

ME 201

Thermodynamics

Homework 11 Solution

1. One component in a household refrigerator is the compressor where refrigerant 134-a enters as saturated vapor at -24°F and is isentropically compressed to 30 psia. Determine the work required in Btu/lb_m and the exit temperature of the refrigerant.

Solution:

System Type: Control Volume (Compressor)

Process: Isentropic

Working Fluid: Refrigerant -134a (compressible)

State 1 (inlet)	State 2 (outlet)
$T_1 = -24^{\circ}\text{F}$	$T_2 = 26.7^{\circ}\text{F}$
$P_1 = 11.62 \text{ psia}$	$P_2 = 30 \text{ psia}$
$s_1 = 0.2286 \text{ Btu}/(\text{lb}_m \cdot ^{\circ}\text{F})$	$s_2 = \mathbf{0.2286 \text{ Btu}/(\text{lb}_m \cdot ^{\circ}\text{F})}$
$h_1 = 99.51 \text{ Btu}/\text{lb}_m$	$h_2 = 107.63 \text{ Btu}/\text{lb}_m$
phase: sat. vap.	phase: sup. vap.

Italicized values are from R-134a table. **Bold** values are calculated.

Inlet State: Fixed

Final State: UNKNOWN

$$\dot{Q} = 0$$

$$\dot{W}_{\text{sh}} = \text{UNKNOWN}$$

KE and PE are negligible

$$\text{1st Law: } 0 = \dot{m}_F(h_1 - h_2) - \dot{W}_{\text{sh}}$$

Approach: We use our process description to fix the final states. Then the first law can be used to determine the required shaft work.

Going to the R-134a tables we find at state 1

$$P_1 = 11.62 \text{ psia}, s_1 = 0.2286 \text{ Btu}/(\text{lb}_m \cdot ^{\circ}\text{F}), \text{ and } h_1 = 99.51 \text{ Btu}/\text{lb}_m$$

For state 2 we know the pressure and the process is isentropic, so that

$$s_2 = s_1 = 0.2286 \text{ Btu}/(\text{lb}_m \cdot ^{\circ}\text{F})$$

We can now go to the tables and find that we have superheated vapor with

$$T_2 = 26.7^{\circ}\text{F} \text{ and } h_2 = 107.63 \text{ Btu}/\text{lb}_m$$

Now using the first law to calculate the shaft work, we have

$$0 = \dot{m}_F(h_1 - h_2) - \dot{W}_{\text{sh}}$$

or solving for w_{sh}

$$w_{sh} = h_1 - h_2 = 99.51 - 107.63 = -8.12 \text{ Btu/lb}_m$$

2. To keep the petroleum flowing in the Alaskan pipeline, it must be heated periodically. What is the heat transfer rate required at a heating station to heat petroleum at constant pressure flowing at 30 kg/s from 0°C to 100°C?

Solution:

System Type: Control Volume (Heat Device)
 Working Fluid #1: petroleum (incompressible)
 Process: Isobaric

State 1 (inlet)	State 2 (outlet)
$T_1 = 0^\circ\text{C}$	$T_2 = 100^\circ\text{C}$
$P_1 = ???$	$P_2 = P_1$

Bold values are calculated.

Inlet State: UNKNOWN

Final State: UNKNOWN

$\dot{Q} = \text{UNKNOWN}$

$\dot{W}_{sh} = 0$

KE and PE are negligible

1st Law: $0 = \dot{m}(h_1 - h_2) + \dot{Q}$

Approach: Once we evaluate the enthalpy change we can solve for the heat transfer rate straight away from the 1st law.

For an incompressible substance we have

$$h_1 - h_2 = c_p(T_1 - T_2) - v(P_1 - P_2)$$

but our pressure change is zero, so that

$$h_1 - h_2 = c_p(T_1 - T_2)$$

From Table A-3(a) we find a c_p for petroleum of 2.0 kJ/(kg·°C), so solving for the heat transfer rate

$$\dot{Q} = \dot{m}(h_2 - h_1) = \dot{m}c_p(T_2 - T_1) = (30)(2.0)(100 - 0) = 6000 \text{ kW}$$