

WHITEPAPER: USING POWER SENSING TO MONITOR AND PROTECT PUMPS

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Pumps play an increasingly important role in today's manufacturing. The global market for pumps is over \$60B, and is expected to continue growing 6% into the future. This investment is exceeded by budgets for running and maintaining these pumps over time. Pumps used for industrial applications represent one of the world's largest consumers of electrical power. According to the Hydraulic Institute, pumping systems account for nearly 20% of the world's electrical energy demand and from 20% to 25% of the energy usage in certain industrial plant operations.

Well managed and maintained pumps can enjoy a long productive life, playing an important role in an efficient manufacturing process. But events can happen! Proactive monitoring and maintenance are important to avoid costly replacement, downtime, cleanup and repairs.

An additional factor for critical and environmentally sensitive pumping applications magnetically coupled, "sealless" or "canned" pumps are increasingly being specified. These pumps offer a number of clear advantages, but since the bearings are now inside these pumps a presence of fluid is needed to remove heat buildup. This requires new thinking about how to protect and monitor them.

A monitoring system that alerts to dry running, provides valuable feedback on process status, flow and viscosity changes, and offers important insight to maintenance needs can deliver short-term payback and ongoing cost savings and process optimization benefits.

Pump power measurement can play a fundamental role in all these key elements and should be considered an important factor in pump subsystem design.



HOW DOES POWER MONITORING WORK?

At the heart of nearly all industrial pumps are three-phase induction motors. The three-phase power creates a rotating field in the stator which 'induces' the rotor to rotate. To measure three-phase power we use the formula:

$$P = (E)(I)(\text{Cos}\phi)(1.73)$$

P = Power (Watts)

E = Voltage Phase to Phase (Volts)

I = Current in each phase (Amps)

Cos ϕ = Power Factor (Ranges from 0 to 1)

1.73 = Multiplication Factor for three phases = $\sqrt{3}$. For single-phase use 1.0

1 Horsepower = 746 Watts

WHAT IS POWER FACTOR?

Let's explain the role of Power Factor in the above equation. In an induction motor the current always lags the voltage. Power Factor is the cosine of this angular lag. For a lightly loaded pump motor, the Power Factor can be as low as .1. You can think of this low Power Factor as electrical inefficiency: current is flowing to the motor to charge the magnetic portion of the circuit, but it is not doing useful work (Power). As the load increases the Power Factor improves and is typically .9 for a fully loaded motor.

Fun fact: the power utility has to produce and deliver the full amount of Amps on the motor nameplate, but only bill for the 'real', 'work', or 'power' part. When Power Factor remains low across a plant, a 'low Power Factor' surcharge is applied to the bill to enable the utility to recoup this difference.

WHY MONITOR POWER INSTEAD OF AMPS?

As you start to load a motor the power factor improves rapidly. The current (Amps) doesn't change significantly until the motor reaches 50% of capacity

Power, on the other hand, is linear. A change in load is a change in Power (HP or kW)

This gives us a signal to monitor and control pumps:

- When flow rate is low, Power is low
- When flow rate is high, Power is high
- At light load conditions, caused by cavitation or dry running, change in Power is 10X more sensitive than Current (Amps).

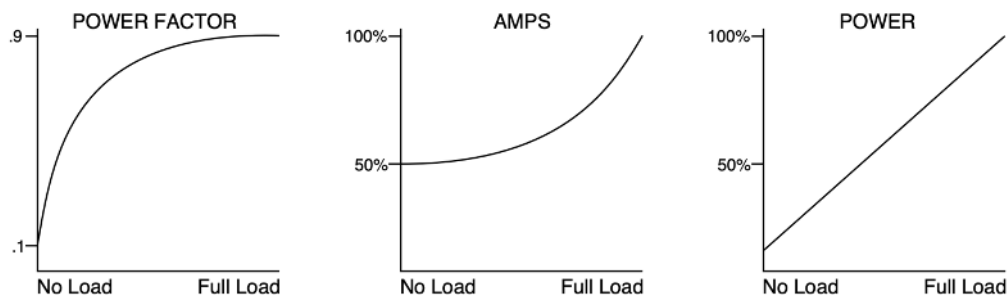
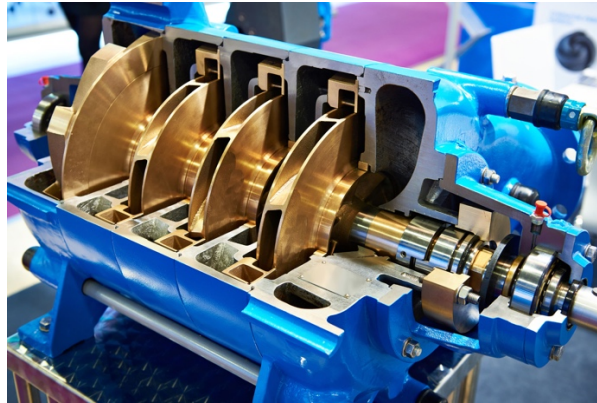


Figure 1.1, 1.2, 1.3 Changes in Power Factor, Current (Amps) and Power with increasing Motor Load

APPLICATION AND SETUP FOR CENTRIFUGAL AND POSITIVE DISPLACEMENT PUMPS

Power monitoring can be applied to both Centrifugal and Positive Displacement Pumps.

CENTRIFUGAL PUMPS



Pump Power (HP) requirements will increase with an increasing delivered flow rate. Figure 2 shows how pump Power HP changes with flow.

With the inlet valve closed (dry running) HP will drop to near zero, enabling relays to be tripped and pumps stopped before the pump overheats (this can be a matter of seconds) and expensive damage occurs. With the discharge valve fully closed (deadhead condition) some fluid still remains in the pump (churning) and HP will not drop as low as compared to when the inlet valve is fully closed (dry running). Note that many pump users are hesitant to close the inlet valve, this is not a prerequisite to setting appropriate trip points when monitoring Power.

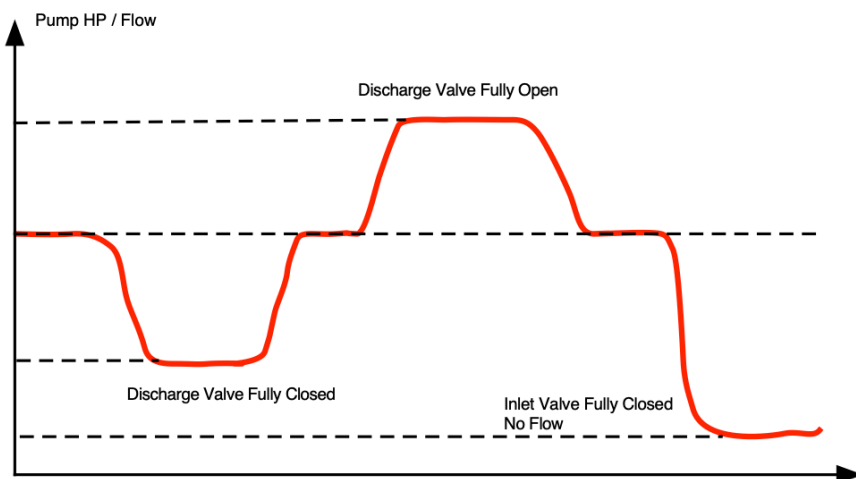


Figure 2 Changes in Power from Steady State with Valve movement

To set up a power monitoring and control system for a Centrifugal pump, users can set a minimum HP Low Trip point over the dead head condition. This will protect against both dry running and deadhead conditions. On the upper end, a High Trip above the maximum flow condition can catch motor bearing problems and protect the pump.

PROCESS CHANGES

Process changes, such as increases to the viscosity of the material being pumped, affects the pump HP level proportionally. The more viscous the material, the more power the pump will pull. The closed / open discharge valve conditions will behave as previously illustrated, but the entire curve will be offset by the change in Power measured due to increased viscosity as shown below in blue. Setting trip points can catch NO FLOW conditions and protect the pump. The HIGH trip point can be set to protect pumps against motor shaft bearing failure or potentially harmful conditions including temperature decline in feeds, or contaminants in the line.

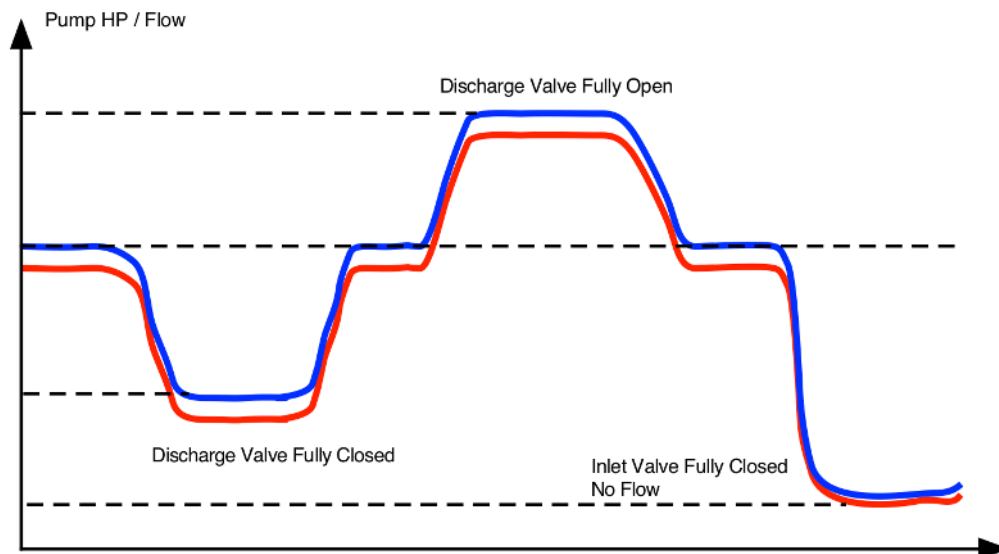
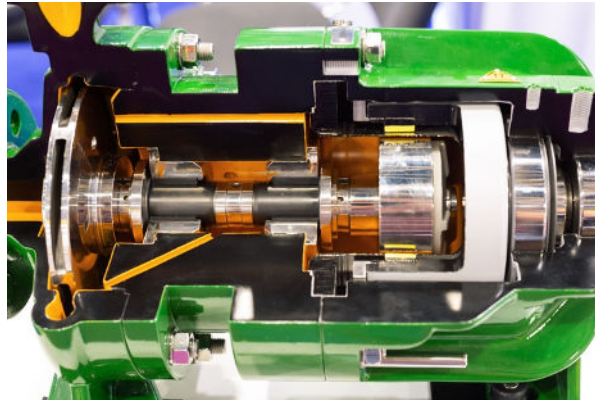


Figure 3 Changes in Power from Steady State with Viscosity change

Additional data gathered over time showing the increase in HP can provide insight into process efficiency and quality of produced product. This curve may shift up over time due to wear, mis-alignment and inefficiency in the pump subsystem design, all indicating the potential need for proactive maintenance.

POSITIVE DISPLACEMENT PUMPS



With a Positive Displacement pump, a blocked outlet will increase pressure in the pump and the HP will increase. The diagram below shows a discharge valve starting to close and the HP starting to increase with pressure in the pump. When the valve again opens, the HP drops back down to the normal pumping power. When Flow is lost, the pump motor goes unloaded. The HP will drop to almost an idle condition on the pump motor until the pump overheats and trouble occurs.

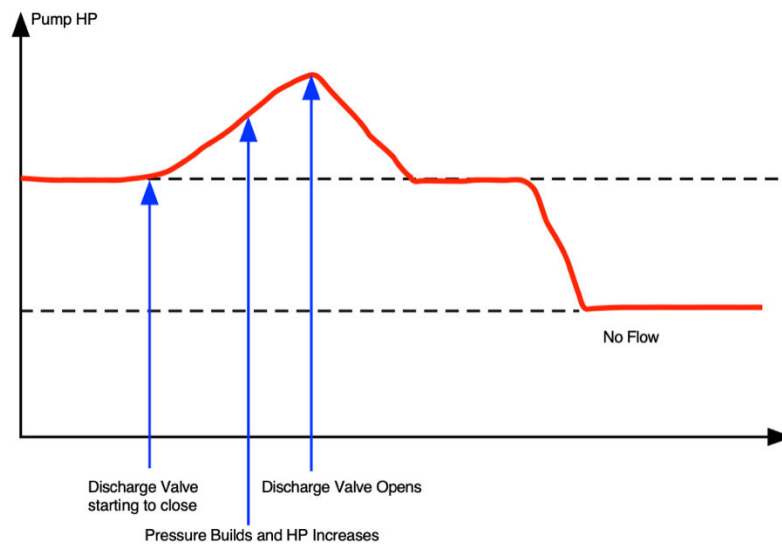


Figure 4 Changes in Power from Steady State with Discharge Valve Closed for a Positive Displacement Pump

COMPARISONS TO ALTERNATIVE MONITORING TECHNIQUES

Power measurement can be used alone or as part of a multi-mode measurement program. Other techniques for measuring pump status include:

FLOW METERS

Measuring flow can provide throughput and viscosity data, critical to understanding subsystem status. A potential downside—the most effective measurements are taken in the flow, leading to reliability and maintenance concerns. Flow Meters can also be costly to install. Leveraging flow sensors in addition to power measurement can be valuable when viscosity changes are important to pump efficiency. Both can provide rapid feedback on flow loss and impeller damage.

VIBRATION SENSING

Measuring vibration provides feedback on pump balance. Since vibration will increase with ongoing wear and misalignment, vibration sensing is commonly used in preventative maintenance programs. Ultrasonic vibration measurement can provide some insight into process state. Vibration sensing is typically easy to install, although may be more expensive than power measurement alternatives. The combination of vibration and Power sensing over time can provide valuable insight into ongoing pumping costs and maintenance efficiencies.

TEMPERATURE MONITORING

When implementing temperature sensing in pumping applications a decision needs to be made to measure temperature in flow, or pump/motor housing. Measuring temperature in flow is most accurate but will require ongoing maintenance. Housing-based solutions are simplest to install, but may suffer from accuracy and latency challenges, particularly in canned pumps. You may also require an ambient temperature sensor to ensure measurements reflect the process, not external factors. Leveraging temperature alone is unlikely to diagnose impeller failure in a timely fashion. When used with Power sensing, temperature monitoring can provide accurate centipoise readings enabling viscosity-based process decision making.

CONCLUSION

Power monitoring can be an important element of a well-managed pump subsystem. Knowing pump motor power status and consumption provides valuable input about infeeds, flows, pressure and viscosity, process efficiency and the changes to the pumping subsystem over time. This can all be vital data to optimizing processes, protecting pumps from dangerous and harmful conditions, and maintaining an efficient pumping process into the future.

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