CH365 Chemical Engineering Thermodynamics

Lesson 7
Enthalpy, Heat Capacity, and Open Systems – Part 2

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Measures of Flow

$$\dot{m} = \text{mass flow rate}\left(\frac{kg}{s}, \frac{lb_m}{hr}, \text{etc.}\right)$$

$$\dot{n} = \text{molar flow rate}\left(\frac{mol}{s}, \frac{lbmol}{s}, \text{etc.}\right)$$

$$\dot{q} = \text{volumetric flow rate}\left(\frac{m^3}{s}, \frac{ft^3}{min}, \text{etc.}\right)$$

$$u = \text{velocity}\left(\frac{ft}{hr}, \frac{m}{s}, \text{etc.}\right)$$

$$\dot{m} = M\dot{n} \qquad M = \text{molar mass} \qquad \text{e.g., } \frac{kg}{s} = \frac{kg}{kmol}\cdot\frac{kmol}{s}$$

$$\dot{m} = uA\rho \qquad A = \text{cross-sectional area} = \frac{\pi D^2}{4} \qquad \rho = \text{density} = \frac{1}{V}\ [=]\ \frac{kg}{m^3}$$

2.23a

$$\text{e.g., } \frac{lb_m}{sec} = \frac{ft}{sec}\cdot ft^2\cdot\frac{lb_m}{ft^3}$$

$$\dot{n} = uA\rho\cdot\frac{1}{M}$$

2.23b – M is missing on p. 47

Equation of Continuity

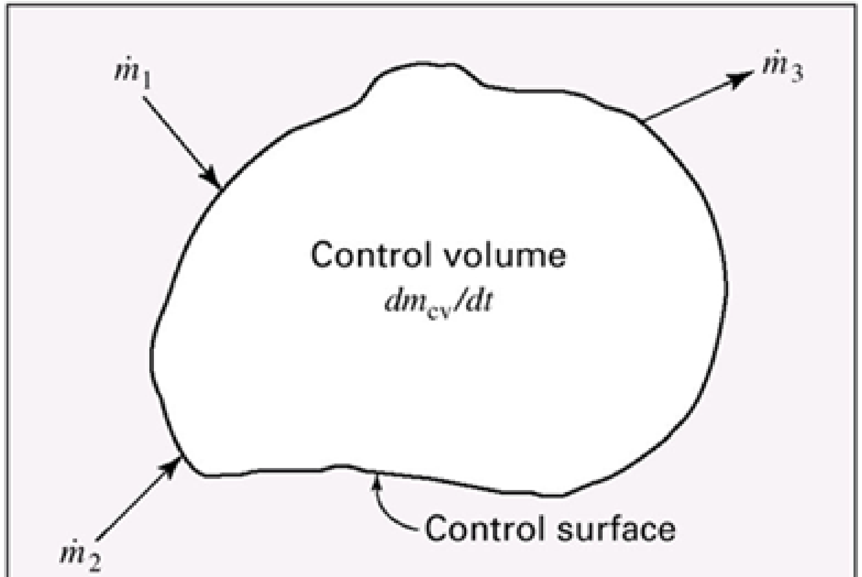


Figure 2.4

This diagram changes in Figure 2.5 in a very important way.

Mass Balance for Open Systems

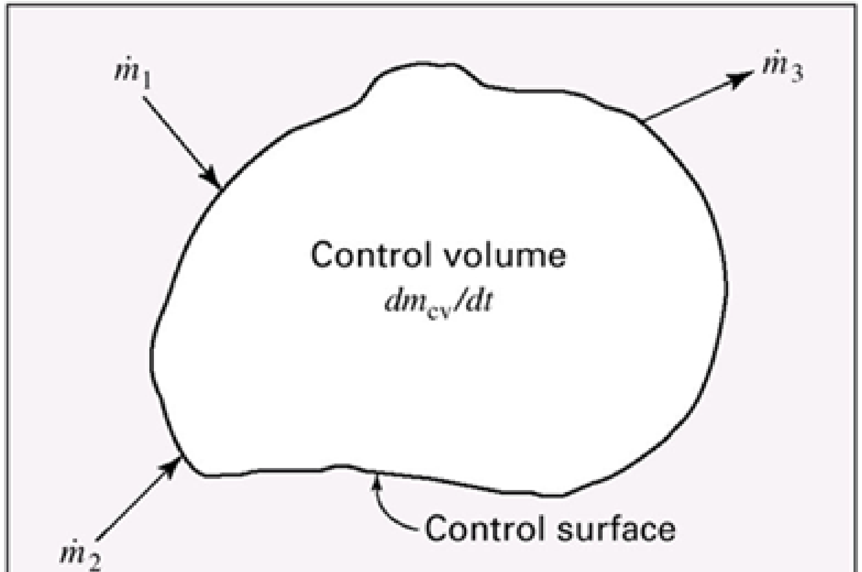


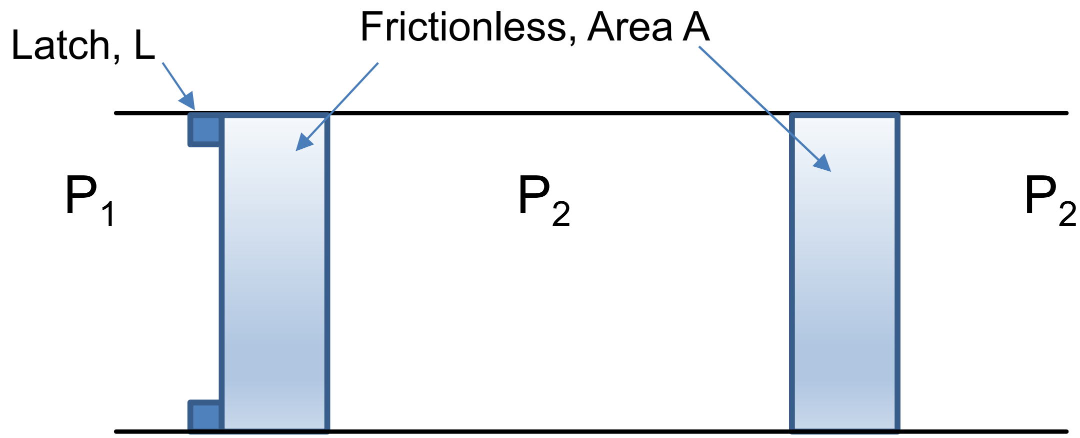
Figure 2.4

This diagram changes in Figure 2.5 in a very important way with the addition of frictionless pistons, but there is no explanation of this in the textbook.

Frictionless "Double Piston"

Understanding the "pistons" in figure 2.5

Initially at rest, how does the system respond to a push?



Reversible

$P_2 > P_1$

Static equilibrium
(all forces balanced)

General Energy Balance

Shaft work is not illustrated in Figure 2.5 but is used in the equations.

Question: How does the system respond to a “push” on the left-hand piston?

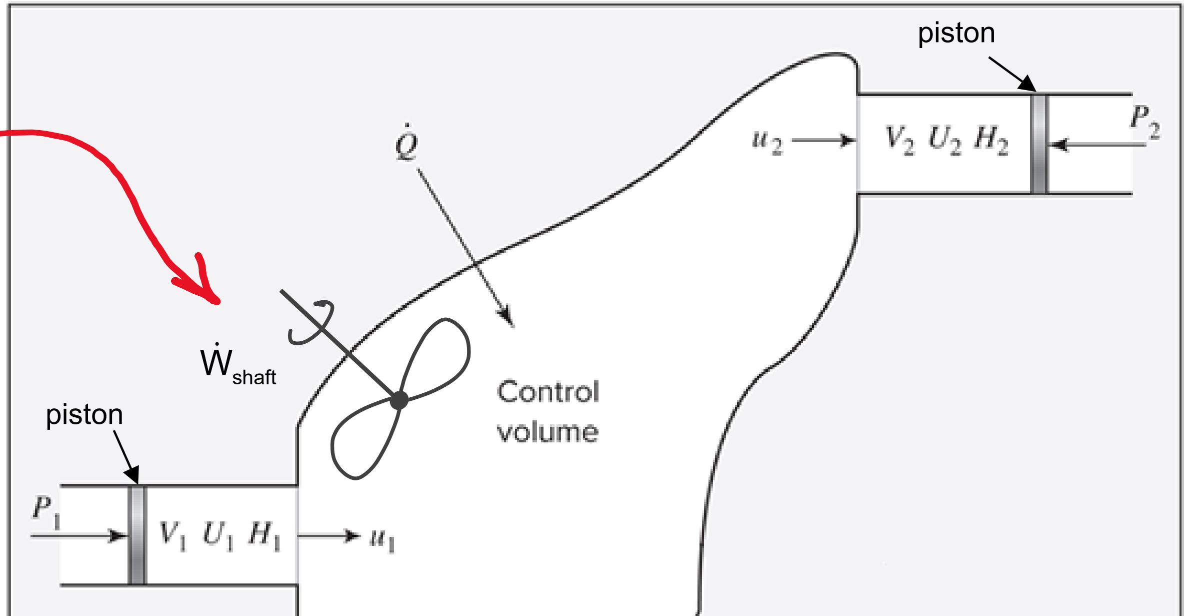


Figure 2.5

Steady-State Systems

$$\Delta\left[\left(H+\frac{u^2}{2}+gz\right)\dot{m}\right]_{fs}=\dot{Q}+\dot{W}_S$$

2.29

general open system steady-state energy balance

$$\Delta\left(H+\frac{u^2}{2}+gz\right)\dot{m}=\dot{Q}+\dot{W}_S$$

2.30

constant flow open system energy balance (constant density) with one inlet and one outlet.

SI units: $$\Delta H+\frac{\Delta\left(u^2\right)}{2}+g\Delta z=Q+W_S$$

English units: $$\Delta H+\frac{\Delta\left(u^2\right)}{2g_c}+\frac{g}{g_c}\Delta z=Q+W_S$$

2.31

First law of thermodynamics for steady-state, steady flow, constant density process with one inlet and one outlet

all properties are energy per mass

$$\frac{\dot{Q}}{\dot{m}}=Q \qquad \frac{\dot{W}_S}{\dot{m}}=W_S$$

$$\Delta H=Q+W_S$$

2.32

Ignoring kinetic and potential energy changes

Questions?