Generating Motion

- Moving a part adds no value (except in packaging)
- Moving a tool adds no value unless work is done on part.
- So, we want to avoid moving parts or tools any more than necessary
  - One metal machining batch factor: 95% of a parts time is spent moving or waiting, 5% of time is on tool, of which only 30% is spent cutting.

Linear Motion

- Linear translation is most common motion
- Linear movement can be caused by:
  - Pneumatic or hydraulic cylinders
  - Rotary motion converted to linear
  - Vibratory systems
  - Electric solenoids
  - Linear electric motors
  - Piezoelectric actuators

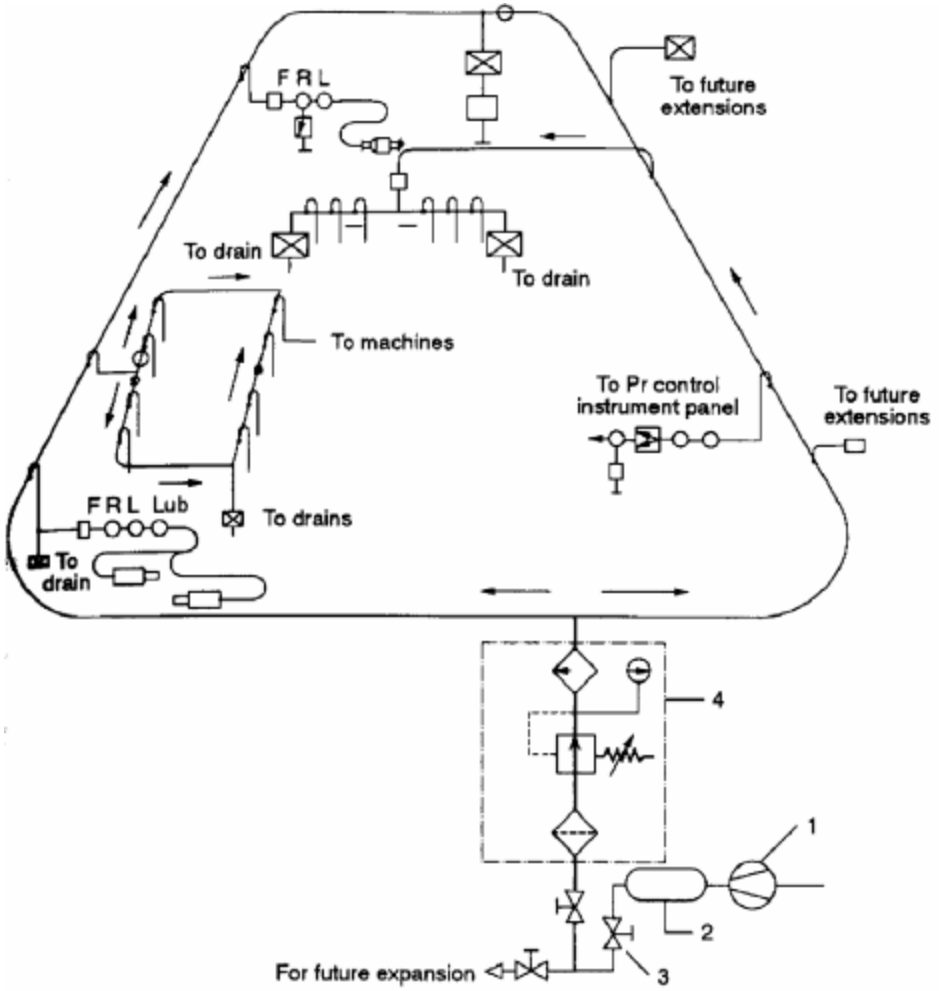
Pneumatic Systems

- Pneumatic power very popular in industry
  - High force, economical linear motion
  - Non-flammable, compressible, storable medium
  - Compact, low heat production actuators
- Pneumatics best suited to discrete motion (not proportional)

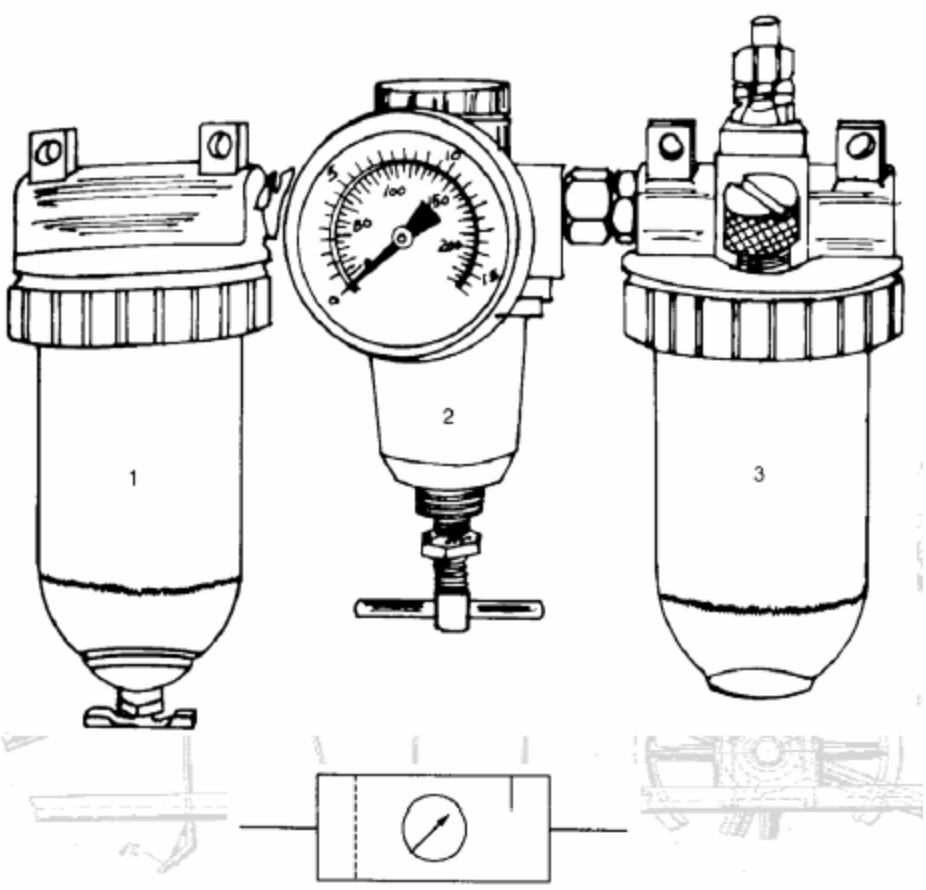
Pneumatic Systems

- Ideal Gas Law: $PV=mRT$
- Boyle's Law: $P_1V_1 = P_2V_2$

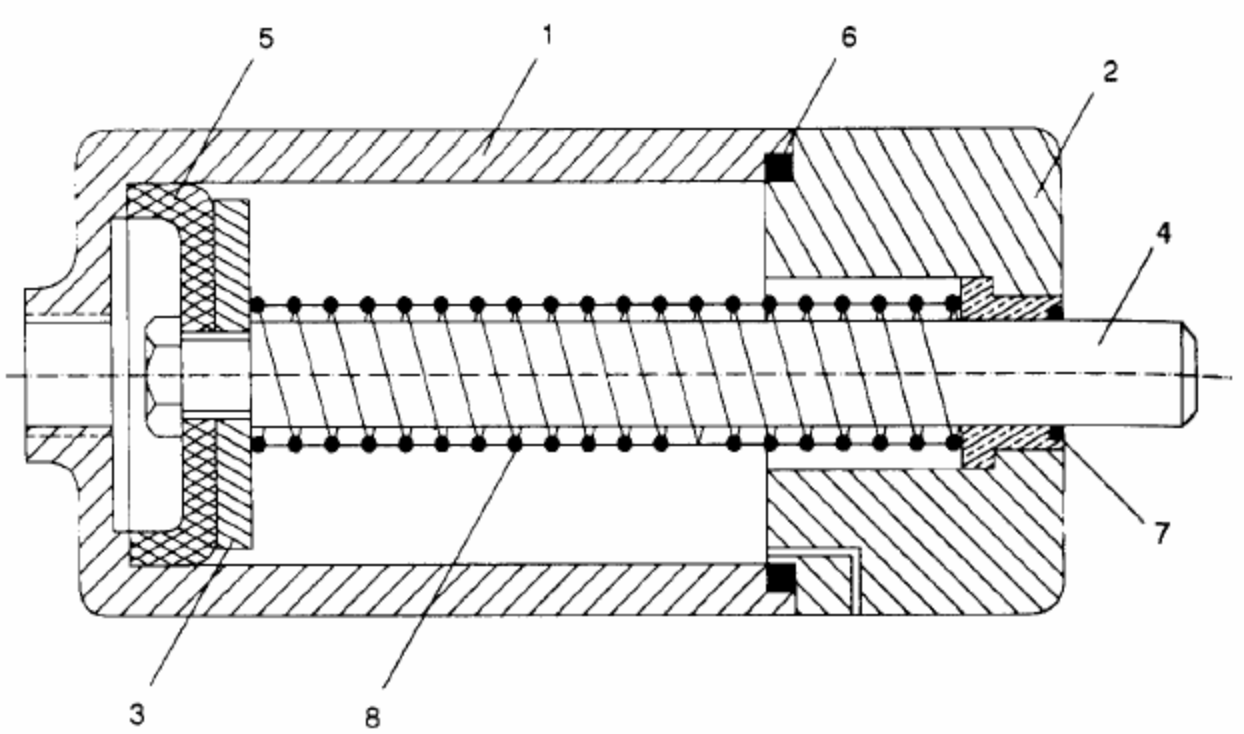
Pneumatic System Layout



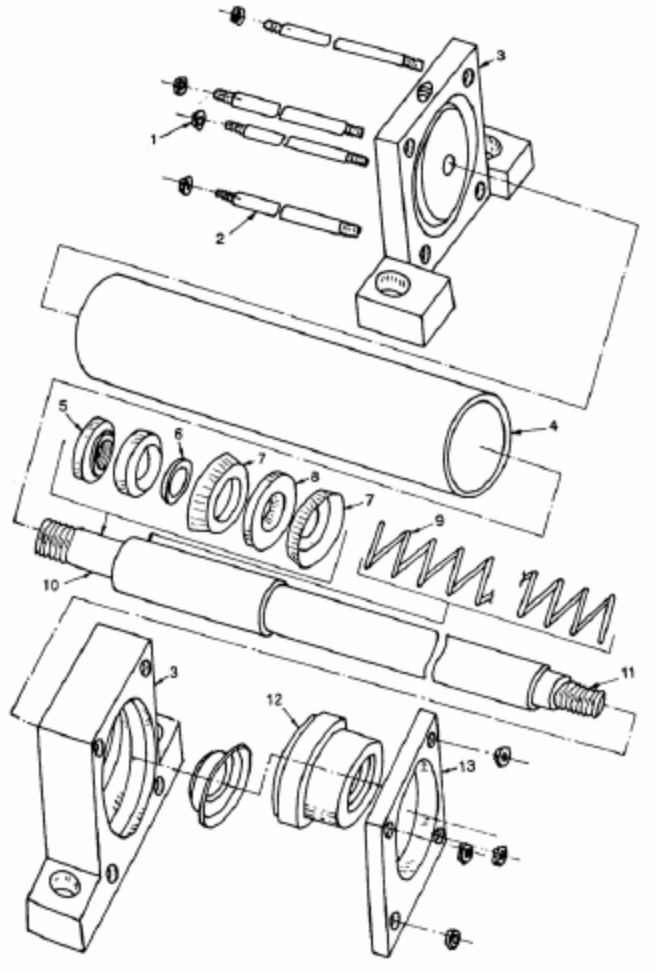
Air Preparation



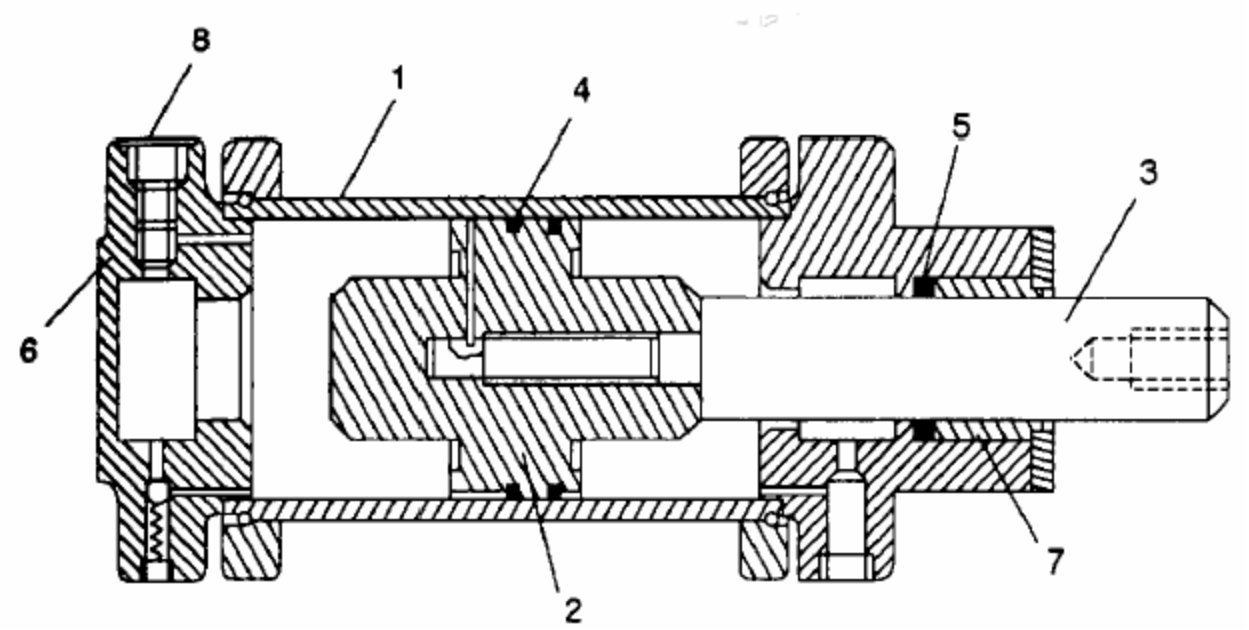
Single-Acting Cylinder



Single-Acting Cylinder



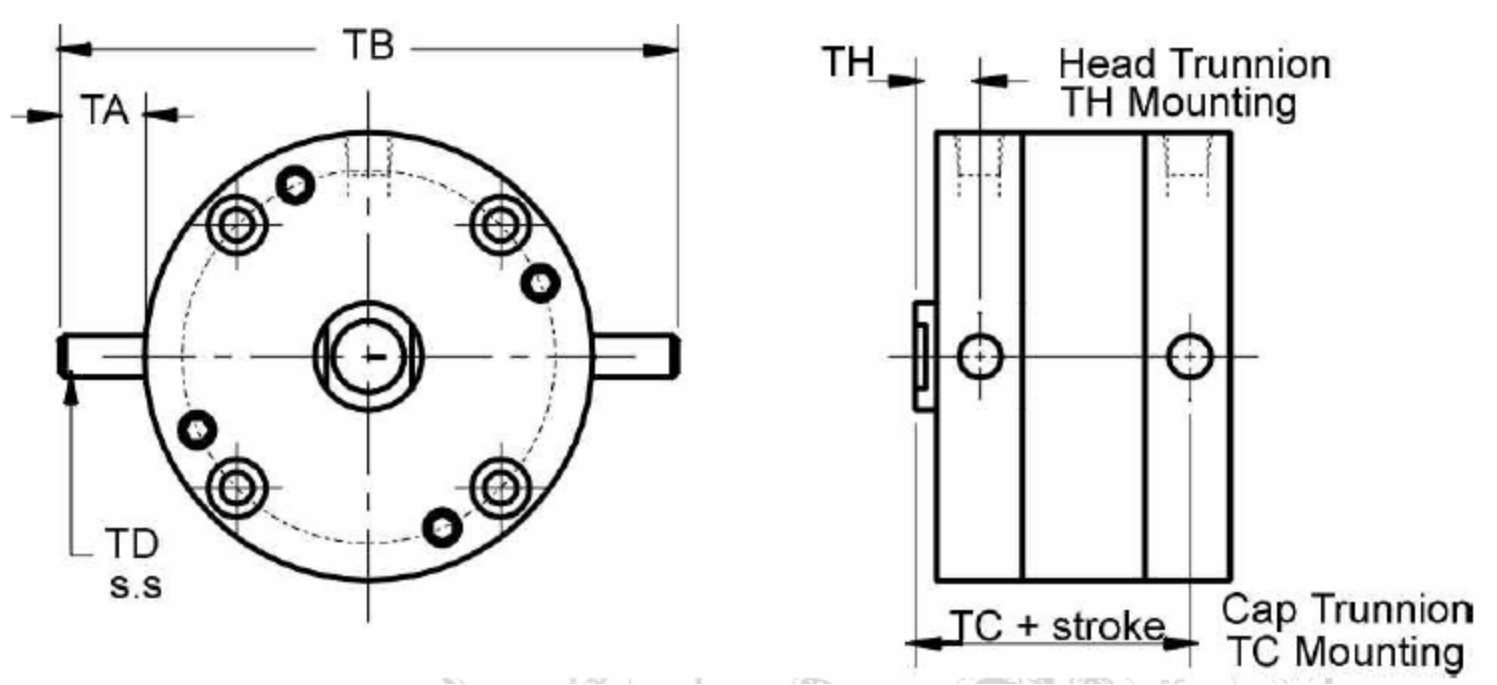
Double-Acting Cylinder



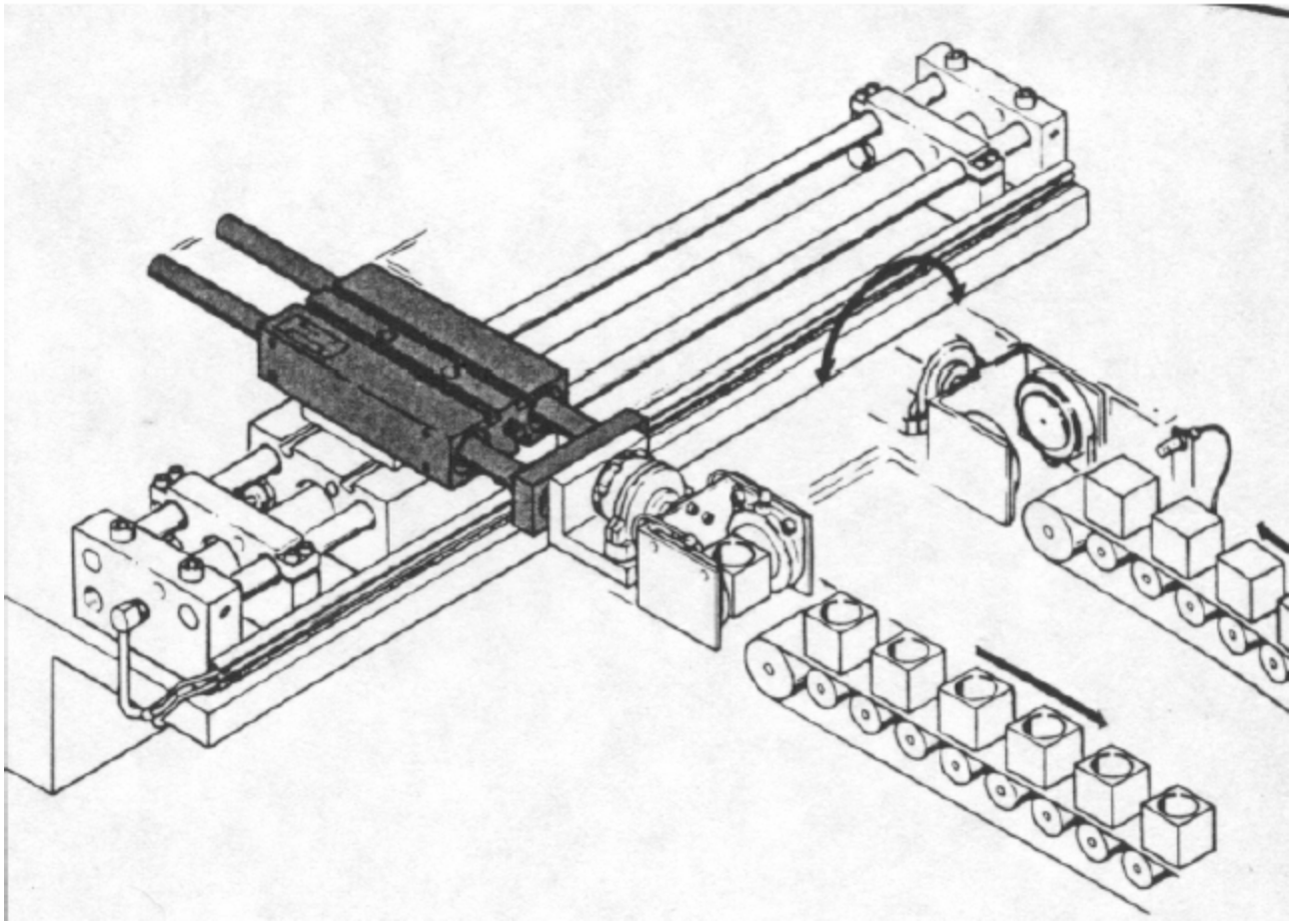
Pneumatic Cylinder Mounting

- Off-axis loading must be prevented!
- Pivoting mounts can eliminate axial loading:
  - Clevis mount
  - Trunnion mount
  - Universal joints
- Shaft may rotate unless antirotation model is used

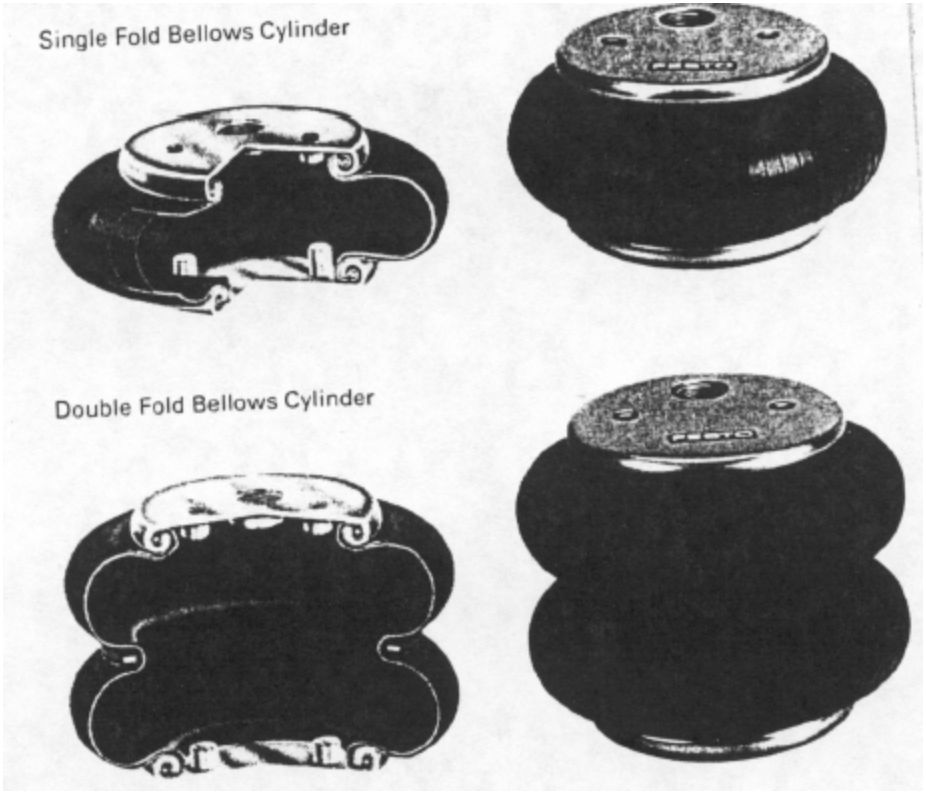
Trunnion Mount

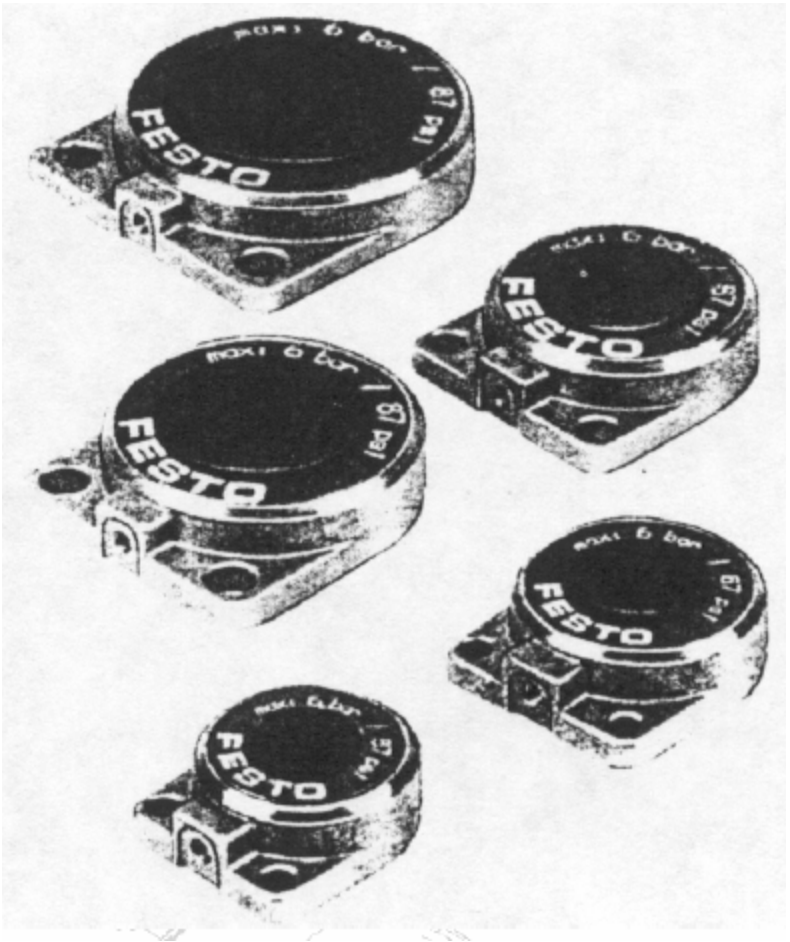


Pneumatic Twin Cylinder

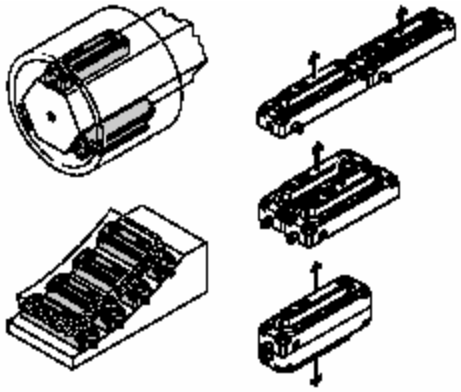


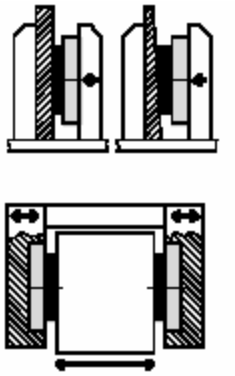
Pneumatic Bellows



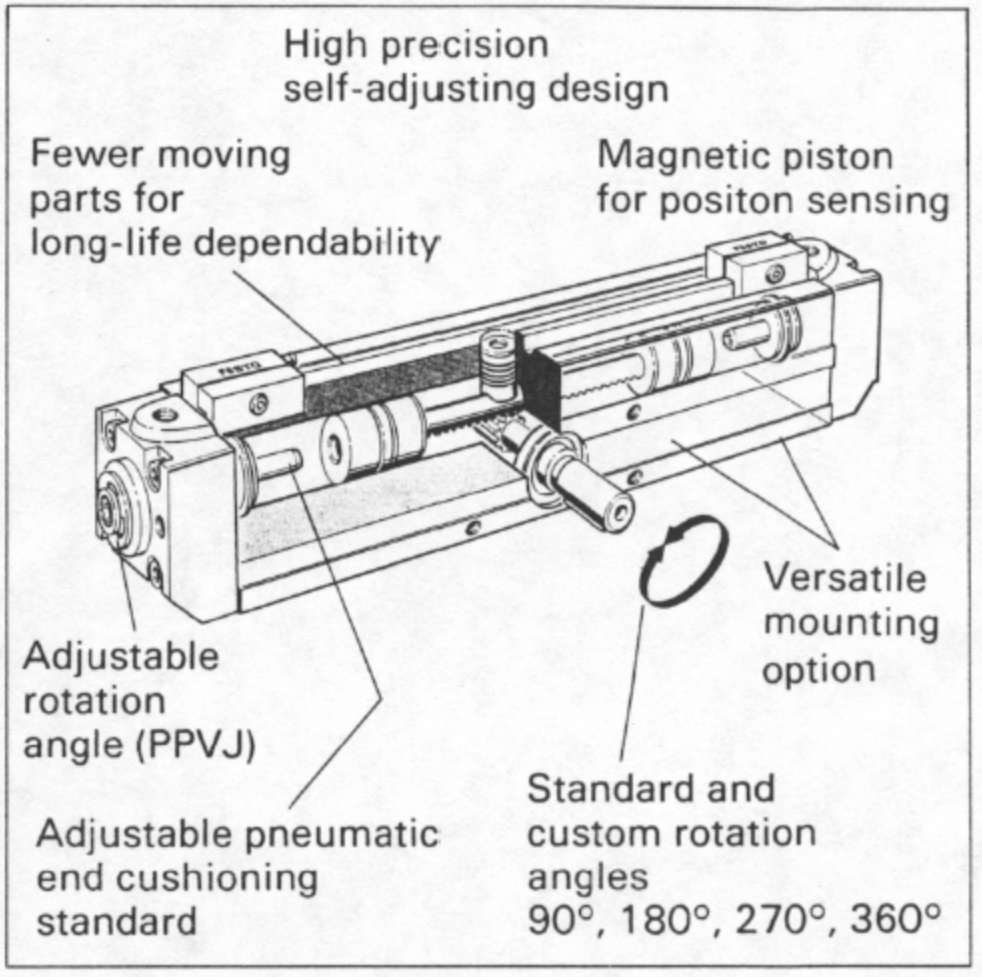


Pneumatic Bellows

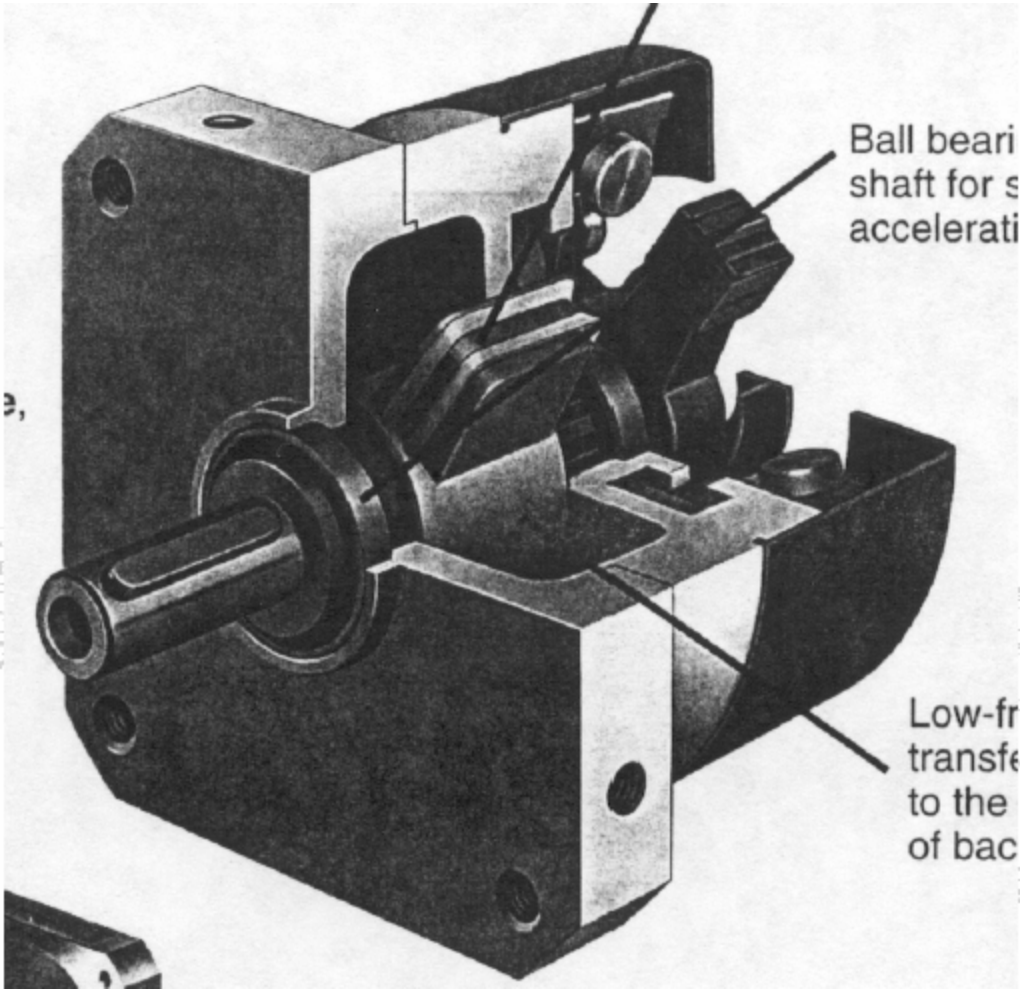




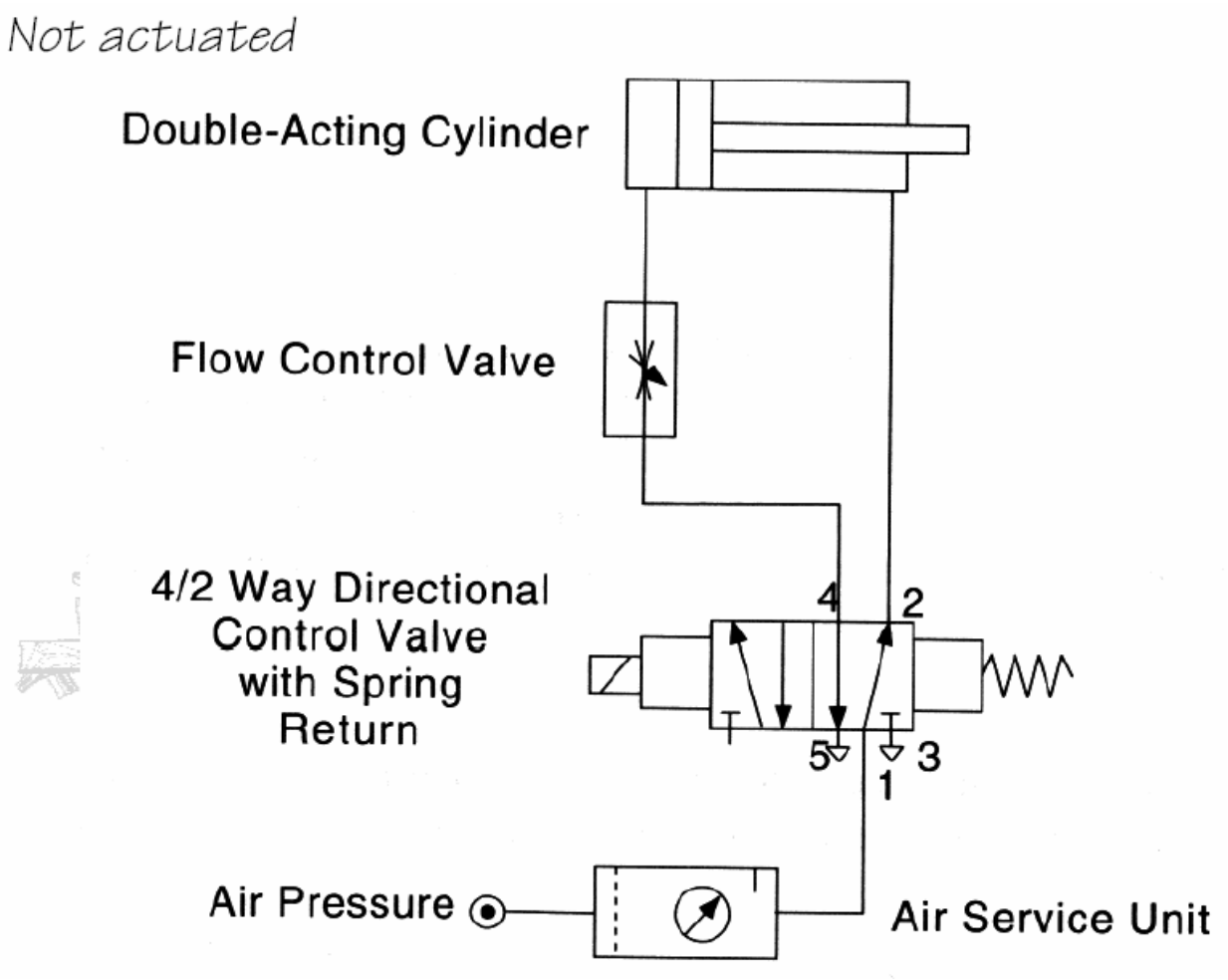
Pneumatic Rotary Actuators



Pneumatic Rotary Actuators

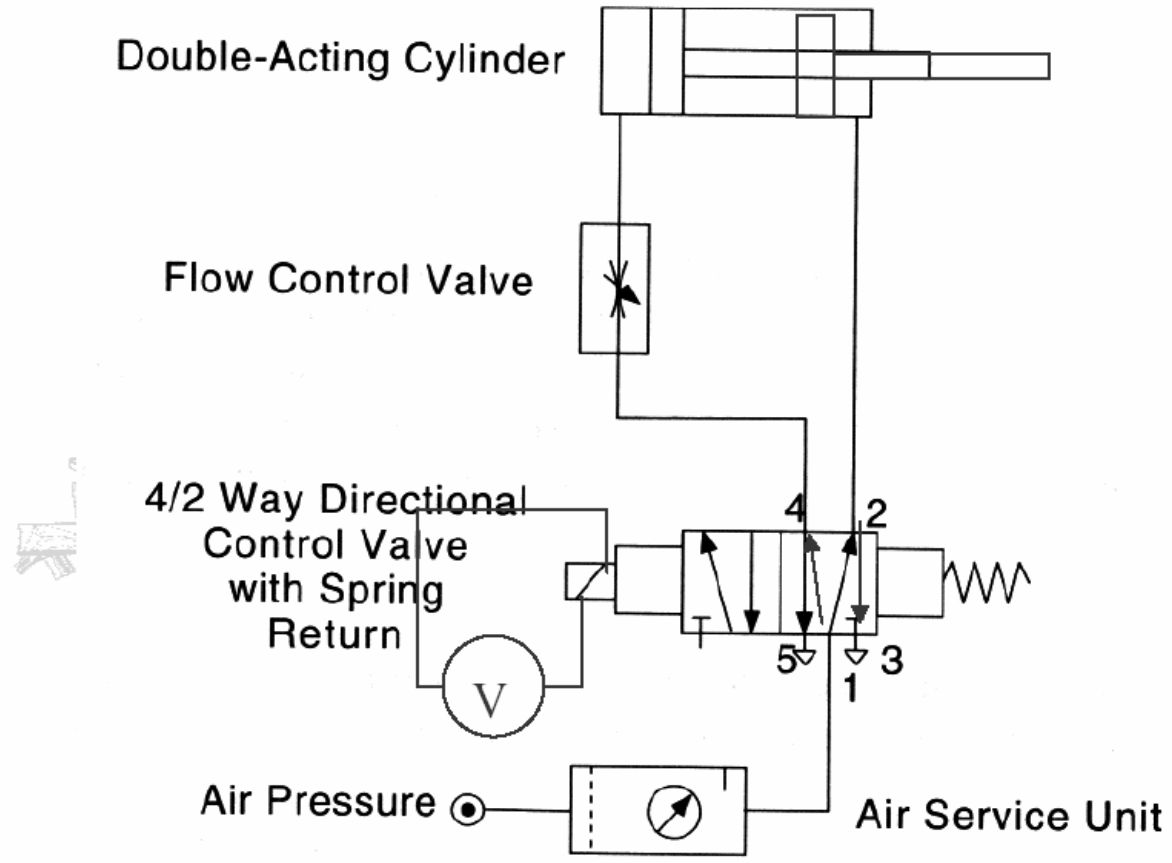


Pneumatic Schematics

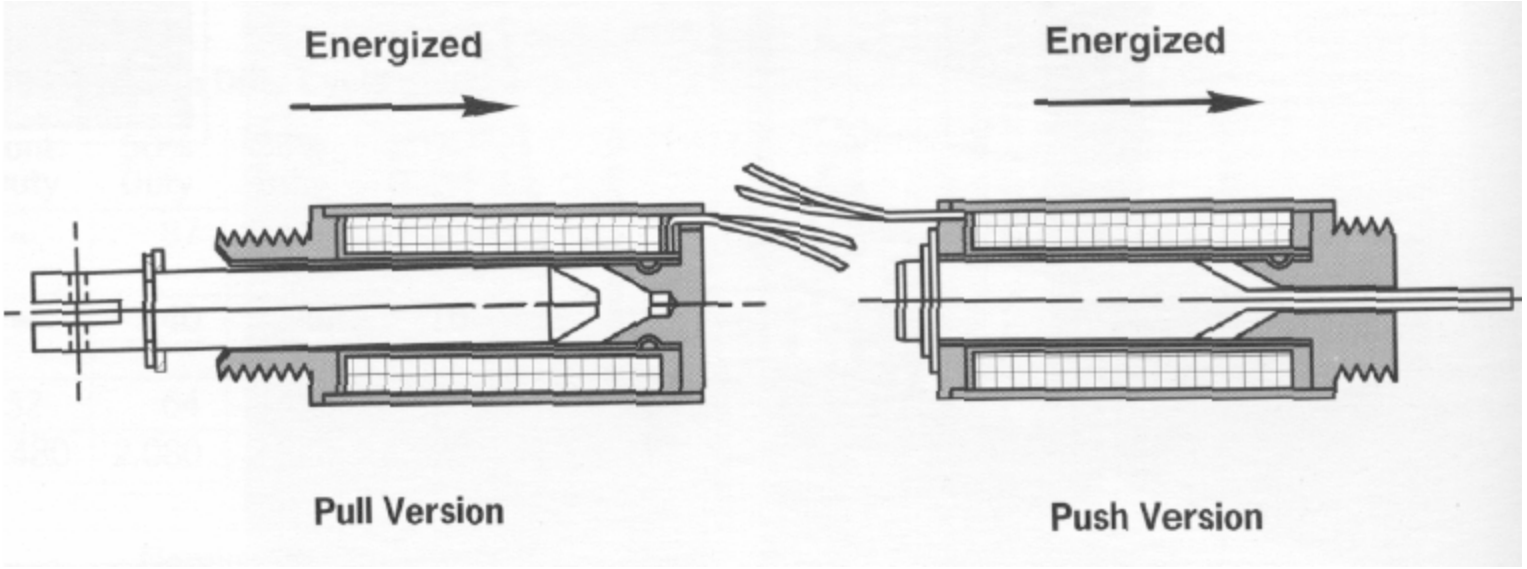


Pneumatic Schematics

Actuated

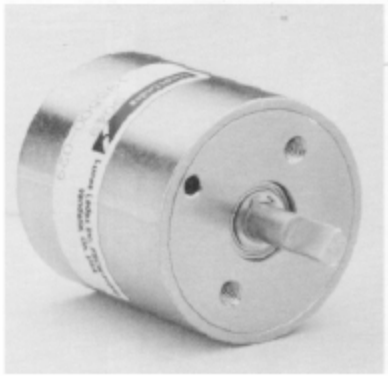


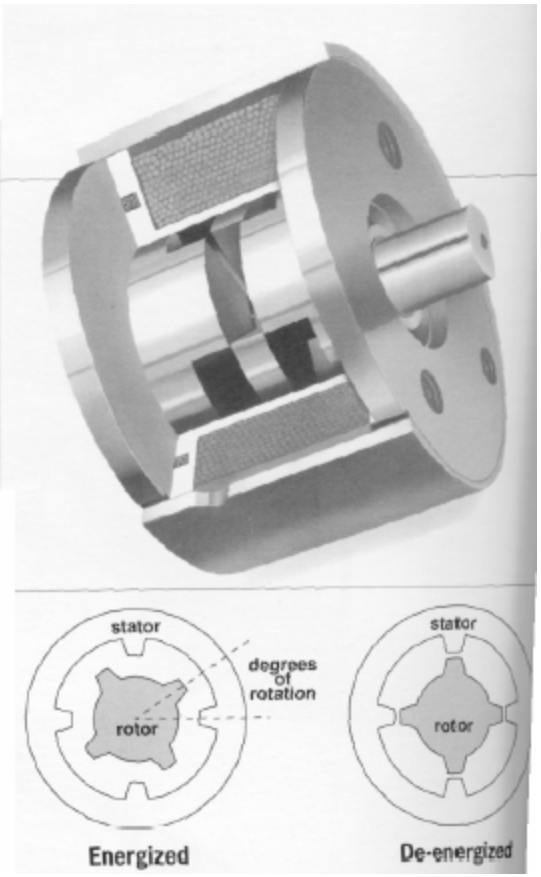
Electric Solenoids



Force $\propto$ stroke^{-1}

Electric Rotary Actuator (solenoid)





Electric Rotary Actuators (motors)

- DC motors
- AC motors
  - stepper (2-phase synchronous)
  - brushless (3-phase synchronous)
  - induction

Step Motors

Figure 2. "One phase on" stepping sequence for two phase motor.

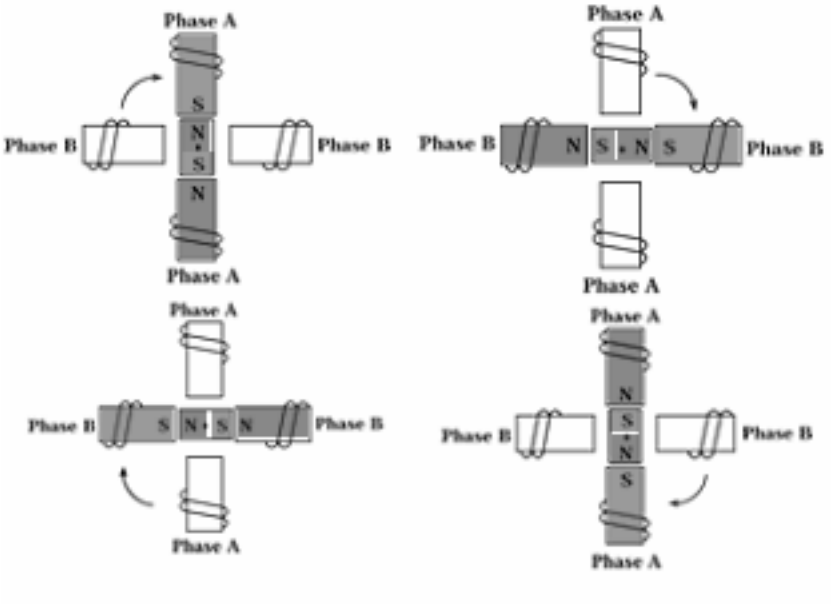
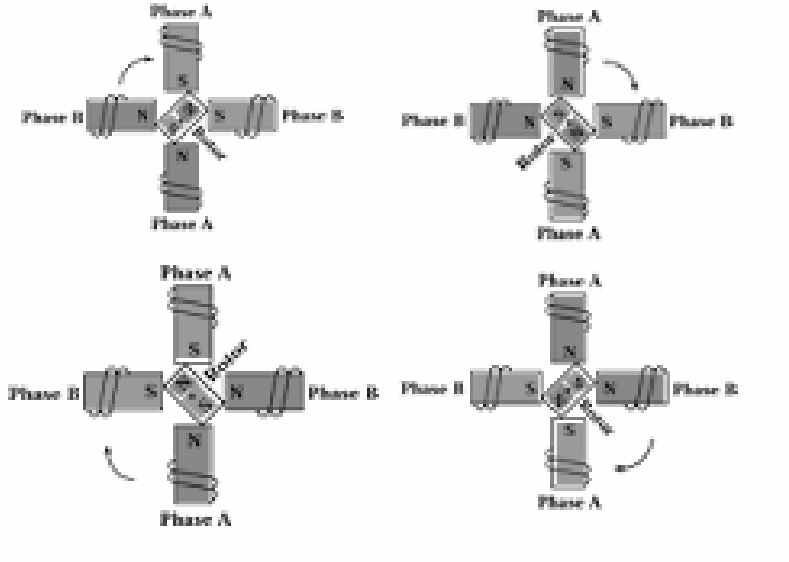
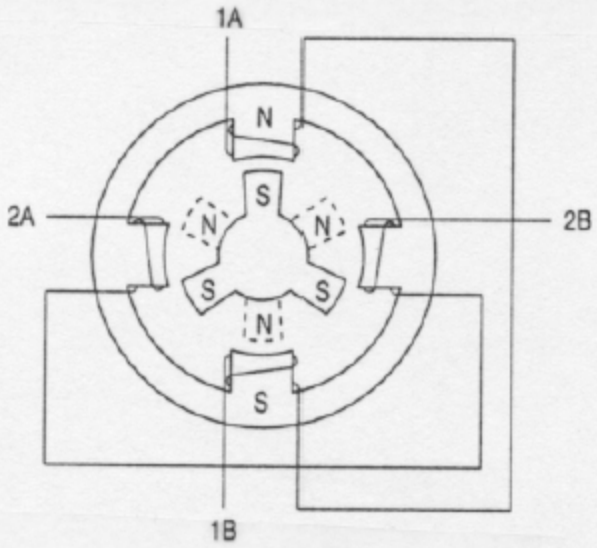


Figure 3. "Two phase on" stepping sequence for two phase motor.

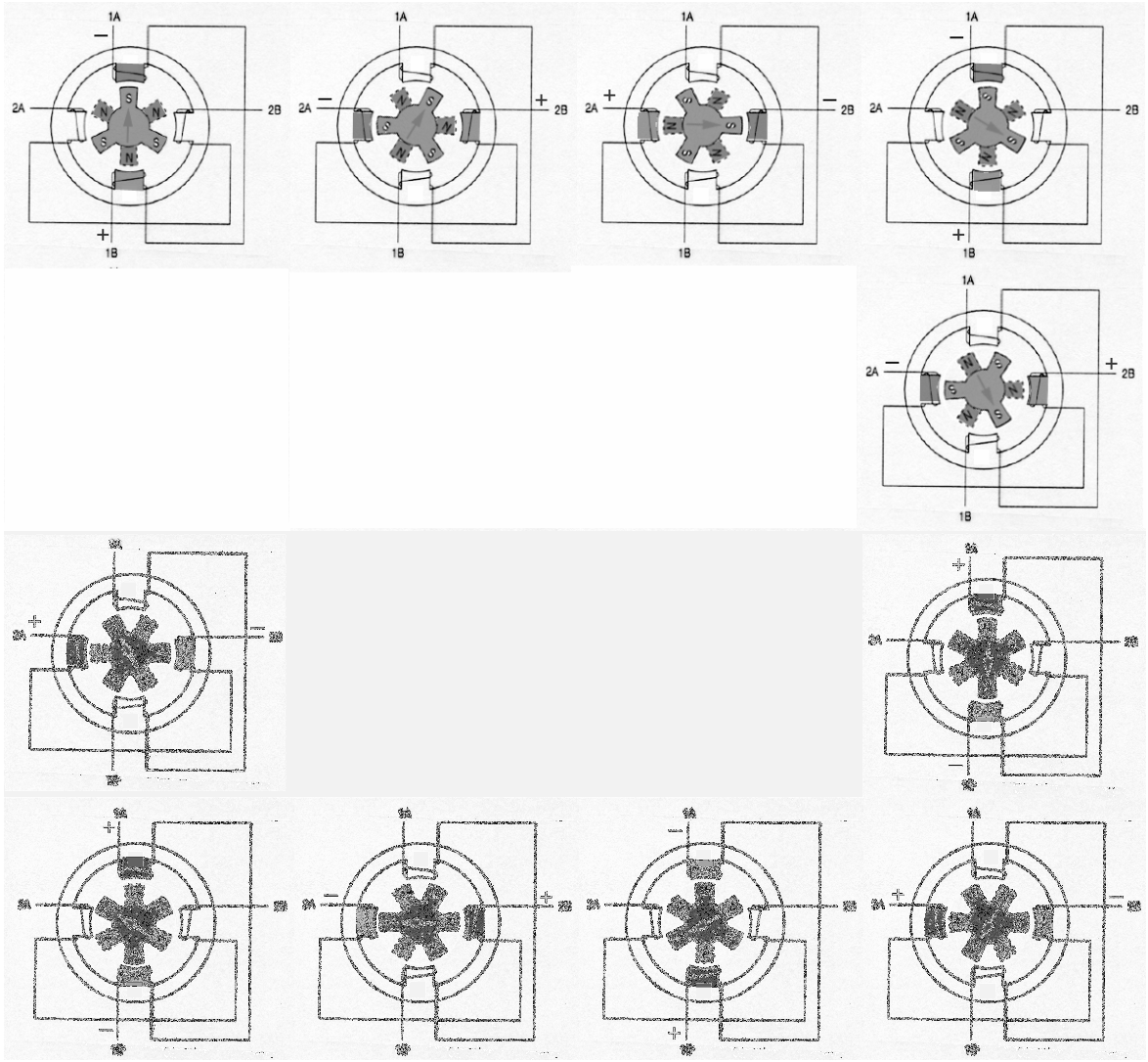


Step Motors

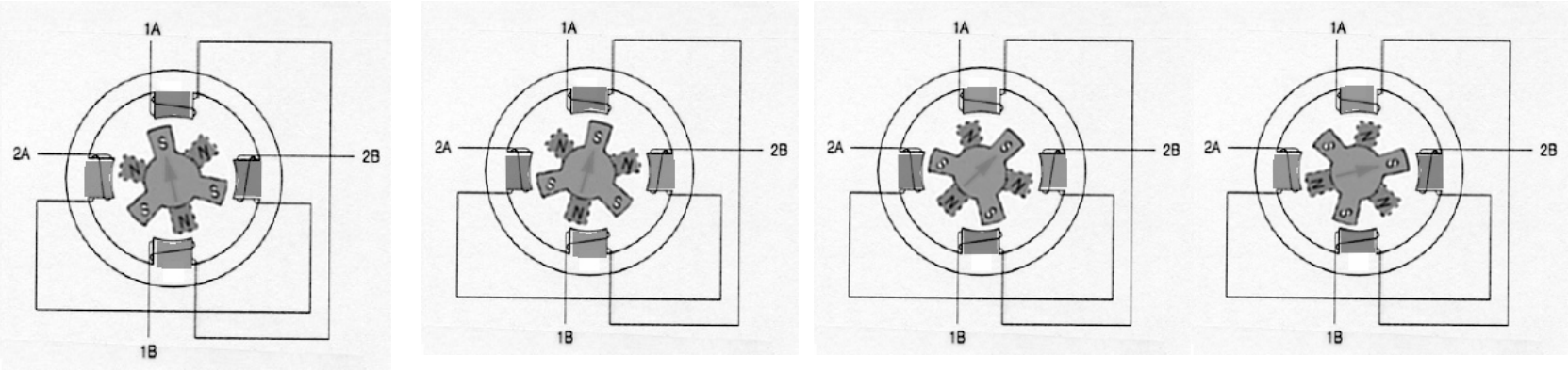
Fig. 1.4 Simple 12 step/rev hybrid motor

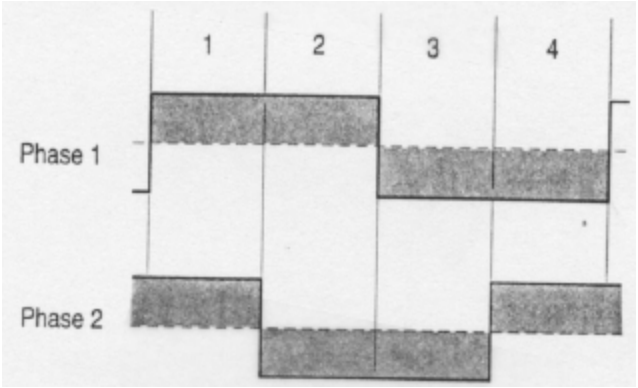


Step Motor
12 step / rev, 1 phase on

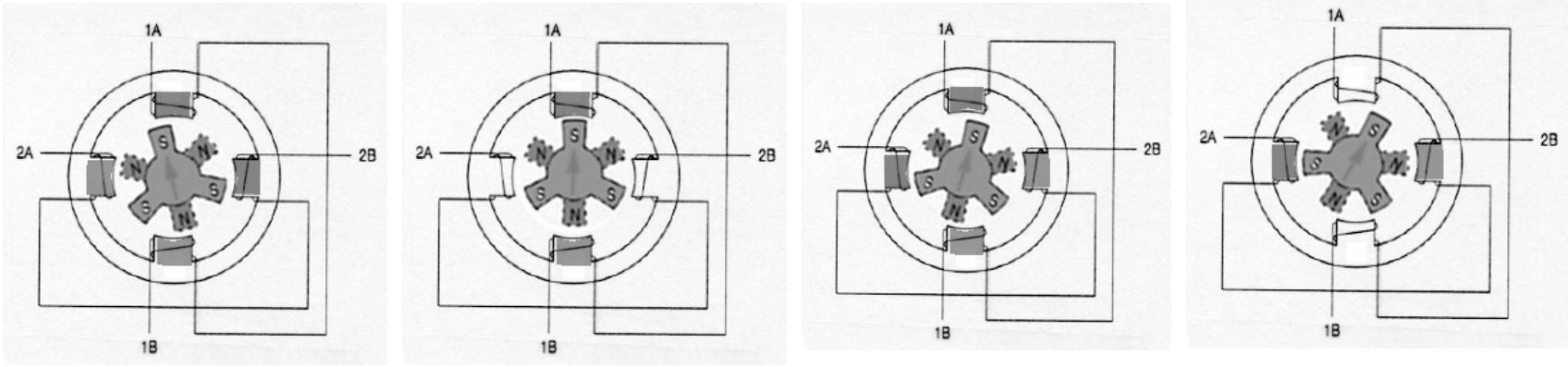


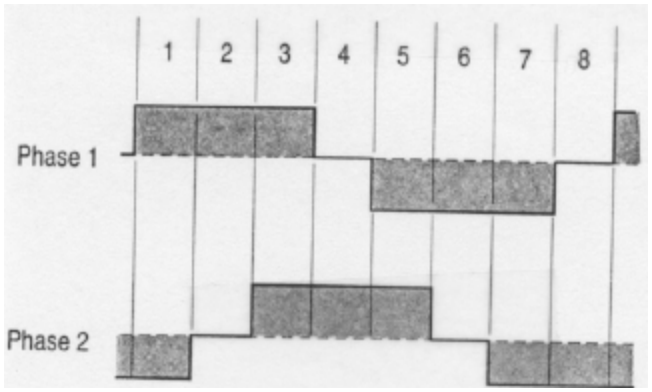
Step Motor
12 step / rev, 2 phase on



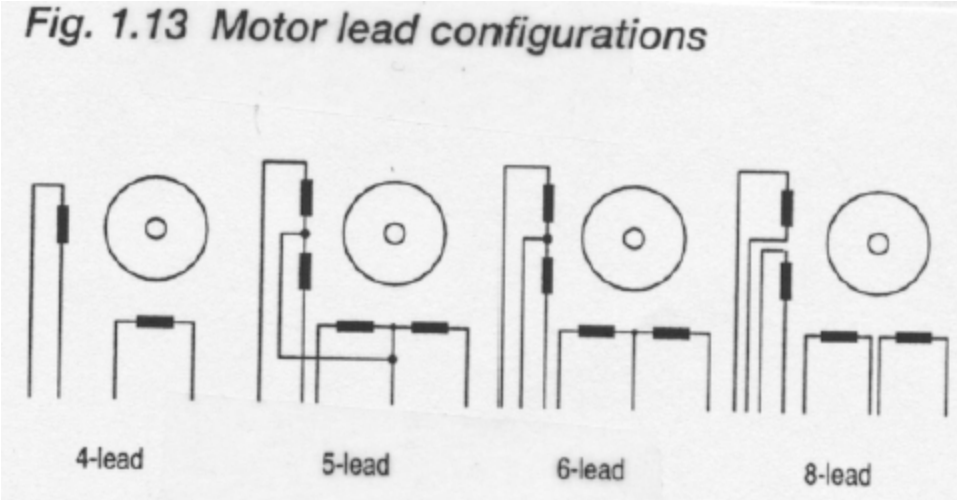


Step Motor
12 step / rev, half-stepping





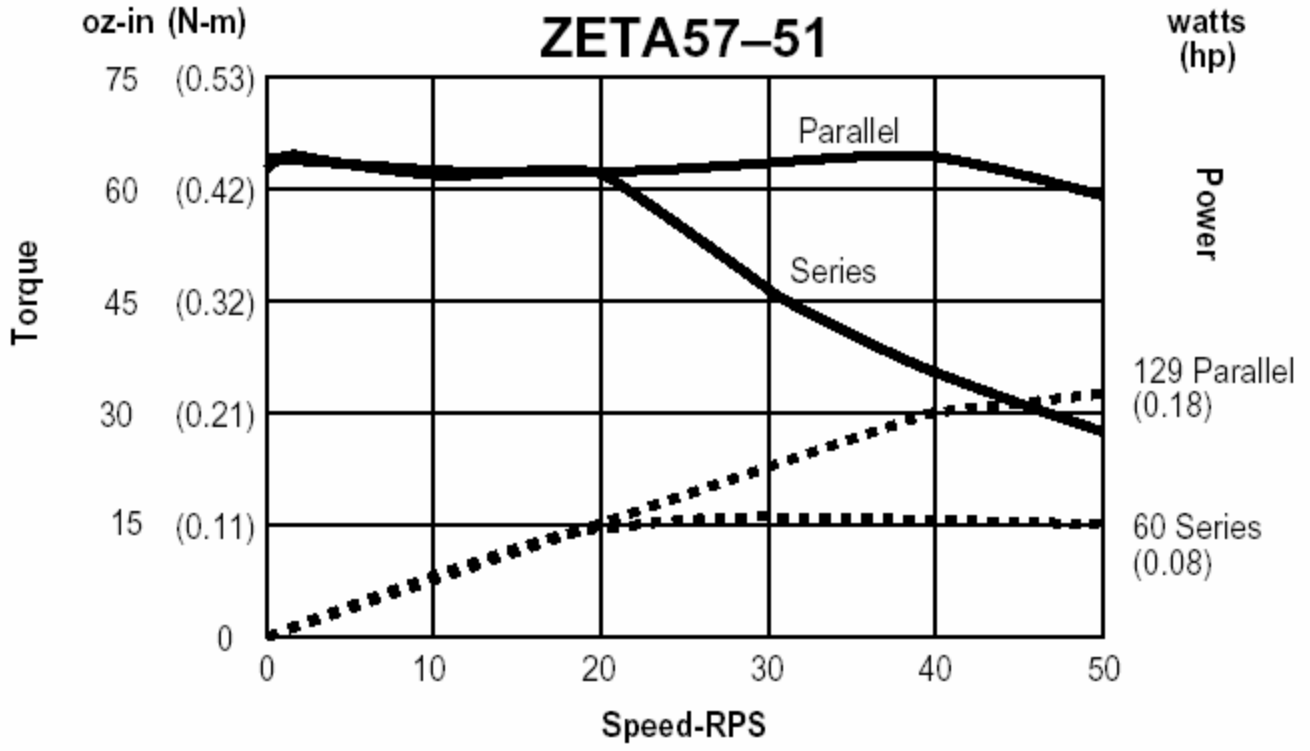
Step Motors



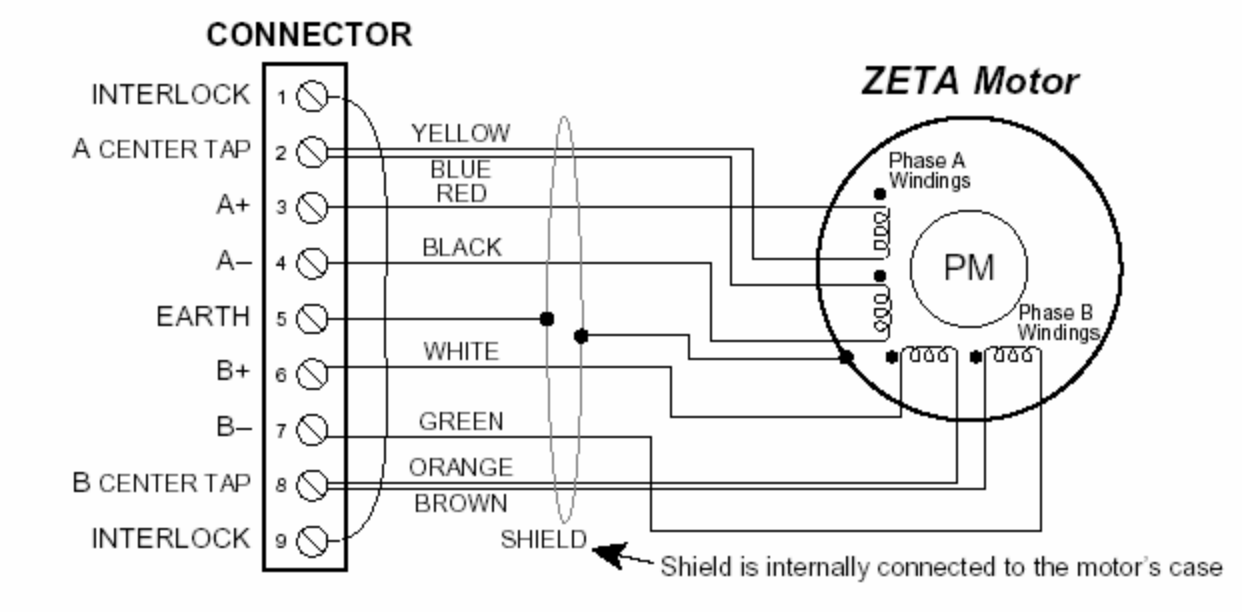
Selecting Step Motors

- Torque
- Speed
- Current
- Lead configuration

Torque / Speed



Series/Parallel Wiring



Step Motor Drives

- Resolution (full, half, microstepping)
- Current Limit (resistor or digital)
- AC powered or DC powered
- Pulse/Direction or Indexing

Resolution

- Full step/Half step
- Microstepping
  - x2,x4,x5,x8,x10,x16,x25,x32,x50,x64,x125,x128,x250,x256 common choices
- Max step frequency
  - PLC: 7kHz pulse rate => 2100 RPM at x1, 8.2RPM at x256 (1.8deg motor)
  - Compumotor 6104: 2MHz pulse rate => 2300RPM at x256
- Resonance problems