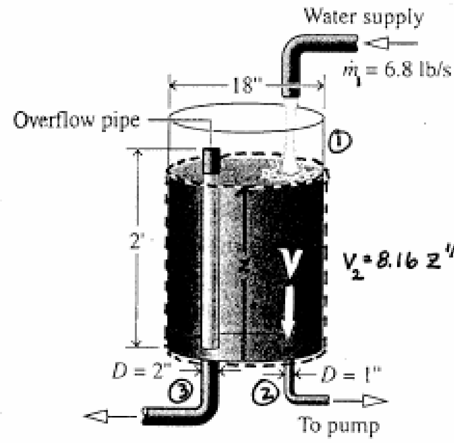
PROBLEM 4.5

KNOWN: Water enters at the top of a tank through a supply pipe at a constant mass flow rate and exits to a pump through a pipe in the bottom of the tank. The velocity of the water exiting to the pump varies with height of the water surface. An overflow pipe stands in the tank.

FIND: Plot (a) the height of the water surface, (b) the rate mass exits to the pump, (c) the rate mass exit through the overflow pipe, each versus time. Determine the time when the water reaches the top of the overflow pipe.

SCHEMATIC & GIVEN DATA:



ASSUMPTIONS: (1) The control volume encloses the water in the tank. The control volume is at steady state when the water level reaches the top of the overflow pipe. (2) The water is incompressible, with $\rho = 1/v_{f\,@\,60°F} = 62.34\ \text{lb/ft}^3$. (3) Initially, the tank is empty.

ANALYSIS: (a) Before the water level reaches z = 2 ft, the mass rate balance is

$$\frac{dm_{cv}}{dt} = \dot{m}_1 - \dot{m}_2 \Rightarrow \rho A_{tank} \frac{dz}{dt} = \dot{m}_1 - \rho A_2 V_2$$

Evaluating the areas:

$$A_2 = \frac{\pi D_2^2}{4} = \frac{\pi (1/12\ \text{ft})^2}{4} = 5.454 \times 10^{-3}\ \text{ft}^2$$

$$A_{tank} = \frac{\pi D_{tank}^2}{4} = \frac{\pi (18/12\ \text{ft})^2}{4} = 1.767\ \text{ft}^2$$

Thus

$$\left(62.34 \frac{\text{lb}}{\text{ft}^3}\right)(1.767\ \text{ft}^2)\frac{dz}{dt} = 6.8 \frac{\text{lb}}{\text{s}} - \left(62.34 \frac{\text{lb}}{\text{ft}^3}\right)(5.454 \times 10^{-3}\ \text{ft}^2)\, 8.16\, z^{1/2}$$

$$\Rightarrow \frac{dz}{dt} = 0.06173 - 0.02519\, z^{1/2} \quad (z \text{ in ft}, t \text{ in s}) \qquad (*)$$

Equation (*) is a non-linear differential equation. By assumption (3), the initial condition is z = 0 at t = 0. The expression can be integrated using the integration feature of IT, as follows:

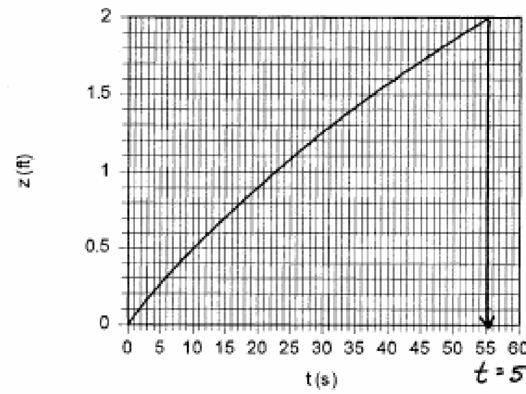
IT Program

```
f = 0.06173 - 0.02519 * z^0.5
der(z,t) = f
```

Using the Explore button, sweep t from 0 to 60 s in steps of 0.1.

The following graph can be obtained from the resulting data using IT:

PROBLEM 4.5 (Contd.)



$t = 55.2$ s ← time to overflow

($z = 2$ ft)

(b) For $t < 55.2$ s, $\dot{m}_2$ varies with z as follows:

$$\dot{m}_2 = \rho A_2 V_2 = \rho A_2 (8.16 z^{1/2})$$

$$= (62.34)(5.454\times10^{-3})(8.16 z^{1/2}) = 2.7744 z^{1/2}$$

at $t = 55.2$ s; $z = 2$ ft and $\dot{m}_2 = 3.9236$ lb/s

For $t > 55.2$ s; $\dot{m}_2 = 3.9236$ lb/s (z remains constant at 2 ft) ← $\dot{m}_2$

(c) For $t < 55.2$ s; $\dot{m}_3 = 0$ (flow hasn't reached the overflow pipe inlet)

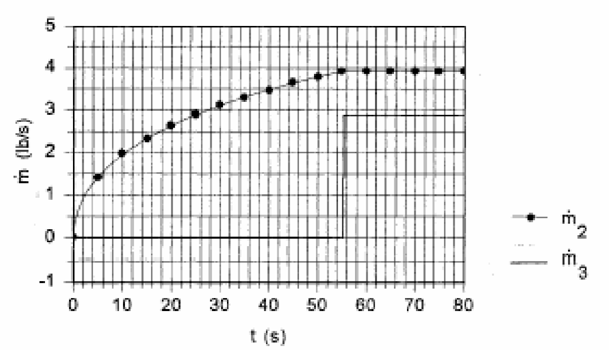
For $t > 55.2$ s; steady state. Thus

$$\cancel{\frac{dm_{cv}}{dt}}^{\,0} = \dot{m}_1 - \dot{m}_2 - \dot{m}_3 \Rightarrow \dot{m}_3 = \dot{m}_1 - \dot{m}_2$$

$$= 6.8 \text{ lb/s} - 3.9236 \text{ lb/s}$$

$$= 2.876 \text{ lb/s}$$ ← $\dot{m}_3$ ($t > 55.2$)

The following plot is constructed using IT:



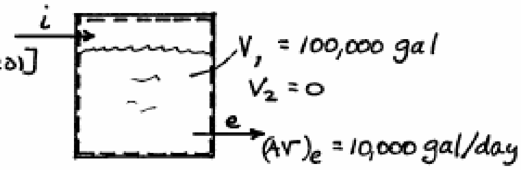
PROBLEM 4.6

KNOWN: A water storage tank contains a known volume of water. The volume flow rates in and out of the tank are given.

FIND: Determine how many days the tank will contain water.

SCHEMATIC & GIVEN DATA:

$(AV)_i = 5000[\exp(-t/20)]$
(t in days)



ASSUMPTIONS: (1) The control volume is as shown on the above sketch. (2) The water is incompressible.

ANALYSIS: The mass rate balance reduces to

$$\frac{dm_{cv}}{dt} = \dot{m}_i - \dot{m}_e$$

With $m_{cv} = \rho V$, and $\dot{m}_i = \rho (AV)_i$ and $\dot{m}_e = \rho (AV)_e$

$$\cancel{\rho}\frac{dV}{dt} = \cancel{\rho}(AV)_i - \cancel{\rho}(AV)_e$$

$$\Rightarrow \qquad \frac{dV}{dt} = (AV)_i - (AV_e) = 5000\,[\exp(-t/20)] - 10{,}000$$

Integrating from $t=0$ to $t=t_f$

$$V_2 - V_1 = \int_0^{t_f} (5000\,[\exp(-t/20)] - 10{,}000)\,dt$$

$$= \left(\frac{5000}{(-1/20)}\exp(-t/20) - 10{,}000\,t\right)\Big|_0^{t_f}$$

① $$= [-100{,}000\exp(-t_f/20) - 1] - 10{,}000\,t_f \qquad (*)$$

With $V_1 = 100{,}000$ gal and for $V_2 = 0$

$$0 = 200{,}000 - 100{,}000\exp(-t_f/20) - 10{,}000\,t_f$$

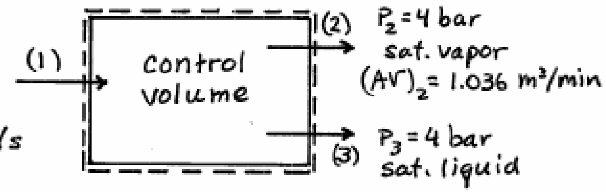
PROBLEM 4.18

KNOWN: Ammonia flows through a control volume at steady state. The control volume has one inlet and two exit, and data are known at each flow boundary.

FIND: Determine (a) the minimum inlet diameter so the ammonia velocity does not exceed 20 m/s. (b) the volumetric flow rate of the second exit stream.

SCHEMATIC & GIVEN DATA:

$p_1 = 14$ bar
$T_1 = 28\,°C$
$\dot{m}_1 = 0.5$ kg/s



ASSUMPTIONS: (1) The control volume is at steady state. (2) The flow at the inlet is one-dimensional.

ANALYSIS: (a) To relate velocity and pipe diameter at the inlet, use Eq. 4.11b

$$V_1 = \frac{\dot{m}_1 v_1}{A_1} = \frac{\dot{m}_1 v_1}{\left(\frac{\pi d_1^2}{4}\right)}$$

Thus, velocity varies inversely with diameter. The minimum diameter corresponds to $V_1 = 20$ m/s.

To get v_1, note from Table A-14 that $T_1 = 28°C$ is less than T_{sat} at 14 bar. Hence, from Table A-13, $v_1 \approx v_{f@28°C} = 1.6714 \times 10^{-3}\ m^3/kg$, and

$$(d_1)_{min} = \sqrt{\frac{4\,\dot{m}_1 v_1}{\pi V_1}} = \sqrt{\frac{(4)(0.5\ kg/s)(1.6714\times10^{-3}\ m^3/kg)}{\pi\,(20\ m/s)}}$$

$$= 0.00729\ m = 0.729\ cm \longleftarrow (d_1)_{min}$$

(b) To find $(AV)_3$, begin with the mass rate balance

$$\cancel{\frac{dm_{cv}}{dt}}^{\,0} = \dot{m}_1 - \dot{m}_2 - \dot{m}_3 \Rightarrow \dot{m}_3 = \dot{m}_1 - \dot{m}_2$$

With $\dot{m} = (AV)/v$

$$(AV)_3 = v_3\left[\dot{m}_1 - (AV)_2/v_2\right]$$

From Table A-14 at 4 bar ; $v_2 = 0.3094\ m^3/kg$ and $v_3 = 1.5597 \times 10^{-3}\ m^3/kg$. Thus

$$(AV)_3 = \left(1.5597\times10^{-3}\ \frac{m^3}{kg}\right)\left[\left(0.5\ \frac{kg}{s}\right)\left(\frac{60\ s}{1\ min}\right) - \frac{(1.036\ m^3/min)}{(0.3094\ m^3/kg)}\right]$$

$$= 0.0416\ m^3/min \longleftarrow (AV)_3$$

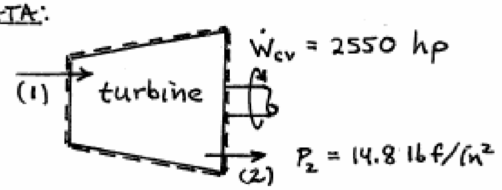
PROBLEM 4.35*

KNOWN: Air expands through a turbine with known conditions at the inlet and exit. The inlet mass flow rate and the power developed are given.

FIND: Determine the exit temperature.

SCHEMATIC & GIVEN DATA:

Air
$P_1 = 160\ \text{lbf/in}^2$
$T_1 = 1560\ {}^\circ\text{R}$
$\dot{m} = 10.5\ \text{lb/s}$



ASSUMPTIONS: (1) The control volume is at steady state. (2) Heat transfer is negligible. (3) Kinetic and potential energy effects are negligible.
1 (4) The air behaves as an ideal gas.

ANALYSIS: Since $h = h(T)$ for an ideal gas, the exit temperature can be found by evaluating h_2. Beginning with the steady-state energy balance

$$0 = \cancel{\dot{Q}_{cv}}^{\,0} - \dot{W}_{cv} + \dot{m}\left[(h_1 - h_2) + \left(\frac{V_1^2 - V_2^2}{2}\right) + g(z_1 - z_2)\right]$$

where $\dot{m}_1 = \dot{m}_2 \equiv \dot{m}$, and with assumption (3)

$$0 = -\dot{W}_{cv} + \dot{m}(h_1 - h_2)$$

or

$$h_2 = -\dot{W}_{cv}/\dot{m} + h_1 \qquad (1)$$

Using data from Table A-22E for h_1 and inserting values into (1)

$$h_2 = -\frac{(2550\ \text{hp})}{(10.5\ \text{lb/s})}\left|\frac{1\ \text{h}}{3600\ \text{s}}\right|\left|\frac{2545\ \text{Btu/h}}{1\ \text{hp}}\right| + 385.08\ \frac{\text{Btu}}{\text{lb}}$$

$$= 213.39\ \text{Btu/lb}$$

Interpolating in Table A-22E

$$T_2 = 888.3\ {}^\circ\text{R} \longleftarrow \qquad T_2$$

---

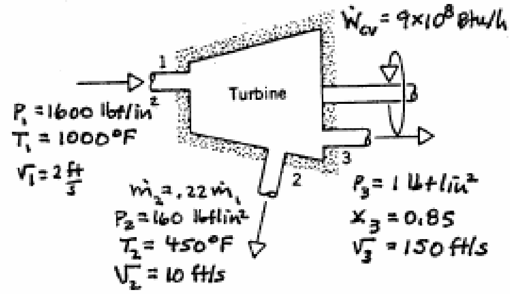
1. The applicability of the ideal gas model can be checked by reference to the compressibility chart.

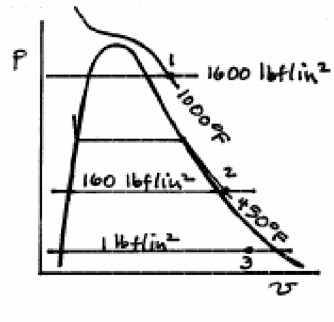
PROBLEM 4.42

KNOWN: Steam passes through an extraction turbine operating at steady state with know inlet and exit conditions. The power output is specified.

FIND: Determine (a) the inlet mass flow rate, (b) the diameter of the extraction duct.

SCHEMATIC & GIVEN DATA:





ASSUMPTIONS: 1. A control volume enclosing the turbine is at steady state. 2. For the control volume, heat transfer and potential energy effects are negligible.

ANALYSIS: (a) To find $\dot{m}_1$, apply mass rate balance: $\dot{m}_1 = \dot{m}_2 + \dot{m}_3$. Then, since $\dot{m}_2/\dot{m}_1 = 0.22$, we have $\dot{m}_3/\dot{m}_1 = 0.78$. Next, apply an energy rate balance:

$$0 = \cancel{\dot{Q}_{cv}}^{0} - \dot{W}_{cv} + \dot{m}_1\left[h_1 + \frac{V_1^2}{2}\right] - \dot{m}_2\left[h_2 + \frac{V_2^2}{2}\right] - \dot{m}_3\left[h_3 + \frac{V_3^2}{2}\right]$$

where the potential energy terms are omitted by assumption 2. Solving

$$\dot{m}_1 = \frac{\dot{W}_{cv}}{\left[h_1 + \frac{V_1^2}{2}\right] - \frac{\dot{m}_2}{\dot{m}_1}\left[h_2 + \frac{V_2^2}{2}\right] - \frac{\dot{m}_3}{\dot{m}_1}\left[h_3 + \frac{V_3^2}{2}\right]}$$

From Table A-4E, $h_1 = 1487$ Btu/lb, $h_2 = 1246.1$ Btu/lb. With Table A-3E data $h_3 = h_{f3} + x_3(h_{g3} - h_{f3}) = 69.74 + 0.85(1036) = 950.3$ Btu/lb. Thus

$$\dot{m}_1 = \frac{(9.\times10^8\ \text{Btu/h})}{\left[1487\frac{\text{Btu}}{\text{lb}} + \frac{(2\ \text{ft/s})^2}{2}\left|\frac{1\ \text{lbf}}{32.2\ \text{lb}\cdot\text{ft/s}^2}\right|\left|\frac{1\ \text{Btu}}{778\ \text{ft}\cdot\text{lbf}}\right|\right] - 0.22\left[1246.1 + \frac{(10)^2}{(2)|32.2||778|}\right] - 0.78\left[950.3 + \frac{(150)^2}{(2)|32.2||778|}\right]}$$

$= 1.91\times10^6$ lb/h ← $\dot{m}_1$

(b) Using $v_2 = 3.228$ from Table A-4E

$$A_2 = \frac{\dot{m}_2 v_2}{V_2} = \frac{(.22)(1.91\times10^6\ \text{lb/h})(3.228\ \text{ft}^3/\text{lb})}{(10\ \text{ft/s})}\left|\frac{1\ \text{h}}{3600\ \text{s}}\right| = 37.68\ \text{ft}^2$$

Since $A_2 = \pi d_2/4$

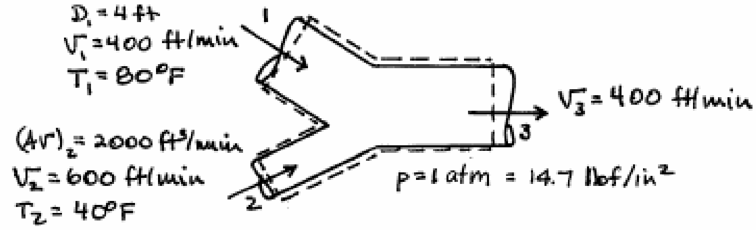
$$d_2 = \sqrt{\frac{4A_2}{\pi}} = \sqrt{\frac{(4)(37.68\ \text{ft}^2)}{\pi}} = 6.93\ \text{ft}$$ ← d_2

PROBLEM 4.68

KNOWN: Two ducts carrying air in a ventilation system merge into one exit duct. Data are known at the inlets and exit.

FIND: Determine the exit temperature and the diameter of the exit duct.

SCHEMATIC & GIVEN DATA:



ASSUMPTIONS: (1) The control volume is at steady state. (2) Heat transfer with the surroundings is negligible, and $\dot{W}_{cv} = 0$. (3) Potential energy effects can be neglected. (4) The air behaves as an ideal gas with constant specific heats.

ANALYSIS: To find T_3, begin with steady-state mass and energy balances

$$0 = \cancelto{0}{\dot{Q}_{cv}} - \cancelto{0}{\dot{W}_{cv}} + \dot{m}_1\left(h_1 + \frac{V_1^2}{2} + g z_1\right) + \dot{m}_2\left(h_2 + \frac{V_2^2}{2} + g z_2\right) - \dot{m}_3\left(h_3 + \frac{V_3^2}{2} + g z_3\right)$$

and $\dot{m}_1 + \dot{m}_3 - \dot{m}_3 = 0 \Rightarrow \dot{m}_3 = \dot{m}_1 + \dot{m}_2$

Combining and incorporating assumption (3)

$$0 = \dot{m}_1\left[(h_1 - h_3) + \cancelto{0}{\left(\frac{V_1^2 - V_3^2}{2}\right)}\right] + \dot{m}_2\left[(h_2 - h_3) + \left(\frac{V_2^2 - V_3^2}{2}\right)\right]$$

Referring to Table A-20E, $c_p = 0.24$ Btu/lb·°R for the temperature range in this problem. Using $\Delta h = c_p \Delta T$

$$0 = \dot{m}_1\left[c_p(T_1 - T_3)\right] + \dot{m}_2\left[c_p(T_2 - T_3) + \left(\frac{V_2^2 - V_3^2}{2}\right)\right] \qquad (*)$$

The mass flow rates are evaluated using Eq. 4-4b and the ideal gas equation of state

$$\dot{m}_1 = \frac{A_1 V_1}{v_1} = \frac{\left(\frac{\pi D_1^2}{4}\right) V_1 p_1}{R T_1} = \frac{\left(\frac{\pi (4^2)\,\text{ft}^2}{4}\right)(400\ \text{ft/min})(14.7\ \text{lbf/in}^2)}{\left(\frac{1545}{28.97}\,\frac{\text{ft}\cdot\text{lbf}}{\text{lb}\cdot°\text{R}}\right)(540°\text{R})}\left|\frac{144\ \text{in}^2}{1\ \text{ft}^2}\right|$$

$$= 369.5\ \text{lb/min}$$

$$\dot{m}_2 = \frac{(AV)_2\, p_2}{R T_2} = \frac{(2000)(14.7)|144|}{\left(\frac{1545}{28.97}\right)(500)} = 158.8\ \text{lb/min}$$

Returning to (*)

$$T_3 = \frac{\dot{m}_1 c_p T_1 + \dot{m}_2\left[c_p T_2 + \left(\frac{V_2^2 - V_3^2}{2}\right)\right]}{(\dot{m}_1 + \dot{m}_2) c_p}$$

Evaluating the kinetic energy term

$$\frac{V_2^2 - V_3^2}{2} = \left(\frac{600^2 - 400^2}{2}\right)\frac{ft^2}{min^2}\left|\frac{1\ min^2}{3600\ s^2}\right|\left|\frac{1\ lbf}{32.2\ lb \cdot ft/s^2}\right|\left|\frac{1\ Btu}{778\ ft \cdot lbf}\right|$$

$$= 0.00111\ Btu/lb$$

Inserting values

① $$T_3 = \frac{(369.5\ lb/min)(.24\ \frac{Btu}{lb \cdot °R})(540°R) + (158.8)\left[(.24)(500) + (0.00111)\right]}{(369.5 + 158.8)(.24)}$$

$$= 528\ °R = 68\ °F \longleftarrow T_3$$

To get D_3, note that

$$\dot{m}_3 = \dot{m}_1 + \dot{m}_2 = 528.3\ lb/min$$

Thus

$$A_3 = \frac{v_3 \dot{m}_3}{V_3} = \frac{R T_3 \dot{m}_3}{P_3 V_3} = \frac{\left(\frac{1545}{28.97}\right)(528)(528.3)}{(14.7)|144|(400)} = 17.57\ ft^2$$

and $$D_3 = \sqrt{\frac{4 A_3}{\pi}} = 4.73\ ft \longleftarrow D_3$$

1. Note that if kinetic energy is neglected there is virtually no effect on the temperature at the exit.

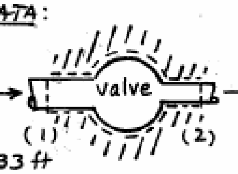
PROBLEM 4.78

KNOWN: Steam flows through a well-insulated valve from specified inlet conditions to a known exit pressure.

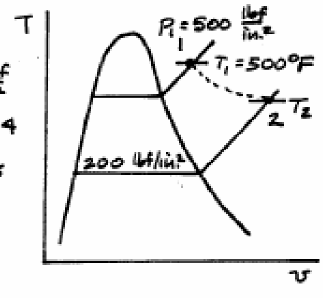
FIND: (a) Determine the exit velocity and exit temperature for a given ratio of inlet-to-exit pipe diameters, d_1/d_2. (b) Plot the exit velocity, temperature, and specific enthalpy versus d_1/d_2 ranging from 0.25 to 4.

SCHEMATIC & GIVEN DATA:

Steam
$P_1 = 500 \frac{lbf}{in^2}$
$T_1 = 500°F$
$d_1 = 1$ in. $= 0.08333$ ft



$P_2 = 200 \frac{lbf}{in^2}$
$0.25 \le \frac{d_1}{d_2} \le 4$
$\dot{m} = 0.11$ lb/s



ASSUMPTIONS: (1) The control volume is at steady state.
(2) For the control volume, $\dot{Q}_{cv} = 0$ and $\dot{W}_{cv} = 0$.
(3) Potential energy effects are negligible.

ANALYSIS: (a) To determine the exit velocity, begin with the mass balance and Eq. 4.11b: $\dot{m}_1 = \dot{m}_2 \equiv \dot{m}$, and

$$\dot{m} = \frac{A_1 V_1}{v_1} = \frac{A_2 V_2}{v_2} \Rightarrow V_2 = \frac{A_1}{A_2} \cdot \frac{V_1}{v_1} \cdot v_2 = \left(\frac{d_1}{d_2}\right)^2 \cdot \frac{V_1}{v_1} \cdot v_2$$

Now, $V_1 / v_1 = \dot{m}/A_1 = 4\dot{m}/\pi d_1^2$. Inserting values

$$\frac{V_1}{v_1} = \frac{(4)(.11 \text{ lb/s})}{\pi (.08333 \text{ ft})^2} = 20.17$$

Thus

$$V_2 = 20.17 \left(\frac{d_1}{d_2}\right)^2 \cdot v(T_2, p_2) \qquad (1)$$

and, with $v_1 = 0.992$ ft³/lb from Table A-4E

$$V_1 = (20.17)(0.992) = 20.01 \text{ ft/s}$$

From (1) we see that it is necessary to fix state 2 to evaluate V_2. Another relation is obtained from the energy balance at steady state.

$$0 = \cancel{\dot{Q}_{cv}}^0 - \cancel{\dot{W}_{cv}}^0 + \dot{m}\left[(h_1 - h_2) + \left(\frac{V_1^2 - V_2^2}{2}\right) + g\cancel{(z_1 - z_2)}^0\right] \qquad (2)$$

or

$$V_2 = \sqrt{2(h_1 - h_2) + V_1^2}$$

with h_1 from Table A-4E

$$V_2 = \sqrt{2\left[1231.5 - h(T_2, p_2)\right]\frac{\text{Btu}}{\text{lb}}\left|\frac{1 \text{ lbf}}{32.2 \text{ lb}\cdot\text{ft/s}^2}\right|\left|\frac{1 \text{ Btu}}{778 \text{ ft}\cdot\text{lbf}}\right| + (20.01 \text{ ft/s})^2} \qquad (3)$$

Equations (1) and (3) can be solved simultaneously using data from Table A-4E and an iterative process. The results are, for $d_1/d_2 = 0.25$

$T_2 = 434.6$ °F

$V_2 = 3.140$ ft/s

PROBLEM 4.100

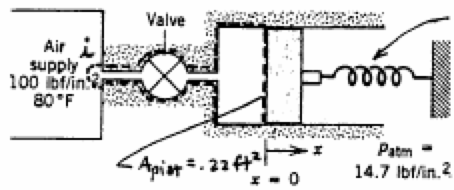
KNOWN: A well-insulated piston-cylinder assembly is connected by a valve to an air supply. The supply conditions and the initial state of air inside the cylinder. Air is admitted slowly causing the piston to compress a spring. The initial and final volumes within the cylinder are known.

FIND: Plot the final pressure and final temperature within the cylinder versus spring constant k varying from 650 to 750 lbf/ft.

SCHEMATIC & GIVEN DATA:

Initially: $p_1 = 14.7$ lbf/in.^{2}
$T_1 = 80°F$
$V_1 = 0.1$ ft^3

Finally: $V_2 = 0.4$ ft^3



ASSUMPTIONS: (1) The control volume is shown on the accompanying diagram, with $\dot{Q}_{cv} = 0$. (2) Conditions in the air supply remain constant. (3) Kinetic and potential energy effects are negligible. (4) The air behaves as an ideal gas. (5) There is no friction between the piston and cylinder wall.

ANALYSIS: The final pressure is found by applying Newton's Law to the piston. Since air is admitted slowly; $\Sigma F_x = 0$. Thus

$$p A_{pist} = p_{atm} A_{pist} + kx$$

with $V - V_1 = x A_{pist}$, the pressure is

$$p = p_{atm} + \frac{k(V-V_1)}{A_{pist}^2} \qquad (a)$$

At $V = V_2$

$$p_2 = 14.7 \frac{\text{lbf}}{\text{in}^2} + \frac{(k \text{ lbf/ft})(0.4-0.1)\text{ft}^3}{(.22^2)\text{ ft}^4}\left(\frac{1 \text{ ft}^2}{144 \text{ in}^2}\right)$$

$$= \left[14.7 + 0.043k\right] \text{lbf/in}^2 \qquad (1)$$

The mass rate balance takes the form; $dm_{cv}/dt = \dot{m}_i$. With assumptions listed, the energy rate balance is

$$\frac{dU_{cv}}{dt} = \cancel{\dot{Q}_{cv}}^{\,0} - \dot{W}_{cv} + \dot{m}_i h_i$$

The specific enthalpy h_i is constant by assumption (3). Thus, combining the mass and energy rate balances and integrating

$$\Delta U_{cv} = -W_{cv} - \int_1^2 h_i \, dm_{cv} \Rightarrow m_2 u_2 - m_1 u_1 = -W_{cv} + h_i(m_2 - m_1) \qquad (2)$$

Since the process occurs slowly, $W_{cv} = \int p\,dV$. With Eq. (a) above

$$W_{cv} = \int_{V_1}^{V_2}\left[\left(p_{atm} - \frac{kV_1}{A_{pist}^2}\right) + \frac{kV}{A_{pist}^2}\right] dV$$

$$= \left(p_{atm} - \frac{kV_1}{A_{pist}^2}\right)(V_2 - V_1) + \frac{k(V_2^2 - V_1^2)}{2A_{pist}^2}$$

PROBLEM 4.100 (Contd.)

$$\therefore W_{cv} = p_{atm}(V_2 - V_1) + \frac{k}{(A_{pist})^2}\left[\frac{V_2^2 - V_1^2}{2} - V_1(V_2 - V_1)\right]$$

$$= p_{atm}(V_2 - V_1) + \frac{k}{2(A_{pist})^2}\left[V_2 - V_1\right]^2$$

$$= \left[14.7\ \frac{lbf}{in^2}\left|\frac{144\ in^2}{1\ ft^2}\right|(0.3\ ft^3) + \frac{k\ (lbf/ft)}{2(0.22\ ft^2)^2}\left[0.3\ ft^3\right]^2\right]\left|\frac{1\ Btu}{778\ ft \cdot lbf}\right|$$

$$= \left[0.816 + (1.195\times10^{-3})k\right]\ Btu \qquad (3)$$

Also, with the ideal gas model equation of state

$$m_1 = \frac{p_1 V_1}{R T_1} = \frac{(14.7\times144\ lbf/ft^2)(0.1\ ft^3)}{\left(\frac{1545}{28.97}\ \frac{ft\cdot lbf}{lb\cdot ^\circ R}\right)(540^\circ R)} = 7.35\times10^{-3}\ lb$$

$$m_2 = \frac{p_2 V_2}{R T_2}$$, where p_2 is given by Eq. (1) (4)

Since $T_1 = T_i = 540^\circ R\ (80^\circ F)$, $u_1 = u(540^\circ R)$, $h_i = h(540^\circ R)$.
Accordingly, T_2 can be determined by solving Eq. (2), together with Eqs. (1), (3), (4) and known values of V_2, u_1, and h_i.