



meet Mr. A.R. Power



Pneumatics and the FIRST Competition



It's all about Power

FIRST Kickoff - 2006
jrg



Pneumatics in 2006 – Why?

The Advantages

- Complete kit
- Weight equal or lighter than comparable alternatives
- Simple
Review the manual that comes with the pneumatic kit and you're ready to go
- Adjustable Force
 - Different bore cylinders change the available force
and
 - By adjusting the applied pressure you can instantly adjust the force

Pneumatics in 2005 – Why?

The Advantages

- **Durable**
no burned up motors – stall with no damage
- **Strong**
from 9 lbs to 180 lbs – easily adjustable
- **Custom cylinders**
in just a few days by UPS
- **Last minute additions**
add a valve or a cylinder quickly

Power Transmission & Control

- Electrical
- Mechanical
- Fluid Power
 - Hydraulics
 - Oil, Water, other liquids
 - Pneumatics
 - Air, other gases

Remember
Liquid or Gas

Pneumatics included in the FIRST kit

- Compressor and related components
- Connectors and tubing
- Valves
- Actuator (1 is included but up to 3 more can be gotten quickly – check the pneumatic manual)

Pneumatics

- Compressor *Converts Energy – Electrical to Pneumatic Analogous to Generator*
- Connectors *Analogous to Wires & Terminals*
- Valves *Analogous to Relays & Controllers*
 - Directional control
 - Flow control
 - Pressure control

Pneumatics

Actuators *Analogous to Motors, Solenoids, etc.*

- Linear – Often called cylinders – can be made to perform complex motions by using mechanical components – **this is the type included in your kit**
- Rotary
 - Limited Rotation
 - Self-contained
 - Rack and pinion or lever
 - Air Motors or turbines
- Clamps

Review Questions

Which is NOT an advantage of pneumatics ?

1. Forces from 9 to 180 lbs. can be easily achieved
2. Custom actuators are available quickly
3. Easy to add extra functionality
4. Force produced by a cylinder can't be changed
5. Simple to apply

Review Questions

Which is NOT an advantage of pneumatics ?

1. Forces from 9 to 180 lbs. can be easily achieved
2. Custom Actuators are available quickly
3. Easy to add extra functionality
4. Force produced by a cylinder can't be changed
5. Simple to apply

Correct answer – 4. Force can be changed by changing the bore (diameter) or changing the applied pressure with the regulator

Review Questions

Which statement is correct ?

1. Your pneumatic kit is complete, although custom cylinders can be gotten quickly.
2. You need to supply an extension cord to power the compressor from a wall outlet.
3. Because air is weightless, it will reduce the weight of your robot when pressurized.
4. The pressure switch is only included to sound an alarm if ambient pressure falls.

Review Questions

Which statement is correct ?

1. Your pneumatic kit is complete, although custom cylinders can be gotten quickly.
2. You need to supply an extension cord to power the compressor from a wall outlet.
3. Because air is weightless, it will reduce the weight of your robot when pressurized.
4. The pressure switch is only included to sound an alarm if ambient pressure falls.

Correct answer – 1. The pneumatic kit is complete.

Compressor

Thomas Industries

Electrically Driven



Relief Valve
on Compressor
Protects compressor

Additional Components



Gauge
Reads available pressure



Pressure Switch
Signals the controller
to start or stop the
compressor



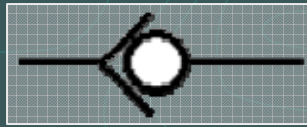
Plug Valve
Stops air flow



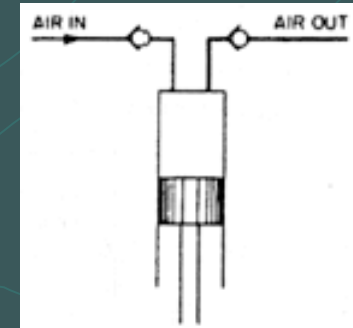
Tank(2 included)
Stores energy

The Compressor System

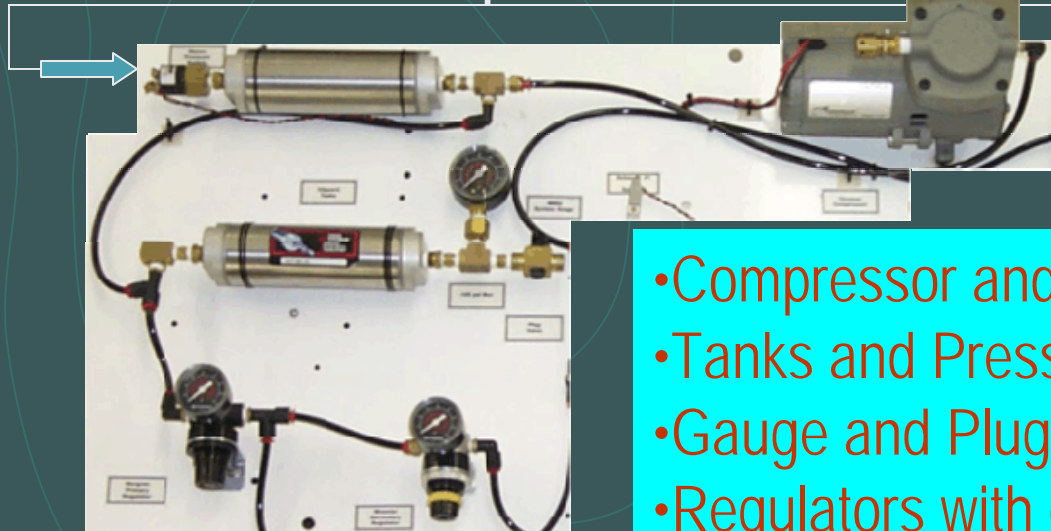
Electrically driven



Check Valve
Flow in **one** direction
built into compressor



Additional components



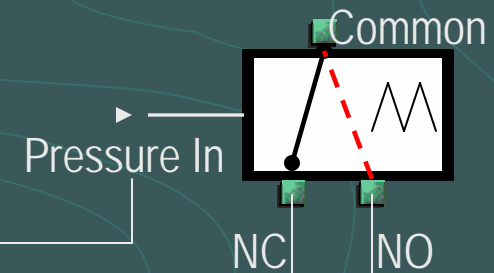
- Compressor and Relief Valve
- Tanks and Pressure Switch
- Gauge and Plug Valve
- Regulators with gauges

The Compressor System Additional Components

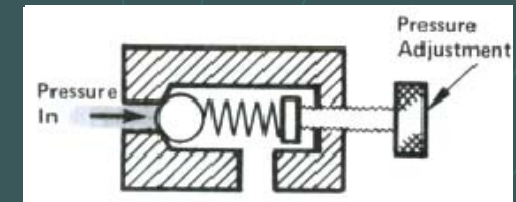
- Tanks & Gauge



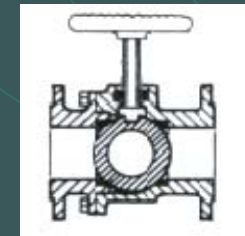
- Pressure Switch



- Relief Valve

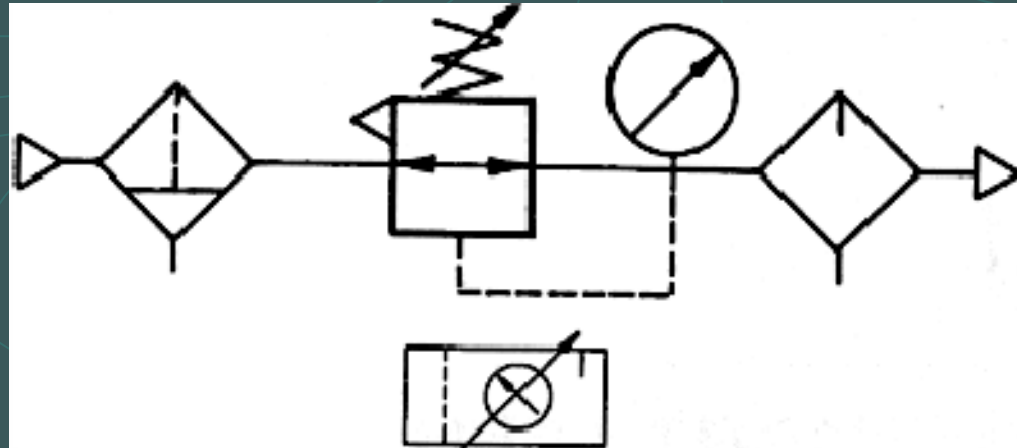


- Plug Valve



Air Supply

Compressed Air is prepared with the use of
Filters – Regulators - Lubricators



Filter – Regulator w/gauge - Lubricator symbol

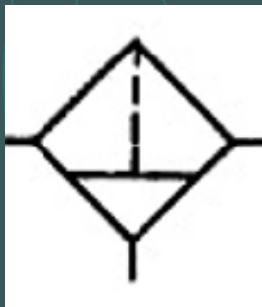
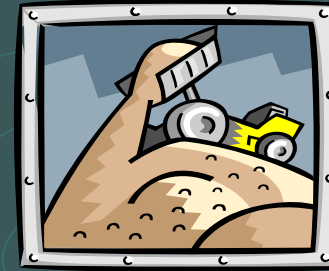
Air Supply

- Ambient air is compressed

But dust, dirt and water are included

In industrial applications, contaminants are removed through the use of

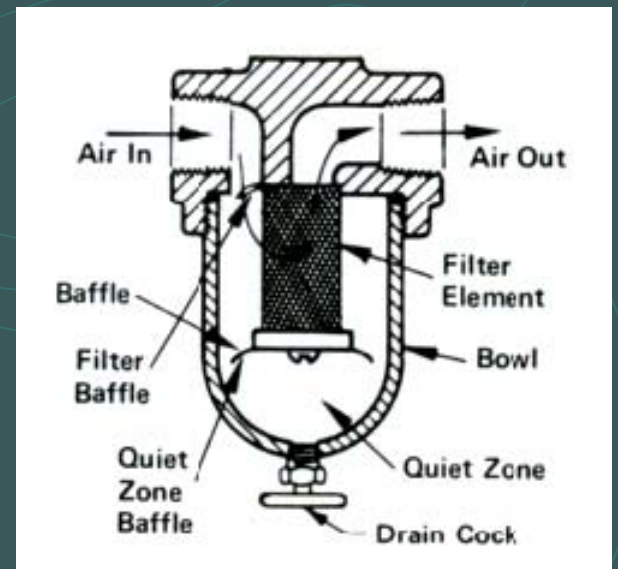
filters



Filter symbol

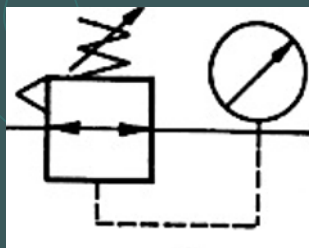
Air Supply - Filters

- Mesh screens or sintered metal baffles remove dirt
- Spinning action forces water and contaminants out of the air stream
- Special filter materials remove other entrained contaminants like oil vapors
- More water can be removed by air dryers
 - Chemical
 - Mechanical



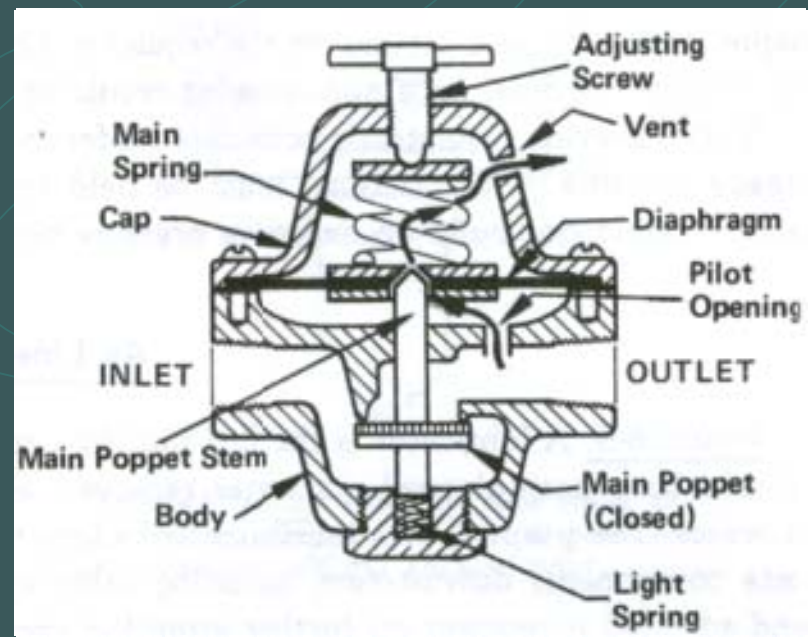
Air Supply - Regulator

- Regulators Control Pressure
 - Relieving type in the FIRST kit – 2 are included



Relieving
Regulator and
gauge symbol

- Non-Relieving type can trap pressure
- The use of Regulators assures maximum efficiency
- Set Regulators to about twice minimum pressure necessary to operate the cylinder under load



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About Pressure

- **Safety MUST** always be considered

Compressed Air is like a coiled spring that can be routed to where it is needed

The bore, stroke and motor horsepower control the pressure from the compressor

- The ratio of the uncompressed volume to the compressed volume is the compression ratio

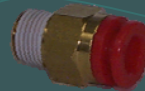
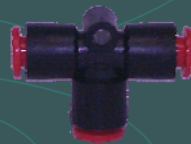
Relief Valve and Regulator control the working pressure

- Compressed Air is stored in two tanks

- The higher the storage pressure, the more usable energy will be available

Connectors

- Hundreds of Variations Available
 - Size, Type of Connection, Number of Ports



- Tubing or Pipe – wrap teflon[®] tape correctly



**Tapered Pipe Thread
Generally Brass**



**Use Teflon
Tape Correctly**

Fittings

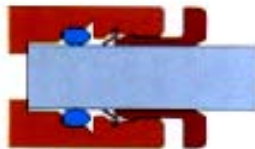
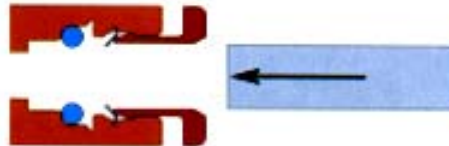
Connection and Disconnection

Method of assembly



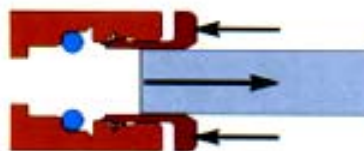
1. Ensure that the end of the tube is cut square and is free from burrs.

2. Push the tube through the release button and grab ring into the fitting.



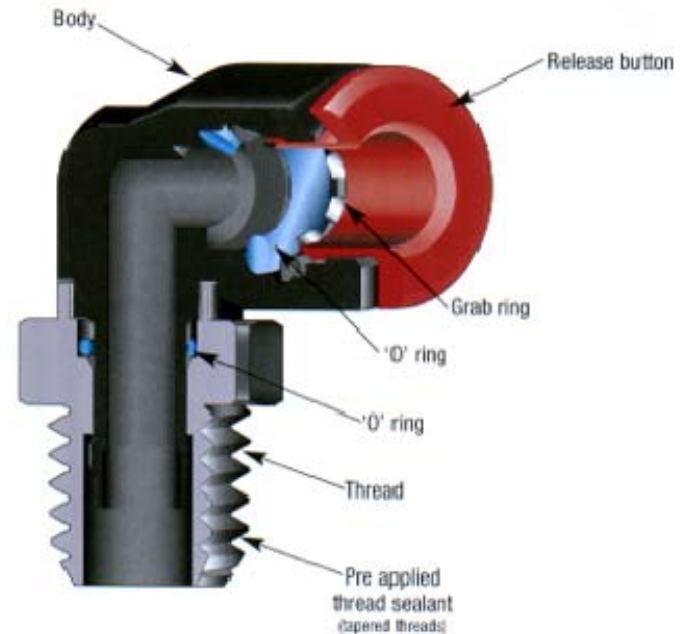
3. Push the tube firmly through the 'O' ring until it bottoms on the tube stop then pull back.

4. To disconnect, push the tube into the fitting, hold down the release button and withdraw the tube.



Typical part

90° Swivel elbow adapter



Some Facts about Pneumatics

● Pressure – Potential Energy

Voltage

- Lbs per in² or Force per unit area
- Absolute Pressure – 14.7 psia at sea level
- Gauge Pressure – measured relative to ambient

● Flow

Current

- cfm or Volume per unit time
- Scfm

More Facts about Pneumatics

- Universal Gas Laws – Boyle's Law

- $P_1 \times V_1 = P_2 \times V_2$ **if Temperature remains constant**
 - That means if you cut the volume in half the **absolute pressure** doubles – That's how the Compressor works

164.1

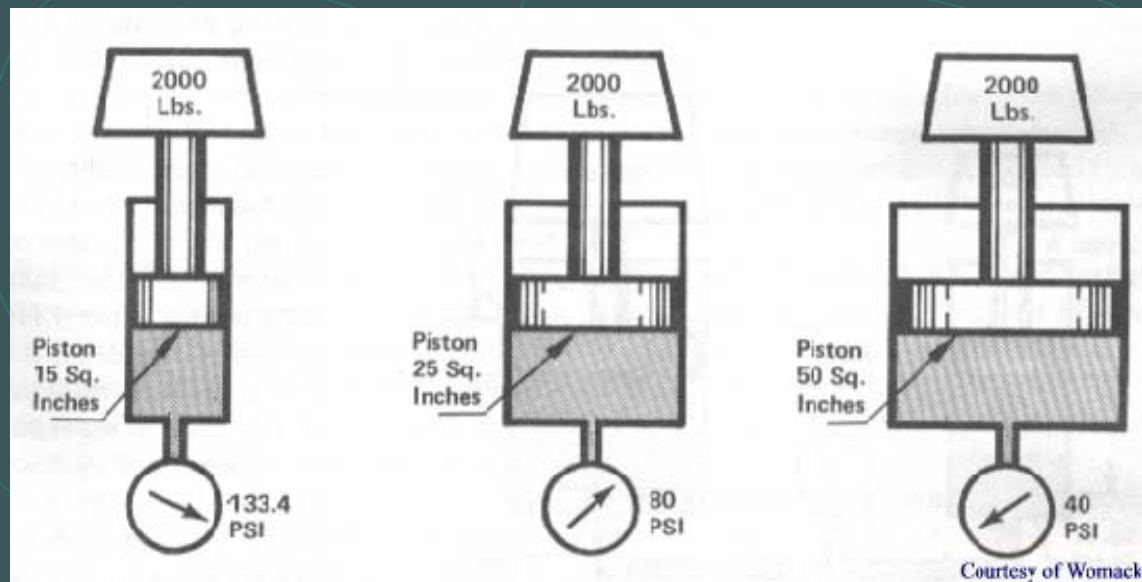
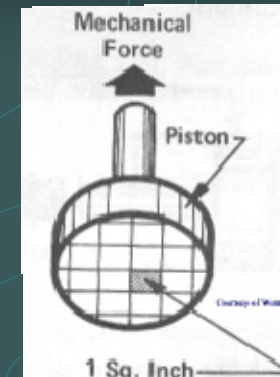
According to Boyle's Law the absolute Pressure will increase 4 times when the volume is reduced by 75%. What will the gauge read?

Courtesy of Womack

Bars Gauge	0	1	2	3	4
Bars Absolute	1	2	3	4	5
PSIG Gauge	0	14.7	29.4	43.5	58.8
PSIA Absolute	14.7	29.4	44.1	58.8	73.5

Force Principles

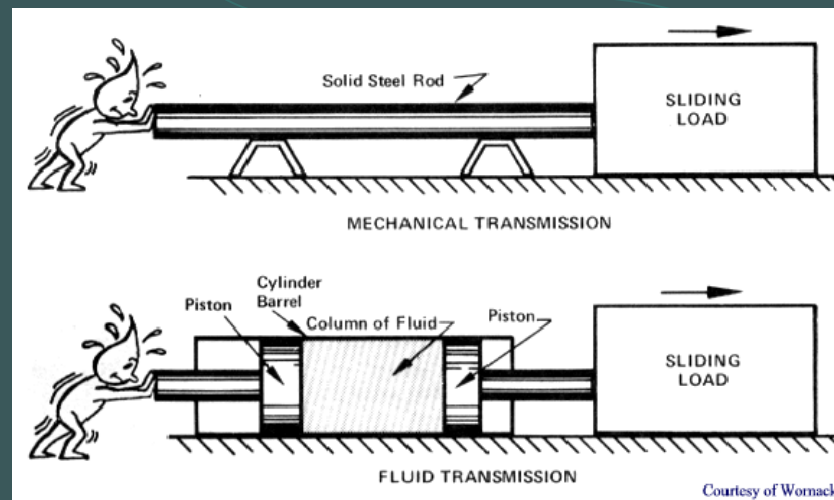
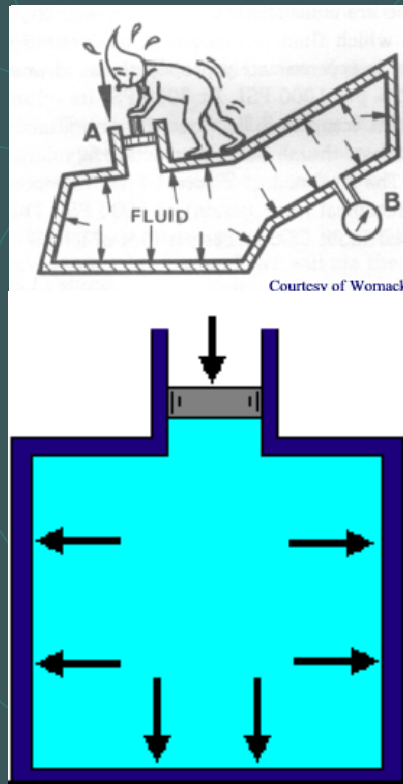
- *Gauge Pressure works against each square inch of piston surface*
- The greater the square inch surface of the fluid, the less internal pressure will be developed.



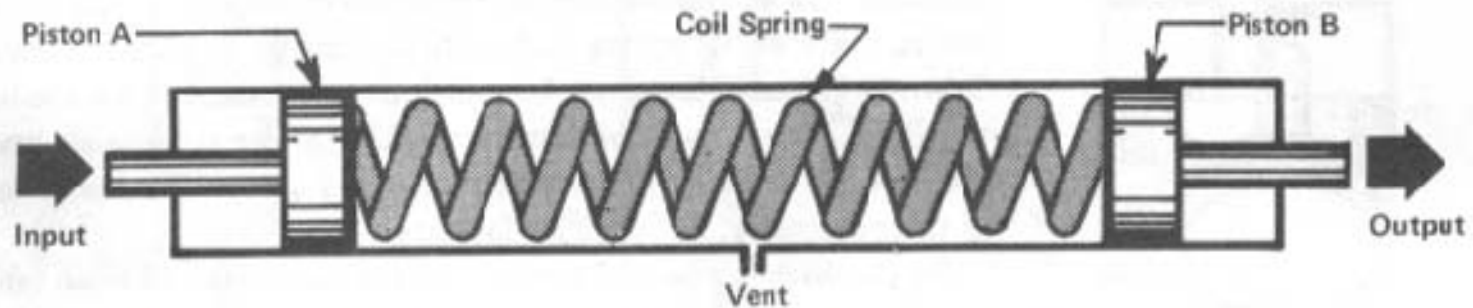
More Facts about Pneumatics

Universal Gas Laws - Pascal's Law

- Pressure acts at right angles to the confining vessel — That's how a cylinder works

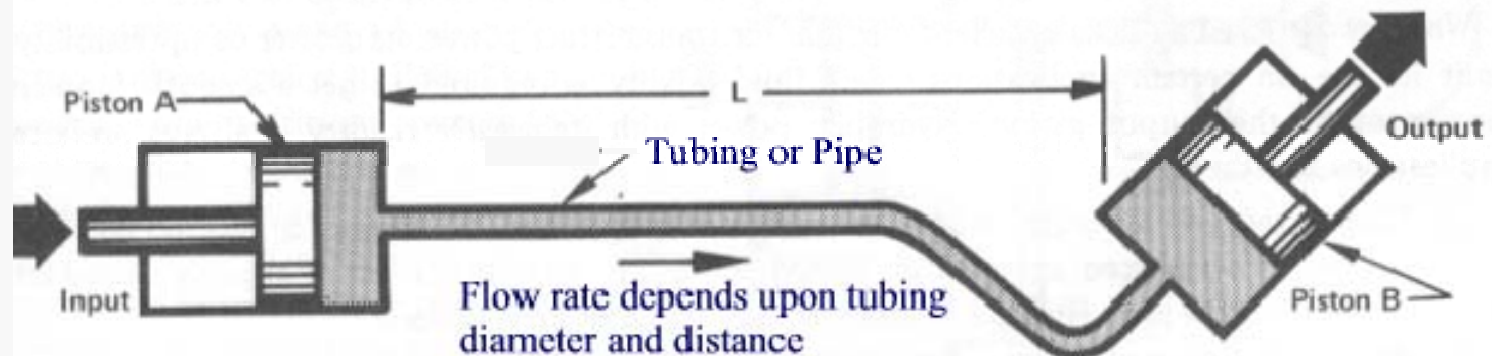


Transmission Principles



Transmission of power through a column of fluid is much like transmitting mechanical power through a coil spring. All fluids are compressible to some degree. Air is very compressible

Courtesy of Womack

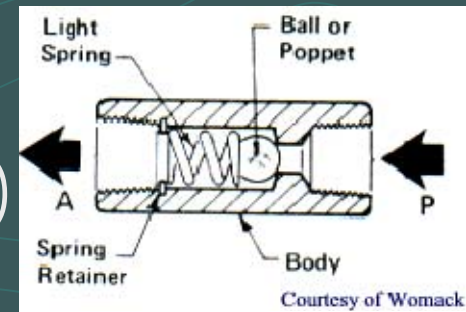


Fluid power has great flexibility. It can be transmitted up or down or around corners and to greater distances than it can by mechanical transmission means.

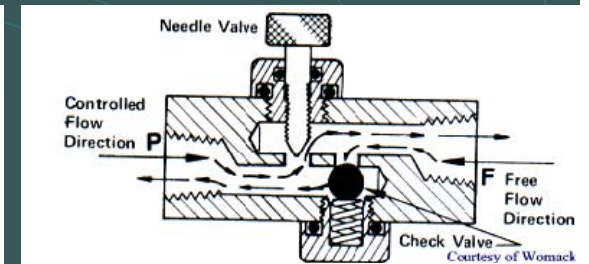
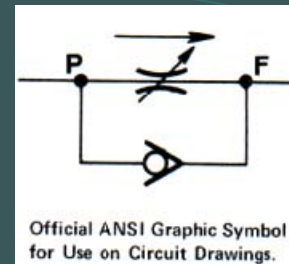
Courtesy of Womack

Valves are in Control

- Control Pressure
 - Relief Valves & Regulators
- Control Flow
 - Check Valves (used on compressor)



- Flow Controls

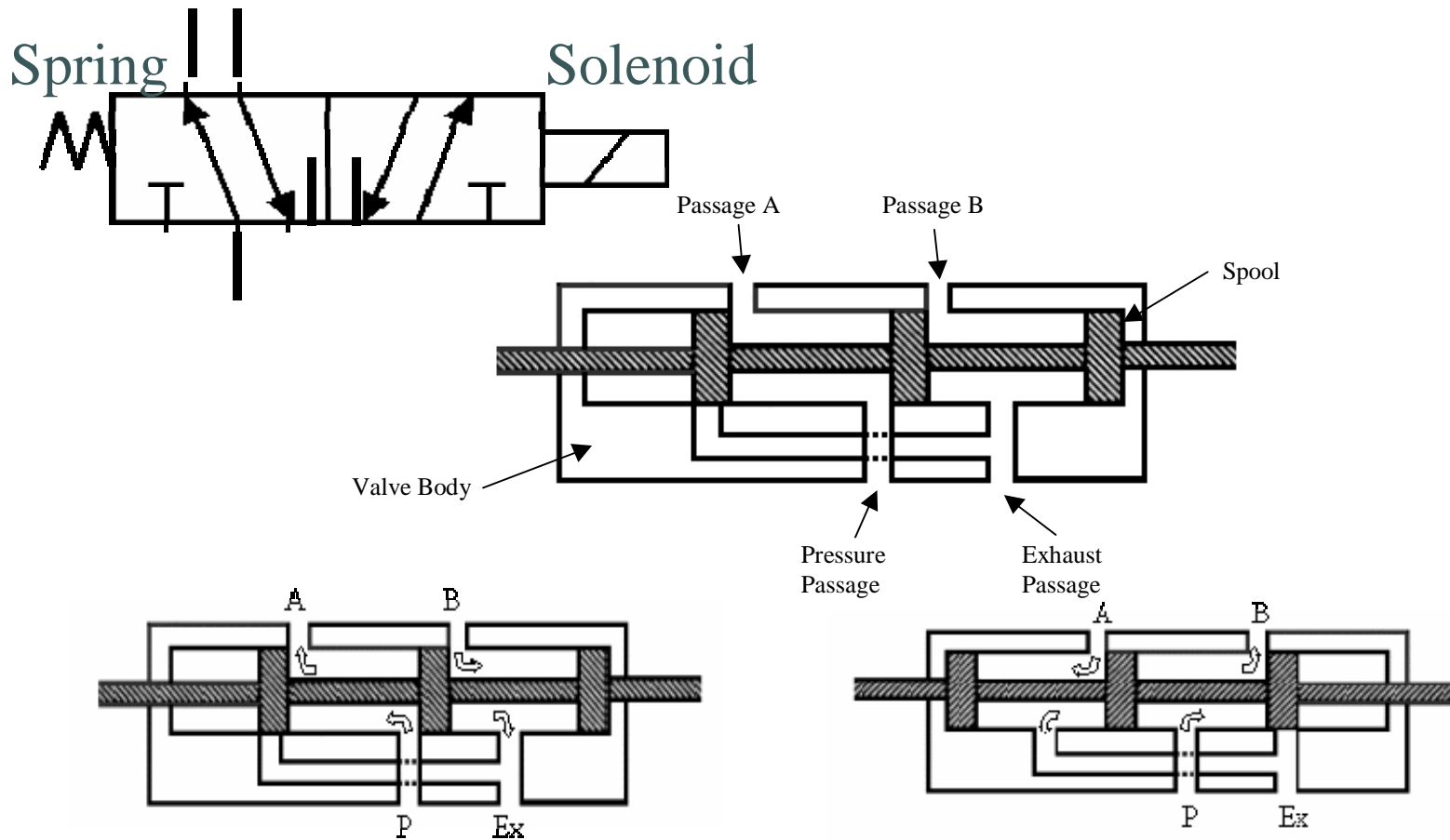


- Needle Valves



4-way 5-port Valves

Directional Control

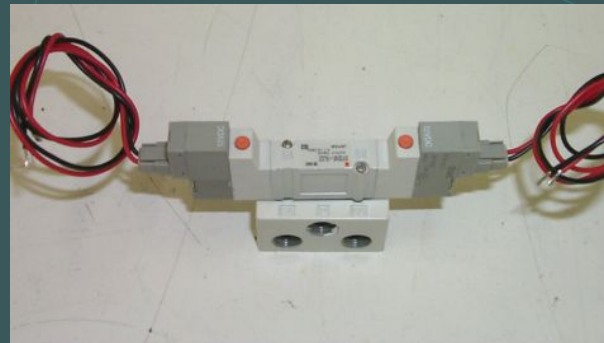


4-way Valves in your kit

- Double Solenoid (detented)

- SMC

- 2 supplied



4-way Valves in your kit

- Single Solenoid (spring offset)

- Festo

- 2 supplied



4-way Valves in your kit

Single Solenoid
Poppet (Spring Offset)

Port Sizes: Integrated Fittings:

1/4" O.D. x .040" wall poly tubing (grey tube nuts)*

or 6mm x 1mm wall poly tubing (black tube nuts)*

*Both supplied with valve

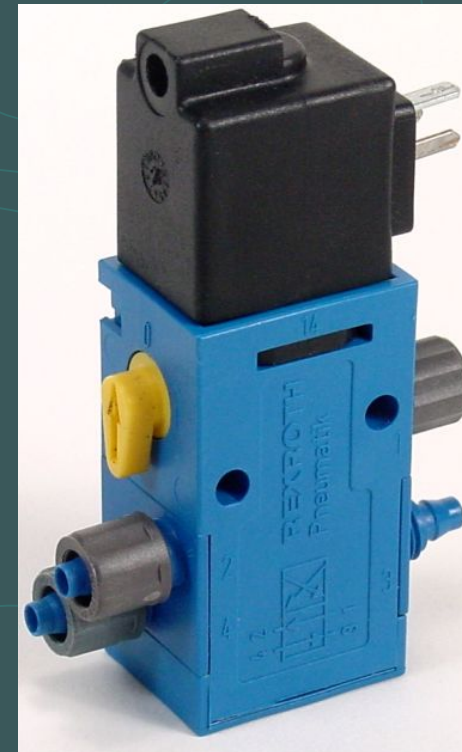
Flow: $C_v = .20$

Power Consumption: 1.6 Watts

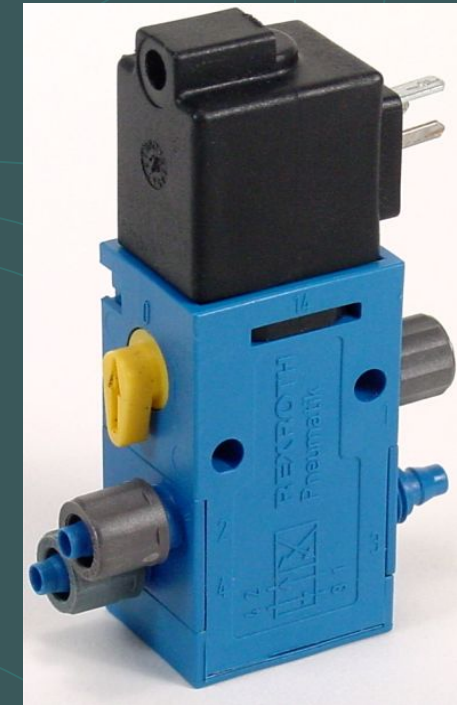
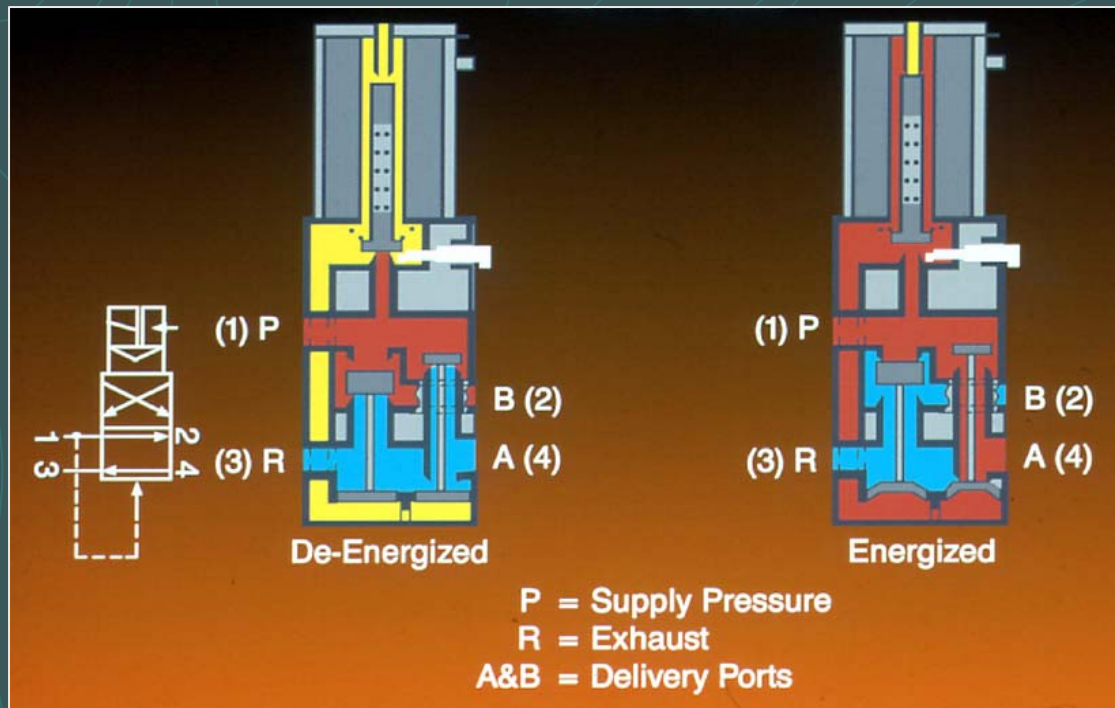
Working Pressure: 20 psi min. (External pilots not available)

150 psi max. (Below 105° F)

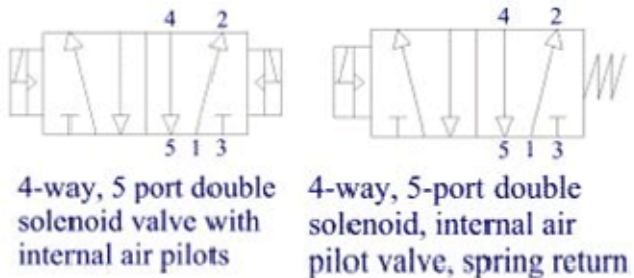
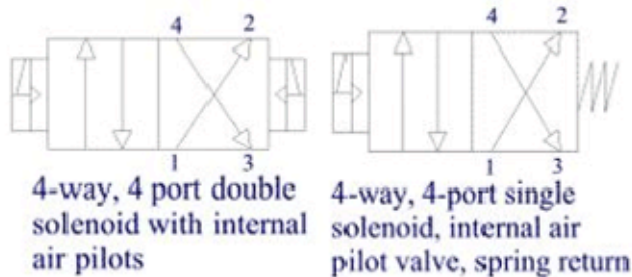
No vacuum service – Electrical Connectors Included



4-way Valves in your kit Construction



Valve Symbols



Pilot Operator

Built in to the 4-way power valves

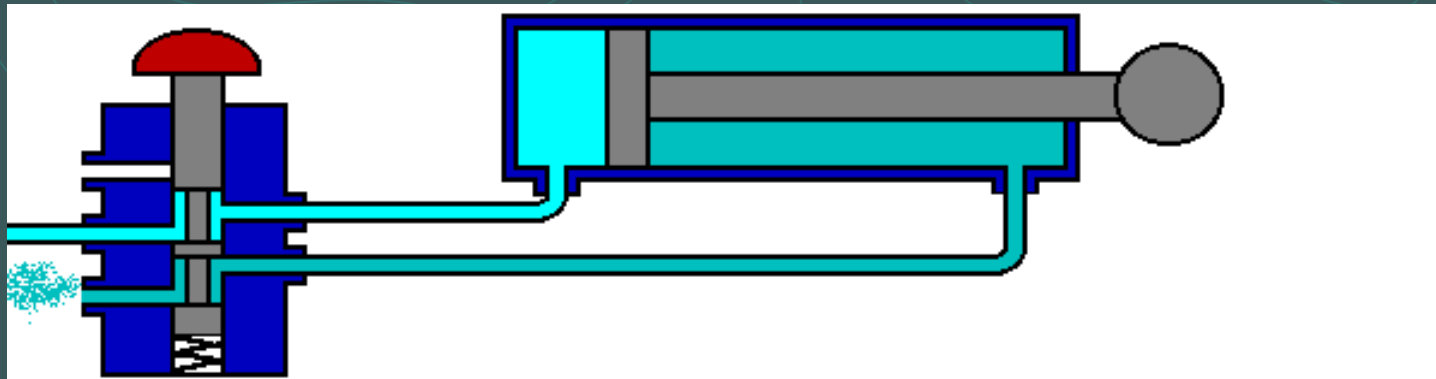
Note: Because the 4-way valves are pilot operated, you must use port #1 as the supply pressure port. The 4-way valves will not operate correctly without consistent pilot pressure supplied from port #1.

All power valves have built in manual overrides.

- The 4-way valves included in the kit are actually pilot-operated valves.
- Pilot-operators are 3-way **nnp or nc** (normally not passing or normally closed) valves built into the main valve.
- This allows low-power solenoids to use the air pressure to switch the main spool. Solenoids that would actually move the main spool would be large, heavy and consume a lot of power.

Compressed Air

is routed by the valve to extend or retract the cylinder



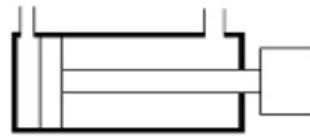
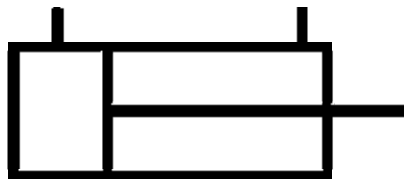
Animations courtesy of Deyes High School
www.deyes.sefton.sch.uk/technology/AS&Alevel/pneumatic_systems.htm

Actuators

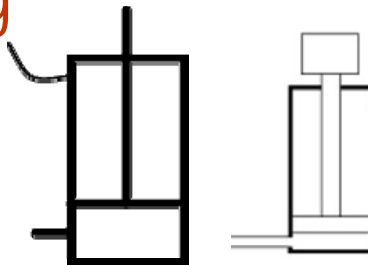
Make things move

Most Common types of Linear Actuators

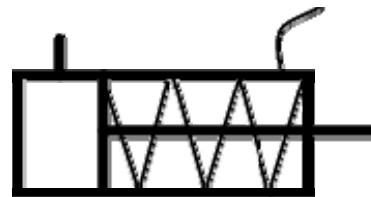
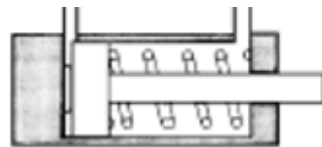
- Double Acting – Single Ended – Double Ended



- Single Acting



- Spring Return



All contain

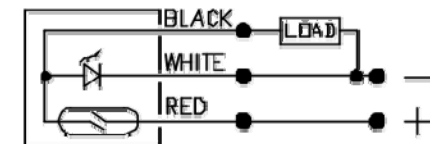
- Cylinder Barrel
- Piston
- Rod
- Seals
- Spring if used

Actuators

Make things move

Actuators available on order

- One linear actuator (cylinder) is included with the kit. This actuator does **not** include a magnetic piston or reed switches
- Three more free actuators can be ordered. One of those may be a rotary actuator. The order form and details are included in the manual. These actuators can be ordered with reed position switches and magnetic pistons.

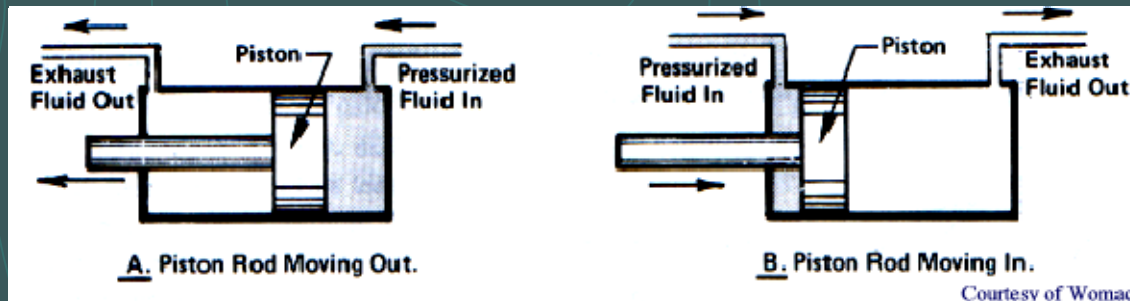
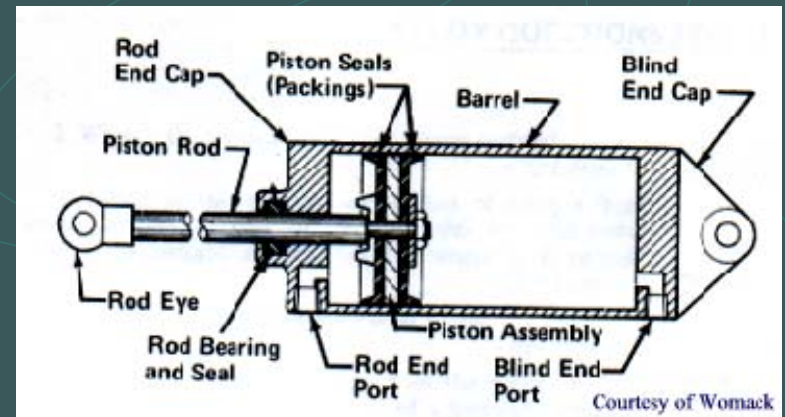


Note the inclusion of reed switches

Actuators

Construction & Operation

Basic Construction



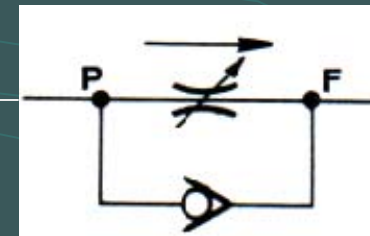
Operation

Actuators

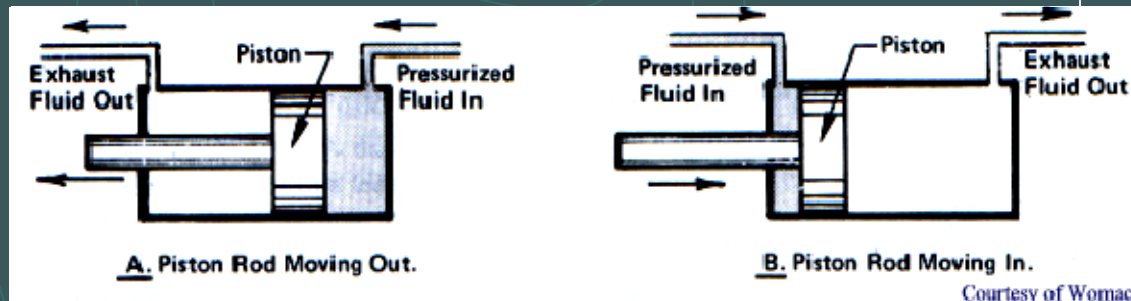
Operation with Flow Controls

Typically Flow Controls are mounted between the 4-way valve and the cylinder as close to the cylinder as practical.

The check valve permits free flow into the cylinder from the valve and metered flow from the cylinder to exhaust



Official ANSI Graphic Symbol for Use on Circuit Drawings.



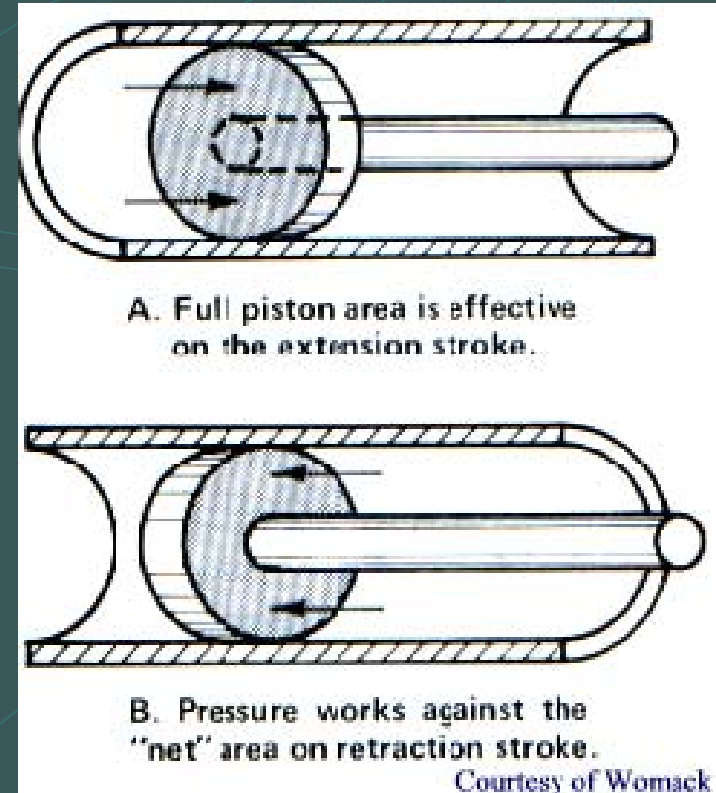
Operation

Actuators

Differential Areas

Force Consideration

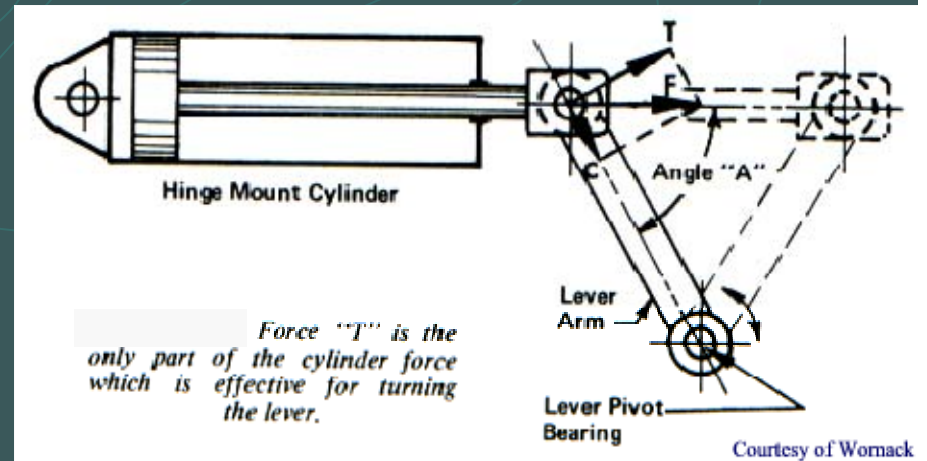
- *Consider the effective area on which the pressure acts*
- *On single ended cylinders there is a differential*
- *Don't forget friction*



Actuators

Angles

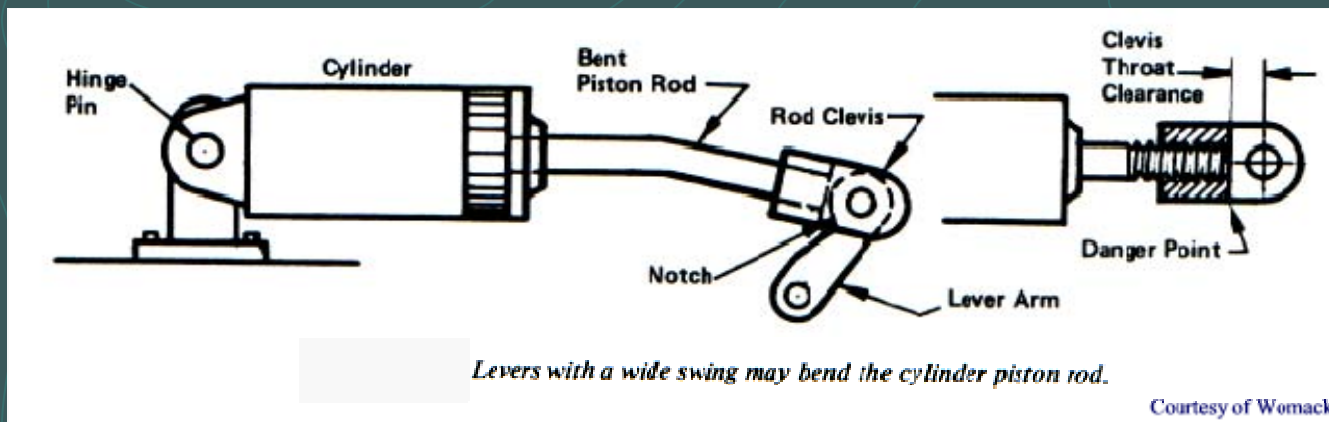
Power Factor	
Angle A•	Factor
10	.174
20	.342
45	.707
50	.766
60	.867
75	.966
90	1.0



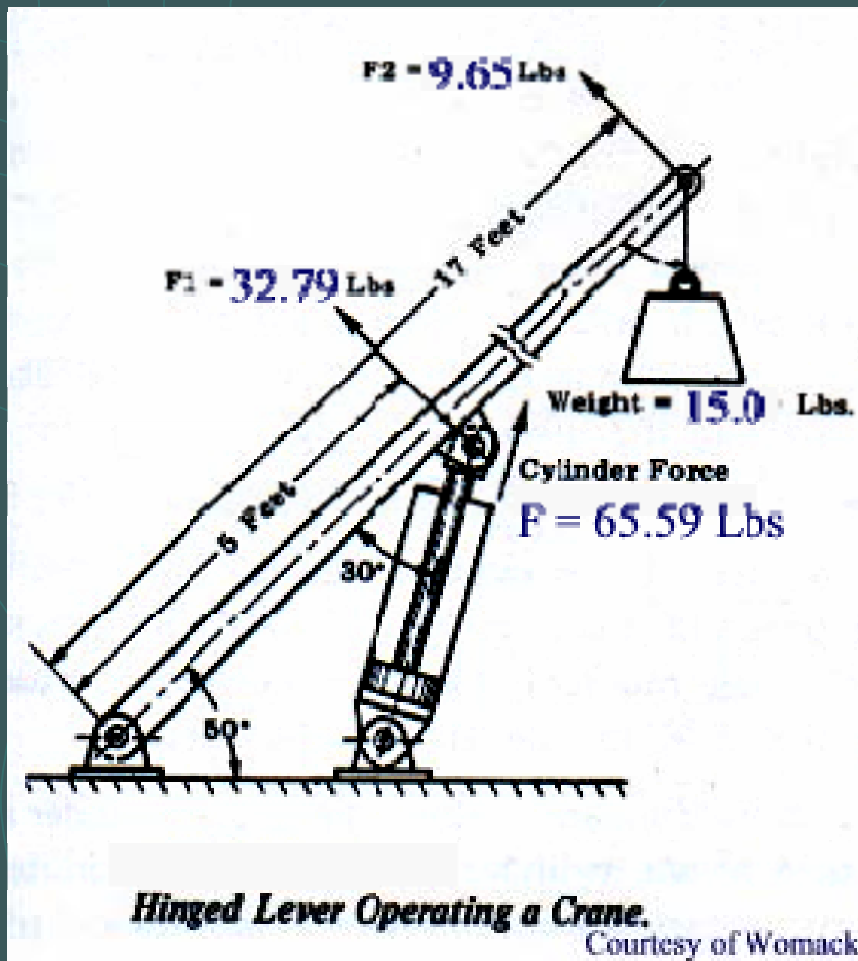
$$\text{Force } T = \text{Cylinder Force} \times \sin A$$

Actuators

Angles



Actuators - Angles

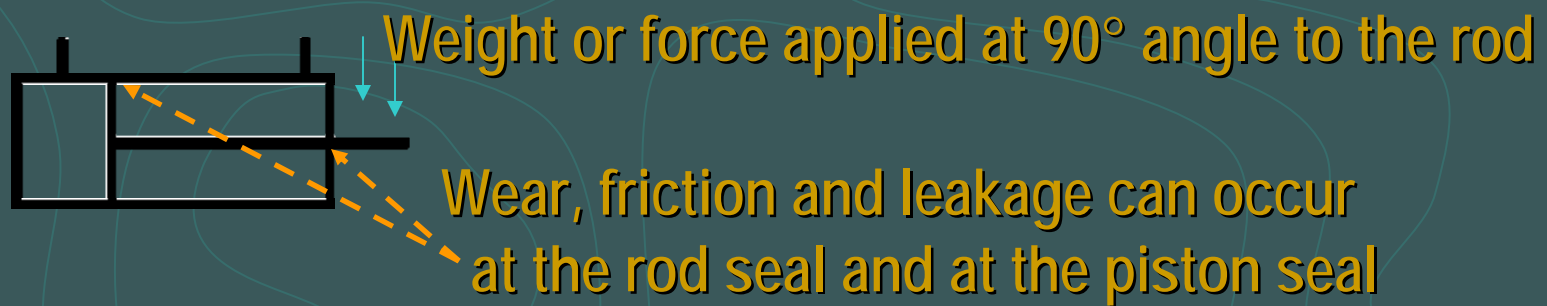


Example:

- Load 15 lbs
- Angle 50°
- Solution
 - **Step 1** – Force at right angles to support weight = $15 \times .643$ (cos 50°) = 9.65 lbs = F2
 - **Step 2** – Effective Cylinder Force at right angles to support weight = $9.65 \times \text{arm ratio } (17/5) = 32.79 \text{ lbs} = F1$
 - **Step 3** – Actual Cylinder Force acting at 30° = $F1 / \sin 30^\circ = \underline{\underline{65.59 \text{ lbs} = F}}$

Actuator (cylinder) Do's and Don'ts

- You do not have to fully extend a cylinder but you'll need an external stop.
- Avoid side-loading – increases friction and wear



- Avoid getting grit or metal shavings on the rod or in the cylinder – causes abrasion and seal damage

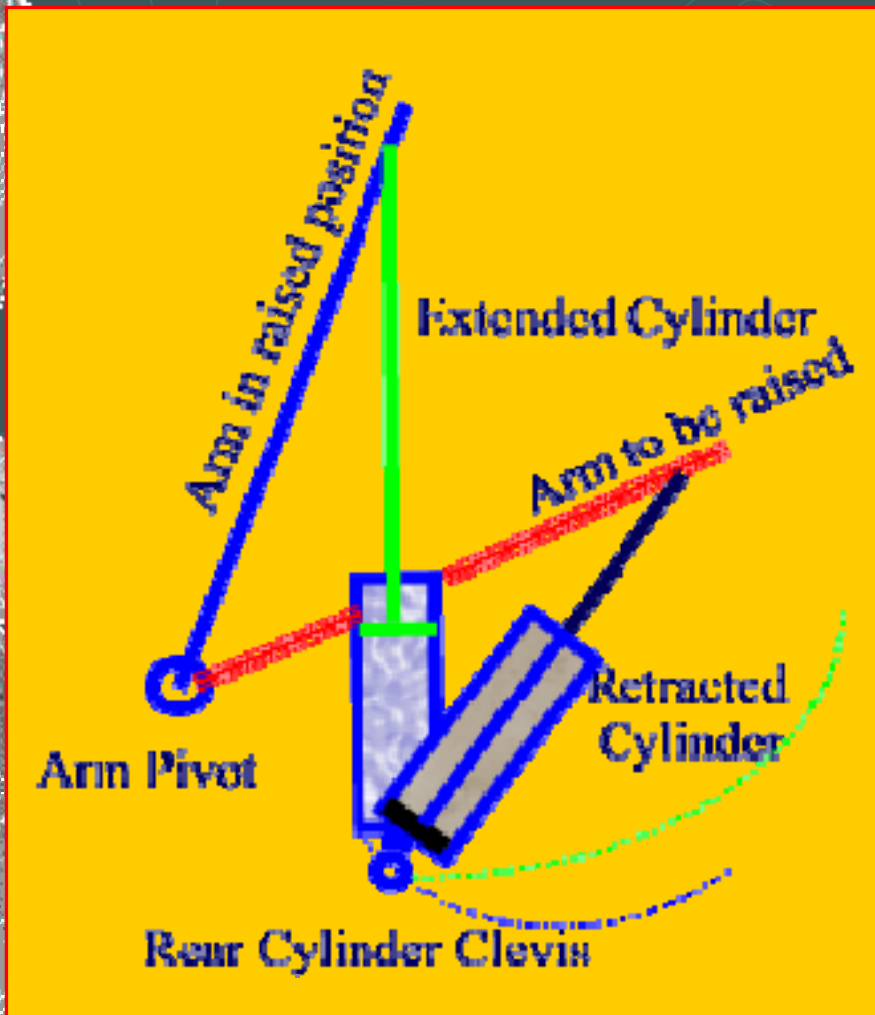
Actuator (cylinder) do's and don'ts

- Use flow controls for safety
- Cylinder Force
 - **Push Force** = $\pi \times \text{cylinder radius}^2 \times \text{Pressure (psig)}$
 - **Pull Force** = Push Force - $\pi \times \text{rod radius}^2 \times \text{Pressure (psig)}$
- Teams may order additional cylinders (including spares) for rapid delivery using the FAX form is on page 16 of the manual that is included in the kit. $\frac{3}{4}$ " , 1-1/2" or 2" bore are available – see form for available strokes
- Avoid leaks – reduces available energy

Actuators – Mounting Thoughts

Example: Arm to be raised by Cylinder

- Determine overall length of retracted cylinder
- Draw an arc from the mounting point on arm
- Determine overall length of extended cylinder
- Draw an arc from the mounting point on arm
- Where **arcs intersect** is the mounting point
- Check for intermediate interference



Calculating Cylinder Dimensions

Based on the drawings in the pneumatic manual included with the kit:

- Retracted length from pivot pin to clevis hole =
 - Base Dimension +
 - Stroke Length +
 - Locking Nut +
 - Clevis Dimension
- Extended length from pivot pin to clevis hole =
 - Retracted Length plus Stroke

Tips & Tricks

- **Minimize Leaks (better yet, remove them completely) by careful use of teflon tape and careful assembly of tubing and fittings. Teflon tape should start two threads back and wrap in the direction of the threads.**
- **With no movement taking place the compressor should charge the tanks and then shut off. It should not restart until a valve and cylinder is operated**
- **Use the Compressor Vibration Isolators. The Compressor is a reciprocating device and will cause sympathetic vibrations throughout your assembly unless they are used.**
- **When ordering custom cylinders, use extreme care on the form, both on the address and models ordered**

Tips & Tricks

- **Pressure Switch must be used as inputs to the controller. They cannot handle the amperage of the compressor.**
- **The Norgren Regulator should be first with the Monnier unit used after that if needed.**
- **Make sure you have adequate pilot pressure (30 psi) for the valves.**
- **When using the double solenoid valve, energize only coil one at time.**
- **Fittings are not required in the exhaust ports unless the circuit requires them.**
- **Always stay clear of cylinders in motion. Until compressed air is being metered, flow controls do little to control speed.**
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