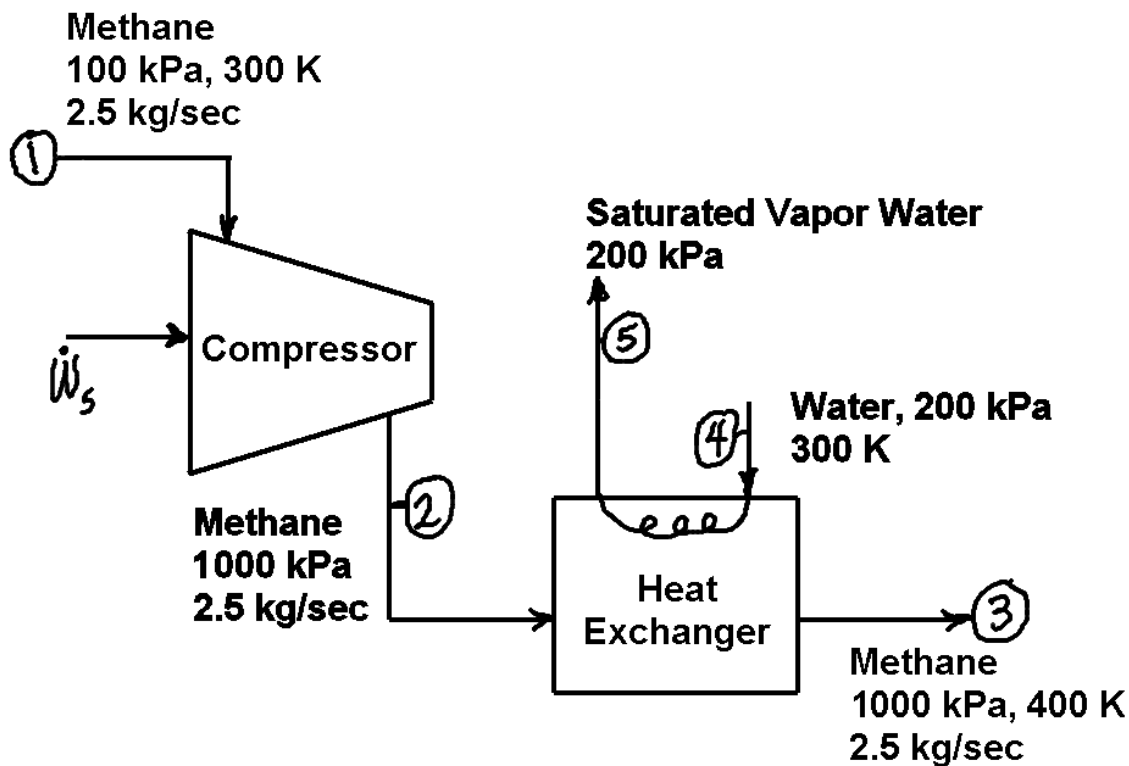


Methane is compressed from State 1 (100 kPa and 300 K) to State 2 (1000 kPa) in a compressor, then it is cooled to State 3 (400 K, 1000 kPa) in a heat exchanger that uses water for coolant and produces saturated steam at 200 kPa. See the diagram below. The following assumptions may be made:

1. The thermal efficiency of the compressor is 0.82.
2. Pressure drop through the heat exchanger for both the water and methane sides is negligible.
3. The compressor operates adiabatically.
4. There is no heat loss from the heat exchanger.
5. The whole process is steady-state, steady-flow (SSSF).



a. 40 points

Find T_2' , h_2' , s_2' , and $\dot{W}_s'$, for the isentropic base case for the compressor. Each property is worth 10 points, and the work requirement is worth 10 points.

b. 40 points

Find T_2 , h_2 , s_2 , and $\dot{W}_s$ for the actual case for the compressor. Each property is worth 10 points, and the work requirement is worth 10 points.

c. 20 points

Find the flowrate, $\dot{m}$, of the water in kg/sec.

Use the steam tables beginning on page 664 and the methane tables beginning on page 710 of your book for all thermodynamic properties.

ES 3053

EXAM II
Solution

April 1, 2002

a. for the compressor

$$m \Delta h = \dot{Q} - \dot{W}_s'$$

 $\Delta S = 0$ for isentropic best case

$$s_1 = 11.6286 \text{ at } T_1 = 300 \text{ K}, P_1 = 100 \text{ kPa}, h_1 = 627.58$$

$$s_2' = 11.6286 \quad P_2 = 1000 \text{ kPa}$$

$$11.5672 \quad 1061.61 \quad 475$$

$$11.6286 \quad h_2' \quad T_2'$$

$$11.7141 \quad 1133.19 \quad 500$$

$$h_2' = 1091.53, \quad T_2' = 485.4 \text{ K}$$

$$\Delta h' = 1091.53 - 627.58 = 463.95$$

$$m \Delta h' = (2.5 \text{ kg/sec}) (463.95 \text{ kJ/kg}) = 1159.88 = -\dot{W}_s' \text{ kJ/sec}$$

$$\dot{W}_s' = -1159.88 \text{ kW}$$

$$b. \dot{W}_s = -1159.88 / 0.82 = -1414.48 \text{ kW}$$

$$\Delta h = 463.95 / 0.82 = 565.79 \text{ kJ/kg}$$

$$h_2 = 627.58 + 565.79 = 1193.37 \text{ kJ/kg}$$

$$1193.19 \quad 500 \quad 11.7141$$

$$1193.37 \quad T_2 \quad S_2$$

$$1206.95 \quad 525 \quad 11.8580$$

$$T_2 = 520.40 \text{ K}, \quad S_2 = 11.8315 \text{ kJ/kg} \cdot \text{K}$$

$$c. \sum \dot{m}_e h_e - \sum \dot{m}_i h_i = \dot{Q} - \dot{W}_s$$

only problem is water at 200 kPa, 380 K — interpolate in saturated liquid table at 27°C. $h_4 = 113.23 \text{ kJ/kg}$

$$(2.5)(1193.37 - 859.98) - \dot{m}_{\text{min}}(2706.63 - 113.23) = 0$$

$$\dot{m}_{\text{min}} = 0.3214 \text{ kg/sec}$$