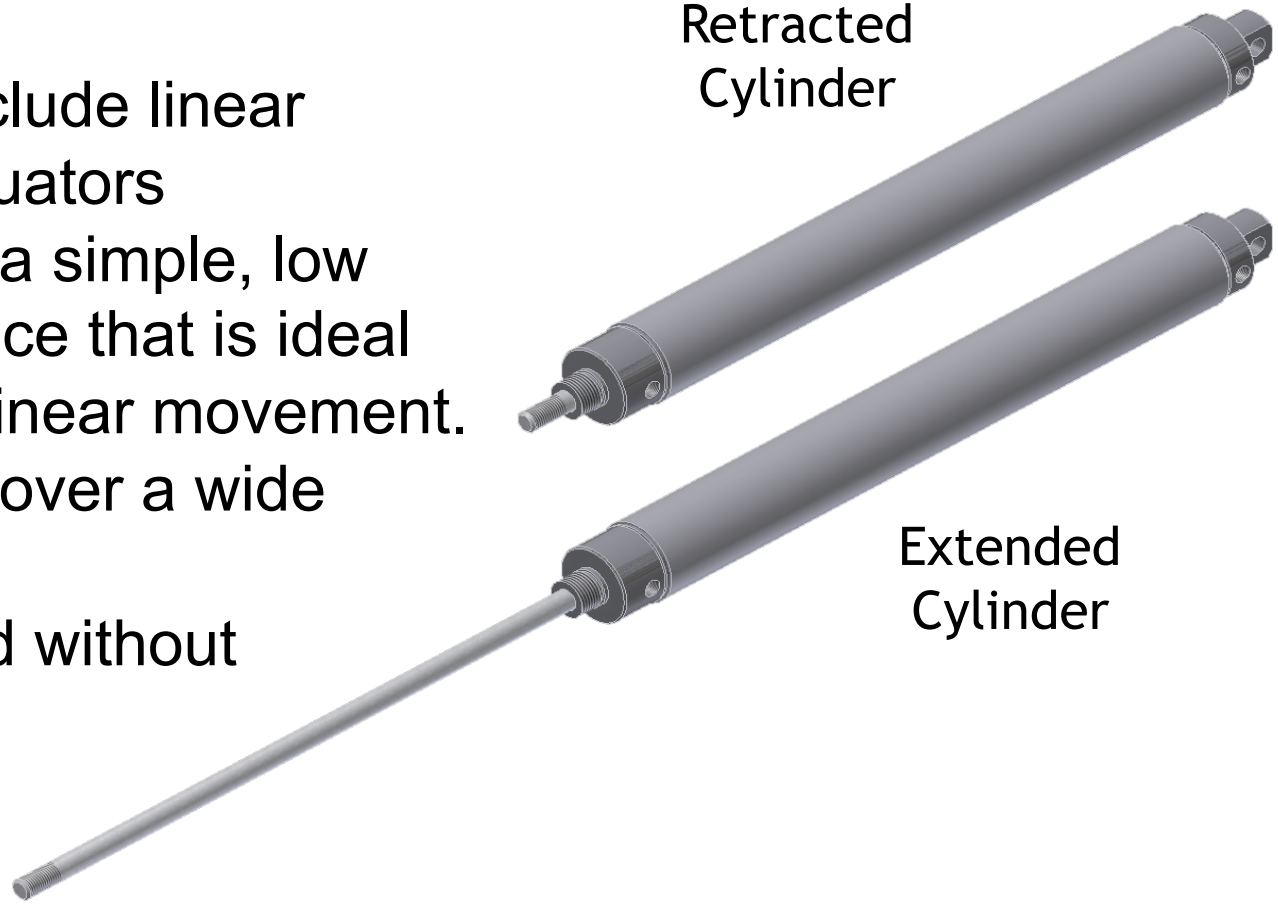
ROCO222: Intro to sensors and actuators

Lecture 10

Pneumatic actuation

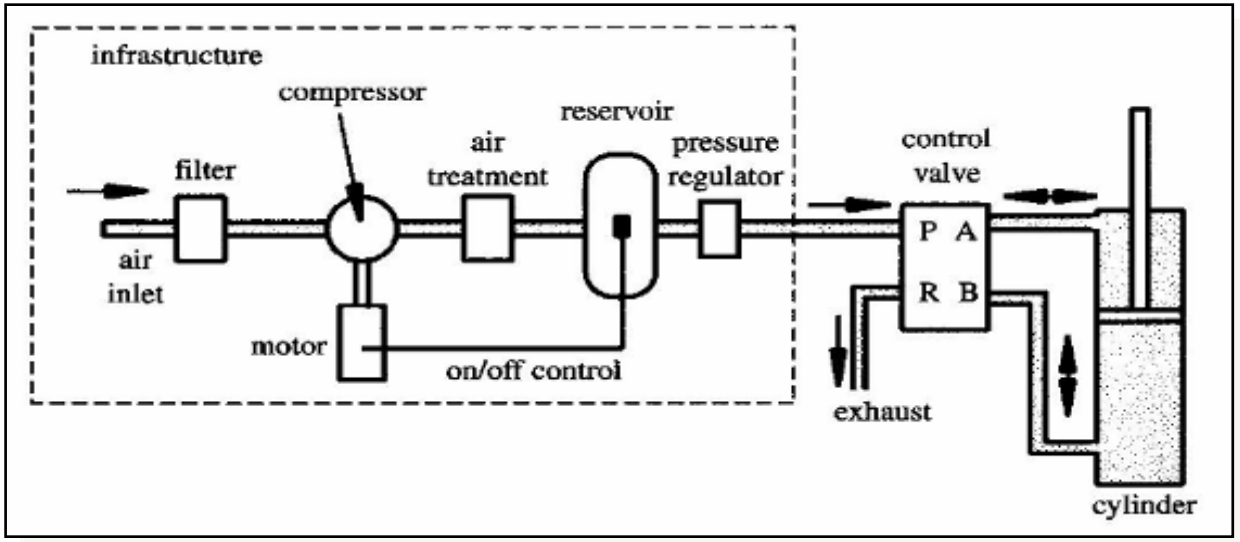
Pneumatics

- Pneumatics mechanisms use air pressure to apply mechanical force and displacement (work)
- The pneumatic devices are essentially binary actuators – either retracted or extended
- Pneumatic actuators include linear cylinders and rotary actuators
- A pneumatic cylinder is a simple, low cost, easy to install device that is ideal for producing powerful linear movement.
- Speed can be adjusted over a wide range
- A cylinder can be stalled without damage



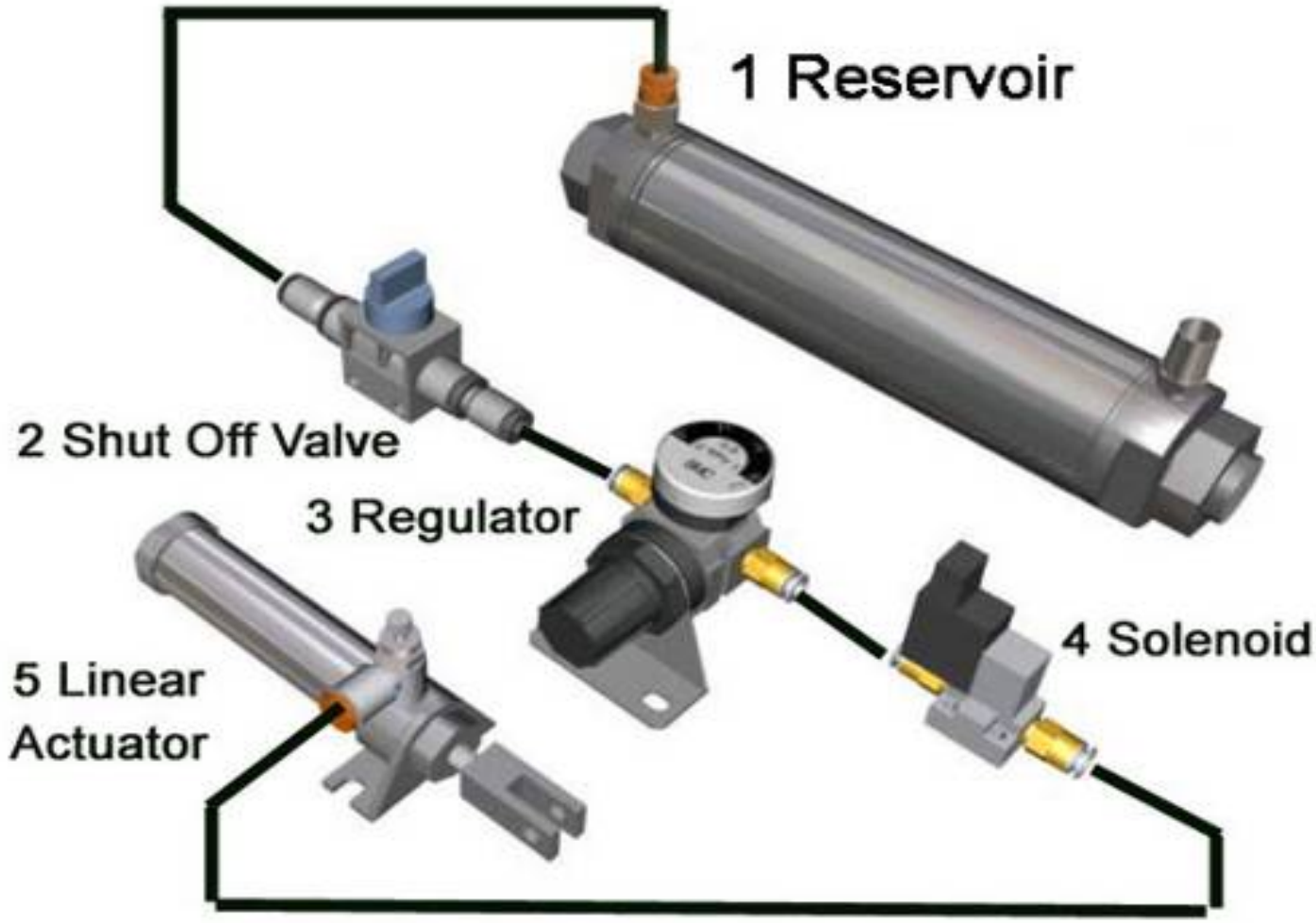
Pneumatic systems

- Pneumatic systems similar to hydraulic systems
- Use compressed air as working fluid rather than hydraulic liquid
- 70psi - 150psi, much lower than hydraulic system pressures, much lower forces than hydraulic actuators
- Energy can be stored in high pressure tanks
- Open systems, always processing new air



Pneumatic system components

Pump
1 Reservoir
2 Shut off value
3 Pressure regulator
4 Solenoid valve
5 Actuator



Basic pneumatic system consist of a source of compressed air, control valves, pipelines & pipe fittings and pneumatic accessories like filter, regulator and lubricator

Advantages and disadvantages of pneumatics

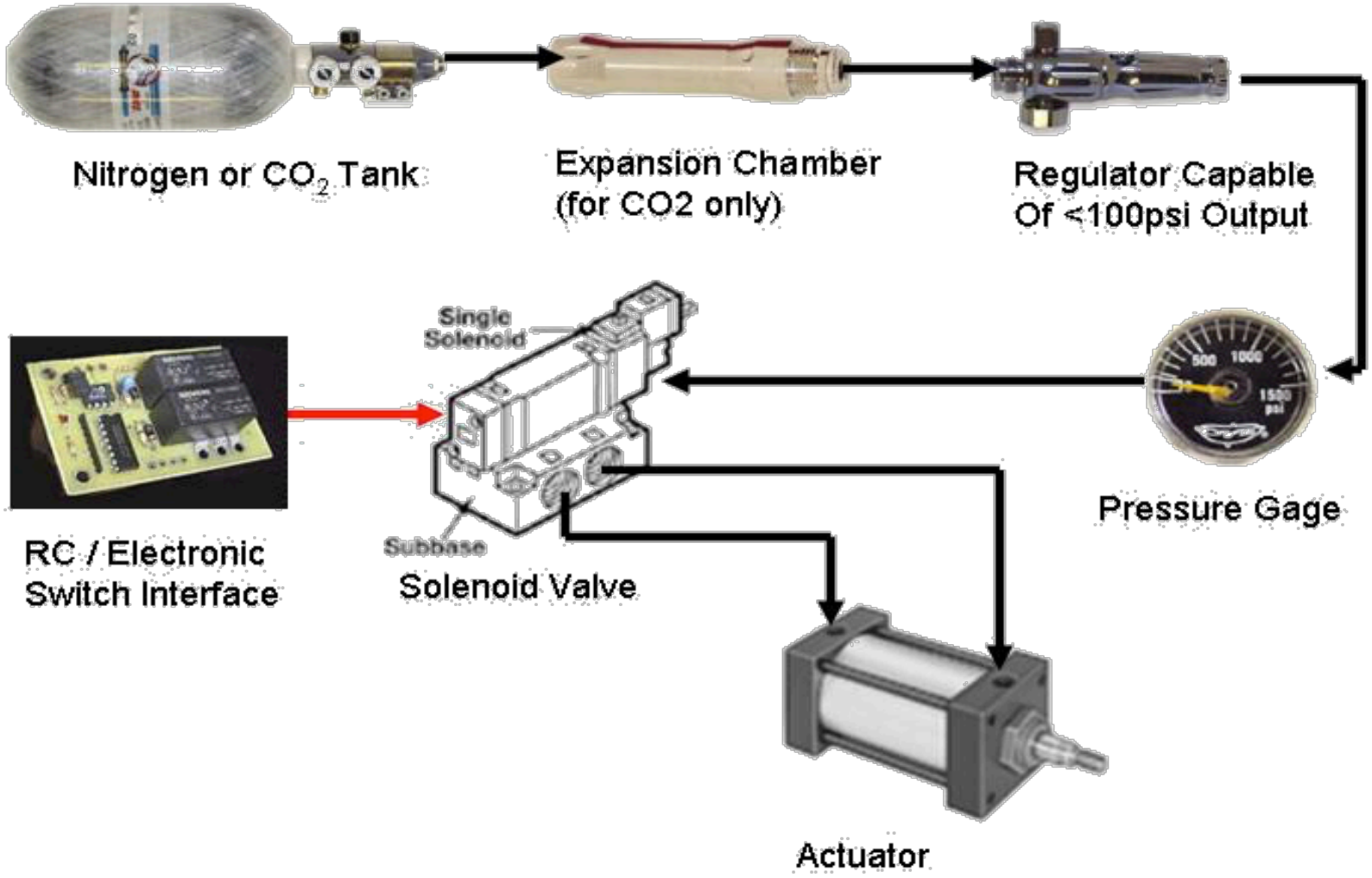
Advantages

- Cylinders much lighter than motors
- Easier to mount than motors
- Simpler and more durable than rack and pinion for linear motion
- Big forces with elasticity from a small, light package
- No leakage problems which you get with hydraulics
- No burnout
- Cylinders can be stalled indefinitely without damage
- Constant force
- Clean (food industry)
- No return lines needed
- Fast system response
- Easy to control
- Force is limited by air pressure and cylinder diameter
- No adverse consequence if cylinder is stopped (no stalled motors) or reversed – compressed air is a spring

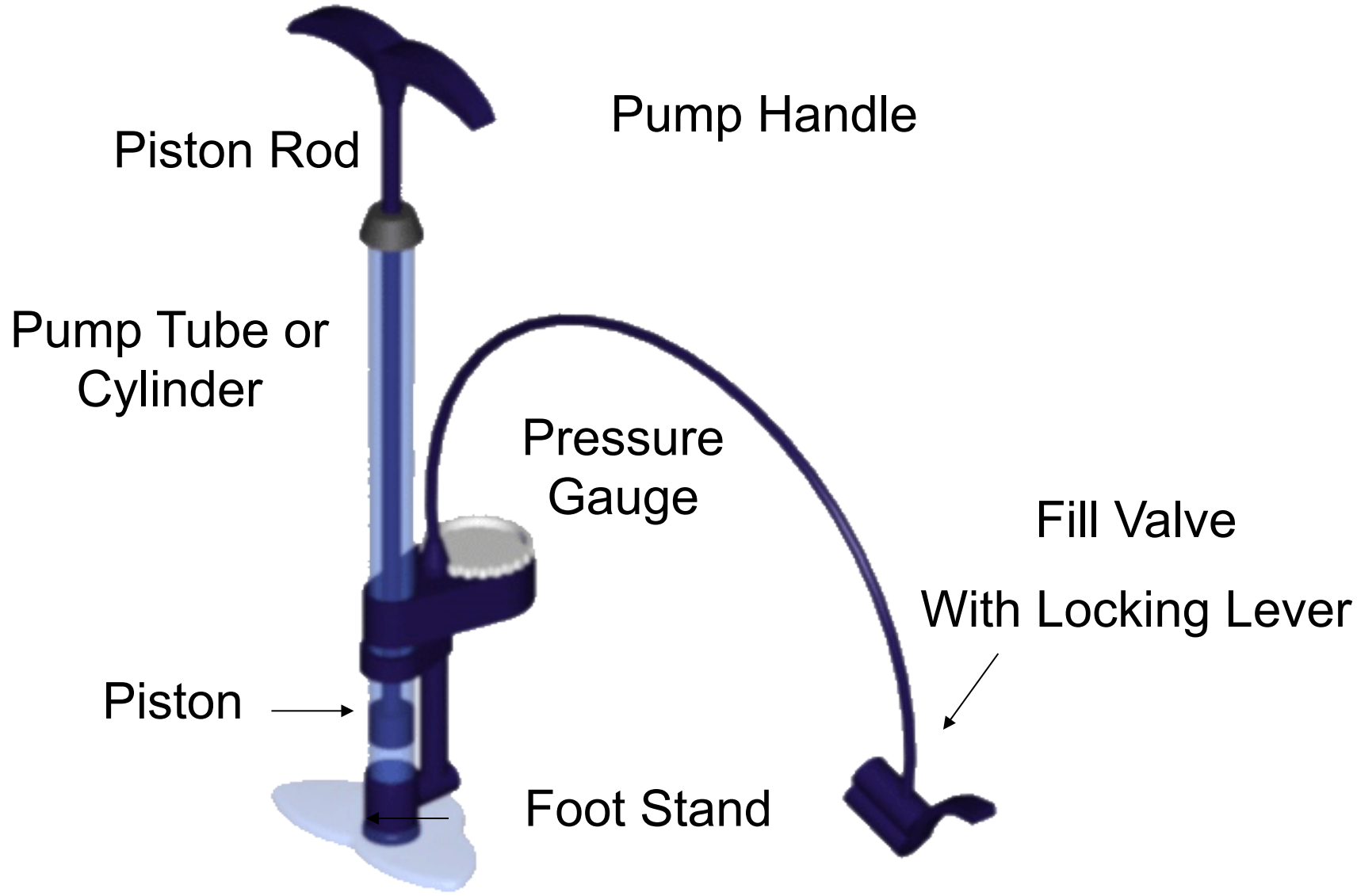
Disadvantages

- Difficult to achieve position control (compressible air)
- Noisy
- A significant cost investment is needed for the first pneumatic device
- Cylinders can be subject to damage
- Repair impossible
- Only well suited to binary actuation

Example mobile pneumatic system



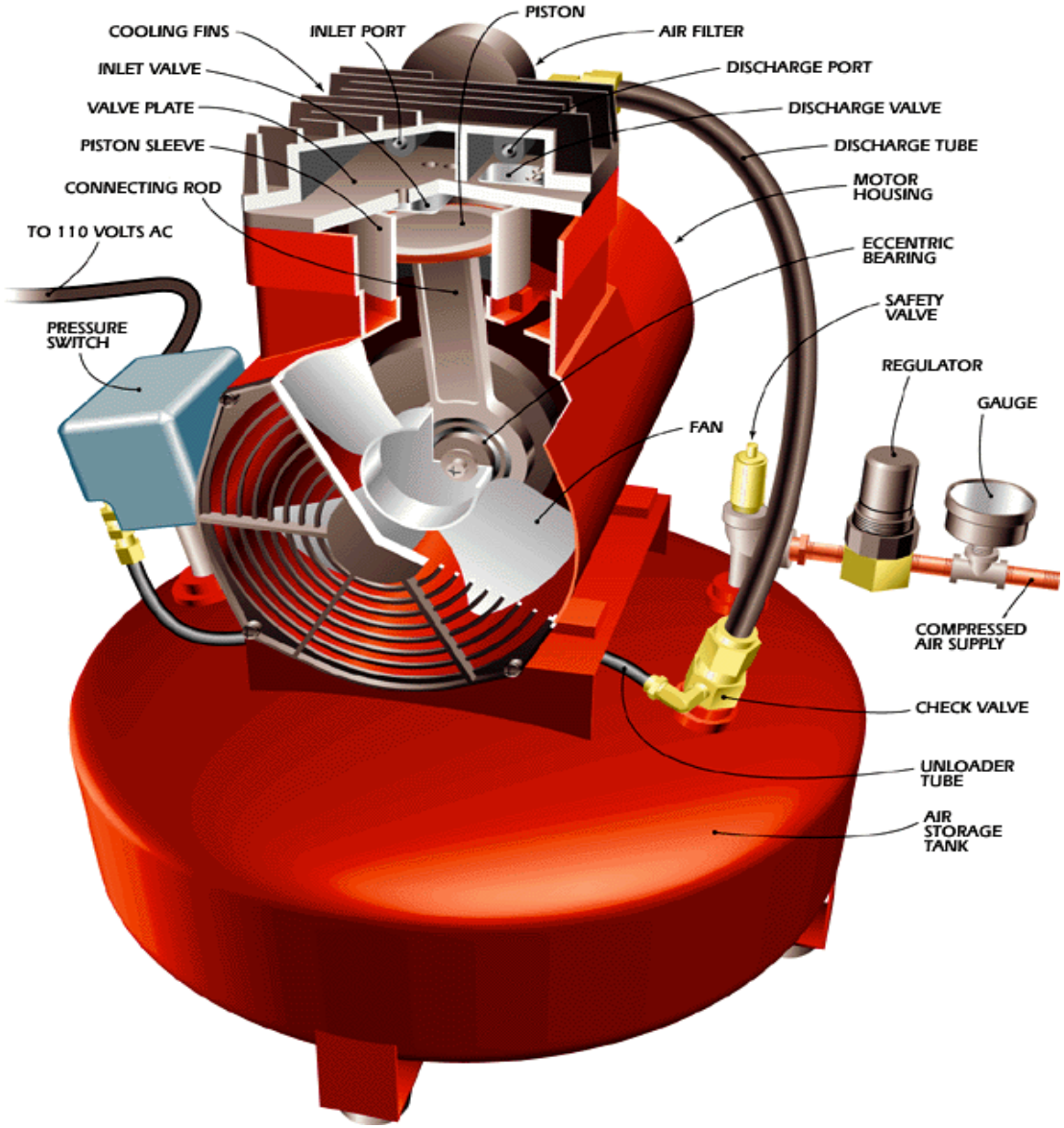
Bicycle Pump



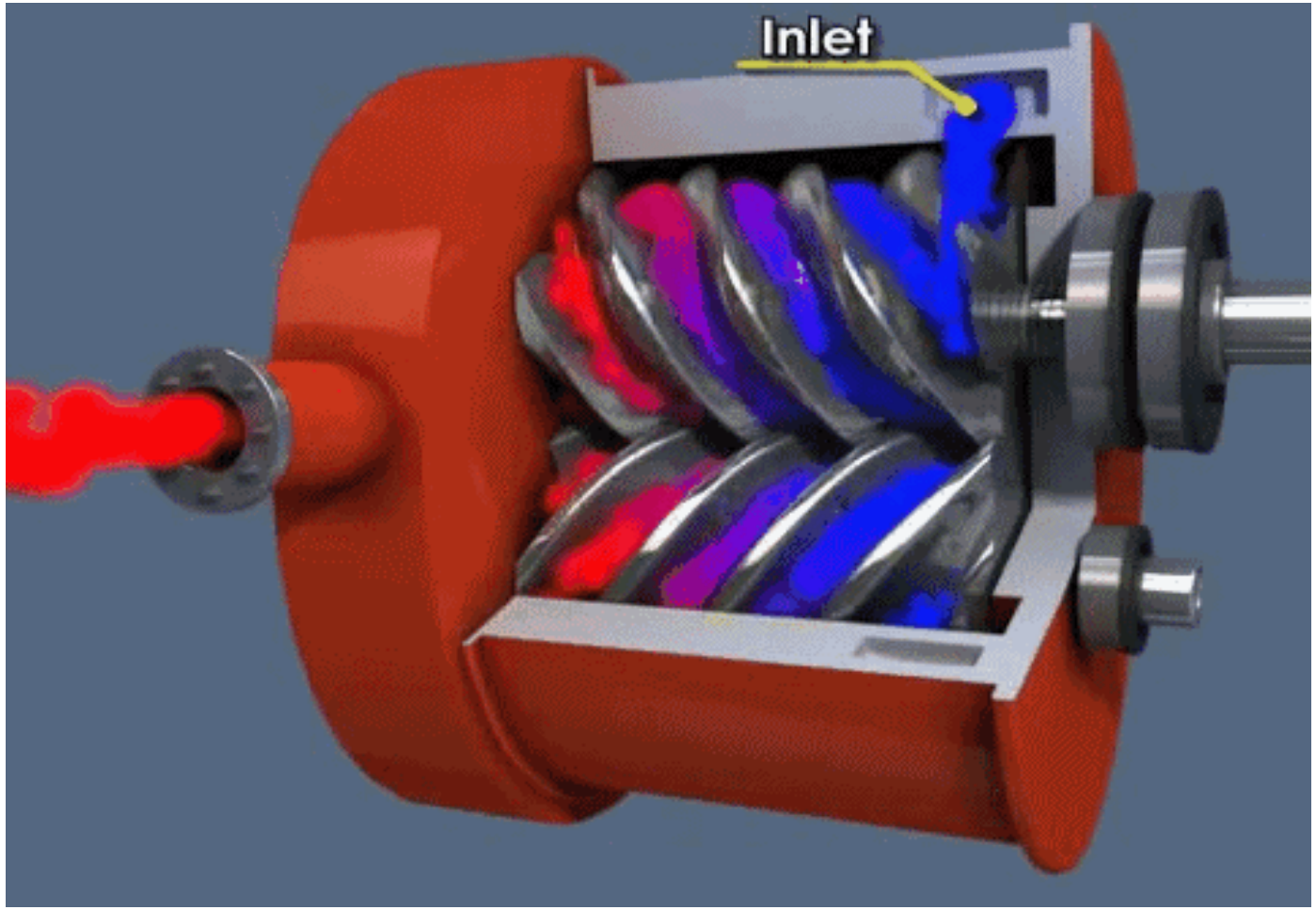
Compressors

- Wide range of compressors available
- Large reciprocating pump types widespread
- Smaller membrane types are quieter

Compressor parts



Compressor screw



Pneumatic Reservoir

Energy Stored as Compressed Air

One Touch Quick Connect Fitting
Connects to 3 Way Valve

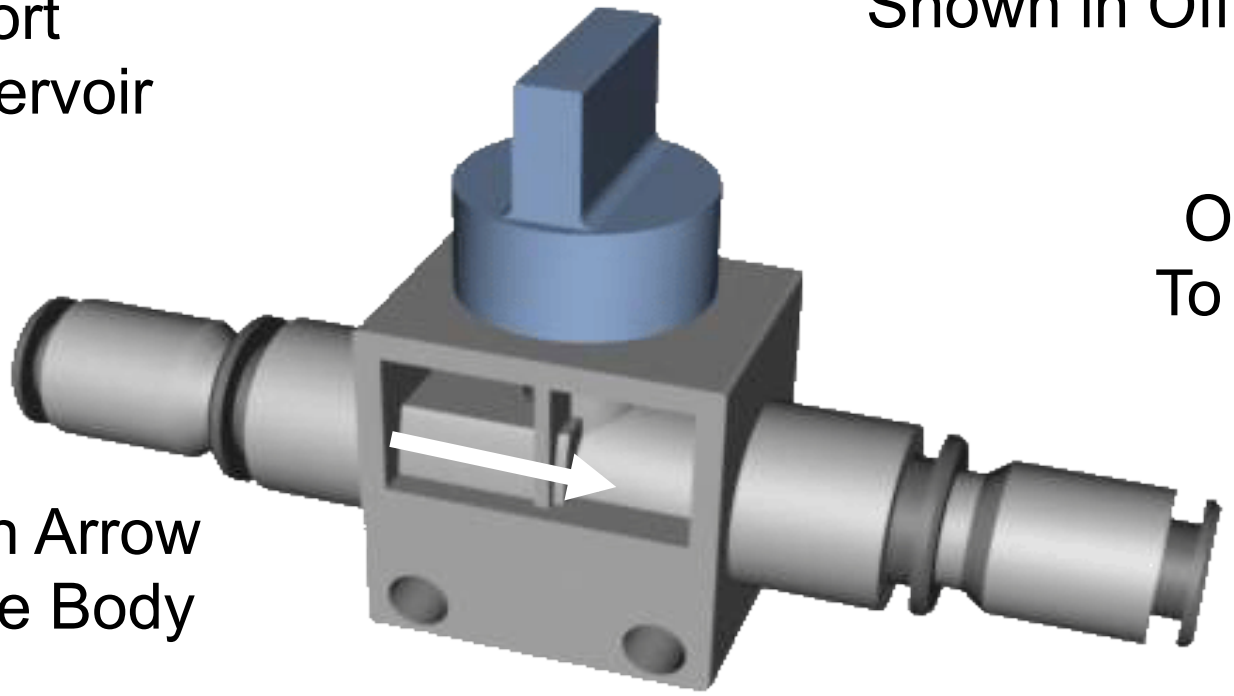
Schrader Valve
Connects to Pump

Air Storage
Capacity is a Function of
Pressure x Volume = Capacity

3 way valve

Finger Knob
Shown in Off Position

Inlet Port
From Reservoir



Outlet Port
To Regulator

Direction Arrow
On Valve Body

Three Operational States or Modes
OFF – Vent – On

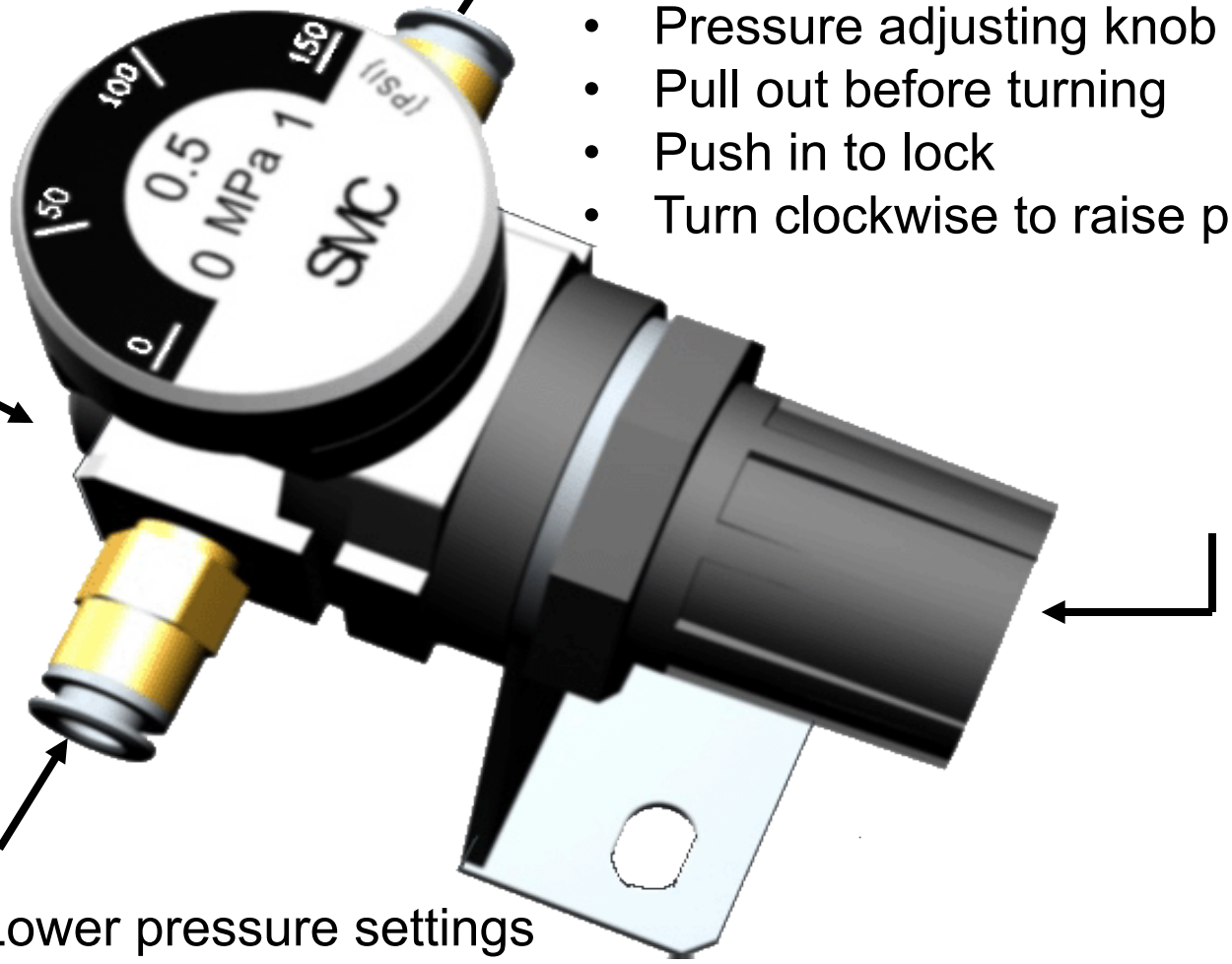
The regulator

Pressure Gauge
0-150 psi
0-1 MPa

Controlled pressure side

- Pressure adjusting knob
- Pull out before turning
- Push in to lock
- Turn clockwise to raise pressure

Air Flow
Directional Arrow

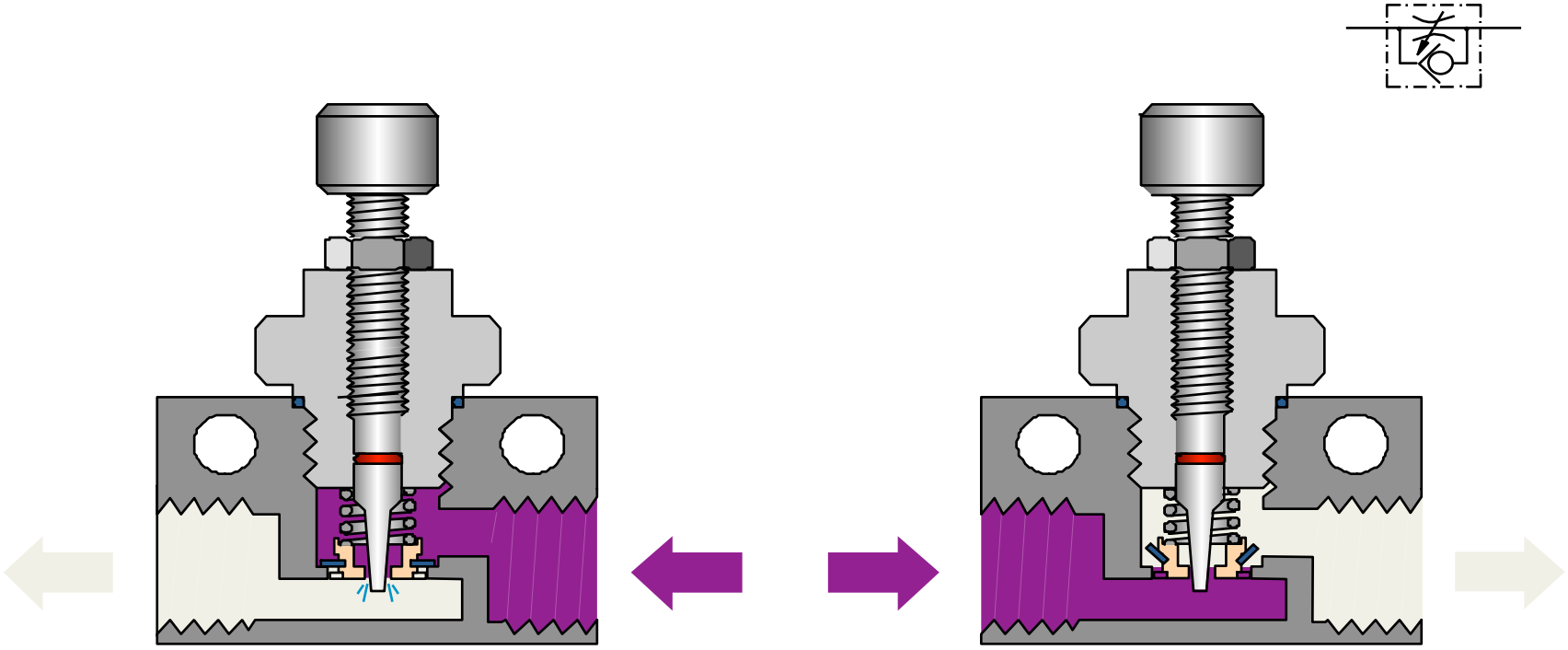


High Pressure
Inlet

Lower pressure settings
means less air consumption

Flow regulator

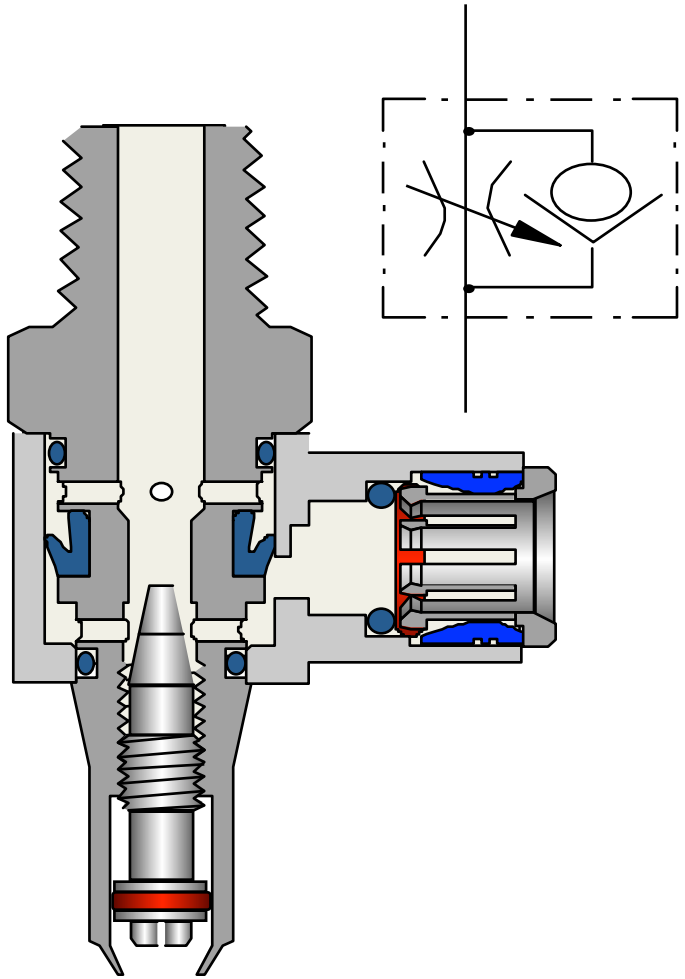
- Uni-directional, line mounted adjustable flow regulator
- Free flow in one direction
- Adjustable restricted flow in the other direction



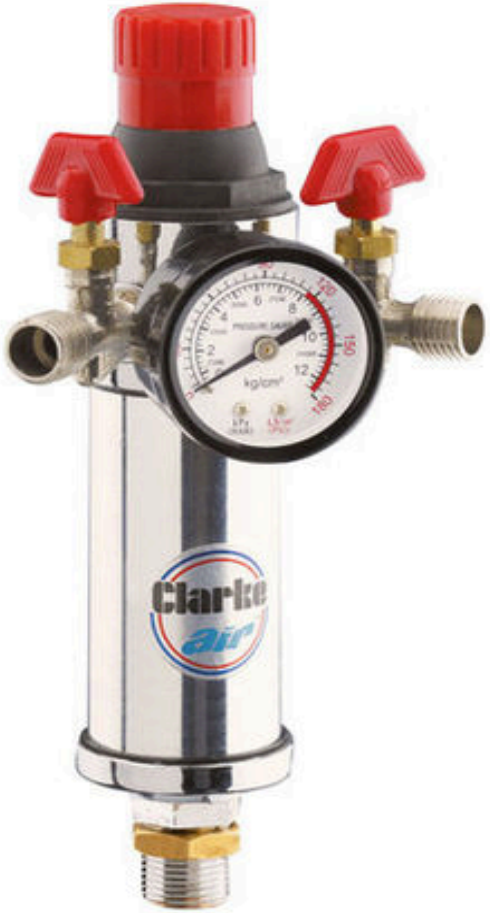
Banjo flow regulator

- Designed to fit directly in to the cylinder port, so placing adjustment at the appropriate cylinder end

- Select the type to give conventional flow restriction out of the cylinder and free flow in



Lots of regulator options



Filter Regulator

Regulator & Lubricator

Quick fit air connectors

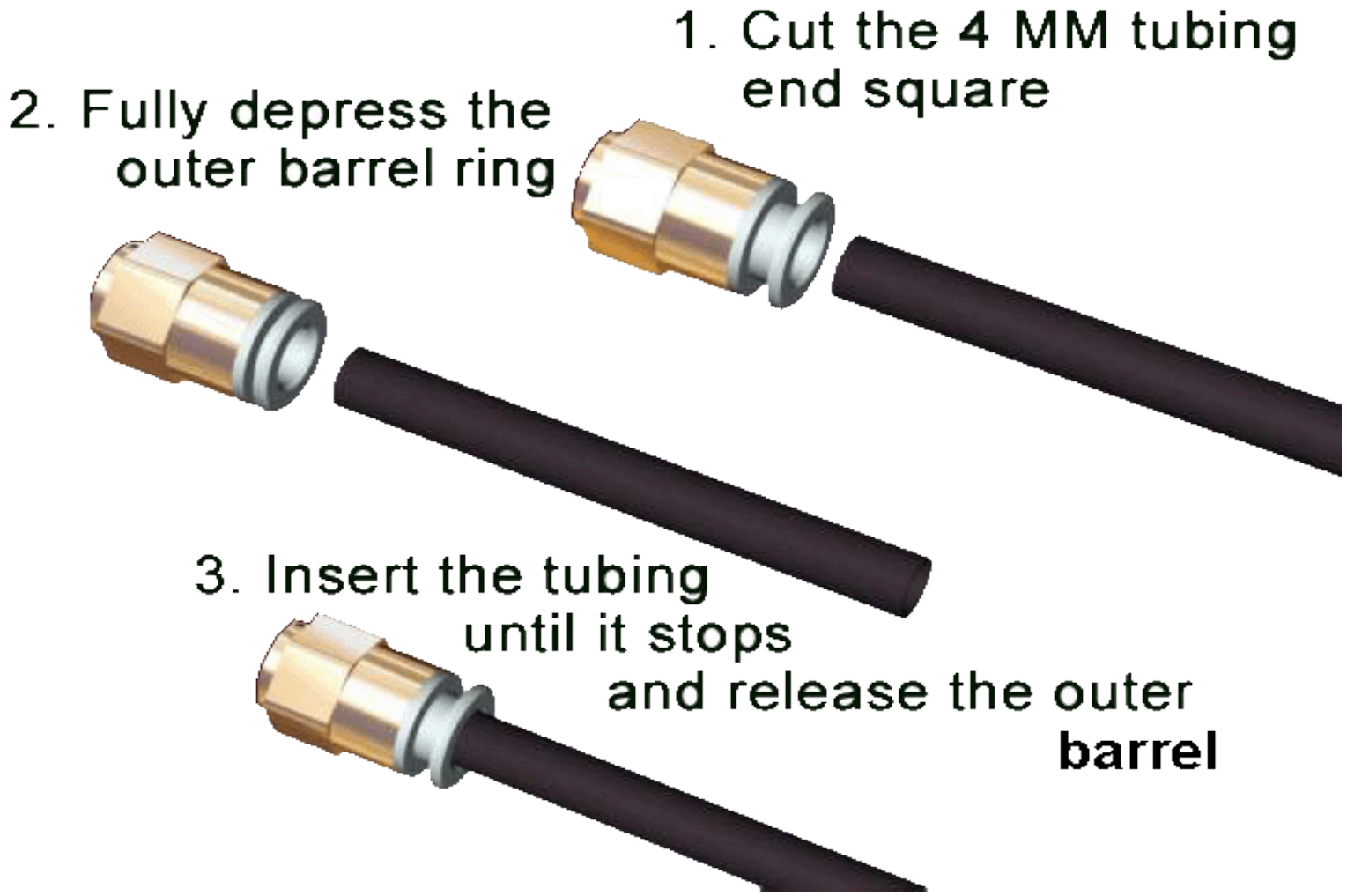
PTFE Tape

Various connectors

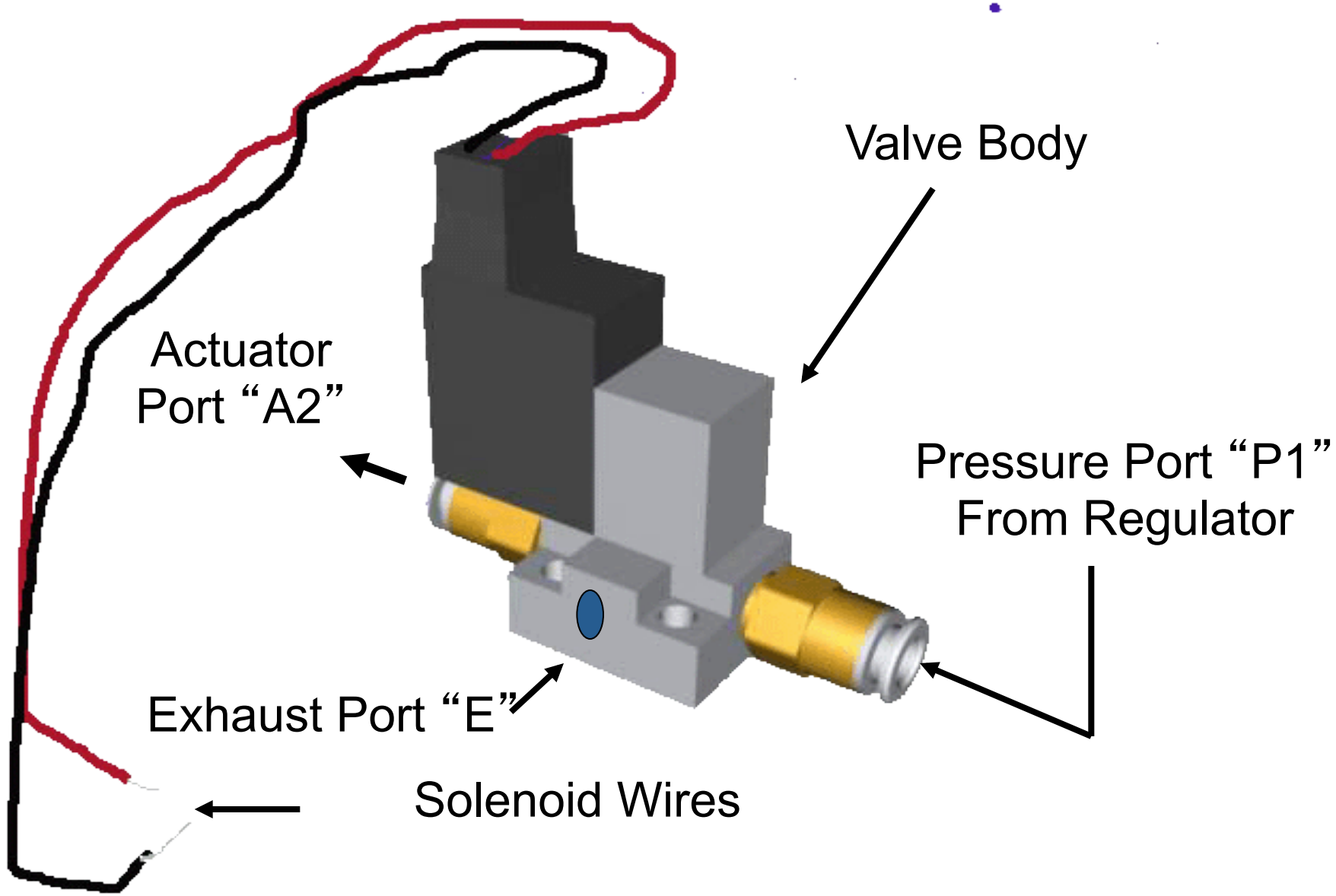
Air hose

Push fit air connectors

One Touch Quick Connectors

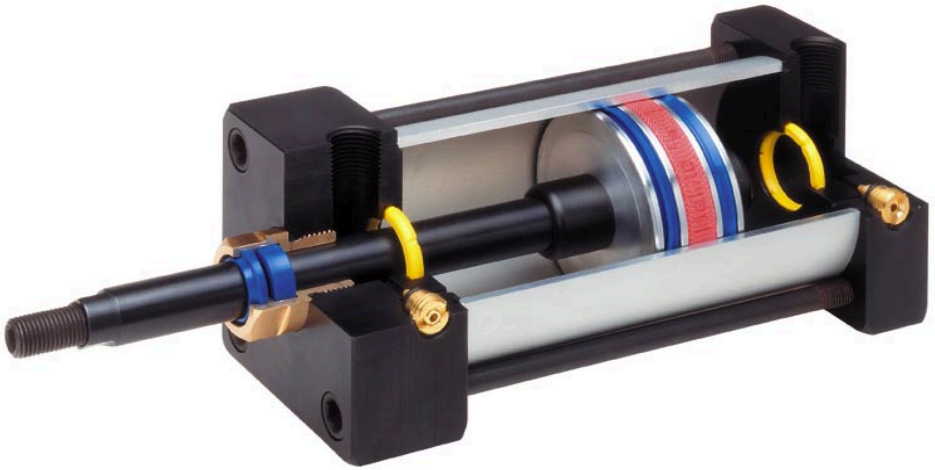


3/2 Solenoid Valve

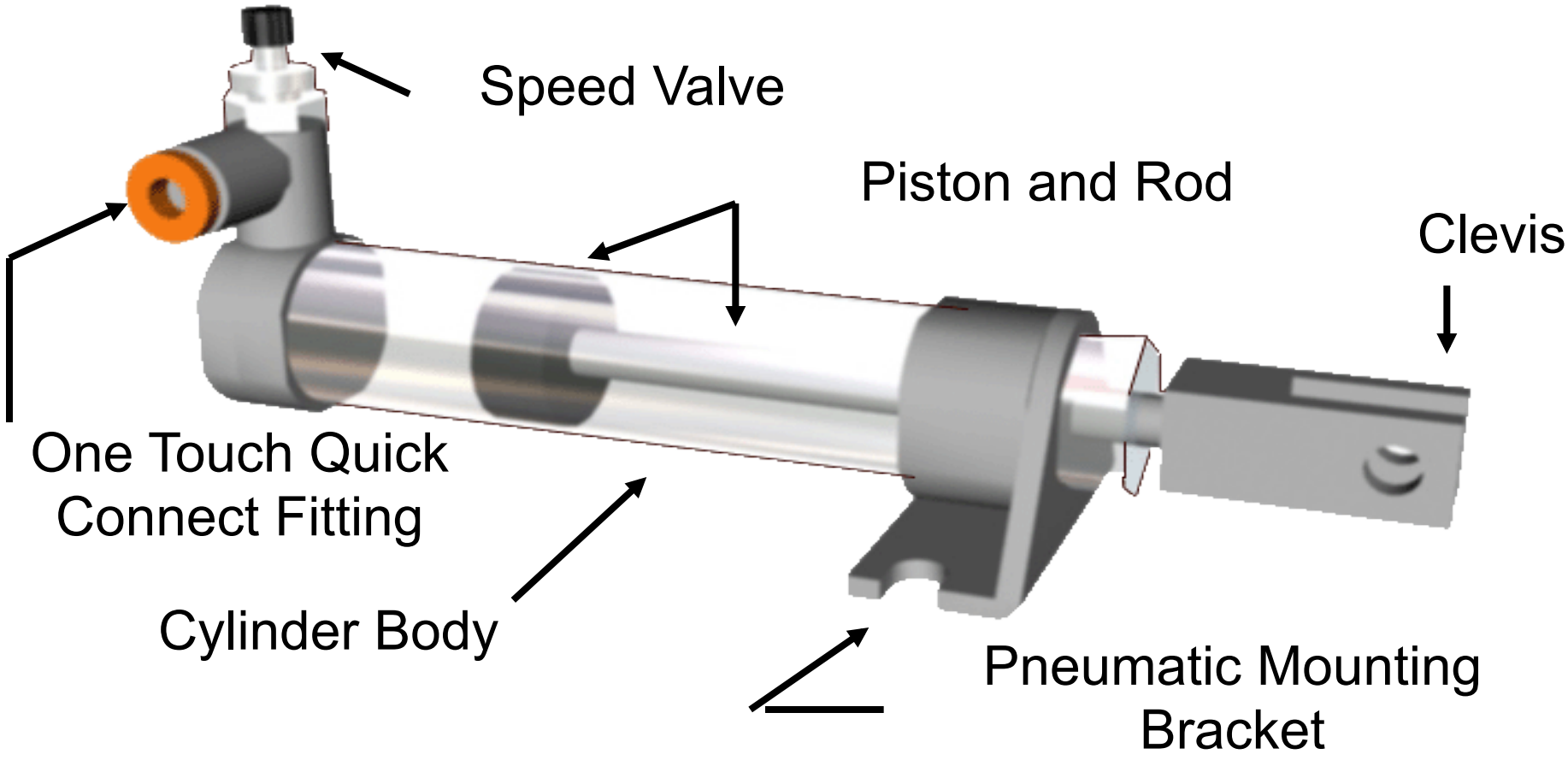


Pneumatic actuators

- Adverse conditions can be easily tolerated such as high humidity, dry and dusty environments and cleaning down with a hose
- The bore of a cylinder determines the maximum force that it can exert
- The stroke of a cylinder determines the maximum linear movement that it can produce
- The maximum working pressure depends on the cylinder design. School cylinders work up to 9 bar
- Thrust is controllable through a pressure regulator



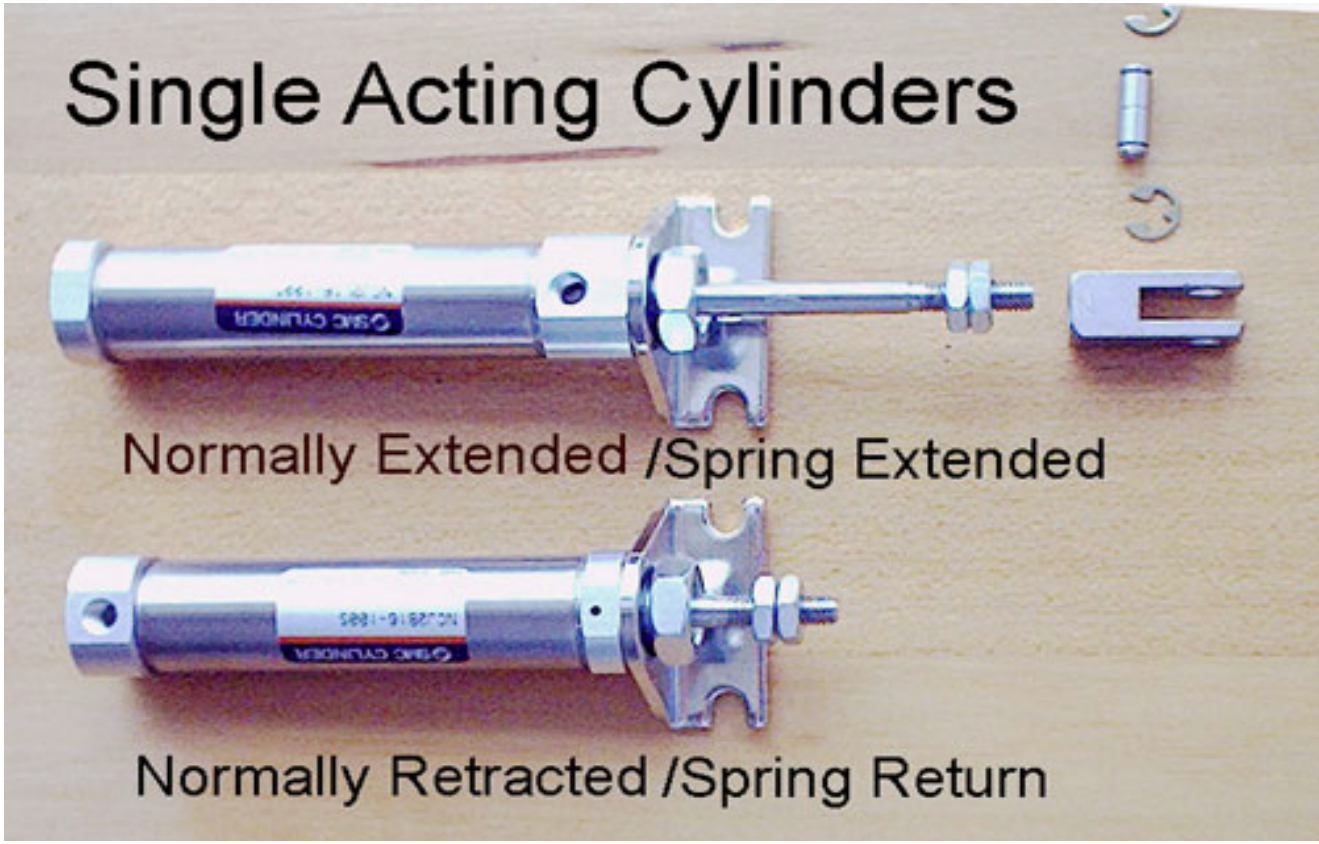
The pneumatic cylinder

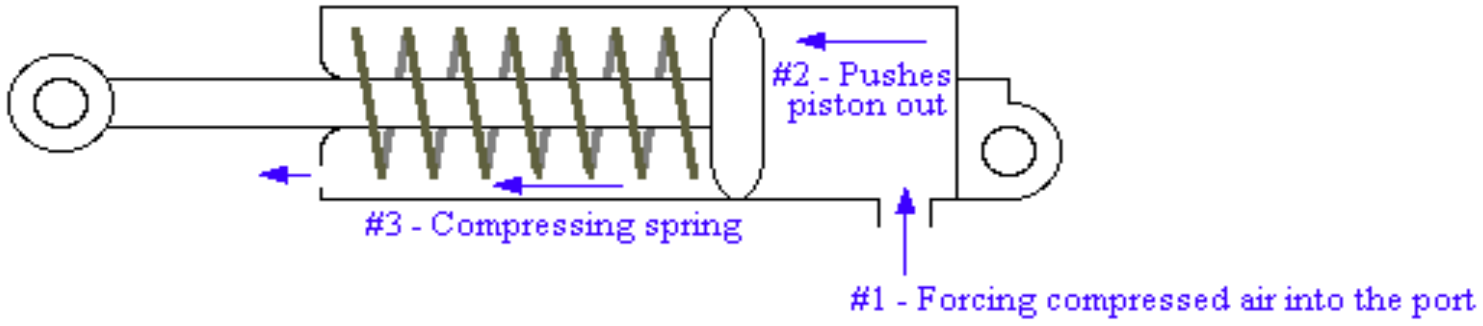


Cylinder Force = Pressure x Piston Area

Single acting spring return

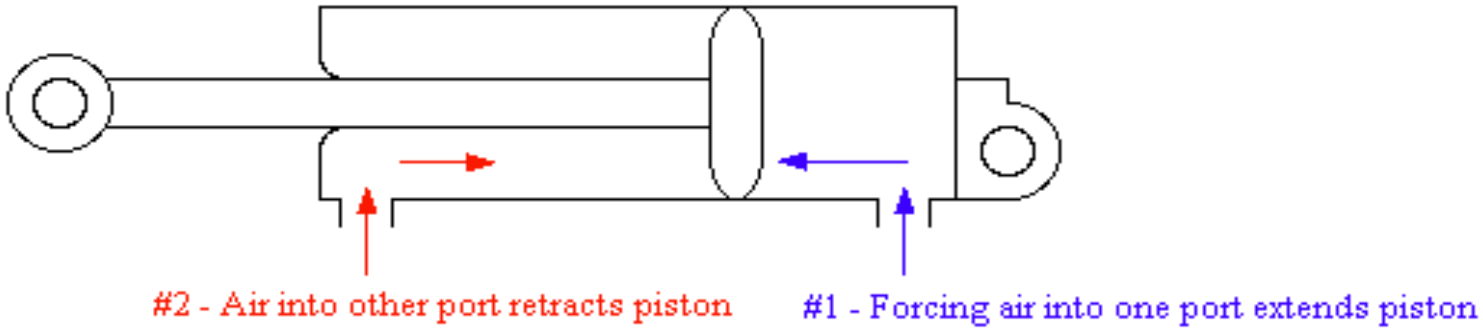
Single acting cylinders have a power stroke in one direction only





Double acting non-cushioned

- Non cushioned cylinders are suitable for full stroke working at slow speed.
- Higher speeds with external cushions



Key air cylinders parameters

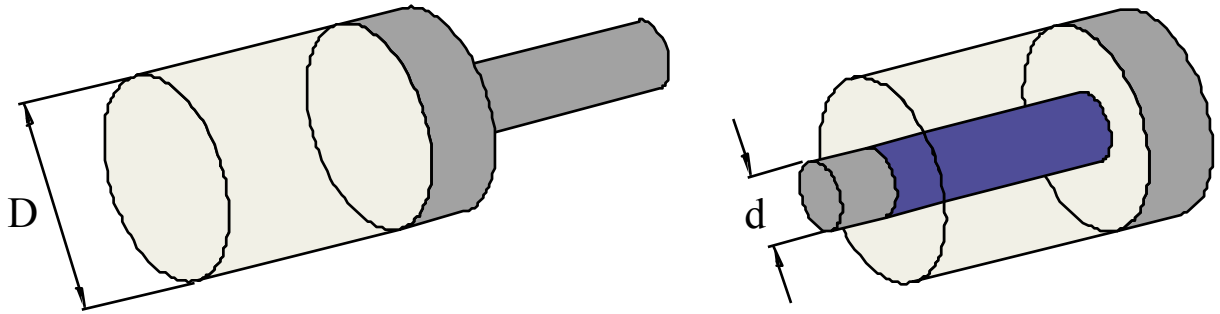
- Stroke length
- Bore size
- Pressure rating

} Force

- Mounting style
- Return type (SAC vs. DAC)
  - Spring force in SAC
- Loads
- Temperature range
- Lubrication
- Material Compatibility

Cylinder sizing for thrust

- The theoretical thrust (outstroke) or pull (in stroke) of a cylinder is calculated by multiplying the effective area of the piston by the working pressure.
- The effective area for thrust is the full area of the cylinder bore “D”.
- The effective area for pull is reduced by the cross section area of the piston rod diameter “d”.



Cylinder sizing for push

- In the formula, P is divided by 10 to convert bar to Newtons per square millimetre (1 bar = 0.1 N/mm^2)

$$push \qquad F = \frac{\pi D^2}{4} \frac{P}{10} \qquad Newtons$$

Where

D = Cylinder bore in millimetres

P = Pressure in bar

F = Thrust or Pull in Newtons

Cylinder sizing for pull

- Pulling force F will be less than the thrust due to the area lost to the piston rod

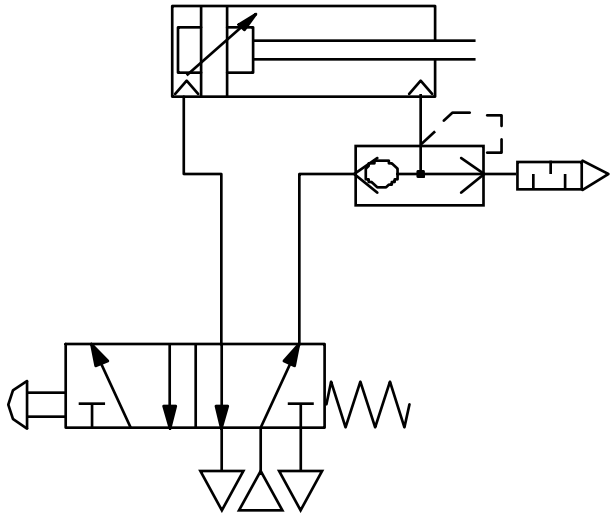
$$Pull \quad F = \frac{\pi (D^2 - d^2) P}{40} \quad Newtons$$

Where

D = Cylinder bore in millimetres
d = Piston rod diameter in millimetres
P = Pressure in bar
F = Thrust or Pull in Newtons

Increasing speed

- In some applications cylinder speed can be increased by 50% when using a quick exhaust valve
- When operated, air from the front of the cylinder exhausts directly through the quick exhaust valve
- Built in cushioning will be less effective

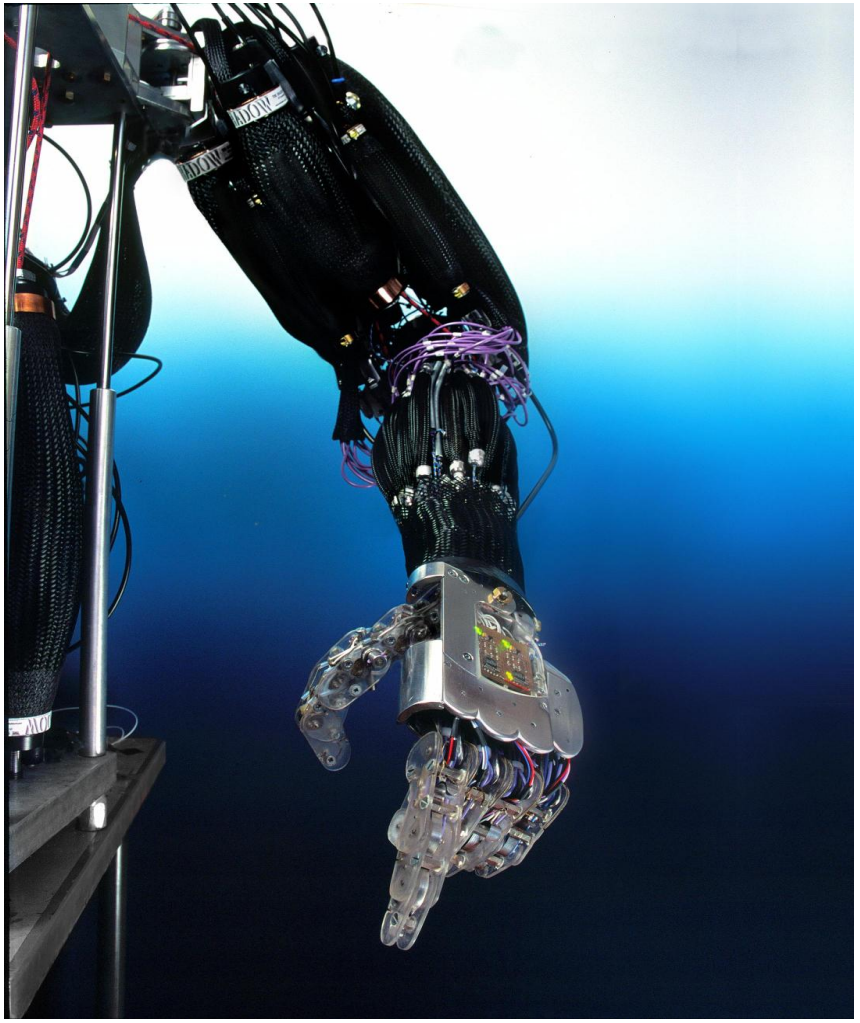


Pneumatic motor

- Pneumatic motors generate lower torque than hydraulic motors but are cleaner

McKibben air muscles

- The McKibben muscle earliest attempt at constructing an artificial muscle
- Consisted of a rubber bladder surrounded by a sleeve made of nylon fibers in a helical weave
- When activated by pressurized air, the sleeve prevented it from expanding lengthwise, and thus the device shortened like living muscles
- Stroke about 40% of free length
- 0-60 psi
- power-to-weight up to 100:1
- Back drivable
- Relatively slow
- Bilateral motion requires pairs of muscles attached on opposite sides of a joint are required to produce



Air muscles construction

The Core of an Air Muscle is a rubber tube....

....wrapped in a tough plastic weave....

....which shortens in a scissor action when pulled out, just like a Chinese finger puzzle. As the rubber tube fills with air it is forced to expand.

McKibben air muscles

- **Lightweight** - Air Muscles weigh as little as 10 grammes - particularly useful for weight-critical applications
- **Lower Cost** - Air Muscles are cheaper to buy and install than other actuators and pneumatic cylinders
- **Smooth -** Air Muscles have no 'stiction' and have an immediate response. This results in smooth and natural movement
- **Flexible** - Air Muscles can be operated when twisted axially, bent round a corner, and need no precise aligning
- **Powerful** - Air Muscles produce an incredible force especially when fully stretched
- **Damped** - Air Muscles are self-dampening when contracting (speed of motion tends to zero), and their flexible material makes them inherently cushioned when extending
- **Compliant** - Being a soft actuator, Air Muscles systems are inherently compliant

Range of air muscles available

Thumbnails	Diameter	Length (Fully Stretched)	Weight (approx.)	Pull (3.5 bar)	Maximum Pull
	6 mm	150 mm (Stretched)	10 g	3 Kg	7 Kg
	20 mm	210 mm (Stretched)	40 g	12 Kg	20 Kg
	30 mm	290 mm (Stretched)	80 g	35 Kg	70 kg

Pneumatic applications

- For operating pneumatic tools such as drills, screw drivers, hammers, chisels
- For pneumatic cranes
- Pneumatic grabbers on robots
- Pneumatic brakes of automobiles, railways and presses
- Agricultural accessories
- Dusters and sprayers

Pneumatic precautions