INDUSTRIAL HYDRAULICS

Snap-on INDUSTRIAL BRANDS

WILLIAMS | BAHCO | CDI TORQUE PRODUCTS

Basic Hydraulic Principles and Troubleshooting Suggestions

Introduction

This booklet is intended to be a handy reference guide to basic hydraulic principles and the mathematics of hydraulics. Suggestions for trouble-shooting of hydraulic systems are also presented. No effort has been made to tell the complete story of hydraulics, or to cover the more complicated aspects of Fluid Dynamics or circuitry. The booklet is designed primarily for those persons whose knowledge of and experience with hydraulic equipment has been limited… to aid them in better understanding the nature and function of “fluid power.”

Williams highly skilled team of engineers in research and development constantly strives to bring new refinements to the design and production of hydraulic equipment. Williams experience and know-how is fast making Williams a leader in the fluid power field.

Williams welcomes every opportunity to work with you and solve your fluid power problems.

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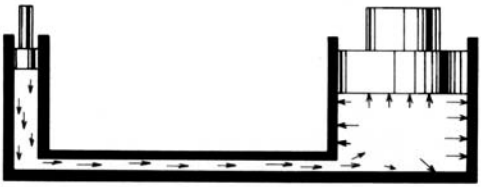
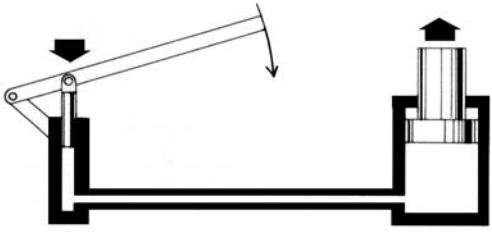
PART 1
Principles of Hydraulics

Pioneers, such as Galileo, Newton and Pascal, discovered interesting phenomena many years in advance of actual practical applications of their theories. Pascal discovered and formulated the “Law of Hydraulics” about the year 1650, but nearly 150 years passed before that law was exploited in a practical application.

Pascal’s law, which states
“*an external force exerted on a unit of area of a confined liquid will be transmitted undiminished to every unit area of the interior of the vessel*” , is the basis upon which every hydraulic device functions.

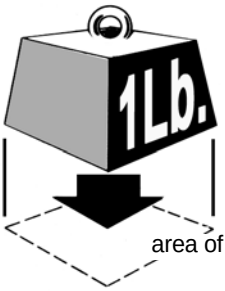


When a mechanic pumps the handle of a hydraulic pump, he is exerting force with a small piston on an area of a confined liquid. That force is transmitted by the liquid, through a hose or pipe, to the interior area of the hydraulic cylinder, including the effective area of the piston. The piston is forced to move. A very simple example of this is shown here:



In variations of the above example, the principle of hydraulics is not changed. The small piston may be moved by a lever, or by the rotary power of an electric motor or gasoline engine; the fluid flows through a pipe, a tube, or a hose; check valves, relief valves and control valves may be introduced into the system along with a reservoir of fluid and return lines. The ram may be a number of different types or shapes. But the action remains the same.

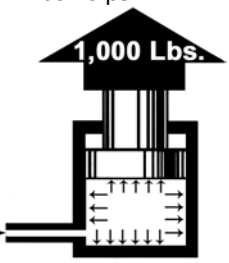
The force input and output of hydraulic devices can be very simply measured and calculated. The pressure produced by the piston on a confined liquid is measured in pounds per square inch, or psi, which can be illustrated thusly:



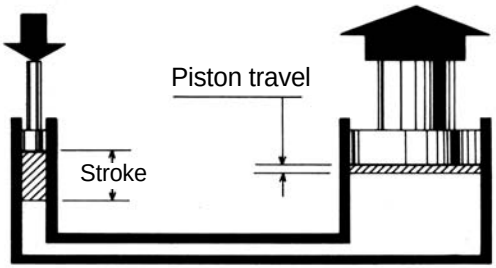
A one pound weight which is placed on an area of 1 sq. in. produces a pressure on that area of 1 psi

If ten pounds force is exerted on an area of ten sq. in., the pressure will still be 1 psi – but if 10 pounds of force is exerted on one sq. inch, the pressure will be 10 psi

The force produced by liquid pressure against a piston will be measured in pounds or tons. If there is a pressure of 100 psi exerted on a piston with an area of 10 square inches, the total force will be 100 (psi) x 10 (sq. in) or 1,000 pounds.



When the small piston is “pushed down” in the pump cylinder, the amount of fluid it will displace will only be enough to move the larger piston a short distance. Therefore, while tremendous force advantage is gained, there is a sacrifice in “distance”.



There is another principle involved in the hydraulic process. Obviously, when a man pushes against a wall with his hand, the force he exerts is opposed by the resistance of the wall. If he pushes against no resistance he would not be able to exert force. His hand would pass freely through the air. So it is with a hydraulic cylinder. A pump may be rated with a pressure out-put of 10,000 psi, but unless there is a resistant force against the cylinder requiring 10,000 psi, the pump will develop only

enough pressure to move the resistant force. Thus, a cylinder rated at 10 tons at 10,000 psi and which is exerting a force of 1 tons, will require considerably less than the 10,000 psi potential out-put of the pump. The pressure will be 1/5 or 2,000 psi in the system.

Hydraulic pump designs take many various forms… gear pumps, vane pumps and piston pumps. Cylinders may be single-acting or double-acting, gravity return, spring return, push type or pull type. There are many types of valves available for almost any kind of control, and the hydraulic units may perform a large variety of functions. A few examples are the devices which raise and lower a barber's chair, the modern automobile brakes, hydraulic equipment used to raise and lower an airplane's landing gear and, of course, the common auto jacks and forcing presses. The applications of hydraulic equipment are limitless.

For many years "low pressure" hydraulics were the primary form, but in recent years the advantages of "high pressure" hydraulics have been recognized and utilized. The safety factor at high pressures is equal to or higher than at low pressures. Well-made equipment can easily handle the high pressures in use today. The prime advantage high pressures have over low pressures in the proportion of size and weight of equipment to power developed. A high pressure pump and cylinder can be considerably smaller than a low pressure unit generating the same amount of force. This size and weight factor is very meaningful when considered in the light of material costs, portability and convenience of design. It is not inconceivable that in the very near future, the working pressures of hydraulic equipment will exceed 100,000 PSI. This is an age of miniaturization and the pioneers in space may well develop a new standard of technology for earth-bound industry.

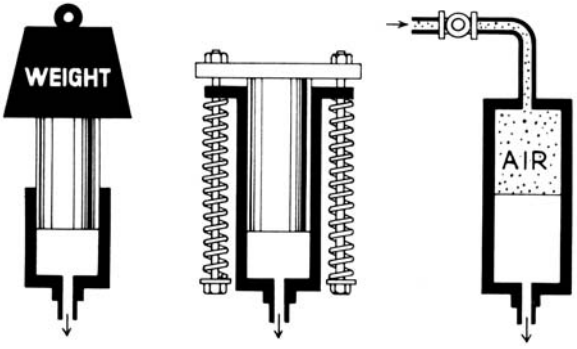
PART II
A Glossary of Hydraulic Terms

A.

Absolute SSU – Saybolt Universal Seconds (SSU) which is the time in seconds for 60 cubic centimeters of oil to flow through a standard orifice at a given temperature.

Accumulator – A storage chamber in which fluid energy may be accumulated and from which it may be withdrawn. The potential energy may be in the form of gravitational work, the elasticity of springs or the compressibility of gases.

Examples:



Actuator – A device for converting fluid energy into mechanical motion such as a cylinder or hydraulic motor.

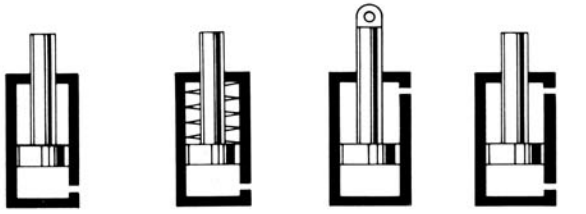
B.

Bleed – The process by which air is removed from the hydraulic system.

C.

Cylinder – A device for converting fluid energy into linear motion. It consists of a movable element such as a piston and piston rod, plunger, or ram operating within a cylinder bore.

- Double Acting – A cylinder in which fluid force can be applied to the movable element in either direction.
- Double Rod – A cylinder with a single piston and a piston rod extending from each end.
- Piston – That part of the movable element which has a greater cross-sectional area than the piston rod.
- Single Acting – A cylinder in which the fluid force can be applied to the movable element, in only one direction.



Gravity Return | Spring Return | Pull Type | Double-Acting

D.

Displacement – The volume of oil, measured in cubic inches, displaced by one complete stroke of a piston.

- Cylinder Displacement is equal to the effective area of the piston times the piston stroke.
- Pump Displacement (hand pump) is equal to the effective area of the piston times the piston stroke.
- Pump Displacement (power driven) is equal to the amount of fluid discharged during one revolution. Normally it is referred to in terms of cubic inches per revolution, cubic inches per minute or gallons per minute (GPM).

E.

Effective Area – That area of the cylinder piston or plunger upon which fluid forces are exerted to impart motion to the piston or plunger. The mathematical formula is: Eff. Area = D^2 x .7854

F.

Filter – A device through which fluid is passed to separate matter held in suspension.

Flash Point – The temperature at which a fluid first gives off sufficient flammable vapor to ignite when approached by a small flame or spark.

Fluid – A state of matter. Gases and liquids are fluid in that the nature of their molecules permit them to flow freely and to conform readily to the shape of any containing vessel.

Fluid Power – Power transmitted and controlled through use of fluid under pressure.

Force – A push or a pull acting upon a body. The force output of a hydraulic cylinder is a product of the circuit pressure (psi) and the effective area upon which it is acting. Force output of hydraulic cylinders is measured in terms of pounds or tons.

G.

Gauge – An instrument which indicates the pressure in the system to which it is connected.

H.

Hydraulics – Engineering science pertaining to liquid pressure and flow.

Hydraulic Power Unit – An assembly of hydraulic components normally consisting of a prime mover (electric motor or internal combustion engine), hydraulic pump, reservoir, valving and associated equipment.

M.

Manifold – A conductor which provide multiple connection ports.

Motor (Hydraulic) – A device for converting fluid energy into mechanical rotary motion. Basic design types include gear, vane and piston units.

P.

Packing – A sealing device consisting of bulk deformable material or one or more mating deformable elements. Common types are “U” packing, “V” packing, “Cup” packing and “O” rings.

“U” packing

“V” packing

“Cup” packing

“O” packing

Pascal’s Law – A pressure applied to a confined fluid at rest is transmitted with equal intensity throughout the fluid.

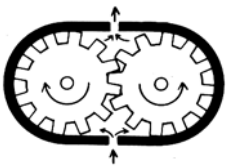
Pour Point – The lowest temperature at which a liquid will flow under specific conditions.

Pressure – Force per unit area usually expressed in pounds per square inch (psi)

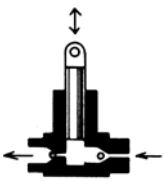
Pump – A device for converting mechanical energy into fluid energy.

- Fixed Displacement – A pump in which the displacement per cycle cannot be varied.
- Variable Displacement – A pump in which the displacement per cycle can be varied.

Common designs include hand actuated units of single and dual displacement capabilities, mechanically driven units of the gear and piston type and combinations thereof.



gear pump



radial piston pump

axial piston pump

R.

Ram – A common term applied to cylinders in general but in particular it is a plunger or piston rod operating within a cylindrical bore.

Reservoir – A chamber, used to store hydraulic fluid, on which, or in which pumps and valves may be mounted. Motors are mounted externally.

S.

Slippage – Internal leakage past components in a hydraulic system.

Solenoid – An electro-magnetic device used to impart linear motion in one direction.

Solenoid Controlled Pilot Operated – A valve which is operated by a solenoid operated pilot valve.

Solenoid Operated – A valve which is positioned by one or more solenoids.

Stroke – The length of allowable travel of a piston in a cylinder.

V.

Valve – A device which controls fluid flow conditions such as pressure, temperature, time, rate or direction.

- •Check – A valve which permits flow of fluid in only one direction.
- •Closed Center – A valve in which all ports are closed in the center position.
- •Directional Control – A valve whose primary function is to direct flow through selected passages.
- •Flow Control – A valve whose primary function is to control flow rate.
- •Needle – A valve with an externally adjustable tapered closure which regulates the flow passage.
- •Open Center – A valve in which all ports are interconnected in the center position.
- •Pilot – A valve applied to operate another valve or control.
- •Pilot Operated – A valve in which operating parts are actuated by pilot pressure.
- •Relief – A valve whose primary function is to limit system pressure.
- •Two or Three Position – A valve having two or three positions to give various selections of flow conditions.
- •Two, Three or Four Way – A directional control valve having 2, 3 or 4 ports for direction of oil flow.

Viscosity Index – A measure of the viscosity — temperature characteristics of a fluid as referred to that of other fluids.

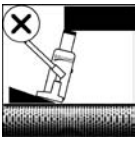
PART III

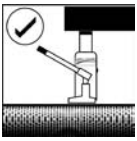
SAFETY INSTRUCTIONS

Jacks

▲Provide a level and solid support for the entire jack base area.

▲Never place any part of your body under the load. Ensure the load is on a solid support before venturing under.

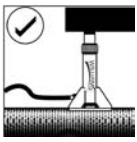




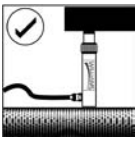
▲The entire jack saddle must be in contact with load. Movement of the load must be in the same direction as jack plunger.

▲Remove the jack handle when it is not being used.

Cylinders



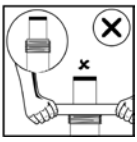
▲Provide a solid support for the entire cylinder base area. Use cylinder base attachment for more stability.



▲The entire cylinder saddle must be in contact with the load. Movement of the cylinder must be parallel with the movement of the load.

▲Do not use cylinder without saddle. This will cause plunger to “mushroom” Saddles distribute load evenly on the plunger.

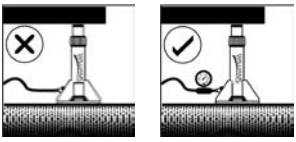
▲As with jacks, never place any part of your body under the load. Load must be on cribbing before venturing under.



▲Always protect cylinder threads for use with attachments.

▲Keep hydraulic equipment away from open fire and temperatures above 150°F (65°C).

General

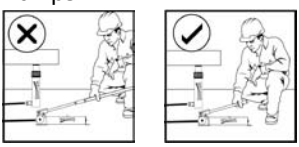


▲Do not override the factory setting of relief valves. Always use a gauge to check system pressure.

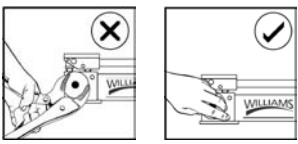
SAFETY FIRST!

- Study, understand, and follow all instructions before operating this device.
- Do not exceed rated capacity. Use only on hard, level surfaces.
- Immediately after lifting, support the vehicle with appropriate means.
- Failure to heed these markings may result in personal injury and/or property damage

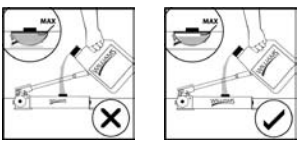
Pumps



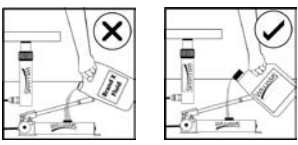
▲Do not use handle extender. Hand pumps should be easy to operate when used correctly.



▲Close release valve finger tight. Using force will damage the valve.

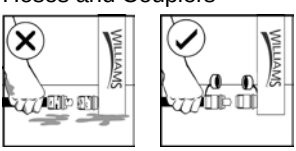


▲Fill pump only to recommended level. Fill only when connected cylinder is fully retracted.

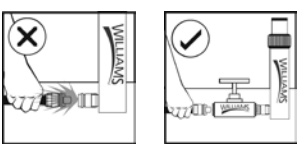


▲Use only genuine Williams hydraulic oil. THe wrong fluid can destroy your seals and pump and will render your warranty null and void.

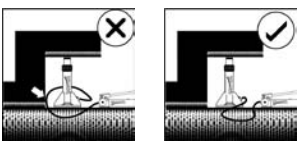
Hoses and Couplers



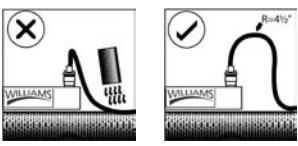
▲Clean both coupler parts before connecting. Use dust caps when coupler parts are not connected.



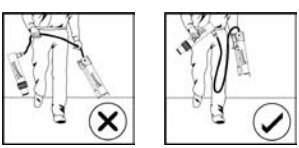
▲Detach cylinder only when fully retracted or use shut-off valves or safety valves to lock-in cylinder pressure.



▲Keep hoses away from the ares beneath loads.



▲Do not kink hoses bending radius should be at least 4½". Do not drive over or drop heavy objects on the hoses.



▲Don't lift hydraulic equipment by the hoses.

PART IV

TROUBLE SHOOTING HYDRAULIC SYSTEMS

Hydraulic systems are made up of precision machined components which require care and attention to insure continued trouble-free operation. The primary attention should be given to keeping all parts CLEAN! Change the oil and oil filter at regular intervals. DIRT IS YOUR WORST ENEMY.

If trouble should develop, the cause can usually be traced to one of the following:

1. Oil used is of wrong viscosity
2. Not enough oil in system
3. Leakage
4. Dirt, damaged packing, water or other foreign matter in system
5. Air in system
6. Structural failure
7. Incorrect adjustments

Some possible causes of trouble and their remedy are listed below for handy reference:

∆ PUMP OPERATES IMPROPERLY

1. PUMP FAILS TO DELIVER OIL

Possible Causes	Remedy
A. Fluid low in reservoir	A. Check level and fill
B. Intake pipe or filter plugged	B. Clean
C. Air leak in suction line. Pump unable to prime, causing noise and erratic action of components	C. Repair leaks
D. Oil of too heavy viscosity	D. See mfr. specs
E. Wrong direction of pump shaft rotation	E.Must be reversed to prevent damage to pump due to lack of lubrication
F. Dirt in pump	F. Clean

2. SYSTEM WON'T DEVELOP PRESSURE

Possible Causes	Remedy
A.Pump doesn't deliver fluid. See causes under "Pump Fails to Deliver Oil" above	A. See remedies under "Pump Fails to Deliver Oil" above
B.Relief valve malfunction 1) Incorrect setting 2) Leakage 3) Valve spring broken	B. See below 1) See mfr. specs & re-set 2) Check valve seat for scoring or dirt 3) Replace spring and re-adjust
C.Re-circulation of oil to tank allowed through system	C.Check directional valve to see that it is not in an open-center neutral position, or in other positions that do not permit oil to re-circulate.
D.Internal leakage in valves or cylinders	D.Check components

3. PUMP NOISE

Possible Causes	Remedy
A.Intake line or intake filter has restriction	A.Clean – be sure lines are fully open
B.Air leaks 1) At intake pipe joints 2) At pump shaft packing 3) Through inlet pipe opening	B. See below 1) Pour oil on joints to check for leak 2) Pour oil around shaft to check for leak 3) Check to see that suction and return lines are below oil level in reservoir
C.Air bubbles	C.Use oil with a foam depressant
D.Reservoir air vent plugged	D.Clean
E.Pump runs too fast	E.Check mfr. Specs
F.Wrong oil viscosity	F.Check mfr. Specs
G.Filter of wrong size	E.Check mfr. Specs
H.Worn or broken parts	H.Replace

4. EXTERNAL OIL LEAKAGE AROUND PUMP

Possible Causes	Remedy
A.Shaft packing worn	A.Replace
B.Damaged head packing	B.Replace
C.Broken or loose parts	C.Check and replace or tighten

5. EXCESSIVE WEAR

Possible Causes	Remedy
A. Abrasive material in oil being circulated	A. Clean or replace filter and change oil
B. Oil viscosity too low	B. Check mfr. Specs
C. Pressures too high for max. rating of pump	C. Check relief or regulator valve settings
D. Drive not aligned	D. Check and correct
E. Air in system	E. Remove air

6. BROKEN PUMP PARTS

Possible Causes	Remedy
A. Pressures above max. pump rating	A. Check relief or regulator valve settings
B. Seizure due to lack of oil in system	B. Check reservoir level, oil filter and suction line
C. Dirt or solids in pump	C. Clean – check filter
D. Head screws too tight	D. See mfr. Specs

∆ ACTUATING MECHANISMS MALFUNCTION

1. SYSTEM INOPERATIVE

Possible Causes	Remedy
A. See causes under “Pump Operates Improperly”	A. See remedies under “Pump Operates Improperly”

2. MECHANISMS CREEP

Possible Causes	Remedy
A.Internal leakage in valves or cylinders	A.Replace packings, check for scored cylinder walls
B.Poppet in valve not seating	B.Check for dirt or damage to seat

3. MECHANISM TAKES TOO LONG TO OPERATE

Possible Causes	Remedy
A.Air in system	A.Bleed the system
B.Internal leaks in coonents	B.Check and repair
C.Worn pump	C.Repair or replace
D.Wrong oil viscosity	D.See mfr. Specs
E.Low auxiliary control pressure	E.Control lines may be too small

4. EXTERNAL OIL LEAKS

Possible Causes	Remedy
A.End caps or gaskets loose	A.Tighten
B.Packing glands	B.Tighten or replace

5. PACKING GLAND WEAR

Possible Causes	Remedy
A.Piston Rod extension	A.Check and correct
B.Off-center load on cylinder	B.Revise set-up
C.Vibration	C.Check and correct

∆ OIL IN SYSTEM TOO HOT

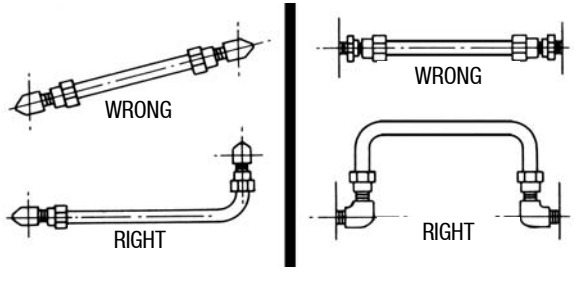
1. HEATING CAUSED BY POWER UNIT

Possible Causes	Remedy
A.Relief valve set at higher pressure than necessary – excess oil dissipated through increased slippage	Reset valve, check mfr. Specs
B.Internal oil leakage	B.Check and repair
C.Oil viscosity too high	C.See mfr. Specs
D.Oil cooler malfunctioning	D.Check and repair
E.Automatic unloading control	E.Repair valve inoperative

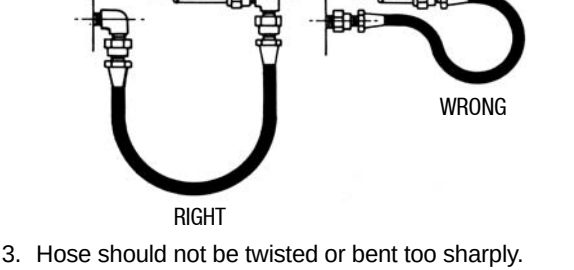
2. HEATING CAUSED BY CONDITIONS IN CIRCUIT

Possible Causes	Remedy
A.Lines restricted	A.If lines are too small or crimped, replace. If lines are plugged, clean
B.Pump deliveries of large volumes not unloaded properly	B.Check valves. Only small pump volumes should be allowed to remain at high pressures when clamping or running idle for long periods of time.
C.Not enough radiation	C.Use artificial cooling
D.Leaks	D.Repair
E.Reservoir too small	E.Use larger reservoir or provide cooling
F.Valves or pipes too small	F.Replace, check mfr. specs

∆ HOSE AND TUBING DO'S AND DON'TS



1. Avoid straight line tubing connections in short runs. This does not provide expansion and contraction due to temperature changes.
2. Care should be taken to eliminate stress from tube lines. Long tubing runs should be supported by brackets or clips. Tubes through bulk heads should have bulk head fittings. This makes possible easy removal, as well as helping to support the tubing.



3. Hose should not be twisted or bent too sharply. The radius of a bend should not be less than 9 times the o.d. of the hose. Use as few bends as possible.

⚠ WARNING

⚠ *This is the safety alert symbol. It is used to alert you to potential personal injury hazards. Obey all safety messages that follow this symbol to avoid possible injury or death.*

⚠ *There are hazards associated with the use of this equipment which can only be avoided by **reading, understanding and following** all the printed materials provided by the manufacturer of the gasoline engine which drives this hydraulic pump.*

- **Read, understand, and follow all** instructions provided with and on this device **before use**.
- All WARNING statements must be carefully observed to help prevent personal injury.
- No alteration shall be made to this device.

- Always wear protective gear when operating hydraulic equipment. Tie up long hair, wear eye and ear protection, and non slip foot wear.

- Keep hydraulic equipment away from flames and heat. Hydraulic fluid can ignite and burn. Do not operate if leaks are detected.

- Crush Hazard - **k**eep hands and feet away from loading area. Avoid pinch points or crush points that can be created by the load, cylinder, or system components.
- To avoid crushing and related injuries: NEVER work on, under or around a lifted load before it is supported by appropriate mechanical means. Never rely on hydraulic pressure alone to support load.

HYDRAULIC PUMPS

- The user must be a qualified operator familiar with the correct operation, maintenance, and use of pumps. Lack of knowledge in any of these areas can lead to personal injury.
- Do not exceed rated capacity of the pump or any equipment in the system.
- Never attempt to lift a load weighing more than the capacity of the output device (cylinder, spreader etc.)
- Do not subject pump and its components to shock loads.
- Burst hazard exists if hose or connection pressure exceeds rated pressure.
- Inspect pump, cylinder, hoses and connections before each use to prevent unsafe conditions from developing. Do not use if they are damaged, altered or in poor condition. Do not operate the system with bent or damaged coupler or damaged threads.
- Never hold or stand directly in line with any hydraulic connections while pressurizing.

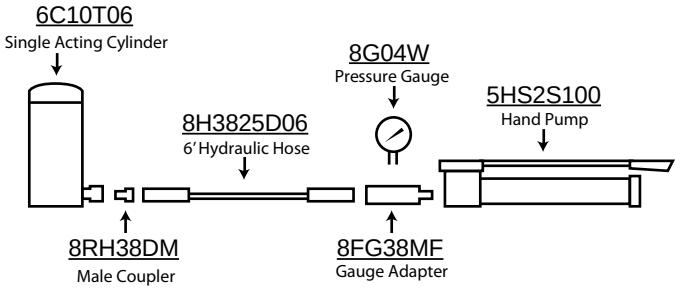
- **ALWAYS** use gauge or other load measuring instrument to verify load.
- **Never** attempt to disconnect hydraulic connections under pressure. Release all line pressure **before** disconnecting hoses.
- Do not operate this device in an extreme temperature, explosive atmosphere or in the presence of conductive liquids.
- Always inspect hoses and connections for damage prior to use.
- Ensure the device is placed on a hard, level surface.
- Ensure that application is stable to work on and around.
- Use only approved accessories and approved hydraulic fluid.
- Never attach ANY component not authorized by manufacturer.
- Do not connect to application which can return more oil to the reservoir than the pump reservoir can hold.
- Do not connect pump to hydraulic system powered by another pump.
- This device is not suitable for use as support device! As the system load is lifted, use blocking and cribbing to guard against a falling load.
- All personnel must be clear before lowering load or depressurizing the system.
- Never try to disassemble a hydraulic pump, refer repairs to qualified, authorized personnel.

HYDRAULIC HOSES & FLUID TRANSMISSION LINES

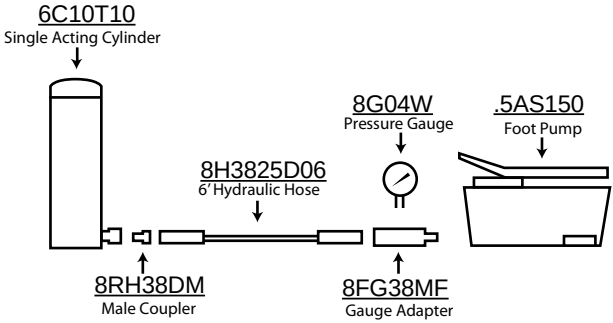
- Avoid short runs of straight line tubing. Straight line runs do not provide for expansion and contraction due to pressure and/or temperature changes.
- Reduce stress in tube lines. Long tubing runs should be supported by brackets or clips. Before operating the pump, tighten all hose connections with proper tools. Do not overtighten. Connections should only be tightened securely and leak-free. Overtightening can cause premature thread failure or high pressure fittings to burst.
- Should a hydraulic hose ever rupture, burst or need to be disconnected, immediately shut off the pump and release all pressure. Never attempt to grasp a leaking pressurized hose with your hands. The force of escaping hydraulic fluid can inflict injury.
- Do not subject the hose to potential hazard such as fire, sharp objects, extreme heat or cold, or heavy impact.
- Do not allow the hose to kink, twist, curl, crush, cut or bend so tightly that the fluid flow within the hose is blocked or reduced. Periodically inspect the hose for wear.
- Do not pull, position or move setup by the hose.
- Hose material and coupler seals must be compatible with hydraulic fluid used. Hoses also must not come in contact with corrosive materials such as battery acid, creosote-impregnated objects and wet paint. Never paint a coupler or hose.
- FAILURE TO HEED THESE WARNINGS MAY RESULT IN PERSONAL INJURY AS WELL AS PROPERTY DAMAGE.

Δ Basic System Set-Ups

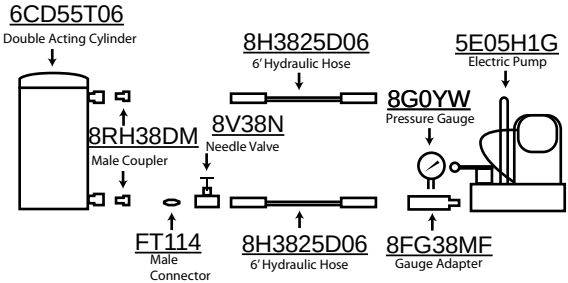
Single Push Application



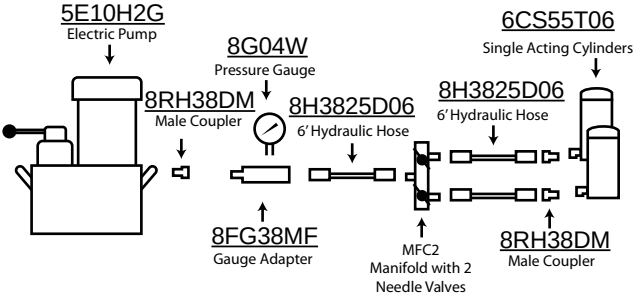
Single-Acting Cylinder with Longer Stroke



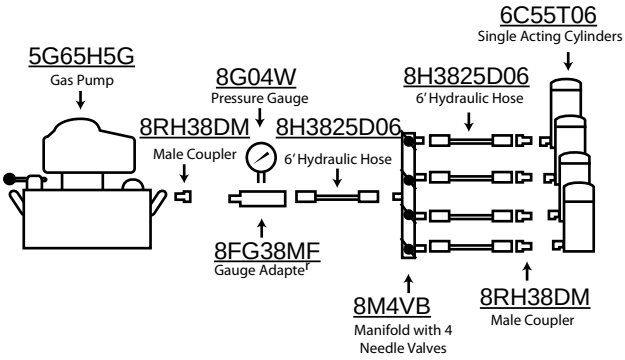
Double-Acting Cylinder Application



Two Single-Acting Cylinders Application



Four Single-Acting Cylinders Application



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