

Spring-return cylinders- Not as simple as you think

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When a circuit must have a fail-safe feature, a spring-return cylinder may provide the simplest way to accomplish it.

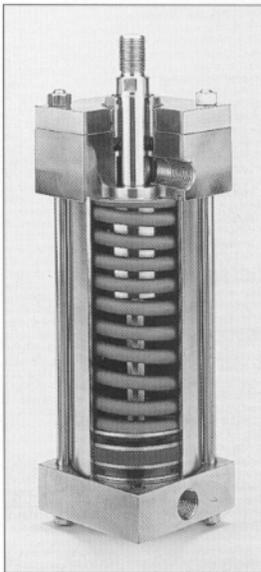


Fig. 1. Cutaway model of all-stainless-steel LSS Series cylinder set up for spring-return operation with stop collar. Bore is 2¼ in., total stroke is 6 in., and effective stroke is 2 in.

Almost any text on cylinders begins with single-acting, spring-return models and implies that these are the simplest form of cylinder. While it is true that mechanical spring cylinders have been around the fluid power industry almost as long as the industry itself, their correct application still involves some thoughtful design decisions.

Springs in conjunction with cylinders provide the force to move a load to a predetermined point (normally considered its *fail-safe* point). Mechanical spring cylinders either use a spring to extend (so the cylinder will stroke to the fully extended position when pressure-pneumatic or hydraulic- is removed from the rod-end port), or retract, Figure 1, (so the cylinder will stroke to the fully retracted position when pressure is removed from the cap-end port). Thus, mechanical spring cylinders can be used in any application where it is required, for any reason, that the cylinder either extend or retract if input pressure is removed by the control or lost by accident.

In most cases, a mechanical spring is the only device that can be coupled to a cylinder to consistently deliver a specific design force when input pressure is lost- and retain that force for as long as the cylinder-assembly integrity is maintained. Depending on application factors such as space, force required, operating pressure, and cylinder configuration, the spring may be installed inside the cylinder, mounted externally on the cylinder body, or adapted to a linkage connected to the cylinder, Figure 2.

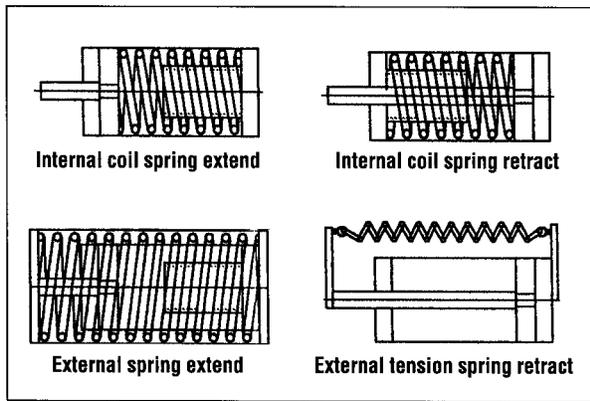


Fig. 2. Simplified drawings of cylinder-and-spring arrangements.

Preliminary information

Designing with mechanical spring cylinders is not a complicated process if complete preliminary information is provided. This critical information should include:

- Initial load- the preliminary force required when the cylinder is at rest. This is the force (plus an appropriate safety factor) the cylinder must generate to keep the application load from moving, i.e., a spring cylinder either fully extended or fully retracted against the required load
- Operating medium- hydraulic systems

generally require a higher initial load than pneumatic systems, due to cylinder seal friction and internal friction losses in the system

- Minimum available system pressure- which has a significant effect on the bore size
- Cylinder stroke required (remember, the barrel has to provide space for the actual stroke, the springs, the piston, and any mechanical stops). The actual operating stroke required obviously will affect the total cylinder stroke, particularly if only low operating pressure is available, or the initial load is higher, calling for a longer barrel
- Cylinder and static-load force, including linkage loads (used to determine the initial load)
- Application load (also used to determine the initial load), and
- The over-force factor- the force the cylinder must develop over and above the total working load to perform the designated task. In simpler terms, it is the design safety factor. Normally, the minimum safety factor should be 1.3:1. For example, if the total load is to be 1000 lbs, the cylinder should develop at least 1300 lbs of force to assure that it will move the load when commanded.

Using this preliminary information, the *final load* can be determined by adding the spring load to the application load. When determining the final load, the spring rate that will produce the final load is also determined. The spring rate- normally specified in pounds per inch- is selected or determined by how much load the cylinder will be required to move, and the seven information items listed previously.

Sometimes the space available for a cylinder will limit the bore size that can fit there. In such a case, a longer spring with a lower spring rate should be considered to reduce the overall cylinder force developed. This can result in a lower overall final load, which may also result in a longer overall cylinder barrel length.

As the required application information is determined, the cylinder's total stroke length can be calculated. A rule of thumb for estimating a spring cylinder's total stroke is that it will be approximately twice the actual stroke required. In extreme cases, the total stroke of a cylinder can be six times as long as the actual stroke- influenced by the initial and final loads, operating pressure, and bore size for the application.

In general, one or two springs can generate the design forces and meet the requirements of the actual stroke; but we have dealt with some application parameters that needed as many as four springs operating in a series (or *tandem*) to develop the design forces.

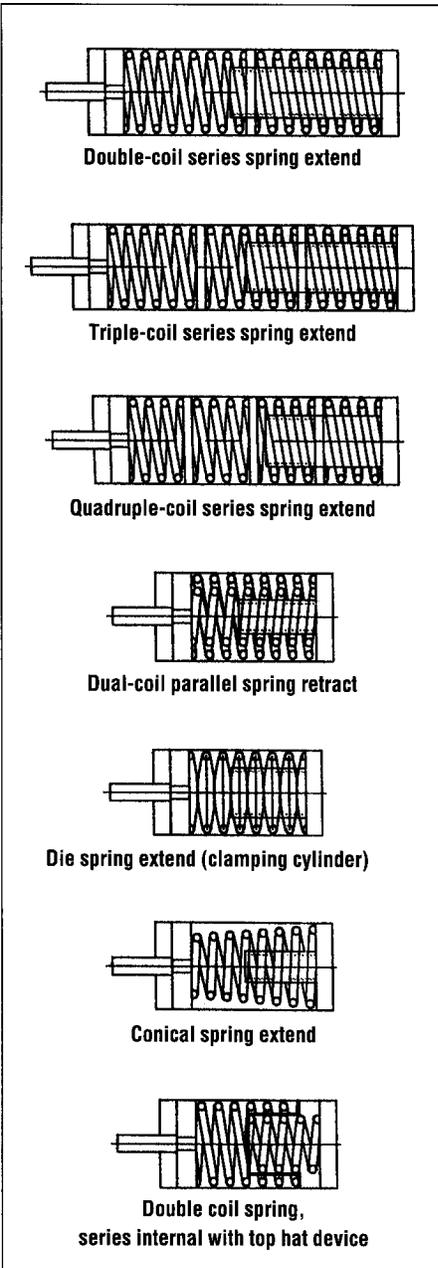


Fig. 3. Additional mechanical spring configurations.

Mechanical spring configurations

Many mechanical spring configurations are used in spring cylinders, Figure 3. Note that the ends of coil springs must be closed and square ground to help prevent the spring from cocking or buckling as it is compressed. When designing the spring-extend or spring-retract cylinder, always make sure that the springs cannot buckle at any point during compression.

Springs in a series can produce longer cylinder actual strokes, with reduced spring forces. When using the series configuration, we suggest that a spring spacer be placed between the ends of the springs in order to help maintain a concentric spring column, which also helps to prevent spring buckling.

Sometimes the total length of a cylinder with series springs will not fit in the available space. If there is enough room inside the cylinder, the double-coil-spring/series-internal arrangement can shorten the cylinder. This method nests one spring inside the other with a top hat-shaped device. The brim of the hat serves as a spacer while its crown maintains the springs' orientation. The combination of two different size springs results in a lower spring rate and a longer working stroke, yet a shorter total length. Because of its higher cost, the system works best with larger-bore cylinders; i.e., bores greater than 10 in.

Triple and quadruple series cylinders are applied on a very limited basis- generally only where other methods have proven not to be feasible. These multiple-spring cylinders perform well if only low operating pressures are available or higher initial load forces are required for the available pressures, in either case in conjunction with a longer actual stroke requirement.

The dual-spring, parallel cylinder uses two springs, one inside the other, with counter-wound coils to prevent locking during compression. This configuration is used where it is necessary to build the spring forces rapidly, have a higher load capacity, but normally results in a shorter barrel length.

Another special configuration that has gained widespread use in the machine tool industry is the die spring cylinder. Die spring cylinders are generally short-stroke/high-spring-force actuators that clamp loads in fixturing-type applications.

Tension springs

For most spring-retract cylinders, a single tension spring is mounted on the outside of the outside of the cylinder. Because it is exposed to the environment, as well as being a potential safety hazard to personnel, health and safety laws may require the spring to be shielded.

The drawings in Figure 2 show many spring/cylinder configurations. Note that where space and designs permit, each of the designs may be adapted to extend or retract a cylinder. Port location and type of spring (tension or compression) would have to suit the application. The designer's experience may be the determining factor in many of these choices.

Spring forces and their uses

When specifying cylinders that use any of these spring configurations, the understanding of spring forces and their uses is mandatory.

A single spring provides the forces as delivered by the rate of the individual spring selected; i.e., a 25-lb/in. rate spring will provide a force equal to the 25-lb/in. rate times the number of inches the spring is compressed. Therefore 3 in. of spring compression will provide a 75-lb total spring force.

A design using this spring might incorporate a 25-lb spring initial load plus 3 in. of cylinder stroke to compress the spring and add 75 lb of force, producing a total spring force of 100 lb. The cylinder would be designed so that the spring would be compressed 1 in. during cylinder assembly. This assembly process is called *pre-compression*.

When the cylinder design calls for the use of multiple springs in a series, knowledge of what forces the springs will produce will be critical to the final design decision.

Two identical springs in double series will produce the sum of one-half of the rate of only one of the springs. This is due to the fact that each of the springs is being compressed at only one-half its rate; i.e., two 50-lb/in. rate springs will produce an effective rate of only 25 lb/in. ($50/2 = 25$). Using these same springs in triple series will produce a spring rate that is one-third the rate of one of the springs. Again, this is due to the fact that each of the springs is being compressed at only one-third its rate; i.e., 16.66 lb/in. ($50/3 = 16.66$). This calculation would be repeated accordingly as the number of springs is configured to meet the requirements of the individual applications.

When using two springs in a parallel configuration, one should be installed inside the other with opposite-wound coil configurations (one clockwise and one counterclockwise). This prevents the coils from interlocking mechanically during compression. The resulting spring force per inch will be the sum of the two springs' rates. For example: a 100-lb/in. spring combined with a 225-lb/in. spring would produce a final rate of the total of 325 lb/in. (Normally, these springs are designed so that both have the same free height.)

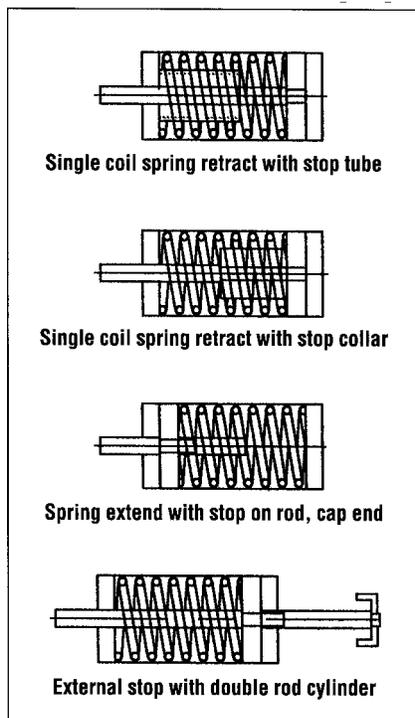


Fig. 4. Typical mechanical-stop arrangements.

Design life expectancy

Users frequently ask about the design life expectancy of a spring used in a spring cylinder, whether the spring is installed internally or externally. Ideally, if the spring is operated within its allowable design yield-stress limits, its service life- and the consequent life of the cylinder- can be considered infinite. But subjecting the spring to stress beyond its yield-stress limits may shorten its life.

To prevent over-stressing, cylinder designers normally install a positive mechanical stop to assure that a compression spring is not compressed beyond its yield stress limits, or that a tension spring is not stretched beyond its yield stress limits during cylinder operation. Figure 4 illustrates a number of stop arrangements. As with any design situation, other methods can be and are used. The design possibilities are limited only by the specific equipment configurations encountered and the experience of the individual designer.

Spring Cylinder Specification Check List	
Summary of cylinder's intended function: _____	
Media	_____
Working pressure	_____
Maximum pressure	_____
Maximum temperature	_____
Bore	_____
Working stroke	_____
Rod diameter	_____
Rod thread	_____
Mounting style	_____
Ports	_____
Cushions	_____
Spring extend or retract	_____
Preload	_____
Final load	_____

Mechanical spring materials

To meet special application and configuration requirements, mechanical springs can be manufactured from a broad range of materials. These include: spring steels, hot-rolled ad hard-drawn musical wire, oil-tempered wire, stainless steels (300 Series, 400 Series, 17-4PH, condition-hardened, and others), Inconel, Hastelloy, beryllium copper, and phosphor bronze. Material selection is influenced by the proposed performance parameters and operating environment, including spring cylinder rate and temperature, for example.

Health and safety concerns

When designing any kind of equipment that uses spring-return cylinders, the issue of personnel safety is always a major concern. Spring-return cylinders can and do store very high levels of kinetic energy in their initial and final loads. Releasing these loads in an uncontrolled manner can damage equipment,

injure personnel, or even result in death. Therefore, it is essential to provide warning labels and tags to alert personnel to these potential hazards. Equally important are instructions for maintenance personnel on the proper assembly and disassembly procedures for these cylinders- with information about the necessary tools and equipment to safely perform maintenance and repair work.

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