TERMODİNAMİK ÇALIŞMA SORULARI

KISILMA VANALARI

5-62 Adyabatik bir kılcal boru soğutma sisteminde soğutucu akışkanın basıncını yoğuşturucu seviyesinden buharlaştırıcı seviyesini düşürmek için kullanılmaktadır. R134a kılcal boruya doymuş buhar olarak -20 °C' de girmektedir.Soğutucu akışkanın buharlaştırıcı öncesi kuruluğunu belirleyiniz.

5-63 Islak buhar olarak adlandırılan suyun doymuş sıvı-buhar karışımı 2000 kPa basınç olan buhar hattından 100 kPa basınç ve 120 °C' ye kısılmaktadır. Buhar hattındaki kuruluk nedir ? *çözüm: 0.957*

5-65 Su buharı iyice yalıtılmış bir vanayla sürekli akışta 8 MPa basınç ve 350 °C sıcaklıktan, 2 MPa basınca kısılmaktadır.Su buharının çıkış sıcaklığını hesaplayınız. *çözüm: 285 °C*

KARIŞIM ODALARI VE ISI DEĞİŞTİRİCİLERİ

5-71 Sabit hacimli bir karışım odasında bir akışkanın sıcak ve soğuk akımları karışmaktadır. Sıcak akışkan karışım odasına 5 kg/s ile ve 150 kj/kg enerji ile girmektedir.Soğuk akışkan 15 kg/s ile girmekte ve 50 kj/kg enerji taşımaktadır.Karışma odasına çevreden 5.5 kW ısı transferi gerçekleşmektedir.Karışım odası sürekli akış şartlarında çalışmakta zamanla kütle ve enerji kaybı ve kazancı olmamaktadır.Akışkan vasıtasıyla karışım odasından taşınan enerjiyi birim kütle için hesaplayınız.

5-72 0,5 kg/s debisinde ve 80 °C sıcaklıkta sıcak su ile 20 °C sıcaklıkta soğuk su , sürekli akışlı bir karışma odasında karıştırılmaktadır.Çıkan akışın 42 °C sıcaklıkta olması isteniyorsa, soğuk su akışının kütle debisi ne olmalıdır? Her üç akışın da 250 kPa basınçta olduklarını kabul ediniz. *çözüm: 0.865 kg/s*

5-76 20000 kg/saat debisindeki su buharı, bir güç santralinin yoğuşturucusuna 20 kPa basınç ve yüzde 95 kuruluk derecesi ile girmektedir. Yoğuşturucuda, boruların içinden akan nehir suyuna ısı geçişi olmaktadır.Isıl kirlenmeyi önlemek için nehir suyunun sıcaklık artışı 10°C ile sınırlanmıştır.Suyun yoğuşturucu çıkışındaki hali, 20 kPa basınçta doymuş sıvı olduğuna göre, soğutma suyunun debisi ne olmalıdır? *çözüm: 297.7kg/s*

5-81 Hava (cp = 1,005 kj/kg.°C) çapraz- akışlı bir ısı değiştiricisinde fırına girmeden önce sıcak egzoz gazları ile ön ısıtmaya tabi tutulmaktadır. Hava ısı değiştiricisinde 95 kPa basınç 20°C sıcaklık ve 0,8 m^3/s debi ile girmektedir.Yanma gazları (cp = 1,10 kj/kg.°C) 160 °C sıcaklık 0,9 kg/s debi girmekte ve 95 °C sıcaklıkta çıkmaktadır. Havaya olan ısı geçişini ve havanın dış ortam sıcaklığını hesaplayınız.

5-86 100 kPa basınç ve 30 °C sıcaklıkta 5 m^3/s hacimsel debisindeki havayı 8°C sıcaklıkta su kullanarak 100 kPa basınç ve 18 °C sıcaklığa düşürmek için soğutulmuş su ısı değişim ünitesi tasarlanmıştır.Suyun kütlesel debisi 2kg/s olduğunda maksimum su çıkış sıcaklığını hesaplayınız. *çözüm: 16.3°C*

Throttling Valves

5-62C The temperature of a fluid can increase, decrease, or remain the same during a throttling process. Therefore, this claim is valid since no thermodynamic laws are violated.

5-63C No. Because air is an ideal gas and $h = h(T)$ for ideal gases. Thus if h remains constant, so does the temperature.

5-64C If it remains in the liquid phase, no. But if some of the liquid vaporizes during throttling, then yes.

5-65C Yes.

5-66 Refrigerant-134a is throttled by a capillary tube. The quality of the refrigerant at the exit is to be determined.

Assumptions **1** This is a steady-flow process since there is no change with time. **2** Kinetic and potential energy changes are negligible. **3** Heat transfer to or from the fluid is negligible. **4** There are no work interactions involved.

Analysis There is only one inlet and one exit, and thus $\dot{m}_1 = \dot{m}_2 = \dot{m}$. We take the throttling valve as the system, which is a control volume since mass crosses the boundary. The energy balance for this steady-flow system can be expressed in the rate form as

$$\dot{E}_{\text{in}} - \dot{E}_{\text{out}} = \Delta \dot{E}_{\text{system}}^{\nearrow 0 \text{ (steady)}} = 0$$

$$\dot{E}_{\text{in}} = \dot{E}_{\text{out}}$$

$$\dot{m}h_1 = \dot{m}h_2$$

$$h_1 = h_2$$

since $\dot{Q} \cong \dot{W} = \Delta\text{ke} \cong \Delta\text{pe} \cong 0$.

The inlet enthalpy of R-134a is, from the refrigerant tables (Table A-11),

$$\left.\begin{array}{l} T_1 = 50°\text{C} \\ \text{sat. liquid} \end{array}\right\} h_1 = h_f = 123.49 \text{ kJ/kg}$$

The exit quality is

$$\left.\begin{array}{l} T_2 = -20°\text{C} \\ h_2 = h_1 \end{array}\right\} x_2 = \frac{h_2 - h_f}{h_{fg}} = \frac{123.49 - 25.49}{212.91} = \mathbf{0.460}$$

5-67 Steam is throttled from a specified pressure to a specified state. The quality at the inlet is to be determined.

Assumptions **1** This is a steady-flow process since there is no change with time. **2** Kinetic and potential energy changes are negligible. **3** Heat transfer to or from the fluid is negligible. **4** There are no work interactions involved.

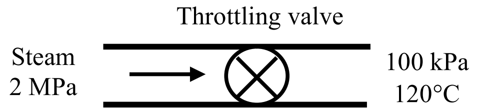
Analysis There is only one inlet and one exit, and thus $\dot{m}_1 = \dot{m}_2 = \dot{m}$. We take the throttling valve as the system, which is a control volume since mass crosses the boundary. The energy balance for this steady-flow system can be expressed in the rate form as

$$\dot{E}_{in} - \dot{E}_{out} = \Delta\dot{E}_{system}^{\nearrow 0 \text{ (steady)}} = 0$$

$$\dot{E}_{in} = \dot{E}_{out}$$

$$\dot{m}h_1 = \dot{m}h_2$$

$$h_1 = h_2$$



Since $\dot{Q} \cong \dot{W} = \Delta\text{ke} \cong \Delta\text{pe} \cong 0$.

The enthalpy of steam at the exit is (Table A-6),

$$\left.\begin{array}{l} P_2 = 100 \text{ kPa} \\ T_2 = 120°\text{C} \end{array}\right\} h_2 = 2716.1 \text{ kJ/kg}$$

The quality of the steam at the inlet is (Table A-5)

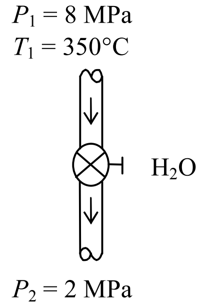
$$\left.\begin{array}{l} P_1 = 2000 \text{ kPa} \\ h_1 = h_2 = 2716.1 \text{ kJ/kg} \end{array}\right\} x_1 = \frac{h_2 - h_f}{h_{fg}} = \frac{2716.1 - 908.47}{1889.8} = \mathbf{0.957}$$

5-69 Steam is throttled by a well-insulated valve. The temperature drop of the steam after the expansion is to be determined.

Assumptions **1** This is a steady-flow process since there is no change with time. **2** Kinetic and potential energy changes are negligible. **3** Heat transfer to or from the fluid is negligible. **4** There are no work interactions involved.

Properties The inlet enthalpy of steam is (Tables A-6),

$$\left.\begin{array}{l} P_1 = 8 \text{ MPa} \\ T_1 = 350°\text{C} \end{array}\right\} h_1 = 2988.1 \text{ kJ/kg}$$



Analysis There is only one inlet and one exit, and thus $\dot{m}_1 = \dot{m}_2 = \dot{m}$. We take the throttling valve as the system, which is a control volume since mass crosses the boundary. The energy balance for this steady-flow system can be expressed in the rate form as

$$\begin{aligned} \dot{E}_{\text{in}} - \dot{E}_{\text{out}} &= \Delta \dot{E}_{\text{system}}^{\nearrow 0 \text{ (steady)}} = 0 \\ \dot{E}_{\text{in}} &= \dot{E}_{\text{out}} \\ \dot{m}h_1 &= \dot{m}h_2 \\ h_1 &= h_2 \end{aligned}$$

since $\dot{Q} \cong \dot{W} = \Delta ke \cong \Delta pe \cong 0$. Then the exit temperature of steam becomes

$$\left.\begin{array}{l} P_2 = 2 \text{ MPa} \\ (h_2 = h_1) \end{array}\right\} T_2 = \mathbf{285°C}$$

Mixing Chambers and Heat Exchangers

5-72C Under the conditions of no heat and work interactions between the mixing chamber and the surrounding medium.

5-73C Under the conditions of no heat and work interactions between the heat exchanger and the surrounding medium.

5-74C Yes, if the mixing chamber is losing heat to the surrounding medium.

5-75 Hot and cold streams of a fluid are mixed in a mixing chamber. Heat is lost from the chamber. The energy carried from the mixing chamber is to be determined.

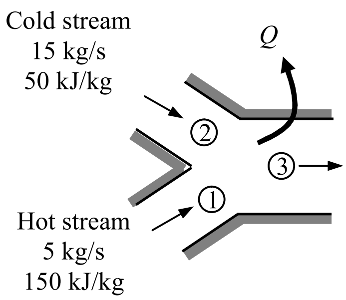
Assumptions **1** This is a steady-flow process since there is no change with time. **2** Kinetic and potential energy changes are negligible. **3** There are no work and heat interactions.

Analysis We take the mixing device as the system, which is a control volume. The energy balance for this steady-flow system can be expressed in the rate form as

$$\underbrace{\dot{E}_{in} - \dot{E}_{out}}_{\substack{\text{Rate of net energy transfer}\\ \text{by heat, work, and mass}}} = \underbrace{\Delta \dot{E}_{system}^{\nearrow 0\ (steady)}}_{\substack{\text{Rate of change in internal, kinetic,}\\ \text{potential, etc. energies}}} = 0$$

$$\dot{E}_{in} = \dot{E}_{out}$$

$$\dot{m}_1 e_1 + \dot{m}_2 e_2 = \dot{m}_3 e_3 + \dot{Q}_{out}$$



From a mass balance

$$\dot{m}_3 = \dot{m}_1 + \dot{m}_2 = 5 + 15 = 20 \text{ kg/s}$$

Substituting into the energy balance equation solving for the exit enthalpy gives

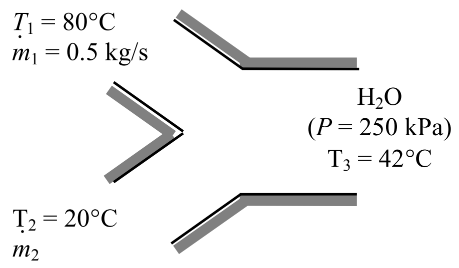
$$\dot{m}_1 e_1 + \dot{m}_2 e_2 = \dot{m}_3 e_3 + \dot{Q}_{out}$$

$$e_3 = \frac{\dot{m}_1 e_1 + \dot{m}_2 e_2 - \dot{Q}_{out}}{\dot{m}_3} = \frac{(5 \text{ kg/s})(150 \text{ kJ/kg} + (15 \text{ kg/s})(50 \text{ kJ/kg}) - 5.5 \text{ kW}}{20 \text{ kg/s}} = \mathbf{74.7\ kJ/kg}$$

5-76 A hot water stream is mixed with a cold water stream. For a specified mixture temperature, the mass flow rate of cold water is to be determined.

Assumptions **1** Steady operating conditions exist. **2** The mixing chamber is well-insulated so that heat loss to the surroundings is negligible. **3** Changes in the kinetic and potential energies of fluid streams are negligible. **4** Fluid properties are constant. **5** There are no work interactions.

Properties Noting that $T < T_{\text{sat @ 250 kPa}} = 127.41°\text{C}$, the water in all three streams exists as a compressed liquid, which can be approximated as a saturated liquid at the given temperature. Thus,



$$h_1 \cong h_{f@\,80°\text{C}} = 335.02 \text{ kJ/kg}$$

$$h_2 \cong h_{f@\,20°\text{C}} = 83.915 \text{ kJ/kg}$$

$$h_3 \cong h_{f@\,42°\text{C}} = 175.90 \text{ kJ/kg}$$

Analysis We take the mixing chamber as the system, which is a control volume. The mass and energy balances for this steady-flow system can be expressed in the rate form as

Mass balance:

$$\dot{m}_{\text{in}} - \dot{m}_{\text{out}} = \Delta \dot{m}_{\text{system}}^{\nearrow 0 \text{ (steady)}} = 0 \longrightarrow \dot{m}_1 + \dot{m}_2 = \dot{m}_3$$

Energy balance:

$$\underbrace{\dot{E}_{\text{in}} - \dot{E}_{\text{out}}}_{\substack{\text{Rate of net energy transfer} \\ \text{by heat, work, and mass}}} = \underbrace{\Delta \dot{E}_{\text{system}}^{\nearrow 0 \text{ (steady)}}}_{\substack{\text{Rate of change in internal, kinetic,} \\ \text{potential, etc. energies}}} = 0$$

$$\dot{E}_{\text{in}} = \dot{E}_{\text{out}}$$

$$\dot{m}_1 h_1 + \dot{m}_2 h_2 = \dot{m}_3 h_3 \quad (\text{since } \dot{Q} = \dot{W} = \Delta\text{ke} \cong \Delta\text{pe} \cong 0)$$

Combining the two relations and solving for $\dot{m}_2$ gives

$$\dot{m}_1 h_1 + \dot{m}_2 h_2 = (\dot{m}_1 + \dot{m}_2) h_3$$

$$\dot{m}_2 = \frac{h_1 - h_3}{h_3 - h_2} \dot{m}_1$$

Substituting, the mass flow rate of cold water stream is determined to be

$$\dot{m}_2 = \frac{(335.02 - 175.90) \text{ kJ/kg}}{(175.90 - 83.915) \text{ kJ/kg}} (0.5 \text{ kg/s}) = \mathbf{0.865 \text{ kg/s}}$$

5-81 Steam is condensed by cooling water in the condenser of a power plant. If the temperature rise of the cooling water is not to exceed 10°C, the minimum mass flow rate of the cooling water required is to be determined.

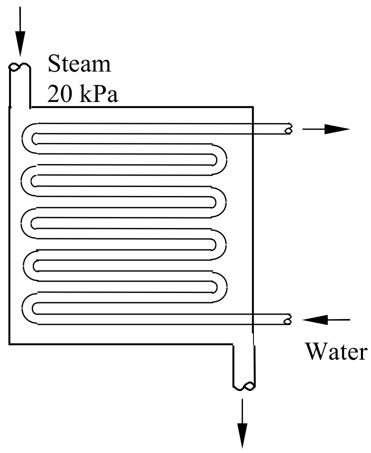
Assumptions **1** This is a steady-flow process since there is no change with time. **2** Kinetic and potential energy changes are negligible. **3** There are no work interactions. **4** Heat loss from the device to the surroundings is negligible and thus heat transfer from the hot fluid is equal to the heat transfer to the cold fluid. **5** Liquid water is an incompressible substance with constant specific heats at room temperature.

Properties The cooling water exists as compressed liquid at both states, and its specific heat at room temperature is c = 4.18 kJ/kg·°C (Table A-3). The enthalpies of the steam at the inlet and the exit states are (Tables A-5 and A-6)

$$\left.\begin{array}{l} P_3 = 20 \text{ kPa} \\ x_3 = 0.95 \end{array}\right\} h_3 = h_f + x_3 h_{fg} = 251.42 + 0.95 \times 2357.5 = 2491.1 \text{ kJ/kg}$$

$$\left.\begin{array}{l} P_4 = 20 \text{ kPa} \\ \text{sat. liquid} \end{array}\right\} h_4 \cong h_{\text{f@20 kPa}} = 251.42 \text{ kJ/kg}$$

Analysis We take the heat exchanger as the system, which is a control volume. The mass and energy balances for this steady-flow system can be expressed in the rate form as



Mass balance (for each fluid stream):

$$\dot{m}_{\text{in}} - \dot{m}_{\text{out}} = \Delta \dot{m}_{\text{system}}^{\nearrow 0 \text{ (steady)}} = 0$$

$$\dot{m}_{\text{in}} = \dot{m}_{\text{out}}$$

$$\dot{m}_1 = \dot{m}_2 = \dot{m}_w \quad \text{and} \quad \dot{m}_3 = \dot{m}_4 = \dot{m}_s$$

Energy balance (for the heat exchanger):

$$\underbrace{\dot{E}_{\text{in}} - \dot{E}_{\text{out}}}_{\substack{\text{Rate of net energy transfer} \\ \text{by heat, work, and mass}}} = \underbrace{\Delta \dot{E}_{\text{system}}^{\nearrow 0 \text{ (steady)}}}_{\substack{\text{Rate of change in internal, kinetic,} \\ \text{potential, etc. energies}}} = 0$$

$$\dot{E}_{\text{in}} = \dot{E}_{\text{out}}$$

$$\dot{m}_1 h_1 + \dot{m}_3 h_3 = \dot{m}_2 h_2 + \dot{m}_4 h_4 \quad (\text{since } \dot{Q} = \dot{W} = \Delta\text{ke} \cong \Delta\text{pe} \cong 0)$$

Combining the two,

$$\dot{m}_w (h_2 - h_1) = \dot{m}_s (h_3 - h_4)$$

Solving for $\dot{m}_w$:

$$\dot{m}_w = \frac{h_3 - h_4}{h_2 - h_1} \dot{m}_s \cong \frac{h_3 - h_4}{c_p (T_2 - T_1)} \dot{m}_s$$

Substituting,

$$\dot{m}_w = \frac{(2491.1 - 251.42) \text{kJ/kg}}{(4.18 \text{ kJ/kg} \cdot ^\circ\text{C})(10^\circ\text{C})} (20{,}000/3600 \text{ kg/s}) = \mathbf{297.7 \text{ kg/s}}$$

5-86 Air is preheated by hot exhaust gases in a cross-flow heat exchanger. The rate of heat transfer and the outlet temperature of the air are to be determined.

Assumptions **1** Steady operating conditions exist. **2** The heat exchanger is well-insulated so that heat loss to the surroundings is negligible and thus heat transfer from the hot fluid is equal to the heat transfer to the cold fluid. **3** Changes in the kinetic and potential energies of fluid streams are negligible. **4** Fluid properties are constant.

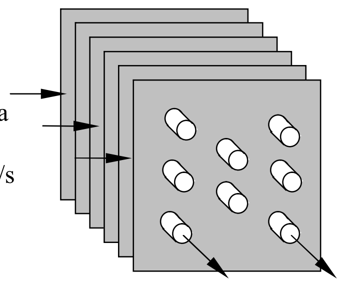
Properties The specific heats of air and combustion gases are given to be 1.005 and 1.10 kJ/kg.°C, respectively.

Analysis We take the exhaust pipes as the system, which is a control volume. The energy balance for this steady-flow system can be expressed in the rate form as

$$\underbrace{\dot{E}_{in} - \dot{E}_{out}}_{\text{Rate of net energy transfer by heat, work, and mass}} = \underbrace{\Delta \dot{E}_{system}^{\nearrow 0 \text{ (steady)}}}_{\text{Rate of change in internal, kinetic, potential, etc. energies}} = 0 \rightarrow \dot{E}_{in} = \dot{E}_{out}$$

$$\dot{m}h_1 = \dot{Q}_{out} + \dot{m}h_2 \quad (\text{since } \Delta\text{ke} \cong \Delta\text{pe} \cong 0)$$

$$\dot{Q}_{out} = \dot{m}c_p(T_1 - T_2)$$



Then the rate of heat transfer from the exhaust gases becomes

$$\dot{Q} = [\dot{m}c_p(T_{in} - T_{out})]_{gas}$$
$$= (0.95 \text{ kg/s})(1.1 \text{ kJ/kg.°C})(160°\text{C} - 95°\text{C})$$
$$= \mathbf{67.93 \text{ kW}}$$

The mass flow rate of air is

$$\dot{m} = \frac{P\dot{V}}{RT} = \frac{(95 \text{ kPa})(0.6 \text{ m}^3/\text{s})}{(0.287 \text{ kPa.m}^3/\text{kg.K}) \times 293 \text{ K}} = 0.6778 \text{ kg/s}$$

Noting that heat loss by the exhaust gases is equal to the heat gain by the air, the outlet temperature of the air becomes

$$\dot{Q} = \dot{m}c_p(T_{c,out} - T_{c,in}) \longrightarrow T_{c,out} = T_{c,in} + \frac{\dot{Q}}{\dot{m}c_p} = 20°\text{C} + \frac{67.93 \text{ kW}}{(0.6778 \text{ kg/s})(1.005 \text{ kJ/kg.°C})} = \mathbf{120°C}$$

5-91 A chilled-water heat-exchange unit is designed to cool air by water. The maximum water outlet temperature is to be determined.

Assumptions **1** This is a steady-flow process since there is no change with time. **2** Kinetic and potential energy changes are negligible. **3** There are no work interactions. **4** Heat loss from the device to the surroundings is negligible and thus heat transfer from the hot fluid is equal to the heat transfer to the cold fluid. **5** Air is an ideal gas with constant specific heats at room temperature.

Properties The gas constant of air is 0.287 kPa.m^3/kg.K (Table A-1). The constant pressure specific heat of air at room temperature is c_p = 1.005 kJ/kg·°C (Table A-2*a*). The specific heat of water is 4.18 kJ/kg·K (Table A-3).

Analysis The water temperature at the heat exchanger exit will be maximum when all the heat released by the air is picked up by the water. First, the inlet specific volume and the mass flow rate of air are

$$v_1 = \frac{RT_1}{P_1} = \frac{(0.287\text{ kPa}\cdot\text{m}^3/\text{kg}\cdot\text{K})(303\text{ K})}{100\text{ kPa}} = 0.8696\text{ m}^3/\text{kg}$$

$$\dot{m}_a = \frac{\dot{V}_1}{v_1} = \frac{5\text{ m}^3/\text{s}}{0.8696\text{ m}^3/\text{kg}} = 5.750\text{ kg/s}$$

We take the entire heat exchanger as the system, which is a control volume. The mass and energy balances for this steady-flow system can be expressed in the rate form as

Mass balance (*for each fluid stream*):

$$\dot{m}_{\text{in}} - \dot{m}_{\text{out}} = \Delta\dot{m}_{\text{system}}^{\nearrow 0\text{ (steady)}} = 0 \rightarrow \dot{m}_{\text{in}} = \dot{m}_{\text{out}} \rightarrow \dot{m}_1 = \dot{m}_3 = \dot{m}_a \text{ and } \dot{m}_2 = \dot{m}_4 = \dot{m}_w$$

Energy balance (for the entire heat exchanger):

$$\underbrace{\dot{E}_{\text{in}} - \dot{E}_{\text{out}}}_{\substack{\text{Rate of net energy transfer}\\\text{by heat, work, and mass}}} = \underbrace{\Delta\dot{E}_{\text{system}}^{\nearrow 0\text{ (steady)}}}_{\substack{\text{Rate of change in internal, kinetic,}\\\text{potential, etc. energies}}} = 0$$

$$\dot{E}_{\text{in}} = \dot{E}_{\text{out}}$$

$$\dot{m}_1 h_1 + \dot{m}_2 h_2 = \dot{m}_3 h_3 + \dot{m}_4 h_4 \quad (\text{since } \dot{Q} = \dot{W} = \Delta\text{ke} \cong \Delta\text{pe} \cong 0)$$

Combining the two,

$$\dot{m}_a (h_1 - h_3) = \dot{m}_w (h_4 - h_2)$$

$$\dot{m}_a c_{p,a} (T_1 - T_3) = \dot{m}_w c_{p,w} (T_4 - T_2)$$

Solving for the exit temperature of water,

$$T_4 = T_2 + \frac{\dot{m}_a c_{p,a} (T_1 - T_3)}{\dot{m}_w c_{p,w}} = 8°\text{C} + \frac{(5.750\text{ kg/s})(1.005\text{ kJ/kg}\cdot°\text{C})(30-18)°\text{C}}{(2\text{ kg/s})(4.18\text{ kJ/kg}\cdot°\text{C})} = \mathbf{16.3°C}$$