

FABCO-AIR

Specifying pneumatic cylinders (with hopes of avoiding a special)

FABCO-AIR – www.fabco-air.com – phone 1-352-373-3578

Specifying an air cylinder might seem an overwhelming task when you consider all the shapes, sizes and types of cylinder products available today. Compounding matters is the spectrum of standard options you can get with any of the offerings out there on the horizon. (Options actually are the good news. They quite often are your key to avoiding the need for a totally custom cylinder.)

Okay. Where do you start? In order to properly specify an air cylinder for any application, four questions must be answered before moving into the heart of the design.

- (1) What work will the cylinder be doing?
- (2) What force is needed to do the work?
- (3) What distance will the cylinder rod have to travel when doing the work?
- (4) How fast will the rod be travelling?

(1) THE WORK LOAD

Will the cylinder be pulling a load horizontally or pushing something up an incline? Will it be lifting a load, or turning a crank arm? Can the load rotate or must it remain in a specific orientation? Will the cylinder be fighting an overhung load situation? Will it be compressing a rivet or clamping parts together while separate machine operations take place?

(2) PUSH AND PULL FORCES

First you'll need to determine the force you need in order to size of your cylinder properly. When the force is known, you can determine the bore size or the power factor of the cylinder you need by using the equation:

$Force = (Pressure\ Available) \times (Power\ Factor)$
or re-stated:

$Power\ Factor = Force \div (Pressure\ Available)$

In this calculation we have not considered any safety factors.

As a starting point, let's use a 50% factor of safety. Therefore, multiply our *Cylinder Power Factor*

above by 1.5 and use the result to calculate the required cylinder bore from the equation:

$(Cylinder\ Power\ Factor) \times 1.5 = \pi (Bore)^2 \div 4.$

Or we can find the appropriate bore using force factor tables in the manufacturers' catalogs as show below in typical tables from FabcoAir cylinder catalogs. Here, sizing guide "A" shows the actual piston area and the extend forces obtainable from various air pressures.

Sizing Guide A – Extend Force (lbs)												
Bore	Piston Area	Pressure										
		40	50	60	70	80	90	100	125	150	175	200
1 1/2"	1.77	71	88	106	124	141	159	177	221	265	309	353
2"	3.14	126	157	188	220	251	283	314	393	471	550	628
2 1/2"	4.91	196	245	295	343	393	442	491	614	736	859	982
3 1/4"	8.30	332	415	498	581	664	747	830	1037	1244	1452	1659
4"	12.57	503	628	754	880	1005	1131	1257	1571	1885	2199	2513
5"	19.63	785	982	1178	1374	1571	1767	1963	2454	2945	3436	3927
6"	28.27	1131	1414	1696	1979	2262	2545	2827	3534	4241	4948	5655

Pulling force

Pulling force, calculated when the cylinder retracts, brings the rod diameter into account. As shown in Figure 1 below, air pressure can act only on part of the piston in retract mode because the rod blocks the center portion of the piston.

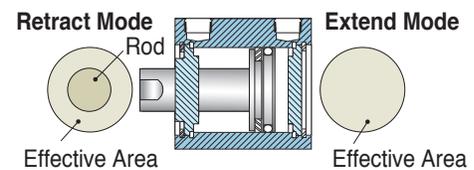


Figure 1 - Effective piston areas

Thus the retract power factor is calculated as an annular ring – *piston area minus rod area*.

Again, helpful tables from cylinder catalogs give rod areas to speed your calculations of "pulling" power factors.

Sizing Guide B - Retract Force Deduction (lbs)												
Rod	Rod Area	Pressure										
		40	50	60	70	80	90	100	125	150	175	200
0.625	0.307	12	15	18	21	25	28	31	38	46	54	61
1.000	0.785	31	39	47	55	63	71	79	98	118	137	157
1.375	1.485	59	74	89	104	119	134	148	186	223	260	297
1.750	2.404	96	120	144	168	192	216	240	301	361	421	481

(3) THE CYLINDER STROKE

What stroke do you need? Pulling a load might require a 15 foot stroke if you're closing the door to a large oven. Lifting a stop gate on a conveyor could require only a 2" motion whereas pushing a load off of the conveyor might require 30" or more. Staking a rivet wouldn't require much stroke at all – most likely only a fraction of an inch.

Whatever your task, knowing the stroke starts to define the type of cylinder you'll need. For purposes of discussion here we classify and show examples of four cylinder types by stroke as follows: (a) Short stroke, (b) Intermediate stroke, (c) Long stroke, and (d) Specialty stroke cylinders. Note that some cylinders may overlap all of the categories.

• **Short stroke, compact cylinders**

These come in a variety of body styles and have strokes as short as 1/16" with bores down to 1/2".



Pancake® Air Cylinders are machined from solid aluminum bar. Bores 1/2" to 4"; strokes 1/16" to 4".



Global Series™ Metric Cylinders have extruded body construction. Bores 12mm to 100mm; strokes 5 mm to 150 mm.



Pancake II® composite body cylinders have tie rod construction. Bores 1/2" to 4"; strokes 1/8" to 4".



Square I® Cylinders have extruded bodies & convenient mounting. 4 bores: 3/4" to 2"; strokes to 6".



Multi-Mount Cylinders have compact, rectangular extruded bodies. Bores to 32 mm; strokes 5 to 50 mm.



Twin Rod, FDF Series Cylinders have extruded bodies. Bores 10 to 32 mm; strokes 10 to 100 mm.

• **Intermediate stroke – strokes to 36"**

We define these as cylinders having strokes to 36". After World War II, fast acting, light duty automation applications gave rise to compressed air as an alternative to hydraulics. The then popular tie-rod cylinder construction was copied using aluminum wherever possible to reduce weight and cut manufacturing costs.



Tie-rod construction shown on a 2-1/2" bore x 7" stroke cylinder with male rod extension. (Model S521-7-MR)



Non-repairable, Stainless steel body cylinders have 12 bores sizes 5/16" to 3" with strokes from 1/16" to 32"



ISO 6432 interchangeable cylinders have a round body style with 6 bores to 40 mm and strokes to 500mm.

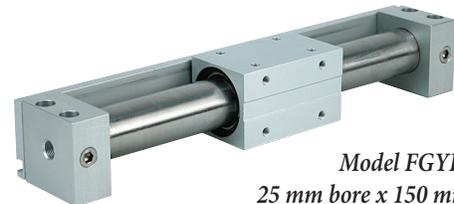
• **Long stroke – strokes to 99"**

We are showing NFPA interchangeable cylinders in this category because their upper stroke limit is 99". But, they are well adapted to applications calling for strokes from 4" and up.



NFPA interchangeable cylinders have strokes to 99" and thus overlap several of our categories. Bores to 14".

Below, magnetically coupled (rodless) cylinders have six bore sizes 10 mm to 40 mm with strokes to 1000" mm.



Model FGYR25x150 25 mm bore x 150 mm stroke



Model FGYB20x100 20 mm bore x 100 mm stroke

• **Specialty stroke – strokes to over 99”**

Cable cylinders, made by several manufactures, are one example of specialty cylinders. As can be seen from the basic drawing, a clamp can be pulled left or right by a cable attached to the cylinder's piston. A 15 foot stroke cable cylinder could be used to

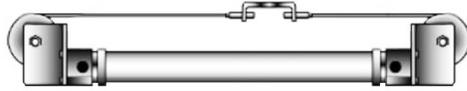


Figure 2 - Cable cylinders can have strokes over 25 feet and can be located remotely from the work load.

control the 15 foot oven door we mentioned earlier. Because the cable can be any length we want, the cylinder can be mounted anywhere that is convenient for your design - directly on the oven or across the room from it if need be.

4) THE CYCLE SPEED

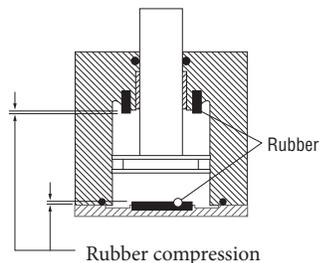
Will the load be moving slowly at a few feet per minute? Or is it reciprocating rapidly at 20 inches per second? Cylinder speed is governed by the amount of air that can enter and exit the cylinder. Thus cylinder port size and control valve size may become issues as you proceed with your design specs.

Fast speed considerations

For fast speeds you'll want to have large cylinder ports and high-flow valves with adequate Cv values. You'll also want to consider the inertial effects on your cylinder and any possible impact damage to the cylinder or your equipment. *Bumpers, adjustable air cushions, shock absorbers or external stops* can resolve most of these issues.

• **Bumper options**

Bumpers are generally used for medium to slow speed applications. They are usually rubber doughnuts bonded to the cylinder head to act as piston stops and absorb the “slap” of the piston. This reduces noise and partially absorbs energy, thus reducing destruction of the cylinder and tooling due to pounding. The amount of rubber



Standard rubber mass provided will compress and give full stroke at normal operating pressure. Mass can be adjusted to meet specific requirements

that extends beyond the normal piston stop is designed to compress and allow full stroke of the cylinder at normal operating pressure.

On applications such as punching, shearing, etc., where high forces are built up and then very quickly released, the proper method of “CATCHING” this load is to adjust the position of the cylinder and tooling so at the point of breakthrough the piston is very close to or touching the bumper. This reduces the dynamic load that the piston and bumper are required to absorb.

However, for high force applications it is highly recommended that shock absorbers be considered and built into the tooling to assist in absorbing the force and dynamic loads generated in such applications.

• **Adjustable air cushion options**

Adjustable cushions are used to bring air cylinders to controlled stops. As a cylinder approaches end-of-stroke, the cushion blocks exhausting air and forces it through an adjustable restriction.

Construction – As shown here on a cut-away view of *Facbo-Air's Model TS200 double rod linear actuator*, one cushion design consists of a needle valve adjacent to the port, a spud attached to the piston, and a lip type seal that acts both as a seal and a check valve.

Operation – As the cylinder nears the end of stroke, the spud enters the check seal, closing off the exhaust port and forcing the captured air to exhaust through the

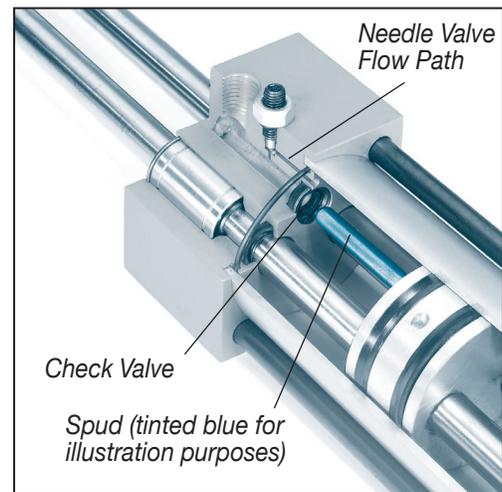


Figure 3 - Model TS200-7-MH3-CL13 showing one type of air cushion construction

adjustable needle valve, providing a smooth, controlled deceleration. On the return stroke, the pressurized air collapses the rim of the lip seal allowing full air flow and providing a quick breakaway.

Cushion length can be specified. A long cushion spud allows the cylinder to be adjusted to stop short of full stroke, and still have plenty of controlled cushioning.

Slow speed considerations

For slow speeds you'll need to consider restricting air flow *leaving* the cylinder using basic flow control valves. Restricting air flow into the cylinder can cause jerky, erratic motion.



**WORK, FORCE, STROKE & SPEED. . .
...MORE CONSIDERATIONS**

At this point you have a pretty good idea of the type of cylinder you need. Now it's time to re-visit the earlier questions and see what answers exist in the form of standard cylinder options.

• **Can the load be allowed to rotate slightly?**

If not, there are numerous **non-rotating options** available. Figure #4 below shows one option on a square head, tie rod cylinder.

Two guide pins incorporated inside the cylinder pass through the piston head. These guide pins prevent rotation of the rod with a tolerance of $\pm 1^\circ$. A rubber disk is included at the end of each guide pin to take up end play and firmly seat the pins in

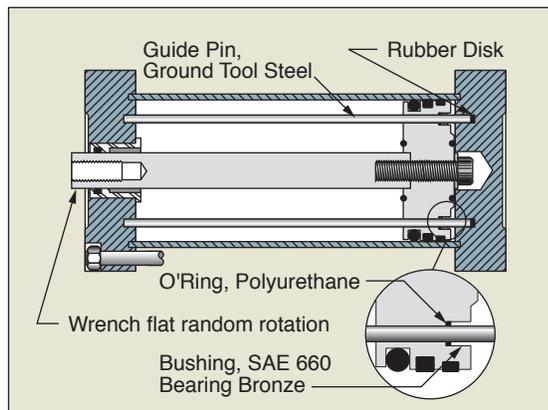


Figure 4: Non-rotating option construction

the precision guide pin holes. Because the guide pins are inside the cylinder, they are protected from the environment, physical damage, and are lubricated by the system lubrication. They require NO additional space, leaving the rod end area free for attachments and tooling as may required by your application.

The internal guide pin approach is also available on short stroke cylinders shown in Figure 5, top next column.



Figure 5:
Cutaway view shows internal guide pins on a Pancake® Cylinder



Figure 6:
Non-rotating, twin rod Pancake II® Cylinders

Twin rod, non-rotating options

Above in Figure 6, twin piston rods are incorporated into the cylinder head to provide *anti-rotation*. The rods are securely fastened to the piston and tied together externally by a rod end tool bar. The tool bar insures that the rods move in tandem and provides an ideal mounting surface for attachments required by your application. The tool bar is furnished with threaded mounting holes or optional counter-bored mounting holes.

External non-rotating options

For applications where anti-rotation and registration are critical, Fabco-Air's FJUK Series has a superior nonrotating feature.

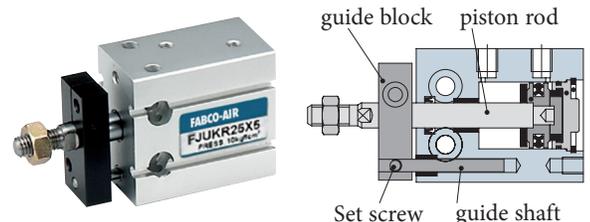


Figure 7: FJUK Series Multi-Mounts cylinder

A guide block is securely attached to the piston rod. A steel guide shaft, attached to the guide block, assures anti-rotation less than 0.8° .

Twin guide shafts options

Global Series™ "GT" metric cylinders provide yet another approach to anti-rotation. Duralon® linear bearings in the body support two chrome plated steel guide shafts that prevent rotation and provide outstanding piston rod support.

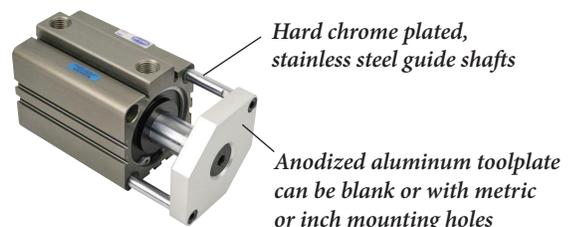


Figure 8: "GT" metric non-rotating cylinders

- Will the cylinder be pushing a load linearly, or turning a crank arm? (The answer determines the type of mount we want for the cylinder.)

Rigid Mounting

For pushing, pulling or lifting along a straight line, we want the cylinder to be rigidly mounted. We could bolt the cylinder to our equipment either by bottom tapped holes or stand it on end and run bolts into sleeve nut mounts in the end cap. Or we could choose any of the other standard rigid mounts from the *Guide to Interchangeable NFPA Mounts* (chart at the right).

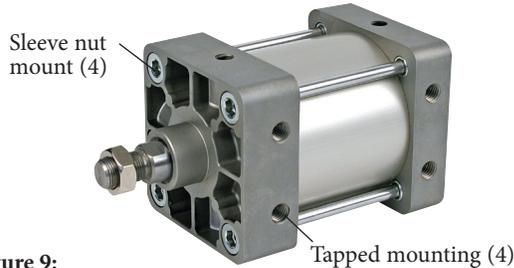


Figure 9:
Bottom tapped mounting holes on a 40 mm bore Model FCQN oem-NFPA cylinder

Flexible Mounting

If turning a crank arm, the cylinder would need to pivot. As you can see below, a rear clevis mount attached to the cylinder would allow it to pivot but restrain lateral motion. Lastly, by attaching the crank to the piston rod with a flexible coupling, we can secure our desired motion.



Figure 10:
Detachable rear clevis allows cylinder to pivot

Flexible Mounting – short stroke cylinders

Short stroke cylinders have many of the same mounts as the big boys. Eye mounts, for example, are available on Pancake® and Pancake® II cylinders.



These mounts also provide a pivot point attachment to allow pivotal motion of the cylinder. To further assist with these types of flexible mounts, rod clevises, rod eyes and mounting brackets are widely available.

Figure 11: Eye mount shown on Pancake Cylinder®

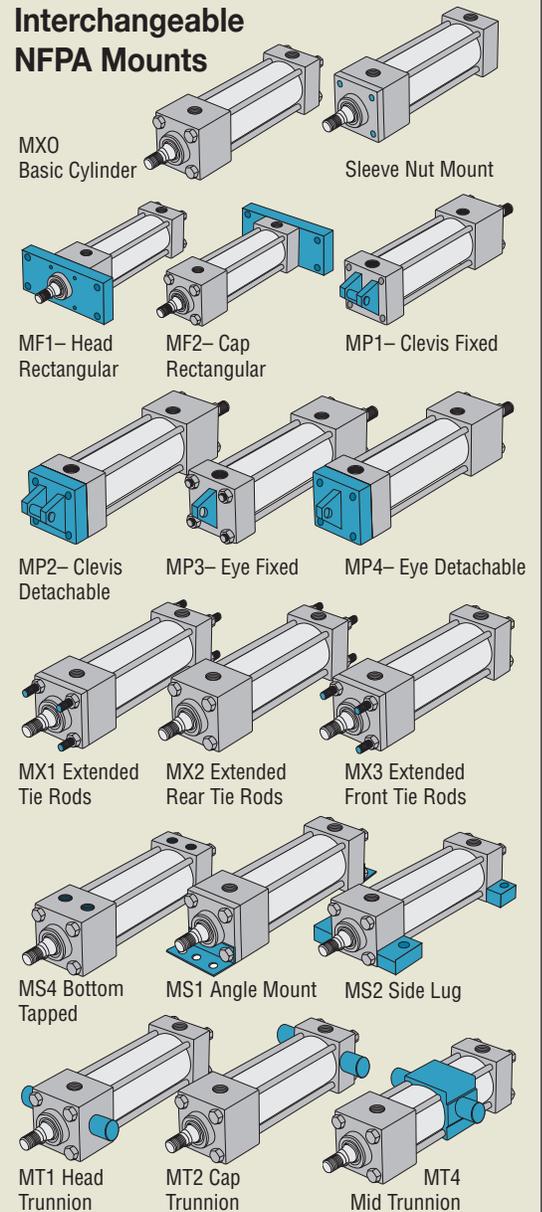
Flexible Mounting – non tie rod cylinders

Most cylinder styles have mounts similar to the NFPA mounts. As example, trunnion mounts are available on our stainless steel body cylinders. Dimensions differ from the NFPA mounts, but they function the same.



Figure 12:
Front trunnion mount shown on F-Series cylinder

Quick reference to the Interchangeable NFPA Mounts



Thru-hole mounting – short stroke cylinders

Thru-hole mounting is available on many short stroke cylinder models. It provides counter-bored holes drilled through the cylinder body for easy mounting with socket head cap screws.

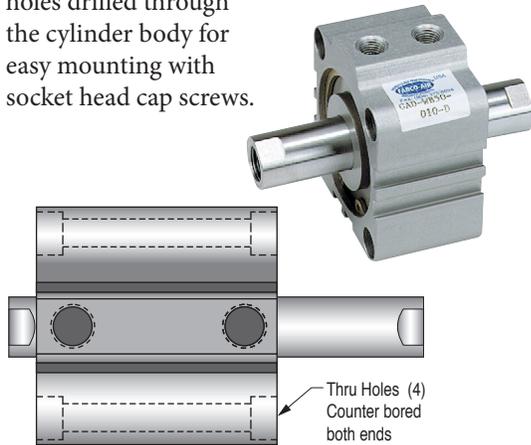


Figure 13: Thru-hole mounting shown on a Global Series™ double rod, double acting cylinder.

We've touched on just a few mounting styles to give you an idea of what's available. Whatever cylinder style you choose, be sure to dig deep in the product catalogs to find the mount best suited to your application.

WORK LOAD . . . MORE QUESTIONS

By now you probably have a good feel for the kind of cylinder you want. But, you need to know a few more things.

• *Does the load require the same or different forces when extending and retracting?*

Spring return cylinders

Often only the work stroke requires full pressure on the piston while the return stroke needs only a minimal force - just enough to return the piston. In such cases, spring return cylinders may be the perfect choice. Below, cutaway views of 1-5/8" bore Pancake® cylinders show how internal springs accomplish the desired cylinder motion without air pressure on the piston.

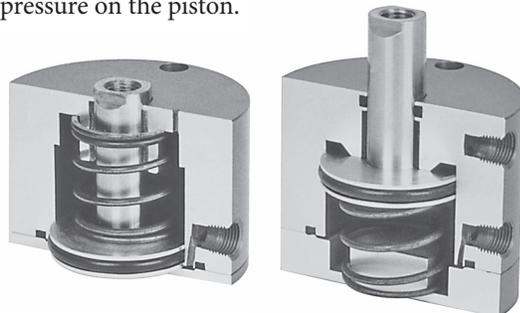


Figure 14a: Spring retract action for push applications

Figure 14b: Spring extend action for pull applications

• *Does the stroke remain fixed, or will it require adjustability?*

Adjustable Retract Stroke

An adjusting screw with a thread sealing locknut mounted in the rear end cap provides a simple, yet rugged adjustment of the cylinder stroke in the retract direction. A fine thread on the adjusting screw will provide precision adjustment. Adjustable retract strokes are offered as standard options for many cylinder styles.

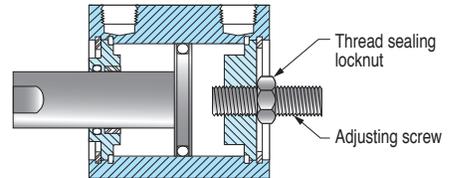


Figure 15: An adjustable retract stroke option

Adjustable Extend Stroke

It is possible to use the back end of a double rod cylinder to adjust the extend stroke. A stop collar, bumper and some kind of impact plate could do the trick. However, if taking this approach, use caution and consider a safety cover to avoid leaving the pinch point exposed!

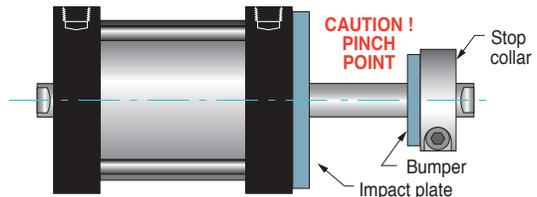


Figure 16: Adjustable extend stroke possibility

Precision Adjustable Extend Stroke

Dial-A-Stroke® is a Fabco-Air exclusive option available on most of our cylinders. It provides a rugged and precision adjustment of the cylinder's extend stroke. The stop tube, adjustment nut with skirt & minimum clearances combine to eliminate pinch points, thus providing operator safety. **Note!** Use caution when mounting to avoid creating pinch points with other parts of your machine design.



Adjustment settings are simplified by convenient scale markings applied to nut skirt and stop tube.



Figure 17: Dial-A-Stroke shown on Pancake® and Tie rod cylinders

- Must the load stop at any intermediate position?

3-Position cylinders

You're in luck. You can get three rod positionings from a single cylinder! Many cylinders styles are offered with 3-position options. Our Pancake®II shown below, is essentially two cylinder bodies combined in a single package. You specify the same or different stroke lengths to set your work positions as required. Nice!



Figure 18a: 3-Position Pancake®II cylinder

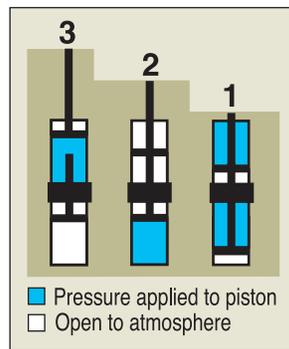


Figure 18b: Piston positions for achieving 3 end-point positions

4-Position cylinders

More luck! You can also get numerous cylinder styles in back-to-back configurations that enable positioning at up to 4 four end-points. As the name implies, two single rod cylinders are assembled with their back end caps attached. As shown below, by anchoring one rod end and allowing the cylinder body to “float”, four distinct end points can be obtained.

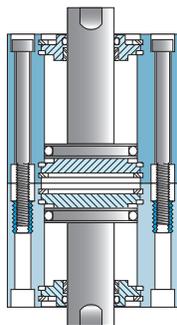


Figure 19a: Assembly view of back-to-back Global Series™ cylinder

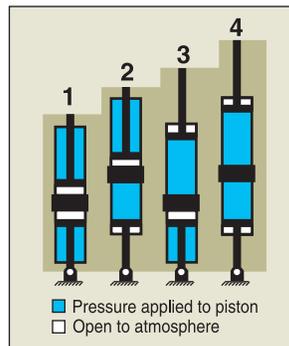


Figure 19b: Piston positions for achieving 4 end-point positions

- Will your cylinder be clamping parts together while separate machine operations take place?

Specialty clamp cylinders

There may be no need to design your own clamping device because specialty clamp cylinders are available as standard products in a wide variety of styles and force ranges.



Figure 20: FML & FHL Series swing clamps are available for both pneumatic and hydraulics

- Are you stopping parts on a conveyor?

Stopper cylinders

Fabco-Air is now offering a modified version of its 32 mm bore Global Series® cylinder for use in conveyor stopping applications. With its new, heavy duty mounting, oversized piston rod and its special rod bearing with increased surface area, the cylinder stands tough against the abuse of side impact loading.



(Model GND-CM032-025D shown)

More Stopper cylinders

Aiding your design efforts, stopper bodies are machined from aluminum extrusion to provide rigid mounting to equipment in a minimum of space. Magnetic pistons are included as standard.



Figure 21: ST Series stopper cylinders

- 7 rod end choices
- adjustable roller direction
- side or bottom tapped mounting and
- shock absorber options and
- spring extend or retract action.

• Will the cylinder have overhung load difficulties?

Cylinder piston rods are supported by a bearing in the front head of the cylinder and the piston itself running inside the cylinder walls. As the rod nears full extension, the distance (“d”) between support surfaces becomes shorter. The piston rod assembly tends to cock causing uneven wear on the bearing surfaces and shortening seal life.

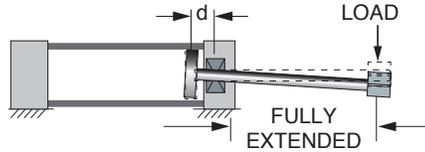


Figure 22a: Over hung load

Stop tubes

One solution to the problem is to install an internal stop tube. The stop tube blocks the piston from reaching the front head thereby increasing the distance between support points. Components wear is reduced and cylinder operating life is extended.

However, to maintain the same work stroke, the length of the cylinder body must be increased by the length of the stop tube. Dealing with the increased package size may present another issue.

Extra Length added

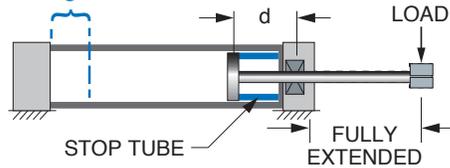


Figure 22b: Cylinder stop tube

Double rod cylinders

If you have room available, a double rod cylinder gives you the best piston rod assembly support. You’ll have rod bearings in both end caps reducing the load on the piston. And you’ll have maximum distance between support points.

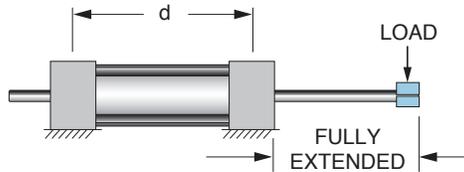


Figure 22c: Double rod cylinder

Twin rod cylinders

As you can imagine, cylinder manufacturers have tackled the overhung load scenario many times in the form of specials. Enough so that some of the specials have turned into standard product line items.

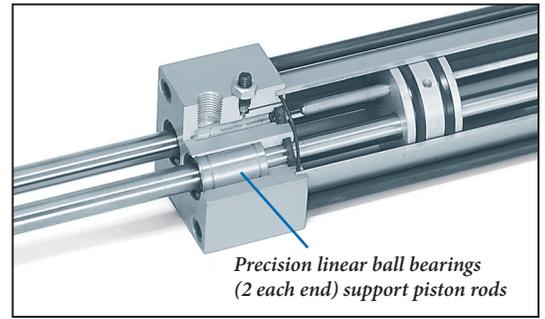


Figure 23: Linear slide packaged in an air cylinder body

Take for example this Model TS200 linear actuator shown in a cutaway view above. In this view we note that the actuator has a pair of precision linear ball bearings guiding the each piston rod. A serious move against overhung loads!

(For reference, the TS Series actuators are available in 6 bores from 1-1/8" to 4", standard strokes to 20" and rod diameters from 1/4" to 1". See Catalog #LS-03.)

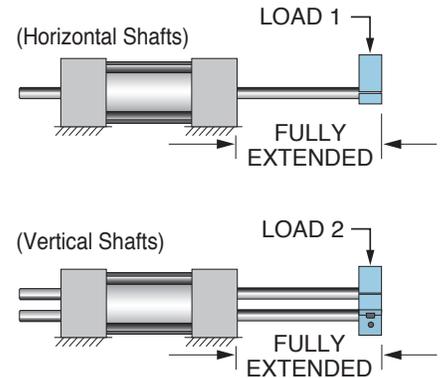


Figure 24: Rod alignment options

Twin rod cylinders can be installed with either of two rod orientations: horizontal or vertical. Vertical shaft alignment will support the largest loads. Load factors are charted for quick reference in the product catalog.



• What are your options when the cylinder you have selected won't fit in the space available?

Sometime just a simple modification to a standard product will do the trick.

For example, the end caps of this Pancake® II Cylinder were milled flat on two sides for precise alignment in tight space. Problem solved!



In another case, only a totally custom cylinder could meet the exact design requirements.

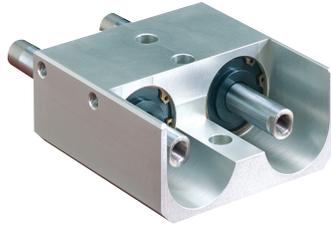


Figure 25: Two cylinders in one body meet space requirements

Above in Figure 25, two 50 mm bore, 2" stroke, double acting cylinders were nested in a single body to enable precise alignment of customer tooling under extremely tight space limitations.

- If minor modifications won't work, are there any other options to avoid going to a custom cylinder?

Okay. Now you'll be making some serious trade-offs. Yes, things will fit if you go to a smaller bore cylinder, but the thrust forces won't be strong enough to do the job. The good news is that there are smaller bore cylinders that do have the force you need. These are the force-multiplying cylinders that have two or more pistons.

Force multiplying cylinders –

Fabco-Air developed these cylinders in the early sixties and copywrote the name "Multi-Power®" Cylinders. With these cylinders, your trade-off is that the cylinder grows longer with each extra piston that you need added. Here's how they work...

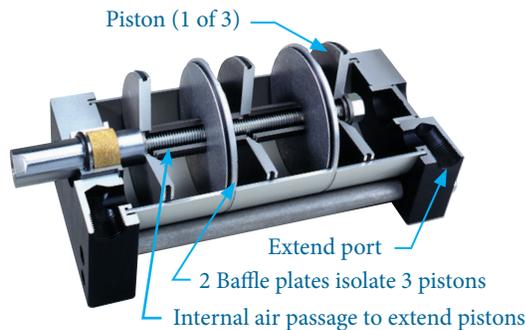


Figure 26: Typical Multi-Power® Cylinder construction

- 1) Fabco-Air attaches multiple pistons to a common shaft.
- 2) An internal air passage through the shaft energizes all pistons simultaneously when the extend port is pressurized making it easy to double, triple, or quadruple your output force.

Multi-Power® cylinders are available in ten bore sizes and can create forces up to 44,000 lbs. of force rivaling many hydraulic systems! They are easy to install having only two port connections. They're available in short stroke body styles as well as tie-rod body styles.



Figure 27. Short stroke Multi-Power® body styles

Example – High Force Cylinder Sizing

Earlier we mentioned crimping a rivet as a possible example of short-stroke cylinder usage. Let's see a crimping application would work. Assume that we need 4800 lbs of force for upsetting a rivet holding a stack of laminations together. Dividing 4800 lbs by 90 psi (our available shop air supply), we will require 53.3 in². of piston area to do the job.

Bore Inches	Stages (No. of Pistons)	Total Effective Piston Area-Square Inches	Equivalent Bore of a Single Piston Cylinder	Force@ 90 psi	Single Stage Retract Piston Area, sq. in.
1/2	2	.35	.6	30	.15
	3	.50	.7	45	
	4	.65	.9	52	
4	2	24.4	5.6	2196	11.8
	3	36.1	6.8	3249	
	4	47.9	7.9	4311	
5	2	38.0	7.0	3420	18.4
	3	56.4	8.5	5076	
	4	74.8	9.7	6732	
6	2	55.3	8.4	4977	27.0
	3	82.3	10.2	7407	
	4	109.4	11.8	9846	
8	2	98.6	11.2	8874	48.5
	3	147.0	13.7	13230	
	4	195.4	15.8	17586	
10	2	153.9	14.0	13851	75.4
	3	229.3	17.1	20637	
	4	304.7	19.7	27423	
12	2	222.9	16.8	20061	109.9
	3	332.8	20.6	29952	
	4	442.7	23.7	39843	

Figure 28: Multi-Power® Cylinder Power Factor Guide

From Figure 28 we see that two standard units meet the piston area requirements: a 5" bore 3-piston (3-stage) cylinder has 56.4-in²; a 6" bore 2-stage unit has 55.3-in². At 90 psi, both will yield forces beyond our needs.

Your challenge deepens if you find that you lack room for the additional cylinder length required with the Multi-Power® approach. What then?

• *If you can't raise the line pressure, could a booster bump it up to the pressure you need?*

Boosters

Fabco-Air BA Series Multi-Power® Boosters use shop air to raise the pressure of another gas or liquid. They are compact and can be mounted in almost any convenient location.



*Fabco-Air BA Series
2-stage Pressure Booster*

Available in 2-1/2 and 4" bores with up to 5 pistons, they deliver power factors ranging from 1.9 to 4.8 times available line pressure. They can be operated with a 4-way air valve.

Using boosters as a pump

A magnetic piston option enables their use as a pump driven by a 4-way, solenoid operated air valve.

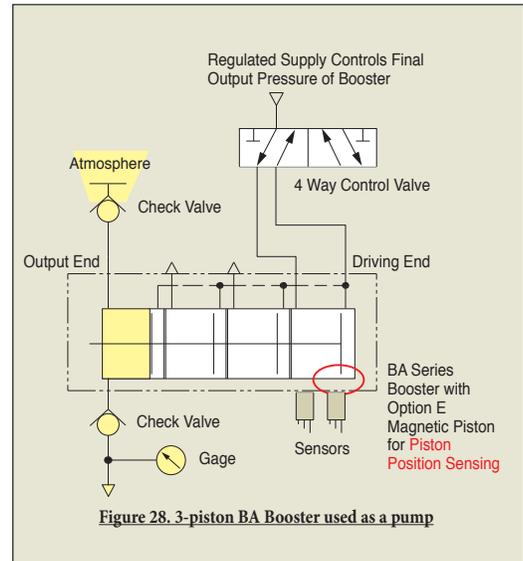


Figure 28. 3-piston BA Booster used as a pump



We have attempted to take some of the stress out of specking pneumatic cylinders by categorizing their shapes, types and sizes and tying them to standard options and alternative products that can (sometimes) help you avoid going to a custom special.

But, when a standard doesn't do it for you, come to us. **Fabco-Air solves problems. Let us help!**

about FABCO-AIR



One of Fabco-Air's 24/7 lights-out machining centers

Fabco has all the popular off-the-shelf pneumatic components you want, ready for immediate shipment. Yet almost half of our business comes from helping customers solve design problems with special pneumatic solutions. We can design, prototype and deliver custom samples within 72 hours!

since 1958

FABCO-AIR, Inc.

With operations housed in 61,000 sq. ft. in Gainesville, Florida, Fabco is dedicated to developing and providing advanced fluid power technology to give our customers the competitive edge they need in their field.

24/7 lights-out precision machining centers drive production, assure product quality and enable reliable delivery.

