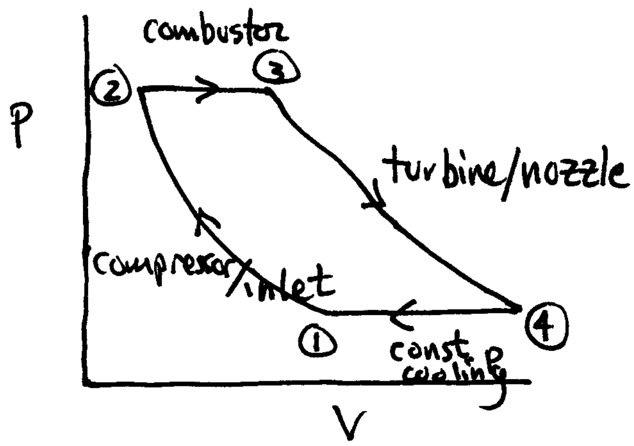
T9 SOLUTIONS BY WAITZ

a)



- COMPRESSOR/INLET (1 → 2), q-s. ADIABATIC COMPRESSION

$$q = 0, \quad -w = C_v(T_2 - T_1), \quad -w_s = C_p(T_2 - T_1)$$

$$w_{flow} = w - w_s = (T_2 - T_1)(C_p - C_v) = R(T_2 - T_1)$$

- COMBUSTOR (2 → 3), CONST. PRESSURE HEAT ADDITION

$$dh = \delta q + v\,dp^{\,0} \quad \therefore \quad q = C_p(T_3 - T_2)$$

$$\Delta u = q - w \quad \therefore \quad C_v(T_3 - T_2) = C_p(T_3 - T_2) - w$$

$$\Rightarrow \quad w = (C_p - C_v)(T_3 - T_2) = R(T_3 - T_2)$$

$$w_s = 0$$

$$w_{flow} = R(T_3 - T_2)$$

- TURBINE/NOZZLE, (3 → 4), q-s. adiabatic expansion (SAME AS COMPRESSOR)

$$q = 0, \quad w = -C_v(T_4 - T_3), \quad w_s = -C_p(T_4 - T_3)$$

$$w_{flow} = R(T_4 - T_3)$$

- COOLING AT CONST. PRESSURE (4 → 1) (SAME AS COMB.)

$$q = C_p(T_1 - T_4), \quad w = w_{flow} = R(T_1 - T_4), \quad w_s = 0$$

b) NET WORK $= W_{1-2} + W_{2-3} + W_{3-4} + W_{4-1}$

$$= C_v(T_1 - T_2) + R(T_3 - T_2) + C_v(T_3 - T_4) + R(T_1 - T_4)$$

$$= \cancel{C_vT_1} - \cancel{C_vT_2} + C_pT_3 - \cancel{C_vT_3} - C_pT_2 + \cancel{C_vT_2}$$
$$+ \cancel{C_vT_3} - \cancel{C_vT_4} + C_pT_1 - \cancel{C_vT_1} - C_pT_4 + \cancel{C_vT_4}$$

$$= C_p(T_3 - T_2) + C_p(T_1 - T_4)$$

$$= q_{2-3} + q_{4-1} = \text{NET HEAT} \checkmark$$

c) NET FLOW WORK $= R(\cancel{T_2} - \cancel{T_1}) + R(\cancel{T_3} - \cancel{T_2}) + R(\cancel{T_4} - \cancel{T_3}) + R(\cancel{T_1} - \cancel{T_4})$

$$= 0 \checkmark$$

NET SHAFT WORK $= C_p(T_1 - T_2) + C_p(T_3 - T_4)$

$$= C_p(T_3 - T_2) + C_p(T_1 - T_4)$$

$= $ NET WORK $\checkmark$

d) FLOW WORK IS THE WORK ASSOCIATED WITH THE RELATIVE CHANGE IN VOLUME OF A CHUNK OF FLUID AS IT PASSES THROUGH A DEVICE.

c) FROM THE SOLUTIONS FOR T7:

$$T_1 = 300K,\ T_2 = 624K,\ T_3 = 1400K,\ T_4 = 673K$$

TURBINE WORK $= C_v(T_3 - T_4) = 716.5(1400 - 673)$

$$W = 521 \text{ kJ/kg}$$

TURBINE SHAFT WORK $= C_p(T_3 - T_4) = 1003.5(1400 - 673)$

$$W_s = 730 \text{ kJ/kg}$$

TURBINE FLOW WORK $= R(673 - 1400) =$

$$W_{flow} = -209 \text{ kJ/kg}$$

COMPRESSOR SHAFT WORK $= C_p(T_1 - T_2)$

$$= 1003.5(300 - 624)$$

$$W_s = -325 \text{ kJ/kg}$$

$= 44.6\%$ OF THE

TURBINE SHAFT WORK GOES TO POWERING THE COMPRESSOR. THE REST IS EQUAL TO THE NET WORK OF THE CYCLE AND IS USED TO DRIVE THE ELECTRICAL GENERATOR.