T11 SOLUTIONS (WAITZ)

a) APPLY SFEE TO COLD SIDE TO DETERMINE J/s TRANSFERRED AS HEAT, $\dot{Q}$. THEN USE THIS IN SFEE FOR HOT SIDE TO SOLVE FOR $T_{OUT,\,HOT}$.

SFEE: $q - w_s = h_2 - h_1 + \frac{c_2^2}{2} + \frac{c_1^2}{2}$

$q = \frac{\dot{Q}}{\dot{m}}$ $\quad h_2 - h_1 = c_p (T_2 - T_1)$ (IDEAL GAS)

COLD SIDE:

$$\dot{Q} = 1\,\frac{kg}{s}\left[1003.5\,\frac{J}{kg\text{-}k}\,(350K - 300K) + \frac{(60\,m/s)^2}{2} - \frac{(50\,m/s)^2}{2}\right]$$

$\boxed{\dot{Q} = 50725\ J/s}$ (+) SINCE ADDED TO SYSTEM

HOT SIDE: $\dot{Q}_{HOT} = -\dot{Q}_{COLD}$ SINCE REMOVED FROM HOT SIDE

$$-\frac{50725\,J/s}{5\,kg/s} = \left[1003.5\,\frac{J}{kg\text{-}k}\left(T_{OUT,\,HOT} - 500K\right) + \frac{(75\,m/s)^2}{2} - \frac{(100\,m/s)^2}{2}\right]$$

$\Longrightarrow \boxed{T_{OUT,\,HOT} = 492\,K}$

b) NO SHAFT WORK DONE, EVALUATE FLOW WORK

$w_f = P_{OUT} v_{OUT} - P_{IN} v_{IN} = R(T_{OUT} - T_{IN})$

$w_{f_{COLD}} = 287\,\frac{J}{kg\text{-}k}\left[350\,k - 300\,k\right] = 14.4\ kJ/kg$

$\dot{W}_{f_{COLD}} = 14.4\,\frac{kJ}{kg} \cdot 1\,kg/s = 14.4\,kW$ (WORK DONE BY FLOW EXPANDING)

$$\dot{W}_{f_{HOT}} = \frac{5\,kg}{s} \cdot 287 \frac{J}{kg\text{-}K}\left[492K - 500K\right] = -11.5\,kW$$

(WORK DONE ON FLOW TO COMPRESS IT)

$$\dot{W}_{f_{NET}} = 14.4\,kW - 11.5\,kW$$

$$= 2.87\,kW$$

(SO THERE IS NET WORK DONE BY THE HEAT EXCHANGER, JUST NOT FLOW WORK)

c) PROCESS IS IRREVERSIBLE — LIKE PUTTING A HOT BRICK NEXT TO A COLD BRICK. (HEAT X-FER ACROSS A FINITE TEMPERATURE DIFFERENCE.) CANNOT PUT SYSTEM BACK TO INITIAL STATE WITHOUT CHANGING THE SURROUNDINGS.

d) THE HOT FLOW ENTERS THE DEVICE WITH HIGH INTERNAL AND KINETIC ENERGY. THE COLD FLOW ENTERS THE DEVICE WITH LOWER KINETIC AND INTERNAL ENERGY. BECAUSE OF THE TEMPERATURE DIFFERENCE, ENERGY FLOWS FROM THE HOT SIDE TO THE COLD SIDE (HEAT TRANSFER), THEREBY RAISING THE KINETIC AND INTERNAL ENERGY OF THE COLD STREAM AND LOWERING THE KINETIC AND INTERNAL OF THE HOT STREAM. THERE IS ALSO FLOW OF ENERGY OUT OF THE SYSTEM DUE TO BOTH OF THE STREAMS EXITING THE DEVICE (INTERNAL ENERGY) AND DUE TO THE NET FLOW WORK DONE ON THE SURROUNDINGS BY THE FLOW ENTERING & LEAVING THE DEVICE.