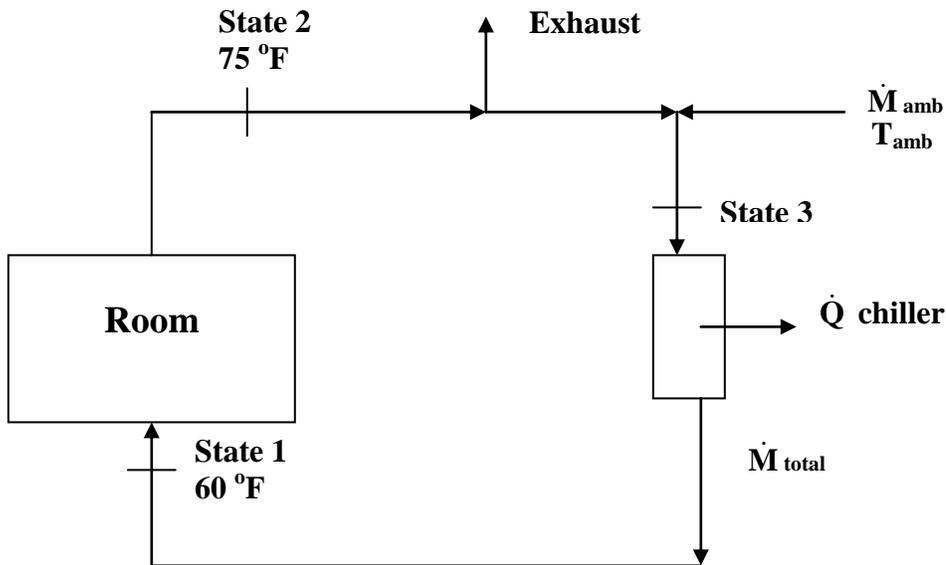


1.



A room at steady state has a supply air stream of cool air entering at 60°F. The lights, office appliances and people transfer heat to the air so that it leaves at 75°F. Consider only sensible heat transfer for this problem, with all temperatures given as dry bulb temperatures. After the air leaves the room some is exhausted from the building. The remainder mixes with ambient air. The mixture is cooled by the chiller down to 60°F. For ventilation requirements \dot{M}_{amb} must be at least 20 percent of the total flow rate. The total air flow rate to the room and the entering temperature, state 1, are held constant. The amount of ambient air can be varied from 20 percent up to 100 % of \dot{M}_{total} (with corresponding increases in the exhaust flow to keep the total flow constant). The temperature changes are small so C_p can be considered constant.

a) For an arbitrary ambient temperature develop an expression for $\dot{Q}_{chiller}$ in terms of \dot{M}_{amb} and \dot{M}_{total} .

b) As the ambient temperature varies between 50°F and 85°F what should \dot{M}_{amb} and \dot{M}_{total} be to minimize $\dot{Q}_{chiller}$?

Show a diagram of the optimum \dot{M}_{amb} and \dot{M}_{total} versus T_{AMB} . At different ambient temperature levels, e.g., 60, 75 °F, the strategy to minimize the chiller cooling requirement may change. This is known as an economizer cycle.

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Homework Set #4

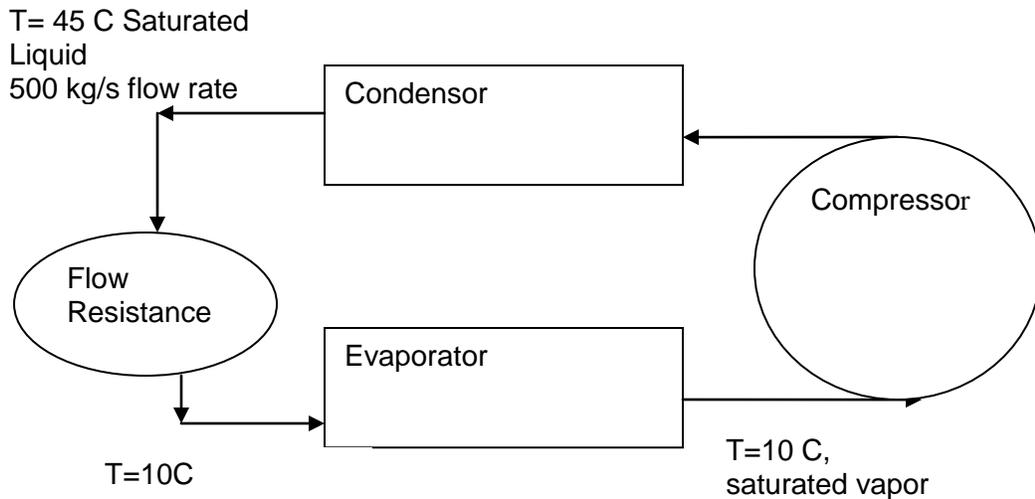
2. An office space is to be kept at 73°F. If cool air is constantly supplied to the space at 60°F and the space can be assumed to be at a uniform temperature, what is the required air mass flow in lb/hr and volume flow in CFM? The same flow of air continually leaves the space. The heat transfer into the space from the outside through an exterior wall is 16,000 BTU/hr. Internal "heat gains" in the office space can be taken as 2.5 W/ft^2 for office equipment and computers and 250 BTU/hr per person. Assume the space ft^2 is occupied by 40 people. The heat given due to people assume is only sensible heating, i.e., it neglects any evaporation or changes in the moisture level in the air. Assume steady state conditions prevail. The floor area of the office is 1500 ft^2 .
- 2b. If all the heat gains are doubled what options are available for the cool air supply to keep the office space at 73°F? What other factors must be considered in choosing an option?
3. A water to air heat exchanger is used to heat the air of a home interior. The air flow rate is 2000 lbm/hr ; the air enters in steady flow at 70° F and leaves the heat exchanger at 100° F . Heating water enters at 130° F and leaves at 110° F .
 - a) If the heat exchanger is operating in steady state and there is negligible heat loss from the outside casing of the exchanger to its surroundings what is the required water flow rate?
 - b) Do you think it's possible to design a heat exchanger with a water temperature drop from 130° F to 110° F while the air outlet temperature is raised to 125° F (for suitable air and water flow rates)?
 - c) Is it possible to have an air outlet temperature of 135° F with these same water temperatures?
4. An air conditioning system uses R-12 (Freon-12) as a working fluid. The flow rate of refrigerant is $1,000 \text{ lbm/hr}$ and it is steady. The refrigerant is condensed in the condenser to saturated liquid at 120° F . From the condenser, it passes through an expansion valve where the pressure is lowered and the outlet temperature is 20° F . The expansion valve is insulated and there is no shaft work. After the expansion valve the Freon enters the evaporator where it receives heat at constant pressure corresponding to the saturation pressure of 20° F . The heat transferred to the Freon in the evaporation provides the cooling to the air passing over the evaporator.
 - a) Find the cooling capacity of the unit in BTU/hr if the outlet of the evaporator is saturated vapor. Find the cooling capacity in tons. Hint: Define a control volume around the evaporator and write the steady flow energy equation.
 - b) Repeat part (a) if the outlet of the evaporator is super heated by 15° F ; that is, the vapor is heated at constant pressure to 15° F above the saturation temperature. Assume the Freon-12 vapor is a perfect gas with C_p equal to $0.15 \text{ BTU/lbm } ^\circ \text{ F}$.

5. An open plan office is to be cooled by natural ventilation. The long axis of the building is aligned in the East-West direction. The depth in the North-South direction is 30 m with operable windows on both the North and South sides. With open windows and negligible air flow resistance in the interior, when the wind is from the South, the air velocity at the Southern window open area can be approximately related to the wind velocity as, $V_{\text{open area}} = 0.35 V_{\text{wind}}$. Assume the North side windows have the same open area as the South windows and there is an equal air flow out of the North side windows. The interior height is 3 m and there is a combined heat input due to lights, people and office equipment of 40 W/m^2 of floor area.
- a) What is the air change rate per hour, ACH, of the building interior as a function of the percent of the South façade used for open window area? The wind velocity is 1.5 m/s.
 - b) Plot the temperature rise of the interior air as a function of the percent of the South façade used for open windows. The wind velocity is still 1.5 m/s.
 - c) How can the building be kept cool when the wind velocity is reduced?
 - d) Compare the performance of natural ventilation between the upper and lower floors of a high rise building.

6. An air conditioning system uses HFC 134a as a working fluid, the refrigerant. The flow rate of refrigerant is 500 kg/hr and it is steady. The refrigerant is condensed in the condenser to saturated liquid at 45 C. From the condenser, it passes through an expansion valve, flow resistance, where the pressure is lowered and the outlet temperature is 10 C. The expansion valve is insulated and there is no shaft work. After the expansion valve the refrigerant enters the evaporator where it receives heat at constant pressure corresponding to the saturation pressure of 10 C. The heat transferred to the refrigerant in the evaporation provides the cooling to the air passing over the evaporator.

What is the enthalpy change of the refrigerant as it flows through the expansion valve?

Find the cooling capacity of the unit in W and BTU/hr if the outlet of the evaporator is saturated vapor. Hint: Define a control volume around the evaporator and write the steady flow energy equation.



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7. MIT has a large number of fume hoods used for wet chemistry experiments. When the hood sashes are open the air velocity, sometimes called the face velocity, must be maintained at a safe level to prevent any dangerous fumes from escaping. The air drawn into the hoods comes from the air supplied to the room. This air must be heated to acceptable temperature levels for the lab occupants. For safety reasons, all of the air flow in such a building must be exhausted and none can be recycled, a once-through system. Use the instruments from class to measure the air flow rate in a new and an older hood as the window is closed.
- a) Estimate for one full sized hood at MIT the energy required to heat the air use during one winter day if the hood is left fully open for 24 hours.
 - b) Use the instruments from class to measure the air flow rate in a new and older hood as the sash is closed.
 - b) Estimate the amount of energy required to heat the air for the entire heating season if the hood is always open.
 - c) Compare this to the energy required to heat an average single family house in Boston for the heating season.
 - d) What steps would you recommend to save energy with the fume hoods at MIT?
8. A single story shopping mall has a floor plan 50m X 100 m. All energy is supplied by electricity. It has been designed with some advanced efficiency features so that the yearly energy use is 100 kWh/m² of floor area. The architect proposes to use a wind turbine on the top of the building to supply all of the electricity. The wind turbine has a horizontal axis and has an average efficiency of 35 percent.
- a) Use the average wind speed in Boston (Logan Airport) to estimate what the diameter of a single turbine to meet the buildings energy?
 - b) What are the practical issues with such a system?

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