UNIT-IV
HVAC AND REFRIGIRATION SYSTEM
\

HVAC

INTRODUCTION

Heating, Ventilating, and Air Conditioning (HVAC) equipment perform heating and/or cooling for residential, commercial or industrial buildings. The HVAC system may also be responsible for providing fresh outdoor air to dilute interior airborne contaminants such as odors from occupants, volatile organic compounds (VOC's) emitted from interior furnishings, chemicals used for cleaning, etc. A properly designed system will provide a comfortable indoor environment year round when properly maintained.

METHOD OF WORKING

An air conditioner cools and dehumidifies the air as is passes over a cold coil surface. The indoor coil is an air-to-liquid heat exchanger with rows of tubes that pass the liquid through the coil. Finned surfaces connected to these tubes increase the overall surface area of the cold surface thereby increasing the heat transfer characteristics between the air passing over the coil and liquid passing through the coil. The type of liquid used depends on the system selected. Direct-expansion (DX) equipment uses refrigerant as the liquid medium. Chilled-water (CW) can also be used as a liquid medium. When the required temperature of a chilled water system is near the freezing point of water, freeze protection is added in the form of glycols or salts. Regardless of the liquid medium used, the liquid is delivered to the cooling coil at a cold temperature.

In the case of direct expansion equipment, the air passing over the indoor cooling coil heats the cold liquid refrigerant. Heating the refrigerant causes boiling and transforms the refrigerant from a cold liquid to a warm gas. This warm gas (or vapor) is pumped from the cooling coil to the compressor through a copper tube (suction line to the compressor) where the warm gas is compressed. In some cases, an accumulator is placed between the cooling coil and the compressor to capture unused liquid refrigerant and ensures that only vapor enters the compressor. The compression process increases the pressure of the refrigerant vapor and significantly increases the temperature of the vapor. The compressor pumps the vapor through another heat exchanger (outdoor condenser) where heat is rejected and the hot gas is condensed to a warm high pressure liquid. This warm high pressure liquid is pumped through a smaller copper tube (liquid line) to a filter (or filter/dryer) and then on to an expansion device where the high pressure liquid is reduced to a cold, low pressure liquid. The cold liquid enters the indoor cooling coil and the process repeats.

As this liquid passes through the indoor cooling coil on the inside of the heat exchanger, two things happen to the air that passes over the coil's surface on the outside of the heat exchanger. The air's temperature is lowered (sensible cooling) and moisture in the air is removed (latent cooling) if the indoor air dew point is higher than the temperature of the coil's surface. The total cooling (capacity) of an AC system is the sum of the sensible and latent cooling. Many factors influence the cooling capacity of a DX air conditioner. Total cooling is inversely proportional to outdoor temperature. As the outdoor temperature increases the total capacity is reduced. Air flow over the indoor cooling coil also affects the coil's capacity and is directly proportional to the total capacity of an AC system. As air flow increases, the total capacity also increases. At higher air flow rates the latent capacity of the cooling coil is reduced. Indoor temperature and humidity also affect the total capacity of the AC system. As indoor temperatures increase, the sensible capacity also increases. Similarly, as indoor relative humidity increases the latent capacity of the AC system increases. Manufacturers of AC equipment typically provide a "performance map" of specific equipment to show how total, sensible, and latent capacity change with changing indoor and outdoor temperatures and humidity. Power consumption and energy efficiency are also provided in these charts.

TYPES OF AC SYSTEMS

Cooling Only Split-System

A split system is a combination of an indoor air handling unit and an outdoor condensing unit. The indoor air handling unit contains a supply air fan and an air-to-refrigerant heat exchanger (or cooling coil), and the expansion device. The outdoor condensing unit consists of a compressor and a condenser coil. Split-systems are typically found in residential or small commercial buildings. These systems have the highest energy efficiency rating (EER) of all the available AC systems. Manufacturers are required to take the EER rating a step further and provide a seasonal energy efficiency rating (SEER) for use by consumers. SEER ratings vary widely and range from 10 to 20. The higher the SEER rating, the more efficient the AC system operates

Cooling Only Packaged-System

A packaged system is a single unit combining all the components described in the split system. Since the unit is a package, it must be placed outside the building and indoor air is "ducted" from the building to the packaged system and back through an air distribution system. These units typically have SEER rating from 10 to 18. If heating is required, an alternate method of heating the interior of the building must be used, usually in the form of electric or gas heating.

Heat Pump

Heat pumps are similar to cooling only systems with one exception. A special valve in the refrigeration piping allow the refrigeration cycle to be operated in reverse. A cooling only system cools the indoor air and rejects heat to the outdoors. A heat pump can also cool the indoor air, but when the valve is reversed, the indoor air is heated. A supplementary electric resistance heater may also be used to assist the heat pump at lower outdoor temperatures. In colder climates, heat pumps require a defrost period. During defrost times the electric heater is the only means of heating the interior of the building. These units are manufactured as either split or packaged systems.

Chilled Water System

In a chilled water system, liquid water is pumped throughout the building to “chilled water coils”. Since the liquid water needs to be at a cold temperature, a “cooling plant” is required. The plant is typically referred to as a chiller plant. Vapor compression equipment in the plant, similar to that described in “How does my AC work”, cool water to a cold temperature and pump the cold water to air-to-water heat exchangers where needed.

Window Air Conditioners

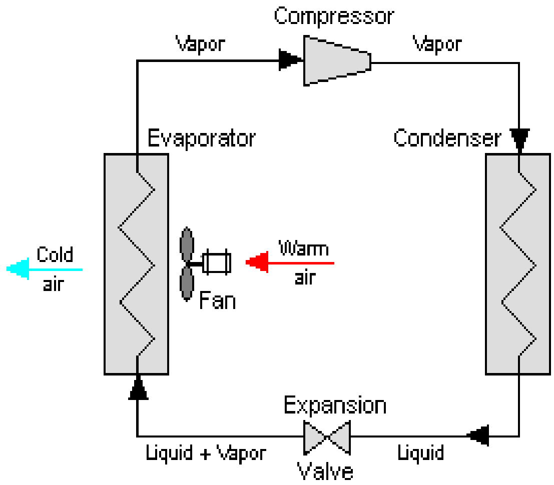
As the name implies, a window air conditioner is typically installed in a window or custom opening in a wall. The Window AC can only cool small areas and are not intended to provide cooling to multiple rooms or zones. These air conditioners are manufactured as cool only or can provide both cooling and heating. An optional damper in the unit can provide fresh outdoor air if necessary.

Packaged Terminal Heat Pump

Packaged terminal heat pumps (PTHP) are similar to a window-mounted air conditioner. These units are typically installed in a sleeve passing through the outdoor wall of an apartment, hotel, school classroom, etc. PTHPs are completely self contained and require only an electrical connection in addition to the opening in the building shell. They use the outdoor air as the heat source in winter and as a heat sink in summer. They also can provide ventilation air. Flexibility and lower installed cost are the primary advantages of the PTHP. Disadvantages include in-room maintenance, higher operating cost, relatively short life, imprecise "on-off" temperature control, and they can be rather noisy.

Refrigeration

Refrigeration is the process of cooling a space, substance, or system to lower a



The basic refrigeration cycle used for single-stage vapor compression has four components in the system. They are the compressor, condenser, metering device, and evaporator. Low-pressure liquid refrigerant in an evaporator extracts heat from the fluid being cooled and evaporates. The low-pressure vapor is then compressed to a pressure at which the refrigerant vapor can be condensed by the cooling media available.

The vapor then flows to the condenser, where it is cooled and condensed. The liquid refrigerant flows from the condenser to a metering device, where its pressure is reduced to that of the evaporator. The cycle is thus completed.

High head pressure can be costly in two ways. First, it presents the danger of a system shutdown; a safety control will stop the compressor motor when the safe maximum head pressure is exceeded in the compressor. Second, an increase in power consumption results when a compressor operates at greater than design head pressure.

Refrigerants, are chemical compounds that are alternately compressed and condensed into a liquid and then permitted to expand into a vapor or gas as they are pumped through the mechanical refrigeration system to cycle

The refrigeration system requires some means of connecting the basic major components - evaporator, compressor, condenser, and metering device - just as roads connect communities. Tubing or "lines" make the system complete so that the refrigerant will not leak out into the atmosphere.

The suction line connects the evaporator or cooling coil to the compressor, the hot gas or discharge line connects the compressor to the condenser, and the liquid line is the connecting tubing between the condenser and the metering device (Thermal expansion valve). Some systems will have a receiver immediately after the condenser and before the metering device, where the refrigerant is stored until it is needed for heat removal in the evaporator.

Refrigerant flows through the compressor, which raises the pressure of the refrigerant. Next the refrigerant flows through the condenser, where it condenses from vapor form to liquid form, giving off heat in the process.

The heat given off is what makes the condenser "hot to the touch." After the condenser, the refrigerant goes through the expansion valve, where it experiences a pressure drop. Finally, the refrigerant goes to the evaporator. The refrigerant draws heat from the evaporator which causes the refrigerant to vaporize. The evaporator draws heat from the region that is to be cooled. The vaporized refrigerant goes back to the compressor to restart the cycle

Compressor: reciprocating, rotary, and centrifugal compressors, the most popular among domestic or smaller power commercial refrigeration is the reciprocating. The reciprocating compressor is similar to an automobile engine. A piston is driven by a motor to "suck in" and compress the refrigerant in a cylinder. As the piston moves down into the cylinder (increasing the volume of the cylinder), it "sucks" the refrigerant from the evaporator.

The intake valve closes when the refrigerant pressure inside the cylinder reaches that of the pressure in the evaporator. When the piston hits the point of maximum downard displacement, it compresses the refrigerant on the upstroke. The refrigerant is pushed through the exhaust valve into the condenser. Both the intake and exhaust valves are designed so that the flow of the refrigerant only travels in one direction through the system

Condenser: The condenser removes heat given off during the liquefication of vaporized refrigerant. Heat is given off as the temperature drops to condensation temperature. Then, more heat (specifically the latent heat of condensation) is released as the refrigerant liquefies. There are air-cooled and water-cooled condensers, named for their condensing medium. The more popular is the air-cooled condenser. The condensers consist of tubes with external fins. The refrigerant is forced through the condenser. In order to remove as much heat as possible, the tubes are arranged to maximize surface area. Fans are often used to increase air flow by forcing air over the surfaces, thus increasing the condenser capability to give off heat.

Evaporator: This is the part of the refrigeration system that is doing the actual cooling. Because its function is to absorb heat into the refrigeration, the evaporator is placed in the area to be cooled. The refrigerant is let into and measured by a flow control device, and eventually released to the compressor. The evaporator consists of finned tubes, which absorbs heat from the air blown through a coil by a fan. Fins and tubes are made of metals with high thermal conductivity to maximize heat transfer. The refrigerant vaporizes from the heat it absorbs heat in the evaporator

Expansion valve: This controls the flow of the liquid refrigerant into the evaporator. Control devices usually are thermostatic, meaning that they are responsive to the temperature of the refrigerant.

Energy Efficiency / Saving Measures in Refrigeration System

a) Cold Insulation
Insulate all cold lines / vessels using economic insulation thickness to minimize heat gains; and choose appropriate (correct) insulation.

b) Building Envelope
Optimize air conditioning volumes by measures such as use of false ceiling and segregation of critical areas for air conditioning by air curtains.

c) Building Heat Loads Minimization
Minimize the air conditioning loads by measures such as roof cooling, roof painting, efficient lighting, pre-cooling of fresh air by air- to-air heat exchangers, variable volume air system, optimal Thermo static setting of temperature of air conditioned spaces, sun film applications, etc.

d)Process Heat Loads Minimization
Minimize process heat loads in terms of TR capacity as well as refrigeration level, i.e., temperature required, by way of:

i) Flow optimization
ii) Heat transfer area increase to accept higher temperature coolant
iii) Avoiding wastages like heat gains, loss of chilled water, idle flows.
iv) Frequent cleaning / de-scaling of all heat exchangers.

e)At the Refrigeration A/C Plant Area

i) Ensure regular maintenance of all A/C plant components as per manufacturer guidelines.

ii) Ensure adequate quantity of chilled water and cooling water flows, avoid bypass flowsby closing valves of idle equipment.

iii) Minimize part load operations by matching loads and plant capacity on line; adopt variable speed drives for varying process load.

iv) Make efforts to continuously optimize condenser and evaporator parameters for minimizing specific energy consumption and maximizing capacity

AIR CONDITIONING SYSTEM

An air conditioner (AC) in a room or a car works by collecting hot air from a given space, processing it to release cool air into the same space where the hot air had originally been collected. This processing is primarily done using five components:

- Evaporator
- Compressor
- Condenser
- Expansion valve
- Refrigerant

An air conditioner (AC) in a room or a car works by collecting hot air from a given space, processing it within itself with the help of a refrigerant and a bunch of coils and then releasing cool air into the same space where the hot air had originally been collected. This is essentially how air conditioners work.

Evaporator

An evaporator is basically a heat exchanger coil that's responsible for collecting heat from inside a room through a refrigerant gas. This component is known as the evaporator, and is where the liquid refrigerant absorbs heat and *evaporates* to become gas.

Compressor

As the name clearly signifies, this is where compression of the gaseous refrigerant occurs. It's located in the outside unit, i.e., the part that's installed outside the house

Condenser

The condenser receives the vaporized refrigerant from the compressor, converts it back to liquid and expels the heat outside. Needless to say, it's also located on the outside unit of the split AC.

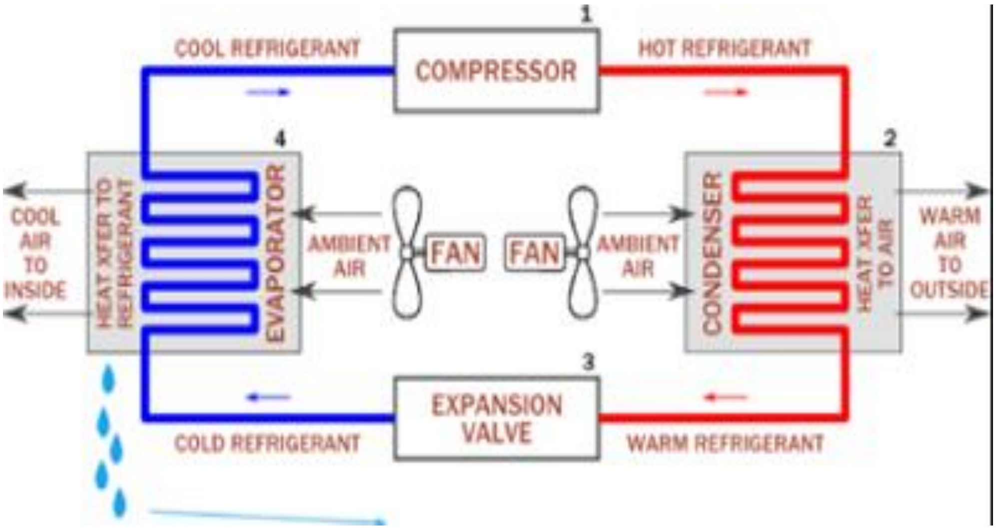
Expansion valve

Also referred to as the throttling device, the expansion valve is located between the two sets of coils (the chilled coils of the evaporator and the hot coils of the condenser). It keeps tabs on the amount of refrigerant moving towards the evaporator.

Note that in the case of window ACs, the three aforementioned components are all located inside a small metal box that is installed in a window opening.

These are the main components of an air conditioner. Now let's look at how they work together to make an AC do what it does.

Air conditioner (AC) working principle



An air conditioner collects hot air from a given space, processes it within itself with the help of a refrigerant and a bunch of coils and then releases cool air into the same space where the hot air had originally been collected. This is essentially how all air conditioners work.

This working fluid exits the compressor as a high-pressure, hot gas, and it moves to the condenser. The outside unit of an air conditioning system has metal fins all around the housing. These fins work like the radiator on a vehicle, and they help dissipate heat more quickly.

When the fluid leaves the condenser, it is much cooler. It's also changed from a gas to liquid because of the high pressure. The fluid makes its way into the evaporator through a minuscule, narrow hole and when the liquid reaches the other side of this passage, its pressure drops. When this happens, the fluid begins to evaporate to gas.

As this occurs, the heat is extracted from the surrounding air. This heat is required to separate the molecules of the liquid into a gas. The metal fins on the evaporator also help exchange thermal energy with the surrounding air.

When the refrigerant leaves the evaporator, it is once again a low-pressure, chilled gas. The process starts all over when it goes back to the compressor. There is a fan that's connected to the evaporator, and it circulates air around the inside of the property and across the fins of the evaporator.

The air conditioner sucks air into the ducts through a vent. This air is used to cool gas in the evaporator, and as the heat is removed from the air, it's cooled. Ducts then blow air back into the house.

This process continues until the inside air of your home or business reaches the desired temperature. When the thermostat senses that the interior temperature is at the desired level, it shuts the air conditioner off. When the room heats up again, the thermostat turns the air conditioner back on until the preferred ambient temperature is achieved again.

Energy Efficiency / Saving Measures in A/C

- Ensure air intake to compressor is not warm and humid by locating compressors in wellventilated area or by drawing cold air from outside. Every 4°C rise in air inlet temperaturewill increase power consumption by 1 percent.
- Clean air-inlet filters regularly. Compressor efficiency will be reduced by 2 percent forevery 250 mm WC pressure drop across the filter.
- Keep compressor valves in good condition by removing and inspecting once every sixmonths. Worn-out valves can reduce compressor efficiency by as much as 50 percent.
- Install manometers across the filter and monitor the pressure drop as a guide to replacementof element.
- Minimize low-load compressor operation; if air demand is less than 50 percent ofcompressor capacity, consider change over to a smaller compressor or reduce compressor speed appropriately (by reducing motor pulley size) in case of belt driven compressors.
- Consider the use of regenerative air dryers, which uses the heat of compressed air to removemoisture.
- The possibility of heat recovery from hot compressed air to generate hot air or water forprocess application must be economically analyzed in case of large compressors.
- Consideration should be given to two-stage or multistage compressor as it consumes lesspower for the same air output than a single stage compressor.
- If pressure requirements for processes are widely different (e.g. 3 bar to 7 bar), it isadvisable to have two separate compressed air systems.
- Keep the minimum possible range between load and unload pressure settings. Check air compressor logs regularly for abnormal readings, especially motor currentcooling water flow and temperature, inter-stage and discharge pressures and temperatures and compressor load-cycle.
- Pneumatic transport can be replaced by mechanical system as the former consumed about 8times more energy. Highest possibility of energy savings is by reducing compressed air use.

Refrigerant selection criteria

The desirable characteristics of 'ideal' refrigerants are considered to be as follows:

- Normal boiling point below 0°C.
- Non-flammable.
- Non-toxic.
- Easily detectable in case of leakage.
- Stable under operating conditions.
- Easy to recycle after use.
- Relatively large area for heat evaporation.

FANS AND BLOWERS

Fans and blowers provide air for ventilation and industrial process requirements. Fans generate a pressure to move air (or gases) against a resistance caused by ducts, dampers, or other components in a fan system. The fan rotor receives energy from a rotating shaft and transmits it to the air

Centrifugal Fan:

The major types of centrifugal fan are: radial, forward curved and backward curved (see Figure 5.3). Radial fans are industrial workhorses because of their high static pressures (upto 1400 mm WC) and ability to handle heavily contaminated airstreams.

Because of their simple design, radial fans are well suited for high temperatures and medium blade tip speeds. Forward-curved fans are used in clean environments and operate at lower temperatures. They are well suited for low tip speed and high-airflow work - they are best suited for moving large volumes of air against relatively low pressures. Backward-inclined fans are more efficient than forward-curved fans. Backward-inclined fans reach their peak power consumption and then power demand drops off well within their useable airflow range. Backward-inclined fans are known as "non-overloading" because changes in static pressure do not overload the motor.

Axial Flow Fan: Types The major types of axial flow fans are: tube axial, vane axial and propeller (see Figure 5.4.) Tubeaxial fans have a wheel inside a cylindrical housing, with close clearance between blade and housing to improve airflow efficiency. The wheel turn faster than propeller fans, enabling operation under high-pressures 250 – 400 mm WC. The efficiency is up to 65%.

BLOWER:

Blower Types Blowers can achieve much higher pressures than fans, as high as 1.20 kg/cm2 . They are also used to produce negative pressures for industrial vacuum systems. Major types are: centrifugal blower and positive-displacement blower. Centrifugal blowers look more like centrifugal pumps than fans. The impeller is typically gear-driven and rotates as fast as 15,000 rpm. In multi-stage blowers, air is accelerated as it passes through each impeller. In single-stage blower, air does not take many turns, and hence it is more efficient. Centrifugal blowers typically operate against pressures of 0.35 to 0.70 kg/cm2 , but can achieve higher pressures.

Energy Saving Opportunities

1. Minimising excess air level in combustion systems to reduce FD fan and ID fan load.

2. Minimising air in-leaks in hot flue gas path to reduce ID fan load, especially in case of kilns, boiler plants, furnaces, etc. Cold air in-leaks increase ID fan load tremendously, due to density increase of flue gases and in-fact choke up the capacity of fan, resulting as a bottleneck for boiler / furnace itself.

3. In-leaks / out-leaks in air conditioning systems also have a major impact on energy efficiency and fan power consumption and need to be minimized.

The findings of performance assessment trials will automatically indicate potential areas for improvement, which could be one or a more of the following:

1. Change of impeller by a high efficiency impeller along with cone.

2. Change of fan assembly as a whole, by a higher efficiency fan

3. Impeller de-rating (by a smaller dia impeller)

4. Change of metallic / Glass reinforced Plastic (GRP) impeller by the more energy efficient hollow FRP impeller with aerofoil design, in case of axial flow fans, where significant savings have been reported

5. Fan speed reduction by pulley dia modifications for derating.

6. Option of two speed motors or variable speed drives for variable duty conditions

7. Option of energy efficient flat belts, or, cogged raw edged V belts, in place of conventional V belt systems, for reducing transmission losses.

8. Adopting inlet guide vanes in place of discharge damper control 9. Minimizing system resistance and pressure drops by improvements in duct system.

Energy Efficiency / Saving Measures in Fans & Blowers

1. Minimizing excess air level in combustion systems to reduce FD fan and ID fan load.
2.Minimizing air in-leaks in hot flue gas path to reduce ID fan load, especially in case of kilns, boiler plants, furnaces, etc. Cold air in-leaks increase ID fan load tremendously,due to density increase of flue gases and in-fact choke up the capacity of fan, resultingas a bottleneck for boiler / furnace itself.
3.In-leaks / out-leaks in air conditioning systems also have a major impact on energyEfficiency and fan power consumption and need to be minimized
4.Fan speed reduction by pulley diameter modifications for derating.
5. Option of two speed motors or variable speed drives for variable duty conditions