Quiz #5

MEMS 0051 - Introduction to Thermodynamics

Assigned: June 24th, 2020
Due: June 25th, 2020, 11:59 pm

Problem #1

You have been asked to evaluate a potential refrigerator for use in an industrial process. The refrigerator needs to be capable of condensing 2 [kg] of water at 101.3 [kPa], moving from saturated steam to saturated liquid water every 60 [s]. The inside of the refrigerator is kept at a stable temperature of -10 °C and rejects heat into a large room at a temperature of 35 °C. To prevent the temperature from increasing in the room, however, the refrigerator can reject heat at a rate of no more than 85 [kW]. Using the steam tables, answer the following:

(a) At what rate, $\dot{Q}_L$, does the heat need removed to condense the water?
The rate of heat that needs removed, $\dot{Q}_L$, is equivalent (but opposite in sign) to the amount of heat that needs removed from the water as it passes through the refrigeration space. This value can be calculated using either the change in enthalpy or entropy. The change in enthalpy is more accurate as using entropy directly to calculate heat transfer implies the process is reversible. In this case, however, the percent difference is neglible, and to demonstrate the concept of entropy, we will use it in this problem. From Table B.1.1:

$$s_1 = s_{g@100\ ^\circ\text{C}} = 7.3548 \text{ [kJ/kg-K]} \qquad s_2 = s_{f@100\ ^\circ\text{C}} = 1.3068 \text{ [kJ/kg-K]}$$

The rate of heat being removed from the water then is:

$$\dot{Q}_w = \frac{mT_w(s_2 - s_1)}{t} = \frac{(2\text{ [kg]})(373.15\text{ [K]})((1.3068 - 7.3548)\text{ [kJ/kg-K]})}{60\text{ [s]}} = -75.23\text{ [kW]}$$

The heat entering the evaporator of the refrigerator then is:

$$\boxed{\dot{Q}_L = 75.23\text{ [kW]}}$$

(b) Is this refrigerator real, ideal, or impossible? Explain your answer. We can determine if the refrigerator is real, ideal, or impossible by either evaluating the Clausius Inequality or by comparing the COP of the refrigerator to its Carnot COP. Calculating COP values:

$$\beta_{REF} = \frac{Q_L}{Q_H - Q_L} = \frac{75.23\text{ [kW]}}{(85 - 75.23)\text{ [kW]}} = 7.70$$

$$\beta_{Carnot} = \frac{T_L}{T_H - T_L} = \frac{263.15\text{ [K]}}{(308.15 - 263.15)\text{ [K]}} = 5.85$$

Note that we used the maximum allowable rate of heat rejection at 85 [kW] for calculating the COP of the real refrigerator. Since we cannot reject any more heat, we have then that:

$$\beta_{REF} > \beta_{Carnot}$$

This means this refrigerator is impossible and should not be recommended for use in this process.

Academic Integrity Statement:

I hereby attest that I have received no assistance (from a friend, from another student, from an on-line resource, such as Chegg, etc.), and that I have provided no assistance to another student, during this examination. All the work presented within is solely my own work.

Signature: ______________________________

Date: ____________________