



The Art of Cylinder Specification

The Right Cylinder for the Right Duty



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Introduction

The first hydraulic press may have been invented in the 3rd Century BC, but the fluid power universe has become a little more complicated since then. Today's hydraulic cylinders, which essentially convert fluid pressure and flow into force and linear movement, are complex devices incorporating a wide range of individual components available in a multitude of dimensions, configurations and materials.

For many OEM design engineers, playing it safe by over-engineering cylinder specifications has become a precautionary habit in the presence of ever-improving cylinder technologies. This article will help clarify why less is sometimes more when it comes to complex hydraulic systems, while identifying some of the many factors to be considered when specifying hydraulic cylinders.



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Hydraulic vs. Pneumatic

Although pneumatic systems are in some respects simpler, they are generally incapable of achieving the transfer of higher loads and forces. Hydraulic cylinders also have the advantage of smoother, more controllable movement as they are devoid of the spring-like action associated with the release of gaseous fluid media. As an added benefit, hydraulic systems can perform ancillary functions such as lubricating and cooling.

However, since the availability of power and media is a non-negotiable factor in fluid power system design, it should be noted that a properly designed and sized pneumatic system can achieve higher performance where a compact footprint is not required. Further considerations of pneumatic cylinder design are outside the scope of this article.



Design Factors in Hydraulic Cylinder Specification

Specifying hydraulic cylinders is essentially a balancing act as each design factor influences one or more of the many other design considerations. For example, the urethane seals ideal for applications as cold as -65°F (-54°C) will tolerate 200°F (129°C) of heat, while other materials capable of tolerating temperatures as high as 500°F (260°C), will do so at the sacrifice of some cold-temperature performance.

Although NFPA standards and ISO-compliant guidelines are a great starting point for hydraulic system design, many industries have guidelines of their own. Working with an engineering manufacturer experienced with all these standards can expedite the design process.

Cylinder manufacturers can offer a range of options capable of achieving the widest scope of performance requirements that increase the likelihood that standard components will meet the design criteria of an application. For example, most cylinder manufacturers offer 19 mount options, which cover the standard NFPA mount offerings. Standard compo-

nents have the additional advantage of being readily available worldwide, expediting just-in-time warehousing and delivery of replacement parts as components reach the end of their service life cycle.

A review of the major factors is to be considered when specifying hydraulic cylinders follows.

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Capacity

Medium-duty systems account for most of industrial applications and are typically at 1000 PSI. Heavy-duty systems are common to applications such as hydraulic presses, automotive applications, and other related industrial applications. Standard

heavy-duty hydraulic cylinders are capable of handling pressures as high as 3000 PSI, with load capabilities relative to the full piston area (in square inches) when exposed to fluid pressure multiplied by the gauge pressure in PSI. Excessive load require-

ments may be achieved without sacrificing other areas of performance through the use of tandem cylinder constructions rather than larger bore or custom high-pressure cylinder designs.

Stroking Distance Requirements

Although custom stroke distances above 10 feet (3.05m) are possible. Pressure rating can be a concern. Rod diameter needs to be determined to handle the

load. If necessary, a pressure rating on load in thrust (push mode) will need to be specified. Rod sag from horizontal applications may result in premature rod

bearing wear. Weighing each positive effect against potential negatives is essential to optimizing hydraulic system performance.

Speed

Every application engineer has his or her own definition of “excessive speed.” As a good rule of thumb, standard hydraulic cylinder seals can easily handle speeds up to 3.28 feet (1 meter) per second. The tolerance threshold for standard cushions is roughly two thirds (2/3) of that speed.

Frequently, a standard low-friction seal is the better choice for higher speed applications. But here too, what you gain in one aspect of performance you lose in another. The greater the fluid velocity, the higher the fluid temperature, so when opting for speed-increasing customizations it is essential to consider the

impact of higher temperatures on the entire hydraulic system. In some hydraulic systems, oversized the ports may eliminate escalated temperature concerns.

Temperature

As previously noted, hydraulic cylinder systems using standard components can be designed to meet application temperatures as hot as 500°F (260°C) and as cold as -65°F (-54°C). But temperatures affect both the “hard” and “soft” design components of

cylinders. Applications requiring temperature extremes at either or both ends of the temperature spectrum require extensive knowledge of the interdependency of individual components to achieve the best balance of short- and long-term

performance expectations. For example, applications near the north or south poles, will see contraction of the seals and metal parts due to the extreme temperatures.

Mounting Styles

There are fundamentally three categories of mounting styles. Both Fixed and Pivot styles can absorb forces on the cylinder's centerline and typically include medium- and heavy-duty mounts for accommodating thrust or tension. A third category of Fixed styles allows the entire cylinder to be supported by the mounting surface below cylinder centerline, rather than absorbing forces only along the centerline.

There are several available standardized mounts within these categories. Engineers can use these variety of mount offerings for an ever-widening number of application requirements. NFPA Tie rod cylinders, which are used in the majority of industrial systems, typically can be mounted using a variety of standard mating configurations from trunnion-style heads and caps to extended tie rod cap and/or head end styles, flange-style heads, side-lug and side-tapped styles, a range of spherical bearing configurations, and cap fixed clevis designs. Most of these mounting options are available for both single acting and double rod cylinders.

The goal of every mounting design is to allow the mount to absorb force, stabilizing the

system and optimizing performance. For rods loaded primarily in compression (push), cap end mounts are recommended; for those in tension (pull), a head end mount is preferred.

It is the amount of tension or compression that determines piston rod diameter; it is the amount of pull or push that determines the bore diameter. Other relevant factors to consider when selecting a mounting style include:

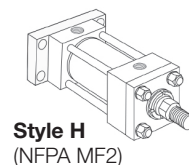
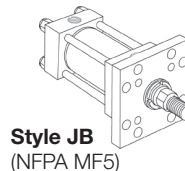
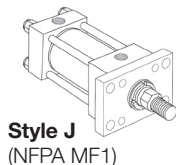
- **Load**
- **Speed**
- **Cylinder motion (straight/ fixed or pivot)**

Every mounting type comes with its own benefits and limitations. For example, trunnions for pivot-mounted cylinders are incompatible with self-aligning bearings where the small bearing area is positioned at a distance from the trunnions and cylinder heads. Improper use of such a configuration introduces bending forces that can overstress the trunnion pins.

Many performance expectations that at first appear to require atypical mounts can be accommodated by existing styles, sometimes with only slight modifications, facilitating replacement and reducing costs.

Mounting Styles

General Practice	
Best Practice	Select mounting styles which absorb force on cylinder centerline
Compression	If the piston rod is loaded primarily in compression, select cap end mounting styles
Tension	If the piston rod loaded primarily in tension, select head end mounting styles



Cylinder Bore Size

Bore size is related to operating pressure; as previously noted, it is the amount of push or pull force required that determines the bore size needed. Earlier

generations of steel and aluminum mill equipment often required the use of non-standard bore and rod sizes. Today, virtually every industrial require-

ment can be met with NFPA standard and/or ISO-compliant components.

Piston Rod Size

OEM design engineers probably request customization of piston rod sizes more frequently than any other hydraulic cylinder component. What is not always considered is the simple fact that push or pull is never independent of stroke length. Just as a pushed rope holds a straight line only in relation to its length (the longer the rope, the more the rope curls), piston rods under compression or tension tend to diffuse force in non-linear directions.

Specifying costly materials such as stainless steel or alloy steels for the rods themselves is another common example of over-engineering. In most extreme applications, chrome plating provides a high level of corrosion-resistance required to optimize system longevity.

Cylinder Configurations

For applications requiring equal force pressure on both sides of the piston, a standard double-acting cylinder configuration using pressure to extend and retract the cylinder, combined with a four-way directional control valve to direct pressure to either the head or the end cap, is almost always preferable to more customized solutions.

An experienced hydraulic solutions manufacturer will be familiar with every conceivable cylinder assembly configuration and the unintended consequences of customizing individual components versus combining standard cylinders in creative ways to meet unusual performance requirements.

Rod Ends / Rod Threading

This is one area where standard options are so vast customization is rarely needed. Additionally, standard threads can be made in inch or metric format. Typically, each available diameter is available in four distinct rod end styles. Even in those rare instances where a modification seems to be called for, it is important to consider the effects of modifications on function-enhancing accessories. The relatively small performance compromise resulting from standardizing rod ends is almost always warranted by the versatility such standardization affords.

Even a modest modification such as under-sizing threads will require de-rating the cylinder and may necessitate special tooling for non-standard pitch, resulting in delays, expense, and the inability to readily mate with accessory components.

Cylinder Body Tube

Standard cylinder bodies are plain steel or chromed plated and will be able to handle a majority of applications. Using alloy steels, stainless steel or brass materials are prevalent in special application like a water type environment.

Stop Tubing

Stop tubing is generally used to lengthen the distance between the rod bearing and the piston bearing in order to reduce bearing load on push-stroke cylinders when the cylinder is fully extended. Stop tubing is especially critical for horizontally mounted cylinders where it helps to restrict the extended position of the rod. In such applications, increased distance helps achieve greater stability and increase bearing life.

Seals

Although it is not common to require all existing material compounds, an experienced hydraulic system manufacturer will offer seals to meet a complete range of temperatures and fluid types, and can help guide an engineer's specification to meet precise application requirements.

Additional Considerations

Every industrial application is unique, and there are many ancillary components involved in hydraulic cylinder specification. Energy-absorbing cushions, pillow blocks, regenerative circuits, over- or under-sizing ports — all these and more contribute to optimizing the performance of hydraulic systems, depending on each application's specific performance requirements.

As with the specification of more fundamental components, selecting appropriate ancillary components can present a specification challenge. For example, cushions are intended to retard the force of motion, but OEM engineers sometimes overlook the fact that fluids are typically not moving very fast anyway and may not require such redundancy in certain types of systems. An engineer may be

tempted to take a “belt and suspenders” approach to designing push/pull systems by using cushions with spring cylinder systems, overlooking the fact that the oil needs to work its way through the cap, hoses, valves and so on. In such cases, specifying standard single action cylinders with cushions may be wiser than attempting to insert cushions into spring cylinders.

Conclusion

There are certainly applications for which specifying the right cylinder for the right duty require some customization either in component size, material type or configuration. However, far more often than not, partnering with an experienced hydraulic system

solution manufacturer early in the design process will save the OEM engineering team time and money while ensuring the system does its assigned duties as efficiently as possible for as long as possible.

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