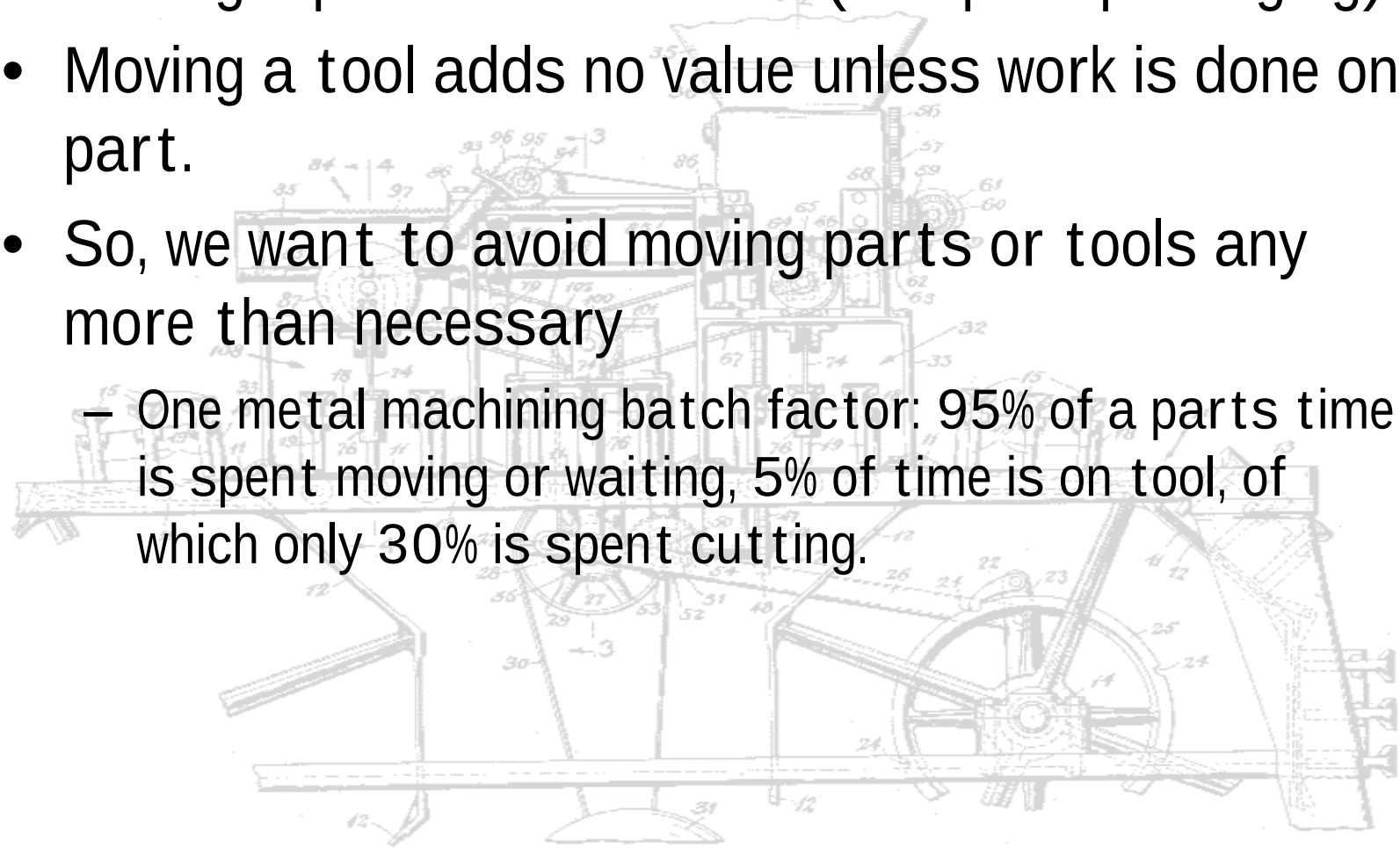
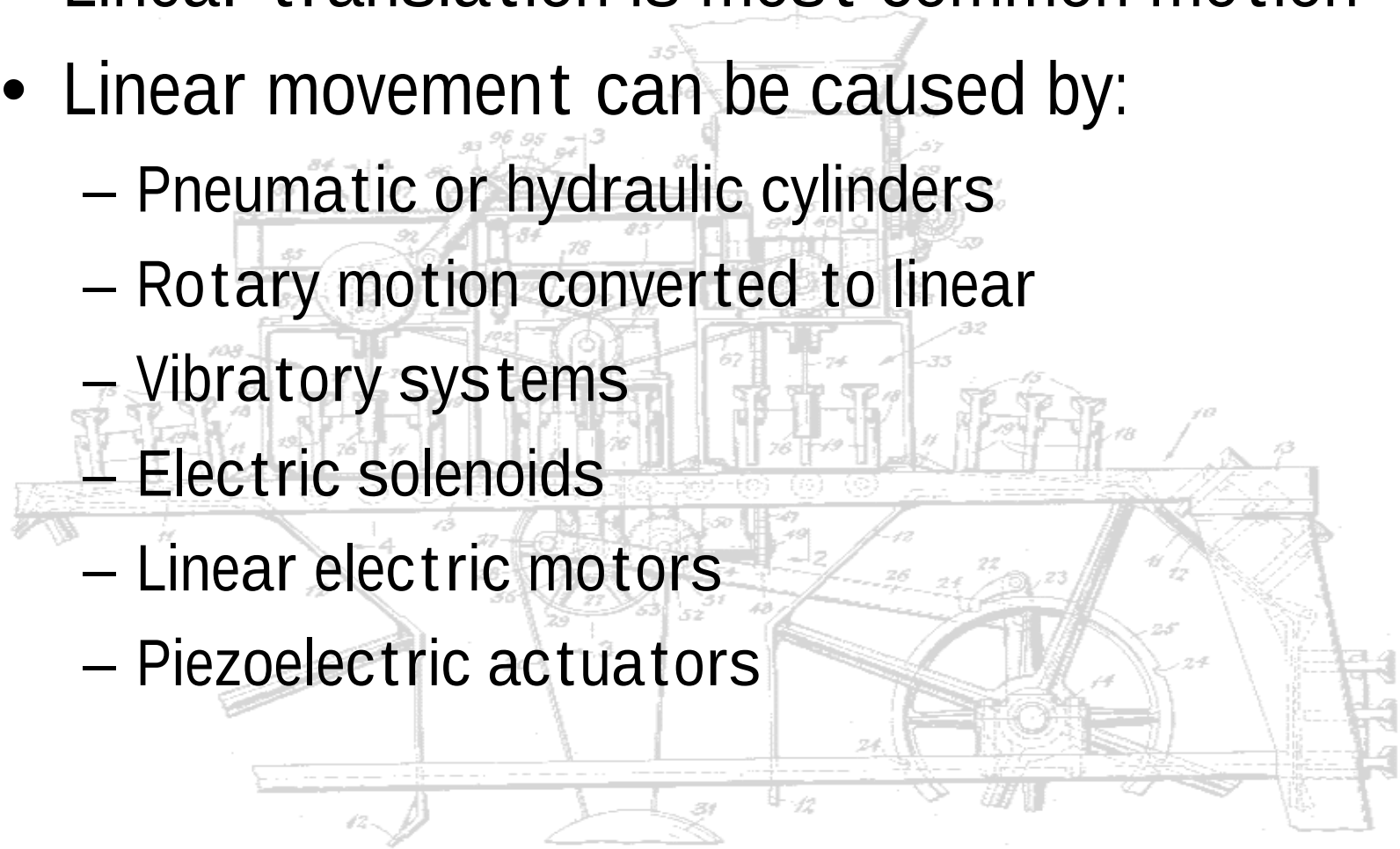
Generating Motion

- 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.



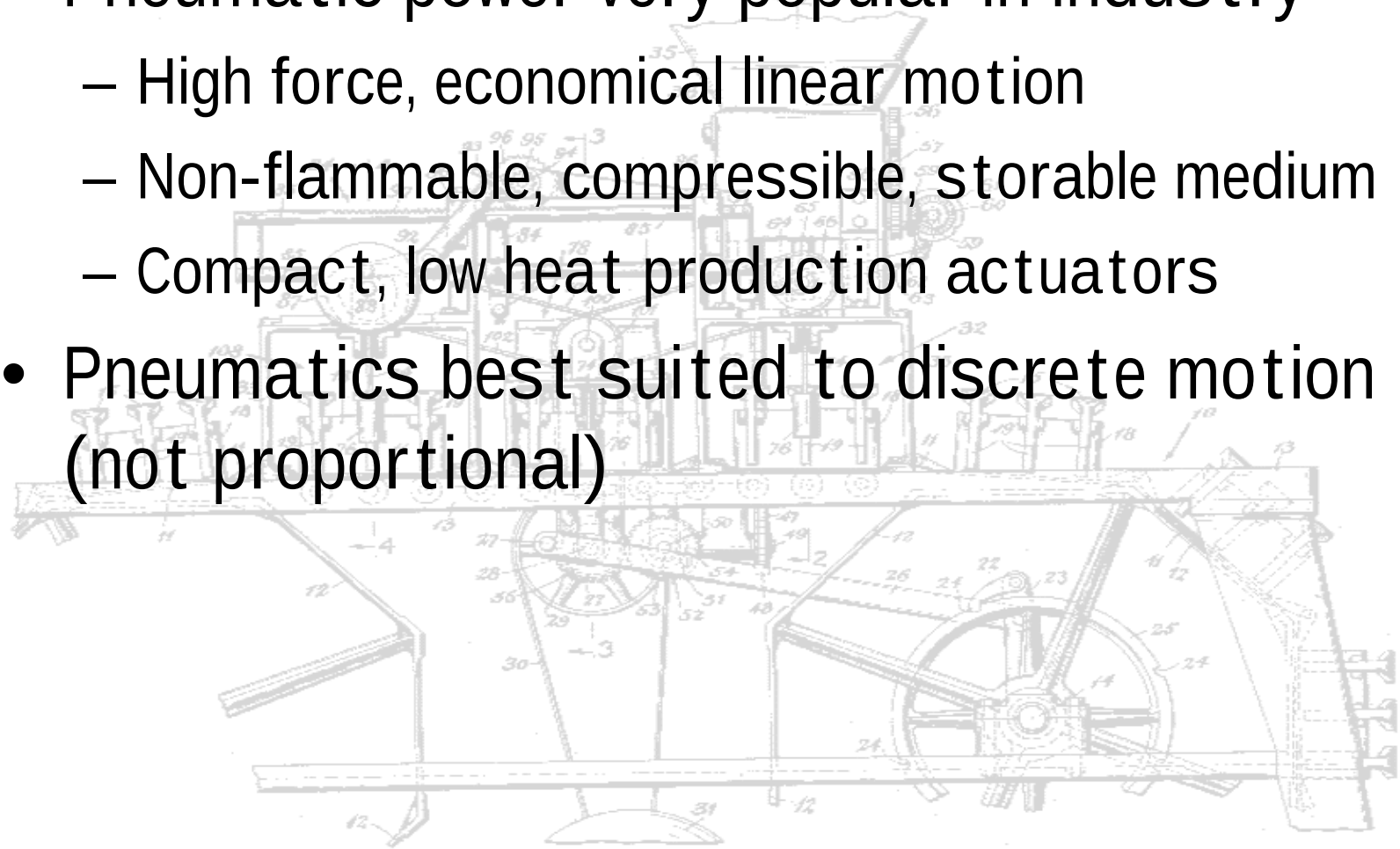
Linear Motion

- 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



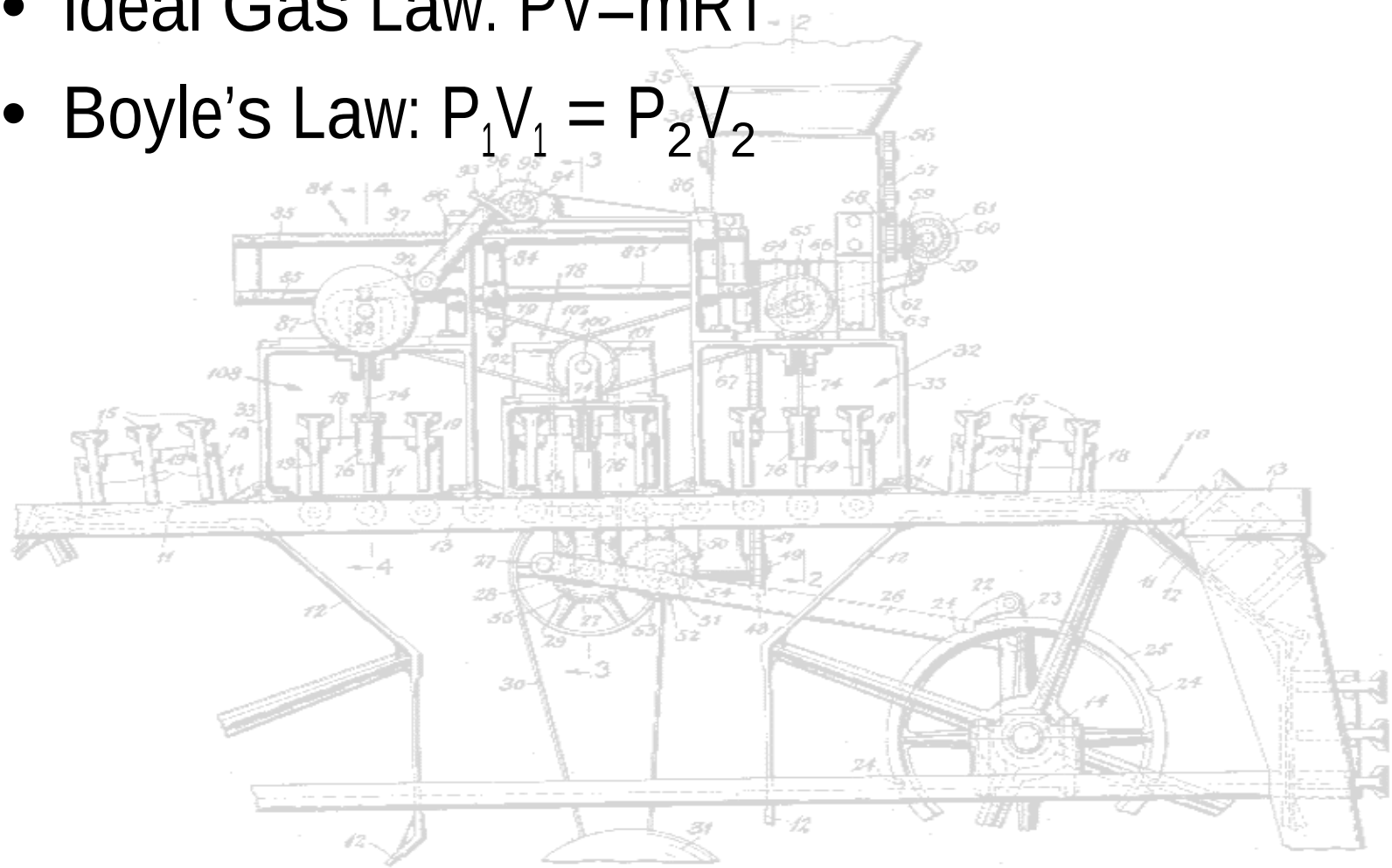
Pneumatic Systems

- 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)

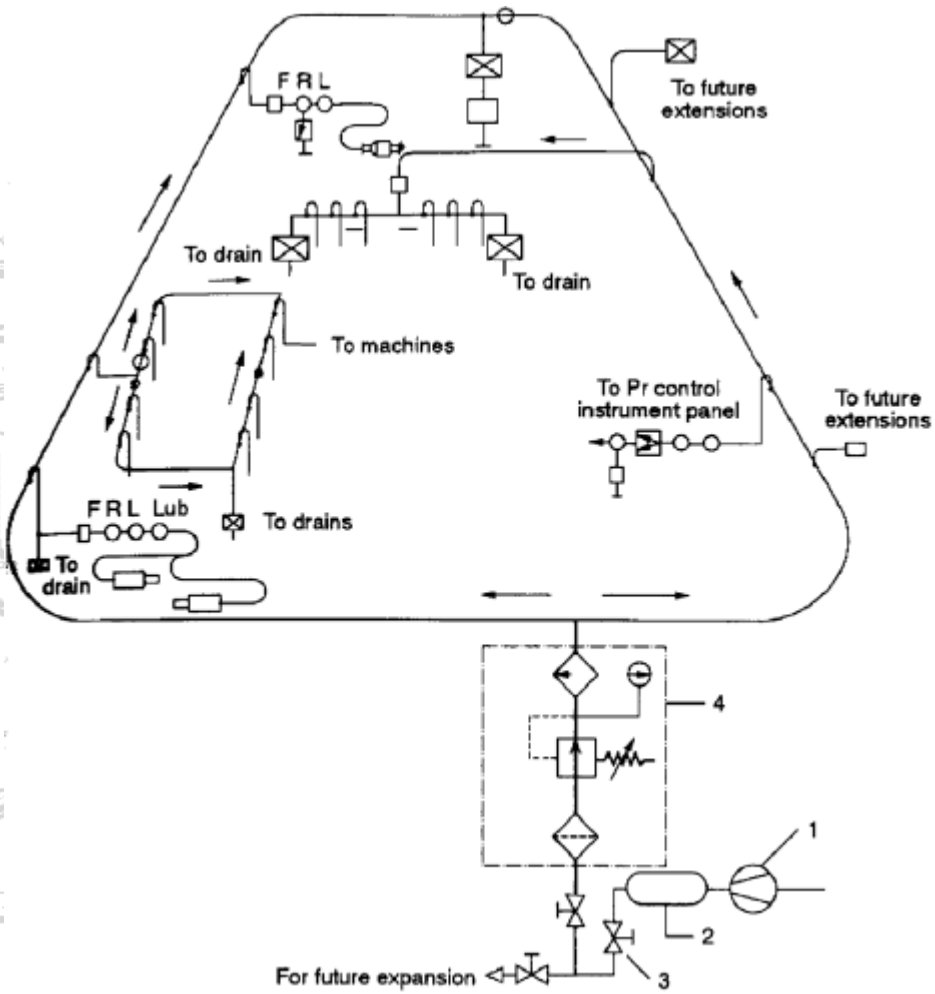


Pneumatic Systems

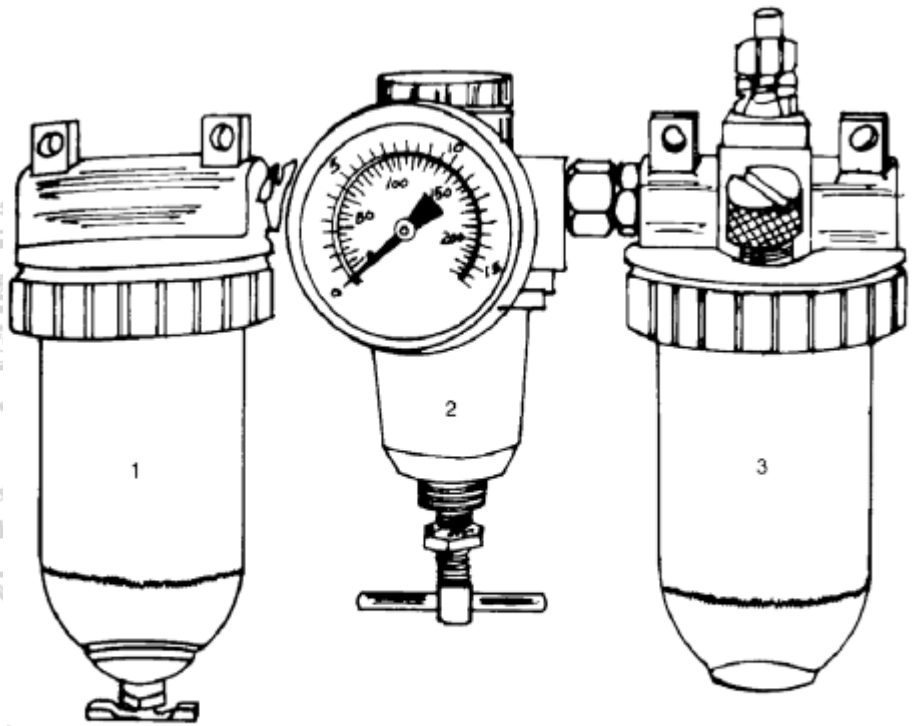
- Ideal Gas Law: PV=mRT
- Boyle's Law: $P_1V_1 = P_2V_2$



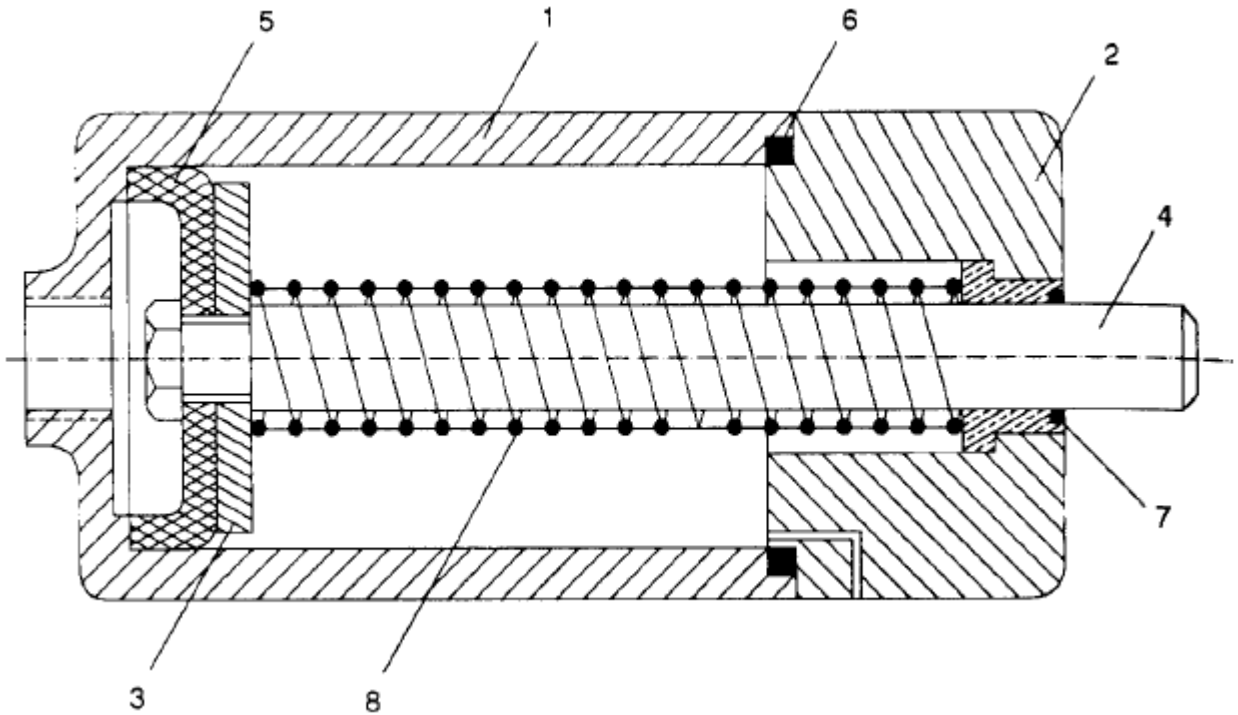
Pneumatic System Layout



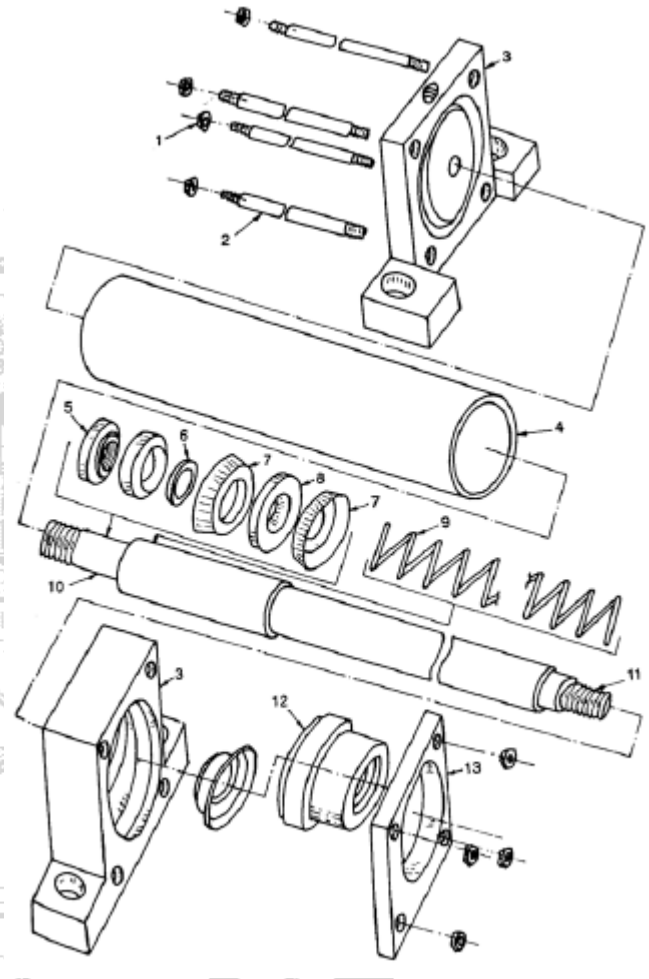
Air Preparation



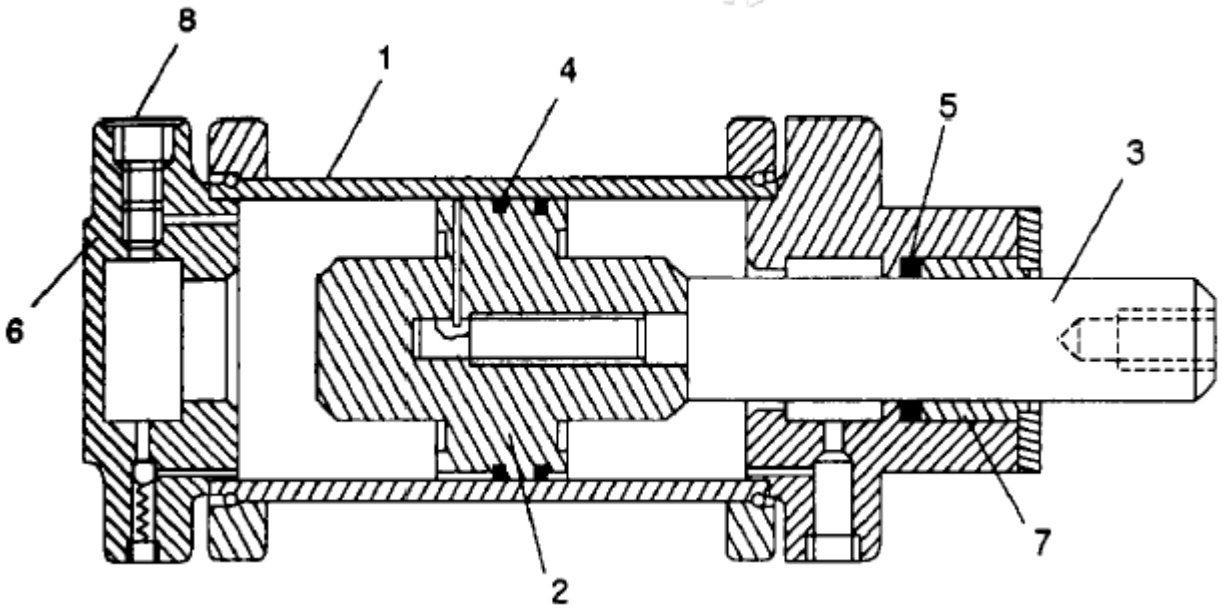
Single-Acting Cylinder



Single-Acting Cylinder

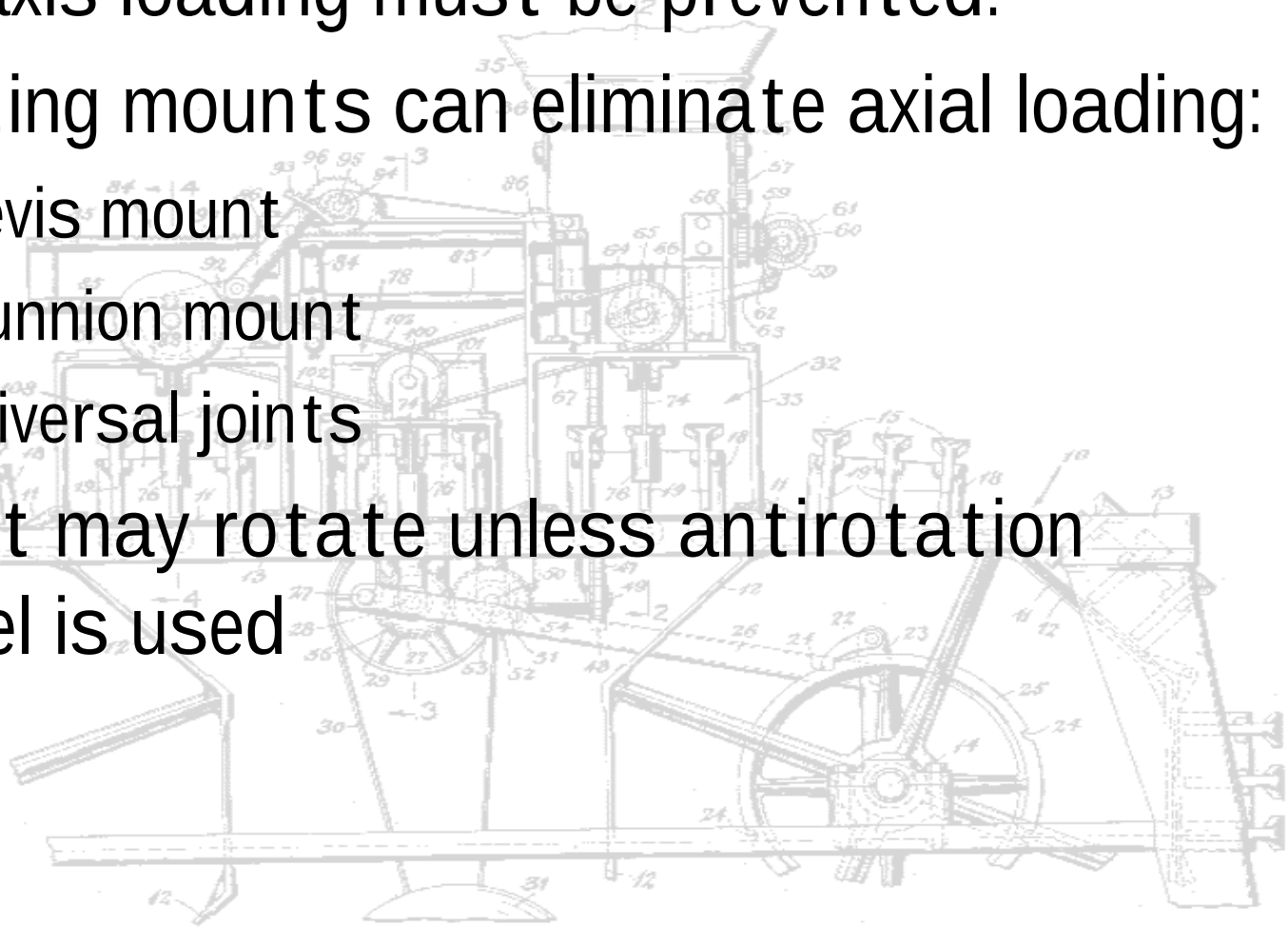


Double-Acting Cylinder

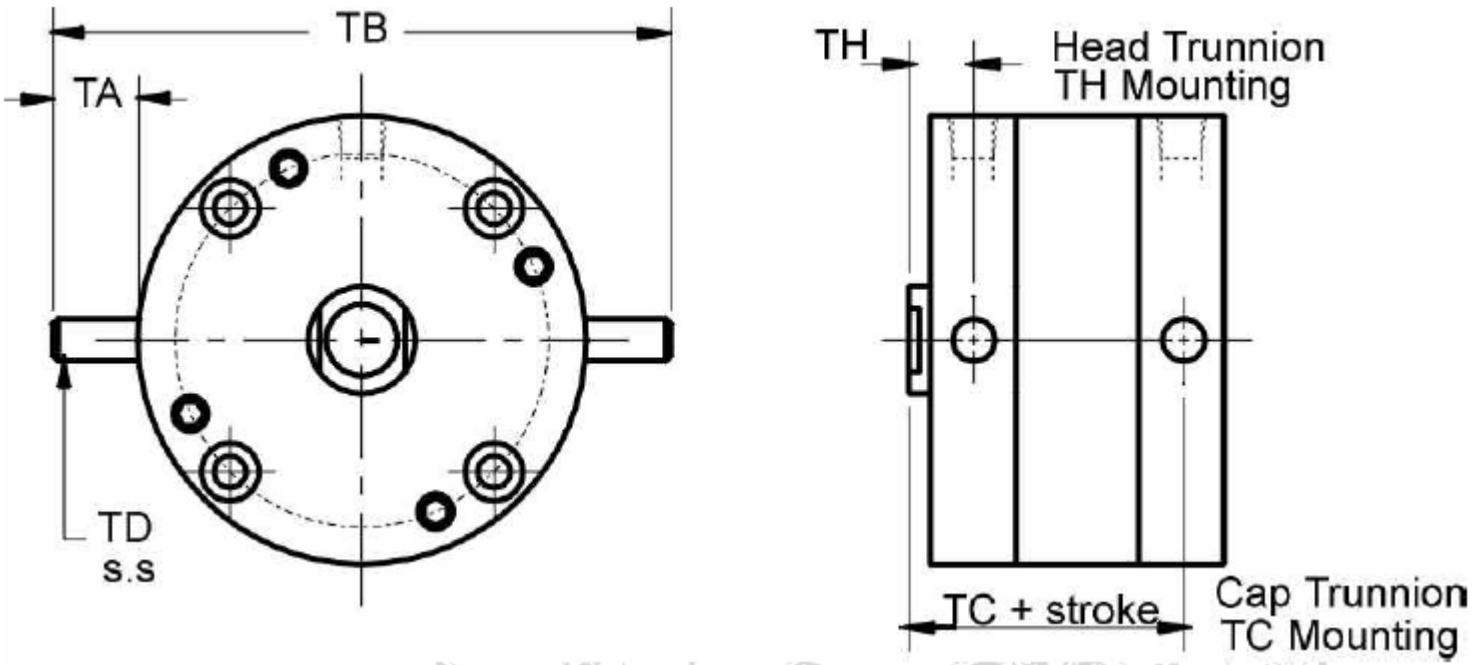


Pneumatic Cylinder Mounting

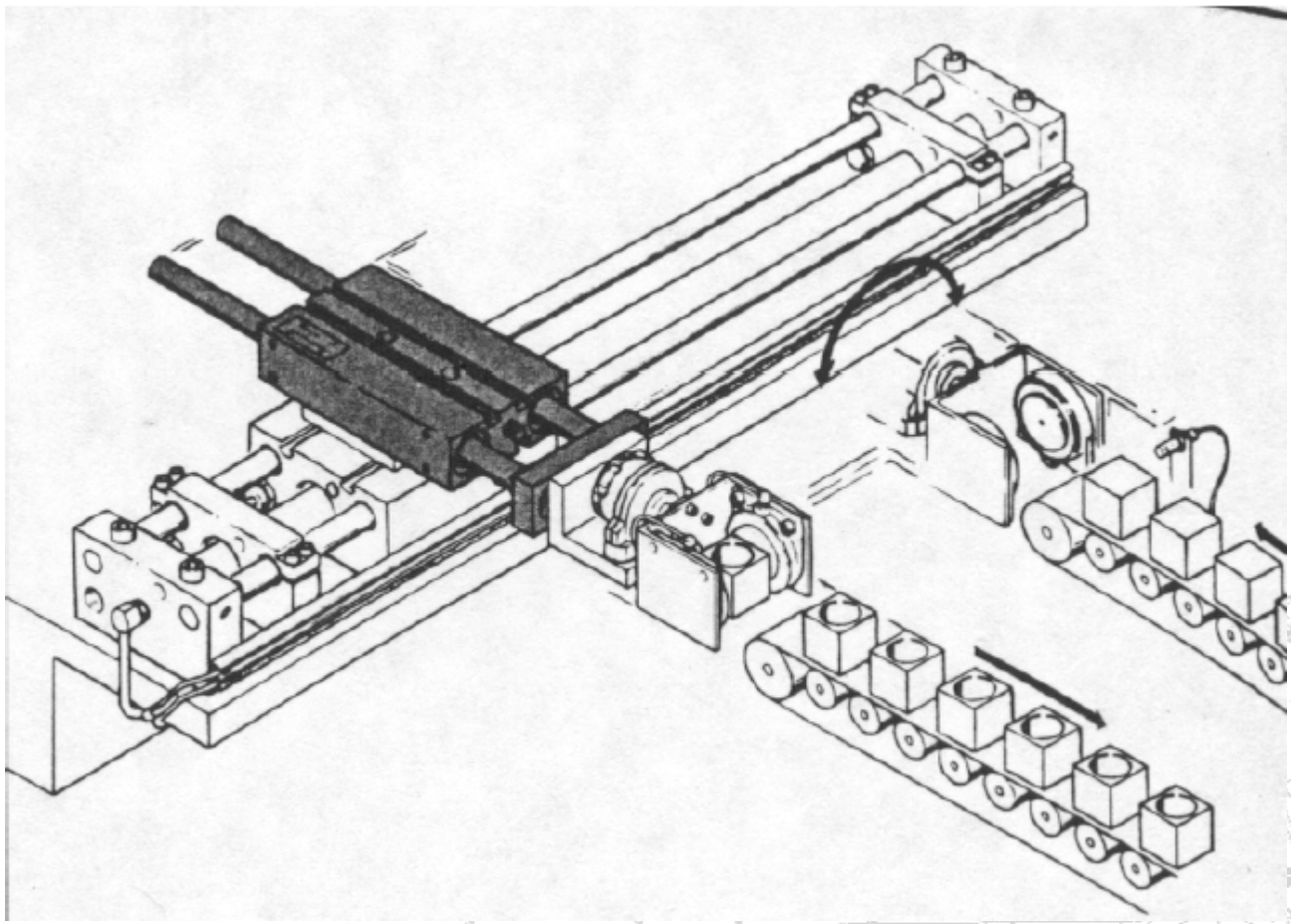
- Off-axis loading must be prevented!
- Pivoting mounts can eliminate axial loading:
  - Clevis mount
  - Trunnion mount
  - Universal joints
- Shaft may rotate unless antirotation model is used



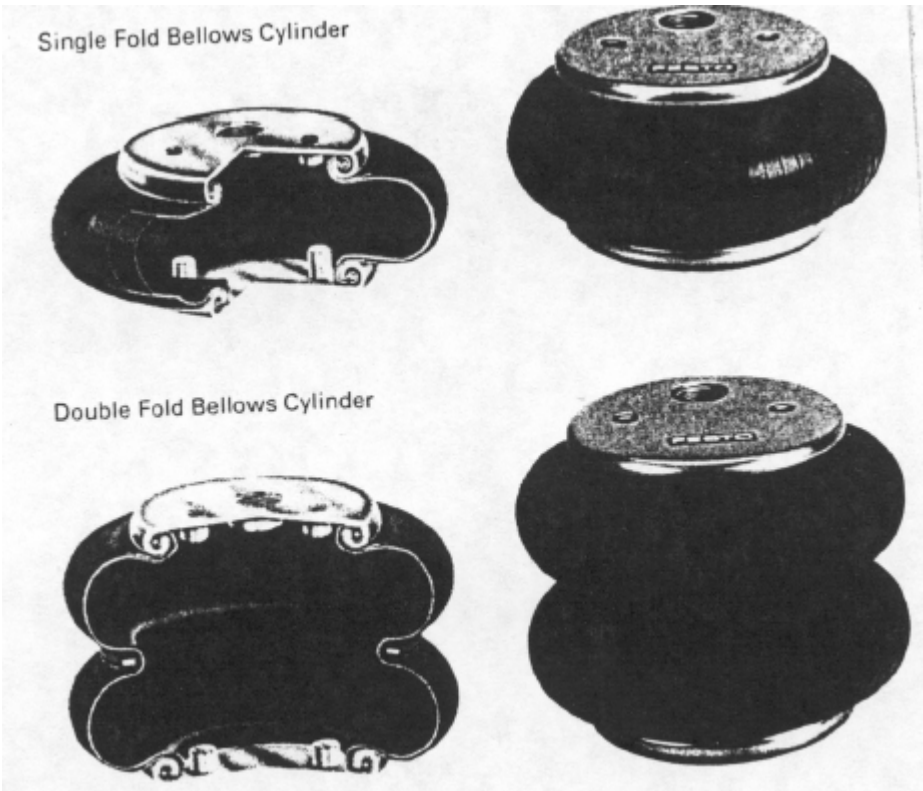
Trunnion Mount

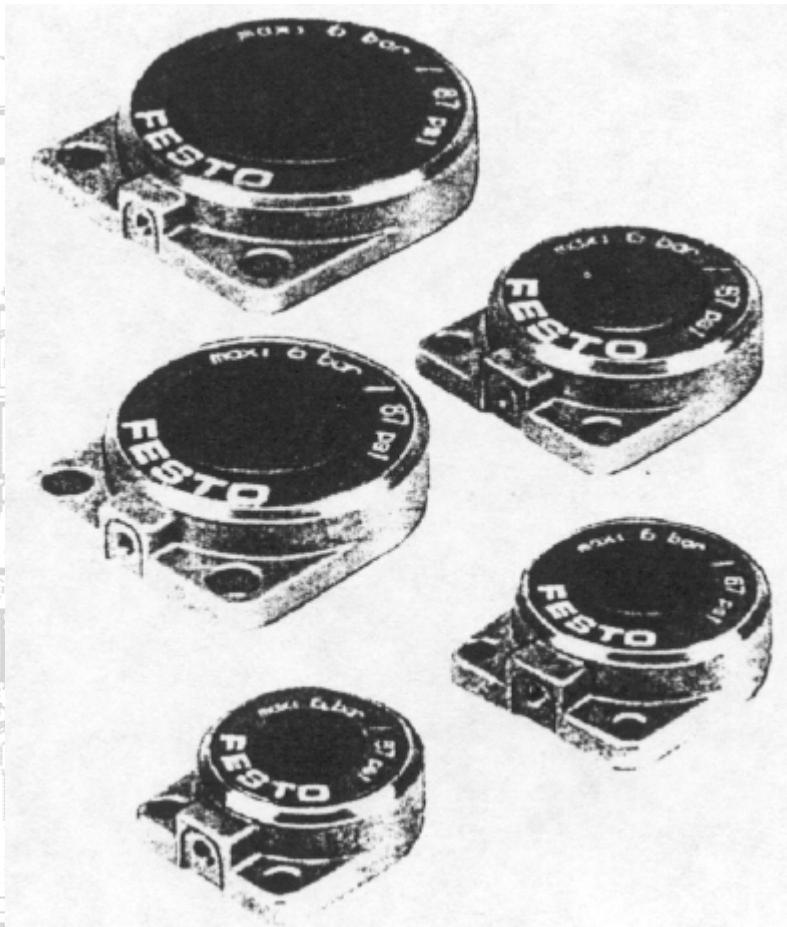


Pneumatic Twin Cylinder

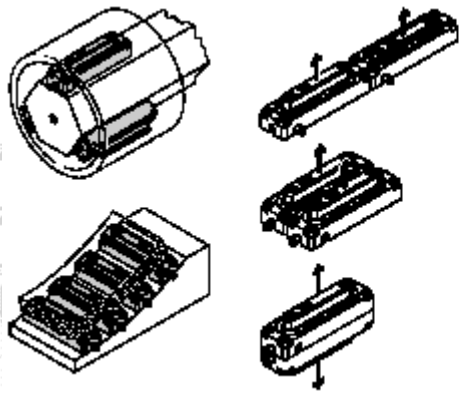


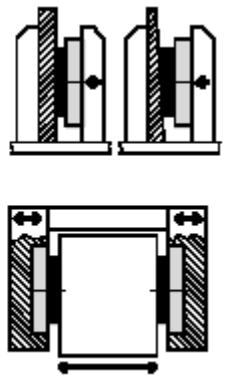
Pneumatic Bellows



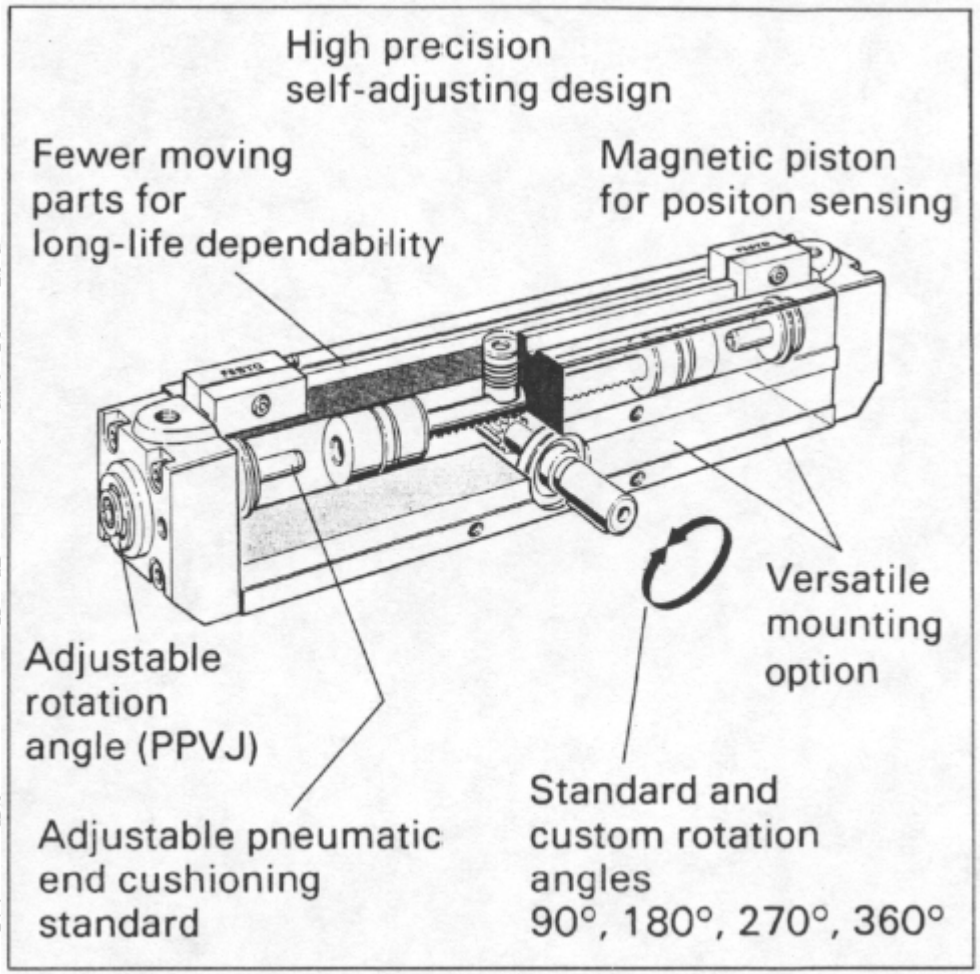


Pneumatic Bellows

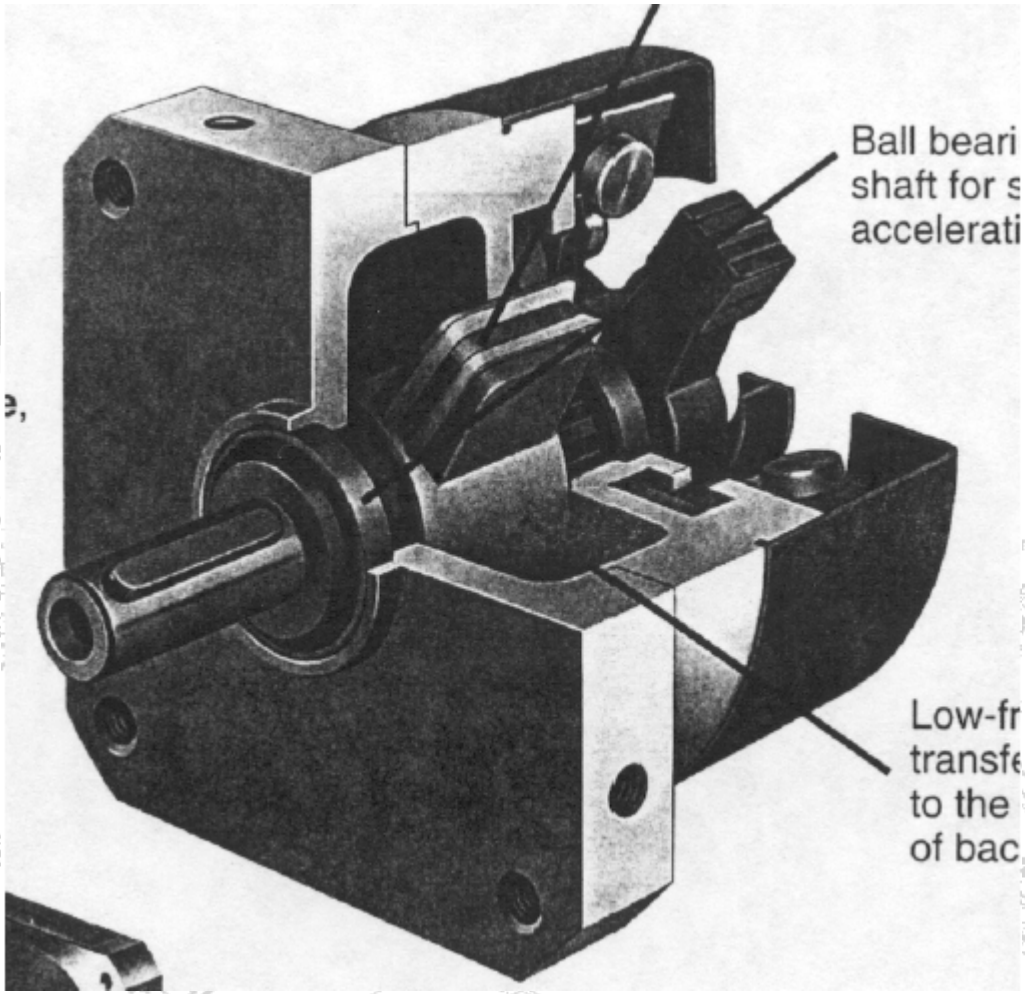




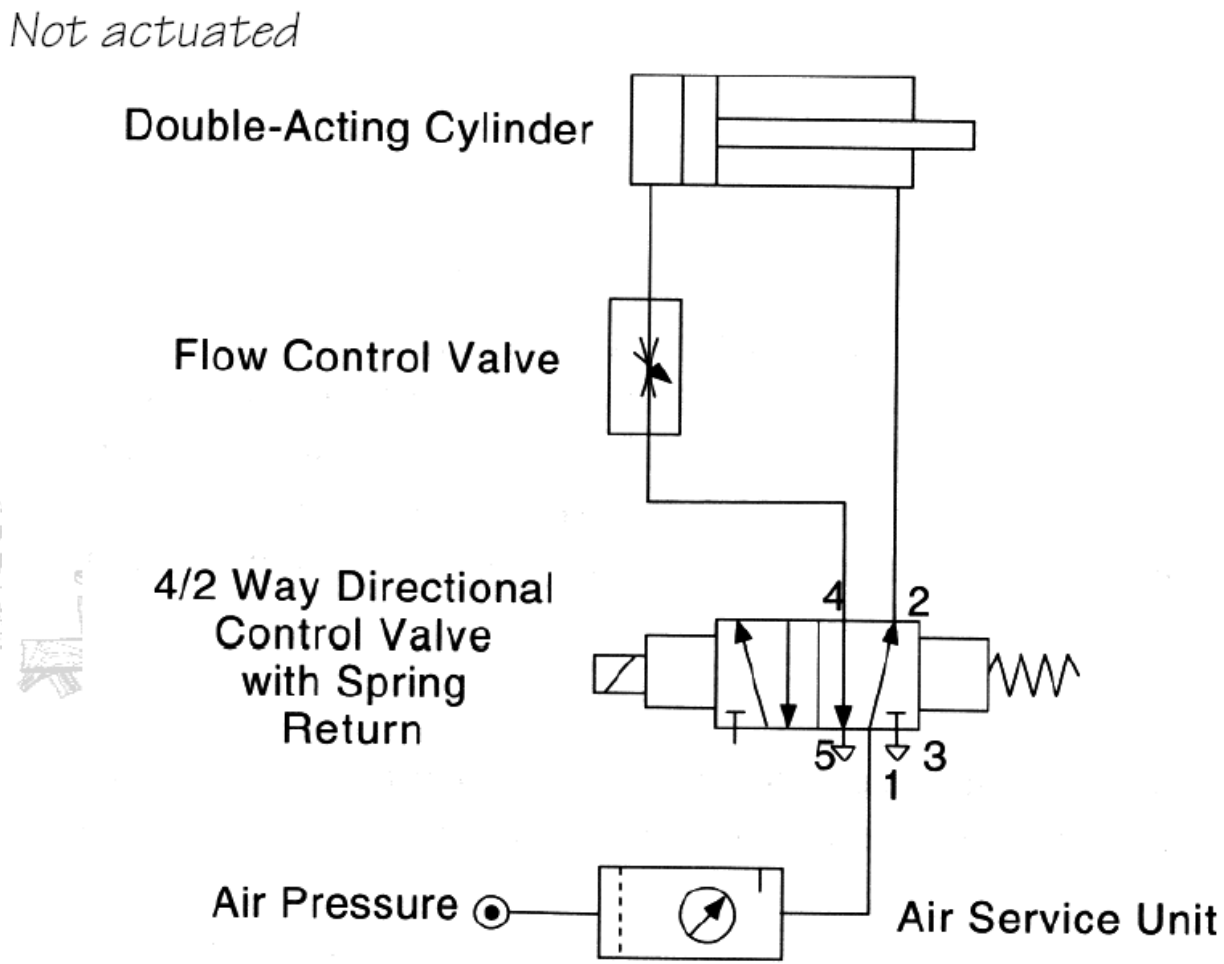
Pneumatic Rotary Actuators



Pneumatic Rotary Actuators

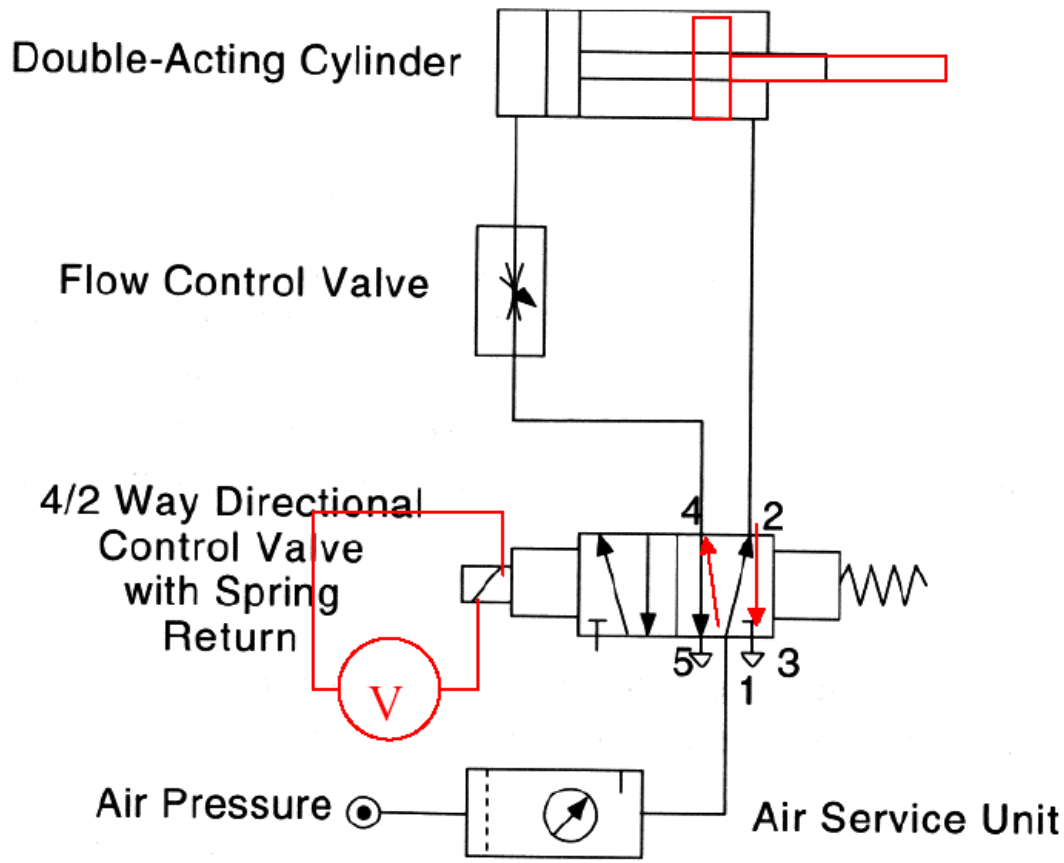


Pneumatic Schematics

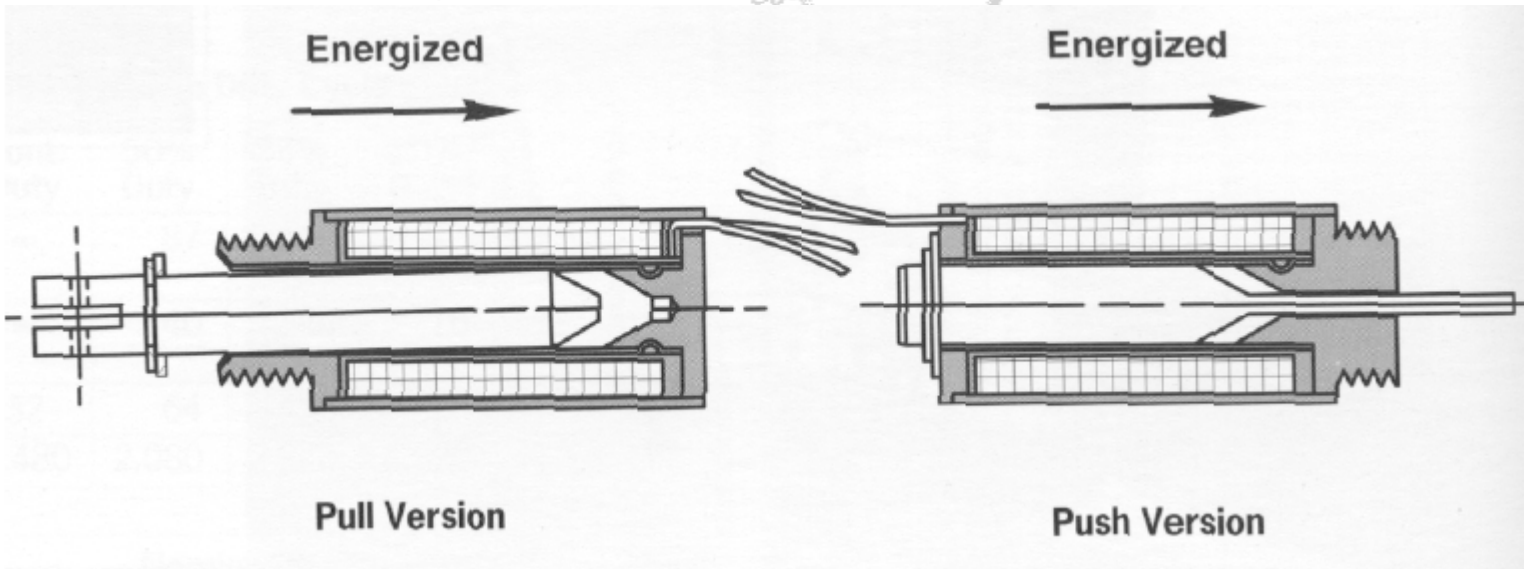


Pneumatic Schematics

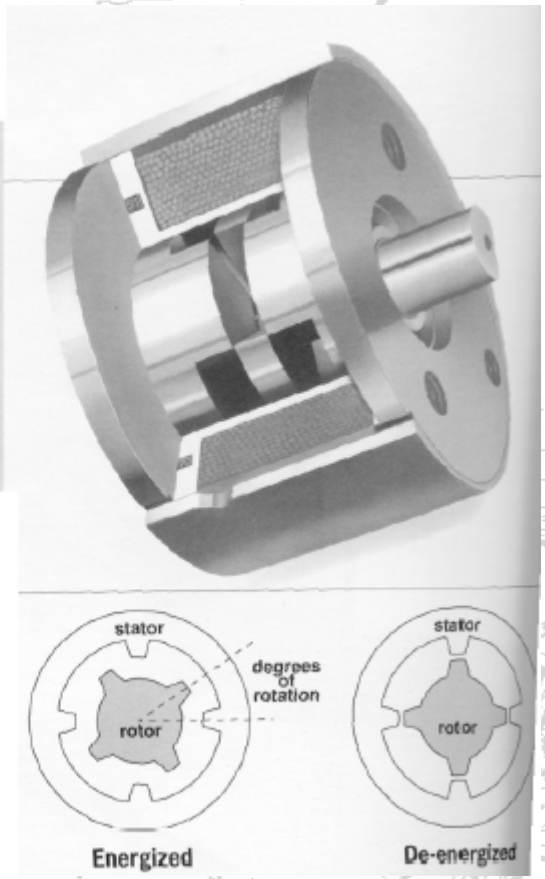
Actuated



Electric Solenoids



Electric Rotary Actuator (solenoid)



Electric Rotary Actuators (motors)

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