Technical Tips

# Maximizing Cylinder Performance

*Reprinted from Machine Design*
*Edited by Kenneth J. Korane*

A checklist of design guidelines ensures the best pneumatic cylinder for an application.

*A position-sensing switch based on giant magnetoresistive technology measures only 0.160 in. in diameter. This design automatically configures to a current-sinking or sourcing load, and offers solid-state reliability, 1-psec response time, and low hysteresis.*

Pneumatic cylinders are a proven way to provide quick, clean, reliable, and inexpensive linear motion, and a multitude of available designs, styles, and options can suit most any conceivable application.

Sometimes though, sorting through the many choices can seem to be a daunting task. But following some simple guidelines lets engineers quickly target the right cylinder for a given application.

One key is to focus on factors that impact cylinder performance. These include the cylinder's size and force relative to load, the working environment, mounting hardware, and options that prevent wear and improve efficiency. Here's a closer look.

## Cylinder Types

Manufacturers generally categorize cylinders by the type of action and physical construction. They usually group linear action into three categories.

**Single acting** cylinders provide power only on the extension or "push" stroke. A separate force, usually an internal spring, returns the piston to its original position in preparation for the next stroke.

**Reverse single acting** designs are similar to single acting, but with the port on the opposite end to provide power only on the retraction or "pull" stroke.

**Double acting** cylinders have dual pressure chambers and provide pneumatic power on both extension and retraction, eliminating the need for a spring.

Single-acting cylinders are simpler and cost less than double-acting products. They require less hose or tubing, fewer fittings, and more economical three-way valves, instead of four-way control valves. However, the spring-return stroke generally lacks the force and speed of a pneumatic return. The need to physically accommodate a spring generally limits single-acting cylinders to short strokes and 2 in. bores or smaller. Double-acting cylinders are also a better choice when it is necessary to control actuation speed.

The fluid power industry classifies cylinders based on physical construction, with the two most common being NFPA cylinders and so-called disposable cylinders. NFPA designs feature tie rods that prestress the cylinder and squeeze the end caps together about the body, a construction that stands up well to high pressure and impact loads. The cylinders are more massive and rugged than disposable designs and usually, for a given size, feature larger-diameter rods and longer rod and piston bearings. NFPA cylinders can also be disassembled and repaired.

Naturally, they cost more than disposable cylinders. In light of the near-universal demand to cut size, weight, and price from designs, users can no longer afford the luxury of specifying over engineered components. As a result, there is a growing trend toward lighter-duty cylinders tailored to the precise demands of given applications.

Another consideration is standard versus custom cylinders. Experts typically recommend looking for off-the-shelf solutions first because they cost less and are readily available for quick delivery.

But sometimes there is a need for something a little different; a special stroke, custom mounting style, or special seal material, for example. Custom units have the advantage of suiting a customer's needs more completely than do standard products, although delivery can be a concern. Keep in mind that some manufacturers routinely produce special designs while, for others, they are merely a side line. Check that the supplier has the technical knowledge and engineering skill to provide preproduction support, prototypes, testing, and engineering documentation, as well as the manufacturing capabilities to quickly and economically fulfill an order.

## Sizing Cylinders

After zeroing in on the type and style of cylinder, focus on the load, velocity, and air pressure to size it. Cylinders should typically provide at least 25% more force than the load to allow for friction.

Although the application may predetermine a cylinder's rod velocity, designers often have some latitude. For best results, use moderate speed whenever possible. That's because the greater the velocity, the greater the additional force needed. Slow speeds (to 4 ips) require 25% more force than the load; moderate speeds (4 to 16 ips) about 50% more; and high speeds (greater than 16 ips) about twice as much.



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Another issue when sizing cylinders is the minimum effective air pressure, and whether or not pressure is constant. This is important because higher pressures accelerate seal wear and stress the cylinder, while inconsistent pressures can lead to system malfunction or failure. Providing consistent air flow at the minimum effective pressure to maintain the desired velocity maximizes life and performance. Size the cylinder to move the maximum load at the minimum acceptable velocity with the minimum available pressure.

After determining the required force and velocity, here's how to find the proper cylinder size that meets specifications. Multiply air pressure P by piston area or power factor A, determined by bore size, to generate force F, or F = PA. After sizing the cylinder, consider these additional factors.

**Stroke length.** Calculate how far the piston must extend or retract to perform the task.

**Spring force.** For single acting cylinders, be certain the spring force can return the piston/rod assembly and customer attachment to the start position.

**Overall dimensions.** Accurately measure the available space to ensure it will accommodate the cylinder's mounting and operating requirements. Consider space-saving disposable cylinders when space is limited.

Next select the mounting style based on the cylinder's size, force, and function. All these factors are necessary because the wrong mounting or improper installation can side load the rod, which creates excessive wear on the piston, piston rod, rod bearing, and seals. With wear comes leakage, and that is how cylinders fail.

Causes of side loading include running the cylinder without piston-rod guidance or support, and misalignment between mounting and piston-rod connections. Side loading in pivot-type mounts occurs when the cylinder weight places a load on the piston and rod bearing joints. (See the accompanying sidebar, "Mounting Cylinders for Long Life", for more information.)

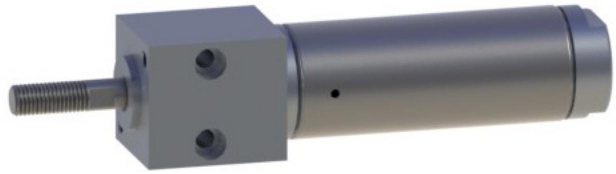
Dual-piston cylinders exert twice the force of traditional cylinders and can handle higher radial loads.

HEPA-type cylinders are more massive and rugged than disposable cylinders, but carry a higher price.

Inconsistent air pressure causes unpredictable stroke speed. Flow controls ensure constant airflow and consistent operation.

*Common Mounting Styles*

Cylinder mounting style has a direct effect on service life because the wrong mounting or improper installation leads to side loading that damages bearing, seal, and other components. Here are some common designs.

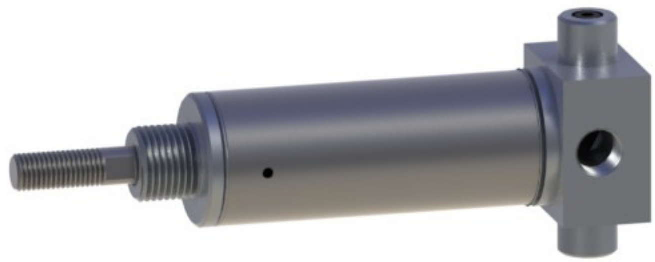


FRONT-BLOCK MOUNTING

FRONT-NOSE MOUNTING

REAR PIVOT MOUNTING

UNIVERSAL MOUNTING WITH
PIVOT OR DOUBLE END



REAR-BLOCK TRUNNION

**Mounting Cylinders for Long Life**

A wide range of cylinder mountings (such as nose, block, universal, pivot, and trunnion) make it possible to find one suited to virtually any application. But some caveats apply. For instance, clevis, pivot, and trunnion mountings eliminate side loads in one plane, but require careful alignment in the other plane. Spherical-ball mounting plates and rod ends, on the other hand, eliminate side loads in both planes on pivot and clevis mountings.

To fully realize the benefits of pivot mountings, use a rod eye or rod clevis on the piston rod. Otherwise it functions as a rigid-mount cylinder. Also, set all pivot pins in parallel to prevent binding or side loading.

Long stroke, pivot-mount cylinders will unavoidably have high side loads because of the rod weight. In these applications a stop tube or dual piston becomes essential. Both spread the distance between the rod bearing and piston, reducing the effective load at these two points.

On trunnion mounted cylinders, fit pillow blocks or mated bearings as close to the cylinder head as possible, to minimize bending stresses in the heads. And never use spherical-bearing pillow blocks on trunnion mounts because they introduce bending stresses.



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Carefully align rigid-mount cylinders (such as side, nose, flange, and face-mounted units) with the direction of travel to avoid side loads. A rod eye or rod clevis will not prevent side loads in out-of-parallel applications. If, for some reason, proper alignment is not possible, apply a rod-end connection that allows some lateral misalignment, such as a commercial rod-end coupler with built-in axial allowance or axial take-up.

**Options**

Many optional components improve cylinder performance or prevent problems such as side or shock loading. Here are a few examples.

**Cushions** designed into one or both ends of the cylinder can control deceleration. This prevents excessive and end-of-stroke impact that leads to premature cylinder failure.

**Bumpers** are built-in elastomeric disks that absorb the end-of-stroke shock impact and are an excellent means of minimizing noise and vibration in a cylinder.

**Stop tubes or dual pistons** help reduce side loads by spreading out the distance between rod bearing and piston, reducing effective loads at these points.

**Speed control** can be crucial to reliable and consistent cylinder performance. Inconsistent air pressure causes unpredictable stroke speed, and pressure that is too low can cause irregular piston movement during the stroke. Install flow controls on the cylinder to ensure constant, controllable airflow for precise and consistent operation.

**Position-sensing** switches are another common control option, expanding cylinder capabilities to include accurate positioning, event timing, sequencing, and synchronization. The switches typically mount on the cylinder body and interact with a permanent magnet attached to the piston to close an electrical circuit and initiate actions such as activating relays, timers, or solenoids. A number of position sensing options are available.

**Magnetic reed** switches represent an older but still-valid technology. They make a mechanical connection when a magnet passes, reading a specific, preselected position. The low-cost devices offer accurate position sensing and are often used with relay logic. However, they are subject to wear, slower than other types of switches, and can exhibit contact bounce.

Hall-effect switches use solid-state technology to provide a compact, accurate, reliable interface between pneumatics and programmable logic controllers. With no mechanical parts to wear out, Hall-effect switches offer virtually infinite life.



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## Environmental Concerns

The working environment dramatically impacts cylinder operation. That's why it is important to select seals, bearings, lubricants, materials, and finishes that counteract environmental conditions.

One instance involves extreme-temperature applications, typically below -20°F (-25°C) or above 200°F (95°C). In such cases expect shorter cylinder life and a higher risk of unexpected failure due to damaged or brittle seals, overstressed metal, or lubricants that turn too thick or too thin. Cylinders that operate below 0°F (-18°C) for extended periods may also need special seal modifications. For best results, specify heat or cold-resistant materials and be especially vigilant with regular maintenance.

Radiation is another concern because it changes almost all materials and, in some cases, causes materials to disintegrate. Here, determine the type and intensity of radiation to accurately estimate cylinder life.

Moisture, salt, chemical fumes, and high concentrations of ozone or toxic gas all accelerate corrosion and shorten seal life. Regular cleaning of cylinders with caustic wash-down fluids can corrode cylinders and shorten life as well. In these instances, special finishes and materials such as plastic or stainless steel may be called for to increase corrosion resistance.

When dust and dirt pose a problem, specify mechanical solutions such as rod wipers and scrapers. These devices clean the rod after each stroke and keep foreign substances out of the cylinder. For extra protection, install rod boots (bellow that fits around the piston rod and expands and contracts as the rod moves).

Finally, lubrication remains key to maximizing pneumatic-cylinder life, as well as ensuring the highest operating efficiency. Today's environmental regulatory concerns are raising interest in non-lubricated cylinders. These often use special seals, bearings impregnated with solid lubricants, as well as coatings such as molybdenum disulfide on the internal bore. Life of some non lube cylinders approaches that of traditional lubricated cylinders, but the latter still lasts longer in most operations. Regardless of design, cylinders not properly lubricated can overheat, damage components, and ruin seals, much as the wrong lubricant can quickly degrade or destroy the seals.