Examen Final – FIS1523 – Termodinámica

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Primer Semestre 2011

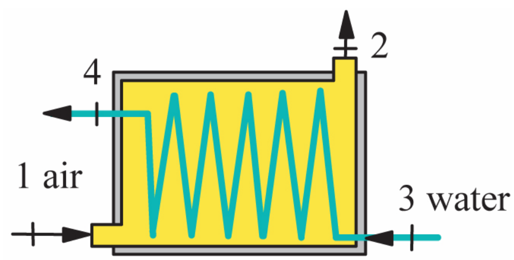
Tiempo: 120 minutos

Tablas Incluidas:

- Propiedades del aire como gas-ideal
- Agua saturada – tabla de temperatura
- Agua saturada – tabla de presión
- Refrigerante 134a saturado – tabla de presión
- Refrigerante 134a supercalentado

Problema 1

Un intercambiador de calor, como el que se muestra en la figura, se usa para enfriar un flujo de aire de 800 a 360 K, sin cambios en la presión que vale 1 MPa. El refrigerante es un flujo de agua a 15°C y 0.1 MPa. Si el agua sale como vapor saturado, ¿cuál es el cociente de los flujos de masa $\dot{m}_{agua}/\dot{m}_{aire}$?

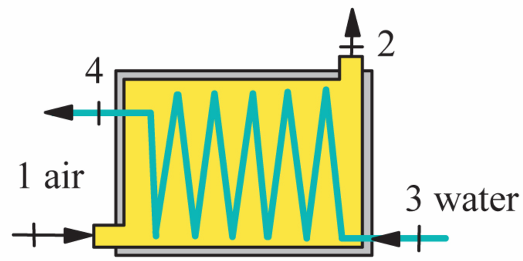


Solución

A heat exchanger, shown in Fig. P6.85, is used to cool an air flow from 800 K to 360 K, both states at 1 MPa. The coolant is a water flow at 15°C, 0.1 MPa. If the water leaves as saturated vapor, find the ratio of the flow rates $\dot{m}_{H_2O}/\dot{m}_{air}$

Solution:

C.V. Heat exchanger, steady flow 1 inlet and 1 exit for air and water each. The two flows exchange energy with no heat transfer to/from the outside.



Continuity Eqs.: Each line has a constant flow rate through it.

Energy Eq.6.10: $\dot{m}_{air}h_1 + \dot{m}_{H_2O}h_3 = \dot{m}_{air}h_2 + \dot{m}_{H_2O}h_4$

Process: Each line has a constant pressure.

Air states, Table A.7.1: $h_1 = 822.20$ kJ/kg, $h_2 = 360.86$ kJ/kg

Water states, Table B.1.1: $h_3 = 62.98$ kJ/kg (at 15°C),

Table B.1.2: $h_4 = 2675.5$ kJ/kg (at 100 kPa)

$$\dot{m}_{H_2O}/\dot{m}_{air} = \frac{h_1 - h_2}{h_4 - h_3} = \frac{822.20 - 360.86}{2675.5 - 62.99} = \mathbf{0.1766}$$

Problema 2

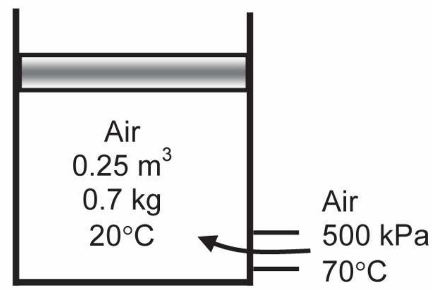
Un dispositivo de cilindro con pistón, aislado de 0.25 m^3 contiene inicialmente 0.7 kg de aire a 20°C. En este estado el pistón es libre de moverse. Ahora se deja entrar al cilindro aire a 70°C y 500 kPa desde una tubería hasta que el volumen aumenta un 50%. Considerar calores específicos constantes a temperatura ambiente.

a) Encontrar la expresión que permite encontrar la temperatura final del sistema
b) Si la temperatura final del sistema fuera 308 K, determinar la cantidad de masa que entró al sistema, el trabajo realizado y la entropía generada

Datos: R_{aire} = 0.287 kJ/kg K; c_p = 1.005 kJ/kg K; c_v = 0.718 kJ/kg K

Solución

Air is allowed to enter an insulated piston-cylinder device until the volume of the air increases by 50%. The final temperature in the cylinder, the amount of mass that has entered, the work done, and the entropy generation are to be determined.



Assumptions **1** Kinetic and potential energy changes are negligible. **2** Air is an ideal gas with constant specific heats.

Properties The gas constant of air is R = 0.287 kJ/kg.K and the specific heats of air at room temperature are c_p = 1.005 kJ/kg.K, c_v = 0.718 kJ/kg.K (Table A-2).

Analysis The initial pressure in the cylinder is

$$P_1 = \frac{m_1 R T_1}{V_1} = \frac{(0.7\text{ kg})(0.287\text{ kPa}\cdot\text{m}^3/\text{kg}\cdot\text{K})(20+273\text{ K})}{0.25\text{ m}^3} = 235.5\text{ kPa}$$

$$m_2 = \frac{P_2 V_2}{R T_2} = \frac{(235.5\text{ kPa})(1.5\times 0.25\text{ m}^3)}{(0.287\text{ kPa}\cdot\text{m}^3/\text{kg}\cdot\text{K})T_2} = \frac{307.71}{T_2}$$

A mass balance on the system gives the expression for the mass entering the cylinder

$$m_i = m_2 - m_1 = \frac{307.71}{T_2} - 0.7$$

(c) Noting that the pressure remains constant, the boundary work is determined to be

$$W_{\text{b,out}} = P_1(V_2 - V_1) = (235.5\text{ kPa})(1.5\times 0.25\text{ - }0.5)\text{m}^3 = \mathbf{29.43\ kJ}$$

(a) An energy balance on the system may be used to determine the final temperature

$$m_i h_i - W_{\text{b,out}} = m_2 u_2 - m_1 u_1$$

$$m_i c_p T_i - W_{\text{b,out}} = m_2 c_v T_2 - m_1 c_v T_1$$

$$\left(\frac{307.71}{T_2} - 0.7\right)(1.005)(70+273) - 29.43 = \left(\frac{307.71}{T_2}\right)(0.718)T_2 - (0.7)(0.718)(20+273)$$

There is only one unknown, which is the final temperature. By a trial-error approach or using EES, we find

$$T_2 = \mathbf{308.0\ K}$$

(b) The final mass and the amount of mass that has entered are

$$m_2 = \frac{307.71}{308.0} = 0.999\text{ kg}$$

$$m_i = m_2 - m_1 = 0.999 - 0.7 = \mathbf{0.299\ kg}$$

(d) The rate of entropy generation is determined from

$$S_{\text{gen}} = m_2 s_2 - m_1 s_1 - m_i s_i = m_2 s_2 - m_1 s_1 - (m_2 - m_1)s_i = m_2(s_2 - s_i) - m_1(s_1 - s_i)$$

$$= m_2\left(c_p \ln\frac{T_2}{T_i} - R\ln\frac{P_2}{P_i}\right) - m_1\left(c_p \ln\frac{T_1}{T_i} - R\ln\frac{P_1}{P_i}\right)$$

Problema 3

Una bomba de calor que opera en un ciclo de refrigeración ideal con R-134a como refrigerante es usada para calentar agua de 15 a 45 °C a razón de 0.12 kg/s. Las presiones del condensador y del evaporador son 1.4 y 0.32 MPa, respectivamente. Determinar la potencia necesaria para el funcionamiento de la bomba de calor.

Solución

A heat pump that operates on the ideal vapor-compression cycle with refrigerant-134a is considered. The power input to the heat pump is to be determined.

Assumptions **1** Steady operating conditions exist. **2** Kinetic and potential energy changes are negligible.

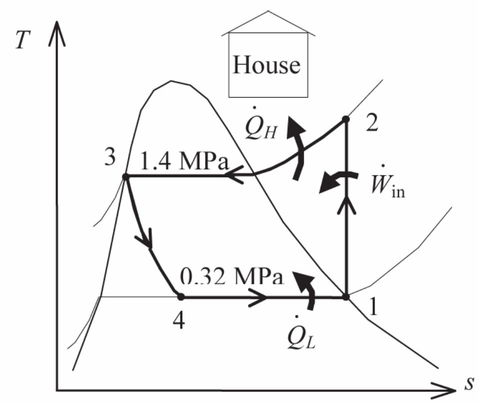
Analysis In an ideal vapor-compression refrigeration cycle, the compression process is isentropic, the refrigerant enters the compressor as a saturated vapor at the evaporator pressure, and leaves the condenser as saturated liquid at the condenser pressure. From the refrigerant tables (Tables A-12 and A-13),

$$\left.\begin{array}{l} P_1 = 320 \text{ kPa} \\ \text{sat. vapor} \end{array}\right\} \begin{array}{l} h_1 = h_{g\ @320\text{ kPa}} = 251.88 \text{ kJ/kg} \\ s_1 = s_{g\ @\ 320\text{ kPa}} = 0.93006 \text{ kJ/kg}\cdot\text{K} \end{array}$$

$$\left.\begin{array}{l} P_2 = 1.4 \text{ MPa} \\ s_2 = s_1 \end{array}\right\} h_2 = 282.54 \text{ kJ/kg}$$

$$\left.\begin{array}{l} P_3 = 1.4 \text{ MPa} \\ \text{sat. liquid} \end{array}\right\} h_3 = h_{f\ @\ 1.4\text{ MPa}} = 127.22 \text{ kJ/kg}$$

$$h_4 \cong h_3 = 127.22 \text{ kJ/kg} \quad (\text{throttling})$$



The heating load of this heat pump is determined from

$$\begin{aligned} \dot{Q}_H &= [\dot{m}c(T_2 - T_1)]_{\text{water}} \\ &= (0.12 \text{ kg/s})(4.18 \text{ kJ/kg}\cdot{}^\circ\text{C})(45-15)^\circ\text{C} = 15.05 \text{ kW} \end{aligned}$$

and

$$\dot{m}_R = \frac{\dot{Q}_H}{q_H} = \frac{\dot{Q}_H}{h_2 - h_3} = \frac{15.05 \text{ kJ/s}}{(282.54 - 127.22) \text{ kJ/kg}} = 0.09688 \text{ kg/s}$$

Then,

$$\dot{W}_{\text{in}} = \dot{m}_R (h_2 - h_1) = (0.09688 \text{ kg/s})(282.54 - 251.88) \text{ kJ/kg} = \mathbf{2.97\ kW}$$