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best practices

By Andrew Obertanec

# Are You Gambling with Your Sightglass?

*Selection Strategies for When Failure Is Not an Option*

Sightglasses are sometimes called "the weakest link" in a processing system because of the fragility of the glass. Actually, that's not necessarily true. A sightglass need not be a weak link in a processing system because glass, when uniquely designed, is not necessarily fragile.

### General Properties of Glass

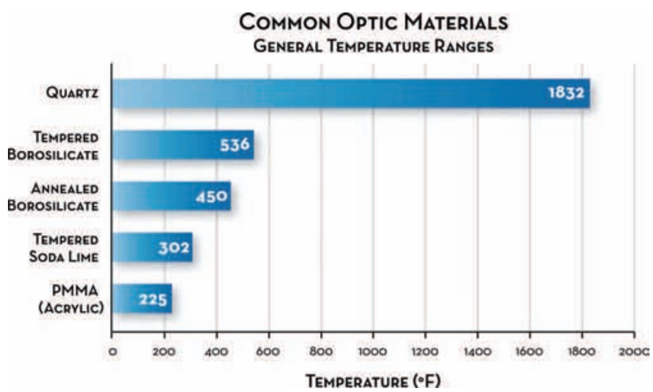
In fact, strength is actually a key characteristic of glass. In its purest form, glass is one of the strongest composites available in the world — even stronger than steel. The tensile stress of virgin (or untouched) glass is one million PSI, as compared to steel's 60,000 PSI.

In practice, untouched virgin glass is not a practical option since it is sensitive to even tiny imperfections. Just the touch of your fingers would reduce its tensile strength from one million PSI to 1,000 PSI. In addition, glass almost always fails under a tensile stress rather than compression. The compressive strength is nearly 200 times its tensile strength.

But even the 1,000 PSI figure does not tell the whole story. Glass is not ductile like steel, so it cannot stretch under tension to absorb the stress. Therefore, imperfections in the glass will create areas of stress concentrations, hastening failure.

Unfortunately, when glass fails under pressure, failure is often sudden and catastrophic. Research has shown that glass can fracture at five miles per second. That's why safety is a critical factor in sightglass selection.

So, the goal in selecting glass elements for sightglasses is to take advantage of the inherent qualities of glass for a particular application.



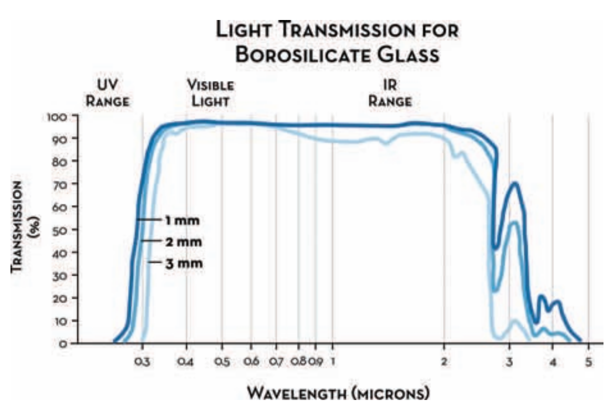

### Glass Types

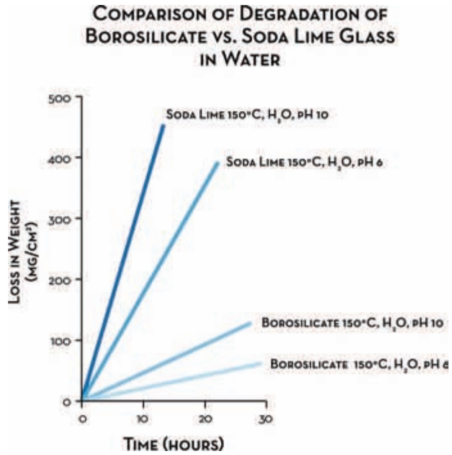
Common types of industrial glass include borosilicate, soda lime, quartz, and sapphire. Quartz and sapphire are actually crystals and exhibit great strength. But sapphire is not used in processing and quartz only where especially high temperature is needed.

Borosilicate glass is the type best suited for use in most chemical and pharmaceutical applications, and therefore this article devotes primary attention to this type of glass. Also, because soda lime glass is sometimes used — often unknowingly — we will compare borosilicate glass to soda lime glass in some detail.

### Glass Selection

The type of glass best suited to any industrial sightglass application should be based on the conditions of service — in particular, working temperature, chemical exposure, and operating pressure.






Standard DIN 7080 rates borosilicate glass to 280 C (536 F) and Standard DIN 8902 rates soda lime sightglass to 150 C (302 F). Very high-temperature equipment, such as ovens and furnaces, may require windows made of quartz. The following chart compares the maximum operating temperatures of glass commonly used in sight windows.

In the past, all sightglasses were made of soda lime glass. That all changed when Corning (*www.corning.com*) developed a process to produce borosilicate glass, offered under the brand name Pyrex, and today borosilicate is a popular choice for sightglass construction. The key characteristics of borosilicate glass include strength, high temperature capabilities, corrosion resistance, high thermal shock resistance and, of course, the main reason for its use – good transparency.

Soda lime glass owes its popularity to its status as a low cost solution. Soda lime glass is used in the manufacture of bottles, light bulbs, and windows. It is comprised of silica, soda, lime, magnesia, and alumina.

Borosilicate glass is similar, but it is made by replacing some of the silica with boric oxide. It is, then, comprised of silica, boric oxide, and alumina. The commonly accepted borosilicate glass standard is an average of 12 percent boron. In addition to sightglass windows, borosilicate glass is used in the manufacturer of cookeries, laboratory equipment, and glass pipe.

## Chemical Resistance

For chemical, biotech, and pharmaceutical applications, one must consider the effect of chemical exposure over time. Glass can suffer chemical degradation from caustic or acidic substances and suffer pitting from mild abrasion. This may weaken glass, dim its transparency, and possibly create crevices where bacteria can hide or leach into the process media. Borosilicate glass is significantly more resistant to chemicals than soda lime glass, as shown in the following chart.

"In investigating for chemically induced disintegration of soda lime and borosilicate glass, it was found that borosilicate was much more resistant. This occurred not only at slightly acidic conditions (pH 6), but also when the pH was raised to a value of 10 (alkaline). As shown on the chart, the degradation of soda lime glass is 10 times greater than that of Borosilicate glass." — Translated from VGB KRAFTTWORKSTECHNIK, Dr. A. Peters, Feb. 1979.

## USP Glass Standards for Pharmaceutical Use

The USP (United States Pharmacopoeia) provides standards that govern the classification of glass into types suitable for specific pharmaceutical uses.

**USP Type I borosilicate glas**s is the least reactive glass available and is required for many applications. It can be used for all applications and is most commonly used to package pharmaceutical materials. All lab glass apparatus is generally Type I borosilicate glass. To meet this standard, a sightglass must pass test procedures defined by USP29-661.

Many sightglasses on the market fail to meet this important standard, and some are not even Type II or Type III; rather they are non-parenteral and should not be used in applications where chemical durability and heat shock are factors.

**USP Type II de-alkalized soda-lime glass** has higher levels of sodium hydroxide and calcium oxide. It is less resistant to leaching than Type I but more resistant than Type III. It can be used for products that remain below pH7 for their shelf lives.

**USP Type III soda-lime glass** is acceptable in packaging some dry powders which are subsequently dissolved to make solutions or buffers. It is also suitable for packaging liquid formulations that prove to be insensitive to alkali. Type III glass should not be used for products that are to be autoclaved, but can be used in dry heat sterilization.

**USP Type NP soda-lime glas**s is a general-purpose glass and is used for nonparenteral applications (noninjectable drugs) where chemical durability and heat shock are not factors. As containers, it is frequently used for capsules, tablets, and topical products.

## Toughened (Tempered) Glass

In addition to chemical and thermal stresses, sightglasses are also subjected to stress from pressure and bending moments in many applications. To help withstand this, the glass can be toughened. How it is toughened may affect its suitability for a particular application.

Flat glass is produced utilizing the float glass process, where molten glass is floated on a bed of molten tin. Then, to

| Glass Breaking Stresses | Annealed Glass | Tempered Glass |
|---|---|---|
| Breaking Stress (typical) (large pane, 60 second load) | 6,000 psi | 24,000 psi |
| Impact Velocity Causing Fracture (typical) (1/4″ pane, 5 g missile, impact normal to surface) | 30 feet/second | 60 feet/second |

anneal it, the hot glass passes through an "annealing lehr," where it is slowly cooled to prevent buildup of internal stresses. Annealing is commonly used in the production of ordinary glass. Further, strength improvement can be accomplished by toughening or tempering the glass in one of two ways.

**Chemical Strengthening:** A chemical solution may be applied to the glass in order to increase the mechanical resistance of the glass. Chemically treated glass is commonly used in applications where thin, strong glass (stronger than window glass) is required.

**Heat Treating:** Annealed glass may be subjected to additional heat treating to further increase its strength. This process makes heat-tempered glass three to five times as strong as annealed glass. Thermally tempered glass is often used in conventional sightglasses.

*A fused sightglass used with sanitary clamps for sight ports and light ports in processing applications or inline visual flow indicators.*

## Fused-Glass Sightglass

Tempering is not the only way to toughen glass. Glass can also be strengthened by placing it in mechanical compression. The most commonly used mechanically prestressed sightglass consists of a stainless steel ring encircling a glass disc.

During manufacturing, the glass is melted within the metal ring as the ring expands. Then, temperature is raised to the point where the glass and the metal ring fuse together. When the unit cools, the glass hardens before the metal ring can shrink back to its original size. This places the metal ring in tension and the glass in uniform radial compression.

This compressive force is so great that if the metal ring is cut the compressive force will be released, and the ring will shear from the glass. Some mistakenly believe that this indicates the glass was not fused to the ring. Actually, it proves only that the compressive force was stronger than the adhesion between the glass and metal. Fusion between the metal and glass is only a byproduct of the manufacturing process and not where its strength lies. Radial compression improves the performance of the glass because it offsets the effects of tensile stress. Under such strong compressive force the glass, in effect, becomes elastic.

In addition, the metal ring contributes to failure-resistance because mounting and sealing pressure are applied to it rather than the glass, virtually eliminating most of the common dangers of imposing bending loads and erosion on the glass. Exceptionally strong bending forces may extend beyond the metal ring into the glass, but the glass remains elastic and able to tolerate bending as long as the compressive force applied by the steel ring exceeds the tensile stress on the glass.

Taken to the extreme, bending force can theoretically exceed the compressive force. But even then, the fused-glass window will not shatter. Rather, it will failsafe because it retains elasticity. When the surface stretches beyond its elastic capability, small cracks usually develop near the surface. The cracks can interfere with visibility, but they do not compromise window integrity. The subsurface glass (product side) is still under compressive stress and can withstand the pressures. The same mechanism relieves the stress of over-pressurization. In addition, the compressive force on the glass can also resist the effects of thermally induced bending, also known as thermal shock. This sometimes happens with a hot vessel and a cold-water wash down.

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