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Foster These **Flow Best Practices**

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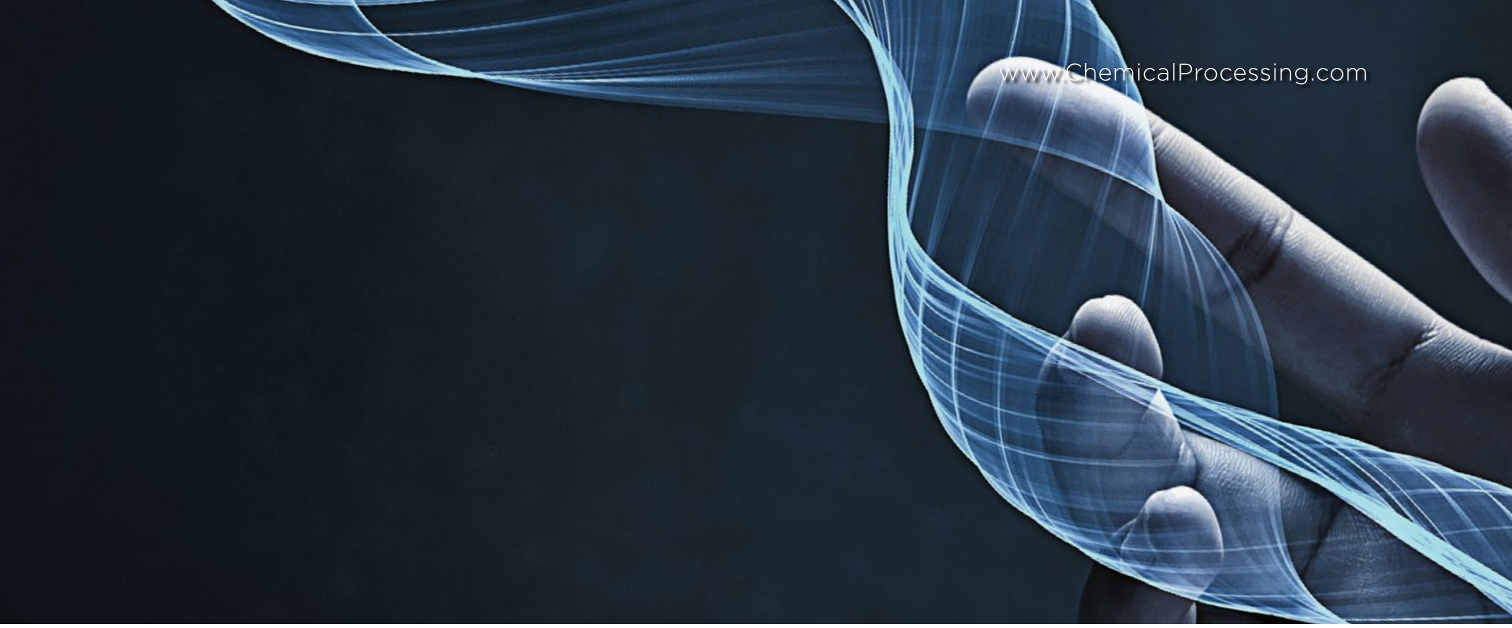


AD INDEX

Can Your Pump Cope with Process Changes?

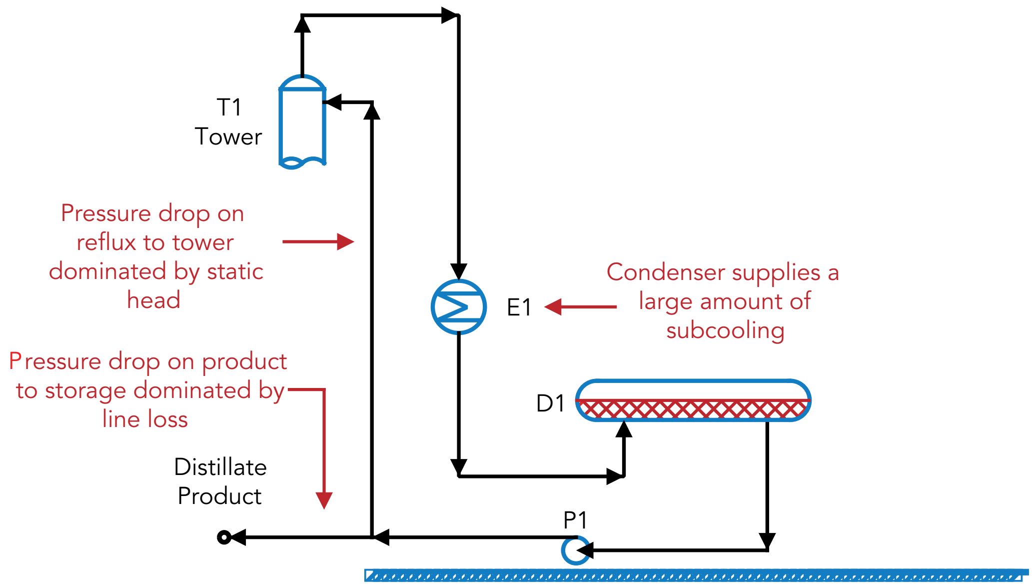
Understand the possible impact of changed dynamic head

By Andrew Sloley, Contributing Editor

Pressure demands in pumped liquid systems come from dynamic and static sources. Friction in the system causes the dynamic losses. For Newtonian fluids, these losses are proportional to the square of the velocity in the system. If flow rate doubles, dynamic pressure drop increases by a factor of four. Static head changes stem from elevation differences or pressure differential between the source and the destination reservoir — and vary with system levels or pressures, not with flowrate. We can simplify the overall terminology to a dynamic pressure change (varying with flow) and a head pressure change (varying with pressure or elevation).

The specific application determines the relative impact of these two factors. Pressure demand for a pump shifting liquid between two atmospheric tanks with close to identical liquid elevations stems almost completely from friction losses. In contrast, the demand when pumping at a low velocity from the ground to a storage tank at a high elevation comes nearly exclusively from head pressure change. Of course, many systems have both dynamic losses and static head changes.

Figure 1 illustrates a system where one pump (P1) sends liquid to two destinations. The pump provides reflux to a distillation tower and also propels the distillate product to storage. Head change dominates pumping the reflux; pressure drop variations due to flow rate changes in the return pipe have very minor impact. On the other hand, pressure demand in pumping the product to storage comes nearly completely from



DEVIATION NOT CONSIDERED

Figure 1. Published pump curve indicated unit was controllable at desired rates for providing reflux and sending product to storage.

dynamic losses; the liquid elevation in the storage tank has hardly any effect.

This system worked without significant problems for many years. However, after a plant expansion, the unit operators complained about difficulty controlling the level in the overhead reflux drum. The source of the problem was interaction of tower performance, changes in dynamic pressure loss for the product, and the head requirements for reflux.

Centrifugal pump discharge head decreases with pump throughput. As the reflux plus product rate rises, discharge head from P1 drops. Pressure requirements on both the reflux line and the product line tightly constrain this system. As the pump discharge head falls toward the pressure requirement for the reflux return, the system works until it reaches a critical limit. This limit slightly exceeds the head requirement imposed by the tower elevation. Because static head dominates the reflux system, if pump discharge head falls even a little below the critical value, reflux rate drops rapidly, even reaching zero in some situations.

The reflux is highly subcooled in this unit. Inside the tower, subcooled reflux condenses rising vapors. If the reflux return rate drops, the vapor rate to the overhead condenser rises. This results in the need to pump even more liquid out of the reflux drum.

Because the product line also tightly constrains the pump, the higher liquid rate can't be returned to the tower or sent down the

A long-in-service pump's dynamic head can vary from the published curve.

product line. The overhead reflux drum fills rapidly.

The operators' solution to avoid a runaway level in the drum is to ensure the tower always has enough reflux. As needed, the operators turn the level controller on the drum off, setting the overhead product rate in manual. This keeps the pump flow rate down (and head up).

But where does the liquid product go? The operators allow the drum level to rise when suppressing the product rate. Eventually, upstream changes enable a lower reflux rate and a drop in drum level while staying within the pump's capacity. That capacity is so tight that for at least 30% of the time the operators are running the drum level on manual to prevent a runaway drum level.

Calculations showed the unit should be tight — but still controllable at the desired rates. This assumed the pump would operate on its specification pump curve. However, many pumps in service for long periods don't operate exactly on their pump curve. With standard maintenance, plants should expect dynamic heads from centrifugal pumps to vary by as much as 5% from published pump curves. In this situation, 5% changed a pump at the limit to one that really couldn't perform the job.

So, don't presume that future pump performance will match the published curve. Check what a 5% drop in head would do for every destination to which that pump sends liquid. ●

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Produce Proper Pipe Specifications

Include adequate detail and appropriate background information

By Dirk Willard, Contributing Editor

The pressure to get the ammonia refrigeration pipe specifications done quickly was palpable. However, I've learned that, even on rush jobs, being correct is more important than being fast. Getting one complaint about late delivery beats facing never-ending gripes if the work is filled with errors.

I've written many pipe specifications. So, let me share some learnings.

First, it's important to realize the specifications must consider regulations and the desires of the operating company and engineering firm. Generally, give the maintenance staff's needs — improved reliability and reduced inventory — high priority. After all, they must maintain what you've specified.

Second, don't count on regulations for clear guidance. To prepare my ammonia pipe specifications, I had to sift through several standards for material-specific instructions for valves. Generally, organizations such as the American National Standards Institute, the American Society of Mechanical Engineers (ASME) and the International Institute of Ammonic Refrigeration don't provide comprehensive details you'll need for a pipe specification. The Chlorine Institute does a better job of defining valves suitable for chlorine service.

Next, let's dig into the weeds a little. Take, for example, hoses, a part of everyday plant life. Yet, organizations don't publish specifications. The State of California provides a comprehensive guide I found

Break a specification into two parts — engineering and tables.

useful; it requires a 500-psig test annually. Most companies won't bother with the risk of poor documentation and just toss the hose.

In the ammonia pipe specification, I accepted nylon as the inner and outer material for hoses smaller than $1\frac{1}{2}$ inches but said larger hose required braided stainless steel for the outer wall. This made sense to me because, for a given wall thickness, larger diameter pipe and hose must defend a bigger area than a smaller hose. You won't find considerations such as these in regulations or standards.

Another issue is the use of lap flanges. These consist of two parts, a flange and a stub that's welded onto the pipe. I worry a sloppy workman can compromise connection integrity. While these flanges may be useful in some low pressure applications, they tend to leak when subjected to thermal expansion or vibration. You certainly don't want them on a 450-psig chlorine railcar. Design engineers should avoid them.

Now, let's consider the structure of a pipe specification. Break it into two parts — engineering and tables. The engineering section supports the structure of the entire document while the tables section is meant for handing to constructors for use by their fabricators.

For engineering, provide the following sections: 1) scope; 2) delivery, storage and handling; 3) codes and standards; 4) related documents (process and instrumentation drawings, etc.); and 5) special topics. In addition, if any changes exist from past work at the plant, include a separate engineering design report.

The delivery, storage, and handling section merely should send the reader to a particular specification for ensuring items are delivered to the fabricators intact and in order. Don't just count on having a specification for this; review it and add to this section if it's insufficient.

Be as specific as possible with codes and standards. Quote sections and even cite crucial passages. Confirm that each passage applies.

Special topics include ones like corrosion allowances, use of alternative materials (e.g., stainless steel instead of carbon steel), welding practices, incompatible chemicals or procedures, acceptable ASME pressure class and unique inspection requirements.

The table is the heart of the pipe specification. Columns should cover in order: item, notes, size, pressure rating, type of end connection and description. The description should reference an ASTM standard. Items include valves, gaskets, pipe, fittings, tubing, flanges, hose and fasteners (bolts, studs and nuts). If you discourage the use of some items like valves, explicitly say why.

Add copious numbered notes to the bottom of the table. Fabricators must know the reason for the choices in the table. You want to convince them to make the right choices.

Painting and insulation are crucial but keep in mind that ASME B31.5, Paragraph 538.2 requires pressure testing of bare uninsulated pipe. After testing, B31.5, Paragraph 520.1.6 mandates application of a "weather-resistant" coating to all "parts." However, this doesn't mean painting flange bolts; don't do that. Sherwin-Williams recommends greasing the bolts to provide a protective coating.

Don't think of pipe specifications as mundane boiler plate. It's your chance to inspire safe construction practices. ●

DIRK WILLARD is a contributing editor for *Chemical Processing*. Email him at dwillard@putman.net

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Measure Reliably in Gas Entrained Medium

Meter ensures minimum flow for safe operation and reduced downtime

Ralf Haut, Krohne, Inc.

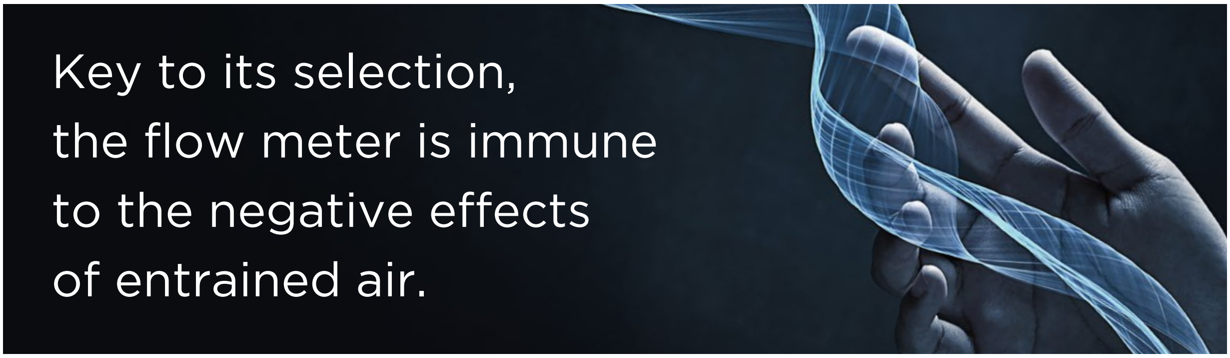
A chemical company in the wider Rhine-Main region in Germany operates a production plant for aldehyde reaction products. These intermediate products are used in the pharmaceuticals industry and agriculture and as curing agents in the manufacture of epoxy resins. The plant needed reliable mass flow meters for improved prodution performance and to ensure safe operation.

MEASUREMENT REQUIREMENTS

Equipment is in place for the production process to ensure plant safety and to minimize the risk to human health and the environment. The design is such that the safety function is controlled using continuous mass flow measurement by two measuring devices operating in series.

The two devices' measurement deviation is monitored as part of the safety concept. The liquids are transported at 70 °C/158 °F and at a density of approximately 1 kg/l or 0.036 lb/in^3. Because of the media's chemical properties and the nature of the process, there is recurrent gas entrainment.

The customer has used mass flow meters by a competitor in the past. However, the gas contained in the medium compromised the devices' measuring performance significantly. For example, when gas bubbles occurred, the measuring devices switched to error mode automatically. There also were major deviations in the readings. It was, therefore, impossible to obtain continuous, reliable measured values.



The operator set about looking for a new technical solution to maintain the safety function so it could measure continuously and reliably despite the occasionally very high gas content.

METERING SOLUTION

The customer opted for the OPTIMASS 6400 C. This Coriolis mass flow meter with twin bent tube design was supplied in a stainless steel version (1.4404/316L) and connected by flange. Because of spatial conditions, the device was installed at the highest point of the plant section, upstream of a descending pipe and on the suction side of a pump.

Key to its selection, the flow meter is immune to the negative effects of entrained air. Patented "Entrained Gas Management" (EGM) functionality enables the device to measure the mass flow continuously, even if entrained gas occurs. Instead of switching to error mode or freezing at the last stable measured value to circumvent the loss of measuring signal, the flow meter can track the measuring tube's actual frequency and calculate the flow reliably.

SAFETY AND REDUCED DOWNTIME

With the OPTIMASS 6400 C the operator can keep track of the flow reliably and continuously and ensure that it does not drop below the minimum. Because of EGM functionality, the two mass flowmeters continue to measure even with a high gas content in the medium. The chemical company no longer has to shut down its plant for safety reasons because of deviations between the two measured values.

The new devices work continuously. For the facility, this means more than just safe plant operation. The company also avoids unnecessary downtime and makes considerable cost savings as the safety equipment can be operated without interruption. This means a permanent increase in product quality and volume. ●

RALF HAUT *is technical manager, Global Industry Division Chemical, for Krohne, Inc. He can be reached at r.haut@krohne.com.*

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Article #4 Endress article

Advances Continue in Flowmeter Technology

Flow meters are getting smarter, smaller and more specialized

By Nathan Hedrick, national product marketing manager for flow, Endress+Hauser

Several of the trends in flowmeter technology simply are expansions, updates and refinements to existing technology, but two trends are turning the flowmeter industry on its ear: advances in flowmeter diagnostics and the adoption of smartphone-like technology to improve access, communications and, in the not-too-distant future, displays attached to flowmeters.

ELECTROMAGNETIC FLOWMETER
Figure 1. The tiny Picomag electromagnetic flowmeter from Endress+Hauser contains a sensor and transmitter in the same housing.

This article looks at trends involving tiny flowmeters, specialty flowmeters, advanced diagnostics, improved communications between flowmeters and the enterprise and the looming trend toward embodying smartphone technology into flowmeters.

TINY FLOWMETERS PACK CAPABILITY

Some flowmeters have been getting smaller over the years. Electromagnetic flowmeters (magmeters) probably lead the trend toward miniaturization, mainly because the size of the flow element need be barely bigger than the pipe or tube carrying the conductive liquid. Tiny magmeters now are available for pipe sizes as small as 0.5 in. (Figure 1).

Coriolis meters measure more than just mass flow rate.

Such tiny flowmeters are ideal for use on process skids, where space often is limited, or in difficult-to-reach locations.

Although tiny, these flowmeters pack extensive capabilities. The Picomag, for example, has 4-20mA, pulse, switch and 2-10V outputs. IO-Link digital communications connectivity provides flexible integration into automation systems. Its Bluetooth wireless interface provides direct access to process and diagnostics data and enables the user to configure the measuring device on the fly. The device can be operated and configured on Android and iOS devices via SmartBlue, Endress+Hauser's free app.

For 2020 and beyond, look for the miniaturization trend to continue expansion into other measuring technologies as well.

Like most flowmeter technologies, magmeters provide a volumetric flow measurement. However, many applications require mass flow measurement, an area in which Coriolis flowmeters excel.

MEASURING MASS FLOW

San Francisco-based Grand View Research says, "The magnetic segment holds the largest share in the market. However, ultrasonic and Coriolis are expected to register the highest compound annual growth rate (CAGR) during the forecast period owing to advancements in technology that make ultrasonic and Coriolis flowmeters highly reliable and accurate."

In its 2018 flow meter market report, Grand View projected a rise in the use of Coriolis flowmeters, noting "Widespread adoption of Coriolis flowmeters in the oil & gas, chemicals and refinery sectors is anticipated to influence the market positively."

One of the main reasons for this increase is the ability of these flowmeters to measure mass flow. This capability used to come with a substantial price premium, but the price difference between mass flow meters and volumetric flow meters is dropping, spurring its use.

Ultrasonic flow meters are noncontact and can be used in very large line sizes. In the past Coriolis flow meters were used mostly on smaller line sizes, but another trend is its increasing size. Several companies offer Coriolis flow meters in line sizes more than 10 in., making them more suitable for use in ship loading and offloading applications. For 2020, expect a continued incursion by Coriolis meters into the overall flow market.

Additionally, users are recognizing that Coriolis meters have a lot of advanced capabilities beyond basic measurement. For example, most Coriolis meters measure not only mass flow rate but also density, temperature and sometimes even viscosity.

These qualitative parameters open up a world of possibilities for users, and there's a growing trend of viewing Coriolis meters as process analyzers. For example, in the oil and gas industry, Coriolis meters can offer a variety of values such as API-referenced correction of volume and density as well as net oil and water cut measurements. In the food and beverage industry, these same density and temperature measurements can be used to derive Brix, proof or % concentration of binary mixtures, among other possibilities.

So, while the price reduction between Coriolis and volumetric flow measurement technologies certainly is a consideration, the additional precision and multivariability are tipping the scales in favor of Coriolis meters for many users.

SPECIALIZED FLOWMETERS

Instrument engineers often used to have to make do with standard flowmeters. When an application was particularly difficult — abrasive, hot, cold, acidic or otherwise unfriendly toward conventional flowmeters — engineers specified stainless steel, ceramic or other liners for flowmeters and hoped for the best. This sometimes led to premature failures.

Today, the availability of exotic materials such as Tantalum, Hastelloy C, Monel, Inconel and a host of specialty alloys makes it possible to fabricate a flowmeter that can handle almost any fluid or gas. In addition, flowmeter manufacturers are more than willing to design and build devices to meet the needs of specific industries.

Complicating the situation are the never-ending and ever-changing regulations from agencies such as the U.S. Food and Drug Administration (FDA), European Union (EU), American Gas Association, the U.S. Environmental Protection Agency (EPA) and dozens of others calling for instrumentation to meet various specs.

For example, a hygienic flowmeter may have to meet American Society of Mechanical Engineers Bioprocessing Equipment (ASME BPE), European Hygienic Engineering and Design Group (EHEDG) and 3A standards and provide full Good Manufacturing Practice (GMP) compliance for sterile processes while at the same time withstanding clean-in-place (CIP) and sterilize-in-place (SIP) operations and high-pressure washdowns. This calls for a specialized flowmeter (Figure 2).

While the instrumentation world always has had specialty flowmeters, manufacturers are producing more devices to meet new regulations, solve new application problems and provide flowmeters for smaller and smaller market niches.

Thanks to improved manufacturing techniques, laser 3-D printing, computer modeling and simulation and advanced microelectronics, manufacturers now can produce specialty flowmeters much faster than before, allowing them to dominate a market quickly.

SMART FLOWMETERS GETTING SMARTER

So-called “smart flowmeters” have been in use for decades, but they are getting much smarter these days and now are capable of self-diagnostics and self-verification.

CORIOLIS FLOWMETER
Figure 2. The Endress+Hauser Proline 300 Coriolis flowmeter is a specialty device for use in hygienic applications.

Self-diagnostics means that the flowmeter can detect when it has a problem by continuous monitoring of relevant internal parameters related to its mechanical, electromechanical and electronic components.

Typically, a failure mode, effects and diagnostic analysis is used during the flowmeter’s design phase to identify critical components in the signal chain, starting at the process-wetted parts and followed by the electromechanical components, amplifier board, main electronic module and outputs. A proper margin of safety then is assigned to every critical path or component.

Firmware in the transmitter monitors the entire signal chain for deviations continuously. For example, if the diagnostics detect an error, Endress+Hauser’s Heartbeat Technology sends an event message that conforms to User Association of Automation Technology in Process Industries (known as NAMUR) recommendation NE 107. The event is displayed on the flowmeter’s front panel and can be sent as a message over a digital communication link to the automation system. The message also includes troubleshooting tips and remedial instructions.

It now is possible to design flowmeters with a self-diagnostics coverage of 94% or higher (in accordance with International Electrotechnical Commission (IEC) 61508) and very low rates of undetected failures. Many but not all flowmeter manufacturers employ a similar type of self-diagnostics, but a new trend is toward self-verification.

Depending on the industry, flowmeters must be calibrated periodically. For example, the chemical industry has requirements for proof testing per IEC 61508 and IEC 61511, while the oil and gas industry must adhere to contractual agreements between buyer and seller and comply with government agency mandates.

But why remove a flowmeter and take it to a lab for calibration if it doesn't need it? Enter self-verification.

A self-verification is done on command from the automation system or at the instrument itself. During self-verification, diagnostics perform checks, and then a report is generated that can be used to verify that the device still is working properly. For example, Endress+Hauser's Heartbeat Technology complies fully with the requirements for traceable verification according to DIN EN ISO 9001:2008, Section 7.6a, "Control of monitoring and measuring equipment."

Self-verification will continue to expand because it saves time and money. Performing self-verification on a flowmeter can extend calibration cycles by a factor of 10 or higher. In some cases, it even may be possible to replace wet calibrations completely with self-verification.

ENTERPRISING FLOWMETERS

Flowmeters used to be wired back to an automation system via a simple but limited system involving 4-20mA wires encased in conduit or laid in a cable tray. At the automation system, the single process variable flow signal was used for control and monitoring of a unit or a process.

The current practice is to use a digital data link to send not only the flow process variable to an automation system but also many other data points related to variables, diagnostics, calibration, etc.

HART, Foundation Fieldbus and Profibus PA/DP have been available for many years, but other industrial Ethernet protocols are growing such as EtherNet/IP and Profinet. Wireless transmission protocols, such as ISA100 and WirelessHART, also are available with some types of flowmeters. For flowmeters not available with wireless communications, adapters are available to convert a 4-20mA or HART output to WirelessHART.

With modern microelectronics, flowmeters (Figure 3) now offer many communications options.

For example, the Endress+Hauser Proline 300/500 Coriolis and electromagnetic flowmeters come with 4-20mA HART, Profibus PA, Foundation Fieldbus, Modbus, EtherNet/IP or Profinet interfaces, as well as recently added Web server, WLAN and LAN capabilities. The new interfaces for networks allow a customer to access the device from anywhere in the plant — or anywhere in the world, for that matter — depending on how it is set up.

One recent advancement is the incorporation of new protocols to ease the connection to an enterprise network. For example, the Proline 300/500 flowmeter has an OPC-UA erver application package built into the flowmeter that allows the device to communicate with an OPC-UA client and be integrated into Industrial Internet of Things (IIoT) applications.

STANDARD COMMUNICATION INTERFACES
Figure 3. Many flow instruments now come with standard communication interfaces and with LAN, WLAN and Web server capabilities for connecting directly to the enterprise.

This is accomplished through networking the flowmeter via either LAN or WLAN. This allows the distributed control system (DCS) or programmable logic controller (PLC) to be dedicated to the control function while this additional path of communication can be dedicated to diagnostic, monitoring or reporting purposes.

What all this means is flowmeters can now shortcut the once complex procedure of getting flow and status information to supervisory control and data acquisition (SCADA), computerized maintenance management system (CMMS), enterprise resource planning (ERP) and other enterprise-level networks. With these new communication capabilities, the software easily can access the data it needs directly from the device. The

SMARTPHONE-MANAGEABLE FLOWMETERS
Figure 4. WLAN, Bluetooth and Web server interfaces allow technicians to monitor, diagnose and configure flowmeters from smartphone apps.

trend will continue to be for more and more flowmeters to offer direct connection to the enterprise network.

WIRELESS CAPABILITIES

Mobile technology also is working its way into flowmeters. As we've seen, flowmeters already can have wireless, Bluetooth and Web server capabilities, which means flowmeters can be accessed, probed, configured and diagnosed over smartphones, tablets and handheld devices (Figure 4).

What already is in place is evident in the aforementioned Picomag. It features an autorotating display that self-orients based on the meter installation.

In the future, the incursion of smartphone technology likely will expand. For example, many displays feature optical or infrared "buttons" so that maintenance can interact with the devices through the cover. This allows for operation in hazardous areas and ensures the housing remains sealed from environmental effects such as humidity and rain.

The industry will continue to see improved interaction with flowmeters that mirrors more closely the way we interact with mobile devices such as smartphones and tablets. ●

NATHAN HEDRICK is national product marketing manager for flow at Endress+Hauser. He can be reached at Nathan.hendrick@us.endress.com

Follow These 6 Tips for Sight Glass Selection

Knowing the forces detrimental to the glass can prevent a system shutdown or catastrophic failure

By John Giordano, L.J. Star

Sight glass applications require varying levels of consideration during the design phase. In all applications, sight glasses will be subjected to forces involving pressure, temperature, thermal shock, caustics, abrasion or impact. The design approach to each application must take these conditions into account. Table 1 compares several types of site glasses and their ability to withstand these various conditions.

The risks are real. When a sight glass fails, it can be extremely dangerous. When a sight

	Temperature Application	Thermal Shock Resistance	Corrosion Resistance	Abrasion Resistance	Pressure Capability	Impact Resistance
Glass Disc Soda Lime	Up to 300°F	Poor	Poor	Poor	Moderate	Poor
Fused Sight Glass Soda Lime	Up to 300°F	Moderate	Poor	Poor	Good	Good
Glass Disc Borosilicate	Up to 500°F	Good	Good	Good	Good	Good
Fused Sight Glass Borsilicate	Up to 500°F	Good	Good	Good	Excellent	Excellent
Quartz Disc	Above 500°F	Excellent	Excellent	Excellent	Good	Moderate

COMPARISON OF SIGHT GLASSES FOR CRITICAL APPLICATIONS
Table 1. Determining the right site glass for a critical application will depend on their ability to withstand various conditions.

glass fails catastrophically, it can cause severe operator injury and even death.

Furthermore, a catastrophic sight glass failure can create costly downtime. In a system made primarily of metal, the weak spots generally are sealing joints and glass. Typically, the failure of a sight glass on a piece of equipment or within a piping system will halt the whole process until the equipment can be repaired or replaced. Moreover, this failure may lead to scrapping the process media. In a pharmaceutical process, the product loss could cost millions of dollars.

Extreme forces, whether internal or external, can have a detrimental impact on the glass components' visibility and strength. Even minor cracks, scratches or abrasions can be a source of weakness within the glass and most likely will lead to failure.

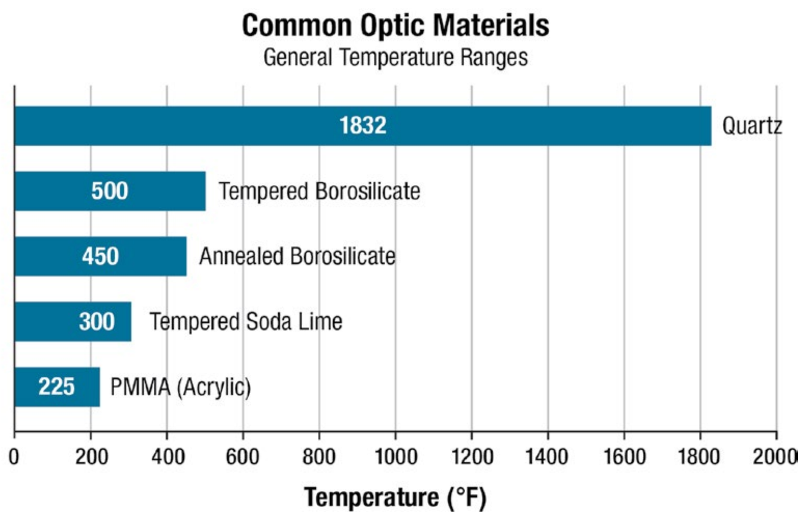
Sight glasses are highly engineered products (Figure 1). These tips on how to select a sight glass will help you to meet your critical application needs. Six conditions — temperature, thermal shock, corrosion, abrasion, pressure and impact — and how to design for them, are addressed.

TEMPERATURE

The temperature within a process system will have an effect on the sight glass. One must consider all possible extremes within which the sight glass must be able to operate. Depending on the temperature range, certain glass types will perform better than others. At temperatures less than 300°F, standard soda lime glass may be used unless the application is for pharmaceutical processing, requires resistance to corrosive chemicals or may be subjected to thermal shock.

SIGHT GLASSES
Figure 1. Sight glasses are highly engineered products designed to withstand harsh conditions.

For applications that involve temperatures up to 500°F, borosilicate glass may be used. At temperatures greater than 500°F, such as in high-temperature steam applications, quartz or sapphire glass is recommended. Figure 2 shows the general temperature ranges for common optic materials.



COMMON OPTIC MATERIALS
Figure 2. Quartz has the largest general temperature range for operations requiring sight glass.

ABRASION

Glass abrasion — physical wearing down of surface material — may occur with fluids that contain granular particles in suspension or with particles carried in process gases. This erosion of the glass may limit visibility and affect its strength. When designing for an abrasive environment, it is critical to prepare a routine maintenance schedule to evaluate the glass materials.

Glass material can be inspected either visually or using ultrasonic equipment, which is a nondestructive way to analyze the wall thickness and determine whether abrasives have reduced the glass material's thickness. It also is helpful in these conditions to mount a shield on the process side of the window to extend the useful life of a sight glass.

PRESSURE

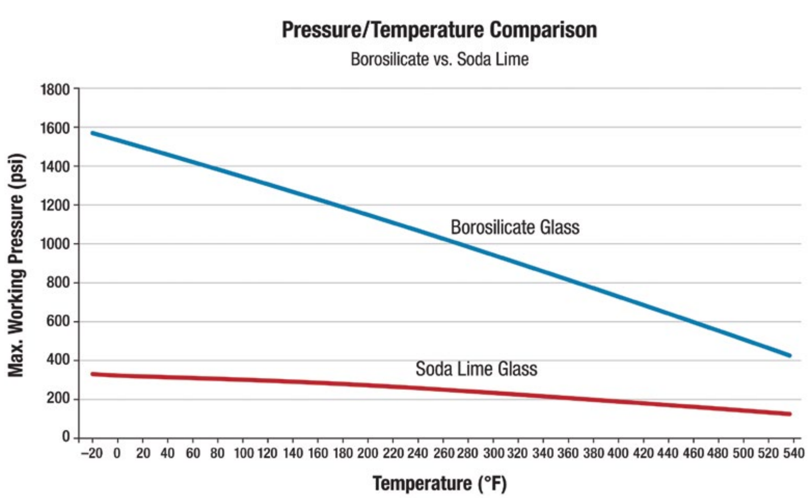
Pressure may be specified as working, design, test or burst.

- Working pressure is the maximum pressure allowable within an operating pressurized environment.
- Design pressure is the maximum pressure that the system has been designed to withhold, including a safety factor typically specified by American Society of Mechanical Engineers (ASME).
- Test pressure is the value typically specified by an end user to go above and beyond the vessel design pressure to ensure that the components will not only meet the design criteria but also incorporate a level of safety that exceeds it.
- Burst pressure is the amount of pressure at which a component will fail. Typically, this test is performed only in highly safety-critical environments such as nuclear facilities. Achieving burst pressure is a costly test as it requires the manufacturer to destroy the component.

The glass materials selected, the unsupported diameter and the glass thickness all play a role in determining a sight glass assembly's pressure capabilities.

The two types of sight glasses are a conventional glass disc and a glass disc fused to a metal ring during manufacturing. Conventional glass typically fails when subjected to significant tension. With fused sight glass windows, the metal ring's compressive force exceeds the tensional force (i.e., pressure) and, as a result, the sight glass will not fail. The metal ring squeezes the glass and holds it in radial compression.

Fused sight glass windows offer high pressure ratings and high safety margins. The strongest fused sight glasses are made from duplex stainless steel and borosilicate glass; this combination creates the highest compression. Figure 3 shows the operating pressure and temperature of fused borosilicate sight glass compared to fused soda lime sight glass at different temperatures.



PRESSURE/TEMPERATURE COMPARISON

Figure 3. This chart compares the operating pressure of fused Borosilicate sight glass and fused Soda Lime sight glass at different temperatures. ***Source: "Compression vs. Fusion in Sight Glass Construction" by Karl Schuller, Herberts Industrieglas GmbH. Used with permission.***

IMPACT

Some applications involve objects that impact the sight glass. An example is a food mixer in which hard chunks of matter may strike the glass. Another example is a wrench dropped by a worker that hits the sight glass. While these events seldom are enough to cause immediate failure, they can create scratches or gouges that may provide a point for tensional force to concentrate. It's always recommended that scratched sight glasses be replaced immediately. Fused sight glasses offer the greatest protection from these situations.

THERMAL SHOCK

Thermal shock can cause cracking as a result of rapid temperature change. Some glass types are particularly vulnerable to this form of failure due to their low toughness, low thermal conductivity and high thermal expansion coefficients. One situation in which thermal shock may occur is during washdown, when cold water comes into contact with a sight glass on a heated vessel. Thermal shock also can occur from within the vessel. This can take place during startup when hot or cold media are introduced or during clean-in-place/sterilize-in-place (CIP/SIP) operations.

During these situations, media are introduced at a temperature very different from that of the sight glass. Initial contact can cause a rapid temperature change in the glass, resulting in failure. Another thermal shock hazard can occur during autoclaving.

If thermal shock is a potential risk within the process system, then, at a minimum, borosilicate glass should be specified. Borosilicate glass has a considerably lower thermal coefficient of expansion than soda lime glass, making borosilicate glass more tolerant of sudden temperature changes. Fused quartz has even greater capability for more extreme temperature environments.

The following calculation is used in determining the thermal shock parameter or the resistance of a given material to thermal shock.

$$k\sigma T(1 - \nu)\ RT = \underline{\qquad\qquad}\ \alpha E$$

where: k is thermal conductivity, σT is maximal tension the material can resist, α is the thermal expansion coefficient, E is the Young's modulus and ν is the Poisson ratio.

CORROSION

Laboratory-grade glass is a formulation of minerals and chemicals that is inert to almost all materials except for hydrofluoric acid, hot phosphoric acid and hot alkalis. Certain process media are caustic or acidic and can etch the glass. The result is a cloudy view with weakened integrity that requires the sight glass to be replaced. Hydrofluoric acid has the most serious effect, where even a few parts per million will result in an attack on the glass.

Careful consideration of the chemicals present within a cleaning process is necessary to ensure that the glass material will not be impacted. For further details regarding the physical characteristics of borosilicate glass, ASTM E438 "Standard Specification for Glasses in Laboratory Apparatus" is available as a reference material. The useful life of a sight glass in these cases may be extended with shields mounted on the process side of the glass. Made of mica, fluorinated ethylene propylene (FEP) or Kel-F material, these shields are not as transparent as glass, so there is a tradeoff in visibility.

Corrosion also is a factor with the metal used in a sight glass window. Most system designers know which type of stainless steel must be used to handle their caustic or acidic process medium, and they will specify this steel to their sight glass supplier. In some cases, a sight glass may be mounted in such a way that the metal ring doesn't come in contact with the process fluid, and therefore lower cost steel may be used (Figure 4). With a bolt-on sight glass mounted on a vessel, only glass and Teflon are exposed to the process medium, thus, instead of expensive Hastelloy, lower cost carbon steel may be used in the sight glass ring (Figure 5). ●

BOLT-ON SIGHT GLASS
Figure 4. A bolt-on sight glass enables the metal ring to be mounted so it doesn't come in contact with the process fluid.

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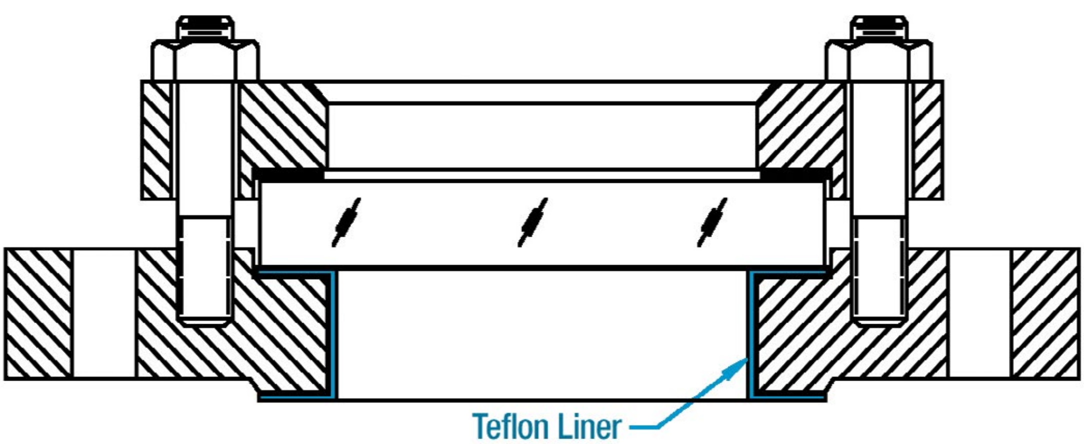

BOLT-ON SIGHT GLASS CUTAWAY
Figure 5. In this cutaway view of a bolt-on sight glass mounted on a vessel, only glass and Teflon are exposed to the process medium. Instead of expensive Hastelloy, lower cost carbon steel may be used in the sight glass ring.

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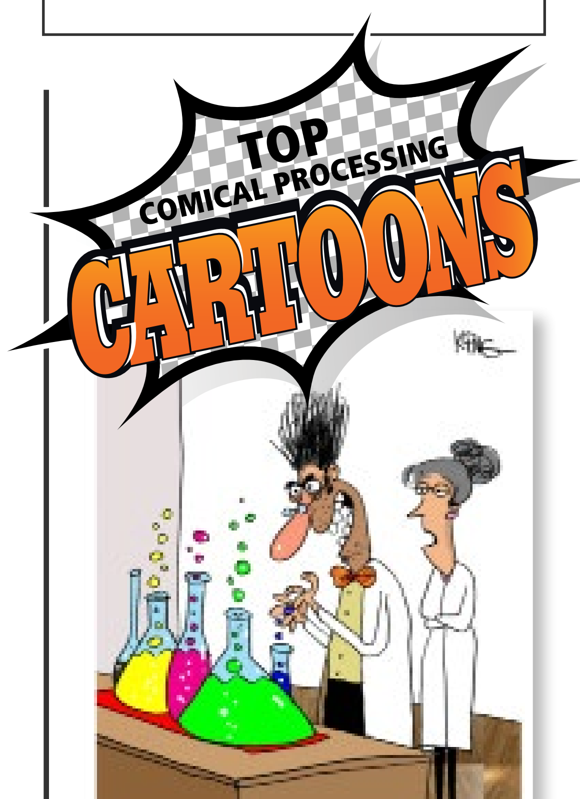

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