

## TYPICAL SEALING SYSTEMS IN COMMON LINEAR FLUID POWER DEVICES

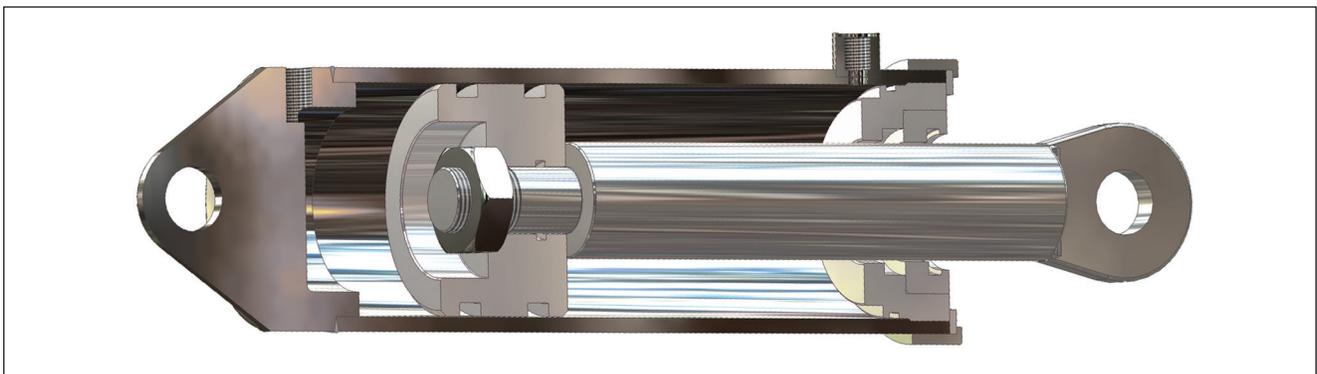
### Contents

Fluid Power Applications.....	1
Single Acting Hyd. Ram .....	2
Single Acting Pneu. Cyl.....	2
Double Acting Cylinder.....	3
Telescoping Cylinder .....	4
Cushioned Double Acting Cyl. ....	4
Dual-Fluid Power Cylinder.....	5
Ram Pressure Intensifier .....	6
Double Acting Intensifier .....	6
Piston-Type Accumulator .....	7
Energy Absorbing Cylinder.....	8
High Shock Cylinder.....	8
Linear-to-Rotary Converter .....	9
Cartridge Valve .....	10
Spool Valve.....	10
Piston Pump.....	11
Diaphragm Pump .....	11

### Fluid Power Applications

When selecting a sealing system for a fluid power device it can be helpful to review sealing components used in similar products. While there are numerous designs of fluid power devices, many share similar characteristics based upon their dynamic motion and function. The following section provides a general overview of common fluid power products along with a description of the sealing systems that are typically used. Despite their considerable variety, reciprocating and oscillating fluid power products fall into relatively few categories. These include:

<b>Power Cylinders</b>	Single-Acting Hydraulic (RAM) Single-Acting Pneumatic Double-Acting Telescoping Cushioned Dual Fluid
<b>Pumping Cylinders</b>	Pressure Intensifier Single Acting Double-Acting
<b>Accumulators</b>	Piston Type
<b>Specialty Cylinders</b>	Energy Absorbing Linear / Rotary Converter
<b>Valves</b>	Cartridge Spool
<b>Pumps</b>	Piston Diaphragm



**Figure 1. Typical Hydraulic Cylinder**

## Single Acting Hydraulic Ram Concept

Hydraulic rams are single-acting power cylinders that do not utilize a conventional piston. Instead, fluid pressure is applied to the end of the rod (ram) to create force for extension and either gravity or an external force is applied for retraction. The principal appeal of this design is its low manufacturing cost for large sized rams. Lower manufacturing costs are attributed to the fact that the cylinder bore does not require a close tolerance or a smooth surface finish. Only the ram itself needs to be ground and polished. Clearances are only important between the ram O.D. and gland I.D.

Rams that are retracted by gravity alone, customarily use low-friction lip-type seals, such as u-cups or squeeze seals made from PTFE. Low-pressure sealing problems, characteristic of lip-type seals, are seldom significant as the throttled exhaust creates back pressure to energize the seal. Hydraulic rams installed in an upward vertical orientation collect contamination around the rod seal housing. To prevent contamination from entering the cylinder, snap-in wipers are recommended. Wear rings

or bearings are frequently required to prevent contact between polished rams and gland housings. Never rely on seals or wipers to provide lateral support.

If the ram is downward-acting, a spring or external retraction cylinder is used to return the ram into the cylinder. Normally, retraction cylinders are single-acting and apply no force to the load. They can, however, be double-acting and add their force to that of the ram. In many applications, the ram is powered hydraulically, while the retraction cylinders are fast-acting pneumatic units.

Externally retracted rams have more latitude in seal selection since the return force can overcome the extra friction of squeeze-type seals. Downward-acting rams typically have low pressure return strokes which may produce leakage if lip type seals are used. Pressures are usually low during the down stroke until the ram contacts the load.



**Figure 2. Single Acting Hydraulic Ram**

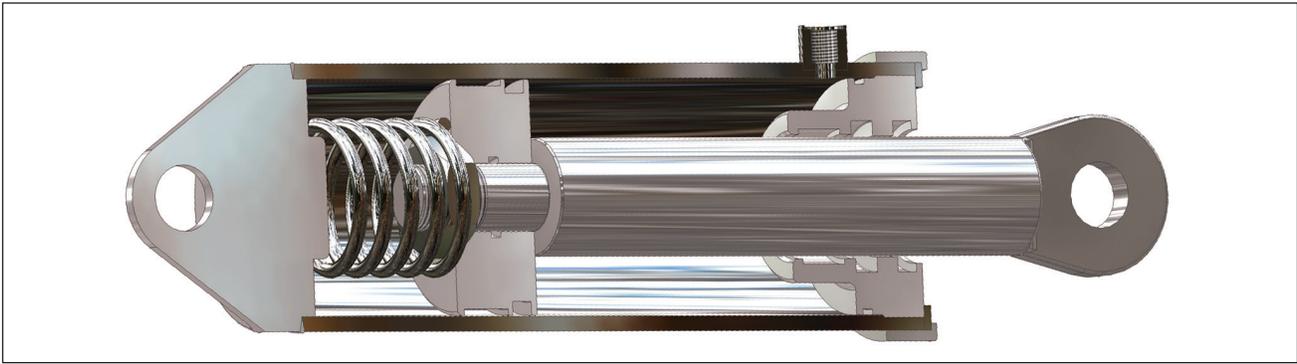
## Single Acting Pneumatic Cylinder

Single-acting cylinders, as in the case of hydraulic rams, rely on mechanical means to retract or extend the rod. The cylinder shown is a typical pneumatic design, using an internal spring to extend the rod and air pressure to retract. The spring and pressure port arrangement could be reversed to provide power extension and spring retraction. The piston seal is typically a rubber u-cup profile. To maintain pre-lubricated surfaces a rounded lip profile can be selected for sealing the piston, and the rod if required.

To reduce cost, o-rings are sometimes considered for pneumatic applications. This can be problematic since o-rings will wipe away pre-lubrication and are prone to

instability, spiral failure, high friction, and rapid wear. Selecting u-cup seals will eliminate these problems.

Snap-in wipers are typically used to prevent contamination from entering the cylinder. These can be either polyurethane or rubber depending on the environment. Bearings for these types of cylinders typically do not see heavy side loads. Filled PTFE wear rings or strips are an excellent choice to ensure low friction performance.



**Figure 3. Single Acting Pneumatic Cylinder**

### Double Acting Power Cylinder

In double acting cylinders fluid pressure is applied to either side of a piston to extend or retract the rod. This is typical of many fluid power cylinders used for hydraulic or pneumatic service at low to high pressures. As shown in Figure 4, seals are required for both the piston and rod glands. Clevis mountings at each end of the cylinder permit alignment with external linkages without bending the rod.

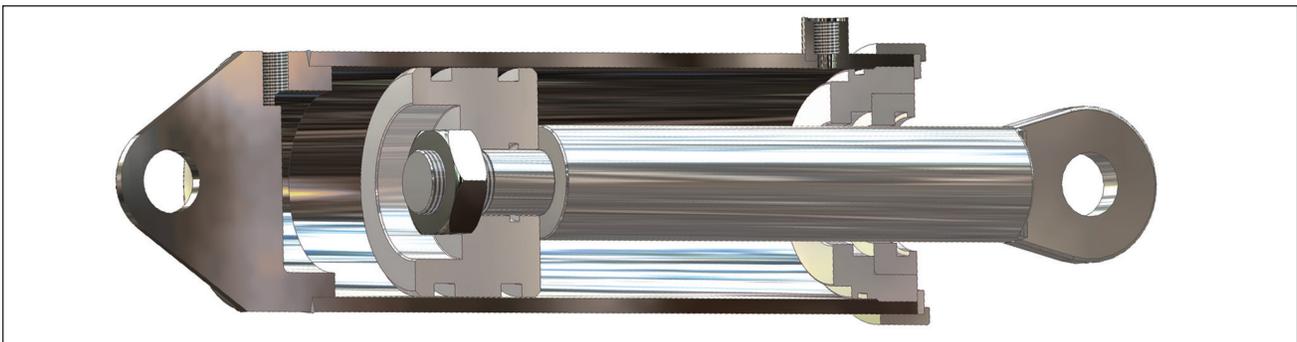
There are many options available to seal double-acting cylinders. Dual grooves shown in the piston are designed for a pair of uni-directional (single-acting) seals installed “back-to-back” such that their sealing lips face away from one another. This orientation allows any fluid that passes by the pressurized seal to easily leak past the unpressurized seal, thus preventing pressure trapping. Never install seals back-to-back with their sealing lips facing one another. This orientation will leak fluid into the space between the seals and pressure trapping will occur. Do not install dual seals in the same groove. The unpressurized seal will not support the pressurized seal resulting in instability and extrusion damage.

The other option to seal the piston is to install a bi-directional seal into a single groove. A single bi-directional seal eliminates installation confusion and the possibility of pressure trapping. Selecting a bi-directional seal allows

more room on the piston for a wear ring to protect against piston and bore contact. Typically, the wear ring is located on the end cap side of the piston to maximize distance between piston and rod bearing surfaces.

In low to medium-pressure cylinders anti-extrusion back-up rings are not normally required. High pressure may cause the cylinder to expand (breath) allowing the seals to extrude into the clearance gap between the piston and the bore. This may also occur at lower pressures in thin-wall, lightweight cylinders. To protect the seals, back up rings are recommended.

Rod seals may be either uni- or bi-directional, squeeze- or lip-type, depending on the application. As pressure requirements increase, and/or stroke and cycle rates increase, the use of multiple profile sealing systems (buffer and rod seal) are recommended. Rod wipers should be selected to match the application. Moving from snap-in wiper profiles to press fit profiles increases contamination protection. The wiper gland, shown in Figure 4, makes it easy to remove and inspect or replace the rod seal. To protect the seals from side loading, the internal side of the rod seal housing can be extended to make room for rod wear rings. Normally such side load forces should be avoided due to their tendency to bend the rod, accelerate wear, and restrict freedom of motion.



**Figure 4. Double Acting Power Cylinder**

## Telescoping Power Cylinder

Telescoping cylinders are usually single-acting cylinders which require an external force, such as gravity or a connected load, for retraction. Through a series of staged extensions this cylinder type provides a long stroke from a much shorter retracted length. They are used extensively to raise hinged beams or booms and dump truck bodies.

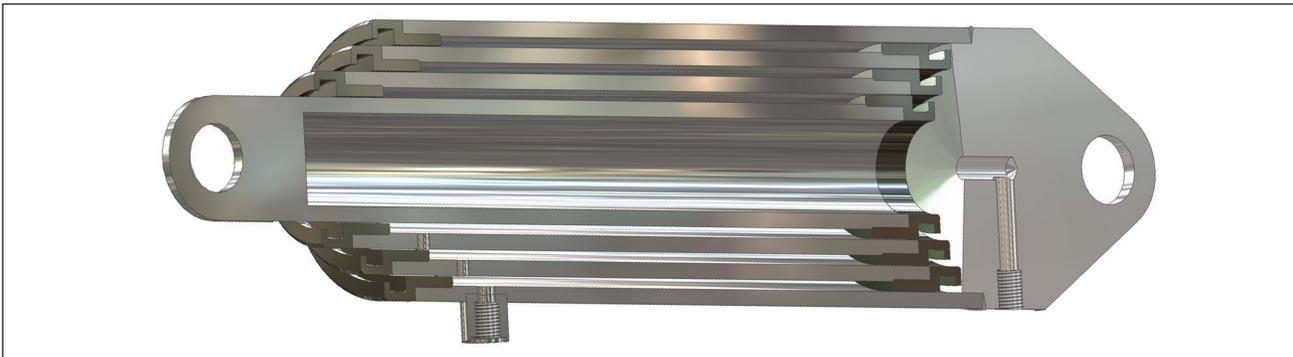
When a telescopic cylinder begins to extend, for most designs, the largest-diameter tube will move first at low speed, and the smallest tube will extend last at a higher speed. Control of input flow can regulate extension speed for more uniformity, which may be helpful when acceleration could cause instability in the connected load. It is also characteristic that the cylinder force diminishes as each successive tube reaches the end of its stroke. These force variations must be considered when matching the cylinder to the application.

The telescoping design shown in Figure 5 utilizes an internal collar to hold the seal and an external collar to hold the wiper. As each stage extends the internal collar bottoms out against the external collar. This prevents

overextension of the tubes. Both collars are designed to also act as bearings. Since such cylinders usually control retraction speed by throttling the exhaust fluid, low-pressure leakage may be minimized enough to permit the use of lip-type seals with virtually no loss of fluid.

The design shown utilizes the inside diameter of each tube as a sealing surface and is never exposed directly to outside contamination. A piston-type profile is required to seal against the tube I.D. Wiper rings become extremely important in telescoping cylinders because so much surface area is exposed to contamination. If the wipers are properly maintained, external contamination will be kept away from the sealing surfaces indefinitely.

Figure 5 shows collars made of bearing metals which would be compatible with the tubing metal. Grooves to hold wear rings can also be designed into the collars. In rod type telescoping cylinders where O.D. sealing is employed, it is simpler to maintain lubrication of these bearing surfaces since both seal and wiper ring would be located in the outboard collar, and the bearings could be immersed permanently in the fluid.



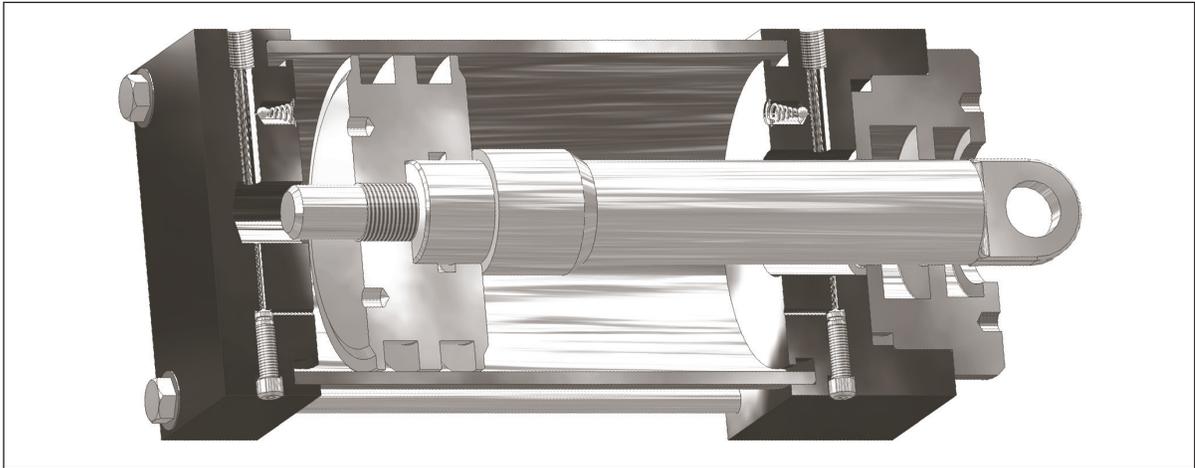
**Figure 5. Telescoping Power Cylinder**

## Cushioned Double Acting Cylinder

Cushioned cylinders provide a means of decelerating the piston during the last part of its stroke. This prevents hard impacts which could be destructive to the cylinder and the connected load. While this feature may be provided in many ways, a common design uses a deceleration cavity through which the fluid exhausts during retraction and extension. To reduce fluid flow a rod extension (end cap side of piston) and enlarged rod (spud) are added to obstruct the exhaust cavity at each end of the stroke. In the design shown, the remaining exhaust is forced through a metering valve which can be adjusted for the desired deceleration. When flow is reversed, check valves in each end of the cylinder by-pass the obstructed flow, permitting rapid acceleration. This is further improved when the rod extension or spud clears the port.

To further control the cushioning effect, uniquely designed cushion seals can be incorporated to prevent flow between the rod extension or spud and the deceleration cavity. These cushion seals are highly effective in pneumatic cylinders but are not recommended in most hydraulic cylinders due to extrusion and spiral failure. Pneumatic cushion seals are uni-directional, designed with a series of slots and pedestals to allow gas to easily flow back into the cylinder. Cushion seals eliminate the need for check valves in pneumatic cylinders.

As for other areas of the cylinder that require dynamic seals, they would be selected based on the application parameters. Seals, wipers and wear rings for the piston and rod follow the guidelines described for dual acting cylinders.



**Figure 6. Cushioned Double Acting Cylinder**

### Dual-Fluid Power Cylinder

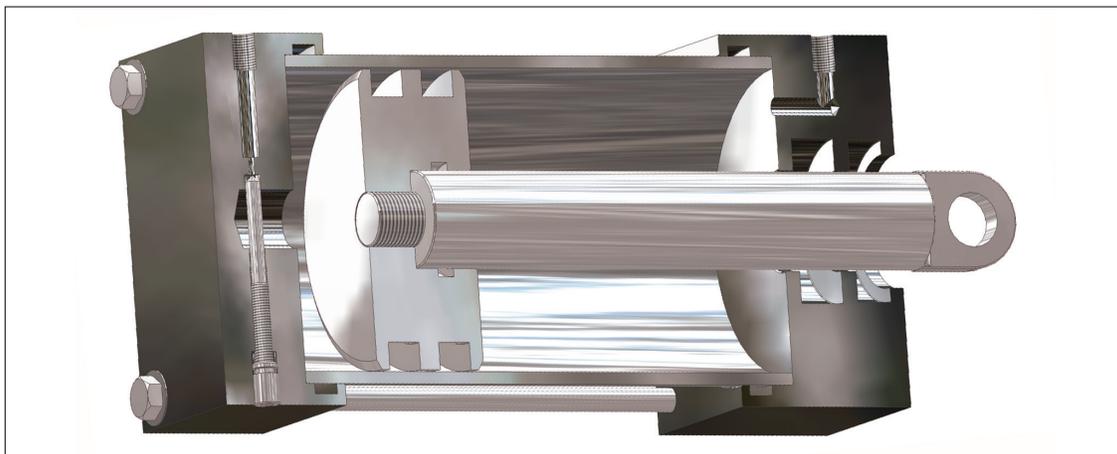
In some applications it is desirable to utilize one fluid (such as compressed air) to drive a cylinder, along with a second fluid (hydraulic fluid) to regulate the cylinder speed. Being virtually incompressible, hydraulic fluid makes a better regulating fluid than compressible gas. The basic design in Figure 7 shows a cylinder in which the rod end is pneumatically driven, and the blind end is hydraulically restrained and regulated. A metering or throttling valve may be adjusted to control the retraction speed. If the hydraulic fluid is transferred into a low-volume accumulator with a captive volume of pressurizing gas, travel will slow down as the reservoir fills and back-pressure builds. If the accumulator is large in relation to the cylinder volume, stroke speed can be held nearly constant for the full travel.

The bi-directional throttling valve shown provides a slow return stroke as well as a regulated power stroke. If fast return is desired, a check valve provision such as that in Figure 6 (cushioned cylinder) would by-pass the

throttling valve. Another frequent strategy is to use unmetered heads on the cylinder, and provide speed control by means of an external needle valve. If fast return is desired, an external check valve connected to by-pass the throttle can be utilized.

While some lubrication assistance is provided by the hydraulic fluid, it is not prudent to rely on it for the total lubrication of the pneumatic end of the cylinder. If long seal life is required, internally lubricated compounds are recommended.

To create a gas spring or dampening effect, it is possible to reverse the ends of the cylinder to apply pneumatic pressure to the blind end, achieving a larger net area and consequently higher force while making it a “push” cylinder. With hydraulic fluid at the rod end, the rod seals are constantly lubricated. Also, since the hydraulic fluid is continuously under pressure, it is possible to use lip-type seals with negligible low-pressure sealing problems.



**Figure 7. Dual-Fluid Power Cylinder**

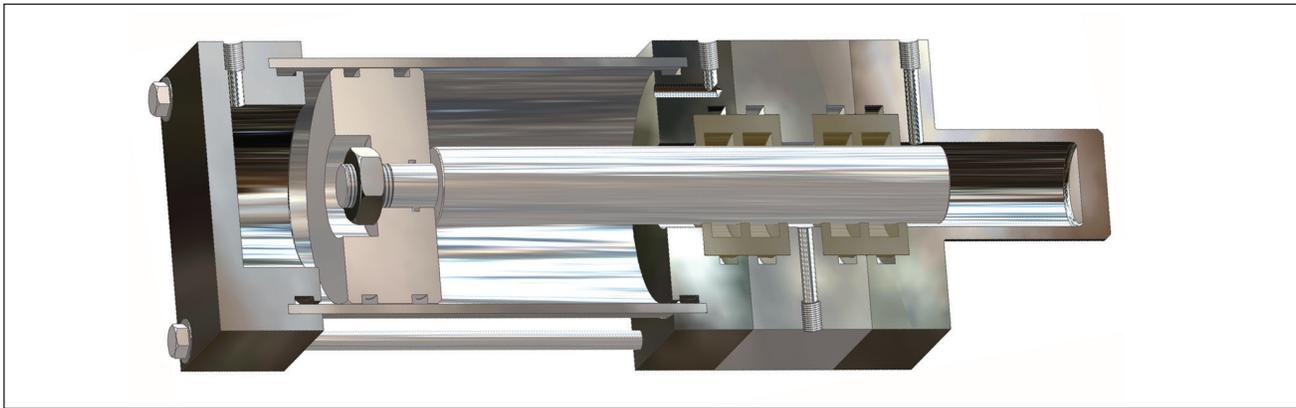
## Ram-Type Pressure Intensifier

Pressure intensifiers utilize the area ratio between the power piston and the ram as a means to multiply output fluid pressure. Inversely, the volume of the output fluid is reduced by the same ratio. Numerous pressure intensifier designs have been mass-produced. The great majority are of the ram type, similar to that in Figure 8. They may be powered by the same fluid as that being boosted to a higher pressure, or by a different fluid. Typical examples include combinations of air, water, steam and oil.

In the design shown, a double-acting power cylinder provides both the pumping and suction stroke to a

ram, which is isolated from the primary fluid by multiple seals. Where very high pressures are created, it may be desirable to add an intermediate-pressure fluid, with good lubricating properties, between the primary and secondary fluid seals. This decreases the pressure drop across the seals to help reduce extrusion, wear and leakage.

To ensure extrusion resistance, care should be taken when selecting seals for the intensified fluid. It may be necessary to include an anti-extrusion device to protect the high pressure seal from extrusion.



**Figure 8. Ram-Type Pressure Intensifier**

## Double Acting Annulus-Type Pressure Intensifier

A popular design for pressure intensifiers is the annulus-type, which utilizes an enlarged rod diameter to provide differing piston effective areas on opposite piston faces. The net effective area on the rod side equals the full piston area minus the rod area. The ratio of the full piston area to the net area of the rod side establishes the intensification ratio.

A significant difference exists between this design and the ram-type intensifiers previously discussed. The pressure direction across the piston seals is reversed. Note that the lower fluid pressure acts on the larger piston face and the intensified pressure is on the inboard annular face. This means that the seals, if uni-directional, must be oriented with their sealing lips facing inboard. It also means that if the seals are installed in piston grooves, the direction of seal drag will encourage extrusion by adding to the intensified pressure. By installing the piston seals in wall grooves, as shown, friction is subtracted from the pressure forces, thereby minimizing the extrusion tendency. By the same logic, if the seals for the rod are installed in wall grooves, the direction of seal drag along with pressure act together to increase the extrusion tendency.

If the intensification chamber (the annular volume) is recharged by fluid under pressure, the double acting version shown will produce higher intensified pressure. This is achieved by adding the force developed in the annulus. The intensified output pressure would be:

$$\text{Output Pressure} = \frac{A_a + A_p \times P_p}{A_a}$$

If the annulus is recharged by a fluid at a different pressure than that of the power fluid ( $P_p$ ), the intensified output pressure would be:

$$\text{Output Pressure} = \frac{(A_a P_p + A_p P_p)}{A_a}$$

In these equations:

$A_a$  = Annulus Area

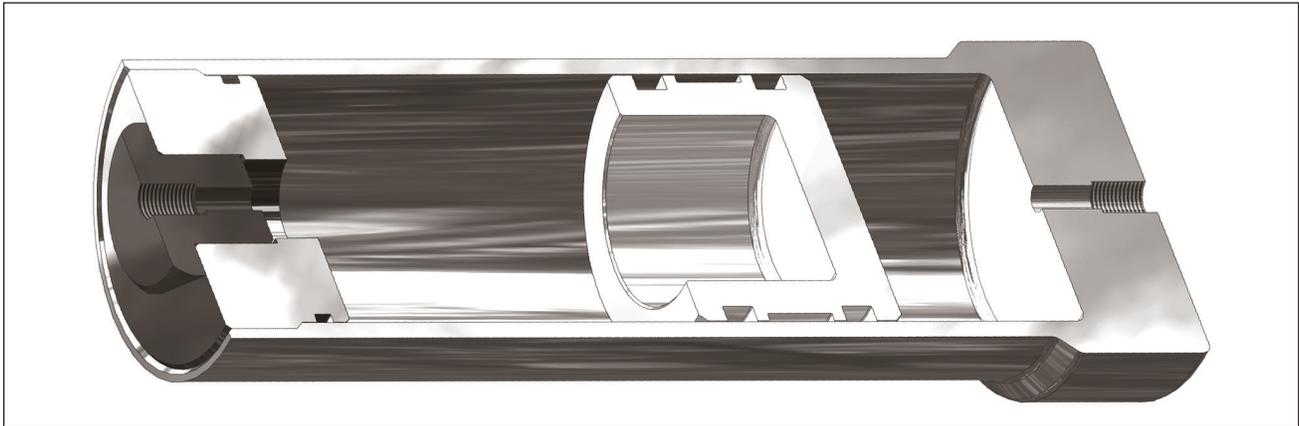
$A_p$  = Piston Area

$P_a$  = Recharging Pressure

$P_p$  = Power Fluid Supply Pressure

As with the ram-type intensifiers, it is often preferred to mount this type vertically to minimize side loads, thereby reducing the size of the bearings.

When the annulus is recharged under pressure (i.e., not by a suction stroke), the piston seals may be lip style with their bases outboard and their sealing face toward the annular volumes. This is possible because pressure in the annulus will always exceed that in the piston area. For the grooved rod, a bi-directional seal may be the better choice, since the pressure directions alternate and considerably more space would be required for a pair of uni-directional seals in separate grooves.



**Figure 9. Double Acting Piston-Type Accumulator**

## Piston-Type Accumulator

In a fluid power system, piston-type accumulators are used to store pressurized fluid for use when additional fluid volume is required. As shown in Figure 9, a wide floating piston separates a compressible gas from a liquid. In this example, pressurized gas is located on the cavity side of the piston. A floating piston also allows for pressure fluctuation in the system.

Piston-type accumulators are unique in that there is very little pressure drop across their seals, even though the system pressure may be very high. Actually, the principal source of pressure drop across the seal is the friction between the seal and the cylinder (plus bearing friction, where used) until the piston reaches the end of its travel.

Designing the system so that there is insufficient fluid to top out the piston is a simple method of preventing high pressures across the seals.

Low friction is not necessarily a design objective in selecting a seal. Squeeze seals, which offer improved low pressure sealing, are desired so long as they provide smooth travel with low wear. If a bi-directional seal is used, additional space is made available for a wider wear ring. The wear ring should be located on the lubricated side of the piston. To help prevent contamination that can damage the seals or increase wear, accumulators should be mounted in the vertical position.

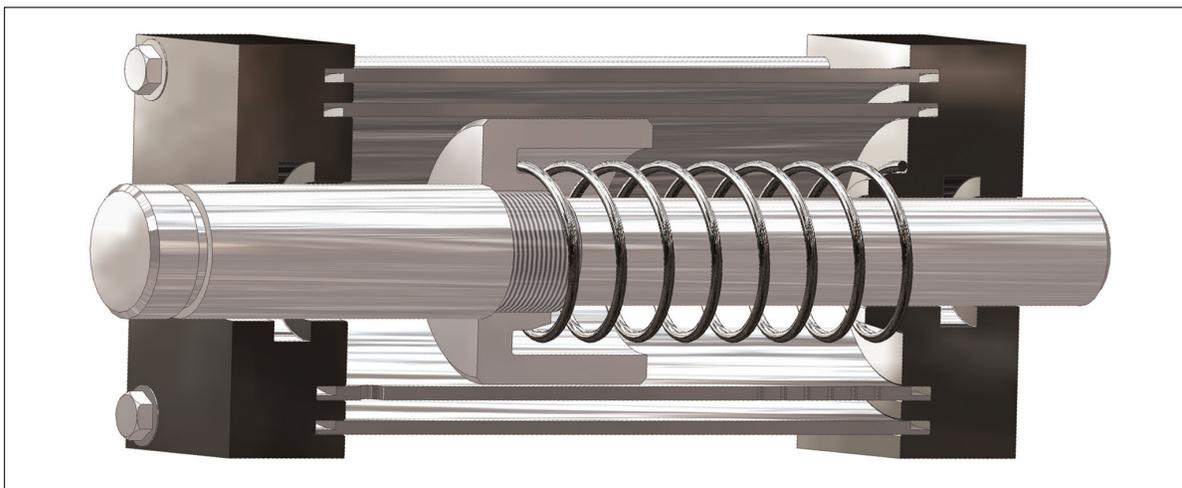
## Energy Absorbing Cylinder

Concentric double walls provide both the transfer channel and space for gas “spring” to accommodate the differential volumes in opposite ends of this energy absorbing design. When a moving mass engages the large rod, it drives the piston against the coil spring. Displaced hydraulic fluid passes through the fixed orifices, through the annular channel, and into the volume on the opposite side of the piston. As the piston covers the orifice ports, flow becomes progressively restricted near the end of the stroke. When the last port is covered, the only exit from the pressurized end is through the small clearance gap between the piston and the cylinder, which provides effective final dampening action. Since the rod diameters in the opposite ends of the cylinder are different, the change in volume on the opposite sides of the piston is not directly proportional (that is, more fluid is displaced than

there is room for on the receiving side). This difference is absorbed by the volume of gas trapped in the top of the annular space.

Some versions of this design utilize a piston seal facing the spring-end of the cylinder, but the shock loading on impact can twist the seal in its groove and set up a high-probability extrusion situation. Where severe impacts are anticipated, choose seals for their high stability and ensure the seal does not travel over the orifice ports.

The return stroke is usually provided by the compressed spring alone. In this design, the return stroke will be slow since the flow must pass through the same fixed orifices in the reverse direction with only the spring energy to drive it. In other designs, the load may also power the return stroke.



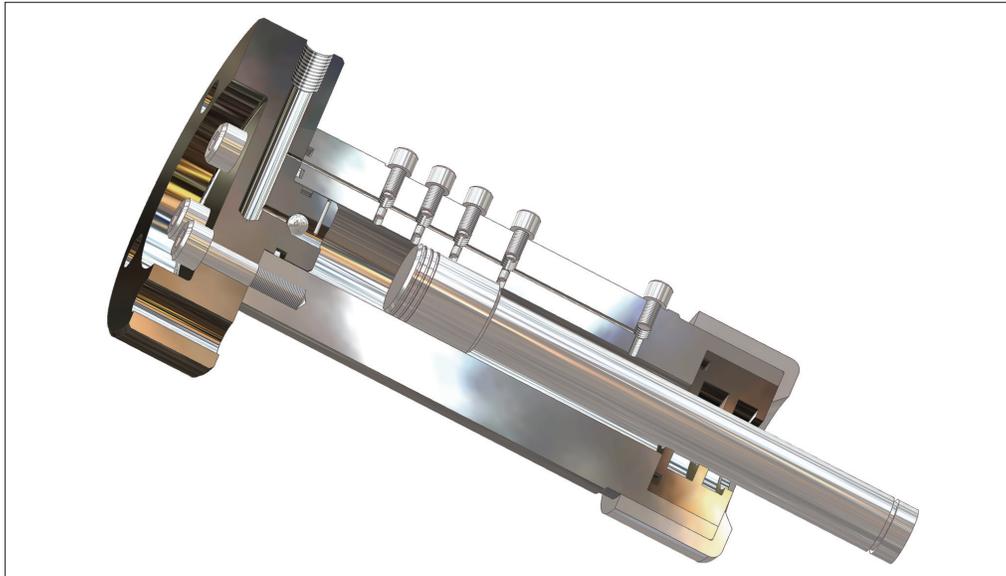
**Figure 10. Energy Absorbing Cylinder**

## High Shock Energy Absorbing Cylinder

Where it is possible to use an external hydraulic accumulator or connect into a hydraulic system with its own accumulator, a ram-type, energy absorbing cylinder may be safer and easier to regulate than the previous design (shown in Figure 10). This design utilizes a snug-fitting ram to isolate the rod seal from shock pressures developed on the ram face. Note that any leakage past the snug-fitting ram will bleed off through the oil return passage with fluid from the orifice plugs. As shown in Figure 11, only a single rod seal is required. A wide variety of rod seals could be used in this application with

the principal deciding factors being the pressure range of the connected hydraulic accumulator, and the friction at the rod and seal interface.

To avoid excessively slow return after compression, a check valve in the blind head will permit oil to by-pass the orifice plugs under pressure from the accumulator. The rate of energy absorption (and its conversion to heat energy) can be varied by adjusting variable orifice plugs (not shown) or by changing the fixed plugs (shown) to plugs with higher or lower clearances.



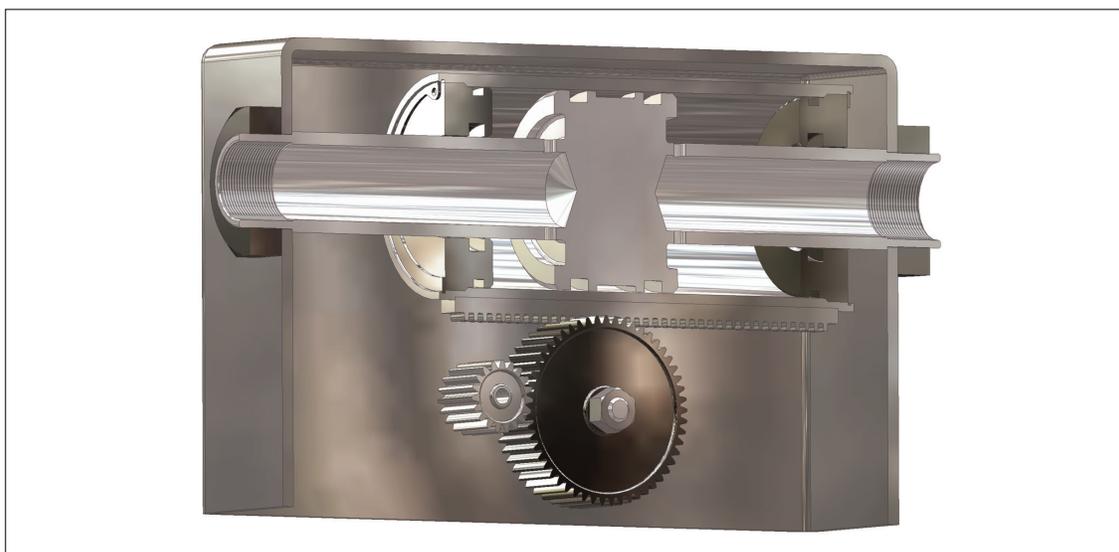
**Figure 11. High Shock Energy Absorbing Cylinder**

### Linear-to-Rotary Motion Converter

A linear-to-rotary motion converter is a rack and pinion type design that utilizes a fluid power linear actuator to drive rotary motion. As shown in Figure 12 the rod and piston are fixed, while the cylinder bore and end glands move in reciprocating motion. A toothed rack engages a pinion gear, which rotates as the cylinder strokes.

Since the rod is fixed, it may be possible to feed the input and exhaust fluid through a hollow portion of the rod as shown. Ports located deep in the rod allow fluid to flow through the cylinder. The fixed double-ends of the cylinder help to maintain a firm, precision engagement between the rack and pinion. Since this engagement

generates some lateral force, a piston bearing may be required to maintain concentricity of the piston in the cylinder. Typically, the piston always remains directly above the pinion, so additional rod bearings may not be required. In applications where an off-center load is imparted by the pinion, it may be necessary to add rod bearings to the end caps to resist the torque on the cylinder. Dual lip seals or a single bi-directional seal can be selected for the piston. Both the piston and rod seals should be selected based on the operating parameters of the application. Although the cylinder shown is positioned in an enclosed area, it may be necessary to add rod wipers to provide additional protection from contamination.

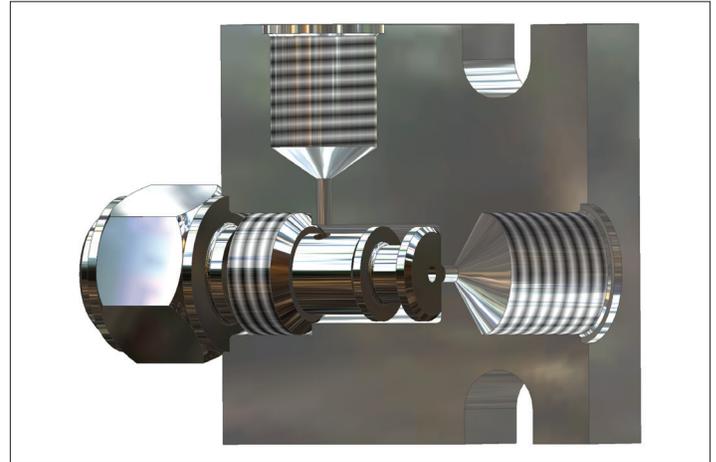


**Figure 12. Linear-to-Rotary Motion Converter**

## Cartridge Valve

Cartridge valves can be thought of as “bodyless”— valves without an integral housing— because they consist of only the internal moving elements of the valves. After a cartridge is inserted into a cavity, such as a manifold with appropriate flow passageways, the resulting valve performs like any conventional valve. Slip-in cartridges are held in the cavity by a cover plate or can be designed to screw directly into the cavity (see Figure 13). Another type of insertable cartridge valve has circumferential grooves. After it is inserted into the cavity, it is held in place by swaging internally with a tapered pin that expands the cartridge diameter into interference contact with the bore.

Historically, an o-ring and a single back up comprise the two piece sealing system used in most cartridge valves. Sealing against a dynamic surface, an o-ring can twist and fail. A single, stable polyurethane profile designed to directly retrofit the traditional groove provides easier installation, improved stability and better extrusion resistance.



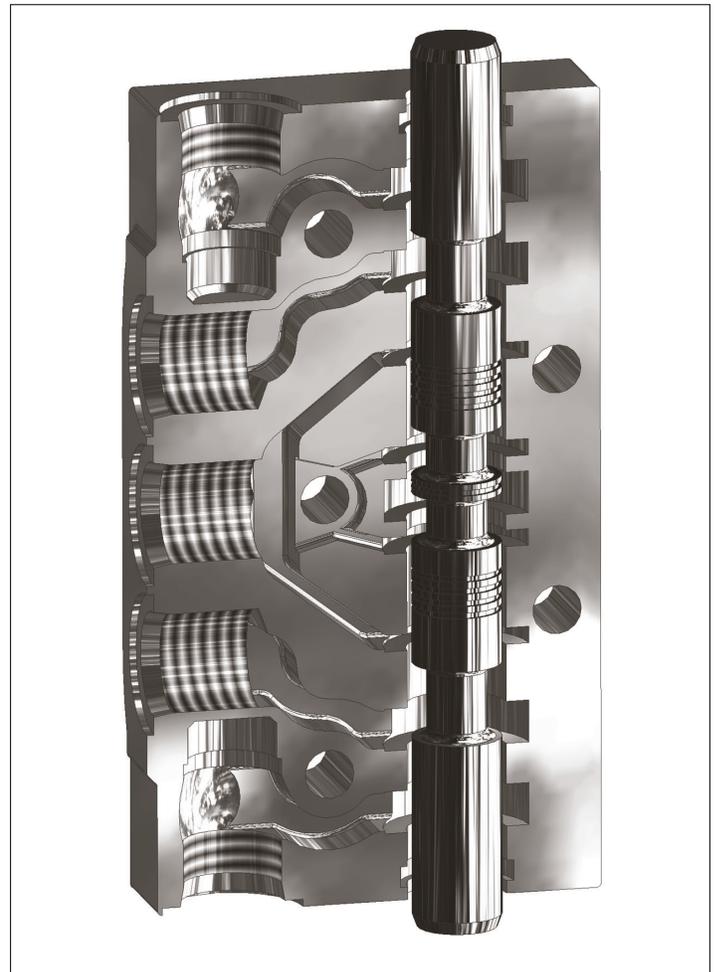
**Figure 13. Cartridge Valve**

## Spool Valve

A spool valve is a directional-control valve in which a spool slides axially in a bore to direct the flow of system fluid. The valve element slides back and forth to block and uncover ports in the housing. Sometimes called a piston type, the sliding-spool valve has a piston of which the inner areas are equal. Pressure from the inlet ports acts equally on both inner piston areas regardless of the position of the spool. Internal sealing is done by a machine fit between the spool and valve body or sleeve. A lip seal and wiper are recommended to seal the external end of the spool.

Spool valves are often classified according to the flow conditions created when it is in the normal or neutral position. A closed-center spool blocks all valve ports from each other when in the normal position. In an open-center spool, all valve ports are open to each other when the spool is in the normal position. Spool valves (see Figure 14) are popular on modern hydraulic systems because they:

- Can be precision-ground for fine-oil metering.
- Can be made to handle flows in many directions by adding extra lands and oil ports.
- Stack easily into one compact control package, which is important on mobile systems.



**Figure 14. Spool Valve**

## Piston Pump

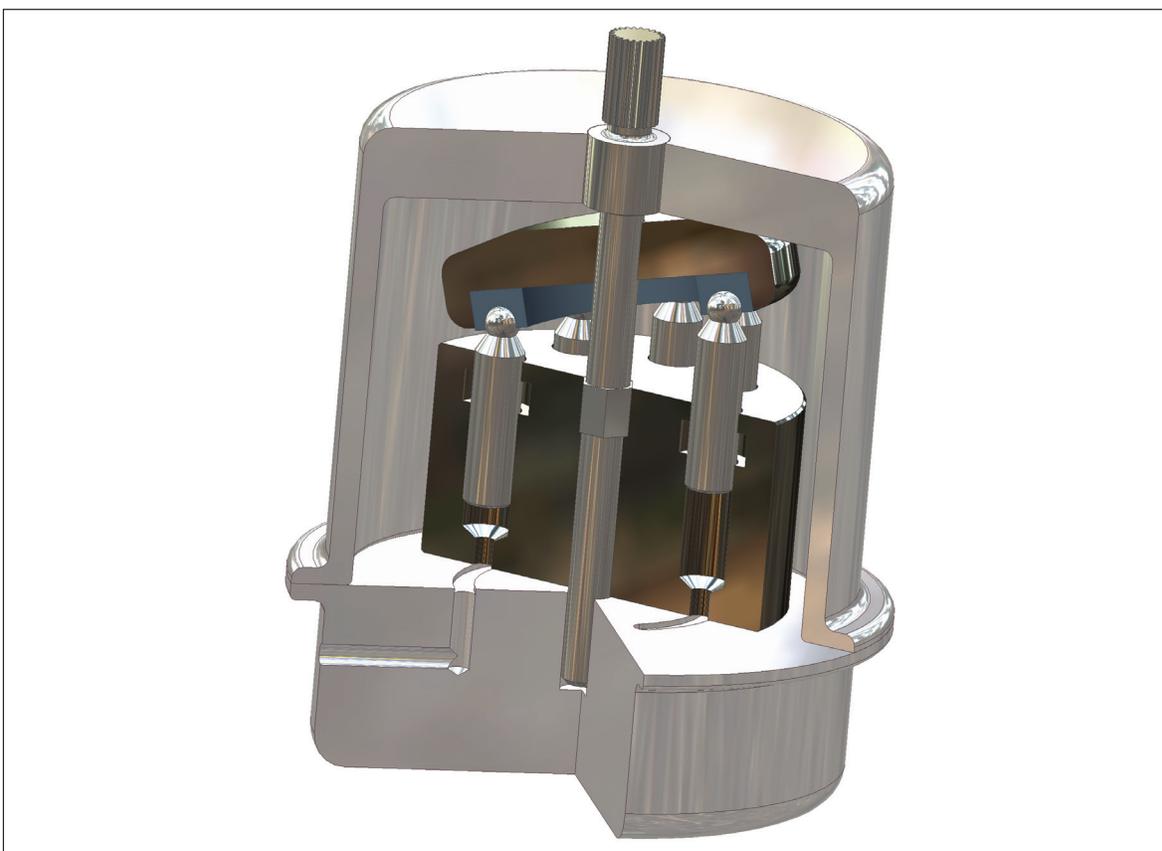
Piston pumps and plunger pumps are reciprocating pumps that use a plunger or piston to move media through a cylindrical chamber. The plunger or piston is actuated by a steam powered, pneumatic, hydraulic, or electric drive. Piston pumps and plunger pumps are also called well service pumps, high pressure pumps, or high viscosity pumps.

Seals are an integral part of piston pumps and plunger pumps to separate the power fluid from the media that is being pumped. A stuffing box or packing is used to seal the joint between the vessel where the media is transferred and the plunger or piston. A stuffing box may be composed of bushings, packing or seal rings, and a gland.

The difference between piston pumps and plunger pumps as compared to rotary piston pumps is the actual mechanism used to transfer the fluid. The piston elements moving along an axis are called axial piston pumps. Rotary piston pumps typically have an internal rotating mechanism that moves the piston.

## Diaphragm Pump

Diaphragm pumps are common industrial pumps that use positive displacement to move liquids. These devices typically include a single diaphragm and chamber, as well as suction and discharge check valves to prevent backflow. Pistons are either coupled to the diaphragm, or used to force hydraulic oil to drive the diaphragm. Diaphragm pumps are highly reliable because they do not include internal parts that rub against each other. In fact, prolonged diaphragm life may be possible if the diaphragm pump is run dry to prime. Typically, wear on the diaphragm or flap is due to the corrosive properties of media fluids or gases and/or excessive air supply pressures. Diaphragm materials such as ethylene propylene (EPDM), polytetrafluoroethylene (PTFE), plastic, rubber, and elastomers provide resistance to chemicals, sunlight, weathering, and ozone. Housing materials include aluminum, brass or bronze, cast iron, plastic and stainless steel. Rugged diaphragm pump housings can withstand high temperatures and may be exposed to various grades of water, oils, and other solvents.



**Figure 15. Piston Pump**

Parker Hannifin Corporation  
**Engineered Polymer Systems Division**  
2220 South 3600 West  
Salt Lake City, UT 84119  
phone 800 233 3900  
[www.parker.com/eps](http://www.parker.com/eps)

