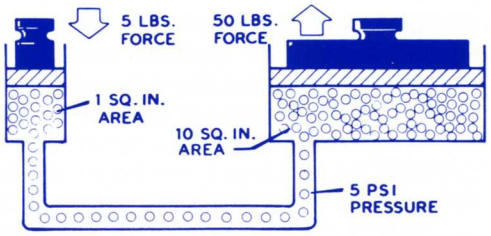
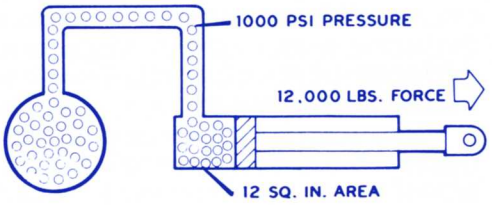
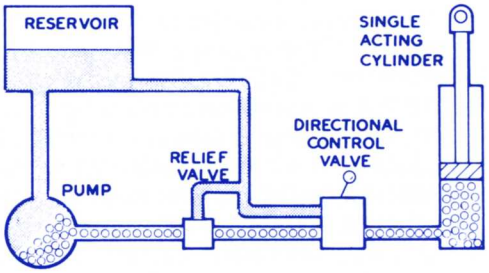
The basis for all hydraulic systems is expressed by Pascal's law which states that the pressure exerted anywhere upon an enclosed liquid is transmitted undiminished, in all directions, to the interior of the container. This principle allows large forces to be generated with relatively little effort. As illustrated, a 5 pound force exerted against a 1 inch square area creates an internal pressure of 5 psi. This pressure, acting against the 10 square inch area develops 50 pounds of force.



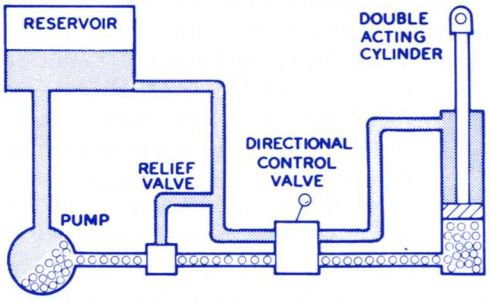
In a basic hydraulic circuit, the force exerted by a cylinder is dependent upon the cylinder bore size and the pump pressure. (There is no force generated unless there is resistance to the movement of the piston). With 1000 psi pump pressure exerted against a 12 square inch piston area (approximately 4" dia.), a force of 12,000 pounds is developed by the cylinder. The speed at which the piston will move is dependent upon the flow rate (gpm) from the pump and the cylinder area. Hence, if pump delivery is 1 gallon per minute (231 cu.in./min.) the cylinder piston will move at the rate of 20 in./min. (231 cu. in. ÷ 12 cu. in./min.).



The simplest hydraulic circuit consists of a reservoir, pump, relief valve, 3-way directional control valve, single acting cylinder, connectors and lines. This system is used where the cylinder piston is returned by mechanical force. With the control valve in neutral, pump flow passes through the valve and back to the reservoir. With the valve shifted, oil is directed to the piston side of the cylinder, causing the piston to move, extending the rod. If the valve is returned to neutral, the oil is trapped in the cylinder, holding it in a fixed position, while pump flow is returned to the reservoir. Shifting the valve in the opposite direction permits the oil to pass through the valve back to the reservoir. The relief valve limits the system pressure to a pre-set amount. Relief valves are commonly incorporated into the directional control valve.

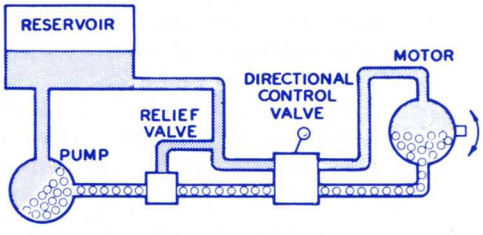


A hydraulic system using a double acting cylinder and a 4-way valve differs from the single acting cylinder system in that the cylinder can exert force in both directions. With the control valve in, neutral flow is returned to the reservoir. When shifted in one direction, oil is directed to the piston side of the cylinder, causing the cylinder to extend. Oil from the rod side passes through the valve back to the reservoir. If the valve is shifted to neutral, oil in the cylinder is trapped, holding it in a fixed position. When the valve is shifted in the opposite position, oil is directed to the rod side of the cylinder, causing the cylinder to retract. Oil from the piston side passes through the valve back to the reservoir.
Cylinder extend force is the result of the pressure (psi) times the piston area (minus any force resulting from the pressure acting against the rod side of the piston). Retract force is a result of the pressure (psi) times the area difference between the rod and the piston (minus any force resulting from pressure acting against the piston side of the cylinder).



Rotary hydraulic motor circuits are basically the same as cylinder circuits. Systems may be uni-directional or bi-directional (as shown). The amount of rotary force (torque) available from the motor is a function of pressure (psi) and motor size. Speed is a function of flow and motor size.

All of the systems described above are open center systems due to the oil flowing through the control valve back to the tank. Most systems are this type. Closed center systems use control valves with the inlet port blocked and variable displacement pumps. With the control valve in neutral, the pump is "de-stroked" to zero flow.



ACCUMULATOR: A container which stores fluid under pressure. Used as an energy source or to absorb hydraulic shock. Common types are piston, bladder and diaphragm.

BLEEDER (BLEED VALVE): A device for removal of pressurized fluid. Used to bleed air from system.

CAVITATION: A gaseous condition within a liquid stream caused when pressure is reduced to the vapor pressure. To be avoided due to destructive effects on pumps and motors.

CIRCUIT; PILOT: Used to control a main circuit or component.

CIRCUIT; REGENERATIVE: Used to increase cylinder speed by directing rod end discharge to the piston side of the cylinder. Can be incorporated into directional control valve as fourth position.

CYLINDER: A device which converts hydraulic energy into linear mechanical motion and force.

CYLINDER; DOUBLE ACTING: A cylinder which can apply force and motion in either direction.

CYLINDER; SINGLE ACTING: A cylinder which can apply force in one direction only.

CYLINDER; DEPTH CONTROL: A mechanical or hydraulic device, adjustable, for limiting cylinder stroke.

CYLINDER; REPHASING: A cylinder design which permits the use of two or more cylinders in series, automatically synchronizing cylinder position at the end of each stroke.

DETENT: A spring device which maintains the spool of a directional control valve in position.

DETENT RELEASE: A mechanical, hydraulic or electrical device for releasing the detent.

FILTER: A device incorporated into a hydraulic system to remove contaminants from the oil.

FITTING: A device for connecting hose or pipe to hydraulic components.

FLOAT SPOOL (POSITION): A spool valve design which connects all ports to the tank (return) port, usually in a detented fourth position, allowing a cylinder or motor to "float".

FLOW RATE: The volume of fluid passing through the system or component in gal. per min. (or l/m)

FLUID POWER SYSTEM: The transmission and control of power through the use of fluid pressure.

MOTOR: A device which converts hydraulic energy into rotary motion, either fixed or variable.

PORT: The internal or external terminus of a passage. The point where the fitting is attached.

PRESSURE: The force per unit area, expressed in pounds per square inch (psi), bars, or atmospheres.

PRESSURE; BACK: The pressure encountered on the downstream or return side of a component.

PRESSURE; CRACKING: The pressure at which a pressure operated valve begins to pass fluid.

PRESSURE; MAXIMUM RATED: The maximum pressure at which a component should be operated on a continuous basis, usually the relief valve setting at maximum flow rate.

PUMP: A device which converts mechanical energy into hydraulic energy, either fixed or variable.

RESERVOIR: A container which stores the liquid in a fluid power system.

SEAL: A device which prevents or controls the escape or passage of hydraulic fluid.

VALVE: A device which controls fluid flow rate, direction, or pressure.

VALVE; DIRECTIONAL CONTROL: A device for directing or preventing the oil flow in a system.

OPEN CENTER (TANDEM) TYPE: Has the inlet port connected to the outlet (tank) port in neutral.

CLOSED CENTER TYPE: Has the inlet port blocked from the outlet and work ports in neutral.

TWO-WAY: A 2 port valve with inlet and outlet ports. THREE-WAY: A 3 port valve (in, out and work) normally used with a single acting cylinder or uni-directional motor.

FOUR-WAY: A 4 port valve (in, out and 2 work) used with double acting cylinders, bi-directional motors.

TWO, THREE, FOUR POSITION: The number of positions in which a valve can be positioned.

SERIES TYPE: A multiple spool valve in which the return oil from the first spool is directed to the inlet of the second spool (and from the second to the third, etc.). This type valve permits simultaneous operation of two or more functions with the same oil flow. However, the total pressure requirements of all functions are accumulative.

PARALLEL TYPE: A multiple spool valve in which the inlet oil is connected to all spools simultaneously. If more than one spool is actuated, the function requiring the lowest pressure will operate first.

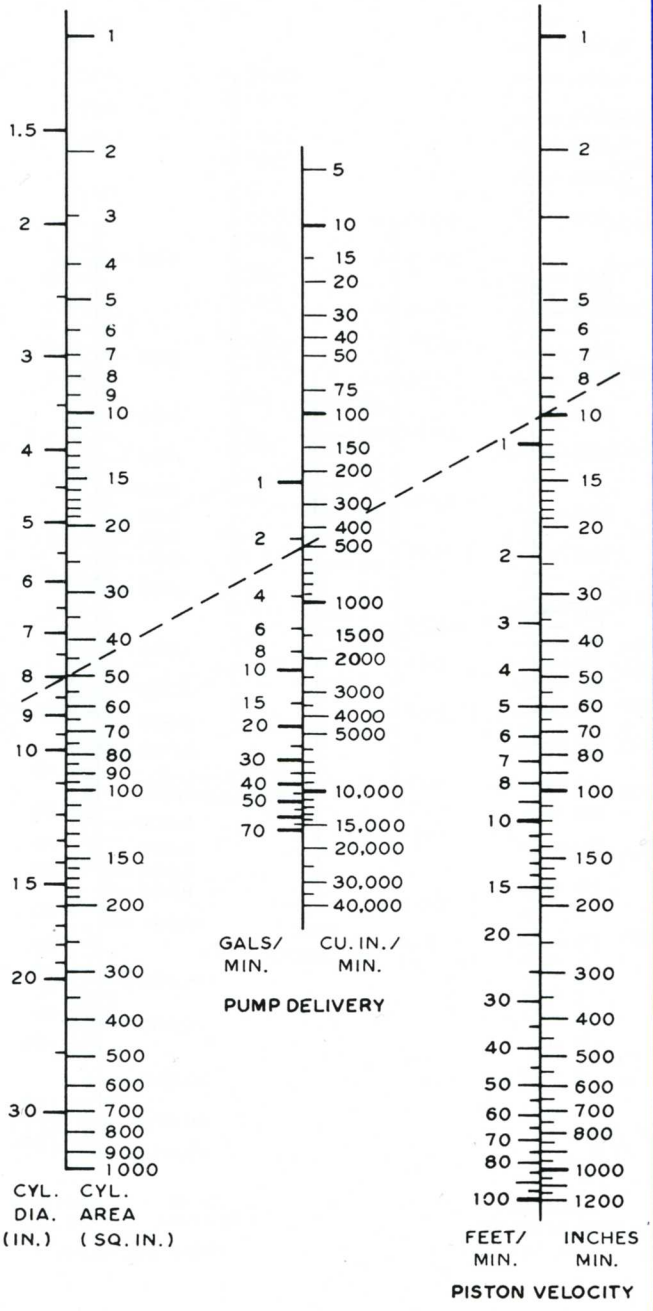
SERIES-PARALLEL TYPE: A multiple spool valve which has all spools connected to the open center passage in neutral. However, when actuated, the upstream valve takes full priority. The return oil is directed to downstream spools as in a series type valve.

POWER BEYOND (HIGH PRESSURE CARRYOVER): A sleeve attachment which permits the oil flow from one valve (when in neutral) to be used by another valve downstream. Hence, a 3-spool valve could be connected to a 2-spool valve to create a 5-spool valve. The first valve takes priority and must have a separate outlet port to return oil from an activator back to the reservoir.

LOAD CHECK (LIFT CHECK): A device which prevents a load from dropping when a valve is shifted, until ample pressure and flow is available to hold or move the load.

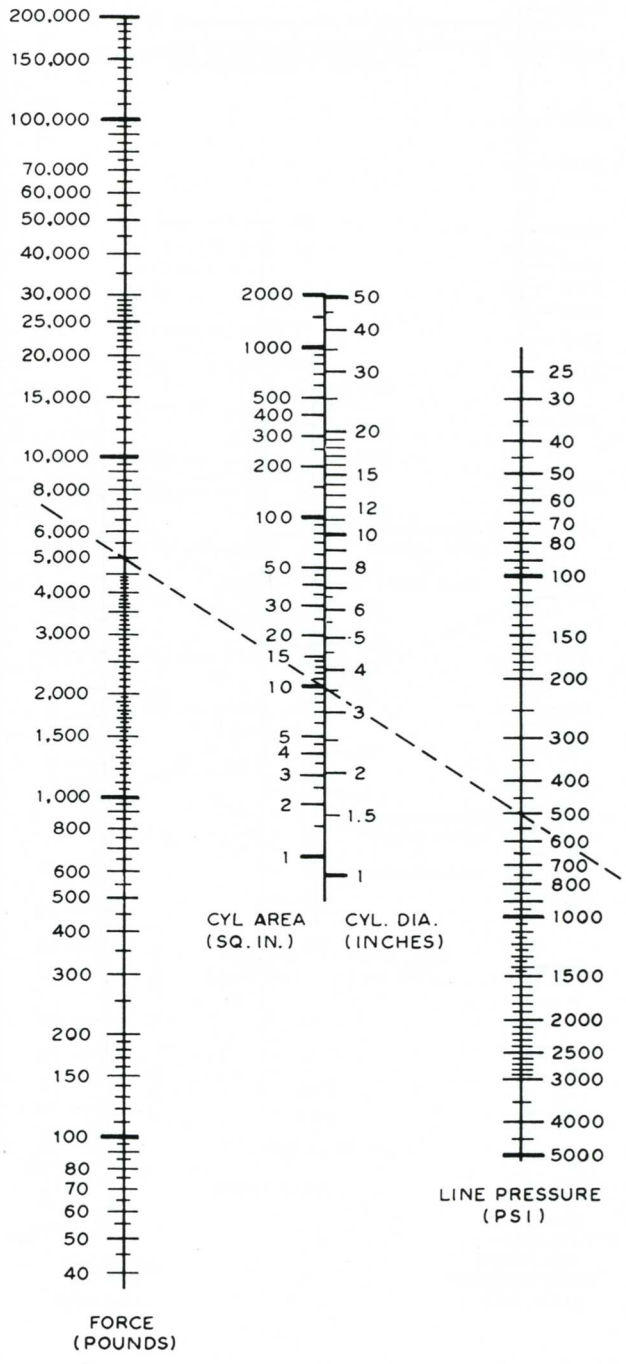
CYLINDER SPEED

$$\text{Pump Delivery (Cu. In. per Min.)} = \frac{\text{Cylinder Area (Square Inches)}}{} \times \frac{\text{Piston Velocity (Inches per Minute)}}{}$$



CYLINDER FORCE

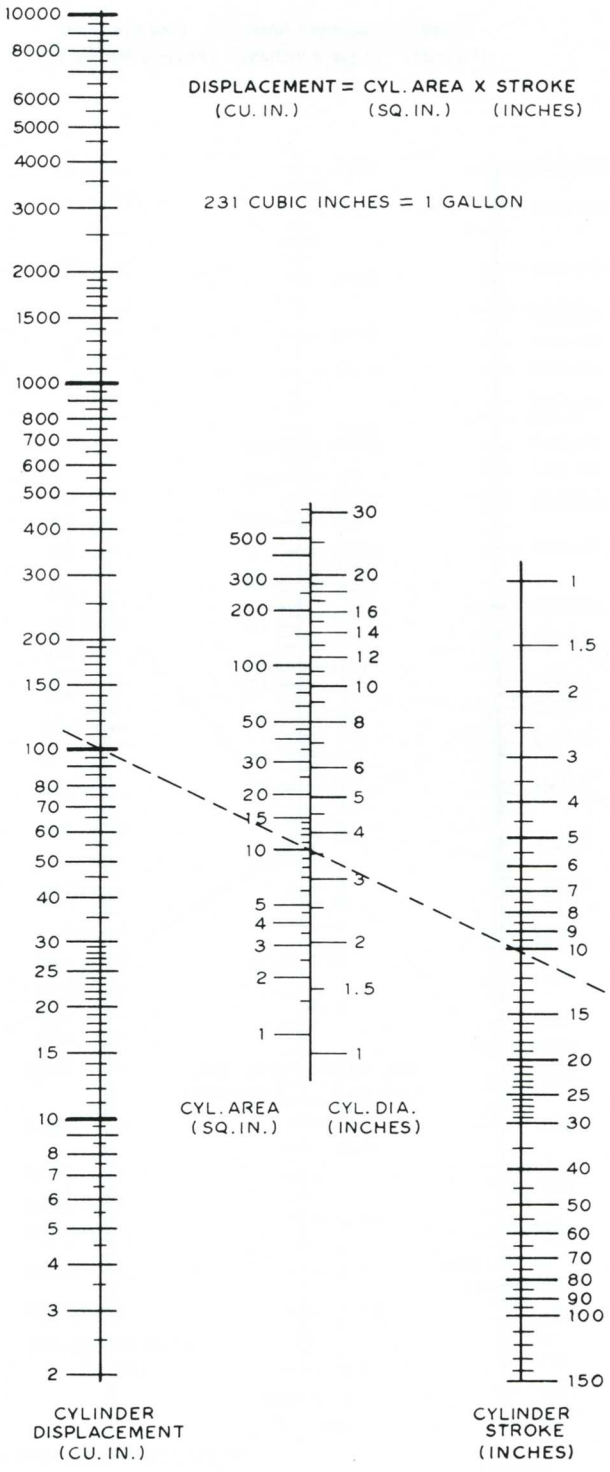
$$\text{Force (Pounds)} = \frac{\text{Cylinder Area (Square Inches)}}{} \times \frac{\text{Line Pressure (Pounds Per Sq. In.)}}{}$$



CYLINDER DISPLACEMENT

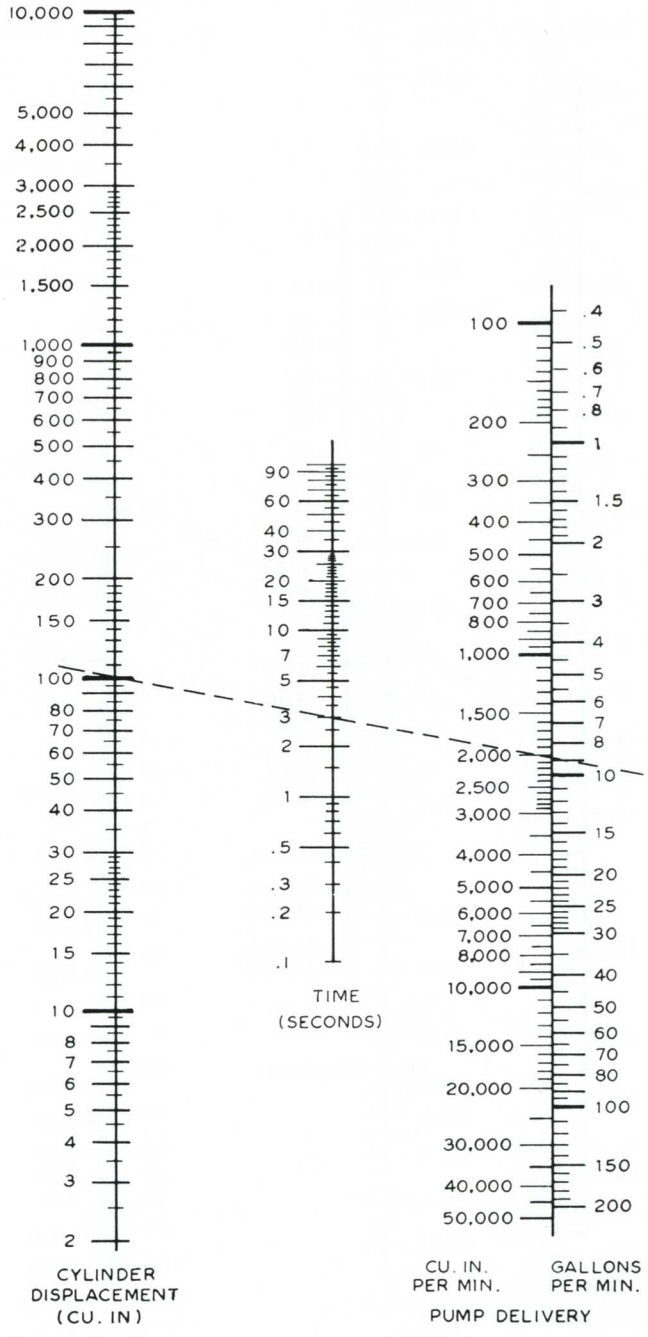
DISPLACEMENT = CYL. AREA X STROKE
(CU. IN.) (SQ. IN.) (INCHES)

231 CUBIC INCHES = 1 GALLON



DISPLACEMENT / TIME

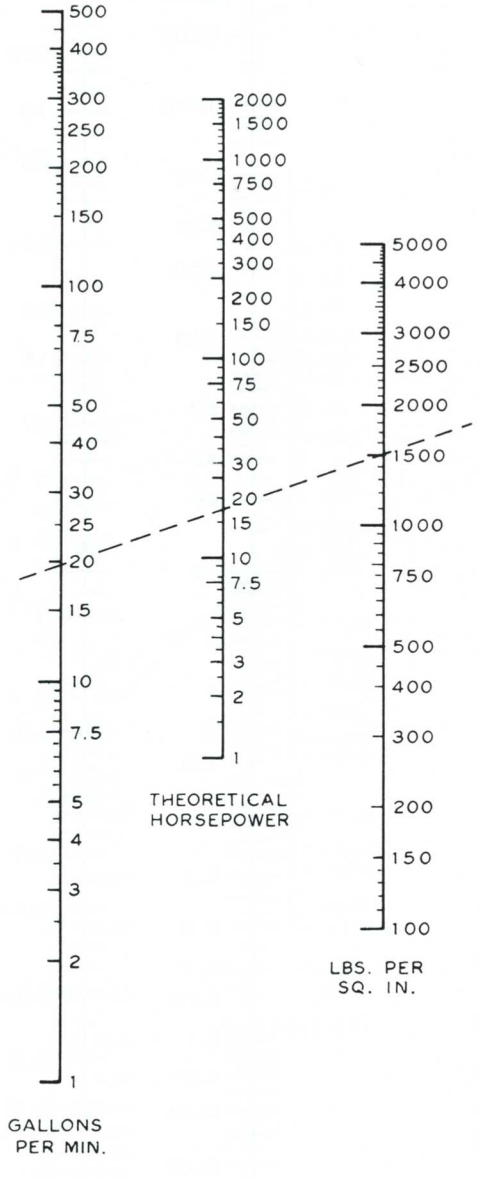
$$\text{TIME (SECONDS)} = \frac{\text{CYL. DISPL. (CU. IN.)} \times .2597}{\text{PUMP DELIVERY (GPM)}}$$



PUMP and MOTOR HORSEPOWER

$$HP = PSI \times GPM \times 0.000583$$

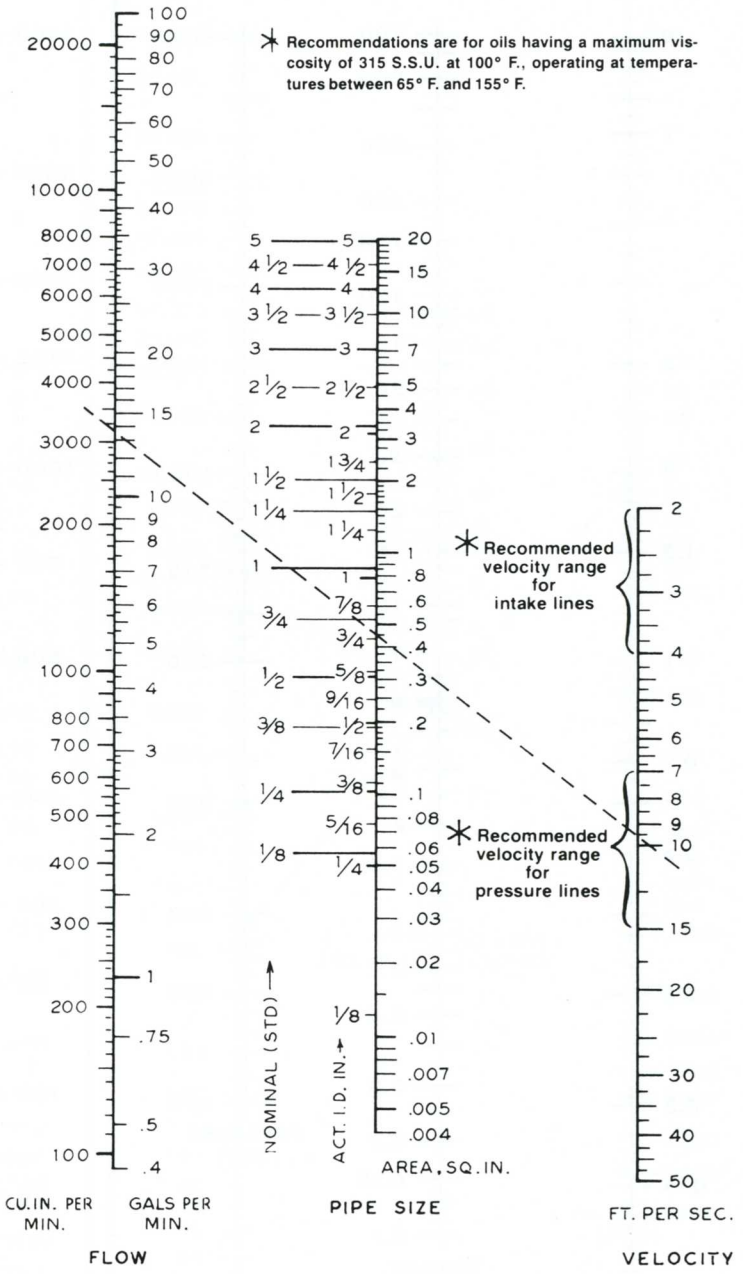
PUMP DRIVE = THL. HP ÷ EFFICIENCY
MOTOR OUTPUT = THL. HP X EFFICIENCY



PIPE FLOW CAPACITY

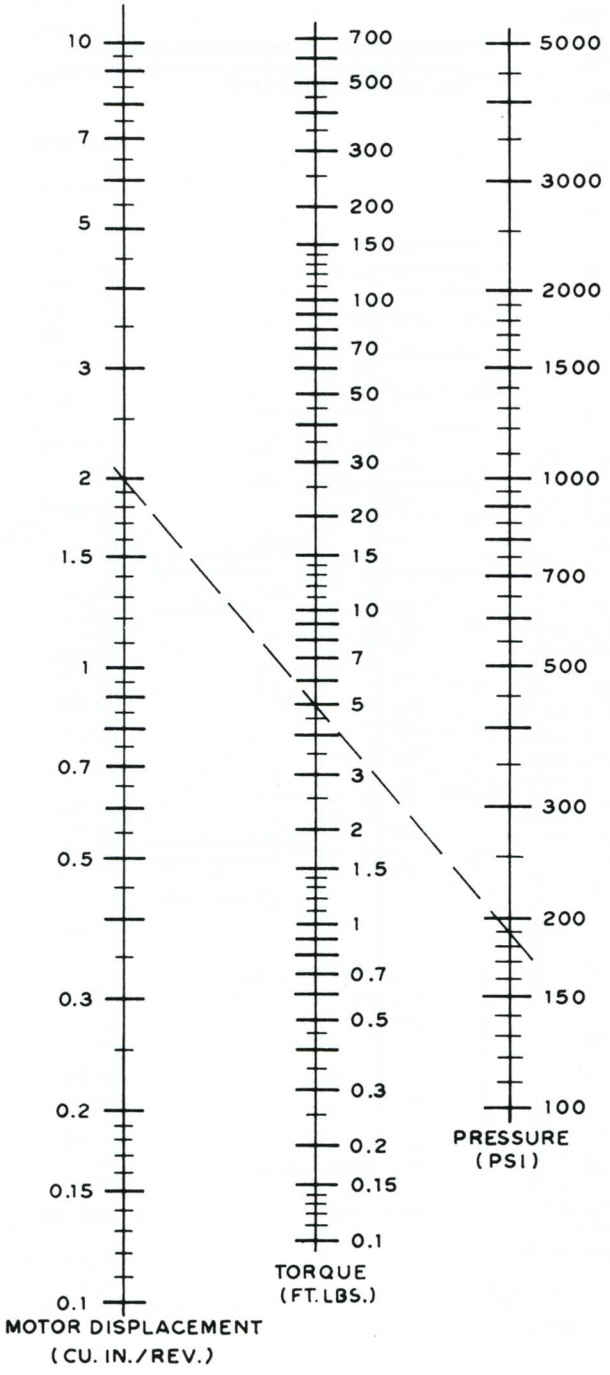
$$AREA = \frac{GPM \times 0.3208}{VELOCITY\ (FT./SEC.)}$$

* Recommendations are for oils having a maximum viscosity of 315 S.S.U. at 100° F., operating at temperatures between 65° F. and 155° F.



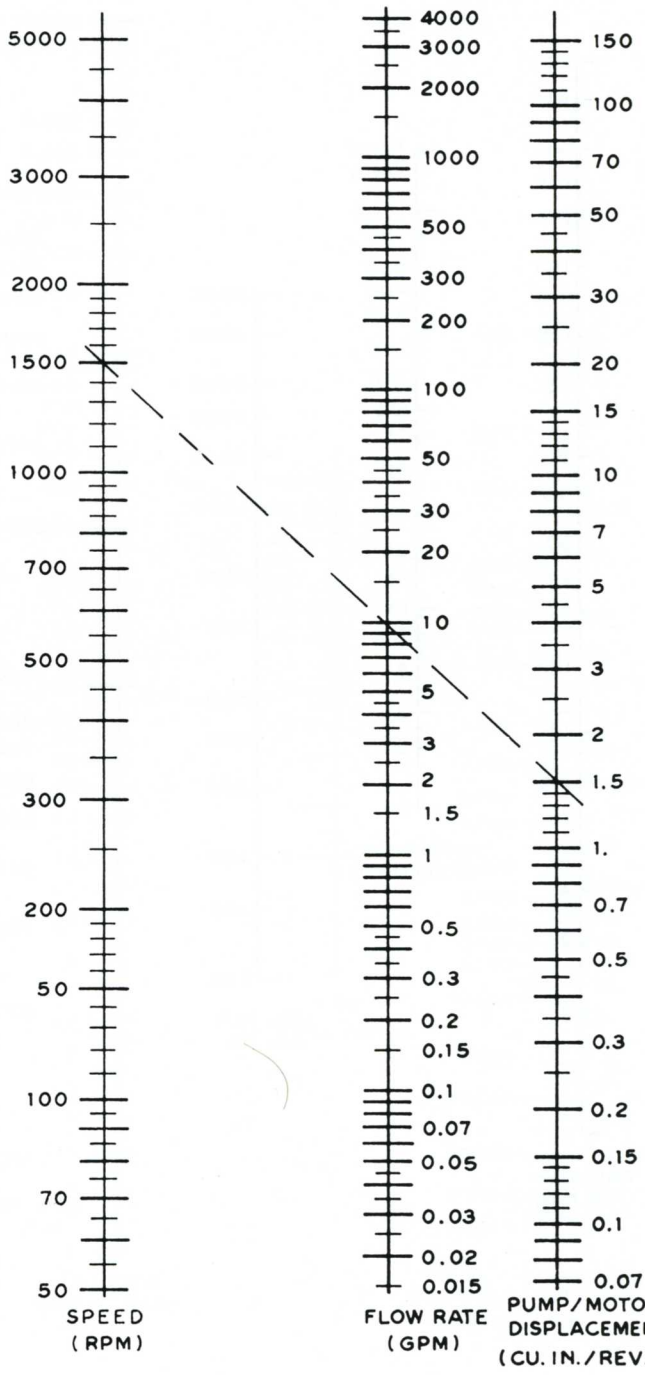
HYDRAULIC MOTOR TORQUE

$$\text{TORQUE} = \frac{\text{DISPL.} \times \text{PRESSURE}}{24\pi}$$



HYDRAULIC MOTOR SPEED

$$\text{FLOW RATE} = \frac{\text{SPEED} \times \text{DISPL.}}{231}$$



LINEAR MEASUREMENT

1 foot (ft.) = 12 inches (in.)
1 yard (yd.) = 3 ft. = 36 in.
1 mile (statute) = 5,280 ft.

To convert	into	Multiply by
inches	centimeters	2.5400
inches	millimeters	25.4000
feet	meters	0.3048
feet	millimeters	304.8000
yards	meters	0.9144
miles	kilometers	1.6093

1 centimeter (cm) = 10 millimeters (mm)
1 meter (m) = 100 cm = 1000 mm
1 kilometer (km) = 1000 meters

To convert	into	Multiply by
centimeters	inches	0.3937
millimeters	inches	0.0394
meters	feet	3.2808
millimeters	feet	0.0033
meters	yards	1.0936
kilometers	miles	0.6214

AREA MEASUREMENT

1 square foot (sq. ft.) = 144 square inches (sq. in.)
1 square yard (sq. yd.) = 9 square feet
1 acre = 4,840 sq. yds.
1 square mile = 640 acres

To convert	into	Multiply by
square inches	sq. centimeters	6.4516
square feet	sq. meters	0.0929
square yards	sq. meters	0.8361
acres	sq. meters	4,047.0
square miles	sq. kilometers	2.5900

1 sq. centimeter (cm^2) = 100 sq. millimeters (mm^2)
1 sq. meter (m^2) = 10,000 cm^2
1 are (a) = 100 m^2
1 sq. kilometer (km^2) = 1,000,000 m^2

To convert	into	Multiply by
sq. centimeters	sq. inches	0.1550
sq. meters	sq. feet	10.7639
sq. meters	sq. yards	1.1960
sq. meters	acres	0.0002
sq. kilometers	sq. miles	0.3861

CUBIC MEASUREMENT (Volume)

1 cubic foot (cu. ft.) = 1,728 cubic inches (cu. in.)
1 cubic yard (cu. yd.) = 27 cubic feet

To convert	into	Multiply by
cubic inches	cu. centimeters	16.3872
cubic feet	cubic meters	0.0283
cubic yards	cubic meters	0.7646

1 cu. centimeter (cm^3) = 1000 cu. millimeters (mm^3)
1 cubic meter (m^3) = 1,000,000 cm^3

To convert	into	Multiply by
cu. centimeters	cubic inches	0.0610
cubic meters	cubic feet	35.3145
cubic meters	cubic yards	1.3079

LIQUID MEASUREMENT (Capacity)

1 pint (pt.) = 28.875 cubic inches
1 quart (qt.) = 2 pints = 57.75 cu. in.
1 gallon (gal.) = 4 qts. = 231 cu. in.

To convert	into	Multiply by
cubic inches	liters	0.0164
pints	liters	2.1132
quarts	liters	0.9463
gallons	liters	3.7853
cubic feet	liters	28.3162

1 centiliter (cl.) = 10 milliliters (ml.)
1 liter (l) = 100 cl. = 1000 ml.
1 kiloliter (kl) = 1000 liters

To convert	into	Multiply by
liters	cubic inches	61.0250
liters	pints	0.4732
liters	quarts	1.0566
liters	gallons	0.2642
liters	cubic feet	0.0353

WEIGHT MEASUREMENT

1 ounce (oz.) = 16 drams
1 pound (lb.) = 16 ounces
1 short ton = 2000 pounds
1 long ton = 2240 pounds

To convert	into	Multiply by
drams	grams	1.7718
ounces	grams	28.3495
pounds	kilograms	0.4536
tons (short)	tons (metric)	0.9072

1 centigram (cg.) = 10 milligrams (mg.)
1 gram (g.) = 10 cg. = 1000 mg.
1 kilogram (kg.) = 1000 grams
1 metric ton (t.) = 1000 kg.

To convert	into	Multiply by
grams	drams	0.5644
grams	ounces	0.0353
kilograms	pounds	2.2046
tons (metric)	tons (short)	1.1023

POWER MEASUREMENT

1 horsepower (hp.) = 746 watts = .7457 kilowatts (kw)

To convert	into	Multiply by
horsepower (U.S.)	horsepower (met.)	1.0139
horsepower (U.S.)	kilowatts	0.7457
kilowatts	horsepower (U.S.)	1.3405

1 horsepower (ps) = 736 watts = .7355 kw

To convert	into	Multiply by
horsepower (met.)	horsepower (U.S.)	0.9863
kilowatts	horsepower (met.)	0.7355
horsepower (met.)	kilowatts	1.3596

GENERAL INFORMATION

CROSS

Abbreviations:

psi	=	pounds per square inch
in. hg.	=	inches of mercury
in. H_2O	=	inches of water
atm	=	atmospheres
ata	=	atmospheres absolute

To convert	into	Multiply by
psi	kg/cm^2	0.0703
psi	bar	0.0690
psi	atm	0.0680
psi	in. hg.	2.0360
psi	in. H_2O	0.4335
in. hg.	psi	0.4912
in. hg.	kg/cm^2	0.0345
in. hg.	atm	0.0334
in. H_2O	in. hg.	0.0735
in. H_2O	kg/cm^2	0.0025

Kg/cm^2 = kilograms per square centimeter
kps/cm^2 = kiloponds per square centimeter
(NOTE: 1 kg/cm^2 = 1 kps/cm^2)
N/m^2 = Newton/square meter = 1 Pascal

To convert	into	Multiply by
kg/cm^2	psi	14.2231
kg/cm^2	bar	0.9807
kg/cm^2	atm	0.9678
bar	psi	14.5000
bar	kg/cm^2	1.0200
bar	atm	0.9869
atm	psi	14.7000
atm	bar	1.0130
atm	kg/cm^2	1.0333
Newtons	kg/m^2	9.8070

TORQUE MEASUREMENT

To convert	into	Multiply by
foot-pounds	kilogram-meters	0.1383

To convert	into	Multiply by
kilogram-meters	foot-pounds	7.2330

USEFUL FORMULAS

Fluid pressure (psi) = Force (pounds) ÷ Area (sq. in.) : $psi = \frac{F}{A}$

Cylinder area (sq. in.) = 3.1416 x Radius^2 (inch.) : $A = \pi r^2$

Cylinder force (pounds) = Pressure (psi) x Area (sq. in.) : $F = PA$

Cylinder speed (ft./sec.) = (231 × GPM) ÷ (12 × 60 × Area) : $v = \frac{.3208\,Q}{A}$

Hydraulic horsepower = Pressure (psi) × GPM ÷ 1714 : $HP = \frac{QP}{1714}$

Fluid motor torque (in. lbs.) = Pressure (psi) × disp. (cu. in.) ÷ 6.2822 : $T = \frac{Pd}{2\pi}$

Fluid motor speed (rpm) = 231 × GPM ÷ disp. (cu. in.) : $n = \frac{231\,Q}{d}$

Fluid motor horsepower = Torque (in. lbs.) × rpm ÷ 63025 : $HP = \frac{Tn}{63025}$

Pump output flow (GPM) = Speed (rpm) × disp. (cu. in.) ÷ 231 : $Q = \frac{nd}{231}$

Pump input horsepower = GPM × Pressure (psi) ÷ 1714 × Eff. : $HP = \frac{QP}{1714\,E}$

MEASUREMENT

MICRO	= one millionth
MILLI	= one thousandth
CENTI	= one hundredth
DECI	= one tenth
DECA	= ten
HECTO	= hundred
KILO	= thousand
MEGA	= million
GIGA	= billion

COMMON ABBREVIATIONS

ASA	— American Standards Ass'n
ASAE	— Amer. Society of Agricultural Engrs.
ASME	— Amer. Society of Mechanical Engrs.
ASTM	— Amer. Society for Testing Materials
ANSI	— Amer. National Standards Institute
API	— Amer. Petroleum Institute
DIN	— German National Standards
FPS	— Fluid Power Society
ISO	— Internat'l Organization for Standards
JIC	— Joint Industries Conference
NCFP	— Nat'l Conference on Fluid Power
NFPA	— Nat'l Fluid Power Association
NMTBA	— Nat'l Mach. Tool Builders Ass'n
NPT	— Nat'l Pipe Thread (tapered)

HYDRAULIC PORT SIZES

Nominal Tube O.D.	Tube Dash No.	Thread Size	Nearest Pipe Port	Pipe Thread	Nearest DIN Port	DIN Thread
1/4	— 4	7/16-20	1/8 NPTF	1/8-27	6mm	M 10 x 1.0
5/16	— 5	1/2-20	1/8 NPTF	1/8-27	8mm	M 12 x 1.5
3/8	— 6	9/16-18	1/4 NPTF	1/4-18	10mm	M 14 x 1.5
1/2	— 8	3/4-16	3/8 NPTF	3/8-18	12mm	M 18 x 1.5
5/8	—10	7/8-14	1/2 NPTF	1/2-14	15mm	M 18 x 1.5
3/4	—12	1 1/16-12	3/4 NPTF	3/4-14	18mm	M 26 x 1.5
7/8	—14	1 3/16-12	7/8 NPTF	3/4-14	22mm	M 26 x 1.5
1	—16	1 5/16-12	1 NPTF	1-11 1/2	25mm	M 33 x 2.0
1 1/4	—20	1 5/8-12	1 1/4 NPTF	1 1/4-11 1/2	30mm	M 42 x 2.0
1 1/2	—24	1 7/8-12	1 1/2 NPTF	1 1/2-11 1/2	35mm	M 42 x 2.0

HYDRAULIC PRODUCT SAFETY

WARNING : Valve lever (spool) may "stick" (not center) under certain conditions allowing the hydraulic equipment to continue to operate and could cause serious injury, death or equipment failure.

VALVE SAFETY: Read and follow instructions carefully. Failure to observe instructions and guidelines may cause serious injury, death or equipment failure. A sticking valve (spool bind) may be caused by one or more of the following factors:

DIRTY OIL: Oil must be filtered to a minimum of 25 microns. Filters should be changed regularly - spin-on types after 50 hours of initial use and then after every two hundred fifty hours of use. Use of a condition indicator is recommended. Consult your tractor or implement owner's manual for filtration and changing recommendations for internal systems.

OIL REQUIREMENTS: Premium quality anti-wear type oil with a viscosity between 100 and 200 SSU at operating temperatures. Certain synthetic oils may cause spool seals to swell and the valve to stick. If in doubt, call CROSS Engineering.

IMPROPER HOOK UP OR MOUNTING: Always use the proper size fittings. Hook up "in" & "out" as noted on the valve body. Do not overtorque pipe fittings. Mounting surfaces should be flat and care should be used when tightening mounting bolts. Over-tightened bolts can cause spool bind and casting breakage. When hooking a valve in series, always use a power beyond sleeve. Consult your tractor or implement manual to make sure you have the proper quick disconnect line connected to the inlet of the remote valve.

MISAPPLICATION: Always use the proper valve for the job. CONVERTA, CD, CS or CA valves should never be used for metered heavy load lifting - loaders or similar applications. Use an open center valve for open center applications and a closed center valve for closed applications. If in doubt, check with your tractor dealer. Contact CROSS if the valve allows the hydraulic equipment to creep excessively.

MAINTENANCE: Make sure all bolts are tightened and torqued to the recommended specification. Bent or broken parts should not be used. Replace immediately. Always use exact replacements.Always protect valve spool from paint overspray.

Faulty quick disconnects can cause high back pressures and sticking spools. Check quick disconnects periodically to make sure they are functioning properly. If valve spool does not center or appears to stick, do not use!

PUMPS & MOTORS SAFETY:

A relief or bypass in your hydraulic system is necessary to prevent pump from breakage due to overpressurization. Use correct fittings and proper oil as noted in the technical service manual packed with each unit. Change oil as recommended by your implement or tractor manufacturer.

CYLINDER SAFETY:

Check clevis clearances before, during and after extending the cylinder and before using the cylinder under pressure to avoid possible injury, or bent or broken rods caused by binding. Never operate a cylinder above recommended pressures. Never use a cylinder as a safety device when transporting equipment.

PINHOLE LEAKS:

If you observe a pinhole leak, discontinue use of the component. If oil has penetrated your skin or contacted your eye, seek medical attention immediately!

FINDING AND SOLVING PROBLEMS: Please read and observe the HYDRAULIC PRODUCT SAFETY SHEET before proceeding further. Your safety is important to us!

Gradual or sudden loss of pressure or flow resulting in a loss of power is common in hydraulic system failure. Any one of the system's components may be at fault. These step-by-step procedures should help you locate and remedy the problem quickly.

1. SYSTEM INOPERATIVE

- **No oil in system, insufficient oil in system.** Fill system. Check for leaks.
- **Wrong oil in system.** Refer to specifications. Change oil.
- **Filter dirty or clogged.** Drain oil and replace filter or filter element.
- **Oil line restriction.** Oil lines dirty or collapsed. Clean or replace.
- **Air leaks in pump suction line.** Repair or replace as necessary.
- **Worn or dirty pump.** Clean, repair or replace. Check alignment. Check for contaminated oil. Drain and flush system.
- **Badly worn components (valves, cylinders, etc.)** Examine and test for internal or external leakage. Replace faulty components. Check for cause of wear.
- **Leakage.** Check all components, particularly the relief valve for proper settings. Refer to technical manuals.
- **Excessive load.** Check unit specifications for load limits.
- **Slipping or broken pump drive.** Repair or replace belts, couplings, etc. Check for proper alignment or tension.

2. SYSTEM OPERATES ERRATICALLY

- **Air in system.** Check suction side of system for leaks. Repair.
- **Cold oil.** Allow ample warm-up period.
- **Dirty or damaged components.** Clear or repair as necessary.
- **Restrictions in filters or lines.** Clean and/or replace elements or lines.

3. SYSTEM OPERATES SLOWLY

- **Oil viscosity too high, cold oil.** Allow oil to warm up before operating machine.
- **Low pump drive speed.** Increase engine speed (check manual for recommendations.)
- **Air in system.** Check suction side for leaks. Repair.
- **Badly worn pump, valves, cylinders, etc.** Repair or replace as needed.
- **Restrictions in filters or lines.** Clean and/or replace elements or lines.
- **Improper adjustments.** Check orifices, relief valves, etc. Adjust per manual.
- **Oil leaks.** Tighten fittings. Replace seals or damaged lines.

4. SYSTEM OPERATES TOO FAST

- **Wrong size or incorrectly adjusted restrictor.** Replace or adjust as necessary.
- **Engine running too fast.** Reduce engine speed.

5. OVERHEATING OF OIL IN SYSTEM.

- **Oil passing thru relief valve for excessive time.** Return control valve to neutral when not in use.
- **Incorrect oil, low oil, dirty oil.** Use recommended oil, fill reservoir, clean oil, replace filter elements.
- **Engine running too fast.** Reduce engine speed.
- **Excessive component internal leakage.** Repair or replace component as necessary.
- **Restriction in filters or lines.** Clean and/or replace elements or lines.
- **Malfunctioning oil cooler.** Clean or repair.

5. OVERHEATING OF OIL IN SYSTEM. (cont'd.)

- **Insufficient heat radiation.** Clean dirt and mud from reservoir and components.
- **Malfunctioning component.** Repair or replace.
- **Reservoir too small.** Recommended size is 1 1/2 times pump gpm.

6. FOAMING OF OIL

- **Incorrect, low or dirty oil.** Replace, clean or add oil as needed.
- **Air leaks.** Check suction line and component seals for suction leaks. Replace.

7. NOISY PUMP

- **Low oil level, incorrect oil, foamy oil.** Replace, clean or add oil as needed.
- **Suction line plugged or too small, inlet screen plugged.** Clean or replace. Follow instructions packed with unit.
- **Use of pipe fitting in inlet.** Replace with correct fitting.

8. BLOWN SHAFT SEAL

- **Pump: wrong pump shaft rotation.** Replace seal. Refer to installation instructions.
- **Motor: failure to hook up drain line.** Replace seal. Refer to installation instructions.

9. LEAKY PUMP OR MOTOR

- **Damaged or worn shaft seal.** Replace seal. Check for misalignment.
- **Loose or broken parts.** Tighten or replace.

10. LOAD DROPS WITH CONTROL VALVE IN NEUTRAL

- **Leaking cylinder seals or fittings.** Replace worn parts.
- **Control valve not centering when released.** Check linkage. Check for spool binding. Repair.

11. CONTROL VALVE DOES NOT CENTER (Binding)

- **See Hydraulic Product Safety sheet.**
- **Valve linkage misaligned.** Repair.
- **Tie-bolts too tight (stack valves).** Loosen as necessary.
- **Valve damaged.** Repair or replace.
- **Handle bracket screws loose.** Tighten.

12. CONTROL VALVE LEAKS EXTERNALLY

- **Tie-bolts too loose (stack valves).** Tighten as necessary.
- **Seals damaged or worn.** Replace.
- **Back pressure or restriction in tank line.** Check quick couplers. Use power beyond when necessary.
- **Cracked port or body.** Replace.

13. CYLINDER LEAKS EXTERNALLY

- **Seals damaged or worn.** Replace.
- **Rod damaged.** Replace.

14. CYLINDER LOWERS WITH VALVE IN "METER UP" POSITION

- **Damaged or leaky load check.** Replace check.
- **Leaking cylinder seal.** Replace seal.
- **Use of a valve without loadcheck.** Replace with recommended valve.

OIL RECOMMENDATIONS: Premium quality anti-wear type oil with a viscosity between 100 and 200 SSU at operating temperatures. Automatic transmission fluids are acceptable. Do not use synthetic fluids. No liability or warranty is assumed for applications using fluids not meeting recommended specifications.

FILTRATION: 25 micron filters are required with 10 micron preferred. If pump inlet filters are used, be certain inlet flow is not restricted. Cavitation will severely reduce pump life.

PUMP SPEED/PORT SIZE LIMITATIONS: If pumps are operated at speeds higher than shown below, cavitation and pump damage can occur.

SERIES & SIZE		PUMP INLET PORT SIZE				
		1 1/16-12 3/4" (-12)	1 5/16-12 1" (-16)	1 5/8-12 1 1/4" (-20)	1 7/8-12 1 1/2" (-24)	2" S.F. 2"
40 SERIES	5	3500	3500			
	7	3400	3500			
	10	2500	3500			
	12	2000	3500			
	15	1750	3000			
	18	1400	2500			
50 SERIES	15		3000	3000	3000	
	19		2300	3000	3000	
	23		2000	3000	3000	
	27		1700	2600	3000	
	33		1400	2100	3000	
	38		1200	1800	2700	
	52		1000	1600	2200	
60 SERIES	40			2000	3000	3000
	51			1750	2500	3000
	61			1400	2200	3000
	71			1000	1900	3000
	81			800	1600	2600
	92			600	1400	2500

BASED ON NO INLET RESTRICTION (6" HG MAX. VACUUM)

PLUMBING SIZE RECOMMENDATIONS: The following is based on 4 ft./sec. inlet velocity and 15 ft./sec. outlet velocity.

GPM	PUMP INLET			PUMP OUTLET		
	PIPE	TUBE	HOSE	PIPE	TUBE	HOSE
5	3/4"	7/8"	3/4"	1/4"	3/8"	3/8"
10	1"	1"	1"	3/8"	1/2"	1/2"
15	1 1/4"	1 1/4"	1 1/4"	1/2"	5/8"	1/2"
20	1 1/2"	1 1/2"	1 1/2"	3/4"	3/4"	3/4"
25	1 1/2"	1 1/2"	1 1/2"	3/4"	7/8"	3/4"
30	1 3/4"	1 3/4"	1 3/4"	1"	1"	1"
35	2"	2"	2"	1"	1 1/4"	1"
40	2 1/4"	2 1/4"	2 1/4"	1 1/4"	1 1/4"	1 1/4"
50	2 1/2"	2 1/2"	2 1/2"	1 1/4"	1 1/2"	1 1/4"
75	3"	3"	3"	1 1/2"	1 3/4"	1 1/2"

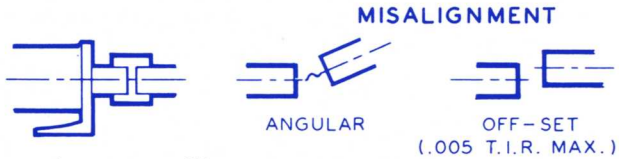
Tube sizes are OD. Hose sizes are ID.
Reduce plumbing size to match pump port size AT PUMP.

MOUNTING: Pumps and motors may be mounted in any position.

DIRECT FLANGE MOUNTING: Mount directly to gear box or engine PTO, carefully inserting shaft and pilot into mating holes. Make certain that shaft size and type matches drive.

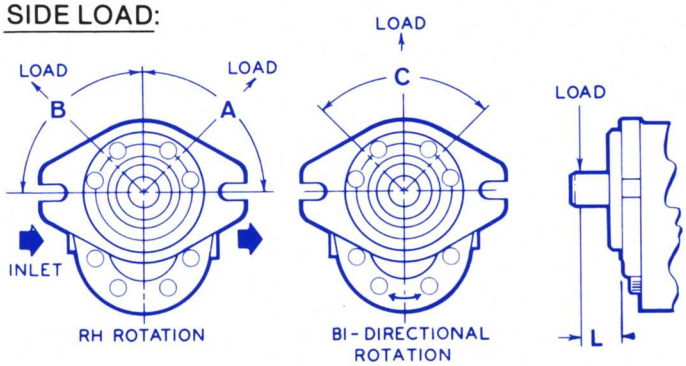
FOOT MOUNT WITH COUPLING:

Excessive wear and reduced life will occur due to misalignment. Minor misalignment can be compensated for by using a flexible coupling.



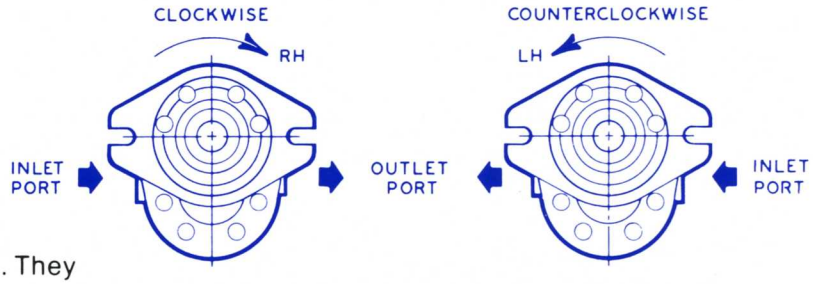
FOOT MOUNT WITH BELT OR CHAIN DRIVE: Excessive wear will occur with misalignment.

SIDE LOAD:



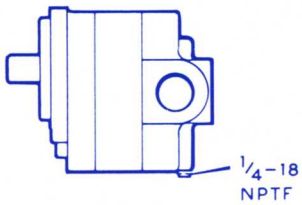
Side loads resulting from belt or chain drives should be kept as close to the housing as possible (ie., keep dimension 'L' to a miminum). For maximum life, loads should be applied at quadrant 'A' for pumps (RH), quadrant 'B' for motors (RH), 'A' for LH motors, 'B' for LH pumps, and 'C' for bi-rotational motors. End thrust not recommended: Contact Cross Engineering for information.

DIRECTION OF ROTATION:



Right hand (RH) or left hand (LH) pumps or motors, if operated in the wrong direction, will result in THE IMMEDIATE FAILURE of the shaft seal. Pump and motor rotation is NOT field reversible. Dual rotation (D) units may be operated in either direction. They also can be operated as either a pump or motor. The correct direction of rotation can be determined by the model number stamped on the front cover.

DRAIN PORT CONNECTION: If the motor outlet port pressure exceeds the rating of the shaft seal (20 psi standard), the drain port must be connected directly to the reservoir. Dual rotation pumps have drain port connections for use as motors.



START-UP PROCEDURES:

1. Prior to installation, check pump or motor for possible damage in shipping or handling.
2. Install unit, tighten fittings and fill reservoir with clean fluid.
3. Fill pump/motor with fluid thru drain port connection or inlet port.
4. Start engine and run at lowest possible speed. Check system for air (suction) leaks and oil leaks. (Use a piece of cardboard or wood when searching for possible oil leaks, DO NOT USE HANDS). Bleed air from system if necessary. Operate system at normal speed.
5. Gradually increase load to normal, checking for leaks, abnormal noises, binding, etc. Operate system for 15 minutes. Shut off and check filters. Clean or replace as necessary.

MAINTENANCE:

1. Clean or replace filters on a regular basis, as necessary.
2. Check for presence of water in oil (cloudy or milky appearance) and for presence of air (foamy oil). A rancid odor indicates excessive heating of the oil.
3. Check reservoir regularly for proper level. Fill as needed. Repair leaks.

REPAIR: Pumps and motors are not field repairable except for replacement of shaft seals, pressure seals and thrust plates. See next page for replacement instructions.

50G SERIES MOTORS: This is the standard series 50 motor combined with a 5.33 to 1 planetary gear reduction unit. Output torque is approximately 5 times that of a standard motor and speed is 1/5 of the speeds shown in the chart on page 1. Mounting is SAE 'C' 4-bolt flange. Dual rotation is standard. The planetary gear reducer uses EP 90 weight gear lubricant (approx. 5 1/2 oz.). Check level by removing the pipe plug at the side of the front cover. To change oil, remove the pipe plug from the bottom, clean plug, drain oil thoroughly. Replace plug and add oil.

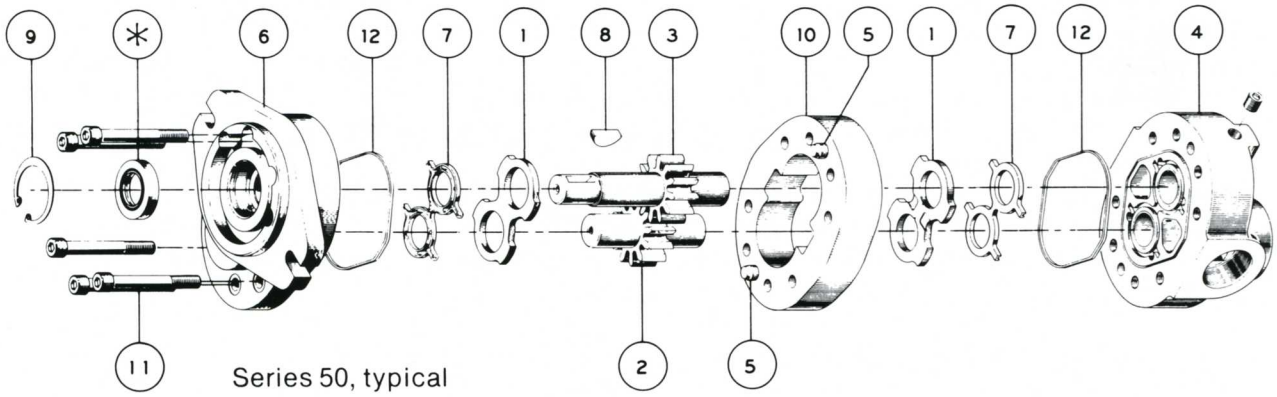
50T SERIES PUMPS: This is the basic 50 series pump combined with a 3 to 1 speed increaser for use with 540 rpm PTO drives. The 50T series pumps are not directly interchangeable with the 50 series due to special shaft and shaft seal. System hydraulic oil is used to lubricate the speed increaser. **PTO torque arm must be attached to keep unit from rotating.**

53 SERIES PUMPS: This is a tandem (dual) pump version of the basic series 50 unit. Each pump section is essentially the same as the standard series 50 pump and data shown in the chart on page 1 applies accordingly.

FOR ALL PUMPS AND MOTORS, REFER TO SPECIFIC SPECIFICATION SHEETS FOR ADDITIONAL DATA AND LIST OF OPTIONS AVAILABLE. WRITTEN WARRANTY AND PARTS LIST AVAILABLE UPON REQUEST.

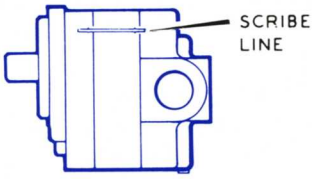
NOTE: If chronic shaft seal failure occurs:

1. Check direction of rotation.
2. Check outlet port or drain port pressure.
3. Replace shaft seal with higher pressure rating seal. (See available seal kits)



Series 50, typical

A. DISASSEMBLY:



1. Remove unit and thoroughly clean. Remove shaft key (8) and any nicks or burrs on shaft.
2. Scribe line on outside of unit across front cover, body and rear cover to assure proper reassembly.
3. Lightly clamp rear cover (4) in vise, shaft up. EXCESSIVE CLAMPING PRESSURE CAN CAUSE DISTORTION.
4. Remove cap screws (11) from front cover (6). (Nuts on series 60).
5. Tap upwards, underneath front cover flange and remove front cover. As unit separates, the body may remain with either the front or rear cover. Remove loose parts (rings, plates, etc.)

*6. To separate body from front cover, clamp body in vise and again tap upwards on front cover flange. To separate body from rear cover, clamp body in vise and tap downward on shaft. Remove static seals (12) and loading seals (7) from grooves. DO NOT DAMAGE GROOVE OR COVER SURFACE.

7. Remove snap ring (9) from shaft seal cavity in front cover using internal snap ring pliers.
8. Clamp front cover in vise, seal down, and drive shaft seal out of cavity using screwdriver held at about a 45° angle. USE CAUTION NOT TO DAMAGE CAVITY.

* Step 6 can be by-passed if only the shaft seal is being replaced.

B. PARTS INSPECTION:

1. Thoroughly clean all parts in solvent and dry with compressed air.
2. Inspect all parts for damage and unusual or excessive wear. If gears, bushings or body are damaged or badly worn, replace unit (Only plates and seals are replaceable).

C. REASSEMBLY:

1. Install new shaft seal (*) in front cover (6). Be sure bearing drain hole is not blocked.
2. Install snap ring (9) and new seals (7, 12) in covers (if needed).
3. Assemble body (10) and rear cover (4) aligning dowel pins (5) and scribed line.
4. Insert thrust plate (1) into body (10) flat side toward seal 7. Lubricate gears and insert.
5. Insert thrust plate (1) over shaft, flat side toward seal 7.
6. Lubricate shaft and slide front cover (6) over shaft and dowel pins (5). Tap if needed.
7. Insert cap screws (11) (or nuts) and tighten evenly as follows:
   Series 40: 35/40 ft. lbs. Series 50: 35/40 ft. lbs. Series 60: 65/80 ft. lbs.
8. Rotate shaft, the maximum torque is:
   Series 40: 15 ft. lbs. Series 50: 20 ft. lbs. Series 60: 25 ft. lbs.
   If greater torque is required, disassemble unit, re-clean and re-assemble.

SEAL KIT NUMBERS:

UNIT TYPE	ROTATION	SERIES 40	SERIES 50	SERIES 53	SERIES 60
P or M	L or R	4P0017-001	5P0017-002	5P0017-007	6P0017-001
P or M	D	4P0017-002*	5P0017-004*	5P0017-008	6P0017-002
T			5P0017-006	5P0017-009	
P or M	D, L or R				6P0017-003*
T	Increaser Gear Box 5P0017-016				
G	Planetary Gear Box 5P0017-013				

*250 psi rated Shaft Seal Kits

CROSS Manufacturing, Inc. 100 Factory St. Lewis, Ks. 67552 316/324-5525