Hydraulic Tools and Equipment

Introduction

Hydraulic tools are an important part of a rescue squad's inventory. They are the backbone of most vehicle extrications and offer an excellent option for heavy lifting operations. As a driver/operator, it is important to understand all aspects of hydraulic tools including not only the tool itself, but their source of power, associated accessories and even the science behind their operation.

Theory

Fluid Mechanics

Hydraulics is the branch of science that deals with the practical applications (as transmission of energy or effects of flow) of liquid in motion. A large part of the theoretical foundation for hydraulics is derived from fluid mechanics, which is the study of the effects of forces and energy on liquids and gases. The term "fluid" is often used interchangeably with the term "liquid". However, a liquid is actually a type of fluid. Fluids are defined as substances that have a tendency to freely flow or conform to the shape of their container. Both liquids and gases meet this criteria and are considered fluids. Therefore hydraulics is the equivalent of pneumatics when dealing with liquids instead of gases.

All fluids are compressible to some extent (changes in pressure and/or temperature will result in changes in their density). However, in most applications the pressure/temperature changes are so small that any changes in density are negligible. Therefore, fluids are often grouped into two categories:

- **Compressible** – a fluid whose density significantly changes with changes in pressure; the volume of a compressible fluid decreases as the pressure exerted on the fluid increases; gases are often considered compressible fluids
- **Incompressible** – a fluid whose density does not significantly change with pressure; the volume of an incompressible fluid will not change as the pressure exerted on the fluid increases; liquids are often considered incompressible fluids

Pressure

Before proceeding further, it is important to review the definition of pressure. Pressure is force per unit area applied in a direction perpendicular to the surface of an object.

$$\textbf{Pressure} \quad \frac{\textbf{Force}}{\textbf{Area}}$$

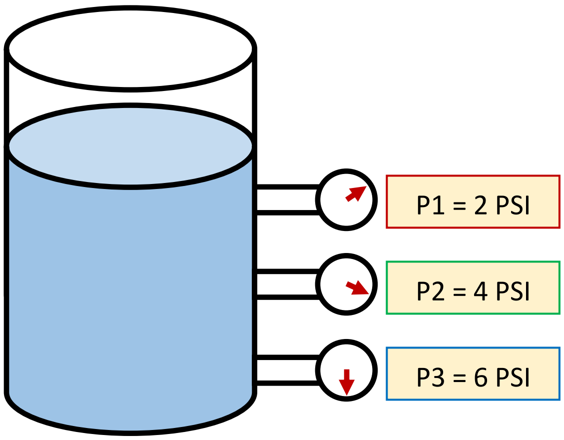
Pressure (continued)

The SI unit of pressure is the pascal (Pa = N/m^2). The U.S. customary system unit of pressure is pounds per square inch (psi = lbs/in^2). As the equation on the previous page shows, pressure is affected by changes in the force being applied or the area in which the force is applied.

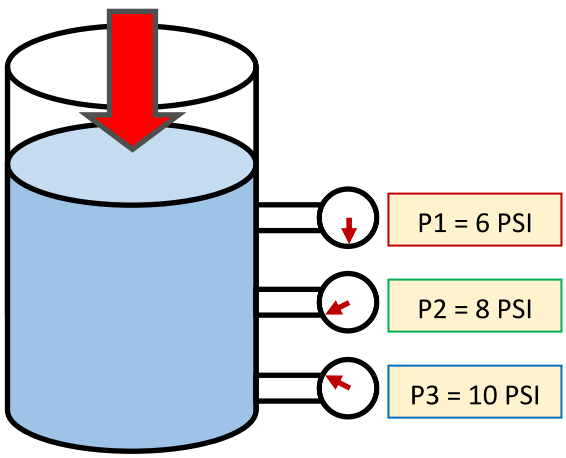
Pascal's Law

One important principle relating to fluid mechanics is Pascal's Law. The law states that any change in pressure at any point in a confined fluid will result in an equal change in pressure (without loss) throughout the rest of the fluid and to the walls of the container.

<u>Example 1:</u>



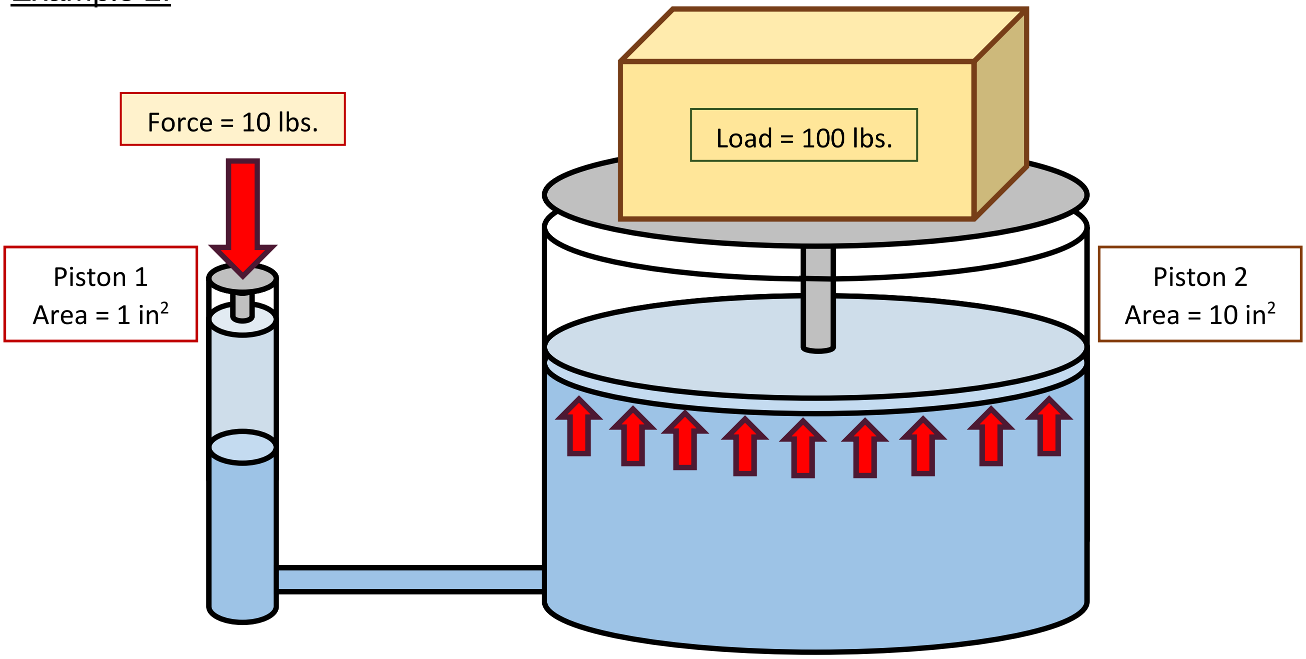
The container on the left contains a fluid. Three pressure gauges are connected to the container at different depths. As the depth of the fluid increases, the pressure increases due to the mass above it.



An additional pressure of 4 psi is applied to the fluid. As a result, the pressure will increase throughout the fluid. According to Pascal's Law, the pressure increase throughout all parts of the container will be equal. Therefore, each pressure gauge will increase by 4 psi.

The above example illustrates Pascal's Law at a basic level. The next example will demonstrate Pascal's Law in a slightly more complex system. This example will show how forces can be multiplied in hydraulic systems, providing the basis for the design of hydraulic rescue tools.

Example 2:



Example 2 demonstrates how a hydraulic lift operates at a basic level. A force is applied to the piston on the left. This force causes an increase in pressure on the hydraulic system, which is transmitted to the cylinder on the right. The pressure acts on the piston on the right, which transmits force to lift the block. One very important aspect of the system shown above is that only 10 lbs. on input force is required to lift the 100 lb. block. How can this be? The answer can be drawn from Example 1 and the application of Pascal's Law:

Remember, **Pressure (P) = Force (F) / Area (A)**

So from the diagram, the pressure in the cylinder on the left is:

Pressure = Force on Piston 1 / Area of Piston 1
Pressure = 10 lbs / 1 in^2 = 10 lbs/in^2 = 10 psi

Pascal's Law states that the pressure in the entire system must be equal. Therefore, if there is 10 psi in the cylinder on the left, there will be 10 psi in the cylinder on the right.

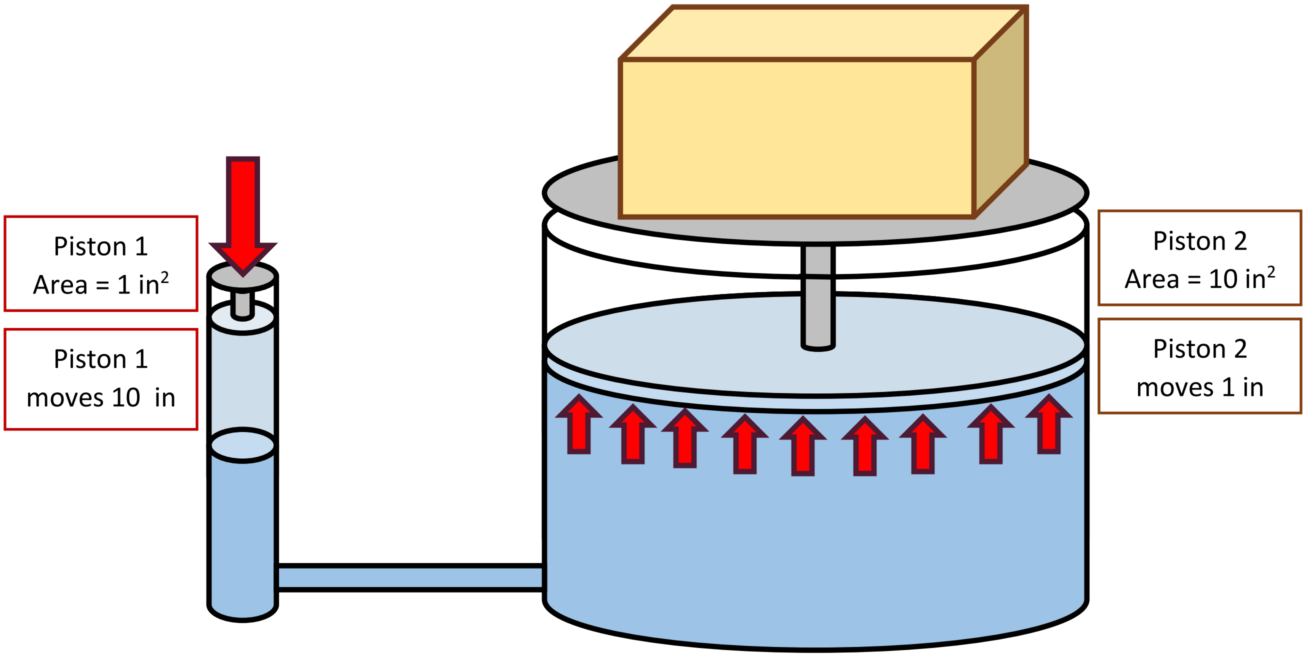
For the cylinder on the right, the pressure is known. Rearranging the equation yields:

Force (F) = Pressure (P) x Area (A)

Force on Piston 2 = (Pressure) x (Area of Piston 2)
Force on Piston 2 = (10 lbs/in^2) x (10 in^2) = 100 lbs

As this example shows, the input force is increased (multiplied) by a factor of 10 because the area of Piston 2 is 10x that of Piston 1.

Another noteworthy point from Example 2 is the fact that Piston 1 moves farther than Piston 2:



The input force was multiplied by a factor of 10 but the resulting movement of the load was reduced by the same factor of 10. It is often said that, "nothing in life is free". Fluid mechanics is no different. The size and shape of the cylinders does not change. Therefore, since the pressure of the liquid remains the same, the volume must remain constant as well.

The volume of liquid in the cylinder can be expressed as:

Volume (V) = Area of the Piston (A) x Distance the Piston Moves (D)

Therefore, for the cylinder on the left:

Volume = (Area of Piston 1) x (Distance Piston 1 Moves)
Volume = (1 in^2) x (10 in) = 10 in^3

If 10 in^3 of liquid is displaced in the cylinder on the left, 10 in^3 of liquid must move to the cylinder on the right. Since the volume is known, the equation can be rearranged:

Distance the Piston Moves (D) = Volume (V) / Area of the Piston (A)

For the cylinder on the right:

Distance Piston 2 Moves = Volume / Area of Piston 2
Distance Piston 2 Moves = 10 in^3 / 10 in^2 = 1 in

Therefore, the tradeoff to gain increased output force is a decrease in lifting height.

Hydraulic System Components

At a basic level, most hydraulic systems are made up of the following components:

- Fluid
- Reservoir
- Pump
- Actuator
- Valves

All of these components can be of different designs and complexities depending on the hydraulic systems application.

Fluid

Hydraulic fluid (or more accurately, “liquid”) is the medium for carrying the pressure through a hydraulic system that is translated into mechanical force and movement. There is a large variety of options for hydraulic fluid, each with specific characteristics to match specific applications. Some of the basic features of an “ideal” hydraulic fluid include:

- Thermal stability
- Hydrolytic stability (the ability to resist chemical decomposition in the presence of water)
- Low chemical corrosiveness
- High anti-wear characteristics
- Long life
- Low cost

To meet these demands, oil-based hydraulic fluids are often utilized. These fluids can be engineered to provide the desired viscosity, anti-wear and anti-corrosion properties with few operating, safety or maintenance problems.

However, there are certain applications where oil-based fluids should be avoided. Fire/rescue operations are examples of such situations. Hydraulic fluid exposure to high heat and/or flame could potentially result in a significant fire hazard. For this reason, most fire/rescue-specific hydraulic fluids fall into the category of fire-resistant hydraulic fluids (FRHFs).

The increased demand for fire-resistant hydraulic fluids came about from tragic incidents involving hydraulic fluid fires in industries such as steel mills, foundries and coal mines. Research was aimed at finding suitable replacements for oil-based fluids that could provide comparable hydraulic system performance without a significant increase in cost.

<u>Water-Containing Fire-Resistant Fluids:</u>

One solution to the problem of fire resistance is water. The introduction of water into hydraulic fluid provides an extinguishing agent should the fluid be exposed to flame. Water glycol and invert emulsions are the two major types of water-containing FRHFs:

- Water glycol – a solution of glycol (e.g. ethylene glycol) in water
  - Contains a variety of additives to provide viscosity, anti-wear and corrosion protection properties as well as a polymeric thickener
  - Approximately 40% water content
  - One of the dominant FRHFs on the market
  - Presents some environmental concerns
- Invert emulsion – a stable emulsion of water in oil
  - Also contains approximately 40% water
  - The outer phase of oil represents the wetting surface and provides the desired characteristics of oil-based hydraulic fluids
  - The inner phase of water acts as the fire-retardant
  - Contains oil-soluble additives to provide corrosion protection and reduce wear as well as emulsion stability

<u>Synthetic Fire-Resistant Fluids:</u>

The other approach to providing fire resistance was to engineer non-aqueous fluids with chemical properties that either resisted burning or generated products of combustion that would help extinguish any flames. The intent of these fluids was to eliminate the use of water, therefore eliminating the undesirable corrosive and wear characteristics.

- Phosphate Esters – the product of a reaction between phosphoric acid and aromatic ring-structure alcohols
  - Extremely fire resistant
  - Provide excellent wear resistance
- Polyol Esters – synthetic hydrocarbon, the product of a reaction between long-chain fatty acids (derived from animal and vegetable fats) and synthesized organic alcohols
  - Good fire resistance
  - Contain additives to provide anti-wear properties, corrosion protection and viscosity modification
  - Biodegradable

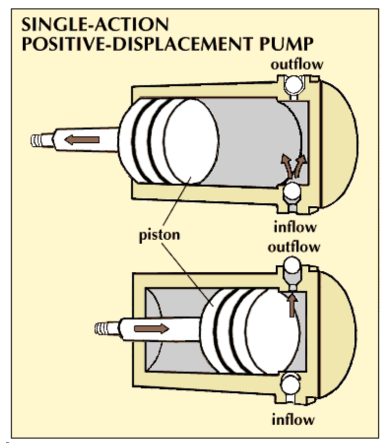
Reservoir

The reservoir is simply the storage tank for hydraulic fluid. Reservoirs come in different shapes and sizes depending upon the application. They are designed to provide sufficient fluid capacity for the rated number of operating tools while also maintaining a reserve. In addition, the reservoir must be large enough to hold the hydraulic systems fluid volume when the tools are not in use. In many cases, the reservoir is mounted in close proximity to the hydraulic pump.

Pump

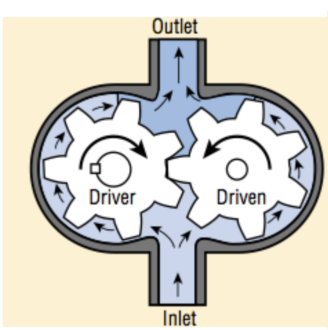
The hydraulic pump is the device that produces liquid movement or flow. (It is important to note that pumps do NOT generate pressure. In liquids, pressure is a function of resistance to flow. A pump's job is to generate that flow.)

As a review from a "Pumps and Hydraulics" class, pumps are classified as either positive-displacement or non-positive displacement. Most pumps used in hydraulic systems are positive displacement. Positive displacement pumps displace (or move) the same amount of liquid for each cycle of the pumping element. The precise and consistent liquid delivery is possible due to tight tolerances between the pumping element and pump housing.

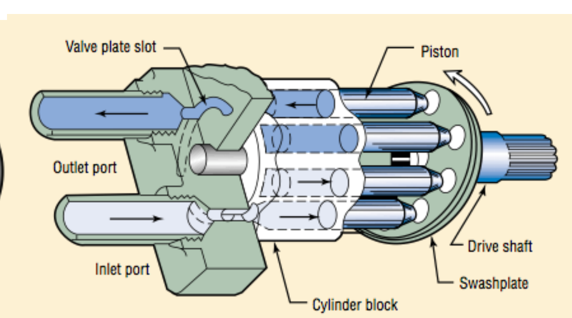


Positive displacement pumps include reciprocating- and rotary-type. Reciprocating pumps are some of the most basic types of positive-displacement pumps. They contain an inlet and outlet and cylinder and piston.

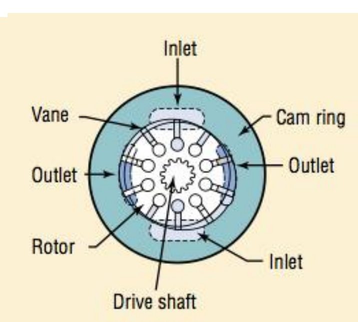
Rotary pumps include gear pumps (both external and internal), vane pumps and piston pumps.



Spur Gear Pump



Axial-Piston Pump



Balanced Vane Pump

Power Sources

Hydraulic pumps can be powered several different ways:

- Manually-operated – for use with single-action reciprocating positive displacement pumps

- Electric motor – can be DC or AC operated; common power source for many apparatus-mounted hydraulic pumps

- Internal combustion engine – provides portability options; common type is a 4-stroke gasoline small engine

- Air pressure – compressed air powers the pump

- Power Take-Off (PTO) driven – PTOs can be mounted to the truck transmission and engaged via a switch in the cab; the hydraulic pump is often connected directly to the PTO

PTO  Pump

Actuator

The hydraulic fluid, pump and power source generate flow and pressure. As described in the first section of this module, this pressure needs to be converted back to force and displacement. This is the job of the actuator.

Actuators can classified into two types:

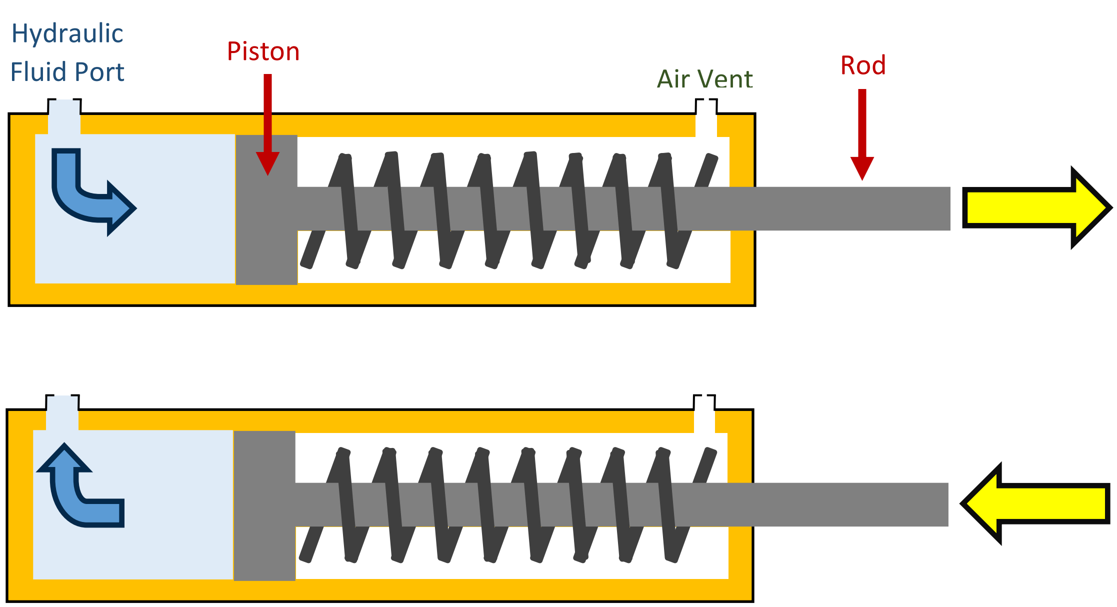
- **Linear (hydraulic cylinders)** – convert pressure and flow into linear force and displacement
- **Rotary (hydraulic motors)** – convert pressure and flow into torque and angular displacement

Hydraulic motors are used for a variety of things in the fire service. Two common examples are rotation of aerial ladders and hydraulic winches. Hydraulic cylinders control extension and elevation of aerial ladders and many of the hydraulic tools on rescue squads and other rescue apparatus.

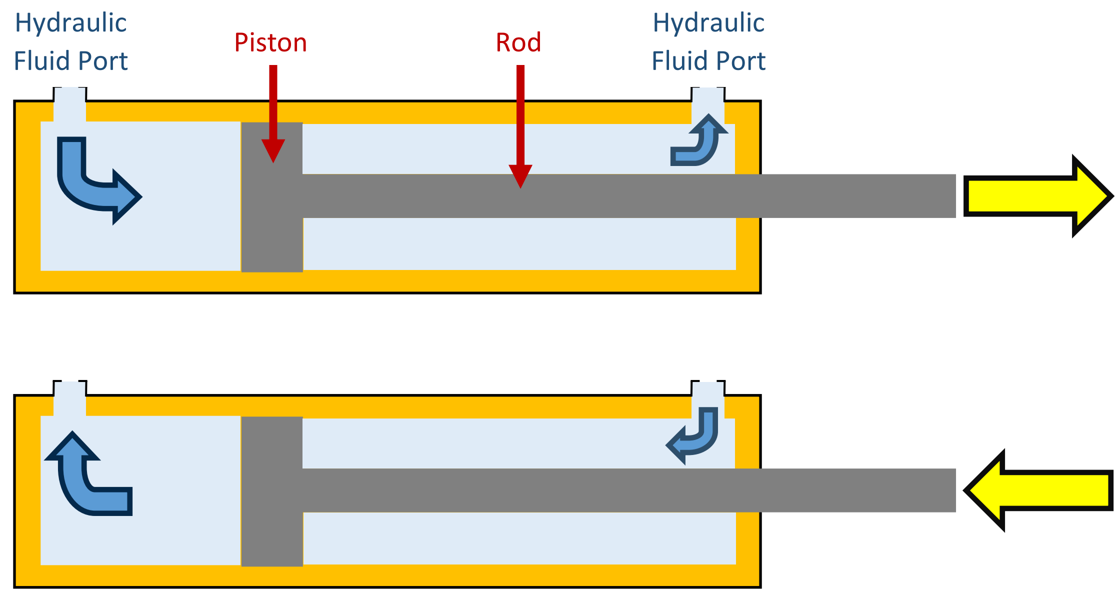
<u>Types of Hydraulic Cylinders</u>

There are two common types of hydraulic cylinders:

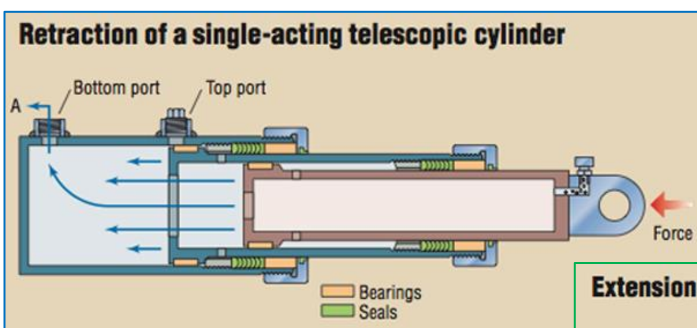
- **Single-Acting** – This type of cylinder is unidirectional (operates in one direction). Hydraulic fluid flows into the head of the cylinder through a single port and pushes on the piston, extending the rod. To retract the piston, a valve must be opened to allow fluid to flow back to the reservoir. The piston retraction is made possible either by gravity, the weight of the load or a mechanical force, such as a spring. Examples of single-acting cylinders are floor jacks and bottle jacks.

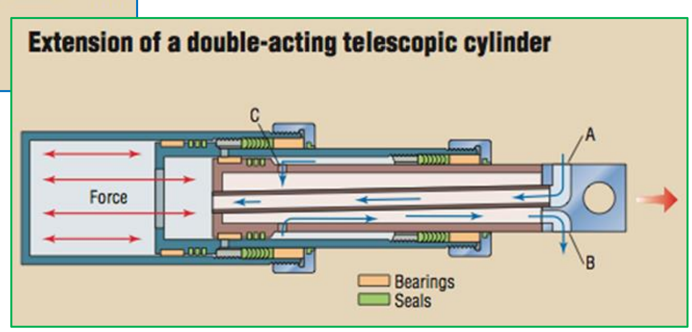


- **Double-Acting** – This type of cylinder is bidirectional (operates in two directions). Unlike single-acting cylinders, there are two ports on a double-acting cylinder, one at each end. To extend the piston, fluid flows from the pump into the port at the cylinder head. As the piston extends, fluid on the opposite side of the piston exits the cylinder through the other port and returns to the reservoir. To retract the piston, a directional valve reverses the fluid flow. Most hydraulic rescue tools utilize double-acting cylinders.



One special design of a hydraulic cylinder is the **telescoping cylinder**. These cylinders contain multiple tubes of progressively smaller diameters nested within each other. Each individual tube represents a stage. Telescoping cylinders have the distinct advantage of increased length at full extension while maintaining a relatively short retracted length. These cylinders can be found in both single- and double-acting designs.





Valves

The valves in a hydraulic system control the movement of hydraulic fluid. They are used to control flow between the reservoir and the pump, the pump and the actuator, and flow within the actuator itself.

Single-acting cylinders typically have a valve or set of valves to control flow between the reservoir, pump and the hydraulic cylinder. They also contain a valve that allows fluid to return from the cylinder to the reservoir.

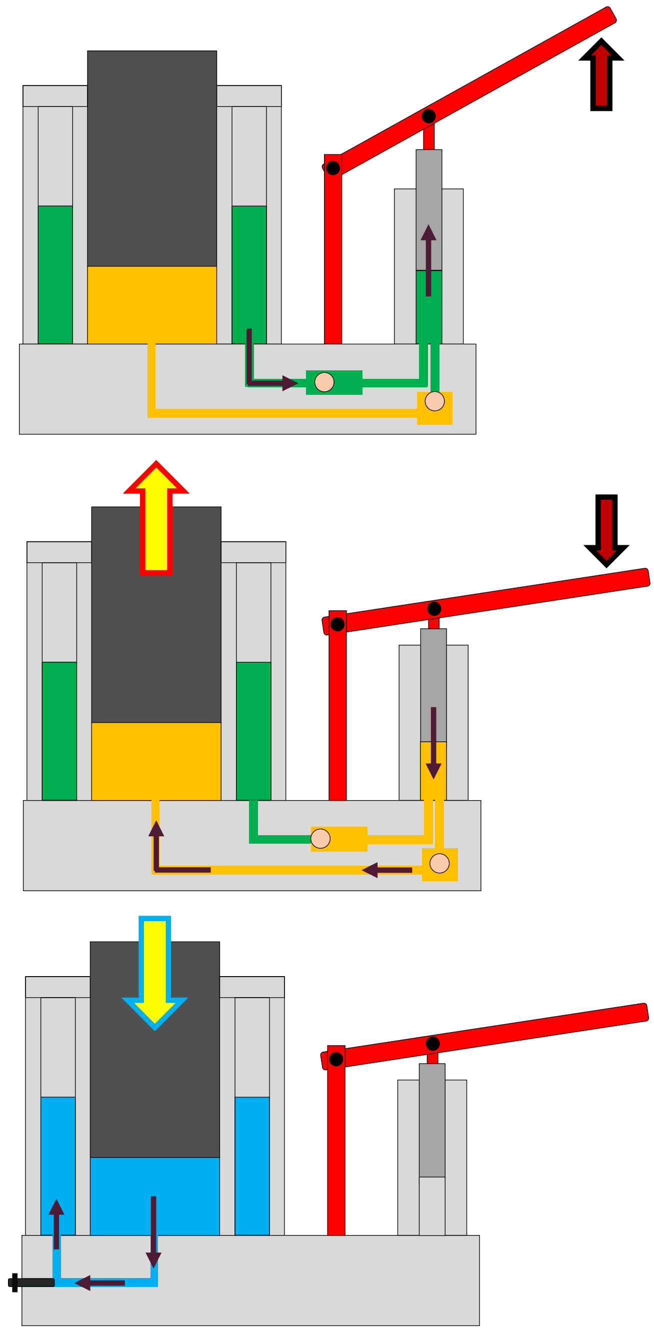
The diagrams on the right show the basic components of a bottle jack. They contain a single-acting cylinder and a reservoir that actually surrounds the cylinder. The pump is a reciprocating style that is manually operated.

Fluid flow between the reservoir and pump and the pump and cylinder is controlled by two ball valves.

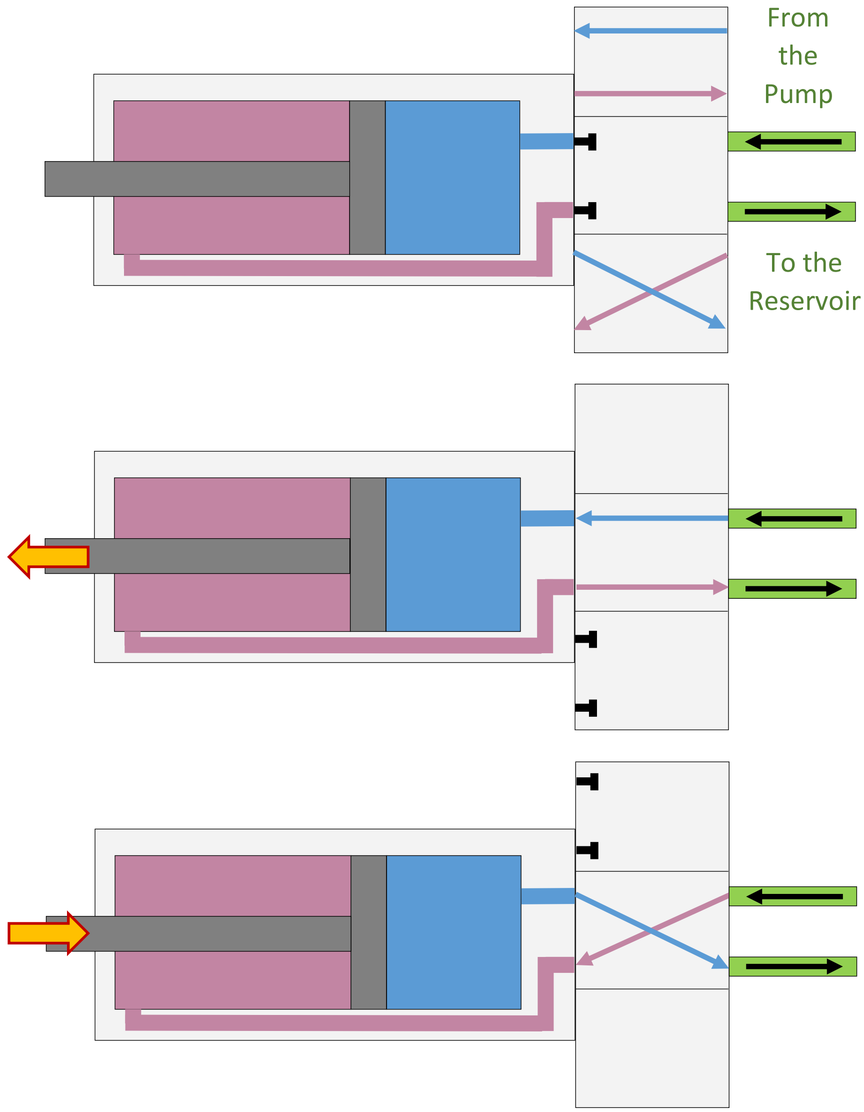
In the top diagram, the ball valve between the reservoir and pump is open, allowing fluid to flow from the reservoir to the pump. The ball valve between the pump and cylinder remains closed.

In the middle diagram, the ball valve between the reservoir and pump closes while the ball valve between the pump and cylinder opens. This allows fluid under pressure to flow into the cylinder, creating lift.

The bottom diagram shows the operation of the release valve. This valve is opened to allow fluid to flow from the cylinder directly to the reservoir, enabling the piston to retract. Gravity along with the weight of the load and piston create the fluid movement.



Double-acting cylinders, such as those on most hydraulic rescue tools, have a slightly different set of valves. One of the valves controls the direction of flow within the actuator. Another valve controls the flow between the reservoir, pump and actuator.



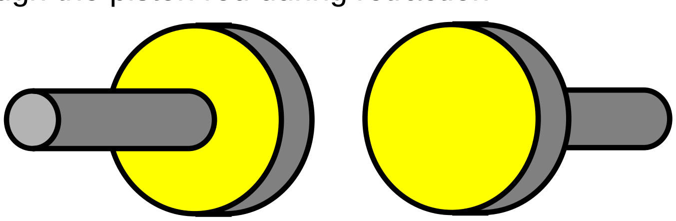
The diagrams on the right show the basic operation of the control valve on a hydraulic rescue tool. There are three different positions: Neutral, Extend and Retract.

The top diagram shows the Neutral position. Fluid flow from the pump is blocked from entering the cylinder.

In the middle diagram, the tool operator rotates the control valve to the Extend position. Fluid is able to flow into the cylinder, pushing on the piston and extending the rod.

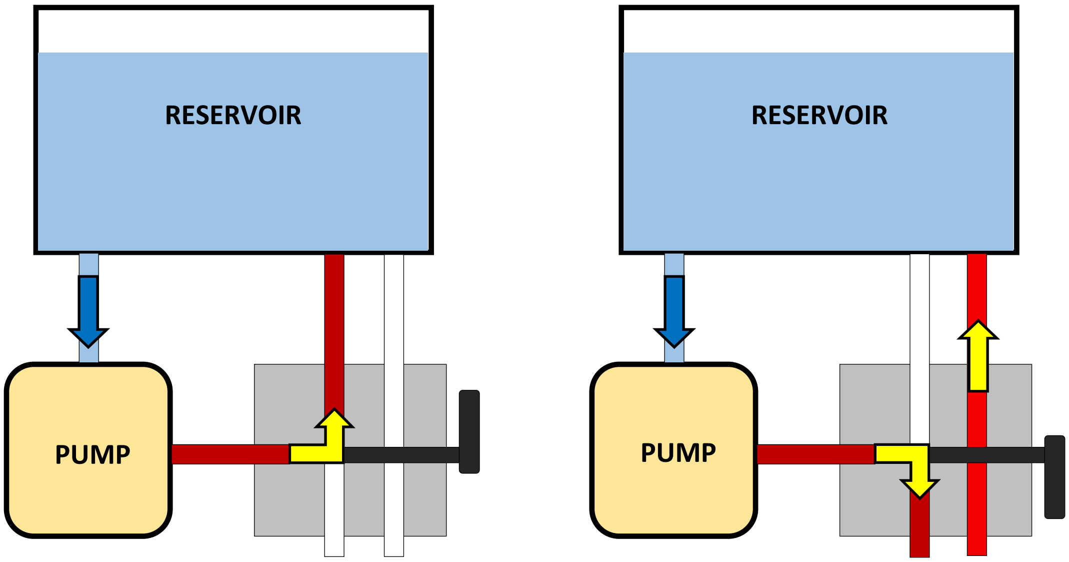
In the bottom diagram, the tool operator rotates the control valve to the Retract position. Fluid flow within the cylinder reverses direction. It now pushes on the opposite side of the piston, retracting the rod.

One noteworthy point about the double-acting cylinder shown above is that the surface areas on each side of the piston are not equal. The surface area on the left is decreased by the presence of the piston rod. This decrease in surface area results in a decrease in force applied through the piston rod during retraction.



Most hydraulic rescue tool systems also have a valve that controls the flow of hydraulic fluid to the tool. This valve has two positions. One position pressurizes the port going to the tool. The other position is a neutral, or “dump”, position that bypasses the tool port and recirculates (dumps) the hydraulic fluid back to the reservoir.

The diagrams below show the basic operation of the dump valve.



The diagram on the left shows the valve in the neutral position. Pressurized fluid from the pump is immediately returned to the reservoir. The diagram on the right shows the tool being pressurized. Hydraulic fluid flows from the pump, through the valve, to the tool and finally back to the reservoir.

Hydraulic Tools

Manually Operated

Some of the most basic types of hydraulic tools carried on fire/rescue apparatus are actually not designed specifically for rescue applications. Instead, many manually operated tools are simply “borrowed” from other industries such as automotive repair.

Bottle Jacks

Bottle jacks are a single acting hydraulic cylinder controlled by a simple reciprocating pump and release valve. The handle on the pump provides the leverage needed to obtain the large output force with a relatively low input force. Bottle jacks can be either single piston or contain telescoping pistons. Many have a threaded post on top of the piston that can be extended for additional height prior to extending the piston.

Bottle jacks are designed for axial loading. Any side or eccentric loading could result in jack instability and/or possible hydraulic cylinder damage.

Capacities range from 1 ton up to 50 tons. Some bottle jacks are outfitted with a small pneumatic motor that can be used in lieu of the manual pump. These are called “air over hydraulic” bottle jacks.

Floor Jacks

Floor jacks are another type of single acting cylinder with a manually-operated reciprocating pump and release valve. The hydraulic cylinder is attached to an arm that pivots as it lifts, creating a Class 3 lever. The lifting point on a floor jack is called the saddle. As the hydraulic piston extends, the lifting arm pivots raising the saddle. However, the rotation of the lifting arm also causes the saddle to move horizontally as well as vertically. To compensate for this horizontal movement, floor jacks are mounted on wheels. Capacities typically range from 1.5 tons up to 20 tons.

Portable Hydraulic Kits

Commonly referred to as porta-power kits, manually-operated portable hydraulic kits are used in the automotive body repair industry. They consist of a single action reciprocating hand pump and hydraulic hose. The pump can be connected to either a spreading tool or ram. The ram can be outfitted with extensions and various end attachments. These smaller hydraulic tools are useful in tight areas where larger hydraulic rescue tools may not fit. Porta-power kits can range from 4-ton up to 20-ton capacities.

Fire/Rescue Portable Hydraulic Kits

Many hydraulic rescue tool companies also manufacture manually-operated portable hydraulic kits. Just like those used in auto body repair shops, fire/rescue kits contain a manually-operated single action hydraulic pump and hose with various tools and attachments. One such kit is the Hurst Mini-Lite kit:

The Mini-Lite kit contains spreaders, cutters and rams. All of these tools are powered by a hand pump.

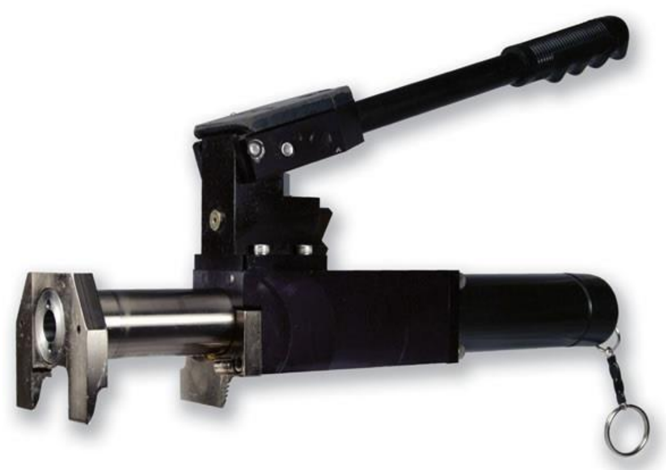
The cutters provide up to 13,000 and 17,000 lbs. of cutting force. The spreaders are rated for 7,300 lbs. of spreading force. Rams can provide up to 10,000 lbs. of force.

Rabbit Tool

The Rabbit Tool is designed for forcible entry applications. It works with the same Hurst Mini hand pump that is used with the Mini-Lite kit and can provide up to 8,000 lbs. of spreading force. The standard Rabbit Tool provides 4 inches of spreading distance. The larger JL-8 Jack Rabbit Tool doubles that spreading distance to 8 inches.

Hydra-Ram

The Hydra-Ram is another forcible entry tool. Developed by Fire Hooks Unlimited, it is very similar to the Rabbit Tool in operation. However, unlike the Hurst design, the Hydra-Ram eliminates a separate pump and hose. Instead, the hydraulic pump and actuator are integrated into a one-piece tool. Two varieties of the tool exist: the Hydra-Ram with 4 inches of spreading distance and the Hydra-Ram II with 6 inches of spreading distance. Both are rated for up to 10,000 lbs. of spreading force.



Paratech HydraFusion Struts

Another fire/rescue-specific hydraulic tool is the HydraFusion strut designed by Paratech. These struts are a combination of a standard Paratech strut used for stabilization and a hydraulic ram. HydraFusion struts are powered by a separate manually-operated hydraulic pump. They are rated for 10 U.S. tons of lift with a safety factor of 2:1. Three different sizes of HydraFusion struts provide lifting/spreading distances of 4, 10, and 16 inches.

Hydraulic Rescue Systems

Types

Hydraulic rescue tool systems are generally identified by their operating pressures. There are two categories: low pressure and high pressure. While there are some similarities, each type of system has unique features and benefits:

<u>Low Pressure</u>

- Operating Pressure: 5,000 psi
- 2-Stage Pumps
- Tools are often heavier than high pressure tools
- Tools tend to operate slower than high pressure, which can provide more precise control and movement

<u>High Pressure</u>

- Operating Pressure: 10,000+ psi
- 2-Stage Pumps
- Tools are often lighter than low pressure tools
- Tools tend to operate faster than low pressure, which can provide speed but may make precise control and movement difficult

In both low and high pressure systems, the tools themselves are very similar in function and appearance. The difference is in the pump. Hurst patented the first hydraulic rescue system, the Jaws of Life®, in the 1970's. It was based on the same principles of fluid mechanics and Pascal's Law outlined at the beginning of this module. Hurst's 5,000 psi rescue systems are still widely used today. Advances in technology and a demand for lighter, faster tools led to the introduction of high pressure systems. As the examples using Pascal's Law demonstrated, the output force of the hydraulic system is dependent upon the fluid pressure and the surface area of the piston. Increasing the operating pressure from 5,000 psi to 10,000+ psi meant that tool pistons could be smaller and still produce the same force as 5,000 psi tools. One of the trade-offs is that high pressure tools must be manufactured with materials and components that will withstand the higher operating pressure. AMKUS is one of the leading manufacturers of high pressure rescue systems. Others include Genesis and Holmatro. Even Hurst manufacturers a line of 10,000 psi rescue tools.

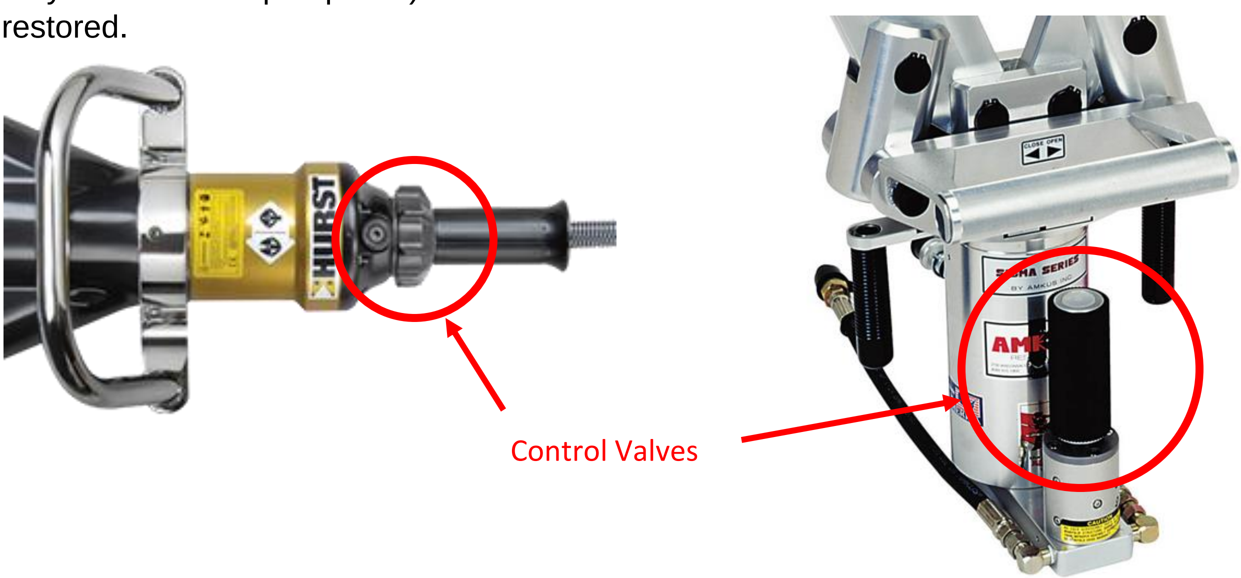
Operation

Most hydraulic rescue systems incorporate 2-stage pumps (Holmatro uses a 3-stage axial pump). Hydraulic tools will perform differently based on differences in hydraulic fluid pressure and flow. Higher pressures result in higher output force from the tool. Higher fluid flows result in faster piston movement and tool operation. Unfortunately, both cannot be achieved at the same time. Increases in hydraulic fluid pressure mean a decrease in flow rate. Likewise, increases in fluid flow rate result in decreases in pressure. The key is gaining both benefits from one pump and tool, and hydraulic rescue tool manufacturers have done just that.

Hydraulic tool users want maximum speed when operating tools that are not under load (e.g. opening cutter blades). To allow this, the hydraulic pump operates in the low pressure/high flow stage (often called Stage 1). Once the tool meets resistance, the hydraulic pump automatically switches to the high pressure/low flow stage (Stage 2) to provide the maximum operating pressure for the tool. Hydraulic tool operators will sometimes notice this switchover represented by a brief pause in tool operation when it meets resistance followed by movement to finish the spread/cut.

Some manufacturers are now incorporating “turbo” or “boost” modes into their pump designs. The idea behind this design is that it allows a user to double the quantity of fluid being supplied to a single tool. The increase in fluid will increase the operating speed of the connected tool during both pump stages.

The majority of hydraulic rescue tools utilize a “dead man” control valve. This valve is designed to revert back to the Neutral position once the operator releases his/her grip. This prevents unintended movement of the tool when not in use. They also incorporate check valves to prevent loss of pressure in the tool should fluid flow be interrupted (e.g. a hydraulic line or pump fails). This allows the tool to hold the load until fluid flow can be restored.



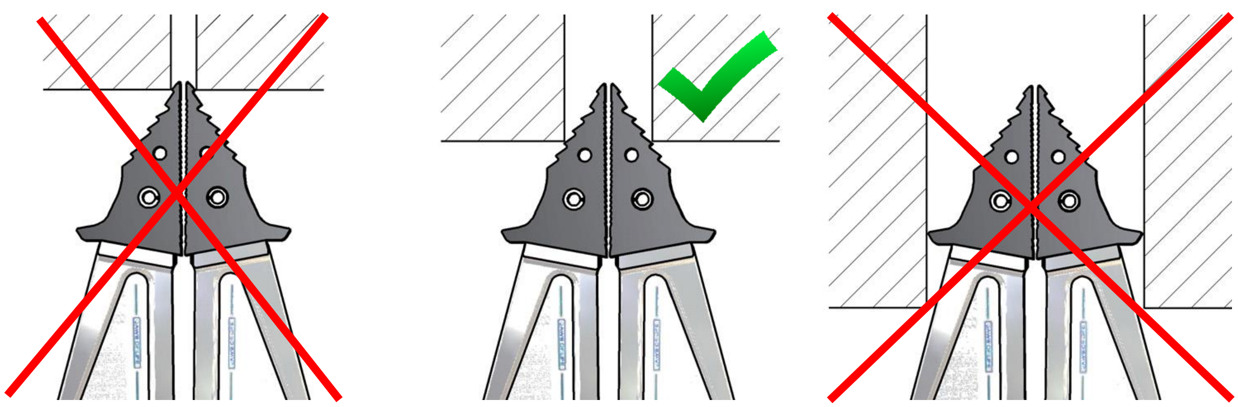
Spreaders

Spreaders use a set of arms connected to a piston rod to apply outward force at the tip of each arm. They can be used for prying and spreading as well as lifting. Spreaders come in different sizes with varying arm lengths. Longer arms provide greater spreading distance at full opening. However, this typically results in a decrease in maximum spreading force.

Spreaders utilize a double acting cylinder so force is applied to the arms as they are both opening and closing. This closing force can be used to pull and pinch objects. One thing to note is that the closing force will be less than the opening force. This is due to the fact that the surface area of the piston is not equal on both sides. The double acting cylinder example from earlier in the module shows this difference.

There are a variety of different spreader tip designs and accessories. Some tips are designed for gripping surfaces while others are used for peeling. Many tips have holes drilled through them for mounting chains to be used in pulling applications.

Whenever spreading, it is important to obtain a good grip with the tips. Spreading should ONLY be done at the tips – using the arms of the tool will result in damage.



"Maximum spreading force" is often advertised by manufacturers to promote their tools. However, one problem with these numbers is that they are obtained by the individual manufacturers who do not necessarily use the same test methods as other manufacturers. To help remedy this issue, NFPA 1936 – Standard on Powered Rescue Tools outlines specific testing guidelines for NFPA-compliant rescue tools.

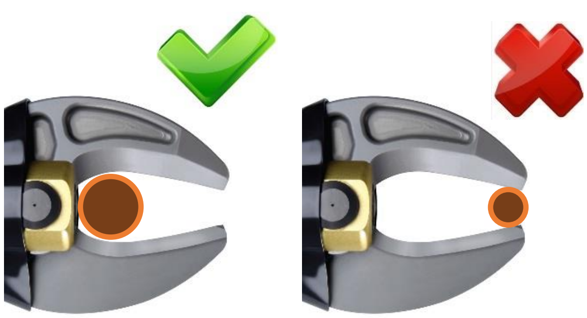
Spreaders (continued)

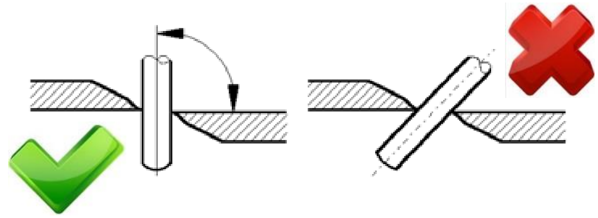
In this test, the holes used for pulling attachments provide the test points. The spreading force exerted by the tool is measured at 10 uniformly spaced intervals that range from the fully closed position to 95% of the fully open position. The measured forces are then converted to a value for force at the tool tip using a specified calculation. The lowest calculated spreading force of all 10 test points is designated as the LSF (Lowest Spreading Force) for that tool. The highest calculated spreading force of all 10 test points is designated as the HSF (Highest Spreading Force) for the tool. The test is then conducted for pulling force, yielding LPF and HPF values.

Cutters

Cutters act as hydraulic scissors to cut through various metals. Similar to spreader arms, cutters contain two pivoting cutting blades connected to a piston rod. The design of the cutter blades dictate the size, shape and strength of materials that can be cut.

Although cutters also utilized double acting cylinders, they are not designed for use in both directions. Their sole function is to cut. The greatest cutting capacity is achieved when the cut is performed as close to the blades pivot point as possible (often referred to as the “notch”). Also, to avoid damage, the cutting blades should be positioned at 90° to the object to be cut.





NFPA 1936 also provides testing procedures and ratings for cutters. In this test, the cutter is tested with six different types of material. It is assigned a rating based on the thickness of material that it is able to completely sever in a single continuous motion. To be NFPA compliant, the cutter must complete a minimum of 60 qualified cuts.

Material Category	A Round Bar	B Flat Bar	C Round Pipe		D Square Tube	E Angle Iron
Material	A-36 Hot-Rolled	A-36	Schedule 40 A-53 Grade B		A-500 Grade B	A-36
Performance Level	Diameter (in.)	Thickness x Width (in. x in.)	Nominal Size (in.)	OD x Wall Thickness (in. x in.)	Dimension x Wall Thickness (in. x in.)	Square Dimension x Thickness (in. x in.)
1	3/8	1/4 x 1/2	3/8	0.68 x 0.09	1/2 x 0.06	1/2 x 1/8
2	1/2	1/4 x 1	3/4	1.05 x 0.11	1 3/4 x 0.06	1 x 1/8
3	5/8	1/4 x 2	1	1.32 x 0.13	1 x 0.08	1 1/4 x 3/16
4	3/4	1/4 x 3	1 1/4	1.66 x 0.14	1 1/4 x 0.12	1 1/2 x 3/16
5	7/8	1/4 x 4	1 1/2	1.90 x 0.15	1 1/2 x 0.12	1 1/2 x 1/4
6	1	3/8 x 3	2	2.38 x 0.15	1 3/4 x 0.12	1 3/4 x 1/4
7	1 1/4	3/8 x 4	2 1/2	2.88 x 0.20	2 x 0.15	1 1/2 x 3/8
8	1 1/2	3/8 x 5	3	3.50 x 0.22	2 1/2 x 0.19	2 x 3/8
9	1 3/4	3/8 x 6	3 1/2	4.00 x 0.23	3 x 0.19	2 1/2 x 3/8

An example of a NFPA cutter rating would be A7/B9/C7/D8/E9.

Combination Tools

Combination tools are hybrids of a spreader and cutter. They are designed to be a multifunctional tool with both spreading and cutting capabilities. Combination tools may not provide the optimum performance of a job-specific tool like a spreader or cutter, but they offer flexibility and extrication options in an all-in-one package. As with spreaders and cutters, combination tools are equipped with various sizes and designs of blades.

To be NFPA compliant, combination tools must undergo testing as both a spreader AND a cutter. Therefore, it will carry both sets of ratings.

Rams

Rams are used for pushing and/or pulling. Unlike spreaders that using pivoting arms, rams utilize only the piston rod to apply linear force. Rams come in a variety of lengths to meet different applications.

Some rams utilize double acting hydraulic cylinders to apply both pushing and pulling force. As mentioned previously, the double acting cylinder will apply more force in one direction. In the case of a ram, the largest force is applied during the push. Pulling force is approximately 50% of the pushing force due to the reduction in surface area on the opposite side of the piston.

Some rams come with attachments for additional functionality. Different bases and tips provide either grip or piecing/cutting capabilities. Ram extensions can also be used to increase the range of the ram.


The NFPA 1936 testing procedure for rams is similar to that for spreaders. The spreading force exerted by the ram is measured at 3 uniformly spaced intervals between the fully retracted position and 95% of the fully extended position. The recorded values will be used to determine the spreading forces, HSF and LSF. If the ram is capable of pulling, the test will be repeated to determine HPF and LPF values.

Another type of ram is the telescoping ram. The 2-stage telescoping action of these rams provide the benefit of increased stroke length while maintaining a relatively small retracted storage length. The 1st stage of extension provides the maximum pushing capacity. Capacity decreases as the 2nd stage engages because the second piston has less surface area than the combination of both pistons in the 1st stage.

Telescoping rams are only designed for pushing. They undergo the same testing requirements as other rams to achieve NFPA compliance.

Hurst Lift Cylinders

The Hurst telescopic lifting cylinders are a type of specialized hydraulic rescue tool. They operate much like a telescoping bottle jack. However, instead of being powered by a hand pump, the Hurst lift cylinders are powered by the Hurst hydraulic system. The higher operating pressures lead to high lifting capacities. Lift cylinders operating on a 5,000 psi system have maximum capacities of just over 96,000 lbs. while cylinders on a 10,000 psi system top out at over 141,500 lbs.

The narrow profile of Hurst lift cylinders make them perfect for applications where large high pressure air bags may not fit (e.g. under rail and METRO cars). The lift cylinders come in 2- and 3-piston models. Numerous attachments and accessories are included with a lift cylinder setup. Hurst lift cylinder operation is more complicated than that of standard hydraulic rescue tools. Proper training from a qualified instructor is highly recommended before use.

Tool Maintenance and Inspection

Hydraulic rescue tools should be inspected on a daily basis and after every use. Visual inspection items include:

- Check general tightness (presence of leaks)
- Existence and stability of the handle
- Covers in good condition
- Spreader and cutter arms are free of cracks and without any chipped spots or deformations
- Cutting blades are free of large gouges
- Spreader tips are securely attached and free of damage

Operational checks should include:

- Ensure the control valve moves freely and is not damaged/leaking and that it returns to the neutral position appropriately
- Operate the tool through its full range of motion and check for:
    - Suspicious noises
    - Hydraulic fluid leaks
    - Unusual movement of spreader arms or cutter blades
- Ensure that the tool does not continue to operate when the dead man control valve returns to the neutral position
- Ensure that cutting surfaces on cutter blades slide over one another and do not make contact

Following use, hydraulic tools should be wiped down with a clean towel. If necessary, a damp rag along with a mild cleaner/degreaser can be used to remove dirt, oil or other contaminants. All components should be immediately dried to prevent corrosion. Do not apply any oils or lubricants to cutter blades as this can lead to loosening of the pivot bolt.

Hydraulic pumps and hoses should also be visually checked prior to operation. Any damage or leaks require repair or replacement prior to use. Couplings should be free of dirt and debris. If necessary, they can be cleaned with a solution of soap and warm water and then rinsed and dried. Fluid levels in pump reservoirs need to be checked and topped off if necessary. Do not overfill reservoirs and only use the manufacturer-approved hydraulic fluid.

All service and repair of hydraulic rescue systems should be handled by a qualified service technician.