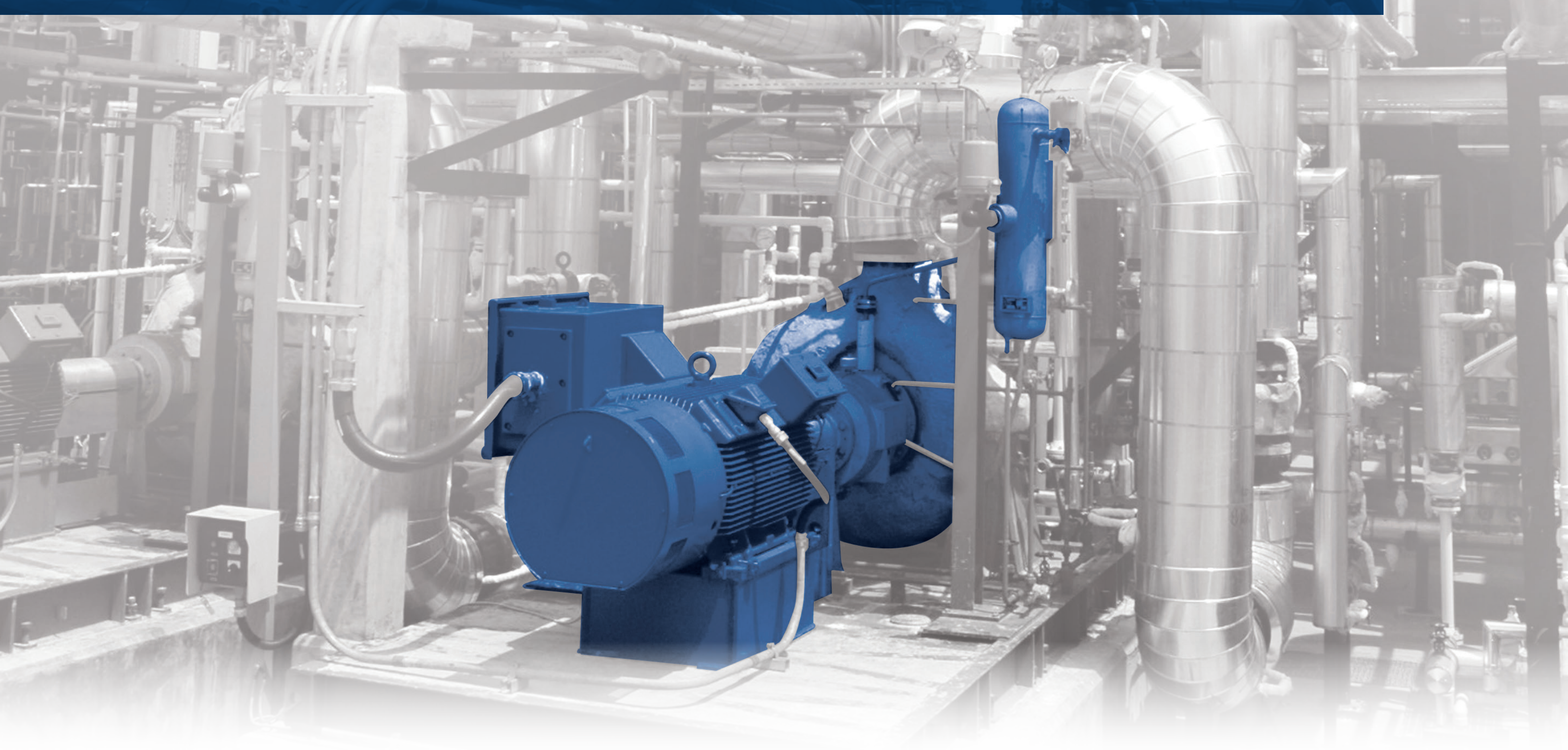
White Paper

Beyond Switches for Pump Monitoring:

What Changed with API Standard 682



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Process Management

Beyond Switches for Pump Monitoring: What Changed with API Standard 682

API Standard 682 (Plans 52, 53 A, B, and C for dual seal pumps) has evolved to include transmitters which enable a more reliable, safer plant.

In May 2014, the fourth edition of API Standard 682 was released. API Standard 682 addresses pump sealing systems in the petroleum, natural gas, and chemical industries, and provides guidelines for selecting and monitoring seals. It is particularly applicable for hazardous, flammable, and/or toxic services where a high degree of reliability is required for improving equipment availability and reducing both emissions to the atmosphere and life-cycle sealing costs.

API 682 was first published in 1994 and has been periodically updated over the years to keep up with pump sealing technology. The second edition of API 682 was adopted by ISO, making it a worldwide standard, ISO 21049.

The third edition was released in September 2004. Over the past decade, technology has improved, and the API 682 committee members used their experiences to determine how to improve process pump reliability and safety. The fourth edition contains many recommendations for pump seals with respect to seal system manufacturers, but these are not the focus of this white paper.

This article instead focuses on pump operations and maintenance, specifically the relevant parts of API Standard 682 Fourth Edition describing changes in instrumentation used to monitor pump auxiliary seal flush systems. The new edition now indicates a preference for continuous measurements using pressure and level transmitters versus the prior practice of using pressure and level switches. While switches are still an acceptable solution for this application, impacted facilities should evaluate all pump monitoring options and the risks associated with each pump application and select their pump seal monitoring systems accordingly.

Costs of failure

Pumps are essential for consistent, safe, and profitable process facility operation. Pump repairs consume an estimated 7% of the maintenance budget in a typical processing facility. In addition, unanticipated pump failures can cause facility slowdowns, shutdowns, and lost revenue opportunities that may never be recovered.

Pump failures can also lead to safety and environmental incidents, and often fires. Negative impacts can include equipment damage, downtime injuries, and even deaths. The result is negative publicity, more frequent environmental agency audits, and remediation costs and fines.

According to API Standard 682 Fourth Edition, offshore platforms, onshore wellheads, refineries, and petrochemical plants need to evaluate what pump monitoring measurements are in place, which measurements require manual field checks, and which should be automated or upgraded to a better option.

Many facilities have limited existing wiring for additional instrumentation, and it's often not economically feasible to implement a wired monitoring solution, especially considering the safety requirements of installing the necessary wiring in an operating process plant. Wireless transmitters provide an economically viable option that is easy and relatively inexpensive to implement.

Pump problems

There are many root-causes for pump damage and related failure. As shown in Table 1, the mean-time-between-failures of pumps varies from less than two years to a best-of-class operation approaching 10 or more.

Table 1. Pump Mean-Times-Between-Failures[1]

Equipment	Location	MTBF (years)
ANSI Pumps, AVG	U.S.A.	2.5
ANSI/ISO Pumps, AVG	Scandinavian P&P Plants	3.5
API Pumps, AVG	U.S.A.	5.5
API Pumps, AVG	Western Europe	6.1
API Pumps, repair-focused refinery	Developing Country	1.6
API Pumps	Caribbean Region	3.9
API Pumps, best-of-class	California, U.S.A.	9.2
API Pumps, best-of-class Petrochemical Plant	Texas, U.S.A.	10.1
All Pumps, Major Petrochemical Co.	Texas, U.S.A.	7.5

1. Source: Pump User's Handbook: Life Extension

Changes to process conditions can result in a change in pump performance, including damage to the pump itself. Additionally, normal mechanical wear can result in the failure of seals, bearings and other pump internals. Misalignment during installation can contribute to problems such as excessive vibration. In fact, vibration is an important variable for monitoring, as it can often identify a variety of different causes in addition to misalignment.

Due to the costs associated with monitoring the process using wired instruments, only a small percentage of a typical process facility's pumps are monitored online. The balance of pumps are inspected only periodically by operations or maintenance personnel on field rounds.

As a result, the majority of process pumps are operating without continuous monitoring, increasing the overall risk of unanticipated pump failures, leaks, fires, and other potentially dangerous situations. Many technician hours are consumed by manual monitoring rounds in an attempt to prevent pump failures, and this still does not always avert a failure. Consider for example, an intermittent pump that is not running, gets missed during a routine field check, or when operations switches from pump A to pump B.

Most pump auxiliary seal flush systems also have limited online measurements. As with pumps, the traditional approach is manual monthly checks in the field, and switches to detect low level, high pressure, or high temperature.

A traditional mechanical switch is not as good as a transmitter because it can only provide a binary measurement, an on/off signal. Unlike a transmitter, a switch cannot indicate distance from an alarm or set-point, and thus cannot be used to predict problems before they occur. Many switches do not have onboard diagnostics, making it difficult to know if the switch is operating properly.

Transmitters indicate a broad range of the measured variable, providing a much more informative measure of operating conditions. Smart transmitters allow for remote configuration, calibration, and diagnostics that provide significant additional value for ease of maintenance.

API auxiliary seal flush piping plans

API Standard 682 defines piping plans for pumps to assist processing facilities select and install various types of sensors and controls for pump auxiliary seal flush systems. Although the standard defines several different plans, the most significant for this discussion are Plans 52 and 53 A, B and C, for dual mechanical seals with a flush fluid for lubrication and cooling. In all plans, heat is removed by cooling water coils in the reservoir or by circulating the flush oil through finned tubes.

Plan 52

Plan 52 uses an external reservoir for providing buffer fluid between the seals of an unpressurized dual seal system. Dual mechanical seals are used where the pumped product is harmful or hazardous and process fluid leakage to the atmosphere should be minimized and contained. They are also used in applications where the process may solidify in contact with the atmosphere, and in applications where additional heat removal from the inner seal is required.

The buffer liquid is contained in a reservoir vented to a collection system to maintain the buffer system pressure close to atmospheric. Leakage of some process liquids into the buffer system may flash to the vapor phase in the seal reservoir, and the vapor vents to the collection system across a restriction orifice. As the vapor flow rate increases, the restriction orifice pressure drop will increase, raising the pressure in the reservoir.

This condition of a high vapor rate can be sensed with a pressure switch or pressure transmitter to sound an alert that maintenance is required. If the pumped fluid remains a liquid at ambient pressure, then an increase in leakage across the inboard seal will cause the fluid level in the reservoir to increase, which can similarly be sensed by a high level switch or level transmitter. The pumped fluid that leaks across the inboard seal mixes with the buffer fluid so buffer fluid contamination also should be considered. Required maintenance associated with seal repairs, filling, draining, and flushing a contaminated buffer system can be significant.

There is no difference with respect to the pump in Plans 53 A, B and C. Users choose among the three pressurized seal plans depending upon the method needed to maintain a sufficiently high pressure above the pump seal chamber pressure. Plans 53 A, B, and C are used to keep the pressure between the seals higher than the seal chamber pressure between the suction and discharge pressure. Pressurized seal systems are used when the pumped fluid is hot or otherwise harmful or hazardous, because pressurized seal flush systems virtually eliminate the risk of leakage to the atmosphere. Pressurized dual seals may also be used in applications where the pump may be operated dry or the pump process fluid may be damaging to the seal faces.

Plan 53 A

A Plan 53 A system consists of dual mechanical seals with a barrier liquid between the seals. The barrier liquid is contained in a pressurized reservoir. There will always be some small leakage flow of barrier liquid into the product. The system uses an external pressure source typically nitrogen, to keep the reservoir pressure sufficiently higher than the pump seal chamber pressure. The reservoir is very similar to the reservoir in Plan 52 with a level transmitter or high and low level switches and a pressure switch or transmitter to alert when the pressure is below the trip point, a low pressure alarm.

Plan 53 B

A Plan 53 B system consists of an external barrier fluid system pressurized by a bladder accumulator that supplies clean flush liquid to the seal chamber. The accumulator and barrier liquid are maintained at a pressure sufficiently higher than the seal chamber.

Plan 53 B differs from 53 A in that pressure is maintained in the barrier liquid system via the accumulator. The accumulator prevents contact between the pressurization gas and the barrier liquid. This prevents gas absorption into the barrier liquid and allows for higher pressure operation. Plan 53 B also relies on temperature readings to calculate the set point for the low pressure alarm, compensating for ambient temperature changes of the accumulator.

Plan 53 C

Plan 53 C uses a piston accumulator instead of a bladder to provide pressurized barrier fluid to the circulation system. The piston accumulator senses pressure from a reference source, normally a line connected to the seal chamber, and generates a higher pressure using an internal spring to protect the seals. To create the reference pressure in the piston transmitter, process fluid is introduced into the spring side of the piston. Seal chamber pressure plus the spring force set the pressure on the seal flush liquid side of the piston.

This requires the materials used in the piston transmitter to be compatible with the process fluid. Process fluids that contains solids, tend to plate out on metal surfaces, or solidify under atmospheric temperatures unsuitable for a Plan 53 C system. The advantage of Plan 53 C is that the spring in the piston always maintains a fixed differential pressure across the inboard seal face. This can reduce wear as the pump is started up from essentially a low pressure to the full discharge pressure.

Over the past decades, dual or tandem mechanical seals were developed for the process industries to improve upon safety in the event of a failure of a single mechanical seal. Generally, pumps in hydrocarbon services in new construction will be specified with dual mechanical seals, but there are many pumps in service that may not yet have been upgraded to dual mechanical seal systems.

If an existing facility is upgrading its mechanical seals from single to dual, then it may select either Plan 52 (unpressurized), or one of the three pressurized plans 53 A, B, or C for the auxiliary seal flush system. One of the three Plan 53 solutions is usually chosen over Plan 52 for dirty, abrasive, or polymerizing products that can either damage the seal faces or cause problems with the buffer liquid system.

All plans need instrumentation to monitor the level, pressure, or temperature in the seal flush reservoirs. For existing process units, there may likely be insufficient spare wires in the vicinity to deliver these measurements to a control room or other location, making wireless instrumentation an attractive option in many cases.

What changed in API Recommended Practice (RP) 682?

The objective of the API 682 committee for the fourth edition was to make recommendations for continuous seal system operation for at least three years (25,000 operating hours), increased availability of the process, and simplified maintenance.

API Standard 682 gives the user several options for selecting instrumentation. The current edition gives preference to using indicating transmitters for pressure and level measurements rather than on-off switches.

With indicating transmitters, a field operator can visually monitor operating parameters at the equipment, and operators can view the same data in a control room. Data from transmitters can be analyzed to predict problems before they occur, such as watching a trend as a measured value approaches an alarm point, for example. Predicting failures before they occur can allow maintenance and repairs to be planned and made prior to a breakdown.

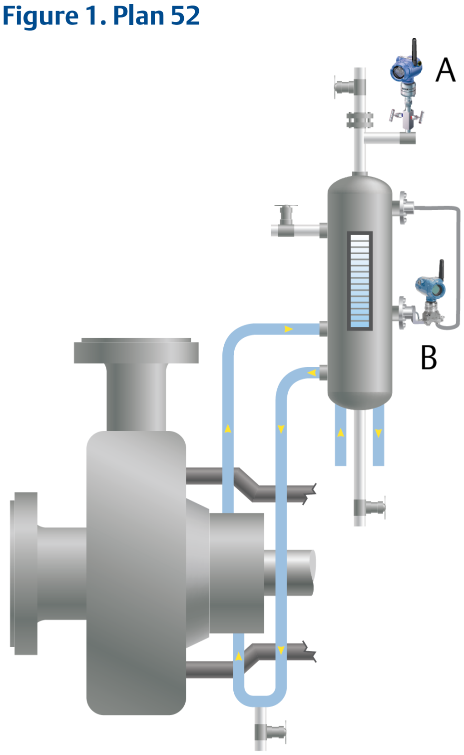
For the unpressurized system defined in Plan 52 (Figure 1), API 682 recommends using pressure and level transmitters. The level transmitter provides a low level alarm in all cases, and a high alarm is specified for cases where the pumped fluid is still liquid phase at atmospheric pressure (non-vaporizing).

Plan 52 is designed to keep the buffer liquid at a pressure less than the seal chamber pressure, which is intended to be less than 40 psig (276 kPa). The pressure signal has a high alarm indicating when the leakage rate of the vaporizing pumped fluid into the reservoir increases to the point where the pressure accumulates to above the high pressure alert setting. This is because vaporizing fluid will increase the reservoir pressure as more flow passes through the restriction orifice to the flare or vapor collection system.

Note

API Standard 682 now recommends a pressure and a level indicating transmitter instead of switches for Plan 52 sealing systems. See Figure 1.

Figure 1. Plan 52



A. Pressure transmitter
B. Hydrostatic level transmitter

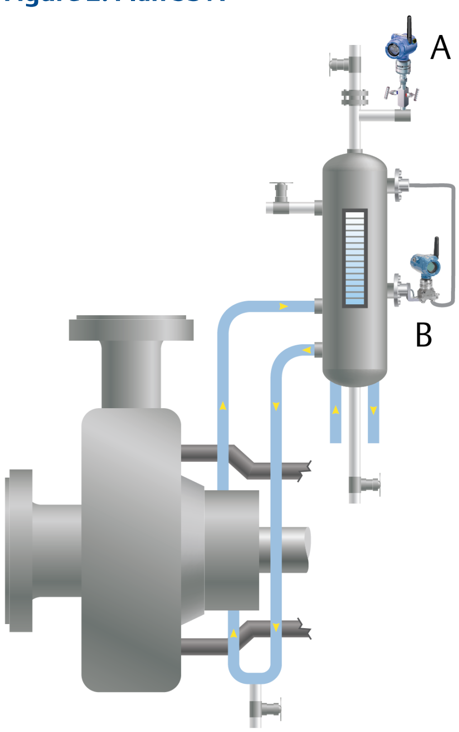
Plan 53 A (Figure 2) defines a pressurized system that uses an external source of pressurization, such as nitrogen. Plan 53 A recommends a pressure and a level transmitter instead of pressure and level switches, as it does for Plan 52. The level transmitter is specified with a low and a high level alarm.

The reservoir pressure must exceed the seal chamber pressure by a minimum of 20 psi (138 kPa). If the reservoir pressure is less than the seal chamber, the normal leakage flow direction across the inner seal will be reversed. The barrier liquid may become contaminated with the process liquid, possibly creating a hazardous barrier liquid and increasing the possibility of seal failure. A low level alarm indicates it is time to refill the reservoir, or a leak has occurred in the outboard seal on the atmospheric side. For Plan 53 A, the pressure should be sufficiently high, and low pressure will be an alarm condition, indicating loss of the external source of pressurization gas.

Note

API Standard 682 also recommends a pressure and a level transmitter instead of switches for Plan 53 A sealing systems. A low pressure alarm would indicate a loss of pressurization gas, and a low level alarm would indicate that it is time to refill the reservoir, or that there might be a leak in the outboard seal. See Figure 2.

Figure 2. Plan 53 A



A. Pressure transmitter
B. Hydrostatic level transmitter

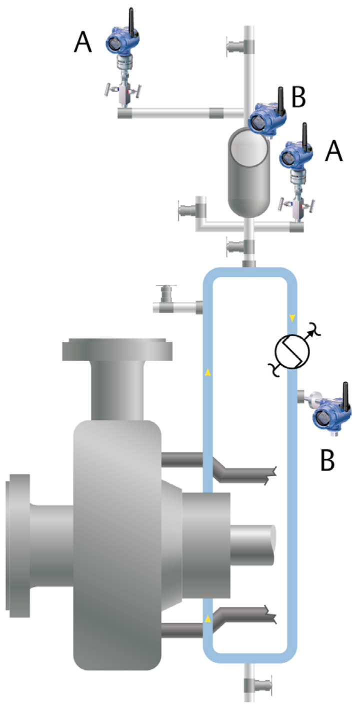
Plan 53 B defines systems where pressure is maintained by an accumulator bladder (Figure 3) and the reservoir is completely filled with barrier liquid; no level measurement is required. Leakage past the inner and outer seals results in a decrease in the flush system pressure. This requires the barrier system be pressurized to a higher initial pressure and allowed to slowly depressurize to the minimum allowable system pressure. At this time, the system would be refilled to restore the maximum working barrier liquid volume.

The low pressure alarm indicates it is time to refill the reservoir, or possibly that an outboard seal failure has occurred. Since the ambient temperature in a refinery can vary considerably from night to day and with seasonal changes, a fixed low pressure alarm setting on a cold day can indicate it is time to refill the reservoir before it is really necessary. On hot days, the accumulator pressure may still be above the low alarm setting, while the inventory of flush fluid is depleted. Therefore, the fourth edition now specifies a low pressure alarm set-point that is a function of the current ambient temperature, and of the pressure and temperature the last time the bladder was charged with nitrogen.

Note

For Plan 53 B in Figure 3, API Standard 682 recommends the buffer fluid inventory be monitored with a pressure transmitter instead of a low pressure switch. The low pressure alarm setting is compensated for changes in ambient temperature. The figure below is also shown with a temperature transmitter instead of a thermometer to monitor the circulating flush fluid temperature.

Figure 3. Plan 53 B



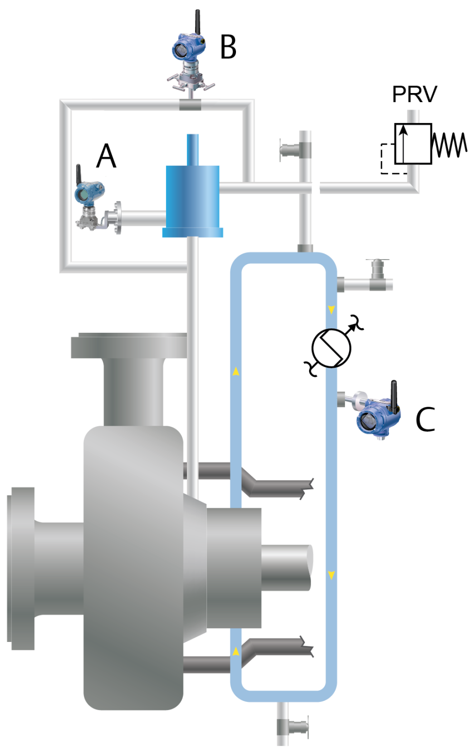
A. Pressure transmitter
B. Temperature transmitter

Plan 53 C defines systems where pressure in the reservoir is supplied by a spring-loaded piston (Figure 4). Level measurement in the piston accumulator may be challenging for both differential pressure (DP) and guided wave radar level sensors. In this case, level switches may be the best option, but additional consultation is necessary to determine the best option.

Note

In some cases, level switches may be a better solution than the level transmitter (LT) shown in Figure 4 for measuring level in the piston accumulator, depending upon the construction of the piston. The figure below is also shown with a temperature transmitter instead of a thermometer to monitor the circulating flush fluid temperature.

Figure 4. Plan 53 C



A. Level transmitter (hydrostatic level transmitter shown)
B. Differential pressure transmitter
C. Temperature transmitter

Level transmitter selection considerations

For all plans, API Standard 682 now gives preference to using level transmitters instead of switches to enable measurement of the level between the high and low points. By monitoring this level continuously, when and where flush fluid should be replenished can be identified. In addition, using the analog level indications from a transmitter, an online monitoring system should monitor the rate of change on the level measurement to alarm operators when the fluid depletes faster than normal. This enables maintenance personnel to take action before a pump seizes and causes considerable damage.

API Standard 682 states that when level transmitters are used instead of switches, the level should be measured using hydrostatic techniques using a pressure transmitter with impulse lines or remote diaphragm seals with capillary. Guided Wave Radar (GWR) Technology could also be considered to measure the level in the reservoirs.

Hydrostatic level measurement can provide continuous indication of the level using a straightforward measurement technique using a pressure transmitter with impulse lines or remote diaphragm seals with capillary. With a pressure transmitter as the basis of this technology, the measurement is easily verified and calibrated. Many process connection options exist with hydrostatic level technology which makes connection to the reservoir simple and it can even be added to existing switch connection points.

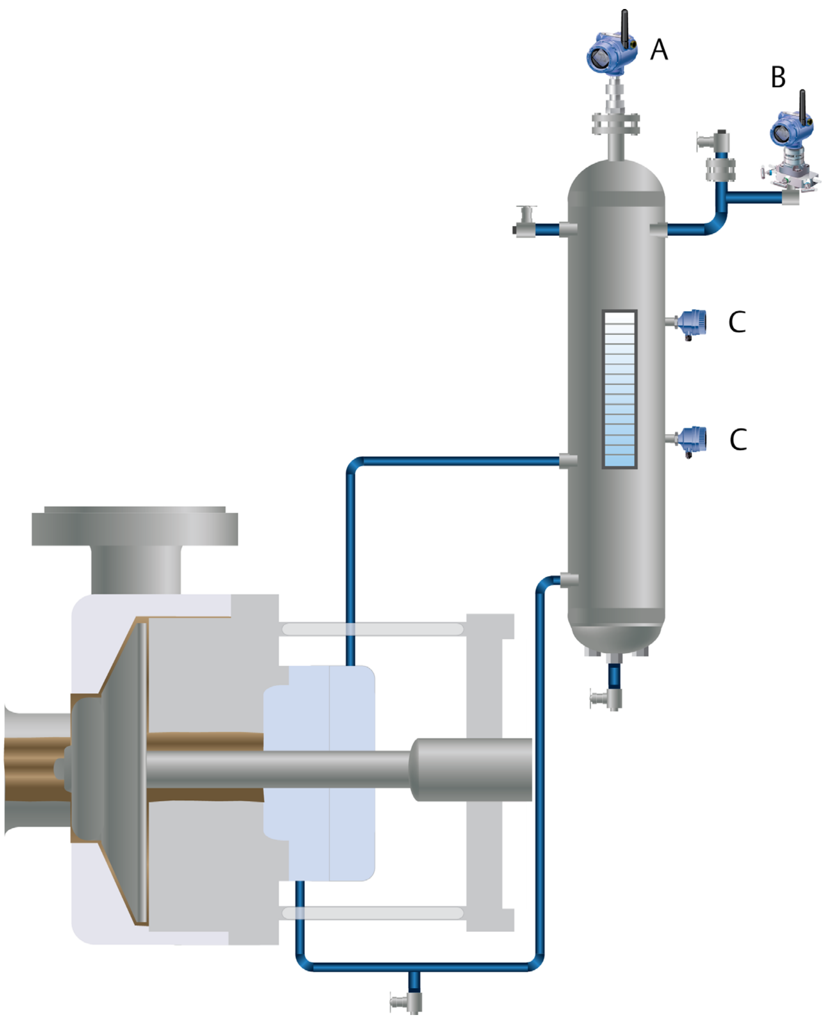
With hydrostatic level measurement, care must be taken to properly specify and install the technology so it delivers the expected results. Impulse piping can be used to connect the pressure transmitter to the reservoir using what is referred to as a wet or dry leg. Impulse piping installations with wet or dry legs have a lower initial installed cost, but require more maintenance to ensure proper performance. Dry leg installations are susceptible to condensation pooling in the piping which causes the pressure transmitter output to shift, so frequent draining or other condensation prevention techniques may be required. Wet leg installations are susceptible to evaporation of the fill fluid which also causes an output shift, so condensate pots or frequent verification of the wet leg level may be required.

Remote diaphragm seal systems with capillary lines can be used in place of impulse lines in hydrostatic level measurements to eliminate the maintenance costs associated with wet/dry leg installations. It is a common misconception that remote diaphragm seals should not be used in applications with small measurement spans such as a pump seal flush reservoir application. However, since capillary lengths are minimal in this application, very good performance is achievable. To ensure a properly designed system, the vendor should be asked to quantify measurement performance for its remote diaphragm seal system.

Guided Wave Radar Technology can also be used to measure reservoir level with accuracies of up to ± 0.2-in. (5 mm), which can be achieved over the level span. With GWR, the radar sensor can be mounted in the center of the reservoir, allowing measurement along the whole length of the reservoir, even down into the cooling coils, below the lower tap of the level instrument as currently shown in the standard.

GWR may require changes to the reservoir to allow installation. Use of GWR technology requires access to the seal flush system from a top access point or an external stilling well. One option to add GWR to existing pump installations is to relocate the vent piping to the top side of the reservoir in order to mount the GWR in the centerline. New pump reservoir installations should be designed to work with GWR if it is the chosen technology. An example installation using GWR is shown in Figure 5.

Figure 5. API Standard 682: Guided Wave Radar Sensors with Optional Level Switches



A. Level transmitter (GWR)
B. Pressure transmitter
C. Optional level switches

Automation recommendations

There are options for conforming with API Standard 682 fourth edition. The preferred option is employing level, pressure, and temperature transmitters that can communicate to a remotely located control system and also provide local indication.

Continuous measurements from indicating transmitters are usually the best option. This enables technicians and rotating equipment specialists to identify problems and plan for timely condition-based maintenance. Pump seal flush system information can be stored in a process historian, trended to identify rate of change, analyzed, and made available online to both control system console operators and maintenance personnel. Local indication of conditions is also provided by the transmitters.

Wireless transmitters

For many installations, the key to an economical pump seal instrumentation scheme is wireless transmitters. Many pumps are located in hazardous areas, in locations that are difficult to reach, or in locations such as wellheads and offshore platforms where electrical power is limited. In many of these cases, using wired transmitters may be too expensive because of the cost to install and maintain the wiring infrastructure.

Wireless transmitters do not require any wiring infrastructure. Installation, therefore, is straightforward: the transmitter merely has to be plumbed into the process to measure level, pressure, or temperature; no wiring is required.

The only electrical requirement is to provide power for a wireless gateway that receives signals from the transmitters and passes them on to a control system through a wireless mesh network. This gateway can be located some distance away from the transmitters, often outside of the hazardous area.

If the pump is remotely located on an offshore platform or wellhead, the gateway can send data from the transmitters via a wired network, RF, mobile phone, or satellite link to a remote control room.

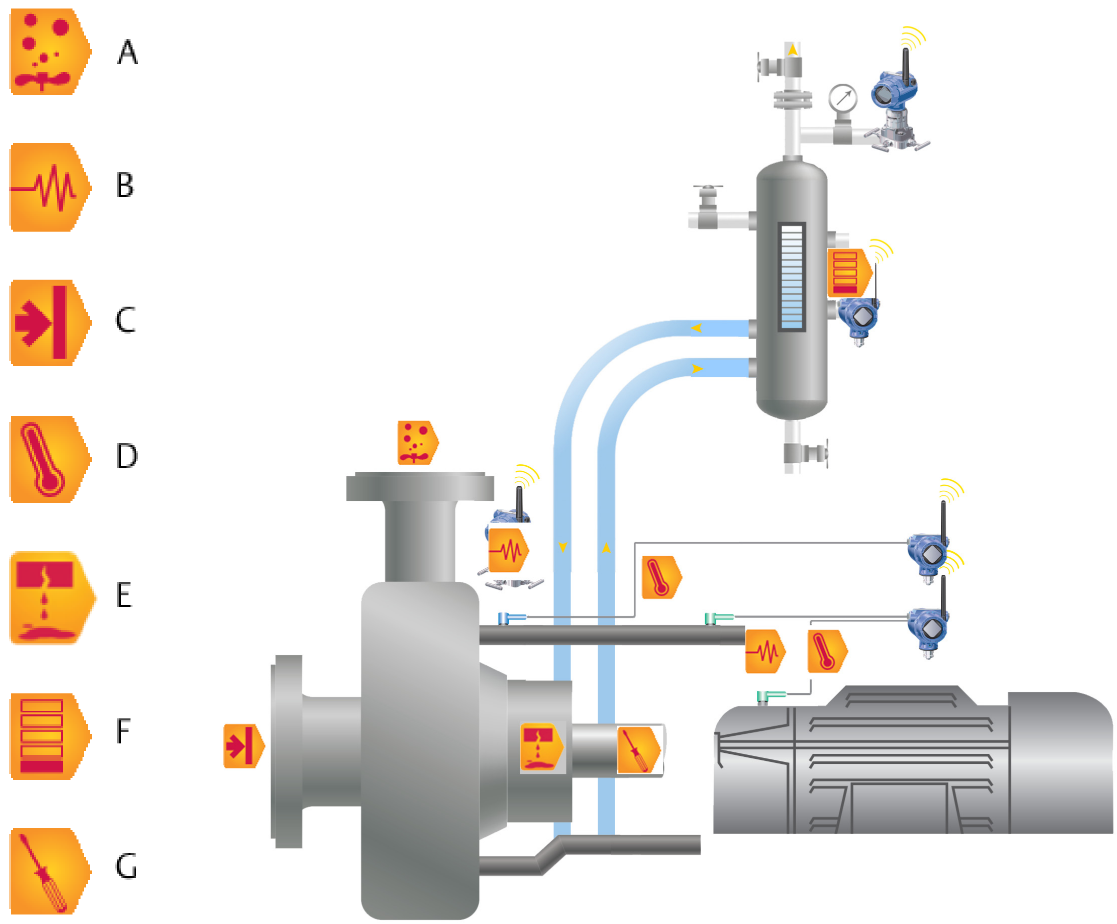
If the pump is in a process plant, the gateway can connect to the plant's control system, usually via a plant-wide wireless network. In a process plant, it may be just as easy to wire the gateway into its existing network architecture. Or for that matter, there may already be an existing wireless field network established to which the gateway can interface.

Once the pump seal flush system is equipped with wireless instrumentation, it is relatively easy to add instruments to a pumping system to measure cavitation, flow, vibration, or other parameters such as temperature, strainer plugging, seal fluid level, and hydrocarbon leaking (Figure 6) to provide a comprehensive pump health monitoring system.

Note

A comprehensive pump health monitoring system can quickly and easily identify many common pump challenges using wireless transmitters. See Figure 6.

Figure 6. Comprehensive Pump Health Monitoring System using Wireless Transmitters



A. Cavitation
B. Vibration
C. Strainer plugging
D. Temperature
E. Hydrocarbon leak
F. Seal fluid level
G. Installation

A pump health monitoring system provides comprehensive condition-based monitoring of pumps, resulting in higher on-stream availability and consequently reduced maintenance costs.

Conclusion

Per API Standard 682 recommendations, indicating pressure, level, and temperature transmitters provide an improved solution compared to traditional switches. This is because transmitters provide a continuous measurement of pump seal flush system parameters instead of a point measurement. Smart transmitters also provide asset diagnostics to ensure the transmitter is working properly, and can allow remote configuration and calibration. Analysis of continuous measurements allows failures to be anticipated, which reduces maintenance costs and increases uptime.

If the indicating transmitters are wireless instead of conventional wired instruments, implementation is much simpler, quicker, and less expensive because there is no wiring infrastructure to install or maintain.

To learn more about Emerson™ Process Management's Pump Health Monitoring solutions, visit www.emersonprocess.com/pumps

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