APPENDIX

CONTENTS PAGE

A

B

C

//// ALPHABETICAL INDEX

I

J

K

L

M

N

O

//// ALPHABETICAL INDEX

P

Q

R

S

T

U

//// ALPHABETICAL INDEX

V

W

Z

//// TYPES OF SEALING MATERIAL

Urethane
Formulated of copolymers of ether or ester based urethanes, this material is used in a wide application of seals, wipers, back-up rings, cushions, bumpers, and a myriad of other uses. Highly resistant to oil swell, ozone, oxidation and abrasion, it also has excellent cut resistance. Urethanes also have high tensile strength and elongation capabilities given their highly resilient properties. Most urethane seals remain flexible and efficient in temperatures ranging from -65° F to +200° F with some able to withstand intermittent temperatures up to +300° F.

Nitrile
The most common nitrile copolymer blend is the compound known as Buna-N. Possessing very good resistance to petroleum based hydraulic oils, Buna-N works well with fuels such as diesel or gasoline. Nitrile seals resist compression set, but their flexibility suffers somewhat in the lower temperature range. Seals made from this material have a low resistance to ozone and must be stored carefully in most environments. Working temperatures are -40° to +240° F.

PTFE
Most PTFE seals, in order to retain their toughness and flexibility, are fortified with short glass fiber, bronze flashes, carbon, graphite, or a combination of these fillers. Because of a lack of resilience (memory) in PTFE, an energizer is most often employed to obtain the desired fit. Benefits are chemical inertness, high heat resistance, low temperature flexibility, low running friction, and non-adhesive characteristics. Temperatures to +500° F are obtainable but are often reduced by the filler or energizer employed.

Fluorocarbon
Fluorocarbon combines high temperature resistance with excellent chemical resistance. Recommended for use with alcohol and aromatic fuels, fluorocarbon is highly resistant to ultraviolet light and ozone. This material is not recommended for use in low temperatures or in aircraft hydraulic fluids. Temperature range is -20° to +400° F.

Ethylene-Propylene
Ethylene-Propylene can be used for sealing phosphate ester hydraulic fluids such as Skydrol. Not suitable for petroleum based fluids, Ethylene-Propylene is highly effective for use with steam, acetone, dilute acids and alkalies. Specially compounded Ethylene-Propylene can be made suitable for automobile brake systems. Temperature range from -20° to +300° F.

Silicone
Silicone is an elastomer made from silicon, oxygen, hydrogen, and carbon. The key use of this material is in static seals employed in a wide (-75° F to +450° F) range of temperatures. Silicone has a high resistance to dry heat, ultraviolet light and ozone. This material is not recommended for dynamic situations due to poor abrasion resistance and high friction characteristics.

GLOSSARY OF TERMS

Bearing/Wear Rings: Soft metal or plastic rings placed in grooves on the piston or in the head to prevent contact between hard metal surfaces.

Durometer: A generic term referring to the instrument and the scale used to measure the relative hardness of various elastomers. The lower the durometer reading, the softer the material.

Dynamic Seal: A sealing device used between mating surfaces that have relative motion.

Elastomer: A rubber-like material having the capacity for large deformation and rapid, complete recovery from the deforming force.

Gland: A groove or open area machined into the head or piston that houses the sealing device.

Static Seal: A sealing device used between mating surfaces that have no relative motion.

Wiper/Scraper: A device placed in the head of a cylinder for the purpose of excluding foreign matter from the inside of the cylinder.

APPENDIX

//// FLUID COMPATIBILITY TABLE

These are general guidelines only, and users must conduct their own functional tests to determine the suitabliity of any compound for their particular application.

R = Recommended
M = Marginal
U = Unsatisfactory
X = Insufficient Data

Fluid	Nitrile	SBR	EPDM	Neoprene	Polyacrylate	Urethane	Silicone	Fluoroelastomer
Acetaldehyde	U	U	R	U	U	U	R	U
Acetamide	R	U	R	R	U	U	M	U
Acetic Acid	M	M	R	R	U	U	R	U
Acetone	U	M	R	M	U	U	M	U
Acetophenone	U	U	R	U	U	U	U	U
Acetylene	R	R	R	R	X	X	R	R
Ammonia	R	R	R	R	U	X	R	U
Ammonium Hydroxide	R	R	R	R	U	U	R	R
Amyl Acetate	U	U	M	U	U	U	U	U
Anderol L-774	M	U	U	U	R	U	U	R
Aniline	U	U	R	U	U	U	U	M
Ansul Ether	M	U	M	U	U	R	U	U
Antifreeze	R	R	R	R	U	U	R	R
Aroclors	M	U	R	U	U	X	M	R
Askarel	R	U	U	U	U	U	U	R
ASTM #1	R	U	U	R	R	R	R	R
ASTM #3	R	U	U	U	R	R	U	R
ASTM Fuel A	R	U	U	R	R	R	U	R
ASTM Fuel B	R	U	U	U	U	R	U	R
ASTM Fuel C	R	U	U	U	U	R	U	R
ASTM Fuel D	M	U	U	U	U	R	U	R
Auto Transmission Fluid	R	U	U	M	R	R	M	R
Beer	R	R	R	R	U	U	R	R
Benzaldehyde	U	U	R	U	U	U	U	U
Benzene	U	U	U	U	U	U	U	R
Benzine	R	U	U	R	R	R	U	R
Benzoic Acid	U	U	U	U	U	U	U	R
Benzophenone	U	U	R	X	U	U	U	R
Benzyl Alcohol	U	U	U	R	U	U	X	R
Bleach	R	R	R	R	U	U	U	R
Borax	R	R	R	U	R	R	R	R
Boric Acid	R	R	R	R	U	R	R	R
* Brake Fliud (non-Petroleum)	U	R	R	R	U	U	U	U
Bromine	U	U	U	U	U	U	U	R
Bromobenzene	U	U	U	U	U	U	U	R
Bunker Oil	R	U	U	U	R	R	U	R
Butane	R	M	U	R	R	U	U	R

Fluid	Nitrile	SBR	EPDM	Neoprene	Polyacrylate	Urethane	Silicone	Fluoroelastomer
Butter	R	U	M	R	R	R	R	R
Butyl Acetate	U	U	U	U	U	U	U	U
Butyl Alcohol	R	R	R	R	U	U	R	R
Butyl Amine	M	U	U	U	U	U	R	U
Butyl Carbitol	U	U	R	M	U	X	U	M
Butyl Cellosolve	M	U	R	M	U	U	R	U
Butyraldehyde	U	U	R	U	U	U	U	U
Carbitol	R	R	R	R	U	U	R	R
Carbitol Acetate	U	U	U	U	U	U	U	R
Carbon Disulfide	U	U	U	U	U	X	U	R
Carbon Tetrachloride	R	U	U	U	U	U	U	R
Carbonic Acid	R	R	R	R	R	R	R	R
Castor Oil	R	R	R	R	R	R	R	R
Cellosolve	U	R	U	U	U	U	U	U
Chassis Grease	R	U	U	M	R	X	U	R
Chloracetic Acid	U	U	R	U	U	U	X	U
Chloracetone	U	U	R	M	X	X	U	R
Chlordane	R	U	U	M	X	X	U	R
Chlorine	U	U	R	U	U	U	X	R
Chlorobenzol	U	U	U	U	U	U	U	R
Chloroform	U	U	U	U	U	U	U	R
Chlorsulfonic Acid	U	U	U	U	U	U	U	U
Chrome Plating Solution	U	U	R	U	U	U	R	R
Chromic Acid	U	U	X	U	X	X	M	R
Citric Acid	R	R	R	R	X	X	R	R
Cod Liver Oil	R	U	U	R	R	U	R	R
Coffee	R	R	R	R	U	U	R	R
Corn Oil	R	U	U	U	R	U	R	R
Creosote	R	U	U	R	R	M	U	R
Creoste Oil	R	U	U	M	X	X	M	R
Creosylic Acid	U	U	U	U	U	U	U	R
Crude Oil	R	U	U	U	R	X	U	R
Cyclohexane	R	U	U	M	R	R	U	R
Cyclohexanol	R	U	U	R	X	X	U	R
Decalin	U	U	U	U	U	U	U	R
Denatured Alcohol	R	R	R	R	U	U	R	R
Diacetone	U	U	R	U	U	U	U	U

*** Requires special formulation of EPDM**

//// FLUID COMPATIBILITY TABLE

Fluid	Nitrile	SBR	EPDM	Neoprene	Polyacrylate	Urethane	Silicone	Fluoroelastomer
Dibutyl Amine	U	U	U	M	U	U	U	U
Dibutyl Phthalate	U	U	R	U	U	X	X	M
Dichloro Aniline	U	U	U	U	U	U	U	M
Dichloro Butane	R	U	U	U	U	U	U	R
Diesel Oil	R	U	U	M	U	U	U	R
Diethyl Benzene	M	U	U	U	X	X	X	R
Diethylamine	R	R	R	R	U	M	R	U
Diethylene Glycol	R	R	R	R	U	U	R	R
Dimethyl Ether	U	U	U	M	M	R	U	U
Dimethyl Formamide	U	X	R	X	X	X	R	U
Dimethyl Phthalate	U	U	R	U	U	X	X	R
Dimethyl Terephthalate	U	U	U	U	U	U	U	R
Dioctyl Phthalate	U	U	R	U	U	U	M	R
Dioxane	U	U	R	U	U	U	U	U
Diphenyl	U	U	U	U	U	U	U	R
Dow Corning 550	R	R	R	R	R	R	R	R
Dow Gard	R	R	R	R	M	M	R	R
Dowtherm A & E	U	U	U	U	U	U	U	R
Elco 28	R	U	U	M	R	R	R	R
Epoxy Resins	X	X	R	R	X	X	X	U
Ethane	R	U	U	R	R	M	U	R
Ethanol	R	R	R	R	U	R	R	R
Ethanolamine	R	R	R	R	U	M	R	U
Ethyl Acetate	U	U	R	U	U	U	R	U
Ethyl Benzene	U	U	U	U	U	U	U	R
Ethyl Cellulose	R	R	R	R	U	R	R	U
Ethyl Chloride	R	R	R	R	M	R	U	R
Ethyl Ether	M	U	M	U	U	R	U	U
Ethyl Formate	U	U	R	R	X	X	X	R
Ethyl Hexanol	M	R	R	R	X	X	X	R
Ethyl Merlaptan	U	U	X	M	X	X	M	R
Ethylene Chloride	U	U	U	U	U	U	U	R
Ethylene Oxide	U	U	R	U	U	U	U	U
Formaldehyde	M	M	R	M	U	U	R	U
Formic Acid	M	R	R	R	X	X	M	U
Freon 12	R	R	R	R	X	R	U	R
Fuel Oil	R	U	U	R	R	U	U	R
Fufuryl Alcohol	U	U	R	U	U	U	U	X
Furan	U	U	X	U	U	X	X	X
Furfural	U	U	R	U	U	X	U	U

Fluid	Nitrile	SBR	EPDM	Neoprene	Polyacrylate	Urethane	Silicone	Fluoroelastomer
Fyrquel	U	U	R	U	U	U	R	R
Gallic Acid	R	R	R	R	U	I	X	R
Gasoline	R	U	U	R	R	R	U	R
Gelatin	R	R	R	R	U	U	R	R
Glucose	R	R	R	R	X	U	R	R
Glycerine	R	R	R	R	U	U	R	R
Heptane	R	U	U	R	R	R	U	R
Hexaldehyde	U	U	R	R	X	X	R	U
Hexane	R	U	U	R	R	R	U	R
Hexanol	R	R	M	R	U	U	R	R
Home Heating Oil	R	U	U	M	R	R	R	R
Hydrazine	R	R	R	R	X	X	R	X
Hydrochoride Acid	R	M	R	R	M	U	U	R
Hydrocyanic Acid	R	R	R	R	U	X	M	R
Hydrogen Peroxide	R	R	R	R	U	X	R	R
Hydrogen Sulfide	U	U	R	R	U	X	M	U
Hydroquinone	M	U	U	U	U	X	X	R
Hypoid Gear Lube	R	U	U	M	R	R	M	R
Iodine	R	R	R	U	X	X	X	R
Iso Octane	R	U	U	R	R	R	U	R
Iso Phorone	U	U	R	U	U	U	U	U
Isocyanate	X	X	X	X	X	X	X	R
Isopar	R	X	U	R	R	R	U	R
Isopropanol	R	R	R	R	U	U	R	R
Isopropyl Acetate	U	U	R	U	U	U	U	U
JP-4(MIL-J-5624)	R	U	U	U	R	R	U	R
JP-4(MIL-J-5624)	R	U	U	U	R	R	U	R
Kerosene	R	U	U	R	R	R	U	R
Lacquers	U	U	U	U	U	U	U	U
Lactic Acid	R	R	R	R	U	X	X	R
Lard	R	U	R	R	R	R	R	R
Linoleic Acid	R	U	U	R	X	X	R	R
Linseed Oil	R	U	M	M	R	X	R	R
Lye Solutions	R	R	R	R	U	U	R	R
Malathion	R	U	U	X	X	X	U	R
Maleic Acid	U	U	U	U	U	X	X	R
Mercury	R	R	R	R	X	X	X	R
Meter-Cresol	U	U	U	R	U	U	U	R
Methacrylic Acid	U	U	R	R	U	U	U	M
Methane	R	U	U	R	R	M	U	R

//// FLUID COMPATIBILITY TABLE

Fluid	Nitrile	SBR	EPDM	Neoprene	Polyacrylate	Urethane	Silicone	Fluoroelastomer
Methanol	R	R	R	R	U	U	U	U
Methyl Acetate	U	U	R	R	U	U	U	U
Methyl Cellosolve	M	U	R	R	U	U	U	M
Methyl Ether Ketone	U	U	R	U	U	U	U	U
Methyl Mercaptan	X	X	R	X	X	X	X	X
Methylene Chloride	U	U	U	U	U	U	U	R
Milk	R	R	R	R	U	U	R	R
Mineral Oil	R	U	M	R	R	R	R	R
Mineral Spirits	R	U	U	U	R	R	U	R
Monovinyl Acetylene	R	R	R	R	X	X	R	R
Mustard	X	R	R	X	X	X	R	R
Naphtha	R	U	U	U	R	R	U	R
Naphthalene	U	U	U	U	X	X	U	R
Naphthenic Acid	R	U	U	U	X	X	U	R
Natural Gas	R	R	U	R	R	R	R	R
Neatsfoot Oil	R	U	R	U	R	R	R	R
Nitric Acid	U	M	R	U	U	U	U	M
Nitrobenzene	U	U	U	U	U	U	U	R
Nitropropane	U	U	R	U	U	U	U	U
Octane	R	U	U	U	U	U	U	R
Octanol	R	R	R	R	U	U	R	R
Oleic Acid	M	U	U	M	X	X	U	R
Oleum	R	U	U	M	X	X	U	R
Oronite 8200	R	U	U	R	X	R	U	R
Oxalic Acid	R	R	R	R	R	X	X	R
Peanut Oil	R	U	M	M	R	X	R	R
Pentane	R	M	U	R	R	U	U	R
Perchlorethylene	R	U	U	U	U	U	U	R
Petroleum Ether	U	U	U	U	U	U	U	R
Phenol	U	U	U	U	U	U	U	R
Phenylhydrazine	U	M	U	U	U	X	X	R
Phosphoric Acid	R	R	R	R	M	U	R	R
Pine Oil	R	U	U	U	U	X	X	R
Potassium Hydroxide	R	R	R	R	U	U	M	U
Propane	R	U	U	R	R	M	U	R
Propanol	R	R	R	R	U	U	R	R
Propyl Acetate	U	U	R	U	U	U	U	U
Pydraul	U	U	R	U	U	U	U	R

Fluid	Nitrile	SBR	EPDM	Neoprene	Polyacrylate	Urethane	Silicone	Fluoroelastomer
Pyranol	R	U	U	R	R	R	U	R
Pyridine	U	R	U	U	U	X	U	U
Rapeseed Oil	R	U	R	R	R	R	U	R
Resurcinol	X	R	R	X	X	X	X	X
SAE 10W30	R	U	U	M	R	R	R	R
Seawater	R	R	R	R	U	U	R	X
Silicone Grease	R	R	R	R	R	R	R	R
Silver Nitrate	R	R	R	R	R	R	R	R
Skelly Solvent	R	U	U	U	X	X	X	R
Skydrol	U	U	R	U	U	U	U	R
Skydrol 500	U	U	R	U	U	U	U	R
Sodium Hydroxide	R	R	R	R	U	R	R	R
Sovasol	R	U	U	R	R	R	U	R
Soy Bean Oil	R	U	M	M	R	X	R	R
Stearic Acid	R	R	R	R	R	U	U	R
Stoddard Solvent	R	U	U	R	R	R	U	R
Sucrose	R	R	R	R	U	U	R	R
Sulfuric Acid	R	R	R	R	R	U	U	R
Tall Oil	R	U	U	M	R	U	X	R
Tannic Acid	R	R	R	R	U	X	R	R
Tar	R	U	U	M	U	X	R	R
Tartaric Acid	R	R	R	R	X	X	R	R
Tetrachloro Ethane	U	U	U	U	U	U	U	R
Tetralin	U	U	U	U	U	U	U	R
Tidewater Oil	R	U	U	R	R	R	R	R
Toluene	U	U	U	U	U	U	U	R
Trichloro Ethylene	M	U	U	U	U	U	U	R
Triethanol Amine	M	R	R	R	U	U	X	U
Turbine Oil	R	U	U	U	R	R	U	R
Turpentine	R	U	U	U	R	U	U	R
UCDN 50HB280X	R	R	R	R	X	X	R	R
Univis J-43	R	U	U	R	R	R	U	R
Varnish	R	U	U	U	U	M	U	R
Vinegar	R	R	R	R	U	U	R	R
Water	R	R	R	R	U	U	R	R
Wheat Germ Oil	R	U	U	M	R	R	R	R
Whiskey & Wine	R	R	R	R	U	U	R	R
Wood Oil	R	U	U	R	X	M	U	R

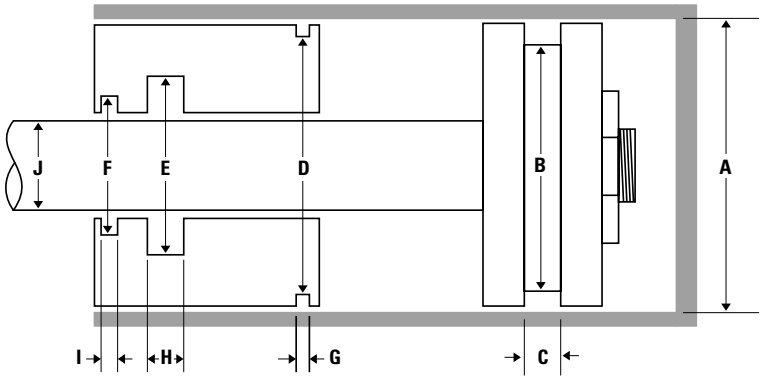
//// HOW TO SIZE GROOVE DIMENSIONS FOR SEALS

HOW OFTEN HAVE YOU RECEIVED A CYLINDER FOR REPAIR AND THE SEALS WERE . . .

- MISSING
- EXTRUDED
- ROLLED
- COOKED
- NIBBLED
- SPLIT
- INCORRECT
- TWISTED
- WORN OUT

The chart below can be used by your counter personnel, repair shops, or sales people to determine the seals you need. Note the dimensions and call our sales staff with your information. If the part number(s) you need can't be located in the catalog, our sales team will be glad to help you .

CALL US TOLL FREE! 1-800-669-9638



FOR A PROFESSIONAL ANALYSIS OF SEAL FAILURE, SEND YOUR DAMAGED SEALS TO OUR ENGINEERING DEPARTMENT.

PISTON SEALS AND BEARINGS

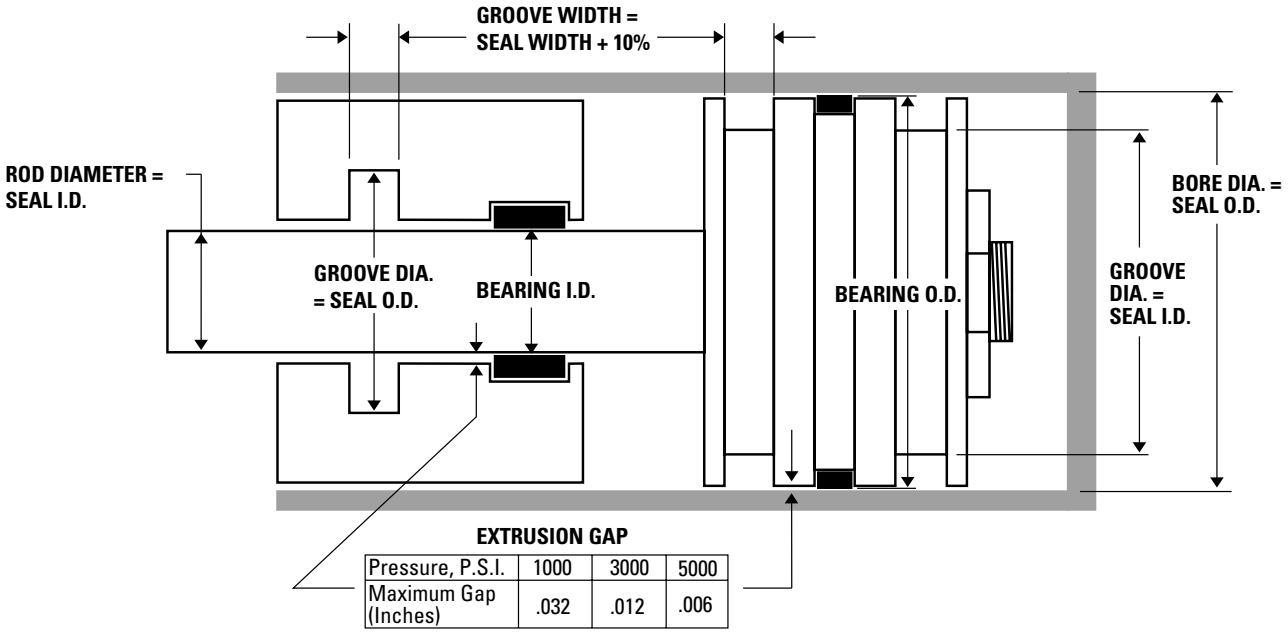
DIAGRAM REFERENCE	DIMENSIONS
A = Bore = Seal O.D.	_____
B = Groove Diameter = Seal I.D.	_____
C = Groove Width = Nominal Seal Width	_____

ROD SEALS AND BEARINGS

DIAGRAM REFERENCE	DIMENSIONS
D = Gland Groove Diameter = Seal I.D.	_____
E = Rod Seal Groove Diameter = Seal O.D.	_____
F = Wiper Groove Diameter = Wiper O.D.	_____
G = Gland Groove Width = Nominal Seal Width	_____
H = Rod Seal Groove Width = Nominal Seal Width	_____
I = Wiper Groove Width = Base Width	_____
J = Rod Diameter = Seal & Wiper I.D.	_____

COPY FOR SHOP & COUNTER USE

//// GROOVE DIMENSIONS FOR URETHANE U-SEALS



Pressure, P.S.I.	1000	3000	5000
Maximum Gap (Inches)	.032	.012	.006

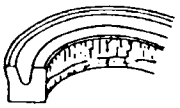
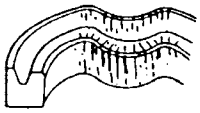
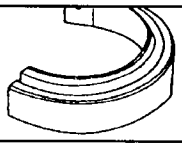
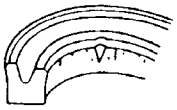
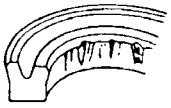
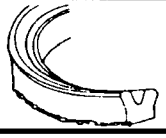
ROD AND ROD GROOVE DIAMETERS

ROD DIAM RANGE, IN.	ROD DIAM. TOLERANCE	GROOVE DIAM TOLERANCE	MAX DIAMETRAL CLEARANCE		
			1000 PSI	3000 PSI	5000 PSI
.125- .687	+ .0 /-.002	+ .004 /-.0	.008	.006	.004
.750- 2.875	+ .0 /-.003	+ .008 /-.0	.012	.008	.004
3.000- 7.000	+ .0 /-.004	+ .010 /-.0	.014	.010	-
7.000- 7.750	+ .0 /-.005	+ .011 /-.0	.016	.010	-
8.000- 9.500	+ .0 /-.005	+ .012 /-.0	.016	-	-
10.000- 15.000	+ .0 /-.006	+ .015 /-.0	.016	-	-

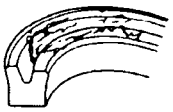
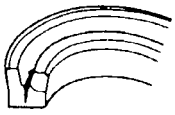
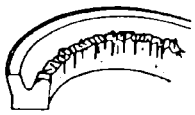
BORE AND PISTON GROOVE DIAMETERS

BORE DIAM RANGE, IN.	BORE DIAM. TOLERANCE	GROOVE DIAM TOLERANCE	MAX DIAMETRAL CLEARANCE		
			1000 PSI	3000 PSI	5000 PSI
.750- 1.062	+ .003 /-.0	+ .0 /-.004	.010	.008	.004
1.125- 1.625	+ .003 /-.0	+ .0 /-.005	.010	.008	.004
1.750- 2.500	+ .003 /-.0	+ .0 /-.007	.012	.008	.004
2.625- 2.875	+ .003 /-.0	+ .0 /-.008	.012	.008	.005
3.000- 3.500	+ .004 /-.0	+ .0 /-.008	.014	.010	-
3.625- 5.625	+ .004 /-.0	+ .0 /-.009	.014	.010	-
5.750- 6.750	+ .004 /-.0	+ .0 /-.010	.014	.010	-
7.000- 8.500	+ .005 /-.0	+ .0 /-.011	.016	.010	-
9.000- 11.000	+ .005 /-.0	+ .0 /-.011	.016	-	-
12.000- 16.000	+ .006 /-.0	+ .0 /-.012	.018	-	-

//// EXAMPLES OF SEAL FAILURES AND THEIR CAUSES

TYPE OF FAILURE	VISIBLE CONDITION	PROBABLE CAUSE	POSSIBLE CURE
HARDENING	Hardening of the dynamic face causing glazing and cracks 	Heat generated by high speed	Slow stroke speed Use alternative seal device
	Hardening of the whole seal. Loss of elasticity. 	High fluid temperature. Deterioration of fluid. Compatibility of seal to fluid	Lower oil temperature. Renew Fluid Change to different seal compound
WEAR	Dynamic face is worn to glossy mirror-like finish 	Insufficient lubrication	Check oil viscosity Use alternative seal device
	Wear on dynamic lip is egg-shaped 	Rod or piston bore not concentric	Hone to within seal specs Replace worn rod or cylinder tube
	Abnormal wear on one side of the dynamic lip 	Worn bearing or wear ring. Excessive lateral load	Replace bearings Increase bearing area
SCARRING	Cut or dent on the lip 	Storage on a nail or peg. Improper installation tool	Store flat in a plastic bag in a closed cardboard box Installation tools should not have sharp edges
	Scratches on the dynamic side 	Scars on the rod or bore. Foreign material in fluid	Hone, polish, and de-burr metal parts Flush system
SWELLING	Material soft and misshaped 	Absorption of fluid. Fluid and seal are incompatible. Water in system	Change seal compound or system fluid Flush system
DETERIORATION	Cracks and loss of elasticity. Material easily crumbles 	High fluid temperature. Exposure to ozone or sunlight	Lower oil temperature Store seals away from sunlight and arc welding area.
GROOVING	Axial cuts on the dynamic side 	Metal chips or other foreign material in system. Imploded air bubbles	Flush system Bleed air from system
EXTRUSION	Extruded material on dynamic side of heel 	Gap between mating surfaces too wide. Worn bearings. Pressure extreme	Employ back-up ring. Replace bearings. Use alternative seal
	Extruded material on static side of seal 	Uneven support surface. Undersize back-up ring	Machine surface. Correct back-up size

APPENDIX

TYPE OF FAILURE	VISIBLE CONDITION	PROBABLE CAUSE	POSSIBLE CURE
FRACTURING	Chunks of material torn from dynamic side 	Excessive back pressure	Check relief valves
	Pressure side of seal burned and broken 	Explosion of residual air at high pressure. "Dieseling"	Check maximum pressure. Bleed air from system
	Long cracks in the "V" portion of the seal 	Frequent high pressure shocks or spikes. Low temperature start-up	Use alternative style seal. Warm system before applying pressure
	Breaking off of entire dynamic side 	Deterioration of material and/or fluid	Use alternative material or seal. Flush system

APPENDIX

/// SEAL FAILURE INSPECTION CHECK LIST

When trying to determine the cause of seal failure, it is imperative that all aspects of the situation be investigated. Often, a seal failure points to another part of the hydraulic system that has failed or been compromised in some way. To help you determine where the potential cause of a failure lies, we have developed a seal failure check list. By filling in the necessary information, you should be able to determine the cause of a failure and decide what measures to take to assure future trouble free operation. If you have any questions regarding this form, please contact our sales staff at **1-800-669-9638 or 1-801-973-7325.**

PLEASE FILL THIS OUT COMPLETELY

1. Describe the application:
   A. Type: ❑ Telescopic ❑ Piston-rod cylinder ❑ Pump/Motor ❑ Other_____
   B. Fluid Medium: Type: _____
   Pressure: normal: _____psi Temperature: system: _____°F ambient: _____°F
   min: _____psi min: _____°F
   max: _____psi max: _____°F
   C. Speed: Cycles/min: _____Length of stroke:_____in Average speed: _____

2. Inspect the application before seal removal:
   A. Amount of leakage:.....❑ Slight ❑ Moderate ❑ Heavy leakage
   B. Condition of area: .....❑ Clean ❑ Dusty ❑ Mud packed
   ❑ Painted ❑ Other _____
   C. Leakage source:.....❑ Between wiper lip and rod ❑ Wiper blown out
   ❑ At gland bolt holes ❑ At gland OD
   ❑ Between piston and rod ❑ Across piston seal ❑ Other_____

3. Inspect external cylinder conditions:
   ❑ Collision that caused a pressure spike in cylinder ❑ Cylinder dented ❑ Side loading present

4. Remove seals and inspect internal cylinder conditions
   A. Shaft: ❑ Rod diameter out of tolerance (check entire length) ❑ Rod is scratched or scarred
   ❑ Eccentricity of rod and cylinder head ❑ Surface finish (RMS) is too smooth or too rough
   B. Bore: ❑ Bore diameter out of tolerance (check entire length) ❑ Bore is scratched or scarred
   ❑ Bore is out of round ❑ Surface finish (RMS) is too smooth or too rough
   ❑ Eccentricity of piston head and cylinder bore
   C. Groove: ❑ Groove dimensions are out of tolerance ❑ Surface is nicked or scratched
   ❑ Surface is dirty or rusted ❑ Surface finish (RMS) is too smooth or too rough
   D. Bearing surfaces: q Improper support causing eccentricity ❑ Abnormal wear of wear ring and/or bearing surfaces

5. Inspect the seals for signs of failure:
   A. Describe the failed seal
   i. Seal type: ❑ Piston ❑ Rod ❑ Static
   Part Number:_____Size: _____Material: _____Profile: _____
   Companion parts: _____
   ii. Operation: ❑ Dynamic: ❑ Rotary ❑ Reciprocating ❑ Oscillating
   ❑ Static:
   B. Describe the conditions of failure
   i. Service length until failure: _____
   ii. Describe seal condition: See Chart in Master Seal Catalog pages 7 & 8

_____

_____

_____

_____

APPENDIX

//// METRIC / INCH CONVERSION TABLE

INCHES		MILLIMETERS
FRACTIONS	DECIMALS	
—	.0004	.01
—	.004	.10
—	.01	.25
1/64	.0156	.397
—	.0197	.50
—	.0295	.75
1/32	.03125	.794
—	.0394	1.0
3/64	.0469	1.191
—	.059	1.5
1/16	.062	1.588
5/64	.0781	1.984
—	.0787	2.0
3/32	.094	2.381
—	.0984	2.5
7/64	.109	2.778
—	.1181	3.0
1/8	.125	3.175
—	.1378	3.5
9/64	.141	3.572
5/32	.156	3.969
—	.1575	4.0
11/64	.172	4.366
—	.177	4.5
3/16	.1875	4.763
—	.1969	5.0
13/64	.203	5.159
—	.2165	5.5
7/32	.219	5.556
15/64	.234	5.953
—	.2362	6.0
1/4	.250	6.350
—	.2559	6.5
17/64	.2656	6.747
—	.2756	7.0
9/32	.281	7.144
—	.2953	7.5
19/64	.297	7.541
5/16	.312	7.938
—	.315	8.0
21/64	.328	8.334
—	.335	8.5
11/32	.344	8.731
—	.3543	9.0
23/64	.359	9.128

INCHES		MILLIMETERS
FRACTIONS	DECIMALS	
—	.374	9.5
3/8	.375	9.525
25/64	.391	9.922
—	.3937	10.0
13/32	.406	10.319
—	.413	10.5
27/64	.422	10.716
—	.4331	11.0
7/16	.438	11.113
29/64	.453	11.509
15/32	.469	11.906
—	.4724	12.0
31/64	.484	12.303
—	.492	12.5
1/2	.500	12.700
—	.5118	13.0
33/64	.5156	13.097
17/32	.531	13.494
35/64	.547	13.891
—	.5512	14.0
9/16	.563	14.288
—	.571	14.5
37/64	.578	14.684
—	.5906	15.0
19/32	.594	15.081
39/64	.609	15.478
5/8	.625	15.875
—	.6299	16.0
41/64	.6406	16.272
—	.6496	16.5
21/32	.658	16.669
—	.6693	17.0
43/64	.672	17.066
11/16	.6875	17.463
45/64	.703	17.859
—	.7087	18.0
23/32	.719	18.256
—	.7283	18.5
47/64	.734	18.653
—	.7480	19.0
3/4	.750	19.050
49/64	.7656	19.447
25/32	.781	19.844
—	..7874	20.0
51/64	.797	20.241

INCHES		MILLIMETERS
FRACTIONS	DECIMALS	
13/16	.8125	20.638
—	.8268	21.0
53/64	.828	21.034
27/32	.844	21.431
55/64	.859	21.828
—	.8661	22.0
7/8	.875	22.225
57/64	.8906	22.622
—	.9055	23.0
29/32	.9062	23.019
59/64	.922	23.416
15/16	.9375	23.813
—	.9449	24.0
61/64	.953	24.209
31/32	.969	24.606
—	.9843	25.0
63/64	.9844	25.003
1	1.000	25.400
—	1.0236	26.0
1-1/32	1.0312	26.194
1-1/16	1.062	26.988
—	1.063	27.0
1-3/32	1.094	27.781
—	1.1024	28.0
1-1/8	1.125	28.575
—	1.1417	29.0
1-5/32	1.156	29.369
—	1.1811	30.0
1-3/16	1.1875	30.163
1-7/32	1.219	30.956
—	1.2205	31.0
1-1/4	1.250	31.750
—	1.2598	32.0
1-9/32	1.281	32.544
—	1.2992	33.0
1-5/16	1.312	33.338
—	1.3386	34.0
1-11/32	1.344	34.131
1-3/8	1.375	34.925
—	1.3779	35.0
1-13/32	1.406	35.719
—	1.4173	36.0
1-7/16	1.438	36.513
—	1.4567	37.0
1-15/32	1.469	37.306

INCHES		MILLIMETERS
FRACTIONS	DECIMALS	
—	1.4961	38.0
1-1/2	1.500	38.100
1-17/32	1.531	38.894
—	1.5354	39.0
1-9/16	1.562	39.688
—	1.5748	40.0
1-19/32	1.594	40.481
—	1.6142	41.0
1-5/8	1.625	41.275
—	1.6535	42.0
1-21/32	1.6562	42.069
1-11/16	1.6875	42.863
—	1.6929	43.0
1-23/32	1.719	43.656
—	1.7323	44.0
1-3/4	1.750	44.450
—	1.7717	45.0
1-25/32	1.781	45.244
—	1.8110	46.0
1-13/16	1.8125	46.038
1-27/32	1.844	46.831
—	1.8504	47.0
1-7/8	1.875	47.625
—	1.8898	48.0
1-29/32	1.9062	48.419
—	1.9291	49.0
1-15/16	1.9375	49.213
—	1.9685	50.0
1-31/32	1.969	50.006
2	2.000	50.800
—	2.0079	51.0
2-1/32	2.03125	51.594
—	2.0472	52.0
2-1/6	2.062	52.388
—	2.0866	53.0
2-3/32	2.094	53.181
2-1/8	2.125	53.975
—	2.126	54.0
2-5/32	2.156	54.769
—	2.165	55.0
2-3/16	2.1875	55.563
—	2.2047	56.0
2-7/32	2.219	56.356
—	2.244	57.0
2-1/4	2.250	57.150

//// METRIC / INCH CONVERSION TABLE

INCHES		MILLIMETERS
FRACTIONS	DECIMALS	
2-9/32	2.281	57.944
—	2.2835	58.0
2-5/16	2.312	58.738
—	2.3228	59.0
2-11/32	2.344	59.531
—	2.3622	60.0
2-3/8	2.375	60.325
—	2.4016	61.0
2-13/32	2.406	61.119
2-7/16	2.438	61.913
—	2.4409	62.0
2-15/32	2.469	62.706
—	2.4803	63.0
2-1/2	2.500	63.500
—	2.5197	64.0
2-17/32	2.531	64.294
—	2.559	65.0
2-9/16	2.562	65.088
2-19/32	2.594	65.881
—	2.5984	66.0
2-5/8	2.625	66.675
—	2.638	67.0
2-21/32	2.656	67.469
—	2.6772	68.0
2-11/16	2.6875	68.263
—	2.7165	69.0
2-23/32	2.719	69.056
2-3/4	2.750	69.850
—	2.7559	70.0
2-25/32	2.781	70.6439
—	2.7953	71.0
2-13/16	2.8125	71.4376
—	2.8346	72.0
2-27/32	2.844	72.2314
—	2.8740	73.0
2-7/8	2.875	73.025
2-29/32	2.9062	73.819
—	2.9134	74.0
2-15/16	2.9375	74.613
—	2.9527	75.0
2-31/32	2.969	75.406
—	2.9921	76.0
3	3.000	76.200
3-1/32	3.0312	76.994
—	3.0315	77.0

INCHES		MILLIMETERS
FRACTIONS	DECIMALS	
3-1/16	3.062	77.788
—	3.0709	78.0
3-3/32	3.094	78.581
—	3.1102	79.0
3-1/8	3.125	79.581
—	3.1496	80.0
3-5/32	3.156	80.169
3-3/16	3.1875	80.963
—	3.1890	81.0
3-7/32	3.219	81.756
—	3.2283	82.0
3-1/4	3.250	82.550
—	3.2677	83.0
3-9/32	3.281	83.344
—	3.3071	84.0
3-5/16	3.312	84.1377
3-11/32	3.344	84.9314
—	3.3464	85.0
3-3/8	3.375	85.725
—	3.3858	86.0
3-13/32	3.406	86.519
—	3.4252	87.0
3-7/16	3.438	87.313
—	3.4648	88.0
3-15/32	3.469	88.108
3-1/2	3.500	88.900
—	3.5039	89.0
3-17/32	3.531	89.694
—	3.5433	90.0
3-9/16	3.562	90.4877
—	3.5827	91.0
3-19/32	3.594	91.281
—	3.622	92.0
3-5/8	3.625	92.075
3-21/32	3.656	92.869
—	3.6614	93.0
3-11/16	3.6875	93.663
—	3.7008	94.0
3-23/32	3.719	94.456
—	3.7401	95.0
3-3/4	3.750	95.250
—	3.7795	96.0
3-25/32	3.781	96.044
3-13/16	3.8125	96.838
—	3.8189	97.0

INCHES		MILLIMETERS
FRACTIONS	DECIMALS	
3-27/32	3.844	97.631
—	3.8583	98.0
3-7/8	3.875	98.425
—	3.8976	99.0
3-29/32	3.9062	99.219
—	3.9370	100.0
3-15/16	3.9375	100.013
3-31/32	3.969	100.806
—	3.9764	101.0
4	4.000	101.600
4-1/16	4.062	103.188
4-1/8	4.125	104.775
—	4.1338	105.0
4-3/16	4.1875	106.363
4-1/4	4.250	107.950
4-5/16	4.312	109.538
—	4.3307	110.0
4-3/8	4.375	111.125
4-7/16	4.438	112.713
4-1/2	4.500	114.300
—	4.5275	115.0
4-9/16	4.562	115.888
4-5/8	4.625	117.475
4-11/16	4.6875	119.063
—	4.7244	120.0
4-3/4	4.750	120.650
4-13/16	4.8125	122.238
4-7/8	4.875	123.825
—	4.9212	125.0
4-15/16	4.9375	125.413
5	5.000	127.000
—	5.1181	130.0
5-1/4	5.250	133.350
5-1/2	5.500	139.700
—	5.5118	140.0
5-3/4	5.750	146.050
—	5.9055	150.0
6	6.000	152.400
6-1/4	6.250	158.750
—	6.2992	160.0
6-1/2	6.500	165.100
—	6.6929	170.0
6-3/4	6.750	171.450
7	7.000	177.800
—	7.0866	180.0

INCHES		MILLIMETERS
FRACTIONS	DECIMALS	
—	7.4803	190.0
7-1/2	7.500	190.500
—	7.8740	200.0
8	8.000	203.200
—	8.2677	210.0
8-1/2	8.500	215.900
—	8.6614	220.0
9	9.000	228.600
—	9.0551	230.0
—	9.4488	240.0
9-1/2	9.500	241.300
—	9.8425	250.0
10	10.000	254.001
—	10.2362	260.0
—	10.6299	270.0
11	11.000	279.401
—	11.0236	280.0
—	11.4173	290.0
—	11.8110	300.0
12	12.000	304.801
13	13.000	330.201
—	13.7795	350.0
14	14.000	355.601
15	15.000	381.001
—	15.7480	400.0
16	16.000	406.401
17	17.000	431.801
—	17.7165	450.0
18	18.000	457.201
19	19.000	482.601
—	19.6850	500.0
20	20.000	508.001

//// CYLINDER PUSH AND PULL FORCES

SQUARE HEAD "HIGH PRESSURE" CYLINDERS

Working Pressure of Hydraulic Fluid P.S.I.

BORE	AREA	ROD	SIZE	50	100	250	500	1000	1500	2000	3000	5000
	PUSH	—		88	177	443	885	1,770	2,655	3.540	5,310	8,850
1-1/2	PULL	STD	5/8	73	146	365	730	1,460	2,190	2,920	4,380	7,300
	PULL	2:1	1	49	98	245	490	980	1,470	1,960	2,940	4,900
	PUSH	—		157	314	785	1,570	3,140	4,710	6,280	9,420	15,700
2	PULL	STD	1	118	236	590	1,180	2,360	3,540	4,720	7,080	11,800
	PULL	2:1	1-3/8	83	166	415	830	1,660	2,490	3,320	4,980	8,300
	PUSH	—		246	491	1,228	2,455	4,910	7,265	9,820	14,730	24,550
2-1/2	PULL	STD	1	206	412	1,030	2,060	4,120	6,180	8,240	12,360	20,600
	PULL	2:1	1-3/4	125	250	625	1,250	2,500	3,750	5,000	7,500	12,500
	PUSH	—		415	830	2,075	4,150	8,300	12,450	16,600	24,900	41,500
3-1/2	PULL	STD	1-3/8	341	681	1,703	3,405	6,810	10,215	13,620	20,430	34,050
	PULL	2:1	2	258	515	1,288	2,575	5,150	7,725	10,300	15,450	25,750
	PUSH	—		628	1,257	3,143	6,285	12,570	18,855	25,140	37,710	62,850
4	PULL	STD	1-3/4	508	1,016	2,540	5,080	10,160	15,240	20,320	30,480	50,800
	PULL	2:1	2-1/2	383	766	1,916	3,830	7,660	11,490	15,320	22,980	38,300
	PUSH	—		982	1,964	4,910	9,820	19,640	29,460	39,280	58,920	98,200
5	PULL	STD	2	825	1,649	4,123	8,245	16,490	24,735	32,980	49,470	82,450
	PULL	2:1	3-1/2	500	1,001	2,503	5,005	10,010	15,015	20,020	30,030	50,050
	PUSH	—		1,413	2,827	7,068	14,135	28,270	42,405	56,540	84,810	141,350
6	PULL	STD	2-1/2	1,168	2,336	5,840	11,680	23,360	35,040	46,720	70,080	116,800
	PULL	2:1	4	786	1,571	3,928	7,855	15,710	23,565	31,420	47,130	78,550
	PUSH	—		1,924	3,849	9,623	19,245	38,490	57,735	76,980	115,470	192,450
7	PULL	STD	3	1,571	3,142	7,855	15,710	31,420	47,130	62,840	94,260	157,100
	PULL	2:1	5	942	1,885	4,713	9,425	18,850	28,275	37,700	56,550	94,250
	PUSH	—		2,514	5,027	12,568	25,135	50,270	75,405	100,540	150,810	251,350
8	PULL	STD	3-1/2	2,032	4,064	10,160	20,320	40,640	60,960	81,280	121,920	203,200
	PULL	2:1	5-1/2	1,326	2,651	6,628	13,255	26,510	39,765	53,020	79,530	132,550
	PUSH	—		3,927	7,854	19,635	39,270	78,540	117,810	157,080	235,620	392,700
10	PULL	STD	4-1/2	3,132	6,264	15,660	31,320	62,640	93,960	125,280	187,920	313,200
	PULL	2:1	7	2,003	4,006	10,015	20,030	40,060	60,090	80,120	120,180	200,300

This table is a ready reference of forces available from either end from various cylinder and rod sizes at a range of pressures. For pressures intermediate between those shown, add force values from two or more pressures whose sum equals the given operating pressure.

//// FLUID MOTOR TORQUE

HORSE POWER													
RPM	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**15**	**20**	**25**
1	63,025	126,050	189,076	252,100	315,125	378,150	441,175	504,200	567,225	630,250	945,375	105,042	131,302
2	31,512	63,025	94,538	126,050	157,563	189,075	220,588	252,100	283,613	315,125	472,688	630,250	787,813
3	21,009	42,017	63,025	84,036	105,042	126,050	147,058	168,067	189,075	210,083	315,125	420,167	525,208
4	15,756	31,512	47,269	63,025	78,781	94,538	110,294	126,050	141,806	157,563	236,344	315,125	393,906
5	12,605	25,210	37,815	50,420	63,025	75,630	88,236	100,840	113,445	126,050	189,076	252,100	315,125
6	10,506	21,009	31,513	42,017	52,521	63,025	73,529	84,033	94,538	105,040	157,563	210,083	262,604
7	9,004	18,007	27,011	36,016	45,018	54,021	63,025	72,029	81,032	90,036	135,054	180,071	225,089
8	7,878	15,756	23,634	31,512	39,391	47,269	55,147	63,025	70,903	78,780	118,172	157,563	196,953
9	7,003	14,006	21,010	28,011	35,014	42,017	49,019	56,022	63,025	70,030	105,042	140,056	175,069
10	6,303	12,605	18,908	25,210	31,512	37,815	44,118	50,420	56,723	63,025	94,538	126,050	157,563
20	3,151	6,303	9,454	12,605	15,756	18,908	22,059	25,210	28,316	31,512	47,269	63,025	78,781
25	2,521	5,042	7,563	10,084	12,605	15,126	17,647	20,168	22,689	25,210	37,815	50,420	63,025
30	2,101	4,202	6,303	8,403	10,504	12,605	14,705	16,807	18,908	21,009	31,513	42,017	52,521
40	1,576	3,151	4,727	6,303	7,878	9,454	11,029	12,605	14,181	15,756	23,634	31,513	39,391
50	1,261	2,521	3,782	5,042	6,303	7,563	8,824	10,084	11,345	12,605	18,908	25,210	31,513
60	1,050	2,101	3,151	4,202	5,252	6,303	7,353	8,403	9,454	10,504	15,756	21,009	26,260
70	900	1,801	2,701	3,601	4,502	5,402	6,303	7,203	8,103	9,004	13,506	18,007	22,509
75	840	1,681	2,521	3,361	4,202	5,042	5,882	6,723	7,563	8,403	12,605	16,806	21,008
80	788	1,576	2,363	3,151	3,939	4,727	5,515	6,303	7,090	7,878	11,817	15,756	19,695
90	700	1,400	2,101	2,801	3,501	4,202	4,902	5,602	6,303	7,003	10,504	14,006	17,507
100	630	1,261	1,891	2,521	3,151	3,782	4,412	5,042	5,672	6,303	9,453	12,605	15,758
150	420	840	1,261	1,681	2,101	2,251	2,941	3,361	3,781	4,202	6,303	8,403	10,504
200	315	630	945	1,261	1,575	1,891	2,206	2,521	2,836	3,151	4,727	6,303	7,878
250	252	504	756	1,008	1,260	1,531	1,765	2,017	2,269	2,521	3,782	5,042	6,303
300	210	420	630	840	1,050	1,261	1,471	1,681	1,891	2,101	3,151	4,202	5,252
350	180	360	540	720	900	1,080	1,261	1,441	1,621	1,801	2,701	3,601	4,502
400	158	315	473	630	788	945	1,104	1,261	1,418	1,576	2,364	3,151	3,939
450	141	280	420	560	700	840	980	1,120	1,261	1,401	2,101	2,801	3,501
500	126	252	378	504	630	756	882	1,008	1,134	1,261	1,891	2,521	3,151
550	115	229	344	458	573	688	802	917	1,031	1,146	1,719	2,292	2,865
600	105	210	315	420	525	630	735	840	945	1,050	1,576	2,101	2,626
650	97	194	291	388	485	582	679	776	873	970	1,454	1,939	2,424
700	90	180	270	360	450	540	630	720	810	900	1,351	1,801	2,251
750	84	168	252	336	420	504	588	672	756	840	1,261	1,681	2,101
800	79	158	236	315	393	473	551	630	709	788	1,182	1,576	1,970
850	74	148	222	297	371	445	519	593	667	741	1,112	1,483	1,854
900	70	140	210	280	350	420	490	560	630	700	1,050	1,400	1,751
950	66	133	199	265	332	398	464	531	597	663	995	1,327	1,659
1000	63	126	189	252	315	378	441	504	567	630	945	1,261	1,576
1100	57	115	172	229	286	344	401	458	516	573	860	1,146	1,432
1200	53	105	158	210	263	315	368	420	473	525	788	1,050	1,313
1300	48	97	145	194	242	291	339	388	436	485	727	970	1,212
1400	45	90	135	180	225	270	315	360	405	450	675	900	1,125
1500	42	84	126	168	210	252	294	336	378	420	630	840	1,050
1600	39	79	118	158	197	236	276	315	355	394	591	788	985
1700	37	74	111	148	185	222	260	296	334	371	556	741	927
1800	35	70	105	140	175	210	245	280	315	350	525	700	875
1900	33	66	100	133	166	199	232	265	299	332	498	663	829
2000	32	63	95	126	158	189	221	252	284	315	473	630	788
2100	30	60	90	120	150	180	210	240	270	300	450	600	750
2200	29	57	86	115	143	172	201	229	258	286	430	573	716
2300	27	55	82	110	137	164	192	219	247	274	411	548	685
2400	26	53	79	105	131	158	184	210	236	263	394	525	657
2500	25	50	76	101	126	151	176	202	227	252	378	504	630
2750	23	46	69	92	115	138	160	183	206	229	344	458	573
3000	21	42	63	84	105	126	147	168	189	210	315	420	525
3250	19	39	58	78	97	116	136	155	175	194	291	388	485
3500	18	36	54	72	90	108	126	144	162	180	270	360	450
3750	17	34	50	67	84	101	118	134	151	168	252	336	420
4000	16	32	47	63	79	95	110	126	142	158	236	315	394
4250	15	30	44	59	74	89	104	119	133	148	222	297	371
4500	14	28	42	56	70	84	98	112	126	140	210	280	350
4750	13	27	40	53	66	80	93	106	119	133	199	265	332
5000	13	25	38	50	63	76	88	101	113	126	189	252	315
6000	11	21	32	42	53	63	74	84	95	105	158	210	263
7000	9	18	27	36	45	54	63	72	81	90	135	180	225
8000	8	16	24	32	39	47	55	63	71	79	118	158	197
9000	7	14	21	28	35	42	49	56	63	70	105	140	175
10000	6	13	19	25	32	38	44	50	57	63	95	126	158

//// HYDRAULIC CYLINDER SPEEDS

Inches / Minute

PISTON DIAMETER	ROD DIAMETER	FLOW - GPM										
		1	2	3	5	10	12	15	20	25	50	75
1	—	298	596	894	1490							
	1/2	392	784	1176	1960							
1-1/2	—	130	260	392	654	1308						
	5/8	158	316	476	792	1584						
	1	235	470	706	1176	2352						
2	—	73	146	221	368	736	883	1120				
	3/4	85	170	257	428	956	1025	1283				
	1	97	184	294	490	980	1175	1465				
	1-3/8	139	278	418	697	1394	1673	2090				
2-1/2	—	47	94	141	235	470	565	675	940	1175		
	1	56	112	168	280	560	672	840	1120	1400		
	1-3/8	67	134	203	339	678	813	1015	1355	1695		
	1-3/4	92	184	277	463	926	1110	1385	1850	2310		
3	—	32	64	98	163	326	392	490	653	817		
	1	36	72	110	184	368	440	551	735	920		
	1-1/2	43	86	131	218	436	523	655	872	1090		
	2	58	116	176	294	588	705	882	1175	1470		
3-1/2	—	24	48	72	120	240	288	360	480	600	1200	
	1-1/4	27	54	82	137	274	330	411	548	685	1370	
	1-3/4	32	64	96	160	320	384	480	640	800	1600	
	2	35	70	107	178	356	428	534	712	890	1780	
4	—	18	36	55	92	184	220	276	368	460	920	
	1-1/4	20	40	61	102	204	244	306	408	510	1020	
	1-3/4	22	44	68	113	226	273	339	452	565	1130	
	2	24	48	73	122	244	294	366	488	610	1220	
	2-1/2	30	60	90	150	300	362	450	600	750	1500	
5	—	12	24	35	58	116	141	174	232	290	580	870
	1-1/2	13	26	39	64	128	155	193	258	320	640	960
	2	14	28	42	70	140	168	210	280	350	700	1050
	2-1/2	16	32	47	78	156	188	235	315	390	780	1170
	3	18	36	55	92	184	220	275	365	460	920	1380
	3-1/2	22	44	66	111	222	266	333	444	555	1110	1665
6	—	8	16	24	41	82	98	123	162	202	404	606
	1-3/4	9	18	27	45	90	107	135	180	225	450	675
	2-1/2	10	20	30	50	100	118	150	200	250	500	750
	3	11	22	33	54	108	130	165	206	270	540	810
	3-1/2	12	24	37	62	124	148	185	245	310	620	930
	4	15	30	44	73	146	176	220	295	365	730	1095
8	—	4	8	14	23	46	55	69	92	115	230	345
	3-1/2	5-1/2	11	17	28	56	68	85	115	140	280	420
	4	6	12	18	30	60	73	90	122	150	300	450
	5	7-1/2	15	22	38	76	90	114	150	185	375	555
	5-1/2	8-1/2	17	26	43	86	104	129	172	215	430	645
10	—	3	6	9	15	30	35	44	60	73	146	220
	4-1/2	3-1//2	7	11	18	36	44	55	75	92	184	275
	5	4	8	12	20	40	47	60	80	100	200	300
	5-1/2	4-1/2	9	13	21	42	50	63	84	105	210	315
	7	5-1/2	11	17	29	58	69	87	115	145	290	435

This chart is based on the formula $V = \frac{231 \times GPM}{\text{EFF. CYL. AREA (Sq. Inches)}}$

//// ELECTRIC MOTOR HORSEPOWER

Required to Drive a Hydraulic Pump

	PUMP PRESSURE PSI										
GPM	**100**	**200**	**250**	**300**	**400**	**500**	**750**	**1000**	**1250**	**1500**	**2000**
1/2	.04	.07	.09	.10	.14	.17	.26	.34	.43	.52	.69
1	.07	.14	.17	.21	.28	.34	.52	.69	.86	1.03	1.37
1 1/2	.10	.21	.26	.31	.41	.52	.77	1.03	1.29	1.54	2.06
2	.14	.28	.34	.41	.55	.69	1.03	1.37	1.72	2.06	2.75
2 1/2	.17	.34	.43	.52	.69	.86	1.29	1.72	2.15	2.58	3.43
3	.21	.41	.52	.62	.83	1.03	1.54	2.06	2.57	3.09	4.12
3 1/2	.24	.48	.60	.72	.96	1.20	1.80	2.40	3.00	3.60	4.81
4	.28	.55	.69	.82	1.10	1.37	2.06	2.75	3.43	4.12	5.49
5	.34	.69	.86	1.03	1.32	1.72	2.57	3.43	4.29	5.15	6.86
6	.41	.82	1.03	1.24	1.65	2.06	3.09	4.12	5.15	6.18	8.24
7	.48	.96	1.20	1.44	1.92	2.40	3.60	4.81	6.01	7.21	9.61
8	.55	1.10	1.37	1.65	2.20	2.75	4.12	5.49	6.86	8.24	11.0
9	.62	1.24	1.55	1.85	2.47	3.09	4.63	6.18	7.72	9.27	12.4
10	.69	1.37	1.62	2.06	2.75	3.43	5.15	6.86	8.58	10.3	13.8
11	.76	1.51	1.89	2.27	3.02	3.78	5.66	7.55	9.44	11.3	15.1
12	.83	1.65	2.06	2.47	3.30	4.12	6.18	8.24	10.3	12.4	16.5
13	.89	1.79	2.23	2.68	3.57	4.46	6.69	8.92	11.2	13.4	17.8
14	.96	1.92	2.40	2.88	3.84	4.81	7.21	9.61	12.0	14.4	19.2
15	1.03	2.06	2.57	3.09	4.12	5.15	7.72	10.3	12.9	15.4	20.6
16	1.10	2.20	2.75	3.30	4.39	5.49	8.24	11.0	13.7	16.5	22.0
17	1.17	2.33	2.92	3.50	4.68	5.83	8.75	11.7	14.6	17.5	23.3
18	1.24	2.47	3.09	3.71	4.94	6.18	9.27	12.4	15.4	18.5	24.7
19	1.30	2.61	3.26	3.91	5.22	6.52	9.78	13.0	16.3	19.6	26.1
20	1.37	2.75	3.43	4.12	5.49	6.86	10.3	13.7	17.2	21.6	27.5
25	1.72	3.43	4.29	5.15	6.86	8.58	12.9	17.2	21.5	25.8	34.3
30	2.06	4.12	5.15	6.18	8.24	10.3	15.4	20.6	25.7	30.9	41.2
35	2.40	4.81	6.01	7.21	9.61	12.0	18.0	24.0	30.0	36.0	48.0
40	2.75	5.49	6.86	8.24	11.0	13.7	20.6	27.5	34.3	41.2	54.9
45	3.09	6.18	7.72	9.27	12.4	15.4	23.2	31.0	38.6	46.3	61.8
50	3.43	6.86	8.58	10.3	13.7	17.2	25.7	34.3	42.9	51.5	68.6
55	3.78	7.55	9.44	11.3	15.1	18.9	28.3	37.8	47.2	56.6	75.5
60	4.12	8.24	10.3	12.4	16.5	20.6	30.9	41.2	51.5	61.8	83.4
65	4.46	8.92	11.2	13.4	17.8	22.3	33.5	44.6	55.8	66.9	89.2
70	4.81	9.61	12.0	14.4	19.2	24.0	36.0	48.0	60.1	72.1	96.1
75	5.15	10.3	12.9	15.4	20.6	25.7	38.6	51.4	64.3	77.2	103.0
80	5.49	11.0	13.7	16.5	22.0	27.5	41.2	54.9	68.6	82.4	109.8
90	6.18	12.4	15.4	18.5	24.7	30.9	46.3	61.8	77.2	92.7	123.6
100	6.86	13.7	17.2	20.6	27.5	34.4	51.5	68.6	85.8	103.0	137.3

This chart is based on the formula $HP = \frac{GPM \times PSI}{1714 \times EFFICIENCY}$

For the purposes of this chart, pump efficiency was assumed to be 85%.

As horsepower varies directly with flow or pressure, multiply proportionately to determine values not shown. For instance, at 4000 PSI multiply 2000 PSI values by 2.

//// AREAS AND CIRCUMFERENCES OF CIRCLES

DIAM.	CIRCUM.	AREA	DIAM.	CIRCUM.	AREA	DIAM.	CIRCUM.	AREA	DIAM.	CIRCUM.	AREA	DIAM.	CIRCUM.	AREA
			1	3.1416	.7854	5	15.708	19.635	12	37.699	113.10	24	75.398	452.39
1/64	.04909	.00019	1/16	3.3379	.8866	1/8	16.101	20.629	1/4	38.485	117.86	1/4	76.184	461.86
1/32	.09818	.00077	1/8	3.5343	.9940	1/4	16.493	21.648	1/2	39.270	122.72	1/2	76.969	471.44
3/64	.14726	.00173	3/16	3.7306	1.1075	3/8	16.886	22.691	3/4	40.055	127.68	3/4	77.764	481.11
1/16	.1965	.00307	1/4	3.9270	1.2272	1/2	17.279	23.758	13	40.841	132.73	25	78.540	490.87
5/64	.24544	.00479	5/16	4.1233	1.3530	5/8	17.671	24.850	1/4	41.626	137.89	1/4	79.325	500.74
3/32	.29452	.00690	3/8	4.3197	1.4849	3/4	18.064	25.967	1/2	42.412	143.14	1/2	80.111	510.71
7/64	.34361	.00940	7/16	4.5160	1.6230	7/8	18.457	27.109	3/4	43.197	148.49	3/4	80.896	520.77
1/8	.39270	.01227	1/2	4.7124	1.7671	6	18.850	28.274	14	43.982	153.94	26	81.681	530.93
9/64	.44179	.01553	9/16	4.9087	1.9175	1/8	19.242	29.465	1/4	44.768	159.48	1/4	82.467	541.19
5/32	.49087	.01917	5/8	5.1051	2.0739	1/4	19.635	30.680	1/2	45.553	165.13	1/2	83.252	551.55
11/64	.53996	.02320	11/16	5.3014	2.2365	3/8	20.028	31.919	3/4	46.338	170.87	3/4	84.038	562.00
3/16	.58905	.02761	3/4	5.4978	2.4053	1/2	20.420	33.183	15	47.124	176.71	27	84.823	572.56
13/64	.63814	.03241	13/16	5.6941	2.5802	5/8	20.813	34.472	1/4	47.909	182.65	1/4	85.608	583.21
7/32	.68722	.03758	7/8	5.8905	2.7612	3/4	21.206	35.785	1/2	48.695	188.69	1/2	86.394	593.96
15/64	.73631	.04314	15/16	6.0868	2.9483	7/8	21.598	37.122	3/4	49.480	194.83	3/4	87.179	604.81
1/4	.78540	.04909	2	6.2832	3.1416	7	21.991	38.485	16	50.265	201.06	28	87.965	615.75
17/64	.83449	.05542	1/16	6.4795	3.3410	1/8	22.384	39.871	1/4	51.051	207.39	1/4	88.750	626.80
9/32	.88357	.06213	1/8	6.6759	3.5466	1/4	22.776	41.282	1/2	51.836	213.82	1/2	89.535	637.94
19/64	.93266	.06922	3/16	6.8722	3.7583	3/8	23.169	42.718	3/4	52.622	220.35	3/4	90.321	649.18
5/16	.98175	.07670	1/4	7.0686	3.9761	1/2	23.562	44.179	17	53.407	226.98	29	91.106	660.52
21/64	1.03084	.08456	5/16	7.2649	4.2000	5/8	23.955	45.664	1/4	54.192	233.71	1/4	91.892	671.96
11/32	1.0799	.09281	3/8	7.4613	4.4301	3/4	24.347	47.173	1/2	54.978	240.53	1/2	92.677	683.49
23/64	1.1290	.10143	7/16	7.6576	4.6664	7/8	24.740	48.707	3/4	55.763	247.45	3/4	93.462	695.13
3/8	1.1781	.11045	1/2	7.8540	4.9087	8	25.133	50.265	18	56.549	254.47	30	94.248	708.86
25/64	1.2272	.11984	9/16	8.0503	5.1572	1/8	25.525	51.849	1/4	57.334	261.59	1/4	95.033	718.69
13/32	1.2763	.12962	5/8	8.2467	5.4119	1/4	25.918	53.456	1/2	58.119	268.80	1/2	95.819	730.62
27/64	1.3254	.13978	11/16	8.4430	5.6727	3/8	26.311	55.088	3/4	58.905	276.12	3/4	96.604	742.64
7/16	1.3744	.15033	3/4	8.6394	5.9396	1/2	26.704	56.745	19	59.690	283.53	31	97.389	754.77
29/64	1.4235	.16126	13/16	8.8357	6.2126	5/8	27.096	58.426	1/4	60.476	291.04	1/4	98.175	766.99
15/32	1.4726	.17257	7/8	9.0321	6.4918	3/4	27.489	60.132	1/2	61.261	298.65	1/2	98.960	779.31
31/64	1.5217	.18427	15/16	9.2284	6.7771	7/8	27.882	61.862	3/4	62.046	306.35	3/4	99.746	791.73
1/2	1.5708	.19635	3	9.4248	7.0686	9	28.274	63.617	20	62.832	314.16	32	100.531	804.25
17/32	1.6690	.22166	1/8	9.8175	7.6699	1/8	28.667	65.397	1/4	63.617	322.06	1/4	101.316	816.86
9/16	1.7671	.24850	1/4	10.210	8.2958	1/4	29.060	67.201	1/2	64.403	330.06	1/2	102.102	829.58
19/32	1.8653	.27688	3/8	10.603	8.9462	3/8	29.452	69.029	3/4	65.188	338.16	3/4	102.887	842.39
5/8	1.9635	.30680	1/2	10.996	9.6211	1/2	29.845	70.882	21	65.973	346.36	33	103.673	855.30
21/32	2.0617	.33824	5/8	11.388	10.321	5/8	30.238	72.760	1/4	66.759	354.66	1/4	104.458	868.31
11/16	2.1598	.37122	3/4	11.781	11.045	3/4	30.631	74.662	1/2	67.544	363.05	1/2	105.243	881.41
23/32	2.2580	.40574	7/8	12.174	11.793	7/8	31.023	76.589	3/4	68.330	371.54	3/4	106.029	894.62
3/4	2.3562	.44179	4	12.566	12.566	10	31.416	78.540	22	69.115	380.13	34	106.814	907.92
25/32	2.4544	.47937	1/8	12.959	13.364	1/4	32.201	82.516	1/4	69.900	388.82	1/4	107.600	921.32
13/16	2.5525	.51849	1/4	13.352	14.186	1/2	32.987	86.590	1/2	70.686	397.61	1/2	108.385	934.82
27/32	2.6507	.55914	3/8	13.744	15.033	3/4	33.772	90.763	3/4	71.471	406.49	3/4	109.170	948.42
7/8	2.7489	.60132	1/2	14.137	15.904	11	34.558	95.033	23	72.257	415.48	35	109.956	962.11
29/32	2.8471	.64504	5/8	14.530	16.800	1/4	35.343	99.402	1/4	73.042	424.56	1/4	110.741	975.91
15/16	2.9452	.69029	3/4	14.923	17.721	1/2	36.128	103.87	1/2	73.827	433.74	1/2	111.527	989.80
31/32	3.0434	.73708	7/8	15.315	18.665	3/4	36.914	108.43	3/4	74.613	443.01	3/4	112.312	1003.8

//// FLUID POWER FORMULAS

BASIC FORMULAS

FORMULA FOR:	WORD FORMULA	LETTER FORMULA
FLUID PRESSURE In Pounds/Square Inch	PRESSURE = FORCE (pounds) / UNIT AREA (Square Inches)	$P = \frac{F}{A}$ or psi = $\frac{F}{A}$
FLUID FLOW RATE In Gallons/Minute	FLOW RATE = VOLUME (Gallons) / UNIT TIME (Minutes)	$Q = \frac{V}{T}$
FLUID POWER In Horsepower	HORSEPOWER = PRESSURE (PSI) X FLOW (GPM) / 1714	$HP = \frac{PQ}{1714}$

FLUID FORMULAS

VELOCITY THROUGH PIPING In Feet/Second Velocity	VELOCITY = .3208 x FLOW RATE THROUGH I.D. (GPM) / INTERNAL AREA (Square Inches)	$V = \frac{.3208Q}{A}$
COMPRESSIBILITY OF OIL In Additional Required Oil To Reach Pressure	ADDITIONAL VOLUME = PRESSURE (PSI) x VOLUME OF OIL UNDER PRESSURE / 250,000 (Approx.)	$VA = \frac{PV}{250{,}000}$ * Approximately 1/2% per 1000 psi
COMPRESSIBILITY OF A FLUID	COMPRESSIBILITY = 1 / BULK MODULUS OF THE FLUID	$C(ß) = \frac{1}{BM}$
SPECIFIC GRAVITY OF A FLUID	SPECIFIC GRAVITY = WEIGHT OF ONE CUBIC FOOT OF FLUID / WEIGHT OF ONE CUBIC FOOT OF WATER	$SG = \frac{W}{62.4283}$
VALVE (CV) FLOW FACTOR	VALVE FACTOR (CV) = FLOW RATE (GPM) x $\sqrt{\text{SPECIFIC GRAVITY}}$ / PRESSURE DROP (PSI)	$CV = \frac{Q\sqrt{SG}}{\Delta P}$
VISCOSITY IN CENTISTOKES	For Viscosities of 32 to 100 Saybolt Universal Seconds: CENTISTOKES = .2253 x SUS – $\frac{194.4}{SUS}$	$CS = .2253\ SUS - \frac{194.4}{SUS}$
VISCOSITY IN CENTISTOKES	For Viscosities of 100 to 240 Saybolt Universal Seconds: CENTISTOKES = .2193 x SUS – $\frac{134.6}{SUS}$	$CS = .2193\ SUS - \frac{134.6}{SUS}$
VISCOSITY IN CENTISTOKES	For Viscosities Greater Than 240 Saybolt Universal Seconds: CENTISTOKES = $\frac{SUS}{4.635}$	$CS = \frac{SUS}{4.635}$

NOTE: Saybolt Universal Seconds is often abbreviated SSU.

PUMP FORMULAS

PUMP OUTLET FLOW In Gallons/Minute	FLOW = RPM X PUMP DISPLACEMENT (Cu. In./Rev.) / 231	$Q = \frac{nd}{231}$	
PUMP INPUT POWER In Horsepower Required	HORSEPOWER INPUT = FLOW RATE OUTPUT (GPM) X PRESSURE (psi) / 1714 X EFFICIENCY (Overall)	$HP_{IN} = \frac{QP}{1714\ Eff}$ or $\frac{GPM\ X\ psi}{1714\ Eff}$	
PUMP EFFICIENCY Overall in Percent	OVERALL EFFICIENCY = OUTPUT HORSEPOWER / INPUT HORSEPOWER X 100	$Eff_{OV} = \frac{HP_{OUT}}{HP_{IN}} X\ 100$	
	OVERALL EFFICIENCY = VOLUMETRIC Eff. X MECHANICAL Eff.	$Eff_{OV} = Eff_{VOL.} X\ Eff_{MECH.}$	
PUMP EFFICIENCY Overall in Percent	VOLUMETRIC EFFICIENCY = ACTUAL FLOW RATE OUTPUT (GPM) / THEORETICAL FLOW RATE OUTPUT (GPM) X 100	$Eff_{VOL} = \frac{Q_{ACT.}}{Q_{THEO.}} X\ 100$	
PUMP EFFICIENCY Mechanical in Percent	MECHANICAL EFFICIENCY = THEORETICAL TORQUE TO DRIVE / ACTUAL TORQUE TO DRIVE X 100	$Eff_{MEC} = \frac{T_{THEO.}}{T_{ACT.}} X\ 100$	
PUMP LIFE B_{10} BEARING LIFE	B_{10} HOURS OF BEARING LIFE = RATED LIFE HOURS X $\frac{\text{RATED SPEED (RPM)}}{\text{NEW SPEED (RPM)}} X \left(\frac{\text{RATED PRESSURE (PSI)}}{\text{NEW PRESSURE (PSI)}}\right)^3$	$B_{10} = \text{RATED HRS.} X \frac{RPM_R}{RPM_N} X \left(\frac{PR}{PN}\right)^3$	

APPENDIX

//// FLUID POWER FORMULAS

ACTUATOR FORMULAS

FORMULA FOR:	WORD FORMULA	LETTER FORMULA
CYLINDER AREA In Square Inches	AREA = π X RADIUS^2 (Inches)	$A = \pi r^2$
	= $\frac{\pi \text{ X DIAMETER}^2 \text{ (Inches)}}{4}$	$A = \frac{\pi D^2}{4}$ or $A = .785D^2$
CYLINDER FORCE In Pounds, Push or Pull	FORCE = PRESSURE (psi) X NET AREA (Square Inches)	F = psi X A or F = PA
CYLINDER VELOCITY or SPEED In Feet/Second	VELOCITY = $\frac{231 \text{ X FLOW RATE (GPM)}}{12 \text{ X } 60 \text{ X NET AREA (Square Inches)}}$	$F = \frac{231Q}{720A}$ or $V = \frac{.3208Q}{A}$
CYLINDER VOLUME CAPACITY In Gallons of Fluid	VELOCITY = $\frac{\pi \text{ X RADIUS}^2 \text{ (Inches) X STROKE (Inches)}}{231}$	$V = \frac{\pi r^2 l}{231}$
	= $\frac{\text{NET AREA (Square Inches) X STROKE (Inches)}}{231}$	$V = \frac{A l}{231}$ l = Length of Stroke
CYLINDER FLOW RATE In Gallons Per Minute	FLOW RATE = $\frac{12 \text{ X } 60 \text{ X VELOCITY (Feet/Sec.) X NET AREA (Sq. Inches)}}{231}$	$Q = \frac{720vA}{231}$ or Q = 3.117vA
FLUID MOTOR TORQUE In Inch Pounds	TORQUE = $\frac{\text{PRESSURE (psi) X F.M. DISPLACEMENT (Cu. In./Rev.)}}{2\pi}$	$T = \frac{psi\ d}{2\pi}$ or $T = \frac{Pd}{2\pi}$
	= $\frac{\text{HORSEPOWER X 63025}}{\text{RPM}}$	$T = \frac{63025\ HP}{n}$
	= $\frac{\text{FLOW RATE (GPM) X PRESSURE (psi) X 36.77}}{\text{RPM}}$	$T = \frac{36.77QP}{n}$ or $T = \frac{36.77Qpsi}{n}$
FLUID MOTOR TORQUE/100 psi In Inch Pounds	TORQUE/100 psi = $\frac{\text{F.M. DISPLACEMENT (Cu. Inches/Revolution)}}{.0628}$	$T_{100psi} = \frac{d}{.0628}$
FLUID MOTOR SPEED In Revolutions/Minute	SPEED = $\frac{231 \text{ X FLOW RATE (GPM)}}{\text{F.M. DISPLACEMENT (Cu. Inches/Revolution)}}$	$n = \frac{231Q}{d}$
FLUID MOTOR POWER In Horsepower Output	HORSEPOWER = $\frac{\text{TORQUE OUTPUT (Inch Pounds) X RPM}}{63025}$	$HP = \frac{Tn}{63025}$

THERMAL FORMULAS

RESERVOIR COOLING CAPACITY Based on Adequate Air Circulation	HEAT (BTU/HR) = 2 X TEMPERATURE DIFFERENCE BETWEEN RESERVOIR WALLS AND AIR (°F) X AREA OF RESERVOIR (Sq. Ft.)	BTU/HR = 2.0 X ΔT X A
HEAT IN HYDRAULIC OIL (approx.) Due to System Inefficiency (SG=.89-.92)	HEAT (BTU/HR) = FLOW RATE (GPM) X 210 X TEMPERATURE DIFFERENCE (°F)	BTU/HR = Q X 210 X ΔT
HEAT IN FRESH WATER (approx.)	HEAT (BTU/HR) = FLOW RATE (GPM) X 500 X TEMPERATURE DIFFERENCE (°F)	BTU/HR = Q X 500 X ΔT

NOTE: One British Thermal Unit (BTU) is the amount of heat required to raise the temperature of one pound of water one degree. One Horsepower = 2545 BTU/HR.

//// FLUID POWER FORMULAS

ACCUMULATOR FORMULAS

PRESSURE or VOLUME w/ Constant "T" (Temperature)	ORIGINAL PRESSURE X ORIGINAL VOLUME = FINAL PRESSURE X FINAL VOLUME	$P_1 V_1 = P_2 V_2$ Isothermic
PRESSURE or TEMPERATURE w/ Constant "V" (Volume)	ORIGINAL PRESSURE X FINAL TEMPERATURE = FINAL PRESSURE X ORIGINAL TEMPERATURE	$P_1 T_2 = P_2 T_1$ Isochoric
VOLUME or TEMPERATURE w/ Constant "P" (Pressure)	ORIGINAL VOLUME X FINAL TEMPERATURE = FINAL VOLUME X ORIGINAL TEMPERATURE	$V_1 T_2 = V_2 T_1$ Isobaric
PRESSURE or VOLUME	ORIGINAL PRESSURE X ORIGINAL VOLUME^n = FINAL PRESSURE X FINAL VOLUME^n	$P_1 V_1^n = P_2 V_2^n$
w/ Temperature Change Due to Heat of Compression	$\frac{\text{FINAL TEMP.}}{\text{ORIG. TEMP.}} = \left(\frac{\text{ORIG. VOLUME}}{\text{FINAL VOLUME}}\right)^{n-1} = \left(\frac{\text{FINAL PRESSURE}}{\text{ORIG. PRESSURE}}\right)^{n-1/n}$	$\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{n-1} = \left(\frac{P_2}{P_1}\right)^{n-1/n}$

NOTE: Where "P" = psia (ABSOLUTE) = psig (GAUGE PRESSURE) + 14.7 psi

VOLUME & CAPACITY EQUIVALENTS

	Cubic Inches	*Cubic Feet*	*Cubic Yards*	*Liters*	*U.S. Gallons*	*Imperial Gallons*	*Water at Max. Density 39.2° F 4° C*	
							Pounds of Water	*Kilograms of Water*
Cu Inches	1	.0005787	.00002143	.016384	.004329	.0036065	.0361275	.0163872
Cu Feet	1728	1	.037037	28.317	7.48052	6.23210	62.4283	28.3170
Cu Yards	46,656	27	1	764.56	201.974	168.266	1685.56	764.559
Liters	61.0234	.0353145	.001308	1	.264170	.220083	2.20462	1
U.S. Gallons	231	.133681	.004951	3.78543	1	.833111	8.34545	3.78543
Imp. Gallons	277.274	.160459	.0059429	4.54374	1.20032	1	10.0172	4.54373
Lbs Water	27.6798	.0160184	.0005929	.453592	.119825	.0998281	1	.453593

APPENDIX

//// COMMON CONVERSION FACTORS

TO CONVERT	INTO	MULTIPLY BY
Atmospheres	cms of mercury	76.0
atmospheres	ft. of water (at 4°C)	33.90
atmospheres	in. of mercury (at 0°C)	29.92
atmospheres	kgs/sq cm	1.0333
atmospheres	kgs/sq meter	10,332
atmospheres	pounds/sq in.	14.70
Bar	newtons/sq m	105
bar	atmospheres	0.9869
bar	at (tech.)	1.0197
bar	psi	14.504
Barrels-Oil	gals-oil	42
BT Units	kg-calories	1.2520
BTUs	ft-lbs	777.9
BTUs	hp-hrs	3.927x10-4
BTUs	kgs-meters	107.5
BTUs	kw-hrs	2.928x10-4
BTU/Min	ft-lbs/sec	12.96
BTU/min	hp	0.02356
BTU/min	kw	0.01757
BTU/min	watts	17.57
Centimeters	inches	0.3937
cm	meters	0.01
cm	mm	10
Cms Mercury	atm	0.01316
cms mercury	ft water	0.4461
cms mercury	kgs/sq meter	136.0
cms mercury	lbs/sq ft	27.85
cms mercury	lbs/sq in	0.1934
Cms/Second	ft/min	1.969
cms/sec	ft/sec	0.03281
cms/sec	km/hr	0.036
cms/sec	meters/min	0.6
cms/sec	miles/hr	0.02237
cms/sec	miles/min	3.728x10-4
Cms/Sec/Sec	ft/sec/sec	0.03281
Cubic Cms	cu ft	3.531x10-5
cu cms	cu in	6.102x10-2
cu cms	cu meters	10-6
cu cms	cu yds	1.308x10-6
cu cms	gals	2.642x10-4
cu cms	liters	10-3
cu cms	pints (liq)	2.113x10-3
cu cms	quarts (liq)	1.057x10-3
Cubic Feet	cubic cms	2.832x104

TO CONVERT	INTO	MULTIPLY BY
cu ft	cu inches	1728
cu ft	cu meters	0.02832
cu ft	cu yds	0.03704
cu ft	gals	7.48052
cu ft	liters	28.32
cu ft	pints (liq)	59.84
cu ft	quarts (liq)	29.92
Cu Ft/Min	cu cms/sec	472.0
cu ft/min	gals/sec	0.1247
cu ft/min	liters/sec	0.4720
cu ft/min	lbs water/min	62.43
cu ft/min	gals/min	448.831
Cu Inches	cc	16.39
cu ins	cu ft	5.787x10-4
cu ins	cu meters	1.639x10-5
cu ins	cu yds	2.143x10-5
cu ins	gals	4.329x10-3
cu ins	liters	1.639x10-2
cu ins	pints (liq)	0.03463
cu ins	quarts (liq)	0.01732
Cu Meters	cc	104
cu M	cu ft	35.31
cu M	cu ins	61,023
cu M	cu yds	1.308
cu M	gals	264.2
cu M	liters	103
cu M	pints (liq)	2113
cu M	quarts (liq)	1057
Cu Yards	cu cms	7.646x105
cu yds	cu ft	27
cu yds	cu ins	46.656
cu yds	cu meters	0.7646
cu yds	gals	202.0
Decimeters	meters	0.1
Degs (Angle)	minutes	60
Degs (angle)	radians	0.01745
Degs (angle)	secs	3600
Degrees/Sec	radians/sec	0.01745
degs/sec	revs/min	0.1667
degs/sec	revs/sec	0.002778
Feet	cms	30.48
ft	ins	12
ft	meters	0.3048
ft	yds	1/3

//// COMMON CONVERSION FACTORS

TO CONVERT	INTO	MULTIPLY BY
Ft of Water	atms	0.02950
ft of w	ins mercury	0.8826
ft of w	kgs/sq cm	0.03048
ft of w	lbs/sq ft	62.32
ft of w	lbs/sq in	0.4328
Feet/Min	cms/sec	0.5080
ft/min	ft/sec	0.01667
ft/min	kms/hr	0.01829
ft/min	meters/min	0.3048
ft/min	miles/hr	0.01136
Ft/Sec/Sec	cms/sec/sec	30.48
ft/sec/sec	Meters/sec/sec	0.3048
Ft-Pounds	BTUs	1.286x10-3
ft lbs	hp-hrs	5.050x10-7
ft lbs	kg-calories	3.241x10-4
ft lbs	kg-meters	0.1383
ft lbs	kw-hrs	3.766x10-7
Ft-lbs/Min	BTUs/min	1.286x10-3
ft-lbs/min	ft-lbs/sec	0.01667
ft-lbs/min	hp	3.03x10-5
ft-lbs/min	kg-calories/min	3.241x10-4
ft-lbs/min	kws	2.260x10-5
Ft-Lbs/Sec	BTUs/min	7.717x10-2
ft-lbs/sec	hp	1.818x10-3
ft-lbs/sec	kg-calories/min	1.945x10-2
ft-lbs/sec	kws	1.356x10-3
Gallons	ccs	3785
gals	cu ft	0.1337
gals	cu ins	231
gals	cu meters	3.785x10-3
gals	liters	3.785
gals	pints (liq)	8
gals	quarts (liq)	4
Gallons, Imp	US gals	1.20095
gallons, US	imp gals	0.83267
Gals Water	lbs water	8.3304
Gallons/Min	cu ft/sec	2.228x10-3
gals/min	liters/sec	0.06308
gals/min	cu ft/hr	8.0208
Horse-Power	BTUs/min	42.44
hp	ft-lbs/min	33,000
hp	ft-lbs/sec	550
hp	hp (metric)	1.014
hp	kg-calories/min	10.70

TO CONVERT	INTO	MULTIPLY BY
hp	kws	0.7457
hp	watts	745.7
Hp-Hours	BTUs	2547
hp-hrs	ft-lbs	1.98x106
hp-hrs	kg-calories	641.7
hp-hrs	kg-meters	2.737x105
hp-hrs	kw-hrs	0.7457
Inches	cms	2.540
Inches	mms	25.4
Ins Mercury	atms	0.03342
ins mercury	ft water	1.133
ins mercury	kgs/sq cm	0.03453
ins mercury	lbs/sq ft	70.73
ins mercury	lbs/sq in	0.4912
Ins of Water	atms	0.002458
ins of w	ins mercury	0.07355
ins of w	kgs/sq cm	0.002540
ins of w	lbs/sq ft	5.202
ins of w	lbs/sq in	0.03613
Kilograms	dynes	980,665
kgs	lbs	2.205
kgs	tons (short)	1.102x10-3
kgs	grams	1000
Kgs/Sq Cm	atms	0.9678
kgs/sq cm	ft water	32.81
kgs/sq cm	ins mercury	28.96
kgs/sq cm	lbs/sq ft	2048
kgs/sq cm	lbs/sq in	14.22
Kilometers	cms	105
kms	ft	3281
kms	meters	103
kms	miles	0.6214
Kms/Hr	cms/sec	27.78
kms/hr	ft/min	54.68
kms/hr	ft/sec	0.9113
kms/hr	meters/min	16.67
kms/hr	miles/hr	0.6214
Kms/Hr/Sec	cms/sec/sec	27.78
kms/hr/sec	ft/sec/sec	0.9113
kms/hr/sec	Meters/sec/sec	0.2778
Kilowatts	BTUs/min	56.92
kws	ft-lbs/min	4.425x104
kws	ft-lbs/sec	737.6
kws	hp	1.341

//// COMMON CONVERSION FACTORS

TO CONVERT	INTO	MULTIPLY BY
kws	kg-calories/min	14.34
kws	watts	103
Kilowatt-Hrs	BTUs	3415
kw-hrs	ft-lbs	2.655x106
kw-hrs	hp-hours	1.341
kw-hrs	kg-calories	860.5
kw-hrs	kg-meters	3.67x105
Liters	ccs	103
liters	cu ft	0.03531
liters	cu ins	61.02
liters	cu meters	10-2
liters	gals	0.2642
liters	quarts (liq)	1.057
Liters/Min	gals/sec	4.403x10-3
Meters	cms	100
meters	ft	3.281
meters	ins	39.37
meters	kms	10-3
meters	mms	103
Meters/Min	cms/sec	1.667
meters/min	ft/min	3.281
meters/min	ft/sec	0.05468
meters/min	kms/hr	0.06
meters/min	miles/hr	0.03728
Meters/Sec	ft/min	196.8
meters/sec	ft/sec	3.281
meters/sec	kms/hr	3.6
meters/sec	kms/min	0.06
meters/sec	miles/hr	2.237
meters/sec	miles/min	0.03728
Microns	meters	10-6
microns	in	39x10-6
Miles/Hr	cms/sec	44.70
miles/hr	ft/min	88
miles/hr	ft/sec	1.467
miles/hr	kms/hr	1.609
miles/hr	meters/min	26.82
Millimeters	cms	0.1
mms	ins	0.03937
Minutes (Angle)	radians	2.909x10-4
Newton	kgs	0.1020

TO CONVERT	INTO	MULTIPLY BY
Ounces	lbs	0.0625
ozs	gram	28.349527
Ozs (Fluid)	cu in	1.805
ozs (fluid)	liters	0.02957
Pounds	ozs	16
lbs	kgs	0.4536
lbs	tons (short)	0.0005
lbs	newtons (N)	4.44
lbs	gram	453.5924
Pounds/Inch	newton-meters	0.1113
Pounds/Foot	newton-mters	1.356
Lbs of Water	cu ft	0.01605
lbs of water	cu in	27.73
lbs of water	gals	0.1204
Lbs of Water/Min	cu ft/sec	2.679x10-4
Pounds/Cu Ft	lbs/cu in	5.787x10-4
Pounds/Cu In	lbs/cu ft	1728
Pounds/Sq In	atms	0.06804
lbs/sq in	ft water	2.311
lbs/sq in	in mercury	2.036
lbs/sq in	kgs/sq cm	0.07031
Radians	degrees	57.29578
Tons (Long)	kgs	1016
tons (long)	lbs	2240
tons (long)	tons (short)	1.12000
Tons (Short)	kgs	2000
tons (short)	kps	907.18486
tons (short)	tons (long)	0.89287
tons (short)	tons (metric)	0.90718
Watts	BTUs/min	0.05692
watts	ft-lbs/min	44.26
watts	ft-lbs/sec	0.7376
watts	hp	1.341x10-3
watts	kg-calories/min	0.01434
watts	kws	10-3
Watt/Hours	BTUs	3.415
watt-hrs	ft-lbs	2655
watt-hrs	hp-hrs	1.341x10-3
watt-hrs	kg-calories	0.8605
watt-hrs	kg-meters	367.1
watt-hrs	kw-hrs	10-3

//// COMMODITY & MATERIAL WEIGHTS

Approximate Weights of Materials

MATERIAL	LBS. / CU. YD.	TONS / CU. YD.
Andesite stone	4,887	2.44
Ashes	1,080	0.52
Asphalt	2,700	1.35
Asphaltum	2,349	1.17
Basalt rock	4,887	2.44
Brick, soft clay	2,718	1.35
Brick, hard clay	3,397	1.69
Brick, pressed	3,806	1.90
Brick, paving	4,246	2.12
Block, paving	3,694	1.84
Bluestone	2,970	1.48
Cement, natural	1,512	0.75
Cement, Portland	2,430	1.21
Cement, Portland, set	4,941	2.47
Cement, Rosendale	1,863	0.93
Cinders	1,080	0.54
Clay, dry	1,701	0.85
Clay, wet	2,970	1.48
Clay & gravel, dry	2,700	1.35
Coal, anthracite	1,536	0.76
Coal, bituminous	1,275	0.64
Coke	837	0.42
Concrete, cinders	2,970	1.48
Concrete, gravel	4,104	2.05
Concrete, limestone	4,050	2.02
Concrete, sandstone	3,915	1.95
Concrete, trap rock	4,185	2.09
Crushed stone	2,700	1.35
Earth, dry, loose	1,890	0.94
Earth, damp, loose	2,106	1.05
Earth, damp, packed	2,592	1.29
Earth & gravel, dry	2,700	1.35
Earth & gravel, wet	3,240	1.62
Earth & sand, dry	2,709	1.35

MATERIAL	LBS. / CU. YD.	TONS / CU. YD.
Earth & sand, wet	3,240	1.62
Fire Brick	3,915	1.95
Fire Clay	3,510	1.75
Garbage	1,150	0.57
Gravel, dry	2,970	1.48
Gravel, out of water	1,620	0.81
Granite	4,536	2.26
Lime, quick, loose	1,431	0.71
Lime, quick, shaken	1,485	0.70
Limestone, solid	4,536	2.26
Limestone, loose	2,592	1.29
Marble, solid	4,455	2.22
Marble, loose	2,592	1.29
Mortar, set	2,781	1.39
Mud, dry	2,430	1.21
Mud, packed	3,105	1.55
Mud, wet	2,916	1.45
Pitch	1,863	0.93
Plaster of Paris	2,646	1.32
Powder, blasting	1,682	0.84
Quartz	4,374	2.18
Rubbish	199.8	0.09
Sand, dry, loose	2,619	1.30
Sand, wet	3,186	1.59
Sandstone	4,023	2.01
Slag, blank	1,890	0.94
Slag, screenings	2,700	1.35
Slag, machine	2,592	1.29
Slag, sand	1,485	0.74
Shale	4,374	2.18
Slate	4,725	2.31
Tar	1,674	0.83
Tile	2,970	1.43
Trap stone	5,849	2.52

STEEL & ALUMINUM GAUGE, THICKNESS AND WEIGHT

GAUGE	THICKNESS (INCHES)	WEIGHT (LBS./FT2)
Steel		
3/8"	0.375	15.320
1/4" (approx. 3 Ga.)	0.250	10.200
3/16" (approx. 7 Ga.)	0.188	7.650
8 Ga.	0.164	6.875
9 Ga.	0.149	6.250
10 Ga.	0.134	5.625
11 Ga.	0.120	5.000
12 Ga.	0.105	4.375
13 Ga.	0.090	3.750
14 Ga.	0.075	3.125
Aluminum		
3/8"	0.375	5.18
1/4"	0.250	3.53
3/16"	0.188	2.65
5/32"	0.156	2.25

APPENDIX

//// NOTES

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