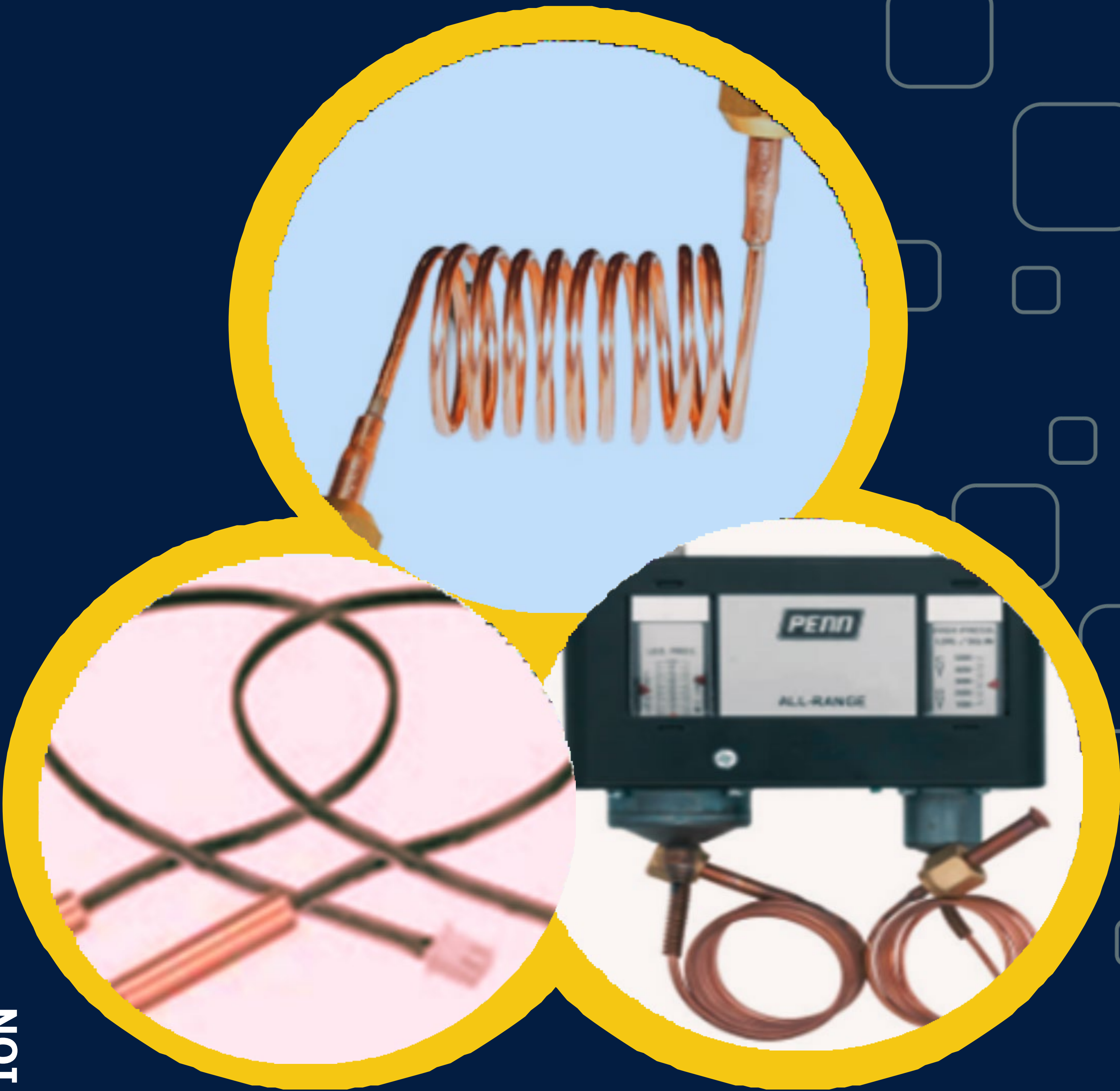
BASIC CONTROL SYSTEM

Air Conditioning & Refrigeration Control System



2024 EDITION

WRITTEN BY

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AIR CONDITIONING & REFRIGERATION CONTROL SYSTEM

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PRE FACE

This eBook presents the topic of basic control system in air conditioning and refrigeration system. It also recognizes the types of control application principles, theoretical and knowledge in air conditioning and refrigeration system and discuss the function of control device.

It is with sincere gratitude to the Publishers that the author acknowledges the results achieved to have been due wholly to their kindly interest and indefatigable efforts. Hope that this new edition will be found to measure fully up to the expectations of readers.

Table Of Contents

Table Of Contents

ACKNOWLEDGMENTS

First and foremost, praises and thanks to A-Mighty, for His mercy and guidance to complete this eBook entitled "Basic Control System". Tonnes of thanks also to team members who have contributed greatly to this eBook. The purpose of establishing this eBook is as a guide for students for better understanding the fundamental of basic control system in air conditioning and refrigeration control system.

During preparing this eBook, we have faced lots of challenges and obstructions but with help of individual in our team members, those obstruction managed to be passed.

Finally, thank you to all individual members who helps in process of writing this eBook. Hopefully this eBook helps the reader to gain more knowledge about the topic.

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CHAPTER 1

Control System 1

1.1 Introduction

Basic control principle in air conditioning and refrigerant is emphasizing on controlling the temperature, pressure, refrigerant, water, air and electrical current flow in system.

The main function of refrigerant control the flow of the refrigerant in the air conditioning and refrigerant system so that the refrigerant can flow smoothly, and the system can operate well

1.2 Definitions of Control

In the simplest term, the control is defined as the starting, stopping or regulation of heating, ventilating, and air conditioning system.

Controlling an HVAC system involves three distinct steps:

- Measure a variable and collect data
- Process the data with other information
- Cause a control action

What is control system

To control means to regulate, to direct or to command. Hence a control system is an arrangement of different physical element connected in such a manner so as to regulate, direct or command itself or some other system.

1.3 Benefit of Control System

- Maintain thermal comfort condition
- Maintain optimum indoor air quality
- Reduce energy use
- Safe plant operation
- Reduce manpower cost
- Identify maintenance problem
- Monitor system performance

CHAPTER 2

TYPE OF REFRIGERANT CONTROLS

2

2.0 Type of Refrigerant Controls

2.1	Devices That Respond to Thermal Change
2.2	The Bimetal Device
2.3	Control by Fluid Expansion
2.4	The Thermocouple
2.5	Electronic Temperature Sensing Device (Thermistor)
2.6	Automatic Expansion Valve
2.7	Thermostatic Expansion Valve
2.8	Low-pressure Side Float
2.9	High-pressure Side Float
2.10	Capillary Tube
2.11	Thermal-Electric Expansion Valve

2.1. Devices That Respond to Thermal Change

- Method of controlling temperature
- To protect equipment (safety device)
- Example: Thermostat (figure 2.1) and Compressor Overload Device (figure 2.1.2)

Figure 2.1 : Thermostat

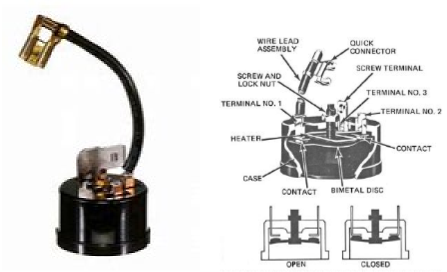

Figure 2.1.2 : Overload Device

- Is probably the most common device user to the detect thermal change. In its simplest from the device consists of two unlike metal strips, attached back to back, that have different rates of expansion.
- Brass and steel are commonly user.

- When the device is heated, the brass expands faster than the steel, and the device is warped out of shape.
- This warping action is a known dimensional change that can be attached to and electrical component or valve to stop, start or modulate electrical current or fluid flow.

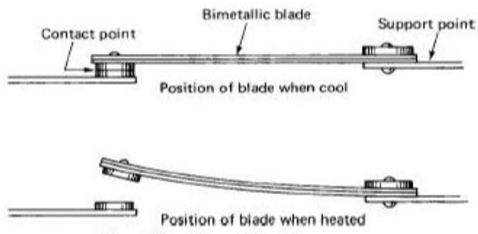

Figure 2.2 : Bimetal Device

2.3. Control By Fluid Expansion

- When the mercury in the bulb is heated and expands, it has to rise up in the tube.
- When it is cooled, it naturally falls down the tube.

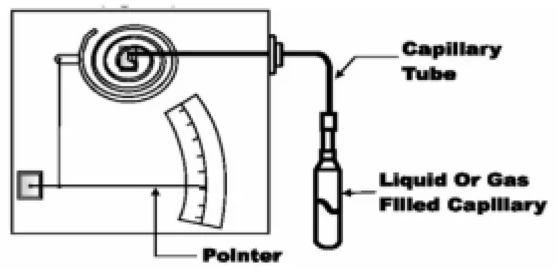

Figure 2.3 : Fluid Expansion

2.4. The Thermocouple

- The thermocouple differs from other methods of controlling with thermal change because it does not use expansion, instead, it use electrical principles.

- When heated on the fastened end, an electrical current flow is started due to the difference in temperature is the two ends of the device.

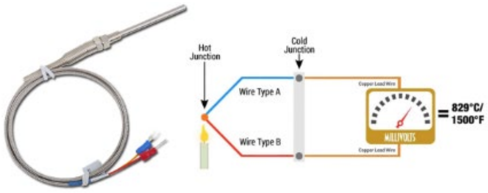

Figure 2.4 : Thermocouple

2.5. Electronic Temperature Sensing Device

- The thermistor is an electronic solid state device known as a semiconductor and requires an electronic circuit to utilize its capabilities. It varies its resistance to current flow based on its temperature.
- The thermistor is very small and will respond to small temperature changes.
- The changes is current flow in the device are monitored by special electronic circuits that can stop, start and modulate machines or provide a temperature readout.

Figure 2.5 : Thermistor

2.6. Automatic Expension valve

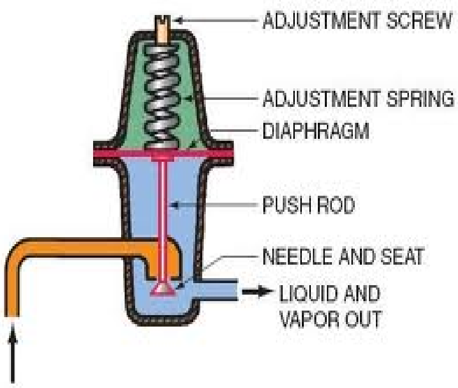

Figure 2.6 : Automatic Expansion Valve

Operational Method

- With unit running, temperature in sensing bulb is about 5°C warmer than the refrigerant temperature in the evaporator
- This temperature difference produces different pressure and different force. This is described as the superheat of the bulb over the refrigerant temperature inside the evaporator
- The pressure in the sensing bulb is greater than the pressure in the evaporator
- As temperature increase or decreases, the pressure will also increase or decrease

2.7. Thermostatic Expansion Valve

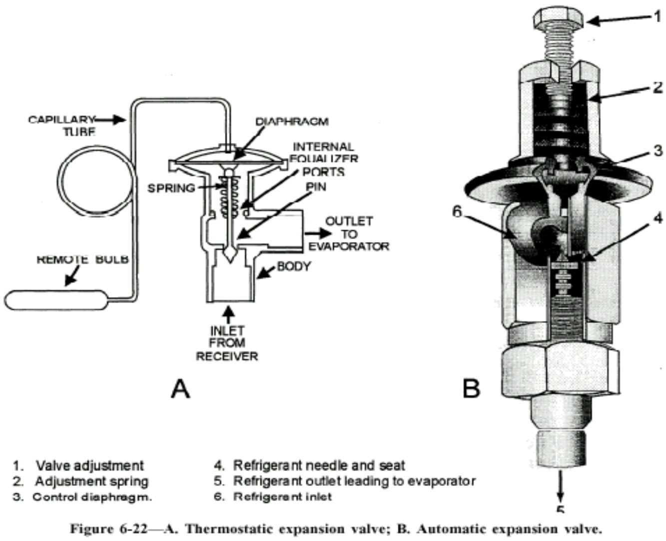

Figure 2.7 : Thermostatic Expansion Valve

Operational Method

- The valve controls the liquid refrigerant, the evaporator coils maintain the correct amount of refrigerant at all the times.
- The valve has a power element that is activated by a remote bulb located at the of the evaporator coils.
- The bulb senses the superheat at the suction line and adjusts the flow of refrigerant into the evaporator.

The advantages of thermostatic expansion valve

- It provides excellent control of refrigerant capacity as the supply of refrigerant to the evaporator matches the demand.

- It ensures that the evaporator operate efficiently by preventing starving under high load conditions
- It protects the compressor from slugging by ensuring a minimum degree of superheat under all conditions of load, if properly selected

2.8. Low Pressure Side Float Valve

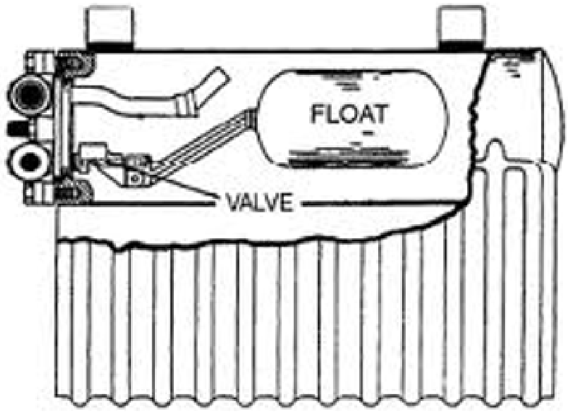

Figure 2.8 : Low pressure side float valve

Operation method

- The low-side float valve controls the liquid refrigerant flow where a flooded evaporator is used.

- The float actuates a needle valve through a lever mechanism.
- As the float lowers,refrigerant enters through the open valve ,when it rises the valve closes

2.9. High – Pressure Side Float Expansion Valve

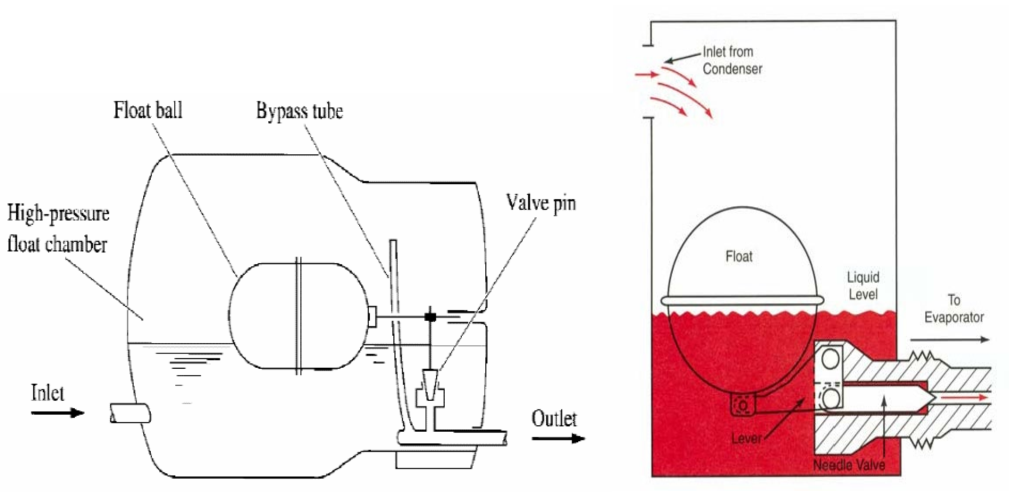

Figure 2.9 : Low pressure side float valve

Operation method

- In a high – side float expansion valve,the valve float is in a liquid receiver or in an auxiliary container on the high-pressure side of the system

- An overcharge of the system floods back and damages the compressor.
- An underchange result in a capacity drop.

2.10. Capillary Tube

Figure 2.10 : Capillary Tube

Operation method

- The length and diameter of the tube are important

- When the quantity of refrigerant in system is correct or the charge is balanced, the flow of refrigerant from condenser to the evaporator stops when the compressor units stops
- Capillary tube is best suited for household boxes such as freezers and windows air-conditioners

2.11. Thermal-Electric Expansion Valve

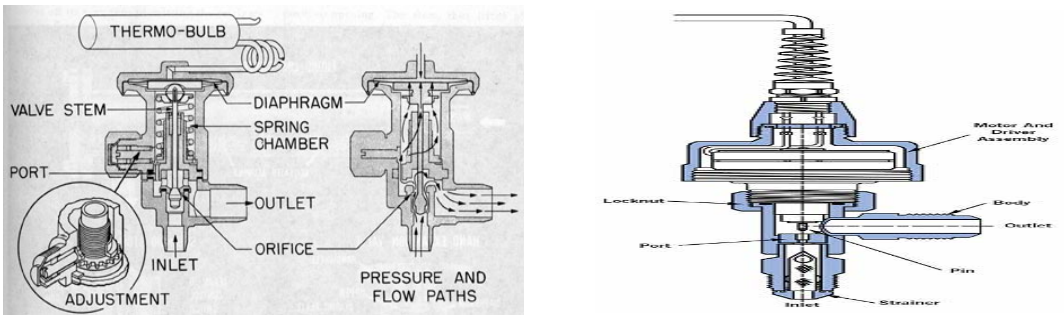

Figure 2.11 : Thermal-Electric Expansion Valve

Operation Method

- Depends on the use of thermistors, which are directly exposed to the refrigerant in the suction line to the control the expansion valve needle opening

- Bleed valves have a small slot in the valve seat. Allowing pressure to balance during the off cycle and allows use of low-torque compressor motor

CHAPTER 3

Categories Of Control System 3

3.0. CATEGORIES OF CONTROL SYSTEM

3.1. Man Made Control System

Example- Cycle of refrigerant in air conditioning system.

The refrigerant of a low-pressure liquid enters the evaporator coil. The process of heat absorption takes place in the evaporator coil and changes the shape of the refrigerant to vapor form before entering the compressor.

The refrigerant in the form of a high-pressure vapor comes out of the compressor into the condenser coil. The heat removal process is nailed in the condenser coil and will deform the refrigerant into a high-pressure liquid form. From the condenser coil, the refrigerant high-pressure liquid will enter the Metering Device and here the control will occur by controlling the rate at which the refrigerant enters the evaporator coil and lowering the pressure to low pressure.

This process will repeat with the controls. Heat absorption in the evaporator coil and heat removal in the condenser coil will cause the refrigerant to change its shape from liquid to vapor and back to liquid again.

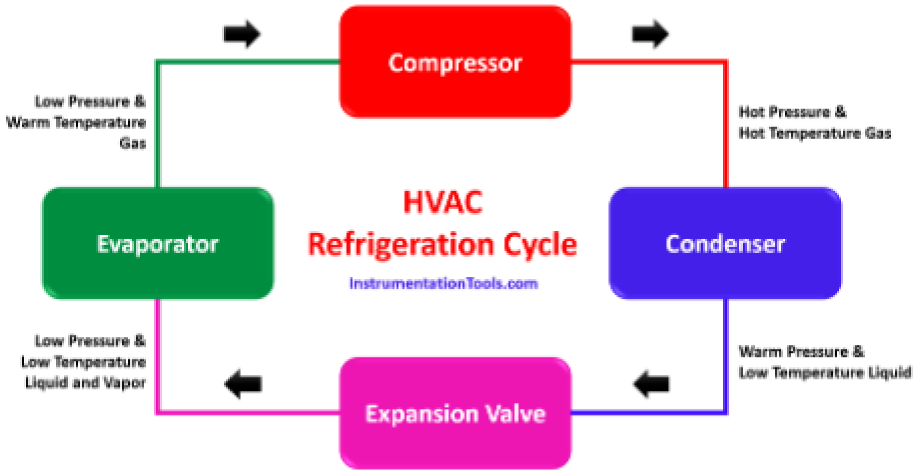

Figure 3.1 : Cycle of Refrigerant in Air Conditioning System

3.2. Natural Control System

Example – Air Flow

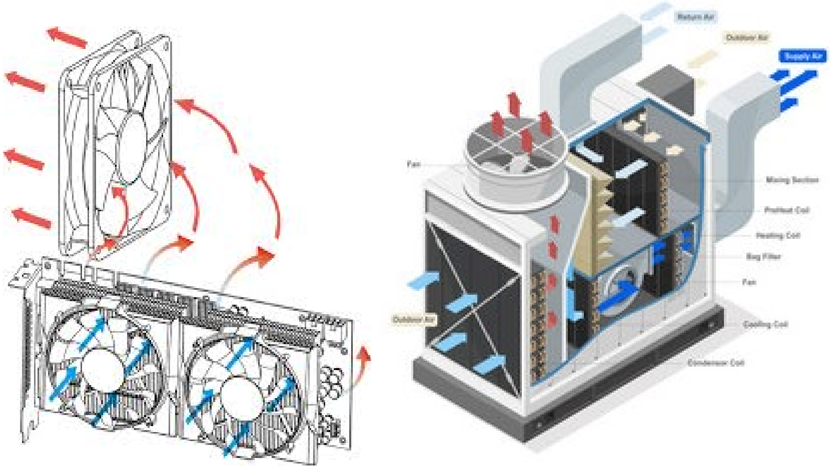

Figure 3.2 : Natural control system

3.3. Combination of Man Made and Natural Controls System

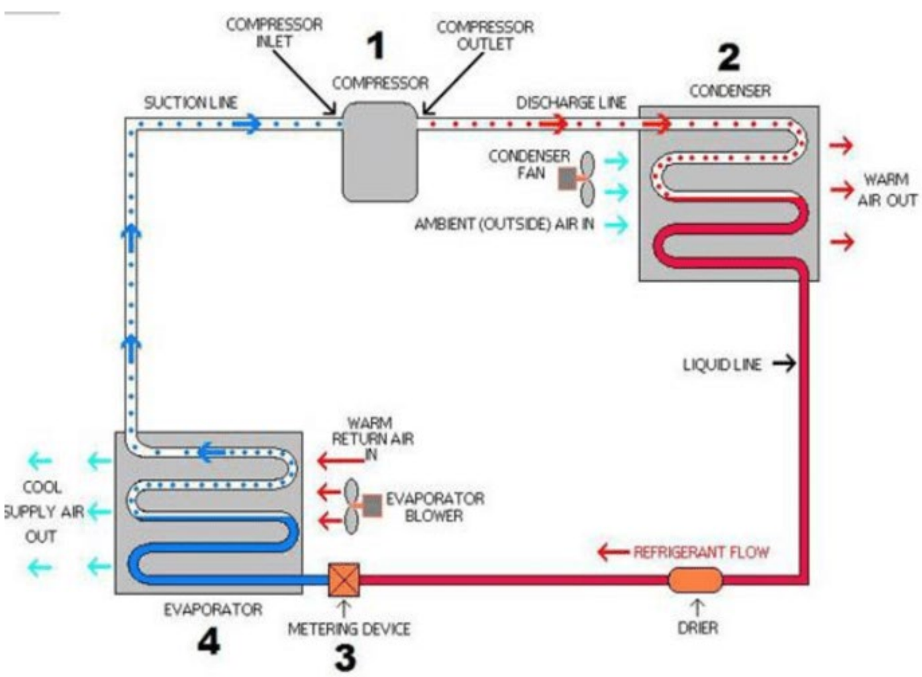

***Figure 3.3 :** Combination of man made and natural controls system*

Air conditioner working cycle.

- Compressor: It drives the refrigerant flow into each part of the air-conditioner so these caused the temperature and the air pressure in the refrigerant being high
- Condenser: It drains heat from the refrigerant.
- Evaporator: It can absorb and transfer the heat in the building to the refrigerant
- Throttling Device: It reduces the air pressure and the temperature in the refrigerant. Generally, it can be used as capillary tube or expansion valve. The cooling system as mentioned above is vapour-compression circulate system which it has the simply working regulation via driving the refrigerant flow along the system and this also passed continually throughout 4 major components as refrigerant circulate system.
- Besides, the followings are its working process. – Firstly, the compressor will absorb and charge the refrigerant for enhancing its pressure and temperature and also move it forward to the evaporator later.

CHAPTER 4

CLASSIFICATION OF CONTROL DEVICE 4

4.0 CLASSIFICATION OF CONTROL DEVICES

4.1. Thermostat

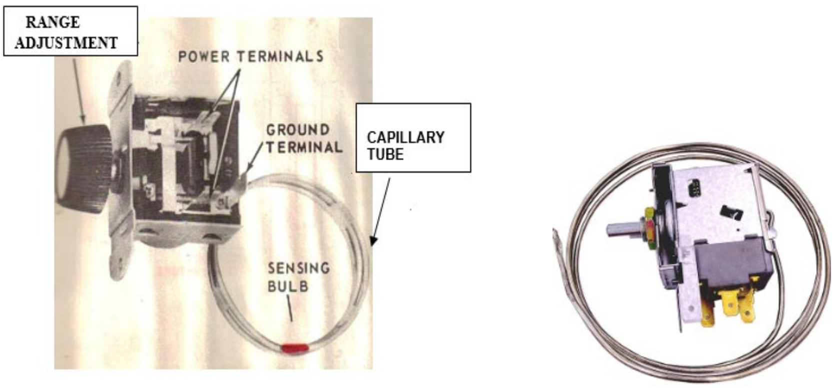

Figure 4.1 : Thermostat

- Electrical components of the control system that control the temperature of the system.

- Operates by disconnecting the power supply to the compressor and condenser fan when the temperature in the evaporator reaches a predetermined level and will resume the power supply when the temperature rises in the evaporator at a predetermined level

4.2. Metering Device (Regulating)

- Control of flow of liquid Refrigerant between the high side slow side of the system.
- Lowering pressure and temperature from high pressure/temperature to low pressure/temperature
- It is at the end of the line between the condenser and the evaporator.

- Metering devices, such as expansion valves and float valves, control the flow of liquid refrigerant between the high side and the low side of the system. It is at the end of the line between the condenser and the evaporator.

4.2.1. Thermostatic Expansion Valve (TXV)

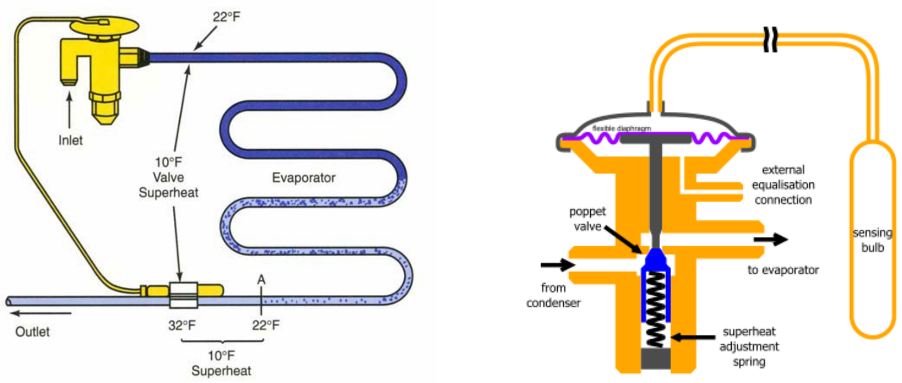

Figure 4.2.1 : Thermostatic Expansion Valve (TXV)

- Basically, TXV has two functions, namely
  - Lower pressure and temperature from high pressure to low pressure before entering the evaporator
  - Controlling the flow rate of refrigerant into the evaporator
- thermostatic expansion valve is not able to regulate the evaporator's temperature to a precise value. The evaporator's temperature will vary only with the evaporating pressure, which will have to be regulated through other means such as by adjusting the compressor's capacity or adjusting thermostat.
- The flexible diaphragm actuates the poppet valve; an increasing pressure in the sensing bulb will press down on the poppet and open the valve further. There is also an adjustable spring providing a closing force on the valve which controls the superheat.

4.2.2. Automatic Expansion Valve (AXV)

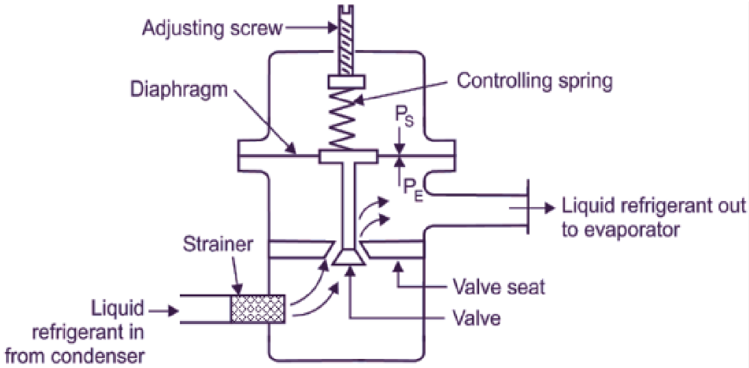

Figure 4.2.2 : Automatic Expansion Valve (AXV)

- An automatic expansion valve (AXV) controls the flow of refrigerant between the condenser and the evaporator in an air conditioning system1. It operates automatically to maintain constant evaporator pressure by controlling the flow of refrigerant2.

- The AXV is a constant pressure regulator. It is designed and constructed to maintain a constant evaporating pressure. The flow of the refrigerant into the evaporator is based on the pressure of the refrigerant in the evaporator.
- As the pressure in the evaporator decreases, the valve opens and allows more refrigerant to flow through it. As the pressure increases, the valve closes and allows less refrigerant to flow through it.

4.2.3. Electronic Expansion Valve (EXV)

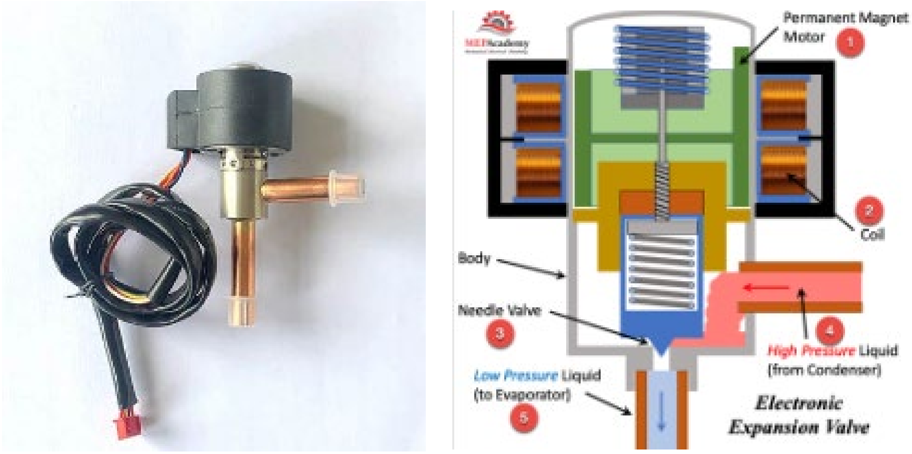

Figure 4.2.3 : Electronic Expansion Valve (EXV)

- basically the function of ETV is the same as other metering devices, control the entry of refrigerant into the evaporator and lower the pressures

- Operates by detecting the temperature (thermistor) placed in the tube after the evaporator to determine whether the quantity of refrigerant is sufficient or not. If it is found that the temperature is still higher than it should be, the EXV will open up more room for the refrigerant to enter the evaporator at a higher rate.

4.2.4. Capillary Tube

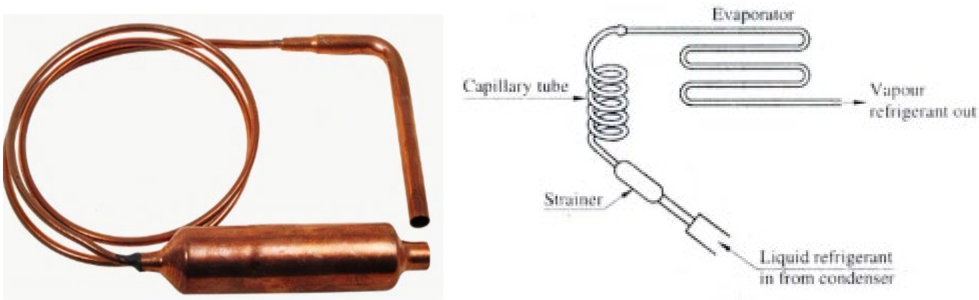

Figure 4.2.4 : Capillary Tube

- Capillary Tube functions to lower the pressure and temperature in the air conditioning and refrigeration system.

- The refrigerant from the condenser enters the capillary tube in the form of a high-pressure liquid.
- The capillary tube will lower the pressure and lower the temperature before the refrigerant enters the evaporator.
- This is the reason for the small capillary tube hole size

4.2.5. Shut Off Valve (Hand Valve)

Figure 4.2.5 : Capillary Tube

- Shut-Off Valves: These valves operate by rotating the spindle. Turning the spindle clockwise closes the valve, while turning it counterclockwise opens it.
- Shut-off valves should always be fully opened (against the backseat) or fully closed (against the valve seat).

4.2.6. Float Valve

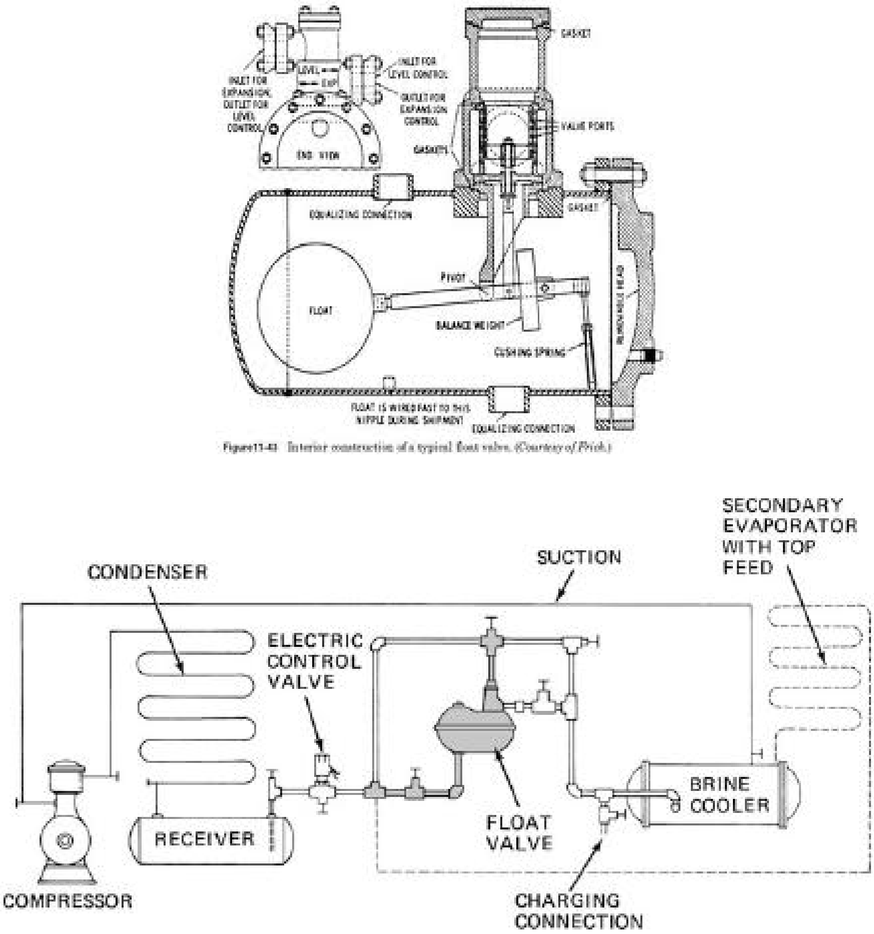

Figure 4.2.6 : Float Valve

- Float Valve is sometimes used to control the level of refrigerant (Fig. 4.2.6). The float valve is mounted on the lever hand mixed in a given point, and is connected to a needle that places at the opening of the valve. If there is no liquid in the evaporator, the ball-lever arm rests to a stop, and the needle is not seated, thus leaving it the valve is open.
- As soon as the liquid refrigerant under pressure compressor enters the float chamber, the float rises with the level of the liquid until, at a given level, needle closes the needle valve opening.
- It is widely used in large systems that require a large amount of refrigerant at one time.

4.3. Fusible Plug (Safety)

- A fusible plug operates as a safety valve when dangerous temperatures are reached in a closed vessel in air conditioning system. Suitable location to install the fusible plug:
- At the system that generates high pressure. It is because the fusible plug is used to release pressure in the system when pressure in the system is higher than the point set.
- A fusible plug is a threaded metal cylinder usually of bronze, brass or gunmetal with a tapered hole drilled completely through its length.
- This hole is sealed with a metal of low melting point that flows away if a pre-determined, high temperature is reached.

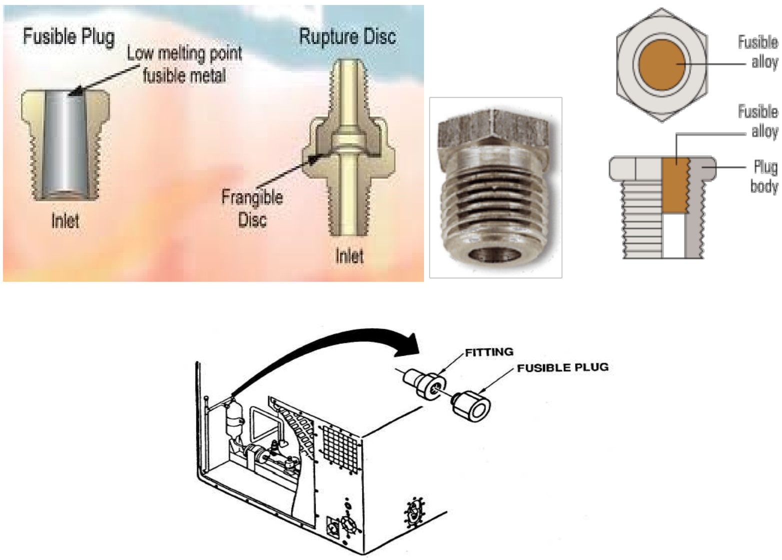

Figure 4.3 : Float Valve

- When the environment or the machinery where the plug is installed experiences temperatures that exceed the alloy's melting point, transforming from solid to liquid.
- This melting action is not just a passive occurrence; it paves the way for a deliberate and strategic venting mechanism. As the alloy melts, it leaves behind a channel within the plug.
- This void now becomes a conduit, facilitating the escape of any pent-up system pressure.

4.4. Pressure Switch

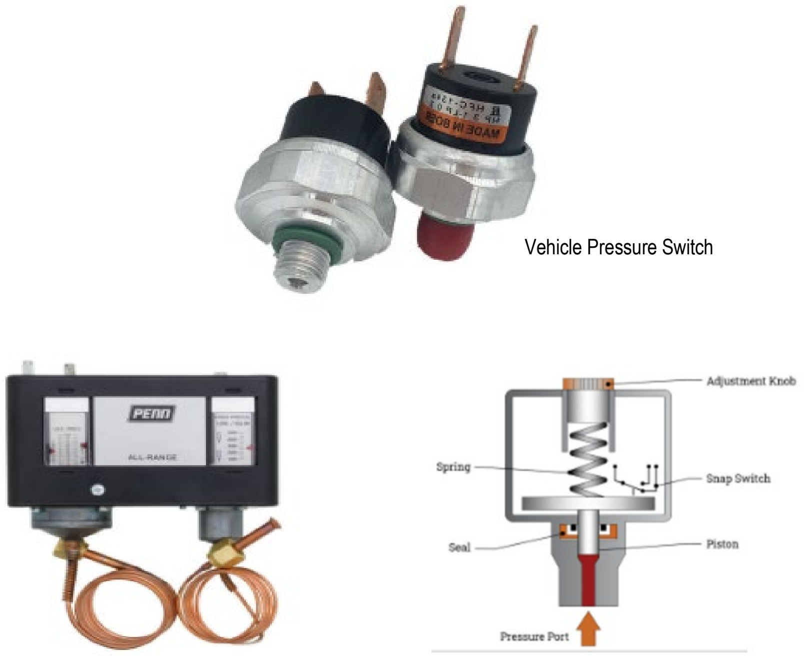

Figure 4.4 : Pressure Switch

- While most refrigeration systems use a thermostat to regulate temperature, an alternative method is a low pressure switch, also called a low pressure control. It works using the relationship between the saturated refrigerant pressure in the evaporator and evaporating temperature.
- This way, the pressure switch can be set to shut off the refrigeration system when the suction pressure returning to the compressor corresponds to the correct evaporating temperature, thereby controlling the temperature of the cooler.
- The pressure switch also works to turn off the power supply to the compressor and condenser fan when the system leaks.
- The high pressure switch position is installed on the high-pressure liquid line after the condenser and before the metering device
- The low pressure switch position is installed on the low-pressure vapor line after the evaporator and before the compressor.

Exercise 1

1. Give the meaning of control in air conditioning and refrigeration system.

2. Express **SIX (6)** benefits of a control related to industrial air conditioning and refrigeration system.

3. List **FOUR (4)** types of refrigerant controls use in air conditioning and refrigeration system.

Answers

SCAN ME

CHECK YOUR UNDERSTANDING

Exercise 2

1. Explain the function and working principle of refrigerant valve state below:-
    i) Thermostatic Expansion Valve (TEV)
    ii) Automatic Expansion Valve (AEV)

2. Categorize **THREE (3)** types of control in air conditioning and refrigeration system and give the example of their uses.

3. Explain the function and working principle of refrigerant valve state below:-
    i) Capillary Tube
    ii) Float Valve

Answers

SCAN ME

CHECK YOUR UNDERSTANDING

Exercise 3

a) Express **FOUR (4)** benefits of a control system in air conditioning and refrigeration system

b) Assign **TWO (2)** types of control devices used in air conditioning and refrigeration system and explain them briefly.

c) Sketch and explain the operation of Thermal-Electric Expansion Valve.

d) Explain **THERE (3)** advantages of thermostatic expansion valve in air conditioning and refrigeration system.

Answers

SCAN ME

CHECK YOUR UNDERSTANDING

Reference

Whitman, W.C., Johnson, W. M., Tomczyk, J.A., & Eugene Silbertein. (2008). Refregeration and air Conditioning Technology (6th Edition). Delmar, Cengage Learning.

Khurmi, R.S. & Gupta, J.K. (2006). A Textbook of Refrigeration and Air Conditioning. S. Chand & Company Ltd.

Haines, R. W. & Hittle, D.C. (2006). Control System For Heating, Ventilating, and Air Conditioning. (6th Edition). Springer.

Mark Schnubel. (2013). **Automotive Heating & Air Conditioning Classroom Manual. (5TH Edition)**. Delmar, Cengage Learning.

Khairuddin, Mohd Zulhairi, Khairol Hisam. (2020). **DJU40152 Refrigerant Handling Module**. Politeknik Ungku Omar.

Hamdan Ali, Shawaludin, Mat Misiah. (1996). **Teknologi Penyejukan dan Penyamanan Udara**. Edusystem Sdn.Bhd.

Air Division (Ozone Protection), Department Of Enviroment. (2014). **Training Manual For Technician in Refrigeration & Air Conditioning Servicing Sector (RACS) (1st Edition)**.. Ministry of Natural Resources & Environment.

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