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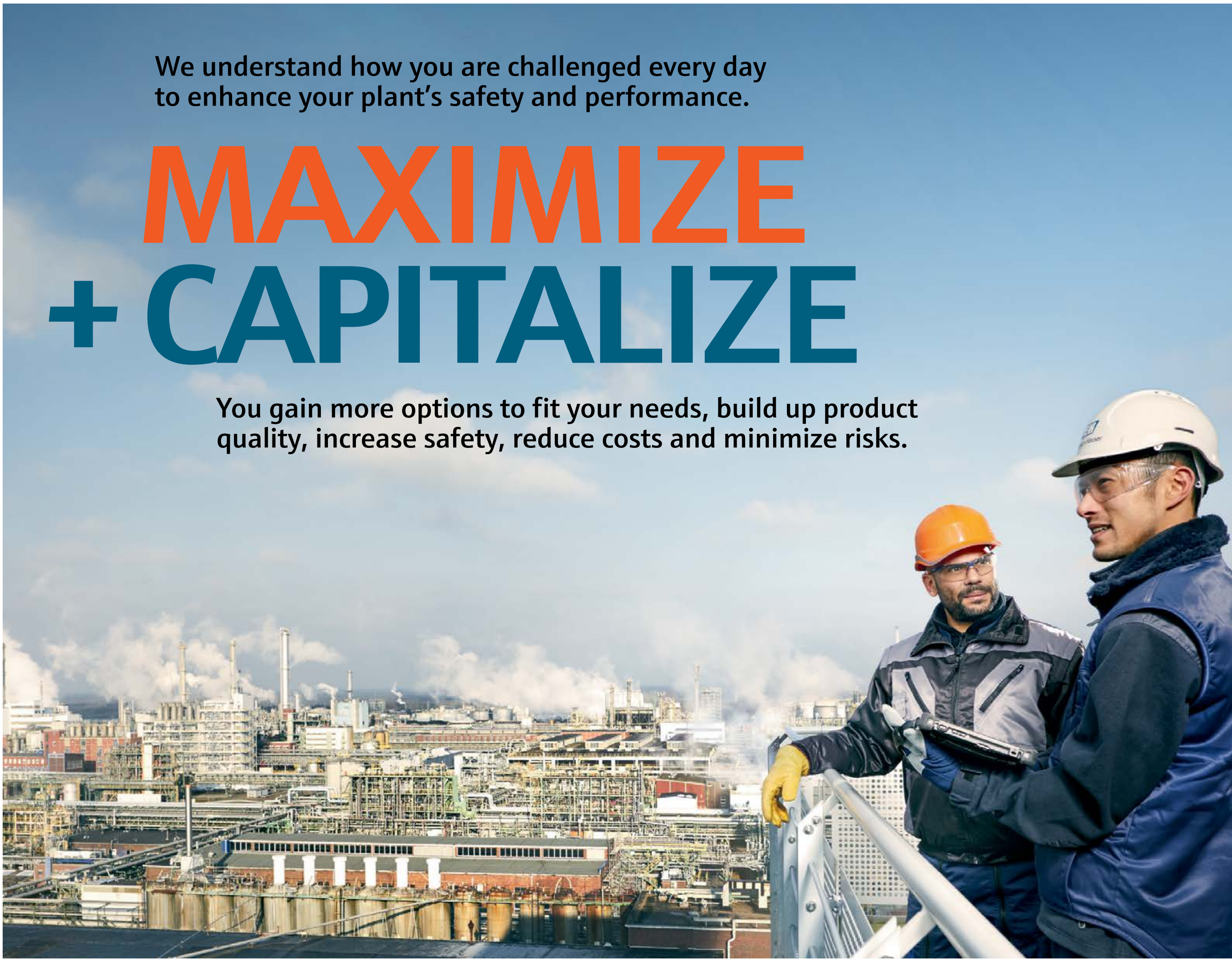

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AD INDEX

Prevent Suction Piping Problems

Follow best practices when designing pump systems

By Amin Almasi, mechanical equipment consultant

Piping issues can directly affect a pump's performance and life. Poorly designed suction piping can result in pump damage and even failure. Quite bluntly, there's no excuse for substandard piping design.

Numerous guidelines and mandates in the technical literature, textbooks, manuals, codes, specifications, etc., call for short and simple suction piping. Yet, some engineers and designers still treat such dictates only as preferences. They install pumps far from suction sources and design long and complex suction piping systems. I personally can attest that many design teams don't heed the guidelines for suction piping. They offer excuses such as there's no space near the suction vessel (tank or drum) or it's more convenient to install pumps near downstream equipment.

As a result, cavitation and other suction-related problems such as turbulence and air entrainment cripple pumping systems in many applications. Root-cause analysis of pump failures often points to long suction piping systems as the culprit. The solution to avoiding future failures usually is redesigning the suction piping to be as short, simple and straight as possible.

You should consider pump location and suction piping at the layout stage. It's simply wrong to fix the location of every vessel, drum or tank and leave pump locations for later. You also should anticipate the addition of small pumps in due course; for such cases, provide spare space around vessels, tanks or other equipment to accommodate these pumps right at the layout stage. In addition, make your best efforts to place any pumps close to the suction source.

Always explore any possible option to install pumps closer (even if only by 1 m) to the suction source. Pump textbooks and nearly all pump catalogues and manuals clearly note that suction piping should be as short, simple and straight as possible. Unfortunately, some design teams opt for the easiest design rather than correct one (as per guidelines).

THE BASICS

For any suction piping longer than a few meters, ensure that you provide enough net positive suction head (NPSH) margin, i.e., $NPSH_A$ - $NPSH_R$, for all potential operating points on the performance curve of the pump from shutoff to near the end of the curve. An adequate margin particularly is needed at or near the end of the curve where $NPSH_R$ is high and $NPSH_A$ is low (because of high flowrate).

Different guidelines offer various recommendations for margin, for instance, 1 m, 1.5 m or 2 m, depending on the criticality of the application, pump details, suction energy, sensitivity of pumps, potential damage due to cavitation, etc. A good recommendation is a minimum NPSH margin of 2 m for the commonly used operating range (say, 70–120% of the rated point) and a minimum NPSH margin of 1 m for the end of the curve to prevent risk of cavitation when the pump operates, even temporarily, at the far-right side of rated point.

Cavitation can cause a wide range of damaging and disturbing effects such as suction pressure pulsations, erosion damage, increased vibration, noise, etc. Check the margin for the worse possible operating cases, for instance, when the suction source is at its minimum head or liquid level, friction in suction piping is at its maximum, etc.

These guidelines may necessitate an increase in the suction piping size. For relatively long and complex suction piping, it's common to see suction piping up to four sizes larger than the size of the pump's suction nozzle; for instance, a 125-mm pump suction nozzle may require 250-mm suction piping (for a relatively long run). If such a size increase isn't viable, consider installing a drum or small tank near the pump to act as the suction source for it.

Connect the pump nozzle to an appropriate length of straight pipe, per the pump manufacturer's guidelines. As a very rough indication, the minimum length of straight pipe needed between an elbow (or any major fitting) and the pump suction nozzle is 4–12 times the diameter of the suction piping. For some high suction energy pumps, this straight length should be up to

> Keeping the suction piping short ensures that pressure drop is as low as possible.

15 times the diameter; for commonly used small pumps, which usually are low suction energy units, this required straight length is somewhere between three and six times the diameter of suction piping.

The straight-run pipe gives a uniform velocity across the suction pipe diameter at the pump inlet. Keeping the suction piping short ensures that pressure drop is as low as possible; this directly affects the NPSH margin. These two factors are important for achieving optimal suction and trouble-free pump operation.

For any suction piping not conforming to short and simple guidelines, check with the pump manufacturer. It's common to ask the vendor to review suction piping and make comments on the performance, functionality, reliability and all guarantees of the pump with that suction piping. The bottom line is that the pump manufacturer should confirm that the pump isn't affected by that suction piping. Remember that pump guarantees often are limited to two or three years, so correct suction-piping design is a better way to ensure proper long-term performance.

TURBULENCE AND AIR ENTRAPMENT

Sizing of suction piping isn't the only area requiring attention. Also, seriously evaluate route, layout and configuration. Suction flow disturbances, such as swirl, sudden variations in velocity or imbalance in the distribution of velocities and pressures, can harm a pump and its performance and reliability. For any suction piping a bit longer than usual or not straight and simple, ensure that adverse effects such as turbulence, disturbances, air entrainment, etc., won't affect the pump set.

Minimize the number of elbows in the proposed suction piping; numerous elbows might present swirl, disturbances and other damaging effects to suction flow and, consequently, to the pump. Eliminate any elbow mounted close to the inlet nozzle of pump. Especially avoid two elbows at right angles because they can produce sustained damaging swirls. There have been cases where a swirl introduced by two elbows in the suction caused high vibration of the pump and subsequent damage to it.

Another type of damaging flow pattern to a pump results from swirling liquid that has traversed several directions in various planes; therefore, avoid complex suction piping routes with multiple directional changes. Usually, the higher the suction energy and specific speed of a pump, in addition to the lower the NPSH margin, the more sensitive a pump is to suction conditions.

Also, eliminate the potential for air entrapment in the suction piping. One of the sources of air or gas entrainment is the suction tank or vessel. You must maintain adequate levels in the suction source (drum, vessel or tank) to keep vortices from forming and causing air/gas entrapment. In addition, ensure there's no air/gas pocket. Particularly avoid high pockets in suction piping; these can trap air or gas. Suction flanges or any connection with potential leaks can be a source of air entrainment; so, minimize the use of flanged connections and eschew threaded ones. Check that all piping and fitting connections are tight in suction vacuum conditions to prevent air from getting into the pump.

Velocity in the suction piping should rise as the liquid moves to the suction nozzle of the pump; this speed increase usually comes from reducers. The suction piping design should provide smooth transitions when changing pipe sizes. Often, two or three reducers are used (usually back to back) to decrease a large size of suction piping to the size of the pump's suction nozzle. Pumps should have an uninterrupted flow into the suction nozzle. Generally, install eccentric reducers with the flat side on top to avoid the potential of forming an air/gas pocket.

Treat isolation valves, strainers and other devices used on the suction side of a pump with great care. Eliminate them if possible. I have seen many unnecessary isolation valves or permanent strainers on the suction of pumps; these cause more harm than good. If you absolutely require a valve, strainer, etc., size and locate any necessary device to minimize disturbances of the suction flow. Install these flow-disturbing items relatively far from the pump to let the provided straight length of piping smooth and normalize the liquid's flow pattern.

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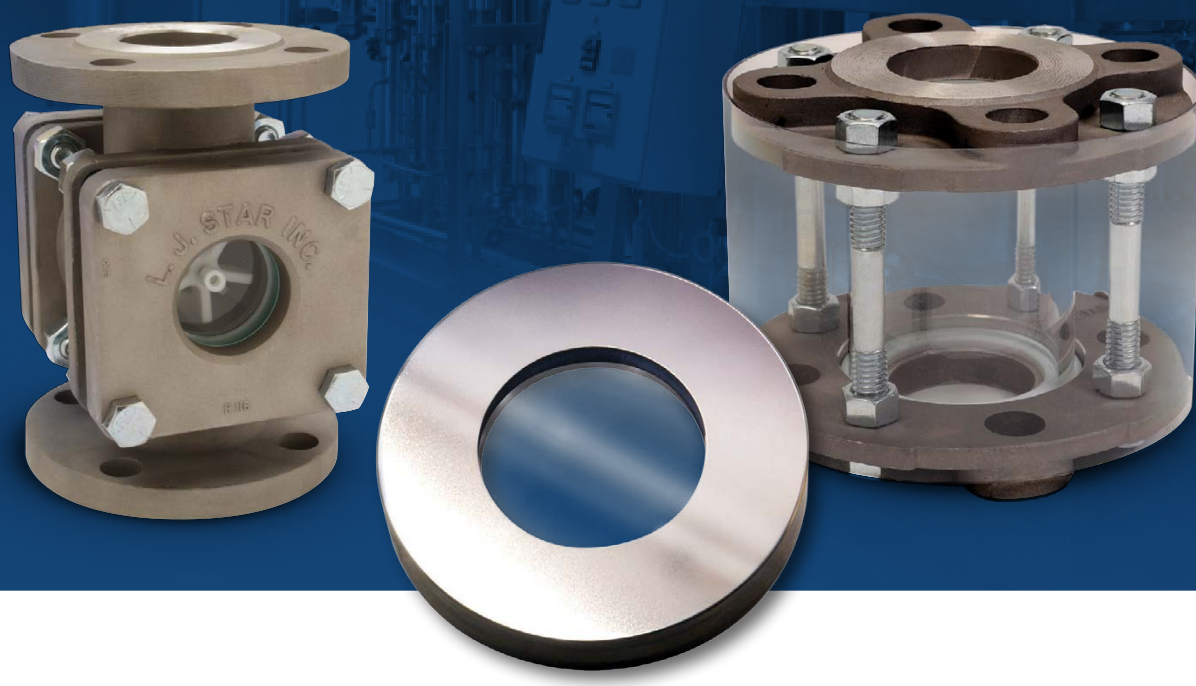

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Head Off Centrifugal Pump Problems

Attention to head tolerances can prevent poor performance and rework

By Jonathan R. Webber, Duncan J. Blaikie and Theresa R. Winslow, Fluor Canada

The oil and gas industry heavily relies upon centrifugal pumps designed to meet API-610 specifications [1]. Familiarity with the pump head tolerances allowed under API-610 is necessary to avoid disappointment with the performance of the purchased pump and additional costs due to rework. These tolerances can result in significant deviation between the expected and actual performance for high-head pumps (e.g., injection or hydrocracker charge pumps). While API-610 provides many other specifications and tolerances, here we'll focus on the tolerances related to the differential head at rated flow and maximum shutoff head.

As part of the procurement cycle, each potential pump vendor will recommend a particular unit and include a predicted performance curve. This performance curve demands careful evaluation to ensure the pump meets all specified requirements. During this review, the process engineer should check that the specified rated differential head requirement is met and that the maximum shutoff head doesn't exceed any system limitations.

After the purchase order is awarded and the pump is built, conducting a certified performance test is sensible. The certified

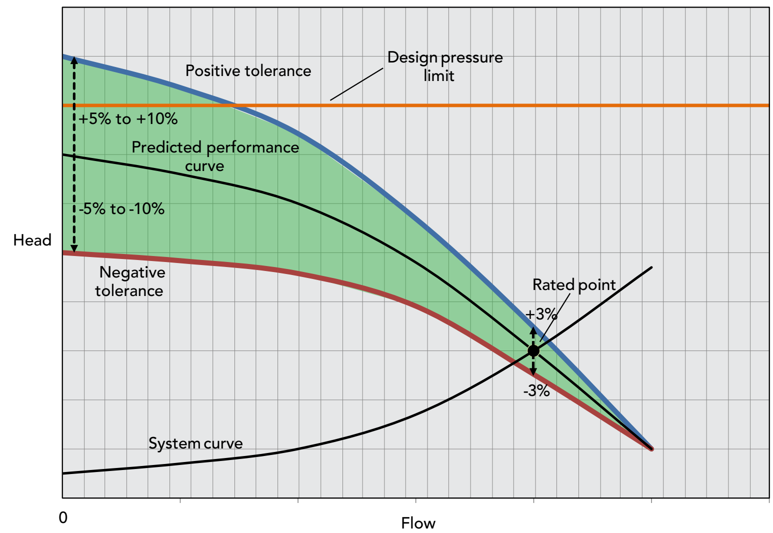
Rated Differential Head, m	Rated Point, %	Shutoff, %
0–75	±3	±10
>75–300	±3	±8
>300	±3	±5

PERFORMANCE TOLERANCES
Table 1. API 610 [1] considers these tolerances acceptable.

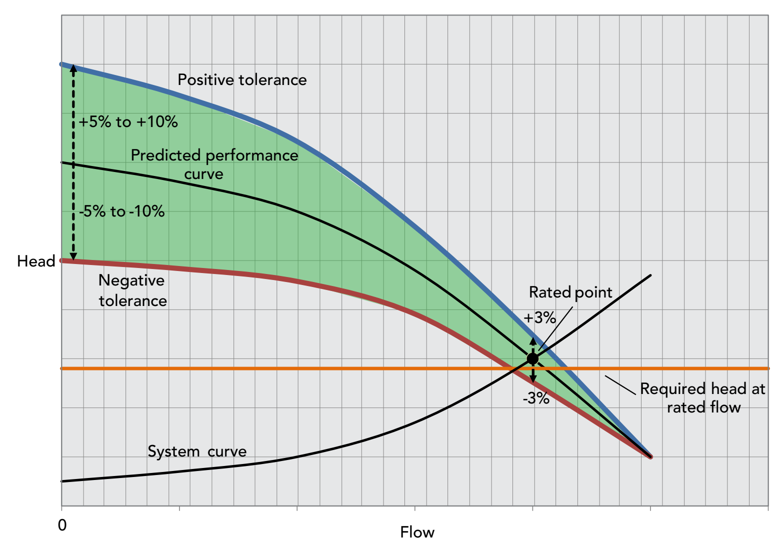
head at the rated flow and pump shutoff must meet the specified tolerances of the predicted performance described in the bid. Table 1 shows the allowable tolerances given in API-610.

POTENTIAL PROBLEMS

Let's now look at two scenarios where the allowable rated and shutoff head tolerances could create unexpected rework and impact project schedule/costs. Brownfield/revamp work can be particularly susceptible to risks because the pump must be integrated into existing systems and the flexibility to modify those designs may be limited.



SHUTOFF HEAD CONCERN
Figure 1. Positive tolerance at shutoff may lead to head that exceeds system design.



INADEQUATE HEAD ISSUE
Figure 2. Negative tolerance at rated flow may mean pump doesn't provide sufficient head.

Scenario 1: Positive tolerance at pump shutoff exceeds system design pressure. The pump shutoff head typically is selected such that it won't exceed design pressures of downstream systems. In certain revamp scenarios to avoid changing piping classes, rerating the piping/vessels or adding a pressure safety valve/high-integrity pressure protection system may be necessary to avoid exceeding design pressure. The proposed pump may be acceptable per the predicted shutoff head — but once the API-610 tolerances are applied, the actual shutoff head could be 5 to 10% higher.

Figure 1 illustrates how the allowable positive tolerance at shutoff can cause a certified performance curve to exceed the design limits of an existing system.

In this scenario, the pump impeller would need to be retrimmed and the pump retested to ensure the system design limits aren't exceeded. This also may impact the rated performance and feasibility of the selected pump.

Scenario 2: Negative tolerance at rated point results in an underperforming pump. Without considering the allowable tolerances of the rated head, the performance of the preliminary curve may appear acceptable. However, a negative deviation of the rated head may lead to a pump that underperforms. For example, a high-head cavern injection pump may require a rated head of around 2,500 m. API-610 allows a tolerance of ±3% of the rated head. If the certified pump has rated head 3% less than the predicted curve, then the pump could lose up to 75 m of developed head. In typical liquefied-petroleum-gas service, this can result in a loss of up to 370 kPa of developed head, which may be significant. The process engineer should consider the potential for reduced head and determine if the system has sufficient hydraulic capacity to absorb deviations between the predicted and certified performance. Figure 2 illustrates how the allowable negative tolerance at the rated point can cause a certified performance curve to fail to meet pressure requirements.

If the system lacks sufficient hydraulic capacity, the pump impeller either would need to be replaced and retested, or a reduced flow may need to be accepted. However, depending upon the design limitations of the system, replacing the impeller to gain head could lead to exceeding the system's design pressure at pump shutoff.

In either scenario, unexpected modifications to impellers and retesting can create additional costs and impact schedule. Pump disassembly and impeller trimming or recasting could be a lengthy process depending upon the size and style of pump. For example, large high-head multistage pumps would take longer to modify. The pump purchaser will bear the costs associated with the required impeller modifications and retesting along with any schedule delays if restrictions on API-610 tolerances weren't specified and agreed upon earlier in the procurement process.

In the worst case, an impeller modification may not allow the selected pump to meet the required conditions; this either would result in accepting a derated performance or switching to a different pump. If a different pump is necessary, the new procurement process would further delay the project.

HEED THIS HEADS-UP

Understanding the tolerances allowed under API-610 with regard to pump shutoff head and rated differential head can avoid costly rework and schedule delays. When specifying the required performance of a pump, the process engineer should identify any potential issues with API-610 allowable tolerances on pump performance and include a note on the datasheet that restricts the tolerances. By determining early on in the procurement cycle that full API tolerances aren't acceptable, the process engineer can help minimize risks to schedule and cost. ●

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1. "Centrifugal Pumps for Petroleum, Petrochemical and Natural Gas Industries," API Standard 610, 11th Ed., Amer. Petroleum Inst., Washington, DC (2010).

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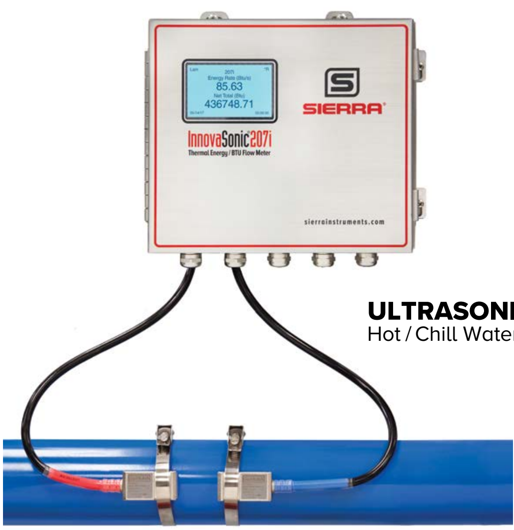

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Size Up a Tall Order

An elevated vessel may provide a worthwhile alternative to a booster pump

By Andrew Sloley and Scott Schroeder

Fixing pump suction head problems can cost a lot, as a recent experience illustrates. In this case, a site added a new unit to compress gas for sending via pipeline to a client. The specification stated the inlet gas would be liquid free. The initial assumption was that a small amount of liquid condensation would occur in the compressor inter-stage coolers. Inter-stage knockout drums would remove the condensate.

After startup, the knockout drums filled rapidly. The liquid rate exceeded the system's handling capacity. Temporary measures included pumping the liquid into trucks for handling. The liquid pumps suffered short lives and high failure rates. The situation clearly was both unsatisfactory and unsustainable.

Lack of understanding composition variability in the feed gas to the compressors caused this problem. The gas came from multiple sources that each had highly variable compositions. About the only stable factor was the absence of free liquid. Sometimes, very little of the gas would condense in the inter-stages while, other times, large quantities condensed.

Elevating a vessel may cause community relations issues.

Investigation showed that composition variability was inherent in the system and wouldn't change. Control systems move variability from where it has a large effect to where the effect is smaller. Here, all the variability ends up in that gas stream. This is the best option for the plant as a whole but poses a problem the engineers handling the gas stream must solve.

The ultimate solution involved a new knock-out drum and a new liquid pump. Nothing else would work. Getting the liquid to where it was useful required high pressure, over 1,000 psig. The engineers chose a reciprocating pump.

Reciprocating pump suction head requirements include head necessary to prevent cavitation from acceleration of the inlet fluid as well as to overcome inlet valve losses for the pump. Here, the best option to get sufficient head called for elevating the vessel 30 ft. While feasible, this arrangement looked "odd" to the project manager — whose preferred solution was to use a low net-positive-suction-head-required ($NPSH_R$) centrifugal pump as a booster to feed the reciprocating pump.

Typically, purchase and installation only account for 20–25% of a pump's lifecycle cost (which also includes both energy and maintenance expenses) over 20 years. In comparison, for a simple separator vessel, the 20-yr lifecycle cost generally splits closer to 75% capital and 25% maintenance.

Table 1 compares the cost of the two options. The installation cost is based on a fully engineered design and a ±10% cost estimate. The lifecycle costs are based on experience and rules-of-thumb for the equipment.

The elevated vessel boasts both lower capital and lifecycle costs. It's the clear choice unless there's an overwhelming reason for having a booster pump. The higher vessel also offers a safety benefit —elevating the vessel above 25 ft removes it from the standard pool-fire zone.

Factor	Relative Expense	
	System With Booster Pump	System with Elevated Vessel
Booster pump cost	120	
Booster pump installation cost	480	
Vessel incremental cost		100
Vessel incremental installation cost		60
Other facilities	130	200
Total installation	730	360
Operation and maintenance, 20 years	2,400	115

COMPARISON OF TWO OPTIONS
Table 1. A system relying on an elevated vessel incurs far lower long-term costs.

You can elevate a vertical vessel with a tall skirt or by installing it on a platform. A skirt is less expensive for most vessels but creates a confined space under the skirt. (A horizontal vessel usually doesn't use a skirt, and so rarely results in a confined space.) Opting for a platform often simplifies maintenance and access.

Elevating the vessel makes it more obvious and easier to see over the plant fence-line. This may cause community relations issues. In this case, that wasn't a concern.

A larger vessel, for example a big storage tank, can change results. So, you must examine each case individually. However, unless you face constraints in modifying an existing plant, using booster pumps to solve NPSH problems often is an expensive choice. ●

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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.

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

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.

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.

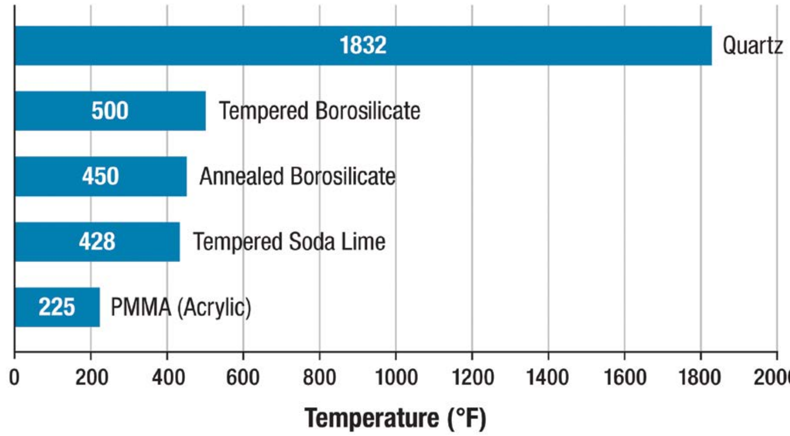
ABRASION

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.

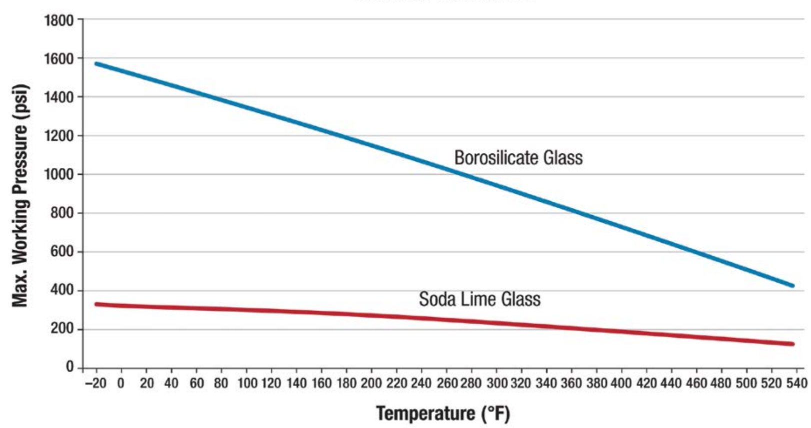


COMMON OPTIC MATERIALS
Figure 2. Quartz has the largest general temperature range for operations requiring sight glass.

- 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.



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.***

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.

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.

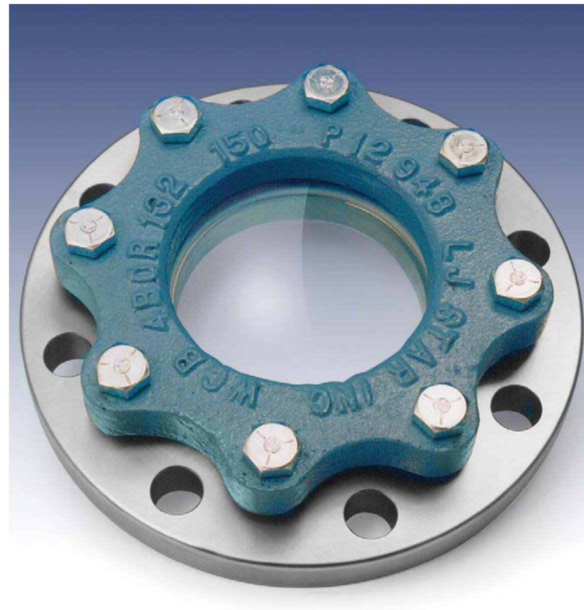
During these situations, media are introduced at a temperature very different from that of the sight glass. Initial contact can cause a rapid temperature change in the glass, resulting in failure. Another thermal shock hazard can occur during autoclaving.

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.

$$k\sigma T(1 - \nu)\ RT = \underline{\hspace{3cm}}\ \alpha E$$

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.

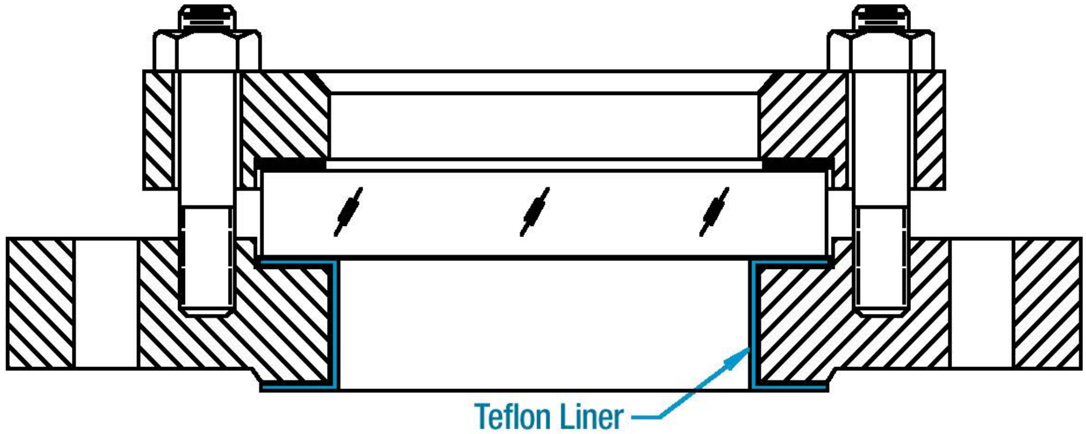


BOLT-ON SIGHT GLASS
Figure 4. A bolt-on sight glass enables the metal ring to be mounted so it doesn't come in contact with the process fluid.

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



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.

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).

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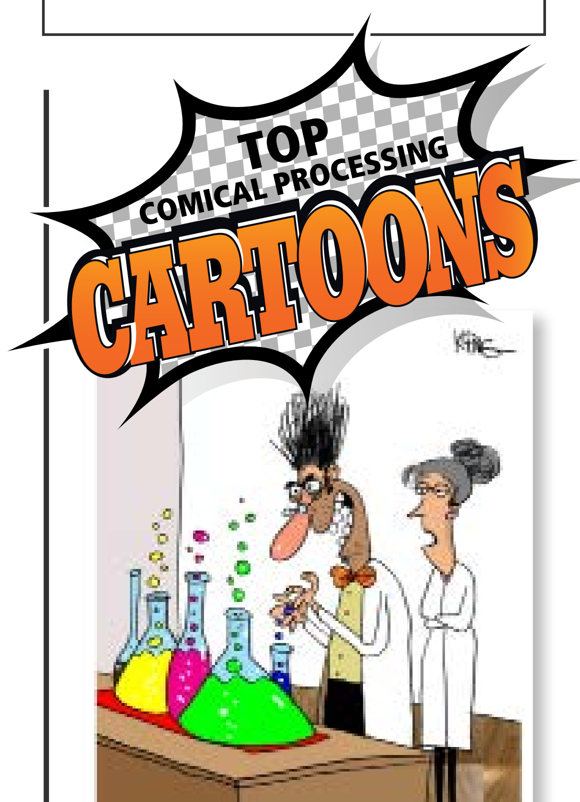

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