2024 January

7. (a) With reference to food storage rooms:

(i) state, with reasons, the possible danger present in a room used for storing vegetables and fruit; (2)

(ii) state the devices necessary to prevent a person from becoming trapped in a storage room. (3)

(b) State FOUR methods of detecting a refrigeration gas leak. (4)

(c) State the name of the international agreement which stipulates that the production and consumption of compounds that deplete ozone in the stratosphere is phased out. (1)

Food Storage and Refrigeration Safety

(a) Food Storage Rooms:

(i) Dangers in Vegetable and Fruit Storage:

There's a potential danger of **oxygen depletion** in a room used for storing vegetables and fruit. Here's why:

- **Respiration:** Fruits and vegetables continue to respire (use oxygen) even after harvesting. This process consumes oxygen ($O2$) and releases carbon dioxide ($CO2$).
- **Confined Space:** In a closed storage room, the oxygen level can gradually decrease as fruits and vegetables consume it without proper ventilation.
- **Dangers of Low Oxygen:**
  - **Suffocation:** If the oxygen level in the room falls below a safe level (around 19.5% or lower), a person entering the room could experience suffocation.
  - **Fire Risk:** Low oxygen levels also increase the risk of fire, as combustion requires oxygen.

(ii) Devices to Prevent Trapping:

To prevent a person from becoming trapped in a food storage room, the following devices are essential:

- **Self-Closing Door:** The door should be self-closing to ensure it automatically closes behind someone entering or leaving the room. This prevents accidental latching from the outside.
- **Panic Hardware:** The door should be equipped with panic hardware (e.g., push bar) on the inside to allow for easy exit in case of an emergency.
- **Signage:** Clear signage should be displayed on the door indicating it's a food storage room and may have low oxygen levels.

(b) Refrigeration Gas Leak Detection:

Here are four methods for detecting a refrigeration gas leak:

1. **Gas Detectors:** Specialized gas detectors can be installed in food storage rooms to automatically detect leaks of specific refrigerants. These detectors trigger alarms when they sense a gas concentration exceeding safe limits.

2. **Visual Inspection:** Regular visual inspections of the refrigeration system are crucial. Signs of a leak might include visible damage to pipes, hissing sounds, or frost formation around connection points. 3. **Sniffing (with caution):** While not the most recommended method, some refrigerants have a distinct odor that can be detected during inspections. However, caution is advised, as inhaling some refrigerants can be harmful. Always prioritize using gas detectors and proper ventilation.
3. **Temperature Monitoring:** A sudden increase in storage room temperature or malfunctioning of the refrigeration system could indicate a refrigerant leak.

(c) Ozone Depletion Agreement:

The international agreement that aims to phase out the production and consumption of ozone-depleting substances is the **Montreal Protocol on Substances that Deplete the Ozone Layer**.

june 2021

June 2021

7. (a) State THREE functions of air conditioning. (3)

(b) With referance to air conditioning, explain EACH of the following:

(i) absolute humidity; (2)

(ii) relative humidity; (2)

(iii) dew point. (3)

Air Conditioning and Humidity

(a) Three Functions of Air Conditioning:

Air conditioning systems provide comfort and improve indoor air quality by performing three main functions:

1. **Temperature Control:** Air conditioners remove heat from the indoor air, lowering the temperature to a desired level set by the user. This creates a cooler and more comfortable environment.

2. **Humidity Control:** Many air conditioning systems also control humidity by removing moisture from the air during the cooling process. This dehumidification helps prevent excessive moisture buildup, which can lead to sweating, discomfort, and mold growth.

3. **Air Circulation:** Air conditioners circulate air throughout the room, ensuring even distribution of cool air and preventing hot and cold spots. This promotes a more comfortable and consistent temperature within the space.

(b) Air Conditioning and Humidity Concepts:

(i) Absolute Humidity:

- **Definition:** Absolute humidity refers to the **total amount of water vapor present in a given volume of air**, regardless of temperature.

- **Units:** It is typically measured in grams of water vapor per cubic meter of air (g/m³) or grains of water vapor per pound of dry air (gr/lb).
- **Air Conditioning:** Air conditioners don't directly control absolute humidity. However, by lowering the air temperature, they can affect how much moisture the air can hold (explained in relative humidity).

(ii) Relative Humidity:

- **Definition:** Relative humidity (RH) is a measure of how much **moisture the air currently holds compared to its maximum capacity** at a specific temperature.
- **Units:** It is expressed as a percentage (%).
- **Air Conditioning:** Air conditioning reduces air temperature. Colder air has a lower capacity to hold moisture. As the air cools in an air conditioner, the relative humidity increases. If the RH becomes too high, the air feels muggy and uncomfortable. To address this, some air conditioning systems have dehumidification features that further reduce moisture content and maintain a comfortable relative humidity level.

(iii) Dew Point:

- **Definition:** Dew point is the temperature at which the air becomes saturated with moisture (100% relative humidity). If the air temperature cools down to the dew point, water vapor condenses into visible water droplets, forming dew or fog.
- **Air Conditioning:** Air conditioners lower the air temperature. As the air cools down, it approaches its dew point. By monitoring the dew point, air conditioning systems can regulate dehumidification to prevent condensation on surfaces within the conditioned space. This helps prevent moisture damage and mold growth.

In summary:

- Absolute humidity indicates the total moisture content in the air.
- Relative humidity indicates how close the air is to saturation at a given temperature.
- Dew point is the temperature at which condensation occurs.

Air conditioners influence both relative humidity and dew point by manipulating air temperature. This allows them to create a comfortable and controlled environment.

aug 2020

Aug 2020

7. With reference to refrigeration plants, describe the effects of EACH of the following, stating remedial actions to be taken in EACH case:

(a) undercharge of refrigerant; (3)

(b) air in the system; (3)

(c) water or moisture in the system. (4)

Refrigeration Plant Issues and Solutions

(a) Undercharge of Refrigerant:

- **Effect:**
  - **Reduced System Capacity:** An undercharged system doesn't have enough refrigerant to absorb heat efficiently. This leads to a decrease in the cooling capacity of the refrigeration plant. The desired temperature in the chilled space may not be achieved.
  - **Increased Compressor Workload:** The compressor has to work harder to circulate the limited refrigerant available. This can lead to higher energy consumption and potential compressor overheating.
  - **Suction Line Icing:** In severe cases, the reduced pressure in the suction line due to low refrigerant can cause moisture in the air to freeze, forming ice on the suction line.
- **Remedial Actions:**
  - **Leak Detection and Repair:** The first step is to identify and repair any leaks in the system that may be causing the undercharge.
  - **Refrigerant Charging:** A qualified technician should safely evacuate any non-condensable gases and properly recharge the system with the correct amount and type of refrigerant according to the manufacturer's specifications.
  - **System Monitoring:** Monitor system pressures and temperatures after recharging to ensure proper operation.

(b) Air in the System:

- **Effect:**
  - **Reduced System Efficiency:** Air acts as a non-condensable gas in the system. It occupies space that should be filled with refrigerant, reducing the system's capacity to absorb heat. This can lead to similar issues as an undercharge, such as reduced cooling capacity and increased compressor workload.
  - **System Noises:** Air in the system can cause unusual noises during operation due to turbulence and circulation of the non-condensable gas.
  - **Oil Circulation Issues:** Air can interfere with the proper circulation of lubricating oil for the compressor, potentially leading to wear and tear.
- **Remedial Actions:**
  - **System Evacuation:** A qualified technician should use a vacuum pump to evacuate the air from the system. This is typically done during system commissioning or after repairs that may have introduced air.
  - **Leak Detection and Repair:** Identify and repair any leaks that may be allowing air to enter the system.
  - **Leak Testing:** After evacuation, perform a leak test to ensure the system remains sealed and air-free.

(c) Water or Moisture in the System:

- **Effect:**
  - **System Acidification:** Water can react with the refrigerant and lubricant oil to form acidic byproducts. These acids can corrode system components and shorten their lifespan.
  - **Ice Buildup:** Moisture can freeze in various parts of the system, particularly the expansion valve and evaporator coil, restricting refrigerant flow and reducing cooling capacity.
  - **System Blockage:** Ice formation can potentially block components like the expansion valve, leading to complete system failure.

- **Remedial Actions:**
  - **Moisture Removal:** A qualified technician can use specialized equipment to remove moisture from the system through a process called dehydration. This may involve evacuation, purging with dry air or nitrogen, and the use of desiccants.
  - **Leak Detection and Repair:** Identify and repair any leaks that may be allowing moisture to enter the system. Common sources include leaks around connections or faulty seals.
  - **System Inspection:** Inspect components like the receiver and sight glass for signs of water contamination.
  - **Preventative Maintenance:** Regular system maintenance, including filter changes and oil analysis, can help prevent moisture ingress and system contamination.

feb 2021

Feb 2021

6. (a) Sketch a thermostatically controlled expansion valve for a vapour compression refrigeration system, labelling all components. (5)

   (b) Describe the operation of the valve sketched in part (a). (5)

Thermostatic Expansion Valve (TXV) in Refrigeration Systems

(a) Components of a TXV:

A thermostatic expansion valve (TXV) is a key component in a vapor compression refrigeration system that regulates the flow of refrigerant into the evaporator. Here's a breakdown of its components with labels:

1. **Inlet Port:** Connects to the high-pressure side of the system, where liquid refrigerant enters the TXV.
2. **Diaphragm:** A flexible membrane separates the high-pressure side from the low-pressure side. The pressure difference acts on the diaphragm.
3. **Sensing Bulb:** Located on the outlet pipe of the evaporator. It contains a liquid or gas that expands or contracts with changes in temperature.
4. **Capillary Tube:** Connects the sensing bulb to the underside of the diaphragm. It transmits pressure changes from the sensing bulb to the diaphragm.
5. **Spring:** A pre-tensioned spring counteracts the force exerted by the diaphragm, regulating the valve opening.
6. **Valve Pin:** Controls the flow of refrigerant by opening or closing the orifice.
7. **Orifice:** A small opening that regulates the amount of refrigerant entering the evaporator.
8. **Outlet Port:** Connects to the evaporator inlet, where the controlled flow of refrigerant enters.

(b) Operation of the TXV:

The TXV operates based on the temperature of the refrigerant leaving the evaporator, also known as the **suction temperature** or **superheat**.

1. **Cooling the Evaporator:** As the refrigerant absorbs heat in the evaporator, the temperature of the refrigerant leaving the evaporator (suction temperature) rises.

2. **Sensing Bulb Response:** The sensing bulb, containing a temperature-sensitive liquid or gas, also experiences this temperature rise. This causes the liquid/gas in the bulb to expand.

3. **Pressure Transmission:** The expansion in the sensing bulb transmits pressure through the capillary tube to the underside of the diaphragm in the TXV.

4. **Diaphragm Movement:** The increased pressure from the capillary tube pushes the diaphragm upwards against the spring tension.

5. **Valve Pin Adjustment:** As the diaphragm moves up, it overcomes the spring tension and pushes the valve pin upwards. This opens the orifice, allowing more liquid refrigerant to flow into the evaporator.

6. **Temperature Regulation:** The increased flow of refrigerant helps to maintain the desired suction temperature by absorbing more heat in the evaporator.

7. **Balancing Act:** If the suction temperature continues to rise, the process repeats, allowing more refrigerant flow. Conversely, if the suction temperature falls too low due to excessive refrigerant flow, the pressure in the sensing bulb decreases, and the spring pushes the diaphragm down, closing the valve orifice and reducing refrigerant flow.

This continuous cycle ensures that the TXV maintains a relatively constant superheat (evaporator outlet temperature) by regulating the flow of refrigerant based on the temperature conditions.

sept 2020

Sept 2020

6. With reference to refrigeration plant;

(a) state THREE indications of a loss in refrigerant charge; (3)

(b) state THREE methods of detecting the location of the source of leakage; (3)

(c) describe a safe method of bringing the gas charge back to its normal working level. (4)

Refrigeration Plant: Refrigerant Loss, Leak Detection, and Recharge

(a) Indications of Refrigerant Loss:

Several signs can indicate a loss of refrigerant charge in a refrigeration plant:

1. **Reduced Cooling Capacity:** One of the most noticeable signs is a decrease in the system's ability to achieve and maintain the desired cooling temperature. The chilled space may not reach the set point, or it may take longer to reach the desired temperature.

2. **Increased Compressor Workload and Run Time:** With less refrigerant circulating, the compressor has to work harder to maintain the required cooling effect. This can lead to longer compressor run times, higher energy consumption, and potential overheating of the compressor.

3. **Changes in System Pressures and Temperatures:** Refrigerant loss typically results in changes to the system's pressure and temperature readings. The suction pressure (low pressure side) may be lower than usual, while the discharge pressure (high pressure side) could also be affected. Additionally,

frost patterns on the evaporator coil might become erratic or uneven.

(b) Methods for Leak Detection:

Here are three methods for detecting the location of a refrigerant leak in a refrigeration plant:

1. **Electronic Leak Detectors:** Specialized electronic leak detectors can be used to pinpoint leaks. These devices are sensitive to specific refrigerants and emit an audible or visual signal when they detect a concentration of refrigerant gas above a certain threshold.

2. **Ultrasonic Leak Detection:** This method uses ultrasonic sound waves. Leaks create turbulence in the escaping gas, which can be detected by the ultrasonic equipment. This method can be effective for pinpointing leaks in areas that may be difficult to visually inspect.

3. **Bubble Testing:** A safer method involves applying a soapy water solution to suspected leak areas. If a leak is present, bubbles will form around the leak point due to the escaping gas creating pressure against the soapy water film. This method is relatively simple but may not be effective for all types of leaks or in areas that are difficult to access.

(c) Safe Refrigerant Recharge:

Recharging a refrigeration system with refrigerant should only be done by a qualified technician who is properly trained and equipped to handle refrigerants safely. Here's a breakdown of a safe method for refrigerant recharge:

1. **System Leak Repair:** The first and most important step is to identify and repair the source of the leak. Leaking refrigerant poses environmental and safety risks. Recharging without fixing the leak will only lead to further refrigerant loss.

2. **System Evacuation:** A qualified technician will use a vacuum pump to evacuate the system. This removes any non-condensable gases (like air or moisture) that may have entered the system during the leak or repairs.

3. **Refrigerant Recovery (if applicable):** If any residual refrigerant remains in the system, a technician will use a recovery unit to capture and store it for proper disposal or recycling.

4. **Refrigerant Charging:** Using specialized equipment and following the manufacturer's specifications, the technician will carefully measure and introduce the correct amount and type of refrigerant into the system. Overcharging can be just as detrimental to the system as undercharging.

5. **Leak Monitoring:** After recharging, the technician will monitor the system for leaks and ensure proper system pressures and temperatures are achieved.

Following these steps ensures a safe and effective refrigerant recharge process that minimizes environmental impact and optimizes system performance.

Nov 2020

6. (a) With reference to food storage rooms:

(i) state, with reasons, the possible danger present in a room used for storing vegetables and fruit; (2)

(ii) state the devices necessary to prevent a person from becoming trapped in a storage room. (3)

(b) State FOUR methods of detecting a refrigeration gas leak. (4)

(c) State the name of the international agreement which stipulates that the production and consumption of compounds that deplete ozone in the stratosphere is phased out. (1)

a) Food Storage Rooms:

(i) Danger in Vegetable and Fruit Storage:

There's a potential danger of **oxygen depletion** in a room used for storing vegetables and fruit. Here's why:

- **Respiration:** Fruits and vegetables continue to respire (use oxygen) even after harvesting. This process consumes oxygen (O_2) and releases carbon dioxide (CO_2).
- **Confined Space:** In a closed storage room, the oxygen level can gradually decrease as fruits and vegetables consume it without proper ventilation.
- **Dangers of Low Oxygen:**
  - **Suffocation:** If the oxygen level in the room falls below a safe level (around 19.5% or lower), a person entering the room could experience suffocation.
  - **Fire Risk:** Low oxygen levels also increase the risk of fire, as combustion requires oxygen.

(ii) Devices to Prevent Trapping:

To prevent a person from becoming trapped in a food storage room, the following devices are essential:

- **Self-Closing Door:** The door should be self-closing to ensure it automatically closes behind someone entering or leaving the room. This prevents accidental latching from the outside.
- **Panic Hardware:** The door should be equipped with panic hardware (e.g., push bar) on the inside to allow for easy exit in case of an emergency.
- **Signage:** Clear signage should be displayed on the door indicating it's a food storage room and may have low oxygen levels.

(b) Refrigeration Gas Leak Detection:

Here are four methods for detecting a refrigeration gas leak:

1. **Gas Detectors:** Specialized gas detectors can be installed in food storage rooms to automatically detect leaks of specific refrigerants. These detectors trigger alarms when they sense a gas concentration exceeding safe limits.
2. **Visual Inspection:** Regular visual inspections of the refrigeration system are crucial. Signs of a leak might include visible damage to pipes, hissing sounds, or frost formation around connection points. 3. **Sniffing (with caution):** While not the most recommended method, some refrigerants have a distinct

odor that can be detected during inspections. However, caution is advised, as inhaling some refrigerants can be harmful. Always prioritize using gas detectors and proper ventilation.

3. **Temperature Monitoring:** A sudden increase in storage room temperature or malfunctioning of the refrigeration system could indicate a refrigerant leak.

(c) Ozone Depletion Agreement:

The international agreement that aims to phase out the production and consumption of ozone-depleting substances is the **Montreal Protocol on Substances that Deplete the Ozone Layer**.

march 2021

March 21

5. With reference to safe storage and handling of refrigerant:

(a) state where the refrigerant gas bottles should be stored; (2)

(b) state the weakest part of the storage bottle; (1)

(c) explain how it can be determined if refrigerant has been leaking from gas bottles; (1)

(d) state the TWO methods of recharging a refrigeration system, stating where the connection to the system should be made for EACH method; (4)

(e) state how excessive refrigerant should be removed from the system without infringing MARPOL regulations. (2)

Safe Storage and Handling of Refrigerant

(a) Refrigerant Storage Location:

Refrigerant gas bottles should be stored in a cool, well-ventilated area that is:

- **Dry:** Moisture can cause corrosion of the bottle and valves.
- **Out of direct sunlight:** Exposure to heat can increase pressure inside the bottle and pose a safety risk.
- **Away from heat sources:** Keep them away from boilers, furnaces, or any source of ignition.
- **Secured:** Store them upright and secured with straps or chains to prevent them from falling or tipping over.

(b) Weakest Part of the Storage Bottle:

The weakest part of a refrigerant storage bottle is typically the **valve assembly**. This is where the pressure gauge and charging hose connect. The valve components like the stem and threads are susceptible to damage if mishandled.

(c) Detecting Leaks from Refrigerant Bottles:

Here are some ways to determine if refrigerant has been leaking from a gas bottle:

- **Visual Inspection:** Look for signs of physical damage to the valve assembly, like cracks or loose connections.
- **Hissing Sounds:** A persistent hissing sound coming from the valve area may indicate a leak.

- **Weight Discrepancy:** If a certified weighbridge is available, compare the bottle's weight to the tare weight (empty weight) marked on the bottle. A significant weight difference could indicate refrigerant loss.
- **Electronic Leak Detectors:** Specialized detectors can be used to identify leaks around the valve area.

(d) Refrigeration System Recharging Methods:

There are two main methods for recharging a refrigeration system:

1. **Liquid Line Charging:** This method involves injecting liquid refrigerant directly into the **liquid line** of the system. The connection point is usually located on the **high-pressure side** of the system, after the condenser and before the filter drier. This method requires careful monitoring of system pressures and temperatures to avoid overcharging.

2. **Vapor Line Charging:** This method involves injecting refrigerant in its vapor state into the **suction line** of the system. The connection point is usually located on the **low-pressure side** of the system, just before the compressor inlet. This method is generally slower but reduces the risk of overcharging the system.

(e) Removing Excess Refrigerant (Complying with MARPOL):

Removing excess refrigerant from a refrigeration system must comply with MARPOL regulations to prevent environmental pollution. Here's how to do it safely and legally:

- **Recovery and Recycling:** The most recommended approach is to use a certified technician with specialized equipment to recover and recycle the excess refrigerant. This ensures proper handling and avoids releasing harmful refrigerants into the atmosphere.

- **Recovery for Disposal (as a last resort):** If recycling is not possible, the refrigerant may be recovered for disposal at a licensed facility that adheres to MARPOL regulations. This disposal process ensures safe handling and destruction of the refrigerant according to environmental standards.

Important Note: Never attempt to release refrigerant directly into the atmosphere. This is a violation of MARPOL regulations and can be harmful to the environment.

april 2021

April 2021

7. (a) State THREE functions of air conditioning. (3)

(b) With referance to air conditioning, explain EACH of the following:

(i) absolute humidity; (2)

(ii) relative humidity; (2)

(iii) dew point. (3)

Air Conditioning and Humidity

(a) Three Functions of Air Conditioning:

Air conditioning systems provide comfort and improve indoor air quality by performing three main functions:

1. **Temperature Control:** Air conditioners remove heat from the indoor air, lowering the temperature to a desired level set by the user. This creates a cooler and more comfortable environment.

2. **Humidity Control:** Many air conditioning systems also control humidity by removing moisture from the air during the cooling process. This dehumidification helps prevent excessive moisture buildup, which can lead to sweating, discomfort, and mold growth.

3. **Air Circulation:** Air conditioners circulate air throughout the room, ensuring even distribution of cool air and preventing hot and cold spots. This promotes a more comfortable and consistent temperature within the space.

(b) Air Conditioning and Humidity Concepts:

(i) Absolute Humidity:

- **Definition:** Absolute humidity refers to the **total amount of water vapor present in a given volume of air**, regardless of temperature.
- **Units:** It is typically measured in grams of water vapor per cubic meter of air (g/m^3) or grains of water vapor per pound of dry air (gr/lb).
- **Air Conditioning:** Air conditioners don't directly control absolute humidity. However, by lowering the air temperature, they can affect how much moisture the air can hold (explained in relative humidity).

(ii) Relative Humidity (RH):

- **Definition:** Relative humidity (RH) is a measure of how much **moisture the air currently holds compared to its maximum capacity** at a specific temperature.
- **Units:** It is expressed as a percentage (%).
- **Air Conditioning:** Air conditioning reduces air temperature. Colder air has a lower capacity to hold moisture. As the air cools in an air conditioner, the relative humidity increases. If the RH becomes too high, the air feels muggy and uncomfortable. To address this, some air conditioning systems have dehumidification features that further reduce moisture content and maintain a comfortable relative humidity level.

(iii) Dew Point:

- **Definition:** Dew point is the temperature at which the air becomes saturated with moisture (100% relative humidity). If the air temperature cools down to the dew point, water vapor condenses into visible water droplets, forming dew or fog.
- **Air Conditioning:** Air conditioners lower the air temperature. As the air cools down, it approaches its dew point. By monitoring the dew point, air conditioning systems can regulate dehumidification to prevent condensation on surfaces within the conditioned space. This helps prevent moisture damage and mold growth.

In summary:

- Absolute humidity indicates the total moisture content in the air.
- Relative humidity indicates how close the air is to saturation at a given temperature.
- Dew point is the temperature at which condensation occurs.

Air conditioners influence both relative humidity and dew point by manipulating air temperature. This allows them to create a comfortable and controlled environment.

aug 2023

AUG 2023

6. With reference to refrigeration plant;

(a) state THREE indications of a loss in refrigerant charge; (3)

(b) state THREE methods of detecting the location of the source of leakage; (3)

(c) describe a safe method of bringing the gas charge back to its normal working level. (4)

Refrigeration Plant: Refrigerant Loss and Recharge

(a) Indications of Refrigerant Loss:

Several signs can indicate a loss of refrigerant charge in a refrigeration plant:

1. **Reduced Cooling Capacity:** One of the most noticeable signs is a decrease in the system's ability to achieve and maintain the desired cooling temperature. The chilled space may not reach the set point, or it may take longer to reach the desired temperature.

2. **Increased Compressor Workload and Run Time:** With less refrigerant circulating, the compressor has to work harder to maintain the required cooling effect. This can lead to longer compressor run times, higher energy consumption, and potential overheating of the compressor.

3. **Changes in System Pressures and Temperatures:** Refrigerant loss typically results in changes to the system's pressure and temperature readings. The suction pressure (low pressure side) may be lower than usual, while the discharge pressure (high pressure side) could also be affected. Additionally, frost patterns on the evaporator coil might become erratic or uneven.

(b) Leak Detection Methods:

Here are three methods for detecting the location of a refrigerant leak in a refrigeration plant:

1. **Electronic Leak Detectors:** Specialized electronic leak detectors can be used to pinpoint leaks. These devices are sensitive to specific refrigerants and emit an audible or visual signal when they detect a concentration of refrigerant gas above a certain threshold.

2. **Ultrasonic Leak Detection:** This method uses ultrasonic sound waves. Leaks create turbulence in the escaping gas, which can be detected by the ultrasonic equipment. This method can be effective for pinpointing leaks in areas that may be difficult to visually inspect.

3. **Bubble Testing:** A safer method involves applying a soapy water solution to suspected leak areas. If a leak is present, bubbles will form around the leak point due to the escaping gas creating pressure against the soapy water film. This method is relatively simple but may not be effective for all types of leaks or in areas that are difficult to access.

(c) Safe Refrigerant Recharge:

Recharging a refrigeration system with refrigerant should only be done by a qualified technician who is properly trained and equipped to handle refrigerants safely. Here's a breakdown of a safe method for refrigerant recharge:

1. **System Leak Repair:** The first and most important step is to identify and repair the source of the leak. Leaking refrigerant poses environmental and safety risks. Recharging without fixing the leak will only lead to further refrigerant loss.

2. **System Evacuation:** A qualified technician will use a vacuum pump to evacuate the system. This removes any non-condensable gases (like air or moisture) that may have entered the system during the leak or repairs.

3. **Refrigerant Recovery (if applicable):** If any residual refrigerant remains in the system, a technician will use a recovery unit to capture and store it for proper disposal or recycling.

4. **Refrigerant Charging:** Using specialized equipment and following the manufacturer's specifications, the technician will carefully measure and introduce the correct amount and type of refrigerant into the system. Overcharging can be just as detrimental to the system as undercharging.

5. **Leak Monitoring:** After recharging, the technician will monitor the system for leaks and ensure proper system pressures and temperatures are achieved.

Following these steps ensures a safe and effective refrigerant recharge process that minimizes environmental impact and optimizes system performance.

oct 2020

30 October 2020

6. With reference to refrigeration systems:

   (a) state the THREE basic principles of refrigeration; (3)

   (b) sketch a direct expansion free standing mechanical refrigeration system, labelling the MAIN components and indicating where EACH of the three principles stated in part (a) occurs. (7)

Refrigeration System Basics

(a) Three Basic Principles of Refrigeration:

1. **Energy Transfer:** Refrigeration doesn't create cold, it removes heat. The system works by transferring heat from a colder space (like the inside of a refrigerator) to a hotter space (usually the surrounding room).
2. **Phase Change:** The system utilizes a refrigerant, a substance that can easily change its state between liquid and gas. During this phase change, the refrigerant absorbs and releases heat.
3. **Work Input:** To continuously move the heat, the system requires an external energy source, typically electricity, to power a compressor.

(b) Direct Expansion System Breakdown:

A direct expansion (DX) system is a common type of mechanical refrigeration used in refrigerators and air conditioners. Here's a breakdown of its main components and where the three principles come into play:

- **Compressor:** This is the heart of the system. It's a pump that increases the pressure of the refrigerant vapor (gas). **(Principle 3: Work Input)**
- **Condenser:** The hot, high-pressure gas from the compressor enters the condenser. Here, the refrigerant releases heat to the surrounding air (usually through coils with a fan) and condenses back into a liquid. **(Principle 1: Energy Transfer)**
- **Expansion Valve (Capillary Tube in some systems):** This valve reduces the pressure of the liquid refrigerant. As the pressure drops, the refrigerant rapidly expands and cools down. **(Principle 2: Phase Change)**
- **Evaporator:** The cold, low-pressure liquid enters the evaporator. Here, the refrigerant absorbs heat from the space being cooled (like the inside of a refrigerator) as it evaporates (turns back into gas). This absorbed heat is then carried back to the compressor to start the cycle again. **(Principle 1: Energy Transfer & Principle 2: Phase Change)**

In summary:

- The compressor uses electricity to pressurize the refrigerant. (Principle 3)
- In the condenser, the hot, high-pressure gas releases heat to the surrounding air, turning back into liquid. (Principle 1)
- The expansion valve reduces pressure, causing the refrigerant to cool down as it expands. (Principle 2)
- In the evaporator, the cold liquid refrigerant absorbs heat from the space being cooled as it evaporates. (Principle 1 & 2)
- This cycle continuously repeats, transferring heat from the cold space to the hot space.

jan 2021

29 January 2021

6. (a) Sketch a vapour compression refrigeration system, labelling the main components. (5)

(b) Indicate the refrigerant conditions at the salient points on the sketch in part(a). (5)

Vapor Compression Refrigeration System

(a) Main Components:

A vapor compression refrigeration system is the most widely used method for air conditioning and refrigeration. It works by circulating a refrigerant through four main components:

1. **Compressor:** Acts as a pump, increasing the pressure and temperature of the refrigerant vapor.
2. **Condenser:** A heat exchanger where the high-pressure hot refrigerant vapor releases heat to the surrounding environment, typically air or water. This process condenses the refrigerant back into a liquid state.
3. **Expansion Valve (or Capillary Tube):** Also known as a throttle valve, this device reduces the pressure of the liquid refrigerant. This pressure reduction causes a drop in temperature.
4. **Evaporator:** Another heat exchanger where the low-pressure, cool liquid refrigerant absorbs heat from the space being cooled, causing it to evaporate (transform into a gas).

(b) Refrigerant Conditions:

- **Compressor Inlet:** Low pressure, low temperature (vapor)
- **Compressor Outlet:** High pressure, high temperature (vapor)
- **Condenser Outlet:** High pressure, moderate temperature (liquid)
- **Expansion Valve Outlet:** Low pressure, low temperature (liquid)
- **Evaporator Outlet:** Low pressure, low temperature (vapor)

may 2021

May 2021

7. (a) State FIVE properties of a refrigeration oil. (5)

   (b) Describe the operation of an Oil Separator in a refrigeration system. (5)

Refrigeration Oil Properties

(a) Five Key Properties:

1. **Viscosity:** Refrigeration oil needs to maintain a proper viscosity across a wide temperature range. It must be thin enough to flow freely at low temperatures (during system startup) and thick enough to provide adequate lubrication at high compression temperatures.
2. **Miscibility:** The oil should be miscible (easily mix) with the refrigerant used in the system. This ensures good circulation and heat transfer within the compressor.
3. **Thermal and Chemical Stability:** The oil must resist breakdown due to high temperatures and pressure within the system. It should also be chemically stable to prevent unwanted reactions with the refrigerant or compressor materials.
4. **Hygroscopic性 (xìng) (xìng):** (Hygroscopicity) The oil should have low water absorption. Water contamination can lead to ice formation in the system, impacting performance and causing potential damage.
5. **Non-foaming:** The oil should not form excessive foam during operation. Foam can reduce lubrication efficiency and hinder heat transfer.

(b) Oil Separator Operation:

An oil separator is a component found in some refrigeration systems, particularly those with large compressors or using specific refrigerants. Its function is to remove excess oil from the refrigerant vapor leaving the evaporator before it reaches the compressor.

Here's how it works:

- The oil-refrigerant mixture exits the evaporator.
- The separator uses various methods (like centrifugal force, baffles, or mesh screens) to separate the oil from the refrigerant vapor due to their different densities.
- The separated oil is then returned to the crankcase of the compressor for proper lubrication.
- The oil-free refrigerant vapor continues to the compressor inlet.

Benefits of using an Oil Separator:

- Reduces oil circulation in the system, improving system efficiency.
- Prevents oil accumulation in the condenser, which can hinder heat transfer.

- Protects the compressor from excessive oil dilution, which can affect lubrication and wear properties.