American Piledriving Equipment

APE Basic Hydraulic Training

Developed By Western Dynamics, LLC
& American piledriving Equipment, Inc.

APE Hydraulics

Understanding some basic hydraulic knowledge and providing examples when working with APE equipment is the goal of this training program.

As You Go Through This Course

- Do not simply look at the pictures, but study them, for each picture tells you something about hydraulics. Read the notes with each picture carefully.
- At the end of this course we will ask some questions to see if you have increased your understanding of hydraulics.

In The Beginning…

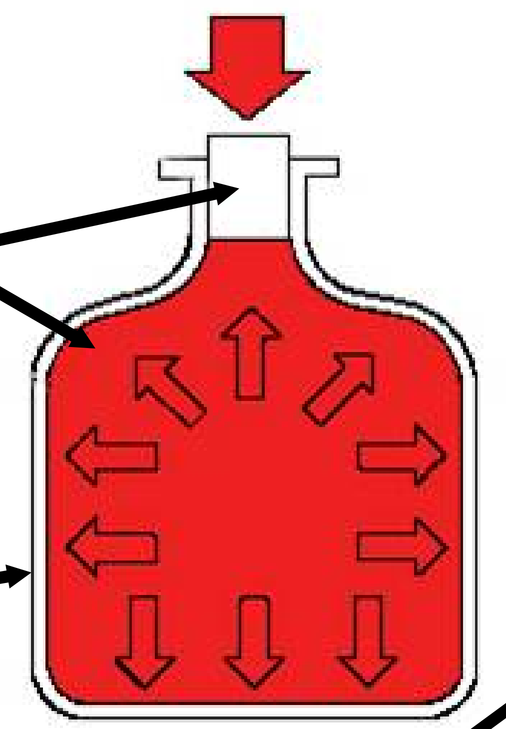
In the 17th century Pascal developed the law of confined fluids.

Pascal's Law, simply stated, says:

"Pressure applied on a confined fluid is transmitted undiminished in all directions, and acts with equal force on equal areas, and at right angles to them".

Pascal's Law

1. The bottle is filled with a liquid, which is not compressible, for example, hydraulic oil.
2. A 10 lb. force applied to a stopper with a surface area of one square inch.
3. Results in 10 lb. of force on every square inch (pressure) of the container wall.



4. If the bottom has an area of 20 square inches and each square inch is pushed on by the 10 lb. of force, the entire bottom receives a 200 lb. push.

10 lbs. x 20 sq. in.= 200

"Pressure applied on a confined fluid is transmitted undiminished in all directions, and acts with equal force on equal areas, and at right angles to them".

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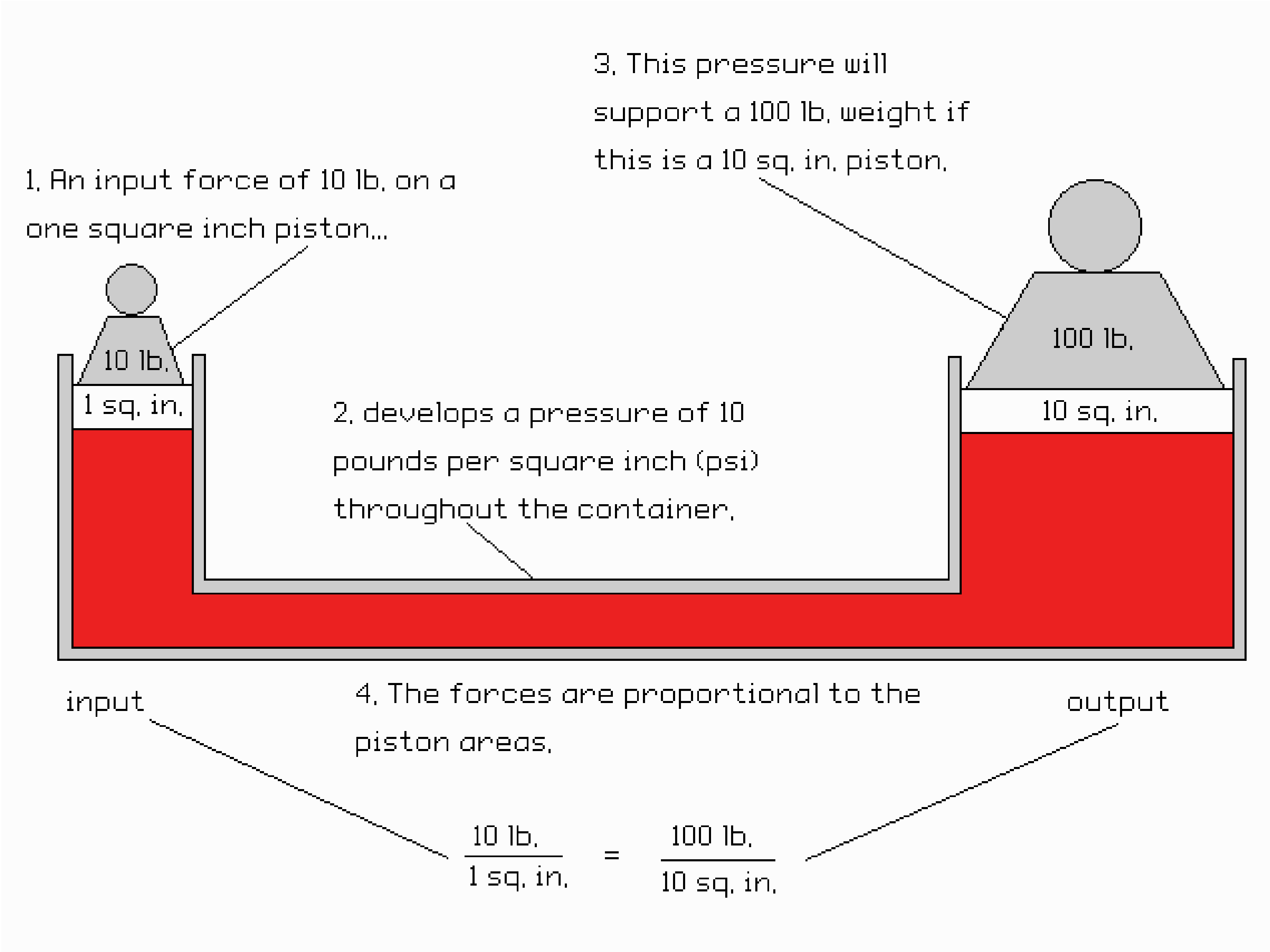
Chapters

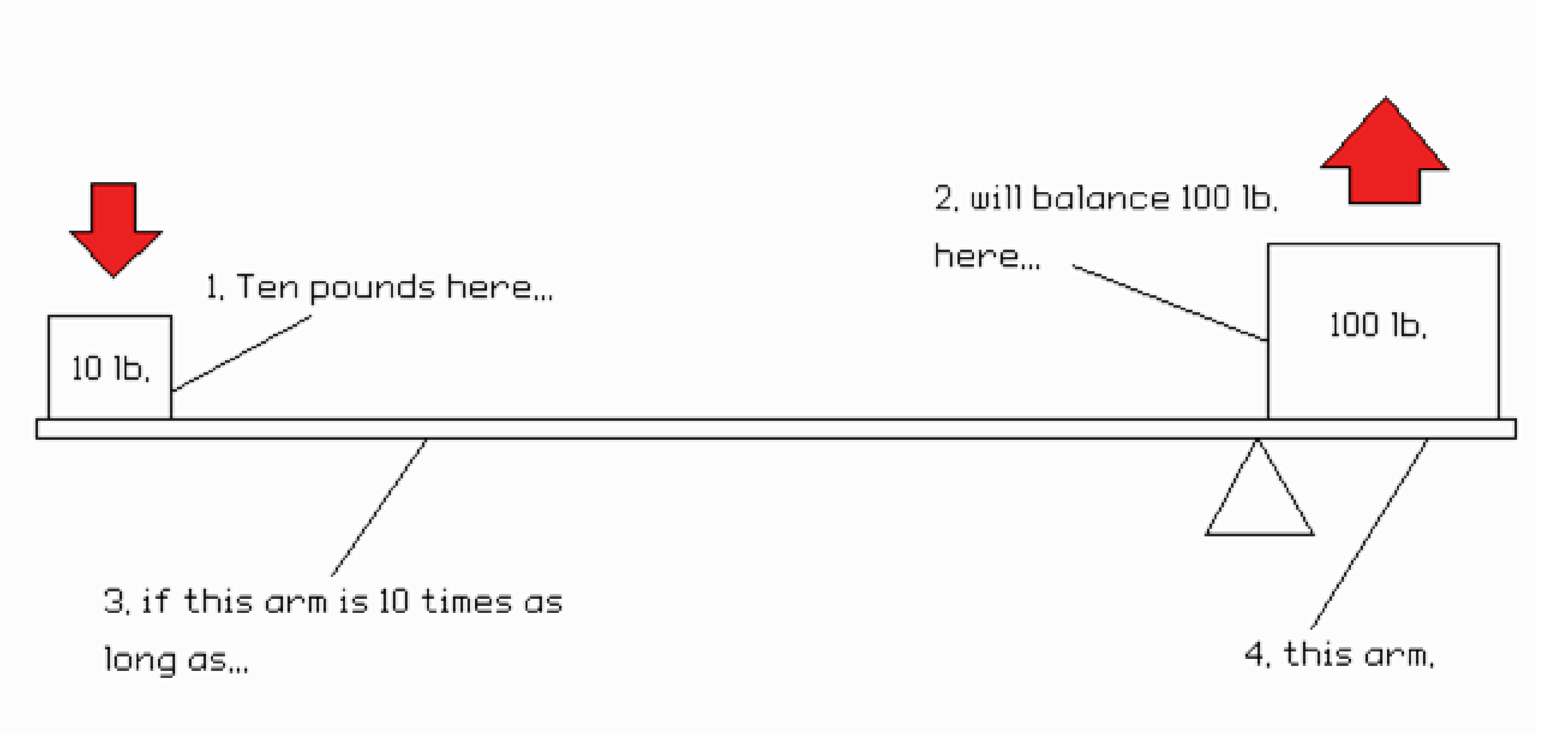
Chapter 1

Introduction To Hydraulics

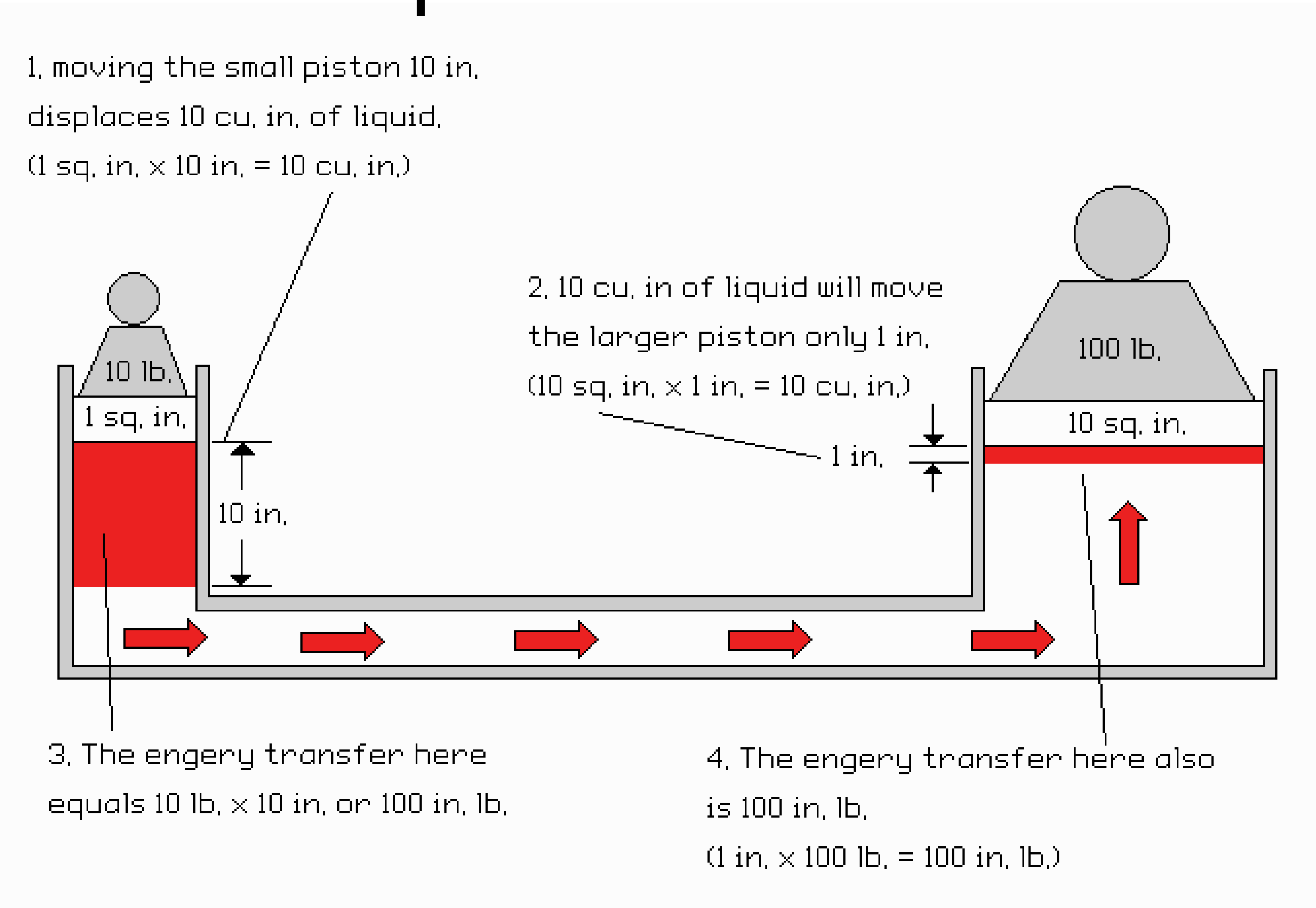
Pascal's Law: A Closer Look



Pascal's Law Explained Using A Fulcrum



Explaining Piston Displacement



Force

Force. The relationship of force, pressure, and area is as follows:

F = PA

where-

F = force, in pounds

P = pressure, in psi

A = area, in square inches

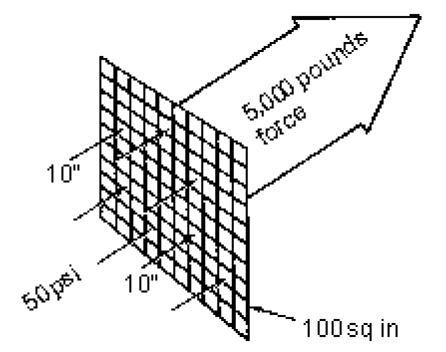


Figure 1-6. Force, pressure, and area

Example:

Figure 1-6 shows a pressure of 50 psi being applied to an area of 100 square inches. The total force on the area is-

F = PA

F = 50 x 100 = 5,000 pounds

Solving For Pressure

F = PA solves for Force. Shifting the same equation will allow you to solve for Force or Pressure.

$$P = \frac{F}{A}$$ *Solves for Pressure*

F = Force

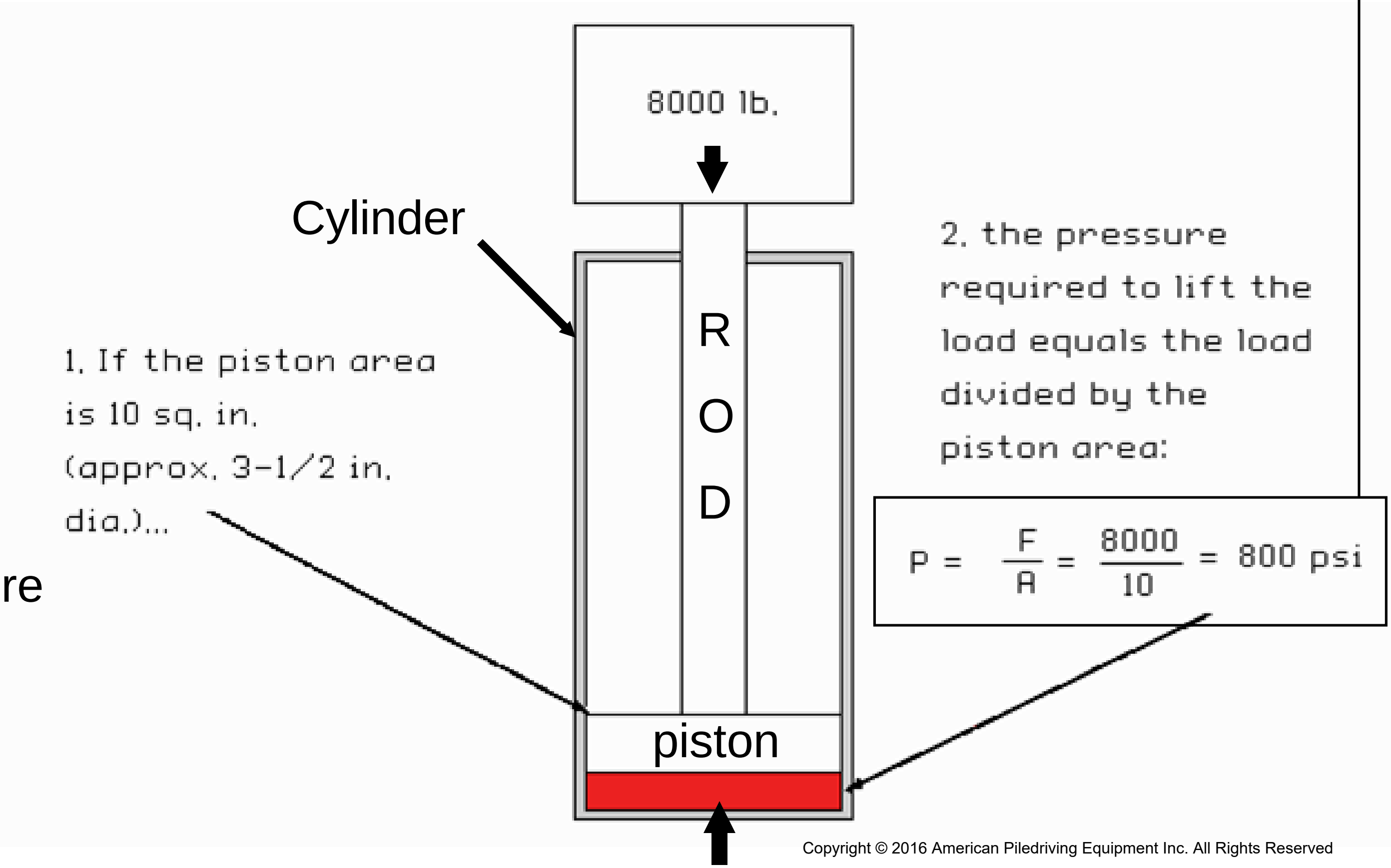
P = Pressure

A = Area in sq. inches

F = PA Solves Force

P = F/A Solves Pressure

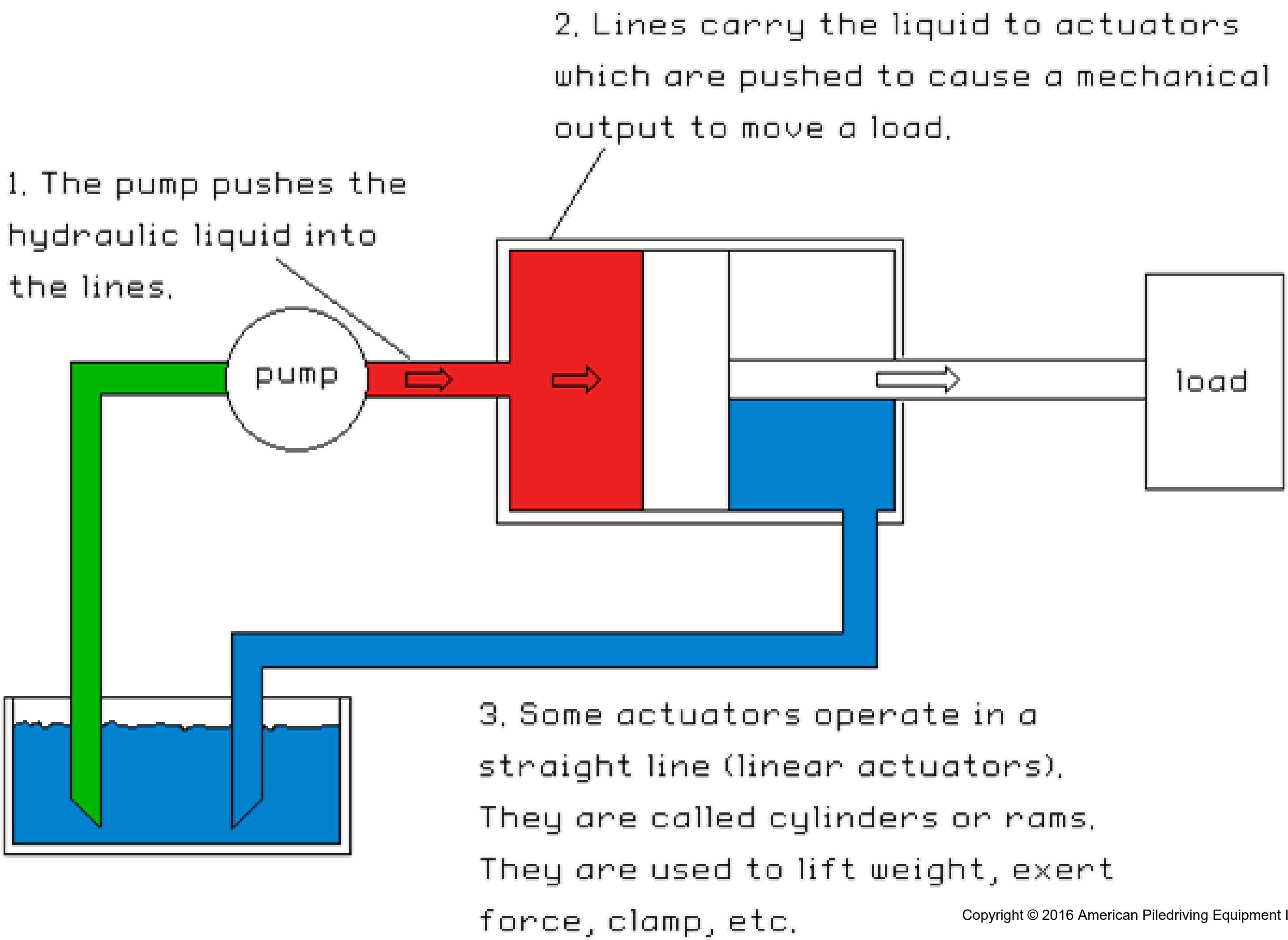
A= F/P Solves Area



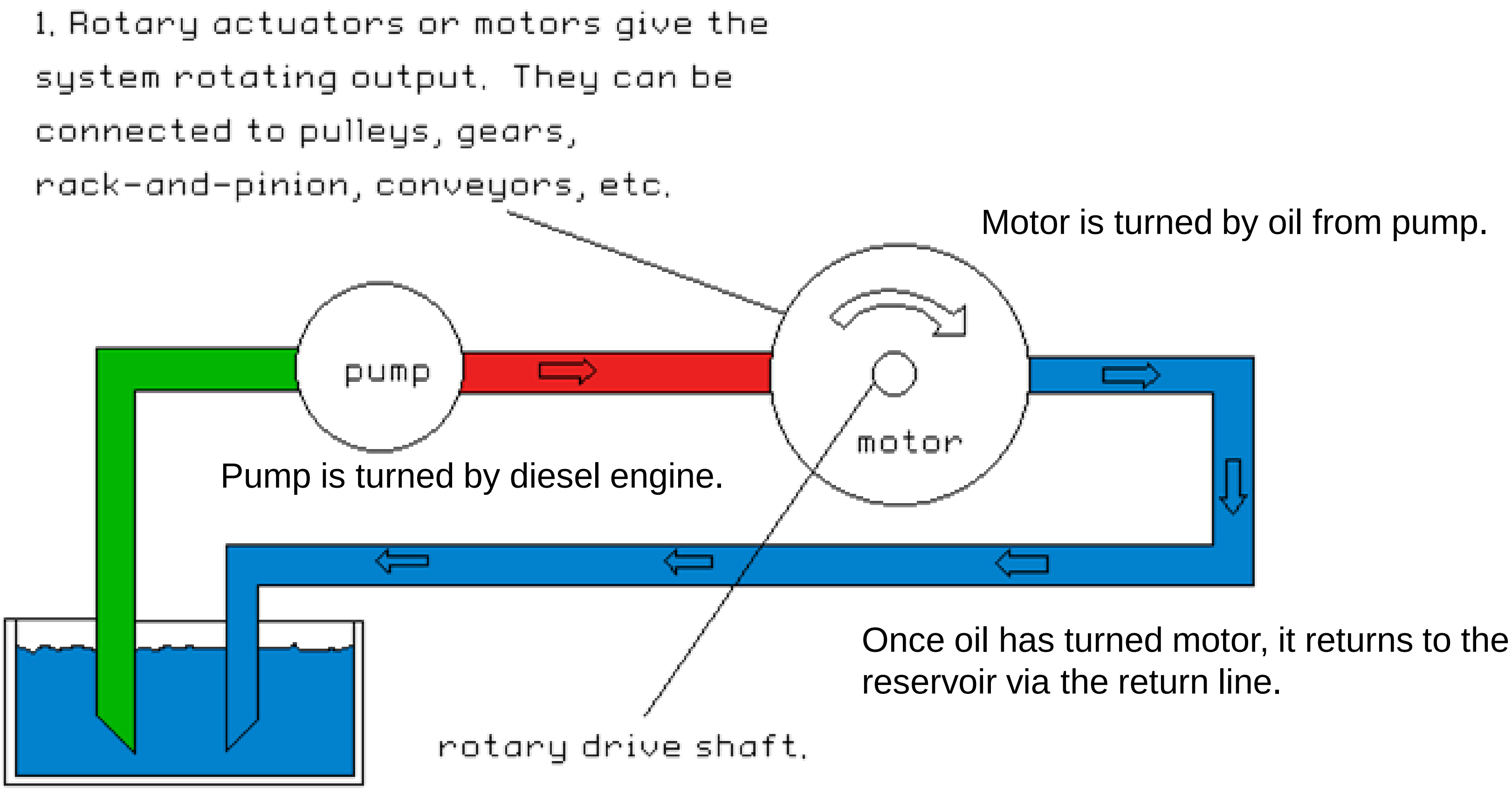
How Many Cubic Inches Of Oil Is In One Gallon?

231 cubic inches

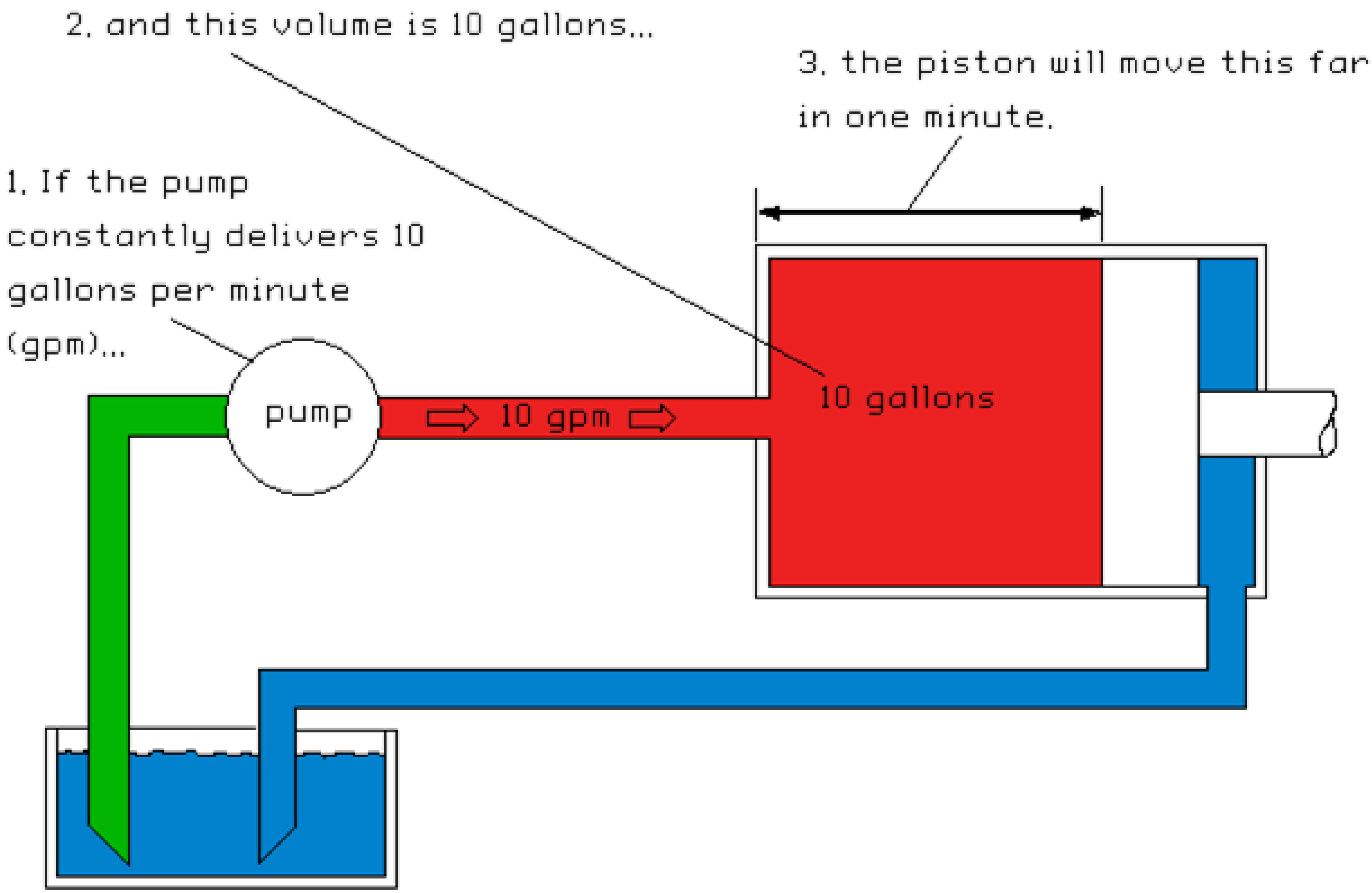
How Hydraulics Performs Work Using A Linear Actuator (Cylinder)



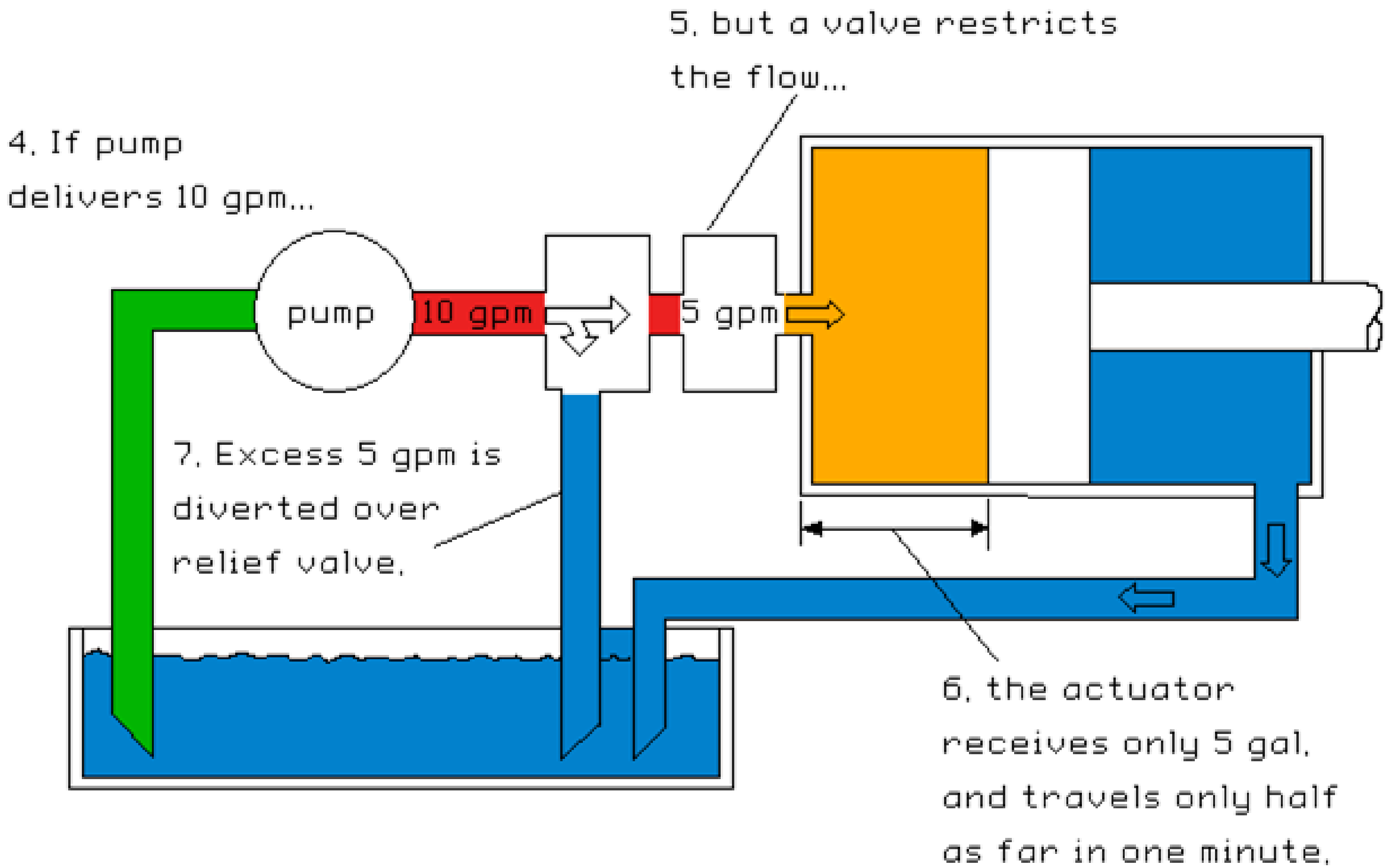
How Hydraulics Works To Rotate A Motor



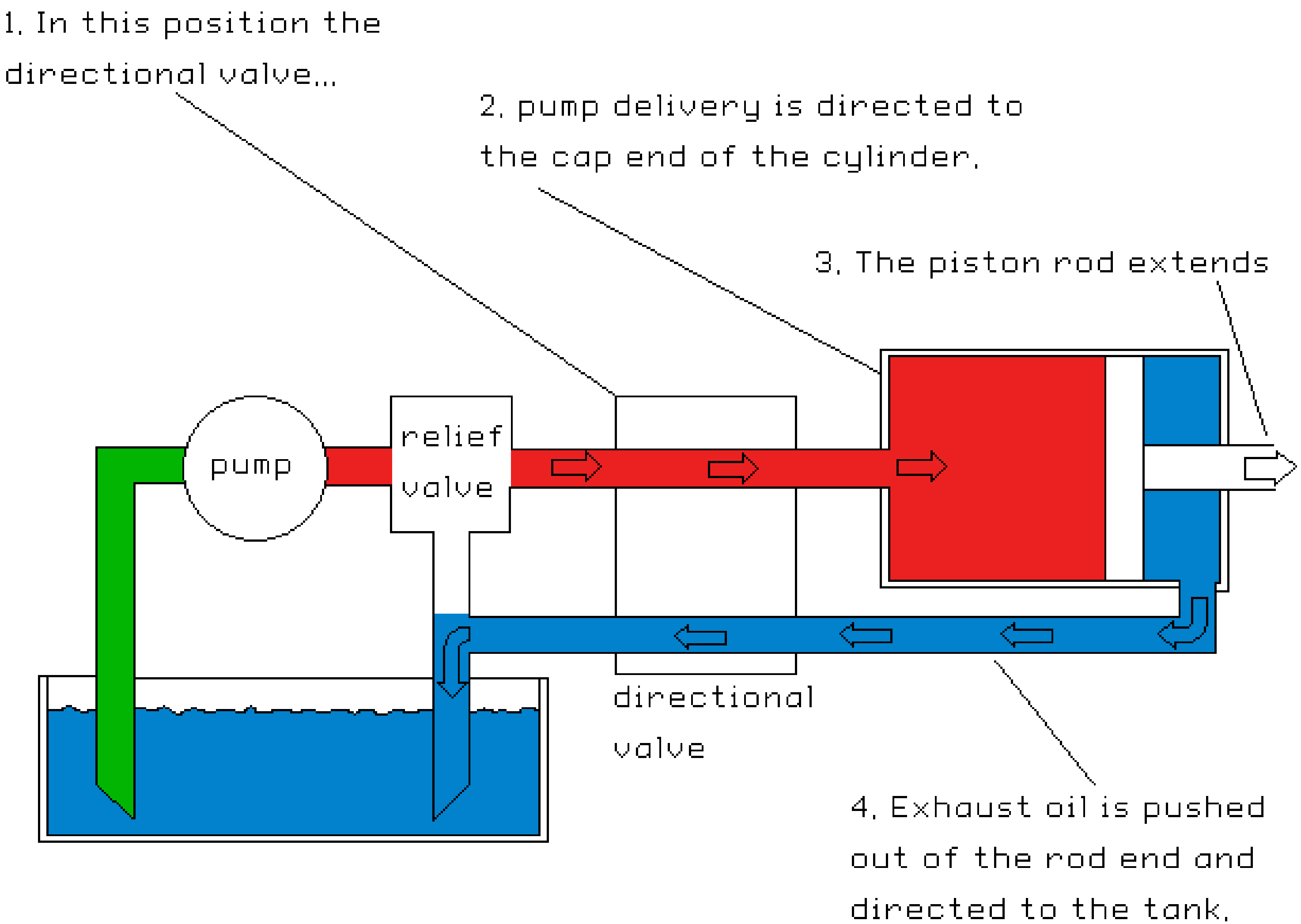
Understanding Gallons Per Minute (GPM)



How Flow Restriction Effects Speed Or Distance

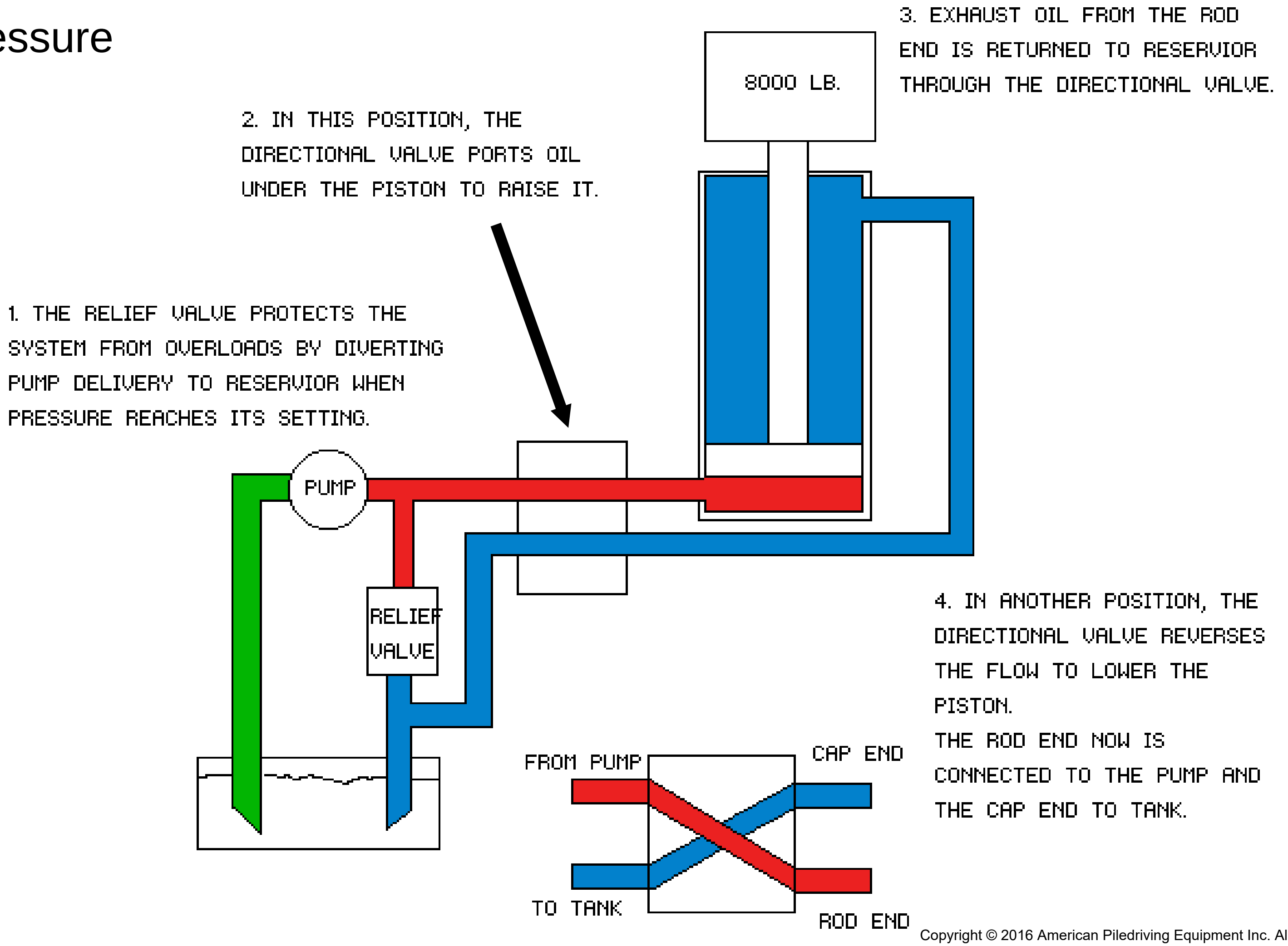


How A Directional Valve Works

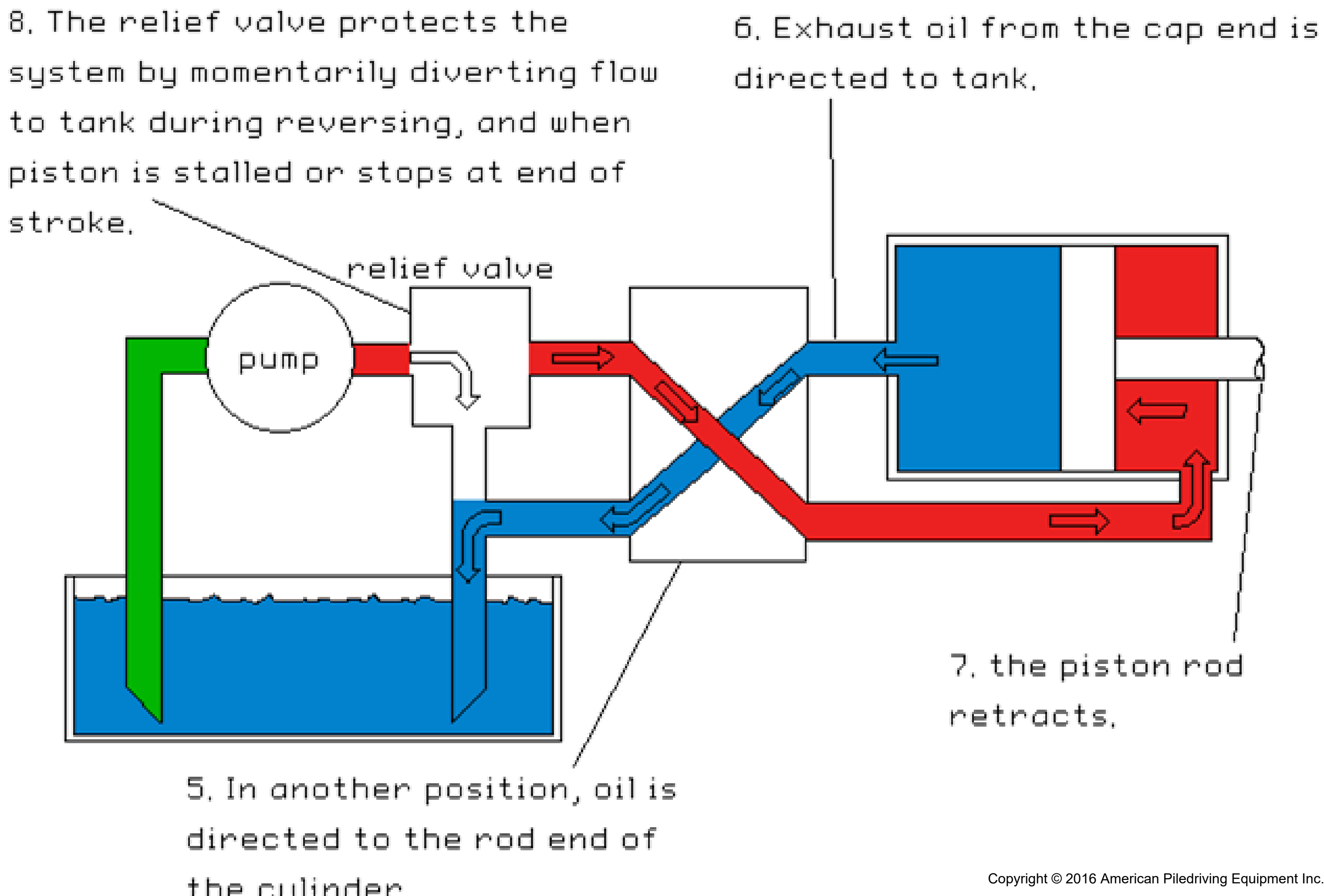


The Directional Valve Switches The Oil Direction

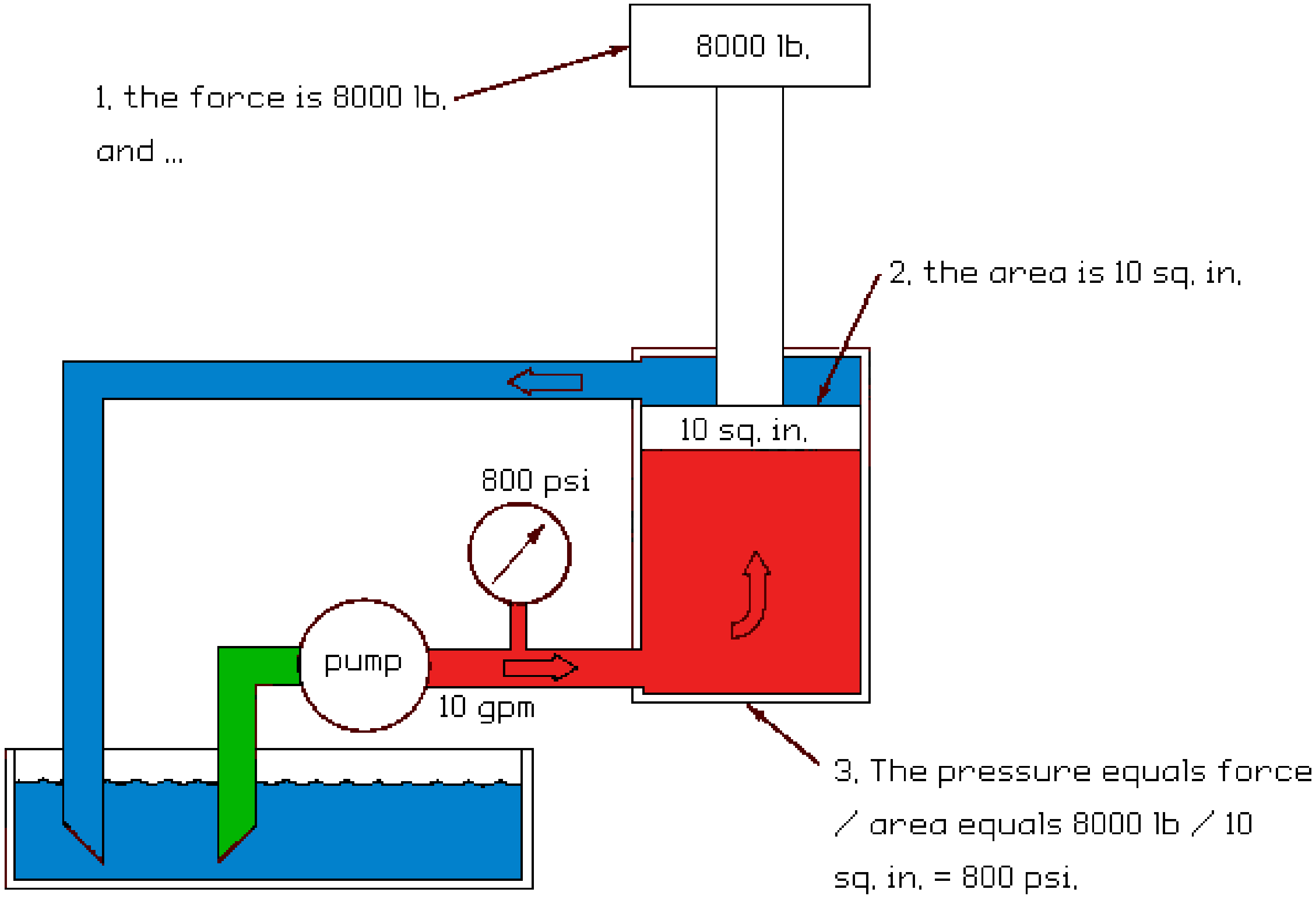
Red color means pressure



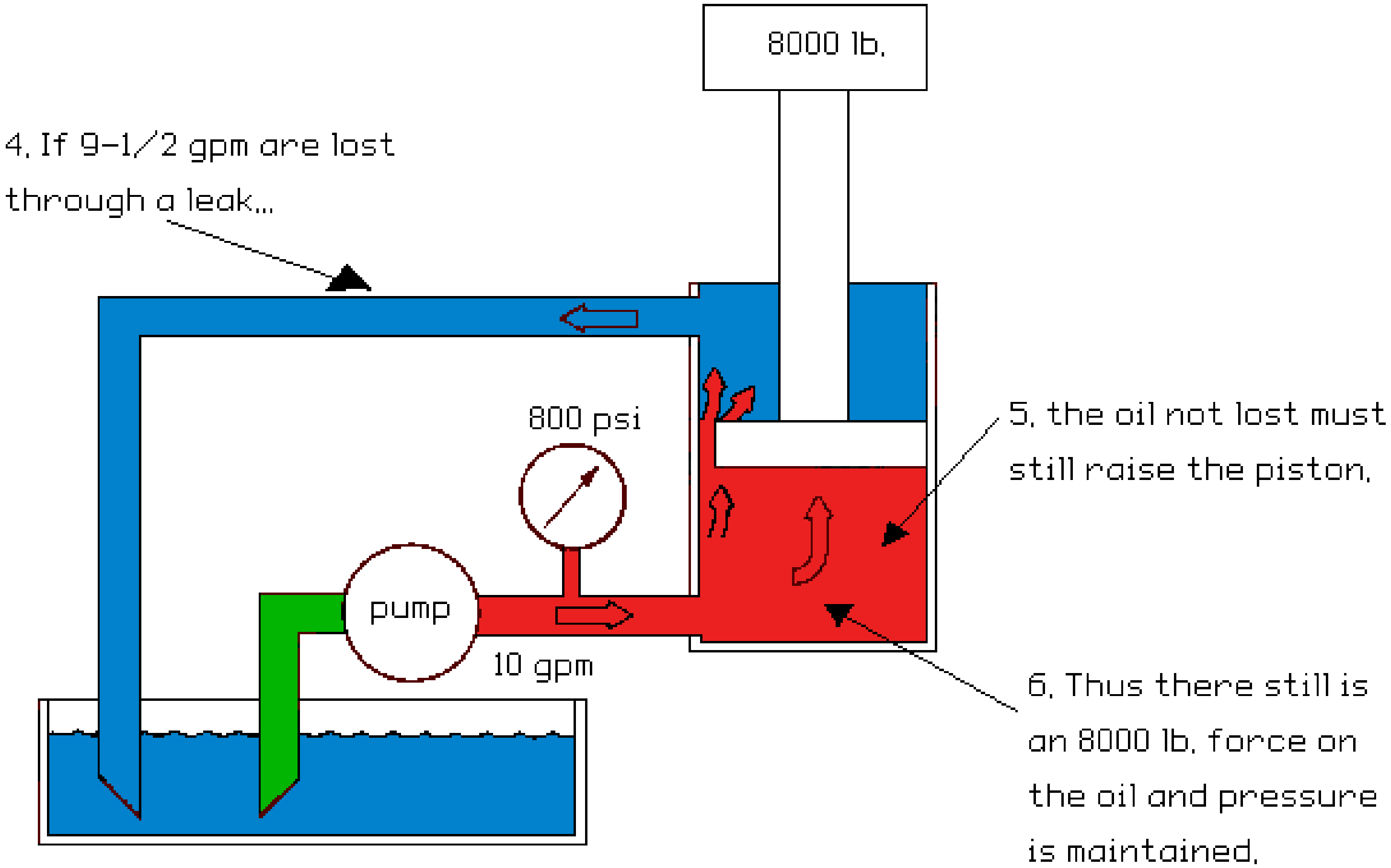
What A Relief Valve Does



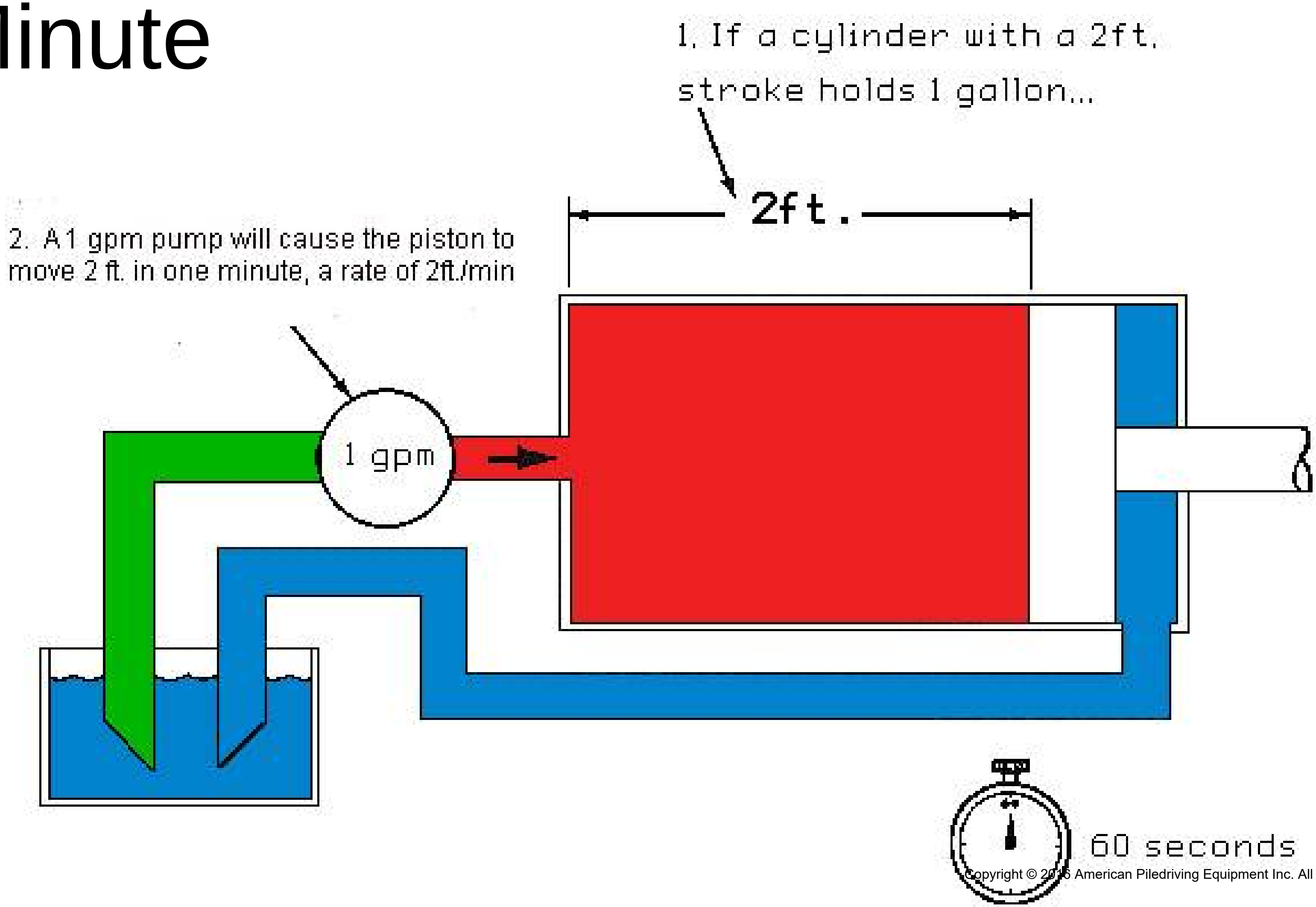
A Pump Doing Work



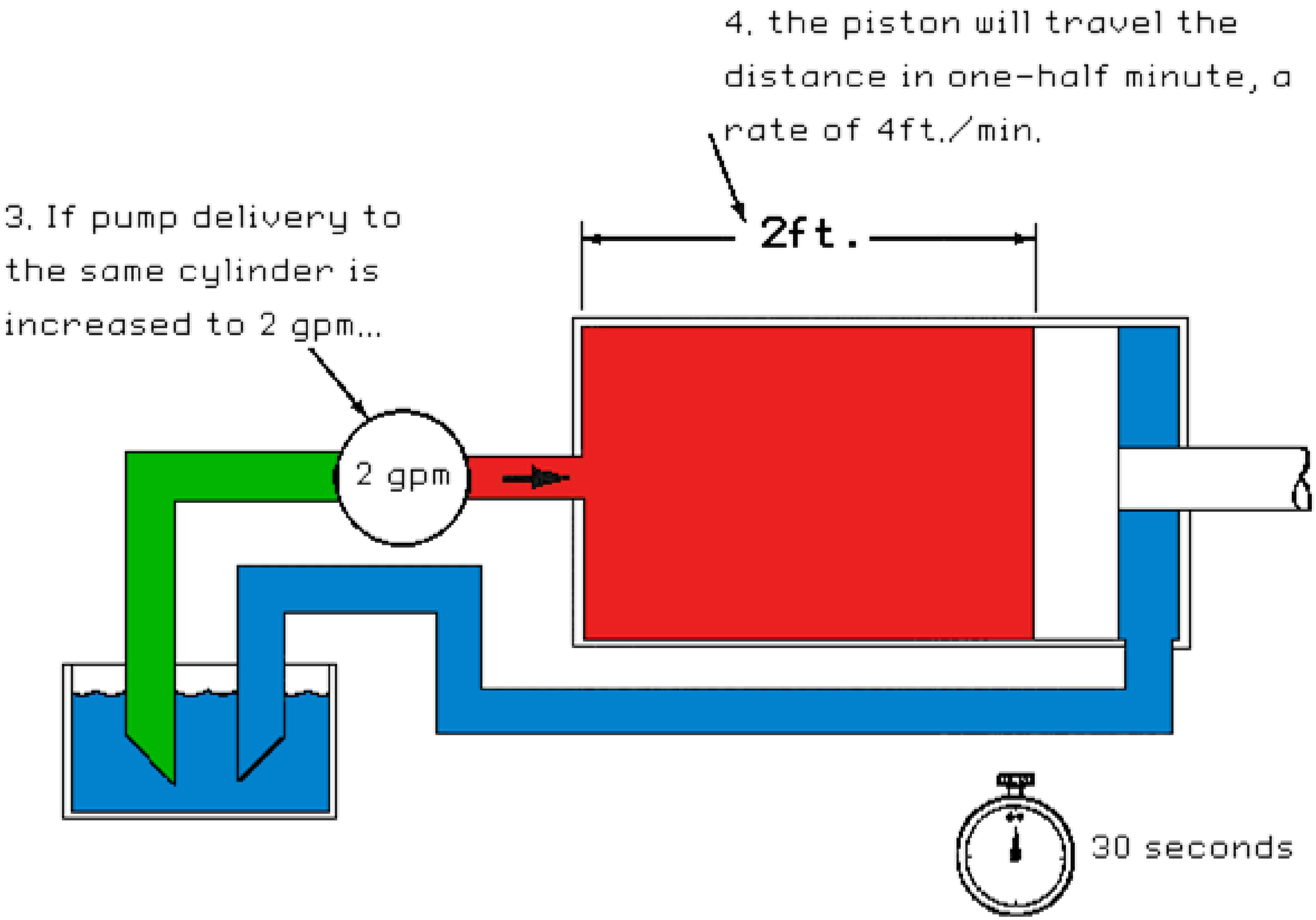
Work Even When Seals Leak Slightly



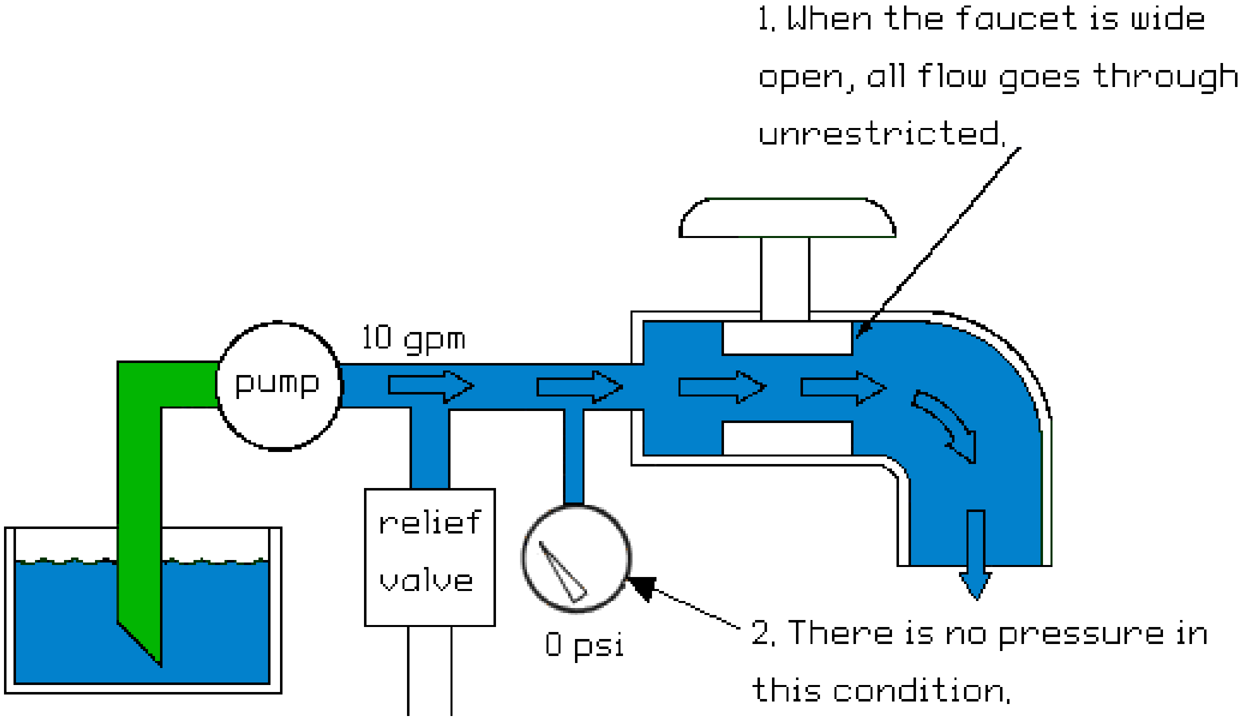
Calculating Speed Per Minute Based On Flow Per Minute



Calculating Speed

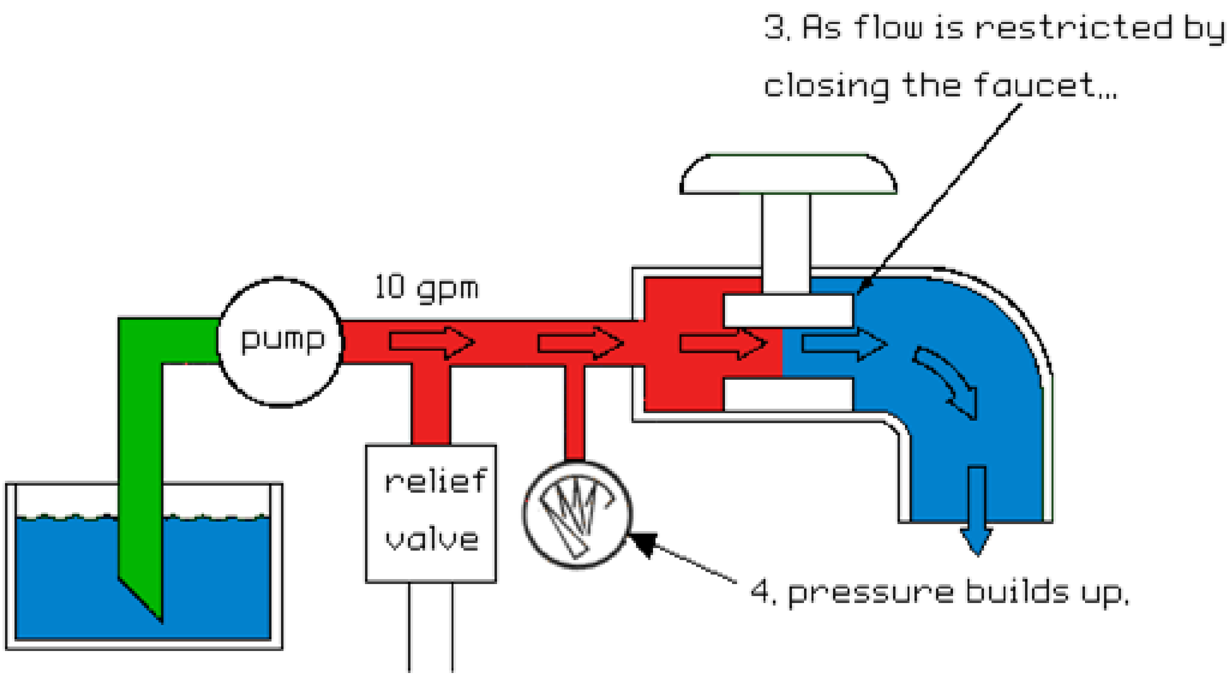


Understanding Unrestricted Flow And Why There Is No Pressure Build Up

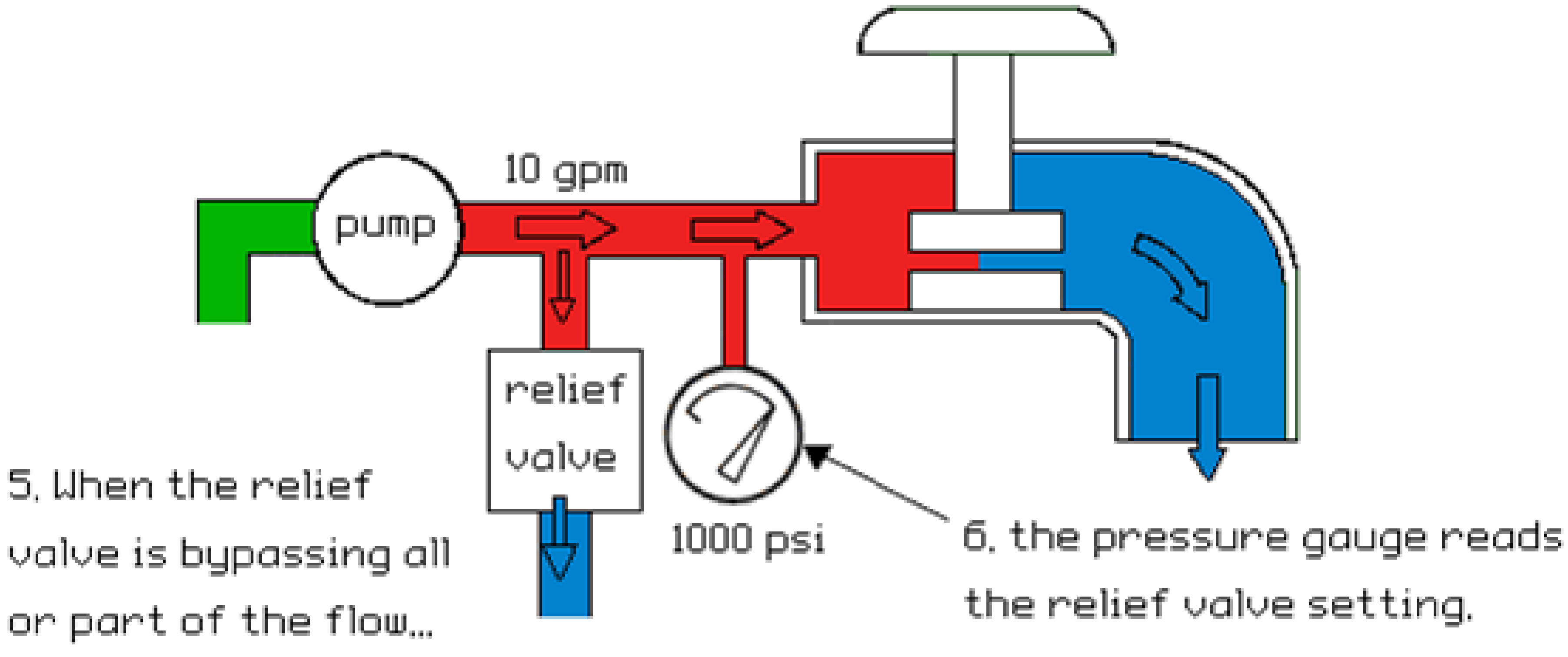


This is like our drive manifold when the vibro is not running. The oil goes through the valve and dumps right back to the tank without building any pressure.

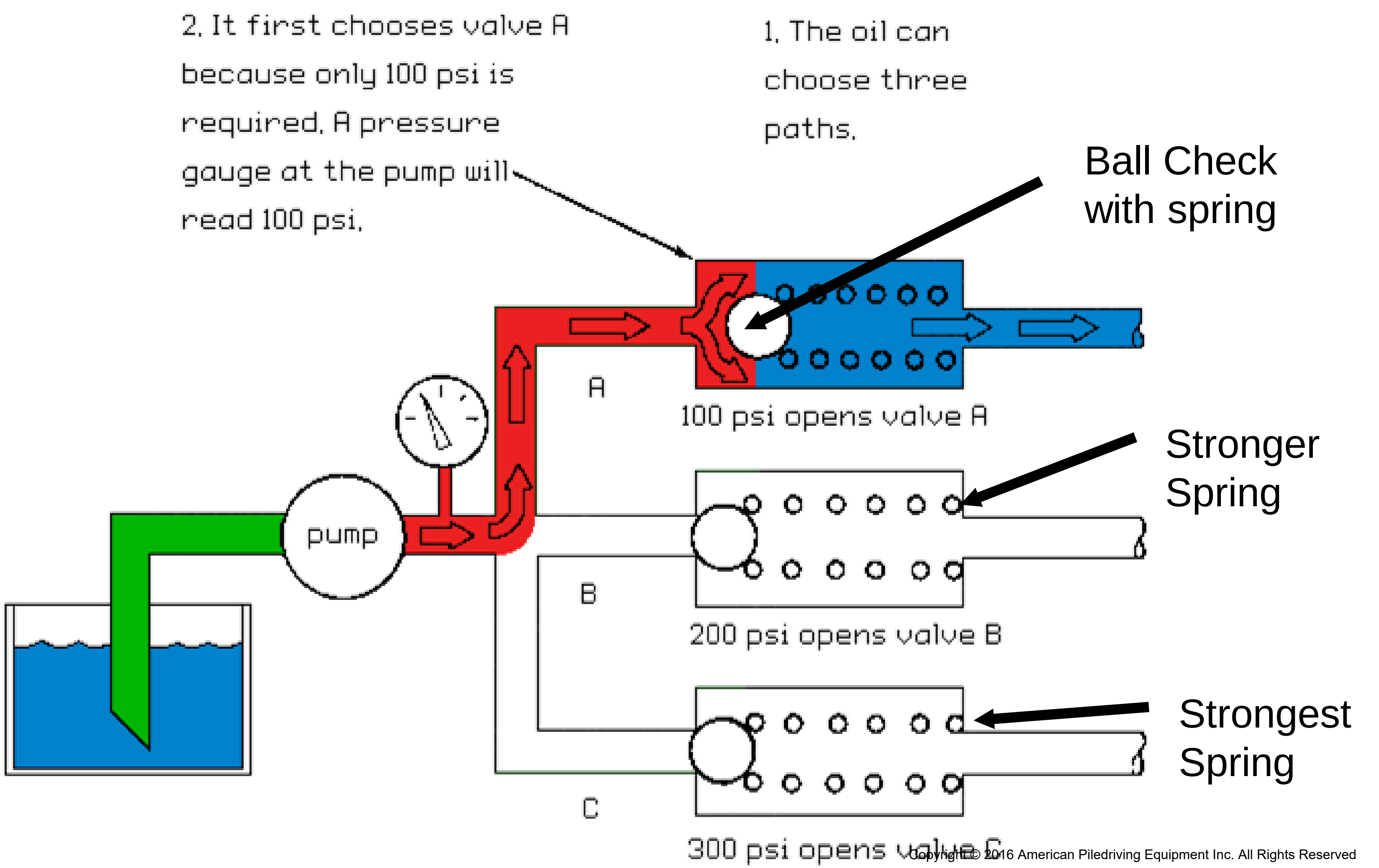
Understanding Pressure And Where It Comes From



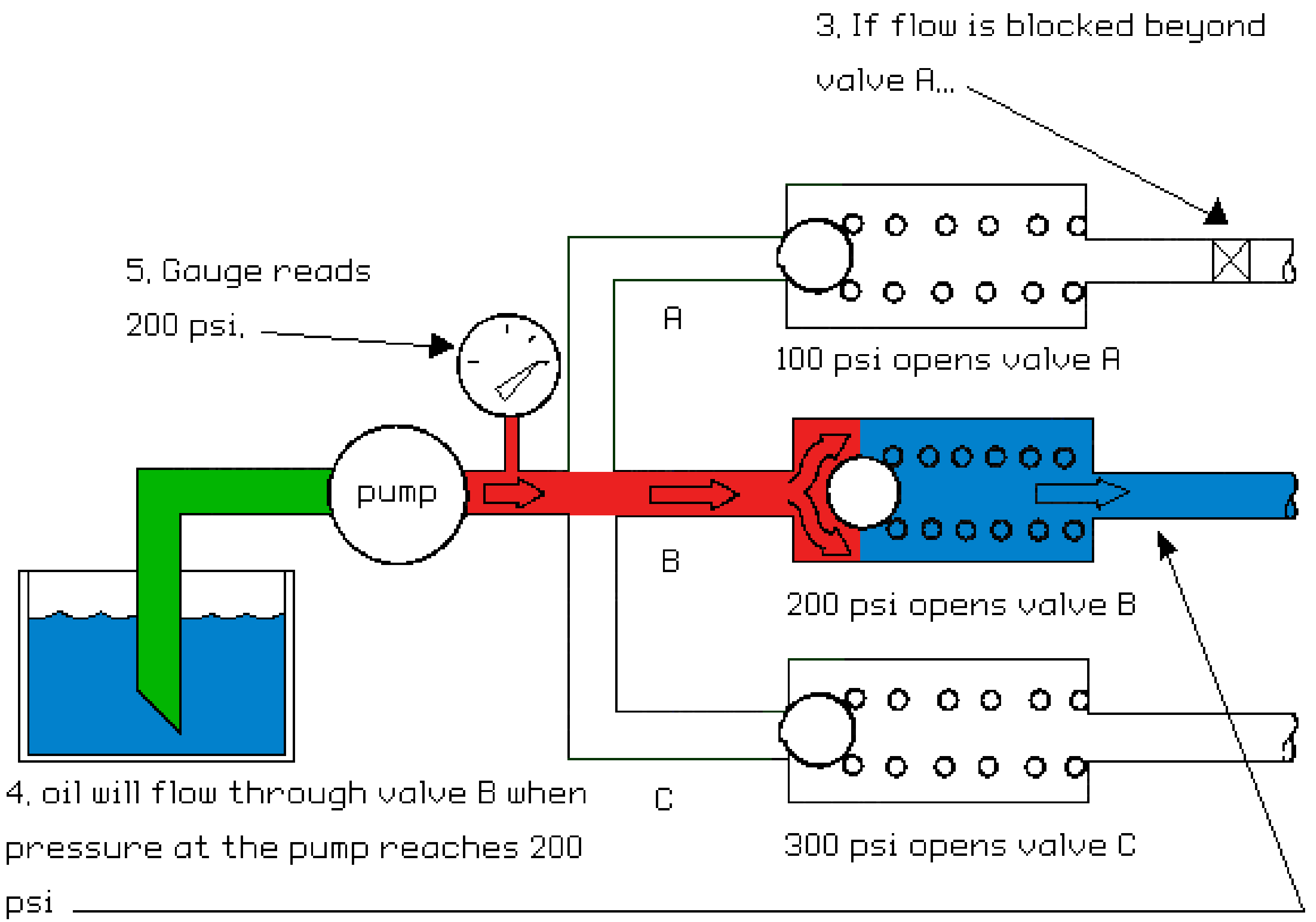
Reading The Relief Valve Setting



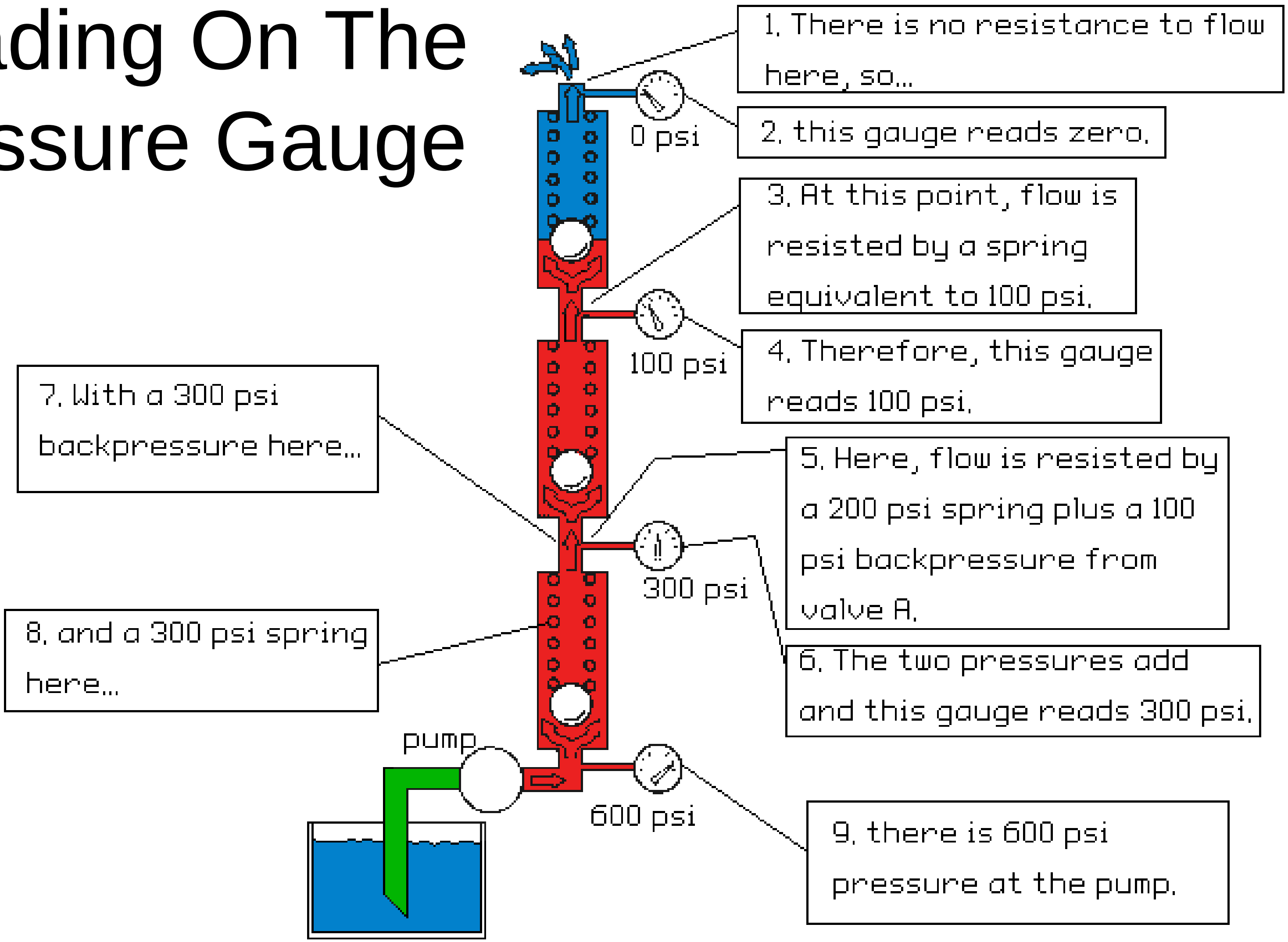
Oil Goes To The Path Of Least Resistance



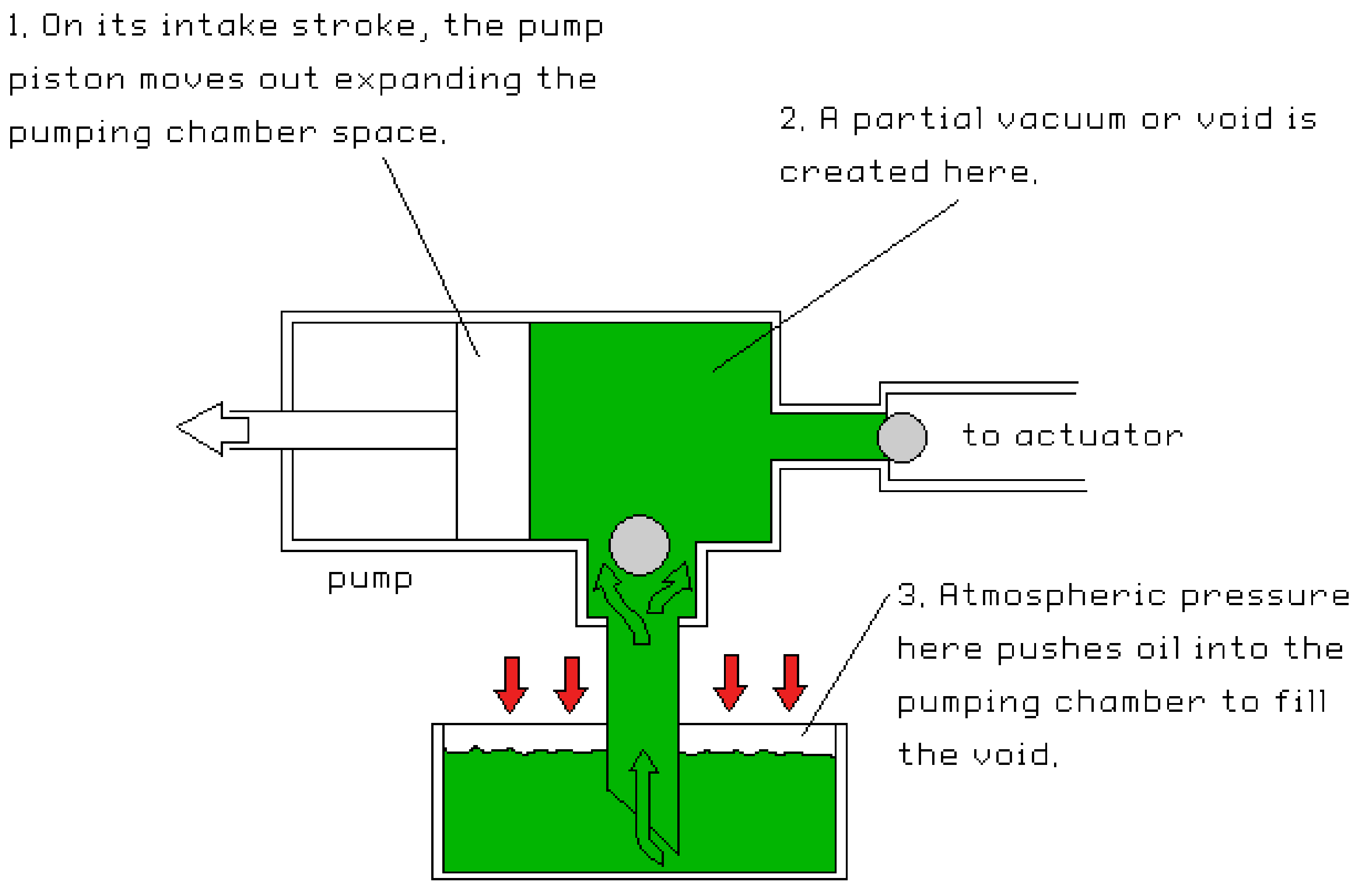
Path Of Least Resistance



Understanding What Your Are Reading On The Pressure Gauge



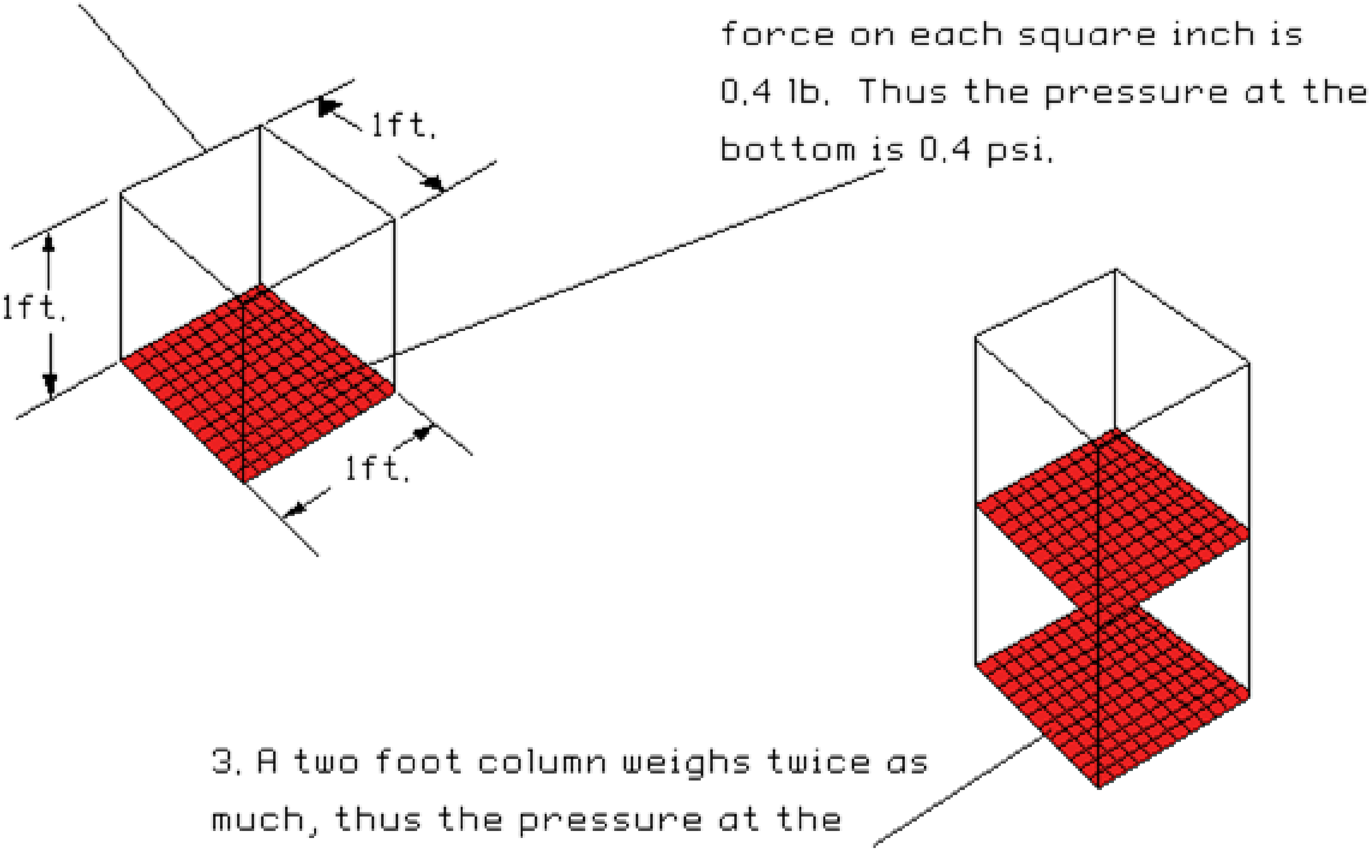
Understanding Atmospheric Pressure



Oil Has Weight

1. A cubic foot of oil weighs about 55-58 lb.

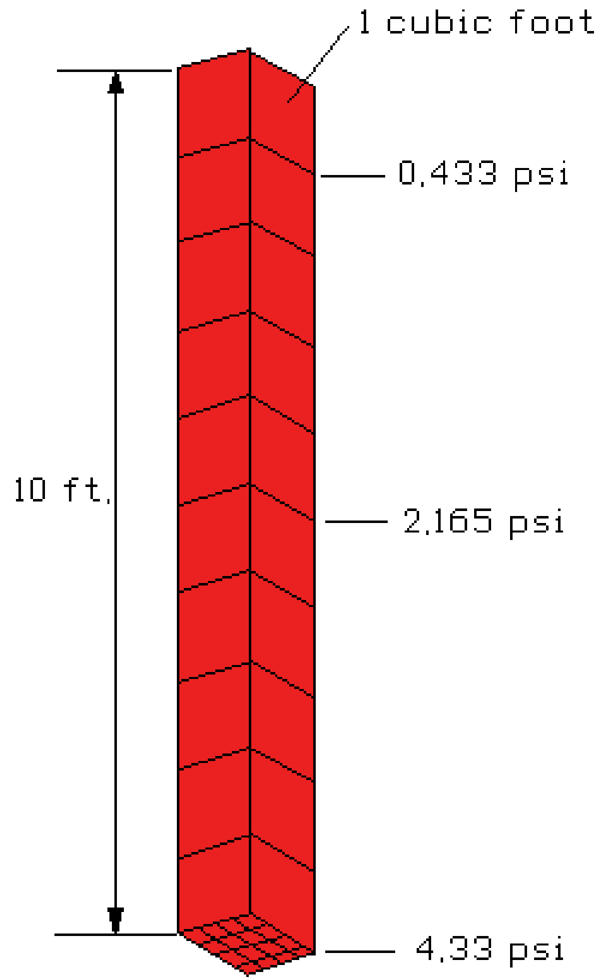
2. If this weight is divided over the 144 sq. in. of bottom, the force on each square inch is 0.4 lb. Thus the pressure at the bottom is 0.4 psi.



3. A two foot column weighs twice as much, thus the pressure at the bottom is 0.8 psi.

Weight of Fluid

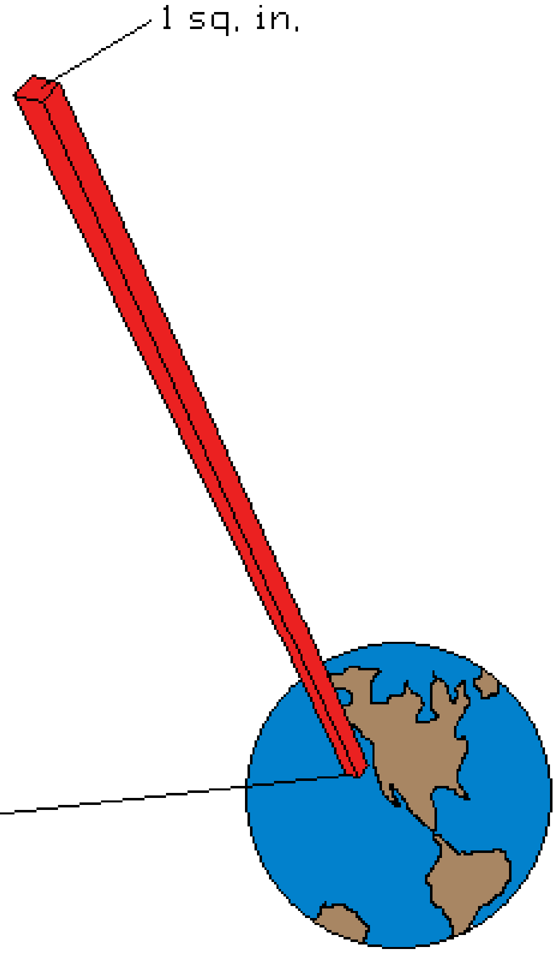
1. A foot-square section of water 10 ft. high contains 10 cu. ft. If each cubic foot weighs 62.4 lb....



2. the total weight here is 624 lb.
The pressure due to the weight is 624 / 144 sq. in. or 4.33 psi

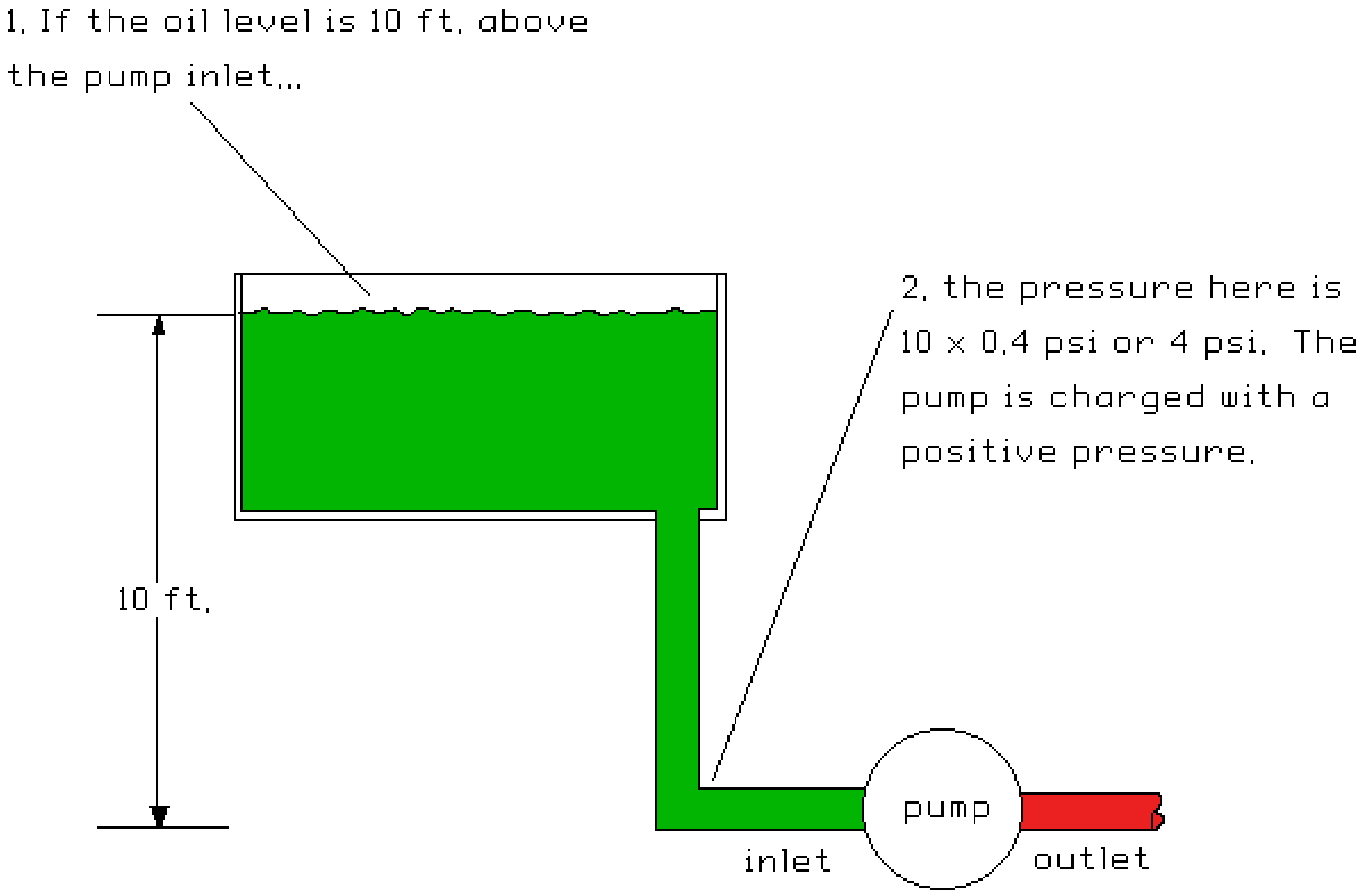
Weight of Air

1. A column of air one square inch in cross-section and as high as the atmosphere...

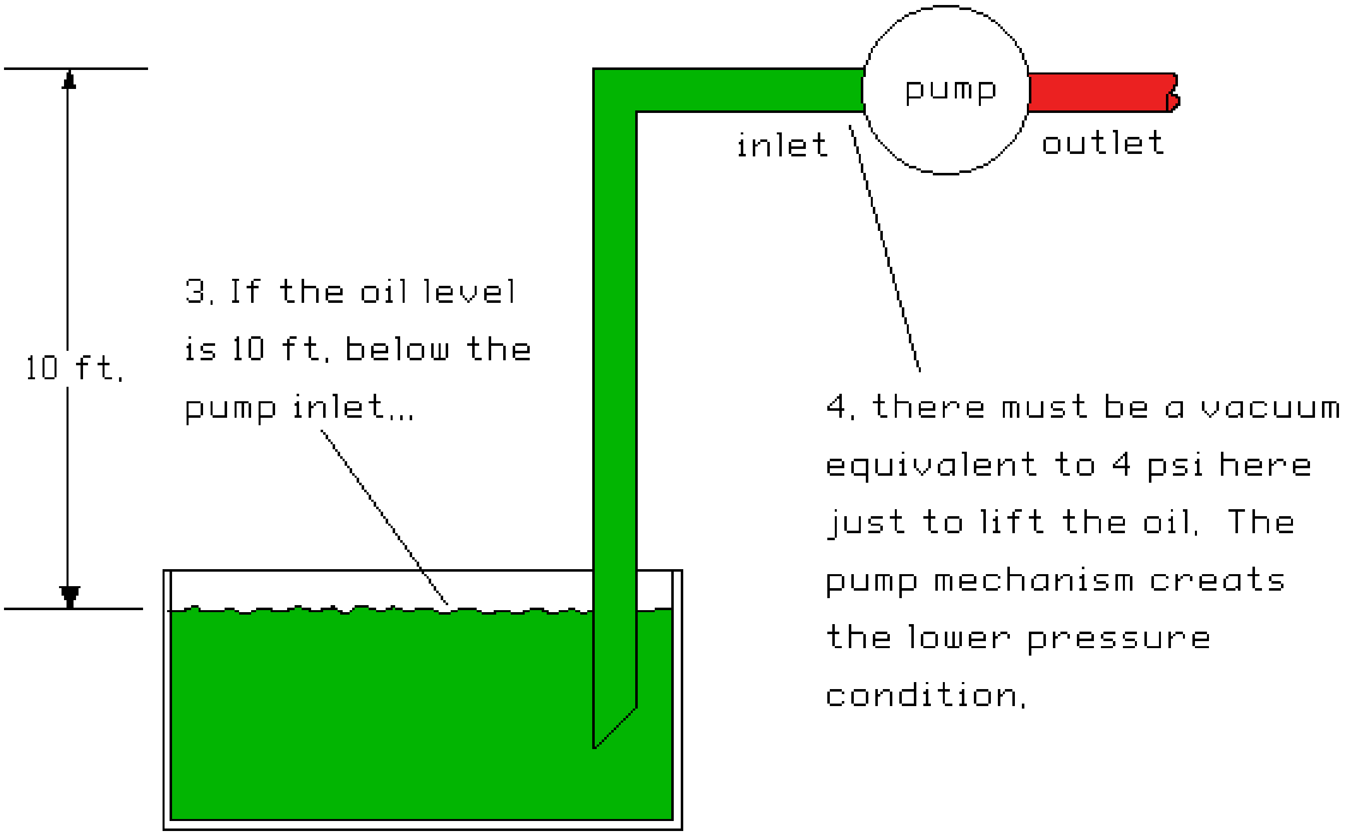


2. weighs 14.7 lb. at sea level. Thus atmospheric pressure is 14.7 psi.

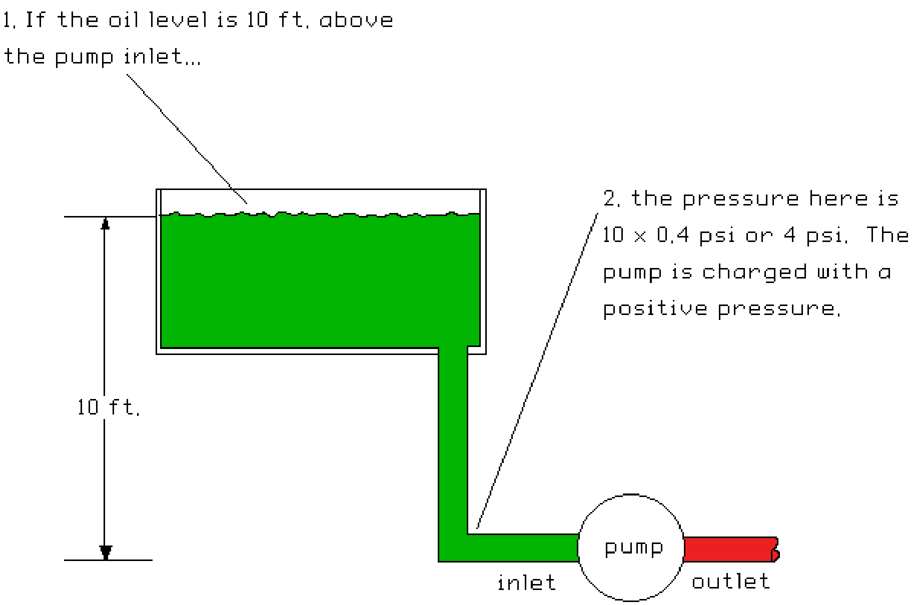
Using The Weight Of Oil To Help Feed A Pump



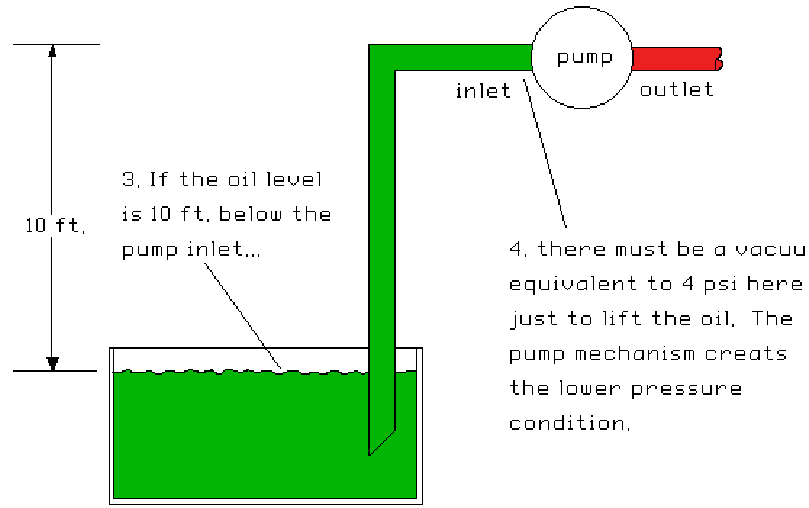
Lifting Oil


pump
inlet
outlet
10 ft.
3. If the oil level
is 10 ft. below the
pump inlet...
4. there must be a vacuum
equivalent to 4 psi here
just to lift the oil. The
pump mechanism creats
the lower pressure
condition.

Air Intake From Loose Connections



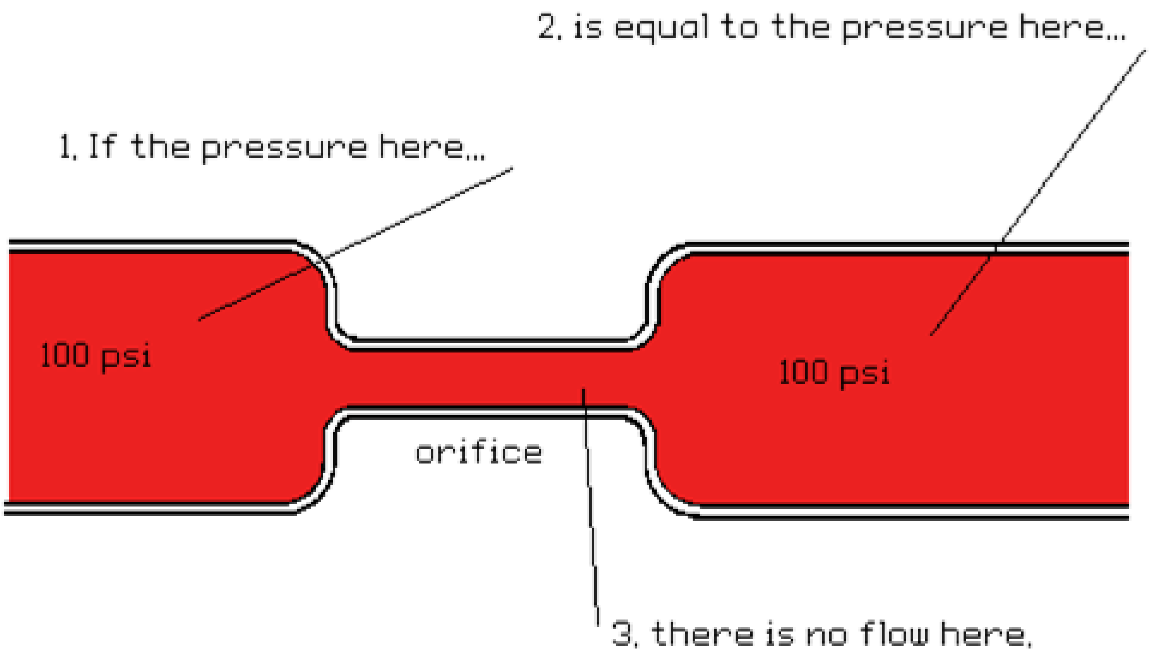
Charged from oil above



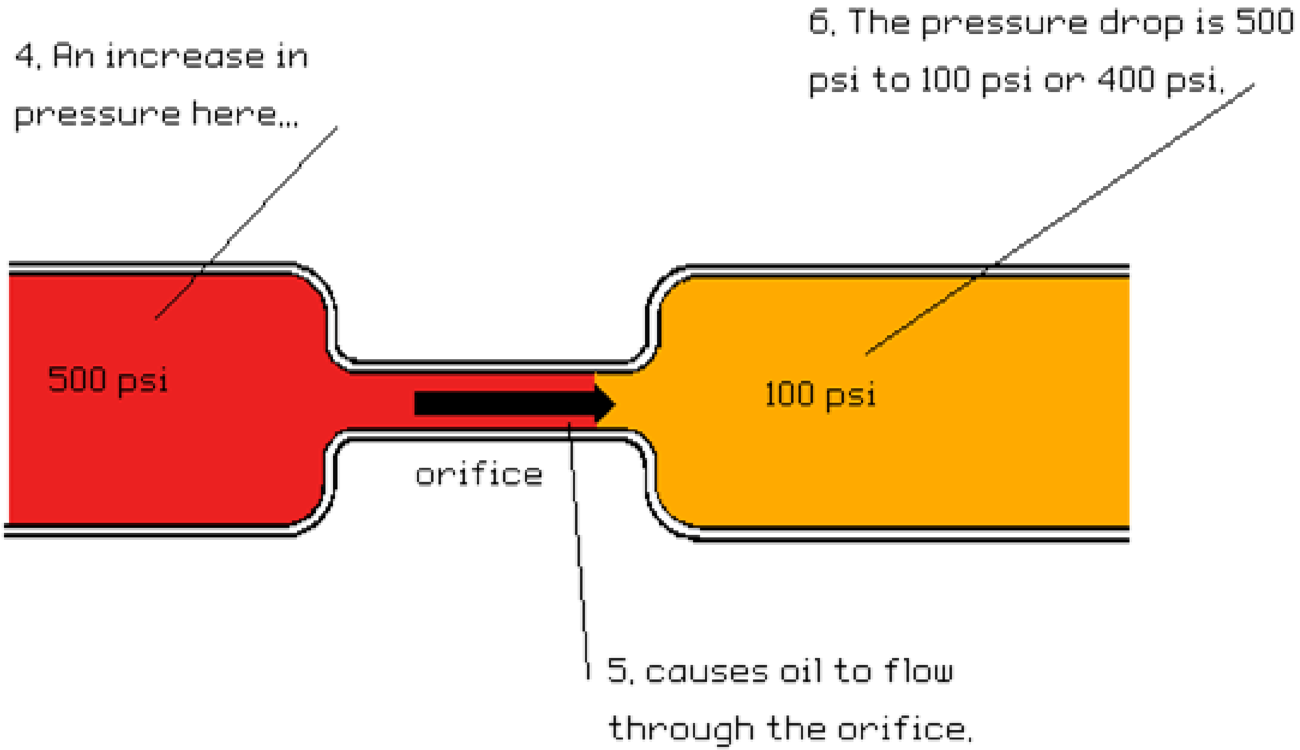
Vacuum required to feed pump

The drawing on the left provides some charged pressure, while the drawing on the right requires vacuum. In either case, if there is any leaks on the suction hose leading to the pump, the leak could draw air into the system. Air in the system can cause pump failure due to cavitation (air in system).

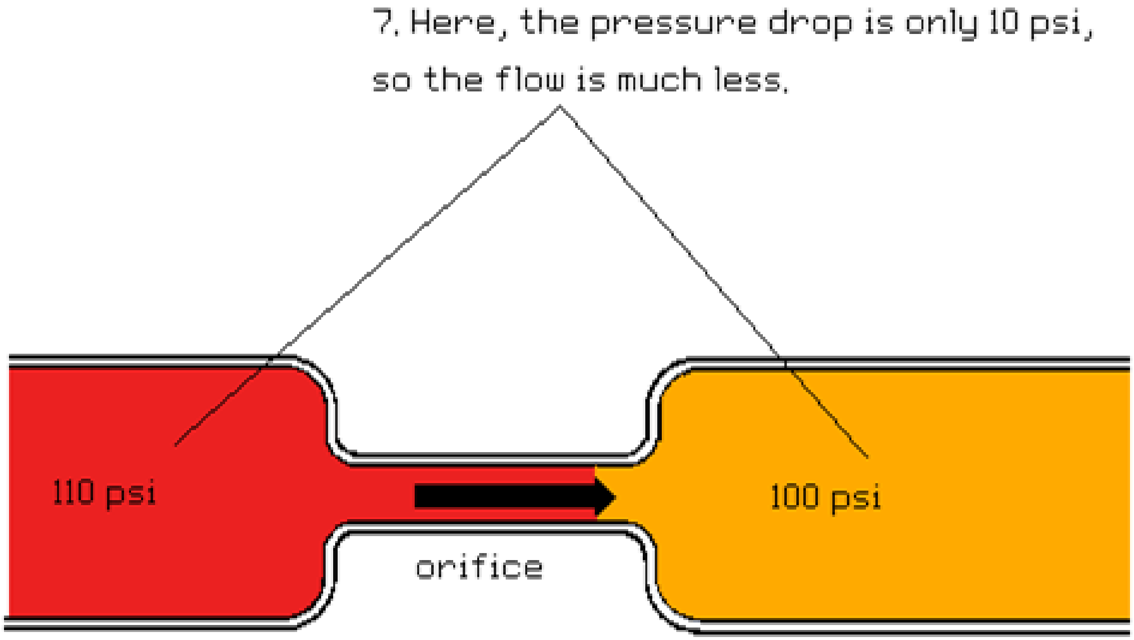
When There Is No Movement Of Oil Then The Pressure Is The Same



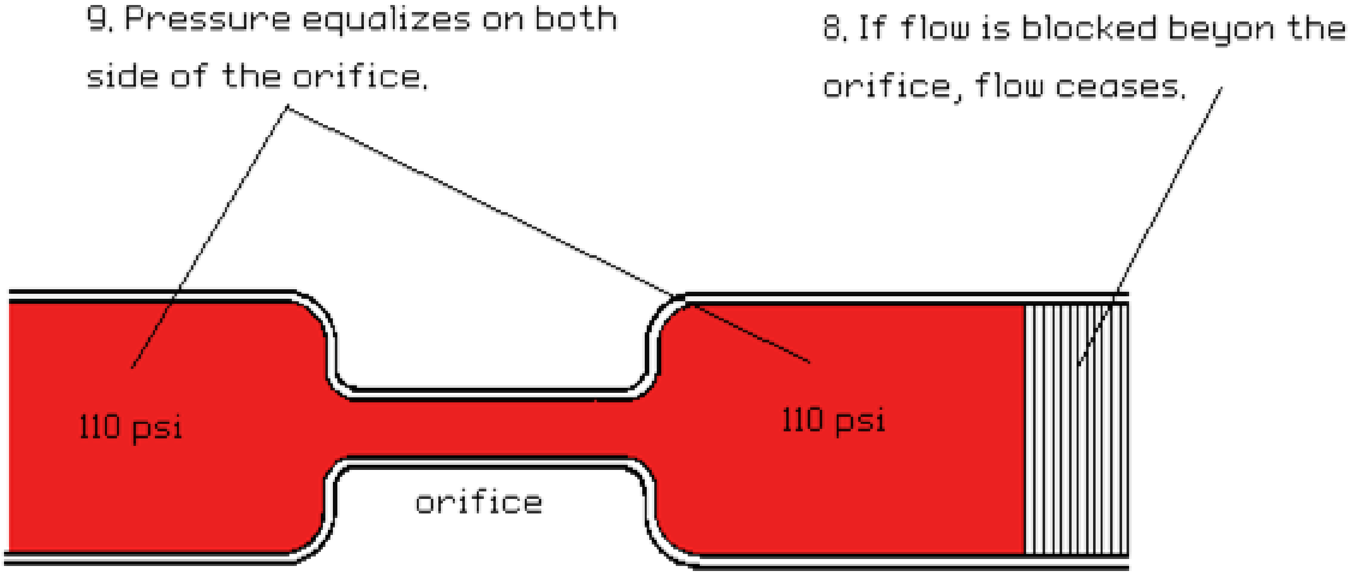
How Pressure Is Lost Through An Orifice



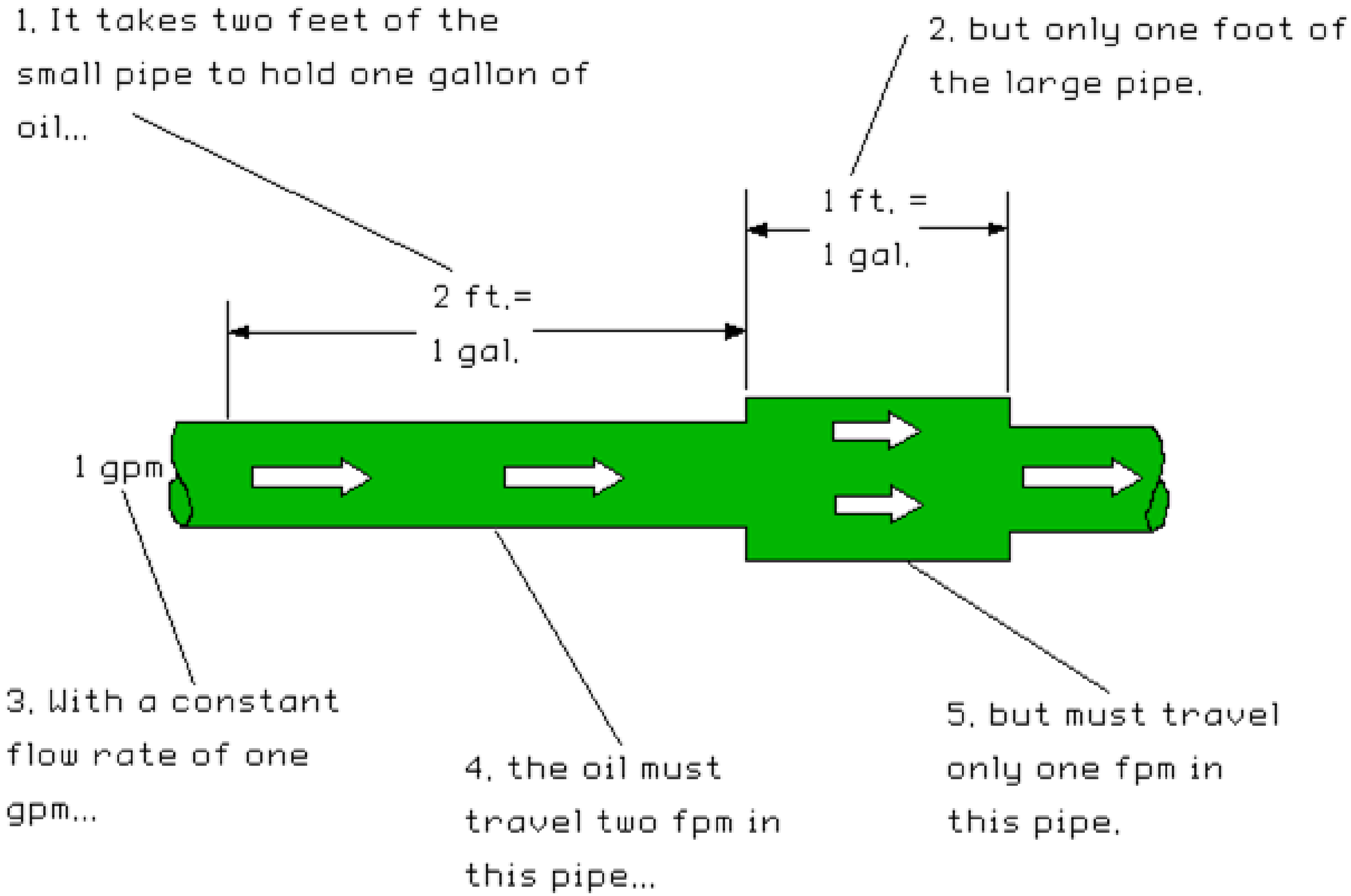
Larger Orifices Steal Less Pressure Or Work



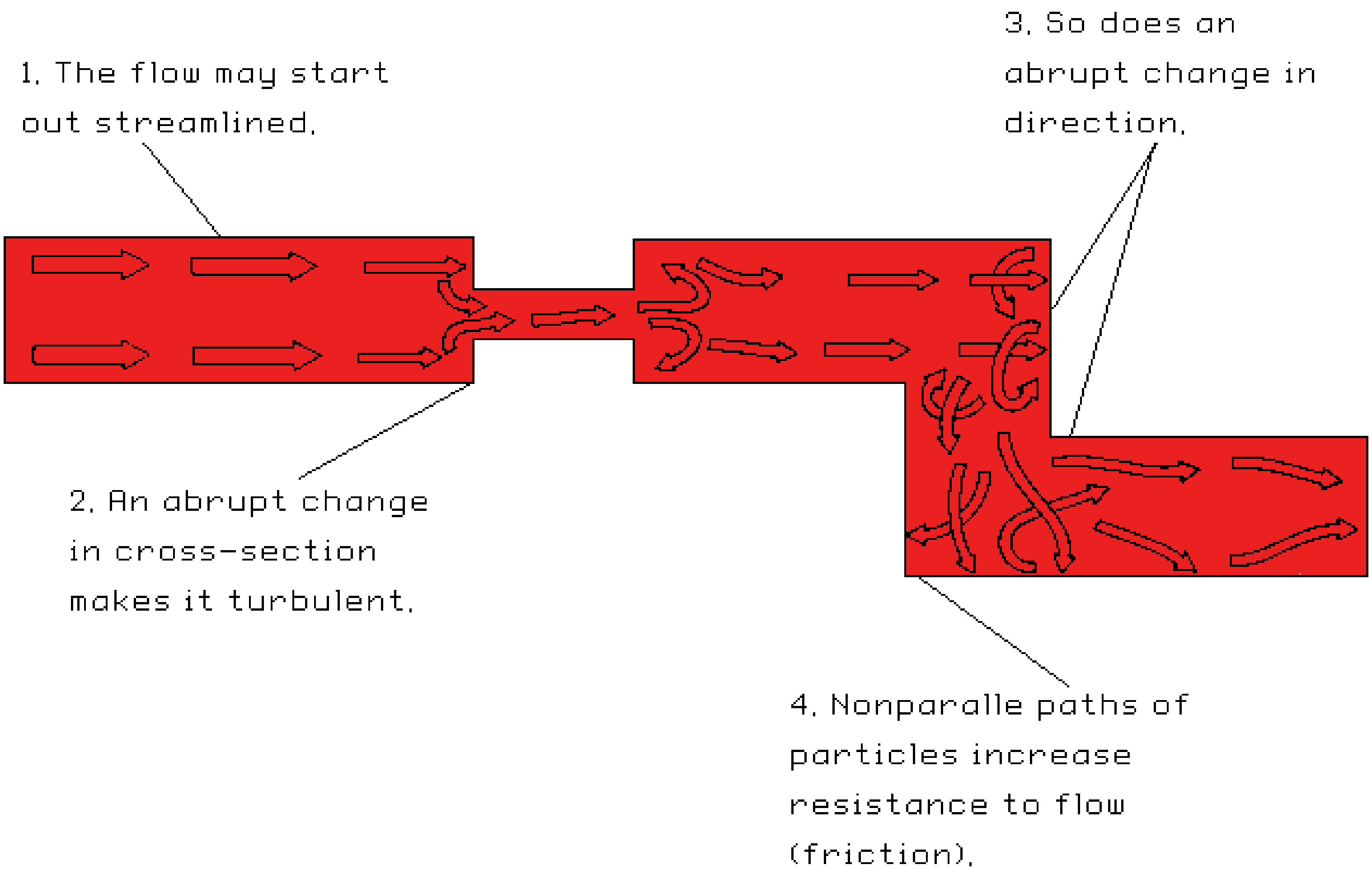
Flow Blocked, Pressure Equalized!



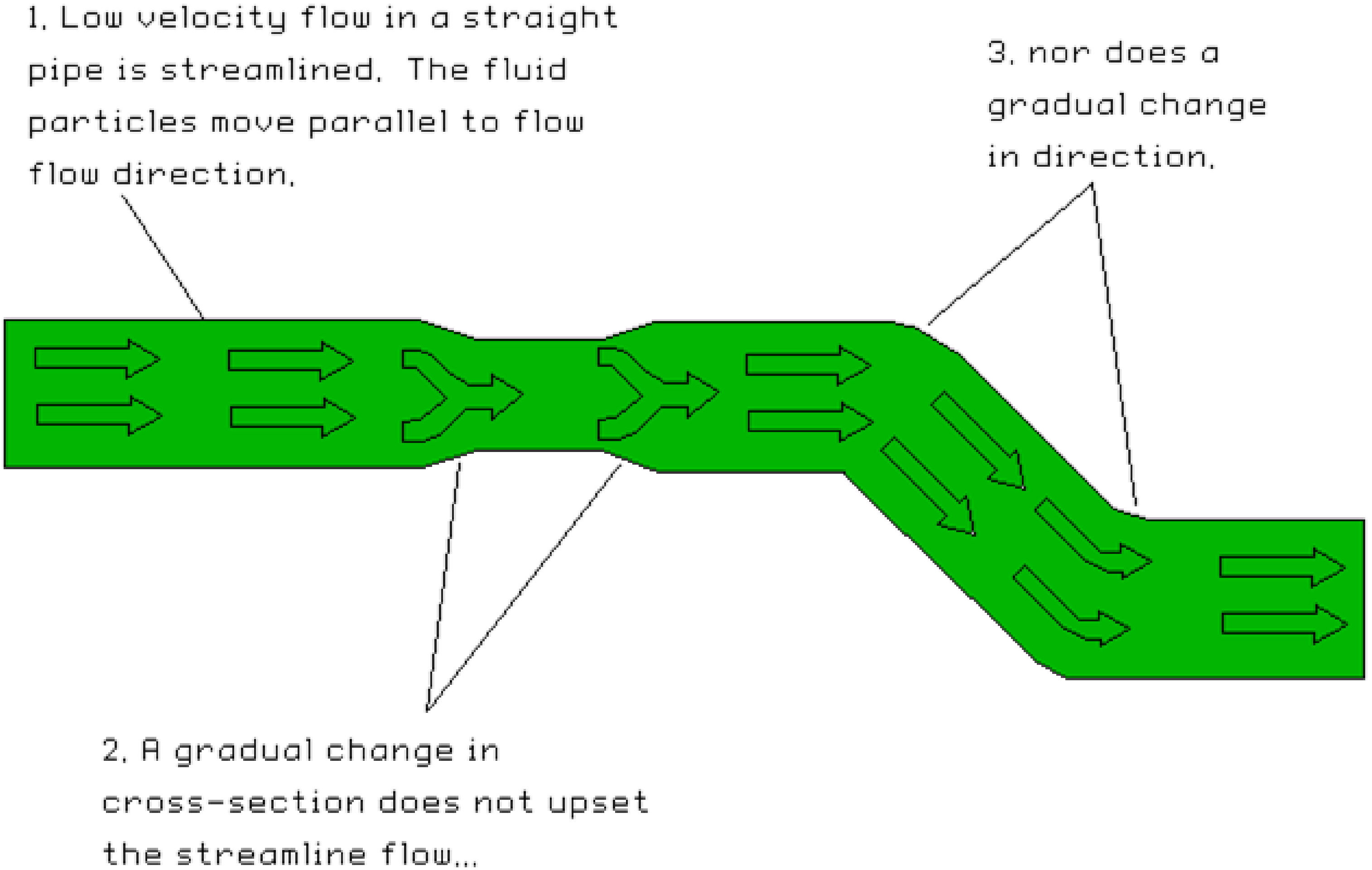
A Review Of Flow



Fast Moving Oil May Become Turbulent



Slow Moving Oil



Chapter 2

Basic Symbols of Hydraulics

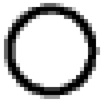
Basic Symbols: Lines

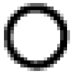
——————— -continuous line - flow line

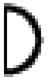
– – – – – – -dashed line - pilot, drain

——·——·—— -long chain thin Enclosure of two or more functions contained in one unit.

Circle, Semi-Circle

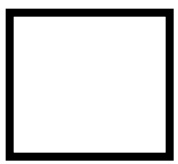
 -circle - energy conversion units (pump, compressor, motor)

 -circle - Measuring instruments

 -semi-circle - rotary actuator

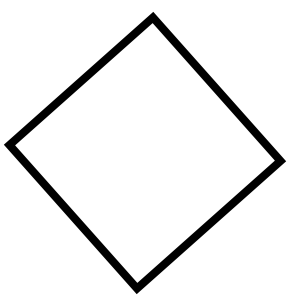
Square, Rectangle, Diamond

Square, Rectangle



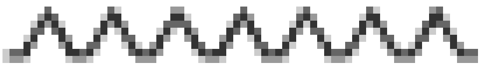
squares - control components

Diamond

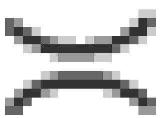


diamond – Condition apparatus (filter, separator, lubricator, heat exchanger

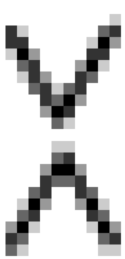
Miscellaneous Symbols



Spring

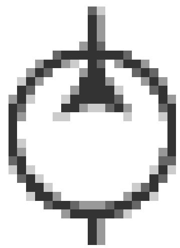


Restriction

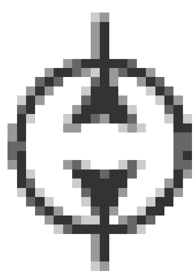


Restriction

Pump Symbols

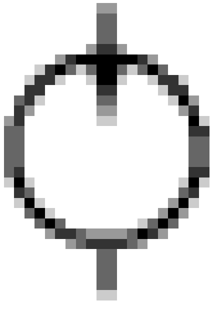


Fixed Displacement Hydraulic Pump-unidirectional (pumps only when rotated in one direction. Will not pump if turned backwards)



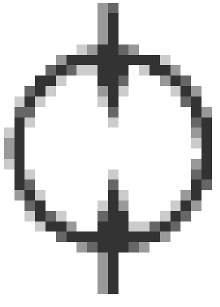
Variable Displacement Hydraulic Pump-bidirectional (pumps when rotated in both forward and reverse rotation)

Motors-Fixed Displacement



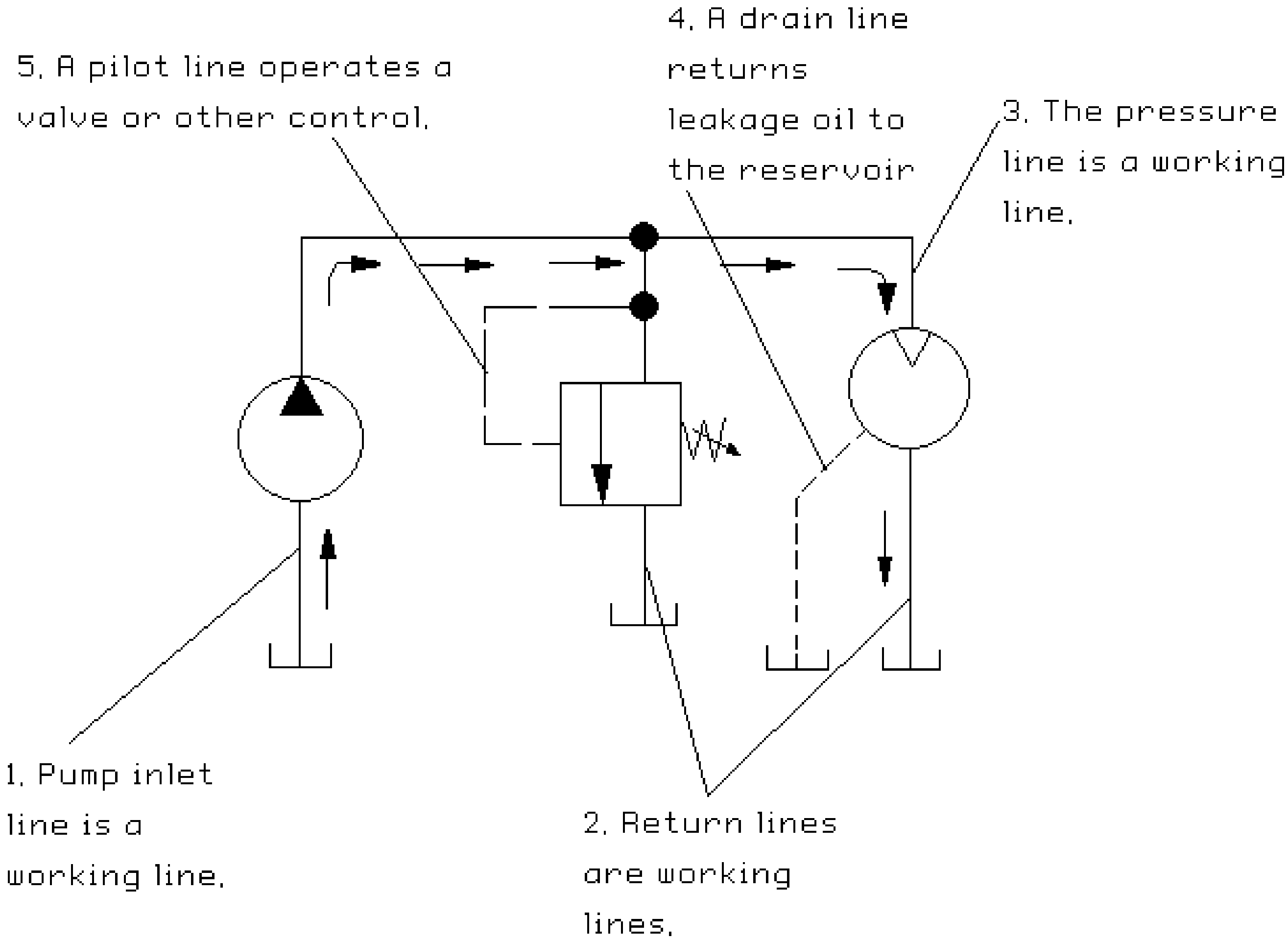
Unidirectional

(rotates only one direction)

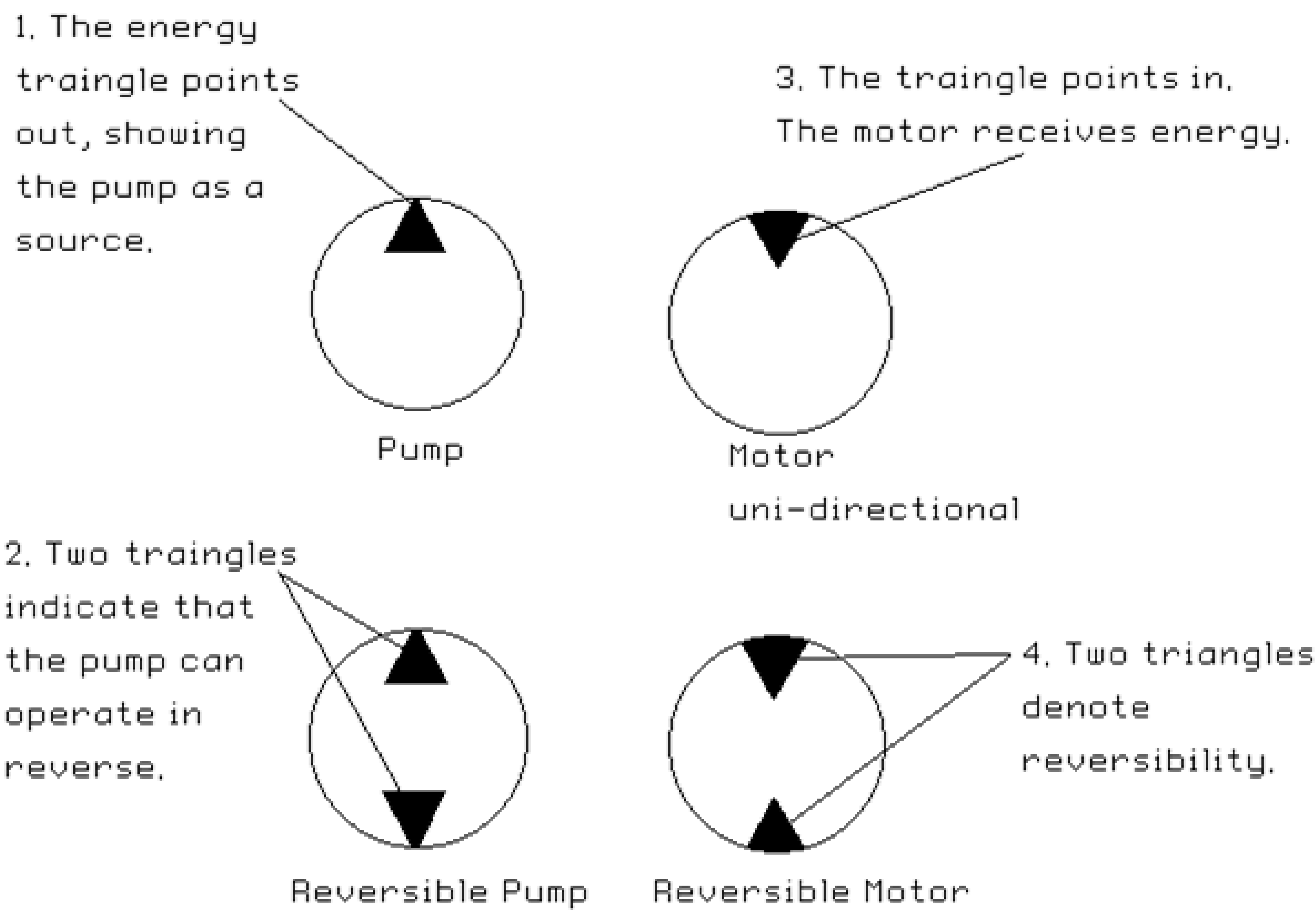


Bidirectional (rotates in both directions)

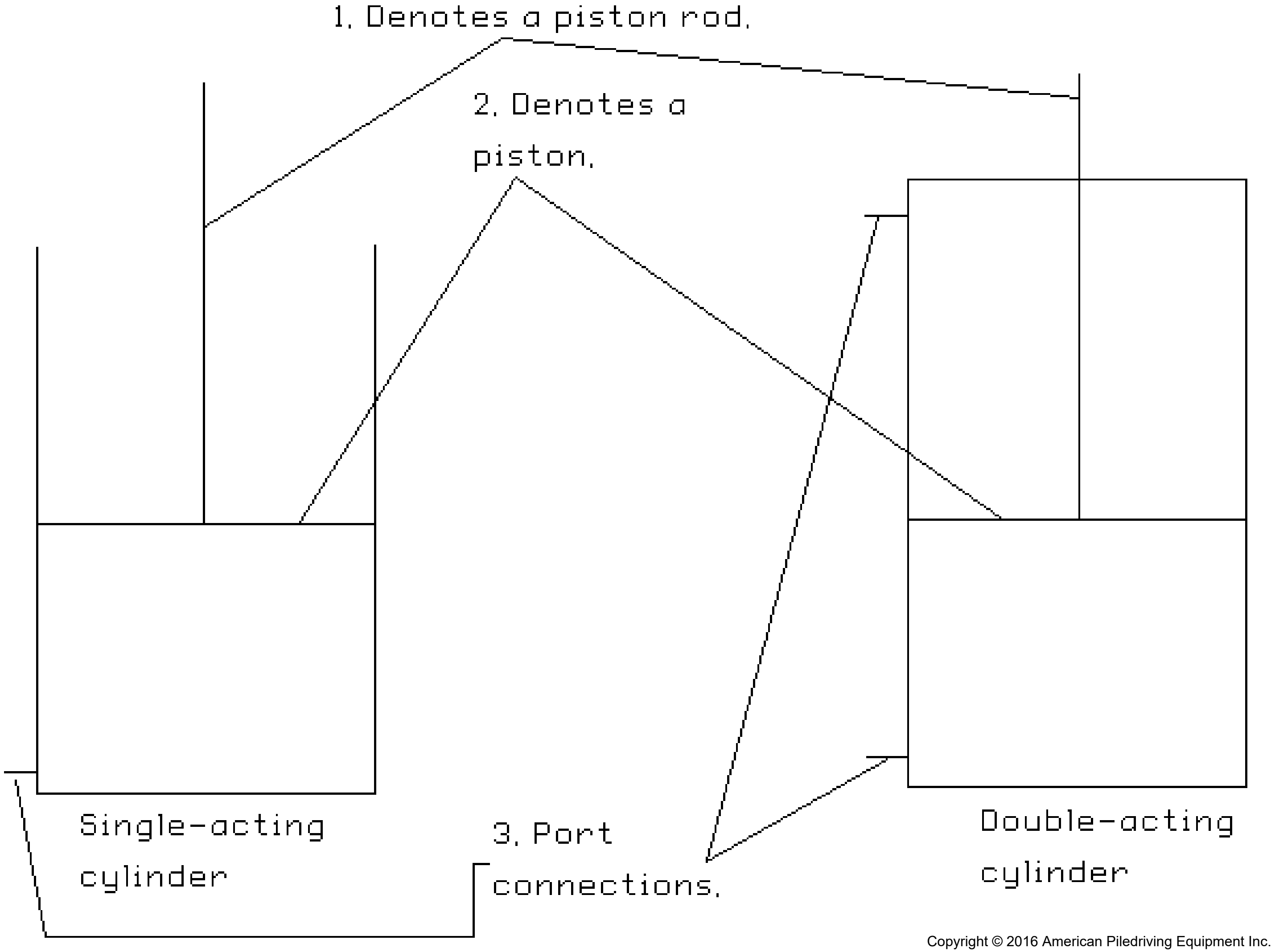
Reading Lines



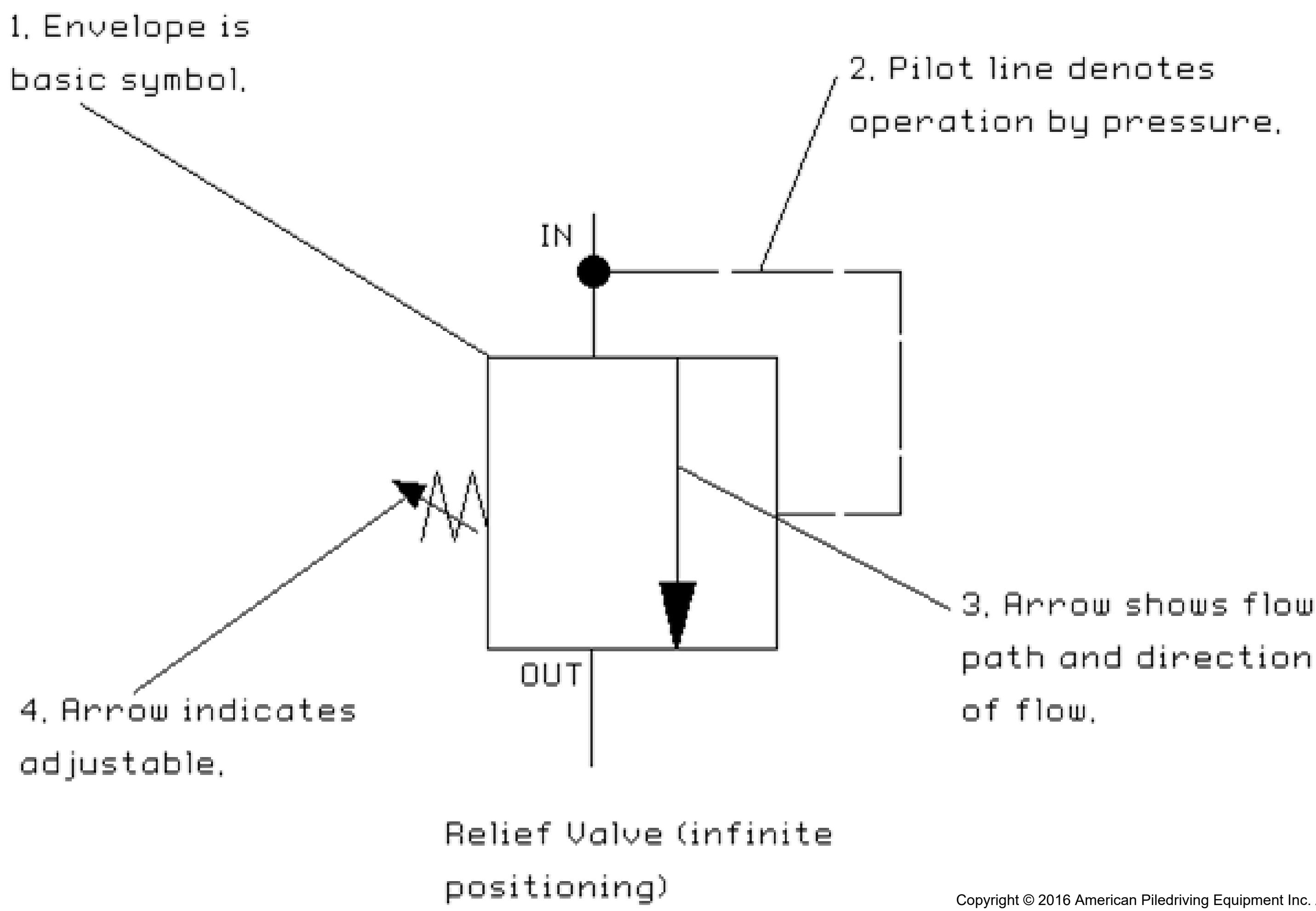
Reading Symbols For Pumps And Motors



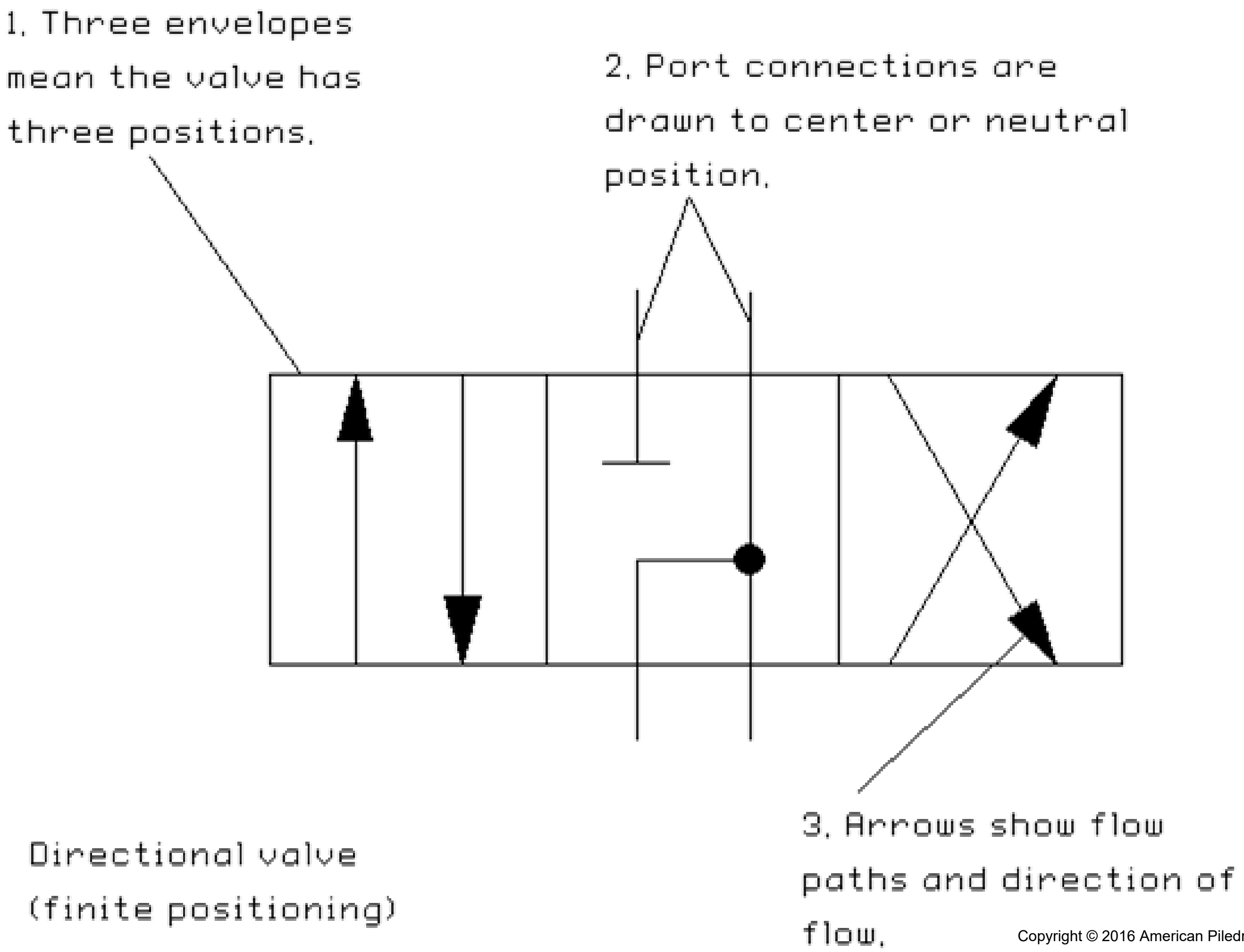
Reading Symbols For Cylinders



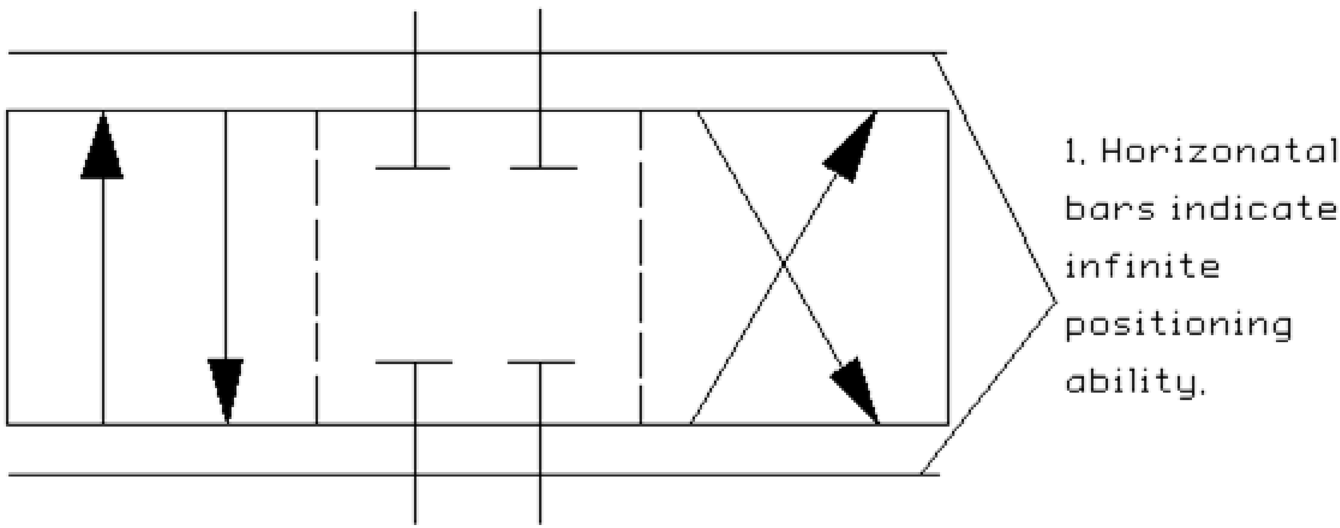
Symbols For Pilot Operated Relief Valves



Understanding Valves

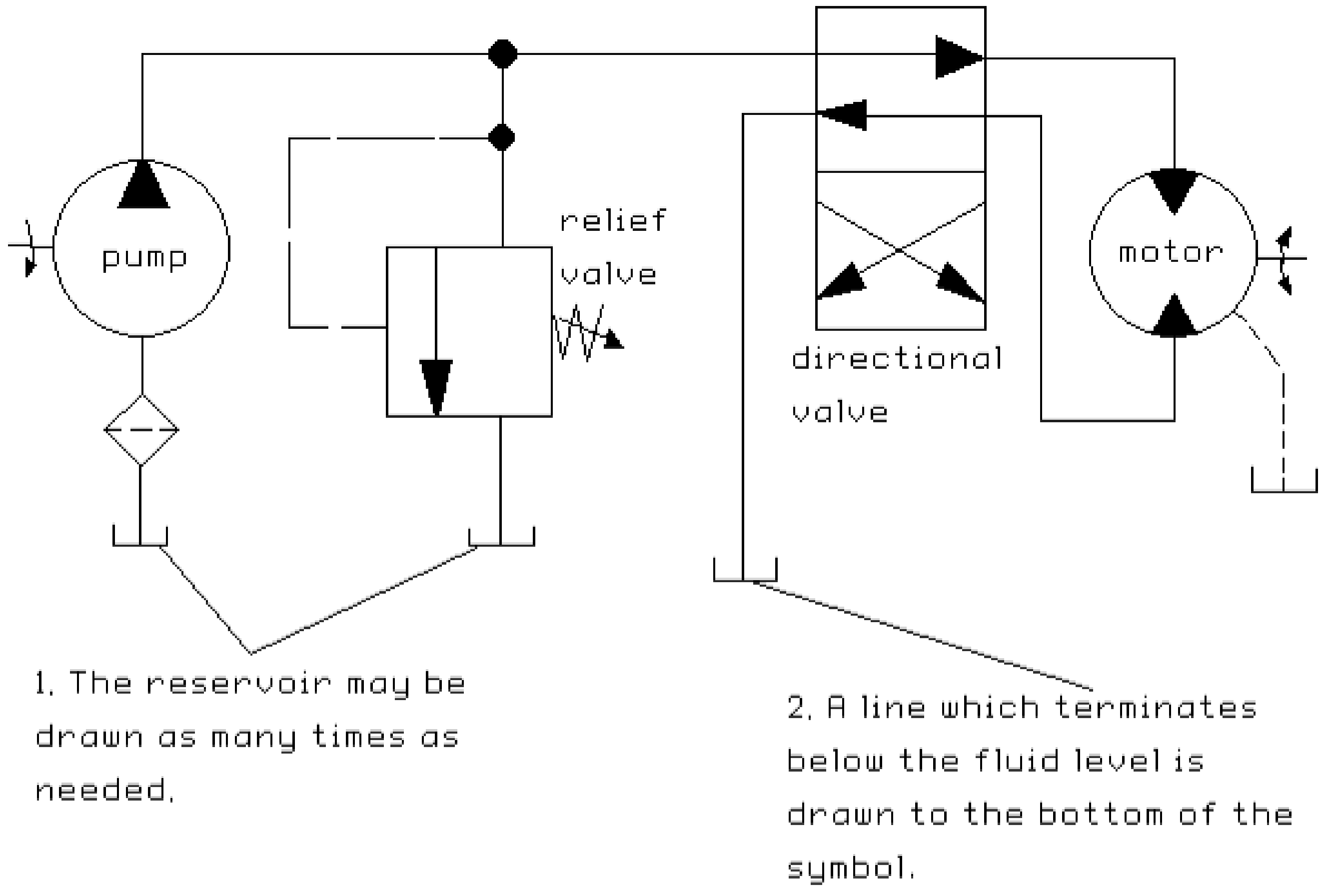


Understanding Valves

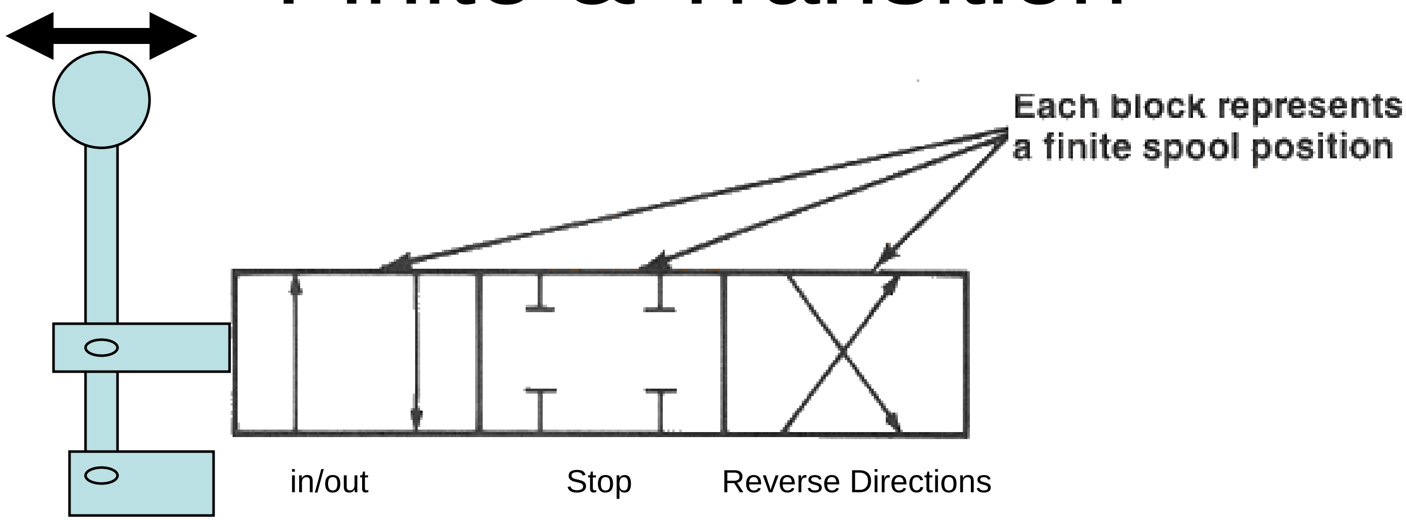


Directional valve
(infinite positioning)

Understanding Reservoir Lines And Symbols

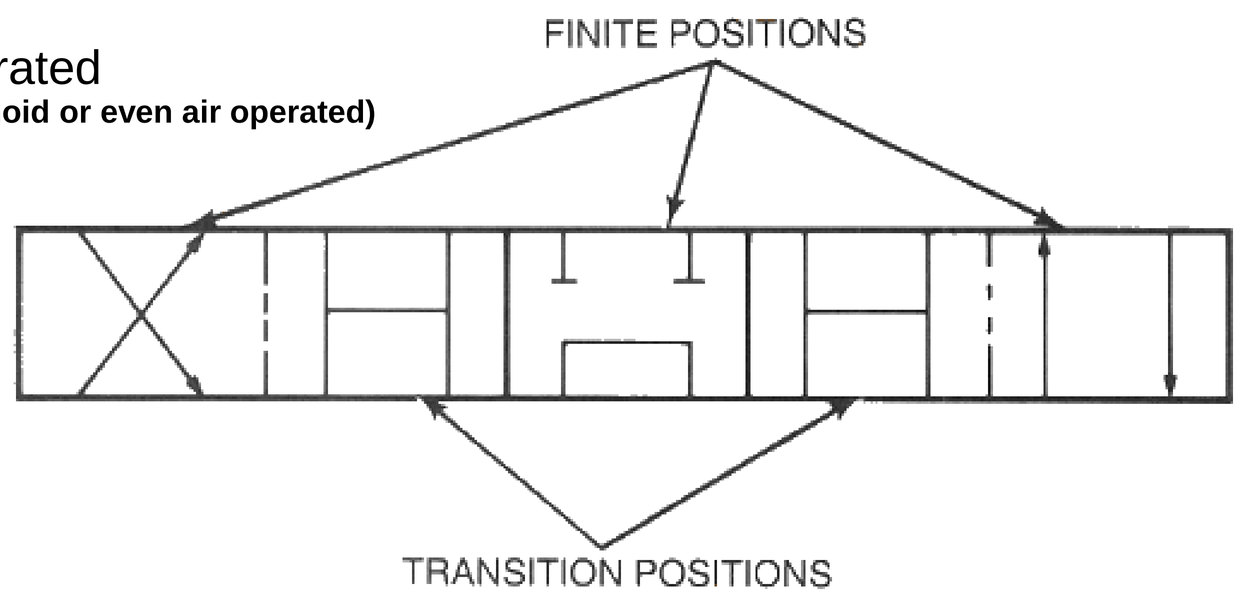


Spool Valve Positions- Finite & Transition



Hand Operated

(could be electric solenoid or even air operated)



Chapter 3

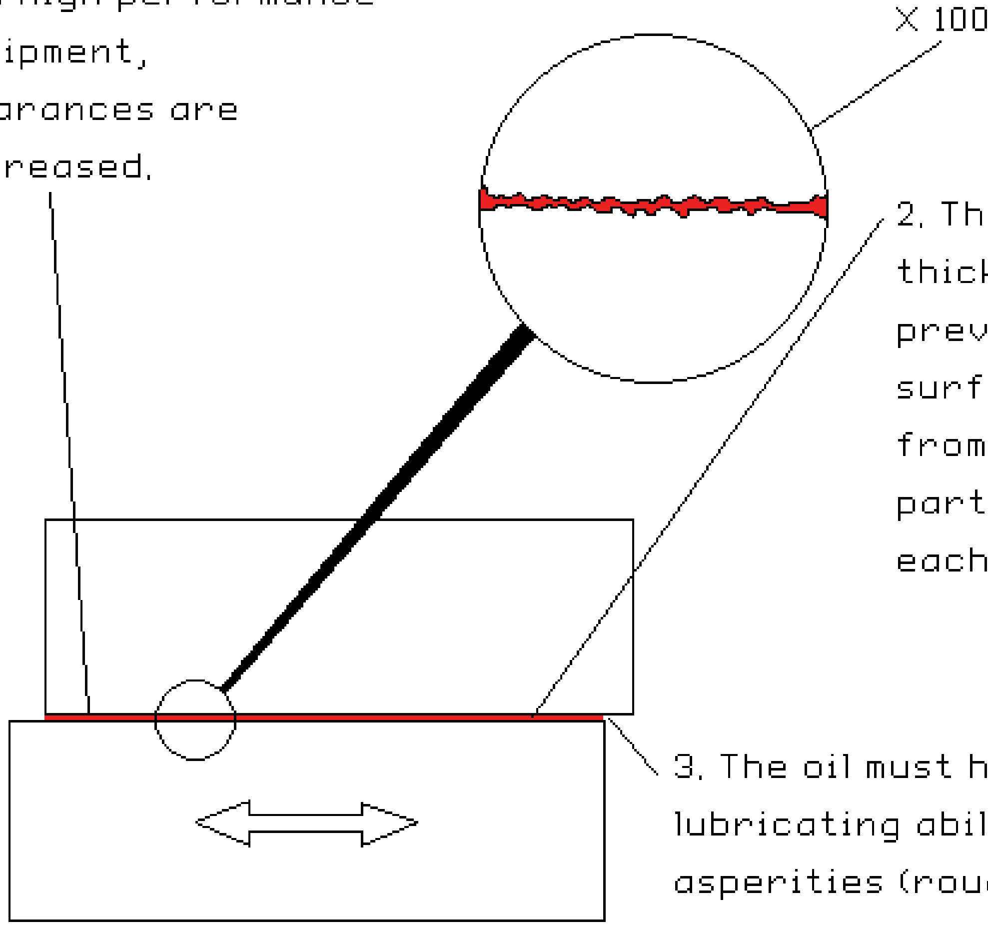
Hydraulic Fluids

APE Hydraulic Fluids

- All APE units use biodegradable hydraulic fluids, and it is friendly to the environment when spills do occur.

Function Of Hydraulic Oil

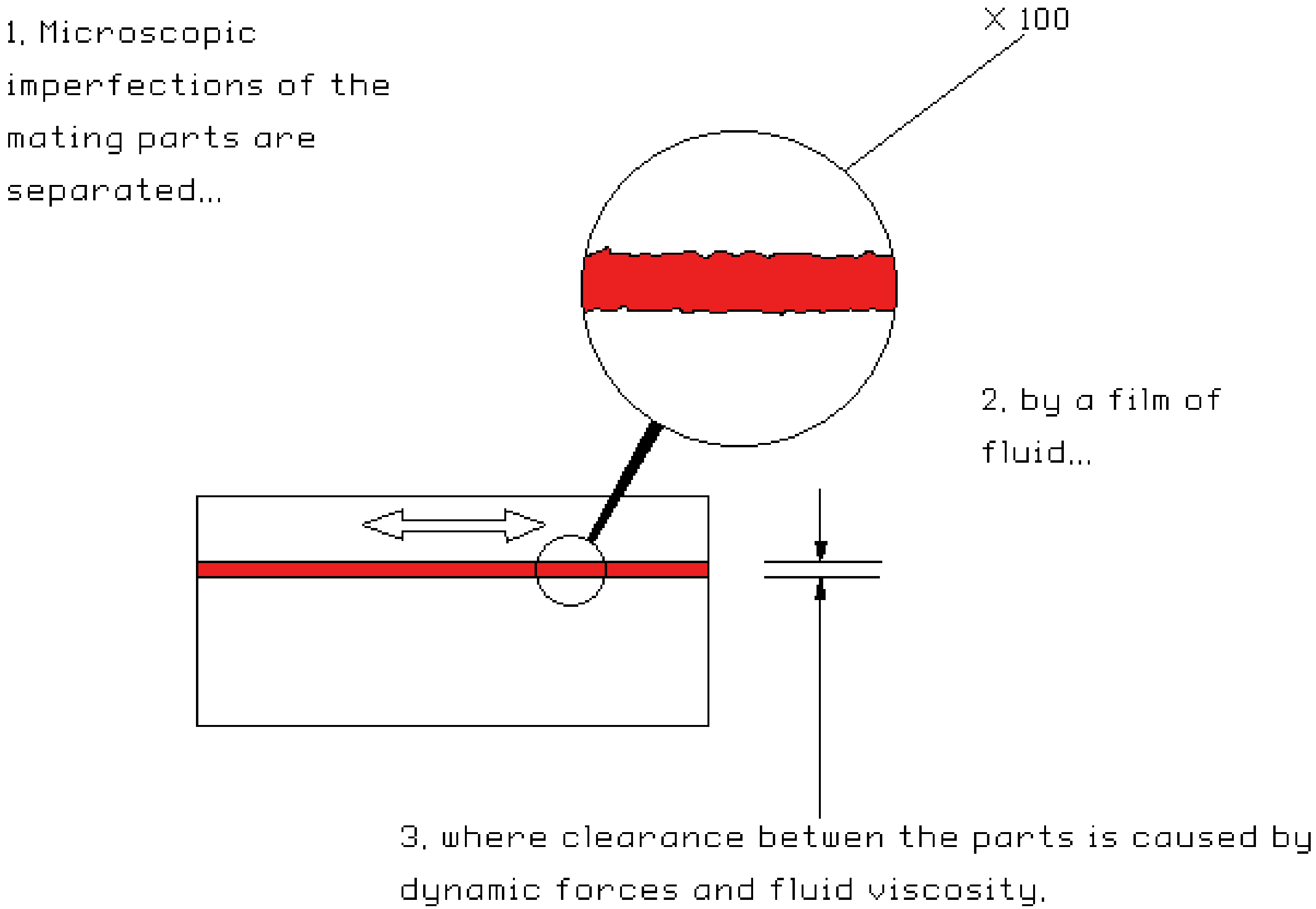
1. In high performance equipment, clearances are decreased.



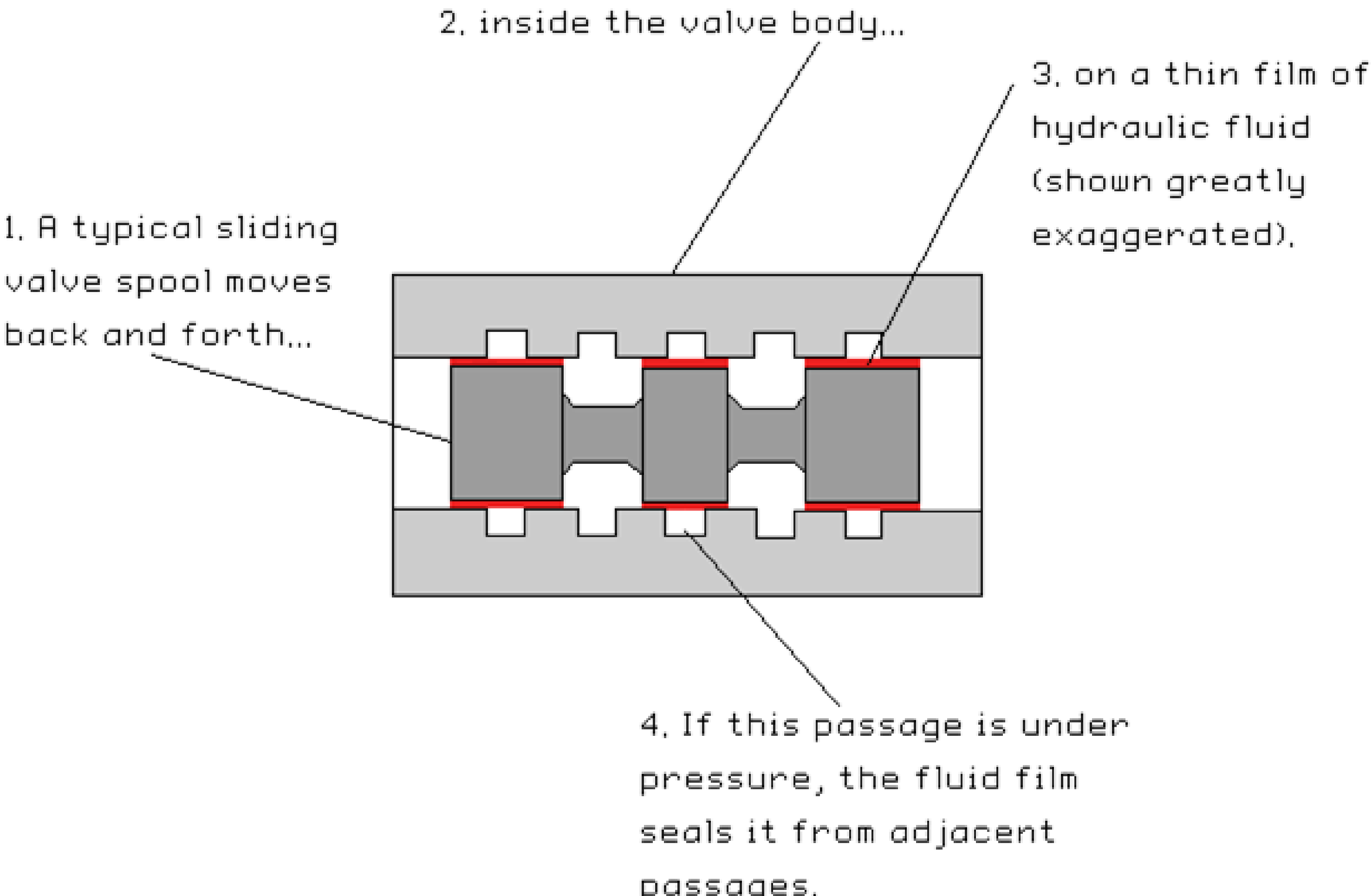
2. The fluid film is not thick enough to prevent the tips of surface imperfections from touching as the parts move against each other.

3. The oil must have superior lubricating ability or the asperities (rough points) will seize and tear causing wear.

How Hydraulic Oil Works To Lubricate Moving Parts



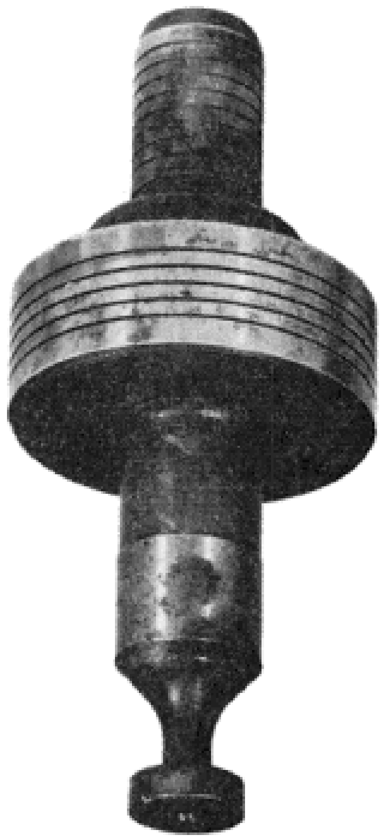
How Hydraulic Oil Effects A Spool Valve



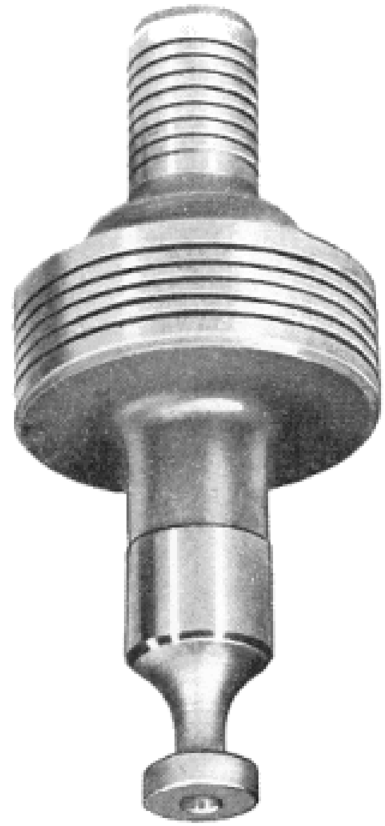
What Happens When Water Gets Into The Oil

Rust caused by moisture in the oil.

Corrosion From Bad Oil



Corrosion

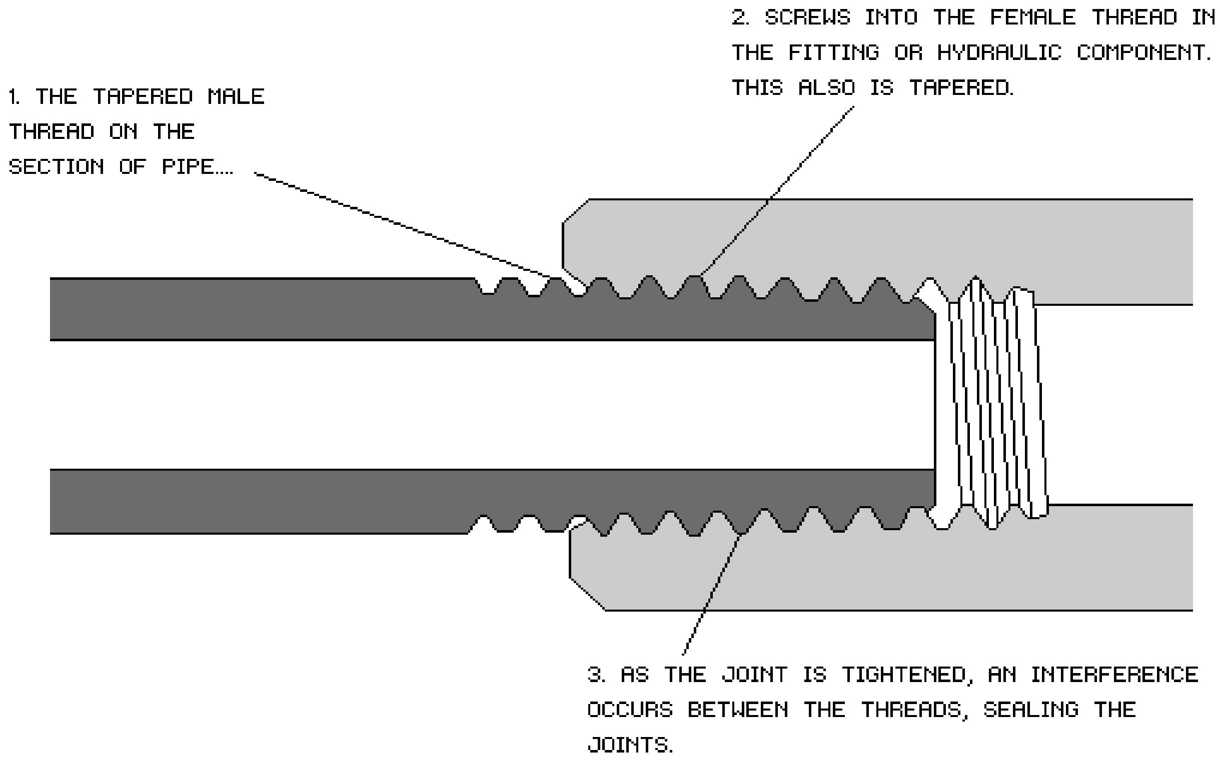


New part

Chapter 4

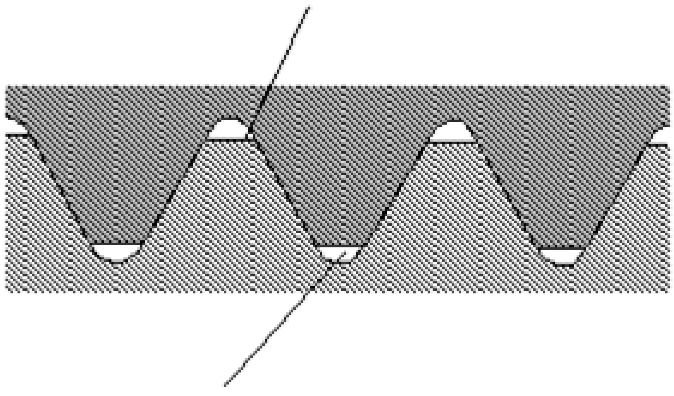
Hydraulic Fluid Conductors And Seals

Pipe Fitting

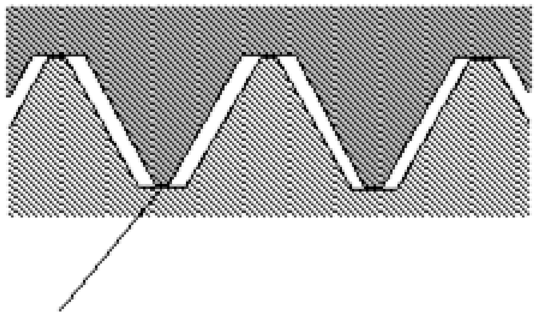


Explanation Of Thread Types

4. IN STANDARD PIPE THREADS (NPT) THE FLANKS COME IN CONTACT FIRST.

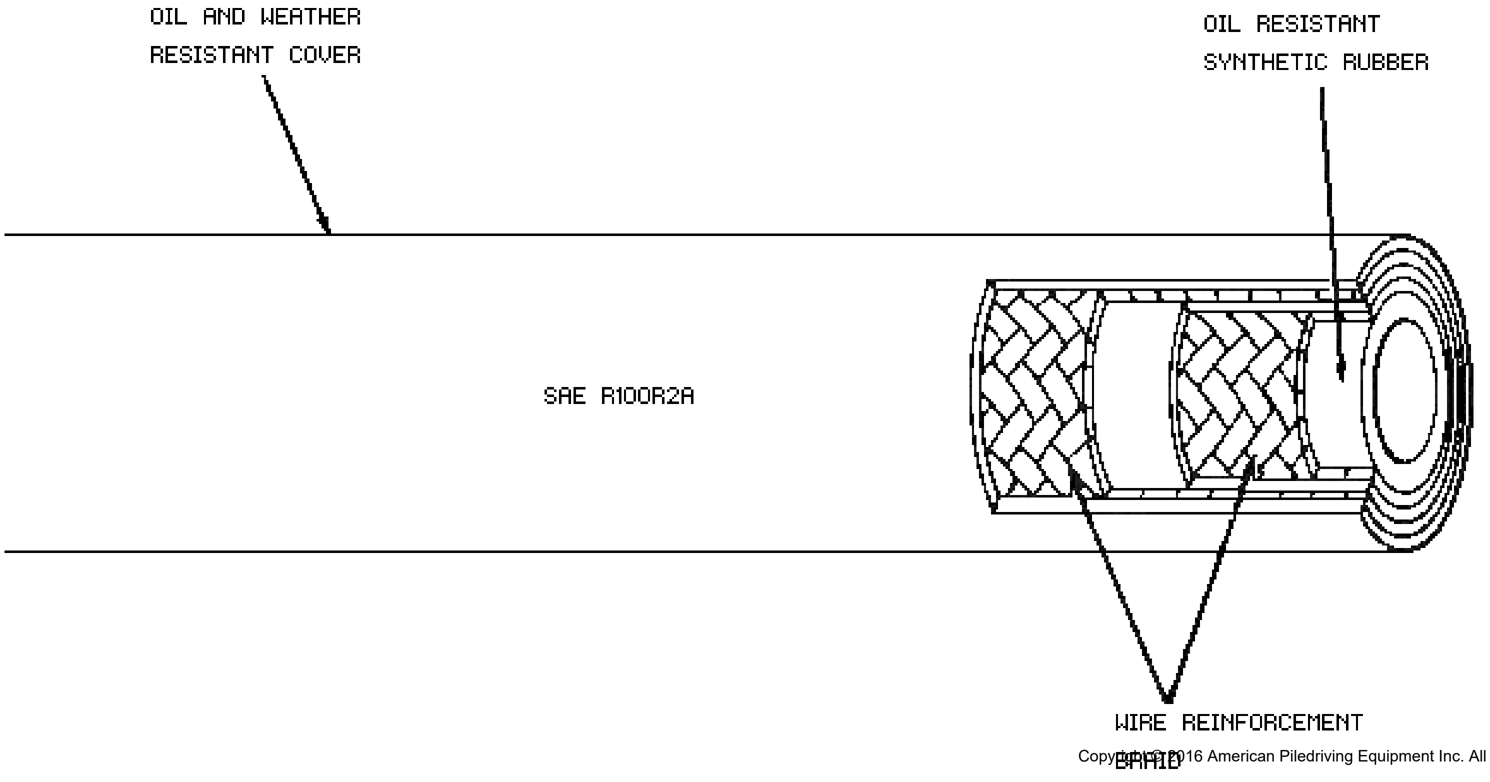


5. THERE CAN BE A SPIRAL CLEARANCE SROUND THE THREADS.



6. IN DRYSEAL (NPTF) THREADS, THE ROOTS AND CRESTS ENGAGE FIRST, ELIMINATING SPIRAL CLEARANCE.

Hydraulic Hose Components



Hose Specifications 100R1 and 100R2

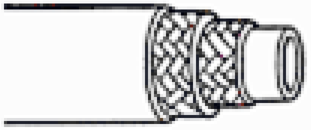
SAE 100R1

Type A — This hose shall consist of an inner tube of oil resistant synthetic rubber, a single wire braid reinforcement, and an oil and weather resistant synthetic rubber cover. A ply or braid of suitable material may be used over the inner tube and/or over the wire reinforcement to anchor the synthetic rubber to the wire.

Type AT — This hose shall be of the same construction as Type A, except having a cover designed to assemble with fittings which do not require removal of the cover or a portion thereof.

SAE 100R2

The hose shall consist of an inner tube of oil resistant synthetic rubber, steel wire reinforcement according to hose type as detailed below, and an oil and weather resistant synthetic rubber cover. A ply or braid of suitable material may be used over the inner tube and/or over the wire reinforcement to anchor the synthetic rubber to the wire.



Type A — This hose shall have two braids of wire reinforcement.

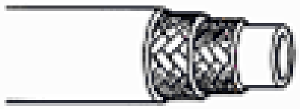
Type B — This hose shall have two spiral plies and one braid of wire reinforcement.

Type AT — This hose shall be of the same construction as Type A, except having a cover designed to assemble with fittings which do not require removal of the cover or a portion thereof.

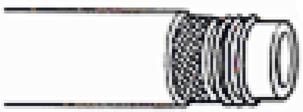
Type BT — This hose shall be of the same construction as Type B except having a cover designed to assemble with fittings which do not require removal of the cover or a portion thereof.

100R3, 100R4, 100R5, 100R6

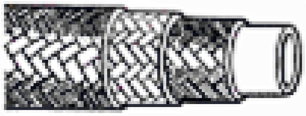
SAE 100R3
The hose shall consist of an inner tube of oil resistant synthetic rubber, two braids of suitable textile yarn, and an oil and weather resistant synthetic rubber cover.



SAE 100R4
The hose shall consist of an inner tube of oil resistant synthetic rubber, a reinforcement consisting of a ply or plies of woven or braided textile fibers with a suitable spiral of body wire, and an oil and weather resistant synthetic rubber cover.



SAE 100R5
The hose shall consist of an inner tube of oil resistant synthetic rubber and two textile braids separated by a high tensile steel wire braid. All braids are to be impregnated with an oil and mildew resistant synthetic rubber compound.

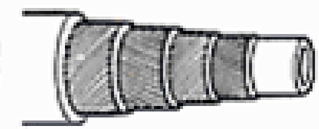


SAE 100R6
The hose shall consist of an inner tube of oil resistant synthetic rubber, one braided ply of suitable textile yarn, and an oil and weather resistant synthetic rubber cover.

100R9, 100R10, 100R11, 100R12

SAE 100R9
Type A — This hose shall consist of an inner tube of oil resistant synthetic rubber, 4-spiral plies of wire wrapped in alternating directions, and an oil and weather resistant synthetic rubber cover. A ply or braid of suitable material may be used over the inner tube and/or over the wire reinforcement to anchor the synthetic rubber to the wire.

Type AT — This hose shall be of the same construction as Type A, except having a cover designed to assemble with fittings which do not require removal of the cover or a portion thereof.



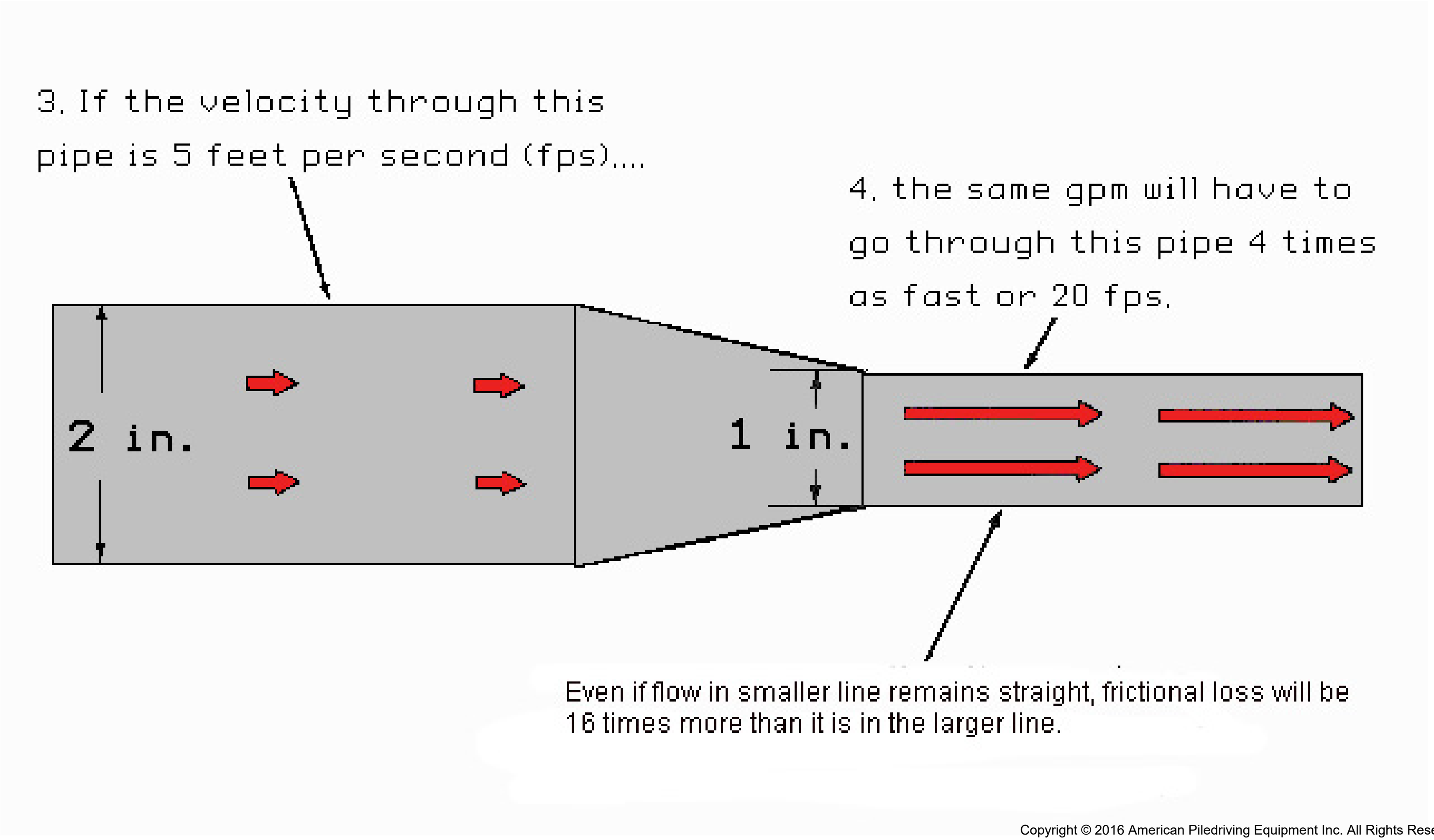
SAE 100R10
Type A — This hose shall consist of an inner tube of oil resistant synthetic rubber, 4-spiral plies of heavy wire wrapped in alternating directions, and an oil and weather resistant synthetic rubber cover. A ply or braid of suitable material may be used over the inner tube and/or over the wire reinforcement to anchor the synthetic rubber to the wire.

Type AT — This hose shall be of the same construction as Type A, except having a cover designed to assemble with fittings which do not require removal of the cover or a portion thereof.

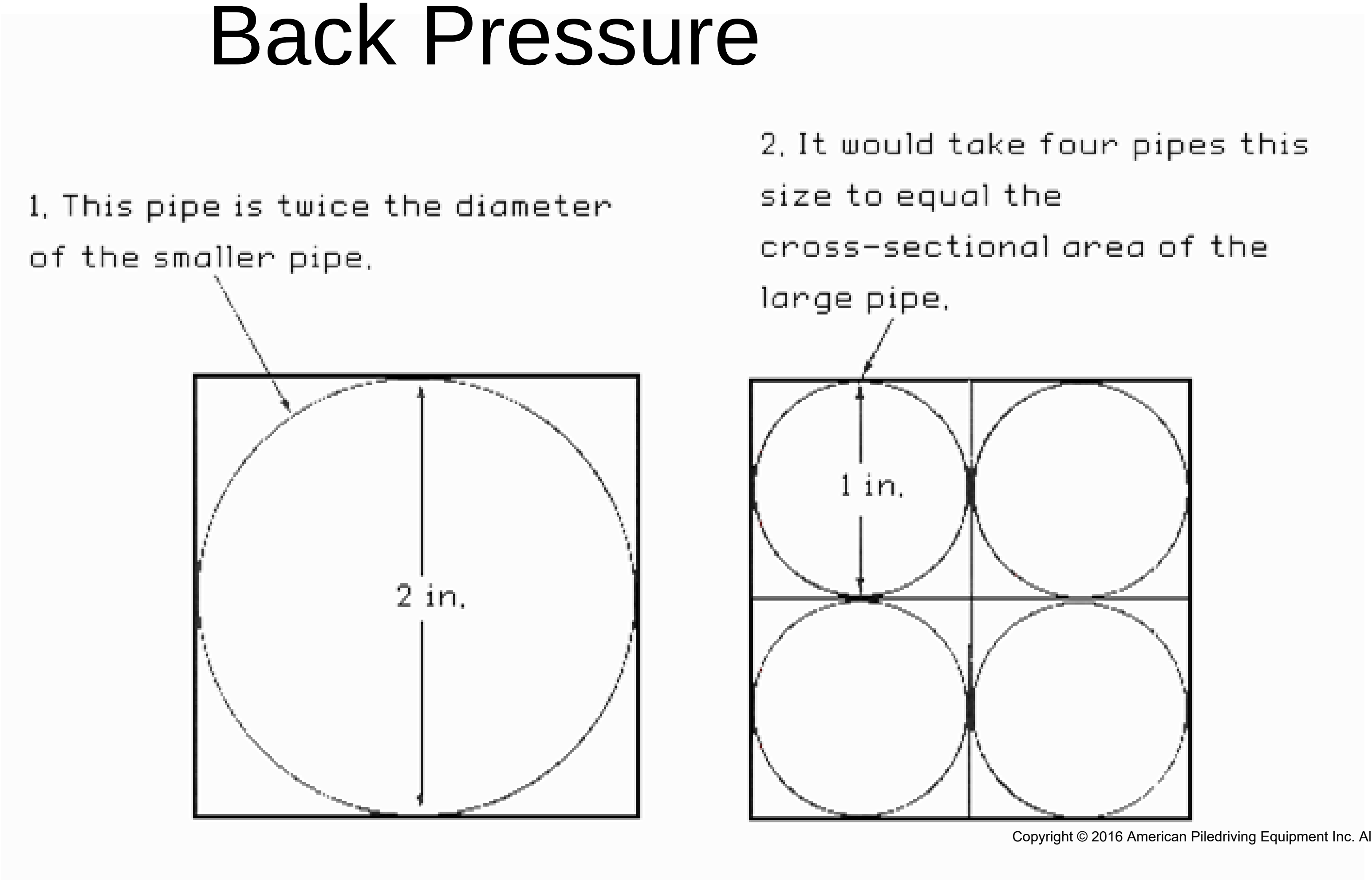
SAE 100R11
This hose shall consist of an inner tube of oil resistant synthetic rubber, 6-spiral plies of heavy wire wrapped in alternating directions and an oil and weather resistant synthetic rubber cover. A ply or braid of suitable material may be used over the inner tube and/or over the wire reinforcement to anchor the synthetic rubber to the wire.

SAE 100R12
This hose shall consist of an inner tube of oil resistant synthetic rubber, 4-spiral plies of heavy wire wrapped in alternating directions, and an oil and weather resistant synthetic rubber cover. A ply or braid of suitable material may be used over or within the inner tube and/or over the wire reinforcement to anchor the synthetic rubber to the wire.

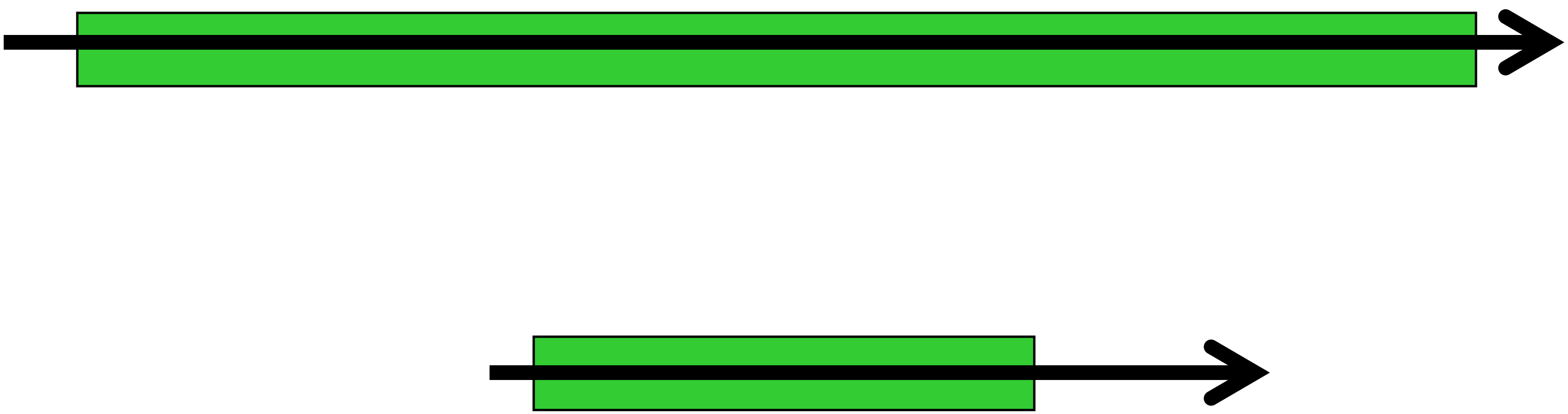
Understanding Speed Of Hydraulic Oil Through Hoses And Why Diameter Matters



Understanding Resistance Through Hoses And Why Diameter Is Key To Reducing Back Pressure

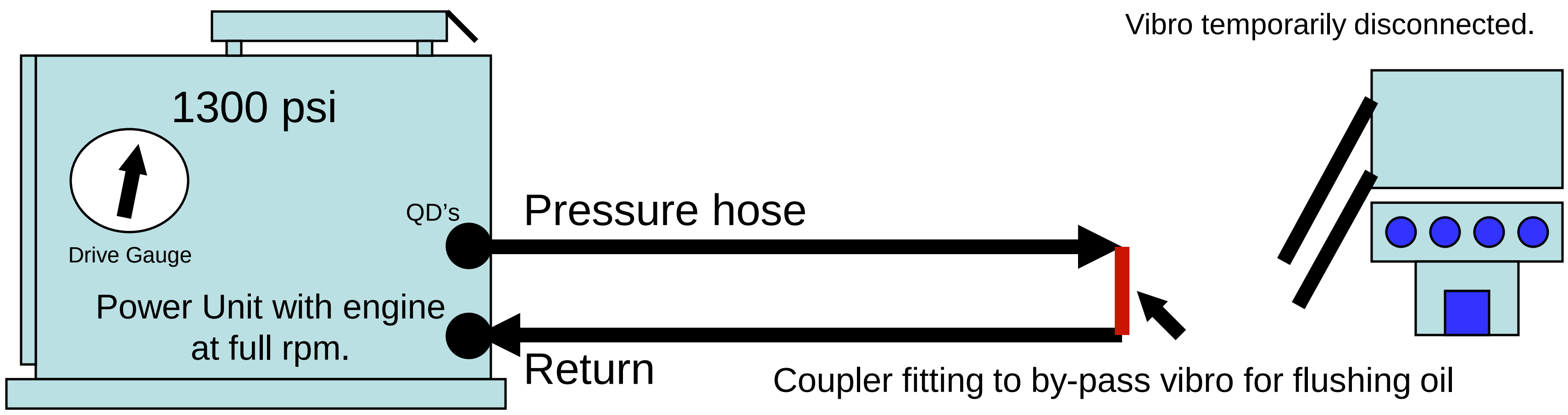


The longer the hose, the more resistance or friction which means less available pressure to do work.



The longer the hose bundle, the more pressure drop you will have. This is why we do not want to run our vibros or drills or hydraulic impact hammers with more than 150 feet of hose. You can have so much hose that there is no available pressure left to do the work of turning the eccentrics or drill. Vibros and drills work better with larger hoses or shorter lengths.

Check Your Pressure With The Oil Flow By-Passing the Vibro.



During new production of vibros and drills, we always flush the hose bundle by putting a coupler at the end of the hose bundle. This allows the oil to pass through the drive line hose an go back to the power unit through the return line. We put a in-line filter on the return line to catch the dirt.

This should be done each time a new hose section on. New hoses are dirty from the work of cutting them and installing fittings. Next time you flush the hoses please take a look at the drive pressure gauge and read the drive pressure. You can then see how much pressure it takes just to push the oil through the hoses.

Note also that this pressure is higher when the oil is cold. Super high back pressure could mean that you have a restriction, like a faulty quick disconnect that is blocking the free flow of the oil. Experiences APE employees know the approximate pressure it takes to push oil through the hoses and can see a problem fast.

One can calculate the friction of oil going through the hoses by reading a chart and doing some math.

Pressure Drop Through Hydraulic Hoses.

* Pressure drop in psi (pounds per square inch)/gpm (gallons per minute) **for 10 feet of hose** (smooth bore) without fittings. Fluid specification: Specific gravity = .85; Viscosity = *v* = 20 centistokes (C.S.), (20 C.S. = 97 S.S.U.).

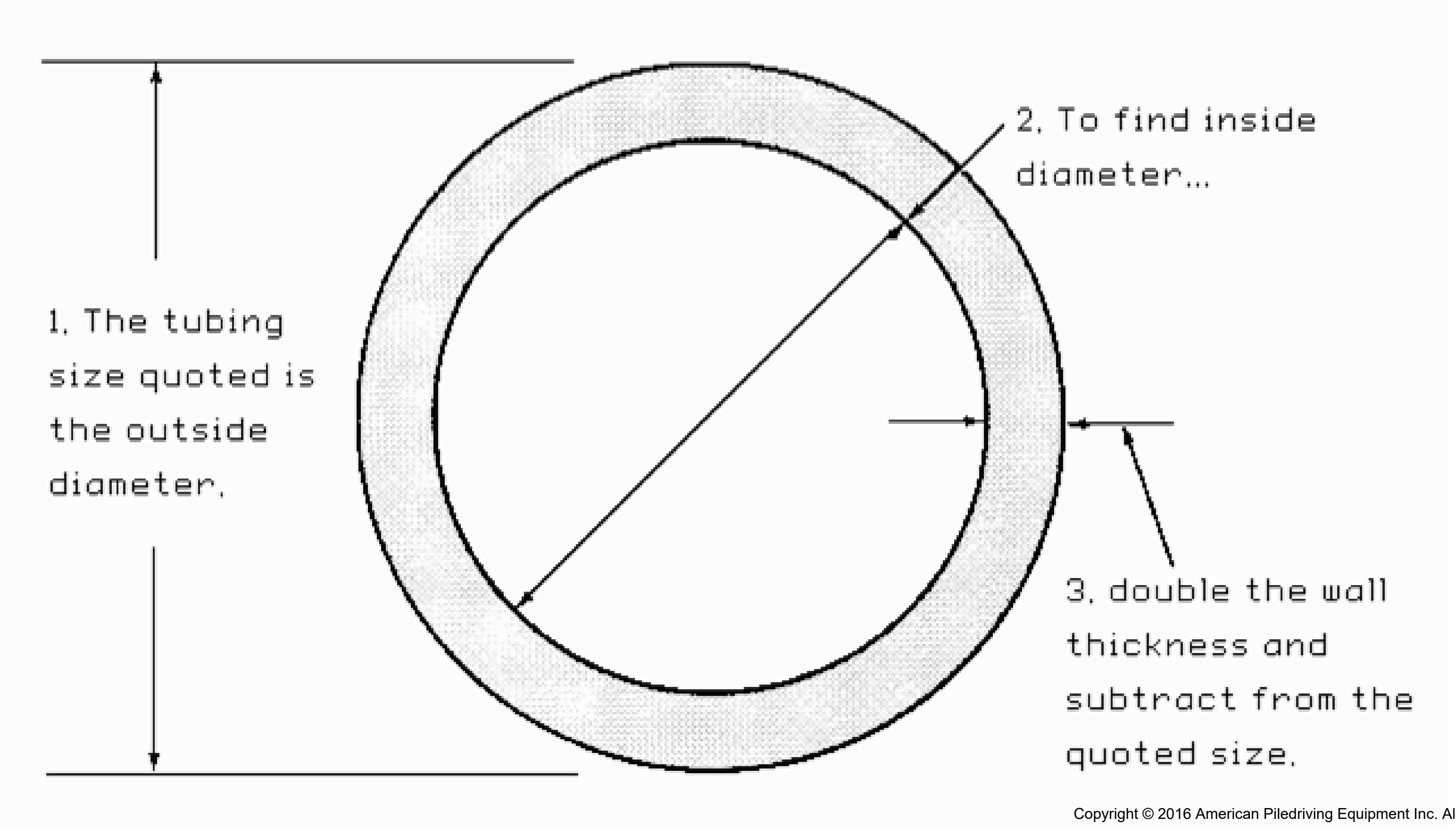
Hose Dash Size →	-04		-05		-06		-08		-10		-12		-16		-20		-24		-32		-40	-48
Hose I.D. (inches) ←	.19	.25	.25	.31	.31	.38	.41	.50	.50	.63	.63	.75	.88	1.00	1.13	1.25	1.38	1.50	1.81	2.00	2.38	3.00
U.S. Gallons per minute .25	10	3.1	3.1																			
.50	19	6	6	2.7	2.7																	
1	40	12	12	5.5	5.5	2.4																
2	95	24	24	10	10	4.8	3.5															
3	185	46	46	17	17	7	5	2.2	2.2													
4		78	78	29	29	12	8	3	3	1.2	1.2											
5		120	120	44	44	18	12	4.5	4.5	1.6	1.6	.72										
8				95	95	39	26	10	10	3.6	3.6	1.4	.60									
10						59	40	15	15	5.7	5.7	2	1	.55								
12						80	52	20	20	7.2	7.2	2.6	1.5	.75	.43							
15							75	30	30	10	10	4.2	2.2	1.2	.67	.38						
18							107	40	40	15	15	6.3	3	1.5	.70	.55	.35					
20								49	49	19	19	8	3.4	2	1.1	.65	.43	.27				
25								72	72	26	26	11	5.5	3	1.6	1	.64	.40	.17			
30										34	34	14	7	3.6	2.2	1.3	.80	.52	.22	.14		
35										47	47	19	9.5	5	2.8	1.7	1.1	.70	.27	.18		
40												25	12	6.5	3.4	2.2	1.4	.90	.38	.24		
50												36	17	9	5.3	3.3	2	1.3	.54	.35	.15	
60												50	23	12	7.5	4.4	2.8	1.8	.75	.45	.20	
70													31	17	9.3	6	3.8	2.4	1	.65	.30	
80													38	21	12	7.1	4.6	3	1.2	.76	.34	.11
90													49	27	15	9	5.9	3.8	1.5	1	.45	.13
100														33	19	12	7	4.7	1.9	1.3	.55	.18
150														60	36	22	13	8.5	3.4	2.2	1	.33
200																36	23	15	6	3.9	1.7	.55
250																54	33	22	8.5	5.3	2.5	.75
300																	45	29	12	7.5	4	1.1
400																		51	21	14	6.5	2.2
500																			32	20	10	3
800																					18	5
1000																						10

*Pressure drop values listed are typical of many petroleum based hydraulic oils at approximately +100°F (+38°C). Differences in fluids, fluid temperature and viscosity can increase or decrease actual pressure drop compared to the values listed.

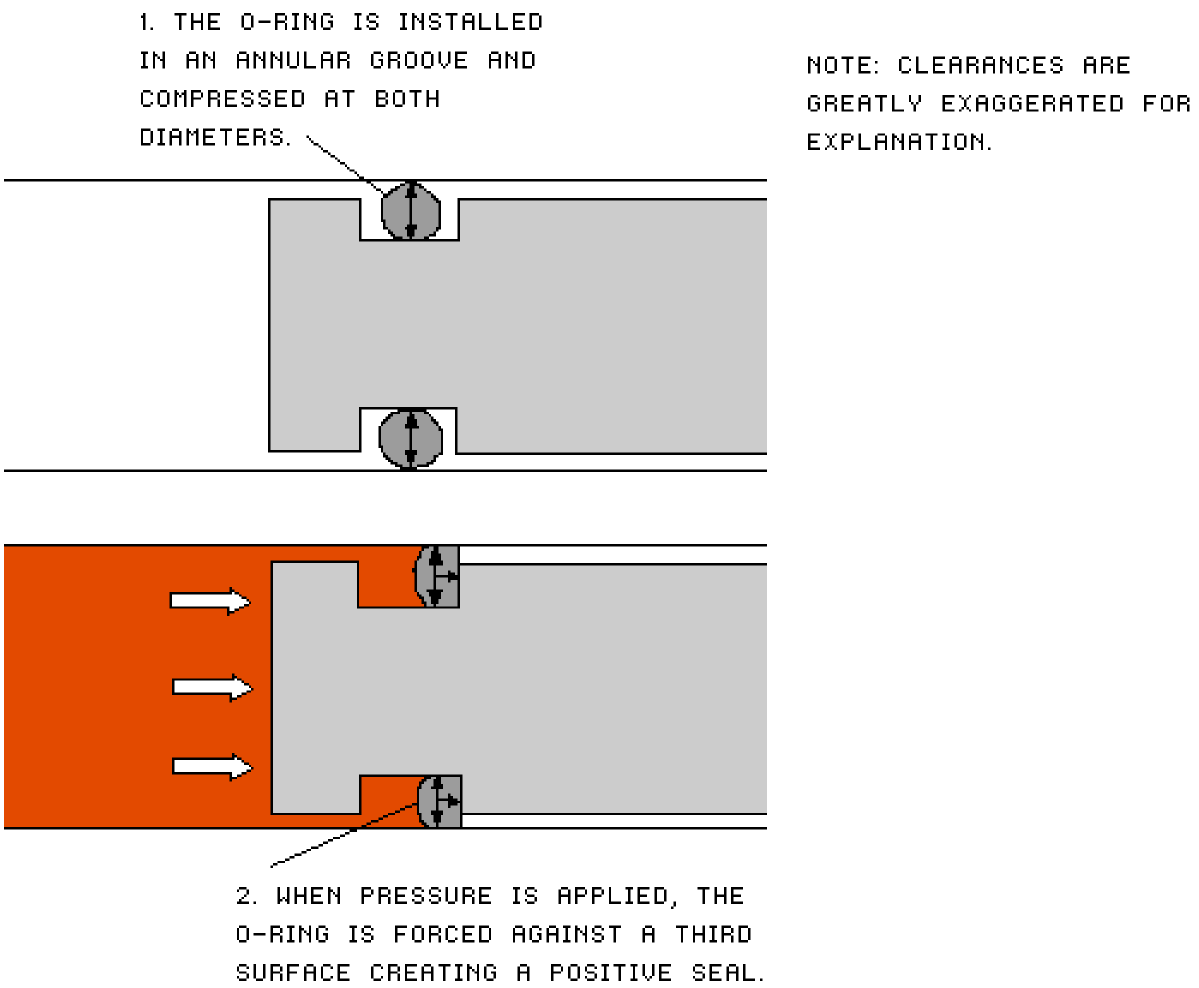
To convert
U.S. gallons into Imperial gallons multiply U.S. gallons by 0.83267. Imperial gallons into U.S. gallons multiply Imperial gallons by 1.20095. U.S. gallons to litres multiply by 3.785. Litres to U.S. gallons, multiply by 0.2642.

Tubing Is Quoted In Outside Diameter. Hydraulic Hose Is Not!

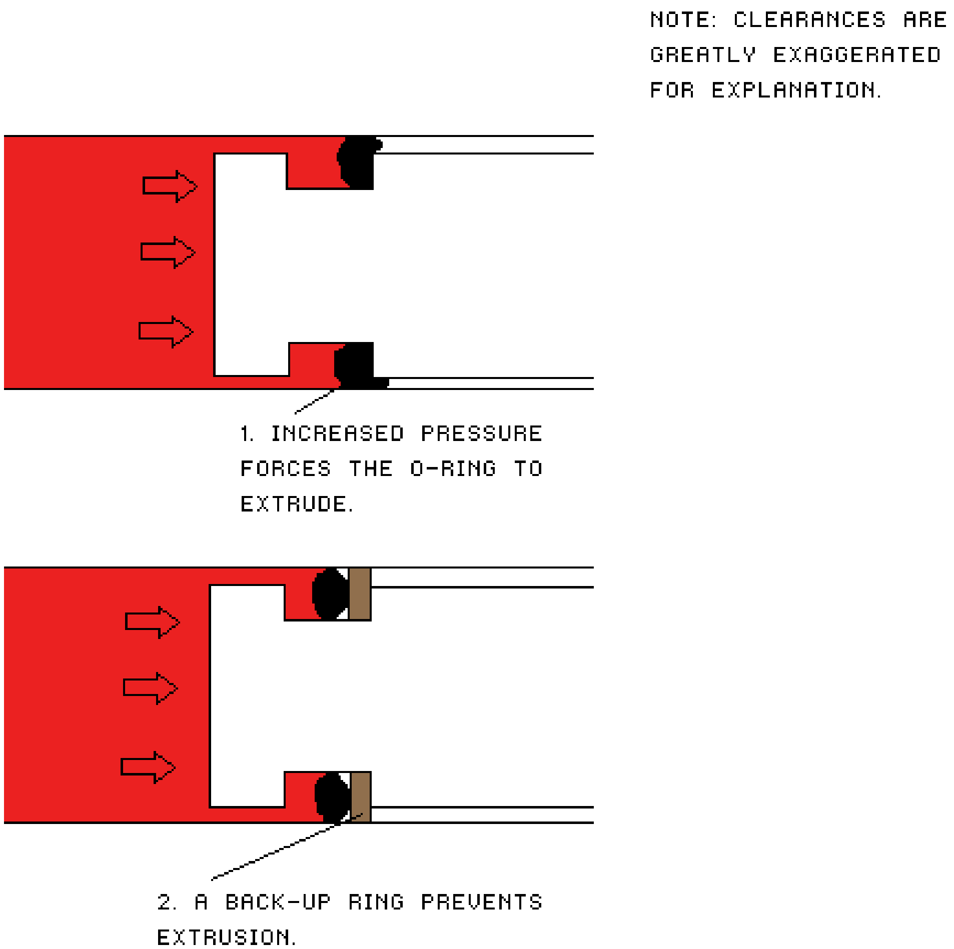
Therefore, when calculating tubing flow restrictions keep in mind that hoses called the same size will actually be less restrictive.



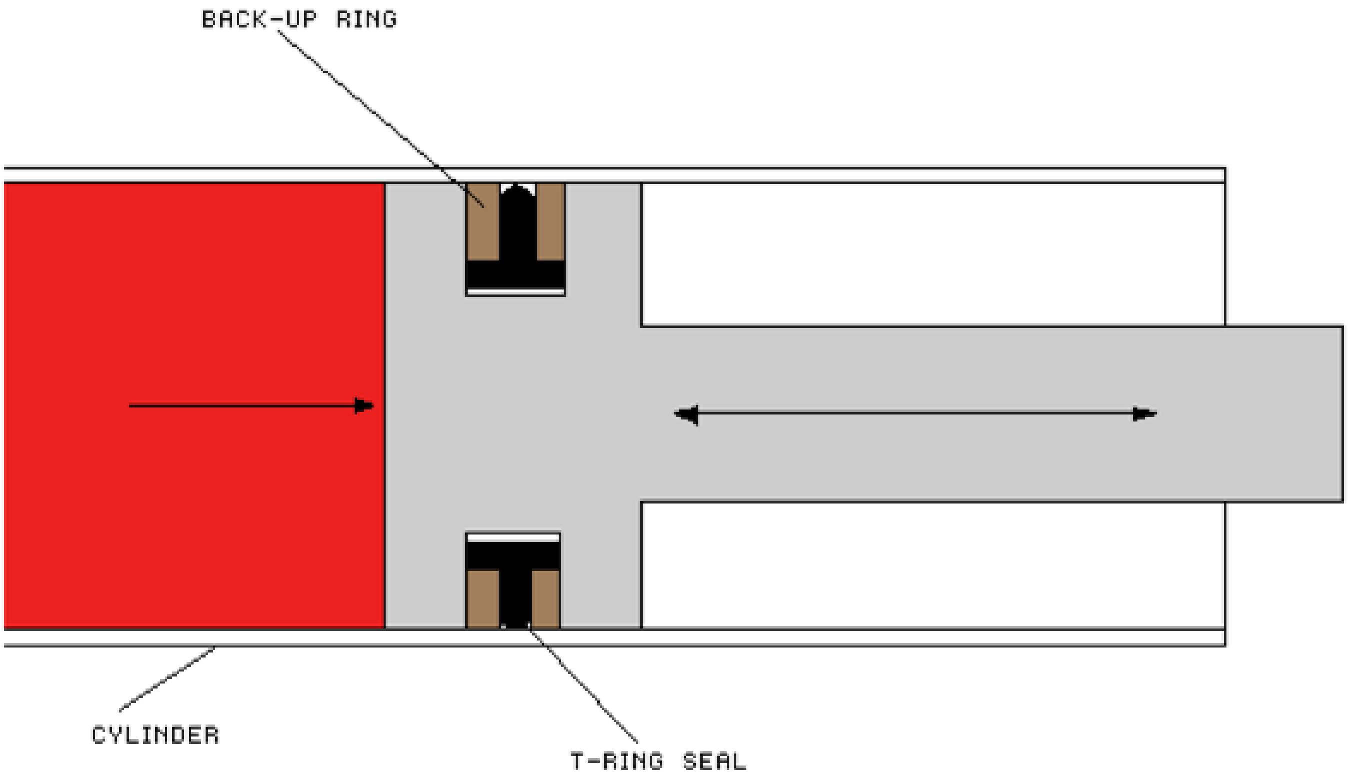
How O-Ring Seals Work



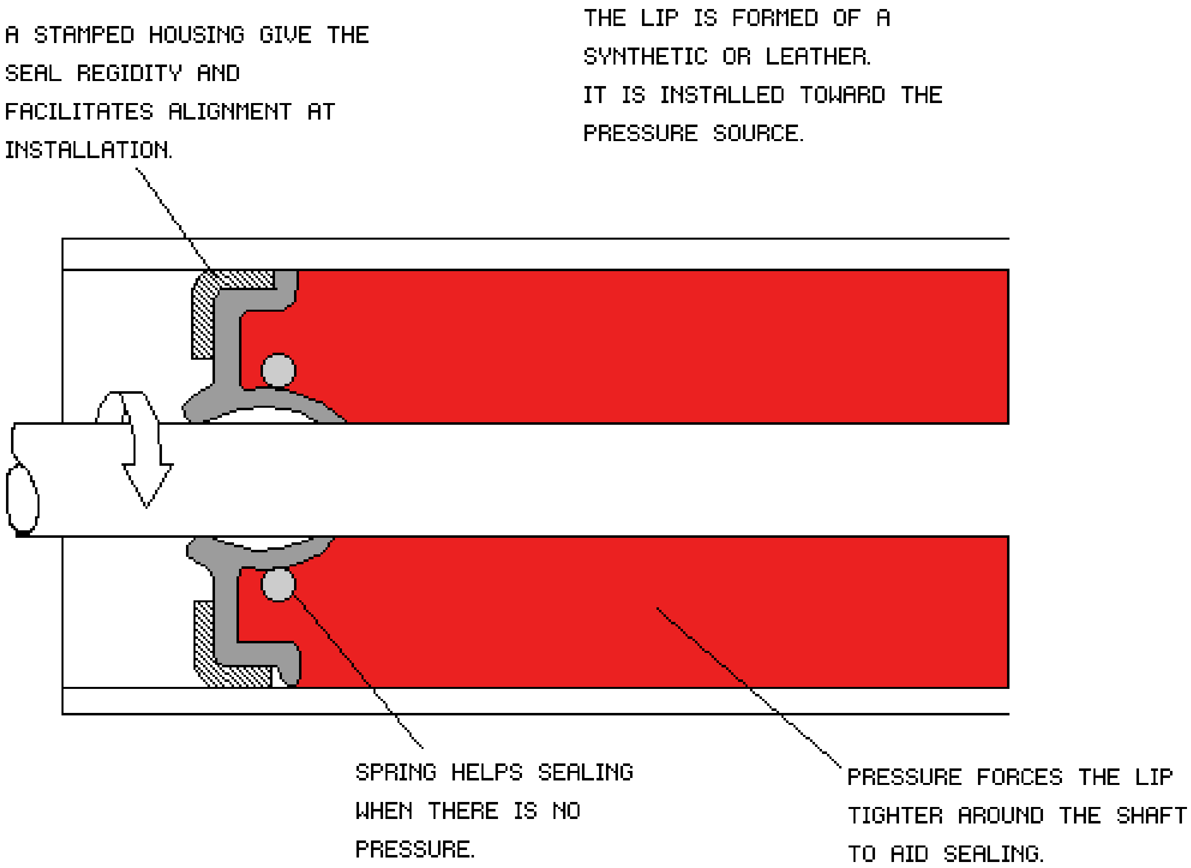
The Need For Back-Up Rings



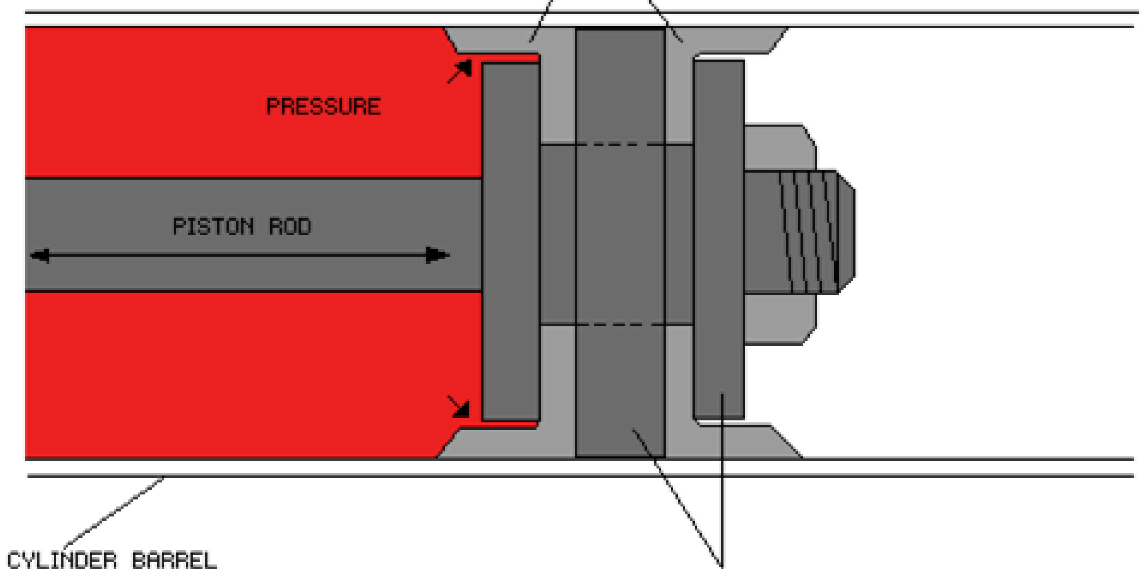
T-Seals With Back-Up Rings On Piston



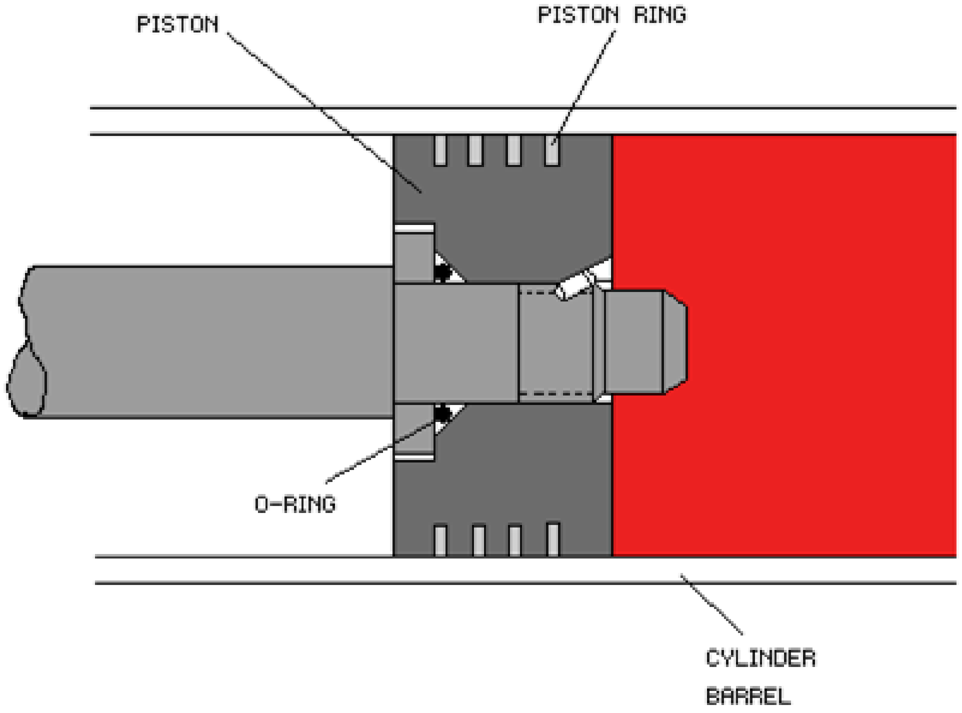
How A Seal Works On a Rotating Shaft



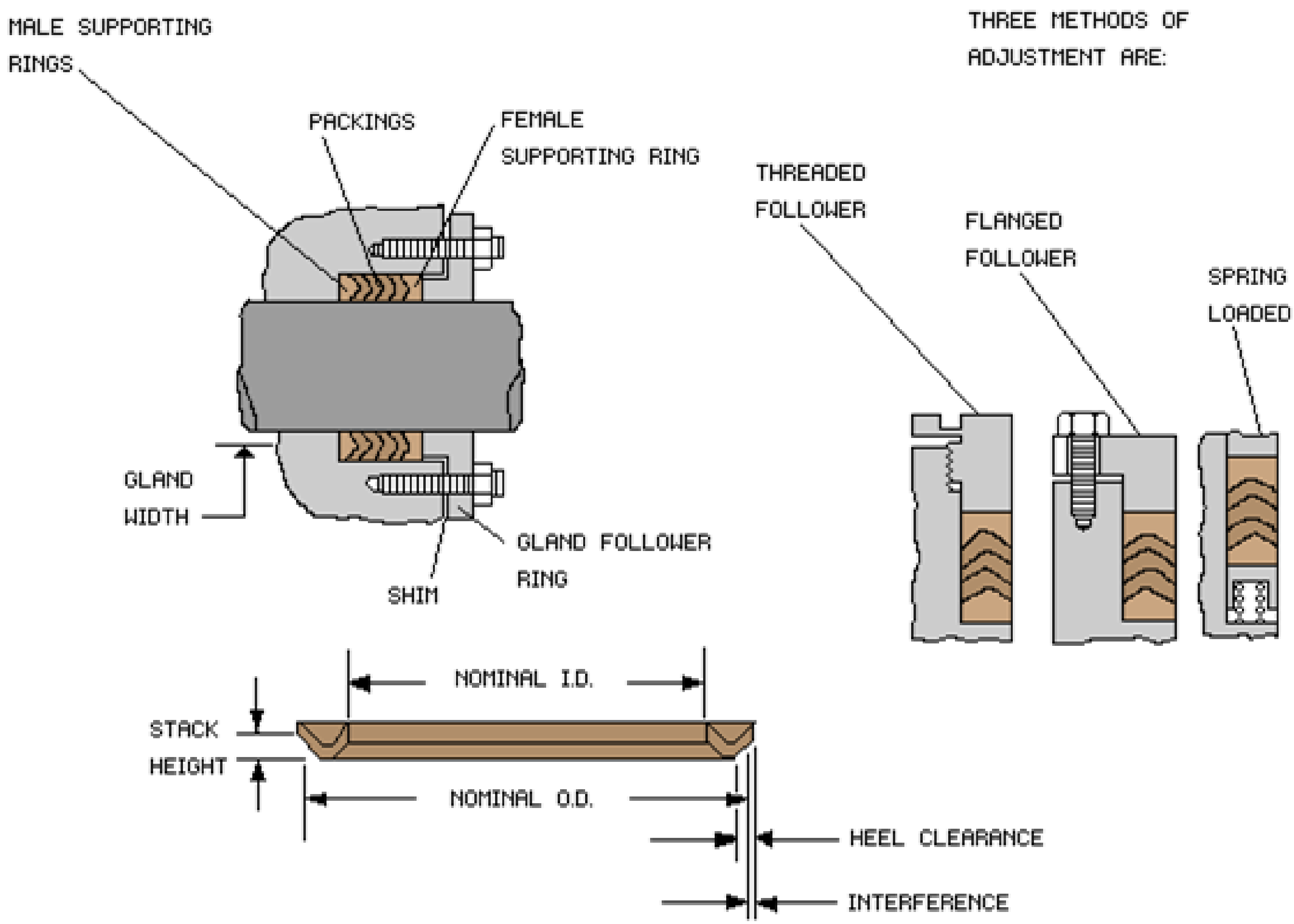
How Clip Seals Work



How Piston Rings Work



How Packing Seals Work



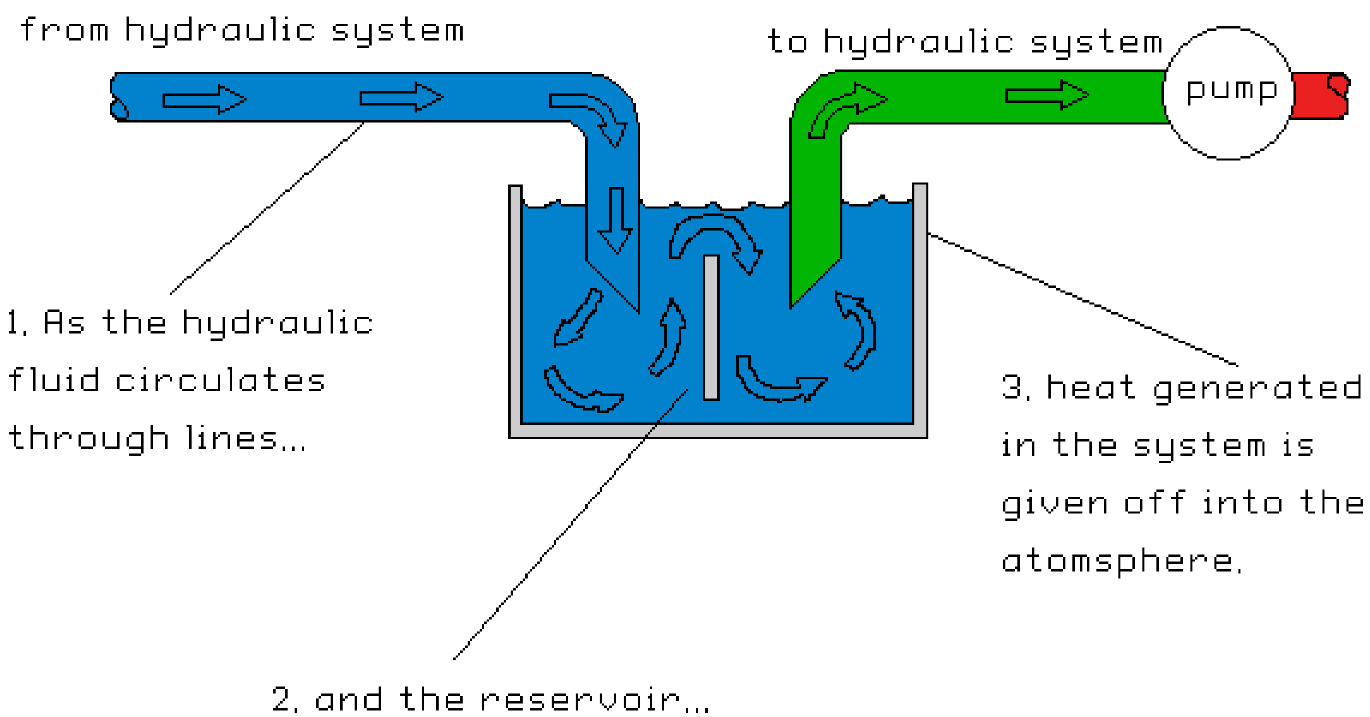
Chapter 5

Reservoirs

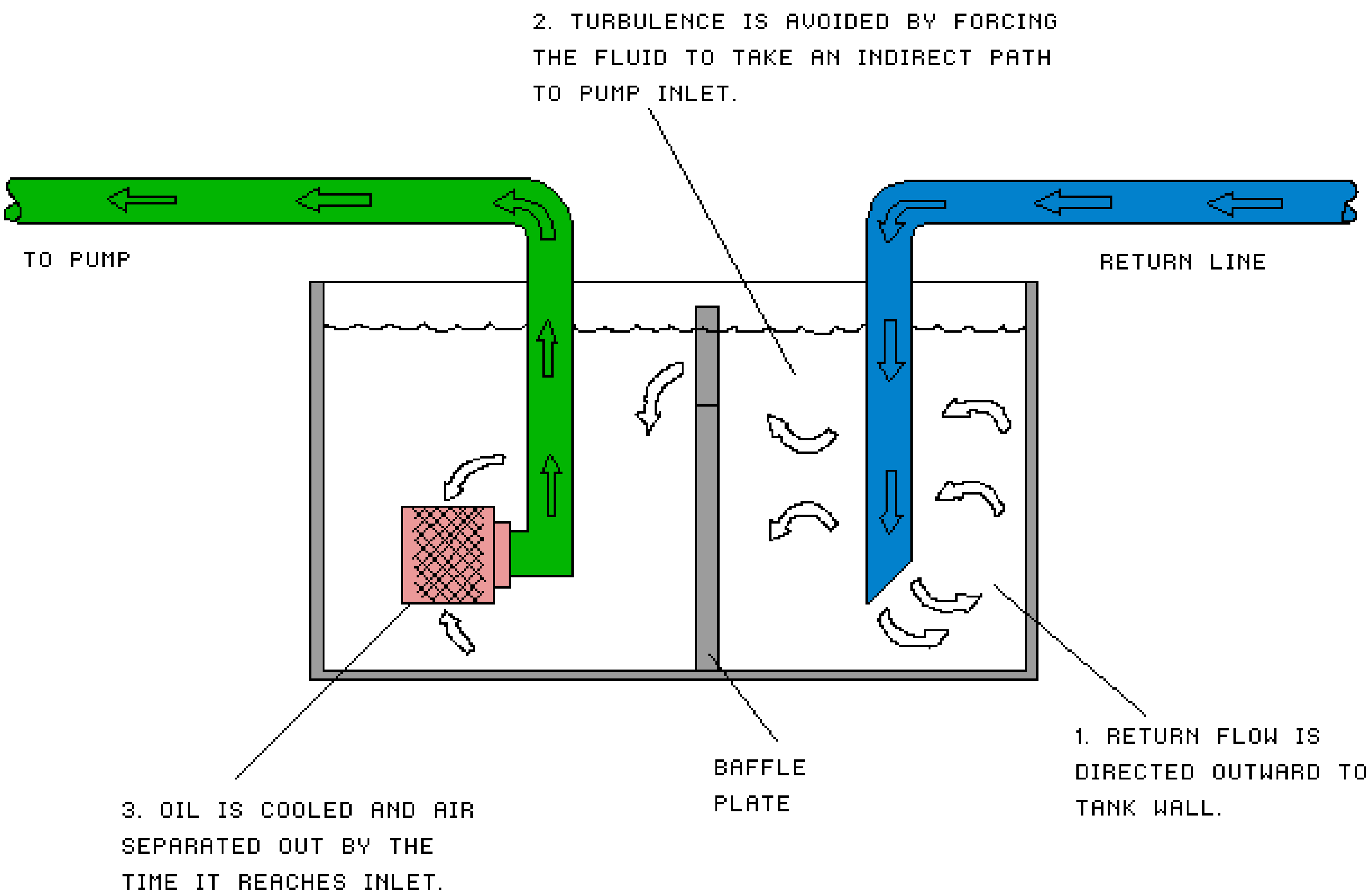
APE Reservoirs

- APE reservoirs are specially designed to separate dirt, water and any contamination from entering the hydraulic system.
- We actually use the oil tank as a trap for filtering out this contamination.
- That is why we ask you to open your oil tanks and clean them out once a year.

Hydraulic Tank Function



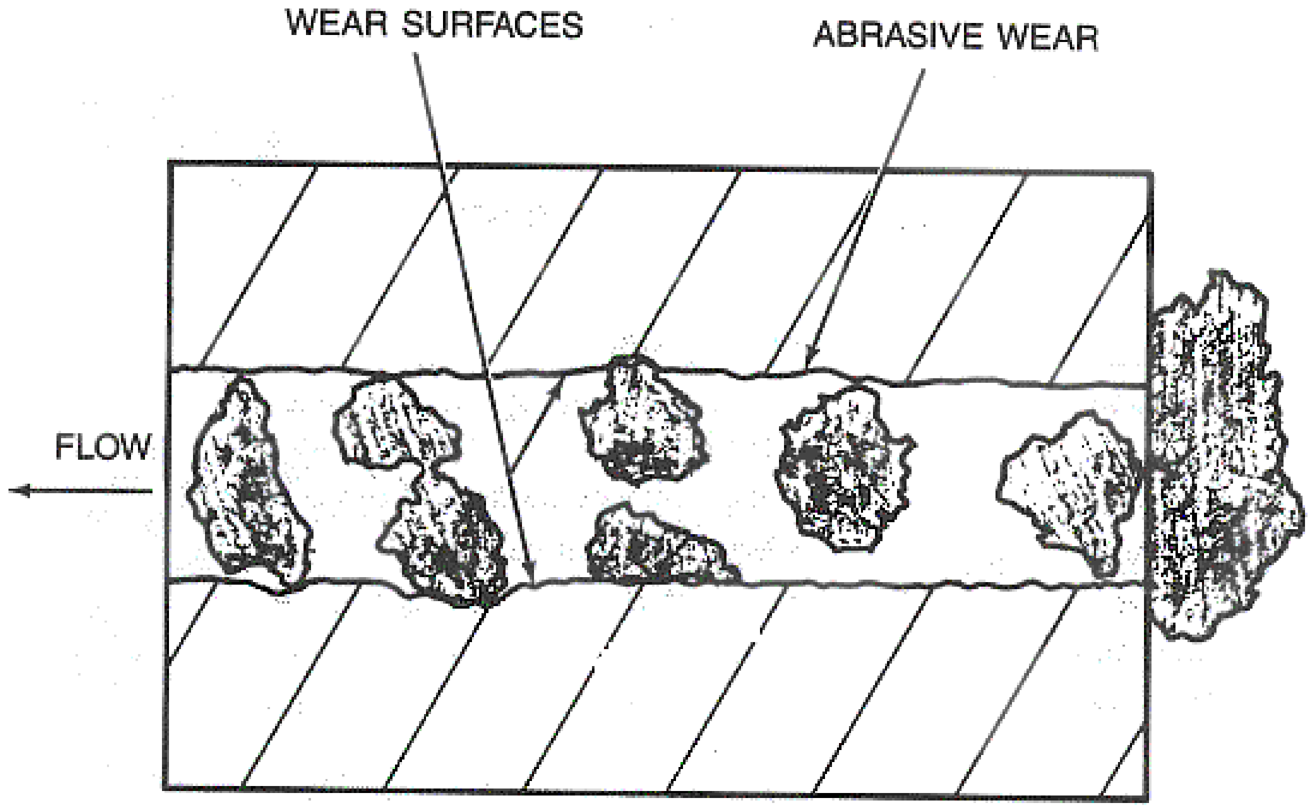
How Reservoirs Work



Chapter 6

Contamination Control

Particles In Hydraulic Oil



Particles, same size or slightly smaller than the clearance between moving surfaces, will interact with both surfaces to cause wear. Very large particles (right) do not normally get into critical clearance areas and thus cause little or no wear. Very small particles (less than one micrometer) usually flow through without abrading either surface.

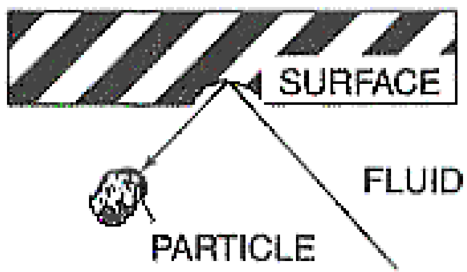
Contaminant Types And Causes

CONTAMINANT-GENERATING MECHANISMS

Type	Primary Cause
• Abrasion	• Particles grinding between moving surfaces
• Erosion	• High velocity particles striking surfaces
• Adhesion	• Metal-to-metal contact
• Fatigue	• Repeated stressing of a surface
• Cavitation	• Restricted flow to pump inlet
• Corrosion	• Foreign substances in fluid (water or chemical)
• Aeration	• Gas bubbles in fluid

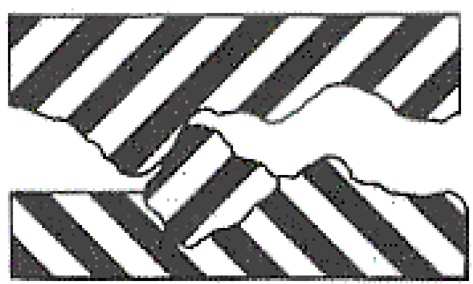
Abrasion Classes

ABRASION CLASSES



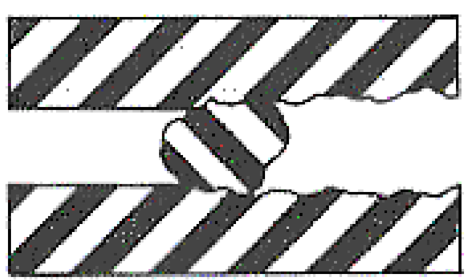
One Body

Contact between surface and the surrounding fluid.



Two Body

- Abrasive particle embedded in a surface making contact with second solid surface.
- Hard asperity of the one surface contacting another softer surface.

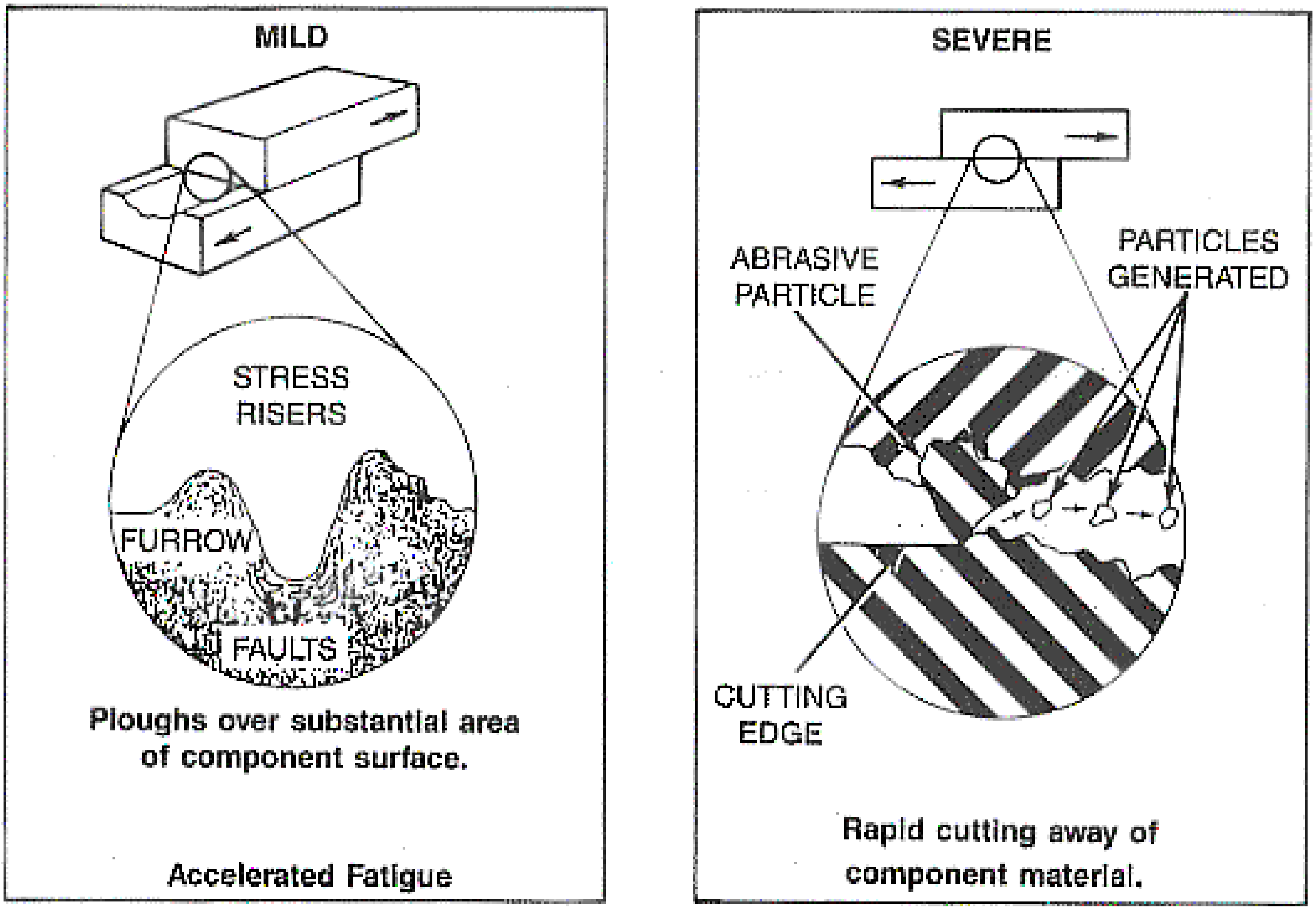


Three Body

Loose abrasive particle making contact with two surfaces.

Particles Bigger Than Oil Film

MECHANISM OF SLIDING WEAR WITH PARTICLES
GREATER THAN THE FILM THICKNESS



Mechanism of sliding wear with particles greater than the film thickness.

Trouble Shooting Contaminates

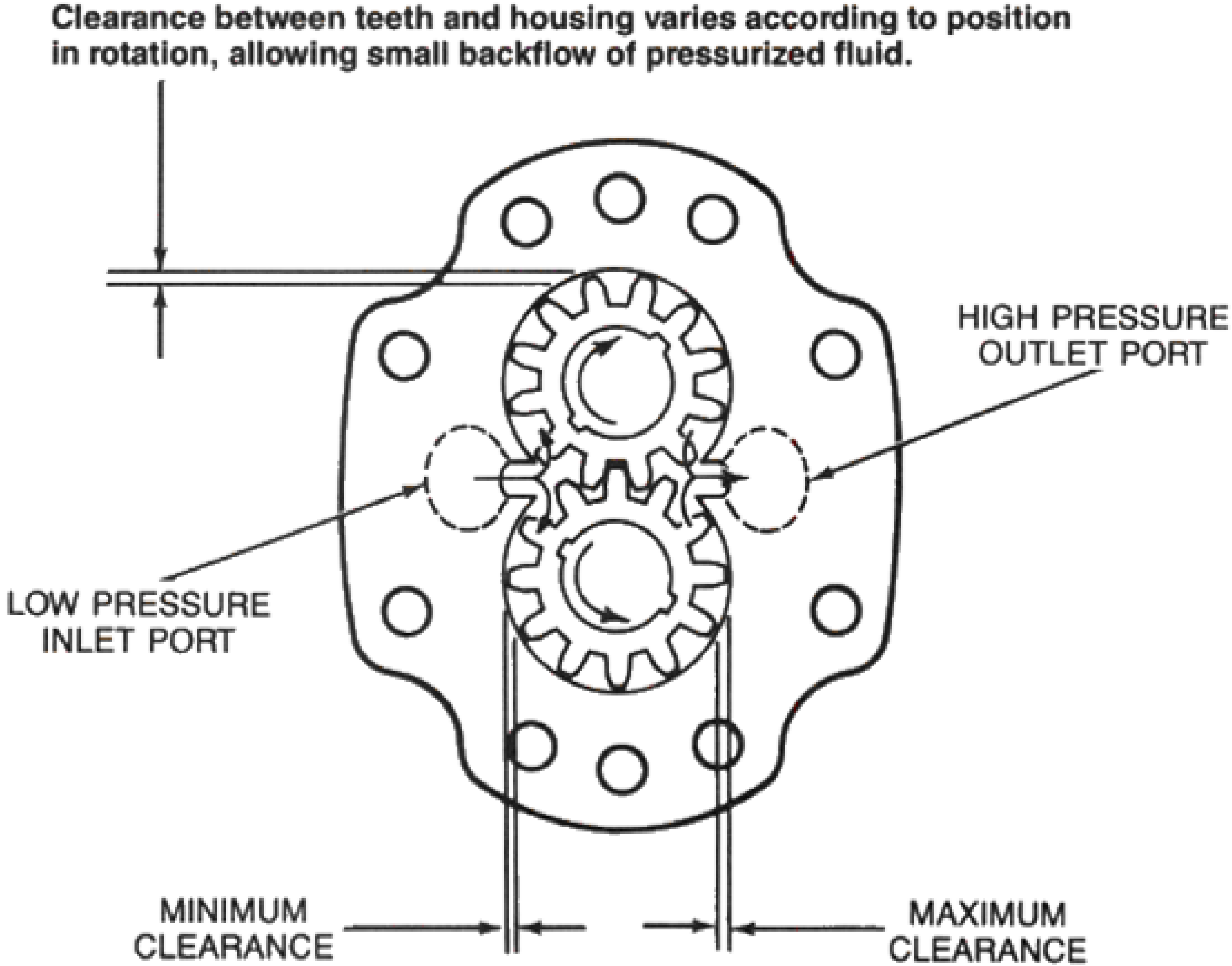
CONTAMINAT	CHARACTER	SOURCE AND REMARKS
ACIDIC BY PRODUCTS	CORROSIVE	BREAKDOWN OF OIL. MAY ALSO ARISE FROM WATER CONTAMINATION OF PHOSPHATE-ESTER FLUIDS.
SLUDGE	BLOCKING	BREAKDOWN OF OIL
WATER	EMUISION	ALREADY IN FLUID OR INTRODUCED BY SYSTEM FAULT OR BREAKDOWN OF OXIDATION-INHIBITORS.
AIR	SOLUBLE INSOLUBLE	EFFECT CAN BE CONTROLLED BY ANTI-FOAM ADDITIVES. EXCESS AIR DUE TO IMPROPER BLEEDING, POOR SYSTEM DESIGN OR AIR LEAKS.
OTHER OILS	MISCIBLE BUT MAY REACT	USE OF WRONG FLUID FOR TOPPING UP, ETC.
GREASE	MAY OR MAY NOT BE MISCIBLE	FROM LUBRICATION POINTS.

Troubleshoot Contaminates

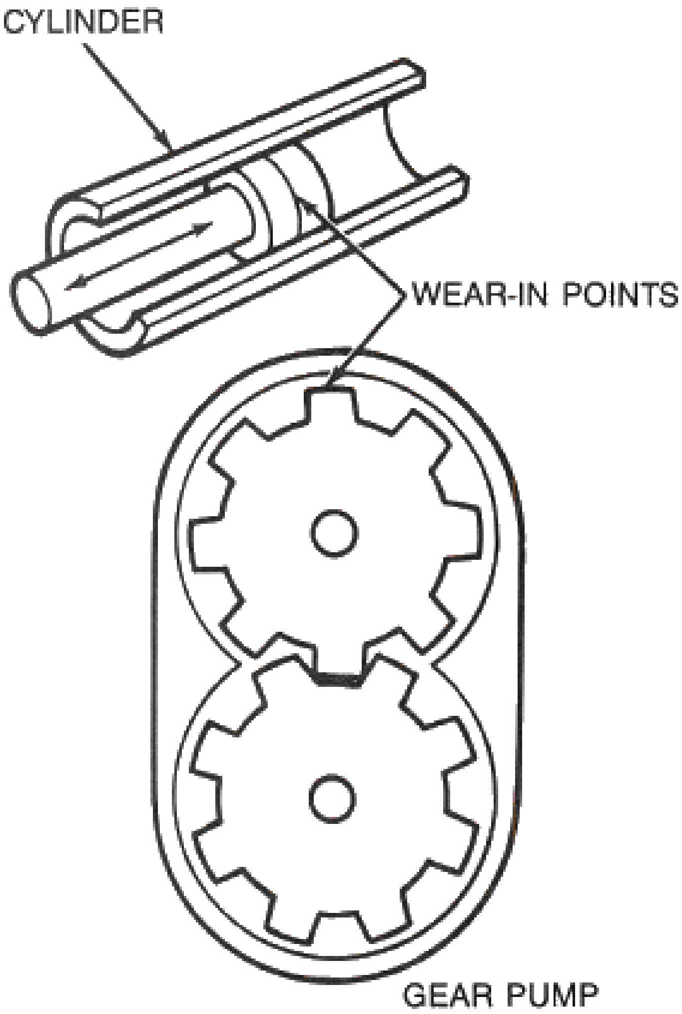
CONTAMINAT	CHARACTER	SOURCE AND REMARKS
SCALE	INSOLUBLE	FROM PIPES NOT PROPERLY CLEANED BEFORE ASSEMBLY.
METALLIC PARTICALS	INSOLUBLE WITH CATALVIC ACTION	MAY BE CAUSED BY WATER CONTAMINATION, CONTROLLABLE WITH ANTI-RUST ADDITIVES.
PAINT FLAKES	INSOLUBLE BLOCKING	PAINT ON INSIDE OF TANK OLD OR NOT COMPATIBLE WITH FLUID.
ABRASIVE PARTICALS	ABRASIVE AND BLOCKING	AIRBORNE PARTICALS (REMOVE WITH AIR FILTER).
ELASTOMERIC PARTICALS	BLOCKING	SEAL BREAKDOWN. CHECK FLUID, COMPATIBILITY OF SEAL DESIGN.

Pump And Motor Clearances That Fail

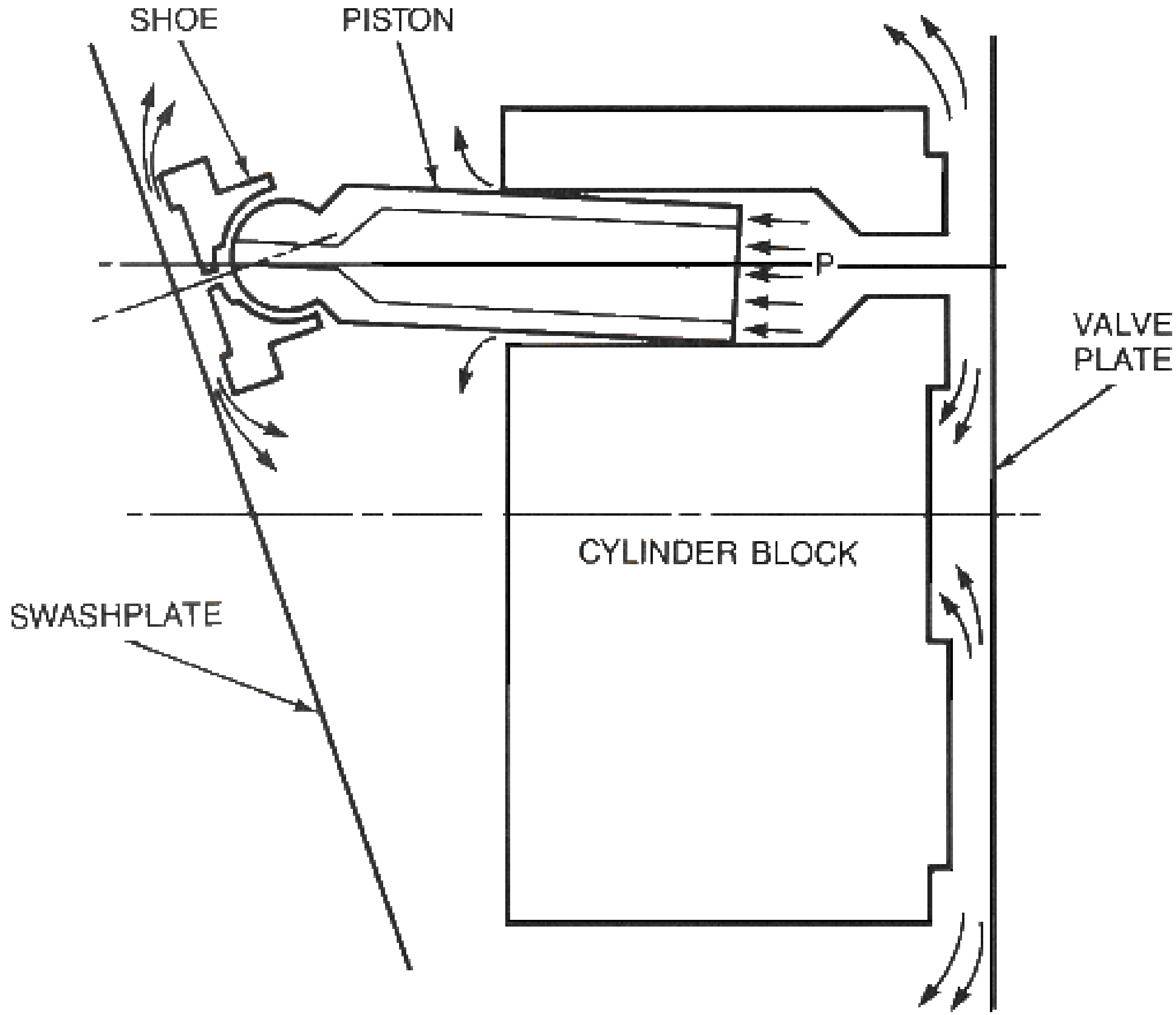
When Oil Is Contaminated



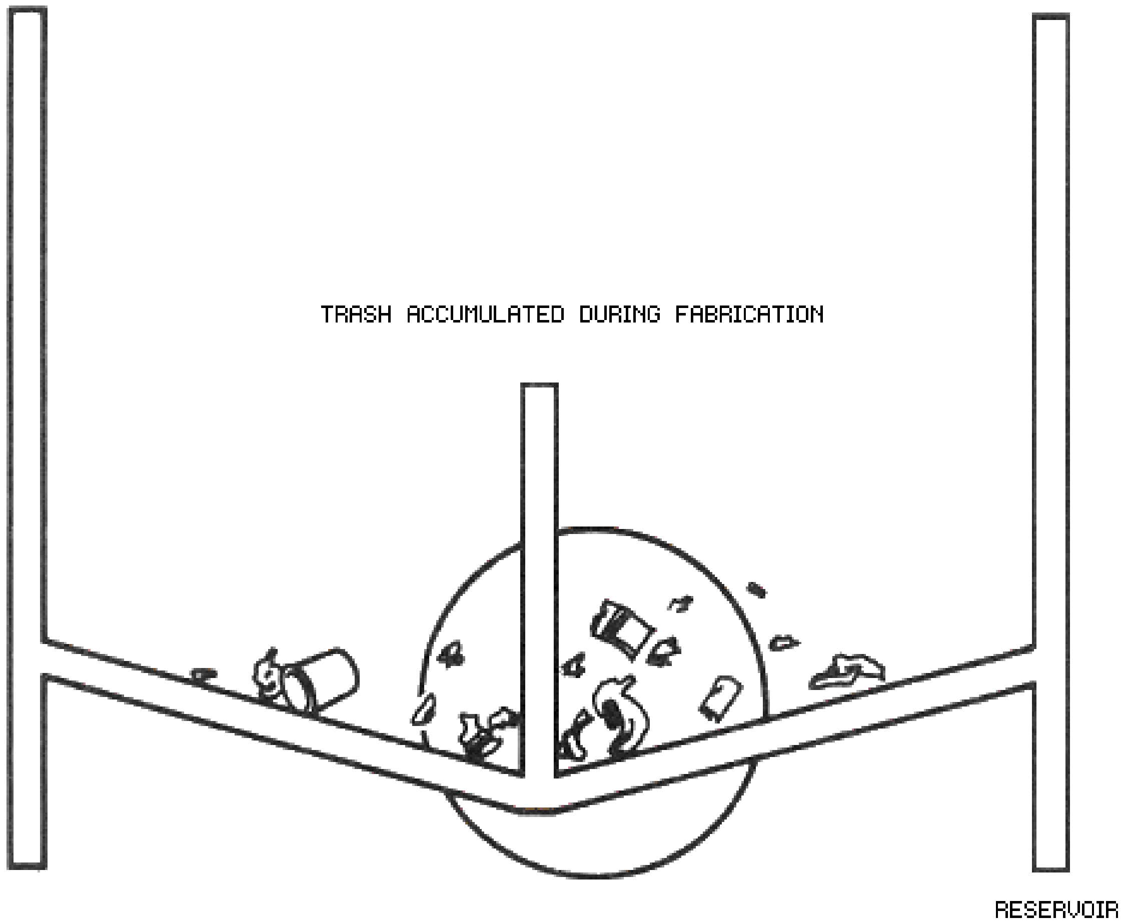
Wear-In Points



Where Piston Pumps And Motors Fail When Oil Is Bad

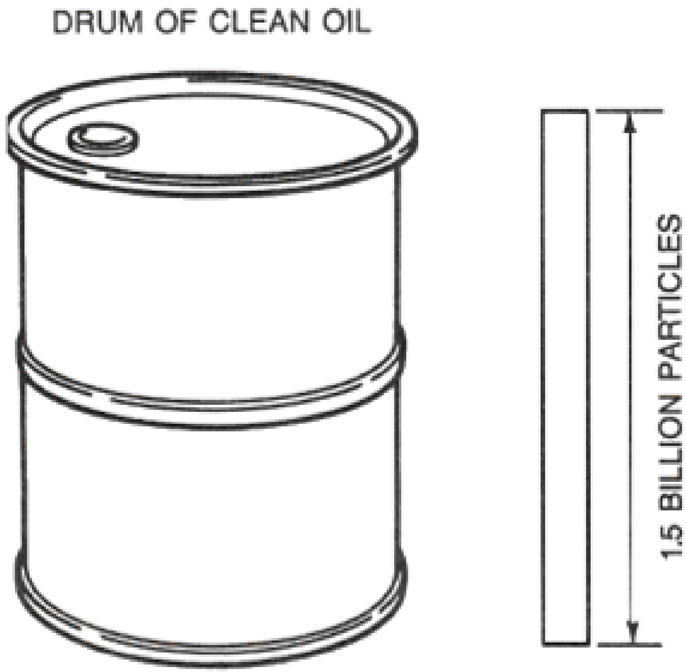


Contaminates From Manufacturing

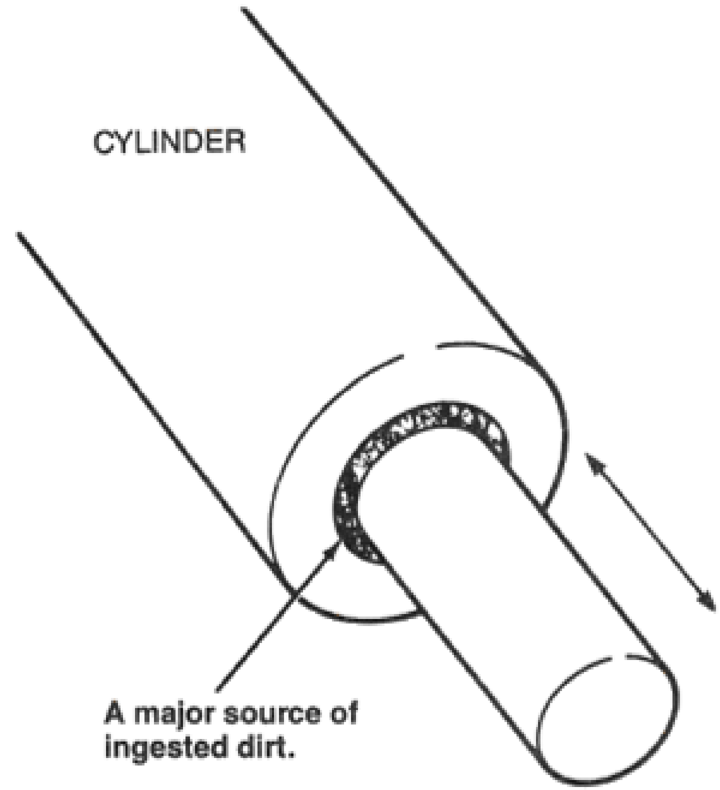


View Of Hydraulic Reservoir

Main Sources Of Contamination

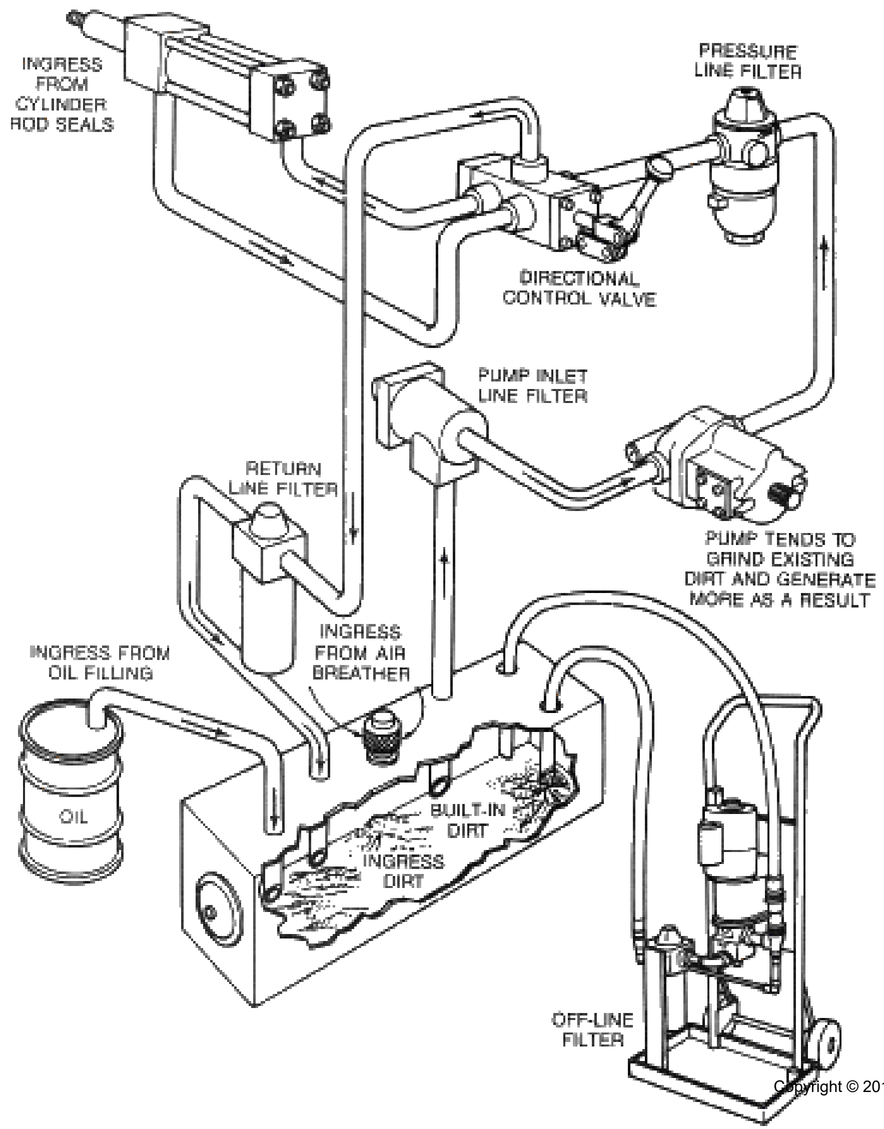


A. OIL STORAGE DRUM

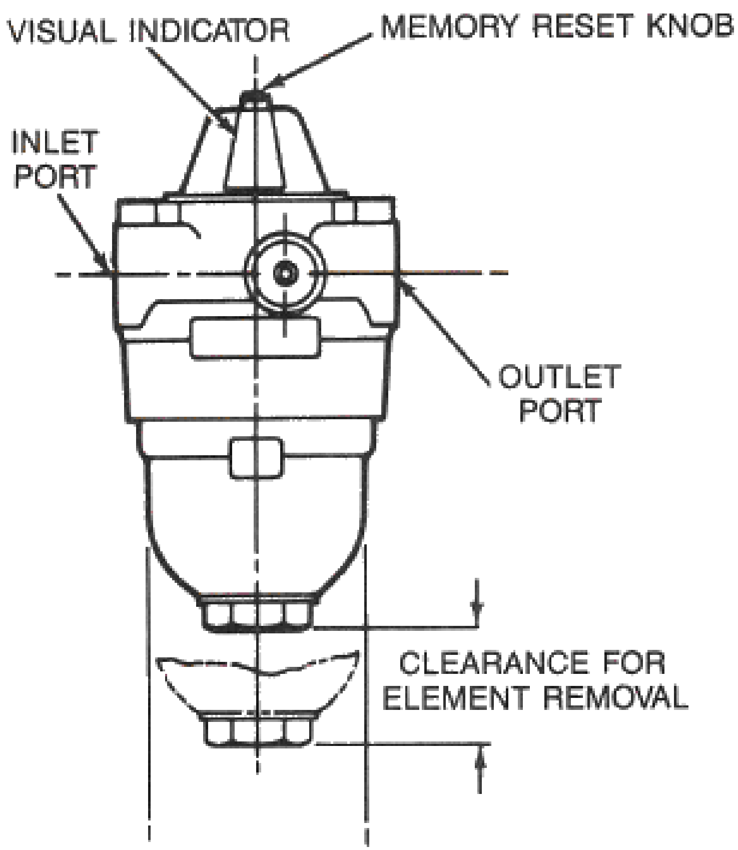


B. CYLINDER ROD

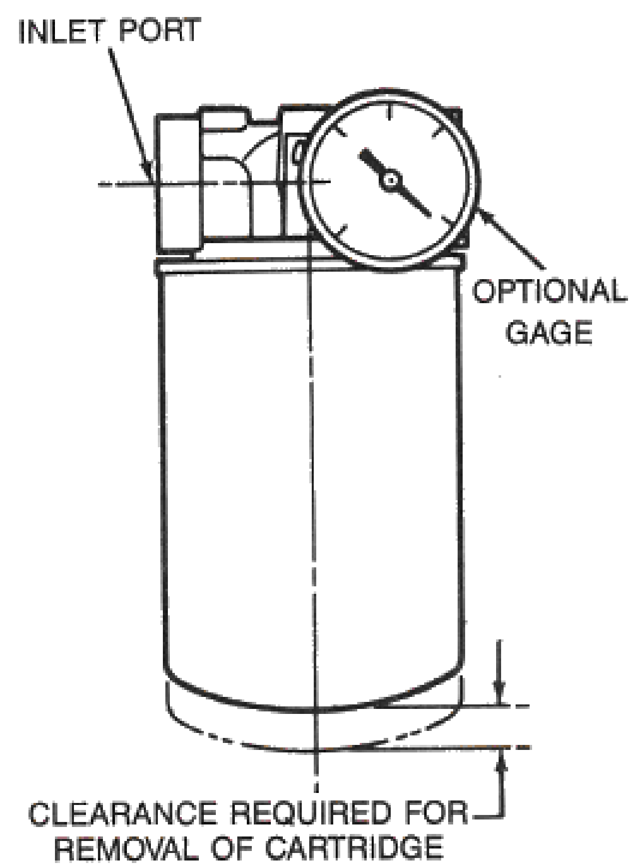
More Sources Of Contamination



Filters



B. BOWL-TYPE

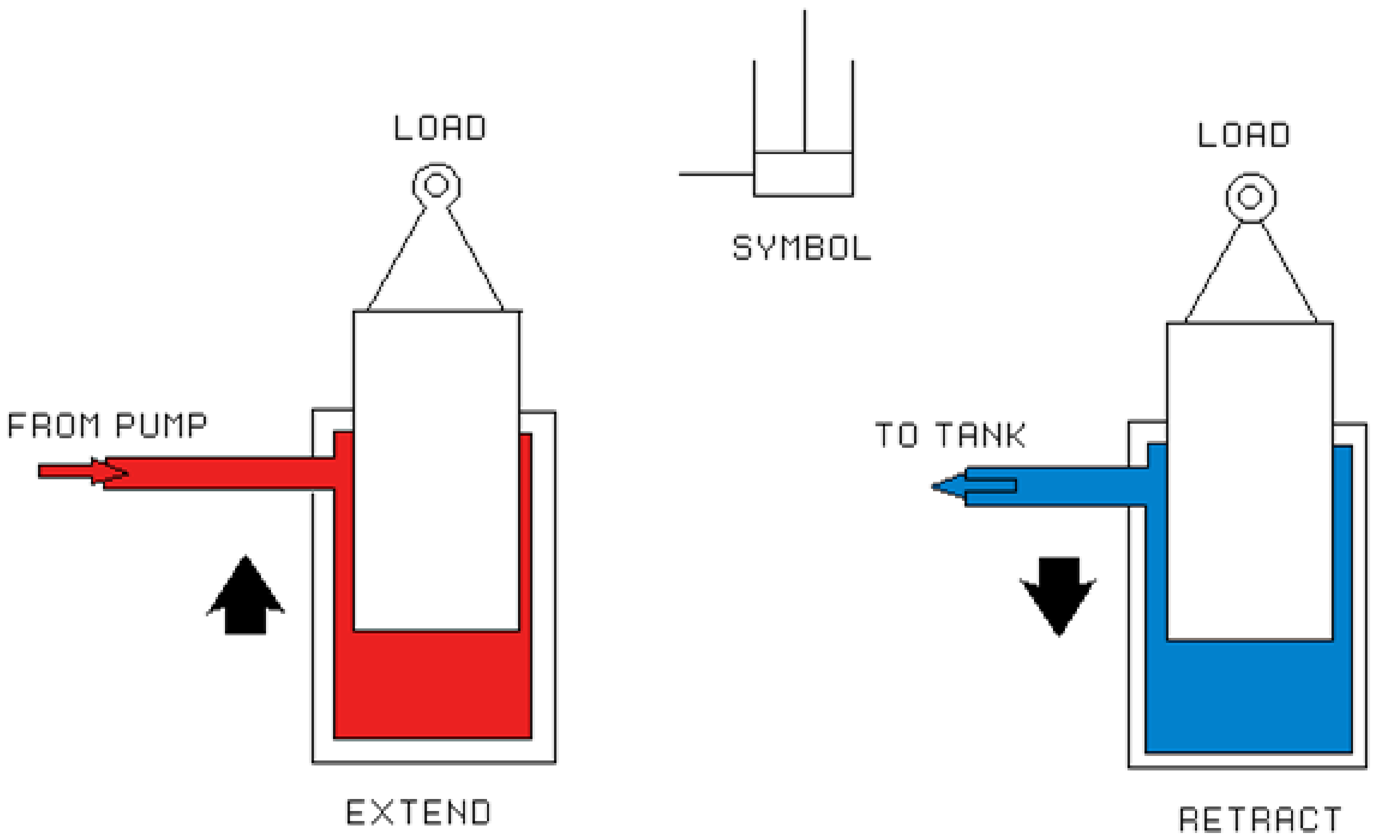


C. CARTRIDGE-TYPE

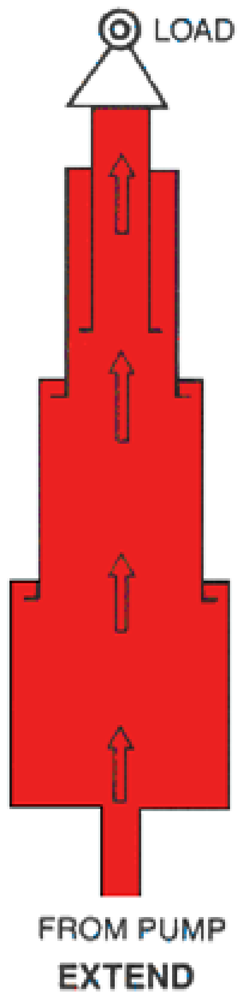
Chapter 7

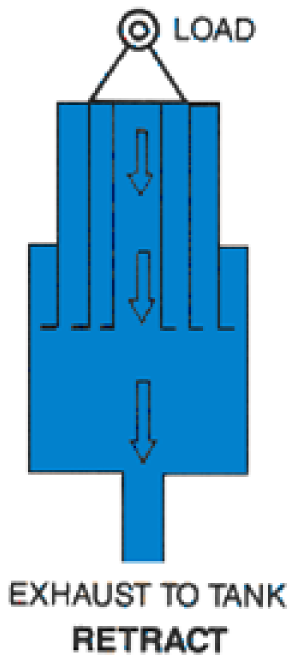
Hydraulic Actuators

Cylinder Actuator

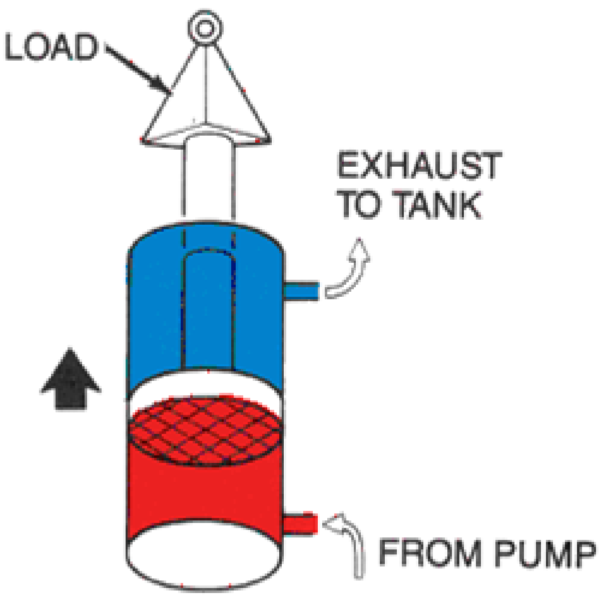


Telescopic Cylinder

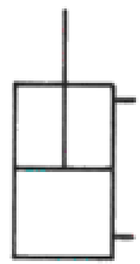


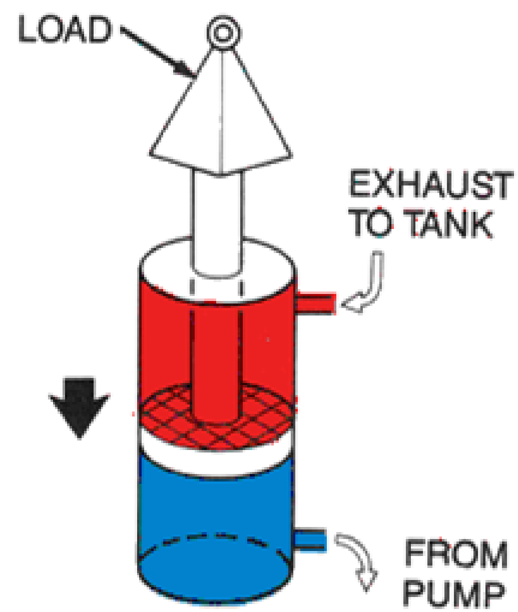


Cylinder



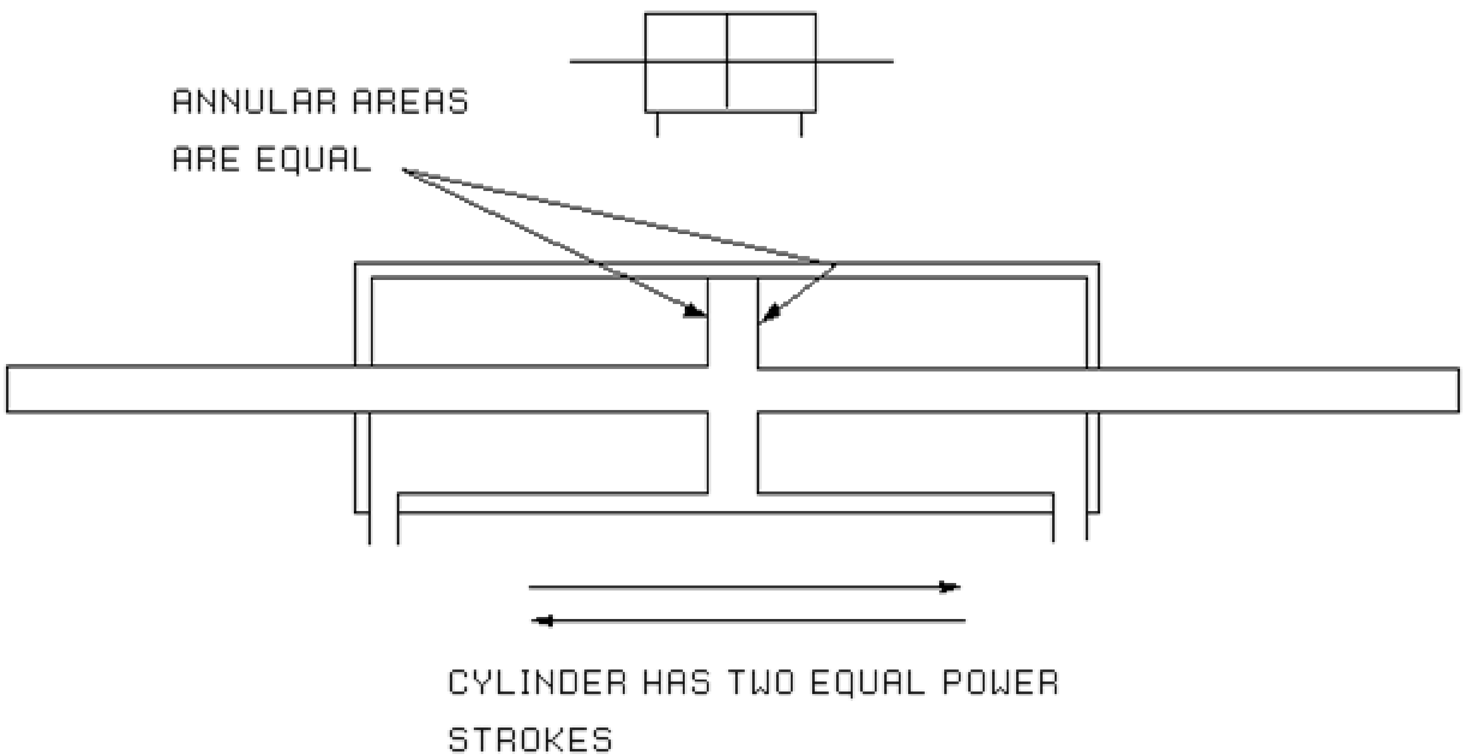
EXTEND CYLINDER



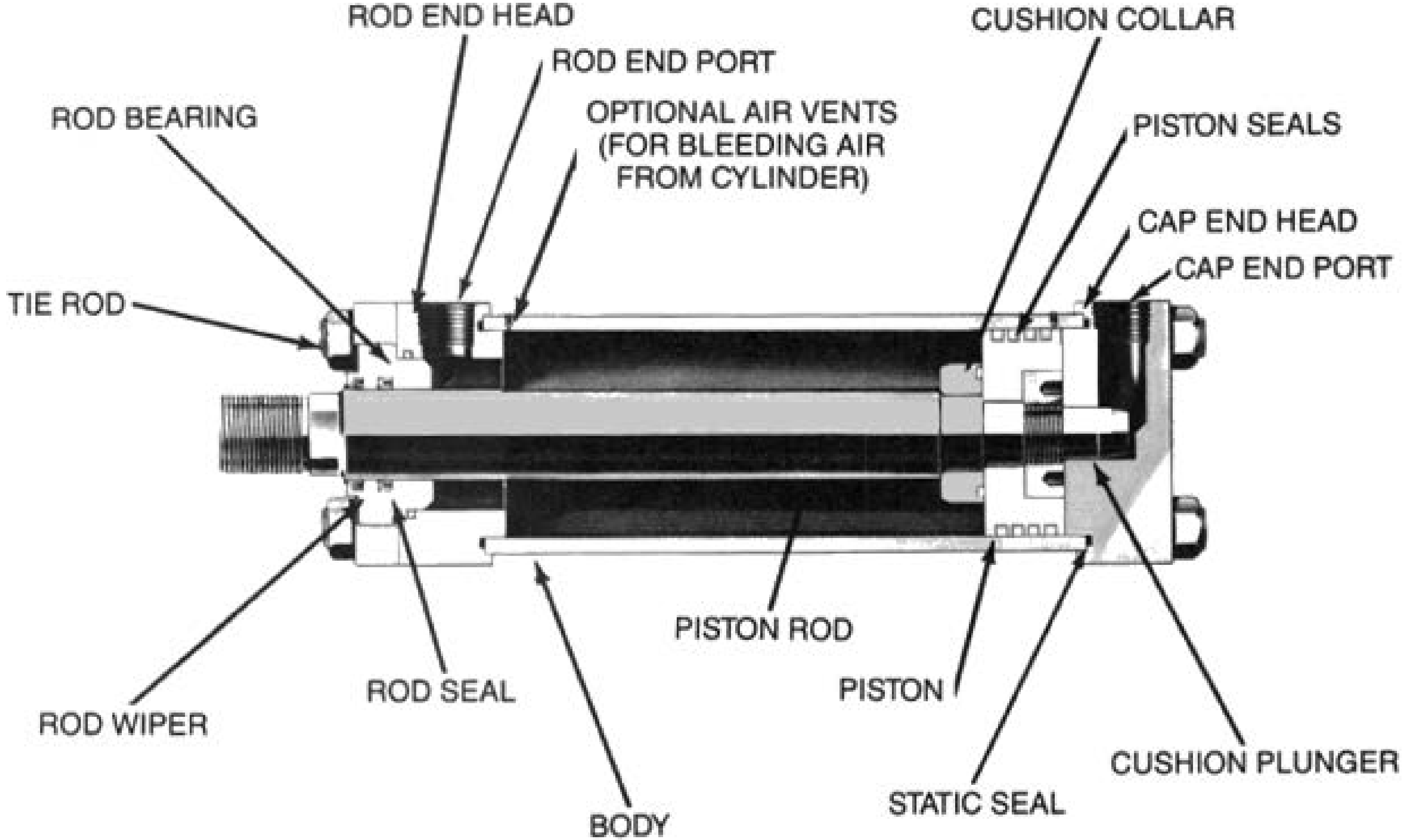


RETRACT CYLINDER

Cylinder With Two Equal Power Strokes



Cylinder Components



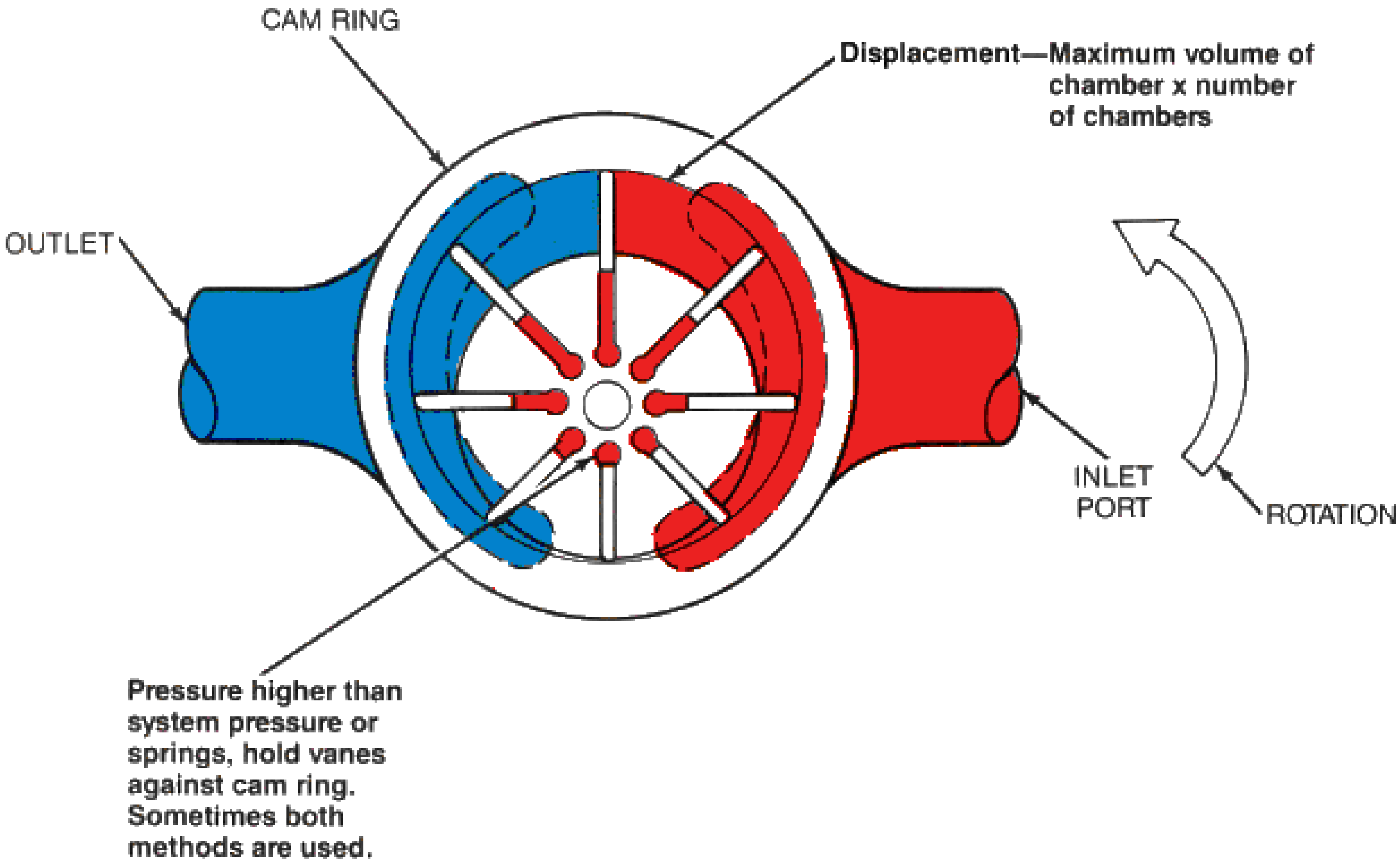
Understanding What Pressure, GPM, And Displacement Means

CHANGE	SPEED	EFFECT ON OPERATING PRESSURE	OUTPUT FORCE AVAILABLE
INCREASE PRESSURE SETTING	NO EFFECT	NO EFFECT	INCREASES
DECREASE PRESSURE SETTING	NO EFFECT	NO EFFECT	DECREASES
INCREASE GPM	INCREASES	NO EFFECT	NO EFFECT
DECREASE GPM	DECREASES	NO EFFECT	NO EFFECT
INCREASE CYLINDER DIAMETER	DECREASES	DECREASES	INCREASES
DECREASE CYLINDER DIAMETER	INCREASES	INCREASES	DECREASES

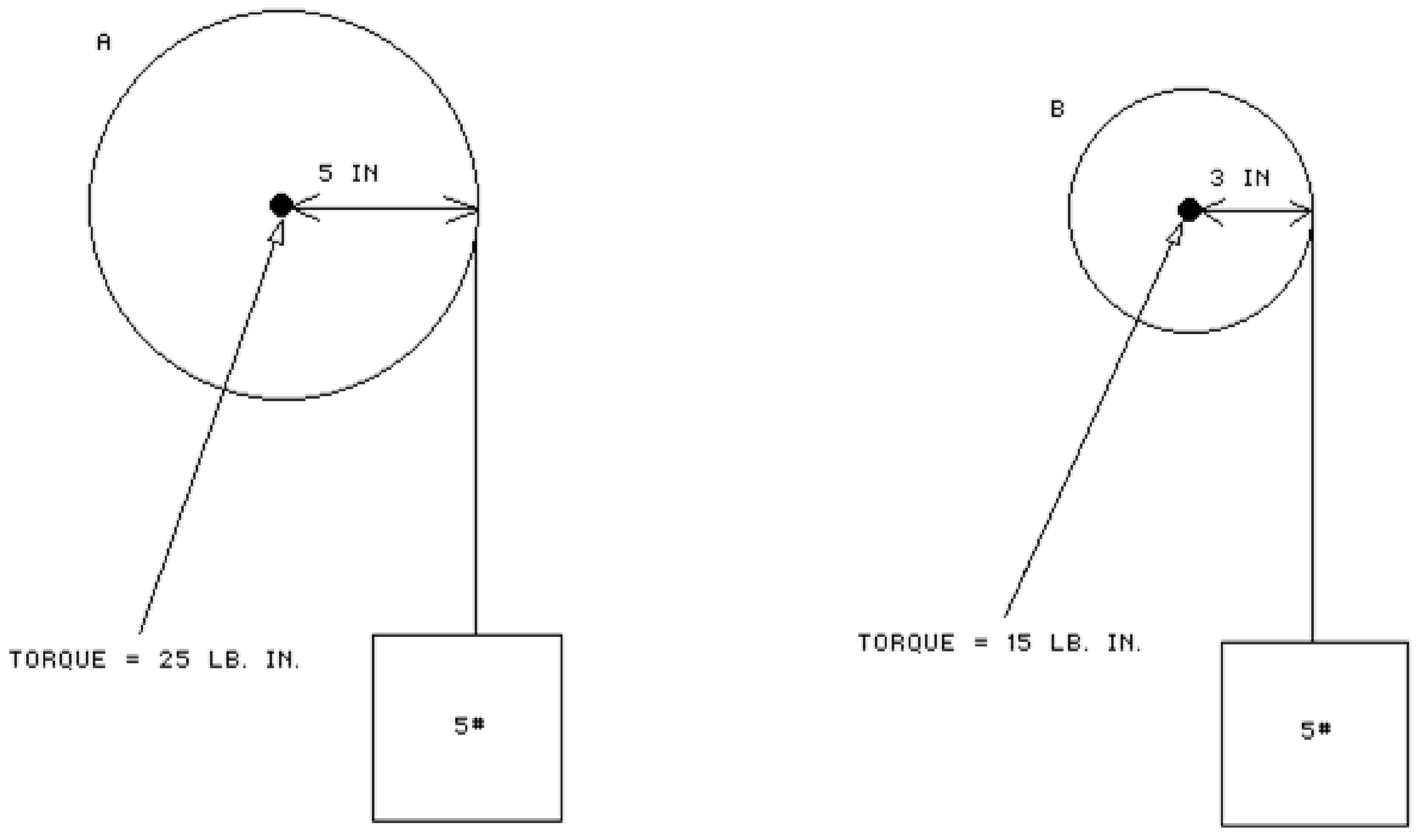
ABOVE TABLE ASSUMES A CONSTANT WORK LOAD.

Cyl. Bore Dia. Inch	Piston Rod Dia. Inch	Work Area Sq. in.	HYDRAULIC WORKING PRESSURE p.s.i.						Fluid Required Per In. Of Stroke		Port Size Dia. Inch	Fluid Velocity @ 15 Ft./Sec.	
			500	750	1000	1500	2000	3000	Gal.	Cu. In.		Flow GPM	Piston Vel. In/Sec.
1½	–	1.767	883	1325	1767	2651	3534	5301	.00765	1.767	½	11.0	24.0
	⅝	1.460	730	1095	1460	2190	2920	4380	.00632	1.460			29.0
	1	.982	491	736	982	1473	1964	2946	.00425	.982			43.1
2	–	3.141	1571	2356	3141	4711	6283	9423	.01360	3.141	½	11.0	13.5
	1	2.356	1178	1767	2356	3534	4712	7068	.01020	2.356			18.0
	1⅜	1.656	828	1242	1656	2484	3312	4968	.00717	1.656			25.6
2½	–	4.909	2454	3682	4909	7363	9818	14727	.02125	4.909	½	11.0	8.6
	1	4.124	2062	3093	4124	6186	8248	12372	.01785	4.124			10.3
	1⅜	3.424	1712	2568	3424	5136	6848	10272	.01482	3.424			12.4
	1¾	2.504	1252	1878	2504	3756	5008	7512	.01084	2.504			16.9
3¼	–	8.296	4148	6222	8296	12444	16592	24888	.0359	8.296	¾	20.3	9.4
	1⅜	6.811	3405	5108	6811	10216	13622	20433	.0295	6.811			11.5
	1¾	5.891	2945	4418	5891	8836	11782	17673	.0255	5.891			13.3
	2	5.154	2577	3865	5154	7731	10308	15462	.0223	5.154			15.2
4	–	12.566	6283	9425	12566	18849	25132	37698	.0544	12.566	¾	20.3	6.2
	1¾	10.161	5080	7621	10161	15241	20322	30483	.0440	10.161			7.7
	2	9.424	4712	7068	9424	14136	18848	28272	.0408	9.424			8.3
	2½	7.657	3828	5743	7657	11485	15314	22971	.0331	7.657			10.2

How A Vane Motor Works



Understanding Torque



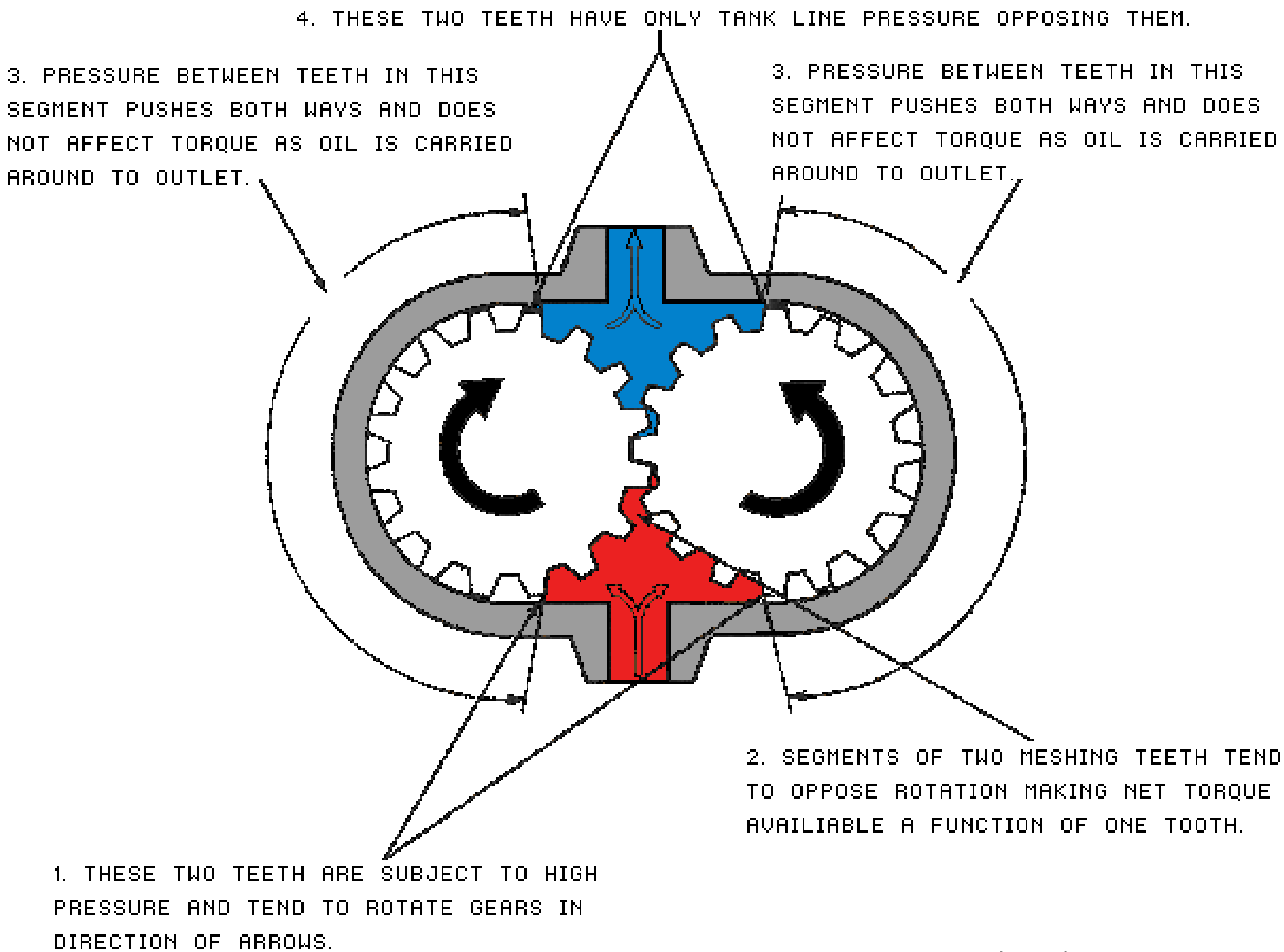
Chapter 8

Hydraulic Pumps / Motors

APE Gear Pumps

- The next slide shows a gear pump and how it works. This type of pump is used on all APE power units to provide flow to run vibros, hammers and drills.
- There are several of these pumps mounted on the engine rear to provide the flow required for APE units.

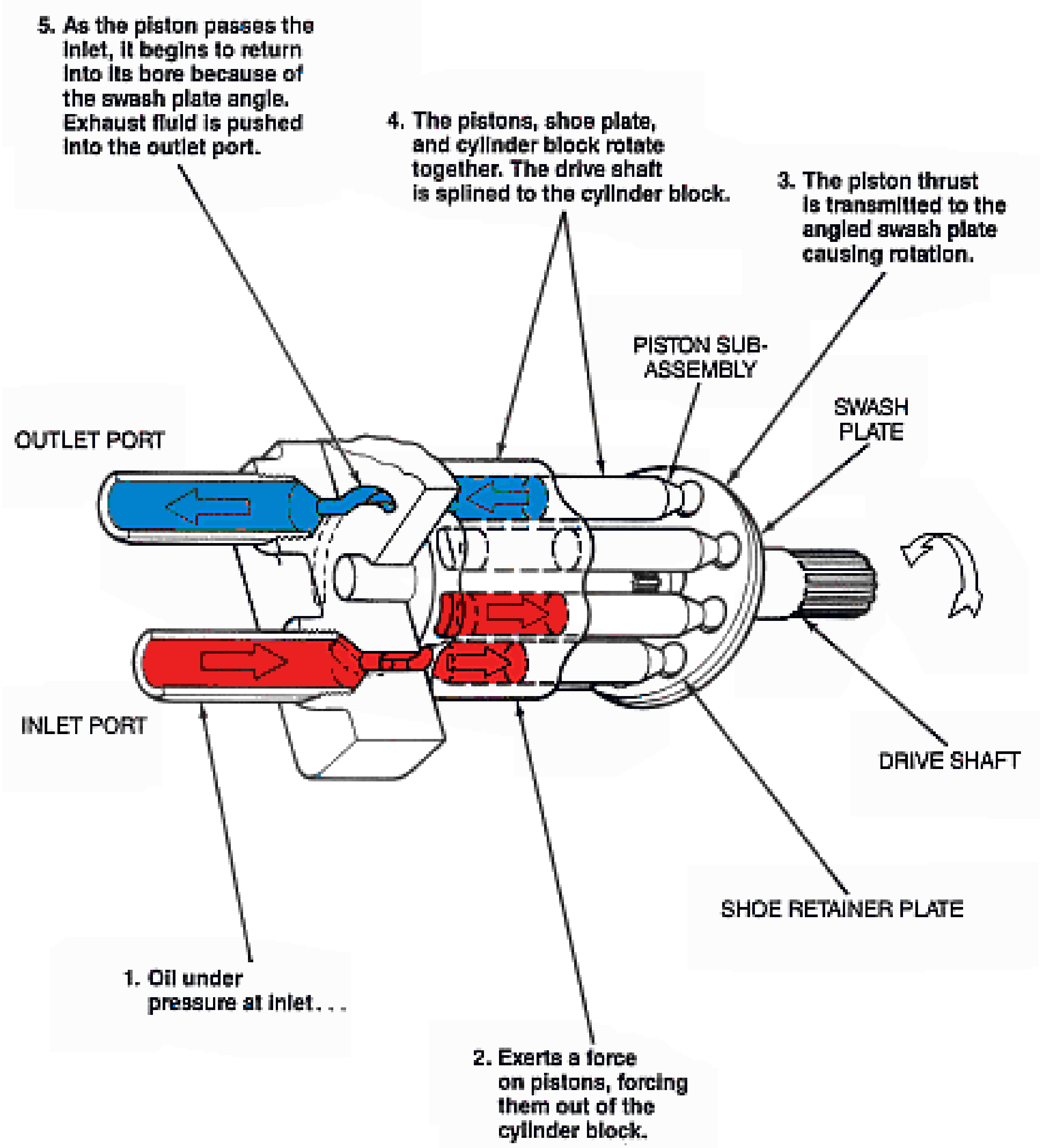
How A Gear Pump Works



APE Piston Pumps

- APE units may use a piston pump (usually for clamp flow) and the next slide shows how they work.
- They are different in design but still produce flow only, the same as a gear pump shown earlier.

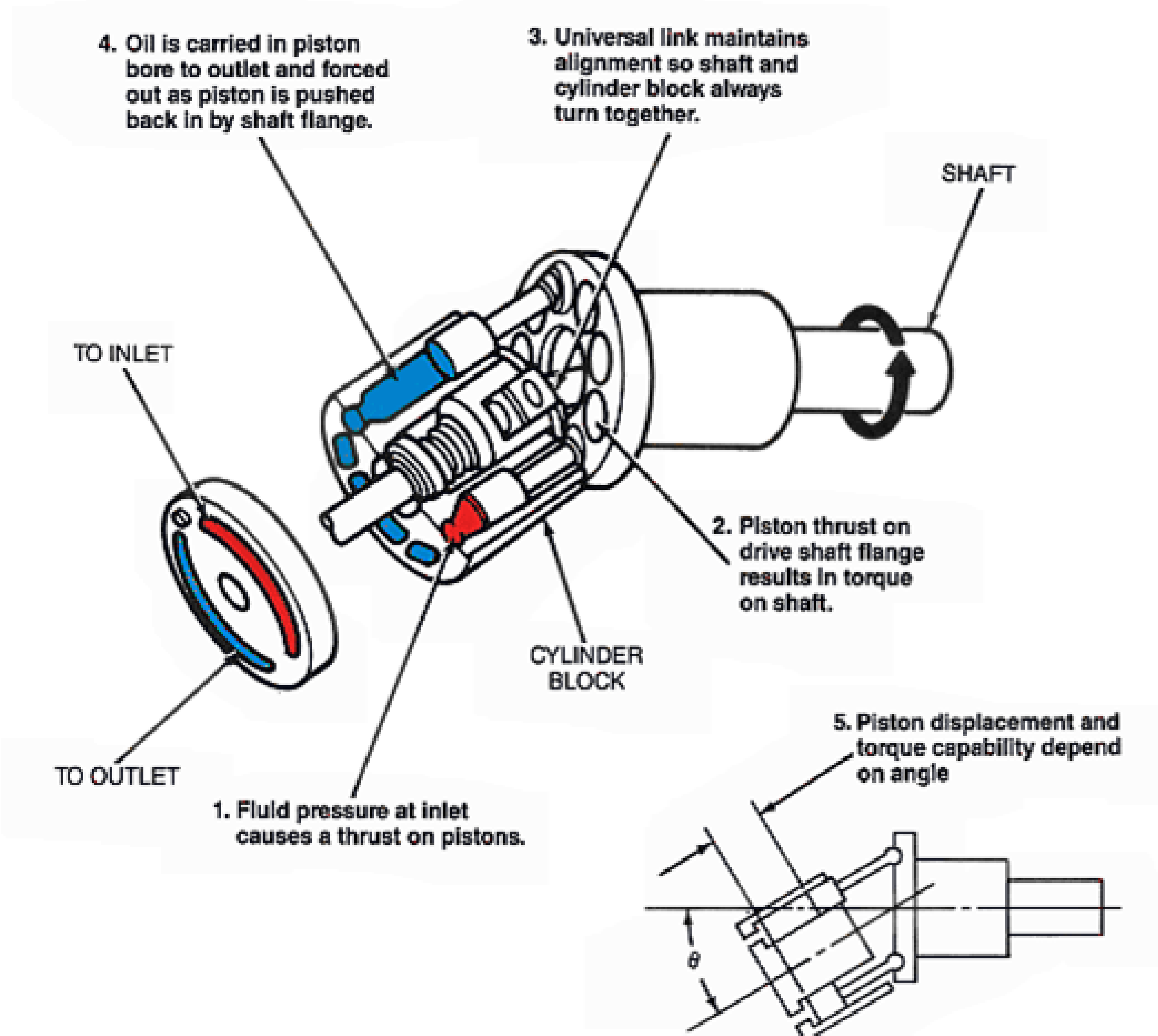
How A Piston Pump Works



APE Vibro Motor

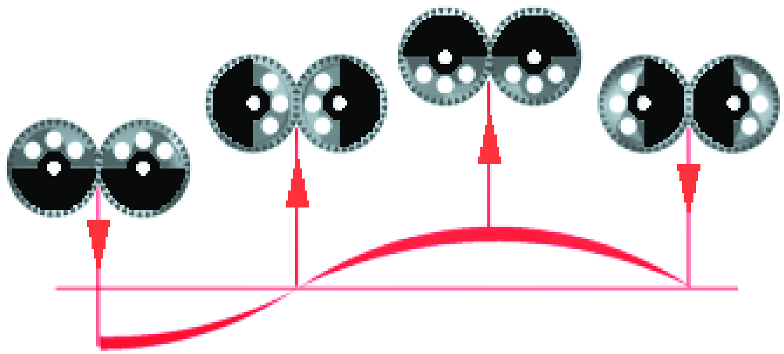
- The next slide shows what a vibro hydraulic motor looks like. It simply takes fluid pressure and converts it to rotational torque to turn the vibro eccentrics in the vibro.
- When the eccentrics turn you get the up and down motion required to vibrate the pile into the ground.

How A Piston Motor Works



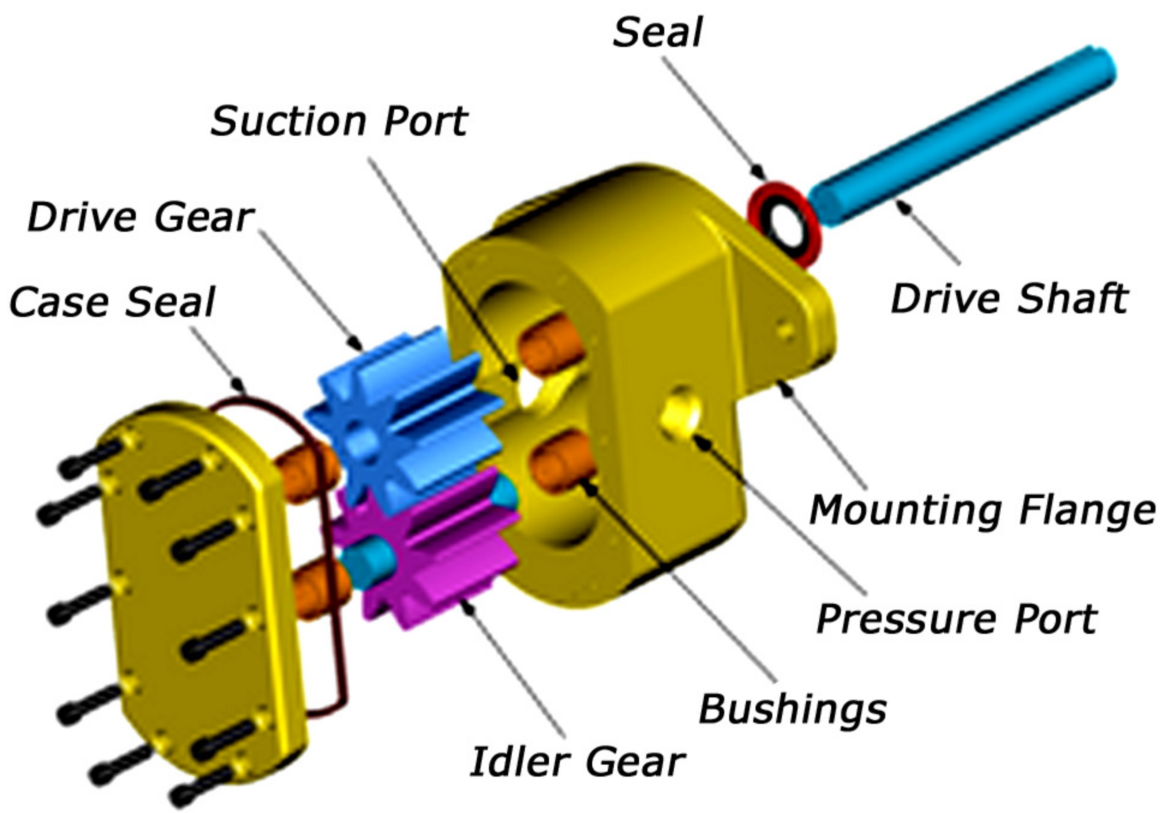
What Motors Turn In The APE Vibro

APE eccentric used in vibros turned by hydraulic motor.



Gear Pump

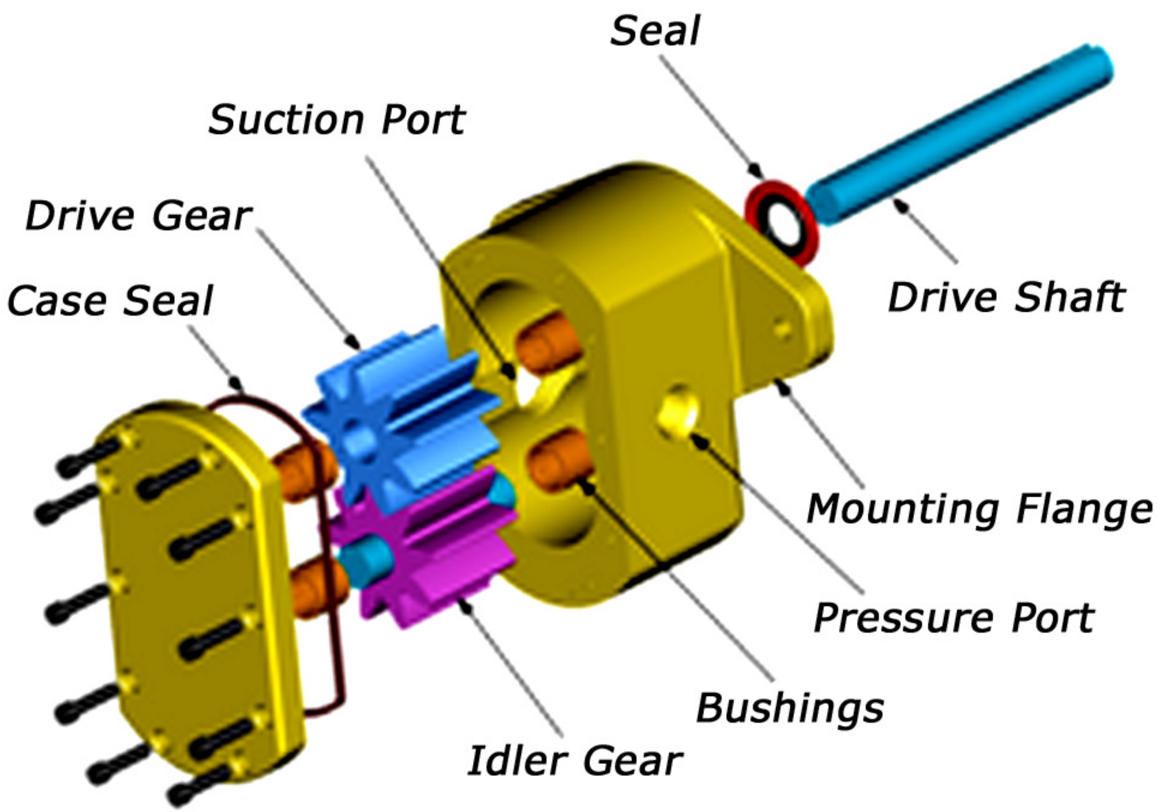
A Gallon
Has 231
Cubic
Inches



The above pump is very simple. Rotating the drive shaft causes the gears to rotate and move oil. The faster the shaft rotates, the more oil it displaces. Output is measured by counting the amount of oil it pumps in one revolution. Gears come in different widths so a wider gear set will move or pump more oil per revolution. Pump output is measured in cubic inches.

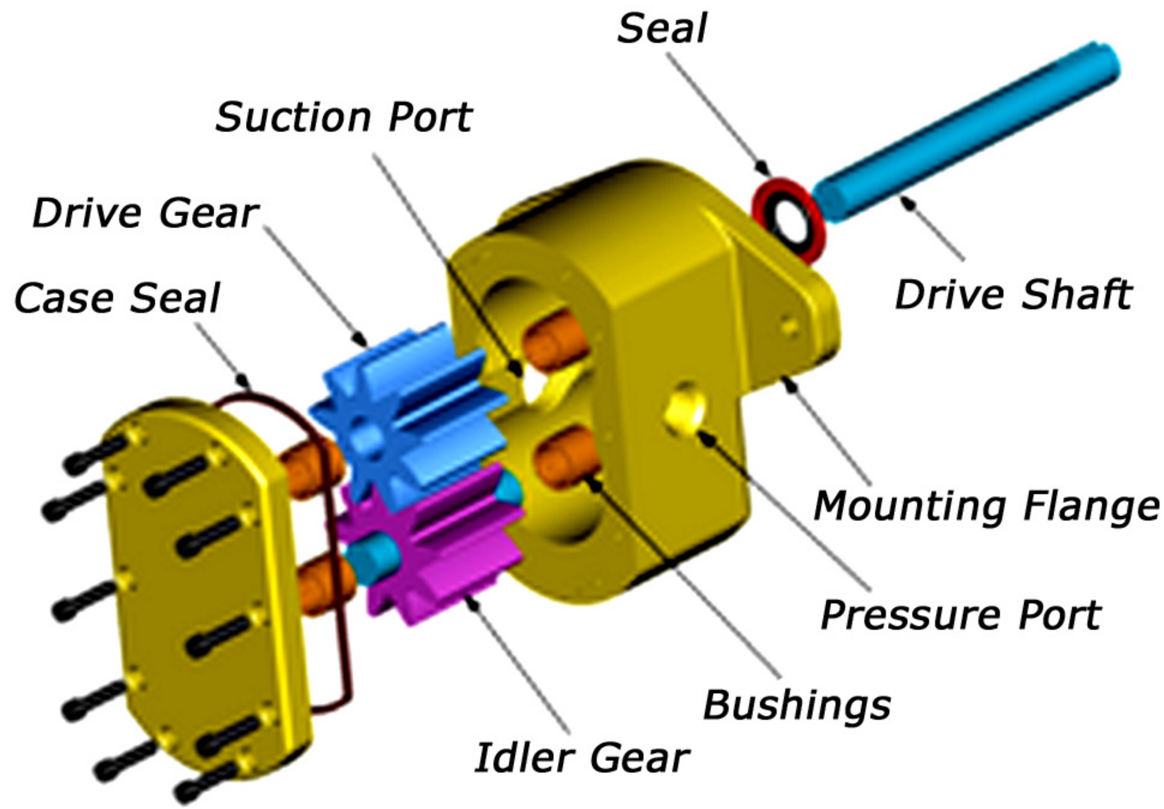
Gear Pump Output:
Cubic Inches X RPM

A Gallon
Has 231
Cubic
Inches



Gear sets are sized in accordance to their cubic inch of output (displacement) per revolution. Therefore, these gears could be size 3.6 which would mean 3.6 cubic inches of displacement per revolution. Total output is measured by calculating total cubic inches per minute so you would multiply 3.6 times the rotational speed per minute to get the total output.

How To Calculate Gallons Per Minute (GPM)



A Gallon Has 231 Cubic Inches

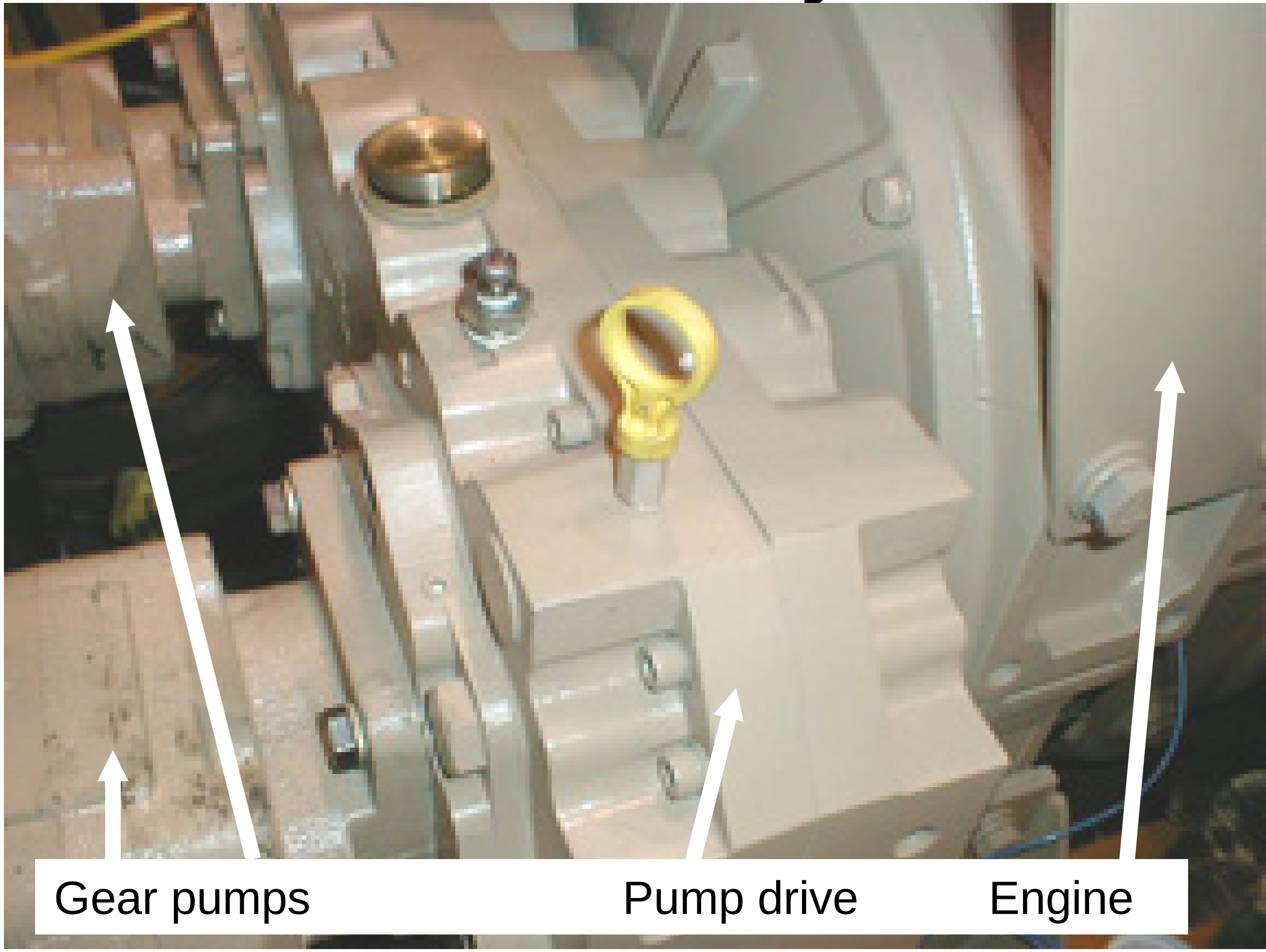
If the gears In this pump are size 3.6 then it displaces 3.6 cubic inches of oil per revolution. To find total gallons per minute (GPM) just multiply the cubic inches of displacement of the gears by the total speed the shaft turns in one minute. Example: Lets say the shaft turns 2100 rpm. The math would look like this: 3.6 X 2100 = 7,560 cubic inches.

There are 231 cubic inches in one gallon so divide 231 into 7,560 as follows:

7,560/231= 32.72 gallons per minute. (theoretical only)

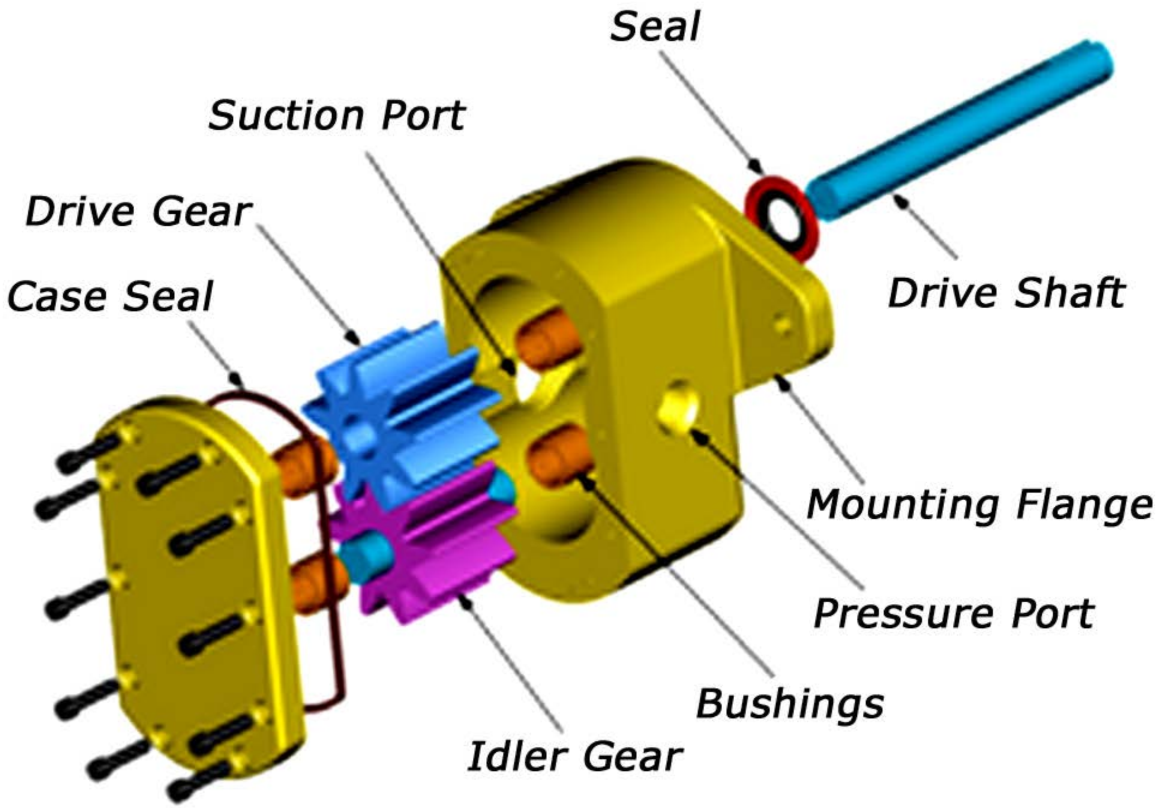
Pump Drives Are Not Always 1:1

When calculating the flow of a gear pump you must consider the ratio of the pump drive. APE pump drives are suppose to be 1:1 with the engine crank shaft. Some pump drives may turn the pump faster (or slower) than the engine is turning. For example, the J&M (ICE) 1412 power unit pump drive ratio was actually a reduction. The engine turned faster than the pumps.



Do not always assume that the pump drive is turning at the same rpm as the engine. Ratios are stamped on the pump drive.

How To Calculate Gallons Per Minute (GPM)



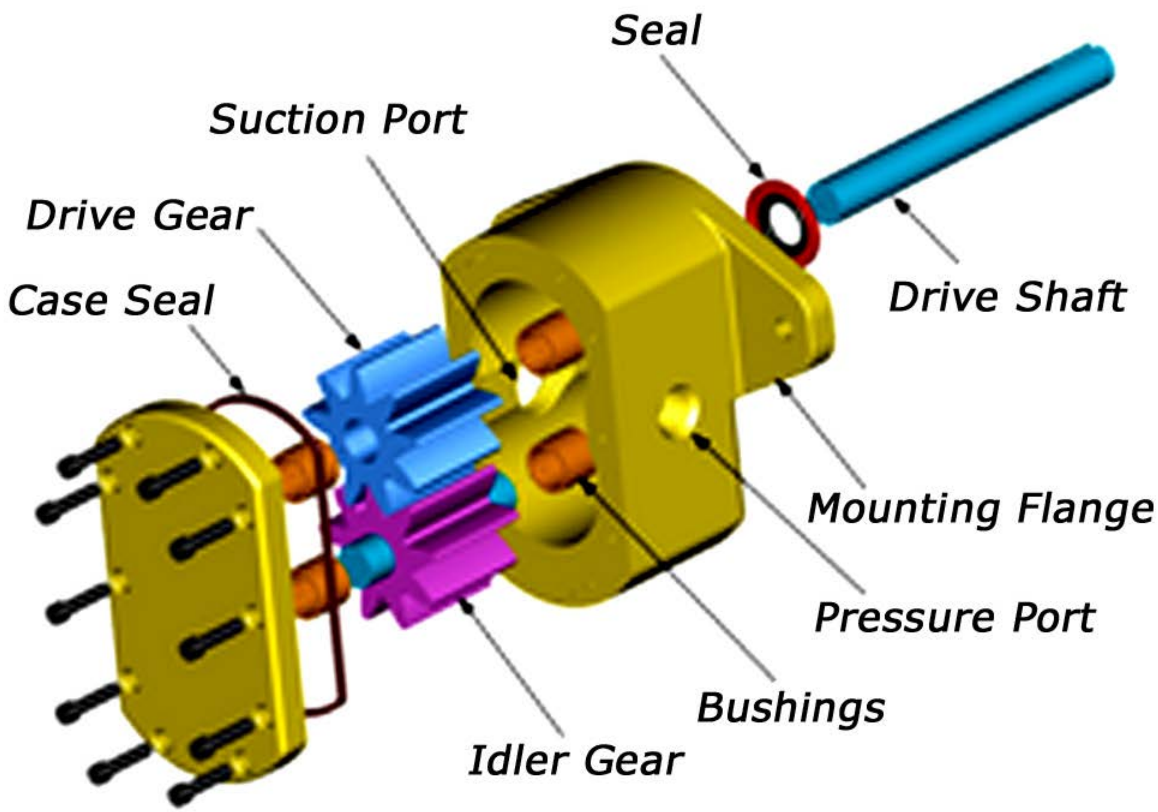
A Gallon Has 231 Cubic Inches

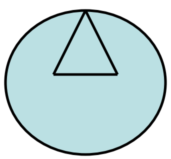
If the gears In this pump are 4.5 cubic inch then it pumps 4.5 cubic inches per revolution. To find total gallons per minute (GPM) just multiply the cubic inches of the gears by the total speed the shaft turns in one minute. Example: Lets say the shaft turns 2100 rpm. The math would look like this: 4.5 X 2100 = 9450 cubic inches.

There are 231 cubic inches in one gallon so divide 231 into 9,450 as follows:

9.450/213= 40.90 gallons per minute. (theoretical only)

Nature Of A Fixed Pump

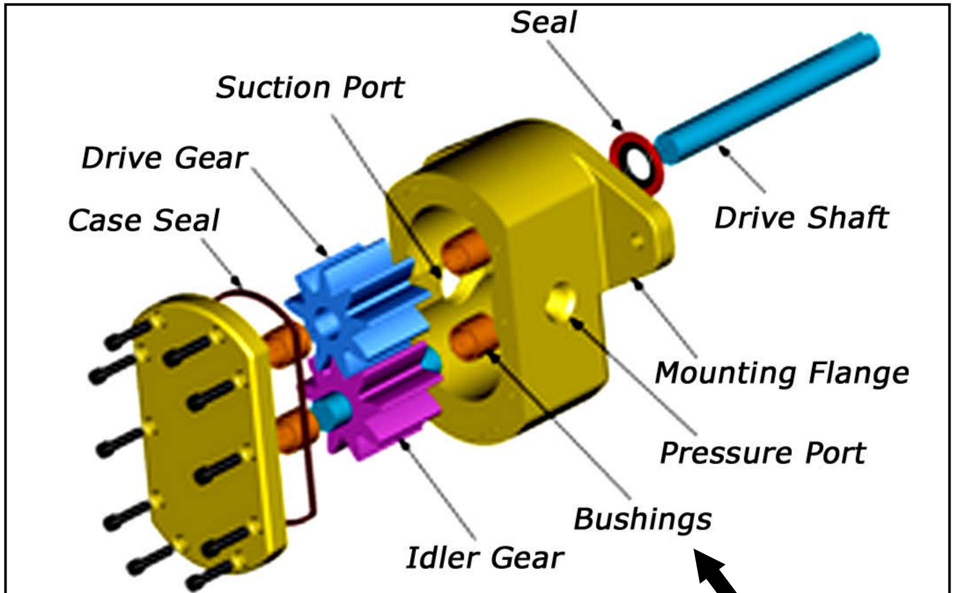


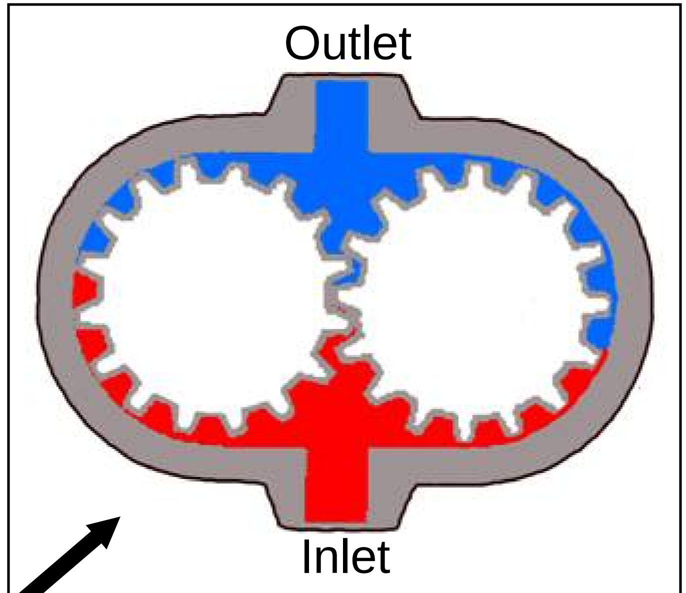


Symbol

What does “fixed pump” mean? It means the pump displaces a fixed amount of oil per revolution. Much like a squirt gun. Squeeze the trigger and it pumps the same amount every time. This pump displaces the same amount every time it rotates. It pumps the moment the shaft turns and keeps pumping until the shaft stops. The faster you turn it, the more oil it displaces. You can slow down the output by slowing down the shaft speed. (turning down the rpm of the engine)

Call A Pump A Pump And A Motor A Motor. Know The Difference!





Gear Pump (This Turns That) **Gear Motor**

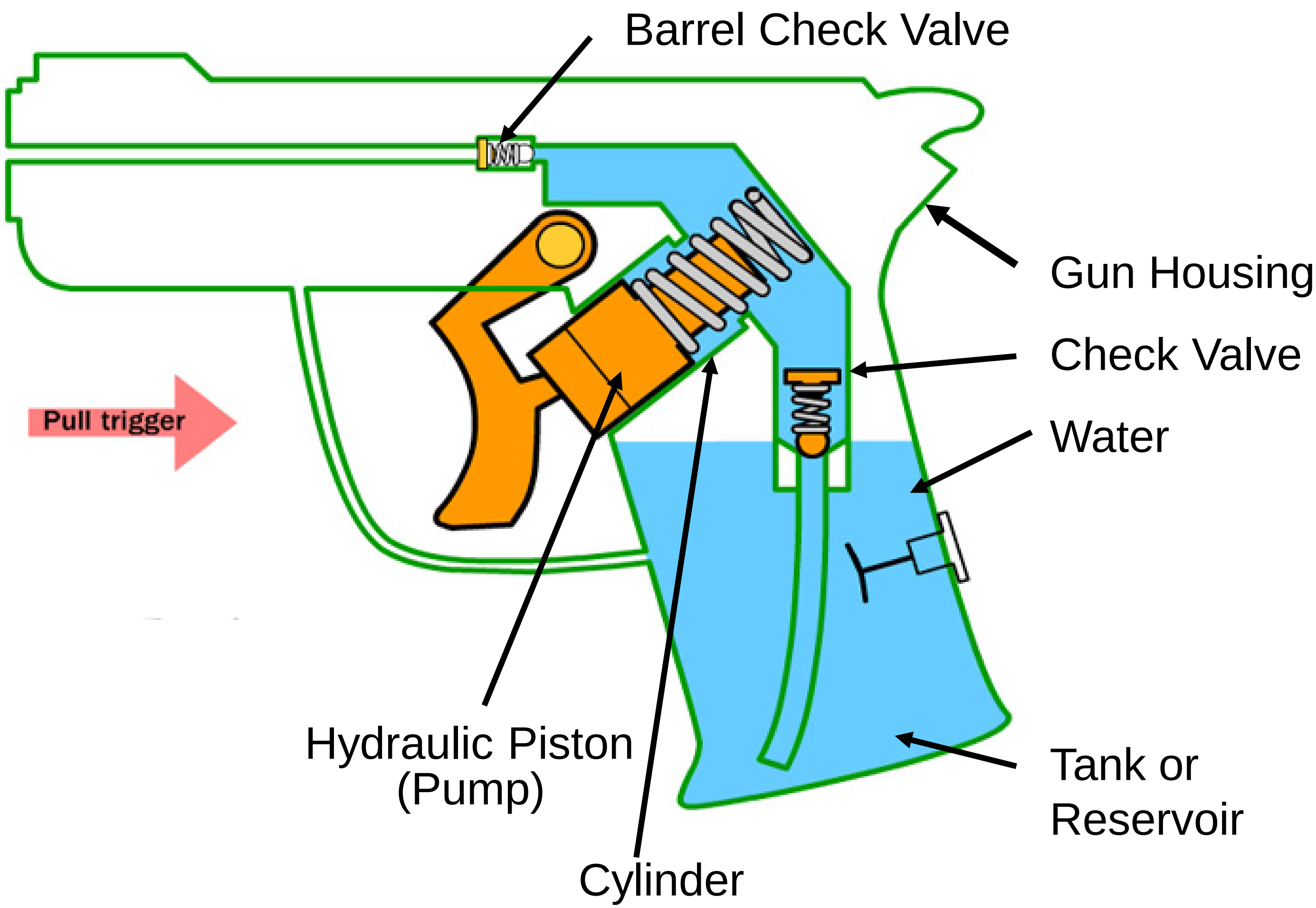
Pumps get turned by engines, motors get turned by pump displacement.

Squirt Gun Hydraulics (Piston Pump)

Squeezing the trigger moves the hydraulic piston inward which forces the compressed water to squirt out the barrel check valve.

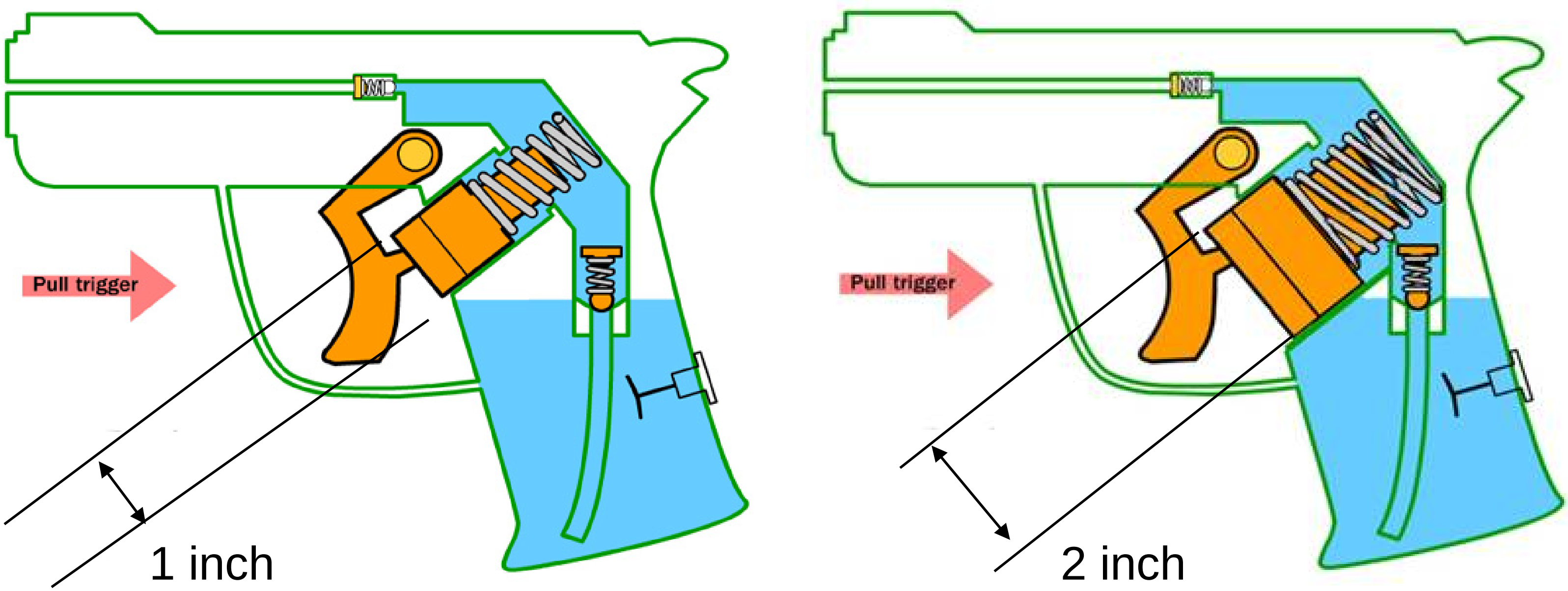
When the trigger is released, the spring moves the piston out, creating a vacuum that opens the tank check valve, sucking new water in the cylinder for the next shot.

Notice the check valves are the key to making hydraulics work.



This is a simple check valve type hydraulic system just like our fuel pump on the diesel hammers; check valves that stop one direction and open in another. The injector on the diesel is really a check valve that works just like the check valve in the barrel of this squirt gun.

Squirt Guns With larger Pistons Can Squirt More Water Per Stroke



Changing piston diameter will increase volume of area. In this case, more water will be trapped in the cylinder on the gun to the right so it will spray more water per stroke. However, it will take more finger muscle to squeeze the one on the right, just as it takes more horsepower to increase pump output. Gear pumps increase with gear size, piston pumps increase with piston size or length of stroke or by adding more pistons.

Delivery, gpm at 1800 rpm			Horsepower Input at 1800 rpm		
0 psi	500 psi	1000 psi	0 psi	500 psi	1000 psi
1.8	1.5	1.1	.20	0.9	1.5
2.7	2.4	2.0	.25	1.2	2.2
3.7	3.4	3.0	.25	1.4	2.6
5.3	5.0	4.7	.30	1.9	3.6
8.2	7.9	7.5	.35	2.8	5.2
11.5	11.0	10.6	.40	3.7	7.0

Figure 17-1. Typical performance table.

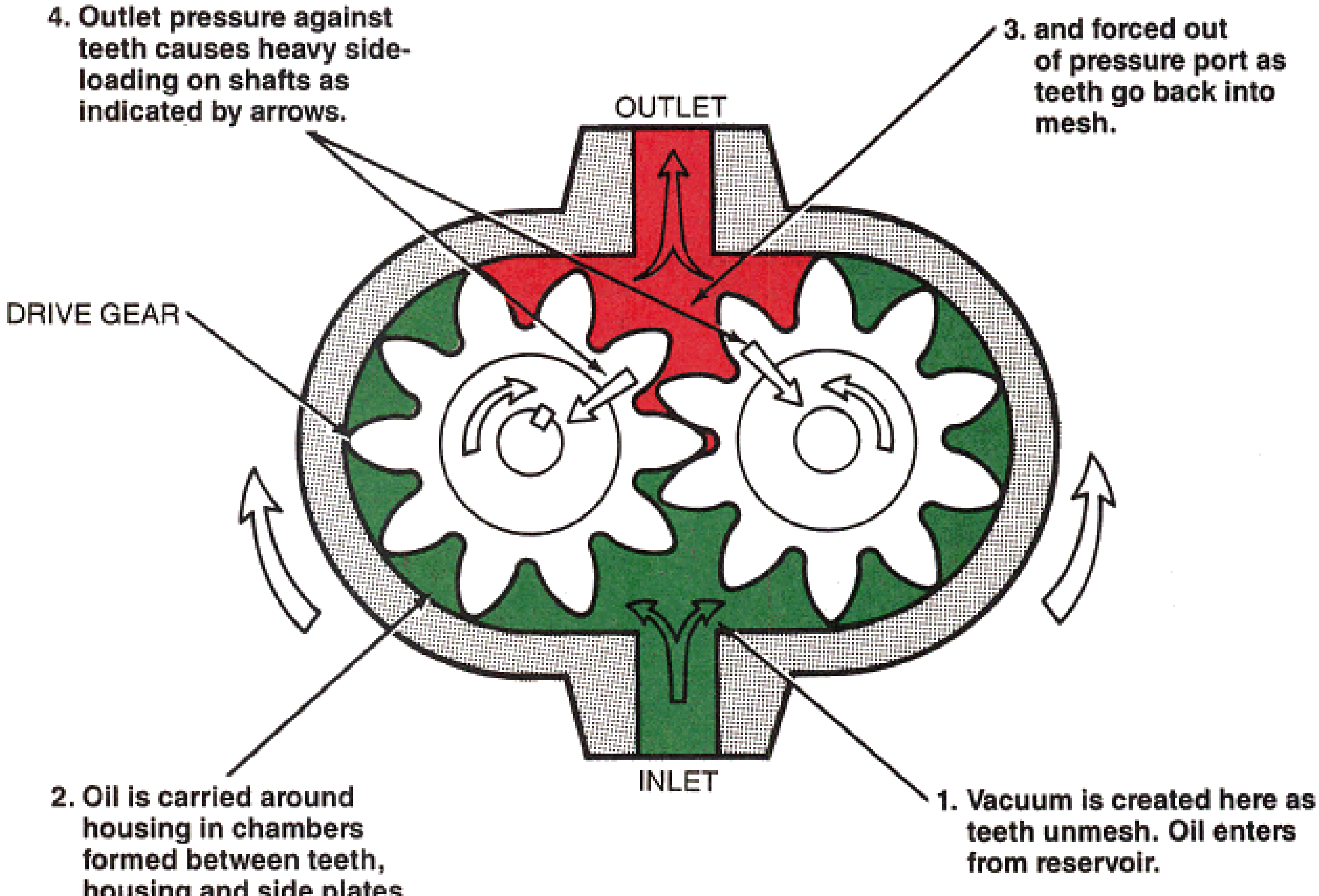


Figure 17-4. External gear pump operation.

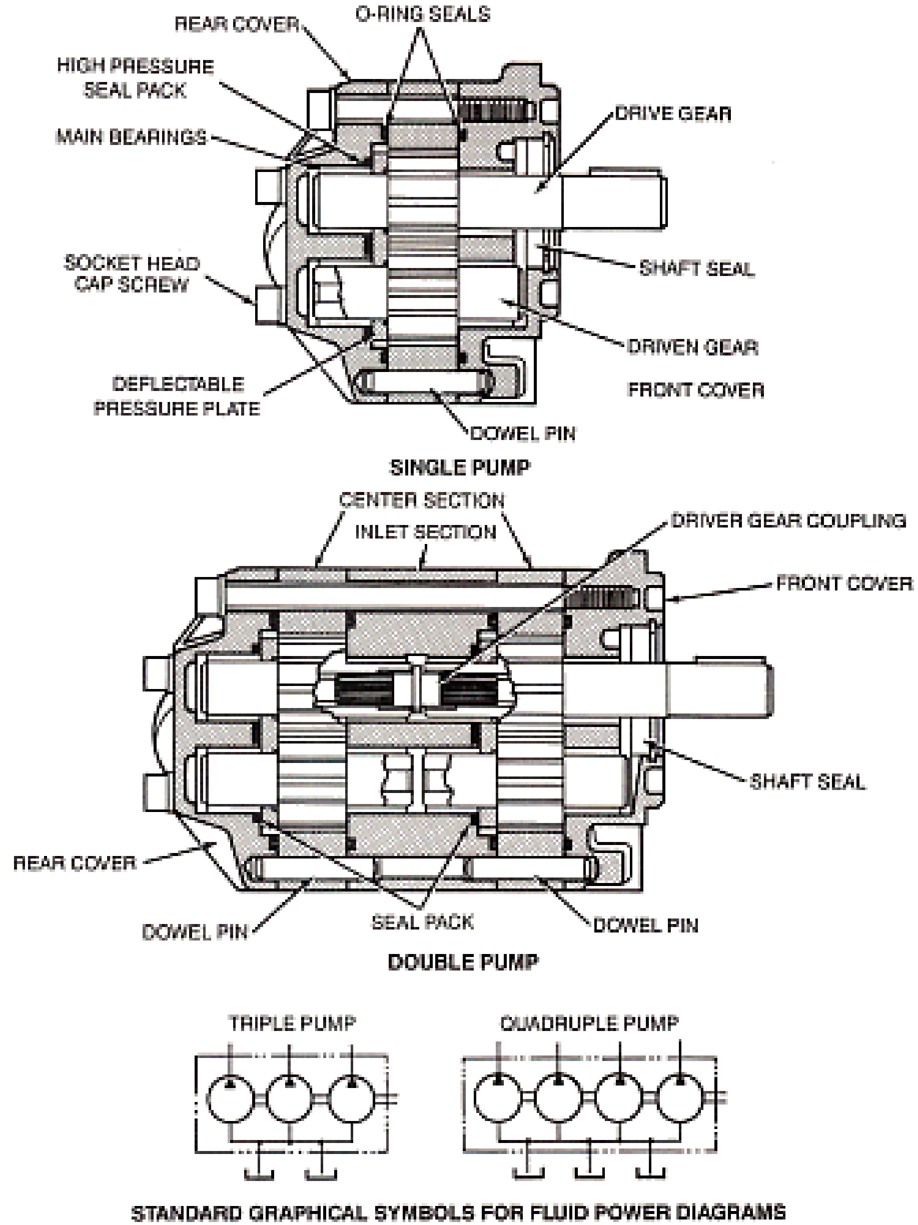


Figure 17-5. Multiple versions of the external gear pump.

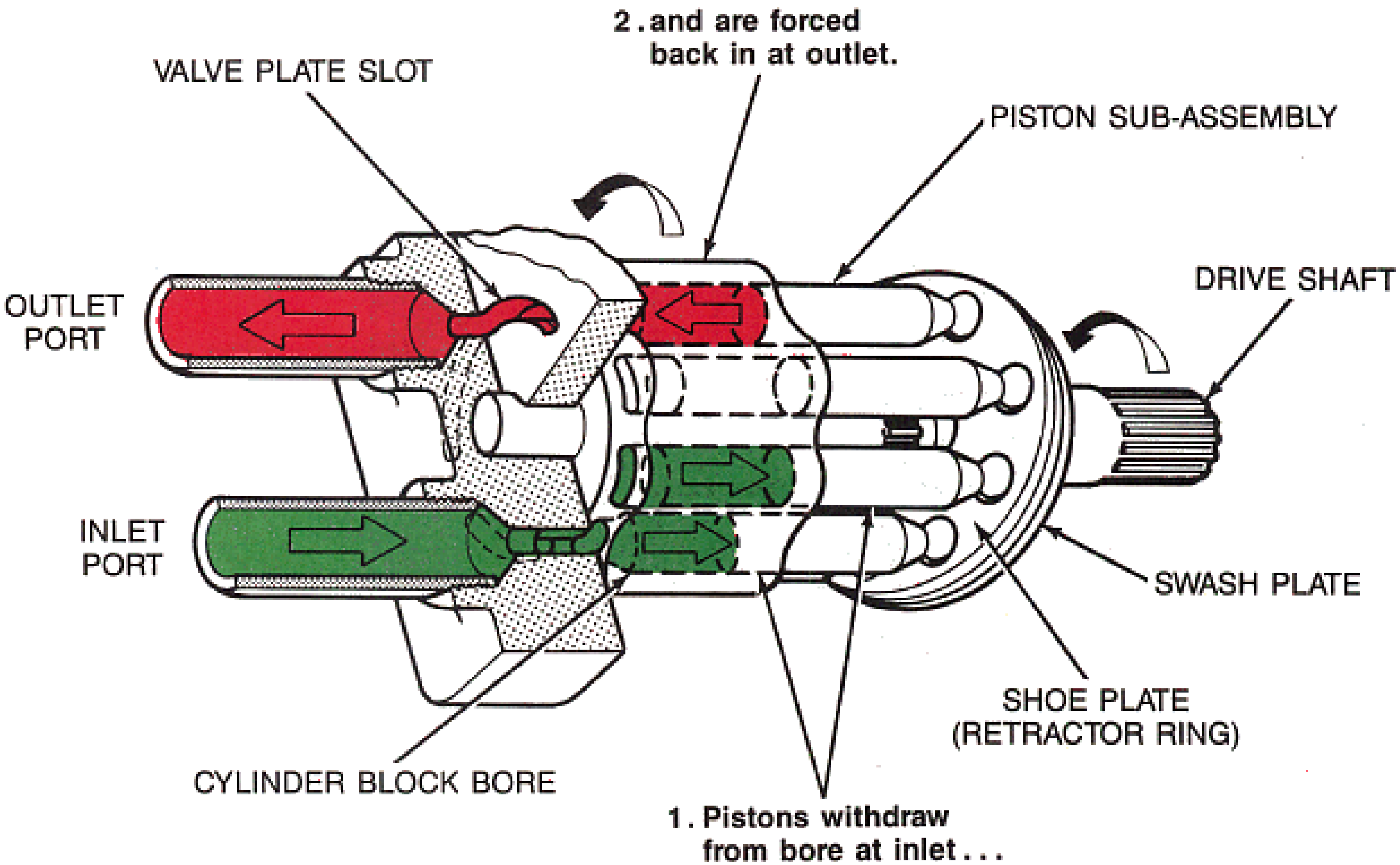
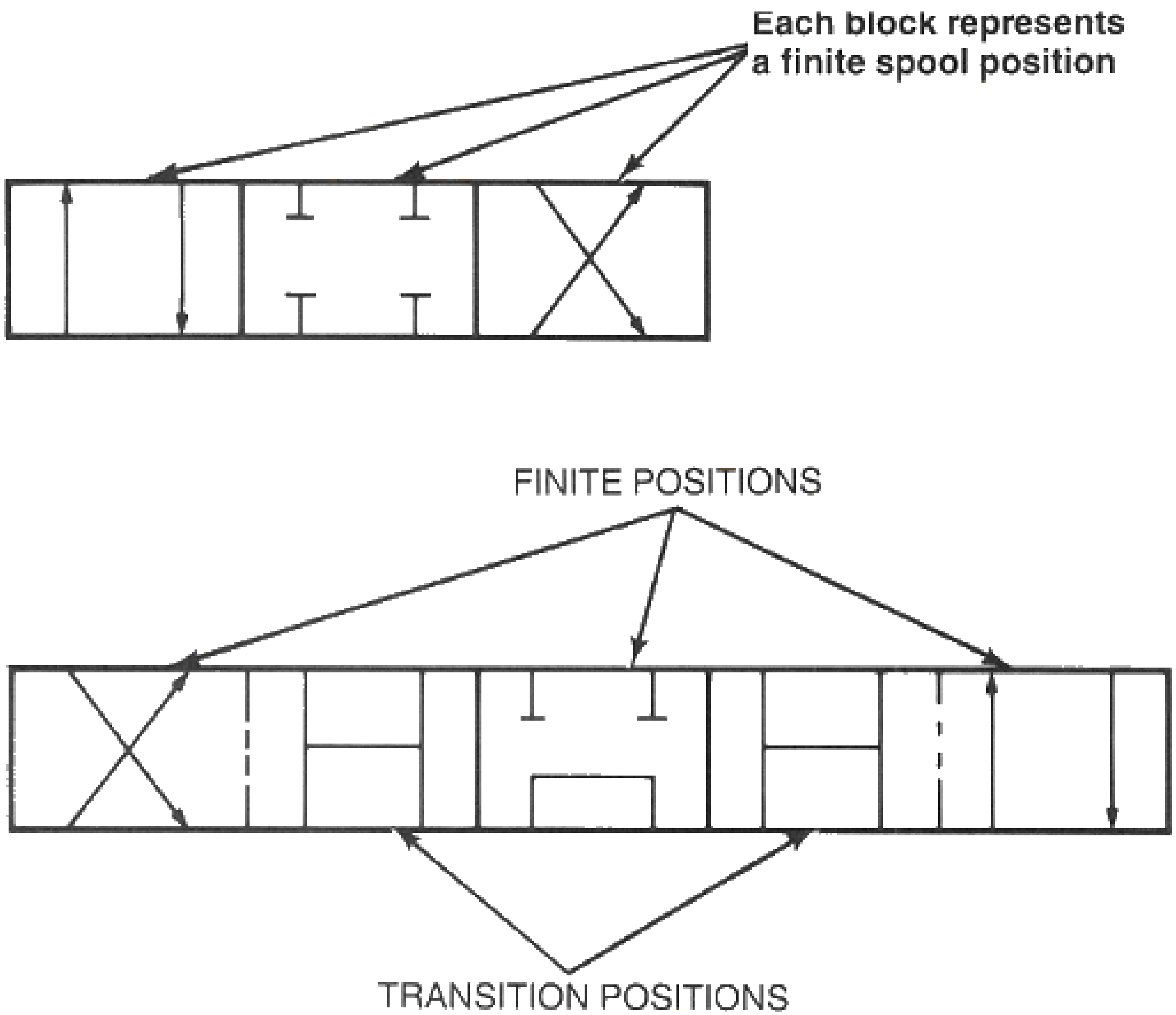


Figure 17-24. Swash plate causes pistons to reciprocate.

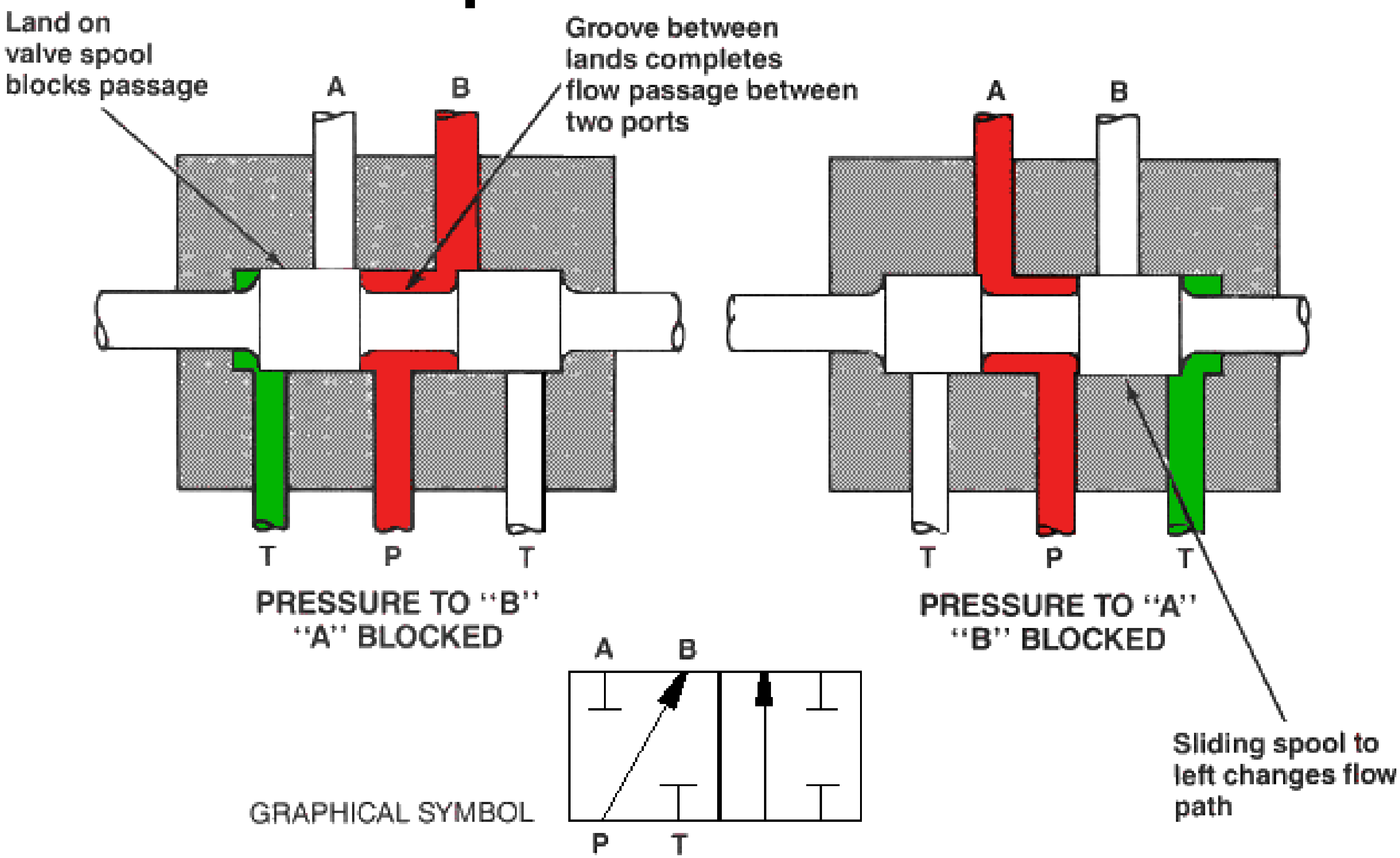
Chapter 9

Directional Valves

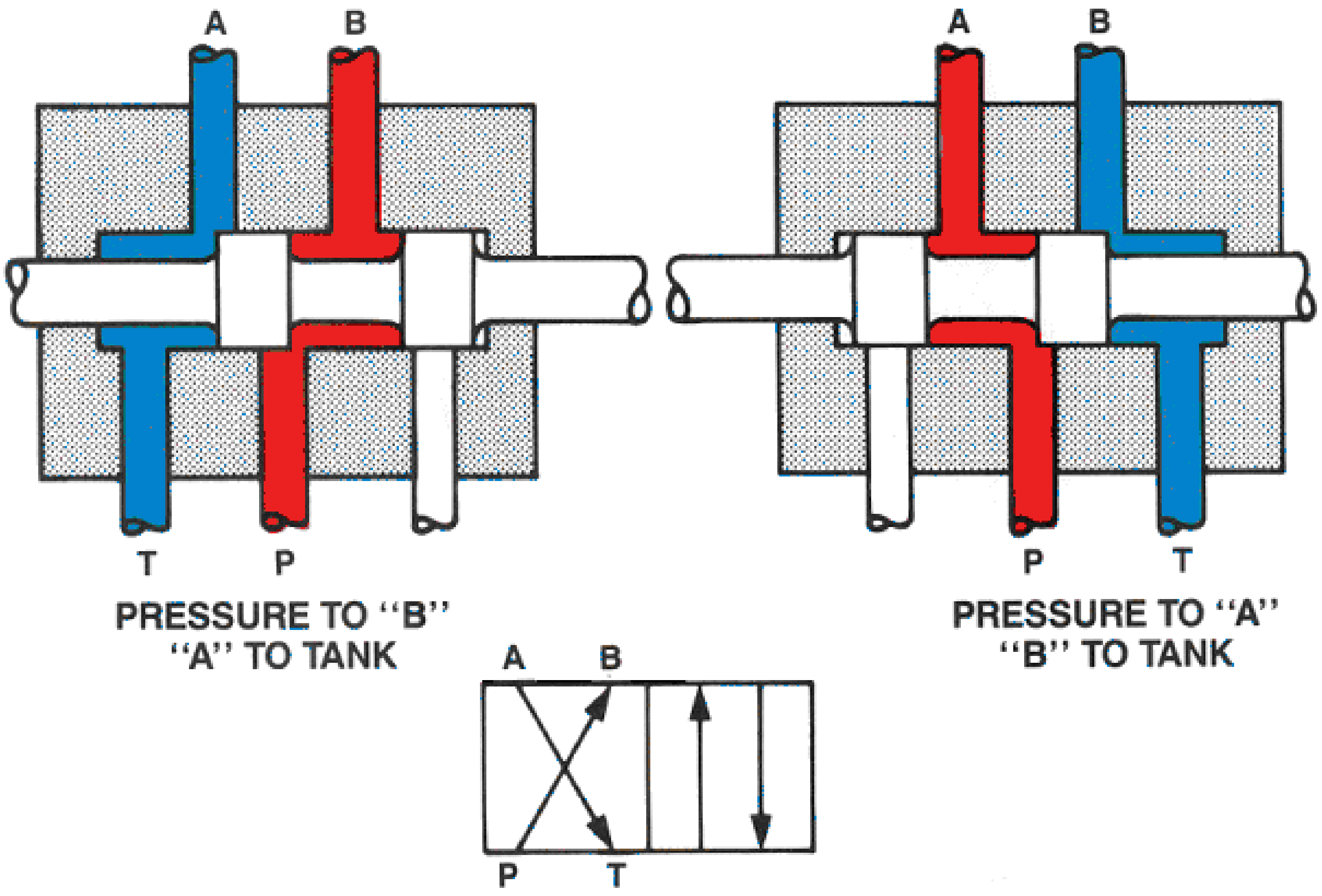
Spool Valves



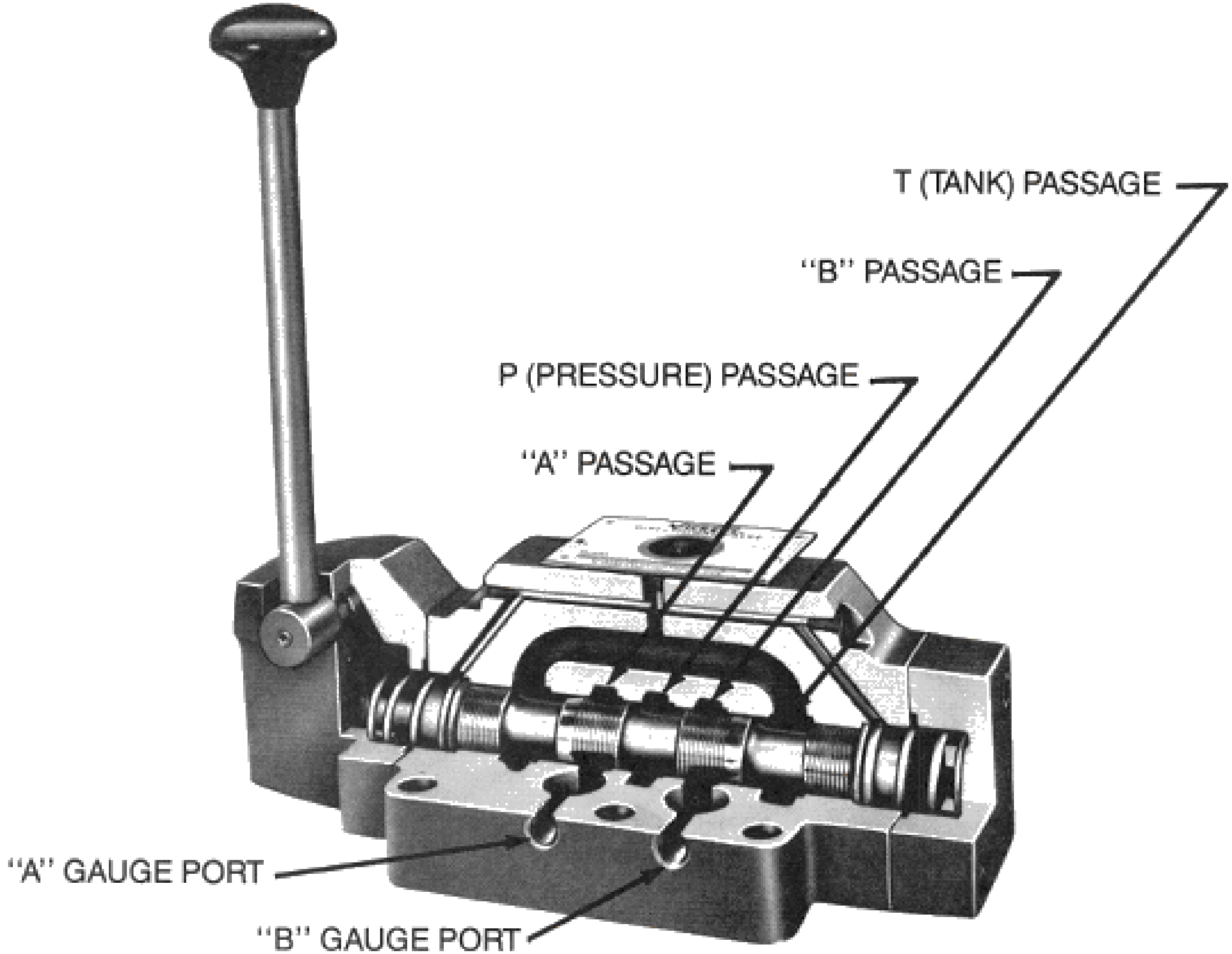
Spool Valves



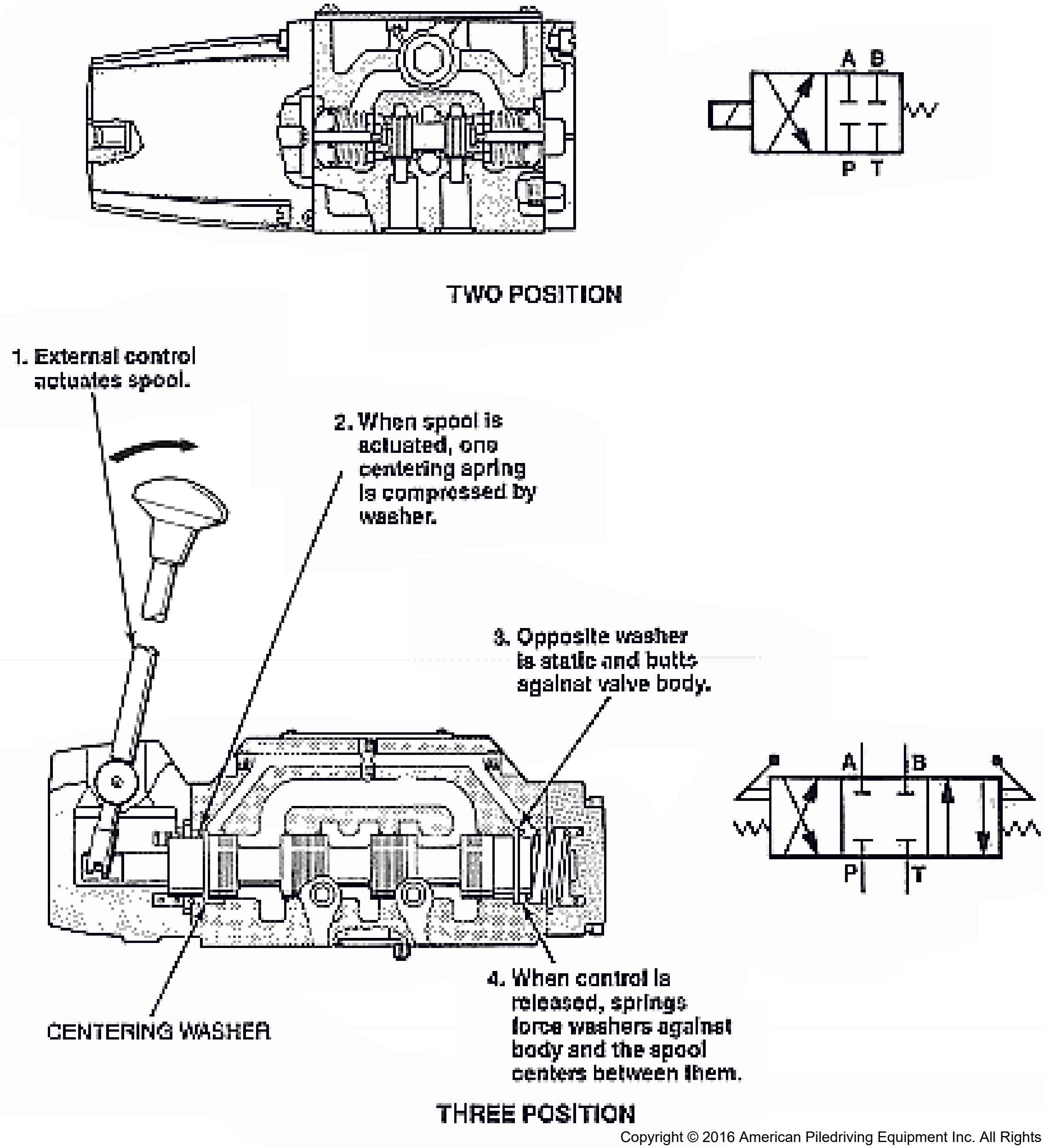
Spool Valves

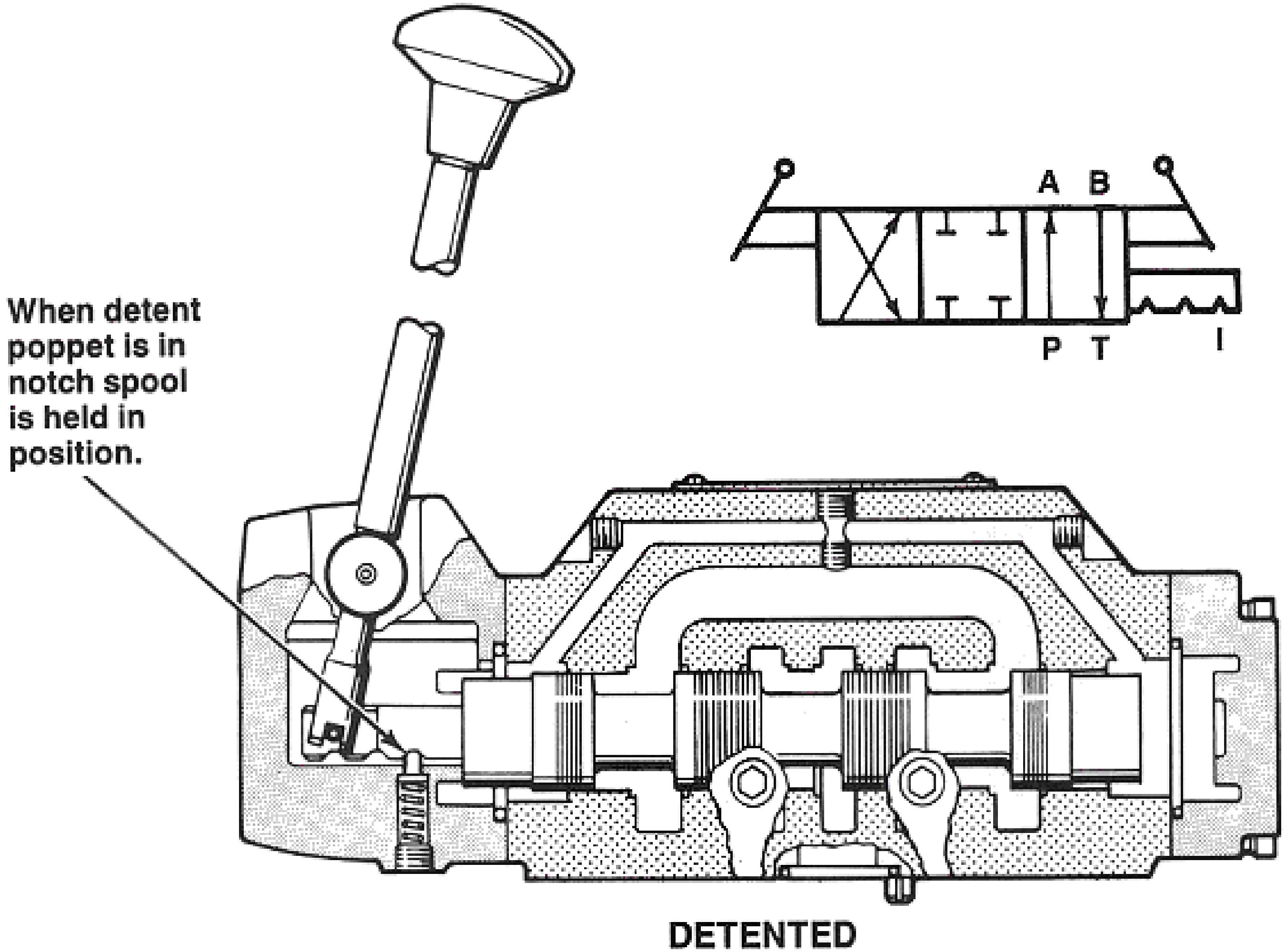


Hand Operated Spool Valves



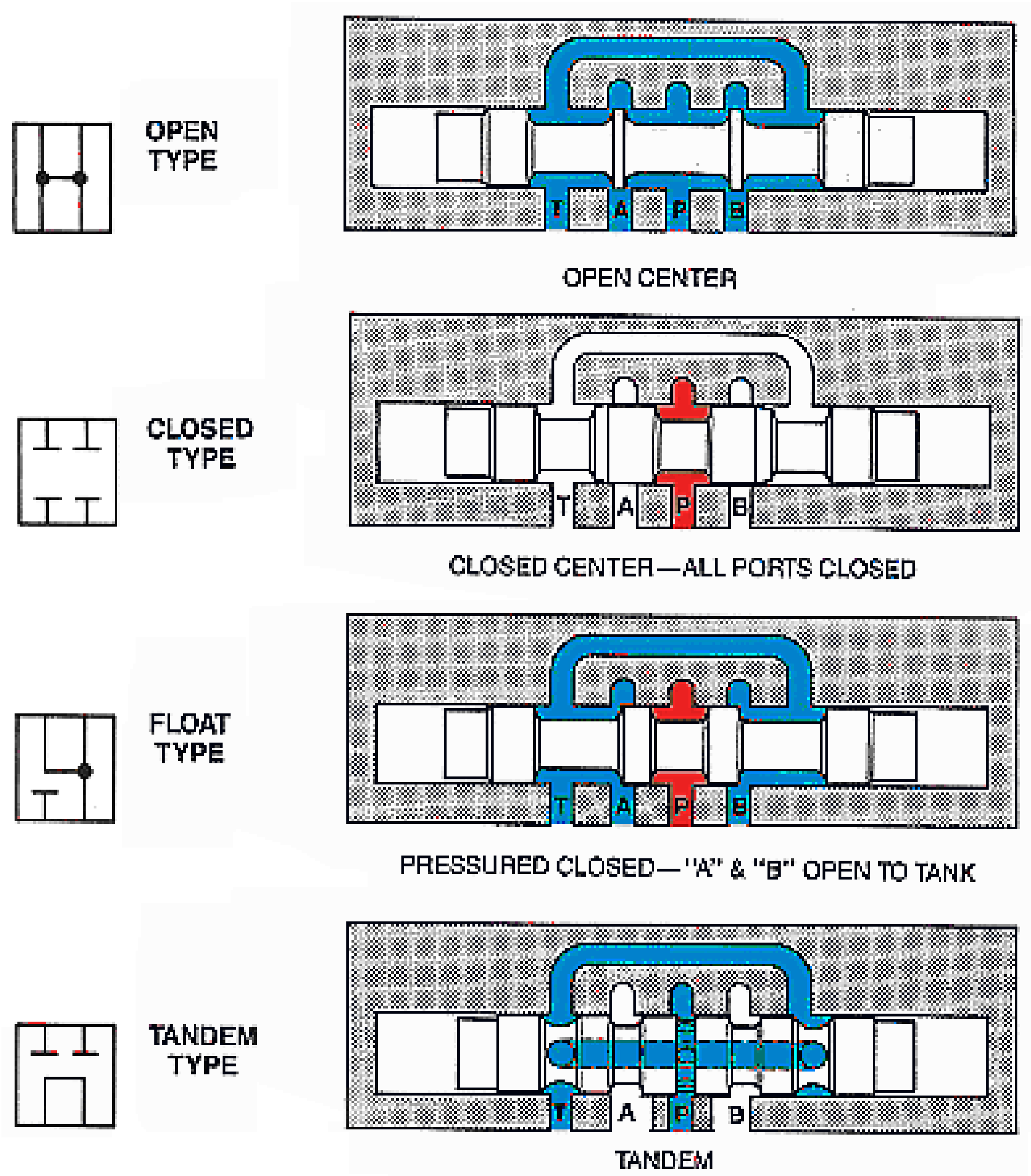
How Hand Operated Spool Valve Works



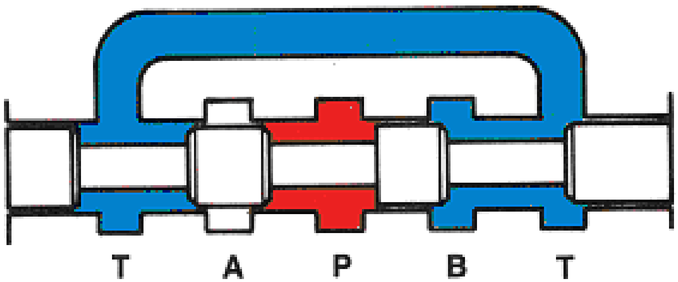


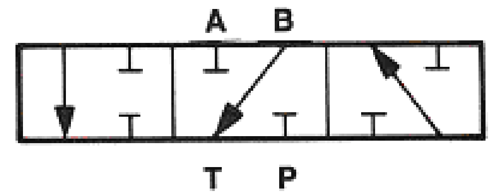
Detented Hand Operated Spool Valve

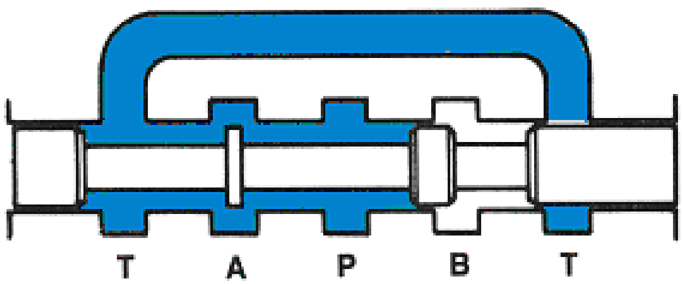
Spool Types

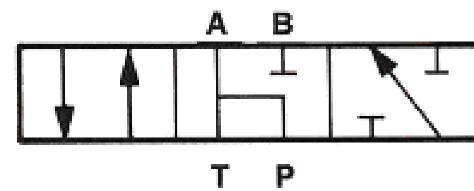

OPEN TYPE
T
A
P
B
OPEN CENTER
CLOSED TYPE
T
A
P
B
CLOSED CENTER—ALL PORTS CLOSED
FLOAT TYPE
T
A
P
B
PRESSURED CLOSED—"A" & "B" OPEN TO TANK
TANDEM TYPE
T
A
P
B
TANDEM

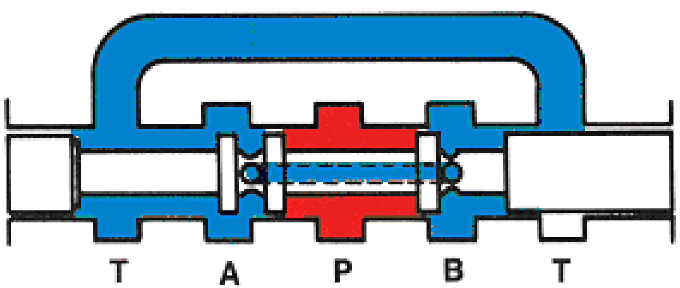
Spool Types

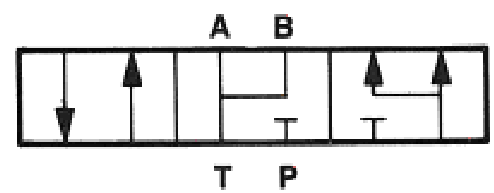




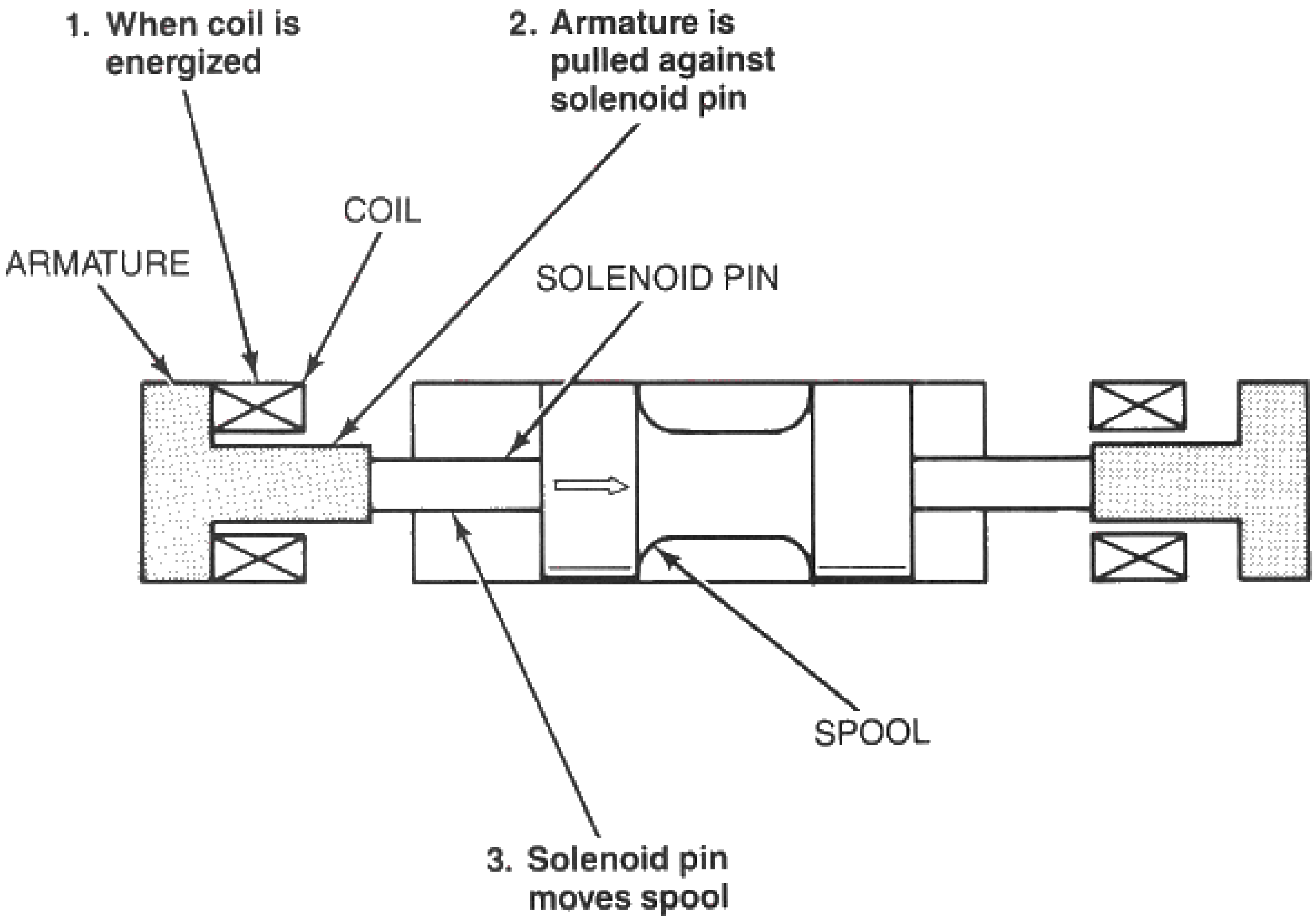


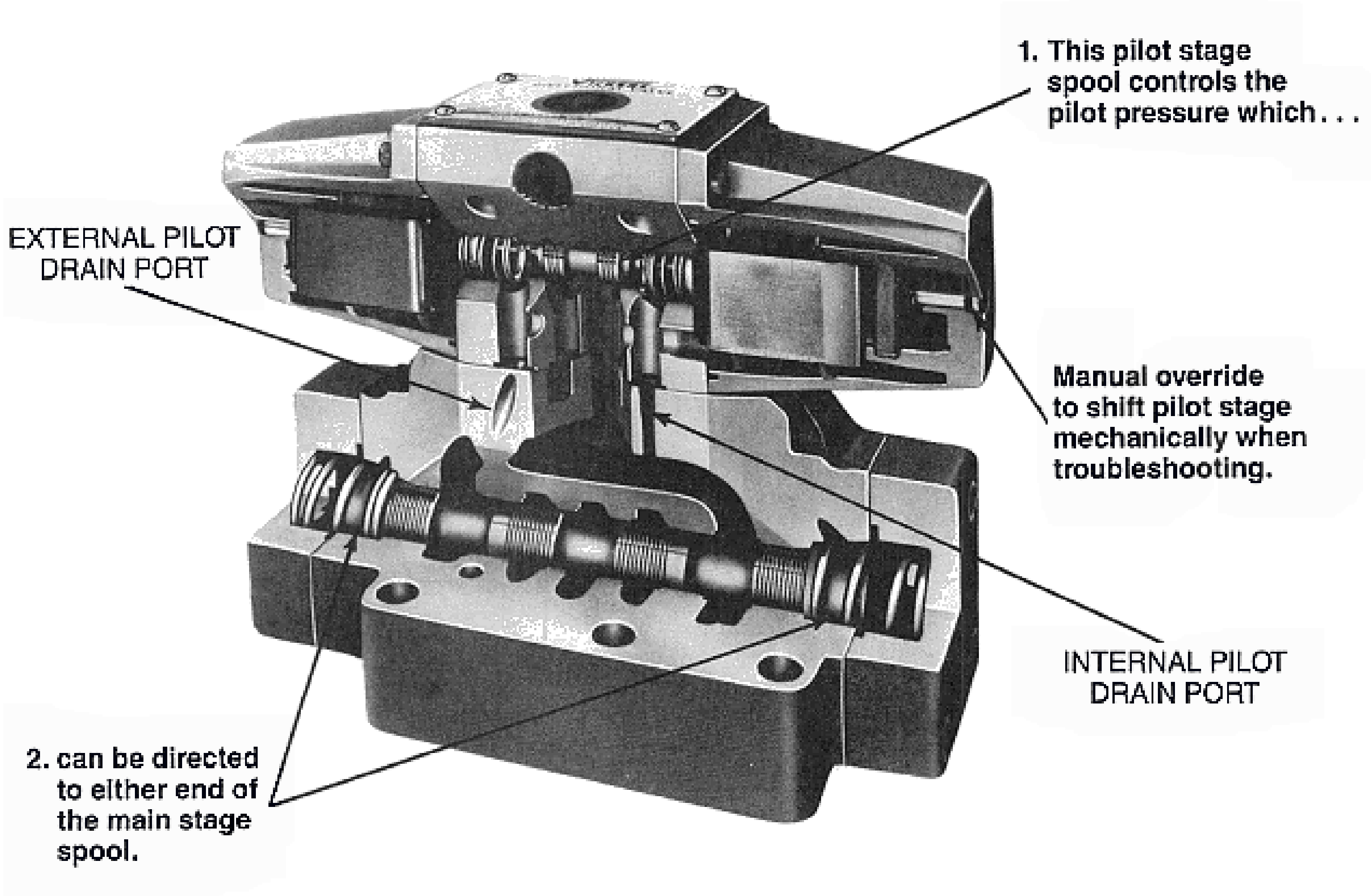






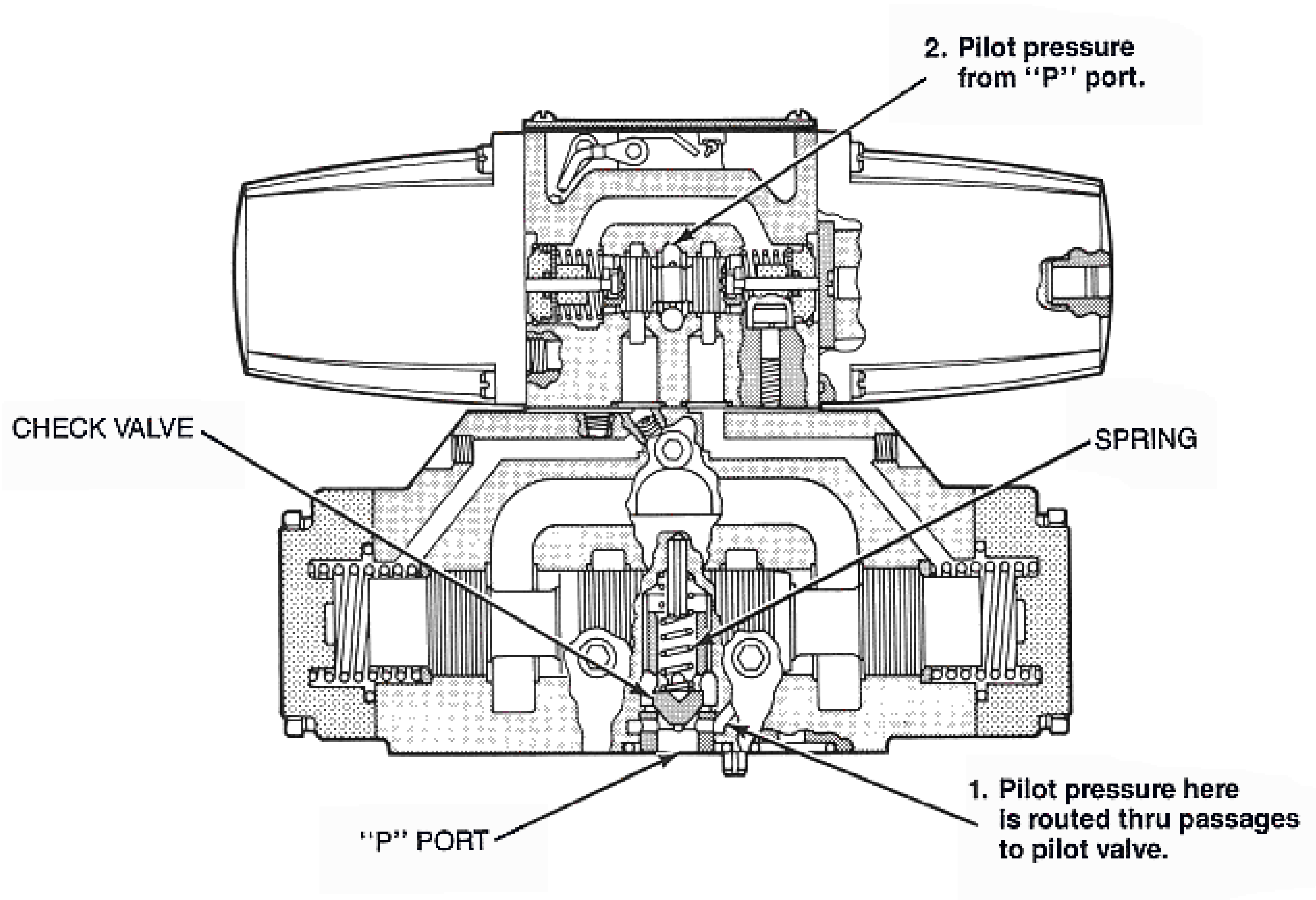
Solenoid Operated Spool Valves



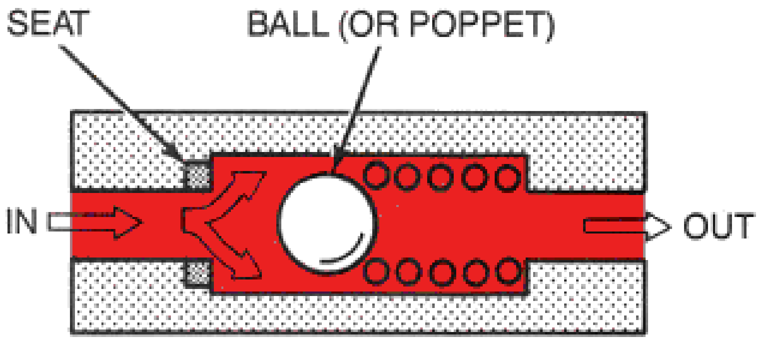


Pilot Operated Spool Valves

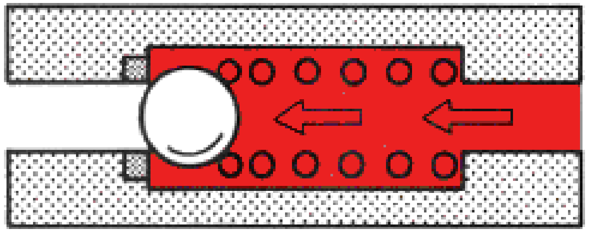
Pilot Operated Spool Valves



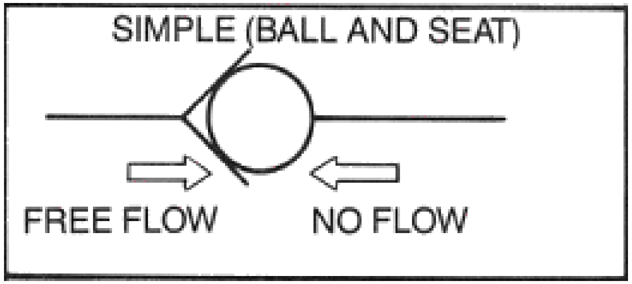
Check Valves



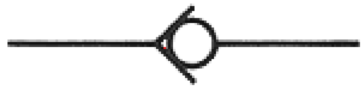
FREE FLOW ALLOWED
AS BALL UNSEATS

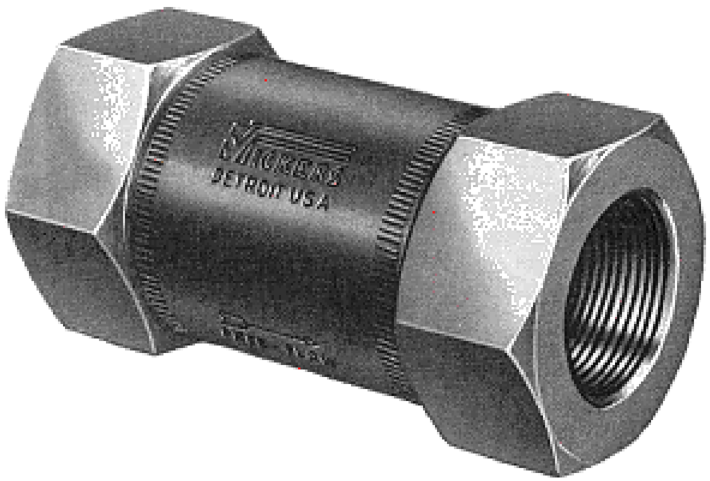


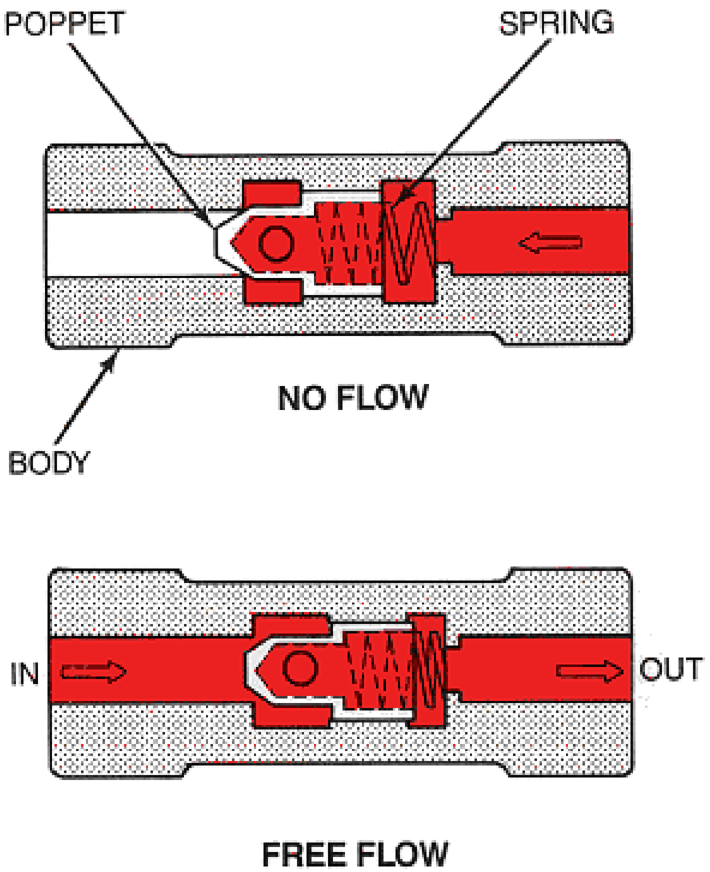
FLOW BLOCKED AS
VALVE SEATS



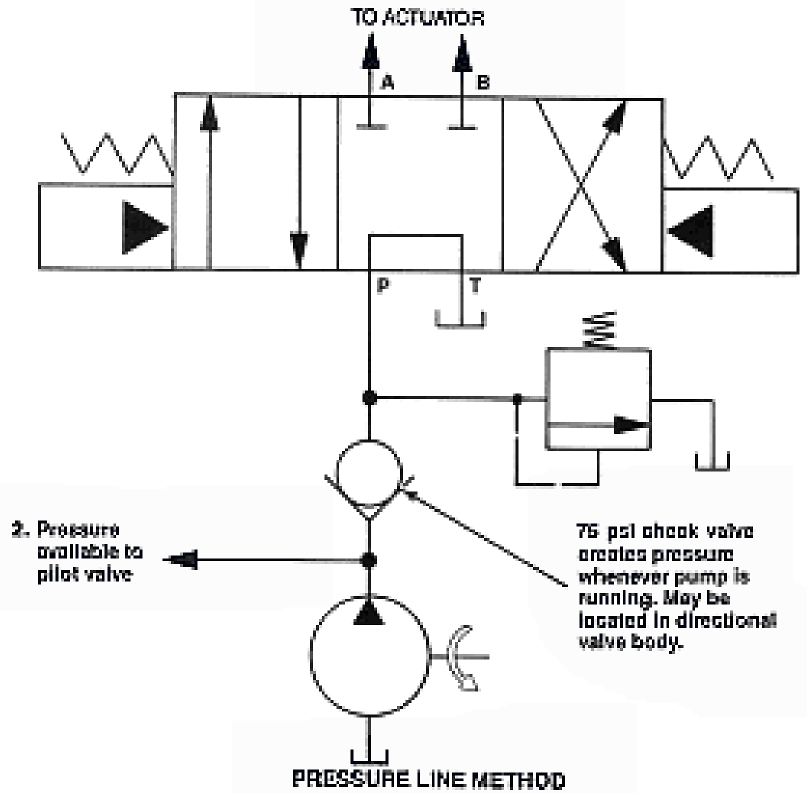
In Line Check Valves

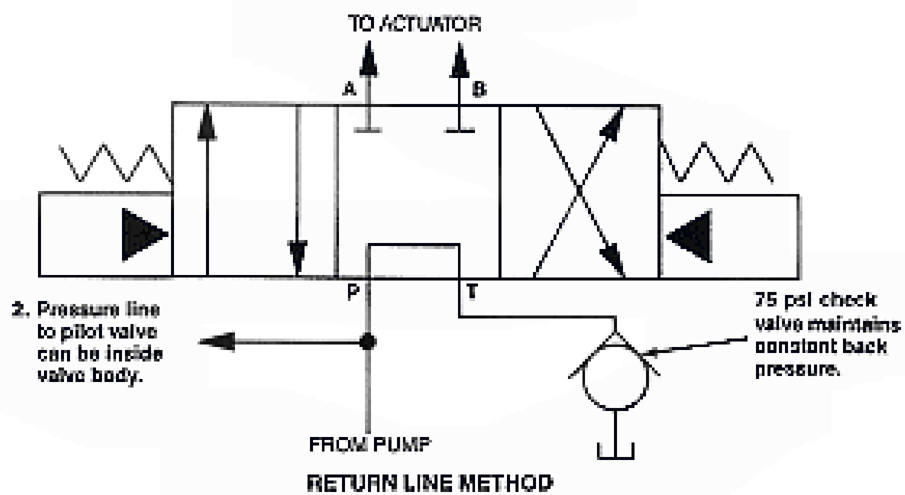




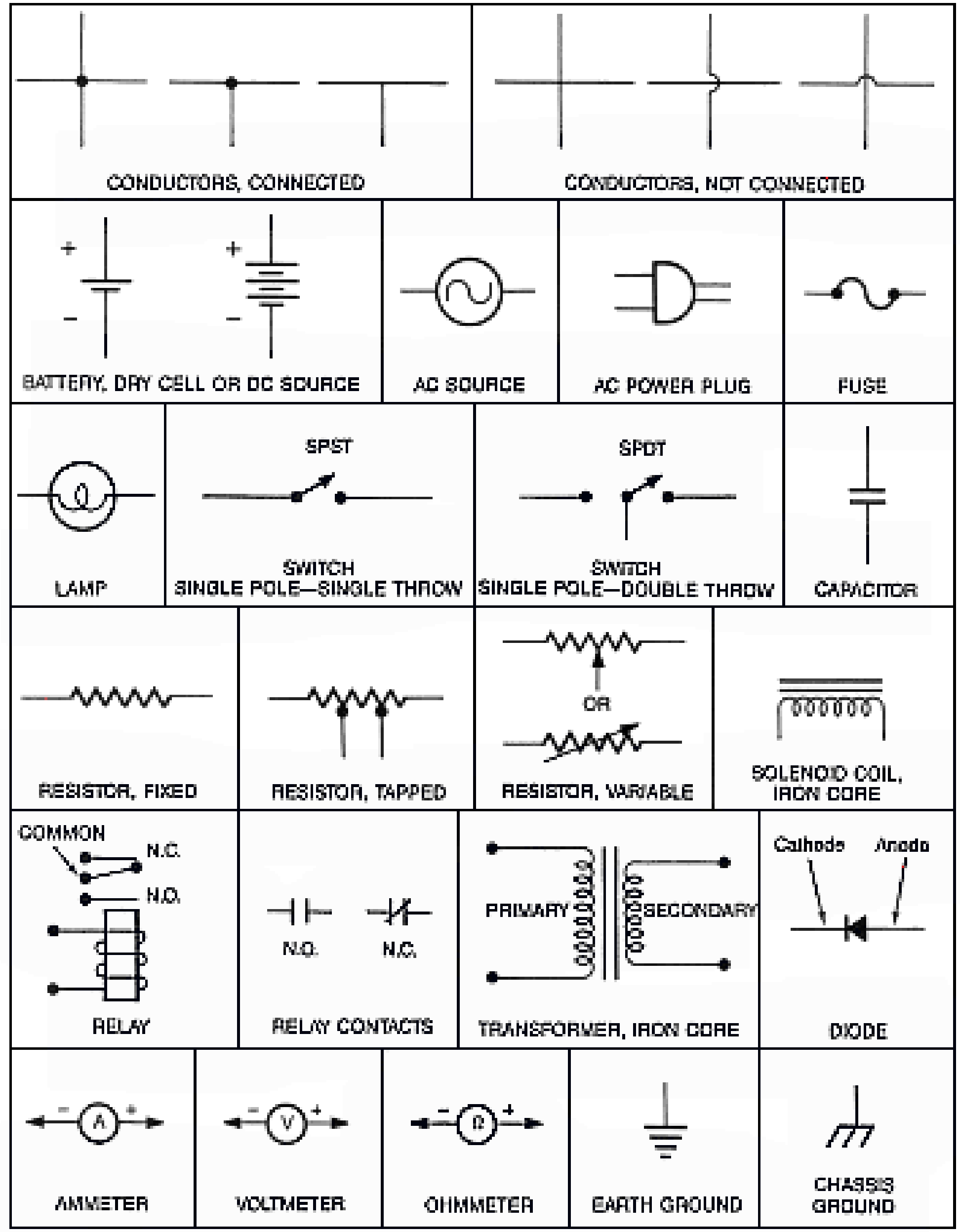


Spool And Check Valves

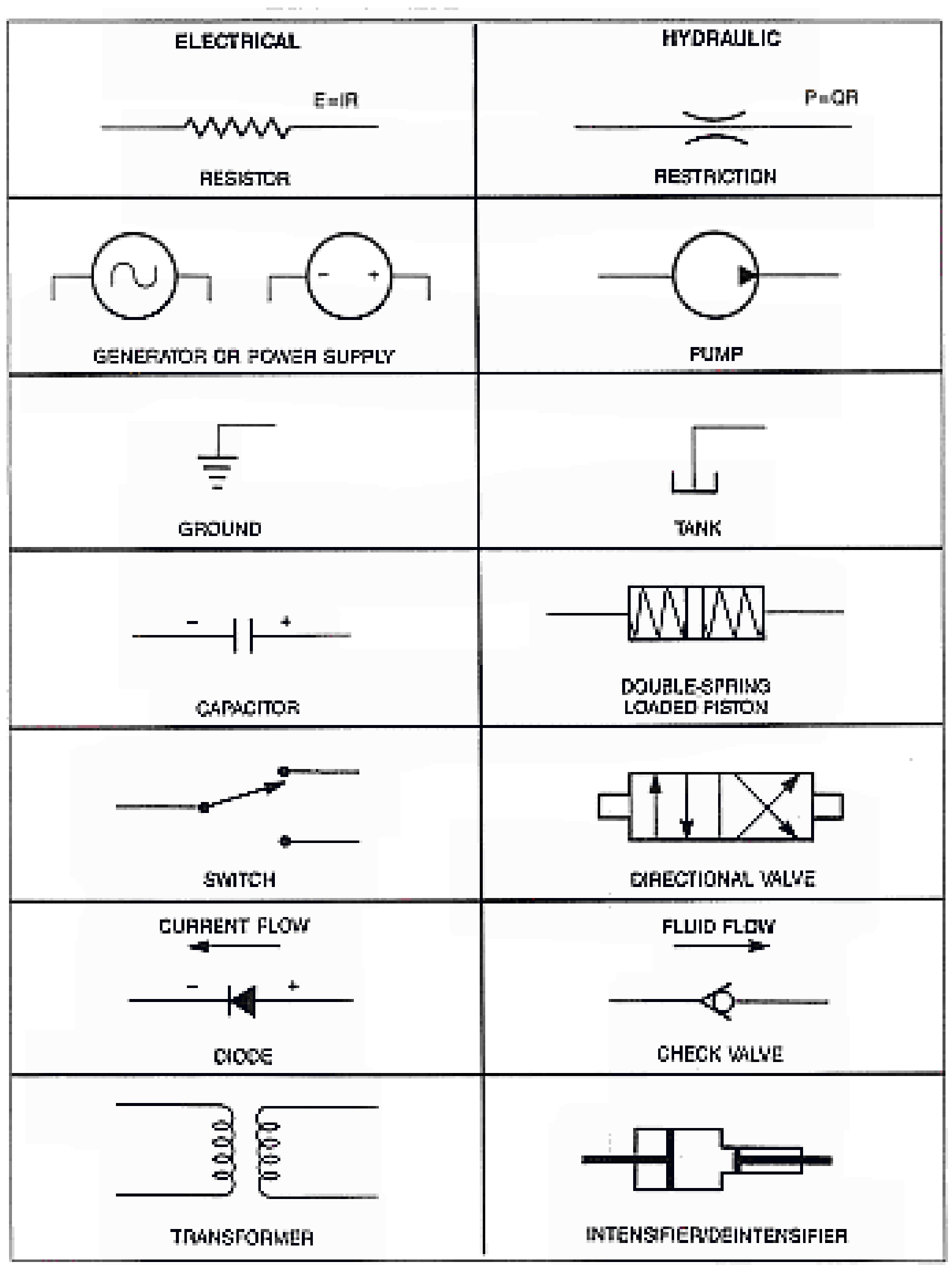




Electric Symbols Shown On Hydraulic Schematics



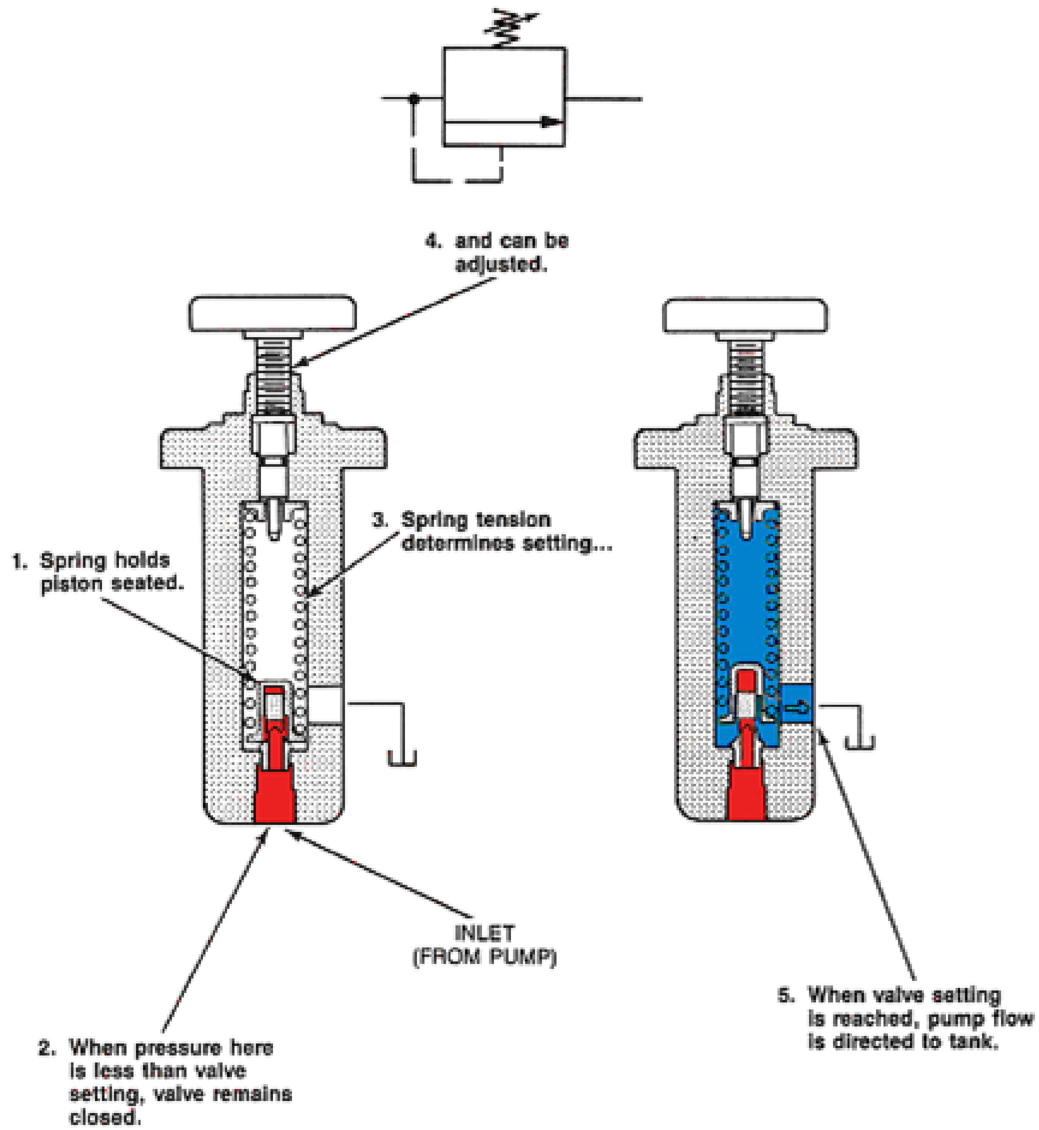
Electrical Symbols



Chapter 10

Pressure Controls

Relief Valves



Pressure-Control Valves

Pressure-Control Valves

A pressure-control valve may limit or regulate pressure, create a particular pressure condition required for control, or cause actuators to operate in a specific order. All pure pressure-control valves operate in a condition approaching hydraulic balance. Usually the balance is very simple: pressure is effective on one side or end of a ball, poppet, or spool and is opposed by a spring. In operation, a valve takes a position where hydraulic pressure balances a spring force. Since spring force varies with compression, distance and pressure also can vary. Pressure-control valves are said to be infinite positioning. This means that they can take a position anywhere between two finite flow conditions, which changes a large volume of flow to a small volume, or pass no flow.

Most pressure-control valves are classified as normally closed. This means that flow to a valve's inlet port is blocked from an outlet port until there is enough pressure to cause an unbalanced operation. In normally open valves, free flow occurs through the valves until they begin to operate in balance. Flow is partially restricted or cut off. Pressure override is a characteristic of normally closed-pressure controls when they are operating in balance. Because the force of a compression spring increases as it lowers, pressure when the valves first crack is less than when they are passing a large volume or full flow. The difference between a full flow and cracking pressure is called override.

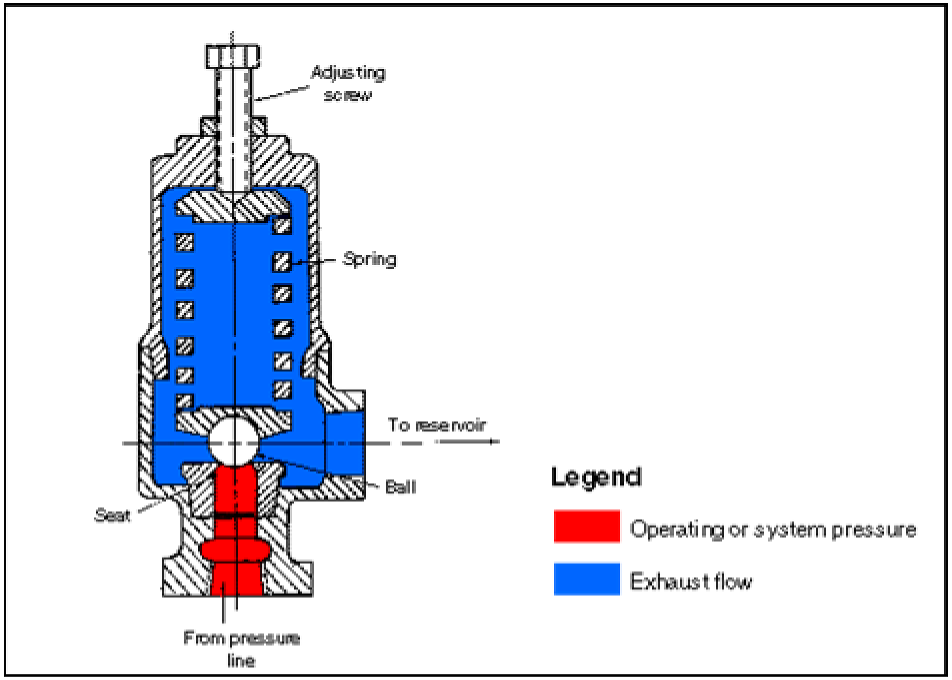
Relief Valves. Relief valves are the most common type of pressure-control valves. The relief valves' function may vary, depending on a system's needs. They can provide overload protection for circuit components or limit the force or torque exerted by a linear actuator or rotary motor.

The internal design of all relief valves is basically similar. The valves consist of two sections: a body section containing a piston that is retained on its seat by a spring's), depending on the model, and a cover or pilot-valve section that hydraulically controls a body piston's movement. The adjusting screw adjusts this control within the range of the valves.

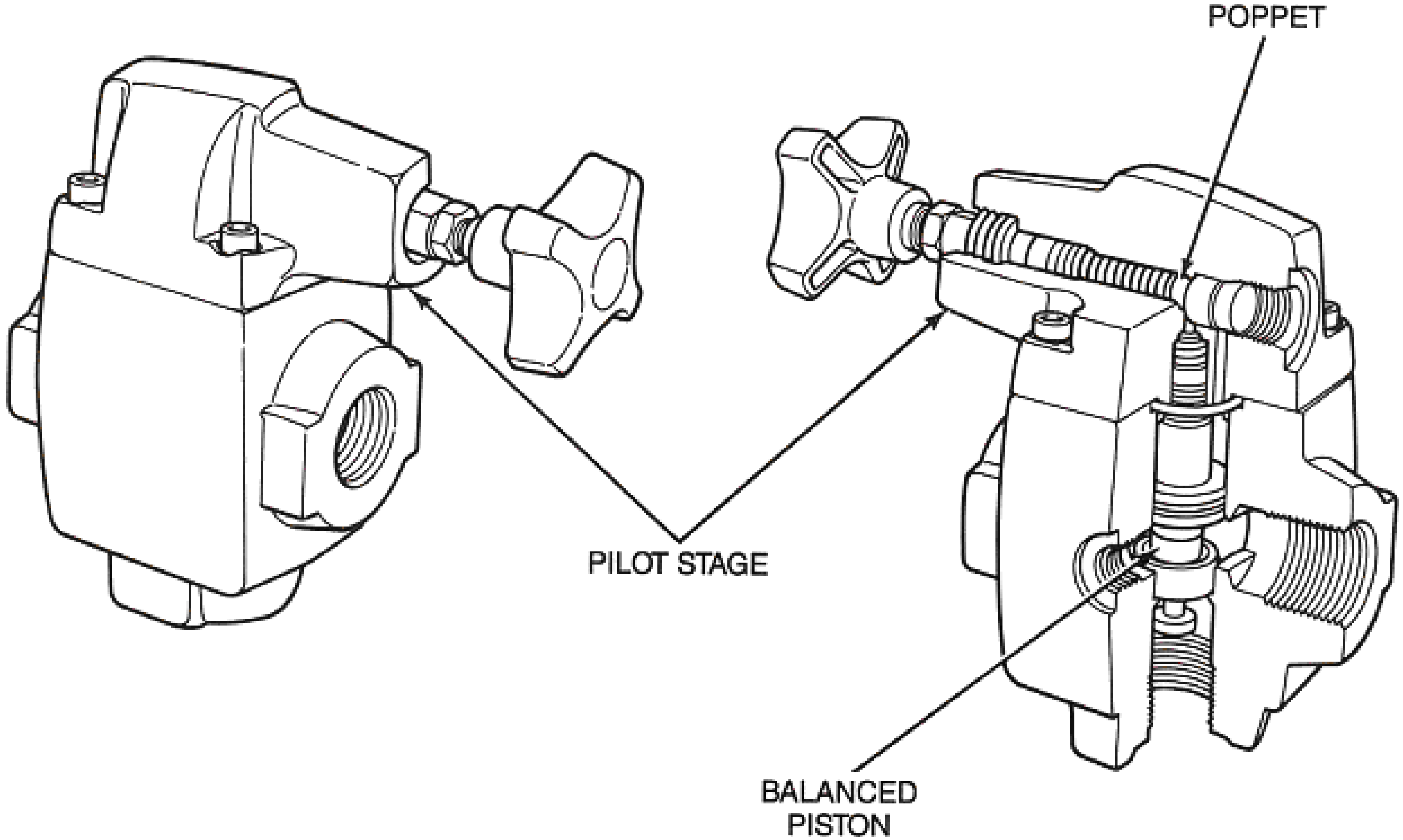
Valves that provide emergency overload protection do not operate as often since other valve types are used to load and unload a pump. However, relief valves should be cleaned regularly by reducing their pressure adjustments to flush out any possible sludge deposits that may accumulate. Operating under reduced pressure will clean out sludge deposits and ensure that the valves operate properly after the pressure is adjusted to its prescribed setting.

Relief Valve, Simple Type

(*1) Simple Type*. Figure shows a simple-type relief valve. This valve is installed so that one port is connected to the pressure line or the inlet and the other port to the reservoir. The ball is held on its seat by thrust of the spring, which can be changed by turning the adjusting screw. When pressure at the valve's inlet is insufficient to overcome spring force, the ball remains on its seat and the valve is closed, preventing flow through it. When pressure at the valve's inlet exceeds the adjusted spring force, the ball is forced off its seat and the valve is opened. Liquid flows from the pressure line through the valve to the reservoir. This diversion of flow prevents further pressure increase in the pressure line. When pressure decreases below the valve's setting, the spring reseats the ball and the valve is again closed.

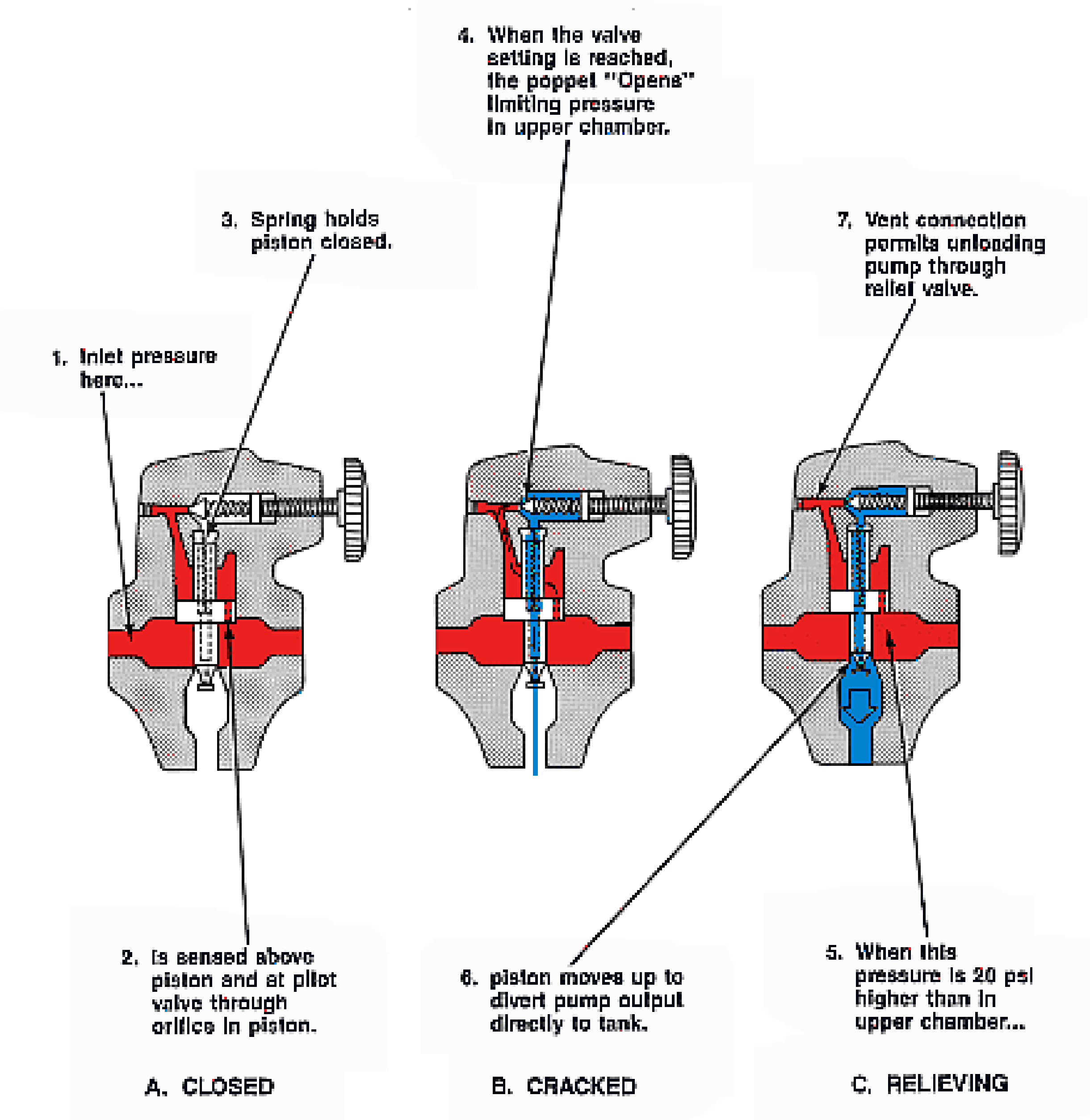


Pilot Operated Relief Valve



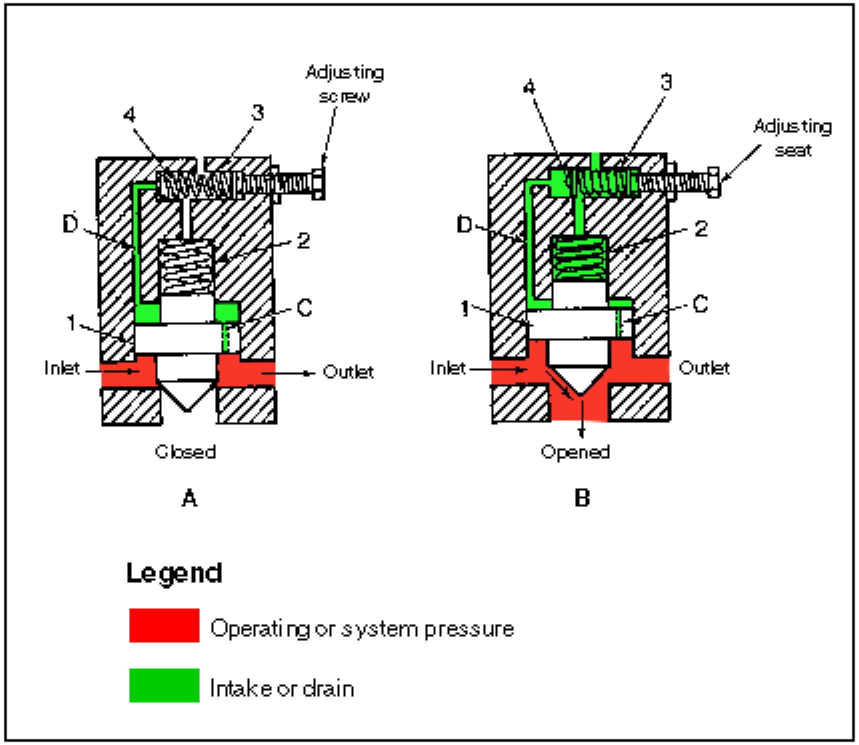
Pilot operated relief valve.

Stages Of A Relief Valve As It Opens

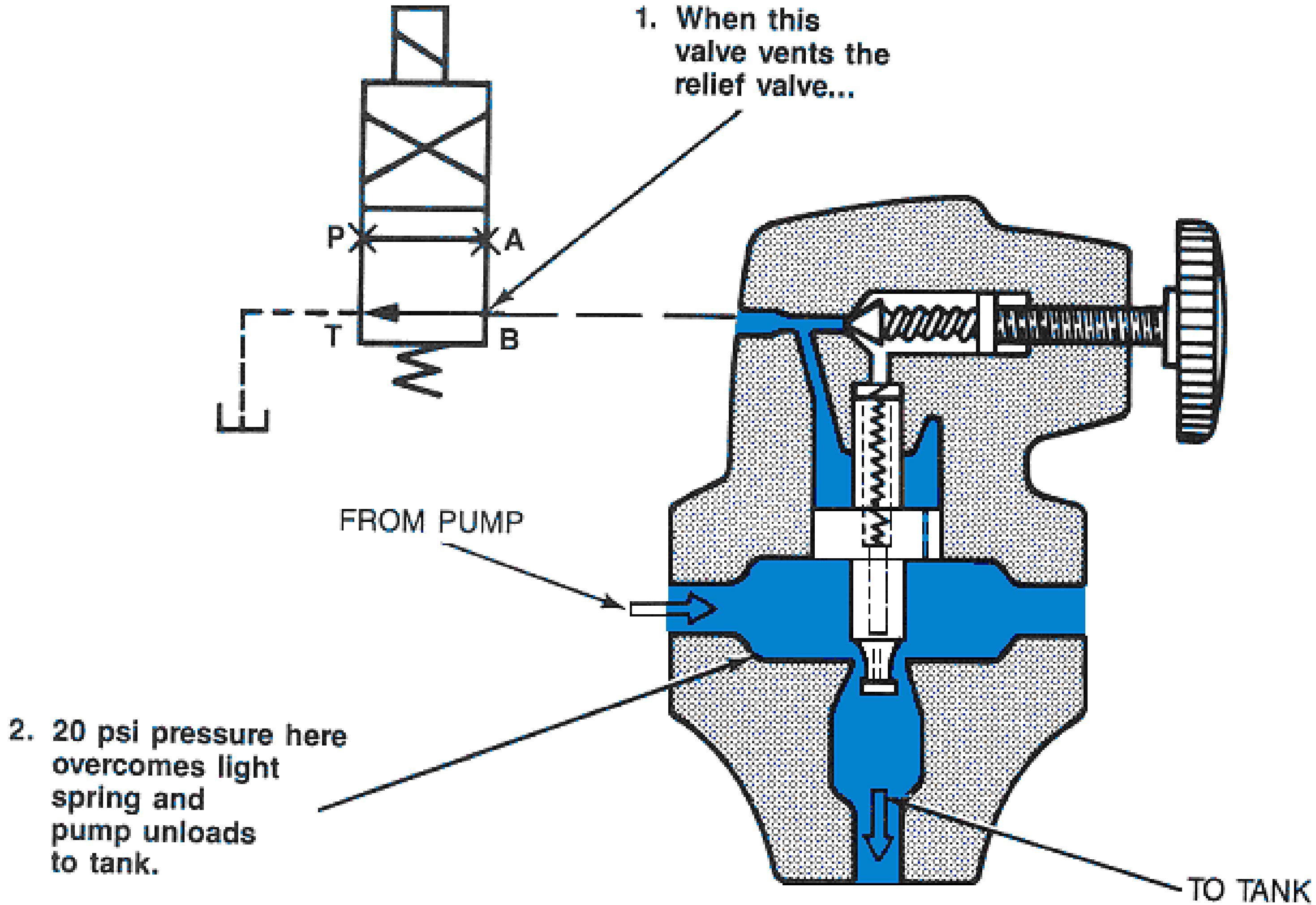


Compound Type Relief Valve

(2) Compound Type. Figure shows a compound-type relief valve. Passage C is used to keep the piston in hydraulic balance when the valve's inlet pressure is less than its setting (diagram A). The valve setting is determined by an adjusted thrust of spring 3 against poppet 4. When pressure at the valve's inlet reaches the valve's setting, pressure in passage D also rises to overcome the thrust of spring 3. When flow through passage C creates a sufficient pressure drop to overcome the thrust of spring 2, the piston is raised off its seat (diagram B). This allows flow to pass through the discharge port to the reservoir and prevents further rise in pressure.



Venting A Relief Valve

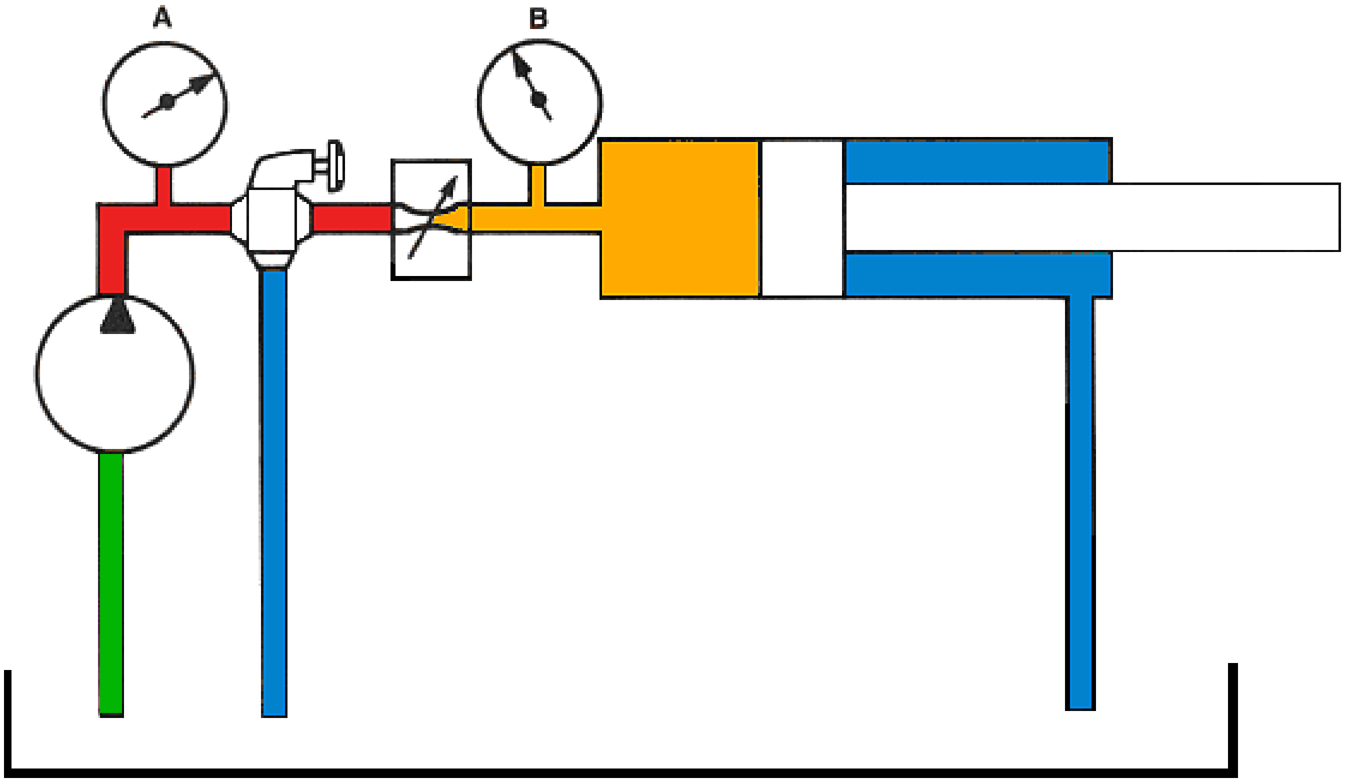


Venting the relief valve.

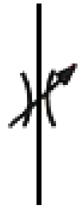
Chapter 11

Flow Controls

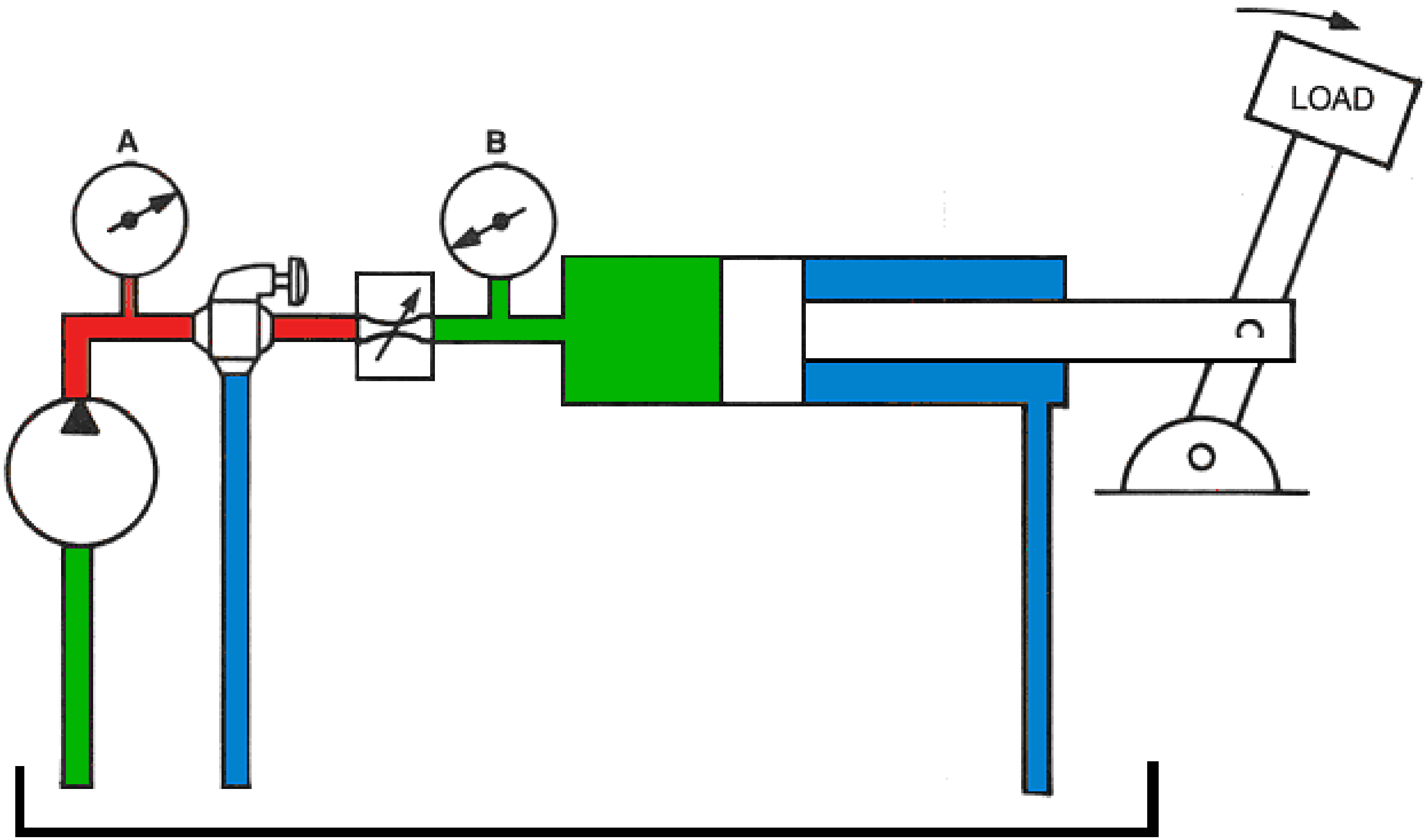
Flow Controls



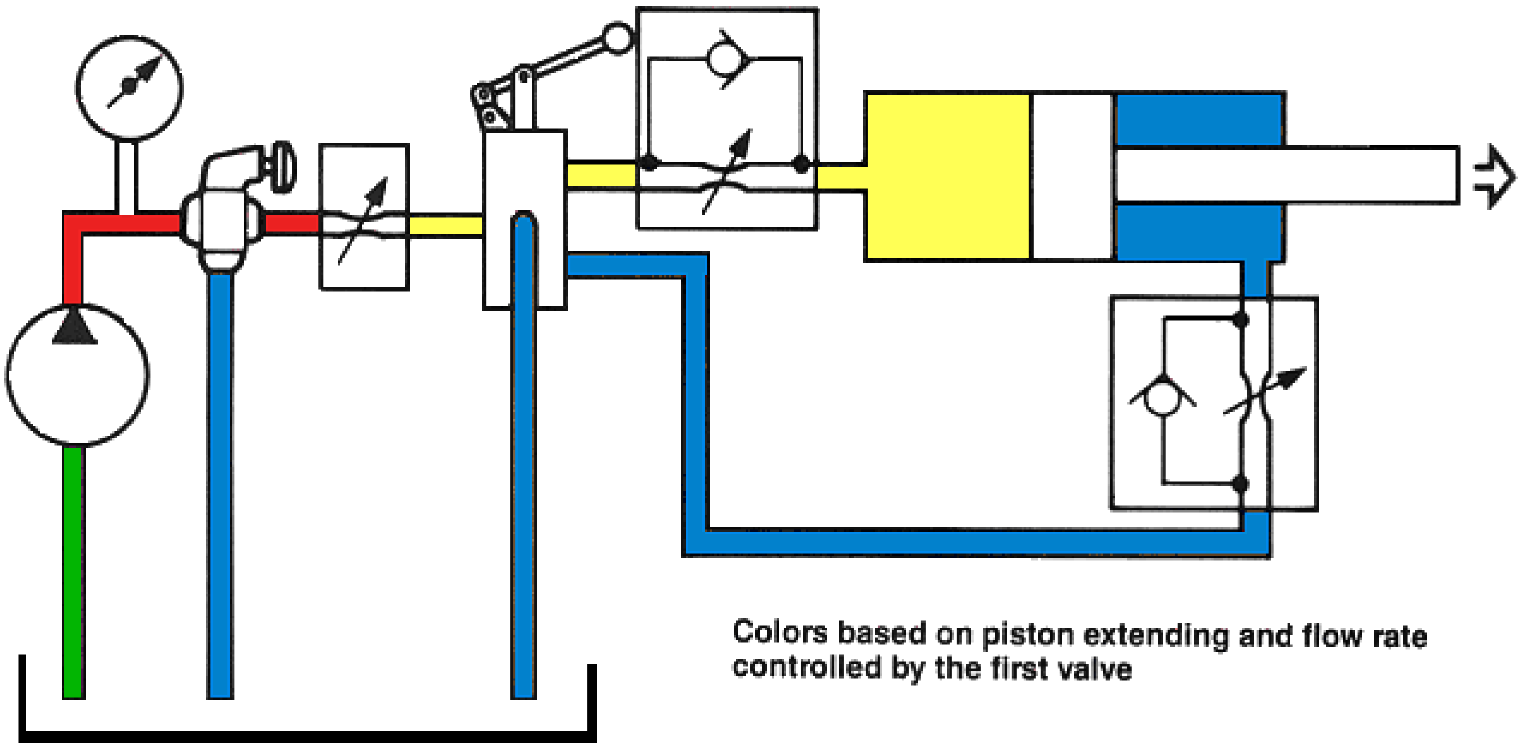
FLOW CONTROL SYMBOL
NON-COMPENSATED



Meter-In Circuit

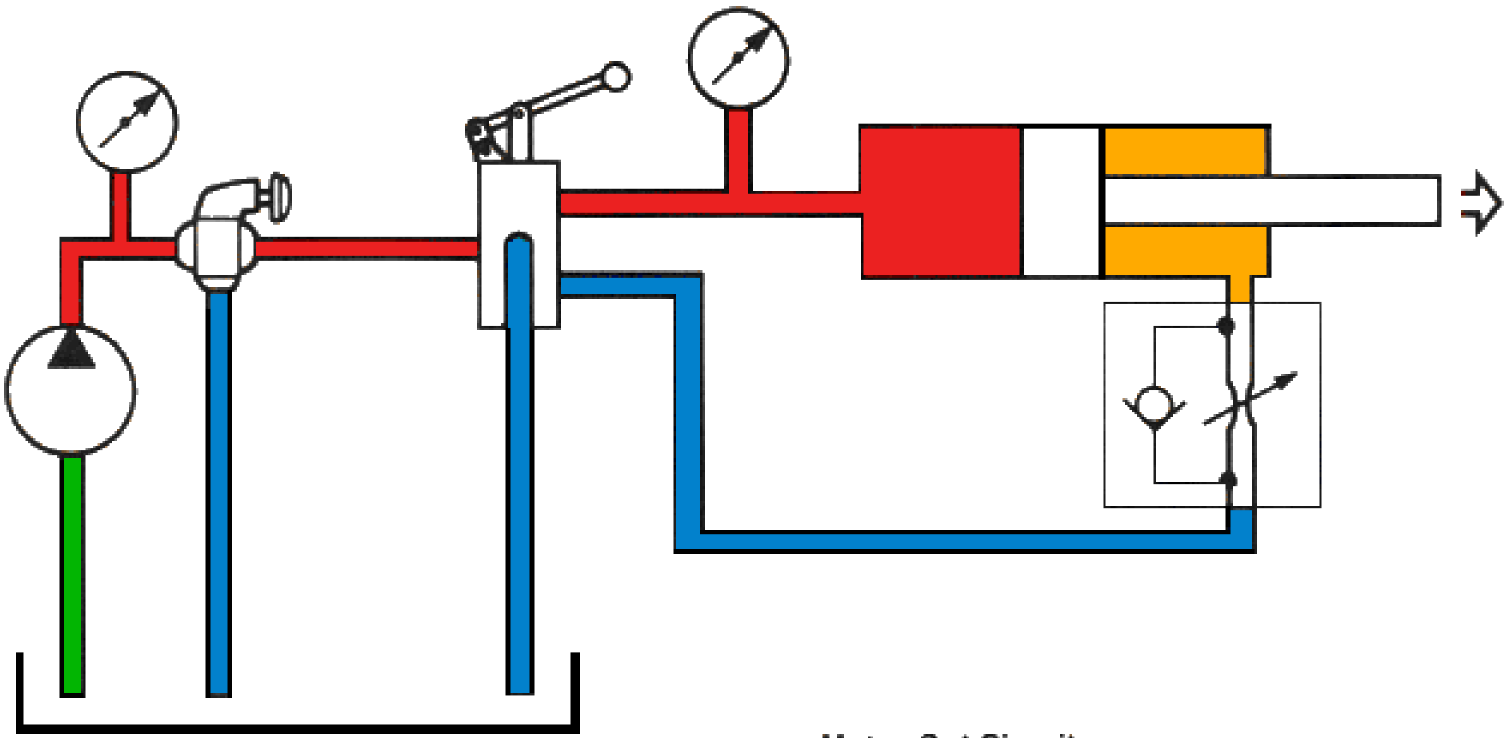


Meter-In Circuits Do Not Control Runaway Loads

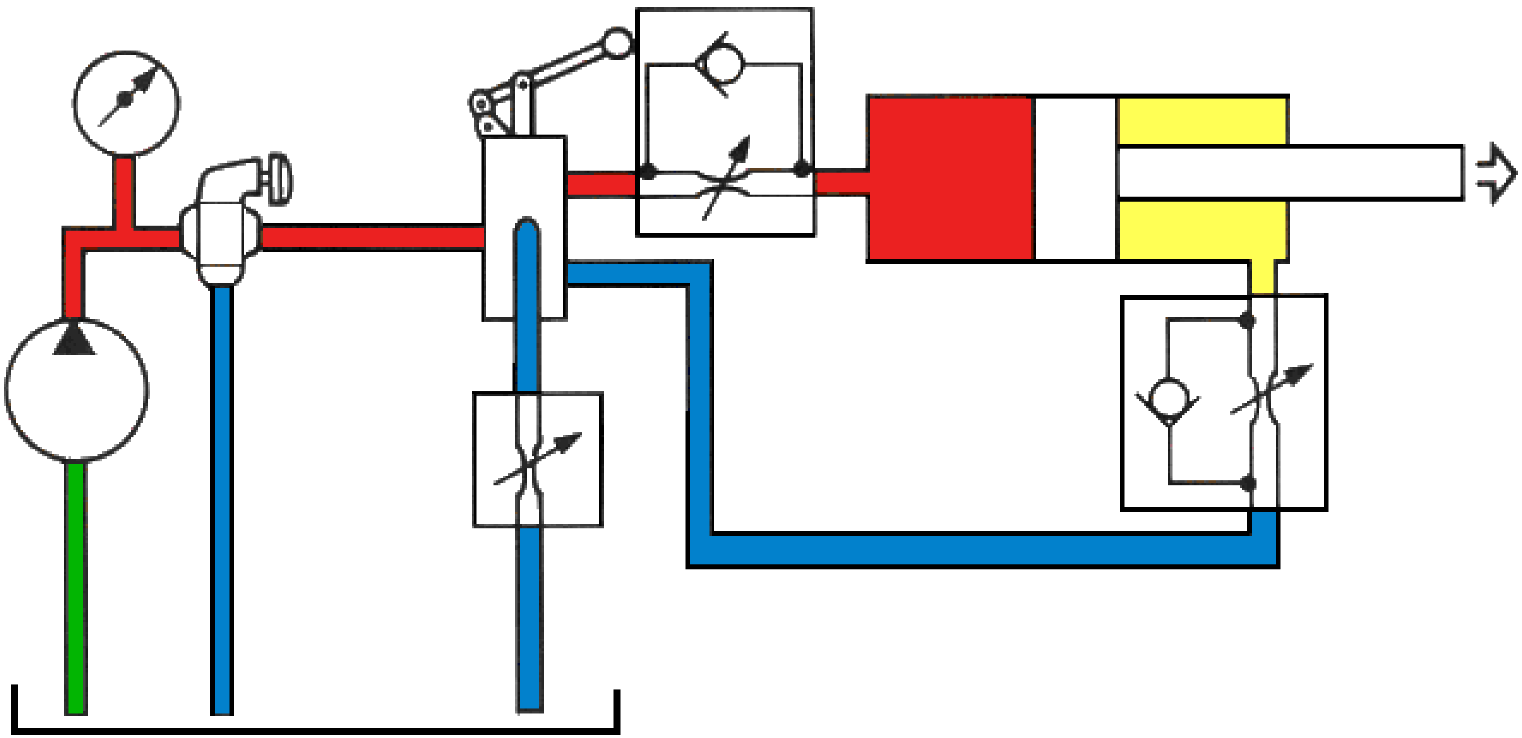


Colors based on piston extending and flow rate controlled by the first valve

Locations for Meter-In Applications

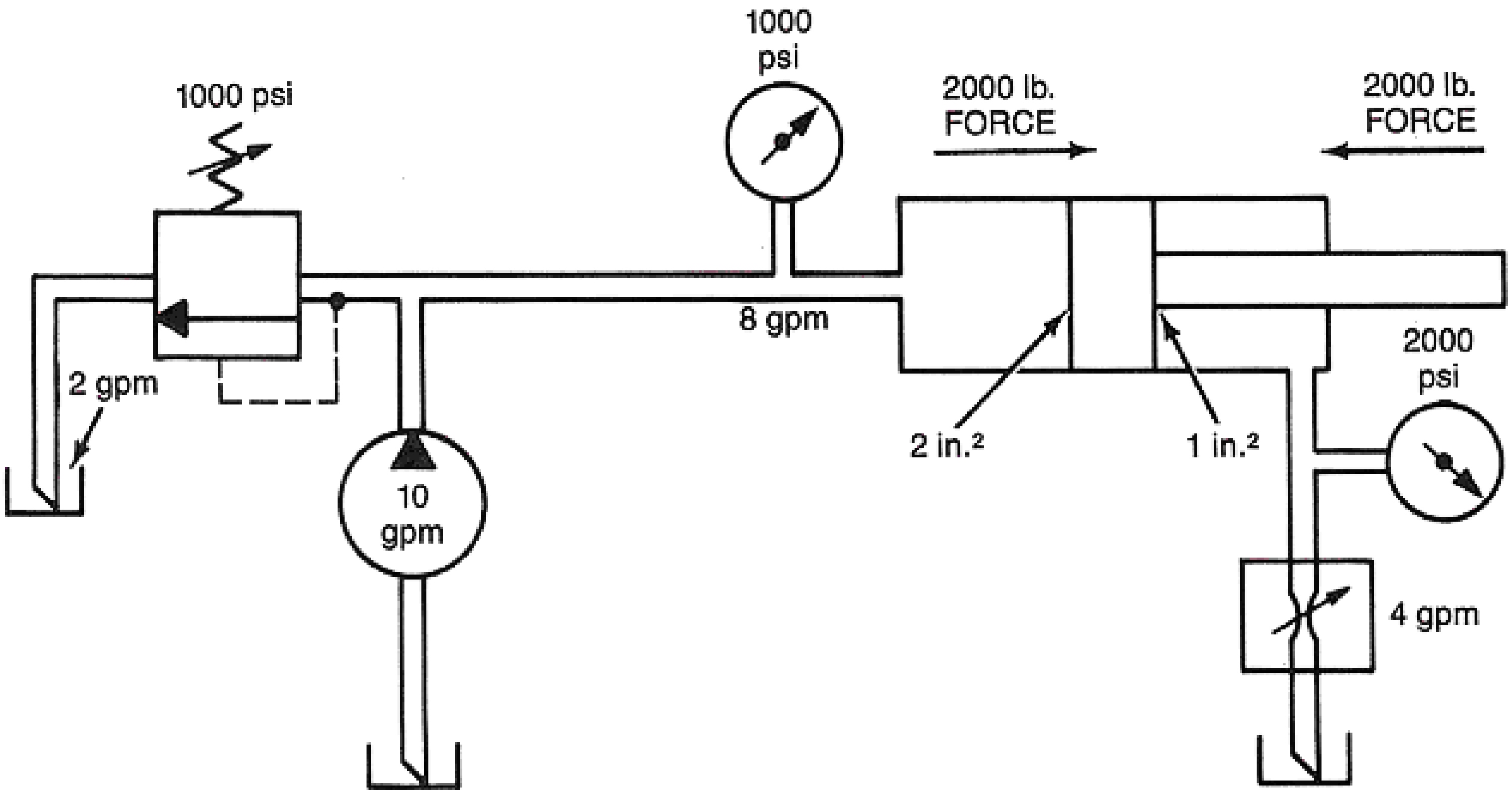


Meter-Out Circuit

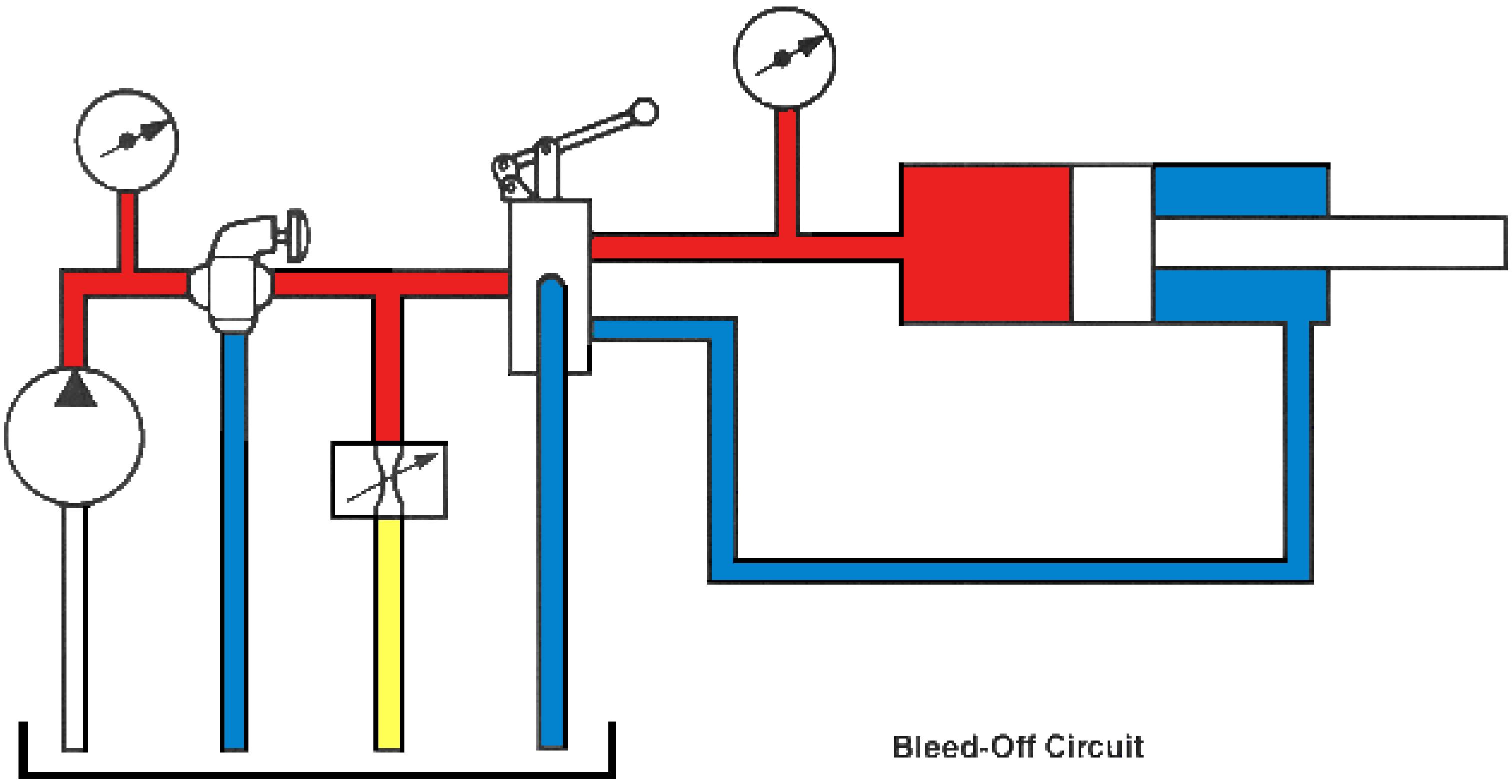


Colors based on piston extending and flow rate
controlled by the rod-end valve

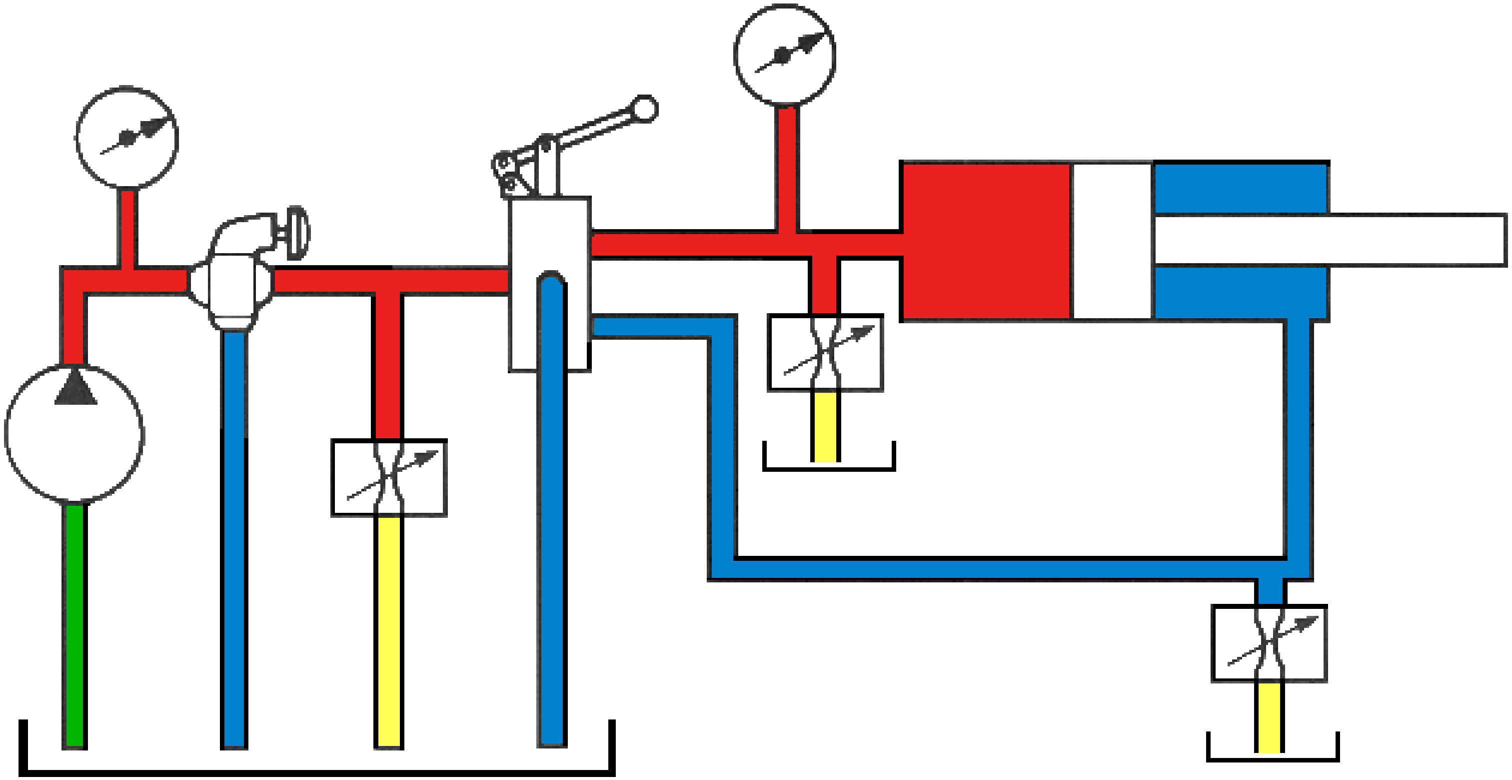
Locations for Meter-Out Applications



Pressure Intensification in Meter-Out Circuits



Bleed-Off Circuit



LOCATIONS FOR BLEED-OFF APPLICATIONS

Chapter 12

Accessories

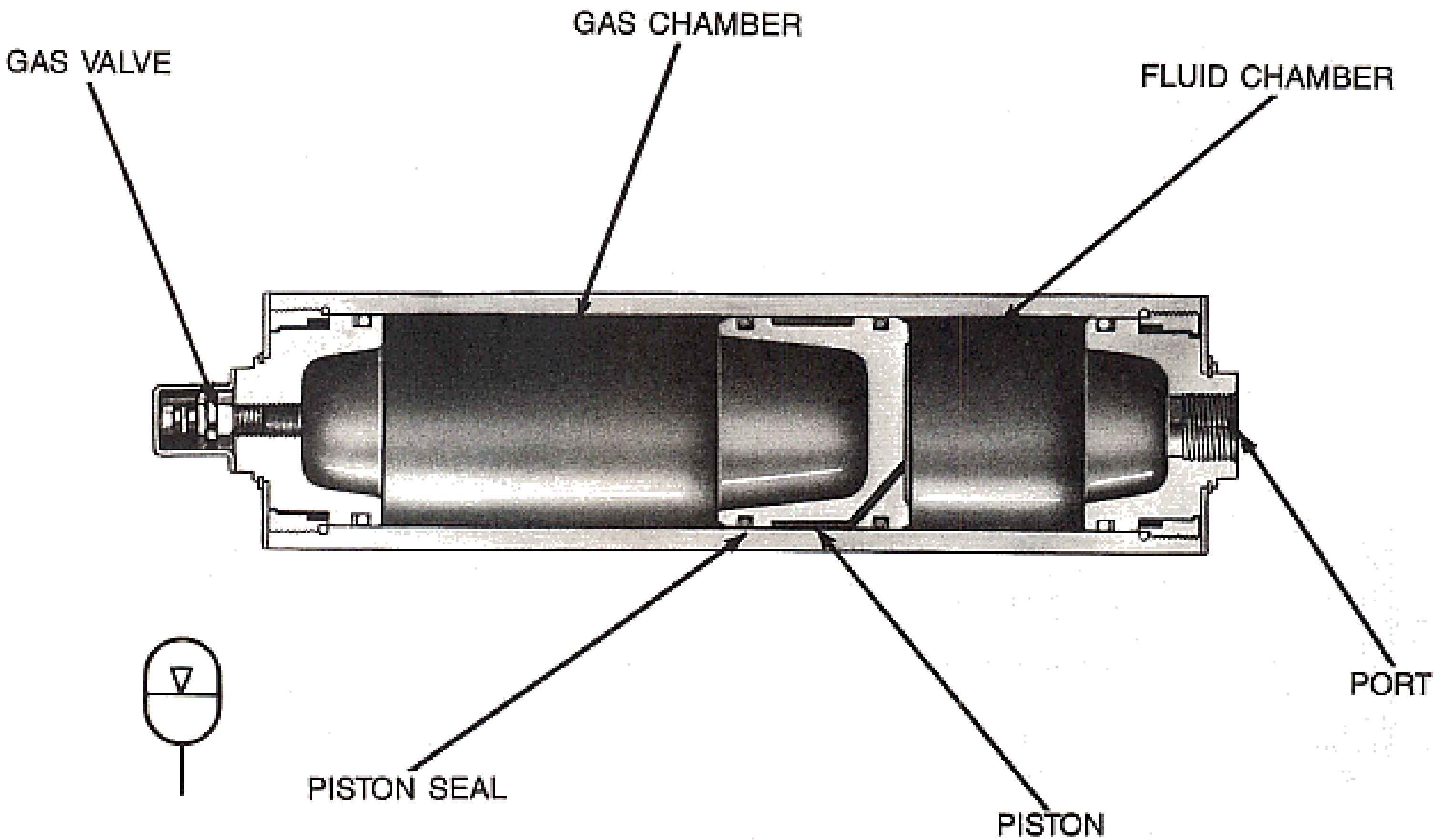
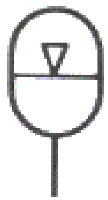
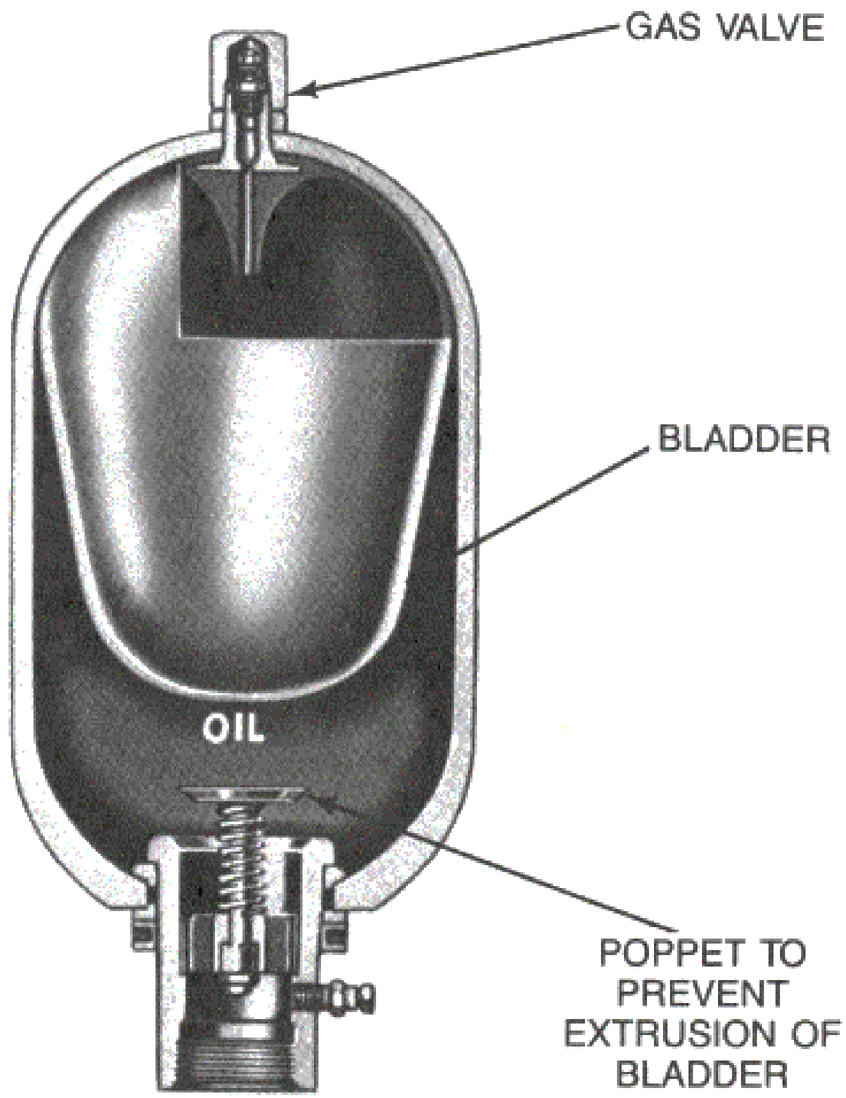


Figure 18-3. Piston accumulator is gas-charged.





Bladder-type accumulator uses rubber separator between gas and liquid.

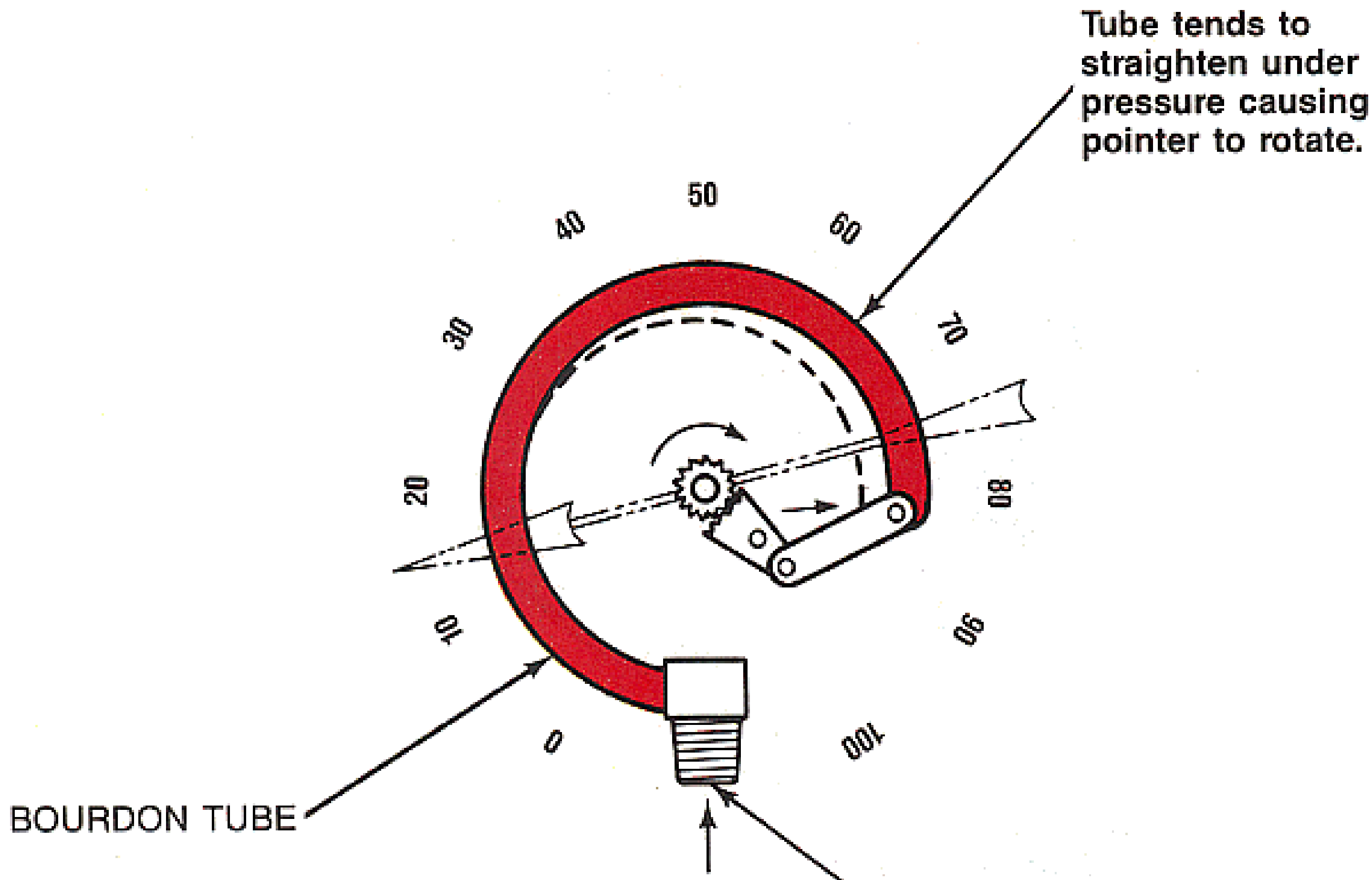
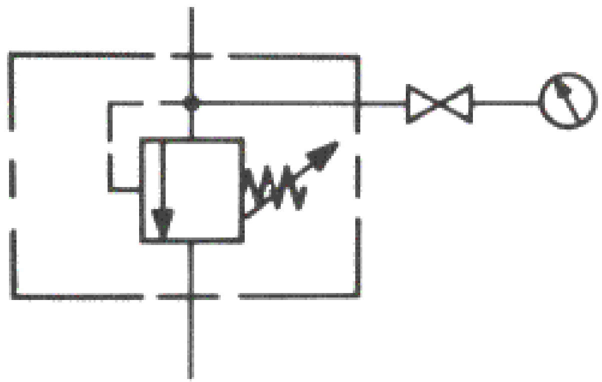


Figure 18-8. The Bourdon Tube gauge.



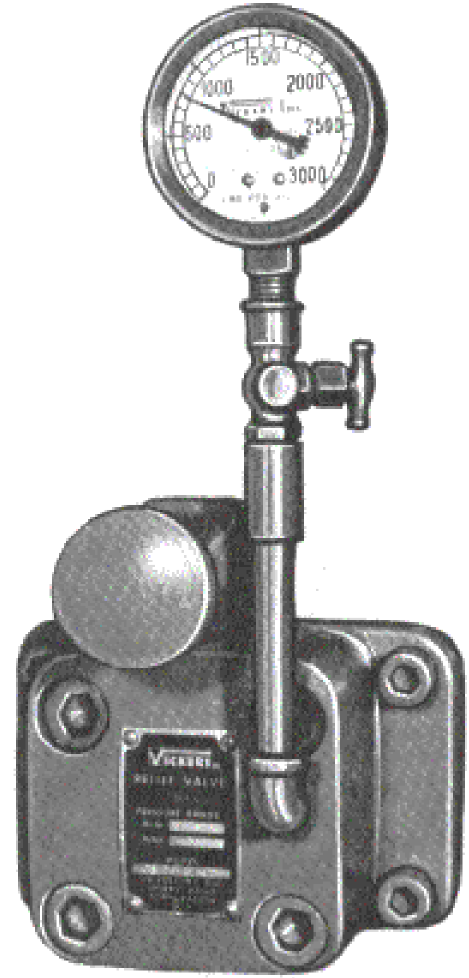


Figure 18-11. Gauge installed with shutoff valve and snubber.

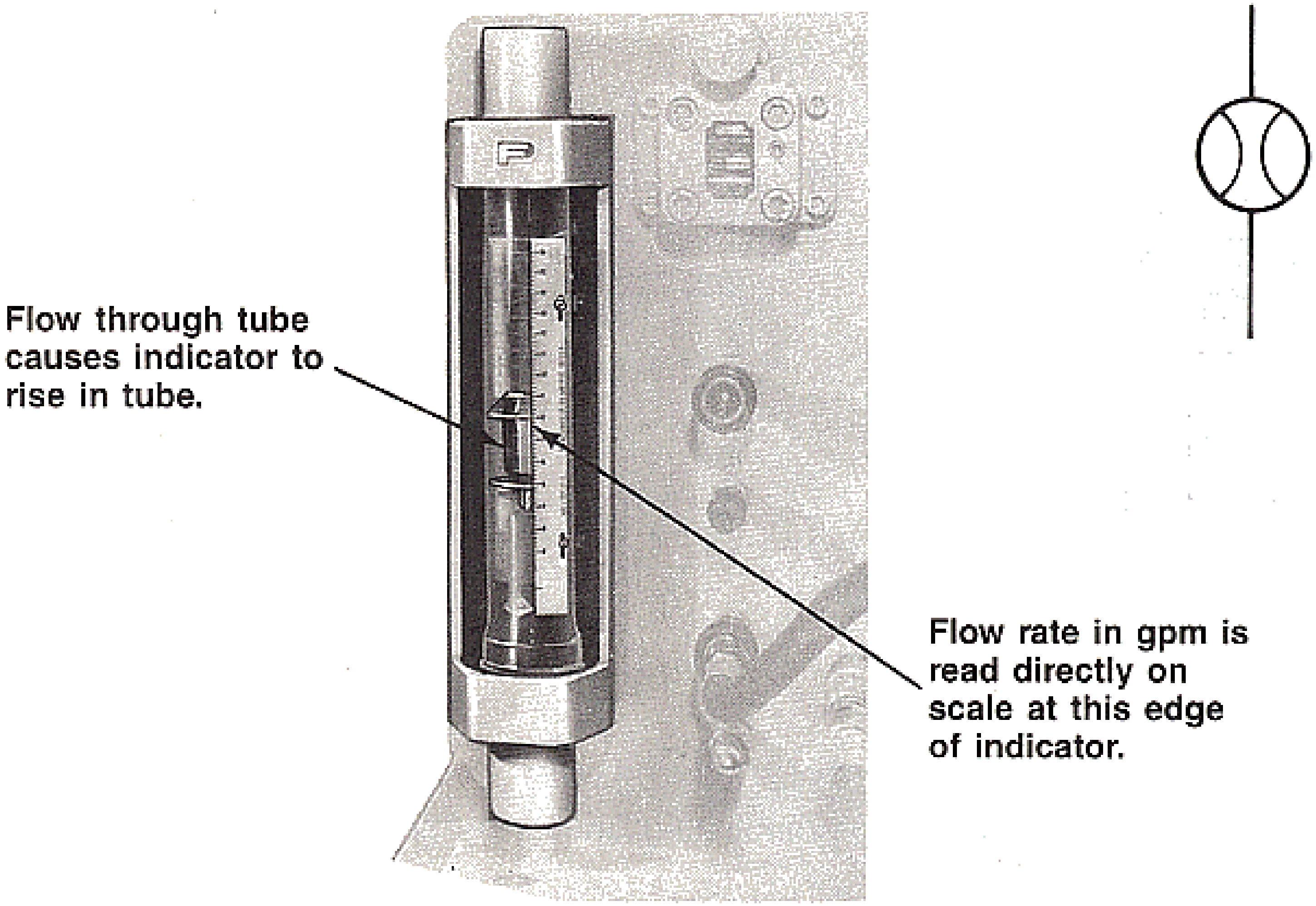
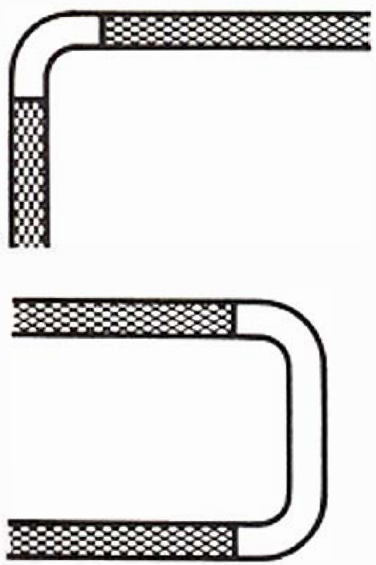


Figure 18-14. Typical flow meter.



For good isolation, use one ol these two combinations.

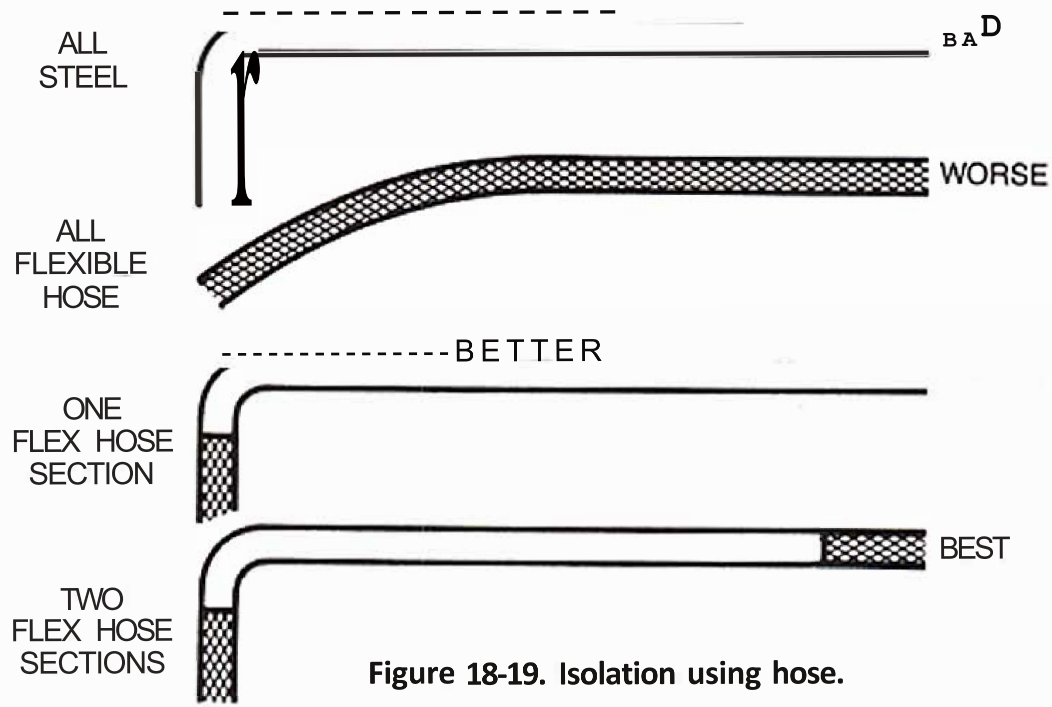


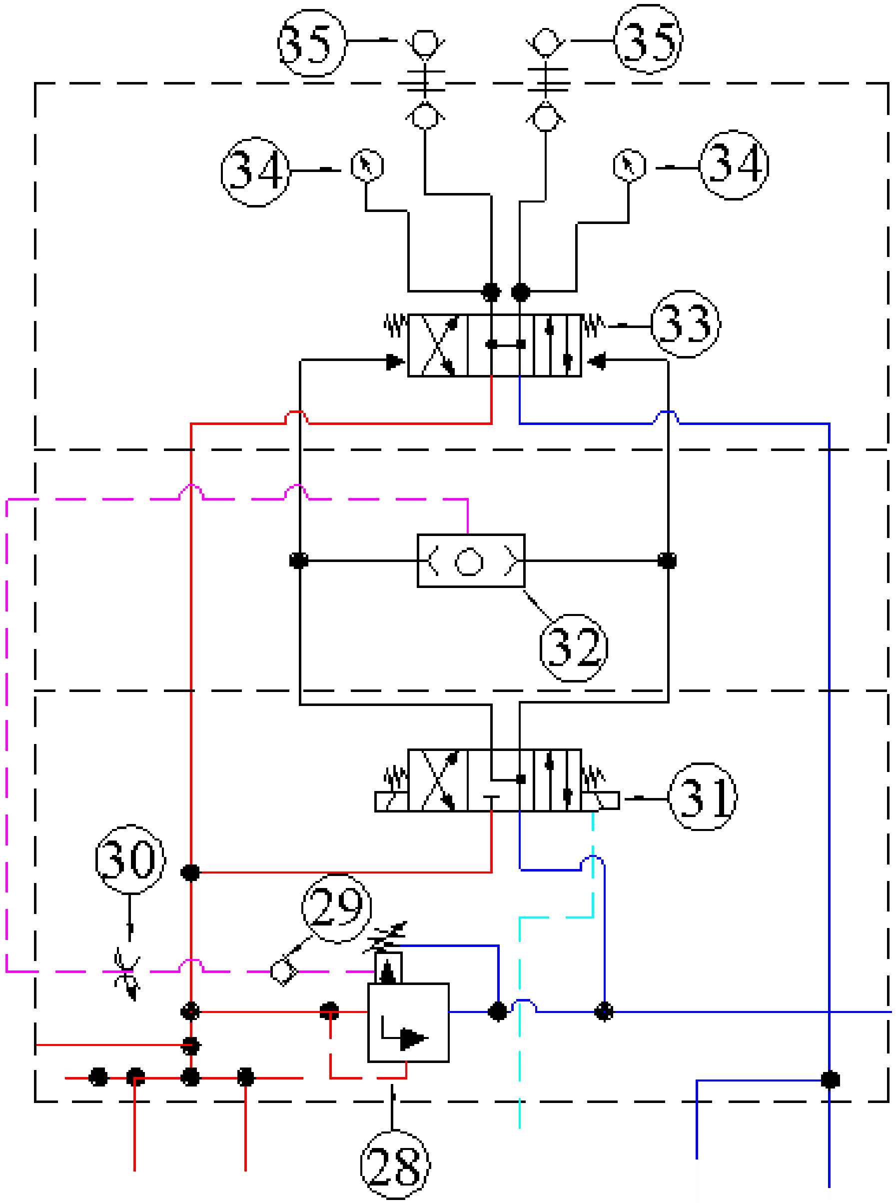
Figure 18-19. Isolation using hose.

Chapter 13

Hydraulic Circuits

How the Hydraulic Circuits Work

- The next few slides will explain how the APE clamp and drive hydraulic circuits and why.
- The reading of hydraulic schematics is not optional, but required to adjust or troubleshoot any hydraulic system.

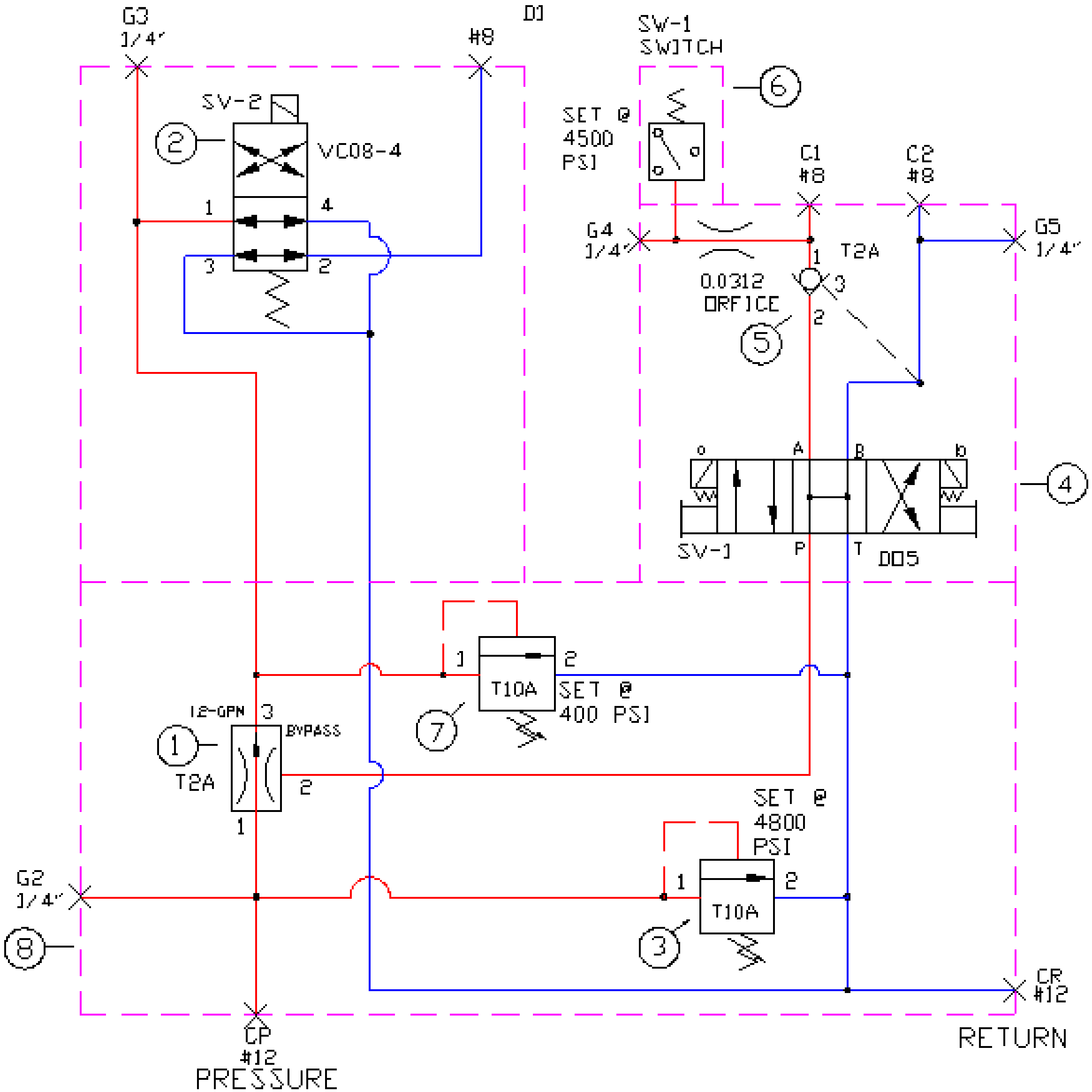


APE drive manifold circuit showing all the working components.

Item #33 is the main directional valve spool, and item #31 is the pilot valve that controls the main drive spool. We use item #32 to sense pressure in forward or reverse lines and send a signal to item #28 the relief valve. We can energize item #31 to either forward or reverse and send pump flow out the main directional control valve item #33.

When item #31 is de-energized the vibro will cost to a stop. All flow in returned through item #33 back to tank. During this de-energizing we sense the line pressure in forward or reverse depending which way we selected item #31, and make the relief valve item #28 dump the pump flow back to tank, which provides a smooth stop of the pump flows. The pump flows now can go to tank both through item #33 and item #28, which reduces hydraulic shock. Item #30 is a needle valve and controls how fast or slow item #28 gets the signal from item #32 shuttle valve. Sometime item #30 requires adjustment, to reduce hydraulic shock when shifting item #33. Either adjust it in or out just a little, you will know when it is set correctly when item #33 can be shifted without hearing any bang or shock.

Item #28, main relief valve controls the maximum hydraulic system pressure, which is set to 4500 psi.

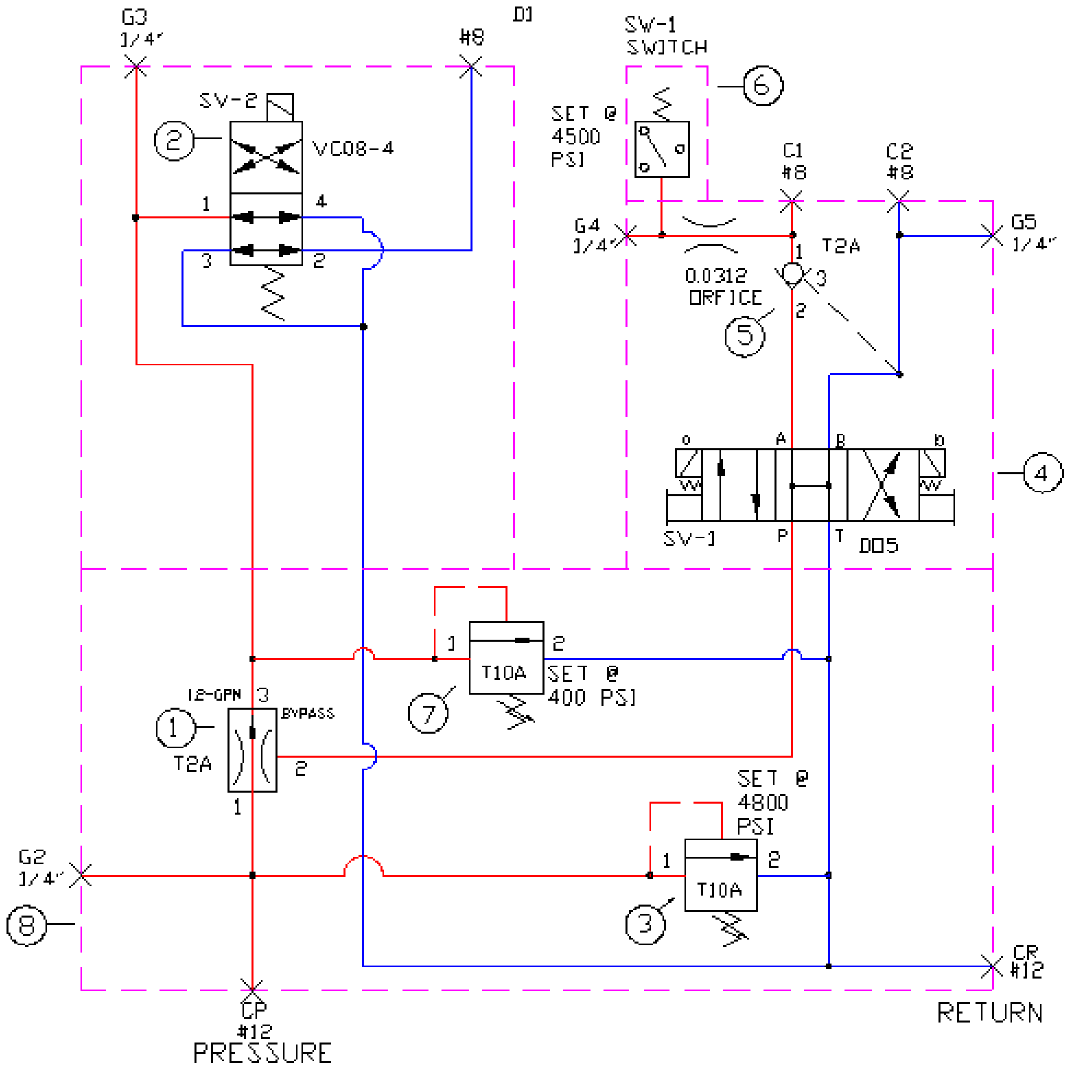


APE Clamp manifold circuit shown to the left.

The new APE clamp manifold circuit is designed to run (shift) a two speed drill whether one is used or not. The pump flow enters at (CP) and part of the pump flow is, about 2-gpm is sent to item #2 for drill two speed shifting. This flow is limited to 375-400 psi maximum by item #7. There is no adjustment on item #1, it is pre-set at 2-gpm. Item #7 is normally pre-set at 375-400 psi and can be adjusted in the field if needed. Item #7 should never be adjusted above 400 psi regardless.

The remaining pup flow (8-12 gpm) is sent to item #4 the clamp open or close directional control valve. Item #3 limits the maximum clamp pressure to 4800 psi maximum and can be adjusted in the field.

Go to the next slide and we will continue.



Item #5 is a pilot check valve used to trap hydraulic pressure on the closed side of the vibro clamp. There is also another one located right on the vibro clamp as well. If item #4 is in the center position, pump flow back to tank, then item #5 will trap any hydraulic pressure in the clamp close line to assure clamp remains closed.

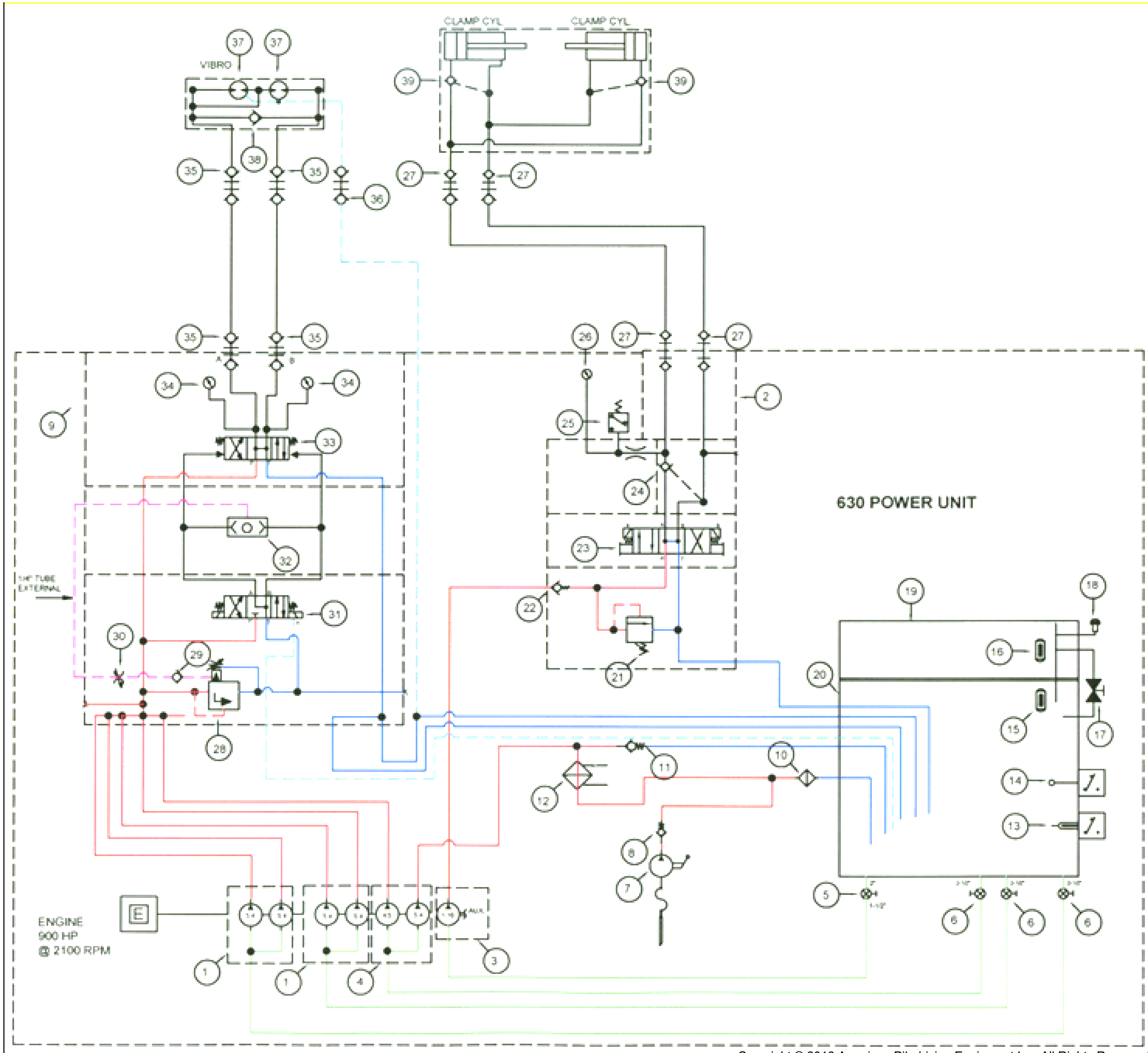
Item #6 is an hydraulic pressure switch, it does two things. 1.) when hydraulic pressure in the clamp close line reaches 4500 psi (rising pressure) it will turn the clamp close light to green. 2.) it will also de-energize item #4 to the center position directing pump flow back to tank. At which time item #5 closes and traps pressure in the clamp close line.

Should the trapped pressure in the clamp close line fall below about 4400 psi, then the pressure switch will sense this and turn the clamp close light off and re-energize item #4 to direct flow back to the clamp close line. In simple terms, the pressure switch keeps clamp pressure on the vibro clamp close line between 4500 psi and 4400 psi as long as the clamp close switch is in the clamp close position.

Typical circuit drawing of APE power unit hydraulic circuit.

Should you request a hydraulic circuit, this is what you will get. <u>All</u> your troubleshooting is done from this drawings, if you cannot read this circuit, you need to study this power point program until you can.

Each field service person is required to have a book containing all the hydraulic circuits APE use's in their products be able to read and understand them.



Drive manifold

Electrical Solenoids

Pilot valve w/spool

Shuttle valve block

Snubber

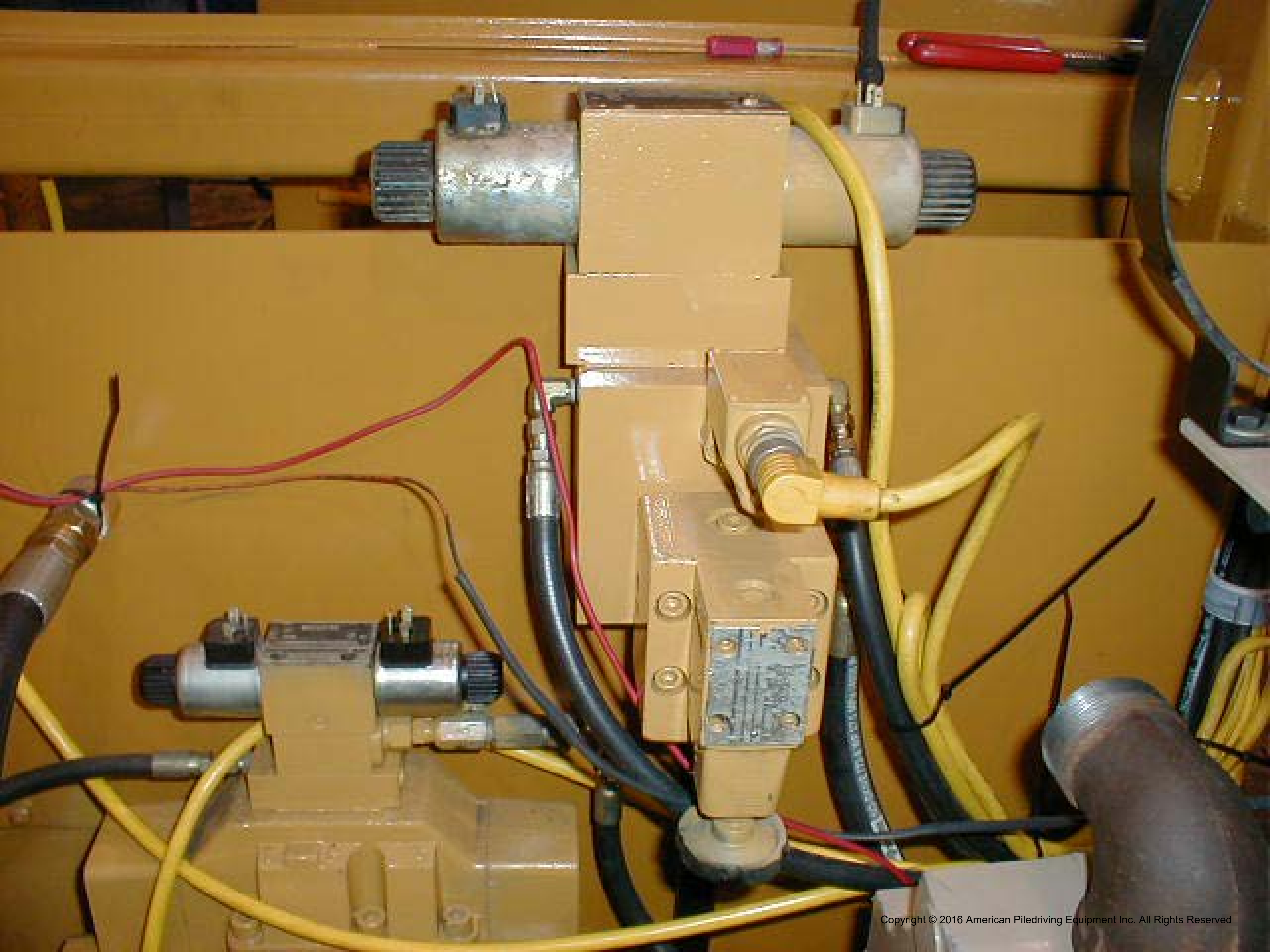
Main pilot operated spool body w/spool

Manifold body

Relief valve

Relief valve unloader

Relief valve setting adjuster

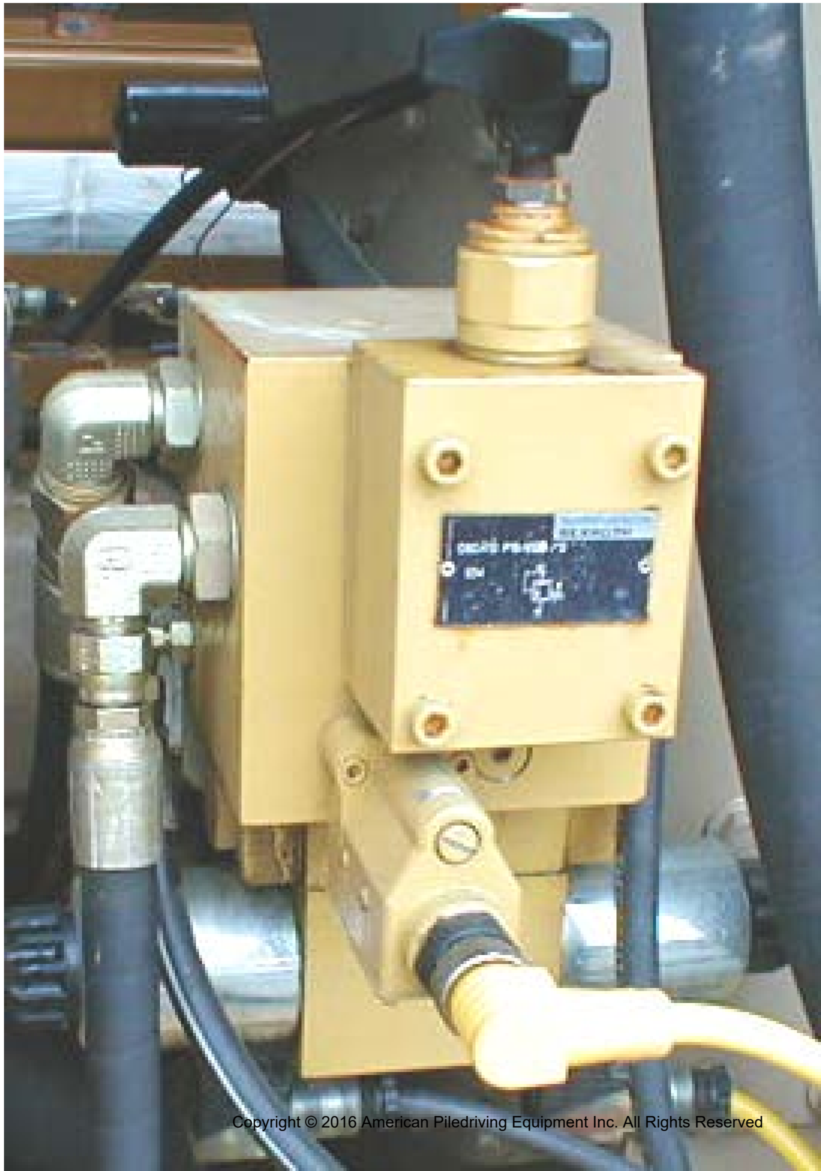


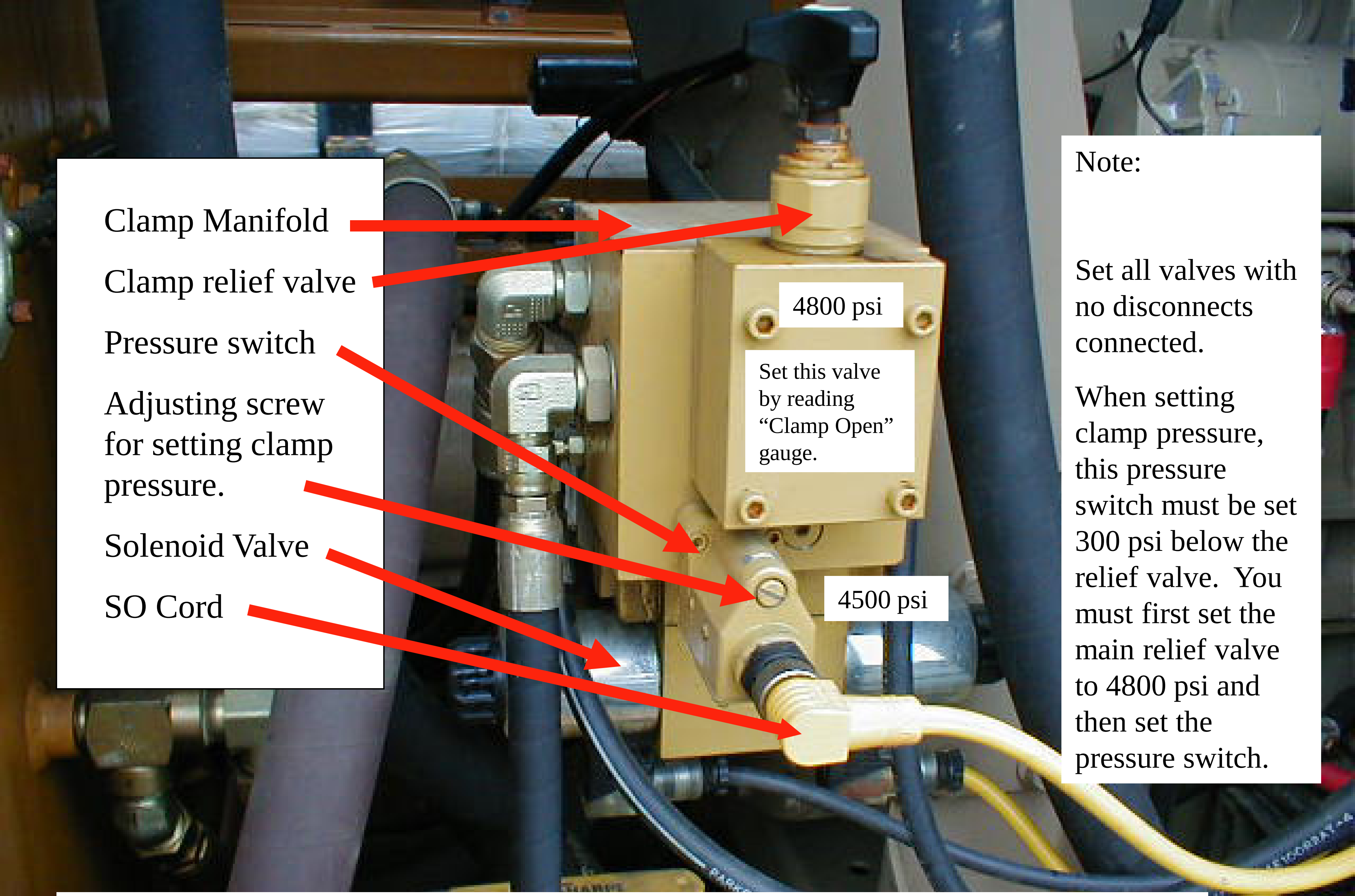
Pressure Switch

Pressure Switches. Pressure switches are used in various applications that require an adjustable, pressure-actuated electrical switch to make or break an electrical circuit at a predetermined pressure.

The APE clamp pressure switch is designed to turn off the clamp solenoid that is pushing the valve to send oil to the clamp. Once the clamp is closed the valve does not need to send any more oil to the clamp so the pressure switch cuts the power to the solenoid so the valve can go to center. At the exact same time, the same switch tells the green light to come on at the pendant. The green light stays on if the pressure does not drop below the pressure switch setting. If the pressure does drop, the switch will turn on the solenoid, sending more oil to the clamp and during this process, the green light will be turned off. The switch also serves as a safety warning device to tell the user that something is leaking or wrong.

A flashing green light on the pendant means the switch is going on and off due to leakage from a hose, seal, or quick disconnect.





Clamp manifold (other than bulkhead mounted)

A Few Review Questions To Answer

We have a few review questions to answer after studying this course. An Excel spreadsheet of the questions can be downloaded from the web page site and you can enter your answers to the questions.

You then can Email this spreadsheet with your name, location and return Email address to info@americanpiledriving.com, we will review your answers and send back to you the results via Email.

This is not optional, it is required. We will maintain in your personnel file completion of this program. You may send in your test answers as many times as you wish, this will not count against you. APE will have more programs in the near future for you to review, and from time to time a question review will be sent to you for completion.

Should you have any suggestions, submit them to the Email address above, and we will consider them.

American Piledriving Equipment, Inc.

THE END