Question #79172

Exactly 1.73 kg of water vapor is contained in a piston–cylinder assembly at a pressure of 1.00 MPa and temperature 600°C. The vapor is isothermally compressed to 80.0 MPa.

Determine the sum of the work and heat energy transports in this process.

Answer:

The first law of thermodynamics is given by:

$$\Delta U = Q - W, \tag{1}$$

where ΔU is the change in the internal energy during a process,

Q and W are the heat and work transport, respectively.

Since there is no change in the internal energy during an isothermal process, (1) gives:

$$Q = W, \tag{2}$$

The heat transfer during an isothermal process is given by:

$$Q = mT(s_2 - s_1), \tag{3}$$

where m = 1.73 kg – the mass of the steam,

T = 600°C + 273 = 873 K – the absolute temperature of the steam,

s_1 and s_2 – the specific entropy of the steam at the beginning and the end of the process.

From the steam table we can find the specific entropy of the steam (see https://www.nist.gov/sites/default/files/documents/srd/NISTIR5078-Tab3.pdf):

s_1 = 8.0310 kJ/kg.K at p_1 = 1.00 MPa and t_1 = 600°C,

s_2 = 5.3674 kJ/kg.K at p_2 = 80.0 MPa and $t_2 = t_1$ = 600°C.

Substitute into (3):

$$Q = 1.73 \cdot 873 \cdot (5.3674 - 5.3674) = -4023 \text{ kJ}.$$

Taking into account (2), we can find the sum of the work and heat energy transports in this process as a double heat:

$$Q + W = 2Q = 2 \cdot (-4023) = -8046 \text{ kJ}.$$