

A large, vibrant red splatter graphic that serves as a background for the word 'Artisan's'. The splatter has several smaller red droplets extending from its edges.

Artisan's

A rectangular metal plate with a grey and black color scheme. It features four hexagonal bolts at the corners and a series of small black arrows pointing outwards from the edges of the text.

ASYLUM



Introduction to Hydraulics

Gui Cavalcanti

4/17/2012

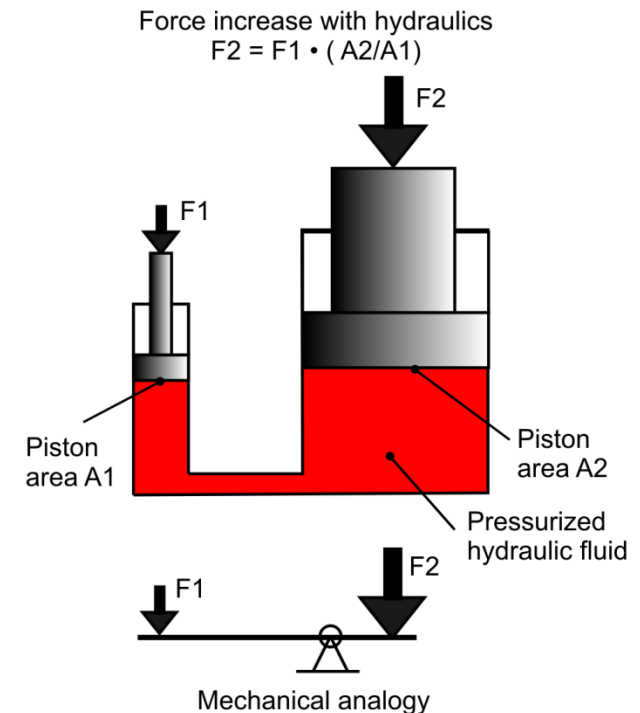
Definition



- **Transmission of mechanical power via incompressible liquids**

- **Hydraulic Power =**
Flow X Pressure
- **Pressure X Area = Force**
- **Flow / Area = Velocity**

- **“Liquid gearing”**



Typical Hydraulic System

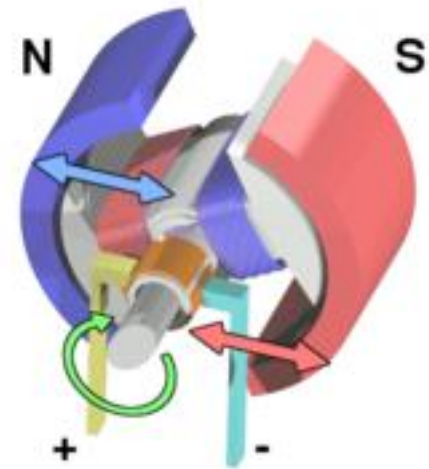


- **One centralized powerplant**
 - **Constant pressure (1,500 to 5,000 psi)**
 - **Variable (demand-based) flow rate**
 - **Flow-control or on/off valves controlling individual actuators**
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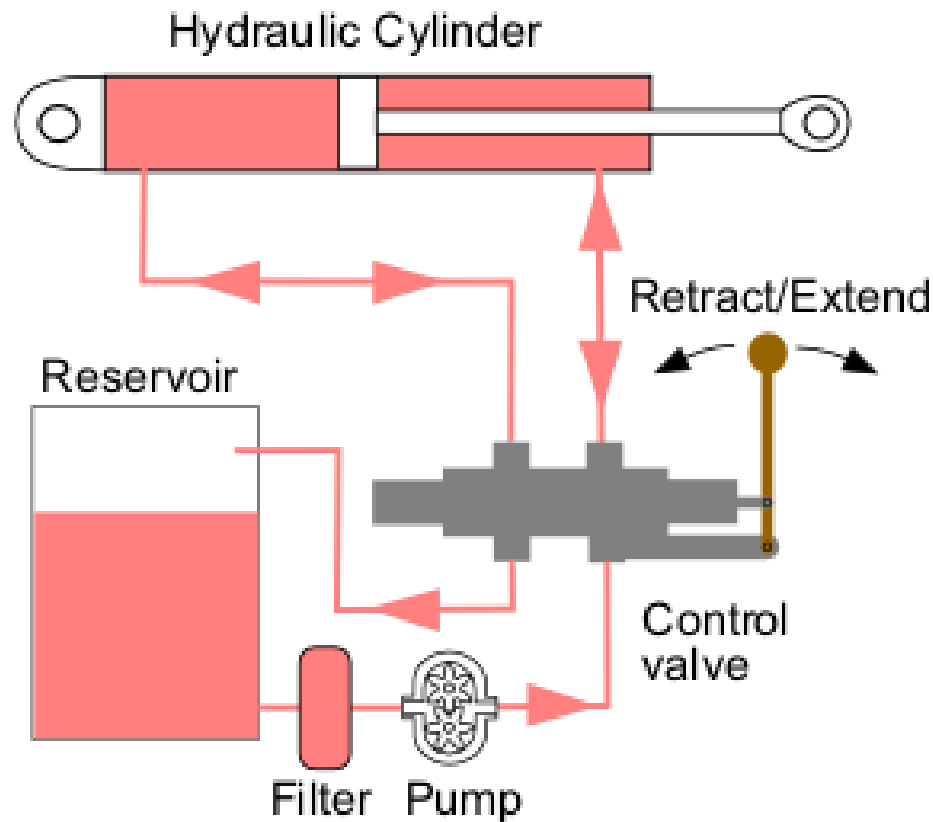
Electric Motor Analogy



- **Imagine a DC electric motor system with the following attributes:**
 - **Constant amperage**
 - **Variable voltage**
 - **Voltage-limited linear amplifiers**
 - **Motors that never burned out**
 - **How would this system behave?**
-



Typical Hydraulic System



System Attributes



- **“Force is free”**
 - **All movement is expensive**
 - **Movement requires power (Flow X Pressure), regardless of physical load**
 - **Any actuator (subject to flow limitations) can produce up to full system power**
 - **Closed valves produce rigid actuators**
 - **Abrupt changes in valves produce abrupt mechanical movements**
-



Example Hydraulic Systems

CAT 320D L



CAT 320D L



- **CAT 320D L Medium-Class Excavator**
 - **52,000 lb operational weight**
 - **6,000 lb arm**
 - **46,000 lb drawbar pull**
 - **35 foot horizontal reach**
 - **25 foot digging depth**
 - **20,000+ lbf digging force**
-

CAT 320D L



**How much power can the CAT 320D L
Excavator's engine generate?**

CAT 320D L



CAT 320D L



148 horsepower

Kia Spectra 2002



- **How much power can my crappy Kia Spectra's engine generate?**
-

Kia Spectra 2002



126 horsepower



Wait. What?

Why?



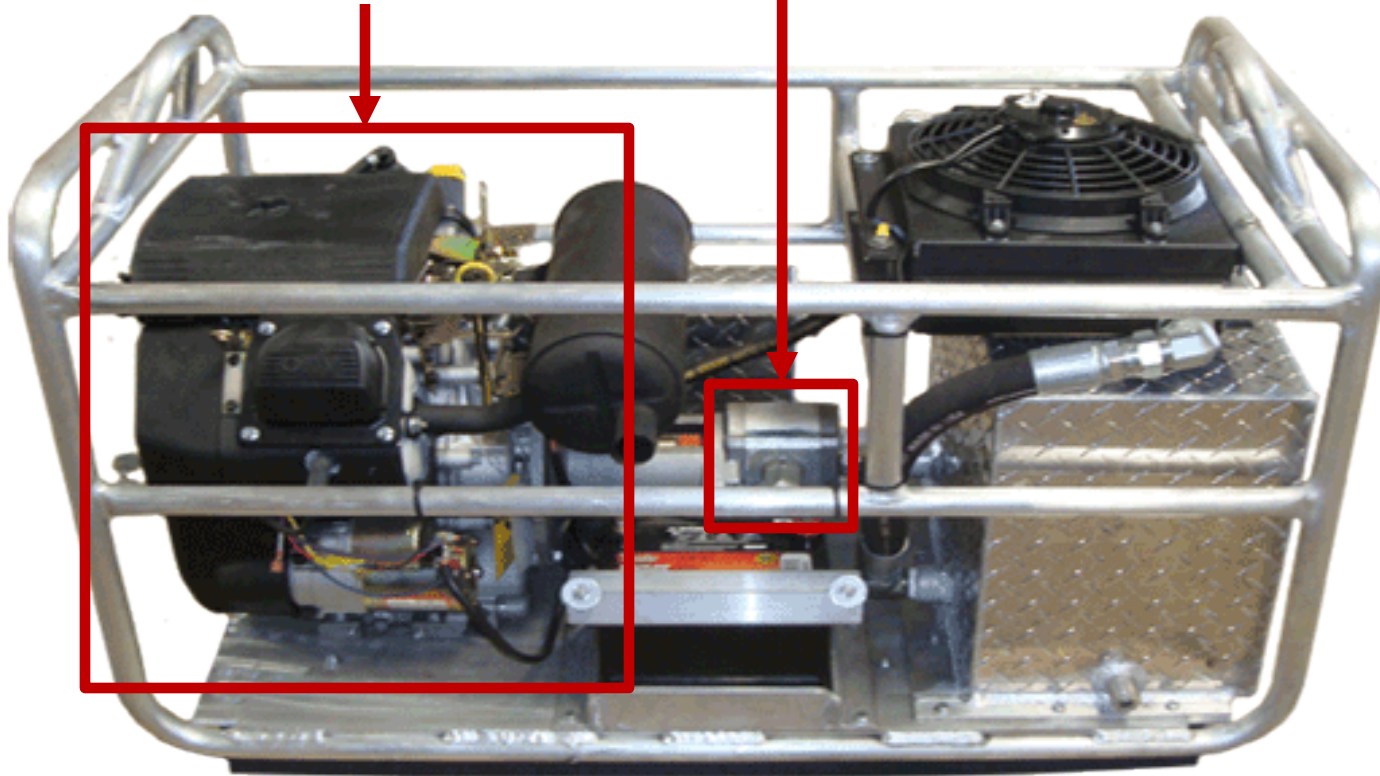
- **Hydraulics offer “perfect” liquid gearing between the powerplant and actuators**
 - **Each joint’s performance is exactly bounded by cylinder size, cylinder placement, valve size, and system pressure**
 - **Raw power at low speeds = high forces**
-

Hydraulics



Engine

Pump



Hydraulics



- **Hydraulics look “small”**
 - **Fluid is incompressible; no big chambers are required for compression**
 - **Limitations on size: material properties, bearing ratings, money you’re willing to spend**
 - **Trade size for heat generation**
-



Hydraulics Safety

Hydraulics Safety



- **Hydraulic systems can harm you in multiple ways. They can easily:**
 - **Burn you**
 - **Cut off limbs**
 - **Cause gangrene**
 - **Cause blunt trauma**
-

Hydraulics Safety



- **Maintain a significant distance between you and any working hydraulic equipment**
 - **Never service equipment while it's running**
 - **Report any leaks immediately**
 - **Never leave a fitting partially tightened; either it's on or it's off all the way**
 - **Beware leaks in hoses**
 - **Assume parts can fly off at any time**
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Requisite Terrifying Image

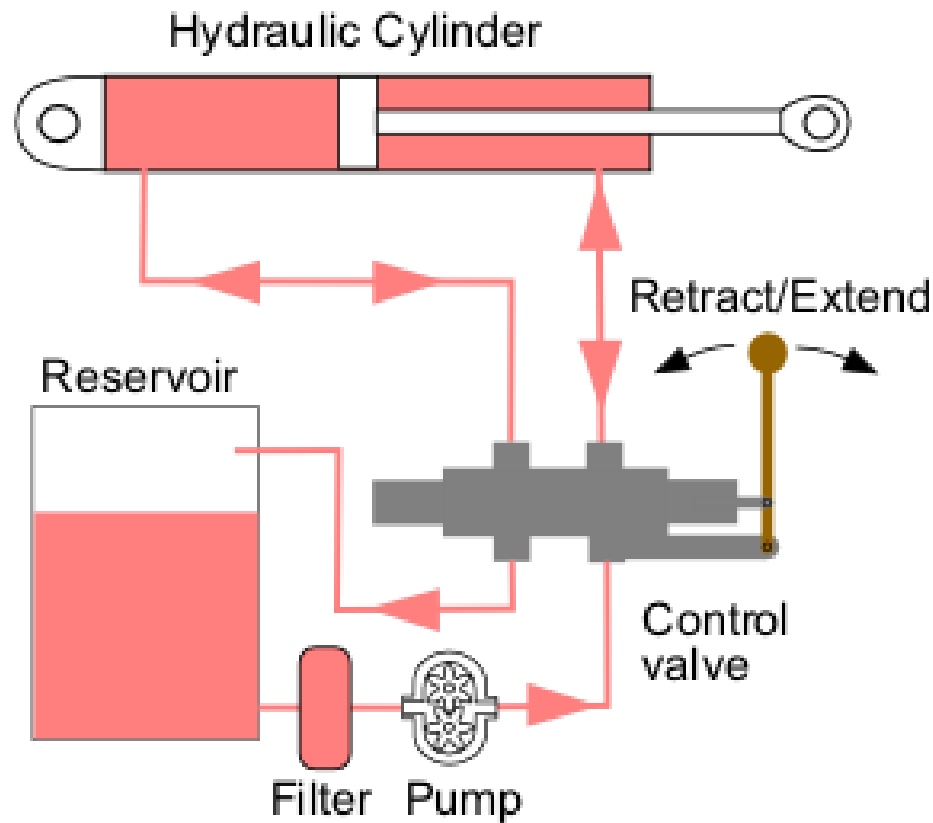
Hydraulics Safety





Hydraulic System Design

Typical Hydraulic System



Hydraulic System Design



- **A couple of standard components:**
 - **Pump system**
 - **Reservoir**
 - **Accumulator**
 - **Oil Cooler**
 - **Filters**
 - **Valves**
 - **Actuators**
-

Pump System

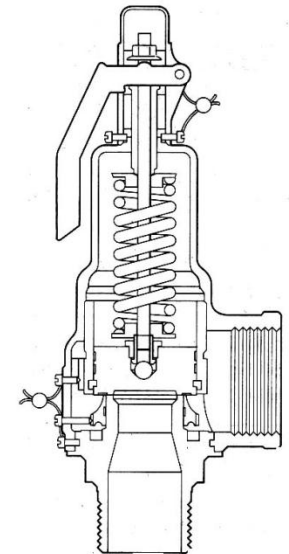
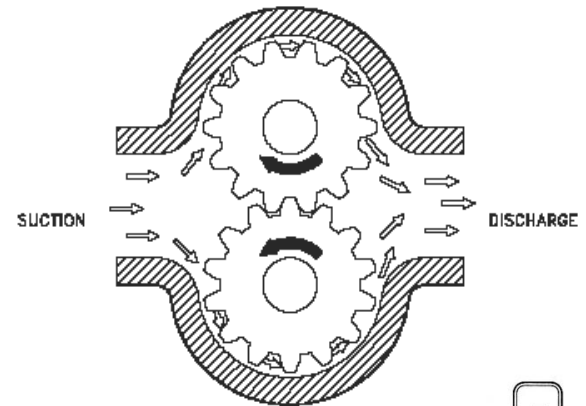


- **Purpose:**
 - **Provide fixed pressure (generally, 1,500 to 5,000 psi) constantly, and flow on demand**
 - **Solutions (in order of price, low to high):**
 - 1. Create fluid flow constantly, but “dump” unused high pressure fluid (Industrial equipment)**
 - 2. Create fluid flow as needed using human-controlled pumps (Lawn mowers, hydraulic tools)**
 - 3. Create fluid flow as needed using mechanically-intelligent pumps (Airplanes, Boston Dynamics)**
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Gear Pumps/Relief Valves



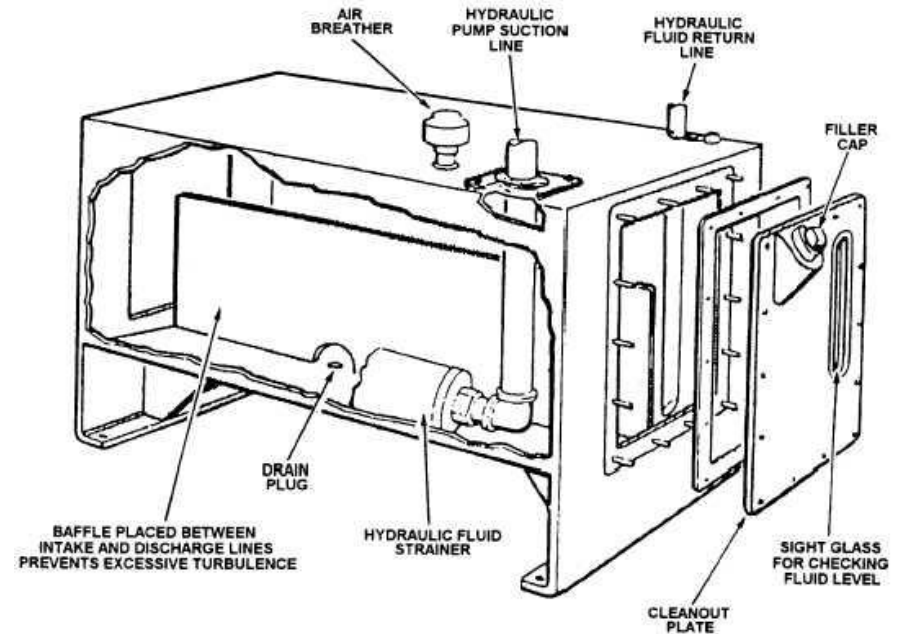
- **Fixed displacement pump**
 - Move X volume per revolution via interface between gear teeth and chamber wall
 - Engine spinning at a given RPM produces a given flow rate
- **Relief valve opens at Y psi**
 - System builds up pressure to Y psi
 - Any flow past the system demand flows through the bleed valve and into reservoir



Reservoir

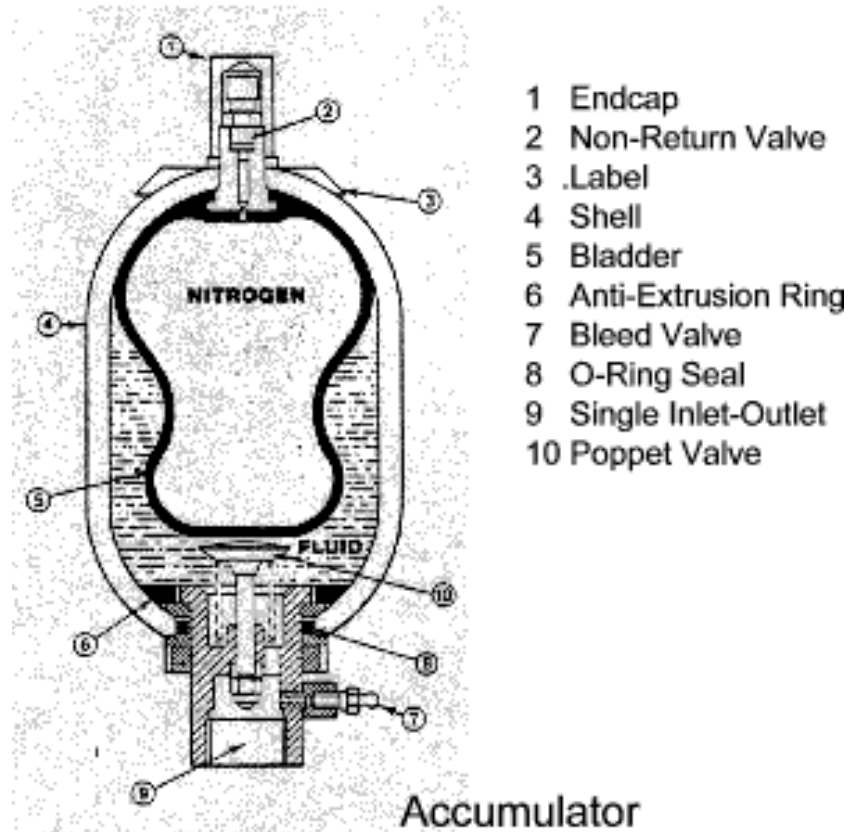


- **Purpose:**
 - **Hold excess fluid**
 - **Prevent turbulence**
 - **Cool fluid**
- **Two main types of circuits:**
 - **Closed Circuit: No access to air. Reservoir is spring-loaded to a fixed low pressure.**
 - **Open Circuit: Ready access to air. Reservoir is at atmospheric pressure.**



Accumulator

- **Purpose:**
 - Even out flow spikes on high pressure side due to actuator demands
- **Solutions:**
 - Embed a high-pressure gas bladder in a liquid tank
 - Spring-load a plunger



Oil Cooler



- **Purpose:**
 - **Hydraulic systems are generally <50% efficient; everything else becomes heat**



Filters



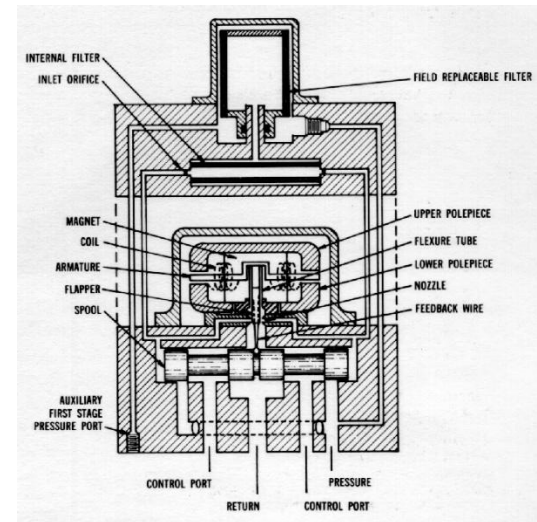
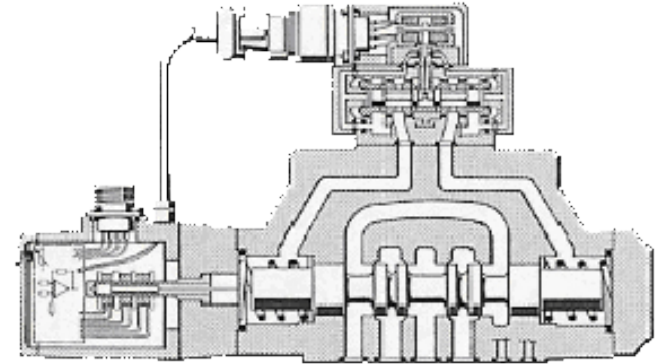
- **Purpose:**
 - **Keep particulates out of reservoir and pump**
- **Particles as small as 10 microns can irretrievably damage a pump**



Valves



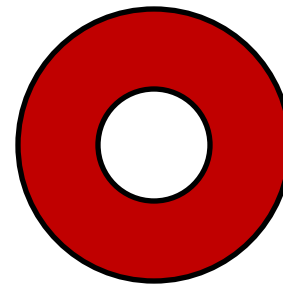
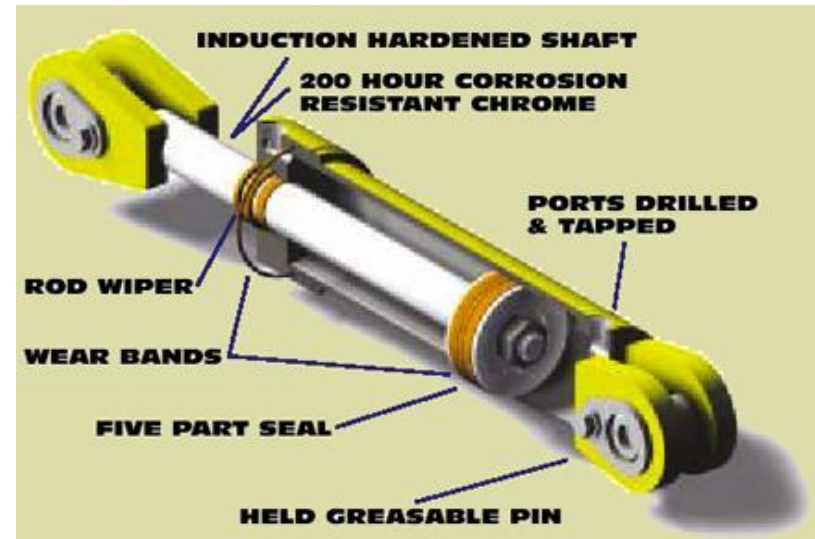
- **Purpose:**
 - **Control fluid flow to actuators**
- **Solutions:**
 - **Solenoid valves (1 Hz; on/off)**
 - **Proportional valves (10 Hz; tuned spring, current-controlled coils)**
 - **Servo valves (100 Hz; small motors, tiny nozzles)**



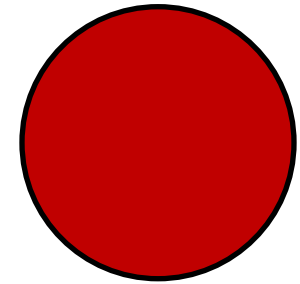
Actuators



- **Purpose:**
 - **Convert pressure and flow into force and velocity**
- **Solutions:**
 - **Cylinders**
 - **Rotary motors**



Retracting Area



Extending Area



Questions?