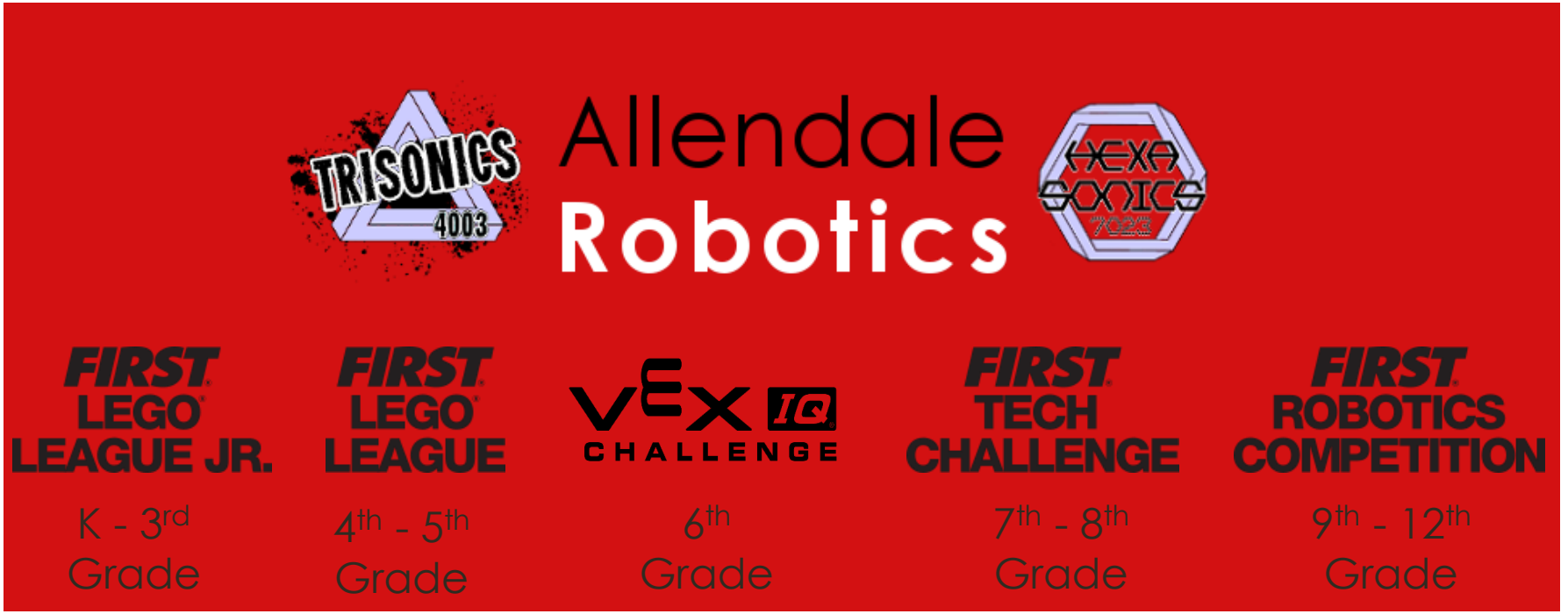
ALLENDALE ROBOTICS
FRC TEAM 4003 - TRISONICS

PNEUMATICS (ADVANCED)

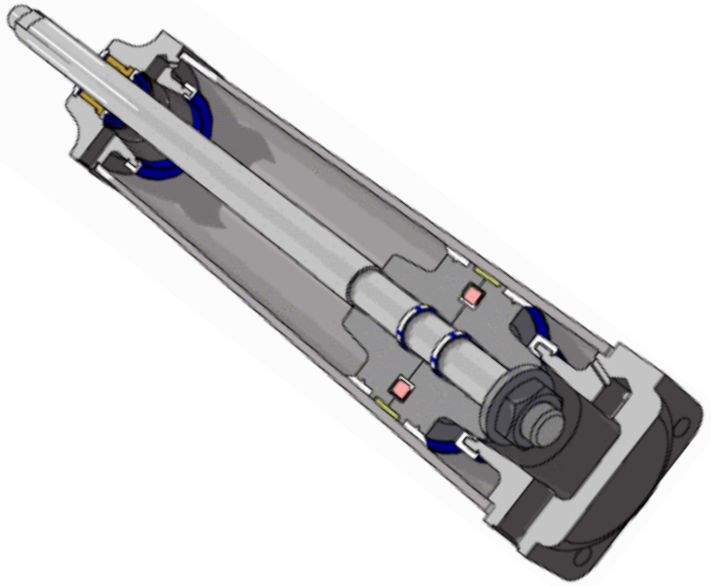


AGENDA

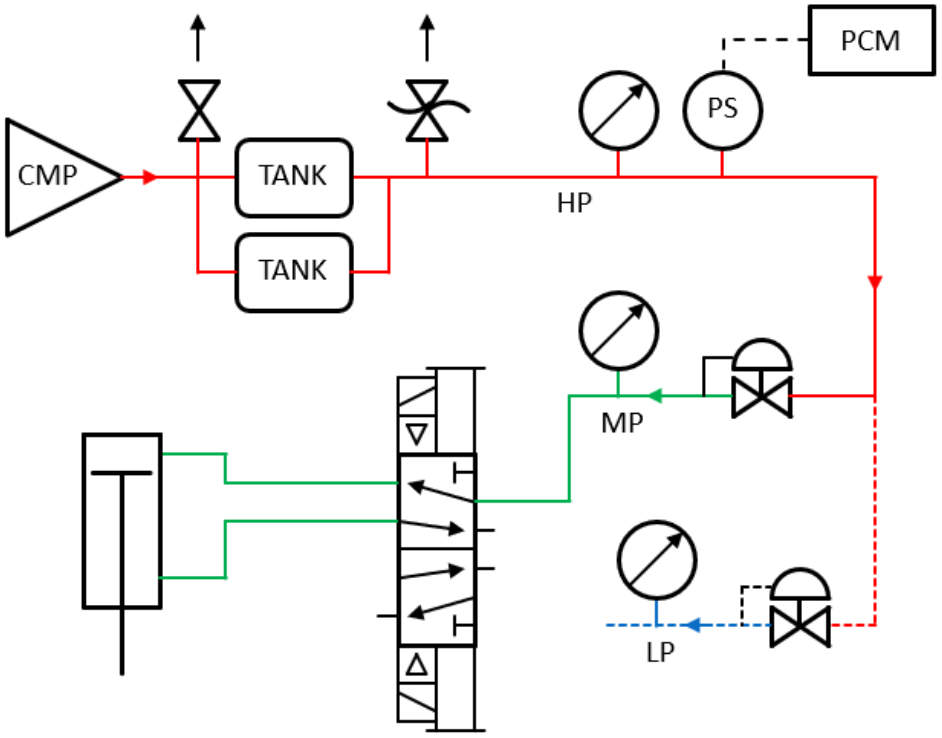
- Quick overview of the system
- Building Tips and Practices
- Sizing Cylinders
- Calculating Air Tank Requirements
- Q&A

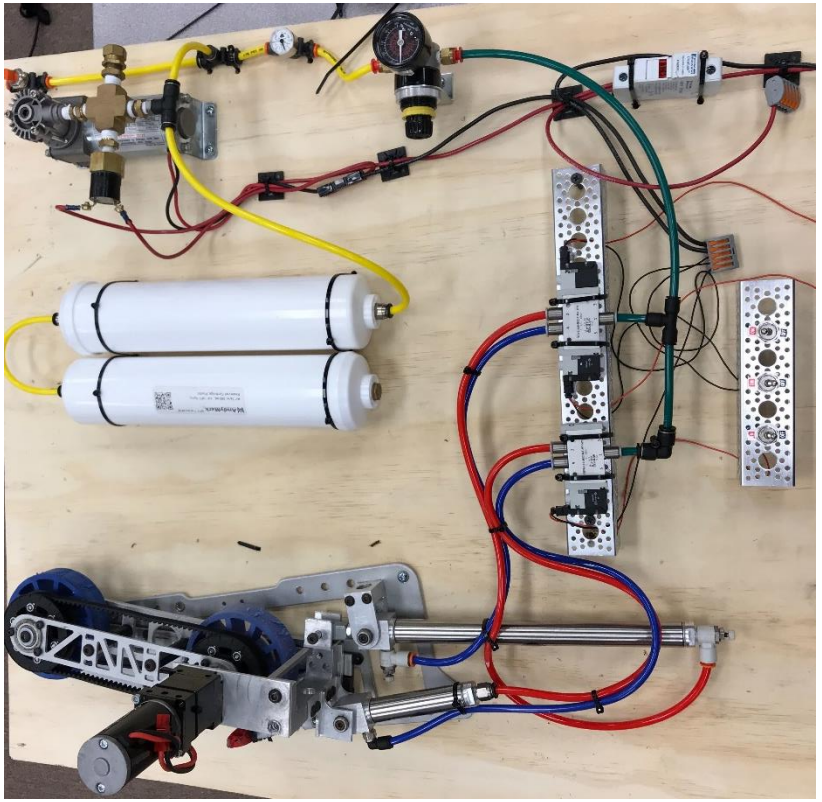
WHAT ARE PNEUMATICS

- Pneumatics use **pressurized gas** to effect a mechanical motion
- Uses the power of Compressed air to create force
- Typically gases such as air, Nitrogen, CO2
- In FRC air is used
- Typically used for linear motion



PUTTING THE SYSTEM TOGETHER





BUILDING TIPS AND SUGGESTIONS

Tips for tube fittings:

- Use plastic push-to-connect fittings where possible(Less weight compared to brass fittings)
- Use fittings with pre-applied sealant when possible

Tips for tube fittings:

- To connect: push tube in until firmly seated
- To remove: press rim down, **then** pull tube out
- Tubes cut at an angle **will** leak

BUILDING TIPS AND SUGGESTIONS

Tips for teflon tape:

- Use 4 to 6 wraps of tape
- Don't use tape more than once
- Wrap tape in the right direction
- Don't allow loose pieces of tape to get into the tubing

BUILDING TIPS AND SUGGESTIONS

Tips for brass fittings:

- Brass is very soft
- Do not over-torque
- Do not use adjustable wrenches
- Use box-end wrenches where possible

CARING FOR YOUR PNEUMATIC SYSTEM

Problems maintaining pressure:

Chronic	leak
Acute	catastrophic pressure loss

Catastrophic pressure loss may be caused by:

- Tube disconnection or breakage
- Component failure

BUILDING A PNEUMATIC SYSTEM

Tips for avoiding leaks:

- Use as few fittings as possible
- Perform leak test as each component is added
- Use *leak test fluid*

Recipe:

- Add 2 tbsp dish soap to empty spray bottle
- Fill spray bottle with water

Directions:

- Shake well
- Cover all exposed electrical parts!
- Spray directly on pressurized pneumatics

CARING FOR YOUR PNEUMATIC SYSTEM

Protect your cylinders—

- Thin wall tube can be crushed by side impacts
- Internal seals will not handle side loads
- Shafts can bend in wrong applications or with side loads
- Not repairable!

SOME CALCULATIONS

- Force of an air cylinder…
  - F=PA
  - Where P is the pressure supplied (psi) and A is the area of the bore off the cylinder (in^2)
  - NOTE: When calculating the retraction force you must account for the rod area.

- Air consumption of a single stroke…
  - C=SA
  - Where S is the stroke length (in) and A is the area of the bore off the cylinder (in^2)
  - NOTE: When calculating the retraction Volume you must account for the rod area.

- Volume of an air tank…
  - V=LA
  - Where L is the length of the air tank (in) and A is the area of the bore off the cylinder (in^2)

SOME CALCULATIONS

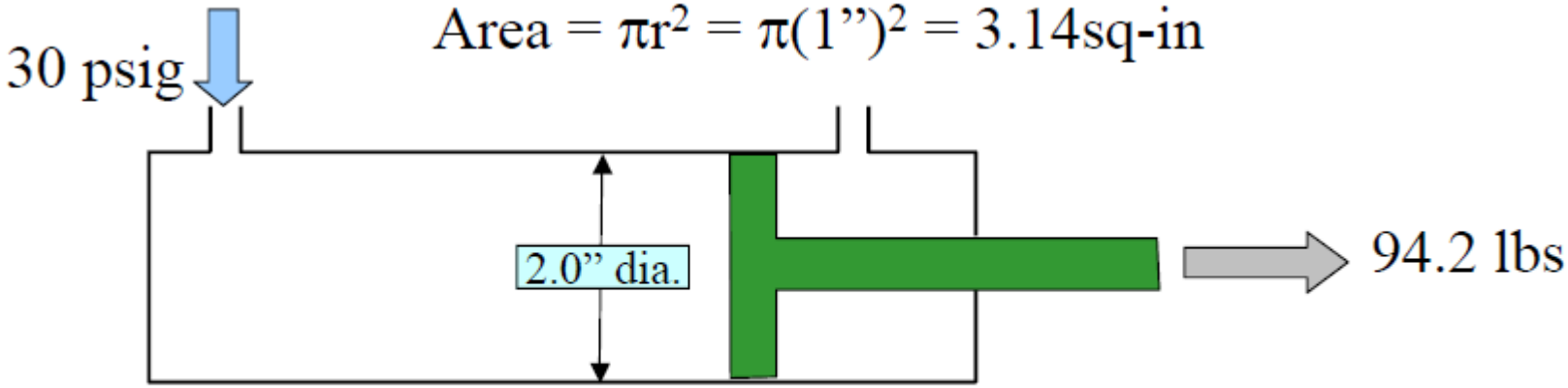
- Equating pressures and volumes…
  - Where P is pressure (psi) and V is volume (in^3).
  - NOTE: when calculating the needed amount of supply air tanks needed P_1 = (Supply Pressure - Working or Minimum Pressure)

These values are approximate and do not account for air leaks and losses from airlines so be sure to incorporate a safety factor (approximately 30% more) when implementing pneumatic components.

FORCE, PRESSURE, & AREA

Cylinder Extention

- Pressure = Force / Area (P=F/A)
- Force = Pressure X Area (F=PA)
- Example: 30 psig in 2" diameter cylinder



Force = 30 psi X 3.14 sq-in = 94.2 lbs

FORCE, PRESSURE, & AREA

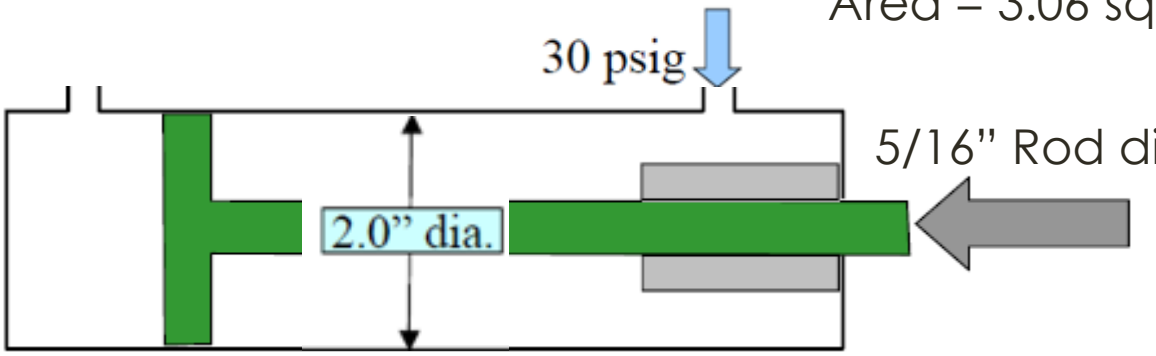
Cylinder Retraction

- Pressure = Force / Area
- Force = Pressure X Area
- Example: 30 psig in 2" diameter cylinder

Area = A(piston) – A(rod)

Area = $\pi(1)^2 - \pi(\frac{5}{32})^2$

Area = 3.06 sq-in



Retract Force = 30 psi X 3.06 sq-in = 91.8 lbs

DESIGNING A SYSTEM

Design Sequence

1. Find the required **stroke length**
2. Find the **force** & set the **operating pressure**
3. Guess how many times you will actuate the cylinder during a typical match
4. Find the required **storage capacity**

DESIGNING A SYSTEM

Sample Problem

You're using an cylinder on your new FRC robot to open and close the game piece manipulator. The cylinder you plan to use has a 1" bore diameter, a 6" stroke, a ¼" diameter rod and the supplied working pressure is 60 psi.

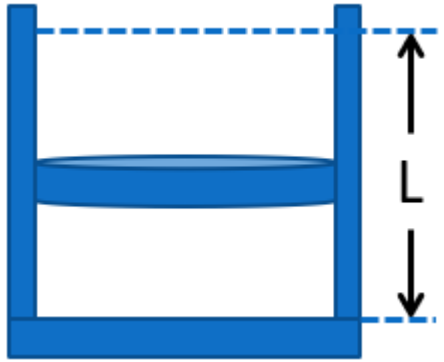
- What is the force of the air cylinder?
- What volume of air would be used if the cylinder extended and retracted 10 times during the course of the match?
- How many air tanks (36 in^3 volume) at supply pressure (120 psi) are need to supply air at 60 psi for this amount of strokes?

BUILDING A PNEUMATIC SYSTEM

Find the Stroke Length

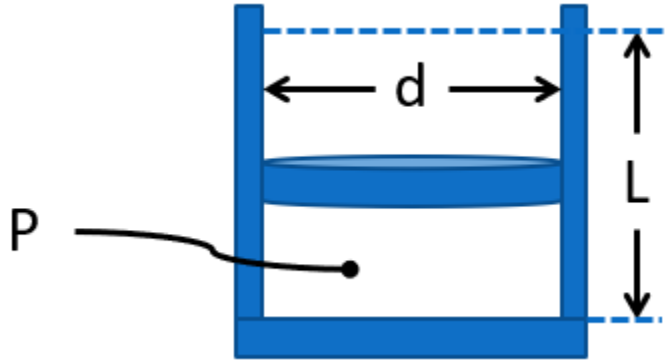
- Stroke length is defined by the application

- Example:
  - Stroke Length: L = 6”



BUILDING A PNEUMATIC SYSTEM

Find the Force and set the Operating Pressure



- Example:
  - Stroke Length: L = 6”
  - Diameter: D = 1 inch
  - Rod Diameter: D_{rod} = 0.25 inch
  - Pressure: Puse = 60 psig = 60 lbf /in^2

  - Extend Area: $A_{Ext} = (r^2)\pi = .785\ in^2$
  - Extend Force: $F_{ext} = (Puse)(A) = 47.1$ lbf
  - Extend Volume: $Vext = (Aext)(L) = .785\ in^2 * 6\ in = 4.71\ in^3$

  - Retract Area: $A_{Ret} = (r^2)\pi - (d_{rod}^2)\pi = .735\ in^2$
  - Retract Force: $F_{ret} = (P_{use})(A) = 44.1$ lbf
  - Extend Volume: $Vext = (Aext)(L) = .735\ in^2 * 6\ in = 4.41\ in^3$

BUILDING A PNEUMATIC SYSTEM

Guess how many times you will actuate the cylinder

- Count both Extension and Retraction for a Double Acting Cylinder
- PEU = Pneumatic Energy units

- Example:
  - Actuations: $N_{actuations} = 10 + 10 = 20$
  - Gas use: $PEU = \sim(N_{actuations})(P_{use})(V_{cyl})$

$$PEU = (10)(60\ psig)(4.71\ in^3)+(10)(60\ psig)(4.41\ in^3)=5472$$

This is in units of *energy*!

BUILDING A PNEUMATIC SYSTEM

Find the Storage Capacity

Storage

Volume $V_{tank} = (L)(A) = 36\ in^3$

Pressure $P_{store} = 120\ psig$

Tanks $N_{tanks} = 2$

Gas storage $\sim (N_{tanks})(P_{store})(V_{tank})$

$PEU = (2)(120\ psig)(36\ in^3)$

$PEU = 8640$

Product Overview

This is a polypropylene plastic air tank accumulator holding 36.0 cubic inches

This tank has 1/4" NPT ports (2).

- Weight: 0.64 pound
- Capacity: 36.0 cubic inches (590 ml)
- Ports: Two 1/4" NPT female (one on each end)
- Material: Polypropylene Plastic
- Working pressure rating: 125 psi
- Burst pressure rating: 500 psi
- Max. temperature rating: 100 F
- Length: 12.1 inches
- Diameter: 2.7 inches

BUILDING A PNEUMATIC SYSTEM

Is the example design OK?

Safety factor η =

$$= \frac{\text{Gas storage}}{\text{Gas use}} = \frac{8640 \text{ in*lbf}}{5472 \text{ in*lbf}} = 1.57$$

Result:

The design should last through the match but remember there is pressure loss and other system losses that can change this.

BUILDING A PNEUMATIC SYSTEM

Example 2: Energy Capacity

- Energy Capacity Example:
  - Storage Tanks
    - Volume = 18.85 cu-in (37.7 cu-in for 2 tanks)
    - Pressure = 120 psig

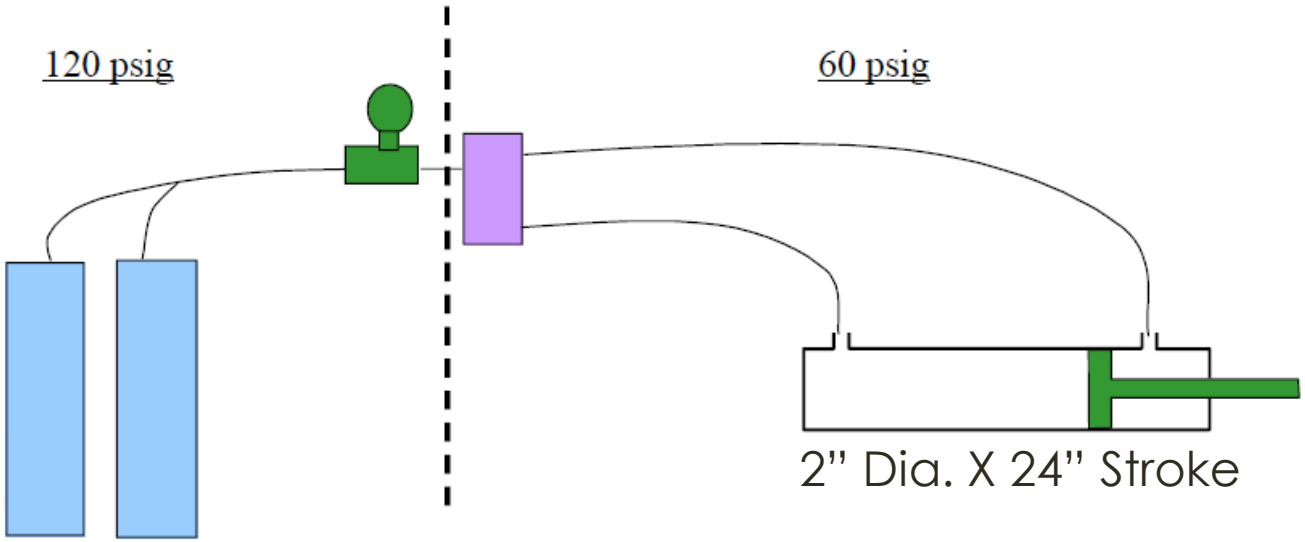
    => Energy Capacity = 4524 (2 tanks)
  - Cylinder - 2” dia x 24” stroke
    - Volume = 75.4 cu-in
    - Pressure = 60 psig

    => Energy Capacity used = 4524
- Conclusion: After 2 extensions and one contraction, the pressure in the tanks drops to less than 20 psig

BUILDING A PNEUMATIC SYSTEM

Example 2: Energy Capacity

120 PSI Side			60 PSI Side			
PEU	P	V	P	V	PEU	Tot PEU
4524.0	120.0	37.7	60.0	75.4	4524.0	9048.0
2262.0	60.0	37.7	60.0	75.4	2262.0	4524.0
1131.0	30.0	37.7	60.0	75.4	1131.0	2262.0
565.5	15.0	37.7	7.5	75.4	565.5	1131.0
282.8	7.5	37.7	3.8	75.4	282.8	565.5
141.4	3.8	37.7	1.9	75.4	141.4	282.8



TOOLS FOR CALCULATIONS

Useful Calculation Spreadsheet

Name	Bore (in)	Length (in)	QTY Per Robot	Single/ Double Acting	Actuations Per Match	Pressure (psi)	Force (lb)	Volume per cylinder (in^3)	Total Volume Per Match (in^3)
Power Intake Crowder/Flipper	1.0625	2	2	2	10	20	17.7	1.8	70.9
Power Intake Extend/Retract	0.75	8	2	2	10	60	26.5	3.5	141.4
Gripper Open/Close	0.875	3.5	1	2	20	60	36.1	2.1	84.2
Gripper Extend/Retract	0.75	16	1	2	10	60	26.5	7.1	141.4
Shifting	0.75	0.5	2	1	10	60	26.5	0.2	4.4
							0.0	0.0	0.0

Max Tank Pressure (psi)	120
Min Tank Pressure (psi)	60
Required Volume (in^3)	395.0

Air Tank Volume (in^3)	35
Required Air Tanks	11.3

SUPPLIERS FOR PNEUMATIC COMPONENTS

AndyMark

- Pneumatic Control Module (PCM)
- Compressor
- Pressure Sensor
- Relief Valve
- Regulators
- Gauges

Automation Direct

- Fittings
- Valves
- Inline Pressure Gauges
- Inline Regulators
- Tubing
- Tubing Cutter (you get one free with the FIRST Voucher)

VEXPro

- Pneumatic Control Module (PCM)
- SMC Valves

Bimba

- Free Cylinders (limited sizes)

FIRST Choice by AndyMark

- Compressor
- PCM
- Relief Valve
- Pressure Sensor
- Tubing
- Misc.

And lots of other places

Q&A

Thank You!