Pneumatics for FIRST Robots

FIRSTFare 2009

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Overview

- Intro
- Kit of Parts Overview
- Cylinder sizing calculations
- System sizing calculations
- Typical applications on your robot
- Pros and Cons

Pneumatics 101

"the use of a pressurized gas to effect mechanical motion"

- Everyday Uses:
  - Air compressor to fill your tires
  - "Shop air" in industrial shops
    - Air-operated hand tools
    - Air-operated paint sprayers
  - Pneumatic systems for industry
    - Packaging lines
    - Blow molded milk bottles
  - The list goes on, pneumatics are everywhere

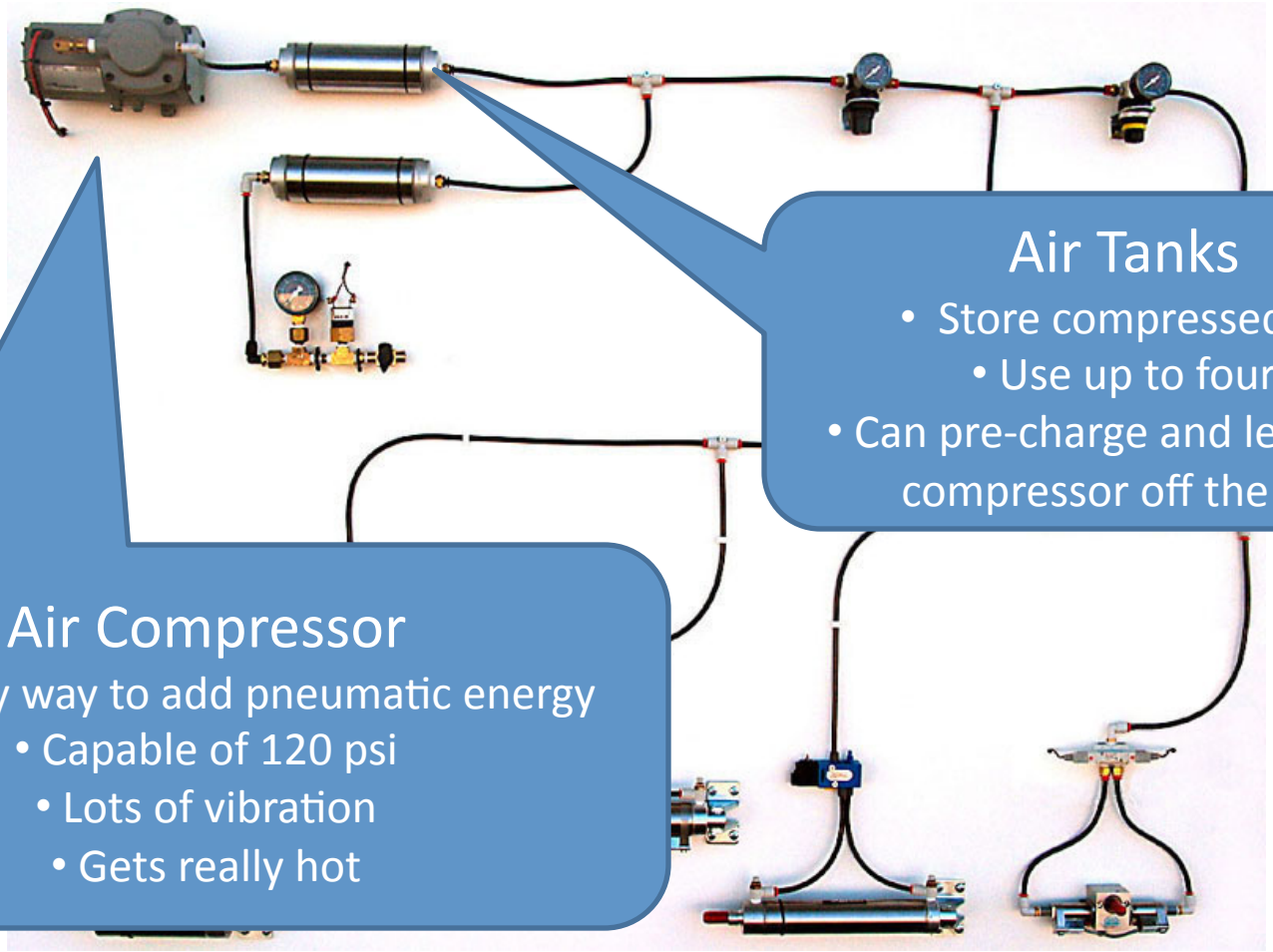
Electrical Analogy

- Pressure = Voltage
- Volume = Capacitance
- Flow rate = Current
- Flow Restrictions = Resistance

- HOWEVER: Air is compressible

  => Some unique non-linearities when compared to electrical systems

2009 Kit of Parts



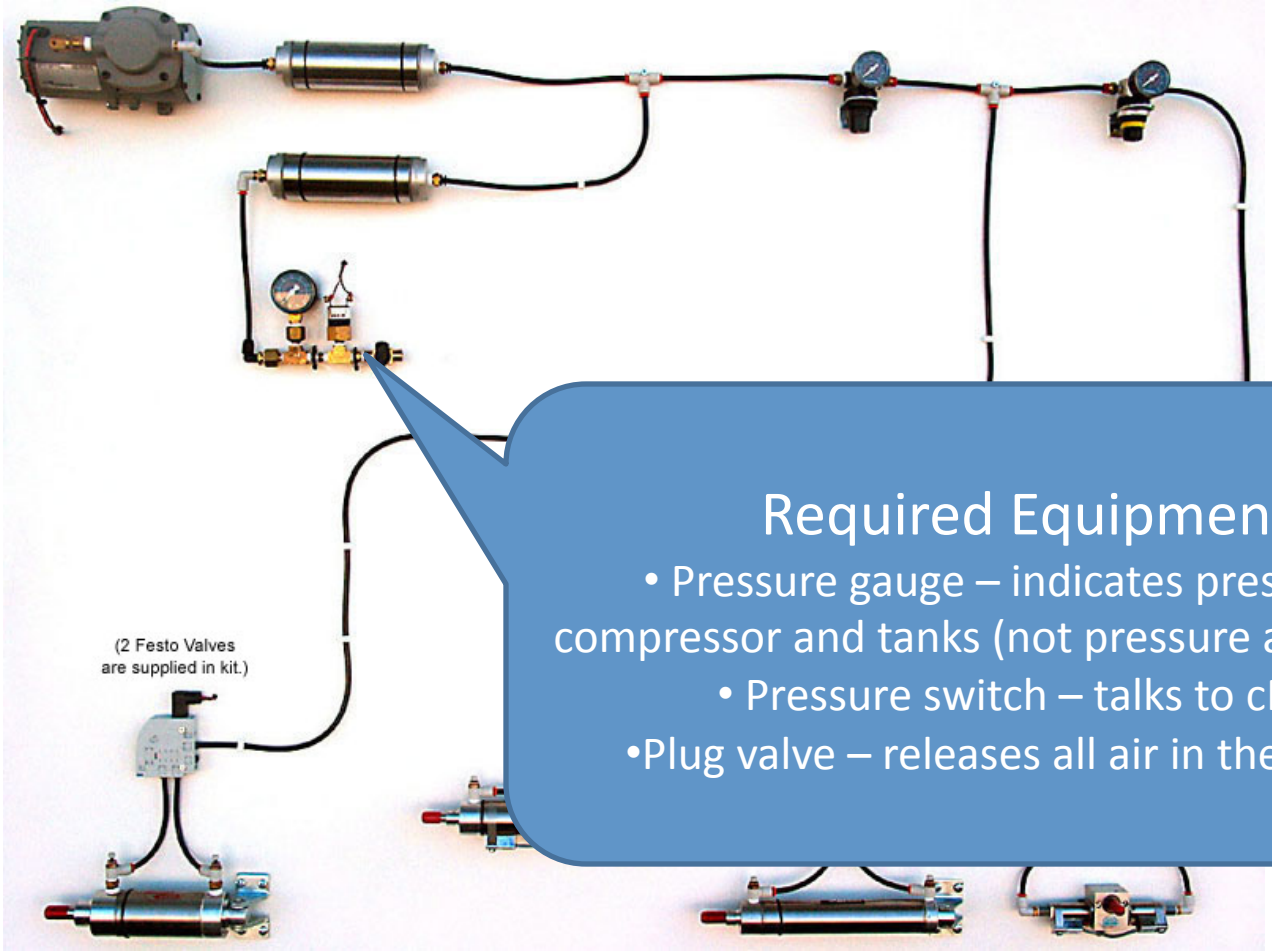
Air Tanks

- Store compressed air
- Use up to four
- Can pre-charge and leave the compressor off the bot

Air Compressor

- The only way to add pneumatic energy
- Capable of 120 psi
- Lots of vibration
- Gets really hot

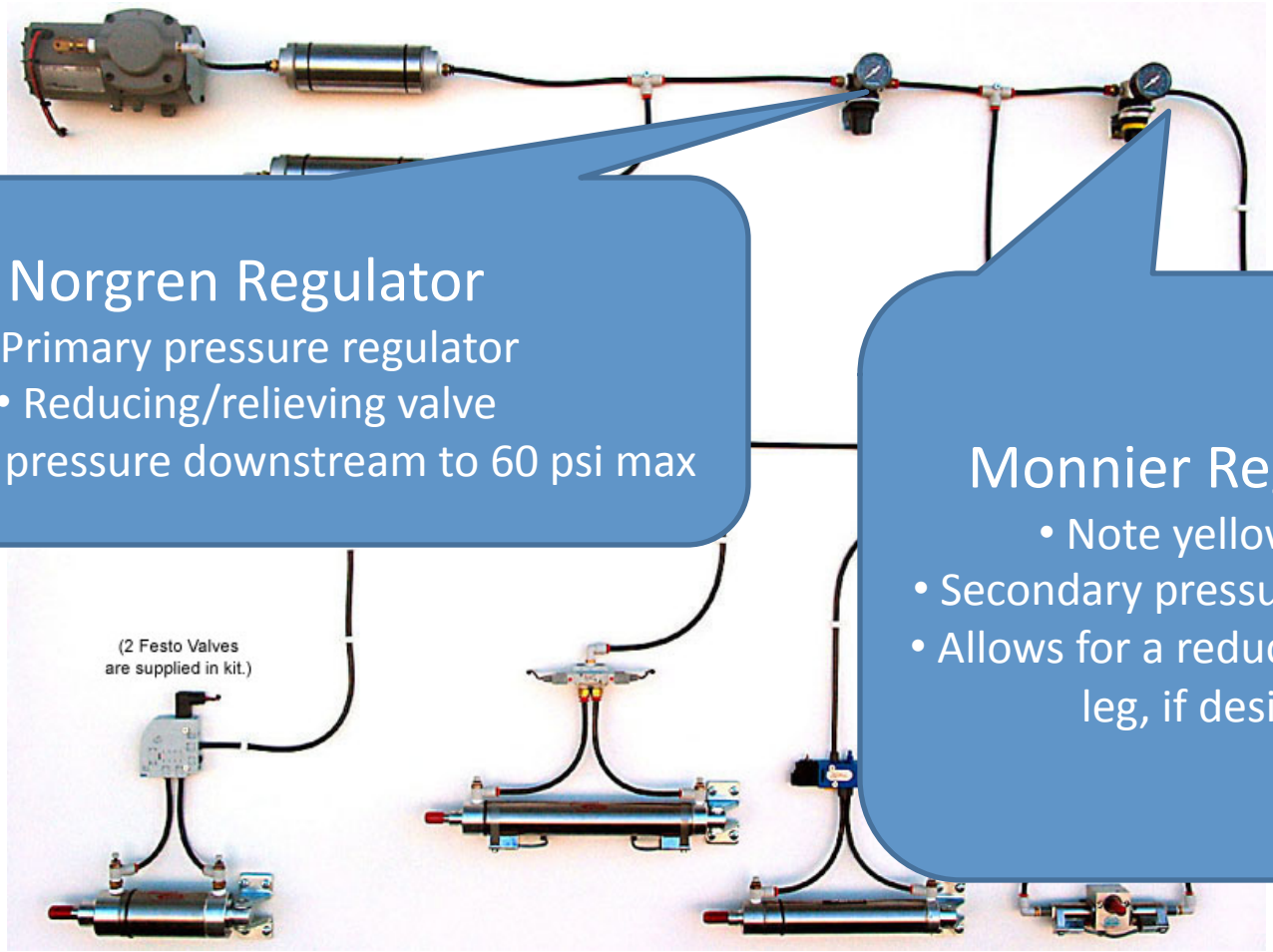
2009 Kit of Parts



Required Equipment

- Pressure gauge – indicates pressure in compressor and tanks (not pressure at cylinders)
- Pressure switch – talks to cRIO
- Plug valve – releases all air in the system

2009 Kit of Parts



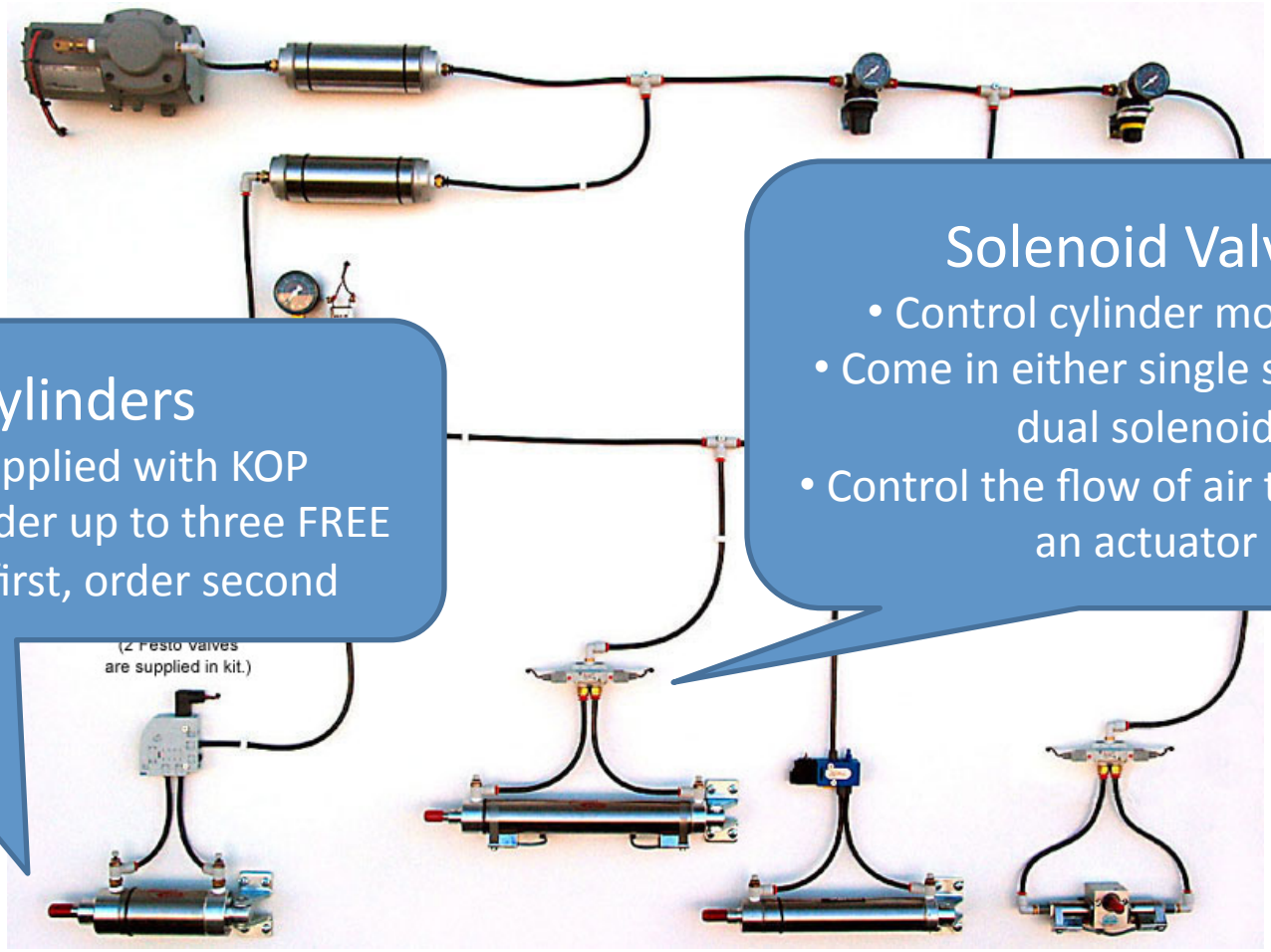
Norgren Regulator

- Primary pressure regulator
- Reducing/relieving valve
- Limits all pressure downstream to 60 psi max

Monnier Regulator

- Note yellow ring
- Secondary pressure regulator
- Allows for a reduced pressure leg, if desired

2009 Kit of Parts



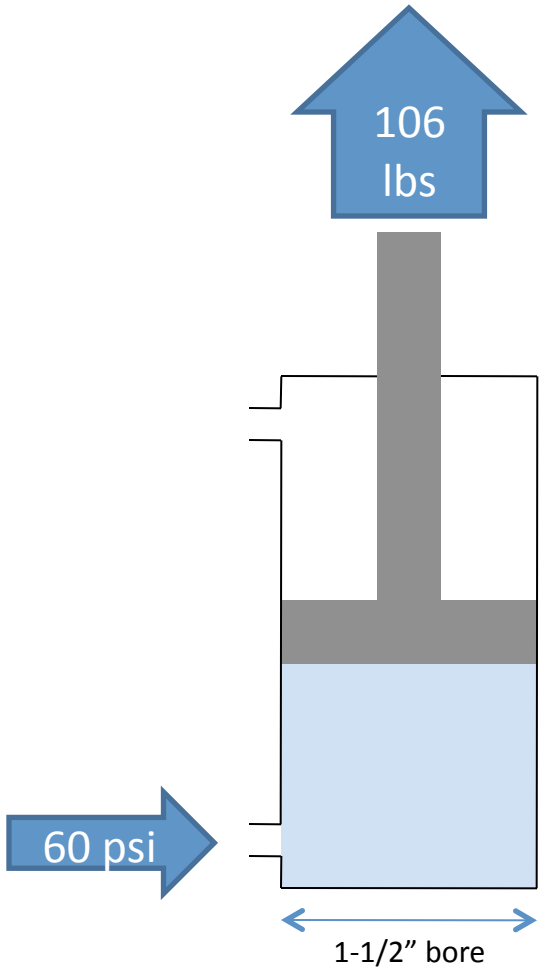
Cylinders

- Not supplied with KOP
- Custom order up to three FREE
- Design first, order second

Solenoid Valves

- Control cylinder movement
- Come in either single solenoid or dual solenoid
- Control the flow of air to and from an actuator

Cylinder Sizing Example



To <u>extend</u> the cylinder, pressurize the <u>cap</u> end port.

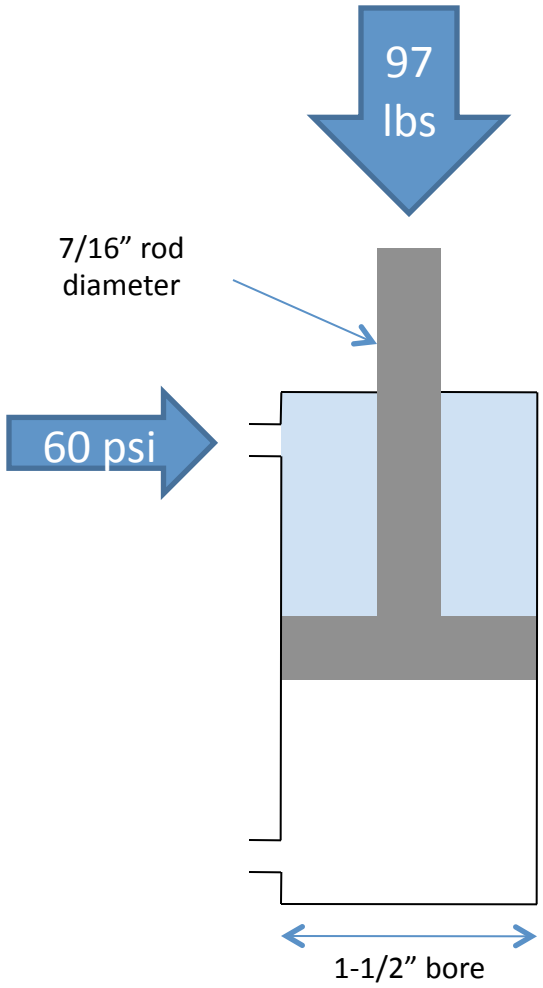
Force (lbs) = Pressure (psi) x Area (in^2)

- Area = $\pi r^2 = \pi * (0.75\ in)^2 = 1.77\ in^2$
- Force = (60 lb / in^2) * (1.77 in^2)
- Force = 106.2 lbs

NOTE:

- Single acting cylinders are only powered in one direction. They require an external force to move in the other direction.
- Double acting cylinders are powered in both directions.

Cylinder Sizing Example



To retract the cylinder, pressurize the rod end port.

Force (lbs) = Pressure (psi) x Area (in^2)

NOTE: The area on the rod end is always less than the area on the cap end.

- Effective Rod End Area = Cap Area – Area of the Rod
- Cap Area = $\pi r^2 = \pi * (0.75\ in)^2 = 1.77\ in^2$
- Rod Area = $\pi r^2 = \pi * (0.21875\ in)^2 = 0.150\ in^2$
- Effective Area = $1.77\ in – 0.150\ in = 1.62\ in^2$
- Force = $(60\ lb / in^2) * (1.62\ in^2)$
- Force = 97.2 lbs

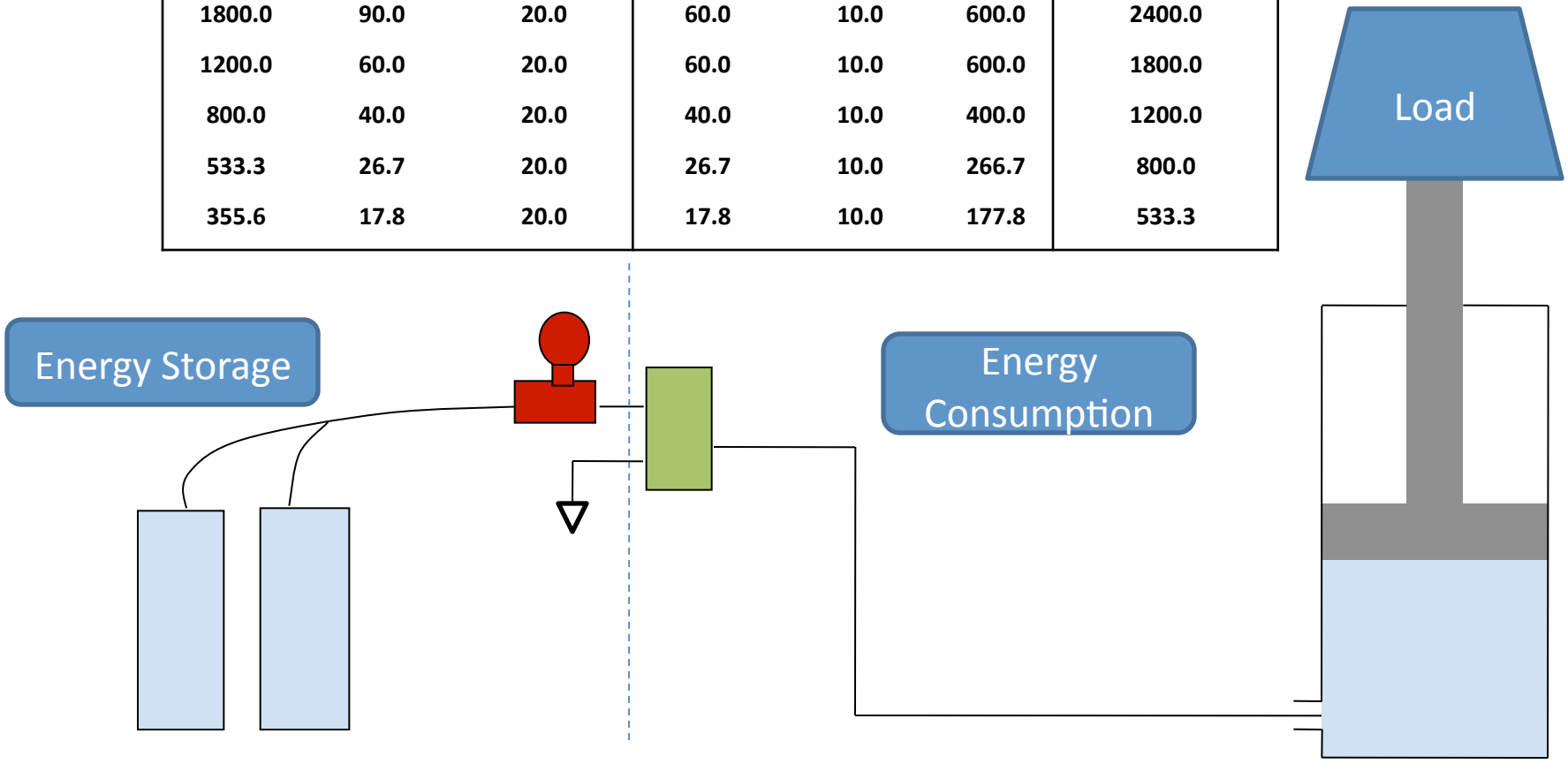
System Sizing Notes

Boyle's Law Says
Pressure * Volume = constant

- Both system pressure and volume are limited quantities
- Therefore, we have a fixed amount of energy that can be stored and used
- To simplify things, we'll introduce a unit of measure call the PEU (pneumatic energy unit)
- PEUs = Pressure x Volume

Energy Usage Example

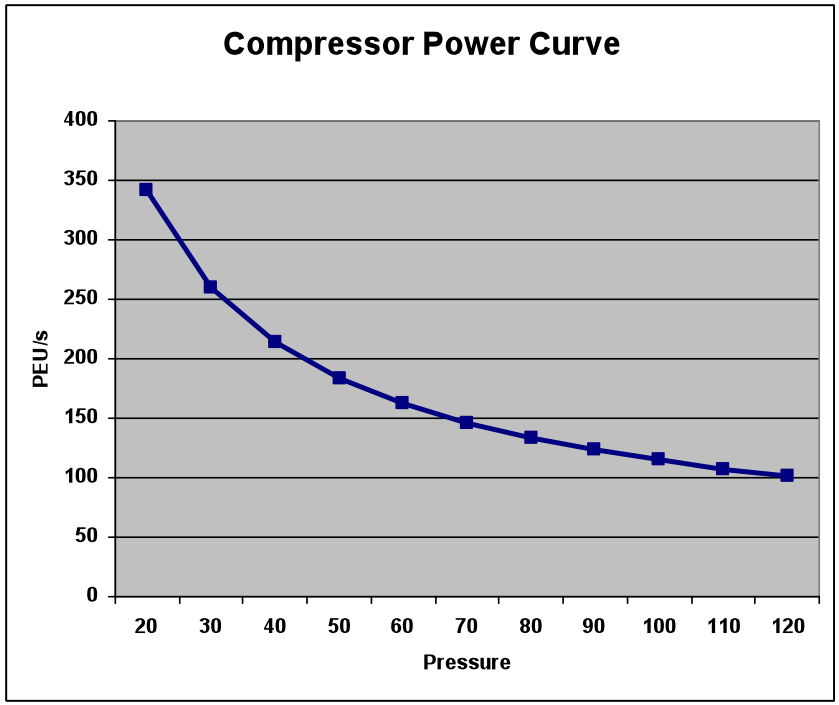
Storage			Consumption			
PEUs	P	V	P	V	PEUs	Total PEUs
2400.0	120.0	20.0	60.0	10.0	600.0	3000.0
1800.0	90.0	20.0	60.0	10.0	600.0	2400.0
1200.0	60.0	20.0	60.0	10.0	600.0	1800.0
800.0	40.0	20.0	40.0	10.0	400.0	1200.0
533.3	26.7	20.0	26.7	10.0	266.7	800.0
355.6	17.8	20.0	17.8	10.0	177.8	533.3



Credit: Raul Olivera

Replacing Used Energy

- Used energy can be replenished by the compressor, but how fast?
- Previous compressor could replace about 110 PEU/s in the cut out range (90 to 120 psig)
- Your mileage may vary – run your own tests!



Pressure (PSI)	PEU/s
20	341.3
30	259.4
40	213.5
50	183.5
60	162.2
70	146.2
80	133.5
90	123.3
100	114.8
110	107.6
120	101.5

Credit: Raul Olivera

Managing the Loss of Energy

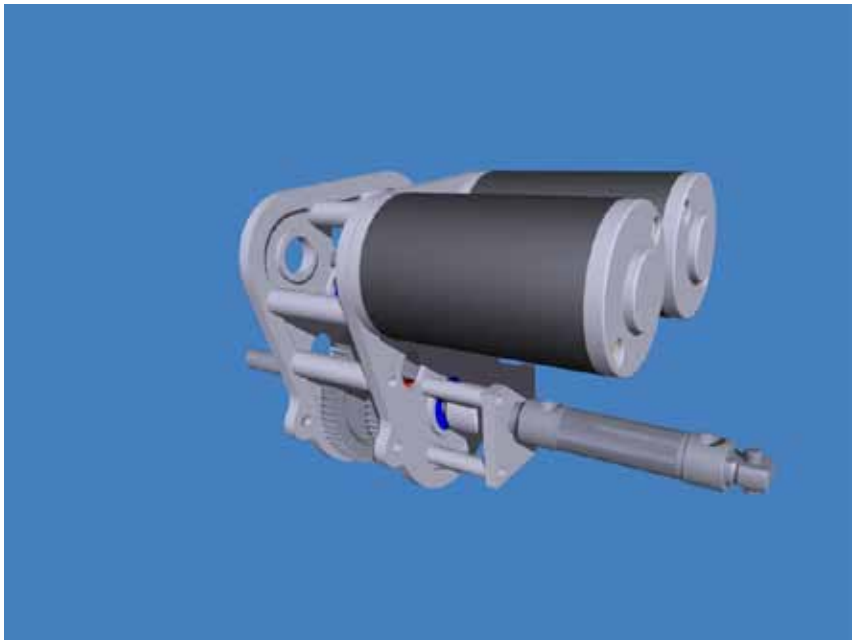
- Use only the amount of energy required, not too much more
- Minimize Volume:
  - tubing length (valve to cylinder)
  - cylinder stroke
  - cylinder diameter
- Minimize regulated pressure
  - But, keep above valve pilot pressure requirement

Typical Applications

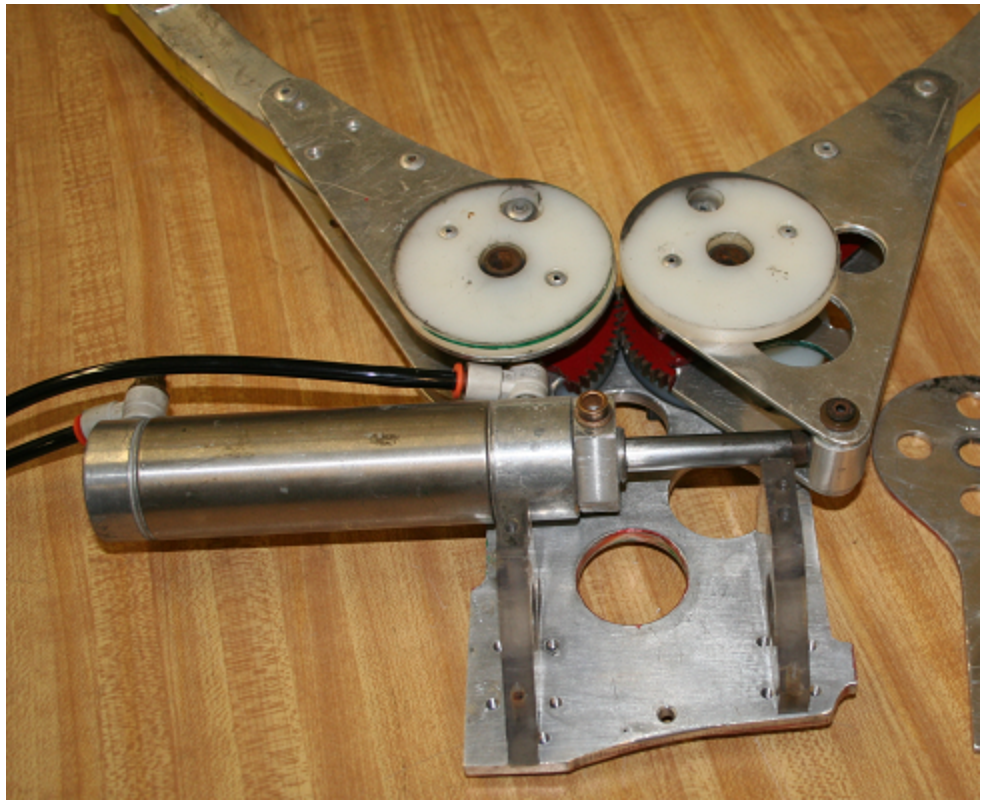
- Two-position linear applications
  - Lifter or gate
  - Transmission shifter
  - Linear pneumatic gripper
  - Braking systems
- Latch release mechanisms

Example: Transmission Shifter

- Toggles between two different gear ratios
  - Low gear = power
  - High gear = speed
- Standard add-on for AndyMark Super Shifter
- Or design your own!
- ¾” bore x ½” stroke cylinder – can easily be used without compressor

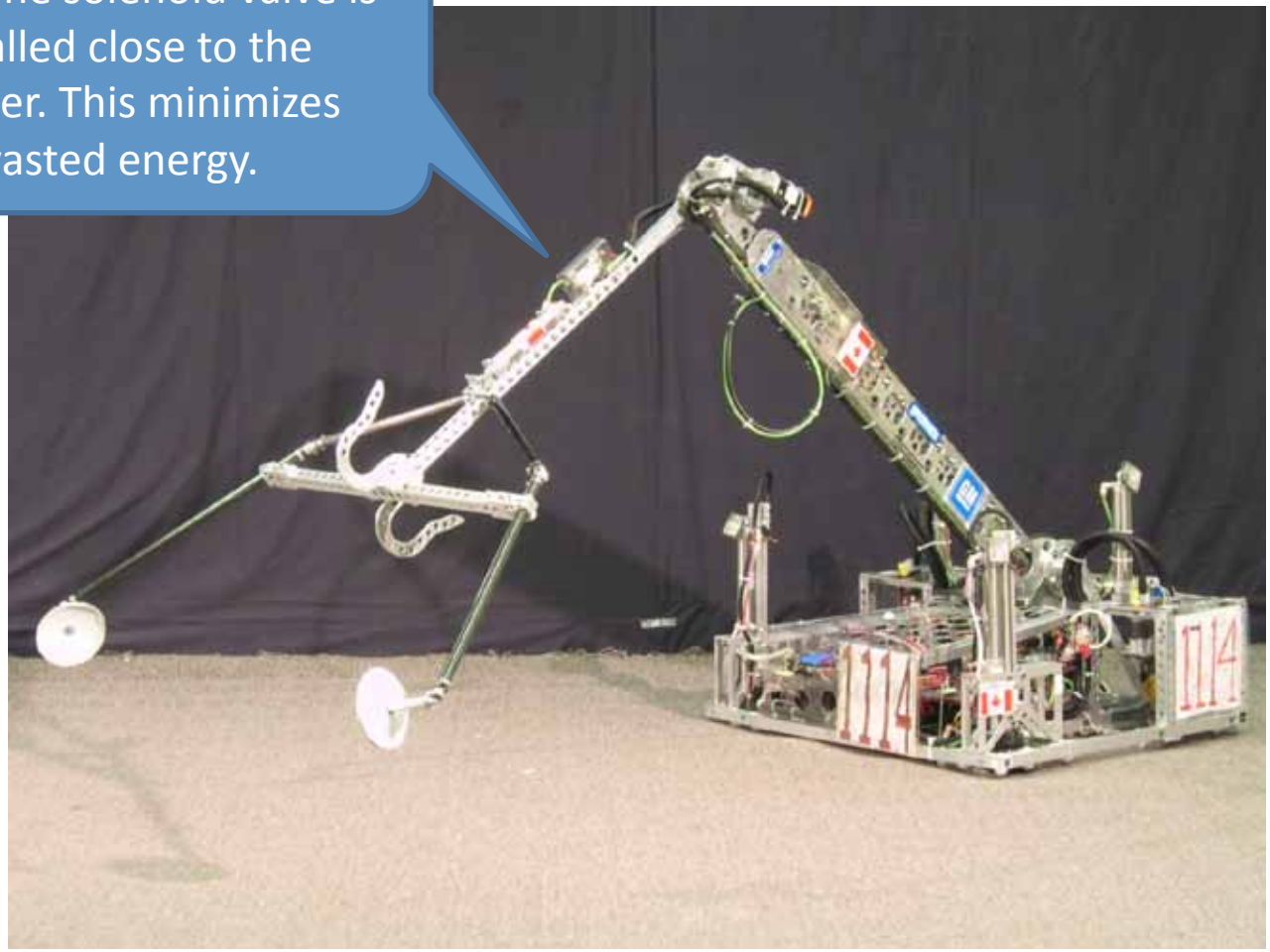


Example: Linear Pneumatic Gripper



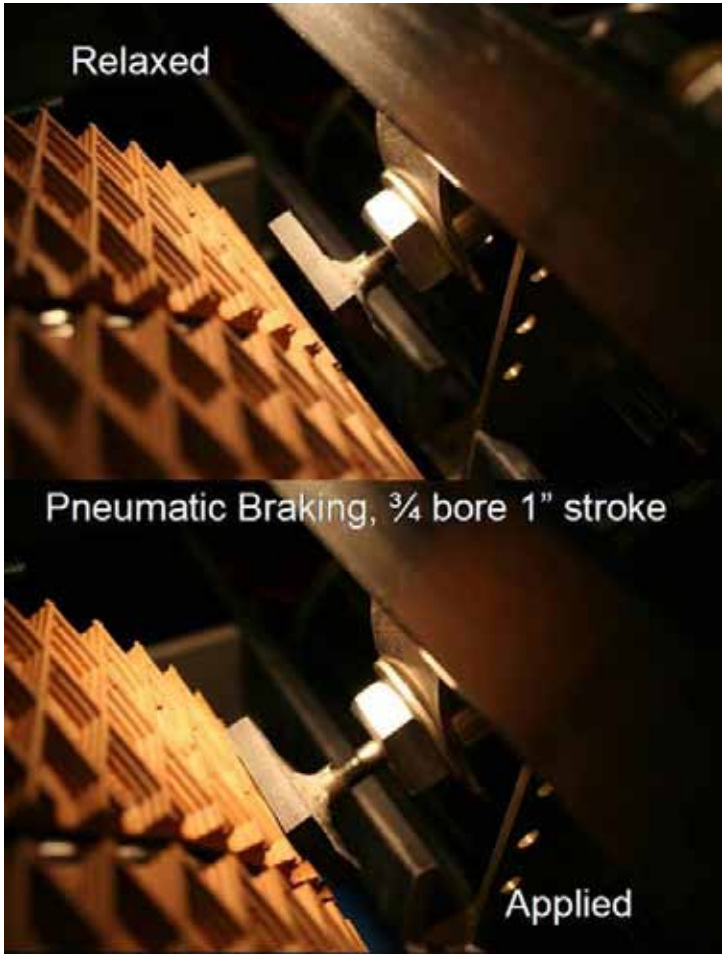
Example: Linear Pneumatic Gripper

NOTE: The solenoid valve is installed close to the cylinder. This minimizes wasted energy.



Example: 1-axis and 2-axis Grippers

Example: Pneumatic Brakes



- Extend cylinder to stop a manipulator, or use on wheels to lock your drivetrain
- Use normally open solenoid if you want the brake applied with no electricity
- Low energy requirements – can easily be used without compressor

The Good and Bad

- PROs
  - Doesn’t overheat
  - Designed to stall
  - High speed
  - Accurate end of stroke position control
  - Can hold without battery power
- CONs
  - Heavy (10 lbs+)
  - Battery drain
  - Space
  - Limited control

General Suggestions

- Order your free cylinders even if you don't use pneumatics this year
- Because of weight and space requirements, look to pneumatics if you have 2+ uses (unless you can leave off the compressor)
- Do not tolerate leaks
- Conserve energy – don't oversize or over-pressurize

Questions?

Thanks to:

Raul Olivera

http://first.wpi.edu/Images/CMS/First/2007CON_Pneumatic_Power_Olivera.pdf

Andy Baker

http://andymark.biz/presentations.html

Ken Stafford

http://first.wpi.edu/Images/CMS/First/2008FRC_Pneumatics_Stafford.ppt

Chief Delphi

http://www.chiefdelphi.com/