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DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

VII Semester

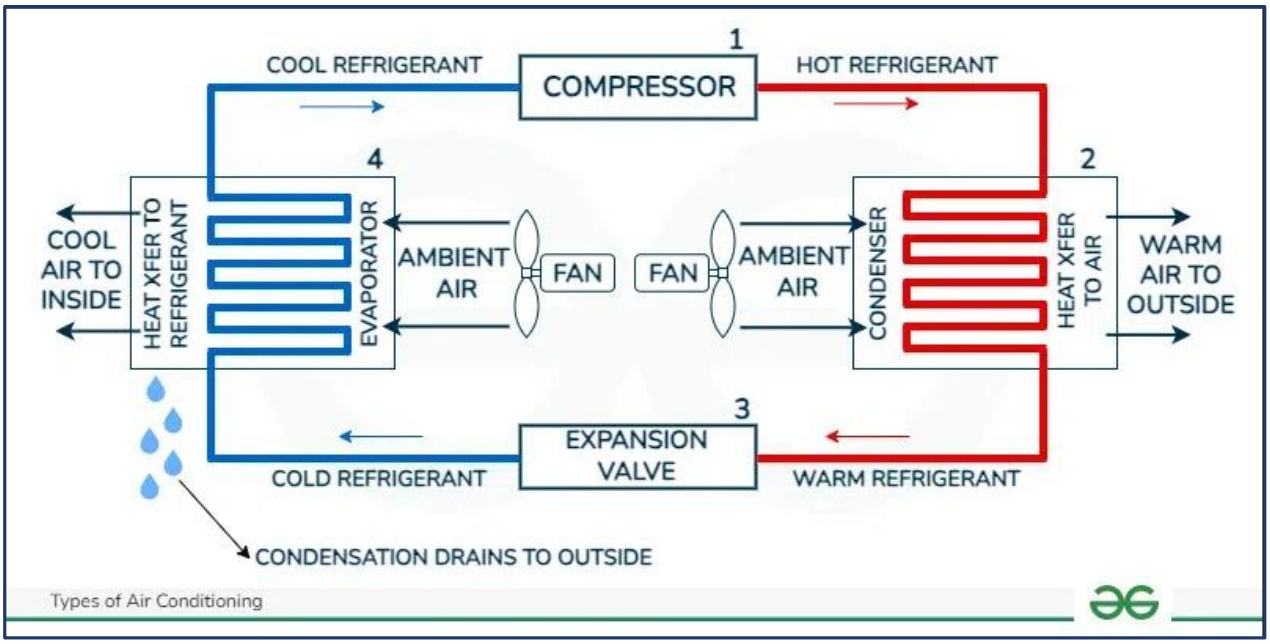
AU3008 Sensors and Actuators

UNIT – 5 - AUTOMATIC TEMPERATURE CONTROL ACTUATORS

5.2 Fixed and variable displacement temperature control

5.2.1 Working of an Air Conditioning System:

- Its works like a pump, an air conditioner draws heat from a space and releases it outside.
- It consists Heat exchanger coil, compressor, and a mechanism that use refrigerant gas in the operation.
- There is an absorption of heat during the transition from a liquid to a gas is a basic concept of physics that underlies the operation of air conditioning equipment.
- Practically, AC move heat from a room's inside to its outdoor.



- The refrigerant initiates as a low pressure, low temperature liquid in the evaporator coil of the house. Here, the heat from the room air is absorbed. In the meantime, heat absorption causes the refrigerant to change from a liquid to a low-pressure gas. The unit outside the home receives this gas after that.
- Here, a compressor is utilized to raise the temperature and pressure of this gas refrigerant.
- It is then moved to the condensation coil, which discharges the heat that was previously trapped inside your house into the atmosphere. A fan pushes air across the condenser for cooling and turning the refrigerant into a high-pressure liquid.
- The cycle is then continued by reintroducing the refrigerant through the expansion valve into the house.

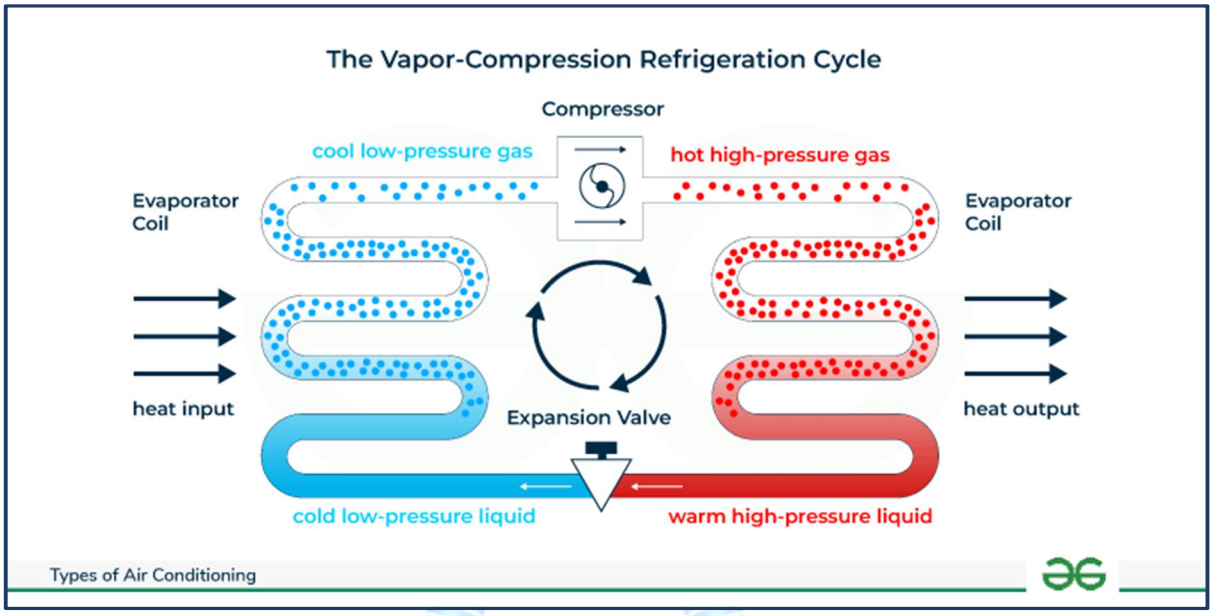
5.2.2 Components of Air Conditioning Systems:

- **Evaporator**-An evaporator consists of a heat exchanger coil that gathers heat from a room's surface. Because it is the part where the fluid refrigerant receives heat from the surrounding air and turns into a gas, this part is called an evaporator. Copper and aluminum are commonly utilized in construction because of their better heat conduction properties. Copper tubes in the evaporator transport the refrigerant, and vents attached to the tubes improve heat transmission from the refrigerant to the surrounding air.
- **Refrigerant**- When a gas moves through the AC's heat exchanger coils, it absorbs heat from the air around it and releases it outside. An AC's refrigerant evaporates and condenses, reducing the temperature of the indoor air.
- **Condenser**- In this part hot gas condenses into a liquid, thus the name. When the high-temperature gas reach to the condenser and pushes air over the heat exchanger, a spinning fan cools the gas and transforms it into a fluid. Condensers, like evaporator units, are commonly made of copper or aluminium. However, they are housed in a facility outside the space.
- **Compressor**- It compress the gas to extremely high pressure. It acts as pump cooling gas from the evaporator to increase temperature. After that high-pressure gas is then sent to outside chamber.

- **Expansion Valve**-The expansion valve, located between the condenser and evaporator, is an essential component in AC systems. It keep the amount of refrigerant in evaporator. Expansion valve converts the high-pressure refrigerant in the condenser into a low-pressure. The evaporator then continues to operate using this low-pressure, low-temperature liquid.

5.2.3 Refrigeration Cycle:

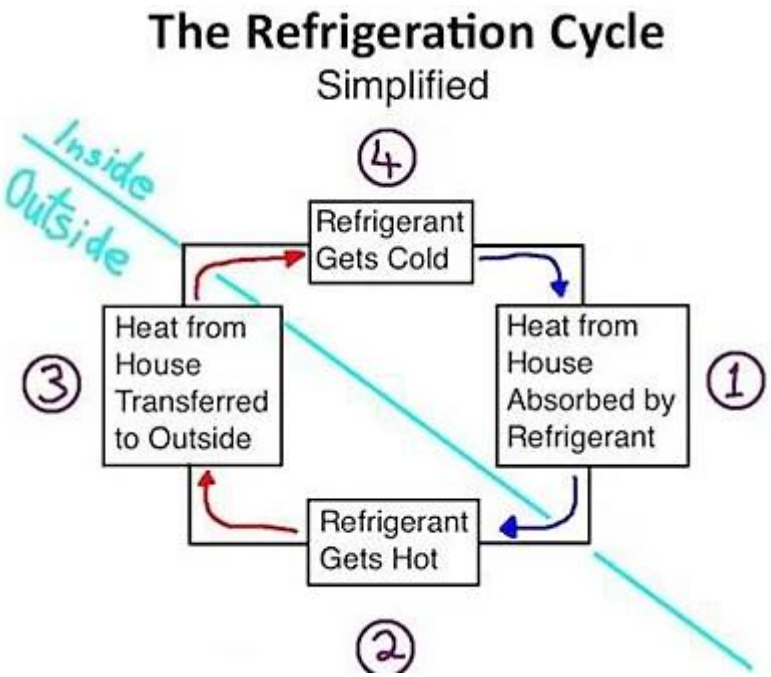
The cycle has 4 basic processes: compression, condensation, expansion, and evaporation



- **Compression process** - It is like the engine of the cycle. The compressor draws the superheated refrigerant vapor through the suction pipe and begins compressing it. The pressure, temperature, and energy of compressed vapor rapidly rise. In contrast, the specific volume was greatly reduced. At this stage, the temperature and energy of refrigerant vapor are the highest in the whole cycle. It produces very hot and high pressure vapor during this process.
- **Condensation process** - Now here condenser job comes into play, it turns gas into liquid or we can say it condense the refrigerant. It is done whenever the outdoor air flows through the condenser's coil which is filled with hot, gaseous refrigerant. It leads to the transfer of the heats from the refrigerant to the cooled outdoor air where the diffusion of excessive heat to the atmosphere takes place. The condenser coils run through the condenser, increasing the surface area of

the pipework and heat transmission to the air. Because of the high pressure and temperature decrease, the refrigerant converts from a vapour to a hot liquid.

- **Expansion process** - The refrigerant then reaches the expansion mechanism in a heated, high-pressure state. The expansion device functions as a catalyst, rapidly reducing the refrigerant pressure and enabling it to boil more easily in the evaporator. The expansion device's main purpose is to lower refrigerant pressure. Because the pressure decreases so quickly at the expansion mechanism, the refrigerant transforms into a mixture of cold liquid and vapor.
- **Evaporation process** - When the refrigerant becomes a cold mixture of liquid and gas (vapor), it starts moving through the evaporator. When the refrigerant has chilled to a cold combination of liquid and gas it starts moving through the evaporator. The evaporator cools the ambient air by boiling (or evaporating) the refrigerant that flows through it. This occurs when warm air passes over the evaporator coil while cold refrigerant flows through it.
- Heat flows through the air to the refrigerant, which immediately cools the air before venting it into space. The evaporator coil, like the condenser coil, wraps around the evaporator to optimize heat transmission from the refrigerant to the ambient air. The heated air aimed to the evaporator quickly boils the low-pressure fluid refrigerant, which flows to the compressor as a cold gas or vapour.



5.2.4 What is a fixed displacement temperature control in air conditioning:

In an air conditioning system, fixed displacement temperature control refers to a system that uses components with a fixed capacity, such as fixed-speed compressors. This means that the system either operates at full capacity or is completely off.

In a **fixed displacement compressor**, the compressor moves a set amount of refrigerant per cycle. To control temperature, the system cycles the compressor on and off as needed:

1. **When Cooling Is Needed**: The compressor runs at full capacity, moving refrigerant through the system, which absorbs heat and cools the indoor air.
2. **When Target Temperature Is Reached**: The compressor turns off, stopping refrigerant circulation. The indoor fan may continue to run, but the cooling stops until the temperature rises again.

- ❒ A fixed-displacement pump has a set flow rate — every stroke of the motor moves the same amount of fluid. Fixed-displacement pumps are
  - ✓ Simple
  - ✓ Relatively inexpensive
  - ✓ Easier to maintain
- ❒ The simplest type of fixed-displacement pump is the gear pump, in which the hydraulic fluid is pushed by rotating gears. In some models, the gears are sequential; in the quieter and more efficient version, the gears are interlocking. Another common variation is the screw pump, which uses the classic Archimedes screw, which looks much like a drill bit, to move the fluid. They have the advantage of providing a high rate of flow at relatively low pressures.

How it works:

1. **Thermostat Senses Temperature:** The thermostat measures the room temperature and compares it to the set point.
2. **System Cycles On/Off:** If the room temperature is higher than the set point, the system turns on and operates at full capacity until the desired temperature is reached. Once the desired temperature is reached, the system turns off.

3. **Inefficient Operation:** This on/off cycling can lead to temperature swings and energy inefficiency. The system may overcool the room and then cycle off, only to turn back on again when the temperature rises.

Advantages of Fixed Displacement Systems:

- **Simple and Reliable:** They are relatively simple in design and tend to be reliable.
- **Lower Initial Cost:** They are generally less expensive to install and maintain.

Disadvantages of Fixed Displacement Systems:

- **Inefficient:** The on/off cycling can lead to energy waste and reduced comfort.
- **Temperature Swings:** The system may struggle to maintain a consistent temperature, leading to discomfort.
- **Increased Wear and Tear:** Frequent on/off cycles can increase wear and tear on the compressor and other components.

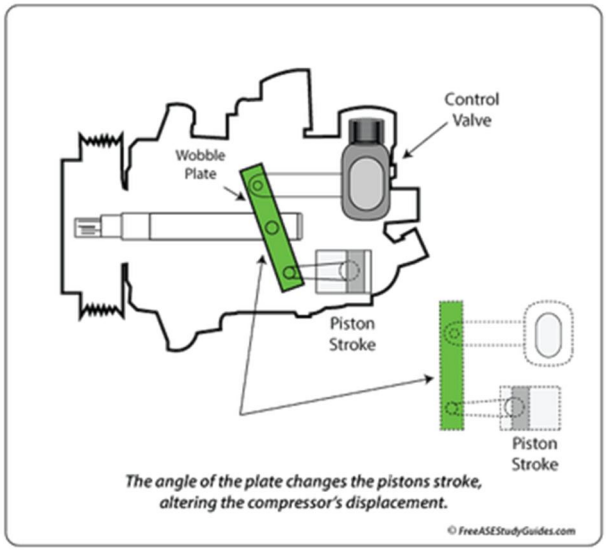
In contrast to fixed displacement systems, variable displacement systems use components with adjustable capacity, such as variable-speed compressors. These systems can modulate their output to match the exact cooling demand, leading to more efficient and precise temperature control.

5.2.4 What is a variable displacement temperature control in air conditioning:

In air conditioning systems, variable displacement temperature control refers to a system that uses components with adjustable capacity. This allows the system to modulate its output to match the exact cooling demand, providing more efficient and precise temperature control.

How it works:

- **Cooling Demand Sensing**: The air conditioning system detects the current indoor temperature and compares it to the desired temperature set on the thermostat.
- **Adjusting Displacement**: Based on the temperature difference, a **variable displacement compressor** adjusts its output by changing the angle or stroke of its internal mechanism. This adjustment controls how much refrigerant is circulated, either increasing or decreasing it as needed:



- The pistons are attached to an axial wobble plate that changes its angle based on the difference in pressure between the top of the piston and the housing.
- When cabin temperatures are warm and air conditioning demand is high, the low side pressure is also high. During this time, the compressor's wobble plate is moved to its greatest angle, increasing the piston's stroke and providing maximum refrigerant displacement.
- As demand decreases, the wobble plate is moved to a lesser angle, providing lesser or minimum output.
- The control valve connected to the suction and discharge ports may be mechanically or computer-controlled. The mechanical valve has a diaphragm that responds to changes in low-side pressure. It increases piston stroke as it opens, increasing the volume or displacement of the refrigerant's flow through the compressor.
- **Computer Controlled Systems**:

  Computer-controlled systems contain temperature and pressure sensors. They control the duty cycle of the valve, adjusting the compressor's displacement. They have a reduced potential for noise and drain on the system. This type of compressor puts less load on the engine, resulting in slightly improved fuel economy and a smoother idle

- Types of Variable-displacement Compressors Used in Automotive HVAC

- In automotive applications, several types of variable-displacement compressors are commonly used:

  - **Swash Plate Compressors**: These compressors utilize a swash plate mechanism to change the angle of the pistons, allowing for variable displacement.
  - **Wobble Plate Compressors**: Similar to swash plate designs, wobble plate compressors adjust their displacement by tilting the piston assembly, providing a compact solution.
  - **Scroll Compressors**: Some scroll compressors are designed to operate in a variable-displacement mode, offering high efficiency and low noise levels.

- **High Demand**: If the room is significantly warmer than desired, the compressor runs at a higher displacement to move more refrigerant, providing maximum cooling.
- **Low Demand**: If the temperature is close to the set point, the compressor reduces its displacement, lowering refrigerant flow to provide gentle cooling and prevent over-cooling.
- **Continuous Operation**: Because the compressor can adjust its output instead of simply cycling on and off, it can run continuously at the optimal cooling level, maintaining a steady indoor temperature with fewer fluctuations.

1. **Variable-Speed Compressor:**

   The heart of a variable displacement system is a variable-speed compressor. This compressor can adjust its speed to match the cooling load. When the cooling demand is low, the compressor operates at a lower speed, reducing energy consumption. As the cooling demand increases, the compressor speeds up to meet the increased load.

2. **Precise Temperature Control:** By continuously adjusting the compressor's output, the system can maintain a consistent temperature without cycling on and

off. This eliminates temperature swings and provides a more comfortable indoor environment.

Advantages of Variable Displacement Systems:

- **Energy Efficiency:** By operating at the optimal capacity, variable displacement systems consume less energy compared to fixed displacement systems.
- **Improved Comfort:** Precise temperature control reduces temperature fluctuations, leading to increased comfort.
- **Reduced Wear and Tear:** The smoother operation of variable displacement systems reduces wear and tear on the components.
- **Longer Lifespan:** Reduced wear and tear can extend the lifespan of the system.

In conclusion, variable displacement temperature control offers significant advantages over fixed displacement systems, especially in applications with fluctuating cooling loads. By providing precise temperature control and energy efficiency, these systems contribute to a more comfortable and sustainable indoor environment.