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TECHNICAL INFORMATION

Bulletin

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SUBMERSIBLE MOTOR PUMPS VS LINESHAFT TURBINES For Deep-Well Service

Although many thousands of vertical pumps are used in the United States, only a small percentage of these pumps are driven by submersible motors. Peerless Pump, having served the deep-well turbine pump market for many years, makes both types of equipment. The submersible motor pump has advantages but these advantages are realized mostly in heavily congested metropolitan areas. A submersible motor pump is generally silent when operating except for the hum of controllers and transformers. Naturally this feature is of prime importance when a pump unit is installed in a residential area.

A submersible motor pump also has greater aesthetic qualities because most of the operating components are below the surface of the ground. Again, this feature is of prime importance in a residential area of a city. In some cases the submersible motor pump will have a lower first cost.

The problems common to all submersible pumps overcome these advantages when the unit is applied in an agricultural area. These disadvantages apply to both the pump and motor. Let's consider each of these components separately where possible.

SUBMERSIBLE MOTORS

A submersible motor must operate submerged

in a fluid which is a very good conductor. Naturally water presents a great many more problems than air as an operating environment. Insulating materials can become extremely critical. In addition, the water pumped from a deep well may contain some abrasive materials. These abrasive materials must be excluded from the operating fluid in the motor or they drastically reduce the life of the bearings which must be maintained at relatively close tolerances to prevent engagement of the rotor with the stator and resultant failure. Some submersible motors utilize a dielectric oil to provide improved insulating and lubrication qualities within the motor. Again, it is necessary to use a mechanical type seal to prevent loss of this oil. In addition the oil pressure inside the motor must exceed the water pressure outside the motor to prevent entry of water into the motor and subsequent failure. This necessitates an equalizing chamber within the motor in conjunction with an oil reservoir. Again, this type of design is highly dependent upon proper operation of the mechanical seal in an abrasive fluid. All mechanical seals have a small amount of leakage to lubricate the sealing faces. Thus the operating life of the motor is determined by the magnitude of this leakage. The rotating seal face can actually act as a pump when bearing tolerances within the motor or misalignment within the motor induces radial run-out of the rotating seal ring.

All submersible motors larger than 10 hp utilize a Kingsbury type thrust bearing to carry the downthrust of the pump unit. This type of bearing must be used because the diameter of the motor is limited by the well size and a Kingsbury or tilting-shoe type bearing gives the maximum amount of thrust capacity in a limited diameter. A Kingsbury type bearing is dependent upon a thin film of fluid between the shoes and the thrust plate to support the rotating parts of the motor and to carry the total thrust load exerted by the pump. Once this film is broken by excessive loads, although they may be of very short duration, the bearing can be severely damaged. This is not true of a ball type bearing as used in a standard vertical motor which will withstand extremely heavy overloads for a short duration with a small reduction in total expected life. Submersible motors which utilize water as a lubricating medium in the motor are more critical than those filled with oil when considering these momentary overloads.

It should be noted that all vertical turbine type centrifugal pumps are subject to axial forces which act in a direction parallel to the shaft. These forces are referred to as hydraulic thrust loads and must be taken by the thrust bearings in the driver. The hydraulic thrust load can be either up or down in direction.

The maximum down-thrust loading in a vertical turbine pump occurs at shut-off or zero capacity. This load may be twice the normal operating thrust load. Although this load may be momentary or of short duration, a submersible motor must have a thrust bearing, which is designed to take this load continuously. In addition, the thrust bearing should have excess capacity sufficient to take any additional shock loads which may occur if there are check valves in the system.

In addition, a lightning arrester should be utilized to protect against high voltage surges in the power system. It is not necessary that power lines be struck by lightning in order to collect these high voltage surges; in fact, if a direct strike is sustained, damage will usually result to the power lines or the electrical equipment connected to the power lines regardless of protective equipment provided. Fortunately, direct strikes are very rare, while undue surges are frequent. These voltage

surges can be protected against through the use of properly selected and applied lightning arresters. A high voltage surge can puncture a very small hole in the motor insulation. All pump motors are susceptible to this hazard. However, it should be kept in mind that the cost of a failure in a submersible motor can be a great deal more than the same failure in a line shaft vertical pump. A submersible must be pulled if for any reason the motor becomes inoperative. In addition, normal motor facilities are not capable of rewinding or in most cases repairing a submersible motor. The degree of technical competence required to perform service on submersibles is a great deal more than that required to service a standard motor, and is frequently not available.

POWER CABLE

When installing a submersible motor driven pump extreme care must be taken not to damage the power cable. A ragged edge in the well casing can cut the cable as it is being installed and cause a short circuit. Water has been known to travel hundreds of feet up and down the cable due to capillary action in the fibers so that the final failure does not always occur at the source of the damage.

The splicing of the power cable to the motor leads is another area where extreme precaution must be taken. Lack of technique in making this splice can result in costly pulling and reinstallation. In some instances the splice between the motor leads and the power cable must be continuously submerged as it requires the cooling of the well water to prevent premature insulation breakdown.

PUMP UNIT

Submersible pumps are universally designed so that the motor is placed below the pump bowls and the pump shaft is in compression rather than in tension as in a conventional lineshaft deepwell turbine pump. When the water lubricated sleeve bearings in the pump bowl units wear, the shaft in compression loses its support and starts to whip, thus reducing the pump life. If the bowl unit is not repaired soon enough, it may ruin the submersible motor. It is always difficult to determine from surface indications that this wear is taking place. However, the loss of an expensive component such as the motor can occur when wear takes place in the bowl unit.

It is important that all submersible pumps be installed in carefully developed wells since the lateral of the pump must be adjusted prior to installation and there is a danger of sand locking if the pump is turned off while an excessive amount of sand is being pumped. If sand locking of the pump unit occurs in a submersible motor driven unit, because of improper original development of the well or because of any abnormal change in the sand structure, it is necessary to pull the pump and motor, free the impellers and clean out the sand from above the motor, sand pump the well and then reinstall the pump and motor. A vertical lineshaft turbine pump can normally be freed if it sand locks by raising and lowering the impellers from the surface. By operating the pump initially well off the bottom seal, sand locking can usually be avoided in a lineshaft turbine pump.

Where any appreciable abrasives are pumped, an increase in initial close running clearances between the impellers and the bowls of an open or enclosed impeller furnished with submersible pumps results in a loss of capacity and efficiency. Lineshaft turbine pumps can be readjusted to recover most of this loss. On a submersible motor pump, it is necessary to pull the pump and motor, readjust the relationship of the impellers to the bowl unit and reinstall the pump and motor.

There is always danger that the motor will be buried in sand if the submersible unit is installed near the bottom of a well. The submersible motor is dependent upon the flow of water past the motor for cooling purposes and when sand builds up around the motor the heat cannot be dissipated and results in motor failure.

It is quite common for competitors to replace bowl units, add column extension and in general service each others pumps at the customer's discretion when the pump unit is a vertical lineshaft type. A manufacturer of submerged motor type deepwell pump units has the customer at his mercy, as it is not possible for other manufacturers to service either the pump or motor satisfactorily. This represents quite an advantage to the submerged motor manufacturer, as he is virtually assured of the repair business on any equipment he sells. However, it leaves the customer in a poor position to bargain and, even

though he may have personal differences with a given manufacturer, he has no choice but to continue with the original supplier.

Lineshaft vertical turbine pumps have a great deal more versatility than a submersible type unit. A lineshaft turbine pump can be driven by a vertical motor, an engine through a right angle gear drive, a horizontal motor through a right angle gear drive, by a flat belt pulley or a V-belt pulley connected to an engine.

A submersible motor driven pump must necessarily run at a constant speed. This speed will normally be 1760 RPM or 3450 RPM for 60 cycle current.

A vertical lineshaft pump can be driven by a variable speed engine which can meet a wide range of operating conditions. It is also possible to drive a lineshaft turbine pump with a constant speed horizontal motor through an increasing or decreasing ratio right angle gear drive to obtain any operating speed required to meet the specific application. Thus it is apparent that a lineshaft turbine pump can be driven from a variety of power sources such as electricity, diesel fuel, natural gas or gasoline.

A lineshaft turbine pump can be arranged for alternate drives in case of power failure. In the case of the submersible motor driven unit it is necessary to set up very costly motor generator sets to supplement the normal power supply, since an engine drive gear head combination cannot be utilized.

It can be generally stated that at capacities in excess of 125% of the design capacity of a vertical turbine, an upthrust condition can occur. In a lineshaft type vertical turbine this upthrust condition is counteracted by the weight of the shafting. Where the upthrust force exceeds the weight of the shafting the excess load is taken in a ball type bearing when the top drive coupling is bolted down. Normally this upthrust condition occurs when a pump is first started and the head conditions seen by the impellers is extremely low. Although this "starting up thrust" is normally momentary, it can be as much as 100 to 200% of the normal down thrust at design.

A submersible motor depends upon a plate type bearing to take this momentary upthrust. A plate type bearing is extremely limited in capacity and is seldom designed to carry the loads involved. Stopping and starting of the pumping equipment accentuates this problem in a submersible.

A continuous upthrust can be encountered where a vertical pump is operated at head conditions lower than originally anticipated. Continuous upthrust protection can be provided in a vertical line shaft type pump by locking down the top drive coupling which transmits this load to a ball bearing in the motor or gear drive. However, submersible motors are not designed to take a continuous upthrust load. There are numerous submersible failures due to operation at heads lower than the design conditions. In many cases it is difficult to avoid this upthrust problem because the standing water level in the well is normally higher than the pumping level thus inducing lowered head conditions on start-up and for a short duration after the pump is running. Where a well draws down to the pumping level over a period of hours, a serious prolonged upthrust condition can be encountered.

When a vertical pump is shut down it will normally rotate in reverse at a speed of 120% to 150% of the normal forward speed. When the pump is rotating in reverse it still develops a thrust which is proportional to the discharge pressure at any given point in time. Some submersible motor bearings are not capable of carrying these thrust loads when they are rotating in a reverse direction.

Due to the design of a submersible motor, which must necessarily be limited in diameter to meet well requirements, we find its electrical characteristics are significantly less desirable than a conventional vertical or horizontal motor of the proper design proportions. The efficiency of a submersible motor is less than that of a conventional type motor for the following reasons:

- a. The limitations due to well diameter result in a lower electrical efficiency.
- b. The disc friction caused by the rotor rotating in a fluid sealed chamber greatly exceeds the losses of a conventional rotor rotating in air.

- c. The cable losses in kilowatts are equivalent to the corresponding lineshaft losses in a standard type turbine pump.

The rotor and stator proportions of a submersible type motor are such that the power factor in most cases is found to be from 5% to 6% below the corresponding power factor of a standard motor of the same rating. It should be noted that the power factor governs what is termed the wattless power required to be transmitted over a line to produce a certain useful power. This means that the lower the power factor the more current must be transmitted for a given output of a motor. If the power factor of a submersible motor is 5% below that of a conventional type motor, the power source must provide to that motor 5% more power for a given output than would be necessary in the case of a higher power factor motor.

The following is a typical comparison of the electrical characteristics of a 100 HP, 1800 RPM, 440 volt submersible versus a standard vertical hollowshaft motor:

Type	Efficiency			Power Factor			Full Load RPM	Starting Current Amps
Motor	½	¾	F.L.	½	¾	F.L.		
V.H.S. Motor	91.5	92.0	92.0	80	86	87.5	1770	1450
Submer. Motor	81.4	85.7	87.0	67	77.5	81.0	1750	1860

The typical characteristics as shown above were submitted by a well known manufacturer of both standard vertical motors and submersible motors in the United States. You will note that the efficiency of the submersible motor at full load is five points lower than a comparable standard vertical motor. In this instance the power factor at full load is 6.5% lower on the submersible motor. The starting or in-rush current is 28% greater for the submersible motor.

On an evaluated basis the submersible motor with its lower efficiency and power factor could cost a great deal more over a period of years. Prior to making a decision to purchase a submersible type pump this evaluation should be made on the basis of hours the pump will be in service over a ten year period.

A submersible motor is more susceptible to failure due to overload conditions, low voltage conditions and voltage surges in the power supply than a conventional vertical motor. This is due to the mechanical limitations placed on the design. Because of this susceptibility it is necessary to use caution in selecting the motor control equipment in a submersible application. If a submersible motor is installed, the overload protection incorporated in the control panel should respond within ten seconds to protect the motor windings. Normal thermal overload relays or heaters used for standard motors will not trip fast enough to protect a submersible motor and special quick trip protection must be used on all three legs. A number of U.S. submersible manufacturers will not guarantee their motors unless all three legs of the power circuit are protected with these special extra-quick trip heaters.

POWER COST EVALUATION FOR A MAJOR SOUTHWEST MUNICIPALITY

The job involved four 350 HP, 1760 RPM, 2300 volt, three phase 60 cycle pump units. The city had installed these four units as submersibles in 1961. They experienced considerable difficulty with the submersible motors. All four units were pulled and the motors rebuilt at least 14 times in three years. Each time these large submersibles were pulled it cost the city \$1,000 and it is estimated that the motor manufacturer paid out a minimum of \$70,000 over this period of time.

Presently the city plans to convert the submersibles to lineshaft vertical turbine type pumps. The attached power cost evaluation illustrates the saving over and beyond the cost of troubles which they have encountered in the past if they utilize a lineshaft turbine pump. On the basis of eight hours per day operation they should save \$27,820 in a ten year period. If the units were to operate 24 hours per day the saving would be \$83,460.

Admittedly, this is one of the worst examples of submersible service but could be considered typical of the problems which can be encountered and their cost to the user in relation to the original equipment cost.

CONCLUSION

In our opinion, a submersible pump may have a place in heavily populated residential areas as a source of water supply. In this application the submersible advantages of quiet operation, unobtrusive surface equipment and low initial cost may outweigh the disadvantages.

**350 HP 4P 2300V.
Power Cost Evaluation at .013 per KWh**

Submersible (FL EFF 87.5) FL KW	299
Vertical Hollowshaft (FL EFF 93.0) FL KW	281
(Drop cable losses cancel line shaft losses)	
KW Difference at Full Load	18

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Yearly Saving per Motor for 8 Hour Day

Year Hours	= 8 hours x 365 days	= 2,920.00
KWH Hours	= 2920 hours x 18 KW	= 53,500.00
Saving per Motor	= 53,500 x .013	= \$695.50
10 year saving per motor to City for 8 hour day		\$6,955.00
10 year saving per motor to City for 24 hour day		\$20,865.00

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10 Year Total Saving to City on Present Installation of 4 Units:

8 hours per day	=	\$27,820.00
24 hours per day	=	\$83,460.00

We believe these facts will give you a realistic power cost picture of conventional versus submersible installation.

In addition to the actual dollar loss in power cost to the City it is conceivable that the shorter life expectancy of submersibles would cost the City an additional dollar amount, proportional to the extent of failure risk beyond warranty and the additional costs involved in labor, down time, exchange and/or repair expense.