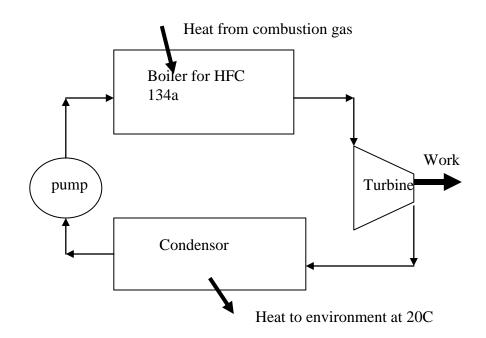**4.42   FINAL**
Open Book

1) (25) A company that makes heat pump components had decided to use their knowledge and some of their existing equipment to make small electric power generators for buildings in the developing world.. They want to use their existing refrigerant, HFC 134a as the working fluid in the power cycle. They plan to burn natural gas as the heat source. Their initial test was disappointing as they only achieved an efficiency of 4 percent. In this test the natural gas was burned with lots of air so the combustion gas only achieved a temperature of 50C. Heat was rejected to the environment; the environment was at 20C

a) If we improve the heat exchangers, the boiler and condenser, by significantly increasing their area while keeping the natural gas and environmental temperatures at 50C and 20C, respectively, what is the limit to the efficiency gain that could be achieved with the power generator?

b) One suggestion is to significantly increase the temperature of the combustion gas while the environment remains at 20 C. They still want to use HFC134a as the working fluid within the power cycle. Reviewing the saturation properties of HC134a are there some practical limits to achieving an efficiency of 20 percent or greater?

c) What is your recommendation for major charges in the overall project concept to achieve a practical power generation device with an efficiency above 30 percent?

Heat from combustion gas

Boiler for HFC 134a

pump

Turbine

Work

Condensor

Heat to environment at 20C

2) (25) The indoor conditions in a room are 21C and 50 %RH. There is still air in the room. When the outside temperature is 0C, the inside glass surface has a temperature of 16C, measured at the center of the glass surface at night. The glass is a double glazed unit with unknown properties. The inside surface of the glass does not have a low e coating on it.

a) With these temperature measurements can you estimate the U value neglecting framing elements?

b) For another window, the same inside glass temperature, 16C is measured when the sun is shining on the window and the room air conditions and the outside temperature are the same as part (a). Is the U value for this window the same as that in part (a)? If not, is the U value of this window larger or smaller than the window in part a? Remember, the U value always refers to the heat transfer through the window without the presence of solar radiation.

c) For the same conditions as part (a), condensation just begins to form on the inside of the framing elements. Can you estimate the U value of a framing element based on its surface area?

d) Without replacing this window in parts a and c, suggest ways to improve its thermal performance.

3. (25) We would like to cool a building so that the interior is maintained at 24 ºC and 50% RH. The outside conditions are 35 ºC and 50% RH. We know that 60% of the heat in the room is sensible and 40% is latent. We will supply 1200 kg/hr of air to the space.

To achieve the supply air conditions, we will use the following processes:

1. Cool the outdoor air by mixing it with some of the return interior air.
2. Sensible cooling to saturation temperature.
3. Dehumidification.
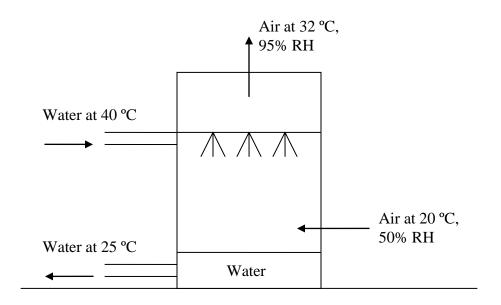4. Sensible heating until we reach the desired supply conditions.

a. We will supply air at 18 ºC. What is the relative humidity of the supply air?

b. During step 1, we will mix 60% return air with 40% outdoor air. What are the resulting temperature and humidity of the mixed air?

c. How much water (in kg/hr) will be removed from the air during step 3?

d. During step 4, what is the rate of sensible heat (in kJ/hr) that we will need to put into the air?

4. (25) A cooling tower can be used to remove heat from water. The cooling tower in the diagram below cools water from 40 ℃ to 25 ℃. Air enters the bottom of the tower at 20 ℃ and 50% relative humidity. Air exits the top of the tower at 32 ℃ and 95% relative humidity. The mass flow rate of the water which enters the tower is 10,000 kg per minute.

a. Assuming steady state, write expressions for the energy and mass balance of this system.

b. What is the mass flow rate of air entering the cooling tower?

c. What is the mass flow rate of water which leaves the cooling tower?

4.42J / 1.044J / 2.45J Fundamentals of Energy in Buildings
Fall 2010