T8 SOLUTIONS (WAITZ)

a) $p_1 = 1\times10^6$ Pa, $T_1 = 200$K, $C_1 = 50\frac{m}{s}$ $\dot{m} = 100$ kg/s

$p_2 = 5\times10^6$ Pa via a q-s ADIAB. PROCESS ∴ pv^{γ} = CONST.

$C_2 = 50\frac{m}{s}$ ∴ $q = 0$

$$p_1 v_1 = RT_1 \implies v_1 = 0.052\ \frac{m^3}{kg} \qquad (R = 260\ J/kg\text{-}K)$$

$$p_1 v_1^{\gamma} = p_2 v_2^{\gamma}, \quad \gamma = \frac{c_p}{c_v} = 1.1 \implies v_2 = 0.012\ \frac{m^3}{kg}$$

SFEE

$$q^{\nearrow 0} - w_s = h_2 - h_1 + \frac{c_2^2}{2} - \frac{c_1^2}{2}$$

OR

$$q^{\nearrow 0} - w = u_2 - u_1 + \frac{c_2^2}{2} - \frac{c_1^2}{2}$$

$$w_f = R(T_2 - T_1) = w - w_s$$

SO

$$w = -\left[c_v(T_2 - T_1) + \frac{c_2^2}{2} - \frac{c_1^2}{2}\right], \quad \frac{p_2 v_2}{R} = T_2 = 230.8K$$

$$w = -78.2\ \frac{kJ}{kg}$$

OR

$$\dot{W} = \dot{m}w = -7.8\ MW$$

$$w_f = 260(230.8 - 200) = 8\ \frac{kJ}{kg}$$

OR

$$\dot{W}_f = \dot{m}w_f = 0.8\ MW$$

$$w_s = -\left[c_p(T_2 - T_1) + \frac{c_2^2}{2} - \frac{c_1^2}{2}\right] = w - w_f$$

$$w_s = -86.2\ \frac{kJ}{kg} \quad \text{OR} \quad \dot{W}_s = -8.62\ MW$$

b) $C_2 = 50\,m/s$, $T_2 = 230.8\,K$, $p_2 = 5\times10^6\,Pa$

$C_3 = 100\,m/s$, $T_3 = ?$, $p_3 = 5\times10^6\,Pa$ $\quad q_{IN} = 1300\,kJ/kg$

$$q - \cancel{W_s}^{\,0} = C_p(T_3 - T_2) + \frac{C_3^2}{2} - \frac{C_2^2}{2}$$

(NO SHAFT WORK BUT CAN STILL BE FLOW WORK)

$$1300\times10^3 = 2800(T_3 - 230.8) + \frac{100^2}{2} - \frac{50^2}{2}$$

$$T_3 = 693.7, \quad v_3 = \frac{RT_3}{P_3} = \frac{260(693.7)}{5\times10^6} = 0.036\,\frac{m^3}{kg}$$

$\boxed{W_s = 0}$ $\quad W_f = R(T_3 - T_2)$

$$W_f = 260(693.7 - 230.8) = 120\,\frac{kJ}{kg}$$

or

$$\dot{W}_f = 1.2\,MW$$

c) $\boxed{W_{s_{TURBINE}} = -W_{s_{PUMP}} = 86.2\,\frac{kJ}{kg}}$ or $\boxed{\dot{W}_s = 8.6\,MW}$

$$\cancel{q}^{\,0} - W_s = C_p(T_4 - T_3) + \frac{C_4^2}{2} - \frac{C_3^2}{2}$$

$$-86.2\times10^3 = 2800(T_4 - 693.7) + \frac{120^2}{2} - \frac{100^2}{2}$$

$$T_4 = 662\,K$$

$$W_f = R(T_4 - T_3) = 260(662 - 693.7) = -8.2\,kJ/kg$$

$\boxed{W_f = -8.2\,\frac{kJ}{kg} \quad \text{or} \quad \dot{W}_f = -0.82\,MW}$