Pressure Measurements in Distillation Columns

Distillation columns use multiple sensors to measure pressure in different sections. For full optimization, it is very important for these pressure devices to work safely and reliably.

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Figure 1: A catalytic reforming unit converts naphtha into high-octane aromatic compounds.

Distillation separates mixtures of liquids by exploiting differences in the boiling points of the various components (distillates). It is used in a wide variety of industry segments including oil & gas, chemical, food & beverage and pharmaceutical. Distillation processes involve equipment such as distillation columns (Figure 1) with trays or packing, reboilers, condensers and reflux drums.

Pressure measurement is one of the most critical parameters for control of distillation processes. A distillation column typically has multiple sensors to measure pressure in various zones (Figure 2). In some cases, redundant measurements are required.

Pressure is measured in a column because separation of fluid in distillation occurs at the specific pressure and temperature required to boil the fluid. If it doesn't maintain a certain pressure, then more or less energy can be required for the separation. This can be unsafe depending on the chemicals involved, and may run the process inefficiently, causing product loss and bad yield issues.

For full optimization, it's important that a desired pressure profile is maintained per process requirements. To maintain the pressure profile, the pressure instruments must work safely and reliably, which requires proper selection, calibration and maintenance.

This article will discuss issues found when measuring pressure in distillation columns and will review solutions, selection criteria and safety.

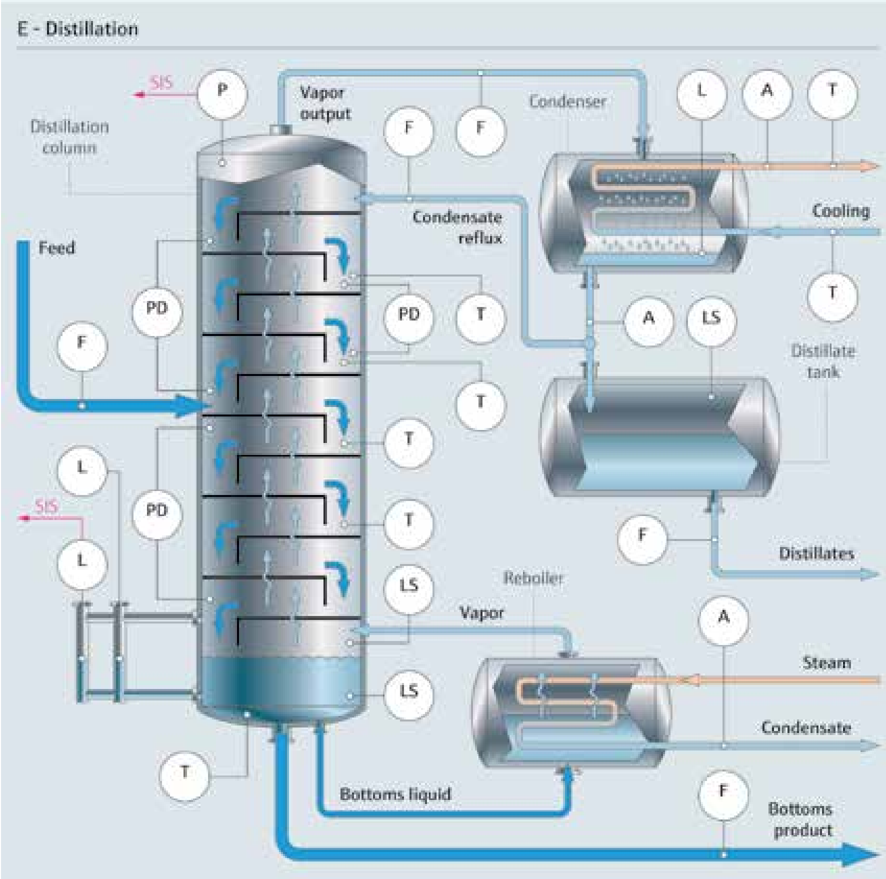

Figure 2: Pressure measurements (P) are taken at multiple locations in a distillation column.

Ambient Temperature Challenges

Pressure sensors are typically installed at multiple points on a distillation column, and an output from each is normally sent to a pressure transmitter via an impulse line, or a remote diaphragm seal with capillary tubes (Figure 3). Transmitters are located at ground level, typically in an enclosure for protection from the elements and environment. A pressure sensor/transmitter combination is referred to as a pressure instrument.

Figure 3: Diaphragm seal and capillary tubes. The capillary tubes may have to run more than 100 ft. to reach the transmitter.

The capillary or impulse tubes—which may have to reach from the top of a 100-ft tower to ground level—are often exposed to the environment, and are therefore subject to temperature extremes.

Ambient temperature changes affect the fill fluid in impulse tubes or capillaries, which in turn has a negative impact on the reliability of pressure measurements. Pressure transmitters by design assume the density of the fill fluid in remote capillary legs is constant. As ambient temperature changes from day to night and from one season to the next, the density of the fill fluid fluctuates as well.

These fluctuations are interpreted by the transmitter not as changes in fill fluid density, but rather as changes in pressure. If not accounted for, these fluctuations can result in significant measurement deviations, posing problems to the reliability and safety of the process.

Typical solutions to counter these fluctuations with traditional remote diaphragm seal configurations range from insulating and/or heat tracing, to installing critical distillation columns in climate-controlled buildings.

These solutions are costly to implement and maintain, and are therefore not typically considered acceptable methods for handling ambient temperature-related drift. Fortunately, new manufacturing methods for remote diaphragm seals address these ambient temperature related issues, as we'll discuss below.

Tough Environment

Most distillation columns run under vacuum conditions for greater efficiency and lower energy consumption. High temperature is required for some processes as well. Vacuum service combined with high temperatures can present many challenges to pressure instrumentation.

Deformation of diaphragm seals and flanges may let atmospheric air enter the vacuum column. Extreme expansion of the fill fluid in remote seal systems can cause seal failure and—in severe cases—cause chemicals to release through damaged flanges and seals, posing potential plant safety issues.

Vibration of the column can cause damage, intensified by mounting issues such as close-coupling to the vessel. Thermal shock is another issue, particularly when the transmitter is mounted too close to the column due to short capillary lengths.

Another challenge is leaking fill fluid into the process as a result of damage to diaphragm seals. Depending on the process, this can result in impurities, causing distillates to be over or under the specified range.

Seal and Fill Developments

To counter these problems, pressure instrumentation suppliers have developed three improvements:

- Asymmetrically flexing diaphragms in remote seals
- Better seal fluid filling techniques
- Elimination of impulse tubes and capillaries

A conventional diaphragm on a remote seal moves symmetrically when pressure is applied and has a high degree of stiffness. This requires thinner or larger diameter diaphragms to provide adequate measurement sensitivity. This common characteristic makes the diaphragm seal more susceptible to impact from process and/or ambient temperature changes.

When using remote diaphragm seals with oil-filled capillaries, the common practice is to use the largest process connection possible and allowable per process requirements to reduce the impact of temperature-induced errors on the measurement. With conventional diaphragms, thermal error for a 2-inch flange is three times greater than that of a 3-inch flange. Often, facilities use concentric reducers or other such adapters to increase the size of remote seals and improve measurement reliability.

Some manufacturers of diaphragm seal systems have recently started using seals that flex asymmetrically in opposite directions around the center point. The result is a diaphragm seal that flexes predictably with good repeatability while using less fill fluid. This allows for thicker diaphragm seals, providing greater durability while still maintaining the sensitivity required for adequate turndown.

This technology significantly reduces thermal errors, even while using smaller remote seals. For example, a 2-inch flange with an asymmetric membrane provides better measurement stability and faster recovery from thermal shocks than a 3-inch flange with conventional diaphragms.

Recently, some manufacturers have begun using new filling processes to address temperature issues. This is because the diaphragm seal, capillary and transmitter is a closed system. The closed system must never be opened, because it allows escape of the fill fluid, which adversely affects temperature and response time effects.

In these new processes, the filling of the fluid under deep vacuum conditions is still similar to standard procedures. However, the amount and type of fill fluid is now pre-determined for each seal system; that is, the instrument supplier fills the seal system with fluid to meet specific temperature and environmental requirements of the particular application. When the fill is performed, the amount of fill fluid that goes into the diaphragm seal system is measured to ensure the device is filled completely.

Because the fill fluid is closely controlled and chosen for the specific application, it is less susceptible to temperature changes.

Eliminating Fill Fluids

To completely eliminate impulse tube and capillary problems, instrument makers now offer pressure sensors with a digital output (Figure 4). The sensor measures gauge or absolute pressure and sends signals back to a pressure transmitter electronically.

Figure 4: A digital output from the Endress+Hauser Deltabar FMD72 eliminates the need for impulse lines or capillary tubes.

For example, the Endress+Hauser FMD72 uses a 4-20mA HART loop to connect the two pressure sensors to the transmitter. The 4-20mA loop provides enough power for the A/D converter in each sensor to convert the pressure signal and impose it onto the 4-20mA signal, along with status and diagnostic information.

Selecting Pressure Sensors

When selecting the correct pressure sensor for installation into a distillation column, several criteria should be considered to provide reliable and safe pressure measurement:

- Measurement span: The span should be 25% more than the pressure range for better accuracy and to accommodate future pressure range changes.
- Material of construction: Diaphragm seals and other wetted parts of the measuring cell should be compatible with the material of the process flange. At a minimum, it should be stainless steel. Depending on the chemicals involved, exotic materials, such as Hastelloy C, Inconel, Monel, Platinum and even gold may be needed.
- The process connection should be 1 to 2 inch at the minimum.
- Measuring cell fill fluid: Consideration should be given to the process and ambient temperature range of the application, as well as the presence of vacuum conditions. Users should consult with the pressure sensor manufacturer to select a suitable fill fluid for the measurement cell and—if used—for the impulse tubes or capillaries.
- Flushing rings should be ordered with diaphragm seals wherever possible and allowed in the process to provide a means to clean diaphragms without removing remote seals from the process.

Summary

Pressure is one of the most common process variables measured in distillation processes. While pressure measurements with remote diaphragm seals have become common in such applications and are considered reliable and safe, they are prone to issues related to ambient temperature. These issues can have an adverse effect on both reliability and safety of the measurement.

Typical solutions to addressing temperature effects on measurement are costly and maintenance-intensive. However, recent developments in remote seals, seal-filling methods and electronic transmission of pressure signals helps minimize these problems and provide more reliable pressure measurements.

About the Author

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