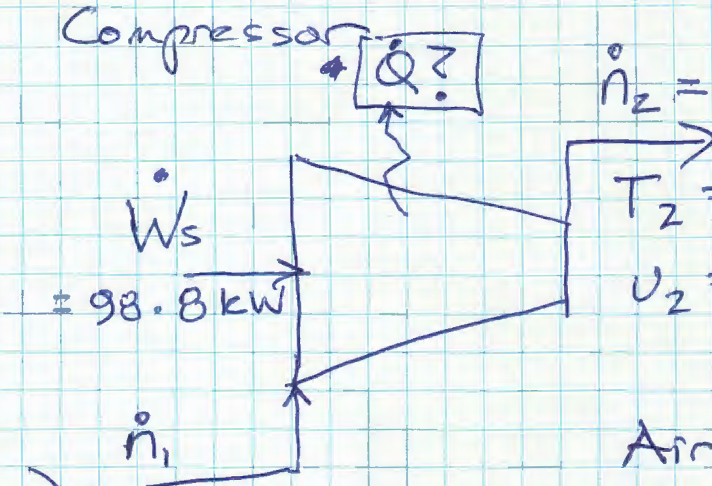
2.26



$\dot{n}_2 = 50$ kmol/hr

$T_2 = 520$ K H_2 (J/mol)?

$u_2 = 3.5$ m/s

H_1(J/mol)? $T_1 = 300$K

$u_1 = 10$ m/s

Air $C_p = \frac{7}{2}R$

assume $\frac{dH}{dP} = 0$

e.s., enthalpy does not vary with pressure

Find $\dot{Q}$?

Equations:

Definition of Cp. (text p41, Eq'n 2.22 for an ideal gas)

$$C_p \equiv \left(\frac{\partial H}{\partial T}\right)_{IG} \qquad dH = C_p\,dT$$

$$\Delta H = C_p\,\Delta T$$

(even if not constant pressure)

Mass Balance (text p46, Eq'ns 2.25, 2.26)

$$\frac{dm_{cv}}{dt} + \Delta(\dot{m})_{fs} = 0$$

but steady-state so

$$\Delta(\dot{m})_{fs} = \Delta(\rho u A)_{fs} = 0$$

$$\dot{m} = \frac{u_1 A_1}{V_1} = \frac{u_2 A_2}{V_2} \quad \left(\begin{array}{l}\text{for 1 entering} \\ \text{+ 1 exiting stream}\end{array}\right)$$

Energy Balance (pg 48)

$$\frac{d(mU)_{cv}}{dt} + \Delta\left[\left(H + \frac{1}{2}u^2 + zg\right)\dot{m}\right]_{fs} = \dot{Q} + \dot{W}$$

(Eq'n 2.28)

but we have steady-state & p. 51 hence

$$\Delta\left[\left(H + \frac{1}{2}u^2 + zg\right)\dot{m}\right]_{fs} = \dot{Q} + \dot{W}_s$$

shaft work

(Eq'n 2.30)

Assume $\Delta zg = 0$ (the compressor is stationary)

then

$$\Delta\left[\left(H + \frac{1}{2}u^2\right)\dot{m}\right]_{fs} = \dot{Q} + \dot{W}_s$$

need to deal with mass flow and mole flow consistency. Kinetic energy requires "mass" but C_p is in J/mol K and flow is given as 50 kmol/hr.

Assume molar mass of air = 29 g/mol

or

29 kg/kmol.

Now

$$\left[(H_2 - H_1) + \left(\frac{u_2^2}{2} - \frac{u_1^2}{2}\right) M_{AIR}\right]\dot{n} - \dot{W}_S = \dot{Q}$$

$$\Delta H = (H_2 - H_1) = C_p(T_2 - T_1) \quad \text{where } C_p = \frac{7}{2}R$$

$$= \frac{7}{2}\left(8.314 \frac{J}{mol\,K}\right)$$

$$= \frac{7}{2}\left(8.314 \frac{kJ}{kmol\cdot K}\right)$$

$$\Delta H = \frac{7}{2}\, 8.314 \frac{kJ}{kmol\,K}(520K - 300K)$$

$$= 6.402 \times 10^3 \frac{kJ}{kmol}$$

$$\left(\frac{u_2^2}{2} - \frac{u_1^2}{2}\right) M_{AIR} = \left(\frac{3.5^2}{2}\frac{m^2}{s^2} - \frac{10^2}{2}\frac{m^2}{s^2}\right) \cdot 29 \frac{kg}{kmol}$$

$$= -43.9 \cdot 29 \left(\frac{kg \cdot m^2}{s^2}\right) / kmol$$

$$\boxed{1 \; kg \frac{m^2}{s^2} = 1 \; J}$$

$$= -1272 \; J/kmol$$

$$= -1.272 \; kJ/kmol$$

subst.

$$\left[6.402 \times 10^3 - 1.272\right] 50 \frac{kmol}{h} - \dot{W}_S = \dot{Q}$$

$$(kJ/kmol)$$

$$320036 \; kJ/h - \dot{W}_S = \dot{Q}$$

But $1 \; kW = 1 \; kJ/s$ need to correct units.

$$320036 \ \frac{kJ}{h} \times \frac{1\,h}{3600\,s} = 88.9 \ \frac{kJ}{s}$$

$$= 88.9 \ kW$$

Now

$$88.9 \ kW - \dot{W}_s = \dot{Q}$$

$W_s = 98.8$ kW (Given)

$$\therefore \quad \dot{Q} = 88.9 - 98.8 = -9.9 \ kW.$$

The compressor is giving off 9.9 kW of heat in compressing 50 kmol/hr.

NOTE: Kinetic energy had very little effect. ⇒ Use for problem 2.42

Steady State Energy Balance

$$\Delta\left[\left(H + \cancel{\tfrac{1}{2}u^2}^{\,0} + \cancel{zg}^{\,0}\right)\dot{m}\right]_{fs} = \cancel{\dot{Q}}^{\,0} + \dot{W}_s \Rightarrow \Delta\left[H\dot{m}\right]_{fs} = \dot{W}_s$$

2.42 $mdot := 4.5\,\frac{kg}{s}$ $\quad H_1 := 761.1\,\frac{kJ}{kg}$ $\quad H_2 := 536.9\cdot\frac{kJ}{kg}$

Assume that the compressor is adiabatic (Qdot = 0). Neglect changes in KE and PE.

$\dot{W}_s = \dot{m}\,(H_2 - H_1)$ all given

$\dot{W}_s = -1.009 \times 10^3$ kW

$Wdot := mdot\cdot(H_2 - H_1)$

$Wdot = -1.009 \times 10^3\,kW$

$$Cost := 15200\cdot\left(\frac{|Wdot|}{kW}\right)^{0.573}$$

$Cost = 799924\,dollars$ **Ans.**

Single cost function that predicts cost in dollars for a given power in kW.