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HEATING, VENTILATION AND AIR CONDITIONING

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About the Author: Dr. Sapna Dinesh *is currently working as an Assistant Professor in Resource Management and Design at Mount Carmel College, Autonomous, Bengaluru which is affiliated with Bangalore City University. She has 7 years of teaching experience and 2.5 years of industry experience. Her areas of research include entrepreneurship and consumerism, micro-green farming, sustainable interior design, and ergonomics. She has published 20 research articles in National peer-reviewed journals and as proceedings and book chapters. She has published two books. Dr. Sapna Dinesh has also developed stress assessment tools for various age groups and a handbook of coping strategies to manage stress for children and parents as an intervention program.*

11.1 INTRODUCTION

HVAC is Heating, Ventilation, and Air Conditioning. HVAC systems control the indoor environment (temperature, humidity, airflow, and air filtering) to condition the air to a preferred temperature and relative humidity. The term HVAC means the entire air system of our living space which determines the indoor air quality.

The term HVAC is often used interchangeably with AC, but they are quite different. AC stands for air conditioning, which is the process of cooling and dehumidifying the air in a room or building. An HVAC system, on the other hand, stands for heating, ventilation, and air conditioning. It combines the AC with other systems to provide a more comprehensive climate control solution.

HVAC provides comfort for people, maintains an effective environment for surroundings, and allows humans to exist under adverse conditions, and HVAC systems are very much required for critical areas like control rooms, electronic equipment rooms, battery rooms, workshop areas, etc.

HVAC systems are designed following basic principles of thermodynamics, heat transfer, and fluid mechanics. In addition to factors that affect the comfort of humans like adequate lighting, proper furniture, and work surfaces, the comfort requirements that are typically impacted by the HVAC system include:

i. Dry-bulb temperature (Temperature of air measured by a thermometer freely hung),

ii. Humidity,

iii. Air movement,

iv. Fresh air,

v. Cleanliness of the air, and

vi. Noise levels.

11.2 HISTORY OF HVAC

For ages, people have used fire for heating and the natural air draft ensured the ventilation for the occupants. However, as central furnaces with piped steam or hot water became available for heating, the need for separate ventilation became apparent. By the 1880s, refrigeration became available for industrial purposes. initially, the Two main uses were freezing meat for transport and making ice. However, in the early 1900s, there was a new initiative to keep buildings cool for comfort.

11.3 OBJECTIVES AND SCOPE OF HVAC SYSTEMS

11.3.1 Objectives of HVAC Systems

The major objective of HVAC systems is to adjust and change the outdoor air conditions to the desired conditions of occupied buildings to achieve the thermal comfort of occupants. HVAC systems are more than just warming or cooling a space. Instead, it serves to improve indoor air quality and provide comfort for everyone inside a building.

Other major objectives are:

i. Maintaining environmental conditions (temperature and humidity) appropriate to the operating requirements.

ii. Increase in Productivity.

iii. Building & Equipment Durability.

iv. Maintaining pressurization between hazardous and non-hazardous areas.

v. Increase Life & Health.

vi. Dilution and removal of potentially hazardous concentrations of flammable/toxic gaseous mixtures in hazardous areas.

vii. Filtration of dust, chemical contaminants, and odors through chemical and carbon-activated filters to maintain purity of air.

viii. The isolation of individual areas and control of ventilation in emergency conditions, through interface with the shutdown logic of the fire and gas detection and alarm safety systems.

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Outside air is drawn inside the buildings and either heated or cooled depending on the outdoor conditions. The air is then distributed into the occupied spaces. HVAC systems Cooling equipment varies from small domestic units to refrigeration machines that are 10,000 times the size.

11.3.2 Scope of Modern HVAC

i. Indoor air quality is one that directly affects us. In many countries, the indoor air quality in buildings is too poor and unsatisfactory. The causes and effects of this poor quality are extremely complex.

ii. Greenhouse Gas Emissions and the destruction of the earth's protective ozone layer are concerns that are stimulating research. New guidelines are evolving that encourage recycling; less energy usage; and low-polluting materials, particularly refrigerants. All these issues have a significant impact on building design, including HVAC systems.

iii. Energy Conservation is an ongoing challenge to find new ways to reduce consumption in new and existing buildings without compromising comfort

11.4 ENVIRONMENT FOR HUMAN COMFORT

i. Thermal conditions include the air temperature. Air Speed, air movement, and other conditions.

ii. The air quality in a space is affected by pollution from the occupants and other contents of the space. the amount of outside air brought into the space to dilute the Pollutants.

iii. The acoustical environment may be affected by outside traffic noise, other occupants, equipment, and the HVAC system.

iv. The lighting influences the HVAC design since all lights give off heat.

v. The physical aspects of the space that influence the occupants include both the architectural design aspects of the space and the interior design.

vi. The psychosocial situation, the interaction between people in the space, is not a design issue.

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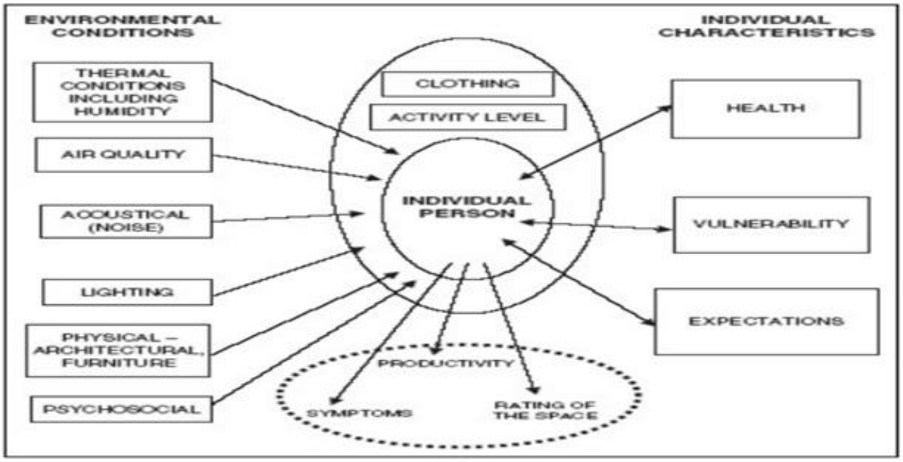


Fig: Personal Environment Model (adapted from "The construct of comfort – a framework for research by W.S. Cain)

11.5 HVAC SYSTEM

11.5.1 HVAC System Selection

The selection of HVAC systems for any building depends on various factors like climate, shape, size, function, architectural design, and age of the building, individual preferences of the owner/HVAC designer. occupant density, the project budget (initial cost, operating cost, maintenance cost, life-cycle cost), environmental impact, noise, etc., performance parameters like heating capacity, cooling capacity, humidity, efficiency, sustainability, constructability, particulate controls, ventilation, etc., life span, controls., energy consumption and time available for construction.

11.5.2 HVAC System Requirements

An HVAC system is primarily based on the following four requirements: Primary equipment, Space requirement, Air distribution, and Piping.

- Primary equipment includes heating equipment (steam boilers/hot water boilers), air delivery equipment (centrifugal fans, axial fans, and plug or plenum fans), and refrigeration equipment (water chillers or refrigerants).
- Space is required for Ezoic, Equipment rooms, HVAC facilities, Fan rooms, Vertical shaft., Equipment access space for installation, replacement, and maintenance.
- Air distribution represents the ductwork for delivering the conditioned air to the desired area in a direct, quiet, and economical way. It consists of air terminal units, fan-powered terminal units, variable air volume terminal units, all-air induction terminal units, and air-water induction terminal units. To prevent heat loss and save energy, all the ductwork and piping should be insulated. To host ductwork, buildings should have enough ceiling space.

- The piping system is essential to deliver refrigerant, cooled water, steam, hot water, gas, and condensate to and from HVAC equipment in a direct, quiet, and affordable way. Piping systems in HVAC design are normally divided into two parts: the piping in the central plant equipment room and the delivery piping. Depending on the governing code requirement, HVAC piping may or may not be insulated.

11.5.3 How Does an HVAC System Work?

The figure below depicts a schematic diagram explaining the basic function of an HVAC system

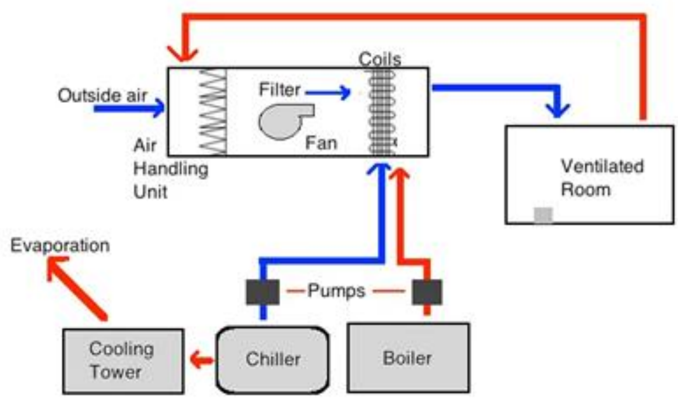


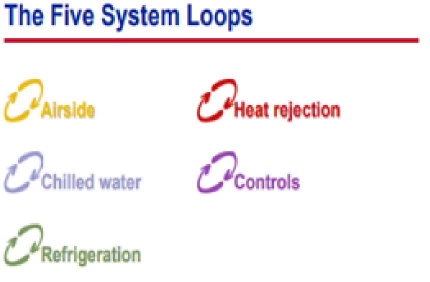
Fig: Schematic of Basic HVAC system

11.5.4 The Five System Loops

Any HVAC system can be dissected into basic subsystems. These subsystems are referred to as “loops.” Five primary loops can describe virtually any type of HVAC system.

- Airside loop (yellow)
- Chilled-water loop (blue)
- Refrigeration loop (green)
- Heat-rejection loop (red)
- Controls loop (purple)

1. **Airside Loop:** The first component of this loop is the conditioned space. The first two comfort requirements mentioned were dry bulb temperature and humidity. To maintain the dry-bulb temperature in the conditioned space, heat (referred to as sensible heat) must be added or removed at the same rate as it leaves or enters the space. To maintain the humidity level in the space, moisture (sometimes referred to as latent heat) must be added or removed at the same rate as it leaves or enters the space.
   Most HVAC systems used today deliver conditioned (heated, cooled,



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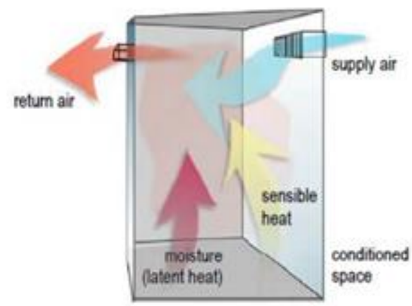
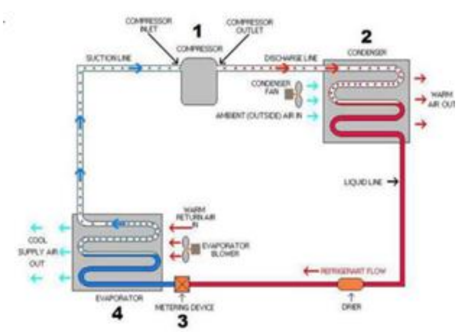
humidified, or dehumidified) air to the conditioned space to add or remove sensible heat and moisture. This conditioned air is called supply air. The air that carries the heat and moisture out of the space is called return air. Imagine the conditioned supply of air as a sponge. In the cooling mode, as it enters a space, this “sponge” (supply air) absorbs sensible heat and moisture. The amount of sensible heat and moisture absorbed depends on the temperature and humidity, as well as the quantity, of the supply air. Assuming a fixed quantity of air, if the supply air is colder, it can remove more sensible heat from the space. If the supply air is drier, it can remove more moisture from the space. To determine how much supply of air is needed for a given space, and how cold and dry it must be, it is necessary to determine the rate at which sensible heat and moisture (latent heat) enter, or are generated within the conditioned space.

2. **Chilled Water Loop:** Chilled water systems in residential HVAC systems are extremely rare. A typical chiller uses the process of refrigeration to chill water in a chiller barrel. This water is pumped through chilled water piping throughout the building where it will pass through a coil. Air is passed over this coil and the heat exchange process takes place. The heat in the air is absorbed into the coils and then into the water. The water is pumped back to the chiller to have the heat removed. It then makes the trip back through the building and the coils all over again.



3. **Refrigeration Loop:** The refrigeration system removes heat from an area that is the low-pressure, low-temperature (evaporator) into an area of high-pressure, high-temperature (condenser). It mainly has the following components
   i. Evaporator
   ii. Compressor
   iii. Condenser
   iv. Metering Device
   - **Evaporator:** This is the coil that is inside of the house. Warm air will pass over the coil which contains the refrigerant, then the refrigerant absorbs the heat which in turn allows the cold air to be distributed to the rooms.
   - **Compressor:** This is the life force of the refrigeration cycle, which will circulate refrigerant throughout the whole system. It will compress cold vapor into hot vapor, it also increases the low vapor pressure into high vapor pressure.



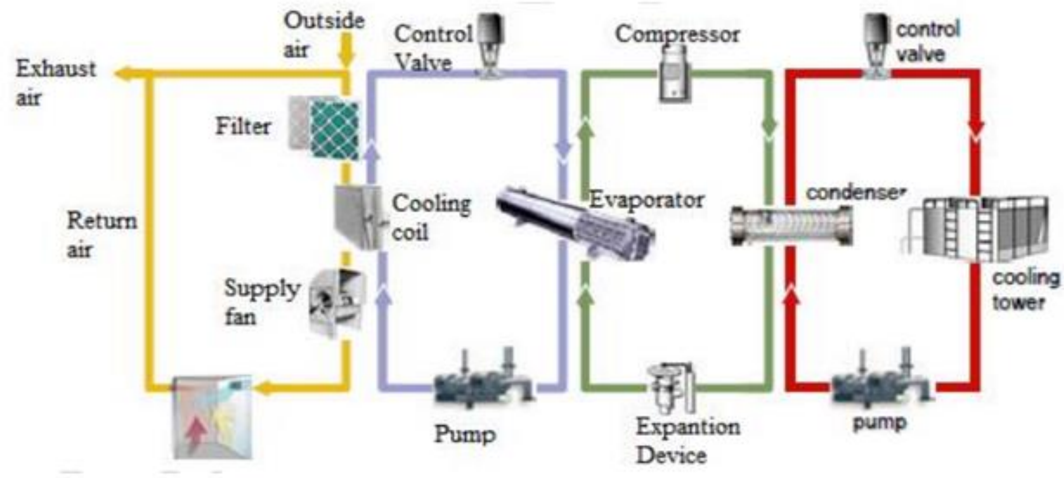
- **Condenser:** This is the coil that is located outside of a central air conditioning system. It removes the heat that is carried through the refrigerant, forcing the hot air out.
- **Metering Device**: Controls the flow of the refrigerant to the evaporator. There are different kinds of metering devices, some of them will have pressure-limiting devices to protect the compressor from overloading, while some will control the evaporator pressure or superheat. Some common metering devices are thermostatic expansion valves, automatic expansion valves, capillary tubes, and fixed bore.

4. **Heat Rejection Loop:** In the refrigeration loop, the condenser transfers heat from the hot refrigerant to air, water, or some other fluid. In a water-cooled condenser, water flows through the tubes while the hot refrigerant vapor enters the shell space surrounding the tubes. Heat is transferred from the refrigerant to the water, warming the water. The water flowing through the condenser must be colder than the hot refrigerant vapor. A heat exchanger is required to cool the water that returns from the condenser at a particular temperature and back to the desired temperature before it is pumped back to the condenser which is done by a heat rejection loop. When a water-cooled condenser is used, this heat exchanger is typically either a cooling tower or a fluid cooler (also known as a dry cooler).

   A fluid cooler is similar to an air-cooled condenser. Water flows through the tubes of a finned-tube heat exchanger and fans draw outdoor air over the surfaces of the tubes and fins. Heat is transferred from the warmer water to the cooler air. The third component of the heat-rejection loop moves the condensing media around the loop. In the case of a water-cooled condenser, a pump is needed to move the water through the tubes of the condenser, the piping, the cooling tower, and any other accessories installed in the heat-rejection loop.

   One method of varying the quantity of water flowing through the water-cooled condenser is to use a modulating control valve. As the heat-rejection requirement decreases, the modulating control valve directs less water through the condenser. If a three-way valve is used, the excess water bypasses the condenser and mixes downstream with the water that flows through the condenser.

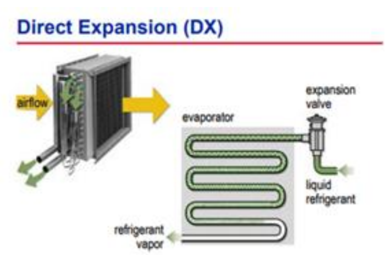
5. **Controls Loop:** The fifth, and final, loop of the HVAC system is the controls loop. Each of the previous four loops contains several components. Each component must be controlled in a particular way to ensure proper operation. Typically, each piece of equipment (which may be comprised of one or more components of a loop) is equipped with a unit-level, automatic controller. To provide intelligent, coordinated control so that the individual pieces of equipment operate together as an efficient system, these individual unit-level controllers are often connected to a central, system-level controller. Finally, many building operators want to monitor the system, receive alarms and diagnostics at a central location, and integrate the HVAC system with other systems in the building. These are some of the functions provided by a building automation system (BAS). The interconnection of the first 4 loops in an HVAC system is shown in the figure below.



11.6 DIRECT-EXPANSION (DX) VERSUS CHILLED-WATER SYSTEMS

Some HVAC systems have chilled water flowing through the tubes of the cooling coil. These systems are referred to as chilled water systems. Other systems have cold, liquid refrigerant flowing directly through the tubes of the cooling coil. These are referred to as direct-expansion, or DX, systems.

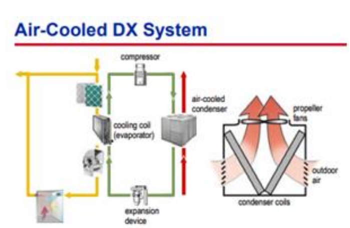
11.6.1 Direct-Expansion (DX) Systems



The term "direct" refers to the position of the evaporator concerning the airside loop. In a direct-expansion system, the finned-tube cooling coil of the airside loop is also the evaporator of the refrigeration loop. The evaporator is in direct contact with the airstream. The term "expansion" refers to the method used to introduce the refrigerant into the cooling coil. The liquid refrigerant passes through an expansion device just before entering the cooling coil (evaporator). This device reduces the pressure and temperature of the refrigerant to the point where it is colder than the air passing through the coil.

The primary difference between a chilled-water system and a direct-expansion system is that the DX system does not include the chilled-water loop. Instead, heat is transferred from the airside loop directly to the refrigeration loop.

11.6.2 Air-Cooled DX System



In an air-cooled DX system, the components of the heat-rejection loop are packaged together. The air-cooled condenser contains propeller-type fans that draw outdoor air across the finned-tube condenser coils. Heat is transferred from the hot refrigerant vapor directly to the outdoor air without the use of a separate condenser-water loop.

In a DX system, the components of the refrigeration loop may be packaged together or split apart. A packaged DX unit includes all the components of the refrigeration loop (evaporator, compressor, condenser, and expansion device)

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inside a single casing. It combines several components of the airside loop with all the components of both the refrigeration and heat-rejection loops. This type of equipment is intended for outdoor installation, commonly on the roof of a building. A major advantage of a packaged DX unit is the factory assembly and testing of all components, including the electrical wiring, the refrigerant piping, and the controls.

11.6.3 Split DX System

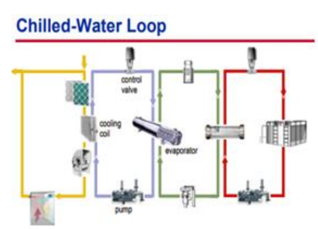
Alternatively, the components of the refrigeration loop may be split apart, allowing for increased flexibility in the system design. The direct expansion system shown in the figure includes an air-cooled condensing unit (which includes compressors and a condenser packaged within a single casing) installed on the ground outside of the building, and a DX evaporator coil and expansion device installed in an air handler that is located inside the building. The components are connected by field-installed refrigerant piping.

It is important to recognize that the allowable distance between the components of a split system is limited to ensure reliable operation. Refrigerant does not flow like water. Refrigerant is in a vapor state during part of its cycle and in a liquid state during the remainder of its cycle. Oil, used to lubricate the compressor, is often carried along by the refrigerant as it flows throughout the system. The sizing and layout of the refrigerant piping are critically important in ensuring that the oil is returned to the compressor at the required rate. All components, including the refrigerant piping and controls, must be carefully selected to work properly over the desired range of operating conditions.

A built-up DX system is one where none of the components are packaged together. This provides the system design engineer with complete flexibility to match components to achieve the desired performance. However, the responsibility falls on the system designer to ensure that the individual components will operate safely and reliably over the desired range of operating conditions. This requires a considerable amount of field design and installation expertise and time. It is more common for a split DX system to have two or more components packaged together by the manufacturer. One example is the air-cooled condensing unit, and another is a package that includes the compressors, the DX evaporator coil, and the expansion devices.

11.6.4 Chilled-Water Systems

In a chilled-water system, the chilled-water loop transports heat energy between the airside loop and the refrigeration loop. It is comprised primarily of a cooling coil, a circulating pump, an evaporator, a control valve, and interconnecting piping. In a chilled-water system, the components of the refrigeration loop (evaporator, compressor, condenser, and expansion device) are often manufactured, assembled, and tested as a complete package within the factory.



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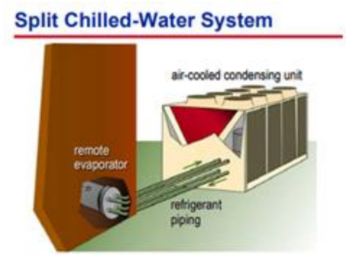

This type of equipment is called a "packaged" water chiller and may include either a water-cooled condenser or an air-cooled condenser. The components are selected and optimized by the manufacturer, and the performance is tested as a complete assembly, rather than as individual components. A major advantage of this configuration is factory assembly and testing of all chiller components, including the electrical wiring, the refrigerant piping, and the controls. This eliminates field labor and often results in faster installation and improved reliability.

Alternatively, the components of the refrigeration loop may be split apart. While water-cooled chillers are rarely installed as separate components, some air-cooled chillers offer the flexibility of separating the components for installation in different locations. This flexibility allows the system design engineer to place the components where they best serve the space, acoustic, and maintenance requirements of the building owner. The chilled-water system shown in Figure includes a packaged, air-cooled condensing unit installed outdoors, next to the building. The other components of the refrigeration loop (evaporator and expansion device) are installed inside the building. These components are connected to the condensing unit with field-installed refrigerant piping. This configuration places the part of the system that is susceptible to freezing (evaporator and water piping) indoors, and the primary noise-generating components of the refrigeration loop (compressors and condenser fans) outdoors. This usually eliminates any requirement to protect the chilled-water loop from freezing during cold weather. Of course, consideration should be given to potential noise problems caused by the outdoor components. This configuration is particularly popular in schools and other institutional facilities, primarily due to reduced seasonal maintenance for freeze protection. A drawback of splitting the components is the requirement for field-installed refrigerant piping. The possibility of system contamination and leaks increases when field-installed piping and brazing are required. Additionally, the components must be properly selected to work together over the desired range of operating conditions. With a packaged water chiller, the selection of the components, and the design and installation of the refrigerant piping, are handled by the manufacturer in the factory.

11.7 HVAC CODES AND STANDARDS

Various well-established codes and standards that are followed at different stages of HVAC system design are listed below:

- ISO 15138, Heating, ventilation, and air-conditioning.
- NORSOK Standard H-001, Heating Ventilation, and Air-conditioning.
- ASHRAE Standard 55 – Thermal Environmental Conditions for Human Occupancy.

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- ANSI/API RP 500: Recommended Practice for Classification of Locations for Electrical Installations at Petroleum Facilities of Class 1 Division 1 or Division 2.
- ASHRAE Standard 62.1 – Ventilation for Acceptable Indoor Air Quality.
- BS 5925: Ventilation principles and designing for natural ventilation.
- ASHRAE Standard 90.1 – Energy Standard for Buildings Except for Low-Rise Residential Buildings.
- BS EN 60079-10: Electrical apparatus for explosive gas atmospheres, Part 10. Classification of hazardous areas.
- IP, Model Code of Safe Practice for the Petroleum Industry: Part 15
- IS – 12332 For Ventilation in Petrochemical Plants & Refineries.
- IS – 3103 For Industrial Ventilation.
- OISD – 163 Safety of Control room for the Hydrocarbon industry.

The Indian Society of Heating, Refrigerating, and Air Conditioning Engineers (ISHRAE) was established to promote the HVAC industry in India. ISHRAE is an associate of ASHRAE. ISHRAE was founded in New Delhi in 1981 and a chapter was started in Bangalore in 1989. Between 1989 and 1993, ISHRAE chapters were formed in all major cities in India.

End of Chapter Exercises

1. Make a report on the contribution of HVAC to the Green Movement.
2. Design a poster to depict the fittings used in the HVAC piping system.
3. Collect pictures of HVAC systems at residential buildings.
4. Make a model of the HVAC system and label it to explain its working.

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