March 2024

6. With reference to air conditioning systems, state the meaning of EACH of the following terms:

(a) heating load; (1)

(b) cooling load; (1)

(c) sensible heat; (2)

(d) latent heat; (2)

(e) absolute humidity; (2)

(f) specific humidity. (2)

Air Conditioning Terminology: Understanding Heating and Cooling Needs

In the context of air conditioning systems, these terms define various aspects of heat transfer and moisture content in air:

(a) Heating Load:

The heating load refers to the amount of heat **required** to maintain a desired temperature within a conditioned space during colder periods. This heat compensates for heat loss from the space due to factors like conduction (through walls and windows), convection (air movement), and radiation. Air conditioners can sometimes be used in reverse cycle mode to provide heating in addition to cooling.

(b) Cooling Load:

The cooling load refers to the amount of heat that needs to be **removed** from a conditioned space to maintain a desired temperature during warmer periods. This heat gain comes from various sources like:

- **External heat gain:** Heat entering the space through walls, windows, and roofs due to solar radiation.

- **Internal heat gain:** Heat generated within the space due to occupants, equipment, lighting, and appliances.
- **Ventilation:** Heat introduced by introducing outdoor air for ventilation purposes.

The air conditioning system is sized based on the maximum cooling load it needs to handle.

(c) Sensible Heat:

Sensible heat refers to the thermal energy that results in a **change in temperature** of a substance (air, in this case) without a change in its state (i.e., not causing a phase change from liquid to vapor or vice versa). When we feel warmer or cooler, we are primarily sensing changes in sensible heat.

(d) Latent Heat:

Latent heat refers to the thermal energy absorbed or released during a **change of state** of a substance. In air conditioning, latent heat is associated with the **evaporation** (absorbing heat) or **condensation** (releasing heat) of water vapor in the air. Dehumidification processes involve removing latent heat by condensing water vapor from the air.

(e) Absolute Humidity:

Absolute humidity refers to the **total mass of water vapor** present in a given volume of air. It is expressed in units like grams of water vapor per cubic meter of air (g/m^3). A higher absolute humidity indicates more moisture content in the air.

(f) Specific Humidity:

Specific humidity refers to the **mass of water vapor per unit mass of dry air**. It is expressed in units like grams of water vapor per kilogram of dry air (g/kg). Specific humidity is a more intensive property compared to absolute humidity, as it represents the moisture content relative to the dry air itself.

June 2023

5. (a) State THREE types of damper that may be used to control the airflow in an air conditioning system. (3)

(b) Describe, with the aid of a sketch, an automatic fire damper installed in a vertical air duct or in those that pass through bulkheads designated as fire boundaries. (7)

Air Conditioning Dampers and Fire Safety

(a) Three Types of Dampers for Airflow Control:

1. **Blade Dampers:** These are the most common type. They consist of a metal blade that pivots within the duct to regulate airflow. The blade angle can be manually adjusted or controlled by a motor for automated operation.
2. **Butterfly Dampers:** These resemble a butterfly valve, with a disc-shaped metal plate rotating on a central axis within the duct. The disc position controls the amount of airflow through the duct. They are often used for complete shutoff or to regulate high-pressure airflow.
3. **Volume Control Dampers (VCDs):** These are specially designed dampers that maintain a constant air pressure throughout the duct system regardless of the damper position. They are particularly useful for balancing airflow in complex duct networks.

(b) Automatic Fire Damper in Air Ducts:

An automatic fire damper is a crucial safety device installed in air conditioning systems to prevent the spread of fire and smoke through ventilation ducts. They are typically located:

- **Vertical air ducts:** These are vertical shafts within the building that carry conditioned air to different floors. Fire dampers are installed at regular intervals along the vertical duct to isolate any fire section.
- **Ducts passing through bulkheads designated as fire boundaries:** Bulkheads are vertical walls within a building that can act as fire barriers. Fire dampers are installed where air ducts penetrate these fire-rated bulkheads to prevent flames and smoke from traveling through the duct system to other compartments.

Functioning of a Fire Damper:

- **Normal Operation:** During normal operation, the fire damper blade remains open, allowing conditioned air to flow freely through the duct.
- **Fire Detection:** When a fire is detected (through heat sensors or smoke detectors), a signal is sent to a fusible link or electrical mechanism connected to the damper blade.
- **Automatic Closure:** The fusible link melts or the electrical mechanism activates, causing the damper blade to automatically close and seal the duct opening. This isolates the fire and smoke within the affected zone, preventing them from spreading to other parts of the building through the ductwork.

Importance of Fire Dampers:

Fire dampers play a vital role in building safety by:

- **Compartmentalization:** They compartmentalize the building by isolating fire and smoke within a specific zone, preventing them from traveling through the ventilation system.
- **Life Safety:** By containing the fire and smoke, fire dampers help protect occupants by providing them with more time to evacuate safely.
- **Reduced Property Damage:** Limiting the spread of fire and smoke minimizes damage to unaffected areas of the building.

Note: Fire dampers require regular inspection and maintenance to ensure they function properly in case of a fire emergency.

March 2021

March 2021

5. Describe, with the aid of a sketch, how the relative humidity may be controlled in an Air Conditioning System. (10)

Air conditioning systems can control relative humidity through a combination of dehumidification and humidification processes. Here's how:

Dehumidification (Moisture Removal):

- **Cooling and Condensation:** The most common method utilizes the air conditioner's cooling cycle. As warm, humid air passes over the cold evaporator coil, the moisture condenses on the coil due to the lower dew point temperature. This condensed water is then drained away, effectively removing moisture from the air and reducing its relative humidity.
- **Desiccant Dehumidification:** This method uses a desiccant material (a moisture-absorbing substance) to attract and hold water vapor from the air. The desiccant is then regenerated by heating it, releasing the captured moisture and allowing it to be reused. This method is typically used in specialized applications or when very low humidity levels are required.

Humidification (Moisture Addition):

In some cases, particularly in dry climates, air conditioning can lead to excessively dry air, which can be uncomfortable and cause health problems. To address this, humidification strategies can be employed:

- **Steam Humidifiers:** These devices boil water to create steam, which is then released into the air, increasing the moisture content.
- **Evaporative Humidifiers:** These work by passing dry air through a water-saturated filter. As the air passes through, it absorbs moisture, increasing the relative humidity.

Controlling Humidity Levels:

- **Humidistats:** These are control devices similar to thermostats but for humidity. They sense the relative humidity in the air and send signals to the air conditioning system to activate dehumidification or humidification processes as needed to maintain a desired humidity level.
- **Integrated Systems:** Modern air conditioning systems may have built-in dehumidification and humidification capabilities. These systems can automatically adjust both temperature and humidity based on user settings and sensor readings.

Choosing the Right Method:

The specific method used for humidity control depends on several factors, including:

- **Desired indoor climate:** Target comfort levels and any specific humidity requirements.
- **Climate:** Whether the primary concern is removing moisture (humid climates) or adding moisture (dry climates).
- **System capabilities:** The features and functionalities of the air conditioning system.

By employing these methods and controls, air conditioning systems can effectively maintain comfortable and healthy indoor environments by regulating both temperature and relative humidity.

April 2021

April 2021

5. (a) State THREE types of damper that may be used to control the airflow in an air conditioning system. (3)

(b) Describe, with the aid of a sketch, an automatic fire damper installed in a vertical air duct or in those that pass through bulkheads designated as fire boundaries. (7)

You've provided a great explanation of air conditioning dampers and fire safety! Here's the information again for easy reference:

(a) Three Types of Dampers for Airflow Control:

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2. **Butterfly Dampers:** These resemble a butterfly valve, with a disc-shaped metal plate rotating on a central axis within the duct. The disc position controls the amount of airflow through the duct. They are often used for complete shutoff or to regulate high-pressure airflow.
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Fire dampers play a vital role in building safety by:

- **Compartmentalization:** They compartmentalize the building by isolating fire and smoke within a specific zone, preventing them from traveling through the ventilation system.
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Note: Fire dampers require regular inspection and maintenance to ensure they function properly in case of a fire emergency.

March 2021

March 2021

4. Describe, with the aid of a sketch, a Direct Expansion Regrigeration System for an air cooler in an air conditioning installation. (10)

In an air conditioning system, a Direct Expansion (DX) refrigeration system plays a critical role in cooling air for an air cooler. Here's how it works:

Components:

- **Compressor:** The heart of the system, it compresses low-pressure, low-temperature refrigerant vapor into a high-pressure, high-temperature gas.

- **Condenser:** A heat exchanger where the hot, high-pressure refrigerant gas releases its heat to the surrounding air (air-cooled condenser) or water (water-cooled condenser). During this process, the refrigerant condenses back into a liquid state.
- **Expansion Valve (or Throttling Device):** This valve regulates the pressure of the refrigerant. As the high-pressure liquid refrigerant passes through the expansion valve, it experiences a sudden pressure drop. This pressure drop causes the refrigerant to partially vaporize (flashing) and its temperature to decrease significantly.
- **Evaporator Coil:** Another heat exchanger located within the air cooler unit. The low-pressure, cold refrigerant liquid from the expansion valve absorbs heat from the warm, humid air passing over the evaporator coil. This absorbed heat causes the refrigerant to evaporate completely and turn back into a gas. The cooled air is then distributed throughout the conditioned space.
- **Piping:** Connects all the components, allowing the refrigerant to circulate through the closed-loop system.

The Cycle:

1. **Compression:** The compressor draws in low-pressure refrigerant vapor from the evaporator coil. It then compresses the vapor, increasing its pressure and temperature.
2. **Condensation:** The hot, high-pressure refrigerant gas enters the condenser. Here, the refrigerant releases its heat to the surrounding air (or water) through the condenser coils. As it loses heat, the refrigerant condenses back into a high-pressure liquid state.
3. **Expansion:** The high-pressure liquid refrigerant passes through the expansion valve. The sudden pressure drop causes the liquid to partially vaporize (flashing) and its temperature to decrease significantly. This creates a cold liquid-vapor mixture.
4. **Evaporation:** The cold refrigerant mixture enters the evaporator coil within the air cooler. Warm, humid air is drawn across the evaporator coil by a fan. The refrigerant absorbs heat from the air, causing it to cool down. The cooled air is then distributed through the ductwork to the conditioned space.
5. **Repeat:** The low-pressure, low-temperature refrigerant vapor from the evaporator is then drawn back into the compressor, and the cycle repeats continuously.

Benefits of DX Systems for Air Coolers:

- **Simple and Compact:** DX systems have a relatively simple design with fewer components compared to other cooling systems. This makes them compact and easier to integrate into air cooler units.
- **Efficient:** DX systems can be quite efficient in terms of energy consumption, especially when compared to chilled water systems.
- **Zonal Cooling:** Individual air coolers with DX systems allow for more control over temperature in different zones of a building.

Overall, Direct Expansion refrigeration systems offer a reliable and efficient solution for cooling air in air conditioning installations.

June 2021

June 2021

5. Explain, with the aid of a sketch, the procedure for *vapour* re-charging of a refrigeration plant. (10)

Recharging Refrigerant in a Refrigeration Plant: A Step-by-Step Guide

Recharging refrigerant in a refrigeration plant is a critical process that requires careful attention to safety protocols and proper procedures. Here's a breakdown of the steps involved:

Preparation:

1. **Safety First: Personal protective equipment (PPE) like safety glasses, gloves, and respiratory protection (if required by the specific refrigerant) must be worn throughout the process. Ensure proper ventilation in the workspace to avoid refrigerant inhalation.**
2. **System Diagnosis: Before recharging, identify and rectify any leaks in the system. A leak detection process using electronic leak detectors or tracer gases is crucial. Repair all leaks to prevent future loss of refrigerant and ensure efficient operation.**
3. **System Evacuation: The refrigeration system needs to be evacuated thoroughly to remove any non-condensable gases (air, moisture) that may be present. Utilize a vacuum pump specifically designed for refrigerant systems. The target vacuum level will depend on the specific refrigerant used but typically reaches below 500 microns (micrometers of mercury). Monitor the vacuum gauge to ensure a good level of evacuation is achieved.**
4. **Refrigerant Recovery (Optional): If the existing refrigerant needs to be replaced or if significant amounts have leaked out, a refrigerant recovery unit should be used to capture and store the existing refrigerant. This recovered refrigerant may be reused after proper cleaning and analysis, following environmental regulations.**

Recharging Process:

1. **Refrigerant Selection: Use the specific refrigerant type designed for the refrigeration plant. Refer to the manufacturer's recommendations and ensure the refrigerant matches the system's design.**
2. **Weighing and Charging: Utilize a calibrated refrigerant charging scale to accurately measure the amount of refrigerant being added. Never charge by guesswork or rely solely on pressure gauges.**
3. **Manifold Gauge Set: Connect a manifold gauge set with hoses to the service ports on the refrigeration system. This allows monitoring of suction and discharge pressures during the charging process.**
4. **Gradual Charging: Open the service valve on the refrigerant cylinder slightly and slowly introduce the refrigerant into the system while monitoring the pressure gauges and weighing the refrigerant added. Refer to the manufacturer's charging chart or system specifications for the target charge amount.**

5. **Superheat Monitoring: Superheat is the temperature difference between the saturated refrigerant vapor temperature at the evaporator outlet and the actual suction line temperature. Monitor the superheat value using a temperature probe placed on the suction line. The target superheat value depends on the specific system and operating conditions. Maintaining the correct superheat ensures optimal system performance and prevents liquid refrigerant from entering the compressor.**
6. **System Monitoring: Continuously monitor the system's operation during the charging process. Observe pressure gauges, temperatures, and listen for any abnormal noises. Ensure the system operates within the manufacturer's recommended pressure and temperature ranges.**

Completion and Verification:

1. **Leak Check: Once the target refrigerant charge is reached based on weight and superheat, re-check for leaks using a leak detector. Ensure there are no refrigerant leaks after the system has been charged.**
2. **System Performance Verification: Run the refrigeration system and verify its performance. Check for proper cooling capacity, adequate dehumidification (if applicable), and normal operating temperatures and pressures.**
3. **Documentation: Record the type and amount of refrigerant added, the date of service, and any observations made during the process. Maintain proper documentation for future reference and regulatory compliance.**

Important Considerations:

- **Refrigerant Regulations: Be aware of and comply with local and national regulations regarding refrigerant handling, use, and disposal. Some refrigerants may require specific licensing or certifications for handling.**
- **Environmental Responsibility: Minimize refrigerant releases into the atmosphere. Recover and reuse refrigerants whenever possible.**
- **Professional Service: For complex systems or if unsure about the process, consider seeking assistance from a qualified refrigeration technician to ensure safe and proper recharging.**

By following these steps and adhering to safety precautions, you can effectively recharge the refrigerant in your refrigeration plant.

Sept 2021

Sept 2021

5. (a) List FOUR reasons for a refrigeration compressor to stop unexpectedly, after running for a short period. (4)

(b) Describe the faults which lead to TWO of the reasons for the stoppage, listed in part (a). (6)

Refrigeration Compressor Unexpected Stoppage: Reasons and Faults

(a) Four Reasons for Unexpected Compressor Stoppage:

1. **Electrical Faults:**
   - **Issues like tripped circuit breakers, blown fuses, or internal motor malfunctions can interrupt power supply to the compressor, causing it to stop unexpectedly.**
2. **Low Suction Pressure:**
   - **If the pressure on the suction side of the compressor drops below a certain level, it may activate a safety mechanism to prevent damage. This could be due to factors like a refrigerant leak, clogged suction line, or malfunctioning expansion valve.**
3. **High Discharge Pressure:**
   - **Conversely, excessively high pressure on the discharge side can also trigger a safety shutdown to protect the compressor. This might be caused by a dirty condenser coil, a blocked capillary tube (in some systems), or a faulty pressure relief valve.**
4. **Overload Protection:**
   - **Modern compressors often have built-in overload protection that cuts off power if the motor gets too hot. This can be caused by excessive load on the compressor due to high ambient temperatures, insufficient airflow over the condenser, or internal mechanical issues.**

(b) Description of Faults for Two Reasons:

1. Low Suction Pressure:

- **Possible Faults:**
  - **Refrigerant Leak: A leak in the refrigerant line allows the refrigerant to escape, reducing the pressure in the system and causing the compressor to shut down on low suction pressure. Identifying and repairing the leak is crucial before restarting the system.**
  - **Clogged Suction Line: A blockage in the suction line due to debris or ice buildup restricts the flow of refrigerant, leading to a drop in suction pressure and compressor stoppage. The blockage needs to be located and cleared to restore proper flow.**
  - **Malfunctioning Expansion Valve: A faulty expansion valve can over-expand the refrigerant, causing too much liquid refrigerant to enter the evaporator. This can lead to insufficient suction pressure and compressor shutdown. The expansion valve may need to be repaired or replaced.**

2. High Discharge Pressure:

- **Possible Faults:**
  - **Dirty Condenser Coil: Dust, dirt, or debris accumulated on the condenser coil reduces its ability to dissipate heat effectively. This causes the discharge pressure to rise, leading to compressor shutdown on high-pressure protection.**

The condenser coil needs to be cleaned thoroughly to ensure proper heat rejection.

- **Blocked Capillary Tube (in some systems): A capillary tube is a small-diameter tube used in some refrigeration systems to meter the flow of refrigerant. A blockage within the capillary tube restricts the flow of refrigerant, leading to a rise in discharge pressure and compressor shutdown. The capillary tube may need to be replaced.**

Note: These are just a few examples, and the specific cause of the compressor stoppage will depend on the individual refrigeration system and its operating conditions. A qualified technician can diagnose the exact fault and recommend the appropriate repair or replacement action.

Sept 2021

Sept 2021

6. Describe EACH of the following vapour compression refrigeration faults, outlining a possible cause for EACH:

(a) undercharge; (3)

(b) overcharge; (3)

(c) short cycling. (4)

June 2020

June 2020

5. Describe EACH of the following vapour compression refrigeration faults, outlining a possible cause for EACH:

(a) undercharge; (3)

(b) overcharge; (3)

(c) short cycling. (4)

Vapour Compression Refrigeration Faults and Causes:

(a) Undercharge (Insufficient Refrigerant):

- **Description: An undercharge situation occurs when there is less refrigerant in the refrigeration system than the manufacturer's recommended amount.**
- **Possible Cause:**
  - **Leak: The most common cause is a leak in the refrigerant line, allowing the refrigerant to escape gradually over time. Regular leak detection and repair are crucial to prevent undercharge.**

(b) Overcharge (Excessive Refrigerant):

- **Description: An overcharge situation exists when there is more refrigerant in the system than recommended.**
- **Possible Cause:**
    - **Improper Charging: Adding too much refrigerant during the charging process is a primary cause. Always use a refrigerant scale and follow the manufacturer's charging guidelines.**

(c) Short Cycling:

- **Description: Short cycling refers to a condition where the compressor starts and stops frequently, failing to complete a full refrigeration cycle. This can significantly reduce efficiency and shorten compressor life.**
- **Possible Causes:**
    - **Low Suction Pressure: As mentioned earlier, a low suction pressure can trigger the compressor to shut down prematurely. Refer to the explanation in the previous answer (b) of question 4 for possible causes of low suction pressure.**
    - **Defective Thermostat: A faulty thermostat that cycles on and off too frequently can cause short cycling. The thermostat may need to be replaced.**
    - **Defrost Timer Issue (if applicable): In systems with automatic defrost cycles, a malfunctioning defrost timer can lead to short cycling if the defrost cycle is not properly initiated or terminated.**

June 2021

June 2021

4. Describe the indications of, and the remedies for, an undercharge on a refrigeration system. (10)

Undercharge in a Refrigeration System: Signs, Causes, and Solutions

An undercharge situation occurs when a refrigeration system has **less refrigerant** than the manufacturer's recommended amount. This missing refrigerant can lead to several issues affecting system performance and efficiency.

Indications of Undercharge:

- **Reduced Cooling Capacity:** The most noticeable sign is a **decrease in the system's ability to cool**. The desired chilled air or water temperature may not be achieved, leading to insufficient cooling in the conditioned space or storage area.

- **Icing on the Evaporator Coil:** Due to insufficient refrigerant flow, the evaporator coil may become excessively cold and start to frost or ice over. This ice buildup restricts airflow across the coil, further reducing cooling capacity.
- **Low Suction Pressure:** With less refrigerant circulating, the pressure on the suction side of the compressor (low pressure) will be lower than normal. This can be monitored using a pressure gauge set.
- **Increased Compressor Running Time:** The compressor may run for longer periods to try and compensate for the reduced cooling capacity, leading to higher energy consumption.
- **Bubbles in the Sight Glass (if applicable):** Some systems have a sight glass, a small window in the liquid line, that allows viewing the refrigerant flow. In an undercharged system, bubbles may be visible in the sight glass, indicating a lack of sufficient liquid refrigerant.

Possible Causes of Undercharge:

- **Refrigerant Leak:** The most common cause is a leak in the refrigerant line, allowing the refrigerant to escape gradually over time. Regular leak detection and repair are crucial.
- **System Service:** If the system has undergone maintenance or repairs that involved opening the refrigerant circuit, there's a chance of improper recharging, leading to an undercharge.

Remedies for Undercharge:

1. **Leak Detection and Repair:** The first step is to identify and repair any leaks in the system. A qualified technician can perform a leak detection test to locate the leak source. Once repaired, the system can be evacuated to remove any non-condensable gases.
2. **Refrigerant Recharge:** After leak repair and system evacuation, a qualified technician can recharge the system with the correct type and amount of refrigerant, following the manufacturer's specifications. They will typically use a refrigerant charging scale and monitor pressure gauges to ensure proper charge level.
3. **System Monitoring:** Once recharged, monitor the system's performance. Observe if the cooling capacity improves, ice buildup on the evaporator coil disappears, and the suction pressure returns to normal levels.

Important Considerations:

- **Safety:** Handling refrigerants can be dangerous. Leave leak detection, system evacuation, and refrigerant charging to a qualified technician certified to handle refrigerants according to local regulations.
- **Professional Service:** For complex systems or if unsure about the process, consider seeking assistance from a qualified refrigeration technician for proper diagnosis and repair of undercharge issues.

By addressing undercharge promptly and adhering to safe practices, you can restore the efficiency and performance of your refrigeration system.

Nov 2018

5. (a) Explain EACH of the following refrigeration terms:

(i) superheated; (2)

(ii) saturation temperature; (2)

(iii) sub-cooled. (2)

(b) Sketch a basic vapour compression refrigeration system, showing the refrigerants condition as explained in part (a). (4)

Refrigeration Terms and Vapour Compression Cycle

(a) Refrigeration Terms:

(i) Superheated:

- **Definition:** In a refrigeration system, a substance is considered superheated when its temperature is **higher than its saturation temperature** at a given pressure. Saturation temperature refers to the temperature at which a substance changes its state (e.g., liquid to vapor) for a specific pressure.
- **Application:** Superheat is typically used in reference to the condition of refrigerant vapor leaving the evaporator coil in a vapor compression refrigeration cycle. The superheated vapor ensures all the liquid refrigerant has evaporated in the evaporator before reaching the compressor, preventing liquid from entering the compressor which can cause damage.

(ii) Saturation Temperature:

- **Definition:** The saturation temperature is the specific temperature at which a substance transitions between its liquid and vapor phases for a given pressure.
- **Application:** In refrigeration, the saturation temperature of the refrigerant is crucial for determining its ability to absorb heat in the evaporator and release heat in the condenser. The refrigerant absorbs heat at its saturation temperature in the evaporator, causing it to evaporate.

(iii) Sub-cooled:

- **Definition:** Sub-cooled refers to a liquid state where the temperature of the liquid is **lower than its saturation temperature** at the current pressure.
- **Application:** Sub-cooling is less common in typical vapor compression refrigeration systems. In some specialized applications, sub-cooling can be used to improve the efficiency of the system by ensuring all the refrigerant remains a liquid before entering an expansion valve.

(b) Basic Vapour Compression Refrigeration System with Refrigerant States:

A vapor compression refrigeration system utilizes a closed loop circulation of refrigerant to achieve cooling. Here's a breakdown of the cycle with explanations of the refrigerant's condition at each stage, referring to the terms explained in part (a):

1. **Evaporator Coil:** Warm air from the space being cooled is drawn across the evaporator coil by a fan. The refrigerant inside the evaporator coil is at a low pressure and a temperature **below** the saturation temperature of the refrigerant at that pressure. This allows the refrigerant to absorb heat from the warm air, causing the air to cool down. As the refrigerant absorbs heat, it evaporates and becomes a **superheated vapor**.
2. **Suction Line:** The low-pressure, superheated vapor refrigerant exits the evaporator and travels through the suction line towards the compressor.
3. **Compressor:** The compressor draws in the low-pressure refrigerant vapor and compresses it. This compression process increases the pressure and temperature of the refrigerant vapor.
4. **Discharge Line:** The high-pressure, high-temperature refrigerant vapor exits the compressor and travels through the discharge line towards the condenser.
5. **Condenser Coil:** The hot, high-pressure refrigerant vapor enters the condenser coil. Here, the refrigerant releases heat to the surrounding air (air-cooled condenser) or water (water-cooled condenser). As the refrigerant loses heat, it condenses back into a liquid state. Ideally, the refrigerant condenses completely at a temperature slightly **above** its saturation temperature at the condenser pressure.
6. **Liquid Line:** The high-pressure liquid refrigerant exits the condenser and travels through the liquid line.
7. **Expansion Valve (or Throttling Device):** The expansion valve is a small device that regulates the pressure of the refrigerant. As the high-pressure liquid refrigerant passes through the expansion valve, it experiences a sudden pressure drop. This pressure drop causes the liquid to partially vaporize (flashing) and its temperature to decrease significantly. The refrigerant exits the expansion valve as a mixture of liquid and vapor, with the liquid portion at a temperature **below** its saturation temperature at the lower pressure exiting the valve.
8. **Repeat:** The cold liquid-vapor mixture then enters the evaporator coil, and the cycle repeats continuously.

By understanding the superheated, saturation temperature, and sub-cooled states of the refrigerant, we can analyze the performance and efficiency of a vapor compression refrigeration system.

Nov 2020

Nov 2020

5. With reference to refrigeration systems:

(a) state the THREE basic laws of refrigeration; (6)

(b) state the location and method of re-setting of EACH of the following:

(i) the High Pressure cut out; (2)

(ii) the Low Pressure cut out. (2)

Question 5. Well answered by most.

Refrigeration System Basics: Laws and Safety Cut-Outs

(a) Three Basic Laws of Refrigeration:

1. **First Law of Thermodynamics (Law of Conservation of Energy):** Energy can neither be created nor destroyed, only transformed. In a refrigeration system, the total amount of heat removed from the cooled space (cold reservoir) plus the heat rejected to the surrounding environment (hot reservoir) equals the work done by the compressor (energy input).
2. **Second Law of Thermodynamics (Law of Entropy Increase):** In a natural process, entropy (measure of disorder) always increases over time. In a refrigeration system, this translates to the need for work input (compressor) to move heat from a colder area (low entropy) to a hotter area (high entropy).
3. **Boyle's Law:** For a fixed amount of gas at a constant temperature, the pressure and volume are inversely proportional. This principle applies to the compression process in the refrigeration cycle. As the compressor reduces the volume of the refrigerant vapor, its pressure increases.

(b) Location and Resetting of Safety Cut-Outs:

These safety cut-out switches prevent damage to the refrigeration system by automatically stopping the compressor if pressure levels go beyond safe operating ranges.

(i) High-Pressure Cut-Out (HPC):

- **Location:** The high-pressure cut-out is typically located on the **discharge line** of the compressor, where the refrigerant pressure is highest.
- **Resetting: Do not reset the high-pressure cut-out** without identifying and fixing the underlying cause of the high pressure. High pressure can be caused by a dirty condenser coil, a blocked capillary tube (in some systems), or a faulty pressure relief valve. Resetting without addressing the cause can lead to compressor failure.

(ii) Low-Pressure Cut-Out (LPC):

- **Location:** The low-pressure cut-out is typically located on the **suction line** of the compressor, where the refrigerant pressure is lowest.
- **Resetting: Consult the equipment manual** before resetting the low-pressure cut-out. Possible causes for low pressure include a refrigerant leak, a clogged suction line, or a malfunctioning expansion valve. Once the cause is identified and repaired, the low-pressure cut-out may have a manual reset button that can be pressed to restart the compressor.

Important Note: Refrigeration systems can contain harmful refrigerants. Always consult a qualified technician for troubleshooting and repairs involving safety cut-outs to ensure proper safety procedures are followed.

Nov 2018

6. (a) State THREE types of damper that may be used to control the airflow in an air conditioning system. (3)

(b) Describe, with the aid of a sketch, an automatic fire damper installed in a vertical air duct or in those that pass through bulkheads designated as fire boundaries. (7)

You've got a great understanding of air conditioning dampers and fire safety! Here's the information again:

(a) Three Types of Airflow Control Dampers:

1. **Blade Dampers:** These are the most common type. They consist of a metal blade that pivots within the duct to regulate airflow. The blade angle can be manually adjusted or controlled by a motor for automated operation.
2. **Butterfly Dampers:** These resemble a butterfly valve, with a disc-shaped metal plate rotating on a central axis within the duct. The disc position controls the amount of airflow through the duct. They are often used for complete shutoff or to regulate high-pressure airflow.
3. **Volume Control Dampers (VCDs):** These are specially designed dampers that maintain a constant air pressure throughout the duct system regardless of the damper position. They are particularly useful for balancing airflow in complex duct networks.

(b) Automatic Fire Damper in Air Ducts:

An automatic fire damper is a crucial safety device installed in air conditioning systems to prevent the spread of fire and smoke through ventilation ducts. They are typically located:

- **Vertical air ducts:** These are vertical shafts within the building that carry conditioned air to different floors. Fire dampers are installed at regular intervals along the vertical duct to isolate any fire section.
- **Ducts passing through bulkheads designated as fire boundaries:** Bulkheads are vertical walls within a building that can act as fire barriers. Fire dampers are installed where air ducts penetrate these fire-rated bulkheads to prevent flames and smoke from traveling through the duct system to other compartments.

Functioning of a Fire Damper:

- **Normal Operation:** During normal operation, the fire damper blade remains open, allowing conditioned air to flow freely through the duct.
- **Fire Detection:** When a fire is detected (through heat sensors or smoke detectors), a signal is sent to a fusible link or electrical mechanism connected to the damper blade.
- **Automatic Closure:** The fusible link melts or the electrical mechanism activates, causing the damper blade to automatically close and seal the duct opening. This isolates the fire and smoke within the affected zone, preventing them from spreading to other parts of the building through the ductwork.

Importance of Fire Dampers:

Fire dampers play a vital role in building safety by:

- **Compartmentalization:** They compartmentalize the building by isolating fire and smoke within a specific zone, preventing them from traveling through the ventilation system.
- **Life Safety:** By containing the fire and smoke, fire dampers help protect occupants by providing them with more time to evacuate safely.
- **Reduced Property Damage:** Limiting the spread of fire and smoke minimizes damage to unaffected areas of the building.

Note: Fire dampers require regular inspection and maintenance to ensure they function properly in case of a fire emergency.

March 2020

March 2020

4. State THREE different methods used to detect a refrigerant gas leak, explaining EACH method. (10)

Here are three different methods used to detect a refrigerant gas leak, along with explanations for each:

1. **Electronic Leak Detector:**
- **Description:** This method utilizes a handheld electronic device that can pinpoint the location of a leak. The detector is equipped with a sensor that reacts to the presence of refrigerant.
- **Explanation:** As the detector is moved around the suspected leak area, the sensor sensitivity increases when it comes close to a leak. The device typically provides an audible or visual alert (light or bar graph) to indicate the intensity of the leak. Different types of electronic leak detectors may be sensitive to specific refrigerants or a broader range.
- **Advantages:** This method is highly sensitive, allowing for the detection of even small leaks. It's also portable and relatively easy to use, making it suitable for initial leak detection.

2. **Soapy Water Solution:**
- **Description:** This is a simple and inexpensive method that can be effective for detecting larger leaks. It involves applying a soapy water solution to the suspected leak areas.
- **Explanation:** Refrigerant gas escaping from a leak will create bubbles when it comes into contact with the soapy water. The presence and size of bubbles can indicate the location and severity of the leak.
- **Advantages:** This method is readily available and easy to implement. It's a good preliminary check for leaks, especially around fittings and connections.

3. **Ultrasonic Leak Detection:**
- **Description:** This method utilizes an ultrasonic detector that can identify the high-frequency sound emitted by escaping refrigerant gas.
- **Explanation:** The detector is equipped with a microphone that picks up the ultrasonic sound waves. These sound waves are inaudible to the human ear but can be detected by the instrument. The detector may provide an audible or visual indication of the leak's location.
- **Advantages:** Ultrasonic leak detection can be effective in noisy environments where electronic detectors might struggle with background noise. It can also be used to pinpoint leaks that may be hidden behind walls or inaccessible areas.

Important Considerations:

- The choice of leak detection method depends on the specific situation, the type of refrigerant, and the size of the suspected leak.
- For large or complex systems, it's recommended to consult a qualified technician for professional leak detection and repair.
- Always follow safety precautions when handling refrigerants. Refrigerants can be harmful if inhaled and some require specific handling procedures.

April 2021

April 2021

4. Describe, with the aid of a sketch, the operation of the FOUR main components in a simple vapour compression cycle for a refrigeration system. (10)

In a vapor compression refrigeration cycle, four main components work together to achieve cooling. Here's a breakdown of their operation:

1. **Compressor:**
- **Function:** The heart of the system, the compressor is a mechanical pump that draws in low-pressure, low-temperature refrigerant vapor from the evaporator coil.
- **Operation:** The compressor utilizes a piston or scroll mechanism to compress the refrigerant vapor. This compression process significantly increases the pressure and temperature of the refrigerant.
2. **Condenser:**
- **Function:** The condenser is a heat exchanger where the hot, high-pressure refrigerant vapor released from the compressor releases its heat to the surrounding environment.
- **Operation:** The condenser typically consists of a series of fins and tubes. The hot refrigerant vapor flows through the tubes, while air (air-cooled condenser) or water (water-cooled condenser) is passed over the fins. As the refrigerant loses heat to the air or water, it condenses back into a high-pressure liquid state.
3. **Expansion Valve (or Throttling Device):**
- **Function:** The expansion valve, also known as a throttling device, regulates the pressure of the refrigerant.
- **Operation:** The high-pressure liquid refrigerant from the condenser passes through the expansion valve. The expansion valve has a small orifice that restricts the flow of the liquid. This sudden pressure drop causes the high-pressure liquid to partially vaporize (flashing) and its temperature to decrease significantly. The refrigerant exits the expansion valve as a mixture of liquid and vapor, with the liquid portion at a much lower pressure and temperature.
4. **Evaporator Coil:**
- **Function:** The evaporator coil is another heat exchanger located within the air-conditioning unit or refrigeration compartment. It absorbs heat from the warm air or space that needs to be cooled.
- **Operation:** The low-pressure, cold liquid-vapor mixture from the expansion valve enters the evaporator coil. The refrigerant absorbs heat from the warm air passing over the evaporator

coil, causing the air to cool down. As the refrigerant absorbs heat, it evaporates completely and becomes a low-pressure, low-temperature vapor again. This vapor is then drawn back into the compressor, and the cycle repeats continuously.

By working together, these components create a closed-loop system where the refrigerant continuously changes state (liquid to vapor and back) to absorb heat from the cooled space and reject it to the surrounding environment, achieving the desired cooling effect.

March 2020

March 2020

5. (a) List FOUR reasons for a refrigeration compressor to stop unexpectedly, after running for a short period. (4)

(b) Describe the faults which lead to TWO of the reasons for the stoppage, listed in part (a) (6)

Refrigeration Compressor Unexpected Stoppage: Reasons and Faults

(a) Four Reasons for Unexpected Compressor Stoppage:

1. **Electrical Faults:**
    - Issues like tripped circuit breakers, blown fuses, or internal motor malfunctions can interrupt power supply to the compressor, causing it to stop unexpectedly.
2. **Low Suction Pressure:**
    - If the pressure on the suction side of the compressor drops below a certain level, it may activate a safety mechanism to prevent damage. This could be due to factors like a refrigerant leak, clogged suction line, or malfunctioning expansion valve.
3. **High Discharge Pressure:**
    - Conversely, excessively high pressure on the discharge side can also trigger a safety shutdown to protect the compressor. This might be caused by a dirty condenser coil, a blocked capillary tube (in some systems), or a faulty pressure relief valve.
4. **Overload Protection:**
    - Modern compressors often have built-in overload protection that cuts off power if the motor gets too hot. This can be caused by excessive load on the compressor due to high ambient temperatures, insufficient airflow over the condenser, or internal mechanical issues.

(b) Description of Faults for Two Reasons:

1. Low Suction Pressure:

- **Possible Faults:**
    - **Refrigerant Leak:** A leak in the refrigerant line allows the refrigerant to escape, reducing the pressure in the system and causing the compressor to shut down on low suction pressure. Identifying and repairing the leak is crucial before restarting the system.

  - **Clogged Suction Line:** A blockage in the suction line due to debris or ice buildup restricts the flow of refrigerant, leading to a drop in suction pressure and compressor stoppage. The blockage needs to be located and cleared to restore proper flow.
  - **Malfunctioning Expansion Valve:** A faulty expansion valve can over-expand the refrigerant, causing too much liquid refrigerant to enter the evaporator. This can lead to insufficient suction pressure and compressor shutdown. The expansion valve may need to be repaired or replaced.

2. High Discharge Pressure:

- **Possible Faults:**
  - **Dirty Condenser Coil:** Dust, dirt, or debris accumulated on the condenser coil reduces its ability to dissipate heat effectively. This causes the discharge pressure to rise, leading to compressor shutdown on high-pressure protection. The condenser coil needs to be cleaned thoroughly to ensure proper heat rejection.
  - **Blocked Capillary Tube (in some systems):** A capillary tube is a small-diameter tube used in some refrigeration systems to meter the flow of refrigerant. A blockage within the capillary tube restricts the flow of refrigerant, leading to a rise in discharge pressure and compressor shutdown. The capillary tube may need to be replaced.

Note: These are just a few examples, and the specific cause of the compressor stoppage will depend on the individual refrigeration system and its operating conditions. A qualified technician can diagnose the exact fault and recommend the appropriate repair or replacement action.