Never Underestimate Overpressure

Overpressure in a process can damage the seals in a pressure instrument's sensor or skew the zero point. Here's how to avoid the problem.

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Pressure is one of the most commonly measured variables in process industries. Accuracy and, more importantly, stability are critical to maintaining a safe, reliable process and maximizing uptime. Pressure is typically measured by an instrument with a sensor and a transmitter. The sensor interfaces to the process to determine the pressure and sends this value to the transmitter. The transmitter converts the signal from the sensor to a type suitable for transmission to a control and monitoring system, such as 4-20 mA or a digital fieldbus communications protocol.

Modern electronic pressure instruments (Figure 1) are extremely safe and reliable with onboard diagnostics and extremely sensitive sensors providing insight into the process and flexibility in application. They can measure either differential pressure (i.e. the difference between two pressures in a pipe or vessel) or static pressure (gauge or absolute pressure).

Figure 1: Overpressure can damage a pressure instrument's sensor, such as this Endress+Hauser Deltabar differential pressure PMD75.

In addition to the sensor, a transmitter consists of several important components. The sensor body is the machined component that houses the sensor. The sensor diaphragm(s) serves to keep process fluid from coming into direct contact with the sensor while allowing the process pressure to be measured by the sensor. The system may also incorporate a manifold which allows the transmitter to be isolated from the process for removal or calibration without having to shut down the process.

In many cases the complete measuring system also includes remote process seals and capillaries with hydraulic fill fluid designed to provide added protection to the transmitter in the case of excessive process temperatures, aggressive process media or process media that could plug impulse lines. While these measuring systems are highly reliable there are many common issues that can affect pressure measurement and speed of response, such as errors caused by ambient or process temperature swings.

These issues can typically be addressed by correct selection and installation (e.g. proper fill fluid selection, insulating/ heat tracing of capillaries, etc.) of the pressure instrument. But there is one common issue that is difficult to avoid but can have severe consequences not only to the sensor, but to the process as well: overpressure.

Overpressure occurs when excessive pressure is applied to one, or both in the case of differential pressure, of the sensor diaphragms of the instrument. This can be either directly to the process diaphragm of the instrument, or to a diaphragm seal either directly connected to the instrument, or remotely connected via a capillary with a non-compressible fill fluid.

Typically, there are three main causes of overpressure in a process: process upset conditions, excessive cycling of valves and incorrect use of manifolds.

Process Upsets

Process upset conditions occur when the pressure, temperature or both exceed the acceptable limits for the pressure instrument's sensor. This could occur during normal operation but is most likely to occur during startup or shutdown. The most obvious effect occurs when there is an actual overpressure applied to the sensor. The less obvious but more likely cause is when the transmitter experiences elevated ambient or process temperatures. This can cause the fill fluid in the seals and capillaries to expand, while also increasing the internal pressure of the fluid such that an overpressure is applied to the sensor.

Even when process conditions are within acceptable limits, there is the possibility of overpressure being applied due to cyclic pressures on the sensor. The repeated "on/off" cycling of pressure from a high pressure to a low pressure can have the same effect as overpressure, causing damage to both the diaphragm and the sensor.

Manifold Issues

More common than process upset conditions is when manifold valves (Figure 2) are improperly closed and opened. Manifolds are used to isolate the instrument's sensors from the process for re-zeroing/recalibrating or removing the instrument without the need to shut down the process. Three-valve and five-valve manifolds are regularly used with differential pressure instruments on DP flow or DP level applications.

It's important when closing the process manifold valves to make sure the valves are fully closed and seated before opening the equalizing valve. A common mistake is opening the equalizing valve before completely closing one or both process valves, allowing line pressure to leak past the valve and impact the sensor diaphragms. Even the most seasoned instrument technician has probably made this mistake on more than one occasion.

In the best-case scenario, an overpressure event has no discernible effect on the sensor's measurement. Most overpressure events, however, result in a shift of the zero-point of the sensor, resulting in the need to re-zero the instrument's transmitter. In some cases, the effect can be severe enough that the instrument must be recalibrated—most likely by removing it from the process and placing it on a bench calibrator.

While neither of these types of incidents should require replacement of the instrument, if left unchecked they can have unforeseen impacts on process operations that could result in unplanned shutdowns. In addition, repeatedly having to re-zero or recalibrate a pressure instrument due to overpressure events uses manpower that could be employed elsewhere in the facility.

In situations where the overpressure event is severe enough or prolonged enough, the diaphragm or the sensor can be irreparably damaged. When this occurs, the only option is to replace the damaged instrument. It can be especially costly and time consuming if the instrument has remote diaphragm seals and capillaries.

Figure 2: Five-valve manifold (to left of transmitter) is used to isolate a pressure instrument's sensor so it can be removed from the line, re-zeroed or calibrated.

Tough Instruments

While this sounds dire, it's incorrect to assume that all instruments are built the same and have the same limitations when faced with an overpressure event. It's important to understand if the specific instrument has internal systems to minimize the effects of overpressure, or if the sensor itself can handle high overpressure without the possibility of hysteresis errors (i.e., the difference in output at any measurement point when approaching the point first with increasing and then with decreasing pressure) or a significant risk of failure.

To understand what steps can be taken by manufacturers, it's important to consider the two most common types of pressure instrument sensors on the market: strain-gauge sensor typically used for differential pressure measurement and ceramic sensors typically used for static pressure measurement.

Strain-gauge sensors come in a variety of types such as piezoresistive, resonant frequency or capacitance styles. Regardless of the sensor type, there are two things common to strain-gauge instruments: metal process diaphragms and fill fluid.

Process diaphragms prevent direct contact of process fluid with the sensor. This can be accomplished both with either internal process diaphragms or remote seal diaphragms (Figure 3), each of which can also protect the entire instrument from elevated temperatures or aggressive chemicals.

These measuring diaphragms can be made from a variety of metals, but all are extremely thin to allow for greater sensitivity to small changes in pressure. As a result, these diaphragms can easily be damaged or even ruptured due to overpressure. In addition, overpressure or repeated cycling of process pressure can cause the diaphragm to deform, resulting in a shift in the measurement. It's important to remember that this can happen even at relatively low overpressures due to repeated cycling of pressure, even within what may be considered acceptable limits.

Expanding Fill Fluids

Hydraulic fill fluids are non-compressible and are used to transfer the pressure from the process diaphragm to the instrument's sensor. There are a wide variety of fill fluids that can be used for different applications. The most common types are silicone oils, which come in grades to handle different process temperatures.

In addition, there are inert oils for applications where silicone is not acceptable, and food-grade fluids for use in food and beverage or pharmaceutical applications. All fill fluids can expand during upset conditions such as elevated process or ambient temperatures or pressures.

This expansion can cause significant overpressures on both the process diaphragm and the sensor, which can result in measurement shifts or irreparable damage to the diaphragm or sensor.

There are several ways for manufacturers to design oil-filled pressure instruments to better withstand overpressure events. These include taking steps to minimize the amount of fill fluid in the instrument, and then designing mechanical systems to absorb the force of the overpressure and keep it from reaching the instrument's sensor.

As previously mentioned, fill fluid expands and contracts according to the process and ambient temperatures of the application. The best way, therefore, to minimize the expansion effects of the fill fluid is to use as little fill fluid as possible. This requires careful design of the instrument to minimize the volume of fill fluid while still having enough fill fluid to maintain the sensitivity of the measurement.

One way this can be accomplished is by minimizing the space between the process diaphragm and the sensor body. Many manufacturers machine the sensor body to match the pattern pressed into the diaphragm. Some even go the added step of hydroforming the process diaphragm against the machined sensor body to ensure an exact match between the diaphragm and the sensor body, resulting in the smallest possible volume of fill fluid in the system.

Some manufacturers are looking to new diaphragm designs on remote seals to better address the effect that temperature has on the fill fluid and the subsequent overpressure that can occur during temperature swings. Remote seals such as the TempC Diaphragm from Endress+Hauser (Figure 4) are designed to greatly reduce the temperature-induced error caused by fill fluid expansion and the resulting overpressure applied to the sensor.

Manufacturers are also implementing internal systems to mechanically minimize the force of overpressure reaching the sensor, allowing the sensor to withstand overpressure without the damage or shift to measurement output normally associated with such events. To address overpressure, these manufacturers are including internal overpressure diaphragms in the sensor body. Rather than act as a thin, sensitive metal barrier to transmit the pressure to the sensor, these overpressure diaphragms are thicker pieces of metal designed to absorb the force of the overpressure.

One of the easiest ways to eliminate fill fluid problems is to employ electronic DP level systems, which eliminate the need for impulse lines or capillary tubes because the sensors connect to the transmitter via wiring. Each sensor is equipped with electronics to convert its reading to a value suitable for sending to the transmitter over commonly used electrical wiring.

Figure 3: Remote seals, as on this Endress+Hauser Deltabar pressure instrument, protect the sensors.

Figure 4: Endress+Hauser TempC remote seal protects the fill fluid from high temperatures.

Cue Ceramics

Oil-filled transmitters make up the majority of industrial installations of pressure instrument, but there are many static pressure applications that can use ceramic sensors that are particularly well-suited to handle overpressure. The major difference between ceramic sensors and oil-filled sensors is the use of a ceramic diaphragm versus a metal diaphragm. The other is that ceramic sensors do not have fill fluid.

The use of ceramic (Figure 5) as the diaphragm material has several benefits in terms of overpressure. The first is that ceramic is extremely hard and rigid, so it will not deform as easily during an overpressure condition. The second is that ceramic is hysteresis-free, meaning that it does not develop a memory when excessive pressure is applied. As a result, a ceramic sensor can be exposed to up to three times the amount of overpressure of an oil-filled sensor—with no adverse effect on the measurement, no memory developing at the diaphragm and no damage to the diaphragm or sensor.

Figure 5: This Endress+Hauser Ceraphire ceramic sensor can withstand three times the overpressure of an oil-filled sensor.

Summary

Modern pressure instruments are highly accurate and provide excellent long-term stability, with a variety of diagnostics to provide greater insight into the process, but they are still highly susceptible to the overpressure events. By better understanding the application and the sources of overpressure, as well as knowing options available from manufacturers, process owners can better avoid the possibility of costly process problems caused by overpressure.

About the Author

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