Related Formulas

MASS FLOW RATE = VOL FLOW RATE x DENSITY

CENTIPOSE = CENTISTOKES x SPECIFIC GRAVITY

SCFM = FACE AREA (ft^2) x FACE VELOCITY (sfpm)

$$\text{PRESSURE (psi)} = \frac{\text{FORCE (pounds)}}{\text{AREA (in}^2\text{)}}$$

$$\text{VOL FLOW RATE(gpm)} = \frac{\text{VOLUME (gallons)}}{\text{TIME (minutes)}}$$

$$\text{INPUT POWER (hp)} = \frac{\text{PRESSURE (psig) x FLOW (gpm)}}{1714}$$

$$\text{VEL THROUGH PIPING (ft/s)} = \frac{\text{0.3208 x FLOW RATE (gpm)}}{\text{INTERNAL AREA (in}^2\text{)}}$$

$$\text{COMPRESSIBILITY OF OIL} = \frac{\text{PRESSURE (psig) x VOL OF OIL UNDER PRESSURE}}{\text{250,000 (approx)}}$$

In additional required oil to reach pressure

$$\text{COMPRESSIBILITY OF A FLUID} = \frac{1}{\text{BULK MODULUS OF THE FLUID}}$$

$$\text{SPECIFIC GRAVITY OF A FLUID} = \frac{\text{WT OF ONE CUBIC FT OF FLUID}}{\text{WT OF ONE CUBIC FT OF WATER}}$$

$$\text{PUMP OUTLET FLOW (gpm)} = \frac{\text{RPM x PUMP DISPLACEMENT (in}^2\text{/rev)}}{231}$$

$$\text{PUMP INPUT POWER (hp)} = \frac{\text{FLOW RATE OUTPUT (gpm) x PRESSURE (psig)}}{\text{1714 x OVERALL EFFICIENCY}}$$

$$\text{OVERALL PUMP EFFICIENCY (\%)} = \frac{\text{OUTPUT HORSEPOWER x 100}}{\text{INPUT HORSEPOWER}}$$

OVERALL PUMP EFFICIENCY (%) = VOL EFF. X MECHANICAL EFF.

$$\text{VOL PUMP EFFICIENCY (\%)} = \frac{\text{ACTUAL FLOW RATE OUTPUT (gpm) x 100}}{\text{THEORETICAL FLOW RATE OUTPUT (gpm)}}$$

$$\text{MECHANICAL PUMP EFFICIENCY (\%)} = \frac{\text{THEORETICAL TORQUE TO DRIVE x 100}}{\text{ACTUAL TORQUE TO DRIVE}}$$

$$\text{PUMP DISPLACEMENT (in}^3\text{/rev)} = \frac{\text{FLOW RATE (gpm) x 231}}{\text{PUMP RPM}}$$

$$\text{PUMP TORQUE (inlbs)} = \frac{\text{HORSEPOWER x 63025}}{\text{RPM}}$$

$$\text{PUMP TORQUE (inlbs)} = \frac{\text{PRESSURE (psig) x PUMP DISPLACEMENT (in}^3\text{/rev)}}{2\pi}$$

RESERVOIR COOLING CAPACITY (BTU/hr) = 2 x ΔT BETWEEN RESERVOIR WALLS AND AIR (°F) x RESERVOIR AREA (ft^2)

HEAT IN HYDRAULIC SYSTEM DUE TO UNUSED FLOW/PRESSURE (btu/hr) = FLOW RATE(gpm) x 1.485 x PRESSURE DROP (psig)

Heat Transfer in Fluids

General

Most fluid power systems require a method of heat transfer (dissipation or absorption).

Producing Heat

Whenever burning fuel or energy expended by the sun produces energy, the results of energy production are work and loss. The energy loss is caused by inefficiencies of the energy process. This energy loss is either released into the atmosphere or transferred to other objects such as a fluid or a reservoir. Some of these losses contribute to the fluid heating (i.e. a fluid pump submerged in the reservoir). Heat is also produced by passing pressurized fluid through orifices, valves, and piping where a pressure drop occurs. Servo drive systems are not possible for this since large pressure drops are used for control. Keeping these pressure drops to a minimum conserves performance and costs. The following table shows the types of systems that will have losses to the fluid and/or the reservoir:

System	% Loss
Simple circuits with minimal valves	25%
Simple circuits with cylinders	28%
Simple circuits with fluid motors	31%
Hydrostatic transmissions	35-40%
Servo based systems	55%
Low pressure fluid transfer systems	15%

These losses are expressed in terms of Horsepower, British Thermal Units (BTU's) or Kilowatts. Heat problems are usually expressed Horsepower in terms of the work expanded and losses absorbed. Cooling problems are usually expressed in BTU/hr and heating problems are expressed in Kilowatts.

Heat Dissipation from Reservoir Walls

When a fluid is heated by the loss of the system the walls of the reservoir will start to absorb heat. This heat will move outward to the outside walls if the air temperature is less than the fluid. If the fluid temperature is less, heat will pass through the wall and heat the fluid.

The general rate at which heat passes is dependent on the wall material, the amount of circulating air temperature difference between the air and the fluid, and fluid type. The general equation for this is:

$$\text{BTU/hr} = 2 \text{ x } \Delta\text{T x reservoir area (ft}^2\text{)}$$

Reservoir Design

Background

Most fluid power systems have a reservoir to store the system fluid. It also includes the following:

- Heat dissipation
- Heat absorption
- Accessory mounting

Design

The available space as well as the strength of the structure must be determined first. The reservoir must be able to withstand any internal pressure developed during operation. The structure must also be able to withstand the weight of not only the system fluid, but mounted accessory components as well. These components include the fluid pump and the driver. Once all the weight is accounted, a structural analysis should be done in order to find structural minimums. These minimums include wall sizes and base structure.

Size

The reservoir needs to be large enough to hold all of the fluid of the system. This includes the amount to fill reserve and piping in order to keep the intake lines submerged. It must also include the amount for the differential volume of fluid that occurs when accumulators or cylinders are filled during operation.

Dissipate Heat

Inefficiencies in a fluid power system will heat the reservoir fluid as it re-circulates. Some of the heat will be dissipated through the reservoir walls through radiation and convection. In order to obtain maximum heat rejection:

- Locate the reservoir near air circulation
- Select a material with coefficient of heat transfer
- Use a light color for the reservoir exterior
- Include cooling fins on the exterior
- Select a location where the ambient temperature is less than the operating temperature
- Keep reservoir from direct sunlight

Mounting Accessories

The reservoir surface is an excellent place to mount several fluid conditioning devices. Some of these include:

- Fluid level gauge
- Oil sample port
- Drain valve
- Temperature gauge
- Fluid cooler/heater
- Breather filler cap with fine filter

Heat Absorption

In some cases, heat must be added to create the proper initial conditions. The most common way to do this is to install a thermostat-controlled electric heater. These heaters need to match the heated fluid to prevent oxidation. Heaters with a 18-20 watt per square inch capacity is most common for hydro carbon-based fluids. In some conditions it may be necessary to insulate the reservoir walls. When installing this heater, make sure it is in a spot that will maximize heat input and circulation

**The information above was taken from the* FLUID POWER DESIGNERS LIGHTING® REFERENCE HANDBOOK *Eight edition.*

General Motor Information

NEMA Voltage Standards

NEMA Motor Nameplate Voltage	Satisfactory Operating Voltage Range (at rated frequency)	Nominal System Voltage
200	180-220	208
230	207-253	240
460	414-506	480
575	518-633	600

Motor Windings for 60 hz Power Systems

General Location	Nominal Power System Voltages	Motor Winding Specifications
US city commercial areas	208/3/60	200/400/3/60
US, parts of Canada, most of Mexico, parts of South America	220/40/3/60 230/460/3/60 240/480/3/60	230/460/3/60
Southeast & northeast US, parts of Canada	550/3/60 575/3/60 600/3/60	575/3/60

- 230/460 or 230 volt motors should not be used on 208 volt systems unless it is within the limits of motor nameplate specs.
- Motors can be wound for other 60hz hertz power suppliers.
- Dual voltage motors should be used for dual voltage power systems. This ensures the best possible adaptability to various starting methods.

Motor Windings for 50 hz Power Systems

General Location	Nominal Power System Voltages	Motor Winding Specifications
British commonwealth nations	230/400/3/60 240/415/3/50	230/400/3/50 240/415/3/50
Continental Europe, some east Mediterranean, some African countries some South American countries	220/380/3/50	220/380/3/50
Japan	200/400/3/50	200/400/3/50
Various countries	550/3/50	550/3/50

NEMA standards state that motors will successfully operate at the rate load under the following:

- A ± 10% variation or rated voltage at rated frequency. This will be within the standard voltage range, however this variation of voltage will alter the performance from the rated voltage.
- A ± 5% variation of rated frequency at rated voltage.
- Provided the frequency variant does not exceed ± 5%, a combined variation of ± 10% of voltage and frequency (absolute values).

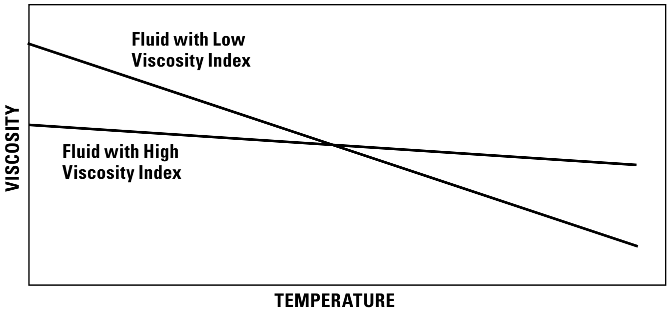
Effects of Voltage Unbalance

Unbalanced currents will flow in the stator windings when the line voltages are not constant on all phases. This could lead to a higher winding temperature, thus potentially damaging the motor. Use a voltmeter to balance the voltages as much as possible. If there is an unbalance, notify the power company so it can be corrected. An example of this is if there is an unbalance of 3.5%, the winding temperature could increase as much as 25%.

Operating Temperature Range of Common Fluids

Fluid Temperature Range	Oil Grade
5W, 5W-20, 5W-30	-10°F to +130°F / -23°C to +54°C
10W	0°F to 180°F / -18°C to +83°C
10W-30 10W-40	0°F to 210°F / -18°C to +99°C
ISO VG 22	-5°F to +140°F / -21°C to +60°C
ISO VG 32	+5°F to +170°F / -15°C to +77°C
ISO VG 46	+15°F to +190°F / -9°C to +88°C
ISO VG 68	+30°F to +210°F / -1°C to +99°C

High and Low Viscosity Index



Oil Properties Example

COMPANY NAME	CATEGORY	BRAND NAME	GRADE/ CALLOUT	POUR POINT °F	FLASH POINT °F	SUS AT 100°F	SUS AT 210°F	ISO VG GRADIENT	VISC INDEX	SPECIFIC GRAVITY
MOBILE OIL CORP.	PREMIUM HYDRAULIC OIL	MOBIL DTE 10 SERIES	11	-50	329	90	40	22	155	0.864
			13	-50	329	150	46	32	150	0.876
			15	-50	329	205	50	46	150	0.878
			16	-50	329	300	60	68	120	0.881
			18	-40	329	480	69	100	120	0.884
			19	-40	329	765	89	150	120	0.891
	GENERAL HYDRAULIC OIL PURPOSE FOR GEARS, BEARINGS, & CIRCULATION	VACTRA NAMED	LIGHT	10	350	150/165	43	32	90	0.8708
			MEDIUM	10	375	215/240	48	46	95	0.8762
			MED HEAVY	10	400	315/355	54	68	95	0.8816
			HEAVY	10	410	470/520	65	100	90	0.8871
			XTRA HEAVY	15	420	710/790	76	150	92	0.8899
			BB	15	440	1000/1165	92	220	95	0.8927
			AA	20	450	1530/1705	114	320	95	0.8986
			HH	25	460	2215/2460	148	460	95	0.9013
	HYDROSTATIC DRIVE FLUID	MOBIL FLUID	350	-40	370	195	52	32/46	163	0.887
			423	-50	395	267	56	46/68	160	0.8927
	AUTOMATIC TRANS. FLUID	ATF (TYPE F) DEXTRON II	210	-50	350	185	52	32/46	180	0.868
			220	-50	320	187	50	32/46	159	0.867
	CIRCULATING OIL	DTE NAMED SERIES	LIGHT	20	395	150/165	44	32	100	0.871
			MEDIUM	20	400	215/240	48	46	100	0.876
			MED HEAVY	20	400	315/355	55	68	100	0.879
			HEAVY	20	410	410/440	60	68/100	100	0.882
			XTRA HEAVY	25	420	710/790	76	150	95	0.887
			BB	25	440	1045/1165	93	220	95	0.89
			AA	25	460	1530/1700	110	320	95	0.897
			HH	25	520	2215/2460	138	460	95	0.9
	COMPRESSOR LUBE OIL	DTE	103	-5	390	575	58	100/150	-	0.922
			105	15	435	1400	84	320	-	0.919
			107	25	450	2300	113	460	-	0.916
	STEAM CYLINDER WORM GEAR	CYLINDER OIL	600W	40	540	2000	142	320/460	99	0.9013
			600W SUPER	40	540	2500	155	460	95	0.899
			EXTRA HECLA	40	565	3650	198	680	95	0.9056
			MINERAL	40	590	4500	230	680/1000	95	0.9042
	ROCK DRILL OIL	ALMO 500 SERIES	525	-10	370	215/245	46	46	90	0.8888
			527	-20	390	535/565	100	100	85	0.8944
			529	-10	400	750/800	150	150	90	0.8967
			532	0	450	1450/1600	320/460	320/460	90	0.8967