HVAC Energy Conservation Through Cooling Water Treatment

An Online Continuing Education Course for Engineers

Course Number: HV-5002

Credit: 5 Hours / 5 PDH / 5 CPD

HVAC Energy Conservation through Cooling Water Treatment

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Water used in air-conditioning systems may create problems with equipment, such as scale, corrosion, and organic growths. Scale formation is one of the greatest problems in air-conditioning systems that have water-cooled condensers and cooling towers. Corrosion is always a problem in an open water re-circulating system in which water sprays come in contact with air. The organic growth we are greatly concerned with is algae or slime. Since algae thrive on heat and sunlight, they will be a problem in cooling towers.

The quality of water is therefore very important in determining the performance of both chiller and cooling towers that utilize water for cooling. Improper water treatment or no treatment at all will increase energy consumption and operating costs while decreasing mechanical equipment efficiency and life expectancy.

This course discusses the waterside problems of open re-circulation cooling water systems, as well as how energy is dissipated from air-conditioning equipment and how effective implementation and tight monitoring of water treatment programs can conserve it.

The course is divided into seven sections:

SECTION 1: Energy Drain in Vapor Compression Systems

SECTION 2: Cooling Water Problems

SECTION 3: Scale Control

SECTION 4: Corrosion Control

SECTION 5: Control of Organic Growths

SECTION 6: Turbidity Control

SECTION 7: Water Treatment System Controls and Monitoring

There is a course summary provided at the end of the course.

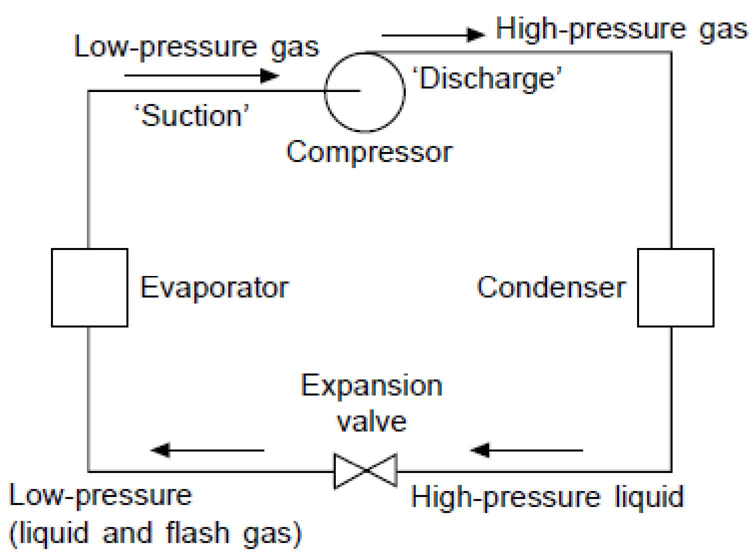
SECTION 1: ENERGY DRAIN IN VAPOR COMPRESSION SYSTEMS

Before we come to the discussion on waterside problems, let us first review some fundamentals about work and energy input to refrigeration chillers.

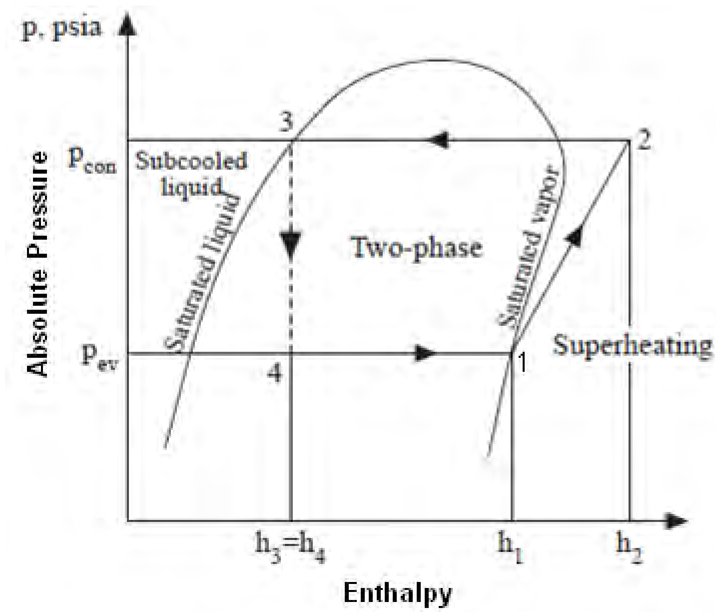
The vapor compression system is the dominant system today for cooling and refrigeration and is being used in all kinds of applications. It consists of four components:

1. The **compressor** raises the pressure of the initially low-pressure refrigerant gas.
2. The **condenser** is a heat exchanger that cools the high-pressure gas so that it changes phase to liquid.
3. The **expansion valve** controls the pressure ratio, and thus flow rate, between the high- and low-pressure regions of the system.
4. The **evaporator** is a heat exchanger that extracts heat from the air causing low pressure liquid refrigerant to evaporate and change phase from liquid to vapor (gas).

A schematic flow diagram of the vapor compressor system and its components is shown below:



A pressure-enthalpy diagram or p-h diagram is often used to calculate the energy transfer and to analyze the performance of a refrigeration cycle:



There are four processes in an ideal single-stage vapor compression cycle:

1. **Isothermal evaporation process 4–1:** The refrigerant evaporates completely in the evaporator and produces refrigeration effect q_{rf}, in Btu/lb:

   $q_{rf} = (h_1 - h_4)$

   Where

   h_1, h_4 = enthalpy of refrigerant at state points 1 and 4, respectively, Btu/lb. The enthalpy difference between point 1 and 4 represents the heat absorbed by the refrigerant in the evaporator and is known as ***"refrigeration effect."***

2. **Isentropic compression process 1–2:** Vapor refrigerant is extracted by the compressor and compressed isentropically from point 1 to 2. The work input to the compressor W_{in}, in Btu/lb, is

   $W_{in} = (h_2 - h_1)$

   Where

   h_1, h_2 = enthalpy of refrigerant at state points 1 and 2 respectively, Btu/lb.

The nodes 2 and 1 on Y-axis represent the condensing pressure (p_{con}) and evaporating pressure (p_{ev}) respectively. The pressure differential between port 2 and 1 is "*the work or energy input for compression*." The greater the difference between the condensing pressure and evaporating pressure, the higher will be the work input to the compressor.

3. **Isothermal condensation process 2–3:** Hot gaseous refrigerant discharged from the compressor is condensed in the condenser into liquid, and the latent heat of condensation is rejected to the condenser water or ambient air. The heat rejection during condensation, q_{2-3}, in Btu/lb, is

   $- q_{2-3} = (h_2 - h_3)$

   Where

   h_3 = enthalpy of refrigerant at state point 3, Btu/lb.

   Total heat rejected by the refrigeration system to the condenser cooling medium $(h_2 - h_3)$ = *Heat absorbed by the refrigerant in the evaporator (refrigeration effect) + heat equivalent of work input during compression.*

4. **Throttling process 3– 4:** Liquid refrigerant flows through a throttling device (e.g., an expansion valve, a capillary tube, or orifices) and its pressure is reduced to the evaporating pressure. A portion of the liquid flashes into vapor and enters the evaporator. This is the only irreversible process in the ideal cycle, usually represented by a dotted line. For a throttling process, assuming that the heat gain from the surroundings is negligible:

   $h_3 = h_4$

   The mass flow rate of refrigerant m_r in lb/min, is

   $m_r = q_{rc} / [60 * q_{rf}]$

Cooling Capacity

Cooling capacity is measured in tons of refrigeration. A ton of refrigeration is defined as the capacity of equipment to remove heat at a rate of 12,000 Btu/hr. Vapor compression systems impose an additional heat load due to the energy required to compress low-pressure, low-temperature refrigerant gas from the evaporator and deliver it to the condenser at a higher pressure. The compressor energy input is approximately 3,000 Btu/hr per ton of refrigeration.

Accordingly, normal heat rejection in a compression system approximates 15,000 Btu/hr per ton of refrigeration. Compression refrigeration systems require a cooling water circulation rate of approximately 3 gpm per ton of refrigeration, with a 10°F temperature drop across the cooling tower.

Coefficient of Performance of Refrigeration Cycle

The coefficient of performance (COP) of a refrigeration system is the ratio of the refrigerant effect to the energy supplied to the compressor.

$COP_{ref} = q_{rf} / W_{in}$

Or

$COP_{ref} = (h_1 –$

It is a dimensionless in ynamic cycle or thermal system. The magnitude

If a heat pump is used to enoted by COP_{hp} is:

$COP_{hp} = q_{2-3} / W$

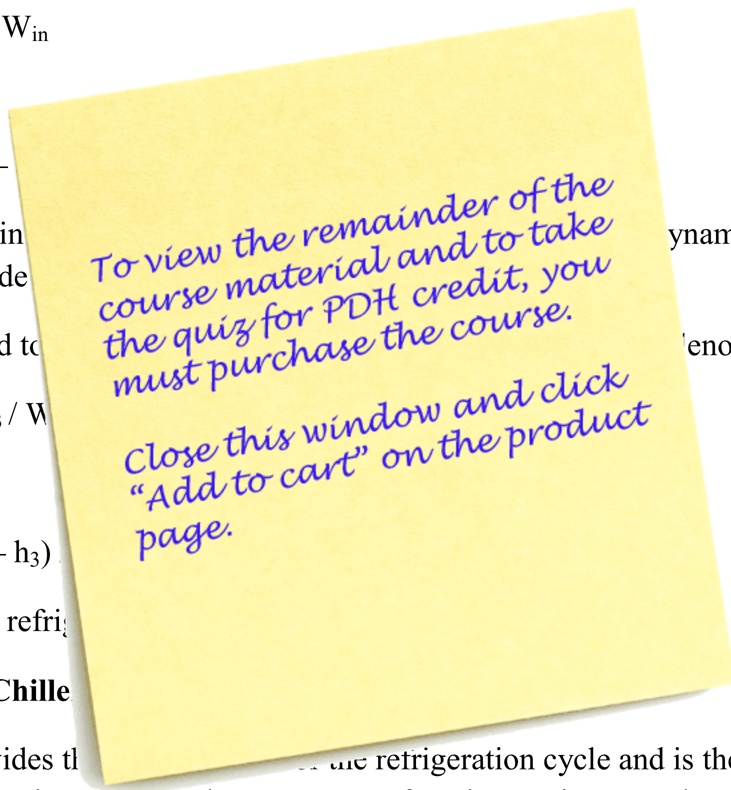
Or

$COP_{hp} = (h_2 – h_3)$

Clearly the COP of a refri

Work Input to the Chille

The compressor provides t the refrigeration cycle and is the primary consumer of electricity in a chiller. The compressor functions to increase the refrigerant temperature and pressure. Anything that increases the workload on the compressor will increase energy consumption.



Work input to the chiller is defined by equation as under:

$W \alpha m, \partial P$

Or