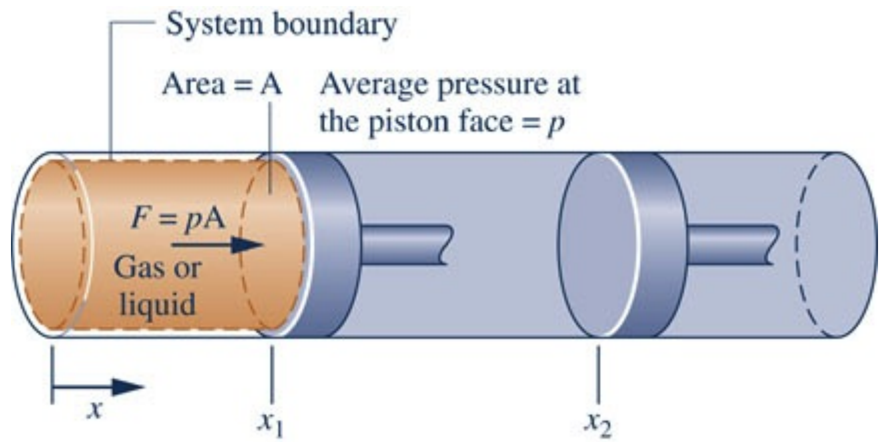
Chapter 2

Energy and the
First Law of Thermodynamics
Continued

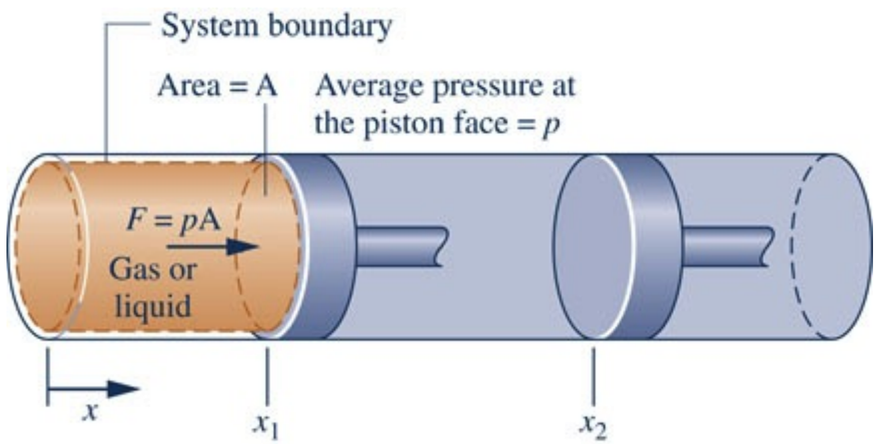
Modeling Expansion and Compression Work

► A case having many practical applications is a gas (or liquid) undergoing an expansion (or compression) process while confined in a piston-cylinder assembly.



Modeling Expansion and Compression Work

► A case having many practical applications is a gas (or liquid) undergoing an expansion (or compression) process while confined in a piston-cylinder assembly.



► During the process, the gas exerts a normal force on the piston, $F = p\mathrm{A}$, where p is the pressure at the interface between the gas and piston and A is the area of the piston face.

Modeling Expansion and Compression Work

► From mechanics, the work done by the gas as the piston face moves from x_1 to x_2 is given by

$$W = \int F dx = \int p\mathrm{A} dx$$

Modeling Expansion and Compression Work

► From mechanics, the work done by the gas as the piston face moves from x_1 to x_2 is given by

$$W = \int F dx = \int p \mathrm{A} dx$$

► Since the product $\mathrm{A}dx = dV$, where V is the volume of the gas, this becomes

$$W = \int_{V_1}^{V_2} p dV \qquad \textbf{(Eq. 2.17)}$$

Modeling Expansion and Compression Work

► From mechanics, the work done by the gas as the piston face moves from x_1 to x_2 is given by

$$W = \int F dx = \int p \mathrm{A} dx$$

► Since the product $\mathrm{A}dx = dV$, where V is the volume of the gas, this becomes

$$W = \int_{V_1}^{V_2} p dV \qquad \textbf{(Eq. 2.17)}$$

► For a compression, dV is negative and so is the value of the integral, in keeping with the sign convention for work.

Modeling Expansion and Compression Work

► To perform the integral of **Eq. 2.17** requires a relationship between gas pressure at the interface between the gas and piston and the total gas volume.

Modeling Expansion and Compression Work

► To perform the integral of **Eq. 2.17** requires a relationship between gas pressure at the interface between the gas and piston and the total gas volume.

► During an actual expansion of a gas such a relationship may be difficult, or even impossible, to obtain owing to non-equilibrium effects during the process – for example, effects related to combustion in the cylinder of an automobile engine.

► In most such applications, the work value can be obtained only by experiment.

Modeling Expansion and Compression Work

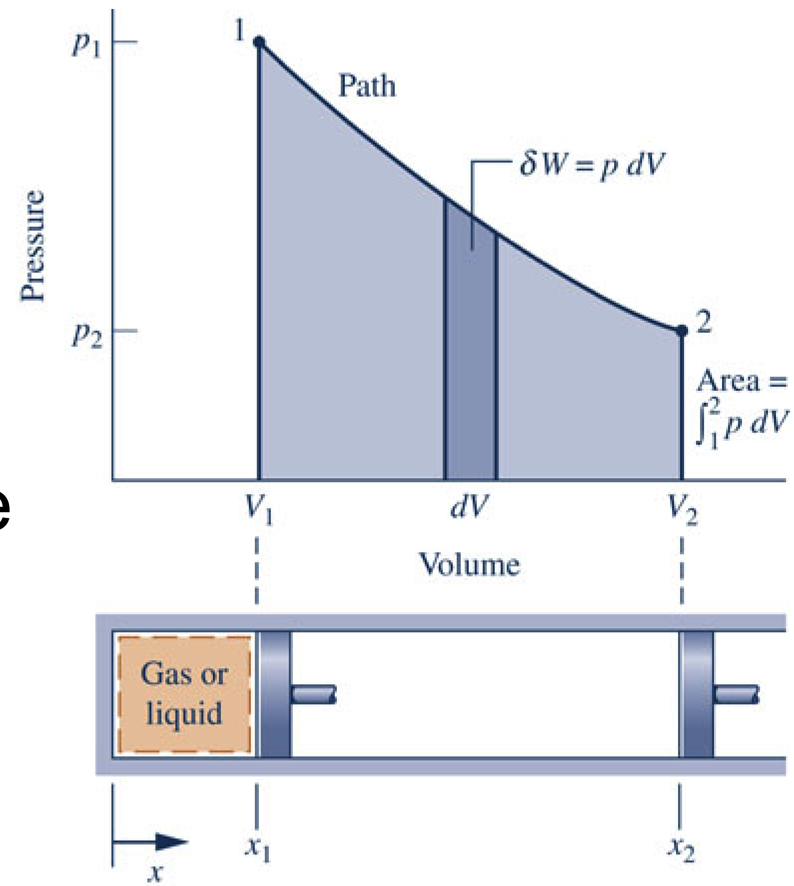
► **Eq. 2.17** can be applied to evaluate the work of idealized processes during which the pressure p in the integrand is the pressure of the entire quantity of the gas undergoing the process and not only the pressure at the piston face.

► For this we imagine the gas undergoes a sequence of equilibrium states during the process. Such an idealized expansion (or compression) is called a ***quasiequilibrium*** process.

Modeling Expansion and Compression Work

►In a quasiequilibrium expansion, the gas moves along a pressure-volume curve, or path, as shown.

►Applying **Eq. 2.17**, the work done by the gas on the piston is given by the **area** under the curve of pressure versus volume.



Modeling Expansion and Compression Work

►When the pressure-volume relation required by **Eq. 2.17** to evaluate work in a quasiequilibrium expansion (or compression) is expressed as an equation, the evaluation of expansion or compression work can be simplified.

Modeling Expansion and Compression Work

► When the pressure-volume relation required by **Eq. 2.17** to evaluate work in a quasiequilibrium expansion (or compression) is expressed as an equation, the evaluation of expansion or compression work can be simplified.

► An example is a quasiequilibrium process described by $pV^n = constant$, where n is a constant. This is called a *polytropic process*.

► For the case $n = 1$, $pV = constant$ and **Eq. 2.17** gives

$$W = (constant)\ln\left(\frac{V_2}{V_1}\right)$$

where $constant = p_1V_1 = p_2V_2$.

$$W = \int pdV \qquad \textbf{(Eq. 2.17)}$$

Modeling Expansion and Compression Work

► Since non-equilibrium effects are invariably present during actual expansions (and compressions), the work determined with quasiequilibrium modeling can at best approximate the actual work of an expansion (or compression) between given end states.