

Protect Sealed and Sealless Pumps with Power Monitoring

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The overall cost of a pump repair can be expensive, especially when sophisticated sealing devices or sealless technology are utilized. When a process pump fails, plant personnel can be put at risk and unscheduled downtime, while always costly, can be particularly burdensome in critical services. For these reasons, monitoring process pumps to prevent failures has become increasingly commonplace. Among the most comprehensive of these monitoring methods is power monitoring.

Determining Power

Pump power can be monitored by measuring electrical motor power, or by using electro-mechanical means such as in-line torque meters, instrumented shafts, and dynamometers. Measurement of electrical power is generally more practical and less costly than other methods, since no pump installation modifications are necessary.

Most industrial service, motor-driven pumps are powered by three-phase alternating current (a.c.) induction motors. The electrical power delivered to these motors can be calculated by using the motor voltage, current and power factor measurements from power transducers. With these devices, power can be calculated as:

$$\text{Power} = \text{Volts} \times \text{Current} \times \text{Power Factor} \times \sqrt{3} \text{ (Watts)} \quad (1A)$$

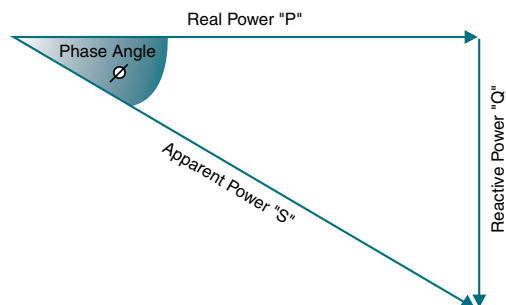
$$\text{Power} = \frac{\text{Volts} \times \text{Current} \times \text{Power Factor} \times \sqrt{3}}{745.7} \text{ (hp)} \quad (1B)$$

Real Power and the Power Factor

In a.c. induction motors, not all of the power delivered to the motor is available as real power (P) for conversion to mechanical rotation of the motor shaft. The inductive characteristics of these motors make them what is known as "reactive" loads in which some of the power, reactive power (Q), is temporarily stored in electromagnetic fields and returned to the source. The combined real and reactive power is called apparent power (S), which can be calculated by multiplying the motor voltage and the current. The ratio of real to apparent power is called the "Power Factor," which is used to determine the real power component of apparent power. The "Power Triangle" in Figure 1 illustrates the real, apparent and reactive power component relationships.

When motors convert electrical power to mechanical power, not all of the real power supplied to the motor is delivered to

Figure 1:
Power Triangle



the shaft. The ratio of the power delivered at the output shaft to the input power delivered to the motor is called the motor efficiency. If the efficiency of the motor is known, it can be multiplied by the real power calculated in Equation 1A or 1B to determine the actual power to the shaft and pump. This is useful in determining abnormal equipment operation conditions by comparing the power to the pump with expected values (from a pump data sheet or performance curve).

Relating Power To Pump Protection

A power monitor is a fault device which tells the operator when a pump is not operating correctly. When a pump is operating at its specified operating point(s), a specific, known level of power is required. Numerous factors can cause an increase or decrease in the power required by a pump, and a sudden change in power may indicate a condition that could damage the pump or sealing device. Typical underload and overload scenarios are discussed in this section.

Low Power/Underload Conditions

Dry-Run/Starved Suction: The condition of a closed suction valve, blocked suction line, empty vessel, or vapor-bound suction can leave a pump precariously void of fluid. Dry-running may result in:

- Mechanical seal failure
- Bushing and journal failure in magnetic drive and canned motor pumps (see Figure 2)
- Sharp temperature rises in conductive containment shells

No Flow/Minimum Flow: A closed or tightly throttled discharge valve may reduce the pump flow rate to an unsatisfactory operating point. Most process pumps require that a certain amount of flow pass through the pump for reliable operation; pump manufacturers define this point as

the minimum recommended continuous flow rate. When flow rates move below this requirement, problems such as the following could result.

- Excessive vibration and increased shaft deflection may seriously reduce mechanical seal and bearing life.
- Process fluid temperature may increase above desired level.
- In sealless pumps, low flow or dead-headed conditions may reduce flow to the containment shell or stator, resulting in marginal lubrication of the bushings and journals.



Figure 2:
Failed Bushing and Journal Parts Caused by Dry-Run

Cavitation: Cavitation is normally indicated by a marked reduction in head and capacity, or even a complete failure to operate. This reduction in performance is characterized by a decrease in power. Depending on the severity of this condition:

- Mechanical seals and bearings can be damaged from the resulting vibration.
- Wet end parts may be subject to pitting erosion, resulting in reduced pump life.
- Reduced circulation and vibration may threaten bushings and journals in sealless pumps.

Unloading/Transfer Applications: Not all underload conditions are unexpected. Power can also be used to indicate low loads from unloading and batch operations.

Other causes of underload conditions include:

- De-coupled magnetic drive pump
- Loss of prime
- Failed spacer coupling
- Abrupt process changes

High Power/Overload Conditions

Pump Operating Above Desired Flow Rate: Several factors could cause a process pump to operate beyond its intended duty point. As a pump moves farther right on its performance curve, power increases proportionally. If the increase in flow becomes excessive, several outcomes are possible. These include:

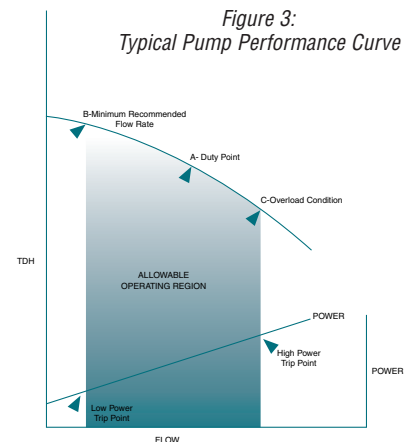
- Increased Net Positive Suction Head Required (NPSHR)
- Magnetic drive pump may de-couple causing excessive heat buildup
- Motor overload

Excessive Wear/Rubbing: An increase in power may indicate excessive wear/rubbing by an impeller, ball bearing, magnet/rotor assembly, damaged journal/bushing, or some other component. Early detection of such a condition may prevent excessive damage to a pump.

Why Monitor Power?

The previous section provides the reader with practical examples of the relationship between underload/overload conditions and power. Figure 3 illustrates this relationship.

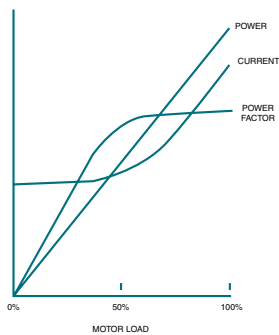
Point A represents the normal operating point of a pump on a performance curve. The area to the left of Point B represents operating points below the manufacturer's minimum recommended continuous flow rate. The area to the right of Point C represents a high load condition(s) from which the pump or motor is being protected. This could be one



or more of the previously discussed examples. The normal, minimum and maximum operating points defined by these points each have a corresponding power level. By monitoring power requirements, safe operation of the pump within the Allowable Operating Region (AOR) can be assured. An effective power monitor must provide means for measuring low power and high power. Additionally, flexible trip delays should be incorporated to allow for short fluctuations outside of the AOR.

Sensitivity: Monitoring of current (Amps) for equipment protection has been practiced for many years. Current monitoring is relatively simple and requires only a current transformer (CT) or transducer and an alarm device or relay.

Figure 4:
Sensitivity = 0% to 100% Motor Load



However, while monitoring current for overload conditions may provide effective protection for wiring, motors, and motor starter components, expensive equipment driven by these motors often require the greater degree of monitoring and protection provided by power monitoring. Power monitoring provides added sensitivity in detecting small changes in equipment load on a lightly

loaded motor, as is often the case with a process pump at low flow conditions.

(See Figure 4).

Known Quantity: A power monitor can display, and be set up, in units of horsepower or kilowatts, information available directly from a pump manufacturer's performance curves and data sheets. A digital numeric display permits setup without operation of the equipment. With current monitoring, however, the pump may need to be operated at or near potentially damaging conditions to determine the required settings.

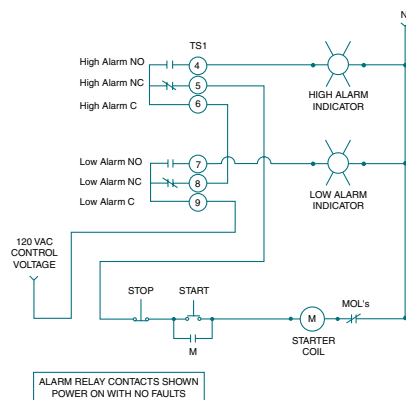
Real-Time Response: Power gives an immediate indication of conditions that may dramatically affect pump life. Other monitoring methods may be slower to respond.

Output

How a power monitor is incorporated into a pumping system may be the most important aspect in preventing equipment failures. The most common method is to incorporate the motor starter control circuit into the monitor's alarm relay contacts.

Figure 5 shows a wiring diagram for this option. This method provides motor shut-off if an underload or overload condition is detected for a period of time greater than the trip delay setting. At this point, it is up to the operator to determine the cause and take corrective action. Similar wiring configurations can utilize the alarm contacts to sound an alarm,

Figure 5:
Power Monitor Alarm Contacts and Motor Starter Control Circuit



switch on a light, etc. Another practical method is to utilize the monitor's 4-20mA output signal. This gives the user the flexibility to incorporate the power reading into the plant control system.

Motor shut-offs, alarms and 4-20mA output signals are only useful if the condition(s) that caused the alarm is addressed. A properly designed monitor will provide flexible trip delays to avoid nuisance trips - the main reason many such devices are overridden or disconnected. The power monitor should also provide a clear indication as to whether the alarm was caused by an underload or overload condition. The cause of the alarm should be determined and a solution implemented prior to restarting the equipment. Serious damage often results from failure to acknowledge a low or high power alarm.

Conclusion

Power monitoring is a comprehensive technique that provides protection from most causes of pump failures. The popularity of this method has spread beyond pumps to encompass blowers, compressors, agitators, fans, and other equipment where protection from misoperation and upset conditions is needed. A properly designed power monitor provides an economical solution to high maintenance costs and lost production caused by unplanned downtime.

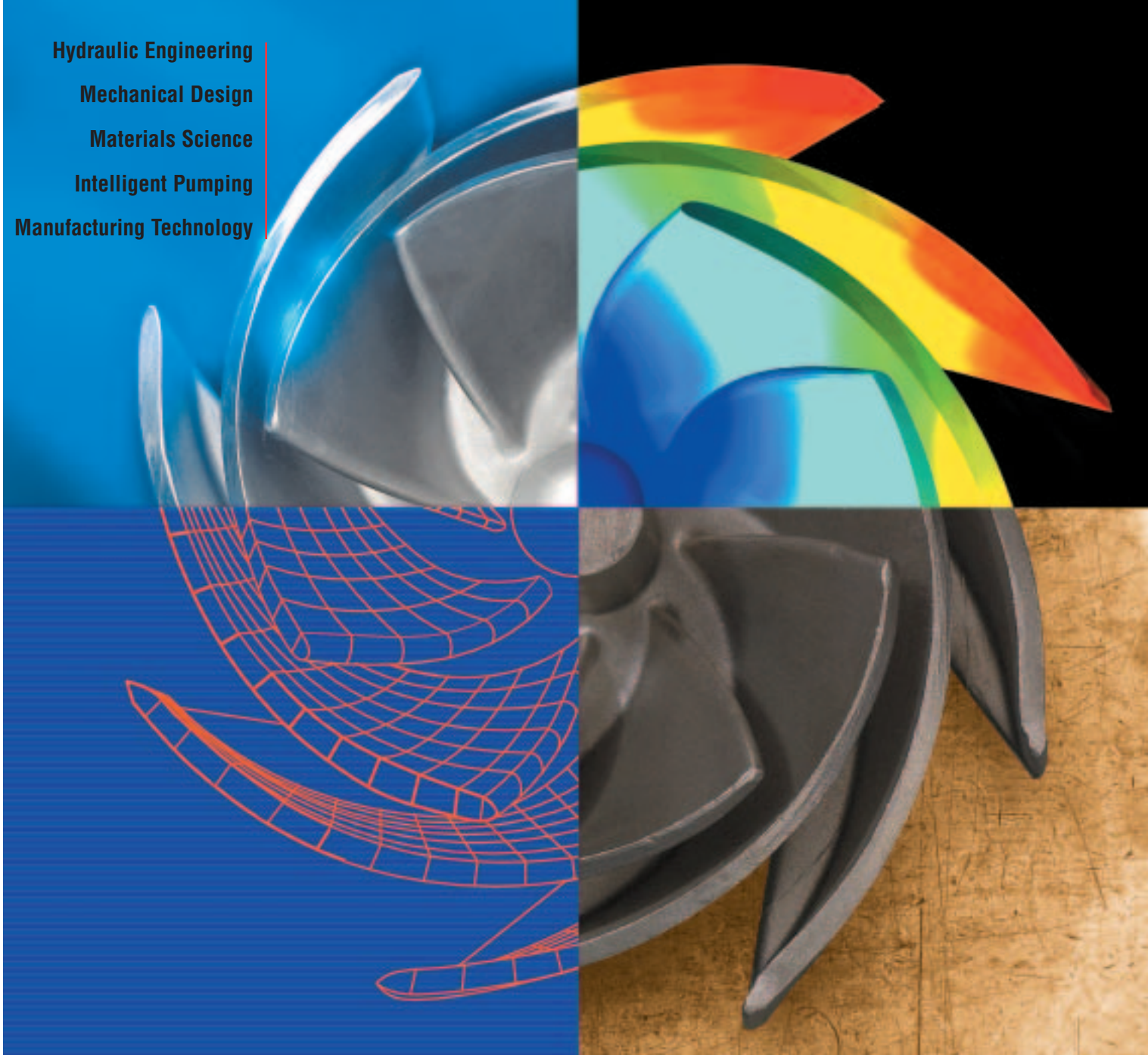


Figure 6:
Flowserve KW941 Pump Power Monitor

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