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The field of energy efficiency is an exciting field to explore. This field allows humans to apply vast technology without consuming a lot of energy resources. The author took the initiative to share the basic knowledge of energy efficiency involving the basics of cooling system, motor speed, air compressor, fan, pump and lighting system.

It is hoped that this eBook can be a reference for prospective polytechnic graduates and others, especially those involved in the field of energy efficiency before venturing into the field of employment later.

Hopefully this script can benefit everyone.

Amrah binti Mat Safri
Shazila Idayu binti Manja
16 July 2020
Port Dickson
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COOLING SYSTEM
Remember the basic HVAC configuration

- List the type of chiller.

- Describe the HVAC basic operation:
  a. Centralized system
  b. Package system
  c. Split Unit
TYPE OF CHILLER

1.1.1

- Air Cooled Type

- Water Cooled Type
Chiller Types & Application

Explained

Air Cooled

Condenser

Evaporator

Expansion Valve

Building Heat

TheEngineeringMindset.com

Water Cooled

Cooling Tower

Condenser

Evaporator

Expansion Valve

Building Heat
Both type of chiller have the same essential components which are, the evaporator, the compressor, the condenser and the expansion valve.

The working principle for both air cooled and water cooled chiller is the same.

A compressor pushes a refrigerant round the inside of the chiller between the condenser, expansion valve, evaporator and back to the compressor.

The only different in air cooled chiller is fan force air across the exposed tubes of the condenser which carry the heat away.
HVAC basic operation

1) Centralized system

2) Package system

3) Split Unit
1) Centralised air-conditioning system

- The central air conditioning plants or the systems are used when large buildings, hotels, theaters, airports, shopping malls etc. are to be air conditioned completely.

- The window and split air conditioners are used for single rooms or small office spaces.

- If the whole building is to be cooled it is not economically viable to put window or split air conditioner in each and every room.

- Further, these small units cannot satisfactorily cool the large halls, auditoriums, receptions areas etc.
Centralised air-conditioning system
2) **Package air-conditioning system**

- The window and split air conditioners are usually used for the small air conditioning capacities up to 5 tons.

- The central air conditioning systems are used for where the cooling loads extend beyond 20 tons.

- The packaged air conditioners are used for the cooling capacities in between these two extremes.

- The packaged air conditioners are available in the fixed rated capacities of 3, 5, 7, 10 and 15 tons.

- These units are used commonly in places like restaurants, telephone exchanges, homes, small halls, etc.
Package air-conditioning system
3) Split air-conditioning system

- The split air conditioner comprises of two parts: the outdoor unit and the indoor unit.
- The outdoor unit, fitted outside the room, houses components like the compressor, condenser and expansion valve.
- The indoor unit comprises the evaporator or cooling coil and the cooling fan.
- Further, the present day split units have aesthetic looks and add to the beauty of the room. The split air conditioner can be used to cool one or two rooms.
Split air-conditioning system
Remember the fundamentals of cooling system

- Define the cooling system
- Describe the component of:
  a. Cooling system
  b. Chiller system
Define the cooling system

- A system, which controls the engine temperature, is known as a cooling system.

Component of cooling system

This system consists of 4 components
- Radiator
- Water pump
- Fan
- Thermostat
BASIC SCHEMATIC LAYOUT

- Heater Control
- Cab heat exchanger
- Engine Block & cylinder head water jacket
- Water pump
- Thermostat
- Fan
- Radiator
COOLING SYSTEM CONSTRUCTION
Radiator

The purpose of the radiator is to cool down the water received from the engine. The radiator consists of three main parts:

(i) upper tank,
(ii) lower tank and
(iii) tubes.

Hot water from the upper tank, which comes from the engine, flows downwards through the tubes. The heat contained in the hot water is conducted to the copper fins provided around the tubes. An overflow pipe, connected to the upper tank, permits excess water or steam to escape.
RADIATOR
PARTS

1. Radiator Core Assembly
2. Outlet Tank
3. Filler Neck
4. Transmission Oil Cooler
5. Oil Cooler Gaskets
6. Oil Cooler Attaching Nuts
7. Drain Cock
8. Outlet Pipe
9. Gaskets
10. Inlet Tank
11. Inlet Pipe

Modern radiator
Water Pump
This is a centrifugal type pump. It is centrally mounted at the front of the cylinder block and is usually driven by means of a belt. This type of pump consists of the following parts:
(i) body or casing,
(ii) impeller (rotor),
(iii) shaft,
(iv) bearings, or bush,
(v) water pump seal and
(vi) pulley.
The bottom of the radiator is connected to the suction side of the pump. The power is transmitted to the pump spindle from a pulley mounted at the end of the crankshaft. Seals of various designs are incorporated in the pump to prevent loss of coolant from the system.
Fan

The fan is generally mounted on the water pump pulley, although on some engines it is attached directly to the crankshaft. It serves two purposes in the cooling system of an engine.
(a) It draws atmospheric air through the radiator and thus increases the efficiency of the radiator in cooling hot water.
(b) It throws fresh air over the outer surface of the engine, which takes away the heat conducted by the engine parts and thus increases the efficiency of the entire cooling system.
THERMOSTAT

• One of the most important parts of the cooling system
• Its purpose is to keep the engine coolant at most efficient temperature
• The thermostat is used to bring the coolant temperature up to operating as quickly as possible
• It is designed to sense the temperature of the coolant
A wax pellet material within the thermostat expands and causes the mechanical motion that opens the thermostat. This allows the coolant to pass through the radiator.
Component of chiller system

Chillers can be found in most medium to large buildings and will produce the chilled water that is used to provide air conditioning. There are many different types of chillers but essentially they all have the same main components.

This system basically consists of 7 components

- Compressor
- Condenser
- Expansion valve
- Evaporator
- Power unit
- Controls
- Water boxes
Compressor:
The compressor is the prime mover, it creates a pressure difference to move the refrigerant around the system. There are various designs of refrigerant compressors, the most common being the centrifugal, screw, scroll and reciprocating type compressors. Each type has its own pro’s and con’s. It is always located between the evaporator and the condenser. It’s usually partly insulated and will have an electrical motor attached as the driving force, this will be either mounted internally or externally. Compressors can be extremely noisy, usually a constant deep droning sound with an overlaying high pitch, hearing protection should be worn when in close proximity to the chiller.
Centrifugal type compressor  
Screw type compressor
Condenser:
The condenser is located after the compressor and before the expansion valve. The purpose of the condenser is to remove heat from the refrigerant which was picked up in the evaporator. There are two main types of condensers, Air cooled and Water cooled.
Water cooled condensers will repetitively cycle “Condenser water” between the cooling tower and the condenser, the hot refrigerant which enters the condenser from the compressor, will transfer its heat into this water which is transported up to the cooling tower and rejected from the building. The refrigerant and the water do not mix they are kept separated by a pipe wall, the water flows inside the pipe and the refrigerant flows on the outside.
Condensers on air cooled chillers work slightly differently, they do not use a cooling tower but instead blow air across the exposed condenser pipes with the refrigerant flowing this time on the inside of the tube.
Water cooled chiller condenser

Air cooled chiller condenser
Expansion valve:
The expansion valve is located between the condenser and the evaporator. It’s purpose is to expand the refrigerant reducing its pressure and increase it’s volume which will allow it to pick up the unwanted heat in the evaporator. There are many different types of expansion valve, the most common at the thermal expansion vale, the pilot operated thermal expansion valve, the electronic expansion valve and the fixed orifice expansion valve.
Evaporator: The evaporator is located between the expansion valve and the compressor, its purpose is to collect the unwanted heat from the building and move this into the refrigerant so that it can be sent to the cooling tower and rejected. The water cools as the heat is extracted by the refrigerant, this “chilled water” is then pumped around the building to provide air conditioning, This “Chilled water” then returns to the evaporator bringing with it any unwanted heat from the building.

Evaporator on an air cooled chiller

Evaporator on a water cooled chiller
Power unit:
The power unit is either mounted directly to the chiller or it can be separated and mounted to the wall of the plant room with power cables running between them. The purpose of the power unit is to control the flow of electrical power to the chiller. These usually contain a starter, circuit breakers, speed controller and power monitoring equipment.
Controls:
The controls unit is typically mounted on the chiller. It’s purpose is to monitor the various aspects of the chillers performance and control these by making adjustments. The controls unit will generate alarms for the engineering teams and safely shut the system down to prevent damage to the unit. BMS connections are also usually present to allow remote control and monitoring.

Chiller controls unit
Water boxes:
Water boxes are mounted to the evaporators and also the condensers of water cooled chillers. The purpose of the water box is to direct flow as well as to segregate the entrance and exit. Depending on the number of passes in the evaporator and condenser, water boxes may have 1-2 flanged entrance or exit holes or they can be completely capped and just redirect flow back into the next pass.

Chiller water box, open ended

Chiller water box, closed end
Understand the performance and efficiency parameters in cooling system

- Explain the performance parameters of cooling system:
  - a. range
  - b. approach
  - c. effectiveness
  - d. cooling capacity
  - e. evaporation loss
  - f. cycles of concentration
  - g. blow down losses
  - h. liquid/gas ratio
The important parameters, from the point of determining the performance of cooling towers, are:

i) "Range" is the difference between the cooling tower water inlet and outlet temperature. (See Figure below).

ii) "Approach" is the difference between the cooling tower outlet cold water temperature and ambient wet bulb temperature. Although, both range and approach should be monitored, the 'Approach' is a better indicator of cooling tower performance. (see Figure below).

Figure: Range and Approach
iii) Cooling tower effectiveness (in percentage) is the ratio of range, to the ideal range, i.e., difference between cooling water inlet temperature and ambient wet bulb temperature, or in other words it is \( \frac{\text{Range}}{\text{Range} + \text{Approach}} \).

iv) Cooling capacity is the heat rejected in kCal/hr or TR, given as product of mass flow rate of water, specific heat and temperature difference.

v) Evaporation loss is the water quantity evaporated for cooling duty and, theoretically, for every 10,00,000 kCal heat rejected, evaporation quantity works out to 1.8 m\(^3\).

vi) Cycles of concentration (C.O.C) is the ratio of dissolved solids in circulating water to the dissolved solids in make up water.

vii) Blow down losses depend upon cycles of concentration and the evaporation losses and is given by relation:

\[
\text{Blow Down} = \frac{\text{Evaporation Loss}}{\text{C.O.C} - 1}
\]
viii) Liquid/Gas (L/G) ratio, of a cooling tower is the ratio between the water and the air mass flow rates. Against design values, seasonal variations require adjustment and tuning of water and air flow rates to get the best cooling tower effectiveness through measures like water box loading changes, blade angle adjustments. Thermodynamics also dictate that the heat removed from the water must be equal to the heat absorbed by the surrounding air:

\[ L(T_1 - T_2) = G(h_2 - h_1) \]

where:
- \( L/G \) = liquid to gas mass flow ratio (kg/kg)
- \( T_1 \) = hot water temperature (°C)
- \( T_2 \) = cold water temperature (°C)
- \( h_2 \) = enthalpy of air-water vapor mixture at exhaust wet-bulb temperature (same units as above)
- \( h_1 \) = enthalpy of air-water vapor mixture at inlet wet-bulb temperature (same units as above)
Understand the types of cooling systems

- Describe a natural draft tower
- Describe a mechanical draft tower
NATURAL DRAFT COOLING TOWER
Natural draft cooling tower basically removes waste heat from the system and release it into the atmosphere.

In this process hot water enters through the series of pumps to the top area of tower near hot water inlet.

Series of nozzles connected to the hot water inlet used to sprays water over the fill and distributed throughout the tower.

Simultaneously air is introduced from the bottom of the tower flowing in upward direction, then circulated inside the cooling tower by natural convection.

While flowing down water emits heat due to evaporation which mixes with the air flowing upward causing water to cool down.

Cooled water is collected into the basin and then used for cooling various hot process fluid.
Advantages:
1. Less operating and maintenance cost.
2. Safe to operate.
3. Energy efficient.

Limitations:
1. Not adoptable with every climate conditions.
2. Large space is required to install.
3. High initial Cost.

Application:
1. Used in power stations and for process cooling applications.
Mechanical draft cooling tower utilizes mechanical devices such as fan or blower to move air through the tower. It is classified into two types.

1. Forced Draft cooling tower
2. Induced Draft cooling tower
I.) Forced Draft cooling tower:

- In forces draft cooling tower air is blown through tower with the help of a fan located at the bottom of the tower.

- Hot water enters from top of the tower. Counter flow of air and water in the fill results in a heat transfer. It uses atmospheric cooling with wet technology.

- This type of cooling tower removes low potential heat generated during production process and having limited application due to recirculation difficulties.
Advantages:
1. Easy maintenance as it has better access to the fan, drives and motor.
2. Suitable for high air resistance.

Limitations:
1. Higher fan power requirement.
2. It may be susceptible to recirculation.

Applications:
1. Petrochemical industry and energy industry.
II.) Induced Draft Cooling Tower

- It works similar to the forced draft cooling tower except for little difference.
- In this type of tower, air is introduced from the bottom and water enters from the top. Water gets spread throughout the tower with the help of spray distribution header.

- Fan is situated at air outlet which draws air across the fill at high level and drawn through the baffled area by fan which causes cooling of the water.
- Time of contact is greater in induced draft which also improves heat transfer area.
Advantage:
1. Less recirculation as compare to Forced draft.
2. Does not require large space to install.

Limitations:
1. Fan, motor and drives located in moist air stream so electrical protection is required.
2. More maintenance required and corrosion is likely.

Application:
1. Best suitable for A/C plants, chemical industries and sugar industries.
Investigate the efficiency between HVAC system in HVAC basic operation:

a. Centralized system
b. Package system
c. Split Unit
1. Reduce Loads Within Space
   - Reduce Equipment Load
   - Improvements to Façade (Walls)
   - Improvements to Façade (Windows)
   - Demand Based Ventilation

2. Improve HVAC System Efficiency
   - System Selection
   - Plant Selection
   - Building Tuning and Commissioning
   - Energy Recovery – Energy recovery involves capturing waste energy and recycling it.
   - Smart Control Strategies
   - Economy Cycle – Economy cycle involves using 100% outdoor air to supply air to the space.
Investigate the performance and operation of cooling system

- Investigate the efficient cooling system operation
- Investigate the performance assessment of cooling system.
How to investigate the efficient cooling system operation

- Maintain the equipment
- Use a programmable thermostat properly
- Seal the heating cooling duct’s
- Seal and insulate with energy star
- Choose the right equipment
- Work with heating and cooling contractor
- Get an energy star quality installation
How to investigate the performance assessment of cooling system.

- Water consumption
- Plant performance
- Cost
- Operations and maintenance (O&M)
- Environmental effect
REFERENCES


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