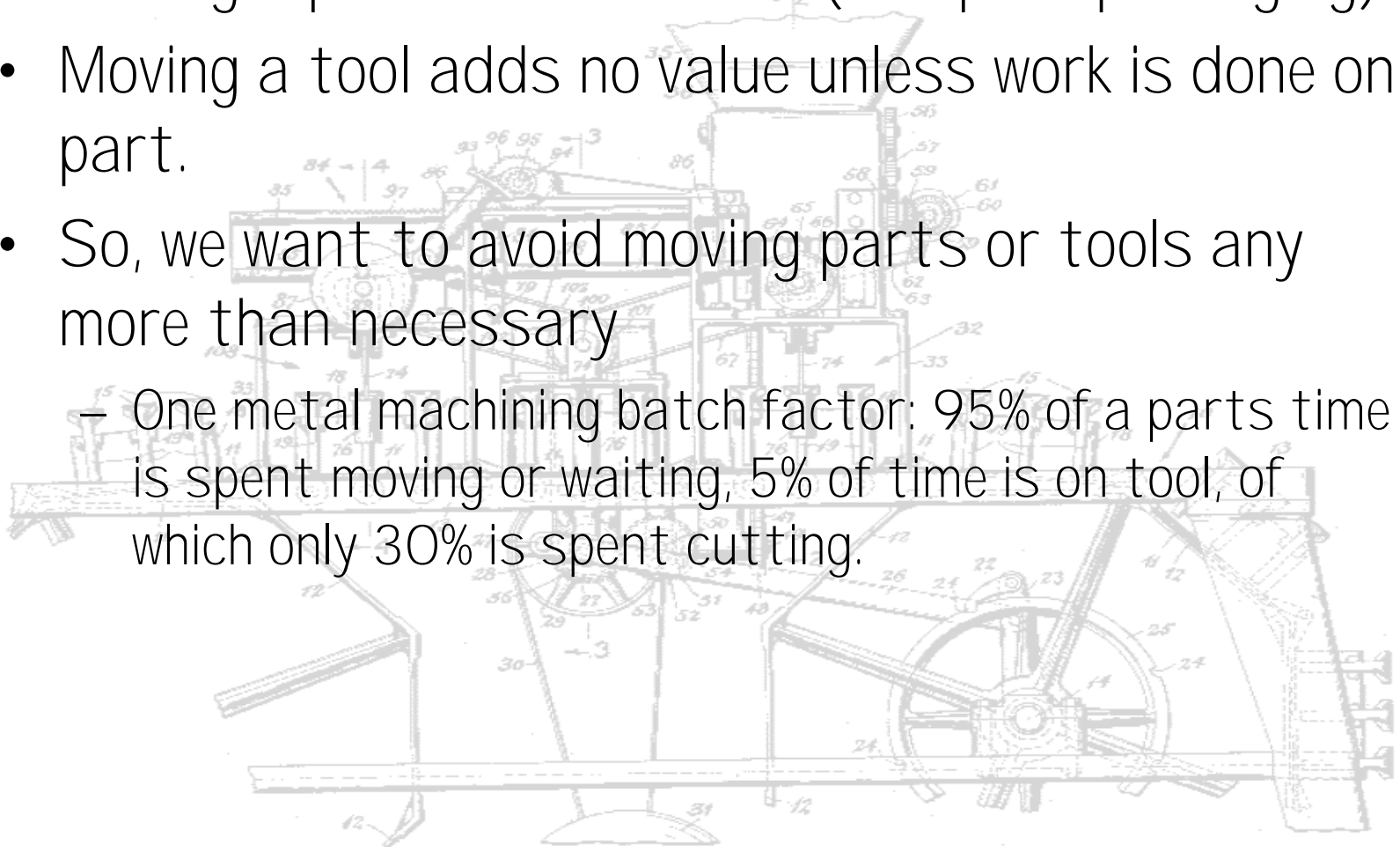


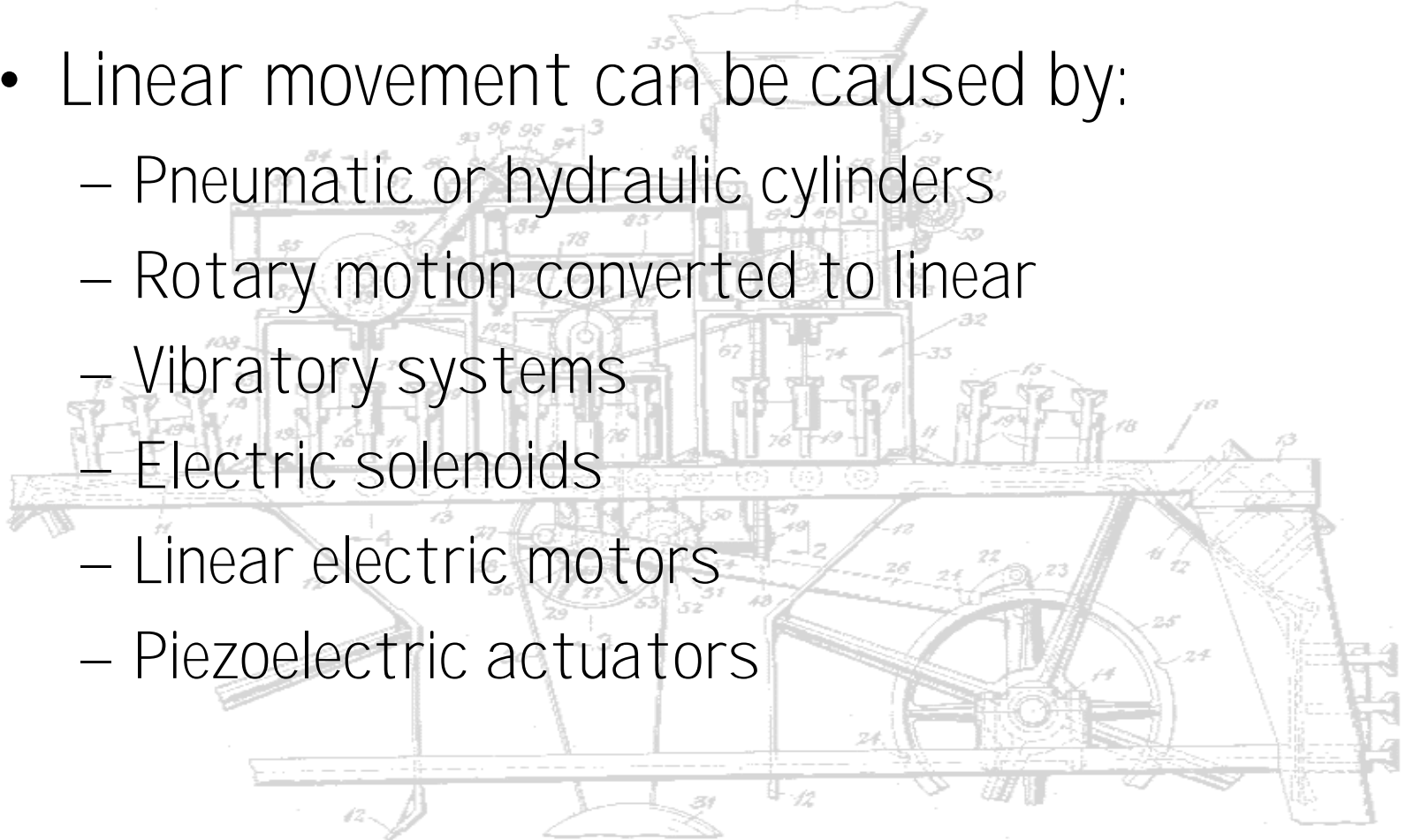
Generating Motion

- 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.



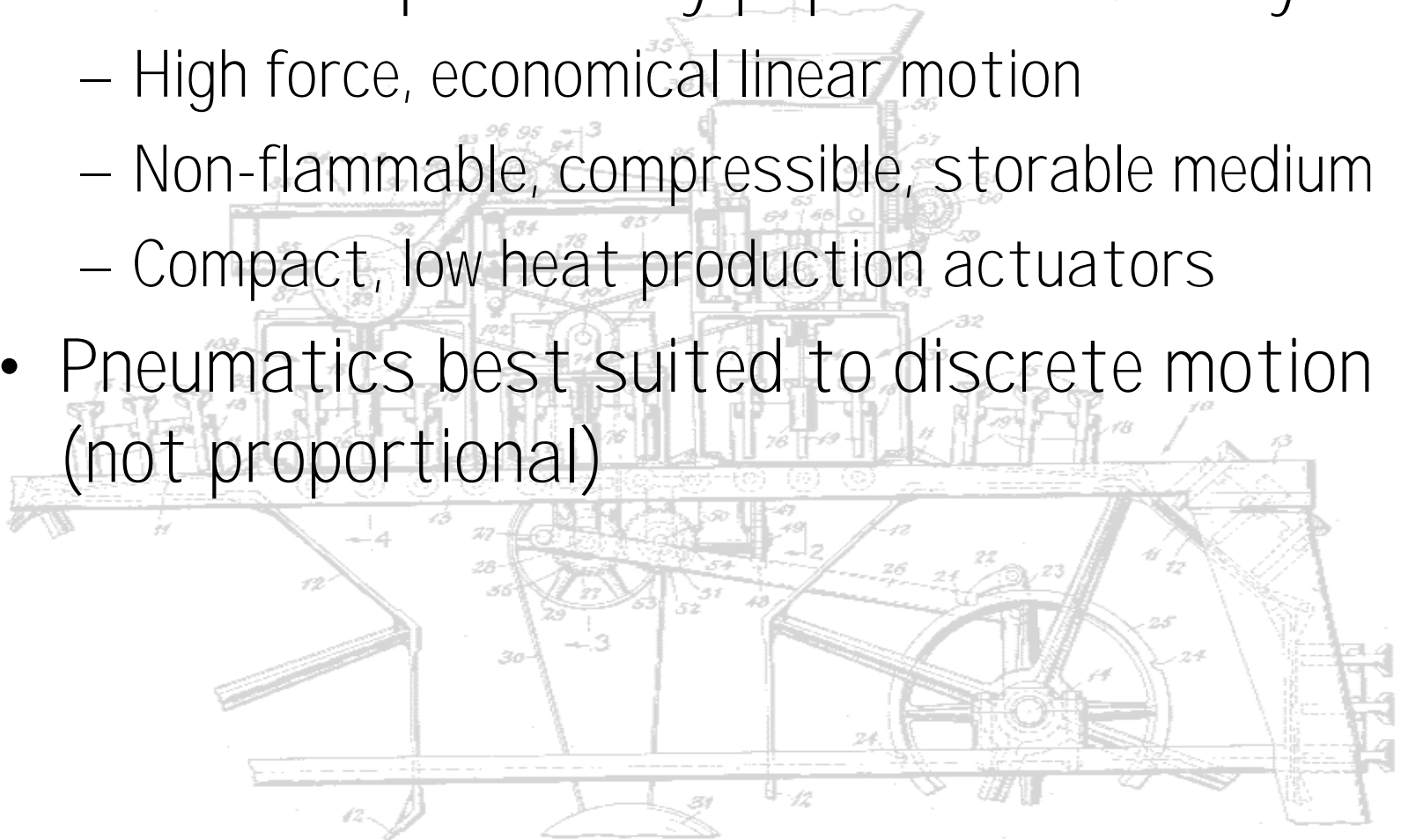
Linear Motion

- 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



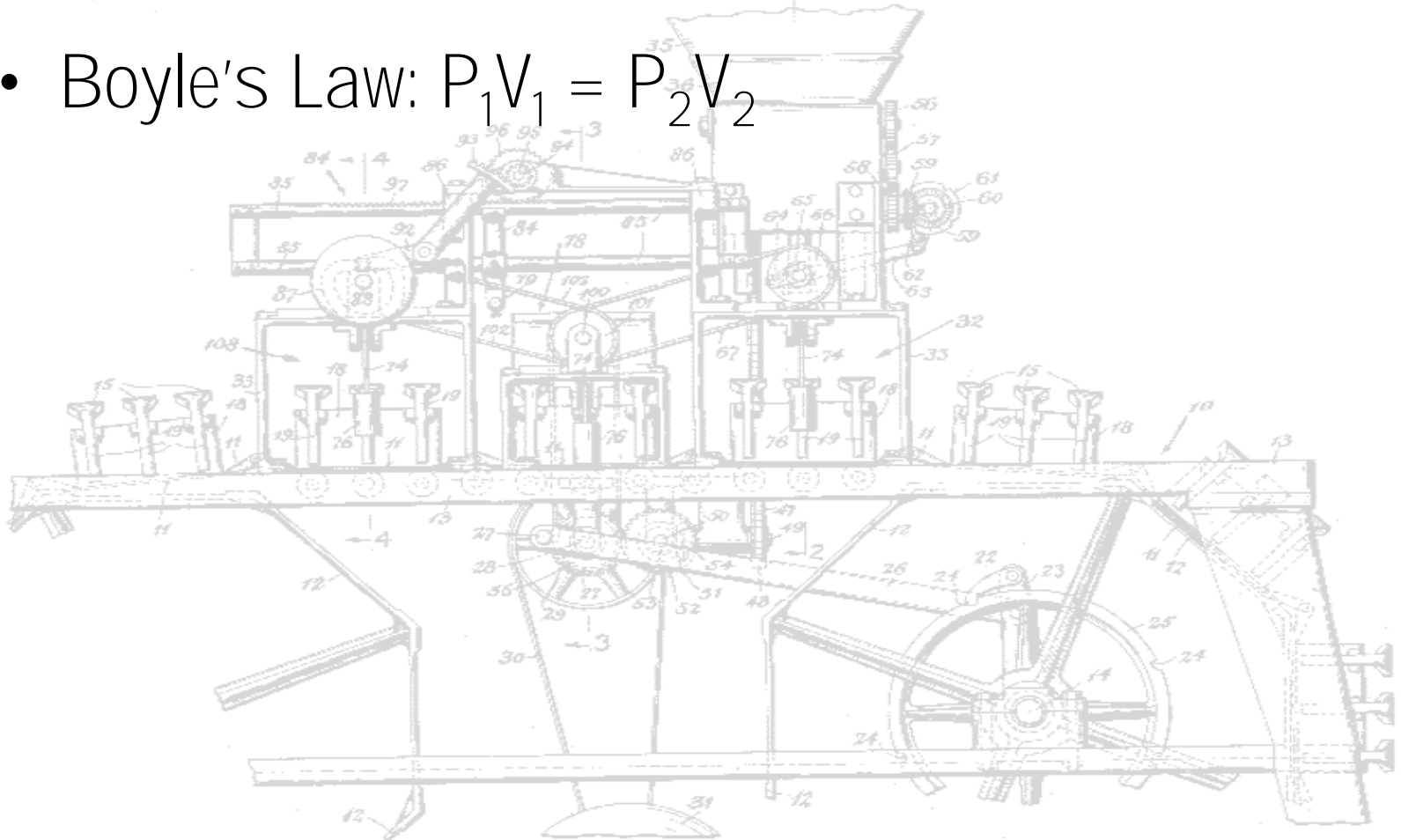
Pneumatic Systems

- 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)

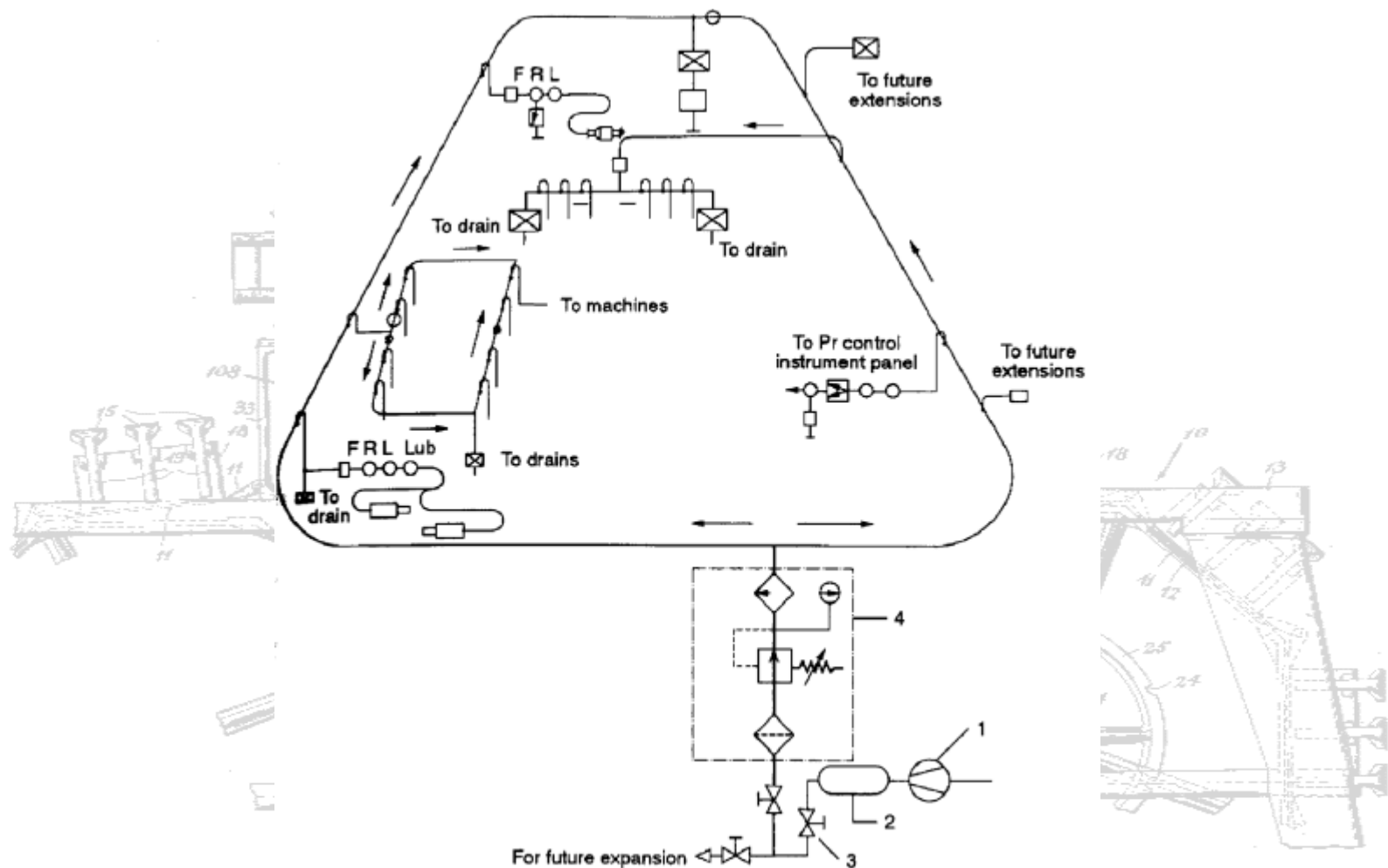


Pneumatic Systems

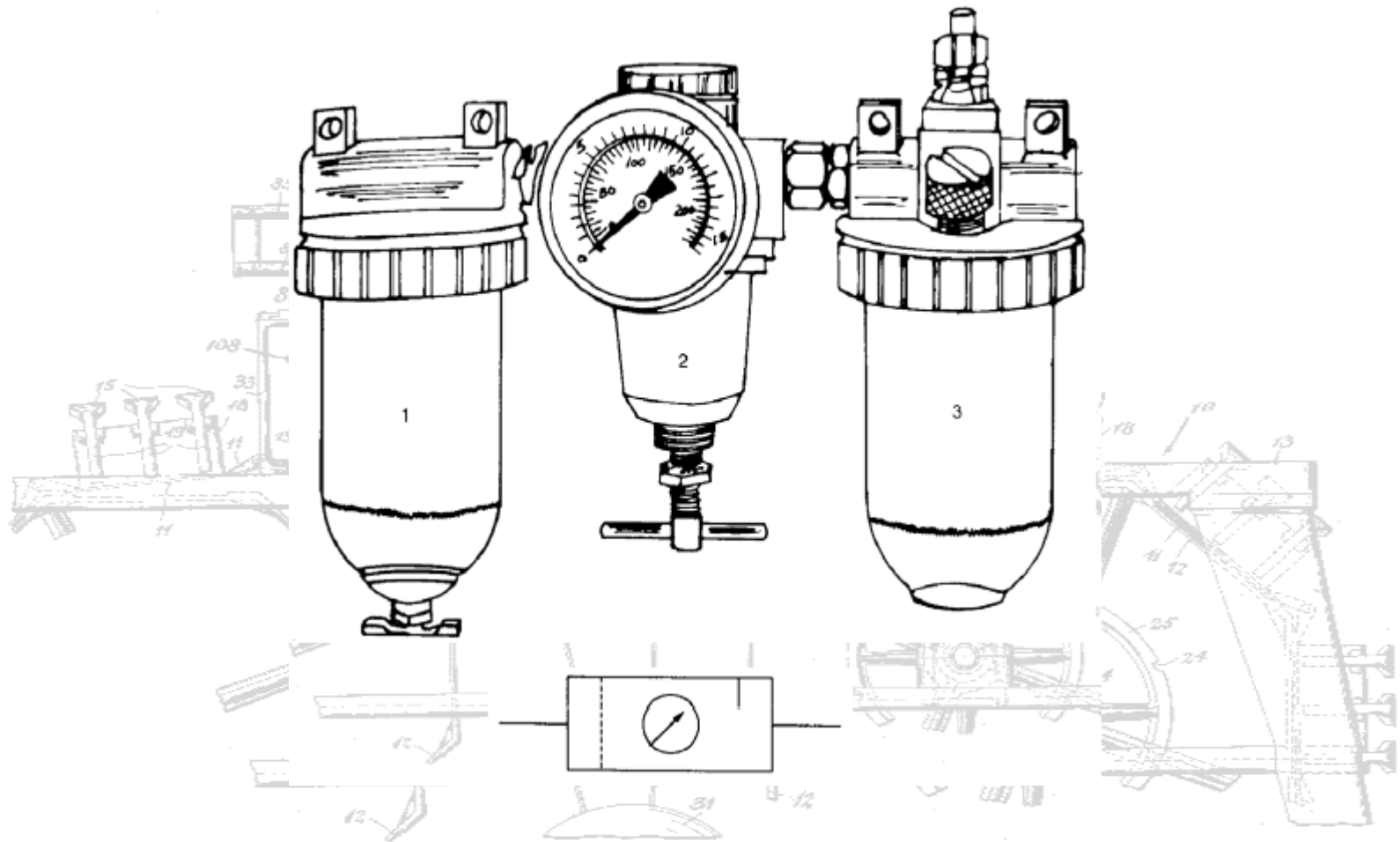
- Ideal Gas Law: $PV = mRT$
- Boyle's Law: $P_1V_1 = P_2V_2$



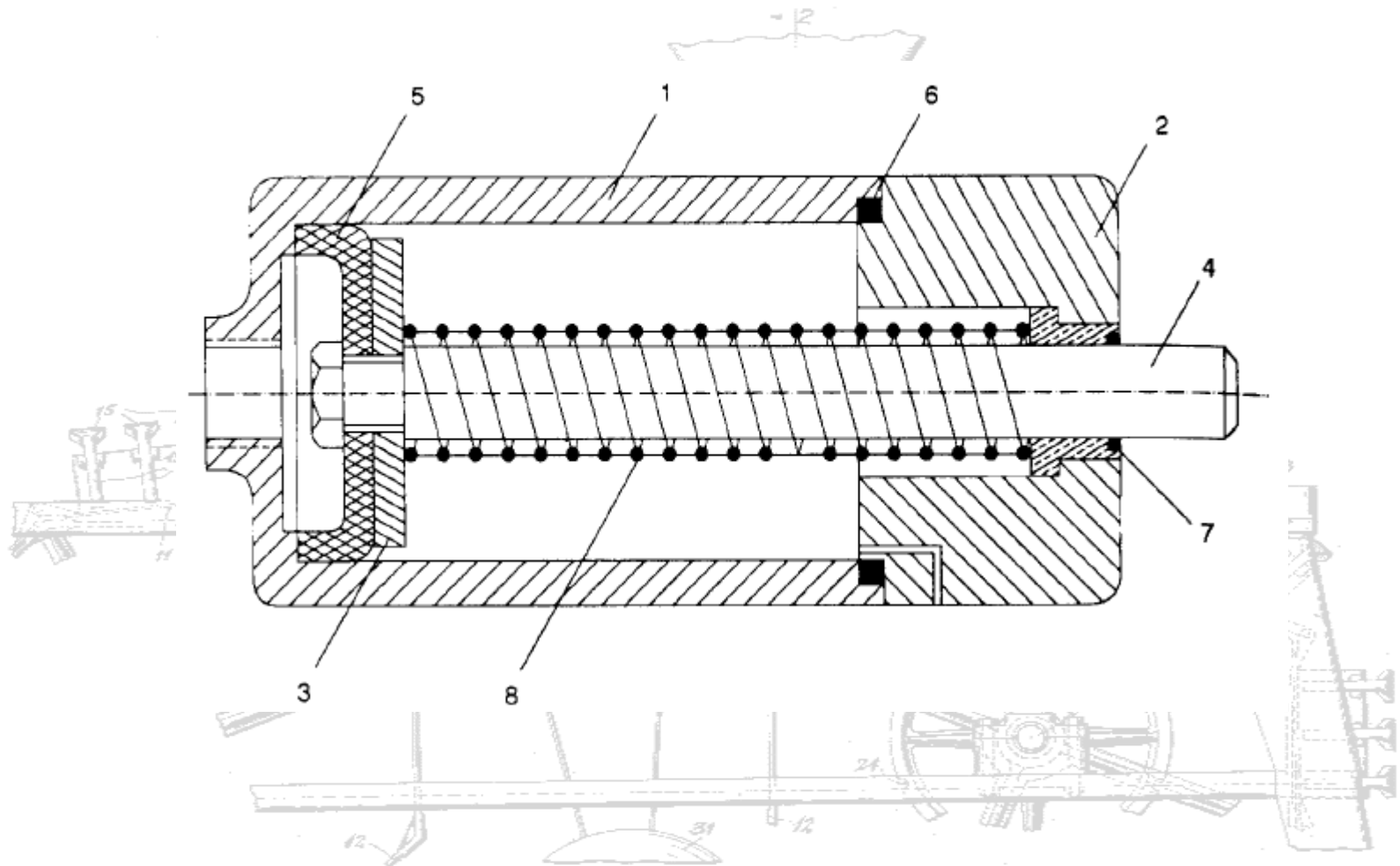
Pneumatic System Layout



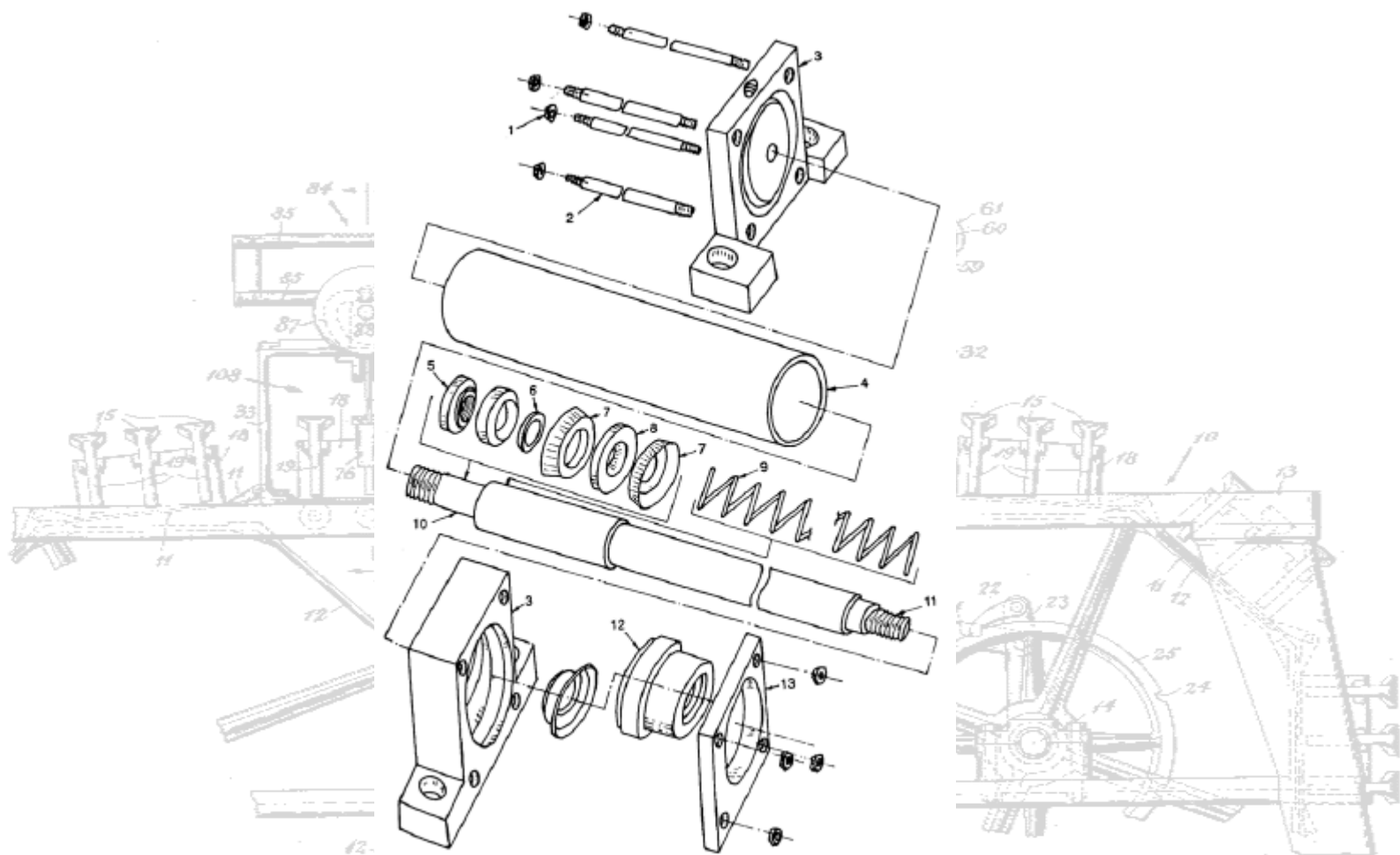
Air Preparation



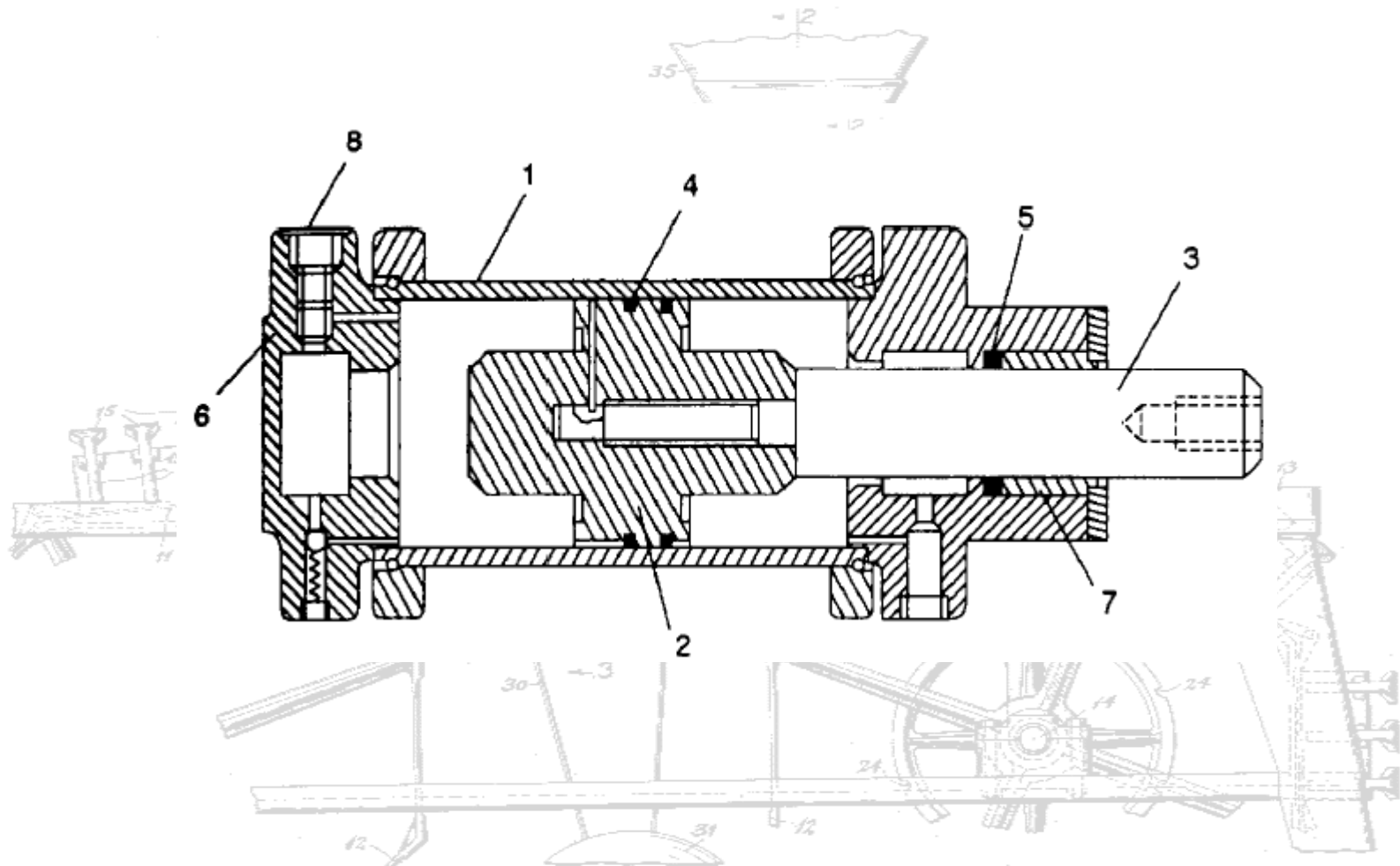
Single-Acting Cylinder



Single-Acting Cylinder

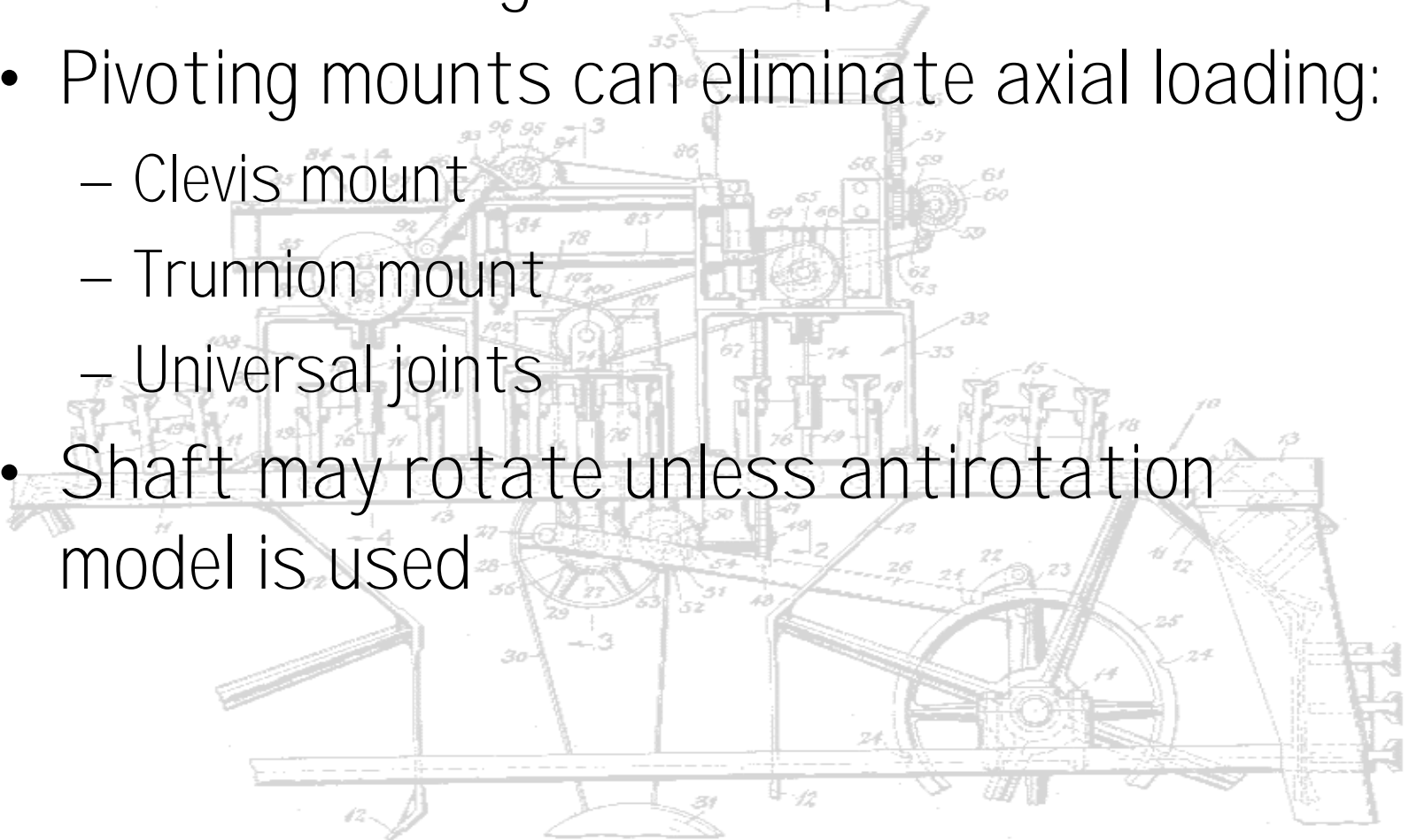


Double-Acting Cylinder



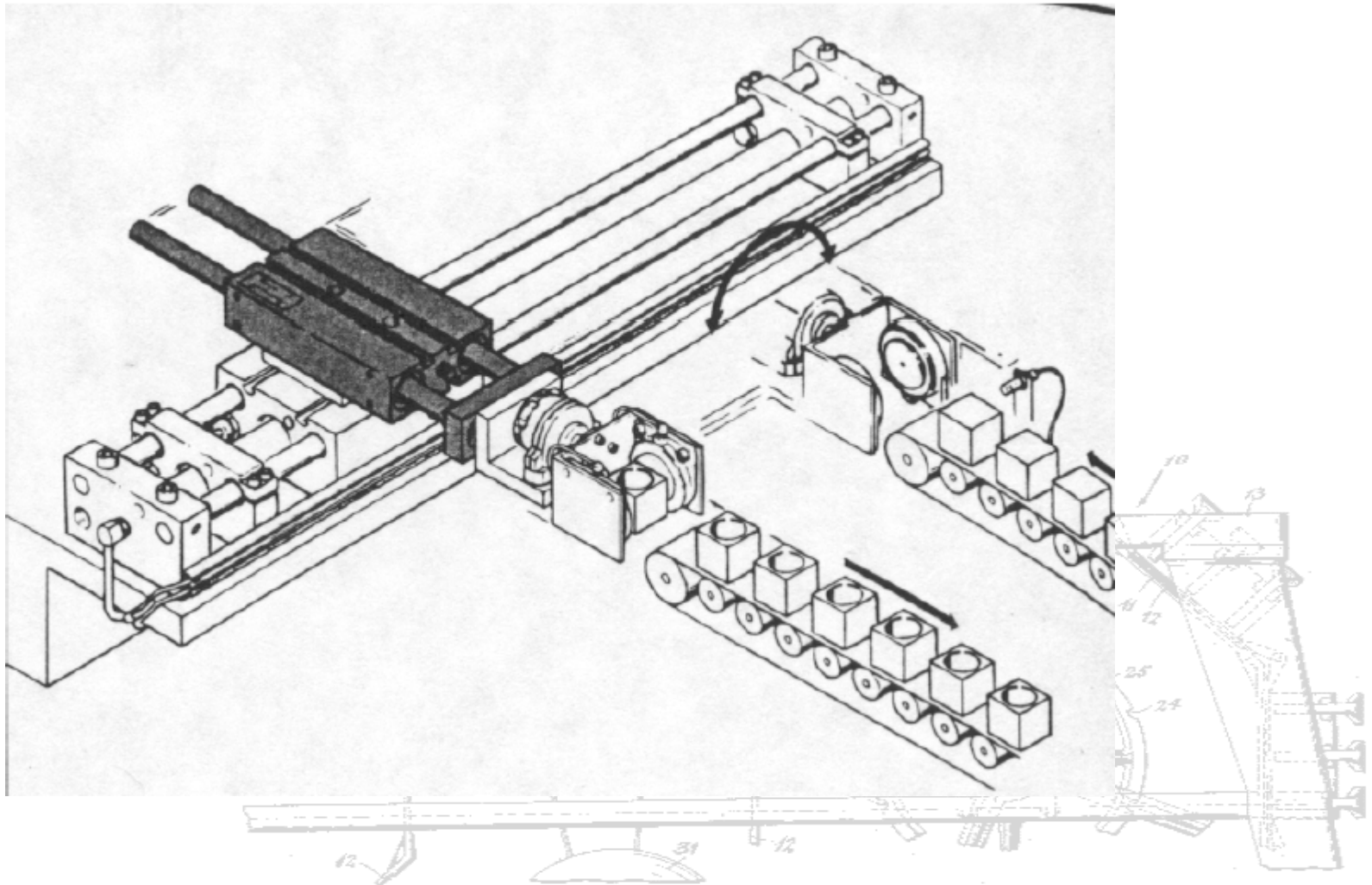
Pneumatic Cylinder Mounting

- 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



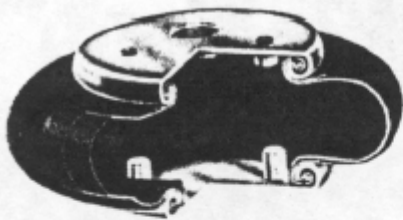
Technical drawings of a circular trunnion component. The left drawing is a top view showing a circular face with a central hub, eight bolt holes arranged in a circle, and two side flanges. Dimensions TA, TB, and TD S.S are indicated. The right drawing is a side view showing the profile of the component with dimensions TH and TC + stroke. Labels 'Head Trunnion TH Mounting' and 'Cap Trunnion TC Mounting' are present.

Pneumatic Twin Cylinder

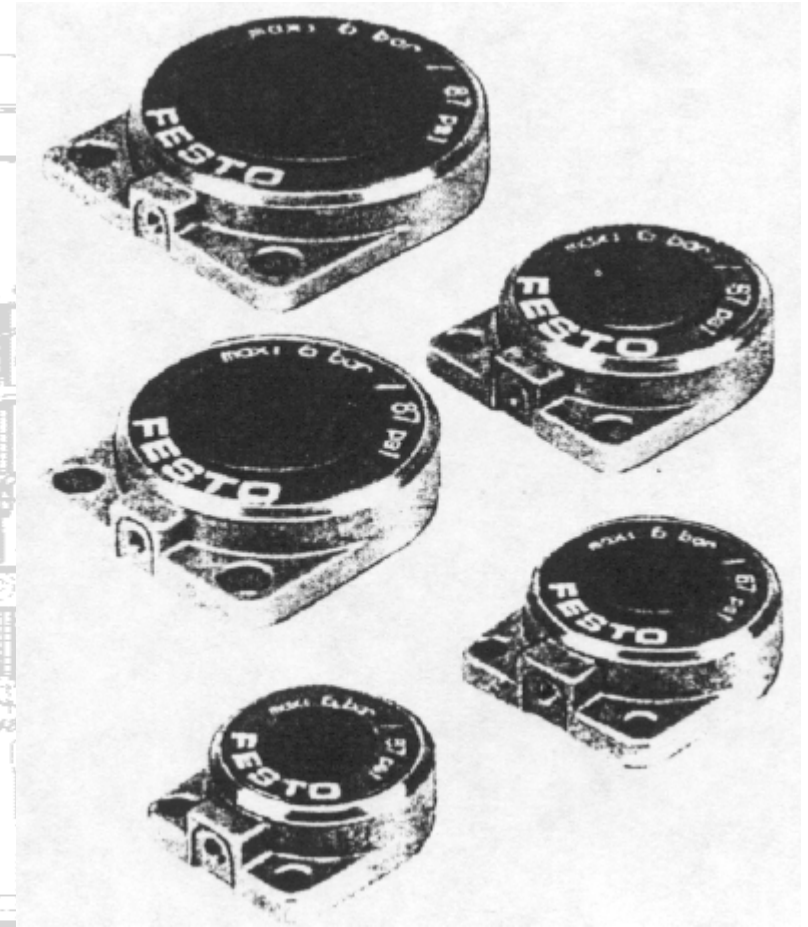
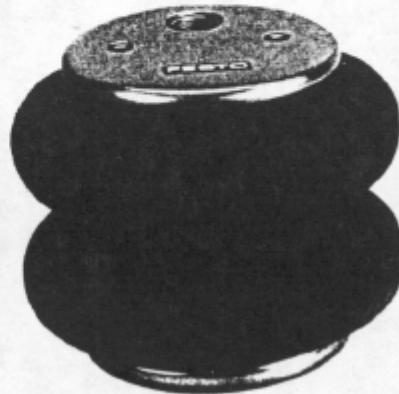
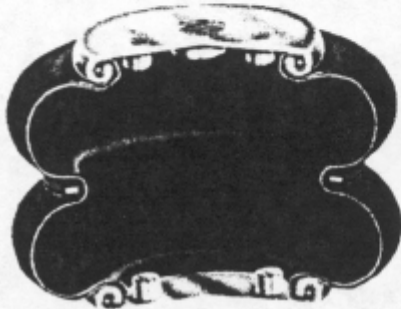


Pneumatic Bellows

Single Fold Bellows Cylinder

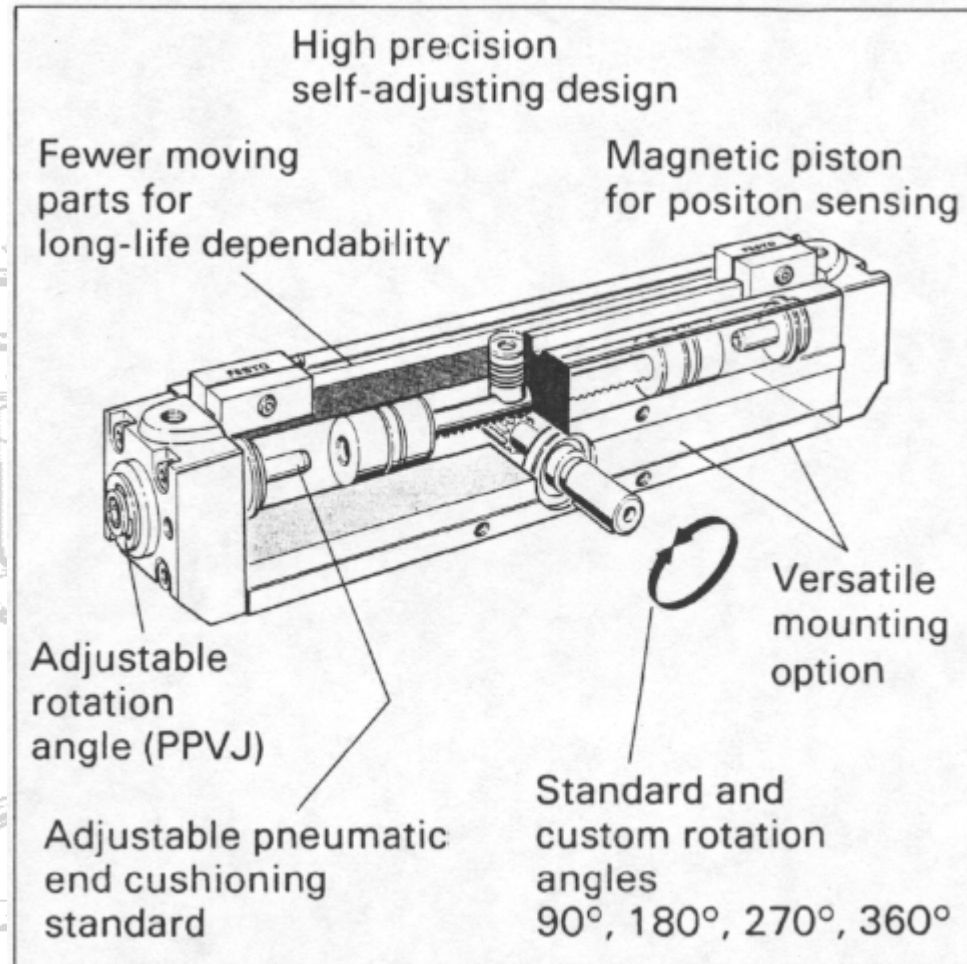


Double Fold Bellows Cylinder

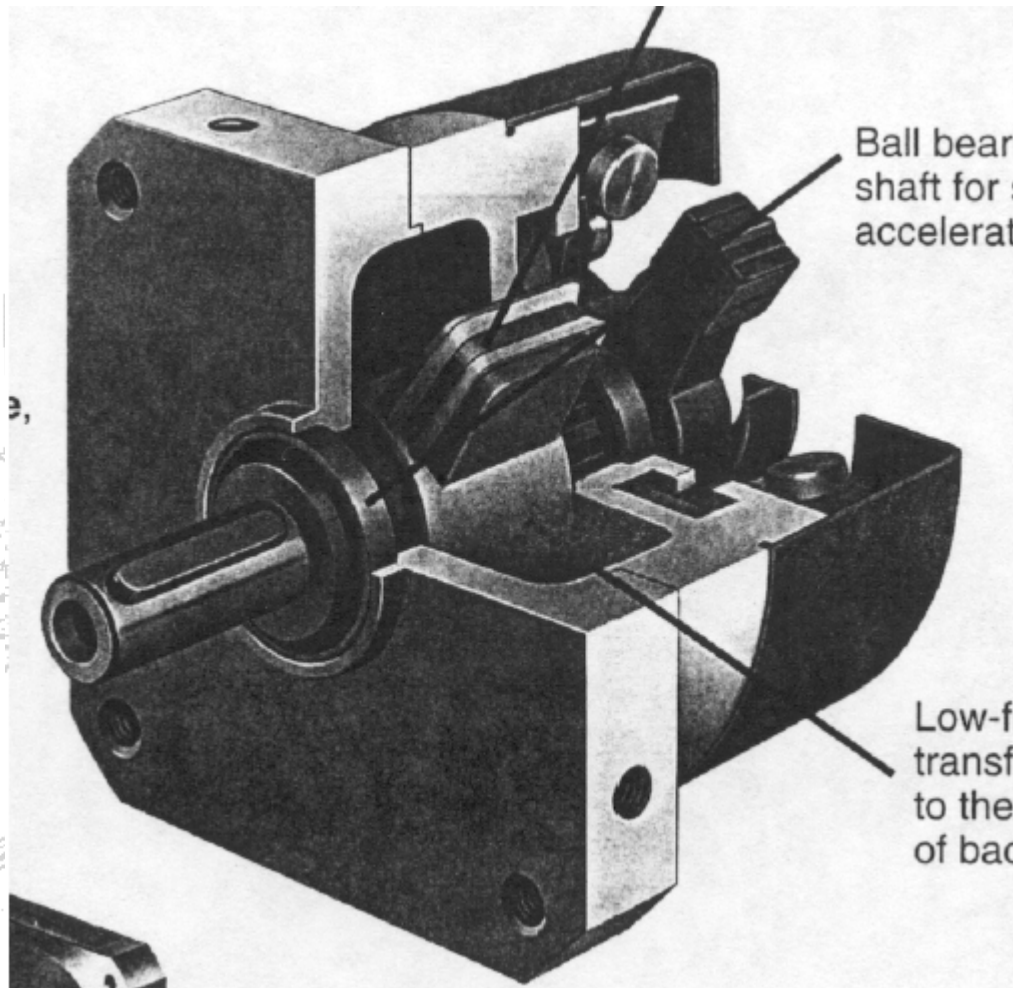


Technical drawing of a mechanical device, likely a pump or engine component. The drawing includes a perspective view and a cross-sectional view. The perspective view shows a main body with a central shaft and a large flywheel, and a separate component with a series of vertical slots. The cross-sectional view shows the internal arrangement of the slots and the shaft. Various parts are labeled with numbers 1 through 35.

Pneumatic Rotary Actuators

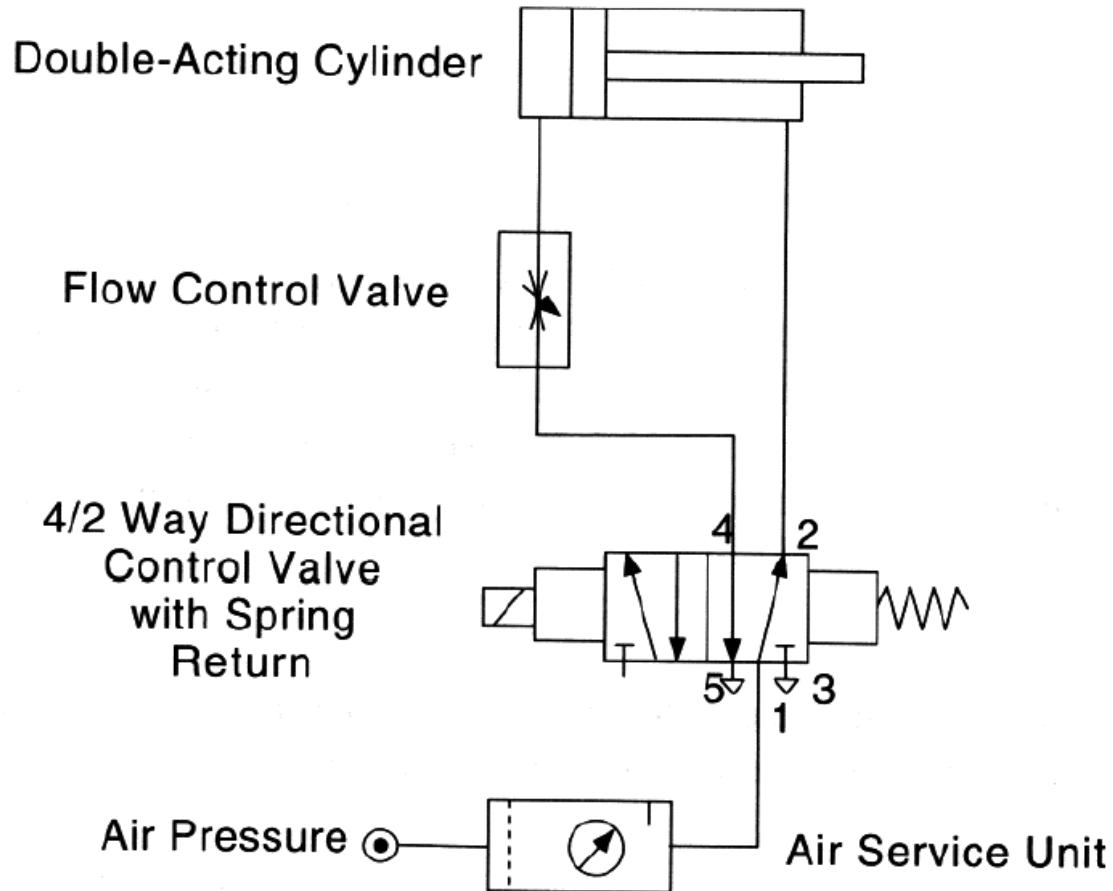


Pneumatic Rotary Actuators



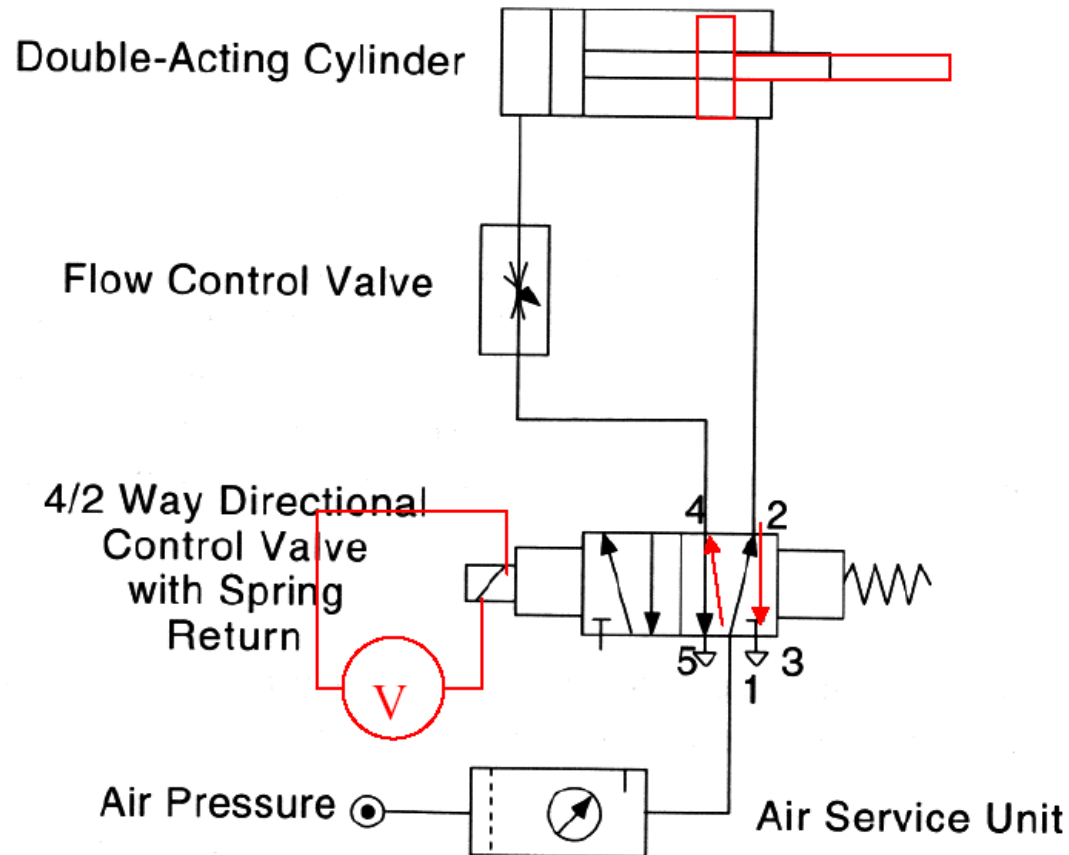
Pneumatic Schematics

Not actuated

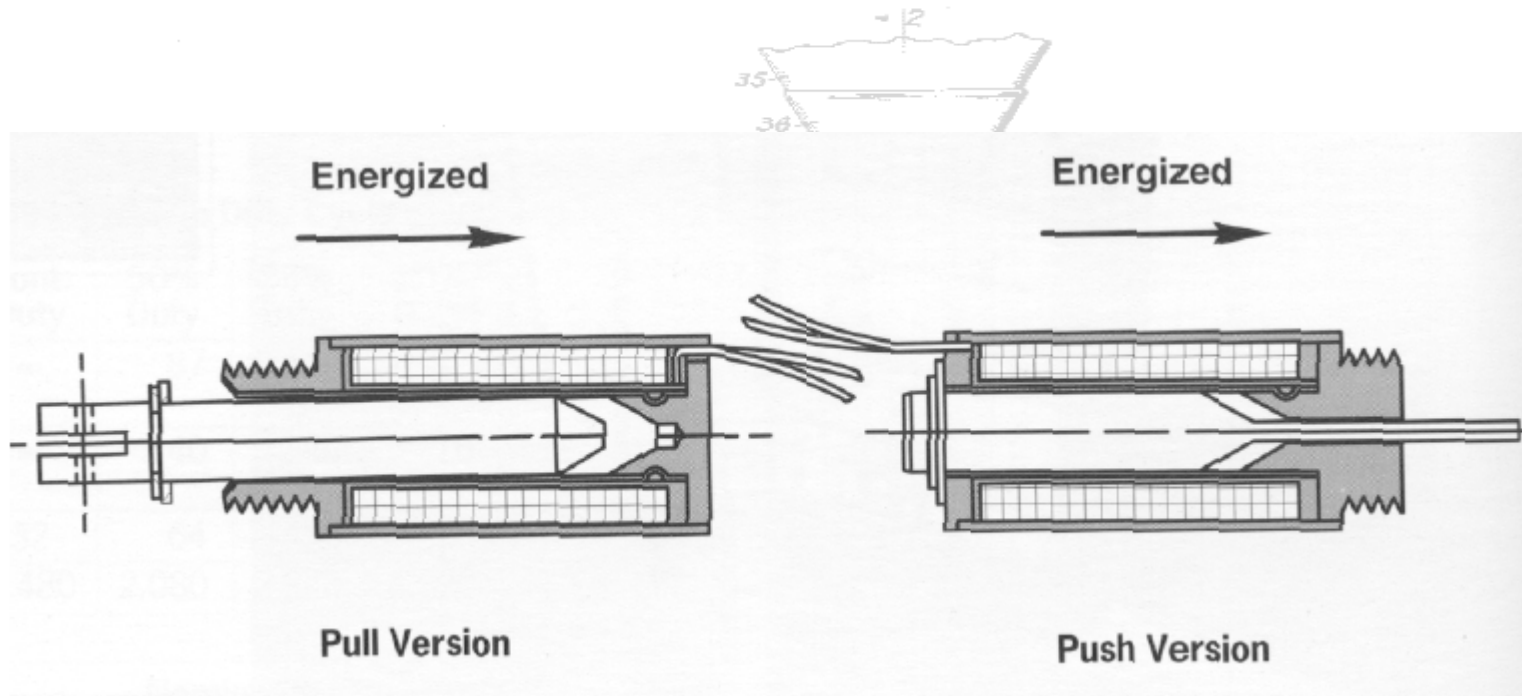


Pneumatic Schematics

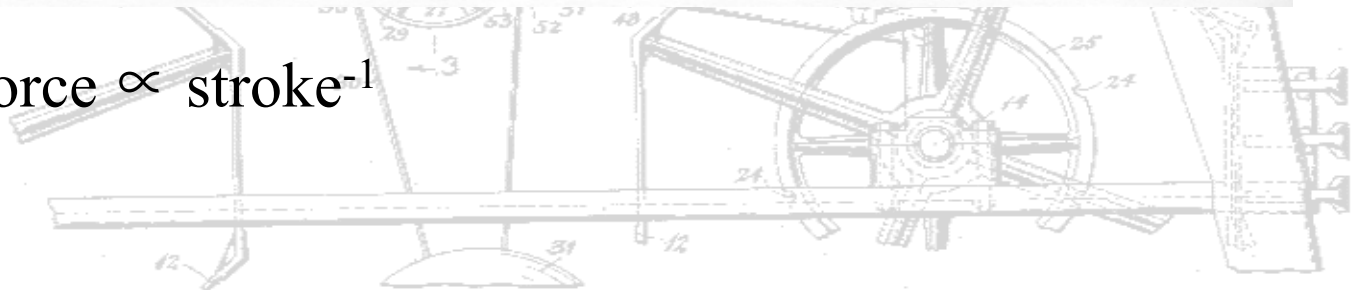
Actuated



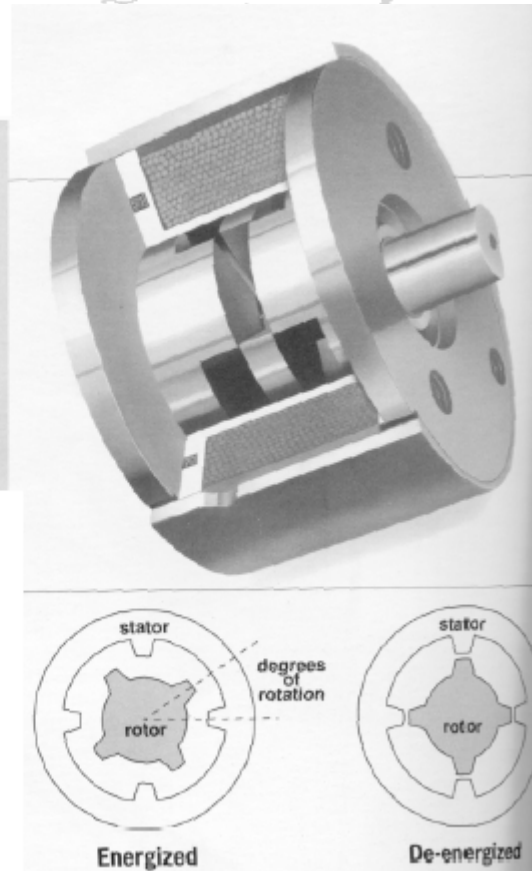
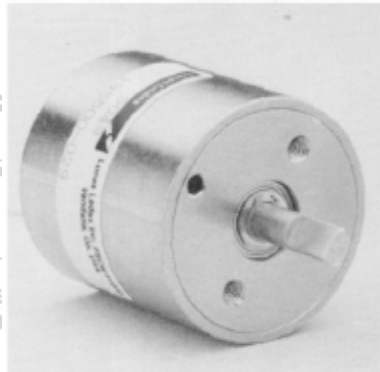
Electric Solenoids



$$\text{Force} \propto \text{stroke}^{-1}$$



Electric Rotary Actuator (solenoid)



Electric Rotary Actuators (motors)

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

