1st LAW EXERCISE

An open system has two mass flow inlets and one exit. The energy flow rates of the two inlets are 385 Btu/hr and 431 Btu/hr. The energy flow rate associated with the exit flow is 362 Btu/hr. The system is experiencing two mechanical power inputs of 4 hp and 5 hp. In addition, there is one electrical power output of 6 kW. The system is gaining heat from an external source at a rate of 300 Btu/min. It is simultaneously losing heat at a rate of 10,000 Btu/hr. Determine the energy transport rate for this system (express your answer in Btu/hr). Is the system gaining energy, losing energy, or is it operating in a steady-state (i.e., no gain or loss)?

a) Draw a system diagram that represents the problem statement.

b) What is the energy rate balance equation for this situation?

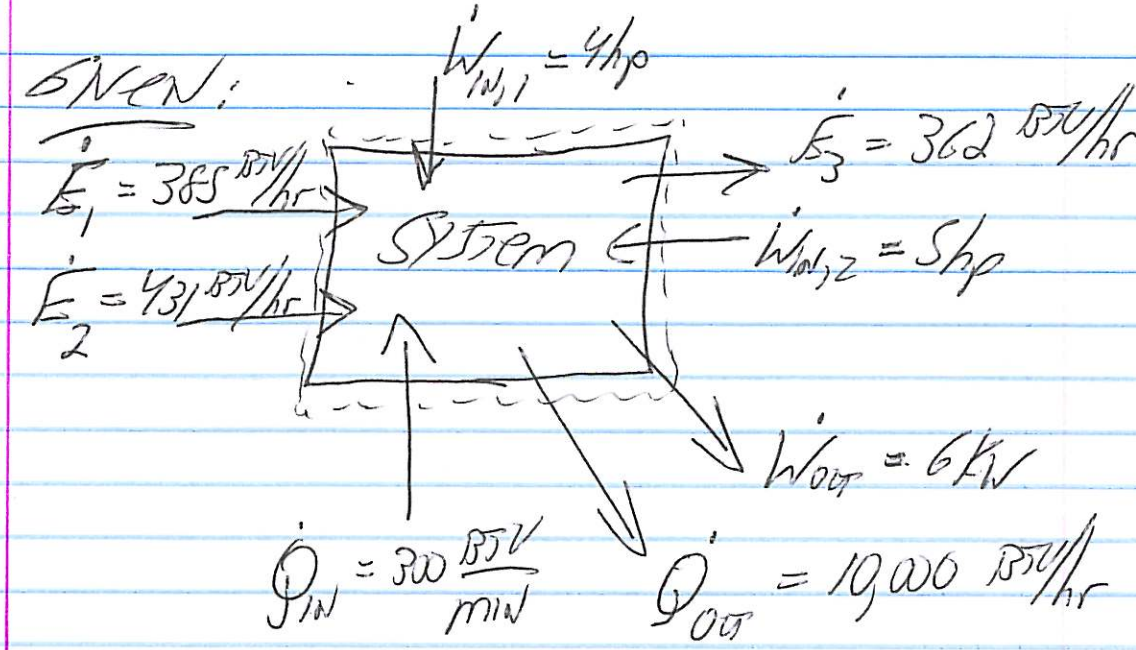
c) What is the sign convention for heat transfer and work terms in the problem?

d) What is the net heat transfer to the system?

e) What is the net work transfer out of the system?

f) What is the energy transport rate for this system?

GIVEN:



FIND: $\dot{E}_T$? +ve (GAINING ENERGY), -ve (LOSING ENERGY), 0 (STEADY-STATE)

SOLUTION:

$$\dot{E}_T = \dot{Q} - \dot{W} + \dot{E}$$

$\dot{Q}$ = NET RATE HEAT TRANSFER IN TO THE SYSTEM

$$\dot{Q} = \left(300 \frac{BTU}{min}\right)\left(60 \frac{min}{hr}\right) - 10,000 \frac{BTU}{hr}$$

$$\dot{Q} = 8,000 \frac{BTU}{hr} \quad \text{(NET INPUT)}$$

$\dot{W}$ = NET WORK TRANSFER RATE OUT OF SYSTEM

$$\dot{W} = (6 kW)\left(\frac{3412 BTU}{kW\text{-}hr}\right) - (5+4)hp\left(\frac{2545 BTU}{hp\text{-}hr}\right)$$

$$\dot{W} = -2,483 \frac{BTU}{hr} \quad \text{(NET INPUT)}$$

$\dot{E}$ = NET ENERGY TRANSFER RATE TO SYSTEM FROM HEAT FLOW

$$\dot{E} = (385 + 431)\ \text{BTU/hr} - 362\ \text{BTU/hr}$$

$$\dot{E} = 454\ \text{BTU/hr}$$

THUS, $\dot{E}_T = 8000\ \text{BTU/hr} - (-2433\ \text{BTU/hr}) + 454\ \text{BTU/hr}$

$$\dot{E}_T = 10,887\ \text{BTU/hr}$$

$$\dot{E}_G = \dot{E}_T = 10,887\ \text{BTU/hr}$$

∴ THE SYSTEM IS GAINING ENERGY