FLUID POWER Design Data Sheet

Revised Sheet 33 – Womack Design Data File

3-PHASE, INDUCTION-TYPE, ELECTRIC MOTORS FOR PUMP DRIVE

Design Data Sheet 3 shows how to determine motor HP required to drive a hydraulic pump rated for (so many) GPM at a certain PSI level. Additional information in the present issue covers other important areas which may affect the selection of the best motor type for a specific job.

Motor housings, fusing, thermal overload protection, and motor starters will be covered in a later issue.

The motor type used on most hydraulic pump drives is the 3-phase, squirrel cage, induction motor, of integral HP in the range of 1 to 500 HP. Information in this issue applies only to this type and may not be applicable to other types.

3-Phase Squirrel Cage Induction Motor

This type motor has a rotor made up of iron laminations but does not have a winding on the rotor; therefore, it has no brushes, commutator, or slip rings. All windings are on the stator which is also constructed of iron laminations with various numbers of north and south poles (in pairs). The motor runs at a constant speed determined by the line frequency (Hertz) and by the number of pairs of magnetic poles which it has. Except for a small amount of speed slip at full load condition, it will not run at slower speeds with out severely overheating.

Design B Motor Speeds - Synchronous and Full Load

No. of Pairs of Poles	Synchr. RPM @ 60 Hz	Full Load RPM @ 60 Hz	Synchr. RPM @ 50 Hz	Full Load RPM @ 50 Hz
1	3,600	3,490	3,000	2,900
2	1,800	1,745	1,500	1,450
3	1,200	1,160	1,000	970
4	900	875	750	725

Full load RPM in the chart has been calculated on a drop in speed (slip) of about 3% from the theoretical or synchronous speed.

Current and Voltage Characteristics

Motor Current. Torque is produced by current flow; the higher the current the greater the torque output. Current is also responsible for temperature rise in the windings. Any operating condition such as low voltage, wrong frequency, or torque overload, which causes current in excess of nameplate rating to flow, will cause an abnormal temperature rise.

Design B motors (most often used on pump drives) can start under full load, but if they must be started frequently, the pump should be unloaded until the motor starts, to prevent high starting current from overheating the motor.

Effects of Low Voltage. Nameplate HP rating is based on full voltage being available. HP output is a combination of voltage times current. If the voltage is too low, then to produce rated HP the current becomes too high, and this causes an abnormal temperature rise. Motors can usually accommodate as low as 90% of rated voltage, and although there will be an abnormal temperature rise, it will not be great enough to damage insulation. For permanent operation on a voltage source known to be low, the HP rating should be reduced by the same percentage that the voltage is low.

Example: A 25-HP, 220 volt meter on a 208-volt line has only 94½% of its rated voltage. Therefore, it should be de-rated to 0.945 × 25 = 23.6 HP (plus service factor if applicable).

Effects of High Voltage. If the motor is not loaded beyond nameplate HP, the full load current will be lower than rating and the motor will run cooler than its rating. However, its starting current and breakdown current (at stall) will be higher than normal. The wiring, fusing, and thermal overload protection will have to be sized accordingly. Also, the motor noise will greatly increase, and may be objectionable.

Voltage Test. On installations where the motor s running at or very near full HP, an unbalance of as little as 3½% between the highest phase voltage and the average of all three voltages may result in a temperature rise of about 25% above the normal rated rise, causing damage to the insulation.

If the voltage, at full load, is unbalanced between phases, either the motor is defective or the power line is unbalanced. To determine where the fault lies, first measure the voltage of all phases. Then, advance all power lines by one phase and repeat the measurements. If the higher voltage advances with the re-connection, the power line is unbalanced. Corrective measures may be taken as follows:

Check for voltage unbalance of each phase where the power line enters the building. If unbalanced more than 3½% at that point, call the utility company for an inspection and corrective measures.

With the motor running at full load, compare the voltage of each phase at the motor with voltage readings taken at the power line entrance. If the voltage loss in any phase is more than 3% check for high resistance in wiring, connections, fuses, circuit breaker, or disconnect switch.

Operating Voltage Range

Nameplate Voltage	Operating Voltage Range*	Available Horsepower Range
115	104 to 126	1 to 15
200	180 to 220	1 to 500
230	207 to 253	1 to 500
230/460	207 to 253	143T-445T
	414 to 506	143T-445T
460	414 to 506	1 to 500
575	518 to 632	1 to 500
2,300	2070-2530	444T & Up

This table shows nominal voltage for which polyphase motors are usually made, and the maximum voltage range over which they can be operated (10% variation from nominal rating).

*Over-voltage (at higher noise) can be tolerated better than under-voltage provided current is limited to nameplate rating.

NEMA Designs

The motor magnetic structure and- windings are designed to obtain certain desired characteristics of torque and speed. Four NEMA designs are available as follows:

Design B. This type is the most often used for hydraulic pump drives but does have some limitations: Starting torque required by the load should not exceed 50% of the motor rated torque; the load reaction should have little or no torque pulsation; load inertia should be no greater than the inertia of the motor rotor; the motor should work against a fairly steady load with infrequent starting and stopping.

Design D. This design may be preferred if starting torque is greater than 50% of rated motor torque. Also, when there may be severe and frequent changes in the torque load.

There are several variations of Design D motors, but all of them have a slip in speed of more than 5% (as compared with less than 3% on a Design B motor). Those having a 5 to 8% slip are reasonably obtainable, but those having a higher slip, up to 13%, should be considered as special order items and may require extended delivery time.

Design D motors are sometimes used to “peak out” a hydraulic pump at a pressure which would severely overload and damage a Design B motor. The slip in speed under full load or overload reduces the input HP and the line current.

Designs A, C, and E. These are seldom used for pump drives. They are capable of starting full torque loads, but line current may be extremely high, requiring special and expensive starting equipment.

Effects of Incorrect Frequency

Most hydraulic systems are operated from a utility-company power line on which the frequency is closely controlled. Where operation is from a small, isolated power source, the frequency must be accurate to within 5% of the motor rating to obtain full motor performance.

If a 60 Hz motor is to be operated from a 50 Hz power source, or vice versa, significant sacrifices must be made in motor performance as shown in this chart:

	60 Hz Motor on 50 Hz Line	50 Hz Motor on 60 Hz Line
HP will be:	16-2/3 less	20% more
Adjust voltage to:*	16-2/3 less	20% more
Full load torque	Same	Same
Breakdown torque	Same	Same
Locked rotor torque	Same	Same
Locked rotor current	5% less	6% more
Speed, RPM	16-2/3 less	20% more
Max. service factor	1.00	1.00
Noise level	Less	More

*Voltage adjustment is to maintain current at rated value, to produce rated shaft torque. Motor current is always a limiting factor on a variation in rated frequency or voltage.

Motor Starting

Any 3-phase induction motor can be switched directly across full line voltage for starting but this produces a very high current surge in the line. Utility companies have regulations which limit the current surge and voltage fluctuation which can be imposed on the power line during motor starting. Usually, motors of 50 or more HP must be started at reduced voltage to limit the current transient. Several types of reduced voltage starters are available.

In addition to the current surge produced when a motor is connected directly across the line, the starting shock may be too severe for some types of loads, and reduced voltage starting may be necessary even on small motors.

Service Factor

The published service factor (usually 1.15 × nameplate HP on continuous duty for motors up to 200 HP) may be used, but only if operating on the correct frequency and on no more than 3% above or below rated voltage, and if operating under all normal environmental conditions as follows:

a. In an ambient temperature no higher than 40°C, nor colder than 0°C.

b. At an altitude no higher than 3,300 feet, nor lower than sea level, nor in a pressurized or evacuated space which results in pressures outside those limits.

c. Installed properly on a rigid base, in a location which provides free and unrestricted circulation of clean, dry, cooling air, and where it can be periodically inspected for lubrication, and given proper maintenance care.

Operation of a motor under conditions causing a higher than rated temperature rise in the windings may shorten the life of the insulation by one-half for a 10°C extra rise.

Safety

In addition to the usual precautions against electric shock the motor frame should be earth grounded. If ground is not carried in with the power wiring a separate ground wire, connected to the motor frame should be run to an outside ground rod. It is not good practice to ground to a water or gas pipe.

Guards should be placed over rotating parts such as couplings, sheaves, or gears connected to the motor shaft, to prevent clothing of personnel from entanglement.

Overloading

A motor may be overloaded for short periods. Data Sheet No. 3 suggests limits for overloading. Excessive line current, far out of proportion to the increase in HP output flows during overloads. For example, a Design B motor overloaded to 150% rated HP may draw about 4 times its normal full load current.

Troubleshooting

Overheating. It is the current through the windings which causes a temperature rise. Motor will not overheat even if run on abnormally high or low voltage or on an incorrect frequency if current is kept to the maximum shown on the nameplate. This means that if voltage and frequency are not within specified limits, the HP load must be reduced as much as necessary to limit the current to nameplate value.

Motor may overheat from being started too frequently, or from being “plugged” for quick stop or reversal.

Winding Burn-out: Insulation breaks down prematurely under conditions of voltage, frequency, or load which cause an abnormally high temperature rise in the windings.

Mechanical. Motors with sleeve or roller bearings must be mounted with shaft within 5 to 10 degrees of horizontal. Motors with shaft vertical must have ball bearings. Unusually heavy side loads, especially when using small diameter gears or sheaves, will reduce bearing life. Motors carrying heavy side loads should have roller bearings.

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