ADAMBOTS
Team 245

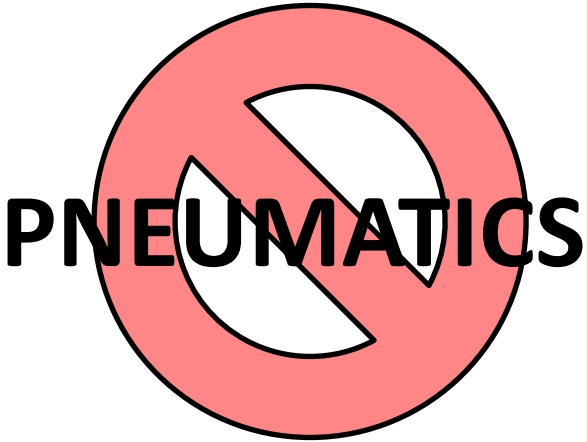
Application of Pneumatic Cylinders

When to Use Pneumatics

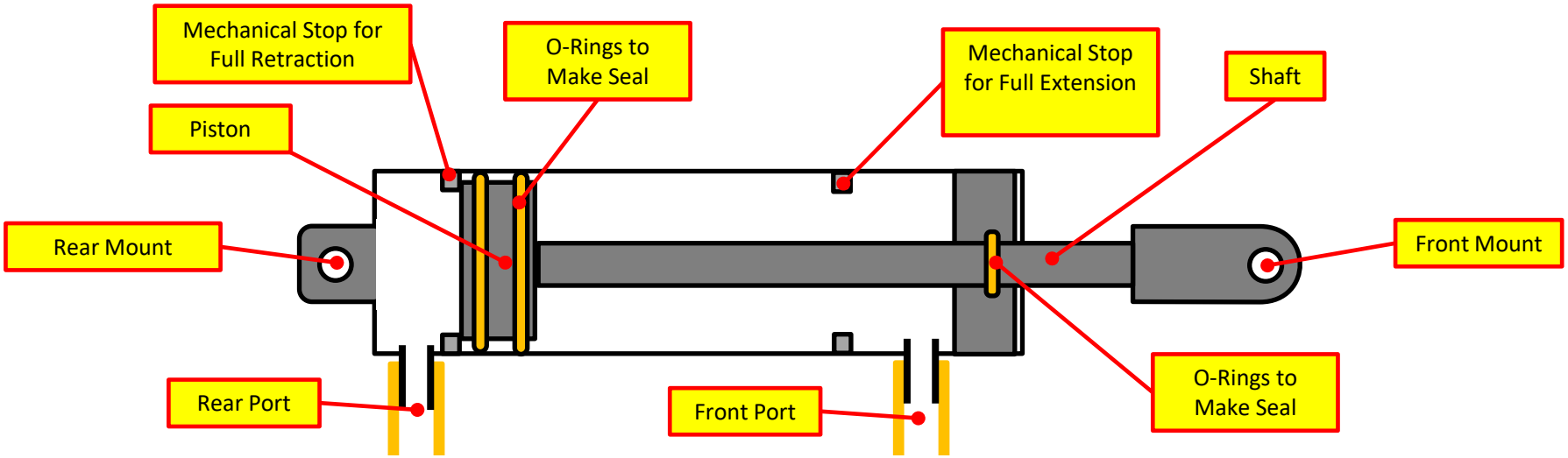
- **Generally,…. Don't Use Pneumatics if you can avoid it**
  - Pneumatics adds an entire new system to robot along with associated complexity and weight

HOWEVER……

- **Pneumatics can be best solution for some design challenges**
  - Application of a force over a limited range of motion
  - High force in a small package
  - Very forgiving, unlike electric motors, it will not burn out if it doesn't move



Anatomy of a Pneumatic Cylinder



Do's and Don'ts

FIRST ROBOTICS COMPETITION

2018 Game & Season Manual

Do:

- **Read thew FIRST technical manual carefully…**
  - There are many rules / limitations for pneumatic systems
- **Max working pressure is 60 Psi**
- **Max Tank storage pressure is 120 Psi**

Don't:

- **Modify pneumatic compressors, valves, tanks, or cylinders**
  - Safety Concern
  - Robot will not pass inspection of these components have been modified
- **Apply sideways force to cylinder shaft**
  - Cylinder will not work if shaft is bent !!!

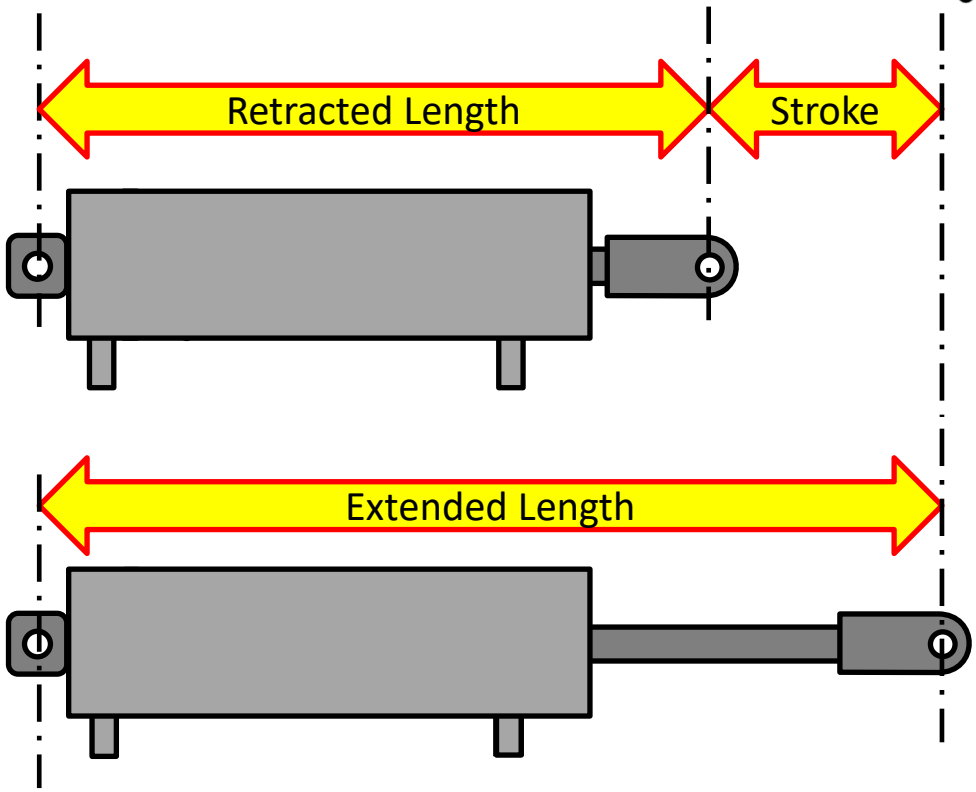
Sizing: Length of Cylinders

4 Factors to consider:

- Retracted Length
- Extended Length
- Stroke
- Mounting configuration and hardware on shaft and base of cylinder

Base Mount

Shaft Tip Clevis

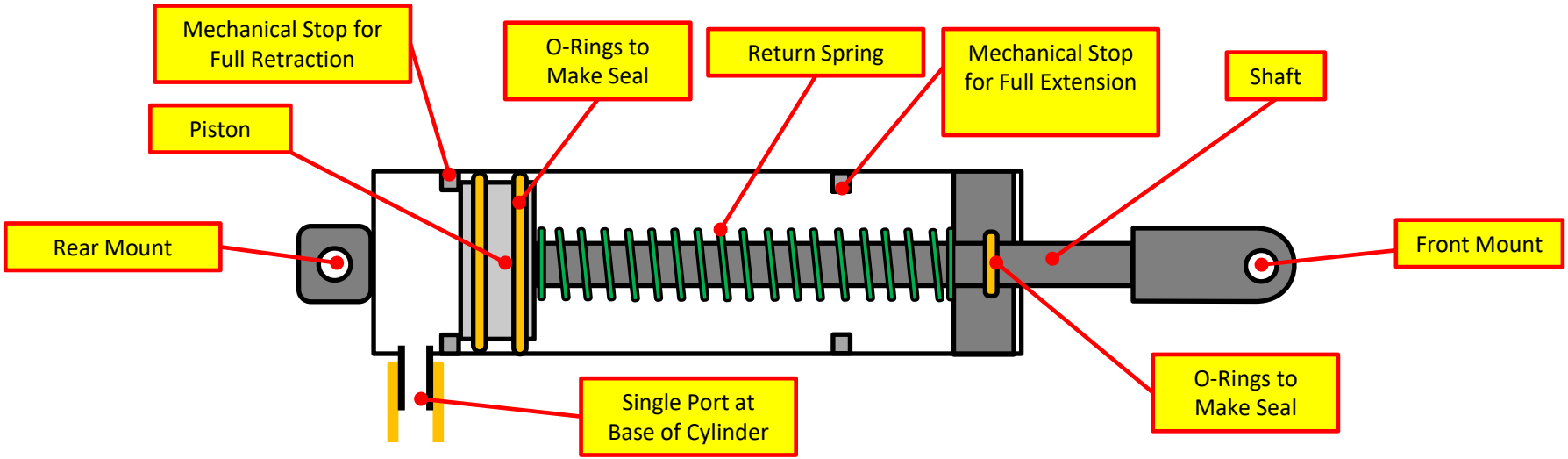


Single Action Cylinder

Single Action Cylinder Shown in Non-Actuated Full Retracted Position

Single action cylinder with single port

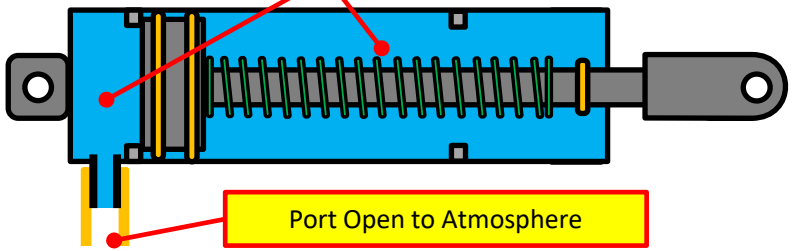
- Extension driven by applied pressure
- Retraction by mechanical spring force and/or compression of air trapped on opposite side of piston



Single Action Cylinder: Operation

Same Pressure on Both Sides of Cylinder at Full Retract

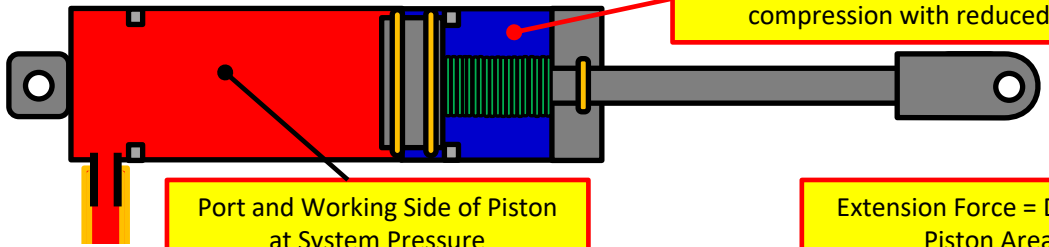
Full Retract Position



Port Open to Atmosphere

Retract Force from Spring Only

Full Extend Position



Pressure higher than Atmosphere due to compression with reduced volume

Extension Force

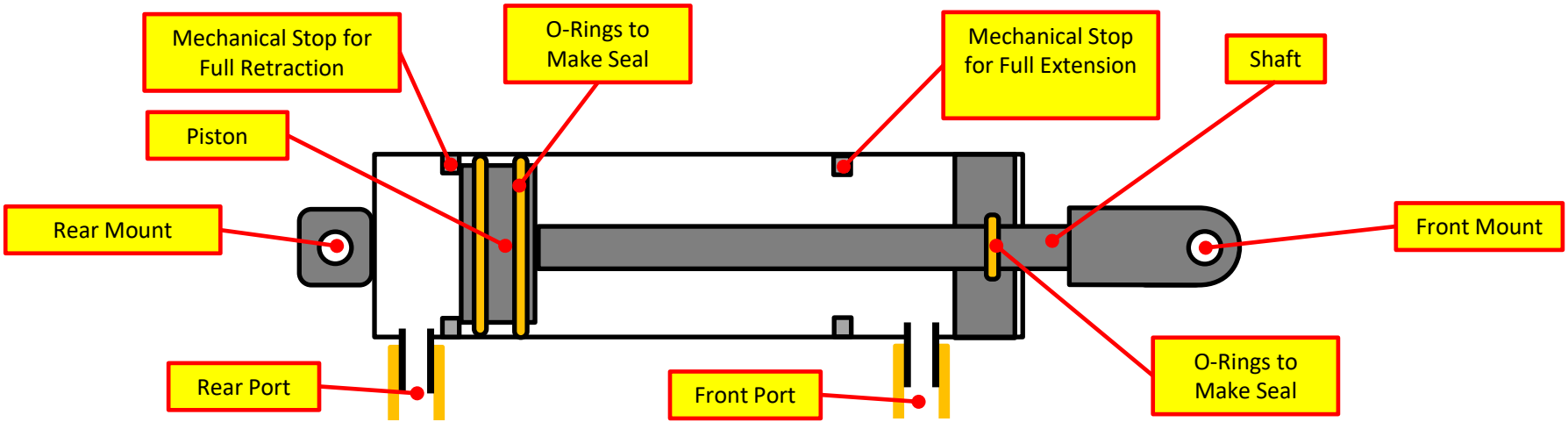
Port and Working Side of Piston at System Pressure

Extension Force = Differential Pressure across Piston x Piston Area – Compressed spring force

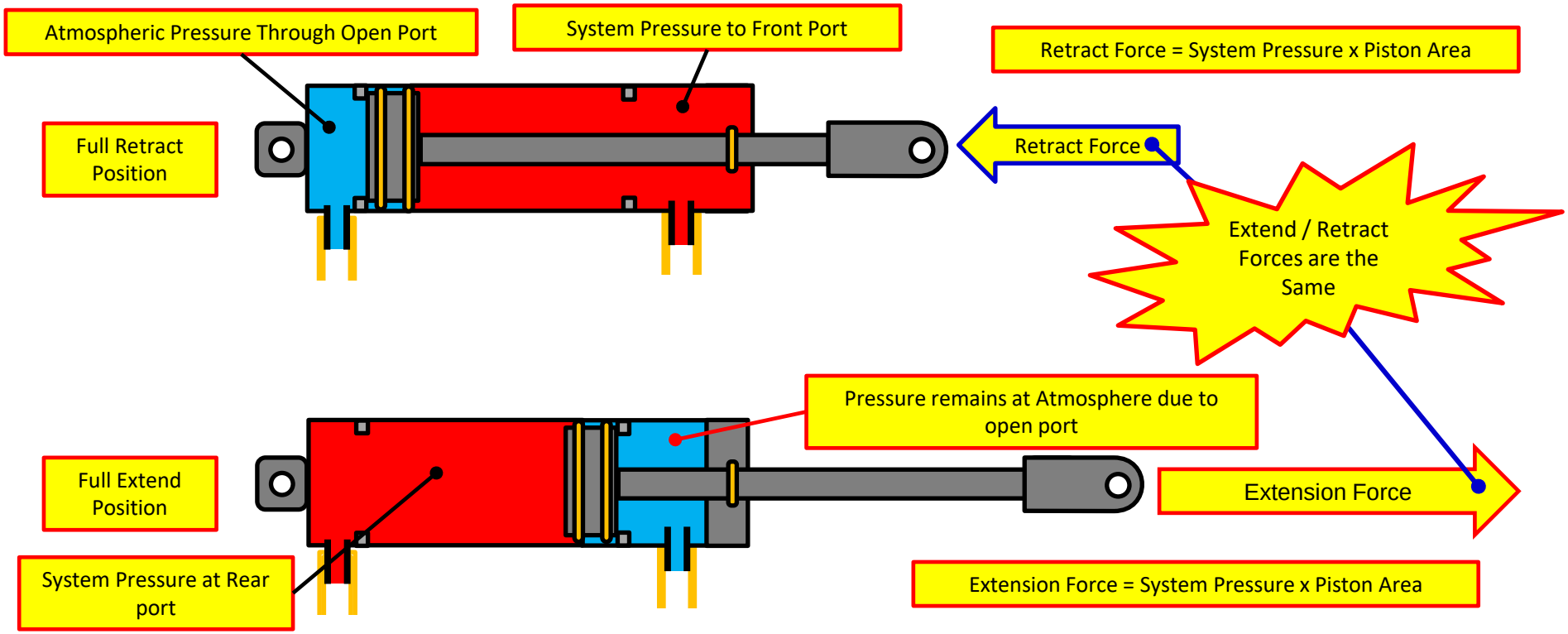
Double Action Dual Port Cylinder:

Double Action Cylinder Shown in Non-Actuated Full Retracted Position

- **Double action cylinder with dual ports**
  - 2-Port design with separate ports on each side of piston
  - Retraction/Extension controlled by applying pressure to either front or back ports

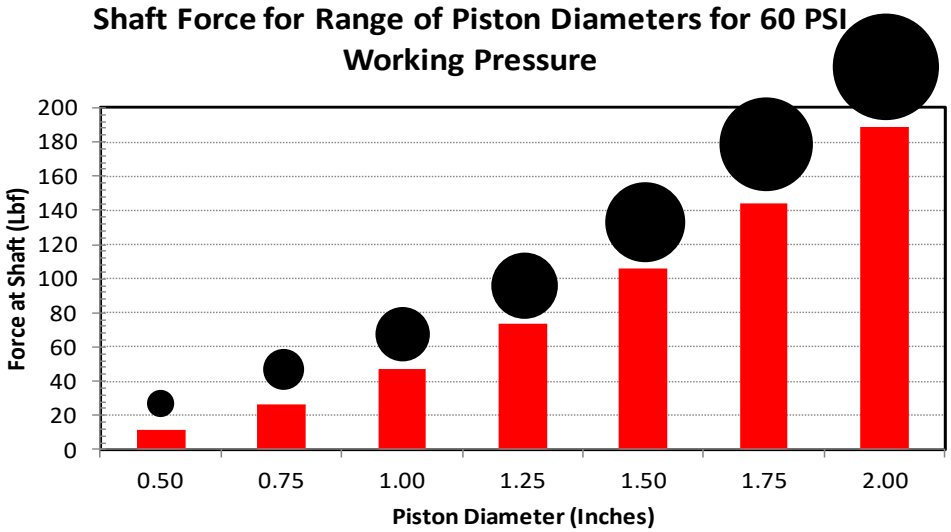


Double Action Dual Port Cylinder: Operation



Force Calculations

- **Extend/Retract Force is determined by system air pressure and area of piston**
- **Force:**
  - Force (Lbf) = Pressure (Psi) x π x Area (In^2) / 4
- **Plot at right shows force at 60 Psi for range of cylinder diameters**



Force at 60 Psi for different size cylinders

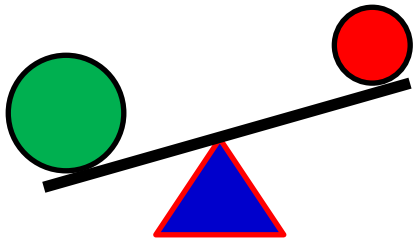
Things to Consider…….

- **Design system using positive end stops within the mechanism**
  - Don’t rely on stops internal to cylinder itself to limit travel
    - Reliance on internal stops eventually damages cylinder itself
  - Not possible to achieve intermediate positions of cylinder for locations between Min/Max extension with a single cylinder configuration
- **Avoid design configuration that can apply side loads to extended shaft**
  - The slightest bend can render cylinder inoperative and bends are difficult to repair
- **Stroke can be slowed with an adjustable orifice to reduce severity of impact when cylinder reaches end of stroke**
  - Mechanism reaching limit stops with immediate application of full pressure can apply excessive impacts that can damage components of mechanism itself

Things to Consider……. (Continued)

- **Is an on-board air compressor needed?**
  - Eliminating a compressor saves weight and packaging space
  - Need to pressurize system prior to every match with an off-board compressor
  - It is essential that pneumatic system is air tight and does not have small leaks
    - Can loose significant on-board air if long delay occurs before match starts

- **Comparison of total air needed for a match vs On-board capacity will determine if an on-board compressor is needed**
  - Calculate air mass at 60 Psi by estimating number of cycles needed per cylinder for a match combined with working volume of each cylinder
    - Use $P_1V_1 = P_2V_2$ formula to calculate air needed per cylinder actuation



Things to Consider……. (Continued)

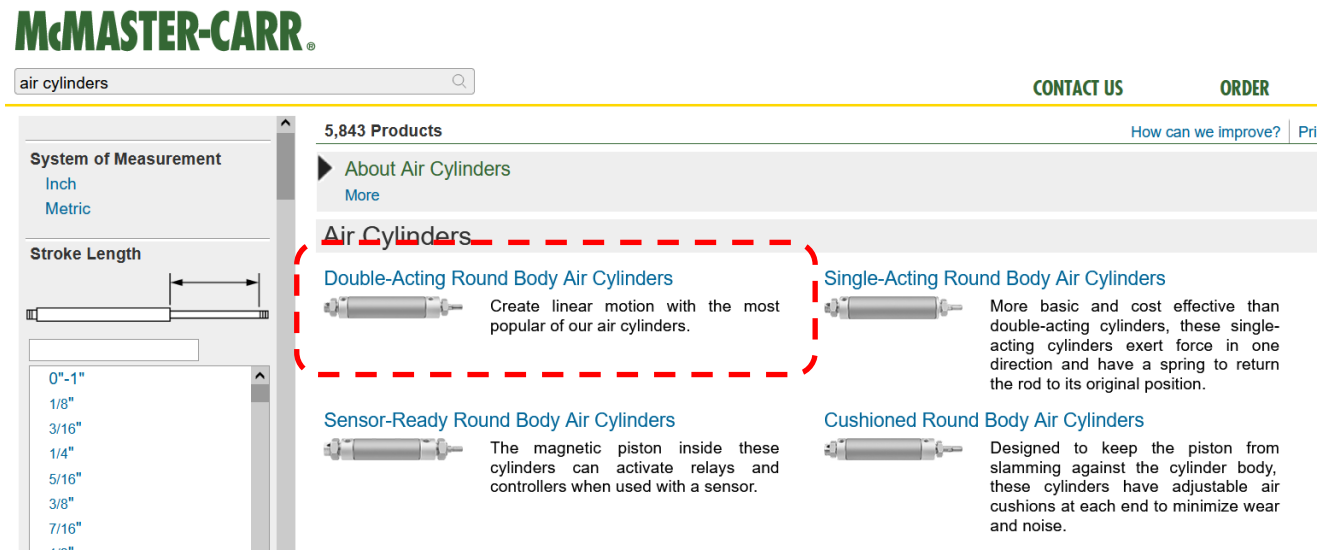
- **Calculate Number of Actuations 1 Clippard tank can provide before Tank Pressure Falls below 60 Psi**
  - Clippard tank volume = 35 In^3
  - ¾” Dia Cylinder with 5” Stroke volume = 2.65 In^3 per Stroke
  - Storage Pressure: 120 Psi
  - Working Pressure: 60 Psi
  - Starting PV @ 120 Psi = 4200 Pound-Inch
  - Ending Tank PV @ 60 Psi = 2100 Pound Inch
  - PV per Cylinder Actuation = 60 Psi x 2.65 In3 = 159 Pound-Inch
  - Available Tank Pv = 4200 – 2100 = 2100 Pound-Inch
  - Number of Actuations keeping 60 Psi Tank Pressure = 2100 / 159 = 13.2
  - 13 Cylinder cycles keeping tank pressure above 60 Psi

Things to Consider……. (Continued)

- **Is Air pressure required at start of autonomous period?**
  - Make sure system is fully charged before putting robot on the field
  - And/or include a delay in Autonomous period program for compressor to build system pressure before using pneumatic controlled features
- **What happens at end of match?**
  - Example: Climb mechanism requires pneumatic pressure to maintain position after end of match when controls are disabled
    - Must ensure desired pneumatic function is maintained after power down by use of proper power off open close valve states
- **Leave adequate space for fittings and pneumatic lines**
  - Position of lines and fittings can change between extended and retracted positions

Source of Air Cylinders

- **McMaster Carr is best supplier of Air Cylinders**
  - https://www.mcmaster.com/air-cylinders/



Source of Air Cylinders

Example: Double Acting Cylinders Select ¾” 6” Stroke

Double-Acting Round Body Air Cylinders

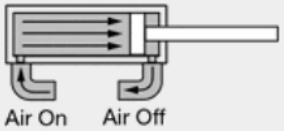
Universal Mount

Lg.					Air Inlet				
Stroke	Retracted	Extended	Force @ 100 psi, lbs.	Body Material	Pipe Size	Thread Type	Gender		Each
12"	15.44"	27.44"	31	304 Stainless Steel	10-32	UNF	Female	6498K442	69.51
3/4" Bore Size (0.86" OD)									
1/2"	5.03"	5.53"	40	304 Stainless Steel	1/8	NPT	Female	6498K631	30.81
1"	5.53"	6.53"	40	304 Stainless Steel	1/8	NPT	Female	6498K632	31.98
1 1/2"	6.03"	7.53"	40	304 Stainless Steel	1/8	NPT	Female	6498K633	33.15
2"	6.53"	8.53"	40	304 Stainless Steel	1/8	NPT	Female	6498K634	34.27
2 1/2"	7.03"	9.53"	40	304 Stainless Steel	1/8	NPT	Female	6498K443	35.45
3"	7.53"	10.53"	40	304 Stainless Steel	1/8	NPT	Female	6498K635	36.62
4"	8.53"	12.53"	40	304 Stainless Steel	1/8	NPT	Female	6498K636	38.91
5"	9.53"	14.53"	40	304 Stainless Steel	1/8	NPT	Female	6498K637	41.20
6"	10.53"	16.53"	40	304 Stainless Steel	1/8	NPT	Female	6498K638	43.55
7"	11.53"	18.53"	40	304 Stainless Steel	1/8	NPT	Female	6498K861	45.84
8"	12.53"	20.53"	40	304 Stainless Steel	1/8	NPT	Female	6498K639	48.19
9"	13.53"	22.53"	40	304 Stainless Steel	1/8	NPT	Female	6498K403	50.48
10"	14.53"	24.53"	40	304 Stainless Steel	1/8	NPT	Female	6498K641	52.77
12"	16.53"	28.53"	40	304 Stainless Steel	1/8	NPT	Female	6498K642	57.41
14"	18.53"	32.53"	40	304 Stainless Steel	1/8	NPT	Female	6498K404	66.31
16"	20.53"	36.53"	40	304 Stainless Steel	1/8	NPT	Female	6498K405	70.95
18"	22.53"	40.53"	40	304 Stainless Steel	1/8	NPT	Female	6498K444	75.58
24"	28.53"	52.53"	40	304 Stainless Steel	1/8	NPT	Female	6498K406	89.44

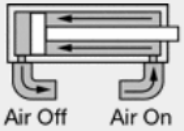
Types of Cylinders Available

Double Acting

Most of our cylinders are double acting, so they have air-extend and air-retract actuation; they use air to exert force in both directions to push and pull. Cylinders have two ports.



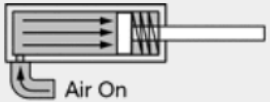
Air extends the rod.



Air retracts the rod.

Single Acting

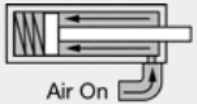
Single-acting cylinders use air to exert force in one direction and have a spring that returns the rod to its original position. They have one port. Choose from air-extend cylinders that use air to push and air-retract cylinders that use air to pull.



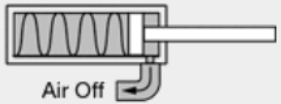
Air extends the rod.

A spring retracts the rod.

Air-Extend Cylinders (Push Style)



Air retracts the rod.



A spring extends the rod.

Air-Retract Cylinders (Pull Style)

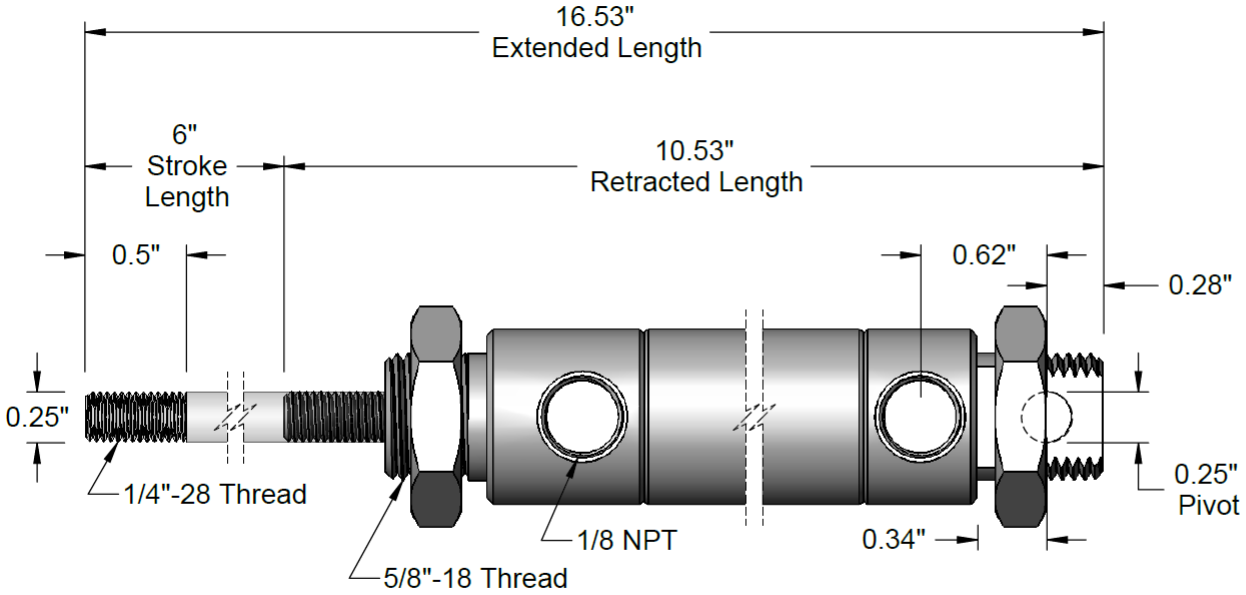
Make sure correct type cylinder is ordered.

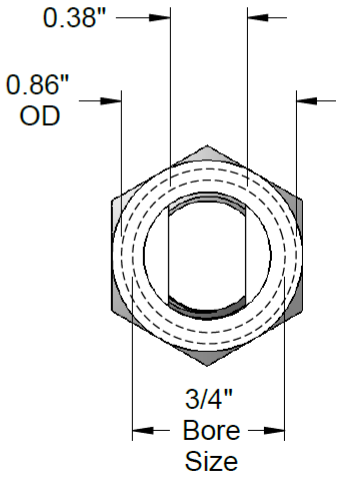
Very easy to select the wrong one

Cylinders smaller than ¾” use 10/32 UNF Pipe thread which is not the standard 1/8” MPT

Source of Air Cylinders

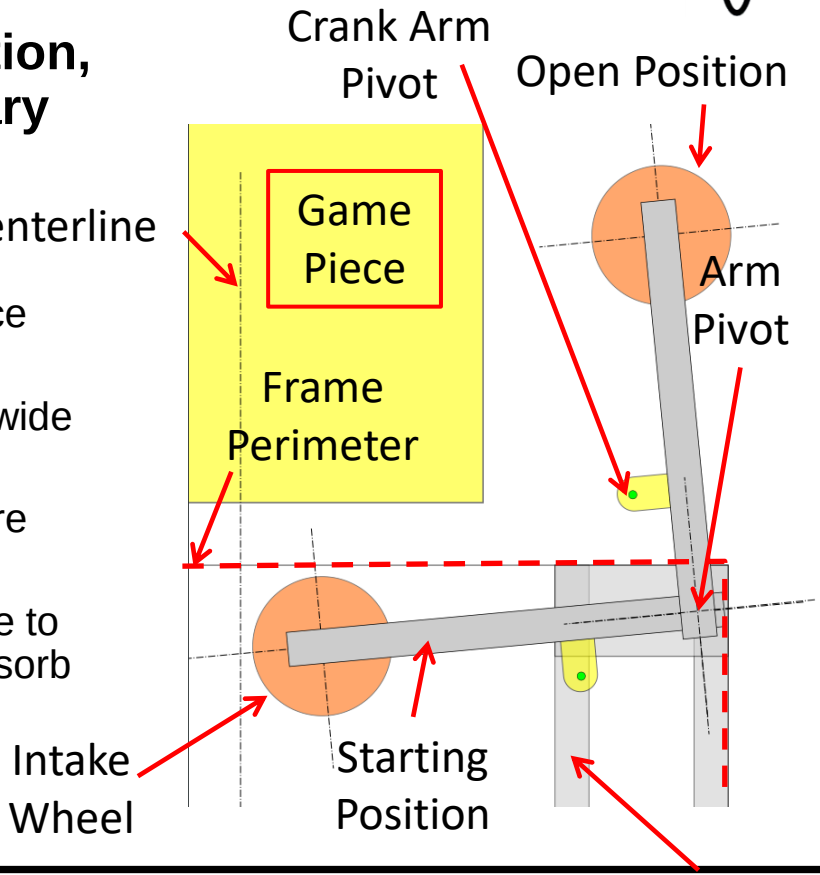
Example: Double Acting Cylinders Select ¾” 6” Stroke





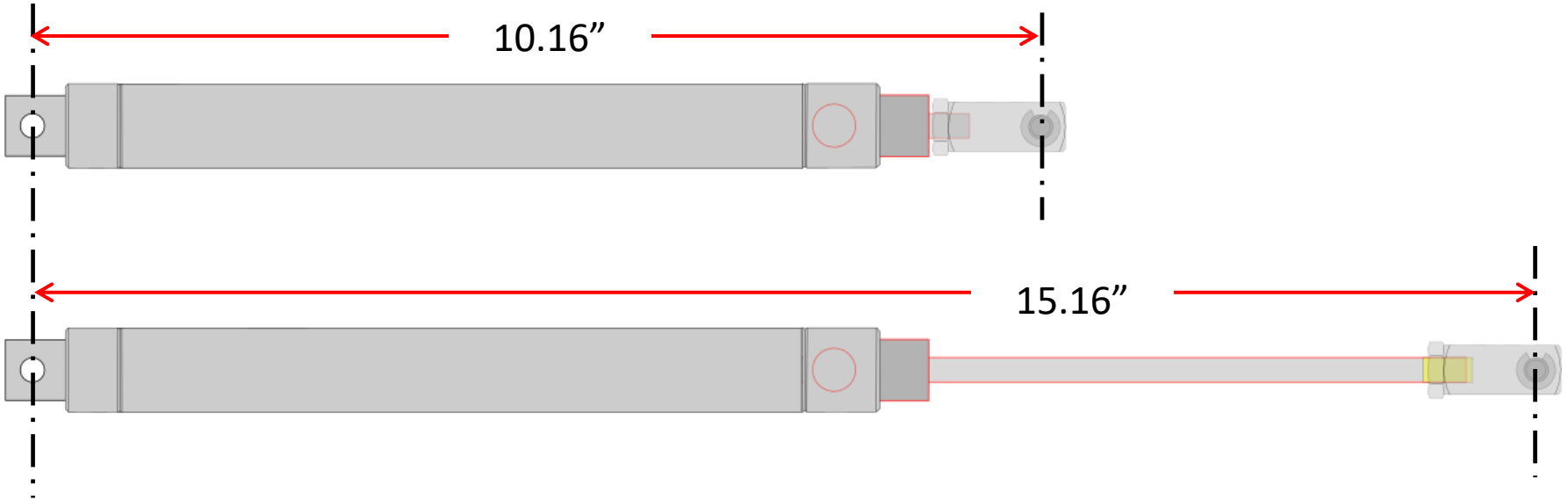
Selection and Packaging of Pneumatic Cylinders

- **Stroke, Required Force, Single/Dual action, need for spring return/extend are primary factors in selecting the correct cylinder**
- **Example:**
  - Need cylinder to actuate arm to intake game piece from floor level
  - Arm must start within frame perimeter and open wide enough to accept game piece
  - Full extension is limited by mechanical stop before cylinder reaches stroke limit
  - Full extension should be less than 90° from frame to allow arm to force cylinder to stroke inward to absorb impact energy
  - Use single acting cylinder with spring extend



Packaging Example

- **Select 5” Stroke ¾” Bore Cylinder and determine retract/extend lengths with clevis attached**



Determine Anchor Point for Cylinder

- Best to locate pivot point aligned with frame rail to minimize needed structure
- Place 10.16” (Retracted Length) radius arc about crank arm starting position pivot
- Place 15.16” (Extended Length) radius arc with center along 10.16 Arc within frame rail position with radius exceeding crank arm at open position
- Satisfactory match if extended cylinder radius exceeds crank arm pivot at Max open arm position
  - 5” Cylinder meets Criteria