earth conductors throughout the electrical installation.

The main purposes of an earthing (or grounding) system in an HVAC&R system are to protect people from electrical shock, safeguard the equipment from faults and voltage surges, and ensure stable, reliable operation of the equipment. By providing a low-resistance path for fault currents to flow into the earth, the earthing system prevents dangerous voltage buildup and helps protective devices like circuit breakers to operate correctly, thus preventing equipment damage, fires, and electrocution.

Earthing provides a safe path for fault currents to flow into the earth, preventing them from passing through operating personnel. It safeguards the equipment's sensitive electronic components from damage caused by lightning strikes and voltage surges, which can cause excessive current flow. By diverting excess electrical current safely to the ground during a short circuit or fault, earthing helps prevent electrical fires and property damage. The earthing system acts as a stable reference point, helping to regulate voltage levels and ensure consistent and safe operation of the unit's electrical components. An effective earthing system ensures that protective devices, such as relays, circuit breakers etc. operate correctly when a fault occurs, disconnecting the power supply and enhancing overall safety.

4.1 Installation and Commissioning of Earthing System

4.1.1 Prior to the installation following details should be ensured:

i) Grounding requirements as per local electrical code and equipment manufacturer's specifications.
ii) Review earthing design and drawings.
iii) Identify the designated grounding points in the main electrical distribution system.
iv) Selection of earthing conductor should be based on fault current capacity, mechanical strength, earth resistivity etc. Ensure the earthing materials comply with standards (IS 3043, IEEE 80, IEC 60364).
v) Confirm soil resistivity tests have been conducted to determine the number and type of earth electrodes required.

4.1.2 Earthing of indoor/outdoor unit (of a split AC)

i) Identify the designated earthing terminal on the indoor/outdoor unit.
ii) Connect it with dedicated earth conductor.
iii) Route the earth conductor with the power supply cable from the distribution panel.
iv) Ensure that the outdoor unit is installed on a metal frame or base that is also bonded to earth.

4.1.3 Earthing of a chilled water system

Earthing of a chilled water system ensures safety of personnel, protection of various system equipment like chillers, pumps, AHUs, panels etc. It will also maintain equipotential bonding across metallic piping network.

i) Chillers (air-cooled / water-cooled):
- Connect earthing terminal on the chiller control panel and compressor body to the main earth bus.
- Bond metallic frames, motor casings, and control panels to earth.

ii) Pumps (primary, secondary, condenser pumps):
- Connect the motor body and control panel to the earth bus.
- Provide at least two earth connections for each motor.

iii) Air handling units (AHUs) / fan coil units (FCUs):
- Earth the motor body, control panel, and casing.
- Ensure flexible electrical connections retain earthing continuity.

iv) Cooling towers:
- Earth the motor, fan drive, and control panel.
- Bond metallic structural supports to the earthing grid.

v) Piping and metallic parts bonding:
- Bond chilled water supply and return piping to the earthing system at multiple points.
- Ensure equipotential bonding between piping, valves, and equipment casings
- For large installations, install earthing jumpers across pipe joints/flanges, especially if rubber-gasketed.
- Bond cable trays, ducts, and metallic supports to the earthing network.

vi) Electrical panels:
- Earth the chiller control panel, pump starter panels, MCCs, VFD panels and distribution boards.
- Provide each panel with two independent earth connections to the main earth bus.
- Ensure that cable glands and armor are properly terminated to earth.

vii) Connection to building earthing system:
- Connect all chilled water system earth conductors to the main earthing bus bar.
- This bus bar should be tied into the building earthing grid or earth pit system.

4.1.4 Post installation testing and verification:

i) Visual inspection
- Confirm that all metallic parts including the outdoor unit frame, indoor unit casing, compressor body, condenser fan motor, AHU/FCU casing, chilled water pumps, cooling

towers, duct supports, and AC control panels are connected to earth. Ensure two separate earth connections for three phase units.

- Check that the earthing conductors are of correct material and size as per the design. Ensure that there are no cuts, loose ends, corrosion, or paint at termination points. Proper color coding is followed.

ii) Continuity test

- Measure resistance between equipment earthing terminal and the main earth bus bar using a multimeter or continuity tester. Ensure that the value is sufficiently low.
- Ensure that there is no open circuit or loose connection in earth conductor.

iii) Earth resistance measurement

- Measure earth pit resistance to which AC system is connected using an Earth Resistance Tester (Megger). Check whether the values are within the accepted values. If resistance is high, improve with multiple earth pits, interconnections, or chemical earthing.

iv) Insulation resistance test

- Conduct IR test between Phase–Earth and Neutral–Earth using 500 V/1000 V Megger. IR should be $\geq$ 1 MΩ as per IEC/IS standards.
- This ensures that there is no leakage current to earth from the power cables feeding the AC units.

v) Functional Verification

Run the AC system and verify:

- No tripping of RCCB/ELCB due to poor earthing.
- No stray voltage or shock felt when touching AC metallic body.
- Voltage imbalance between phases for three phase load is within acceptable limits. Ideally less than 2%.

4.1.5 Documentation and handover

- Handing-over documentation shall include complete records of all test results and grounding/earthing layouts.
- These documents must be formally signed off by the installer, supervisor, and client representative.

5.0 Installation, Testing and Commissioning of Motors and Drives

5.1 Motors are essential part of HVAC equipment, which converts electrical energy into mechanical (rotational) energy. In the case of compressors this rotational force or torque, is then transferred to the compressor's pump mechanism, which compresses the refrigerant and then sends it to a condenser. In blowers or fans this rotational force or torque is used to rotate the fan, which then creates airflow by drawing in air and pushing it through the system.

5.2 Pre-Installation checks:

5.2.1 Physical inspection:

- Inspect the motor for any damage or defects that may have occurred during shipping or storage.
- Check for cleanliness and ensure there are no obstructions or blockages in the vents.
- Verify that the motor's base, mounting bolts, and other components are secure and properly aligned.

5.2.2 Mechanical checks:

- Manually rotate the motor shaft to confirm it turns freely and smoothly without any resistance or unusual sounds.
- Check for any leakage in the lubrication system and ensure the lubrication reservoir is properly filled.
- Confirm that the motor is appropriate for the area's classification (e.g., dust, moisture).

5.2.3 Documentation and nameplate verification:

- Verify the motor's nameplate details against project specifications.
- Confirm that all necessary documentation, certifications, and drawings are available and conform to project requirements.

5.2.4 Site preparation:

- Ensure a ready foundation and confirm the availability of utilities like electricity and water as specified.

5.2.5 Installation of motors

5.2.5.1. Foundation and mounting:

- Ensure the motor is rigidly mounted on a flat, stable foundation, as this is critical for preventing vibration and premature failure.

5.2.5.2 Alignment:

- Properly align the motor with the driven equipment (e.g., pumps, fans) to avoid excessive load on bearings and shafts.

5.2.5.3 Electrical connections:

- Make secure electrical connections at the terminal box and ensure correct phasing. Route the power supply via appropriate cables and make all electrical terminal connections for the motor.

- Connect the earthing wires/strips of motor to main earthing grid to ensure proper grounding of motor.
- Check the location of starter panels/drives panels to ensure its location with reference to motor location (Indoor or outdoor). Panels located in outdoors shall be with weatherproof enclosure.

5.2.6 Mechanical components:

- Carefully fit coupling parts or pulleys, avoiding hammering, which can damage the bearings.

5.3 Pre-commissioning of motors

Pre-commissioning of motors is associated with the activities carried out after installation but before energization to ensure that the motor is mechanically, electrically and functionally ready for safe operation. Key pre-commissioning activities are listed below:

5.3.1 Documentation and verification

- Confirm the availability and review the installation and operation manuals to ensure all manufacturer-specific guidelines are followed.
- Check that the motor's nameplate details (voltage, current, power rating) match the project's specifications and approved drawings.

5.3.2 Physical and mechanical checks

- Visual Inspection: Inspect the motor for any physical damage, cleanliness, and ensure it is properly mounted on its foundation. Check the motor placement as per type of application indoor or outdoor.
- Manual Rotation: If the motor size allows, attempt to turn the shaft by hand to ensure it rotates freely and without any unusual sounds or resistance, indicating proper bearing condition.
- Fastener tightness: Verify that all mounting bolts, terminal box connections and other fasteners are tight and secure.

5.3.3 Electrical checks

- Earthing: Confirm that the motor and its associated electrical panels are correctly and securely earthed.
- Insulation resistance and winding resistance: Measure the insulation resistance to ensure there are no faults within the motor windings using an insulation resistance tester. Measure the phase-to-phase winding resistance to ensure it's equal across all phases.
- Phasing: Check the phasing of the motor's power cables to ensure correct electrical connections.
- Cable connections: Ensure that the power and control cable connections at the motor terminal box and the control panel are tight and correct.
- Protective devices: Check the motor protection relay settings and verify tripping/alarms. Test the functionality of the motor starter, overload protection, circuit breakers and any associated protection relays.

5.3.4 Commissioning activities of motors

Following successful installation and pre-commissioning activities, the commissioning and energization of the motors are carried out.

5.3.4.1 Initial energization:

- Perform a brief 'uncoupled run' with the motor uncoupled from its driven equipment.
- Measure the no-load current and monitor for unusual noises or vibrations to ensure the motor is operating correctly.
- Check the direction of rotation by briefly energizing the motor for a few seconds.
- During the run, measure vibration levels and bearing temperatures to identify potential issues.

5.3.4.2. Energizing and testing:

- Once initial energization is successful, perform a final test run to confirm the motor operates without disrupting the system.
- Verify that all motor operations, including speed, torque and output meet the specified requirements.
- Monitor the current / power drawn and verify the same with approved data sheets.
- Record all test results and data for future reference and to confirm compliance with standards.

5.3.5 Documentation and handover:

- During this stage, commissioning report, as-built drawings, operation and maintenance manuals etc. shall be furnished to the client. Further, the motors along with associated equipment shall be handed over to operation and maintenance team.

6.0 Installation, Testing and Commissioning of EC Motors

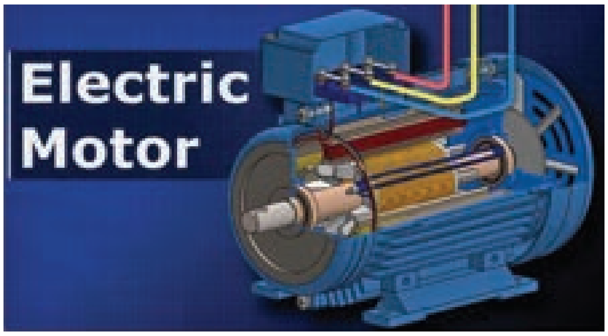


Figure 17.4 (a): Electric motors

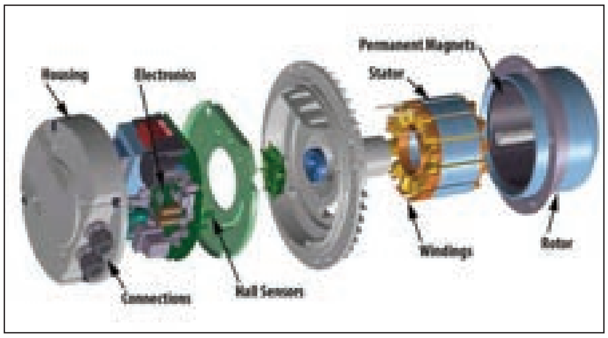


Figure 17.4 (b): EC Motors

6.1 EC motors are used in a wide range of applications requiring high energy efficiency, precise speed control and low maintenance. They are quiet operation and compact in size.

6.2 Installation and commissioning procedure for E C Motors.

6.2.1 Pre-Installation checks:

6.2.1.1 Physical inspection.:

- Inspect the motor for any damage, corrosion or signs of wear. Check for cleanliness and ensure there are no obstructions or blockages in the vents.
- Check the fan blades for any damage or obstructions that could cause imbalance during rotation.
- Verify the motor's physical fit with the mounting surface to prevent misalignment.

6.2.1.2 Mechanical checks:

- Perform a manual rotation test by turning the motor shaft by hand to check for free, smooth rotation.
- Listen for any unusual binding or abrasive sounds during the manual rotation, which could indicate bearing issues or foreign objects.
- Confirm that the motor is appropriate for the area's classification (e.g. dust, moisture).

6.2.1.3 Documentation and nameplate verification:

- Verify the motor's nameplate details against project specifications.
- Confirm that all necessary documentation, certifications, and drawings are available and conform to project requirements.

6.3 Site preparation and mounting

- Ensure a ready foundation and confirm the availability of utilities like electricity and water as specified.
- Ensure the motor is rigidly mounted on a flat, stable foundation, as this is critical for preventing vibration and premature failure.
- Check for proper alignment with the connected equipment to prevent excessive load on the bearings and shaft.
- For belt-driven systems, ensure the belt tension is at the recommended level to avoid undue strain.

6.4 Electrical connections

- Make secure electrical connections at the terminal box. Route the power supply via appropriate cables and make all electrical terminal connections for the motor.
- Connect the earthing wires/strips of motor to main earthing grid to ensure proper grounding of motor.
- Check the location of control panels to ensure its location with reference to motor location (Indoor or outdoor). Panels located outdoors shall be with weatherproof enclosure.

6.5 Pre-commissioning of EC motors

Pre-commissioning of EC motors is associated with the activities carried out after installation but before energization to ensure that the motor is mechanically, electrically and functionally ready for safe operation. Key pre-commissioning activities are listed below:

6.5.1 Documentation and verification

- Confirm the availability and review the installation and operation manuals to ensure all manufacturer-specific guidelines are followed.
- Check that the motor's nameplate details (voltage, current, power rating) match the project specifications and approved drawings.

6.5.2 Physical and mechanical checks

- Visual inspection: Inspect the motor for any physical damage, cleanliness, and ensure it is properly mounted on its foundation.

Check the motor placement as per type of application indoor or outdoor.

- Manual rotation: If the motor size allows, attempt to turn the shaft by hand to ensure it rotates freely and without any unusual sounds or resistance, indicating proper bearing condition.
- Fastener tightness: Verify that all mounting bolts, terminal box connections and other fasteners are tight and secure.

6.5.3 Electrical checks

- Earthing: Confirm that the motor and its associated electrical panels are correctly and securely earthed.
- Insulation resistance and winding resistance: Measure the insulation resistance to ensure there are no faults within the motor windings using an insulation resistance tester. Measure the phase-to-phase winding resistance to ensure it's equal across all phases.
- Polarity and phase sequence: Check the electrical polarity and phase sequence to ensure the motor will rotate in the correct direction.
- Cable connections: Ensure that the power and control cable connections at the motor terminal box and the control panel are tight and correct.
- Protective devices: Check the motor protection relay settings and verify tripping/alarms. Test the functionality of the motor starter, overload protection, circuit breakers and any associated protection relays.
- Control system setup: Confirm the control settings on the ECM's integrated electronics are configured correctly.

6.5.4 Commissioning activities of E C motors:

Following successful installation and pre-commissioning activities, commissioning and energization of the EC motors are carried out.

6.5.4.1 Initial Energization:

- Perform a brief 'uncoupled run' with the motor uncoupled from its driven equipment.
- Measure the no-load current and monitor for unusual noises or vibrations to ensure the motor is operating correctly.
- Check the direction of rotation by briefly energizing the motor for a few seconds.
- During the run, measure vibration levels and bearing temperatures to identify potential issues.

6.5.4.2 Energizing and testing:

No-load test

- Apply power to the motor and run it without any load.
- Monitor vibration levels and listen for any abnormal noise, which could indicate issues.
- Measure the input voltage and current to ensure they are within the motor's specifications.

Operational test (with load):

- Connect the motor to its driven equipment and apply the expected operating load.
- Verify that all motor operations, including speed, torque and output meet the specified requirements.
- Perform a tri-axial vibration measurement to confirm it meets the specified limits as per standards.
- Verify the motor's speed control functionality and its responsiveness to commands.

Electronic system functionality:

- Test the integrated control system, ensuring it responds correctly to varying load conditions and provides proper protection. Check the communication with central monitoring system through control panel.
- Monitor the current / power drawn and verify the same with approved data sheets.
- Record all test results and data for future reference and to confirm compliance with standards.

6.5.5 Documentation and handover:

- During this stage, commissioning report, as-built drawings, operation and maintenance manuals etc. shall be furnished to the client. Further, the motors along with associated equipment shall be handed over to operation and maintenance team.

7.0 Starting and Power Conditioning

7.1 Installation, Testing and Commissioning of Variable Frequency Drives

VFD's function is to control the speed, torque and direction of AC electric motors by precisely adjusting the frequency and voltage of the power supplied to them. VFDs improve motor performance and efficiency by ensuring smooth starts and allowing for speed adjustments to meet specific application demands, leading to reduced energy consumption and extended equipment lifespan.

Figure 17.5 (a): VFD

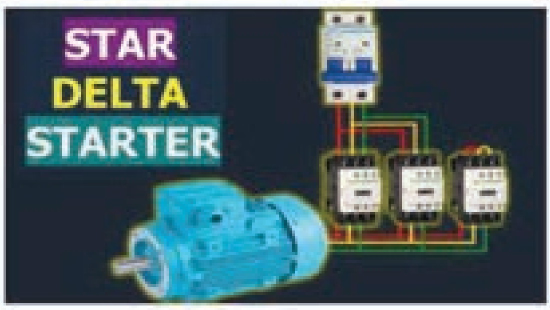


Figure 17.5 (b): Start delta starter

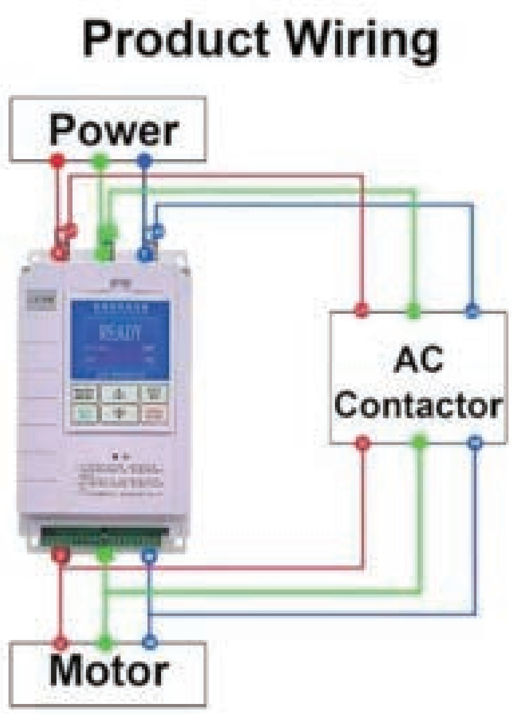


Figure 17.5 (c): Soft starter

7.1.1 Check the location where VFD is to be installed. It shall be dry, well-ventilated indoor area away from direct sunlight, excessive moisture, dirt, dust, oil mist, corrosive or flammable gases.

7.1.2 Ensure temperature and Humidity in the environment where VFD is located stays within the manufacturer's specified range.

7.1.3 Verify the cooling air path and heat sinks are clean and unobstructed to prevent overheating.

7.1.4 Confirm the installation location is not subject to excessive vibration that could damage the drive.

7.1.5 Verify the VFD nameplate details against project specifications.

7.1.6 Confirm that all necessary documentation, certifications, and drawings are available and conform to project requirements.

7.1.7 Mount the drive vertically with adequate clearance for cooling, ensuring it's not on flammable materials like wood.

7.1.8 Verify the cooling air path and heat sinks are clean and unobstructed to prevent overheating.

7.1.9 Make secure electrical connections at the terminal box and ensure correct phasing. Route the power supply via appropriate cables and make all electrical terminal connections for the VFD.

7.1.10 Connect the earthing wires/strips of VFD to main earthing grid to ensure proper grounding of motor.

7.1.11 Check the location of VFD to ensure its location with reference to motor location (Indoor or outdoor). VFD located in outdoors shall be with weatherproof enclosure.

7.1.12 Connect necessary control cabling required for the VFD.

7.1.13 Confirm that the VFD are correctly and securely earthed. Check the phasing of the power cables to ensure correct electrical connections. Ensure that the power and control cable connections at the VFD are tight and correct. Ensure the downstream motor is not mechanically jammed.

7.1.14 Check the protection breaker / relay settings in the panel and verify tripping. Test the functionality of the VFD, overload protection, circuit breakers and any associated protection relays

7.1.15 Powering up: After verifying connections, power ON the VFD. Observe the VFD's cooling fan for proper operation. Measure the DC bus voltage.

7.1.16 Parameter configuration: Input essential parameters, including control source, speed reference, motor data (voltage, current, RPM), acceleration/deceleration times, and I/O configurations.

7.1.17 Keypad control: Use the keypad to give a run command and speed reference to check the VFD's operation and ensure no trips occur.

7.1.18 Connect the motor and run the VFD from the keypad to verify the correct motor direction of rotation. Monitor for abnormal noise, oscillation, or hunting from the running motor. Confirm smooth acceleration and deceleration. Verify the VFD output matches the input speed reference.

7.1.19 Load testing: Record the motor's current at various speeds, both no-load and full-load, if applicable. Check for any VFD trips during operation.

7.1.20 Test the VFD's operation using external (remote) control signals. Test the operation of the bypass starter (If available), both with the motor connected and disconnected. Record all test results, settings, and any observed deficiencies in a commissioning report. Power cycle the VFD and repeat the test to ensure consistent performance.

7.2 Installation, Testing and Commissioning of DOL/Star-Delta Starters

7.2.1 A Direct-On-Line (DOL) starter applies full line voltage to a motor to start it. It is a simple, economical, and effective method for small to medium-sized motors like those in pumps, conveyors, and fans.

7.2.2 A star-delta starter's main function is to reduce the starting current and torque of a three-phase induction motor by initially connecting its windings in a star (Y) configuration, which applies reduced voltage, and then switching to a delta (Δ) configuration to achieve full power after the motor reaches a sufficient speed. This protects the motor from overheating and electrical stress, and also prevents large voltage sags on the power supply system during startup.

7.2.3 Check the location where starter is to be installed. It shall be dry, well-ventilated indoor area away from direct sunlight, excessive moisture, dirt, dust, oil mist, corrosive or flammable gases.

7.2.4 Ensure temperature and humidity in the environment where starter is located stays within the manufacturer's specified range.

7.2.5 Confirm the installation location is not subject to excessive vibration that could damage the starter panel.

7.2.6 Check the internal wiring / cabling of the starter.

7.2.7 Mount the starter vertically with adequate clearance from equipment and adjoining walls. Make secure electrical connections at the terminal box and ensure correct phasing. Route the power supply via appropriate cables and make all electrical terminal connections for the starter. Connect the earthing wires/strips of starter to main earthing grid to ensure proper grounding of motor. Check the location of starter to ensure its location with reference to motor location (indoor or outdoor). Starter located in outdoors shall be with weather-proof enclosure. Connect necessary control cabling required for the starter.

7.2.8 Confirm that the starter panel are correctly and securely earthed. Check the phasing of the power cables to ensure correct electrical connections. Ensure that the power and control cable connections are tight and correct. Ensure the downstream motor is not mechanically jammed. Perform insulation resistance tests (Megger tests) on internal wiring. Check the proper functioning of selector switches, push buttons, timers and indicator lights. Check the protection breaker / relay settings in the panel and verify tripping. Test the functionality of the starter, overload protection, circuit breakers and any associated protection relays.

7.2.9 Power-on: Safely energize the starter and supply. Manually press the STOP and RESET buttons to ensure they are responsive. Check the contactor's normally open (NO) and normally closed (NC) contacts for proper continuity. Set the overload relay to a value (e.g., 10-15%) lower than the motor's rated working current for initial testing.

7.2.10 With the motor uncoupled from its driven equipment, start the motor to measure the no-load current and observe for any unusual sounds or vibrations.

7.2.11 Full load test: Once the uncoupled run is successful, couple the motor to its driven equipment. Energize the coupled system and monitor its operation, measuring the operating current.

7.2.12 Star-delta starters start-up: Press the start button to energize the main and star contactors. The motor should begin rotating in the star configuration, which provides a reduced voltage and limited inrush current.

7.2.13 Delta transition: After a pre-set time, the timer will switch off the star contactor and simultaneously energize the delta contactor. This connects the motor windings in delta, and the motor runs at full voltage and speed.

7.2.14 Timer adjustment: The transition time from star to delta is crucial. It should be long enough for the motor to reach approximately 75-80% of its full load speed, but not so long that it causes excessive current to flow in the star connection.

7.2.15 Monitoring and adjustment: Adjust the timer based on the specific motor characteristics and load to achieve optimal performance.

7.2.16 Operational checks: Confirm that the system operates correctly and within its rated current and performance parameters. Test the starters operation using external (remote) control signals.

7.3 Soft Starter

7.3.1 A soft starter functions by gradually increasing the voltage supplied to an electric motor, resulting in a smooth, controlled startup that reduces mechanical strain and starting current. This process limits inrush current and torque, prolonging the motor's lifespan, reducing wear and tear on connected equipment. Check the location where soft starter is to be installed. It shall be dry, well-ventilated indoor area away from direct sunlight, excessive moisture, dirt, dust, oil mist, corrosive or flammable gases.

7.3.2 Ensure temperature and humidity in the environment where soft starter is located stays within the manufacturer's specified range.

7.3.3 Verify the cooling air path and heat sinks are clean and unobstructed to prevent overheating.

7.3.4 Confirm the installation location is not subject to excessive vibration that could damage the drive.

7.3.5 Verify the soft starter nameplate details against project specifications.

7.3.6 Confirm that all necessary documentation, certifications, and drawings are available and conform to project requirements.

7.3.7 Mount the soft starter vertically with adequate clearance for cooling, ensuring it's not on flammable materials like wood.

7.3.8 Verify the cooling air path and heat sinks are clean and unobstructed to prevent overheating.

7.3.9 Make secure electrical connections at the terminal box and ensure correct phasing. Route the power supply via appropriate cables and make all electrical terminal connections for the soft starter.

7.3.10 Connect the earthing wires/strips of soft starter to main earthing grid to ensure proper grounding of motor.

7.3.11 Check the location of soft starter to ensure its location with reference to motor location (Indoor or outdoor). Soft starter located outdoors shall be with weatherproof enclosure.

7.3.12 Connect necessary control cabling required for the soft starter.

7.3.13 Confirm that the soft starter is correctly and securely earthed. Check the phasing of the power cables to ensure correct electrical connections. Ensure that the power and control cable connections are tight and correct.

7.3.14 Ensure the downstream motor is not mechanically jammed.

7.3.15 Check the protection breaker / relay settings in the panel and verify tripping. Test the functionality of the soft starter, overload protection, circuit breakers and any associated protection relays. Review the manufacturer's manual for parameter settings and ensure they are appropriate for the application. This often involves setting the starting voltage, acceleration time, and current limits.

7.3.16 Apply Line Voltage: Energize the soft starter by applying the line voltage to the input terminals.

7.3.17 Switch on the soft starter to run mode and initiate a start. Observe that the voltage across all three phases increases gradually and equally to the full line voltage. Watch for smooth acceleration and control of starting current.

7.3.18 Bypass Operation: Ensure the internal bypass relays close once the motor reaches nominal speed after a defined acceleration period.

7.3.19 Verify the soft starter's built-in protections will trip the starter and stop the motor during faults. Observe the motor's starting behavior during the test run. Adjust the starting voltage to ensure immediate motor start without excessive humming. Set the acceleration time to be as short as possible to minimize thermal stress on the motor and device, but long enough for the motor to reach full speed before the bypass closes. Confirm the load matches the motor and that the soft starter's current limit does not trigger prematurely.

8.0 Safety and Protection Devices

In an air-conditioning plant, safety and protection of operating personnel and equipment is very

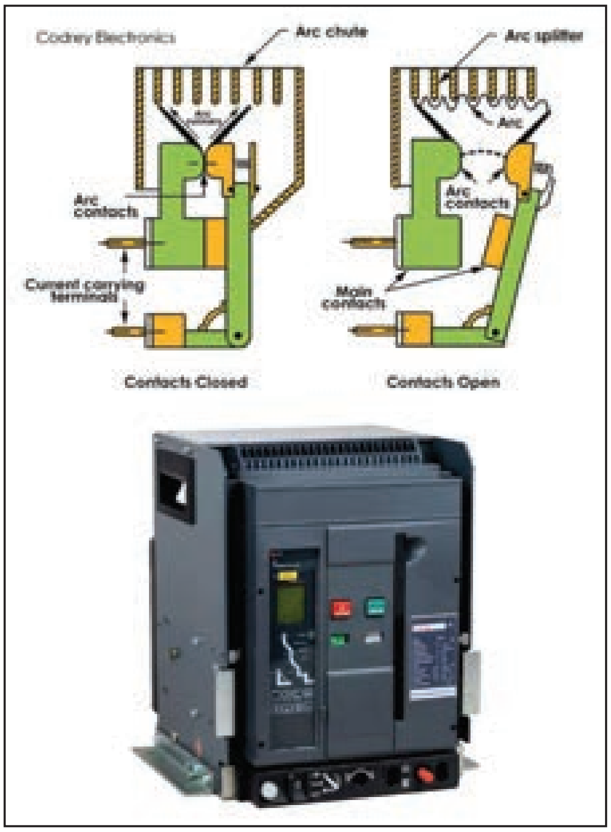


Figure 17.6: Air circuit breaker

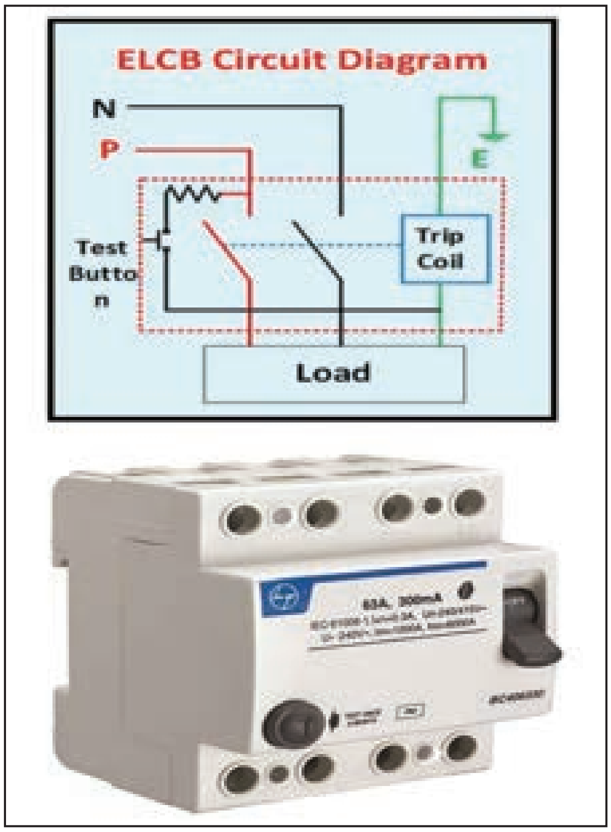


Figure 17.8: ELCB

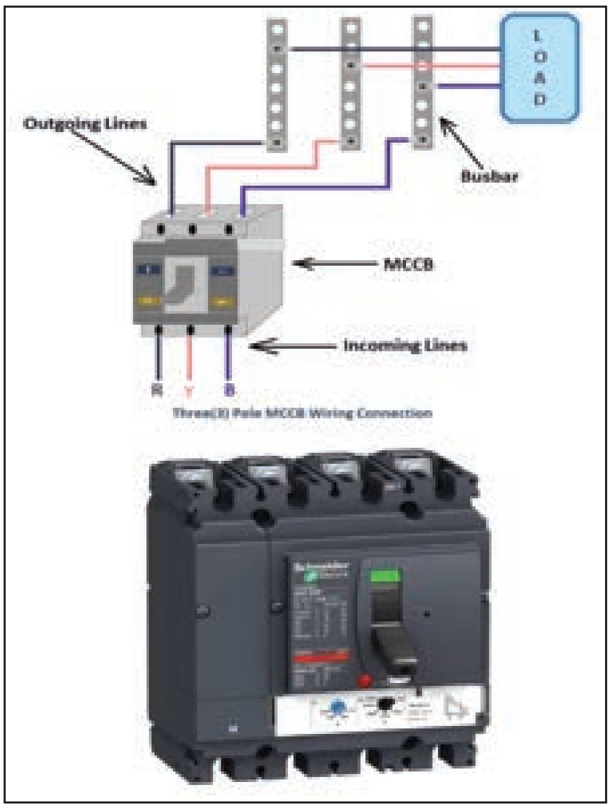


Figure 17.7: MCCB

critical. Several safety and protection devices are installed at various levels to safeguard the equipment and to ensure safe operation. Some key protection measures are listed below.

8.1 Electrical Safety and Protection Devices

- Switchgear including circuit breakers / MCCBs protect against overloads and short circuits.
- Fuses are the fast-acting protection against short-circuits.
- Overload relays prevent motor overheating due to excessive current.
- Earth fault / leakage relays trip system in case of insulation failure or current leakage.
- Phase-failure/ single phase preventing relays protect motors from single phasing.
- Phase-sequence relay ensures monitor the correct sequence of phases in a three-phase motor and prevent equipment damage from incorrect rotation.
- Under-voltage / Over-voltage relays prevent operation outside voltage limits.
- Surge arrestors / SPD intend protect against lightning and voltage spikes.

8.2 Refrigeration Circuit Safety Devices

- High pressure cut-out (HP cutout) is a critical compressor safety switch that protects the chiller compressor against abnormally high discharge pressures, ensuring safe operation, equipment longevity, and system reliability.
- Similarly, Low pressure cut-out (LP cutout) protects compressor from running under low suction pressure which could be an indication of leakage, blockage, loss of refrigerant etc.
- Oil pressure safety switch (OSS) will trip the compressor if lubricating oil pressure is too low.
- Temperature sensors and thermostats protect from over-temperature in compressor discharge line, bearings, or motor windings.
- Solenoid valves are automatic shut-off devices in refrigeration circuits that block refrigerant flow when compressor is off, thereby preventing refrigerant migration, oil dilution, and compressor damage.

8.3 Mechanical and Operational Safety Devices

- Vibration switch is a mechanical/electronic safety device that automatically shuts down compressors, pumps, or cooling tower fans when abnormal vibration is detected, thus protecting against mechanical failure.
- Flow switches are mandatory safety interlocks in chilled and condenser water circuits, ensuring water circulation is maintained before compressors run, thus preventing freezing, overheating, and severe compressor damage.
- Level switches act as low-level cut-outs, high-level alarms, and make-up controls in AC plants, ensuring water availability in cooling towers, sumps, and expansion tanks. They protect pumps and chillers from dry running, cavitation, and system downtime.
- Strainers and filters with DP switches are first-line check in chilled/condenser water circuits. They ensure clean water circulation, protect pumps, and maintain efficient heat transfer in chillers. DP monitoring ensures maintenance is timely and proactive.
- Safety relief valves on heat exchangers protect against overpressure caused by thermal expansion of trapped liquid, preventing shell/tube rupture and ensuring safe plant operation.

8.4 Fire and Personnel Safety

- Smoke detectors in AHUs / ducts will detect the presence of smoke in the event of fire and initiate an action that will shut down AHU to prevent smoke spread.
- Fire dampers will close automatically in case of fire to stop fire/smoke propagation.
- Emergency stop push buttons is provided at plant room entry for immediate shutdown.
- Earthing and bonding will ensure no dangerous potential on metallic parts.
- Pressure gauges and temperature indicators will help in monitoring abnormal conditions.

8.5 Installation and Commissioning of Safety and protection devices

8.5.1 Electrical Safety and Protection Devices

8.5.1.1 Pre-Installation Checks

- Verify approved SLD, wiring diagrams, and GA drawings to confirm ratings including voltage, current and fault level of circuit breaker and relay.
- Inspect equipment for physical damage during transport/storage. Ensure installation area is clean, dry, ventilated, and meets clearance requirements.
- Check receipt of manufacturer's manuals, test certificates, and accessories.

8.5.1.2 Installation of Circuit Breakers

- Mount breaker in cubicle/panel (fixed/draw-out).
- Check alignment with busbars and terminals.
- Tighten connections with torque wrench to recommended values.
- Provide insulation barriers/shrouds as required.
- Connect control wiring for trip/close coils, auxiliaries, interlocks.
- Verify smooth racking in test/service/isolated positions to be ensured for draw-out breakers.
- Ensure earthing of breaker body/panel.

8.5.1.3 Installation of Relays

- Mount relay in relay panel / switchgear compartment.
- Ensure correct orientation and accessibility.
- Complete control wiring as per schematic diagram complete with connections with CT, PT, DC supply and trip coil connections.
- Ensure correct burden and accuracy class of CTs/PTs for relay operation. Verify CT polarity and earthing.

- Provide proper shielding and separation of control and power wiring.

8.5.1.4 Pre-Commissioning Tests for Circuit Breaker

- Mechanical Tests to ensure manual ON/OFF operation, motorized/spring charged operation, mechanical and electrical interlocks etc.
- Electrical Tests including phase-to-phase, phase-to-earth insulation resistance (IR), Contact resistance, secondary injection test, primary injection test, functional check from local and remote operation.

8.5.1.5 Pre-Commissioning Tests for Relays

- Power Supply Verification to verify supply voltage, auxiliary supply connections etc.
- Wiring and polarity tests include polarity check for CT and PT, continuity of trip circuit, trip circuit supervision etc.
- Relay Functionality Tests-

Some important functionality tests are mentioned below:

- In Secondary Injection Test, test current/voltage is injected into confirm relay pickup, time delay, and trip characteristics.
- Primary Injection Test is used for protection relays in breakers. This rest is conducted by injecting actual current into CT circuit.
- Verify settings of pickup current, time dial, instantaneous trip, earth fault levels etc.
- Check outputs: trip contacts, alarms, flags/LED indications.

8.5.1.6 System Functional Tests for Relay and Breaker Integration

- Perform secondary injection to simulate a fault and verify that the relay generates a trip signal and operates the breaker.
- Verify breaker closing after trip reset.
- Wherever applicable, check Building Management System communication.

8.5.1.7 Energization

The following procedure is generally adopted for the energization of switchgear:

- Confirm all test results are within limits.
- Put breaker in OFF position before energization.
- Energize system gradually, close breaker on no-load first.
- Monitor for abnormal heating, noise, or smell.
- Load system step by step while observing relay indications.

8.5.1.8 Documentation and Handover

- Record all test values (IR, contact resistance, relay calibration, injection test results).
- Prepare commissioning report with acceptance signatures.
- Provide O&M manuals, test certificates, and relay setting sheets to client.
- Hand over the system to operations team.

Chapter 18

Controls and BMS

1.0 General

Proper and correct installation and subsequent maintenance of controls and control systems is critical to the safety and operation of HVAC Systems.

Based on their functionality, controls can be categorized as:

- Operating Controls,
- Safety Controls,
- System Controls, and
- Optimization Controls.

Further, based on the energy used in their operation, controls can be categorized as:

- Electro-mechanical,
- Pneumatic,
- Electronic or Digital.

1.1 Electromechanical as well as pneumatic controls have been largely superseded by electronic/digital controls. Further, many of the safety and operating controls have become part of factory assembled equipment packages such as chillers and AHUs and their actions/outputs are brought out to the respective equipment control panel from where signals are taken by digital controllers for record or action. The installation engineer in the field does not have to deal with these control elements. However, an overview of such controls is included in this chapter just to make the installer aware of the existence of these controls as a part of the system.

1.2 A Control system generally consist of a Sensing Element, a Controller, Controlled Device and Auxiliaries such as relays, contactors, switches, transducers etc. Changes in the controlled variable is sensed or measured by the sensing element to produce a proportional effect on the controlled device.

In addition to the basic purpose of controlling a device advanced control systems have the capability for remote monitoring, logging, trending etc.

2.0 Analog and Digital Signals

2.1 An analog signal is a continuous wave which may vary in signal strength as well as frequency. Continuously measured variables such as temperature, RH, flow rates are all examples of analog signals. Analog input devices are directly connected to the input of the controller. Analog outputs provide continuously varying outputs to equipment's such as control valves or dampers.

2.2 A digital signal is a discreet signal and can give one of two values: 0 or 1. Hence, they are called binary inputs and outputs and these are devices are physically connected to the controller. Examples are ON/OFF status or commands to a pump or to a solenoid valve.

2.3 An analogue controller receives and acts on data continuously. A digital controller converts electronic signals into digital values and performs mathematical/logic operations on these. The controller reconverts the resultant values once again to electronic signal to operate the controlled device which could be an actuator or a valve. Data is sampled at specified intervals and the interval can be so chosen for uninterrupted control performance.

3.0 Type of Control

3.1 Snap acting or ON/OFF control: Control can take only one of two positions – either ON or OFF. Two position controllers cannot offer close control of the controlled variable. Also, frequent cycling of electrical systems is not recommended. Therefore, proportionating controls are preferred for most applications over snap acting controls.

3.2 Proportionating control: The controller produces a signal that is proportionate to the error signal. The correcting element (controlling element) which could be a valve or a damper receives a signal proportionate to the correction needed. Output is continuous and modulating. Signals usually range from 4 to 20 mA or 0 to 10 volts.

3.3 Proportional-integral (PI) control: An integral control is one where the rate of change of control output is proportionate to the input error signal. This can be integrated with a proportionating control to give a PI control.

3.4 Derivative control: In a derivative control, change in the controller output from a set point value is proportionate to the rate of change of the error with time. This results in a large control output as soon as the error signal is detected. Hence, the control function depends on the rate of change and not on the absolute error value.

3.5 PID (proportional-integral-derivative) control: This controller combines all the three functions maintaining normally steady condition but is able to respond quickly to sudden load changes. The performance of the PID Controller is smoother as compared to the other two and brings the controlled variable to set value without overshoot or fluctuations.

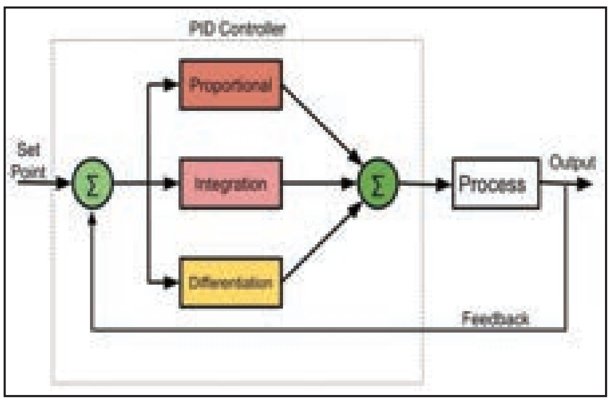


Figure 18.1: Proportional-integral control characteristics

4.0 Direct Digital Control

DDC is a control loop in which a digital controller periodically updates a process as a function of a set of measured variables and a given set of control algorithms. DDC receives electronic signals from sensors, converts them to numbers and performs mathematical and logic functions with the help of a microprocessor. The output is again a number which is converted back to a pneumatic or electrical signal to operate a device such as an actuator or a valve. The microprocessor accepts sampling data at chosen intervals and recalculates the program using new data and adjusts its output accordingly. The word 'digital' in DDC refers only to processing of data and not to inputs or outputs which could be analogue in nature. Analog inputs are converted to digital and back to analogue using converters which are part of the controller.

4.1 Key part of the DDC is the program logic that resides in the controller. The elements of a microprocessor-based controller are:

- Microprocessor
- Program Memory
- Working Memory
- Timing Device (Clock)
- Input and Output Devices

4.2 Microprocessor based controllers can be either zone level controllers or system level controllers.

Figure18.2: Microprocessor based control configuration

Zone level controllers typically control terminal units and have limited input-output capability and have standard control sequences.

System level controllers offer customized programs to handle specific application requirements. They are expandable with input-output extension boards and master-slave input-output modules.

Both zone and system level controllers can be equipped with communication ports which allow parameters to be passed on to either a local operator terminal, to other controllers or to a BMS.

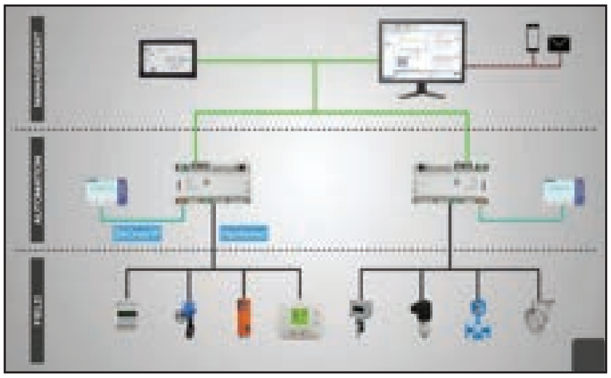


Figure 18.3: Simplified BMS architecture

5.0 BMS Architecture

A Building Management System (BMS) has a four-tier architecture.

Tier 1 – User interface which can include graphics as well as live trending of real time data. User is able to operate, monitor and control the entire facility from here.

Tier 2 – Supervisory controllers that network a variety of field controller networks seamlessly into the system. They perform scheduling, trending, alarm detection and facility wide custom programmed applications.

Tier 3 – Field controllers which are intelligent stand-alone DDCs that are connected to and control various mechanical or electrical systems throughout the facility.

Tier 4 – Sensors, relays, actuators and other field devices which continuously measure and monitor the control variable and report them to the field controller and also carry out the commands receive, d from the field controller.

User access is provided to BMS through user terminals with web browsers either directly connected to the network or remotely connected via the internet.

5.1 BMS uses automatic control loops to control and modulate the action of field devices such as actuators, valves etc. Control can be ON/OFF, proportionate or floating and are available with feedback loops.

5.1.1 Control systems can be open-loop or closed-loop. In open-loop controls, the control device acts on the process variable with no reference either to the controlled process variable or to any external factors which can affect the process. A closed -loop controller, in addition, has a means to measure the process variable on a continuous basis in order to activate or modulate the control device.

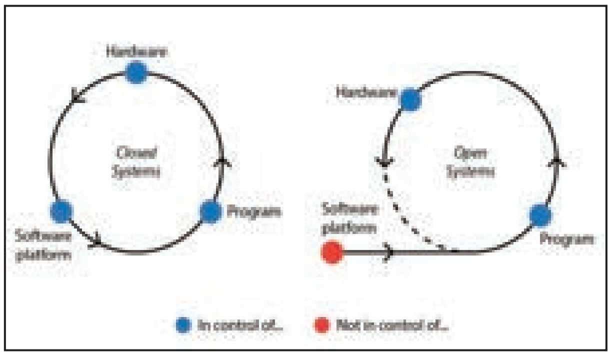


Figure 18.4: Open and close loop control system

5.1.2 In a typical field installation of a closed-loop system, there will be 3 elements: a sensor, a controller and an actuator. Closed loop controllers can also have a feedback loop which continuously compares the reference value of the process variable (also known as a set point) with the current value and keeps on modifying the action of the controlled device.

5.2 Field controllers are intelligent devices that receive inputs and give commands to field devices. Input devices could be sensors and output (field) devices could be actuators. They report current status and receive supervisory commands from supervisory controllers. Field controllers are usually direct digital controllers.

5.2.1 A DDC is customized to its intended use by incorporating design logic for that application which may include set points, design logic, timers, trend logs, alarms etc. They operate on a protocol such as MODBUS, BACnet etc. Some modules have LCD screens and touch pads. Field devices are connected to DDC in a daisy chain using twisted pair or shielded cables. Wireless connections are also becoming increasingly popular. Manufacturers specify the number of field devices that can be connected to a DDC as well the maximum wiring length possible to sensors or actuators. DDC provides power supply to the devices connected to it. The microprocessor in the DDC works using digital inputs and outputs. Therefore, it becomes necessary to convert analog inputs and outputs using analog to digital and vice-versa converters. The controller processes input data, applies the programs built in the software as per the control logic and commands an output action. These controls the relays, actuators, positioning devices etc. to control the system parameters. There can be provision for the operator to enter parameters or commands through a key board or a touch screen.

Figure 18.5: A direct digital controller (DDC)

5.2.2 DDC may be application specific with a single control loop. They can also be stand-alone controllers which cannot be networked. On the other hand, they can be networkable to form distributed control and the control protocol can be pre decided.

Figure 18.6: Input output module

Sensor and controller can be combined in a single device or they may be in two separate devices.

5.2.3 DDC is selected based on the number of input/output devices (I/O points) that are involved for the specific application. Capability of a DDC (I/O point capacity) can be enhanced by adding an input/output module (IOM). IOM does not have any programming logic but are useful to enhance the I/O capacity either on the sensor-actuator bus or the field controller bus.

5.3 A communication protocol defines the communication behavior of each component of the network.

5.4 Serial communication ports (RS 232, RS 485 etc.) allow user data to be sent on a time series basis one bit at a time. Each port has a specific capacity to transfer data.

5.5 A Local Area Network (LAN) refers to a group of DDCs on a network connected through co-axial cable, fiber-optic cable or through a wireless network. Ethernet is a common network protocol for exchanging information across a LAN. Other popular network protocols are MODBUS, LONWORKS, BACnet etc. Sometimes different devices in a building may use different network protocols and then it becomes necessary to use a Gateway or a Translator between different protocols.

5.6 Routers are devices that connect multiple networks. Routers do not change either the form or the content of a network-to-network message.

5.7 Supervisory controllers are web-based network engines which use communication protocols to connect a variety of field controller networks into a single seamless system. They support and perform full set of building automation features such as scheduling, trending, alarm detection, data sharing, energy management, totalization and customized control routines. They may include a graphical system-user interface which can be accessed through a web browser. Remote access can also be made available through internet or intranet connectivity. Multiple users can concurrently connect to the supervisory controller and security and access priority can be predefined and programmed.

5.7.1 Supervisory controller provides integrated control, supervision and network management services for one or more networks and provide direct control over inputs and outputs. They can be used to control a host of building services such as HVAC, electrical systems, lighting, water management, waste processing and disposal etc., in the process enhancing operating efficiencies.

5.7.2 Supervisory controllers are selected based on the number of hardware points and field devices that it can support. Modern supervisory controllers use open network protocols and may also include client-server devices where the user can add required protocol drivers. Supervisory controllers' hardware and software design is modular and user can add accessories such as communication cards, Input-Output modules and other software options.

5.8 User interface can be a computer using a standard web browser to access the network engines as well as present and historical data and trends. Simple graphics and trending of real-time data help to monitor, control and operate the entire facility from a single workstation.

6.0 Field Devices

6.1 Sensors are field devices which convert a physical property into a conveniently measurable effect or signal such as current, voltage etc. Sensors are available for:

> Temperature/humidity/enthalpy

> Pressure

> Flow rate

> Indoor air quality

Sensors have a sensing element or transducer which converts the measured parameter into a transmittable (usually electrical) signal. It also has a transmitter which accepts the output of the sensor and converts it into an Industry Standard signal type (e.g.: 4 to 20 ma, 0 to 10 volts) as per the network protocol. Sometimes, the sensor also has a display device where the measured value can be displayed.

6.2 Temperature sensors can be of three types: thermocouples, RTDs or thermistors.

Thermocouples use current flowing in a circuit consisting of two dissimilar metals which are joined at different temperatures.

RTDs (Resistance Temperature Detectors) make use of variation in electrical resistance of a metal with respect to temperature changes.

Thermistors work on the same principle as RTDs but use temperature-resistance relation of a semi-conductor. Thermistors are more accurate compared to thermocouples or RTDs; hence widely used.

6.3 A thermostatic switch is a two-position ON/OFF Control. In a typical application, this may be located either in the return air passage or in the conditioned space. A thermistor measures the rise in temperature at the place where it is located and actuates an electrical circuit which starts the compressor. Conversely, a fall in temperature causes a reverse action which shuts off the compressor. Cut in/cut off temperature can be adjusted as also the differential between the cut in and cut off temperatures can also be adjusted.

Figure 18.7: Thermostat switch

Figure 18.8: A room thermostat (ON/OFF type)

6.4 Working principle of a proportionating thermostat is very similar to that of a two-position one but the variation in temperature sensed by the thermistor is made to alter an electrical resistance proportionate to the change which in turn is connected to a two directional modulating motor. The modulating motor through linkages can be made to operate a variety of devices such as a modulating three-way valve or a modulating damper. Thus, an increase in room temperature where the thermostat is mounted (with its in-built sensor) can be made to open a chilled water control valve proportionately increasing the chilled water flow through the cooling coil of the AHU serving the area. This, in turn, increases the cooling provided by the AHU, thus bringing back the room temperature to its set position.

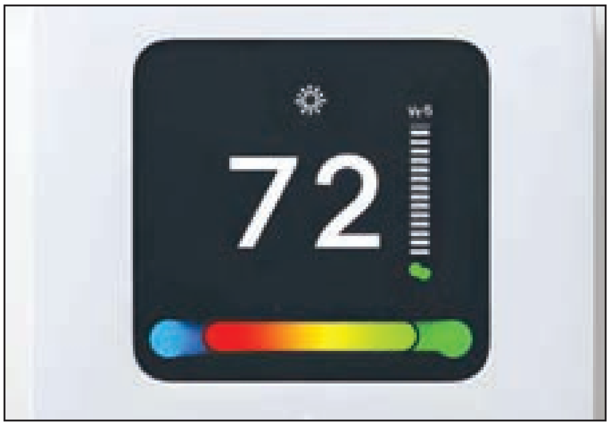


Figure 18.9: Proportioning type room thermostat

6.5 A Solenoid valve is a two-position (on and off) valve used in refrigerant lines, chilled or hot water piping as well as in compressed air lines. Three-way solenoid valves are used for compressor capacity control, as a pilot solenoid or on external equalizer lines of thermostatic expansion valves (TEV).

6.6 Refrigerant metering devices such as TEV, liquid level control in flooded chillers are flow control devices. A TEV controls refrigerant flow based on the load on the evaporator. The feeler bulb of the TEV which is filled with the same refrigerant as charged in the system (in case of air conditioning application) is clamped to the suction line close to the evaporator. The operation of the valve is controlled by:

i) Pressure of refrigerant in the feeler bulb which tends to open the valve.
ii) Pressure of refrigerant in the evaporator which tends to close the valve and

Figure 18.10: Thermostatic expansion valve

iii) Spring pressure which is adjustable and assists the closing action.

Operation of the valve is determined by the superheat of the refrigerant gas at the point where the bulb is clamped to the suction line. TEV constantly modulates the flow of refrigerant to maintain the level of superheat for which it is adjusted with the help of the spring pressure. Thermostatic expansion valves have been replaced by electronic expansion valves in most refrigeration systems.

6.7 An electronic expansion valve (EXV) serves the same function as the TEV by maintaining the pre-selected constant superheat. This is achieved through a microprocessor control operating the valve orifice size. EXV controls the suction gas superheat at the point of entry of the suction gas into the compressor.

Figure 18.11: Electronic expansion valve

6.8 Mixing and diverting valves are used for regulating liquid flow through cooling/heating coils, heat exchangers etc. The diverting valve has one inlet port and two outlet ports whereas the mixing valve has two inlets and one outlet. The valve is actuated by a sensor which is a pressure transducer which may be snap action or modulating type depending on the type of control and actuator used.

6.9 Pressure sensors are generally of the piezo-electric type and makes use of the potential difference between two faces of a crystal when it is either stretched or compressed. They are ideal to monitor fluctuating pressures.

6.9.1 A back pressure regulating valve may be used to prevent the evaporator pressure falling below a set point regardless of reduction in load and is used to facilitate use of multiple evaporators with a single compressor (such as in a multi-room cold store) where the valve is installed on the suction line of the highest temperature evaporator and other evaporators catering to lower temperatures all operate at lower pressures.

6.10 Safety controls are generally snap action types and are wired in series with the motor starting circuit. They, usually, are manual reset types.

6.10.1 A high pressure switch cuts off the compressor when discharge pressure exceeds a set point.

6.10.2 A low pressure switch cuts off the compressor when suction pressure falls below a set point. This can also be used to protect the chiller against freeze-up by connecting it to the refrigerant side of the chiller and cut off is set slightly higher than the saturation temperature corresponding to the freezing point of the liquid being cooled.

6.10.3 Fusible plug is a metal fitting filled with a soft metal which will melt and blow off when the temperature rises above a set point or when the pressure rises above a pre-set limit.

6.10.4 A pressure relief valve is used to relieve excess pressure in the condenser, liquid receiver or flooded chiller. The valve disc is set to open when the system pressure exceeds a pre-set spring pressure. This valve setting MUST NOT be adjusted in the field.

6.10.5 An anti-freeze thermostat guards the chiller against freeze up. Sensing element is inserted into the medium being cooled (water or brine) where it attains the lowest temperature and the cut-off point is set a safe 2 degrees above the freezing point of the liquid.

6.10.6 Oil safety switch used on the compressor senses the net pressure (difference between oil pressure at compressor delivery and oil pressure at compressor suction) and actuates a cut-off switch. A time delay relay is incorporated in the circuit to enable the compressor to start initially (when the pressure is zero). Trip circuit is activated only after lapse of 45 to 60 seconds from compressor start by which time the oil pressure should have built up. This switch is a manual reset type.

6.11 Electrical protections and overload cut offs are detailed in Chapter 17.

6.11.1 Calibrated overload relays are incorporated in starter circuits of all motors. They have time delay relays which allow the high starting current to pass for a specified time.

6.12 Flow switches are provided in condenser and chilled water lines to ensure that water flow is available above specified limits before equipment is started.

6.13 Fire dampers and combination fire and smoke dampers are located at specified locations in the air distribution system and are normally kept open. They are shut off either through an electrical signal or through a fusible link.

6.14 Variable Frequency Drives (VFDs) are used to regulate speeds of compressors, pumps, fans, etc. and are very effective for capacity control coupled with energy saving. Installation details of VFDs are given in Chapter 17.

6.15 Flow sensors:

6.15.1 Pitot tubes measure velocity of an air stream based on two ends of a tube one facing the air stream and the other placed perpendicular to the air stream.

6.15.2 Orifice plates measure pressure difference across a pipe or duct by the throttling action of the flow through the orifice.

6.15.3 Venturi meters also work on the same principle as orifice plates but have a gradual reduction in the bore forming a throat section rather than an abrupt orifice.

6.15.4 Hot wire anemometers are used for airflow measurement and are sensitive enough to detect and measure flows even at low speeds.

6.15.5 Turbine flow meters are generally used in liquid in pipe applications.

6.16 Humidity sensors used with digital controls use resistive or capacitive type.

6.17 Dew point sensors can either be a chilled mirror type or a saturated salt solution type. Chilled mirror sensor estimates RH when dew starts forming on its mirror surface. In the saturated salt solution type an RTD surrounded by a wick impregnated with lithium chloride solution and heated by a heating element is used. The temperature at which power from the heating element just balances the latent heat of the wick gives the dew point RH.

6.18 Comfort sensors which measure the perceived comfort based on dry bulb temperature of the space, moisture content, mean radiant temperature and air speed are available which can be integrated with BMS.

6.19 Indoor air quality (IAQ) sensors non-selectively measure the concentration of all oxidizable gases collectively. They consist of a tube coated with a thin film semi-conductor, a pair of electrodes and a small heating element. The semiconductor absorbs the volatile organic compounds (VOCs) resulting in release of electrons which alters the resistance across the two electrodes producing a signal which is captured and measured.

6.20 Occupancy sensors are available as ultrasonic or infrared.

Ultrasonic motion sensors generate high frequency sound waves and any movement in the room causes a change in the frequency due to Doppler effect and the sensor compares the resultant frequency with the emitted frequency and any change indicates movement in the space.

Infrared sensors detect any moving infrared heat source such as a person or an animal with in the space and a signal is generated.

It is also possible to combine the high error immunity of Infrared with the high sensitivity of ultrasonic in the same sensor.

6.21 All field devices of the BMS shall be installed as per manufacturer's instructions. Devices shall be installed in enclosures suitable for the location with respect to temperature, humidity and IP rating. Where required, suitable transformers may be installed in the enclosure and adequate earthing provided. An un-interrupted power supply shall be provided to the BMS.

7.0 Controlled Devices

BMS uses automatic control loops to control and modulate the action of field devices such as actuators, valves etc. Control can be ON/OFF, proportionate or floating and are available with feedback loops.

Control systems can be open-loop or closed-loop. In open-loop controls, the control device acts on the process variable with no reference either to the controlled process variable or to any external factors which can affect the process. A closed-loop controller, in addition, has a means to measure the process variable on a continuous basis in order to activate or modulate the control device.

In a typical field installation of a closed-loop system, there will be three elements: a sensor, a controller and an actuator. Closed loop controllers can also have a feedback loop which continuously compares the reference value of the process variable (also known as a set point) with the current value and keeps on modifying the action of the controlled device.

A few examples of controlled devices are given below:

7.1 Valves: Motorized flow control valves can be plug valves, ball valves, globe valves or butterfly valves. They could either be two-way or three-way valves depending on their inlet/outlet connections to the system. Actuators shall provide a tight shut-off while closing against a differential pressure.

In a globe valve, a rack and pinion arrangement converts the rotary motion of the actuator into a straight-line motion of the valve spindle.

A ball valve consists of a ball with a hole drilled through it rotating within the valve body. Direction of the motion of the ball is perpendicular to the forces created by water pressure and actuator does not have to push against water pressure. Close-off pressure rating of ball valves depends on how well the ball is seated against the body.

Butterfly valves consist of a heavy ring enclosing a disc that rotates on an axis. Close-off rating is a function of how tightly the disc fits into the seat and how hard it can be pushed close.

Pressure independent valves are control valves with integral pressure regulators. The integral pressure regulator maintains a constant differential pressure across the valve orifice regardless of system pressure fluctuations.

7.2 Actuators: Actuators can be normally open or normally closed.

Normally open actuators provide full flow when the actuating force is removed and normally closed actuators assume the closed position when the force is removed.

Electric actuators operate a valve stem or a damper stem by an electric motor through a gear train and linkage. They can be:

- Uni-directional
- Spring return or spring loaded (some electric actuators use a capacitor instead of a spring to return the actuator to its normal position)
- Reversible – suitable for proportional operation.

Actuators have input power options such as 220 volts or 24 volts and have IP rating to suit safety and performance requirements.

Valves, especially large size valves, are sometimes equipped with position indicators with 0 to 10 volt position feedback signal.

7.3 Dampers are provided in air distribution networks and they can be rectangular or round in shape. Blade operation can be parallel or opposed.

In parallel operation, all blades rotate in the same direction whereas opposed blade dampers have adjacent blades rotating in opposite directions. Generally, parallel blade dampers are used with ON/OFF actuators and opposed blade dampers are used with proportionating actuators.

Different types and applications of dampers are described in Chapter 11 on Air Distribution.

8.0 Installation of a BMS

Installation involves supply of different control panels, consisting of DDC panels, supervisory controllers, user interface systems etc. and a network of field devices like sensors and actuators as well as junction boxes and stand-alone control panels which may be mounted on (or) installed near mechanical or electrical equipment. This involves coordination with respective equipment manufacturers for required configuration and integration information

8.1 It will be a good starting point to list down the systems and sub-systems involved, the suppliers, their scope of work as per their contracts with the owner and the scope of BMS system integrator.

8.2 For some of the equipment such as a chiller or a smart AHU, all field devices may be wired by the manufacturer and brought to a control panel. In such case, it is only necessary for the BMS integrator to review the I/O list and communication protocol before wiring it to the respective DDC. In certain other cases, both the sensors and the control devices such as actuators will require to be individually wired from the controller.

8.3 As an illustration, installation of BMS for some of the commonly used equipment/devices is given below:

8.3.1 Chiller: List all data points at the chiller control panel as per Input/Output (IO) summary list and its communication protocol. Is there a chiller plant manager (CPM) or chiller plant optimizer (CPO). Review its IO list and communication protocol, is there an automatic tube cleaning system (ATCS). If it is there, review its IO list and integration requirement of BMS with ATCS control panel.

8.3.2. Primary/secondary pumps: Sequencing and balancing of run hours. Communication protocol with VFD, its control logic and location of sensors.

8.3.3 Valves: Identify valves controlled by BMS and their control logic. Provide for feedback as required.

8.3.4 Cooling towers: Sequencing and balancing run hours. Control logic for CT fans including VFDs if provided.

8.3.5 AHU / TFA / DOAS: Review the list of AHU location floor-wise. What type of fans? If smart AHU, the OEM would have programmed the logic. If not, the AHU documentation shall include EC fan (or) VFD communication protocols, wiring schemes and program configuration information. Locate TFA and DOAS units and review all their I/O points and protocols.

8.3.6 VAV boxes and zone controls: For each AHU / TFA / DOAS review the air flow ducting drawings and understand the thermal comfort design scheme. Integrate VAV boxes and room temperature sensors based on number of VAV loops and DDC panel location. Understand the zone control operation logic. If it involves motion sensors (or) employee access cards, integrate them with the system.

8.3.7 Fan coil units: FCU room temperature sensors are mostly stand-alone controllers. Understand the required controls and integration with BMS, as per design scheme.

8.3.8 Other Systems: BMS will be controlling and / or retrieving data from other building systems such as electrical, plumbing, fire protection systems. BMS Integrator shall have a clear idea of all such systems and how they are integrated with one another. It is a normal practice for the Facility management team to monitor and control the entire campus utilities from the BMS room. All the Supervisory Controller panels and the HMI screens with required software are usually located in the BMS control room.

9.0 Works Associated with Installation of BMS

- Laying cables and routing
- Installation of field devices (sensors, actuators etc.) and control panels
- Mapping all devices, configuring as per design scheme
- Integrating whole system using the operating software
- Testing and commissioning

9.1. Laying of cables and routing

Field cabling and containment are described in Chapter 17: Electrical. Certain aspects related to cabling for BMS are further elaborated below.

9.1.1 Types of Cables

- Twisted pair cable is commonly used. They have resistance to electromagnetic interference.
- Fiber optic cables help to transmit large amounts of data over long distances at high speeds.
- Co-axial cables are used in specific applications where there is a need for high-frequency transmission or when reliable signal integrity is required.

9.1.2 Each type of cable has different specifications regarding bending radius, maximum lengths, and proximity restrictions from other electrical components or sources of interference like motors or high-voltage lines. Disregarding these guidelines can compromise signal quality and overall performance. While making the site layout for cabling, clearly mark the type of cable also, to avoid mistakes.

9.1.3 Plan the BMS wiring layout, before starting any wiring work. Firm up plans for cable routing, distance between devices, and accessibility for maintenance purposes. Use correct specification cables and appropriate high-quality cables that are specifically designed for BMS applications. These cables should have good insulation properties, be resistant to interference, and able to handle the required voltage levels. Label all the wires in a visible manner. This is essential for troubleshooting and future maintenance. Clearly mark each cable with its corresponding device or terminal point so that anyone working on the system can easily identify them.

9.1.4 Separate low voltage and medium/ high voltage lines. Use earthing wire consistently, without adopting any shortcuts. This will ensure electrical safety and reduce noise in signal transmission within the BMS system. Install reliable grounding systems according to local electrical codes.

9.1.5 All communication cables shall be run separately with a clear gap from power wiring. Preferably use separate conduits and trays.

9.1.6 Controls and communication cables will have 'distance limits' specified very clearly. Understand these limitations, note them down and strictly follow them.

9.1.7 Analog signal cables can have electro-magnetic interference (EMI) disturbances from their neighboring devices and cables. Please follow correct cabling practice. Ensure proper shielding around sensitive wires.

9.1.8 Follow manufacturer's instructions when it comes to wiring practices for specific devices or components. Improper termination techniques such as loose connections or using incorrect connectors may result in intermittent faults that are difficult to diagnose later on.

9.1.9 Once all wiring connections are made, perform comprehensive testing using appropriate equipment to verify proper functionality before commissioning the entire system.

9.2 Control Panels

9.2.1 Check nameplate details and equipment tags. Check for damages and missing components. Verify with approved shop drawings.

9.2.2 Check cable trunking wire conduits, selector switches, push buttons etc. for manual operations.

9.2.3 Check circuit protection (MCB) ratings.

9.2.4 Check cables and equipment earthing or grounding.

9.2.5 Check panel devices are labelled, wired correctly and are tightly secured.

9.2.6 Check I/O devices labelled and wiring tagged as per drawings. Check digital inputs and outputs are operational.

9.2.7 Check sensors, transmitters and other field devices, as specified in the relevant shop drawings are installed and wired properly.

9.2.8 Check control system interlocks hooked up and are functional

9.2.9 All system sensors, gauges and meters shall be calibrated with calibration certificates.

9.2.10 Check that all field devices inside the building are installed based on the approved coordination drawings. Check the required identification for all system accessories are done. Control enclosures shall comply to BS EN 60947 and BS EN 61439.

9.2.11 Control panels shall include suitable LED lighting that automatically illuminates when the door is opened.

9.2.12 All control panels, control enclosures, marshalling boxes and control ancillaries shall be of correct IP rating for the environment that they are to be installed in i.e. IP 54 for inside locations and IP65 for external installations.

9.2.13 All internal panel wiring shall be identified by numbered ferrules, which are to be detailed and indicated on the wiring diagrams. The wiring diagrams are to be updated if modifications are carried out during installation and a fresh ‘as-built” set of wiring diagrams are to be placed in a plastic wallet in the Controls Enclosure

9.2.14 Verify service clearances are provided as required.

10.0 Installation of Field Devices

10.1 Install VAV Boxes, room temperature sensors and the VAV controllers as per manufacturers recommendations. Strictly adhere to number of VAVs allowed per data trunk or loop.

10.2 Install AHU sensors like damper actuators, differential pressure sensor across air filter, temperature sensors, air flow sensor, duct static pressure sensor, chilled water control valves, CO2 sensor etc. as per approved drawing and as per specification.

10.3 Similarly install other sensors like chilled water pump differential pressure sensors, flow sensors, cooling tower sump temperature sensors etc. as per approved drawing and specification.

10.4 Ensure that field devices for HVAC equipment like night time operating split AC for UPS room, server rooms etc. are installed as per approved shop drawings and manufacturers recommendations.

11.0 BMS Room Installation

11.1 The BMS room installations include all the control panels consisting of supervisory controllers and user-interface HMI equipment.

11.2 The electrical cabling related and control panel related installation points already discussed are applicable here also. In addition to this, it is a good practice to have a complete set of BMS documentation few of which are listed below:

- Whole BMS system time schedules, set points and parameters
- Control panel drawings: to include parts list, front panel HMI screen display details.
- Input and output (I/O) module schedules
- Field equipment schedule
- Valve schedule, where appropriate
- BMS controller network schematic
- Sample graphics

12.0 Wireless Technology

Wireless technology is now available for BMS connectivity and the wireless platform allows access across multiple levels of the BMS. Wireless devices can co-exist with hardwired devices on the same network. Sensors, routers, coordinators are all available with wireless connectivity. Sensors can be battery operated and can have built-in capability to check signal strength as well as low battery condition mapping. Where wireless devices are used, availability of repeaters to form a mesh network shall be ensured.

12.1 Internet of Things (IOT) allows one common IT platform to link all smart sensors and devices to interchange information and through analytical software, optimize the control automatically.

12.2 BMS allows relevant data to be accessed (including history and trends) in a second and allows the operator not only to take corrective action but also to observe the result of that action. This, practically, can be done from anywhere with an internet connection. This results in faster problem resolution, enhanced efficiency, lower operating costs and improved building performance

Chapter 19

Noise and Vibration

1.0 Noise and vibration control measures shall be designed at the project's inception and shall continue during installation phase. Noisy equipment shall be located as far away as feasible from noise and vibration sensitive areas.

2.0 If the building design permits, central air plant may be located away from the building areas which are noise sensitive. All equipment and piping shall be installed with vibration isolators. Ventilation passages shall be equipped with acoustical louvers, duct silencers or acoustically lined plenum. Electrical connections to equipment shall be made with slack, flexible conduits.

3.0 To dampen reflected sound from hard surfaces, sound absorption material shall be used in equipment rooms.

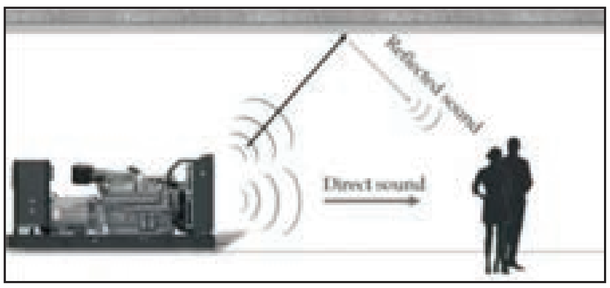


Figure 18.1: Dampening reflected sound

4.0 High velocity ducts shall not be installed in noise sensitive areas. Ducts and plenum shall be suspended from structures using neoprene or spring-based hangers.

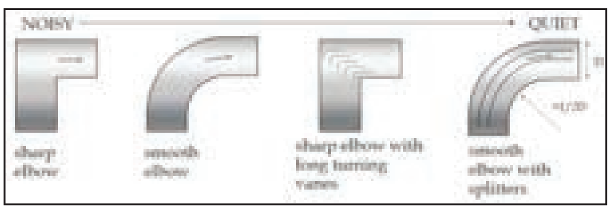


Figure 18.2: Noise reduction in ducting

5.0 Fans shall be selected with care. Generally, large diameter, low speed fans are less noisy. Ducts may be lined with sound absorbing material. Attenuators or silencers shall be used in supply and return ducts. Fans can also be housed inside acoustic boxes.

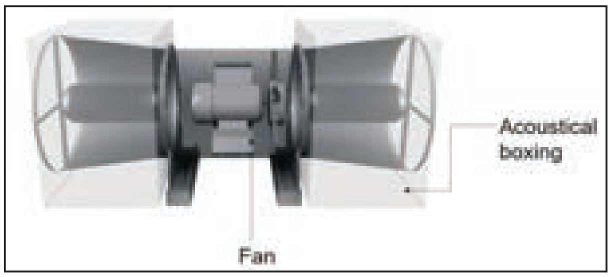


Figure 18.3: Fan housed in acoustic boxing

6.0 Masonry or drywalls of higher density are more effective in dampening noise. For reducing both upward and downward noise transmission from equipment rooms consider monolithic slab

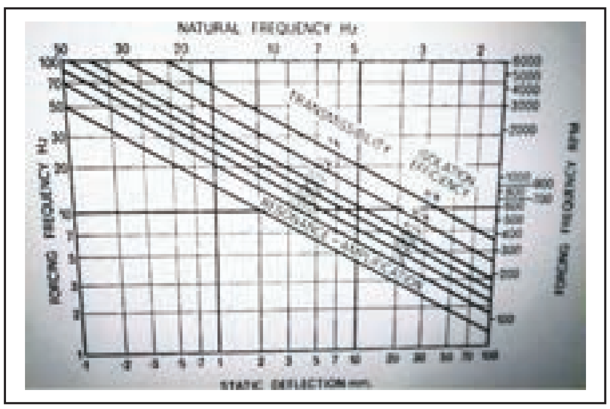


Figure 18.4: Vibration isolation efficiency chart

weighing minimum 500 kg/m². Where noise control is critical, consider floating floor of minimum 500 kg/m² density.

7.0 For structure borne noise control, machines shall be mounted on resilient mounts. Resilient mounts shall be selected based on static and dynamic loading as well as forcing frequency. A vibration isolation chart is given below:

8.0 Pipes, cable trays and ducts shall be isolated from the building structure with neoprene or spring hangers. Flexible connectors shall be installed between pipes, ducts and vibrating machines.

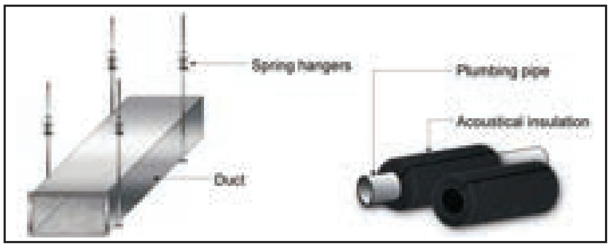


Figure 18.5: Isolating ducts and pipes

9.0 Where roof top equipment is likely to spread objectionable noise to surroundings, noise barriers, insulated jackets and hoods may be used to dampen noise transmission.

Figure 18.6: Noise dampening from rooftop machines

10.0 All partitions shall be extended up to ceiling slab. All penetrations shall be sealed.

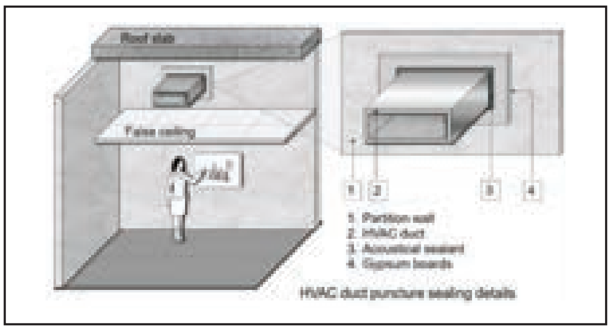


Figure 18.7: Duct penetration ceiling

11.0 Shaft walls shall provide for sufficient reduction of noise from the shaft to noise sensitive areas nearby. If required, they shall be acoustically treated. Pipes, ducts, conduits shall be vibration isolated so that mechanical vibration and structure borne noise is not transmitted to building structure. Fig 18.8 illustrates typical fixing details.

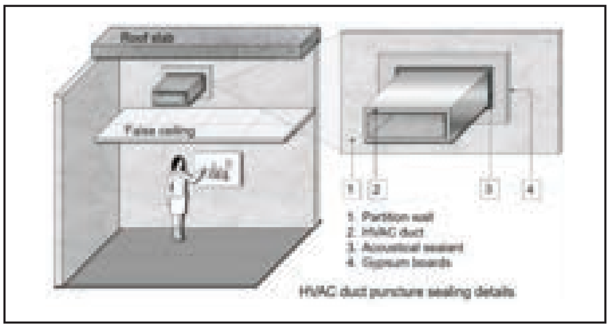


Figure 18.8: Mounting details of pipes in shaft

12.0 For complete and detailed information on Noise and Vibration Control, the reader is advised to refer to ASHRAE Publication 'Noise and Vibration Control for HVAC Systems' by Mark E Schaffer.

Chapter 20

Corrosion and Protection from Corrosion, Painting and Labelling

1.0 General

Corrosion by definition means the irreversible damage or destruction of material due to chemical contaminants in the atmosphere or due to electrochemical reaction thus impacting the intended use of the material. Manufacturer takes care of the general corrosion resistance of products as a part of the design specifications. In this chapter, we shall look at how we can reduce or prevent corrosion by adapting sound installation practices.

1.1 Corrosion is a natural process that converts a refined metal into a more chemically stable form such as oxides, hydroxides and other forms of salts. It is a diffusion-controlled process, occurs on exposed surfaces and is the gradual change in the original properties by chemical and/or electrochemical reaction with the chemicals in the environment. Corrosion can also occur in materials other than metals, such as Polymers not only as a chemical interaction with the chemicals in the environment but also due to exposure to radiation such as UV. Corrosion degrades the useful properties of materials and structures including strength and appearance.

1.2 The HVAC equipment and the supporting structures at the site and installation have materials and components such as steel, copper, aluminum, brass, various types of plastics, insulating material, electronic control boards. All these can get corroded. Degradation due to corrosion can lead to deterioration of performance, early failure and can also lead to safety issues. Localized general corrosion is mostly an outcome of galvanic corrosion and can be taken care of at the design stage of the equipment. General corrosion which is dependent on the environment can be taken care to a large extent by adopting good installation practices.

1.3 For a comprehensive understanding of the phenomena of corrosion, please refer to ISHRAE Guide on this subject.

2.0 Types of Corrosion

2.1 Galvanic corrosion starts with contact of dissimilar metals in presence of electrolyte. Any form of water is an adequate electrolyte. If any one of the conditions (contact, dissimilar metals or electrolytes) is not present, galvanic corrosion cannot occur. The electrolyte apart from water may contain chloride contaminants from sources such as sea water, rock salts, cement dust, pool cleaners, laundry facilities and household cleaning agents, which are typically sodium or calcium chloride-based compounds. Other contaminants that contribute to the formation of electrolytes include sulphur and nitrogen bearing

Figure 20.1: Galvanic corrosion

compounds. Ammonia can also contribute to the formation of electrolyte.

2.2 Micro corrosion is localized corrosion and if the unit is installed in the proximity of swimming pool areas, water treatment facilities, open sewage systems, diesel and vehicle exhaust emissions, landfills, fossil fuel burning power plants, animal farms etc. chances of micro corrosion occurring is high.

2.3 Macro corrosion occurs in areas adjacent to sea coast, industrial sites and heavily populated urban areas.

3.0 Classification of Corrosion

3.1 Coastal

Abundance of sodium chloride (salt) and sulphur compounds that are carried by sea spray, mist, fog, or prevailing winds. Sea spray, mist and fog contain tiny droplets of salt water that can be transported many miles by ocean breezes. Land formation, distance from the coast and the direction of the prevailing winds influence costal corrosion.

3.2 Industrial

Has the potential to produce a variety of corrosive compounds. Industrial environment can exist on a macro or micro scale and depend on the type of the industry. Specific chemicals can be related to the type of chemical manufacturing and a mitigation plan needs to be developed based on the industry source.

3.3 Urban

Highly populated areas generally have high levels of automobile emissions. This condition elevates concentrations of oxides of sulphur (SOx) and nitrogen (NOx) which, in combination with humidity, become potent mixtures. Open sewage lines, untreated disposal of water in lakes and rivers in the urban areas contribute to this type of corrosion.

3.4 Rural

Rural environment may contain high level of ammonia and nitrogen contamination from animal excrement and fertilizers.

4.0 Prevention of Corrosion

4.1 Galvanic Corrosion

This is best handled during manufacture of equipment. Prevention is based on ensuring that one or more of the three features do not exist. Break the electrical contact using plastic insulators or coatings between the metals. Select metals close together in the galvanic series. Prevent ion movement by coating the junction with an impermeable material, or ensure environment is dry and liquids cannot be trapped.

4.1.1 Corrosion of heat exchanger coils: The most common cause is galvanic corrosion due to aluminum and copper contact resulting in degradation of aluminum fins. Various options are available; however, the most common solution is using coated fins stock. This creates an insulating barrier and thus prevents the galvanic corrosion. In saline environment such as sea shore, landfills, open sewage areas total coating of coils and copper parts is recommended. Copper tube copper fin coils with tinning is an excellent solution. Extra care should be taken while storing the units at site under construction before installation specially if the period between the installation and commissioning is large.

4.1.2 Microchannel heat exchangers: The use of microchannel heat exchangers is increasing due to higher heat transfer efficiency for a given area. Microchannels are aluminum tube in multichannel geometry brazed to aluminum fins and headers. The header tubes, channels and fins are zinc coated which melts to form welded joints; zinc forms sacrificial material to prevent corrosion. The most susceptible joint is copper-aluminum joint of liquid and gas connection where galvanic corrosion can occur leading to gas leak. E-coating is a normal practice for coil and epoxy coating for the copper joint.

Figure 20.2: Microchannel heat exchanger

4.1.3 Plate type heat exchangers: The construction uses copper cladded SS plates (0.2 mm thick) of non-corrosive grade with channels embossed to form path for water and refrigerant. The brazing of plates is by melting of cladded copper at high temperature in inert atmosphere. The weakest part is the copper portion which joins the plates. Corrosion can occur due to stagnant water with chlorine, or acids formed over a period.

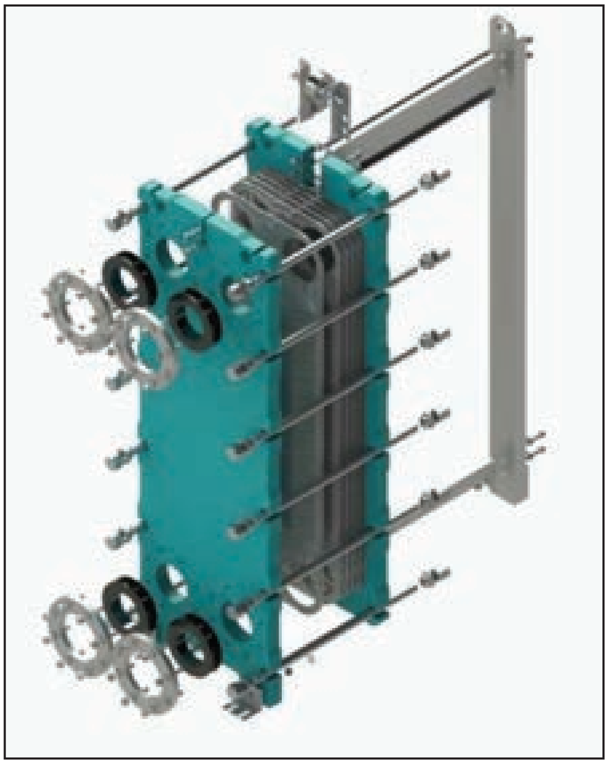


Figure 20.3: Plate type heat exchanger

4.1.4 Formicary corrosion: Ant's-nest corrosion occurs when oxygen, moisture and a specific corrodent, usually an organic acid, are simultaneously present on a copper surface. The nature of the attack is of a sub-microscopic nature; pits created by this type of corrosion are so fine that they are not visible to the unaided eye. The corrosion initiates from the tube surface and progresses rapidly into the tube wall. The corroding atmosphere is formed due to construction practices which emit VOCs, including formaldehyde. Plywood, engineered wood products such as flooring and cabinetry, latex paint and sheet vinyl flooring have been identified as major sources for these compounds. The most common organic acids are formic and acetic acids. All of these compounds are aggressive to copper, resulting in ant's-nest corrosion.

Ant's nest corrosion mostly occurs during the phase of prolonged gap between installation and commission and usage. This is because after the installation the interior design work continues for a period and the emission of VOC is the highest. Further as the unit is not working there is a stagnation and entrapment of VOCs. It is also found that in closed rooms and areas such as guest rooms the corrosion can start. Coating of return bends, connecting pipes helps.

4.1.5 Brazing: Brazing is the activity of interconnecting pipes during the installation and commissioning. It is a manual skill-based activity and the most vulnerable elements to be taken during the process are flux residue, excess oxidation, formation of phosphoric acid in Cu, Cu alloys, pitting of brass parts, copper coated mild steel (e.g., compressor joints). The minimum requirement to avoid corrosion is to deploy a skilled brazer and pass an inert gas such as nitrogen from inside the tube during the brazing process.

4.1.6 Steel structures: Corrosion starts in presence of moisture and oxygen and does not occur in the absence of either. Apart from the general corrosion, there are various types of localized corrosion that can also occur: bimetallic, pitting and crevice. The rate of the corrosion process depends on factors such as micro-environment in terms of humidity, wetness and atmospheric pollution. The mitigation is by using coated steel with sacrificial material such as electroplating, Hot dip galvanizing or metal spray followed by paint coating based on environment requirements. Surface preparation and minimization of the interval between surface preparation and metal coating. When surface treatments are used to retard corrosion, great care must be taken to ensure complete coverage, without gaps, cracks, or pinhole defects.

Design and process considerations include removal of the sharp edges, projections, and steel contamination such as weld sludge. It should be ensured that the construction is designed of supporting structure so that water and muck do not accumulate. Selection of coating material should be done based on the environmental conditions.

4.1.7 Hardware: Hardware holds the parts together and is very important as the structure, unit, sub assembly and components can get displaced and break if the corrosion considerations are not given sufficient importance. The traditional method is to use hardware with zinc coating by hot dip or electrolytic process followed by passivation. However, this process has limitations due to uneven deposition, faster degradation of sacrificial material, limitation in coating thickness, difficulty in application on heat treated parts and lower impact resistance. The recent development is of the zinc flake coating adopted by auto industry which gives superior protection.

4.1.8 Electronic components: Corrosion is one of the most common reasons for electronic component failure. This happens due to environmental contaminants and conditions. Contaminants include fine and coarse particles such as chlorides, sulphates, sodium, ammonium, potassium, magnesium, and calcium, gases such as sulphur dioxide and nitrogen oxide in relatively humid environment. These chemicals attack the tracks on the PCB, connections and leads of sensors. Conformal coating gives best protection in most of the cases. In highly corrosive environment the enclosure is kept in a positive pressure of air or nitrogen.

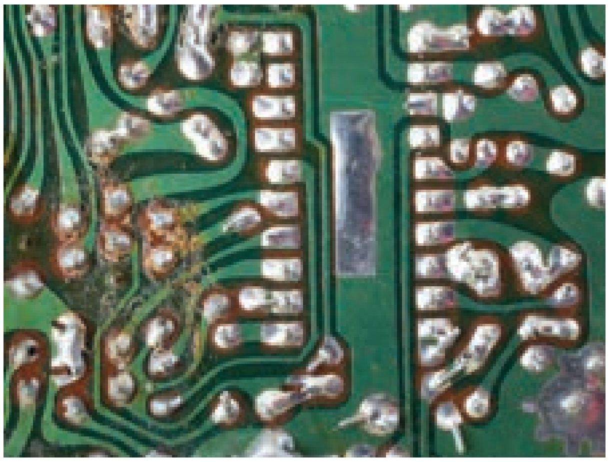


Figure 20.4: Corrosion on electronic parts

4.1.9 Fretting corrosion: This is a form of accelerated atmospheric oxidation which occurs at the interface of contacting materials undergoing slight, cyclic relative motion and is observed in soft as well as hard metals. In electric contacts involving non-noble metals, fretting action can cause rapid increase in contact resistance, proceeding to virtual open circuits in a matter of minutes. Applying synthetic and natural oils have been found to be effective in preventing / minimizing fretting corrosion. Liquid lubricants have the ability of excluding oxygen from the contact, thus preventing oxidation of wear debris and freshly exposed contact material.

4.1.10 Corrosion due to UV radiation: UV exposure leads to discoloration, degradation and also alters the properties of material. Almost all synthetic polymers require stabilization including protective coating on sheet-metal parts. In plastic parts UV attack by sunlight can be prevented by adding UV stabilizing chemicals to the polymer when mixing the ingredients, prior to shaping the product by injection molding. Selection of material for out-door application should be with 1000 hours UV resistance.

4.1.11 Refrigerants: Strong inorganic acids such as HCl and HF formed by the decomposition of refrigerants. Weaker organic acids are produced from decomposition or hydrolysis of the lubricants. Moisture reacts with polyol ester (POE) lubricants to form the parent organic acids and alcohols. All these acids and alcohols act on the internal parts of refrigeration systems such as iron, aluminum, copper. to form salts or can catalyze hydrolysis reaction at higher temperatures

Counterfeit refrigerants can cause huge damage to the system as the properties get altered and impact the performance. R40 refrigerant is highly corrosive with aluminum and forms explosive mixture leading to fire.

4.1.12 Commissioning: During commissioning, ensure that the units are installed with free air supply on condenser heat exchanger so that the discharge gas temperatures are within the specified limits to avoid disintegration of refrigerant. Follow advised vacuuming process to remove moisture to avoid formation of corrosive acids.

5.0 Painting and Labelling

5.1 All surfaces to be painted shall be thoroughly cleaned with a wire brush to remove rust and other extraneous substances. One coat of zinc chromate primer shall be applied over the cleaned surface. It shall completely cover all exposed surfaces. Once the prime coat is completely dry, finish painting shall be done. Second coat of finish painting shall be done just before hand over. Galvanized steel ducts may be painted without a prime coat. Dry Film Thickness (DFT) of finished painting shall be 250 microns minimum.

5.2 Color code shall be used for easy identification of various items in an air conditioning and ventilation systems or correct identification.

5.3 Color band shall be 150 mm wide, superimposed on ground color to distinguish the type and condition of fluid. The spacing of band shall not exceed 4.0 m.

5.4 Further identification may also be carried out using lettering and marking direction of flow. For identification markings for ducting, please refer to Section 3.2.12 and *Figure 10.3.*

5.5 The scheme of color code for painting of pipe work services for air conditioning installation shall be as indicated in *Table 20.1.*

5.6 In addition to the color 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 20.1: Scheme of color code of pipe work services for air conditioning installation

Sl. No.	**Description**	**Ground Color**	**Lettering Coloring**	**Color Band**
(1)	**(2)**	**(3)**	**(4)**	**(5)**
i)	Cooling water	Sea green	Black	French blue
ii)	Chilled water	Sky blue	Black	Black
iii)	Central heating	Dark blue	Black	Canary yellow
iv)	Condensate drain pipe	Black	White	
v)	Vents	White	Black	
vi)	Valves and pipe line fittings	White with black handles	Black	
vii)	Belt guard	Black yellow diagonal strips		
viii)	Machine bases, inertia bases and plinth	Charcoal grey		
ix)	Compressor /motor	Dark grey		
x)	Chiller	Dark grey		
xi)	Refrigerant Piping	Red		
xii)	Pumps/motor	Canary yellow		
xiii)	Cooling Tower	Steel blue		
xiv)	Ducts and supports	Black		
xv)	Air Handlers	Fiesta blue		
xvi)	Electric Panels	Steel grey		

Chapter 21

Safety Aspects in Installation and Commissioning

1.0 General

Installation activities involve, lifting, shifting to the location either in the basement, roof top or on the external façade of high-rise building, pressure testing, connecting to the power systems, refrigerant management and testing. This need coordinated activities of multiple operators working at heights and in confined spaces, handling of refrigerants and other gases such as nitrogen or oxygen, pressure testing, brazing and welding, working with electrical circuits, using power tools, and use of cranes, chain pully blocks, forklifts etc. These activities involve specialized skill. The team involved can be as small as a two-person team for room/split AC to a large team with each having specific role for specific periods for activities like lifting and shifting, electrical connections, etc. It is therefore important to ensure that the safety is addressed in a holistic manner. Considering that the work may involve multiple agencies and will span over a period of time, it is essential to have a structured approach to ensure the safety of both personnel as well as equipment.

1.1 Further, safety is a legal requirement and any personal injury, death and material damage can have serious consequences.

1.2 Kindly refer to ISHRAE publication 'HVAC Safety at Sites' for full understanding of safety aspects of HVAC systems. Safety is not a one-time exercise and needs to be monitored on a continuous basis. ISHRAE has launched an application 'Avighna' which is comprehensive and evaluates the site safety effectively. It is recommended that this application is used to monitor safety at job sites.

2.0 The steps below are recommended to address safety at Installation sites:

2.1 Build a safety organization structure with clear roles and responsibilities. If, it is not possible to have an independent safety officer or a specialist, the site in-charge or the operator himself should take this responsibility. The structure should have clarity on reporting, emergency situation handling with contact numbers. Training in classroom and onsite is essential.

2.2 Site survey: A comprehensive site survey must be conducted. Following points need to be covered.

a. Setup of safety organization
b. Conduct safety audit. Avighna app is recommended.

2.3 Following practices shall be followed to make sites safe:

2.3.1 No person below 18 years should be allowed to work in site.

2.3.2 All personnel details, such as name, specific skill set and emergency contact person details with telephone number should be recorded.

2.3.3 All personnel working at the project premises need to undergo safety induction training.

2.3.4 Alcoholic beverages, drugs/intoxicant substances, cigarette, beedi smoking shall be strictly prohibited.

2.3.5 Safety helmet, safety shoes, ear plug or ear muff, hand gloves, safety goggles, safety harness and clothing for body protection should be made mandatory at the work site.

3.0 Site activities for Installation and commissioning can be classified into two categories:

Activities of general nature and Activities for specific purpose of HVAC. The work may be carried out in multiple shifts and most accidents occur due to a lack of illumination. Proper illumination must be provided and it must be ensured that changes are made as the work areas change with the progress of activity. Coordinate with the customer's representative to highlight and address this aspect in an effective manner as generally illumination in common use areas is under owner's scope. Following are the recommended guidelines:

3.1 Material Storage

- Display "Danger" signs for inflammable / explosive material.
- Sand buckets shall be kept at handy location.
- Material shall be stored only at the designated places.
- Guidelines for storage of each type of material (e.g. Fire resistant, chemicals etc.) and indexing of the material storage shall be properly done.
- Material shall be neatly stacked and secured to avoid sudden fall.

3.2 Lifting and Shifting

The activities involved are mobilization of manpower, transportation by trailer, crane selection and operation (if applicable), lifting gears, rigging, movement of cranes and trailers and manual handling of material inside the building. Associated risk is of vehicle accident, fall of material, collision, personal injuries, property damage etc.

Following shall be ensured:

3.3 Vehicle

Select the vehicle / trailer of suitable capacity. Do not load the vehicle beyond the guard post and secure material properly. Exercise extra care for oversized objects. Ensure availability of all legal documents. Check the condition of the vehicle being used. Check if the driver is adequately experienced for driving the vehicle and holds valid license.

3.4 Manual Handling and Shifting of Material Inside the Building

The risk involved could be lifting of excess capacity or dropping the load leading to personal injuries. Deploy right number of people for the job. Use safety gloves. Ensure that only desired material, tool, equipment or machinery is issued after proper certification and validation. Identify a group leader for the task and use correct posture for lifting. Follow the guidelines of maximum manual load to be lifted by law.

3.5 Slings

The risk associated is breaking of the sling or D shackles leading to personal injury as well as damage to the equipment being lifted. Check the sling for broken wires, and general condition of rope sling. Ensure that the sling is provided with thimble and three equidistant cable clips. Ensure that the safe working load is not exceeded. Use four slings for balanced operation. For more than one sling, ensure proper angle between slings. Ensure the proper strength and precautions depending on type, number and usage of the sling. Do not use bolt in place of shackle pin and ensure that the pin is correctly locked. Ensure that the shackles do not lean on one side while lifting and are always attached to the hooks. Eye bolt length shall be at least one to one and a half times the diameter of the bolt and are fully drilled on the load. Apply plain eyebolts for vertical lifting and lifting angle of shoulder eyebolt shall not be less than 45º. Do not use sling though a pair of eye bolts. Ensure that the hooks are with safety latches and is in vertical position. Remove latches only after the load is located at a safe place.

Figure 21.1: Sling

3.6 Chain Pulley

Use of chain pulley block for lifting moderately heavy loads is common practice. The risk involved is of failure of chain pulley block, fall of material and personal injury. Check physical condition and capacity of the chain pulley block by check hook, chain and safety latch. Ensure that the chain pulley block is anchored on a permanent structure or hard base. Using color codes is very common for equipment certification. Check the color code to ensure that the equipment is inspected recently. Use proper Personal Protective Equipment (PPE). Ensure adequate light. Barricade the working area to avoid trespassing.

3.7 Crane

Using a crane increases efficiency. Enough care needs to be taken for safe operation. The risks involved are falling of the load from heights, failure of the crane, breakage of slings/shackles resulting into loss of property as well as personal injury.

3.7.1 Crane selection: Select the proper crane type and load handling capacity. Ensure that the crane is certified for operations by proper authorities. Check the condition of the crane and its maintenance record.

3.7.2 Crane and operator: Check for third party certification and ensure that the operator has adequate license as well as experience of crane operation. Ensure that the operator has understood the operation correctly. All lifting gears should be third party certified by competent authority. The equipment slings should be marked with 'SWL' for the suitable load. Replace all damaged gears with repaired / new.

3.7.3 Crane set up and movement of load by crane: Ensure that the crane is anchored on a levelled hard surface. Ensure that the boom strength is adequate considering the load, wind direction and the height to which the load is to be lifted. Use out-rigger pad. Extend the out-rigger completely. Barricade the crane swing area and check for obstruction overhead. Take a dry run before commencing the actual operation.

3.7.4 Riggers and rigging the load: Use only experienced riggers. All riggers must use PPEs. Use proper gears and slings of adequate capacity, duly inspected for rigging operation. Pay attention to the center of gravity and use protective pads for sharp corners and bends. Ensure that there is no sudden hoisting or lowering of load. It may break the sling.

3.7.5 Load movement by crane: Only trained personnel must carry out the operation. Examine the path of load movement in advance. Inform all those who may need to take adequate precaution while moving outside barricaded area but in the vicinity of the movement. Prepare the landing place in advance as the load should not be held for a long time by the crane. Ensure that the boom angle is maintained and signaler is continuously directing the operator for safe movement. Ensure that the load is moved slowly without any jerks. Provide a guide rope and ensure that the rope is properly used. Carry out all operation in good weather conditions and in adequate light. No lifting / shifting operations to be carried out in night unless planned well. Under no circumstances, use untrained, non-qualified operator and inexperienced supervisor.

4.0 Working at Heights

Working at heights is unavoidable at construction sites. Normal working for HVAC activities will be at normal heights not exceeding about 4 meters. However, occasional working at higher elevations could also be involved. In case of installation of ducted systems or room ACs, one may have to work at heights. For working at heights, we generally use ladders, scaffolding, swings, platforms or scissor lifts. Risk associated with working at heights is fall of the material as well as of the working personnel, failure of the ladder or platform rope leading to fall etc. Injury to the personnel could vary from minor to fatal and hence adequate precautions are necessary.

Figure 21.2: Working at height with scaffolding

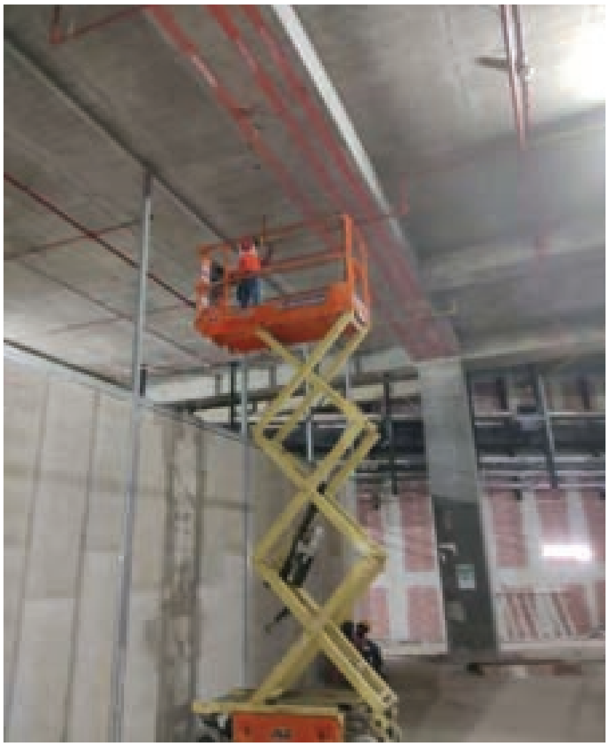


Figure 21.3: Working at height with scissor lift

4.1 Ladders are commonly used for reaching heights. Risk associated with ladders is fall of individual or material resulting into material damage or injuries to the personnel. Choose correct type of ladder for the activity. Inspect the ladder for any breakages or loose rungs, cracks or splits. Check if the ladder is warped and tie rods are in good condition. Do not use ladder if it is corroded or decay is noticed on the wooden member. Do not use painted ladder as it is likely to cover the defects. Use ladders of the proper length. Straight ladders for gaining access to elevated work areas shall extend a minimum of 1 meter above the floor or platform to be accessed. (Ensure that the ladder is placed at a safe angle 75° to horizontal ground (i.e., one meter out to four meters up).

Operator shall face the ladder and use both hands while ascending and descending. Wooden or fiberglass ladders shall be used around electrical equipment and metallic ladders shall not be used. Ladders shall primarily be used only for accessing/reaching at heights and shall not be used to stand and do work. Use standing type ladders wherever possible. Also step ladders are recommended for safe usage. Place ladder on levelled, firm surface. Place it against a support adequate to take the load of the ladder, worker etc. If the ladder is more than 6m long, a second worker shall stand at the bottom of the ladder holding it upright with both hands and with one foot resting on the bottom rung. The topmost rung shall not be less than 1 m from top. It will ensure adequate holding space. Recommended ladder angle is 75°. Use of safety belt is essential while climbing up the ladder. Minimum light tools should be taken up the ladder. Alternately, provide tool belt or tool bag to the worker. Do not use short length ladders or make shift ladders. Only one person shall climb up the ladder at a time. Use extension ladders if required. In such case overlap needs to be at least 1.5 rungs to 2 rungs depending on the height of the ladder. After the use, store the ladder horizontally on racks with an adequate number of support points. Do not store near heat sources or dampness or directly under sunlight. Ladders need to be kept clean and free from oil / grease / mud or any other item that may make the steps slippery.

4.2 Swings are used when one has to work for longer duration at a particular point. Though it is not the safest way of working, it is unavoidable for small jobs where scaffolds cannot be made and ladder cannot reach. Ensure that, the rope used has adequate load bearing capacity, the platform is sturdy and can accommodate a person comfortably. Supervisor shall be available during the entire duration of the work. The ropes shall be properly anchored to a very stable and sturdy structure. Safety belt used shall be properly anchored and other safety PPEs shall be correctly used.

5.0 Tools

Hand tools as well as power tools are used at HVAC work sites. While hand tools may cause minor injuries, power tools may cause serious injuries. Hand tools have a risk of personal injury as well as injury to the eye or face. Ensure the training on usage of the tools. All hand tools must be inspected and certified at regular intervals and color coded properly. Inspection before starting the work is essential to ensure that the tools are in good condition. Use job specific PPEs. Do not use tools with mushroomed / damaged heads. Use tools with proper tool handles.

5.1 Power tools: Hazard associated with usage of power tools is similar to usage of hand tools but extent could be more serious. User shall have experience and shall be trained to use the required tool. All power tools must be double insulated and earthed properly. Periodic maintenance, duly recorded is mandatory for the power tools. Check the inspection chart and color of the month sticker for using the power tool. Use electrical plug and do not insert loose wires / cables in electrical supply point. Use safety shoes while using power tools.

6.0 Pressure Testing

Pressure testing is an important activity in installation and commissioning. We need to carry out pressure testing for ducts, pipes and equipment in case if it has arrived in uncharged condition. Hydraulic pressure testing is carried out for pipes whereas nitrogen pressure testing is carried out for HVAC equipment as well as for ducts.

6.1 Hydraulic: Pressure testing shall only be carried out by competent personnel supervised by a qualified and experienced supervisor. The area around the pressure testing system shall be barricaded. Caution signs shall be placed at appropriate places and once the test is over, the signs and posters shall be removed. Suitable contingency arrangements shall be in place to handle any unexpected leaks during the course of the pressure testing. Tool box talks shall be given to the crew carrying out pressure testing. Continuous monitoring of the lines under pressure shall be ensured. Adequate first aid kits shall be available at site. Appropriate test manifold, hydraulic hose, calibrated pressure gauges and calibrated pressure relief valves shall be available for pressure testing. Only prescribed test pressure shall be used for pressure testing (normally 1.5 times the working pressure).

6.2 Refrigerant side testing: Ensure electrical LOTO has been applied. Accidental switching on of the compressor could lead to explosion. Test pressure should not exceed 1.5 times the normal operating pressure. Vacuum pump shall have a plug top with earthing. Vacuum pump oil shall not spill on the floor. Vacuum shall be measured by calibrated vacuum gauge and should be held as prescribed by the manufacturer. Only Nitrogen shall be used for pressure testing. No other gas shall be charged for testing.

6.3 Refrigerant charging: Refrigerant charging is a very important activity in HVAC field. Cold burns can happen in case human body comes in contact with liquid refrigerant. Use appropriate PPEs while charging the refrigerant. Only trained personnel shall charge refrigerant. Ensure that the system is properly vacuumized before charging the refrigerant. All precautions required for identification of refrigerant and handling pressurized cylinders are taken care. Always charge liquid refrigerant only. It is essential to charge the measured quantity of refrigerant. Never charge refrigerant if vacuum level is not satisfactory. Avoid accidental mixing of refrigerants. In case of cold burn, seek first aid immediately.

6.4 Electrical control panels: Working on electrical control panels require utmost care. Use appropriate PPEs such as safety shoes, hand gloves etc. as appropriate. Only qualified electrician should be deployed to carry out the activities. Ensure that the panel is securely grouted either to the wall or to the foundation on the floor. Ensure that the rubber mat is available under the feet while working on electrical panel. Ensure that cable insulation is not damaged while entering the cables through the cable entries provided. Use cable glands / connectors / duly crimped lugs, etc. Ensure that the panel is made in line with the standard electrical practices. Ensure that the start / stop operations have a lockable handle. Ensure that panel, lamps and hooters are in working condition. Ensure that the panel is properly earthed. In case of bus bars inside the panel, ensure they are properly insulated. On charging the panel, check for any leakages or abnormalities. Similar care should be taken while installing and commissioning smaller

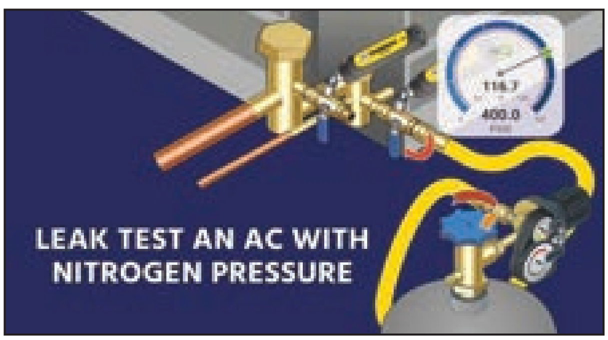


Figure 21.4: Pressure testing of refrigerant piping

Figure 21.5: Working on electrical panel

panels or Motor control centers for AHUs, fans, etc.

6.5 Lock Out and Tag Out (LOTO): Electrical power, pressurized air and pressurized water distribution have caused accidents particularly when released remotely or inadvertently. At HVAC sites, where work is going on, use of power tools and power operated equipment is common. As compared to a stable operation, at the construction site, the work force as well as the area of operation is constantly changing. Most accidents happen due to electrocution, as multiple people operate the power lines. In order to avoid these accidents, it is important to follow the LOTO procedures. The person who is in charge of the activity, must also be in charge of the isolating switches and panels, and be able to identify and control the tapping he is using. It is dangerous for one person to either switch ON or OFF the power circuit, when another person is working.

6.5.1 LOTO guidelines: Identify employees as follows.

- Authorized employees are the ones who Lock Out and Tag Out before commencing the operation.
- Affected employees are the ones who use the equipment or are carrying out the operation under Lock Out and Tag Out.
- Other employees are those who are in the area of Lock Out and Tag Out.

6.5.2 The Lock Out and Tag Out procedure is extremely important before working in confined places, as it is hard to escape from such spaces. A Lock Out device is usually a padlock with a tag clearly indicating 'Do Not Operate', which prevents the energizing, operation, or blockage-cum-stoppage of the equipment by anyone other than the authorized person.

In case of a group of people who are using the same energy source, a group Lock Out device must be used.

Figure 21.6: Lock Out devices and tags

Figure 21.7: Some more Lock Out tags

7.0 Personnel Protective Equipment (PPE)

7.1 Head protection (helmets): Use only ISI marked helmets.

- Always wear the helmet with the strap fastened to the chin, and adjusted well.
- Ensure that the helmet is used on the head directly, so that the shock can be absorbed.
- Never modify the helmet for air-circulation, etc., by drilling holes.
- Always use safety helmets only. Do not use sports helmets.
- The helmet should be stored properly, so that the interior surface of the helmet does not get damaged.
- Before using the helmet, inspect it for cracks, breakages, functioning of the chin strap, and size.
- If an inappropriate helmet is used, it will not give adequate protection.

7.2 Hearing protection (ear plug and mufflers): Protection against noise hazards is the most neglected area, as it does not reflect immediately, unlike a physical injury. There is enough study available on short-term and long-term exposure to noise hazards. Hearing protection must be used compulsorily for sound levels at the work place exceeding 85dBA.

Table 21.1: Harmful exposure to noise hazards

S Short-Term Exposure (hours/day)	Sound Pressure Level dBA Scale
8	90
6	92
4	95
3	97
2	100
1	105
0.5	110

7.3 Eye and face protection (goggles, safety spectacles and face shield): The classification of hazards shall be first carried out for impact, optical radiation and chemicals, as described below and suitable protection gear shall be used:

- Impact is caused while chipping, grinding, masonry work, wood work, etc.
- Optical radiation is caused while welding, gas-cutting, soldering, brazing and while carrying out laser work. It is also caused by radiant energy, glare and intense light.
- Chemical exposure is caused during painting, refrigerant charging, etc., in the form of splash, vapor and mist.

7.4 Hand and arm protection (cotton and rubber gloves). Hand and arm protection is required in both mechanical and electrical activities. The hazards during various activities are as listed in *Table 21.2.*

Table 21.2: Hazards associated with various activities

Short-Term Exposure (hours/day)	Sound Pressure Level dBA Scale
8	90
6	92
4	95
3	97
2	100
1	105
0.5	110

Different gloves are to be selected for different operations, and must be used:

- Chrome leather gloves shall be used for welding, gas-cutting and brazing.
- Cotton gloves with leather palms shall be used during material handling and sheet metal working, to avoid cuts and abrasions.
- PVC/rubber gloves shall be used while handling chemicals, paints, solvents, oil and grease.
- Rubber-insulated gloves, tested for appropriate voltage, shall be worn while working on electrical equipment. As a standard practice, the gloves shall be tested before they are issued to the workers and not left to them, as the workers may end up using damaged gloves. Gloves shall also be inspected for cuts, punctures, wear-and-tear, etc.
- Electrical gloves shall be given special attention, as the hazard can be fatal. Only certified gloves and suitable for the rated voltages shall be used. A quick field air test shall be conducted on the electrical gloves. The gloves shall be inflated with air, and checked for damage. The inflated gloves should be held near the ear and examined for any hissing sound.

7.5 Body protection (safety aprons): Body protection is required during welding, gas-cutting, handling chemicals, radiography, and pressure testing. Body protection equipment is an apron, which covers the chest, waist and legs, down till the knees. In case of welding and brazing, it is recommended that cotton clothes should be used. The selection of construction of protective equipment depends upon the work an operator will carry out. Aluminized fabric and fire resistance cloth protects the body from hot metal parts and splash. Leather protects from hot metal sparks, flying chips and mild impacts. Rubber aprons should be used while working with chemicals. In case of pressure testing, impact resistance aprons, similar to the ones used by the hockey goal-keeper, shall be used.

7.6 Foot protection (safety shoes): Foot protection is required against impact and compression injuries, electrical shock and slipping. Certified shoes with steel toes and shock proof safety shoes shall be used. The safety shoes shall comply to IS standards.

7.7 Fall protection (body harness, life line, etc.): Most of the accidents in HVAC installation occur while working at heights. It is a common belief that safety belts are a hindrance to working and it is observed that operators are at high risk when they move from one place to the other, with or without the safety belt anchored. Following shall be practiced:

- Always use a full body harness waist safety belt.
- Practice to use double anchor safety belts, when the person has to move during their work.
- In case a person has to travel in an area elevated more than 2 meters above ground level, a life line rope should be attached and provided. The strength of the life line rope along with its anchoring shall be checked using dummy weights, such as sand gunny bags.
- Anchor points shall be provided with life line ropes, while working on the roof.
- Full body harness with double lanyard rope, grab and fall arrestor attached to the vertical life line shall be provided while moving up and down the ladder.
- Accidents happen even with full body harness, due to swing falls and impact on the adjacent walls, pillars, etc. Care should be taken to adjust the length of the body harness attachment, to minimize the swing.
- The body harness, anchor points and life lines must be examined from time to time, and training should be imparted with practical examples.

Figure 21.8: Body harness

8.0 Storage of Material

8.1 Paints, varnish and thinners are flammable materials, and have special storage requirements:

- Bulk storage and daily usage requirements shall be separated.
- Paint scrapings, paint-saturated racks and debris shall be removed from the working area and stored in an identified scrap area. Care shall be taken to remove this unwanted material at weekly or monthly intervals, based on the quantity generated.
- Flammable material like insulation, plastics, etc., shall not be kept close to the paints and thinners.
- Adequate ventilation shall be provided in areas where flammable and combustible materials are stored.
- Fire entry crushers and fire buckets are recommended for the type of chemicals stored.
- The storage and issue as well as loading and

unloading of flammable chemicals shall be handled under the supervision of a trained person.

5-S activity and house-keeping shall be undertaken as a daily routine.

8.2 Cylinders (gas): In the HVAC industry, oxygen, acetylene and LPG cylinders are used for gas-welding, gas-cutting and brazing. Nitrogen cylinders are used for pressure testing.

- Oxygen requires special care, as any leak in oxygen enhances the risk of combustion and explosion.
- All cylinders shall be correctly marked as per color codes.
- The cylinders shall be segregated and kept separately, without mixing.
- Typically, cylinders shall be stored vertically.
- During the handling of cylinders, a cylinder trolley shall be used. Avoid rolling of the cylinders. Rolling on the bottom edge is recommended for short distances only.
- Never lift cylinders by attaching chains, strings, etc., to walls. Never drag or pull the cylinders by holding the valve. All transport devices shall have a securing system.
- Oxygen cylinders shall be stored at least six meters away from LPG and acetylene.
- Always change the cylinders when stored, as the diameter-to-length proportion tends to tripping.
- The cylinders can be stored in outdoor storage with a well-fenced area, on raised concrete pads, and protected from weather and rain. Never store cylinders on wet soil, as it can cause corrosion. In case of indoor storage, the floor should be flat and have walls, and the enclosure shall be of non-combustible material.
- Tripping of cylinders is quite common, and the best practice is to carry them individually.
- Relevant and adequate posters, indicating the type of chemical content, and guidelines in case of emergency, shall be displayed in sufficient number and appropriately.
- Cylinders shall not be exposed to temperatures above 50ºC or below -30ºC. Under no circumstances shall direct heat be applied to cylinders while working in sub-zero conditions. Hot water below 50ºC should be used for warming.
- General Precautions: Empty cylinders should be stored in a separate and segregated area where it is ensured that the walls are appropriately closed, as empty cylinders can exhale and inhale atmospheric air. Empty cylinders do contain residual gases, and should be treated with all precautionary measures to be taken for full cylinders. Empty cylinders shall always be marked and labelled as empty.

9.0 Emergency Response Plan

9.1 Though all precautions are taken, accidents do occur. It is therefore necessary to have a well-established emergency response plan.

9.2 Emergency preparedness helps to minimize the human suffering and economic losses that can result from emergencies. It should be understood that the size and complexity of projects, as well as their access and location, have a bearing on the degree of planning necessary for emergencies.

9.3 Some guidelines towards developing an emergency response plan follow.

9.3.1 Plan development should include the following:

- Hazard Identification/Assessment
- Emergency Resources
- Communication Systems
- Administration of the Plan
- Emergency Response Procedure
- Communication of the Procedure
- Debriefing and Post-Traumatic Stress Procedure

9.4 Because HVAC construction sites are frequently changing, the process of hazard assessment must be ongoing, to accommodate the dynamic environment. Once hazards are identified, the next task is to assess the potential or risk involved in each. For each hazard identified, ask "What can go wrong and What are the consequences".

9.4.1 For each potential hazard it is important to identify resources necessary for an appropriate emergency response. For most events in HVAC construction, a simple analysis based on the experience of the people involved in the project is likely to be sufficient.

9.4.2 It is important to identify which resources are available and to have contingency plans in place to make up for any deficiencies.

9.4.3 The most important information on projects are the telephone numbers of the fire brigade, ambulance, police stations, closest hospitals and super specialty hospitals. Telephone numbers of senior management personnel shall also be available, as off-site co-ordination is possible. It is important to know the facilities or limitations available in that location. What is the response time? What must site personnel do in the mean time?

9.4.4 Other on-site resources such as fire extinguishers, spills containment equipment, and first aid kits must be maintained and clearly identified. Construction equipment may be included among potential emergency resources. Personnel, especially on-site medical staff or workers trained in first aid, should be included in the plan.

9.4.5 There may be situations where outside resources are so far away that an adequate response is not possible. In these situations, resources may have to be obtained and maintained on site. Examples would include fire protection or ambulance/medical resources in remote areas.

9.4.6 An important key to effective emergency response is a communications system that can relay accurate information quickly. To do this, reliable communications equipment must be used, procedures developed, and personnel trained. It is a good idea to have a backup system in place, in case the system is rendered useless by the emergency. For example, telephone lines may be cut.

9.4.7 The type and location of the emergency communication system must be posted at the project site. This will include the location of telephones, a list of site personnel with cellular phones or two-way radios, and any other equipment available. Emergency phone numbers and the site's address and location should be posted beside all site phones. On large sites, the location of emergency phones must be clearly marked.

9.4.8 A communication system must be made up of strategically placed equipment and properly defined responsibilities. The emergency response plan posted in a conspicuous place in the project must identify the designated equipment and the authorized people to operate it.

9.4.9 Slow response, lack of resources, or the absence of trained personnel will lead to chaos in an emergency. To minimize human suffering and financial loss, all personnel must know their responsibilities under the emergency response plan.

Chapter 22

Introduction to Commissioning

1.0 General

Commissioning is the process of assuring that all sub systems and equipment of the HVAC System are designed, installed, tested, operated and maintained according to the operational requirements of the owner or end user.

Commissioning of HVAC Systems is a structured process and shall be carried out in line with ISHRAE Standard 10003-2020 (or its latest amendment).

2.0 For complete information on Commissioning of HVAC Systems, please refer to ISHRAE Commissioning Guidebook 2025.

3.0 In respect of unitary equipment such as room (window air-conditioners), non-ducted split units, package units or VRF, this process shall involve connecting the unit (after installation) to a suitably sized power outlet, switching on the unit and recording the temperature/RH/air movement/ air quality in different locations in the conditioned space. The process shall also involve whether the unit's contracted features are operational and whether the compressor switches off once the set temperature is achieved. Air flow from the unit as well as noise level shall be appropriately measured and recorded. Capacity/power consumption is verified with factory issued test certificates.

4.0 The various stages of the structured commissioning process are given in the Commissioning Flow Chart given in *Figure 22.1.*

5.0 Various stages of the process are briefly described hereunder.

5.1 Initiating the Process: Owner shall designate Commissioning Authority (CxA) at

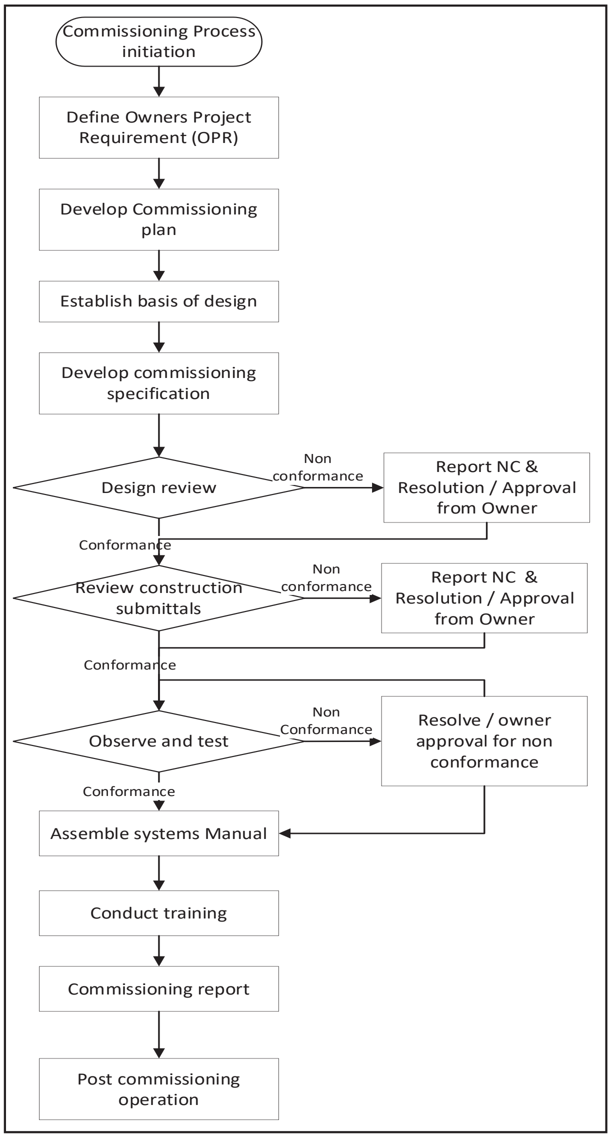


Figure 22.1: Commissioning flow chart

the start of the process. CxA shall either be a member of the Owner's Project Team or an independent agency appointed for this specific purpose. CxA shall have adequate knowledge and experience to guide the project through various stages of the process. Engagement of CxA shall be for a minimum period extending to one year from date the building/facility is put to use. It shall be the responsibility of CxA that that all non- conformances, warranty issues, seasonal and occupancy related performance issues are fully resolved during her tenure with the project.

Owner shall be responsible for defining scope of the commissioning plan, incorporating CxA into the project team and establishing the commissioning budget.

Role of CxA and contractual requirements for Commissioning shall be a part of all sub contracts including contracts with architects/consultants.

5.2 Owners Project Requirements (OPR) shall include all functional requirements of the project and owner's expectation regarding its use and operation.

5.3 Commissioning plan shall be a written document scheduling the commissioning activities. This shall include scope, resources required at each stage, agreed timelines and roles and responsibilities of each member of the project team.

5.4 Basis of Design document details design team's approach to meet OPR.

5.5 Commissioning specifications shall be established for all equipment and systems.

5.6 Commissioning Design Review shall involve verifying conformance of all equipment and systems to meet OPR. This shall not be a peer review of the design.

5.7 Testing shall involve preparation of check lists, test procedures and report forms which shall be agreed by all concerned. Person responsible for executing test protocols shall be identified.

5.8 Functional performance testing shall involve recording the operation, then initiating a change in one or more parameters and recording the changes in performance. This shall be done in auto mode with functional BMS and controls.

5.9 All information required to operate, maintain and if required, modify the system in future. Systems manual shall be approved by owner and kept updated.

5.10 Operation and Maintenance training shall be documented. Evaluation and feedback are important.

5.11 Final Commissioning Report shall summarize the entire process and shall have Owner's acceptance.

5.12 Post Occupancy commissioning shall include all delayed and seasonal tests, warranty actions/ records and resolution of all non-conformance with owner's specific approval.

5.13. For each piece of equipment, sub system and system, Check Lists shall be made use of for delivery, installation, start up and readiness of commissioning. Sample check lists available in ISHRAE Standard 10003-2020 may be suitably adapted for use.

5.14 Individual pieces of equipment, sub systems shall be considered ready for testing only when the complete installation is over, pressure testing/leak testing (as specified) are completed and required utility connections are made to the satisfaction of CxA. It shall be verified that all blank offs, shipping bolts etc. have been removed. Where specified, manufacturer/supplier shall inspect and certify that the equipment/system is ready to start.

5.15 Testing of all equipment/systems shall be in line with the documented protocol which is agreed between the manufacturer/vendor, CxA, Design Consultant, Project Management Consultant and any other agency who may have jurisdiction over the project. Check lists, reporting formats and standards applicable shall all be agreed in writing beforehand.

5.16 Training and documentation for data collection leading to energy analysis shall form part of the process. It is recommended that all individual loads greater than 15 kW be monitored for energy management.

5.17 Static inspections that verify proper installation (e.g. belt tensions, coupling alignments, oil levels, labelling, gauges and instrumentation in place, sensors calibrated etc.) shall be submitted by the vendor to CxA with the request for start-up.

5.18 Pre-commissioning cleaning of the installed ducting and leak testing of the ducts (where specified) shall be carried out prior to staring of AHU/fans.

5.19 Activities where the equipment is initially energized, tested and operated shall be completed before Functional Performance Testing (FPT). FPT shall involve testing under dynamic situations such as low load, full load, varying ambient, power outage, distress and emergency conditions etc. FPT shall establish that the equipment/system performs as designed under all these conditions. Systems shall be operated integrally through all specified operation sequences. Each step of FTP shall be planned in advance, agreed between vendor and CxA, performed under supervision and results tabulated in a pre-agreed format. In case FPT cannot be performed due to any reason (such as ramp up period) before the equipment/ plant is put to beneficial use, same shall be recorded and Owner's approval taken.

5.20 Operation of all controls and safety cut outs shall be demonstrated and recorded. All measuring instruments shall have valid calibration certificates which shall be part of the record.

5.21 Handover documentation shall include all information Owner/User will need to operate, maintain and if required, modify the system at a later date. Hand over documents shall include the following as a minimum requirement.

- Updated and approved (by owner) systems manual.
- Final commissioning report.
- Set of as-built drawings.
- Full set of design calculations.
- Spare parts lists/ordering procedure.
- Warranty records, escalation matrix.
- List of non-conformances with resolution records.
- List of accessories/ tools/ spare parts supplied with system.
- Operation and maintenance manuals provided by equipment supplier.
- List of spares and escalation matrix.

6.0 Balancing of air and water systems is one of the very important activities forming part of commissioning.

6.1 Air System Balancing

Air distribution system shall be balanced so that air quantities measured at fan discharge and at various outlets shall be within +/-10% of the design airflows. Branch duct adjustments shall be permanently marked after the balancing is complete. Throttling losses in the system shall be minimum. Tests shall be carried out for each fan and AHU. All dampers after adjustment shall be set and locked in position. All air and static pressure measurements shall be done with probe type meters. After balancing the fan speed shall be suitably adjusted. Duct leakages shall be tested and validated as specified.

6.1.1 Airflow balancing shall be carried out by adjusting the flow at each diffuser to match the right percentage of total airflow in the ductwork. Balancing shall be done based on the ratio between measured and designed flow rate. Following steps may be followed for Proportional Balancing:

- Ensure all VCD, VAV and fire dampers are in fully open position.
- Adjust the damper of each diffuser proportionately to the same ratio in each branch duct.
- Adjust each branch duct VCD in each main duct so that each branch duct has the same proportion of airflow.
- Adjust each main duct VCD.
- Adjust fan speed (through VFD or belt pulley) or the main VCD after the AHU to ensure that each diffuser has the right airflow rate.
- Measure and record airflow rate at each diffuser and compare it with design airflow (within +/-10%)

6.2 Water System Balancing

6.2.1 Water balancing (of chilled water/brine) shall be done as under:

- Keep all balancing, control and isolating valves in fully open position.
- Measure the water flow across each balancing valve and compare it with design flow.
- Identify the index value (lowest flow ratio) in each branch.
- Keep index valve fully open.
- Throttle the farthest valve to the same ratio and after that every valve in the branch starting from the lowest ratio.
- Monitor index valve percentage after throttling each valve gradually. By the time the last valve is completed, the flow is balanced at all valves including the index valve.
- Record the reading at all valves.

6.2.2 Where Pressure Independent Balancing and Control Valves (PIBCV) are used, the proportional balancing described above is not required. Each valve may be set to correct water flow rate as per manufacturer's instructions.

7.0 Cleaning/Flushing of Duct/Pipe Work

Though a very important pre commissioning activity, proper cleaning of duct and pipework is many times neglected leading to disastrous consequences. Proper method of cleaning of ducts and pipes after installation is completed is given below:

7.1 In duct work, access doors shall be provided next to dampers and these access doors shall be used to clean the duct work. Prior to commissioning of the system, entire duct shall be cleaned. Where specified, such cleaning shall be done by duct cleaning systems using robots. Otherwise, the fans shall be run with only pre-filters in place (to protect coils) and the entire dust shall be blown off. After the cleaning, pre filters shall be replaced.

7.2 Pipe work shall be cleaned and flushed before commissioning. Flushing of system shall be done bypassing sensitive parts such as chiller and heat exchanger tubes. This will require proper planning at design/execution stage. Before filling up the system with clean water, all shut off and control valves shall be kept fully open. Continuous air venting shall be done. Pump shall be started only after filling up and air venting is completed. Additional flushing pumps may be used over and above system pumps and the primary pump strainer basket mesh shall not be less than 3 mm when flushing starts. Flushing velocity from 1.0 m/s to 1.25 m/s is recommended. Pressure drop across pumps shall be monitored during the process so that pump cavitation is avoided.

7.2.1 Dynamic flushing in several steps is recommended. First the primary ring main may be flushed, thereafter the main pipes and lastly the horizontal mains in each floor. After each round of flushing, the strainer basket shall be changed. Each loop needs to be flushed till the water is clean and the strainer basket does not collect sediments. Flushing of horizontal main pipes shall start at the topmost floor and finish at the lowest floor. After flushing in sections is completed, full system flushing shall be carried out. After flushing is complete, the water sample shall be analyzed to determine successful flushing.

Glossary of Terms

A

Absorption – It is a process whereby a material extracts one or more substances present in an atmosphere or mixture of gases or liquids accompanied by physical change or chemical change, or both, of the material

Access Door – A door provided in a unit casing, wall, floor, ceiling, duct, etc., to permit inspection, entrance, or availability to concealed parts or devices.

Accumulator – It is a storage chamber for low side liquid refrigerant, also known as surge drum or surge header; also, a pressure vessel whose volume is used in a refrigerant circuit to reduce pulsation.

Actuator – A controlled motor, relay or solenoid in which the electric energy is converted into a rotary, linear or switching action . An actuator can effect a change in the controlled variable by operating the final control elements a number of times. Valves and dampers are examples of mechanisms which can controlled by actuators.

Acoustic Enclosures – are an effective solution for reducing noise and improving the sound quality in a variety of environments, particularly in the industrial sector. In addition to the reduction of noise, enclosures offer many benefits that enhance workplace environments, such as: improvements in employee well-being, focus, productivity, and communication, prevention of occupational hazards, and compliance with standards and regulations.

Air Conditioner, Room – It is a factory-made, encased assembly designed as a unit primarily to provide free delivery of conditioned air to an enclosed space, room, or zone. It includes a prime source of refrigeration for cooling and dehumidification and means for circulating and cleaning air. It may also include means for ventilating and heating.

Air Conditioning – It is the process of treating air so as to control simultaneously its temperature, humidity, cleanliness and distribution to meet the requirements of the conditioned space. requirements of the occupants of the conditioned space.

Air Conditioning of a Unit, Cooling (Heating) – It is a specific air-treating combination, consisting of means for ventilation, air circulation, air cleaning, and heat transfer, with control means for cooling.

Air Conditioning, to meet the Comfort – It is the process of treating air so as to control simultaneously its temperature, humidity, cleanliness, and distribution to meet the comfort (or heating).

Air, Outdoor – It is the air taken from outdoors and, therefore, not previously circulated through the system.

Air, Outside – It is external air; atmosphere exterior to refrigerated or conditioned space and ambient (surrounding) air.

Air Purge System – is used to flush electrical control equipment with clean air before it is turned on. This ensures that the functionality of the equipment is not affected or damaged by the contaminants from the surrounding environment.

Air, Recirculated – It is the returned air passed through the conditioner before being again supplied to the conditioned space.

Air, Return – It is the air returned from conditioned or refrigerated space.

Anemometer – It is an instrument for measuring the velocity of a fluid.

Annealed Soft Copper Tubing – It is a flexible, seamless material widely used in various applications, including plumbing, refrigeration, and HVAC systems.

Anchoring: Anchoring machines are specialized drilling rigs used in construction for anchoring, soil stabilization, and foundation reinforcement.

Approach – In an evaporative cooling device, the difference between the average temperature of the circulating water leaving the device and the average wet-bulb temperature of the entering air. In a conduction heat exchanger device, the difference in temperature between the leaving treated fluid and the entering working fluid.

Area, Free – It is the total minimum area of the openings in an air inlet or outlet through which air can pass.

Aspect Ratio – It is the ratio of the length of the core of a grille, face, or register he width in air distribution outlets. In rectangular ducts, it is the ratio of width to depth.

B

Baffle – It is a partition or deflector used for diverting fluid, usually in the form of a plate or wall.

Boiling Point – It is the temperature at which the vapor pressure of a liquid equals the absolute external pressure at the liquid-vapor interface.

Breaker – It is a relatively poor conductor of heat used to join the liner and outer shell of an internally refrigerated container such as a refrigerator.

Brine – Any liquid cooled by the refrigerant and used for the transmission of heat without a change in its state, having no flash point or a flash point above 68ºC.

British Thermal Unit (Btu) – It is the quantity of heat required to raise the temperature of one pound of air-free water through one degree Fahrenheit at a constant pressure of one normal atmosphere. NOTE: This definition is given only for guidance though we use SI units. 1Btu = 0.2519 kcal/h.

C

Calorie – It is the quantity of heat required to raise the temperature of 1 g of water through 1°C, at a constant pressure of one normal atmosphere.

Capacity – It is the usable output of a system or system component in which only losses occurring in the system or component are charged against it.

Capacity, (Dehumidifying) Air Conditioner, Useful Latent – It is the available refrigerating capacity of an air conditioner for removing latent heat from the space to be conditioned.

Capacity, Air Conditioner, Useful Sensible – It is the available refrigerating capacity of an air conditioner for removing sensible heat from the space to be conditioned.

Capacity, Air Conditioner, Useful Total – It is the available refrigerating capacity of an air conditioner for removing sensible and latent heat from the space to be conditioned.

Capacity, Condensing Unit – It is the refrigerating effect in kcal/h produced by the difference in total enthalpy between refrigerant liquid leaving the unit and the total enthalpy of the refrigerant vapor entering the unit.

Capacity, Refrigerating – It is the rate of heat removal from a medium or space to be cooled at stated conditions. The term refrigerating effect is used to denote heat transfer to or from the refrigerant itself in a refrigerating system, whereas the term refrigerating capacity is used to denote the rate of heat removal from a medium or space to be cooled.

Capacity, Refrigerating Compressor – It is the rate of heat removal by the refrigerant assigned to the compressor in a refrigerating system. This is equal to the product of the mass rate of refrigerant flow produced by the compressor and the difference in specific enthalpies of the refrigerant vapor at its thermodynamic state entering the compressor and the refrigerant liquid corresponding at saturation temperature to the pressure of the vapor leaving the compressor.

Capacity, Refrigerating, Net – It is the remaining rate of heat removal from all sources by the evaporator of a refrigerating system, at stated conditions, after deducting internal and external heat transfers to the evaporator that occur before distribution of the refrigerating medium and after its return.

Capacity, Refrigerating System – It is the cooling effect produced by the change in total enthalpy between the refrigerant entering the evaporator and the refrigerant leaving the evaporator.

Capillary – It is the action by which the surface of a liquid, where it is in contact with a solid (as in a slender tube), is raised or lowered.

Capillary Tube – In refrigeration practice, it is a tube of small internal diameter used as a liquid refrigerant flow control or expansion device between high and low sides; also used to transmit pressure from the sensitive bulb of some temperature controls to the operating element.

Ceiling Outlet – A round, square, rectangular, or linear air diffuser located in the ceiling which provides a horizontal distribution pattern of primary and secondary air over the occupied zone and induces low velocity secondary air motion through the occupied zone.

Chilling (Cooling) – It is the process of lowering of the temperature of a substance by the removal of heat in the temperature range above freezing.

Chilling Room – It is a room where products are cooled prior to cold storage.

Circuit Breaker – A switch type mechanism that opens automatically when it senses an overload (excess current).

Coefficient of Performance, Compressor, Heat Pump – It is the 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.

Coil – A cooling or heating element made of pipe or tubing with or without external fins.

Coil, Direct Expansion – It is a coil using the direct method of refrigeration.

Coil, Expansion – An evaporator constructed of pipe or tubing.

Cold Storage – It is a process of preserving perishables on a large scale by refrigeration.

Comfort Cooling – Refrigeration used for comfort as opposed to refrigeration used for storage or manufacture.

Comfort Zone – Average of the range of effective temperatures over which the majority (50 percent or more) of adults feel comfortable; extreme of the range of effective temperatures over which one or more adults feel comfortable.

Compression – In a compression refrigeration system, it is a process by which the pressure of the refrigerant is increased.

Compression Efficiency – It is the ratio of work required to compress, and reversibility, all the vapor delivered by a compressor (per stage) to the actual work delivered to the vapor by the piston or bladder of the compressor.

Compression, of Compression Multistage – It is the process in two or more steps, where the discharge of one earlier stage compressor is connected with the suction of next higher stage compressor.

Compressor, Booster – It is a compressor for very low pressures, usually discharging into the suction line of another compressor.

Compressor, Centrifugal – A nonpositive displacement compressor which depends for pressure rise, at least in part, on centrifugal effect.

Compressor, Motor, Sealed (Hermetic Type) – A combination consisting of a compressor and motor, both of which are enclosed in the same housing, with no external shaft or shaft seals, the motor operating in the refrigerant.

Compressor, Open-Type – It is a refrigerant compressor with a shaft or other moving part extending through its casing to be driven by an outside source of power, thus requiring a shaft seal or equivalent rubbing contact between a fixed and moving part.

Compressor, Positive Displacement – It is a refrigerant compressor in which increase of refrigerant gas or vapor pressure is attained by changing the internal volume of the compression chamber.

Compressor, Reciprocating – It is a positive displacement compressor in which the change in internal volume of the compression chamber(s) is accomplished by the reciprocating motion of one or more pistons.

Compressor, Refrigerant – It is a component of a refrigerating system which increases the pressure of a compressible refrigerant fluid and simultaneously reduces its volume, while moving the fluid through the device.

Compressor, Rotary– It is a positive displacement compressor in which the change in internal volume of the compression chamber(s) is accomplished by the rotary motion of a positive displacement member(s).

Compressor, Screw – It is a positive displacement compressor in which pressure in intermeshing screws is increased by contrarotating members.

Compressor, Sealed Unit – A motor compressor assembly having the compressor contained within a gas-tight casing through which no shaft extends. Drive is usually by a motor within the same casing but may be induced by external means.

CKD Condition – CKD stands for Completely Knocked Down. It applies to goods broken down entirely into parts and shipped separately, requiring full assembly on arrival. CKD classification impacts GST compliance, invoicing, e-way bills, and customs under the GST framework

Condensate – The liquid formed by of a vapor. In steam heating, water condensed from steam; in air conditioning, water extracted from air, as by condensation on the cooling coil of a refrigeration machine.

Condensation – It is the process of changing a vapor into liquid by the extraction of heat. Condensation of steam or water vapor is effected in either steam condensers or dehumidifying coils and the resulting water is called condensate.

Condenser (Refrigerant) – A heat exchanger in which the refrigerant, compressed to a suitable pressure, is condensed by rejection of heat to an appropriate external cooling medium.

Condenser, Air Cooled Refrigerant – It is a refrigerant condenser in which heat rejection is accomplished entirely by raising the temperature of the air used as a cooling medium.

Condenser, Atmospheric Refrigerant – It is a condenser cooled with water which is exposed to the atmosphere.

Condenser, Evaporative Refrigerant – A refrigerant condenser in which part of the heat rejection may be accomplished by raising the temperature of an air steam passing over a heat exchange surface and the remainder by evaporation of water sprayed or otherwise distributed over the heat exchange surface.

Condenser, Open-Shell-and-Tube – It is a condenser in which the cooling fluid usually water passes through a number of tubes in order to liquefy the refrigerant passing through the shell.

Condenser, Secondary – It is the condenser of a secondary system, also, a condenser and a secondary system where the condenser is cooled by the evaporator of the secondary system.

Condensing Unit, Hermetically Sealed – A sealed condensing unit in which the housing is permanently sealed by welding or brazing and is not provided with means of access for servicing internal parts in the field.

Condensing Unit, Mechanical, Performance Factor – It is the ratio of its capacity to its energy input, expressed in kcal/kWh.

Condensing Unit, Refrigerant – An assembly of refrigerating components designed to compress and liquefy a specific refrigerant, consisting of one or more refrigerant.

Conductivity, Thermal – It is the time rate of heat flow through unit area and unit thickness of a homogeneous material under steady conditions when a unit temperature gradient direction perpendicular is maintained to area. Materials in the are considered homogeneous when the value of the thermal conductivity is not affected by variation in thickness or in size of the sample within the range normally used in construction.

Conduit – A round cross section electrical raceway of metal or plastic.

Control – It is any manual or automatic device for regulation of a system or component in normal operation. If automatic, the implication is that it is responsive to changes of pressure, temperature, or any other property whose magnitude is to be regulated.

Controller, High Pressure – A pressure controller designed to control the pressure at a selected point on the high pressure side of a refrigerating system.

Controller, Low Pressure – A pressure controller designed to control the pressure at a selected point on the low pressure side of a refrigerating system.

Controller, Pressure – It is an automatic control device actuated by pressure, designated to be responsive to pressure convection, transfer of heat by the movement of fluid.

Convection, Natural – Circulation or movement of gas or liquid (usually air or water) taking place due to differences in density resulting from temperature changes

Cooler, Brine (Water) – Evaporator for cooling brine in an indirect system.

Cooler, Cold Storage – An insulated room maintained at O°C or above.

Cooling Coil – It is an arrangement of pipe or tubing which transfers heat from air to a refrigerant or brine.

Cooling, Direct Method of – It is a system in which the evaporator is in direct contact with the material or space refrigerated or is located in air circulating passages communicating with such spaces.

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

Cooling, Indirect Method of – It is a system in which a liquid, such as brine or water, cooled by the refrigerant, is circulated to the material or space refrigerated or is used to cool air so circulated.

Cooling, Regenerative – It is the process of utilizing heat which must be rejected or absorbed in one part of the cycle to perform a useful function in another part of the cycle by heat transfer.

Cooling, Surface – It is a method of cooling air of other gas by passing it over cold surfaces.

Critical Velocity – It is the velocity above which fluid flow is turbulent.

Cycle, Defrosting – It is a refrigeration cycle which permits the cooling unit to defrost during 'OFF' period.

Cycle, Refrigerating – A sequence of thermodynamic processes through which a refrigerant passes, in a closed open system, to absorb heat at a relatively low temperature level and reject heat at a higher temperature level.

D

Damper – A valve, or plate, used to regulate the flow of air or other fluid.

Damper, Multiple Louvers – It is a damper having a number of adjustable blades.

Defrosting – It is the process of removing frost from an evaporator coil.

Dehumidification **– It is the process of removing** water vapor from air by cooling below the dew point or the removal of water vapor from air by chemical or physical methods.

Dehumidifier – An air cooler or washer used for lowering the moisture content of the air passing through it and an absorption or adsorption device for removing moisture from air.

Dehydration – The removal of water vapor from air by the use of absorbing or adsorbing materials; and the removal of water from stored goods.

Desiccant – Any absorbent or adsorbent, liquid or solid, that will remove water or water vapor from a material. In a refrigeration circuit the desiccant should be insoluble in the refrigerant.

Design Working Pressure – It is the maximum allowable working pressure for which a specific part of a system is designed.

Dew Point, Apparatus – That temperature which would result if the psychometric process occurring in a dehumidifier, humidifier, or surface cooler were carried to the saturation condition of the leaving air while maintaining the same ratio of sensible to total heat load in the process.

Diffuser, Air – A circular, square, or rectangular air distribution outlet generally located in the ceiling and comprised of deflecting members discharging supply air in various directions and planes and arranged to promote mixing of primary air with secondary room air.

Diffuser, Air, Adjustable Flow Rate – It is an air diffuser incorporating a device for varying air flow rate without affecting the direction of the air jets

Diffuser, Air Ceiling – It is an air diffuser suitable only for ceiling mounting.

Draft – A current of air, when referring to the pressure difference which causes a current of air or gases to flow through a flue, chimney, heater, or space; or when referring to a localized effect caused by one or more factors of high air velocity, low ambient temperature, or direction of air flow, whereby more heat is withdrawn from a person's skin than is normally dissipated.

Drier – A manufactured device containing a desiccant, placed in the refrigerant circuit, its primary purpose being to collect and hold within the desiccant all water in the system in excess of the amount which can be tolerated in the circulating refrigerant.

Drift – In a water spray device the entrained unevaporated water carried from the device by air movement through it.

Drift Eliminator – The drift eliminator is one of the cooling tower parts that is used to minimize the amount of process water loss within the cooling tower for resource usage efficiency as well as keeping an eye on environmental concerns.

Dry Ice – A term used to describe solid carbon dioxide (CO_2) on account of its sublimation into gas without intermediate liquefaction.

Duct – A passageway made of sheet metal or other suitable material, not necessarily leak tight, used for conveying air or other gas at low pressures.

E

EPDM – EPDM is a versatile synthetic rubber known for its excellent weather resistance, durability, and cost-effectiveness, making it ideal for various outdoor applications. EPDM stands for Ethylene Propylene Diene Monomer, a type of synthetic rubber that is widely used in many industries due to its unique properties. It is made from a combination of ethylene, propylene, and a diene monomer, which allows for crosslinking and enhances its performance characteristics.

Enthalpy – A thermodynamic property of a substance defined as the sum of its internal energy plus the quantity pv/J, where p = pressure of the substance, v = volume, and J = mechanical equivalent of heat.

Enthalpy, Specific – It is enthalpy per unit weight of a substance.

Equalizer – It is a piping arrangement to-maintain a common liquid level or pressure between two or more chambers.

Equalizer, External – In a thermostatic expansion valve, a tube connection from a selected control point in the low-side circuit to the pressure sensing side of the control element such that the control-point pressure is transmitted to the actuating element (diaphragm or bellows). This connection provides a means for compensating for the pressure drop through accessories and the evaporator.

Equalizer, Internal – In a thermostatic expansion valve, an integral internal port or passage whereby the actuating element (diaphragm or bellows) is exposed to pressure leaving the valve.

Exhaust Opening – It is any opening through which air is removed from a space which is being heated or cooled, or humidified or dehumidified, or ventilated.

Expansion refrigerating effect Valve, Capacity – It is the in kcal/h produced by the evaporation of refrigerant passed by the valve under specified conditions.

Expansion Loops – are essential components in piping systems that manage thermal expansion and contraction, helping to reduce stress and prevent damage. Expansion loops are specially designed sections of piping that are bent into shapes (such as U or Z shapes) to accommodate the thermal expansion and contraction of pipes

Expansion Valve, Superheat – It is the difference between the temperature of the thermal bulb and the temperature corresponding to the pressure at the outlet or at the equalizer connection, when provided, of a thermostatic expansion valve.

F

Fan, Attic – An exhaust fan to discharge air near the top of a building while cooler air is forced (drawn) in at a lower level.

Fan, Centrifugal – A fan rotor or wheel within a scroll-type housing and including driving mechanism supports for either belt drive or direct connection.

Fan, Economizer – A device which prevents operation of the fan motor on a cold diffuser during the shutdown period after the coil has been defrosted.

Fan, Exhaust – A fan used to remove or exhaust air from a space.

Fan, Propeller – A propeller or disc-type wheel within a mounting ring or plate and including driving mechanism supports for either belt drive or direct connection.

Fan, Shroud – A protective housing which surrounds the fan and which may also direct the flow of air.

Fan, Tube-axial – A propeller or disc-type wheel within a cylinder and including driving mechanism supports for either belt drive or direct connection.

Fan, Vane-axial – A disc-type wheel within a cylinder, a set of air guide vanes located either before or after the wheel, and including driving mechanism supports either for belt drive or direct connection.

Filter – It is a device to remove solid material from a fluid.

Fin – An extended surface to increase the heat transfer area, as metal sheets attached to tubes.

Field balancing – It is the process of correcting equipment imbalance while it is still installed and operating in the field. Here are some key points: a) It allows for balancing of rotating parts without removing them from the machine, saving time and effort. b) Field balancing is typically performed using vibration analysis to identify imbalances in the machine's rotating components. c) This technique is often used to fine-tune the system for acceptable performance under actual operating conditions. d) It involves adding field correction weights to improve machine vibration at specific locations. e) The advantages of field balancing include no need for dismantling machine structures, making it more efficient than conventional shop-floor balancing.

Flammability – It is the ability of a material to burn.

Flare Fitting – It is a type of soft-tube connector which requires the flaring of the tube to. provide a mechanical seal.

Flash Point – Temperature of combustible material, as oil, at which there is a sufficient vaporization to support combustion of the material.

Freeze-Up – It is failure of a refrigerating unit to operate normally due to formation of ice at the expansion device. A valve may freeze shut or open, causing improper refrigeration in either case. On a coil, frost formation to the extent that air flow stops or is severely restricted.

Freezing Point – It is the temperature at which a given liquid substance will solidify or freeze upon removal of heat. Freezing point for water is 0°C.

Fumes – Solid particles commonly formed by the condensation of vapors from normally solid materials such as molten metals. Fumes may also be formed by sublimation, distillation, calcination, or chemical reaction wherever such processes create airborne particles predominantly below one micron in size. Such solid particles sometimes serve as condensation nuclei for water vapor to form smog.

Fusible Plug – It is a device having a predetermined melting temperature member for the relief of pressure (gauge):

G

Gas – It is a usually highly superheated vapor which, within acceptable limits of accuracy, satisfies the perfect gas laws.

Gas, Flash – It is the gas resulting from the instantaneous evaporation of refrigerant in a pressure reducing device to cool the refrigerant evaporation temperature at a reduced pressure.

Gas, Foul (Non-condensable) – It is a gas in a refrigerating system, which does not condense at the temperature and partial pressure at which it exists in the condenser, therefore imposing a higher head pressure on the system.

Generator – Basic part of an absorption system, provided with means of heating, used to drive refrigerant out of solution.

H

Head, Dynamic – In flowing fluid, the sum of the static and velocity pressures at the point of measurement (same as total head).

Head, Static – The static pressure of a fluid expressed in terms of the height of a column of the fluid, or of some manometric fluid, which it would support.

Heat, Latent – 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.

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

Heat Pump, Cooling and Heating – A refrigerating system designed so that the heat extracted at a low temperature and the heat rejected at a higher temperature may be utilized simultaneously alternately or for cooling and heating functions respectively.

Heat, Sensible – Heat which is associated with a change in temperature; specific heat exchange of temperature; in contrast to a heat interchange in which a change of state (latent heat) occurs.

Heat, Specific – The ratio of the quantity of heat required to raise the temperature of a given mass of any substance one degree to the quantity required to raise the temperature of an equal mass of a standard substance (usually water at 15°C) one degree.

Humidity, Relative – The ratio of the mol fraction of water vapor present in the air to the mol fraction of water vapor present in saturated air at the same temperature and barometric pressure. Approximately, it equals the ratio of the partial pressure or density of the water vapor in the air to the saturation pressure or density, respectively, of water vapor at the same temperature

Hygrostat – It is an automatic control, responsive to humidity.

I

Ice Bank – It is a thermal accumulator in which during off-peak periods of refrigeration demand, ice is formed, and in which, during peak periods of refrigeration demand, compressor capacity is supplemented by melting ice.

Infiltration – It is air flowing inward as through a wall, leak, etc.

Insulation – Granulated, shredded, or powdered material prepared from vegetable, animal, or mineral origin. It can come in bulk or batt form.

Insulation, Sound – It is an acoustical treatment of fan housings, supply ducts, space enclosures, and other parts of system and equipment for isolation of vibration or to reduce transmission of noise.

Insulation, Thermal – A material having a high resistance to heat flow and used principally to retard the flow of heat.

J

Joint, Mechanical – A gas-tight joint obtained by the joining of metal parts through a positive holding mechanical construction (such as flanged joint, screwed joint, flared joint).

Joint, Soldered – A gas-tight joint obtained by the joining of metal parts with metallic mixtures or alloys which melt at temperatures below 538ºC.
Joint, Welded – A gas-tight joint obtained by the joining of metal parts in the plastic or molten state.
Junction Box – Metal box in which tap to circuit conductors is made. Junction is not an outlet since no load is fed from it directly.

K

Kilovolt Ampere – Product of the voltage times the current. Different from kilowatts because of inductive loads in an electrical system. Abbreviated kVA, kilowatts is equal to kVA times power factor.
Kilowatt – 1000 watts. Abbreviated kW.
Kilowatt-Hour – A measure of electrical energy consumption;1000 watts being consumed per hour. Abbreviated kWh.

L

Liquid Line – It is the tube or pipe carrying the refrigerant liquid from the condenser or receiver of a refrigerating system to a pressure-reducing device.
Liquid Refrigerant Receiver – A vessel in a refrigerating system designed to ensure the availability of adequate liquid refrigerant for proper functioning of the system and to store the liquid refrigerant when the system is pumped down.
Leak Detector – A device used to detect refrigerant leaks in a refrigerating system, halide torch – a flame tester that generally uses alcohol and burns with a blue flame, but when the sampling tube draws in freon vapor, the flame color changes to bright green.
Load – The amount of heat per unit time imposed on a refrigerating system or the required rate of heat removal.
Load Factor – It is the ratio of actual mean load to a maximum load or maximum production capacity in a given period.
Louver – An assembly of sloping vanes intended to permit air to pass through and to inhibit transfer of water droplets.
Low-Pressure Side (Low Side) – It is that portion of a refrigerating system operating at the evaporator pressure.

M

Main – It is the pipe for distributing to or collecting from various branches.
Manifold – It is that portion of main in which several branches are close together. Also, single piece in which there are several fluid paths.
Manometer – An instrument for measuring pressures; essentially a U-tube partially filled with a liquid, usually water, mercury, or a light oil, so constructed that the amount of displacement of the liquid indicates the pressure being exerted on the instrument
Mass – The quantity of matter in a body as measured by the ratio of the force required to produce a unit acceleration to the acceleration.
Modulating – It is a control, tending to adjust by increments and decrements; also, one modified by variation of a second condition.

N

N.C. – Normally closed contacts of a relay . Contacts are close circuited when the relay is de-energised
N.O. – Normally open contacts of a relay . Contacts are open circuited when the relay is de-energised
Neutral – The circuit conductor that is normally grounded at zero voltage difference to the ground.
NRV – Non-return valves, are essential components in fluid systems that allow fluid to flow in only one direction, preventing backflow and protecting equipment. A non-return valve (NRV), also known as a check valve, one-way valve, or retention valve, is a mechanical device designed to allow fluid (liquid or gas) to flow in one.

O

Oil Traps: are essential components in air conditioning systems that ensure proper lubrication of the compressor and prevent oil migration, thereby enhancing system efficiency and longevity. Oil traps are installed in HVAC systems to manage the refrigerant oil that circulates within the system.
Oil Separator – A device for separation oil and oil vapor from the refrigerant, usually installed in the compressor discharge line.
Ohm – A measure of pure resistance in an electrical circuit.
"On-off" Control - A two position action which allows operation at either maximum or minimum condition ,or on or off, depending on the position of the controller.
Open Circuit – The condition when either deliberately or accidentally, an electrical

conductor or connection is broken or open with a switch.

Ozone – Triatomic oxygen (O_3) sometimes used in air conditioning or cold storage as an odour eliminator; can be toxic in certain concentrations.

P

Phase – a) In thermodynamics, one of the states of matter, as solid, liquid, or gaseous; b) Electrically, alternations an alternating current whose have a definite time relation to the rotational position of the alternator. In a polyphase machine, the phases are separated by 360 electrical degrees divided by the number of phases.

Plenum Chamber – An air compartment connected to one or more distributing ducts.

PMC – Project Management Committee. Group responsible for overseeing a project.

Point, Critical – Of a substance, state point at which liquid and vapor have identical properties; critical temperature, critical pressure, and critical volume are the terms given to the temperature, pressure, and volume at the critical point. Above the critical temperature or pressure there is no line of demarcation between liquid and gaseous phases.

Pre-cooling – It refers to the practice of preparing fruits and vegetables for shipment by cooling before or after they enter a car.

Pre-heating – In air conditioning, to heat the air in advance of other processes.

Pressure – The normal force exerted by a homogeneous liquid or gas, per unit of area, on the wall of the container.

Pressure, Absolute – Pressure referred to a perfect vacuum. It is the sum of gauge pressure and atmospheric pressure.

Pressure, Atmospheric – It is the pressure due to the weight of the atmosphere. It is the pressure indicated by a barometer. Standard atmospheric pressure or standard atmosphere is the pressure of 76 cm of mercury having a density of 13.595 1 g/cm^3 under standard gravity of 980.665 cm/sec^2.

Pressure, Hydrostatic – The normal force per unit area that would be exerted by a moving fluid on an infinitesimally small body immersed in it if the body were carried along with the fluid.

Pressure, Operating – It is the pressure occurring at a reference point in a refrigerating system when the system is in operation.

Pressure, Static – 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.

Pressure, Suction – An operating pressure in a refrigerating system measured in the suction line at the compressor inlet.

Pressure, Total – It is the sum of the static pressure and the velocity pressure at the point of measurement.

Pressure, Vapor – The pressure exerted by vapor. If a vapor is kept in confinement over liquid so that the vapor can accumulate above the liquid, the temperature being held constant, the vapor pressure approaches a fixed limit called the maximum or saturated vapor pressure dependent only on the temperature and the liquid. The term vapor is sometimes used synonymous with saturated vapor.

PSIG – refers to the pressure specified by a gauge, hence the name – pounds per square inch, gauge or psig. The ‘G’ here means it is a relative measurement.

Psychrometry –The branch of physics relating to the measurement or determination of atmospheric conditions, particularly regarding the moisture mixed with the air.

PTFE Lining – A specialized process that applies a polytetrafluoroethylene layer to the interior of pipes, vessels, or equipment to create chemically inert, non-stick surfaces resistant to extreme temperatures and corrosive substances.

Pump Down – It is the operation by which the refrigerant in a charged system is pumped into the liquid receiver.

Purging – It is the act of blowing out gas from a refrigerant containing vessel, usually for the purpose of removing non-condensables.

R

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

Refrigerant Charge – The designated amount of refrigerant required for proper functioning of a closed refrigerating system.
Refrigerant, Flammable – Any refrigerant which will burn when mixed with air, such as ethyl chloride, methyl chloride, and the hydrocarbons.
Refrigerant, Secondary – Any volatile or non volatile substance in an indirect refrigerating system that absorbs heat from a substance or space to bc refrigerated and rejects this heat to the evaporator of the refrigerating system.
Register – It is a combination grill and damper assembly covering an air opening.
Resistance, Thermal – It is the reciprocal of thermal conductance.
Resistively, Thermal – It is the reciprocal of thermal conductivity.
Respiration – It is the release of carbon dioxide and heat by the ripening of perishables in storage; also, the breathing process of animals.
Retention – It generally refers to the act or process of retaining or holding onto something. In various contexts, it can refer to the preservation, continuation, or memory of something over time.
Return Air – Air returned from conditioned or refrigerated space.
Rigging Hooks – Rigging hooks are vital connectors in lifting. They securely attach loads to equipment like cranes and hoists. Understanding their types ensures safe and efficient material handling.
Room Dew Point – It is the dew-point) temperature of the conditioned room or space.
Room Dry Bulb – It is the dry bulb temperature of the conditioned room or space.

S

Saturation – It is the condition for co-existence in stable equilibrium of a vapor and liquid or a vapor and solid phase of the same substance. As an example, steam over the water from which it is being generated.
Seasonal Energy Efficiency Ratio (SEER) – The total quantity of heat delivered or removed by heating or cooling equipment in BTU divided by the total electrical energy input in kilowatt hours over an entire season.
Sensible Heat Ratio, Air Cooler – It is the ratio of sensible cooling effect to total cooling effect of an air cooler.
Seasonal Performance Factor (SPF) – The ratio of the total quantity of heat delivered by a heat pump, (including supplement resistance heaters) to the total quantity of energy input (including supplementary resistance heaters) for the total annual heating hours below 69°F.
Sensible Heat Factor (SHF) – The ratio of sensible heat to the total heat.
Seismic – Subject to or caused by an earthquake.
Semi-extended Plenum – A trunk duct that is extended as a plenum from a fan or HVAC unit to serve multiple outlets or branch ducts.
Shielded Cable – Special cable used with equipment that generates a low voltage output . Used to minimize the effects of frequency “noise” output signal.
Short Circuit – An electric circuit with zero load, an electrical fault
SMACNA – Sheet Metal and Air Conditioning Contractors’ National Association
Sound Attenuator – A device or equipment that prevents, reduces or absorbs sound.
Strainer – It is a device for withholding foreign matter from a flowing liquid or gas.
Sub-cooling – Process of cooling refrigerant below condensing temperature for a given pressure; also, cooling a liquid below its freezing point where it can exist only in a state of unstable equilibrium.
Superheat (Specific) – It is the difference in specific enthalpies of a pure condensable fluid between vapor at a given temperature above saturation and vapor at the dry saturated state at the same pressure.
Suction Line – It is the tube or pipe which carries the refrigerant vapor from the evaporator to the compressor inlet.
System, Absorption – A refrigeration system in which the refrigerant gas evolved in the evaporator is taken up in an absorber and released in a generator upon the application of heat.
System, Cascade – It is that system having two or more refrigerant circuits, each with a pressure imposing element, condenser, and evaporator, where the evaporator of one circuit cools.
System, Commercial – A refrigeration system used in a commercial and/or a business place, such as a meat market, store, florist shop, hotel, office building, restaurant, candy shop, bakery, or other place of similar commercial enterprise, assembled and installed in the manufacturing and or business portion of any building.
System, Cycle Defrost – In household refrigerators and combination refrigerator-

freezers only, a system in which the refrigerated surfaces of the general refrigerated compartment are defrosted by an automatic defrost system. Defrost water is disposed off automatically or collected in a container for subsequent manual removal. A characteristic of a cycle defrost system is that nominal refrigerated food temperatures are maintained during operation of the automatic defrost system.

System, Direct Expansion – A refrigerating system in which the evaporator is in direct contact with the refrigerated material or space or the evaporator is located in air circulating passages communicating with such spaces.

System, Duct – It is a series of ducts, elbows, and connectors to convey air from one location to another.

System, Flooded – A system in which only part of the refrigerant passing over the heat transfer surface is evaporated, and the portion not evaporated is separated from the vapor and recirculated.

System, Indirect – It is a refrigerating system in which a liquid, such as brine or water, cooled by the refrigerant, is circulated to the material or space refrigerated or is used to cool air so circulated.

System, Self-Contained (Single Packaged) Refrigerating – It is a completely factory-assembled and factory-tested refrigerating system in a suitable frame or enclosure, in which all of the refrigerant containing parts are permanently connected at the factory.

System, Unitary Refrigerating – A complete factory-assembled and factory-tested refrigerating system comprising one or more assemblies which may be shipped as one unit or separately but which are designed to be used together.

T

Temperature, Critical – The saturation temperature corresponding to the critical state of the substance at which the properties of the liquid and vapor are identical.

Temperature, Dew-Point – The temperature at which the condensation of water vapor in a space begins for a given state of humidity and pressure as the temperature of the, vapor is reduced; the temperature corresponding to saturation (100 percent relative humidity) for a given absolute humidity at constant pressure.

Temperature, Dry-Bulb – It is the temperature of a gas or mixture of gases indicated by an accurate thermometer after correction for radiation.

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

Temperature, Saturation – Of a fluid, the boiling point corresponding to a given pressure; evaporation temperature; condensation temperature.

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

Thermostat – An automatic control device actuated by temperature and designed to be responsive to temperature.

Thermocouple – It is a device for measuring temperature, utilizing the fact that an electromotive force is generated whenever two junctions of two dissimilar metals in an electric circuit are at different temperature levels.

Ton of Refrigeration – The quantity of heat absorbed in the melting of 1 ton (2,000 lb) of water ice per 24 h, that is, 72575 kcal/day, or 3,024 kcal/ hour.

Tower, Water-Cooling – It is an enclosed device for evaporatively cooling water by contact with air.

Tower, Water-Cooling, Atmospheric – One in which the air movement through the tower is dependent only upon atmospheric conditions; also known as natural draft cooling tower.

Tower, Water-Cooling, Forced-Draft – It is a mechanical draft water-cooling tower having one or more fans located in the air entering the tower.

Tower, Water-Cooling, Induced-Draft – It is a mechanical draft water-cooling tower having one or more fans located in the air leaving the tower.

Tower, Water-Cooling, Mechanical-Draft – It is a water-cooling lower utilizing one or more fans to move the air through the tower, the fans being an integral part of the tower

Throttling, of a Fluid – It is an irreversible adiabatic process which consists of lowering pressure by an expansion without work.

Transmission – In thermodynamics, a general term for heat travel; properly, heat transferred per unit.

U

UVGI – Ultra-violet germicidal irradiation.

V

Valve, Suction Pressure Regulating – An automatic valve located between the evaporator outlet and the compressor inlet that is responsive to its own outlet pressure and functions to throttle the vapor flow so as to prevent; the suction pressure at the compressor inlet from exceeding a selected value. It is used primarily to prevent overload on compressor motors.

Valve, Water Regulator – It is an automatic valve to control the flow of cooling water through a condenser.

Valve, Back Pressure (Evaporator Pressure Regulator) – An automatic valve located between the evaporator outlet and compressor inlet that is responsive to its own inlet pressure or to the vapor flow when necessary to prevent the evaporator pressure from falling below a selected value.

Valve, Charging – A valve used to charge or add refrigerant to the system or add oil to the compressor crankcase

Valve, Check – It is a valve allowing fluid flow in one direction only.

Valve, Constant Pressure Expansion – It is a controlling device for regulating the flow of volatile refrigerant into a cooling unit, actuated by changes in pressure of the low side.

Valve, Diaphragm – A form of packless valve, manually or mechanically actuated; also a valve actuated by pressure of a motivating fluid on one side of the diaphragm which seals the motivating fluid from the flowing fluid controlled by the valve. Flowing and motivating fluids may, but need not, be the same.

VSD (Variable Sequence Drive) – It is an equipment that regulates the speed and torque output of an electric motor . It controls the flow of energy from the mains to the process, sitting between the electric supply and the motor.

Vapor Barrier – A moisture impervious layer applied to the surfaces enclosing a humid space to prevent moisture travel to a point where it may condense due to lower temperature.

Ventilation – It is the process of supplying or removing air by natural or mechanical means to or from any space. Such air may or may not have been conditioned.

Viscosity – It is that property of semi-fluids, fluids, and gases by virtue of which they resist an instantaneous change of shape or arrangement of parts. It is the cause of fluid friction whenever adjacent layers of fluid move with relation to each other.

Vibration Isolator – It is a device designed to reduce or eliminate the transmission of vibrations from one component to another, protecting sensitive equipment and structures from damage. It is an elastic element that connects equipment to its foundation, effectively reducing the vibration forces transmitted from the equipment to the foundation and vice versa.

Volume, Specific – It is the volume of a substance per unit mass; the reciprocal of density.

W

Water, Make-Up – Water supplied to replenish, as water replacing that lost by evaporation.

Water Hammer – Banging of pipes caused by the shock of closing valves (faucets)

Wet Bulb (WB) – The temperature registered by a thermometer whose bulb is covered by a saturated wick and exposed to a current of rapidly moving air. The wet bulb temperature also represents the dew point temperature of the air, where the moisture of the air condenses on a cold surface.

Wet Bulb Depression – Difference between dry bulb and wet bulb temperature.

Y

Y Strainer – It is a mechanical filter used in piping systems to remove unwanted solid particles from liquids, gases, or steam, ensuring the protection of downstream equipment. A Y strainer operates by utilizing a straining element, typically made of mesh or perforated metal, to capture solid particles while allowing clean fluid to pass through. Its Y-shaped design allows for installation in both horizontal and vertical pipelines, making it versatile for various applications.

Z

Zoning – The practice of dividing a building into small sections for heating and cooling control. Each section is selected so that one thermostat can be used to determine its requirements.

List of References and Standards

The standards and references listed below contain provisions which, through reference in this text, constitute system provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards listed below.

S. No.	Standard No.	Item	Description
1	IS 1391 - Part 1	Window AC	Specifications for window air conditioners
2	IS 1391 - Part 2	Split AC	Specification for split air conditioners
3	IS 11329	Heat Exchangers	Finned type Heat exchangers for RACs
4	IS 8148	PAC	Specification for packaged air conditioners
5	IS 18728	VRF	Multiple Split ACs and Air to Air Heat Pumps
6	IS 18794	AHU	AHU specifications
7	IS 16590	Chillers	Liquid Chiller Packages
8	IS 11561	Cooling Tower	Code of practice for testing water cooling tower
9	IS 7613	Air Filters	Method of testing panel type air filters for air conditioning and ventilation
10	IS 16753	High Efficiency Filters	High efficiency filters and filter media for removing particles
11	IS 1239	Piping	
12	IS 10773	Copper Piping	Wrought copper tube for refrigeration and AC
13	IS 11338	Thermostat	Thermostat – specification
14	IS 10617	Hermetic compressor	Hermetic compressor specification
15	IS 302	Electrical safety	Safety of Household and similar electrical appliances
16	IS 732	Electrical House hold	Code of practice for Electrical wiring installation
17	IS 694	PVC Insulation	PVC insulation for cables
18	IS 659	Safety	Safety code for air conditioners
19	IS 996	Motors	Single phase motors
20	IS 3615	Glossary	Glossary of Terms
21	IS 2927	Brazing	Specs for brazing alloy
22	ASHRAE 34	ASHRAE 34	Designation and safety classification of refrigerant
23	BIS - 7498 / CED 46	BIS - NBC	National Building Code - BIS
24	BEE - 6578	ECSBC - BEE	Energy Conservation Sustainability Building code- BEE
25	IS 18847 / ISO 22712	Competency of Service Personnel	Refrigeration systems and Heat pump - Competency of service personnel
26	IS 11327	Condensing Unit	Specification for requirements for refrigerant condensing units
27	IS 16678 -3 / ISO 5149 -3	Safety - Installation	Refrigeration systems and Heat pump - Safety environmental requirements for refrigeration system - Installation site

28	IS 16678 -4 / ISO 5149-4	Safety Operation	Refrigeration systems and Heat pump - Safety environmental requirements for refrigeration system - operation, maintenance, repair, recovery
29	IS 2379	Color Code	Color code for identification of pipe line
30	IS / ISO 817	Safety	Refrigerants - Designation and safety classification
31	IEC 60335-2-40	Safety	Safety Standard for Flammable refrigerants
32	TG 1003 - ISHRAE	Commissioning of HVAC	ISHRAE Commissioning Process Standard for HVAC System
33	IS 16678 Part 4	Safety	Safety and Environmental requirements - Operation, maintenance, repair and Recovery
34	SMACNA	Ducting	Sheet Metal and AC Contractors National Association
35	MED 27948	Service Valves	Service valves for AC&R purposes – Specification
36	IS 655	Duct	Air duct specification
37	IS 14164	Insulation	Industrial application and finishing of thermal insulation material - Code of practice
38	IS 3792	Insulation	Grade for heat insulation of non-industrial building
39	IS 18932	Expansion Valve	Electronic Expansion Valve - Specification
40	ISO 5151	Testing	Non ducted air conditioner and heat pump- Testing and rating for performance
41	ISO 16358	Seasonal performance	Air cooled air conditioner - Part 1 Cooling seasonal performance factor
42	IS 9968	Electrical cord	Elastomer insulated and sheathed cord
43	IS / IEC 60730 -2-9	Sensor	Temperature sensing control
44	IS 4758	Noise	Method of measurement of noise emitted by the machine
45	IS 737	Aluminum sheet/ pipe	Aluminum sheet / pipe
46	IS 277	GI sheet	Zinc coated G I Sheet
47	IS 9902	Leak test	Helium leak test
48	9844	Corrosion test	Corrosion resistance test
49	ISO 91.120.10	Insulation	Thermal insulation of building
50	IS / IEC 60335 -2-34	Compressor	Semi Hermetic compressor
51	IS 8183	Insulation	Specification Resin bonded glass wool insulation for slabs
52	Is 9842	Insulation	Specification for Resin bonded glass wool insulation for pipe section
53	IS 4671	Insulation	Specification for Expanded polystyrene
54	IS 12436	Insulation	Specification for Polyurethane and Polyisocyanurate Foam
55	EN 14304 / DIN EN 8497	Insulation	Specification for Nitryl Foam
56	IS 702	Bitumen	Spread blown grade bitumen 85/25 uniformly
57	DW 143	Ducting	Leakage classes for ducting
58	IS 12432	Overdeck insulation	Overdeck insulation with sprayed Polyurethane Foam
59	BS 476 Part 6and 7	Insulation - Fire	Fire propagation properties for Class O
60	TG 1001-2016	ISHRAE - IEQ	Standard for Indoor Environmental Quality
61	ISHOO1HFG	ISHRAE Fan Guide Book	Guidebook for Fans
62	IS 302 (Part 2/Sec 40): IEC 60335 -2-40	Safety - electrical	Safety of Household and Similar Electrical Appliances Part 2 Particular Requirements - Section 40 Electrical Heat Pumps, Air Conditioners and Dehumidifiers

COVER 3

About ISHRAE

The Indian Society of Heating, Refrigerating and Air Conditioning Engineers (ISHRAE) was founded in 1981 at New Delhi by a group of eminent HVAC&R professionals. ISHRAE has over 13,000 HVAC&R professionals as its members today along with 10,000 student members, and operates from 44 Chapters and sub-Chapters spread all over India, with its HQ in Delhi. It is led by a team of elected officers who are members of the Society working on a voluntary basis, collectively called the Board of Governors. In pursuance of its objectives, ISHRAE works in the areas of Research, Standards, Education and Training, and Publication of Technical Books and a Journal. It also organizes world-class annual exhibitions ACREX and REFCOLD, besides hosting technical seminars and conferences. ISHRAE is a responsible and socially-conscious Technical Society.

Objective

- Advancement of the Arts and Sciences of Heating, Ventilation, Air Conditioning and Refrigeration Engineering and Related Services.
- Continuing education of members and other interested persons in the said sciences through lectures, workshops, product presentations, publications and expositions.
- Rendition of career guidance and financial assistance to students of the said sciences.
- Encouragement of scientific research.

Activities

Knowledge Dissemination: ISHRAE conducts conferences, seminars, exhibitions, workshops, panel discussions and product presentations throughout the country with both national and international participants to discuss, promote and display the state-of-the-art technologies, systems, products and services.

Books and Publications: ISHRAE publications help its members and the industry to keep up with technical developments, latest trends and sunrise technologies. ISHRAE publishes Standards, books on fundamentals of various topics, HVAC&R Handbooks and the extremely popular and informative ISHRAE Journal. The latest publication is on Insulation

Exhibitions cum Conferences: ISHRAE organises ACREX India, the largest international exposition in South Asia on the Air Conditioning, Refrigeration, Ventilation and Building Services industry. Held annually, ACREX showcases the latest technologies and innovations, and provides a platform for buyer-seller meets for technical and commercial personnel in the HVAC&R field. To serve the interests of the Refrigeration and Cold-chain sector, ISHRAE organises REFCOLD annually. ISHRAE is a member and active supporter of the National Centre for Cold-chain Development (NCCD).

Education: ISHRAE is actively engaged in Education and Training, and offers several courses for technical professionals, some with post-examination certification. This helps to bring trained manpower into the HVACR industry.

Research: ISHRAE promotes research in the field of HVAC&R technologies. It offers financial support to graduate and post-graduate students to carry out innovative R&D work in technology, systems and processes. ISHRAE partners with the industry, academia and the government to carry out scientific research at Institutes of Excellence associated with ISHRAE.

Standards: ISHRAE works in the national interest with various government ministries and departments; for example, in the development of Standards and drafting of the National Building Code for the Bureau of Indian Standards, working on Energy Conservation Building Code with the Bureau of Energy Efficiency, and with the Ozone Cell of the Ministry of Environment, Forest and Climate Change on refrigerant gases. ISHRAE has also developed a pioneering Standard on Indoor Environmental Quality.

Student Activities: ISHRAE student chapters in more than 150 engineering colleges encourage students to opt for careers in the HVAC&R industry with industry exposure including factory visits. The K-12 initiative of ISHRAE reaches out to young school children to make them aware of subjects like energy conservation and environmental concerns through drawing competitions, poster designs, quizzes and more, with emphasis on STEM education to inculcate scientific fervour and help them to grow up as responsible citizens.

Global Reach: ISHRAE works in close co-operation with other similar societies and organisations, both at national and international levels, for the promotion and development of concepts like health and safety, sustainability, Green buildings, energy efficiency and environmental responsibility, often interacting with UN bodies like UNDP and UNEP.

ISHRAE is indeed looked upon as a repository of technical knowledge in the HVAC&R and Building Services Industry globally by peer organizations and the Government.

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