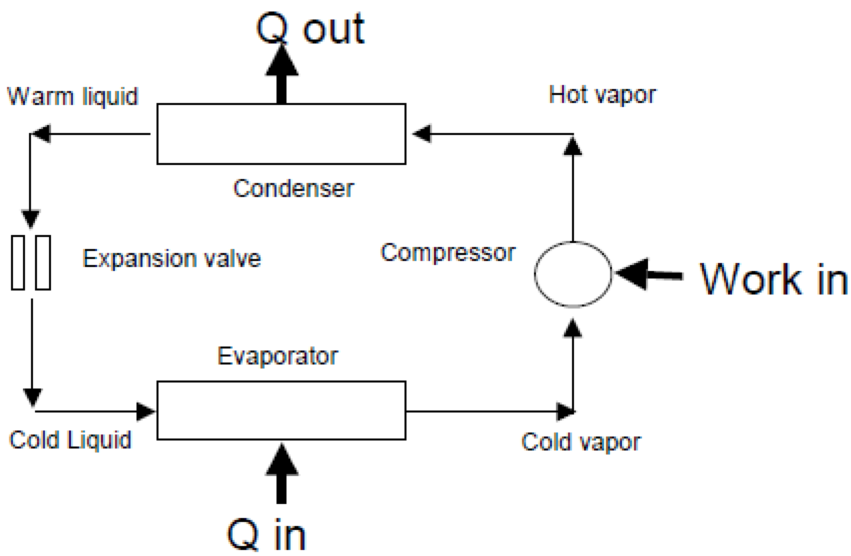
X-6 2019 Vapor Compression Cycle

Procedure and Analysis

Basic Cycle



The efficiency of this cycle is the ratio of Qin (heat removed from a space) to the Work of Compression (cost). This is called the COP for Coefficient of performance.

Campus Plant Chiller

Each team must assemble in SPL123 at its usual lab time. Safety glasses, earplugs, and shoes with enclosed heels and toes are required. Flip-flops or equivalent may not be worn. The facility is an active operation, responding to weather conditions and other situations. The procedure below may be modified as a result, and you will be briefed before walking to the plant. Unless the situation requires otherwise we will observe the two new, large chillers in the facility behind the new Science and Technology building. These chillers are well instrumented.

The Objective is to obtain operating data to calculate the COP (Coefficient of Performance) of an operating chiller. We will obtain data to calculate it three different ways and compare.

1. Instead of air, these machines "chill" water. The water, similar to steam, is circulated to all buildings, and at each building used to cool air.
2. Each team will be given three separate data sheets, one for each COP calculation. Record on your data sheet the date, time of day, weather conditions (sun, rain, cloudy, etc.) and the ambient temperature. Also, record which chiller you are looking at, and in particular be sure to note the type of refrigerant that it uses. It is good engineering practice to copy or photograph the nameplate on the machine.

3. Identify the key parts and relate them to the block diagram. Each chiller has a graphical display. Photographing it may be useful for report preparation. Some data will be found on the Control Room monitor. You will be provided with Data Sheets for guidance.
    - Data Sheet 1 – Thermodyamic COP. Record the refrigerant pressures and temperatures of each point in the refrigeration cycle. These are on the machine touch panel.
    - Data Sheet 2 – Chilled water Flow COP. Unlike your car or apartment window unit, instead of chilling air, water is chilled down and then circulated to campus buildings. Record the flow and temperatures of the chilled water leaving and returning. Temps and flows are shown on the monitor.
    - Data Sheet 3 – Compressor Power Consumption. Record the three phase motor electrical data for calculation of watts on the touch panel.
4. We will go outside the building to observe cooling tower operation. No data will be recorded beyond what we obtain from touch panels and control room monitor.

Analysis – Calculate the cooling load and the performance of the Chiller observed.

Note: Enthalpies can be read from the R-123 property chart, but not accurately. Property data curve fits are given on the data sheets, valid to within about 1% in the range we are seeing. E.g., Given Tsat, then Psat, h_f , h_{fg} , and h_g can be calculated. The h at the compressor out is SUPERHEATED, and must be estimated from the chart, given T_{exit+}.

1. Data Sheet 1. Determine the thermodynamic state (p, T, h) of the refrigerant at each point in the thermodynamic cycle. Note that with the refrigerant on the shell side of the condenser and evaporator has a free surface. The temperatures at points 3 & 4, and points 4 & 1, are equal. The enthalpies however are not equal. Plot the chiller's thermodynamic cycle on the P-h diagram provided. Label each part of the cycle. Draw arrowheads to indicate the direction of refrigerant flow. Calculate COP based on enthalpies.
2. Data Sheet 2. The data for the evaporator chilled water flow (inlet and outlet water temperature and mass flow rate) provides a good estimate of the cooling load. Calculate the cooling load at the time of observation.

    Evaporator water gain in energy (heat removed from buildings)

    $Qevap = m_{evap} * c_p * (Tin – Tout)_{evap}$ (get units right)

    Cooling tower water energy (heat from buildings plus heat from compressor)

    $Q_{cond} = m_{cond} * c_p * (Tout – Tin)_{cond}$

    Calculate the amount of heat being dumped to the atmosphere by the cooling tower using the condenser water flow and temperatures. The difference between this heat and the cooling load is (or should be) the amount of energy added by the compressor. Calculate the Coefficient of Performance (COP) of this machine, based on your data for the water temperature changes.

3. Data Sheet 3. Compressor Power and Evaporator Chiller
   Using the equation shown on your data sheet, calculate total compressor power being used to lift refrigerant from low temperature to high temperature. Calculation will give watts.
   There is not a refrigerant flow meter on the machine. However, an estimate can be made: $M_{ref} * h_{fg,ref}$ = using enthalpy change in the evaporator. Calculate M_{ref}. The enthalpy change is at the Tsat,Psat conditions of point 1 (This calculation takes some account of there being an “Economizer” in these machines that improves cooling effect over that being computed in Data Sheet 1).

   Convert to common units (e.g., watts, or Btu/hr). Calculate the COP =Cooling/Power.

Uncertainty Analysis

Consider each of the measurements that you made (temps,flow,pressures) and also the references required (property tables, P-h chart).

List each one, and give a value for its uncertainty (e.g., ΔP_{evap}, ΔT_{evap}, Δkw_{comp}, etc.), and a short statement of your basis (e.g., fluctuations during observation, no knowledge of instrument used, etc). There is no simple equation to use for doing Propagation of Errors. How might you estimate the overall uncertainty?

Discussion and Conclusions

You calculated the COP three ways: Are they different? How different?

The Control Room Monitor showed a calculated number called KW/Ton*. This is sort of a layman’s COP. Home Depot selling window units will usually display this. For this chiller we do not know what values of KW and Ton are being used. Should we believe? CONVERT this KW/Ton in to a COP (e.g., convert to common units and invert). How does this compare to your other COP measurements?

Based on your observations, which COP value to you, an engineer, believe? Why?

In a short paragraph comment on the value of observing and taking data on a plant scale (large boilers, chillers) compared to only textbook or tabletop labs related to the same subjects.

Design Objective – Provide Facilities Management a short letter giving the performance of the specific chiller you observed and weather conditions.

*An ancient, but still used, rating for a refrigeration device uses the unit “tons.” The origin of this term is the amount of energy required to make or melt one ton of ice in 24 hours. Its value is now defined as 12,000 Btu/hr, or about 3.5 kilowatts.

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Mr. Graham:

Team   from the Mechanical Engineering Department observed the operation of Chiller #   on Date at Time.

Weather conditions were (OA Temp, OA wet bulb, wind, sunny/cloudy, etc.)

Based on operating data on the chiller control touch panel and ECUP Monitor displays we calculated the Coefficient of Performance three different ways. The average COP was…

We believe the most accurate value of COP under these conditions is…

Thank you for allowing us to provide this service.

Sincerely

Names