Engineering Design *An Introduction*

Chapter 14

Designing Pneumatic Systems

Karsnitz • O'Brien • Hutchinson

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Introduction

- Pneumatic systems
  - Driven by compressed air
- Hydraulic systems
  - Use a liquid instead of a gas
- Fluidics
  - Refers to both hydraulic and pneumatic systems

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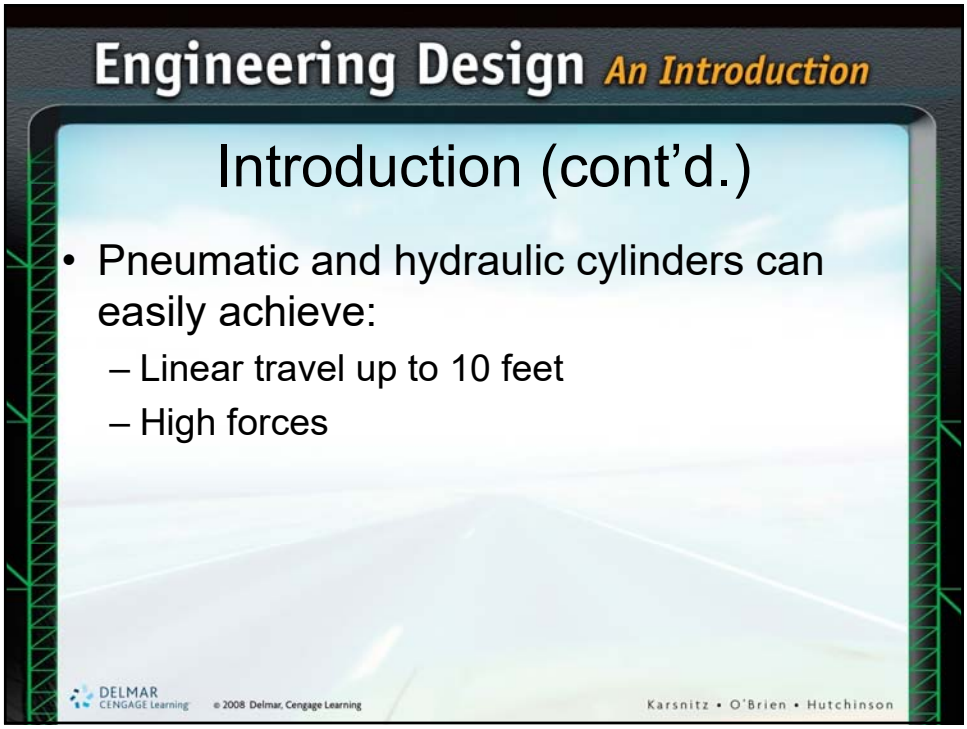
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Introduction (cont'd.)
• Pneumatic and hydraulic cylinders can easily achieve:
– Linear travel up to 10 feet
– High forces
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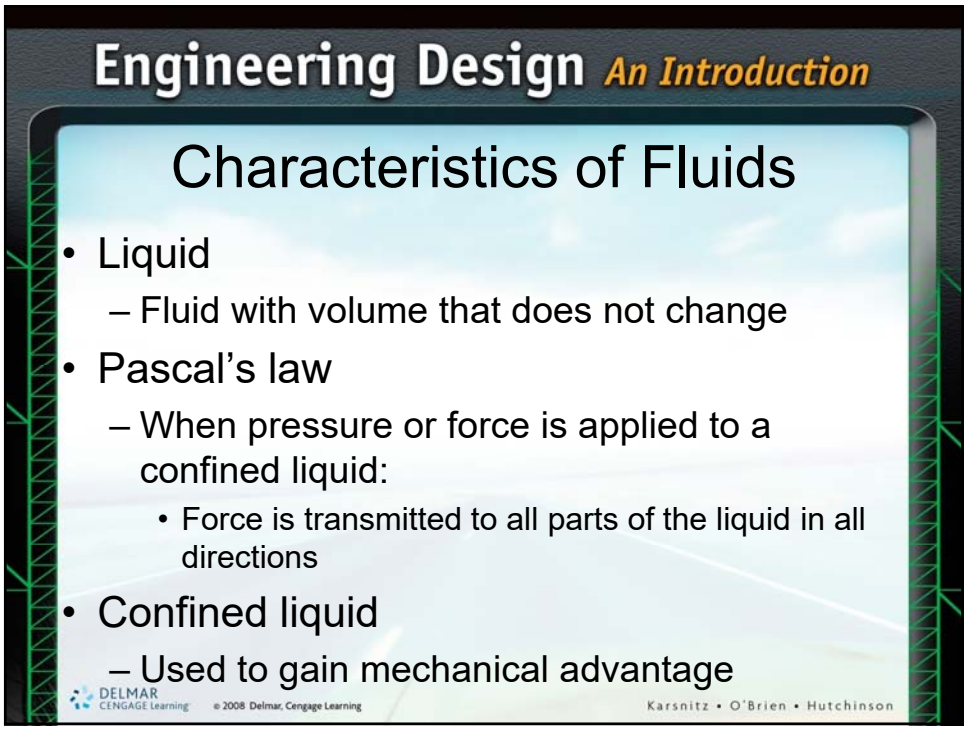
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Characteristics of Fluids
• Liquid
– Fluid with volume that does not change
• Pascal's law
– When pressure or force is applied to a confined liquid:
• Force is transmitted to all parts of the liquid in all directions
• Confined liquid
– Used to gain mechanical advantage
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Characteristics of Fluids (cont'd.)

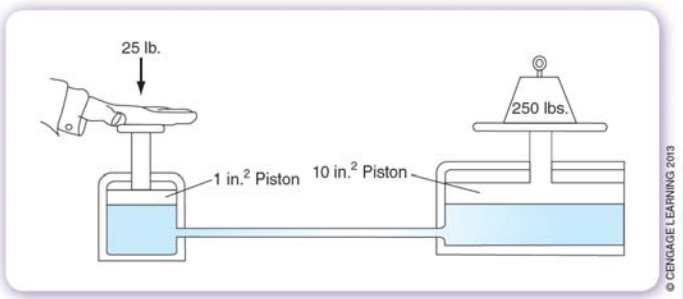

Figure 14-3: Fluids can transmit and multiply force.

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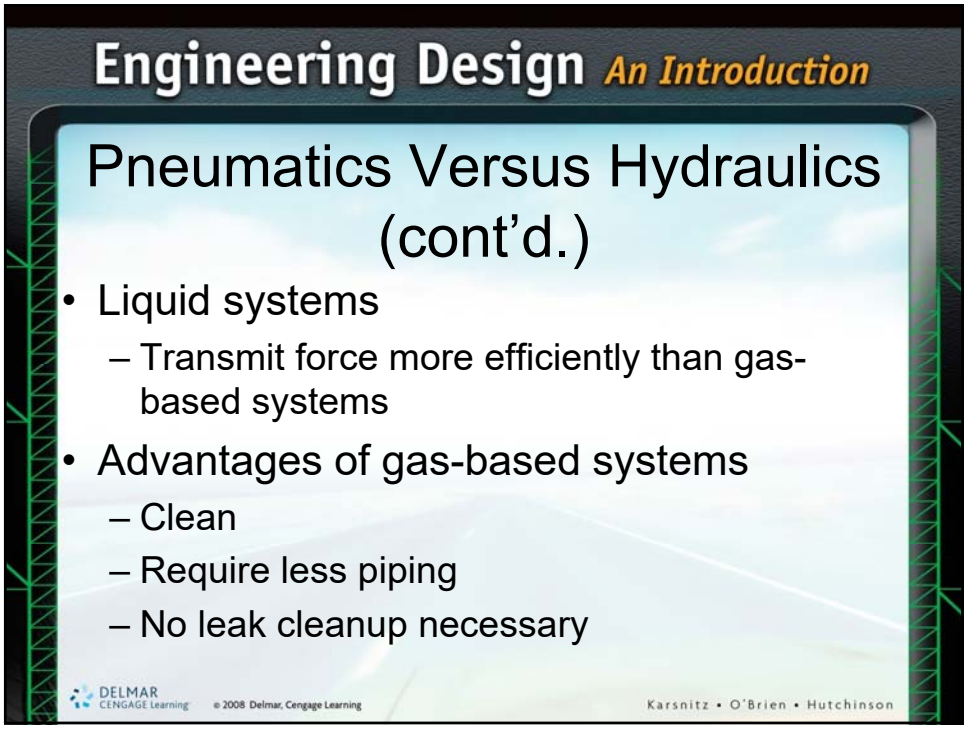
Pneumatics Versus Hydraulics

- Hydraulic system
  - Allows precise linear movement
  - Movement can be stopped at any point
- A variety of hydraulic fluids exist
- Pneumatic system
  - Valves allow a gas under pressure to enter a cylinder
  - Pressure of the gas pushes the piston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Pneumatics Versus Hydraulics (cont'd.)
• Liquid systems
– Transmit force more efficiently than gas-based systems
• Advantages of gas-based systems
– Clean
– Require less piping
– No leak cleanup necessary
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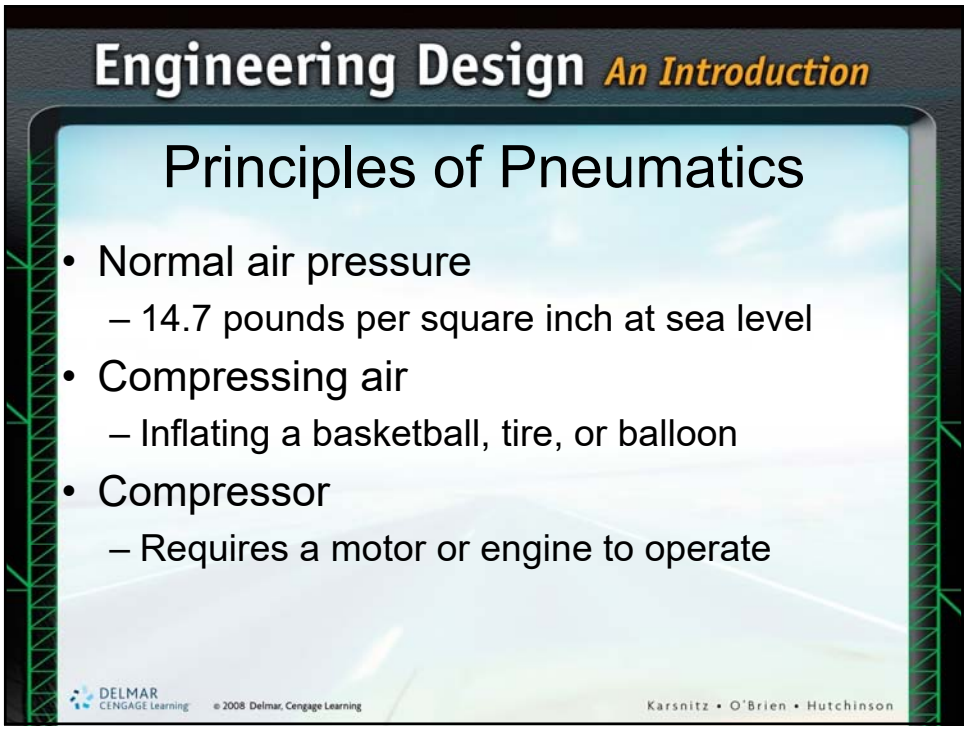
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Principles of Pneumatics
• Normal air pressure
– 14.7 pounds per square inch at sea level
• Compressing air
– Inflating a basketball, tire, or balloon
• Compressor
– Requires a motor or engine to operate
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Principles of Pneumatics (cont'd.)

- Types of compressors
  - Reciprocating piston compressor
  - Sliding vane compressor
- Pressure regulator
  - Used to maintain pressure at a fixed level

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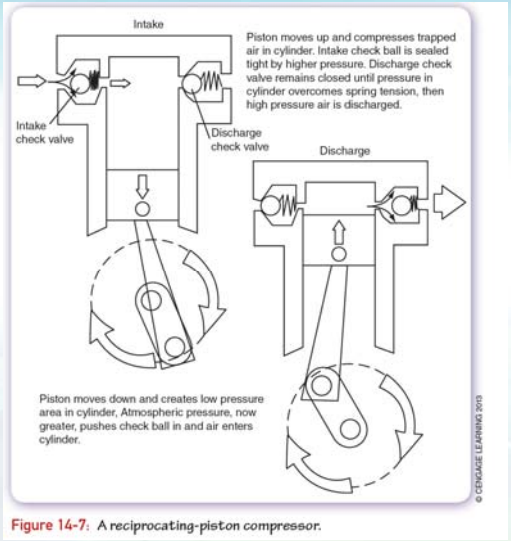

Figure 14-7: A reciprocating-piston compressor.

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Pneumatic System Components

- Pneumatic cylinder
  - Container with one moveable wall

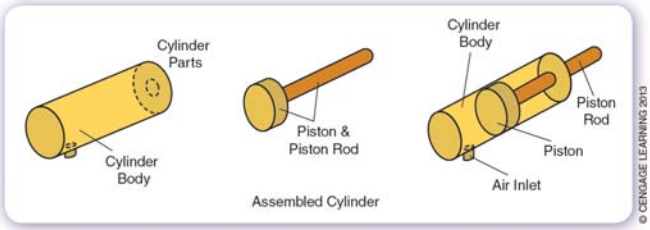

Figure 14-9: A pneumatic cylinder.

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Cylinders and Control Valves

- Single-acting cylinders
  - One port or opening that can discharge gas

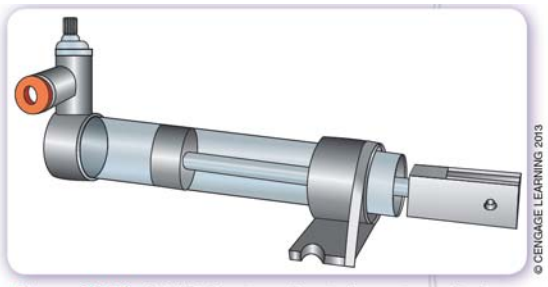
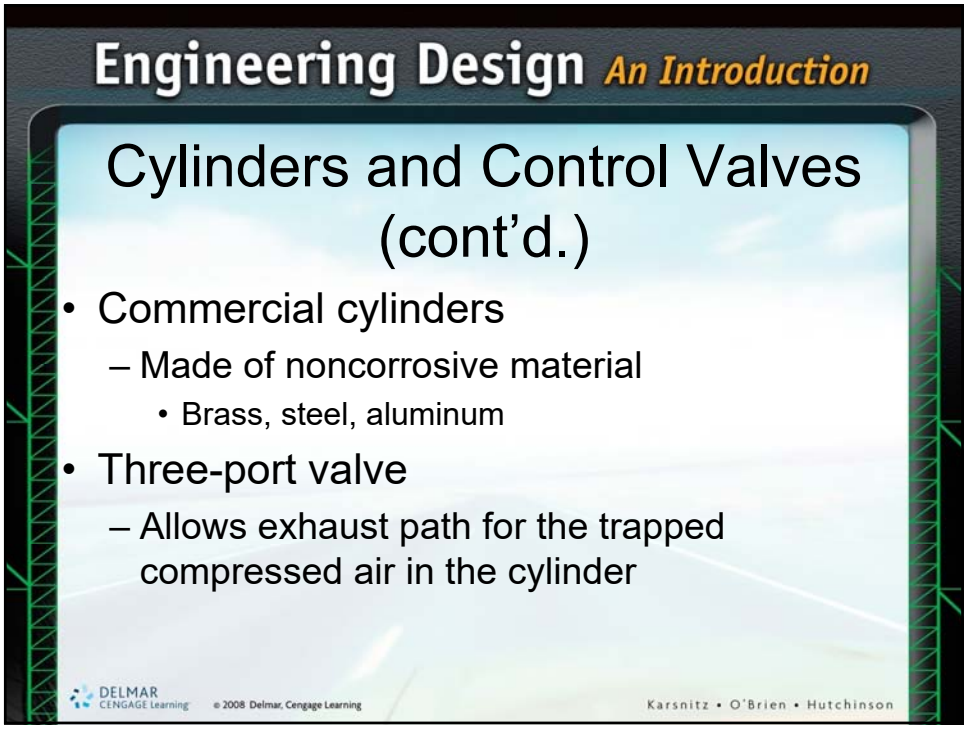


Figure 14-12: A CAD drawing of a single-acting cylinder showing the piston inside.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Cylinders and Control Valves (cont'd.)
• Commercial cylinders
– Made of noncorrosive material
• Brass, steel, aluminum
• Three-port valve
– Allows exhaust path for the trapped compressed air in the cylinder
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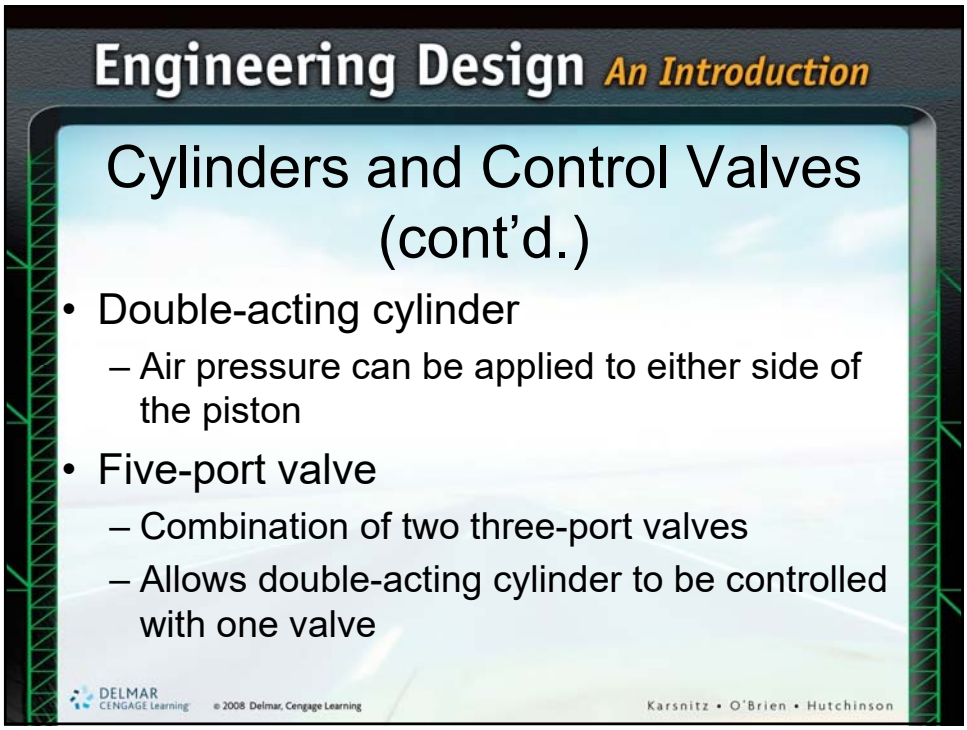
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Cylinders and Control Valves (cont'd.)
• Double-acting cylinder
– Air pressure can be applied to either side of the piston
• Five-port valve
– Combination of two three-port valves
– Allows double-acting cylinder to be controlled with one valve
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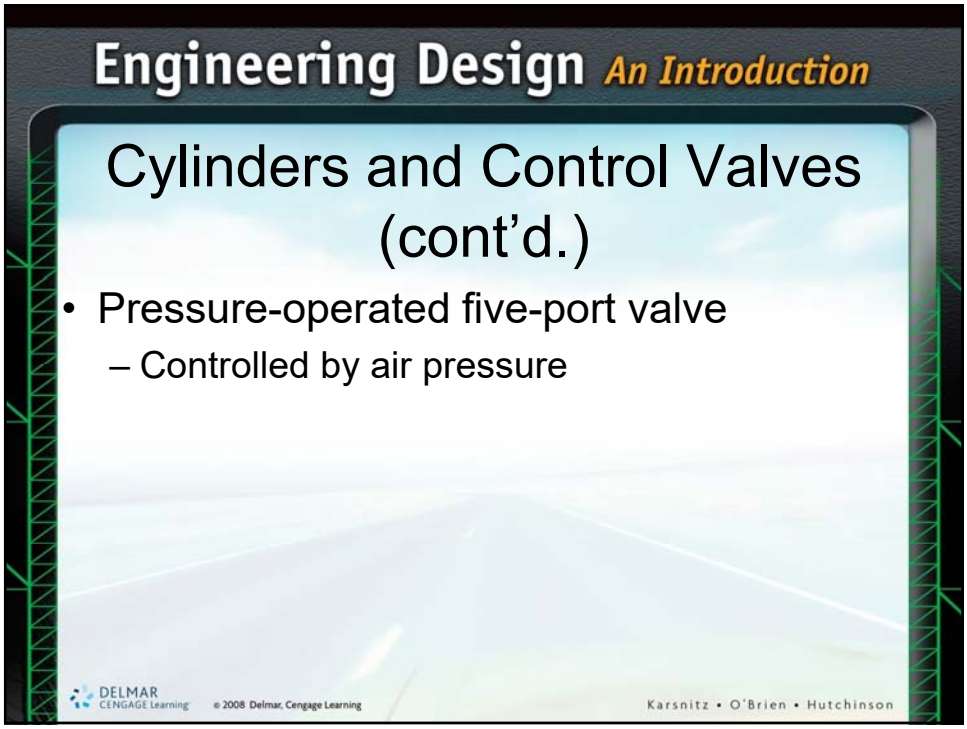
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Cylinders and Control Valves (cont'd.)
• Pressure-operated five-port valve
– Controlled by air pressure
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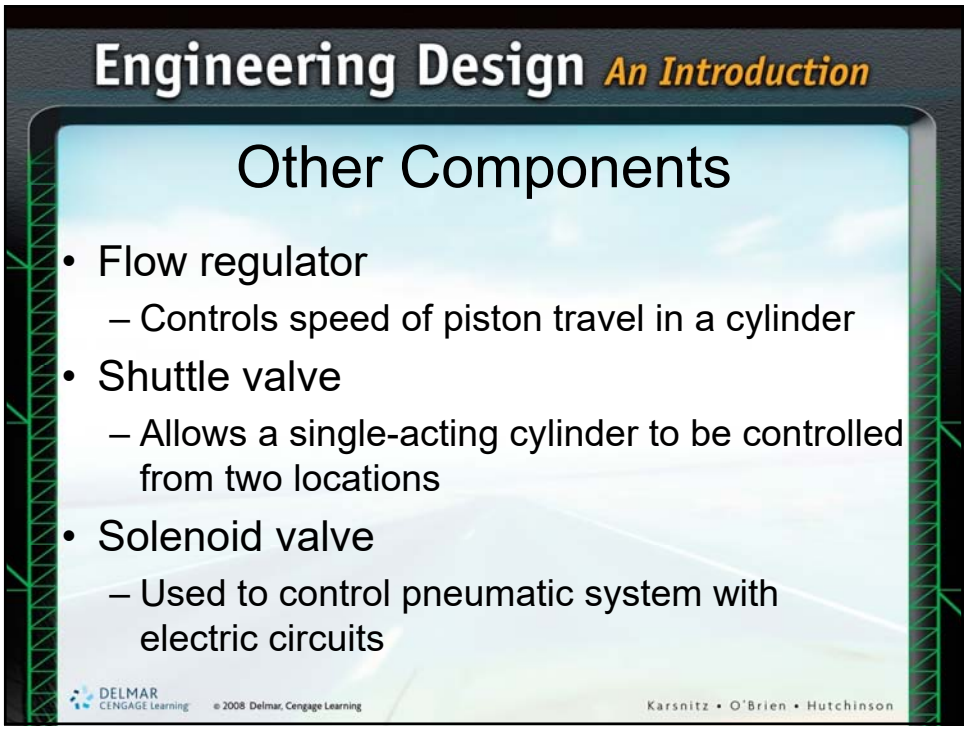
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Other Components
• Flow regulator
– Controls speed of piston travel in a cylinder
• Shuttle valve
– Allows a single-acting cylinder to be controlled from two locations
• Solenoid valve
– Used to control pneumatic system with electric circuits
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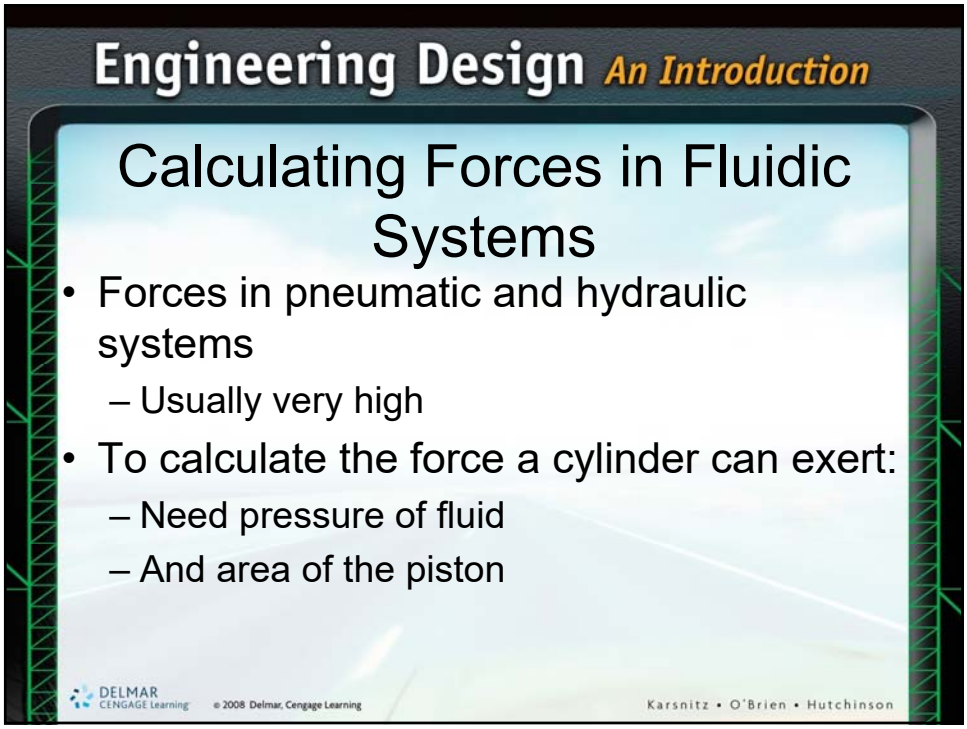
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Calculating Forces in Fluidic Systems
• Forces in pneumatic and hydraulic systems
– Usually very high
• To calculate the force a cylinder can exert:
– Need pressure of fluid
– And area of the piston
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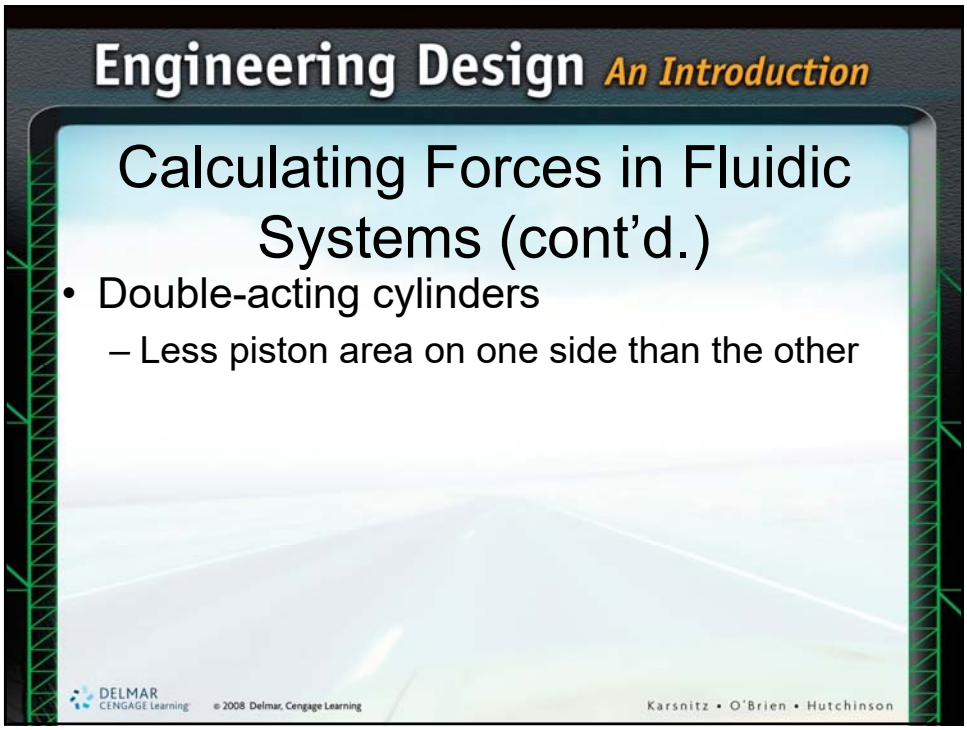
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Calculating Forces in Fluidic Systems (cont'd.)
• Double-acting cylinders
– Less piston area on one side than the other
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Example: Calculating Force in a Hydraulic System

Situation: You are designing a simple hydraulic system to rotate the base of a robotic arm. When you push on the piston in cylinder A, piston B extends and rotates the circular base, Figure 14-25. [Figure 14-24 gives symbols for common pneumatic parts.]

Problem: Find the distance piston B will travel.
You need to know the distance that piston B will travel if piston A moves 1 1/4 inches. You also need to know the force that piston B can exert if a force of 3 pounds is applied to piston A.

You Know: Diameter of piston A = 1 1/4 inches
Length of travel of piston A = 1 1/8 inches
Diameter of piston B = 3/4 inch

You Need to Find: Volume of liquid that the travel of piston A will displace
How far piston B will travel if that amount of liquid enters cylinder B (see Figure 10-25)

Solution: Find volume displaced by travel of piston A:
Diameter = 1.25 inches so
radius = 0.625 inch
Area of piston A = πR^2
$= 3.14(0.625\text{ in})^2$
$= 3.14(0.39\text{ in}^2)$
$= 1.22\text{ in}^2$
Volume = (Area)(Length)
$= (1.22\text{ in}^2)(1.125\text{ inches})$
Volume displaced = 1.37 cubic inches = 1.37 in^3
Find area of piston B:
Diameter 0.75 inch so radius = 0.375 inch

Figure 14-24: Schematic symbols for basic pneumatic components.

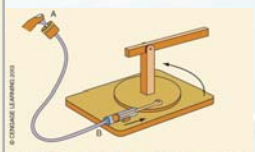

Figure 14-25: Physical design for a rotating arm.

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Example: Calculating Force in a Hydraulic System (continued)

Area of piston B = πR^2
$= 3.14(0.375\text{ in})^2$
$= 3.14(0.14\text{ in}^2)$
Area of piston B = 0.44 in^2

Find piston travel of B:

$$\text{Length of travel} = \frac{\text{Volume}}{\text{Area}}$$
$$= \frac{1.37\text{ in}^3}{0.44\text{ in}^2}$$

Length of Travel of Piston B: = 3.11 inches

Finding Forces: How much force does piston B exert if the input force on piston A is 3 pounds?

Find the pressure that exists within piston A:
Pressure = (input force) / (area of piston A)
= 3 pounds / 1.22 square inches
Pressure = 2.46 psi

[Key: Pressure is the same throughout the liquid so the pressure at piston B is the same at piston A.]

Find force that piston B exerts:
Force = (pressure)(area of piston)
= (2.46 psi)(0.44 square inches)

Force = 1.08 pounds

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Basic Pneumatic Circuits

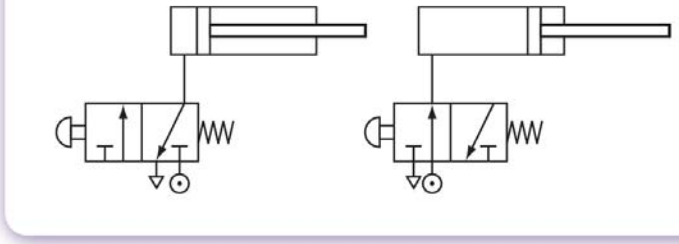

Figure 14-27: Single-acting cylinder controlled by a three-port valve, shown in both the inactivated (left) and activated (right) positions.

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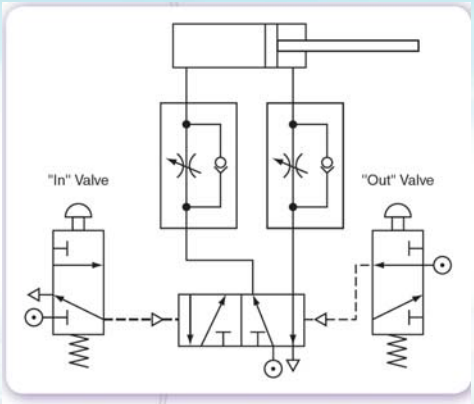
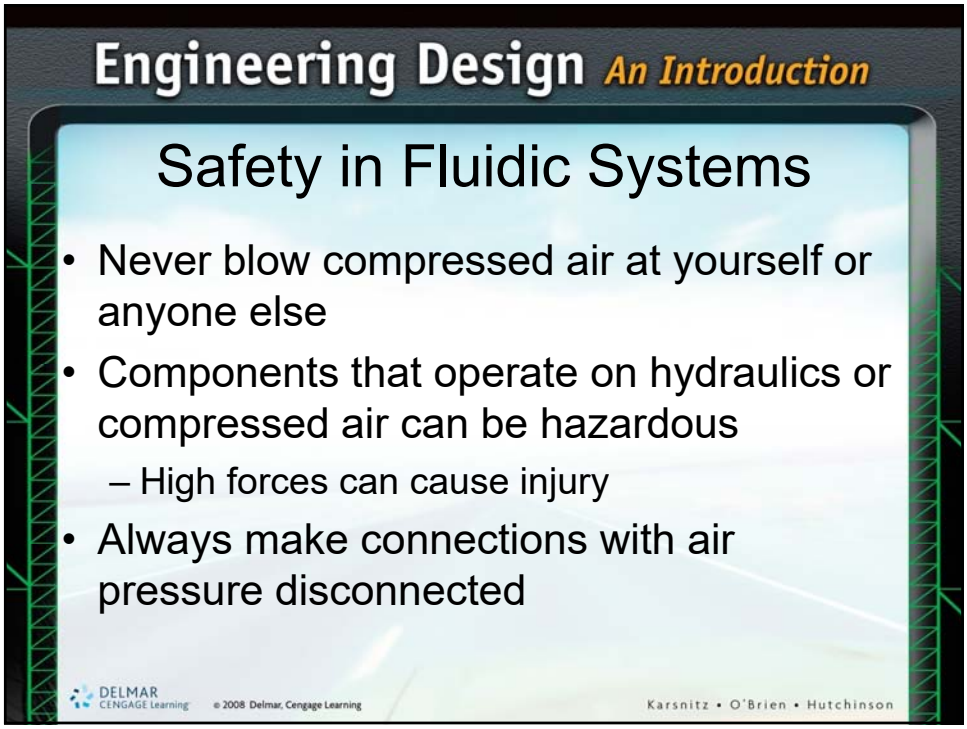


Figure 14-28: A double-acting cylinder controlled by a pressure-operated five-port valve. Three-port valves control the pressure-operated valve, and flow regulators control the speed of the piston on both the extend and retract movements.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Safety in Fluidic Systems
• Never blow compressed air at yourself or anyone else
• Components that operate on hydraulics or compressed air can be hazardous
– High forces can cause injury
• Always make connections with air pressure disconnected
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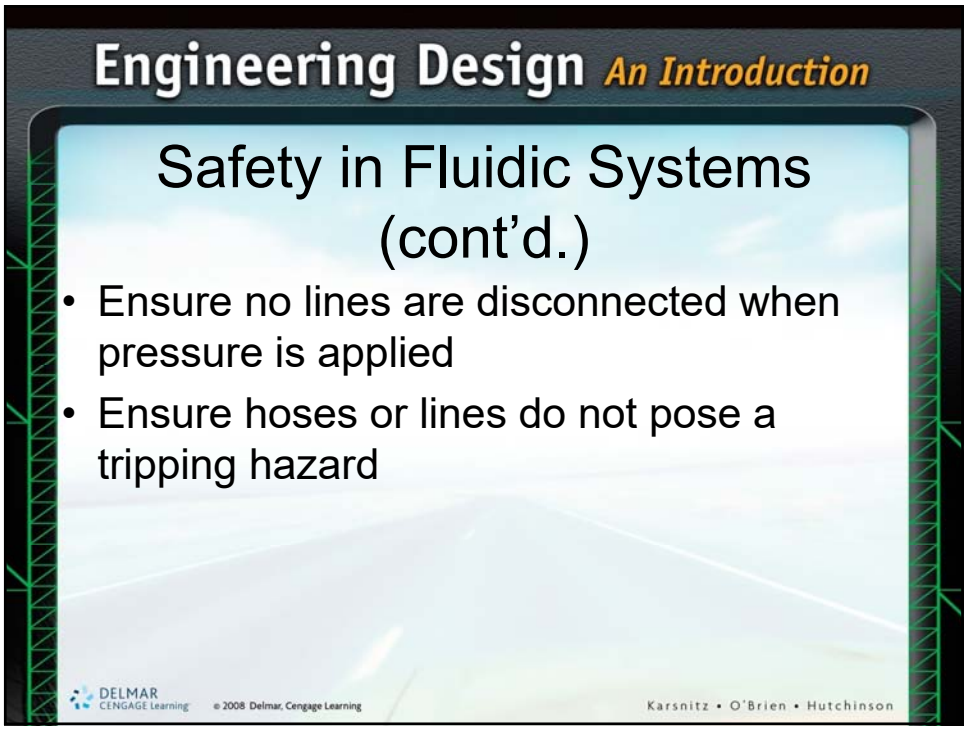
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Safety in Fluidic Systems (cont'd.)
• Ensure no lines are disconnected when pressure is applied
• Ensure hoses or lines do not pose a tripping hazard
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