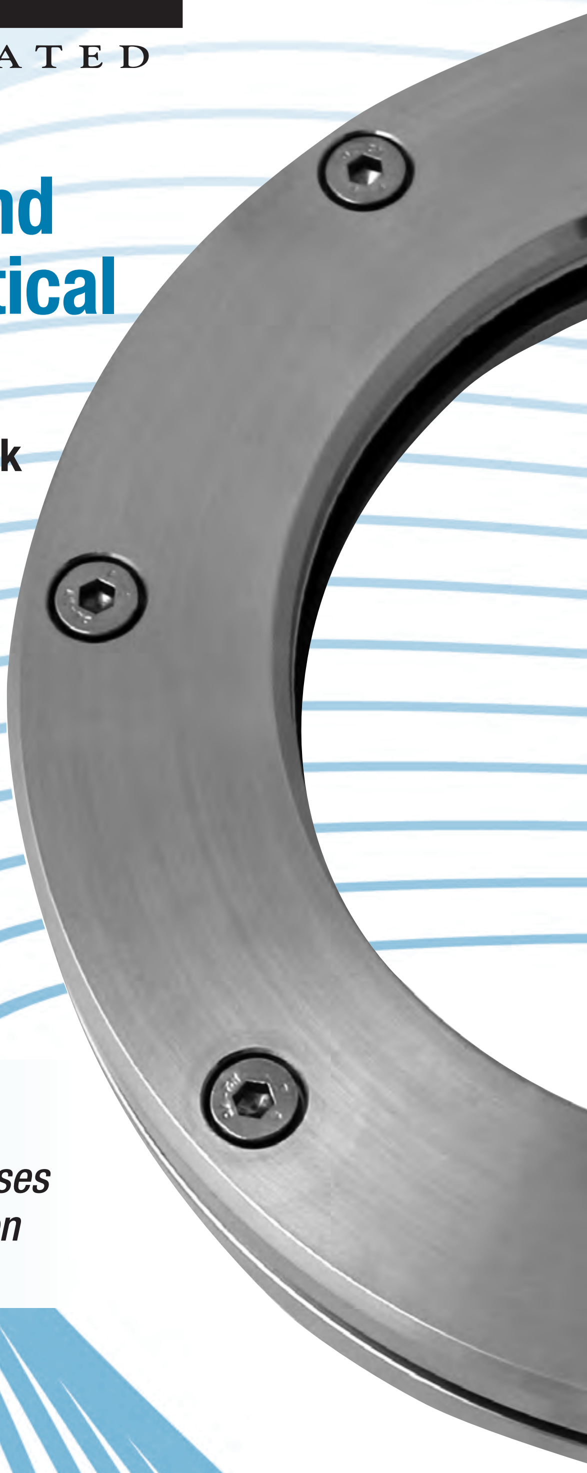
L.J.STAR INCORPORATED

Chemical and Pharmaceutical Sight Glass

Application Handbook



How to Specify and Understand Sight Glasses for Process Observation

This handbook is dedicated to the memory of Edward K. Lofberg, a glass expert with Corning Glassworks for more than 40 years who was instrumental in helping L.J. Star develop expertise in the application of glass for process observation.

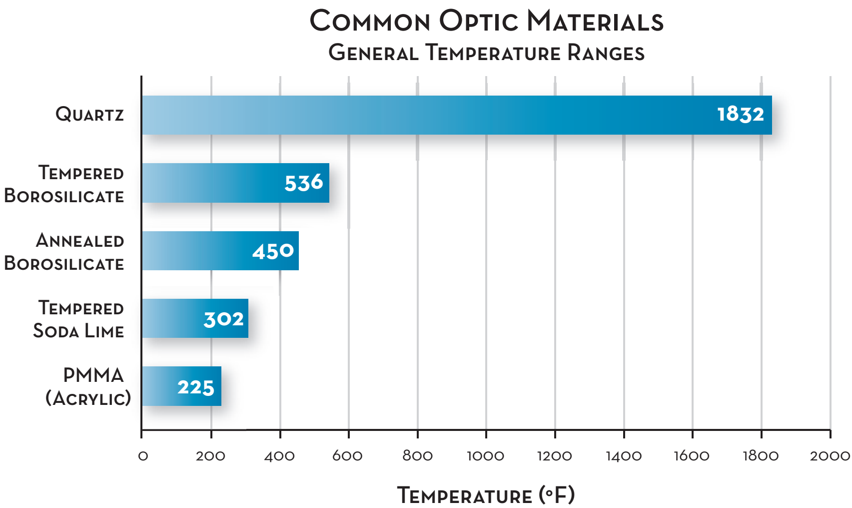
Introduction

Improperly specified, installed or maintained, sight glasses can easily become the weakest link in a chemical or pharmaceutical processing system. They may provide less than needed observation capabilities, they may require frequent maintenance and replacement, they may be difficult to illuminate and, in worst case, they may actually fail, endangering workers and causing extensive destruction and downtime.

This is a completely needless circumstance. An understanding of the nature of the various types of glass, the various sight glass design options and materials of construction, and proper maintenance procedures will provide process observation and illumination that will serve and survive through the life of the system.

L.J. Star Incorporated
P.O. Box 1116
Twinsburg, OH 44087
Tel: (330) 405-3040
Fax: (330) 405-3070
www.ljstar.com

Standard DIN 7080 rates borosilicate glass to 280°C (536°F) and Standard DIN 8902 rates soda lime sight glass 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 commonly known glass in sight windows.

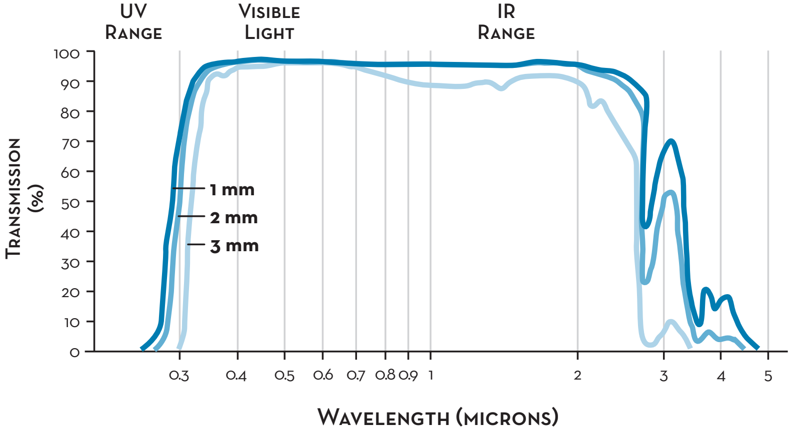


Borosilicate Glass vs. Soda Lime Glass

It used to be that all sight glasses were made of soda lime glass. Then Corning developed borosilicate glass (brand name Pyrex®) and today this is a popular choice for sight glass construction. The key characteristics of borosilicate glass include strength, high temperature capabilities, great corrosion resistance, low thermal expansion (high thermal shock resistance), and of course, the main reason for its use – the ability to see through it.

PYREX® is a registered trademark of Corning Incorporated.

Light Transmission for Borosilicate Glass

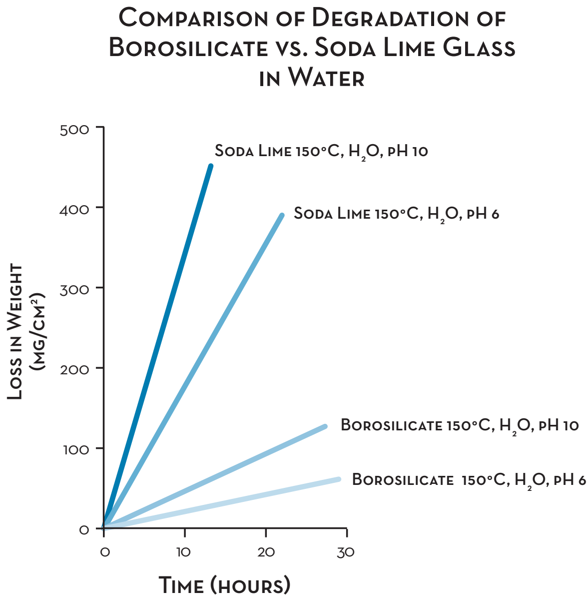


Soda lime glass owes its popularity to the fact that it is the least expensive and most common type of glass. Soda lime glass is used in the manufacture of bottles, light bulbs and windows. It is comprised of silica, soda, lime, magnesia and alumina.

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. Borosilicate glass is used in the manufacturer of cookeries, laboratory equipment and glass pipe, in addition to sight glass windows. It has high chemical resistance, high strength, and a low coefficient of thermal expansion (high resistance to thermal shock).

Chemical Resistance

For chemical, biotech, and pharmaceutical processing applications, it is important to consider the effect of chemicals on the sight glass over time. Glass is not chemically inert, and will react even with water. Glass can suffer chemical degradation from caustic or acidic substances and suffer pitting from mild abrasion. These conditions may dangerously weaken glass, obscure 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. This considerable divergence in resistance properties begins at 134°C, the initial temperature in the study.

Translated from "VGB KRAFTTWORKSTECHNIK," Dr. A. Peters, Feb. 1979.

Independent Statements Regarding Use of Borosilcate Glass

There is a wealth of citations in literature that strongly support the use of borosilicate glass in sight glasses. Following are a few:

> *"Borosilicate glasses have the widest use for chemical equipment. Because of low thermal expansion, these withstand higher operating temperatures and show greater resistance to thermal shock than soda-lime glasses. They also have excellent chemical durability."*
>
> Glass Engineering Handbook
> McGraw-Hill Book Company, 1984

> *"Soda-Lime glass (Herculite®) is relatively inexpensive but has the poorest thermal-shock and thermal-stress resistance."*
>
> Selecting Sight Flow Indicators
> *Chemical Engineering*, July 4, 1977

Herculite® is a registered trademark of PPG Industries.

"Resistance to thermal shock generally decreases as the coefficient of thermal expansion increases."

Kopp Glass Inc.
Color Filter Glasses, February 1991

"Lime glasses are low in cost, easily hot worked and are usually specified for service where high heat resistance and chemical stability are not required."

Properties of Selected Commercial Glasses
Corning Glass Works

"Soda-Lime glass is the most common (90% of glass made), and least expensive form of glass. It usually contains 60–75% silica, 12–18% soda, 5–12% lime. Resistance to high temperatures and sudden changes of temperature are not good and resistance to corrosive chemicals is only fair."

Corning Museum of Glass
(Available on the Internet)

"Because of its high thermal expansion (three-fourths of steel), lime glass in its annealed state does not have the thermal shock resistance required for chemical process equipment."

Installation and Maintenance of Glass Equipment
Chemical Engineering, April 26, 1965

"Where fracture due to thermal stressing cannot be handled with safety toughened glass, borosilicate glass rather than soda-lime glass might be considered."

CBD.60 Characteristics of Window Glass
(Available on the Internet)
Canadian Building Digest

"Soda-Lime glasses are not very chemically durable and are subject to fracturing from quick thermal changes."

Glass Alchemy, Ltd. Glossary
(Available on the Internet)

Toughened (Tempered) Glass

In addition to chemical and thermal stresses, sight glasses are also subjected to stress from pressure and bending moments in many applications. To help withstand this, the glass is normally toughened. There are a variety of methods used to toughen glass. Since the manner in which it is toughened may affect its suitability for a particular application, it is important that engineers be aware of the different methods so that the appropriate glass is specified.

Flat glass is produced utilizing the float glass process, where molten glass is floated on a bed of molten tin. The hot glass passes through an "*annealing lehr*," where it is slowly cooled to prevent buildup of internal stresses. This allows the glass to be cut and otherwise processed afterward. Annealing is commonly used in the production of ordinary glass. (See **Figure A**.) Further strength improvement can be accomplished by toughening or *tempering* the glass.

To temper glass, one of two methods may be used:

Chemical Strengthening: A chemical solution may be applied to the glass in order to increase the mechanical resistance of the glass. The properties of chemically strengthened glass are similar to those of thermally treated 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. Glass is heated to approximately 680°C, almost its softening point. It is then quenched or cooled with a steady high-pressure flow of compressed air. This process quickly cools the surfaces which go into compression while the core (inside) is allowed to cool more slowly and goes into tension. This process makes heat tempered glass three to five times as strong as annealed glass. When fractured, rapidly cooled (fully tempered) glass releases the tensile energy stored in the core and breaks into many fragments, similar to automotive rear window safety glass and glass basketball backboards. (See **Figure B**.) If, instead of cooling the glass rapidly, it is allowed to cool slowly, it becomes twice as strong as annealed glass. When fractured, these broken glass fragments are linear and will normally remain in the frame.

Thermally tempered glass is often used in conventional sight glasses.

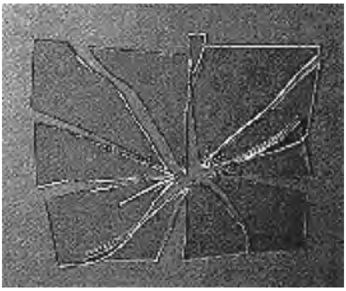


Figure A. Fractured ordinary annealed glass

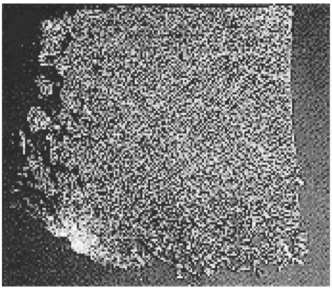


Figure B. Fractured toughened safety glass

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

Federal Specification DD-G-1403C for heat-treated glass divides it into two categories, fully tempered glass and heat-strengthened glass, and it specifies minimum compression values for each. For fully tempered glass, the surface compression must be 10,000 psi or more, or the edge compression must be 9,700 psi or more. For heat-strengthened glass, the surface compression must be between 3,500 psi and 10,000 psi, or the edge compression must be between 5,500 psi and 9,700 psi. With this wide range of compression values, the fracture characteristics of heat-strengthened glass may range from those typical of annealed glass (3,500 psi level) to those of fully tempered glass (9,700 psi level).

Fused-Glass Sight Glass

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 sight glass consists of a stainless steel ring encircling a borosilicate glass disc. The key to its success is that the manufacturing process introduces a prestress that causes the steel ring to apply a uniform radial compression onto the glass. During heating, 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 shrinks back to its original size. This places the metal ring in tension and the glass in uniform radial compression.

The 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 this indicates that the glass was not fused to the ring. Actually, it proves that the compressive force was stronger than the adhesion between the glass and metal. In reality, fusion between the metal and glass is only a by-product 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. There are almost no process conditions under which external tensile stress would overcome the compressive 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 fail safe 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.

Sight Glass Design and Application

Because glass is so sensitive to imperfections, there are several factors that will contribute to sight glass failures. First is *improper design*. A cover flange, or hold-down flange, that is too thin will create a bending load on the glass as the flange bends during bolt tightening. This scenario can crack the glass, which creates a hazard even before the system is in operation. This situation may easily go undetected prior to start-up since the cover flange can hide the cracks. Even too few bolts will create point loads from uneven compression on the glass, which again may result in cracking.

Another design flaw may be a *cushion gasket that is too soft* or *too thick*. Under pressure, this will not create good flat support, similar to lying in a feather bed, and will create a bending load on the glass that will result in a tensile stress on the surface of the glass. Again, an undetectable hazardous situation created even before start-up.

A third and more obvious design flaw is *inadequate glass thickness*. This can lead to failure as the internal pressure exceeds the maximum pressure capability of the glass. This can occur as a result of the use of an incorrect coefficient, improper formula or a miscalculated unsupported glass diameter.

Another reason for conventional glass failure is *improper installation*. Examples are over-tightening and uneven torquing which produce bending loads on the glass and can potentially result in cracking. One more common cause of failure due to improper installation is trapped debris. Even the smallest dirt particles or product spill build-up can be enough to scratch, pit or bend the glass. Often, gaskets become baked onto the flanges and portions are left behind when removed. Again, this creates a very dangerous situation.

A very difficult flaw to discover is created during the manufacturing of the sight glass components. The lower and upper flanges, and even the glass, may not have flat and parallel surfaces as a result of poor or low tolerance manufacturing. These are difficult to determine since most of these defects are not visible to the naked eye. A flaw in any of these components will again result in a bending load on the glass.

One of the most common causes of glass failure is *incorrect use and mishandling*, such as using the sight port as a handy place to rest a wrench. Any surface defects, *even those that cannot be seen by the naked eye*, create a source for breaks to originate, also known as stress concentrations. Even though a bending load is required to open these cracks, they significantly reduce the pressure capabilities of the glass.

Impact from an object will also weaken the glass considerably. Such an impact can create a pitting, or depression, in the surface, which produces a stress concentration point, resulting in a hazardous situation in pressure applications. This is comparable to making a slight cut or tear on a piece of paper, and then pulling on it. In fact, the same thing is done when glass is cut. A glasscutter is used to score the glass, creating a small depression in the surface, and then a bending moment breaks the glass along the scratched surface. This is similar to a sight glass with a surface scratch and pressure behind it creating a bending moment.

Another misuse of glass often occurs during *maintenance and inspection*. Conventional glass discs and gaskets should not be removed from the sight glass assembly and re-used. Corning Glass Works states this in its Sight Glass Use and Care Manual because compressing the glass between two flanges will create scratches and pitting in the glass.

The last possible cause of failure may result from *unknown variables during processing*. There are many situations that may not be realized, understood, or expected after start-up. One such example is thermal shock, or a quick or drastic change in temperature. This can occur in various ways. First, and most common, is when a sight glass is subjected to cold ambient temperatures and the start-up causes a quick rise in temperature. If the bottom surface of the glass expands too quickly relative to the top, the surfaces will move against each other until they crack. Another thermal shock scenario happens during external wash down cleaning; a cold liquid directed on the top surface of the glass quickly cools down a hot sight glass. Again, a quick change in temperature on one surface and the glass can fail. Heat generated from a high wattage luminaire can also cause thermal shock.

A less obvious type of thermal shock is called shadowing. The area of glass that is protected and sealed by the gasket and flanges is not directly exposed to the heat or cold of the processing. This "shadowed" area remains closer to ambient temperature while the exposed viewing area sees temperatures near that of the product.

This extreme temperature difference within the glass will produce opposing forces that may exceed its limitations. Again, the result is failure.

A second service condition that creates a hazardous situation is over-pressurization. A miscalculation or an unexpected increase in system pressure could exceed the design pressure of the sight glass. Often, there are systems in place to relieve this sudden increase in pressure; however, these systems may not eliminate the initial burst of pressure, which is exerted throughout the vessel or pipeline, which includes the glass.

The last service condition that can create a sight glass failure is the *degradation of the glass over time*. Chemicals, and even water, will corrode glass. There are several chemical resistance charts that illustrate the loss of weight of glass when exposed to various chemicals. Another source of degradation is the continuous friction from an abrasive, and even a non-abrasive, product against the glass, which we call erosion. In both cases, this occurrence will etch the glass and weaken it considerably, to where normal operating conditions may result in catastrophic failure.

Determining Sight Glass Thickness

A recommended minimum thickness of a window required to withstand a pressure differential can be calculated by the following formula:

$$T = U \sqrt{\frac{(0.302)P}{\sigma}}$$

T = Glass thickness (inches)
U = Unsupported diameter (inches)
P = Operating pressure (psi)
σ = Allowable stress (psi)

Allowable stress (psi) of commonly used glass:

Glass Type	σ (psi)
Borosilicate (Tempered)	3,000
Borosilicate (Annealed)	1,000
Quartz	750
Soda Lime (Tempered)	2,100

Critical Standards for Specifying Sight Glasses

Sight glasses are highly engineered products. Although brands look alike, differences in their specs have tremendous importance for worker safety, sanitary processes, and maintenance costs. Here are the critical specs and standards for sight glass selection:

DIN 7079 Standard for Fused-Glass Sight Glasses in Metal Frames

The DIN 7079 standard for fused-glass sight glasses sets standards for fusion, thermal properties, strength, and chemical resistance. This is a stringent standard, and not all sight glasses can meet its specifications.

DIN 7080 Standard for Borosilicate Glass Quality

The DIN 7080 standard means the glass has passed tests for material strength, shock endurance, chemical resistance and compression. There is no reason not to insist on this high quality glass.

Factory Mutual (FM)

Factory Mutual has defined standards that sight glasses should meet in order to provide safe operation. Use of FM approved products may in some cases reduce plant insurance costs.

ASME-BPE

The ASME BPE (Bio-Processing Equipment) Standard standardizes specifications for the design, manufacture and acceptance of vessels, piping and related accessories for use in equipment used in the biopharmaceutical industry. Sanitary sight glasses should meet ASME-BPE standards at a minimum.

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 Glass)

USP Type I borosilicate glass is the least reactive glass available. It can be used for all applications and is most commonly used to package water for injection, un-buffered products, chemicals, sensitive lab samples, and samples requiring sterilization. All lab glass apparatus is generally Type I borosilicate glass.

To meet this standard, a sight glass must pass test procedures defined by USP29-661. USP standards require the use of Type I glass for many applications.

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

USP Type II (De-Alkalized Soda-Lime Glass)

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)

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 (Non-Parenteral)

USP Type NP soda-lime glass is a general purpose glass and is used for non-parenteral applications (non-injectable drugs) where chemical durability and heat shock are not factors. These containers are frequently used for capsules, tablets and topical products.

Lighting Considerations

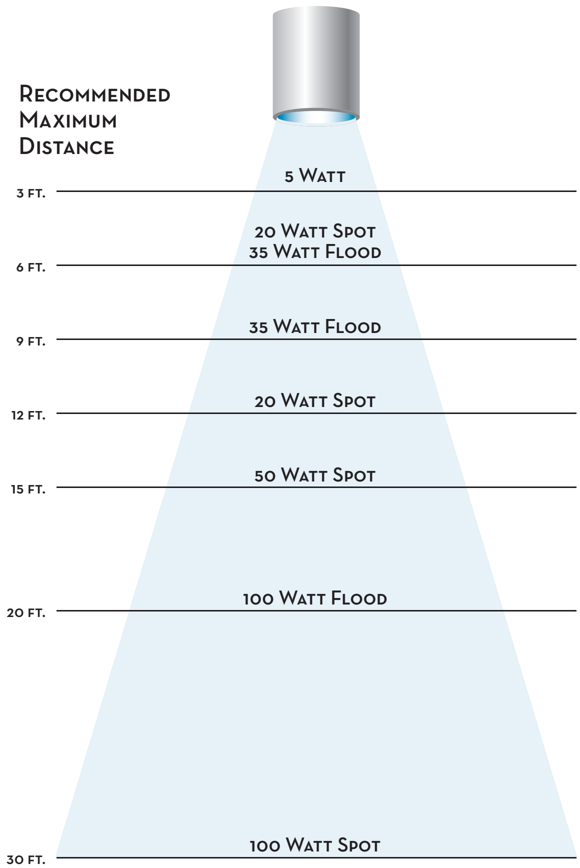
Chances are pipelines and vessels are too dark for level detection and to view important stages of a process through a sight glass. Flashlights cannot supply sufficient lighting, and may cause a glare on the sight glass, making visual inspection virtually impossible. If the view port is small, there may not even be enough room to combine viewing and lighting. Illumination may be supplied by adding lights (also called "luminaires") on sight glasses.

When deciding upon a proper light for an application, be sure to consider all of the properties of the light. The size, weight, voltage, wattage, materials of construction, mounting configuration, and light pattern are all very important factors.

How to know what wattage light the application requires

The wattage of the bulb you select should be based on the distance of the bulb from the target. The following figure shows the maximum recommended distance for bulbs of different wattages.

The brightness of a light can be measured in lumens. However, because process lighting is focused with a reflector, a better unit of measure is the foot-candle, which measures reflected light rather than direct light. The shape of the reflector and its position in relationship to the bulb affects how wide or narrow the beam will be.



Lighting options

Lights are available in many different sizes and options. If the light needs to be installed in a hazardous area, explosion proof lights are also available. If a port is too small to utilize a standard light, try a fiber optic light – it can fit even the smallest of ports. Cameras, remote electronic timers, pneumatic timers, and pushbutton switches are also available as accessories.

Mounting lights

Lights use different mounting configurations, from a "half-moon" type designed to fit a weld-on sight port to the latest sleek sanitary design where the light fits directly into a sanitary fitting for one-piece mounting right onto the ferrule. For existing sight ports, some lights are made to mount easily onto the cover flange. Often, the construction of the light interferes with the design of an existing port. Special ports require special mounting – ask your vendor to design a mounting configuration to suit your needs.

Factors of Reflected Light

Measurement of Light

Lumens is a measurement of light in all directions. This unit of measurement is best used for incandescent bulbs.

When a reflector is used, the light is reflected in one direction. As a result, lumens is not an effective measurement of reflective light. Therefore, the unit of measurement that measures light at a distance from the bulb is called candela, or more commonly referred to as foot-candles. Another effective unit of measurement of reflective light is called lux. Foot-candles can be converted to lux by the following formula:

$$\text{Foot-Candles} \div 0.0929 = \text{Lux}$$

Generally speaking, foot-candles and lux are inversely proportional to the distance squared. For example, a lux of 200 at a distance of 5 ft. from a bulb is 50 lux at a distance of 10 ft. In other words, if the distance is doubled the lux is reduced to ¼ of the original lux.

Maximizing Light Output

In order to maximize the light output using a reflector, the center of the bulb's filament must be placed at the focal point of the reflector. The intention is to have all the light directed in a parallel manner (see Figure A). There will always be some angle of light since some light will be direct (see Figure B). A typical angle of reflection for a spot configuration is 10°.

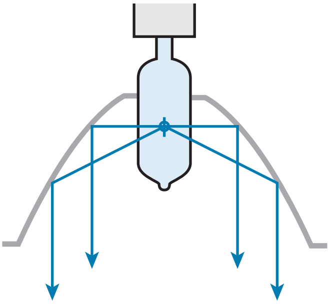


Figure A

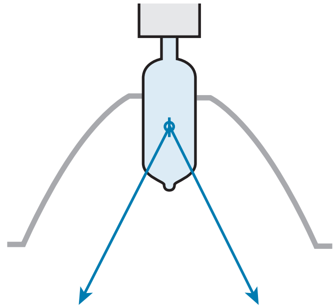


Figure B

Flood Light

It is not always desirable to have a narrow light beam or a spot light. There are three ways to accomplish this, but keep in mind that light efficiency will be compromised. The first way is to position the center of the filament further from the base of the reflector's focal point. In doing so, light is reflecting at angles other than parallel with the ends of the reflector (see Figure C). In addition, this allows for more direct light to be generated.

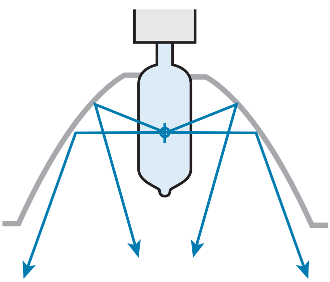


Figure C

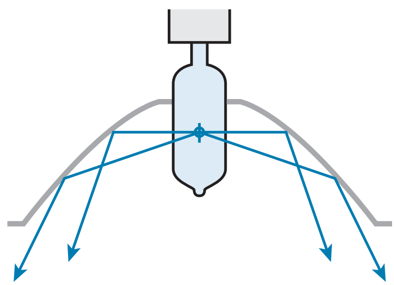


Figure D

A second method is to design the reflector at a slightly different parabolic shape so as to reflect the light at angles (see Figure D). A third way can be accomplished by a dimpled glass lens which is usually incorporated into the bulb and reflector, known as an encapsulated bulb. A common example of this is an outdoor floodlight. A typical angle of reflection for a floodlight is approximately 30–35°.

The surprising relationship of voltage to brightness

A bulb with lower voltage (say 24V) will give light more efficiently than a bulb with higher voltage, such as 120V. First we must illustrate the basic power formula:

$$\text{Voltage} \times \text{Amperage} = \text{Wattage}$$

As the voltage increases and the wattage remains the same, the amperage must be reduced. In other words, the amperage is inversely proportional to the voltage, assuming the wattage remains constant.

As a result, the higher the voltage the more resistance is needed. Therefore, a longer, thinner filament is required. A shorter, thicker filament has two benefits: First, a thicker filament can burn hotter and produces a brighter, whiter light. Second, a shorter filament produces more light at the reflector's focal point, resulting in more efficient reflections.

Light vs. Heat

A typical halogen bulb produces 15% light and 85% heat. Heat comes from the infrared light of a bulb, which cannot be seen by the naked eye.

There are three ways to reduce the IR light (or heat) from a light source. First is the use of a cool beam bulb. This type of bulb incorporates a reflector that allows IR light to pass through while reflecting the white or visible light. However, this is not 100% efficient in eliminating IR light from exiting the luminaire since some light is direct and does not pass through the reflector.

A second method of reducing IR light is to incorporate an IR mirror. This device, placed opposite the reflector, reflects the IR light back into the luminaire while allowing the visible light to pass through.

A third solution, similar to the IR mirror, is an IR filter. However, instead of reflecting the IR light, the filter absorbs it while allowing the visible light to pass through. This device is not as efficient as the above mentioned mirror. The combination of a cool beam bulb and an IR mirror is very efficient.

Lastly, LED lights are now available that do not add heat to the process. These lights have the additional advantage of extremely long life, which reduces maintenance costs.

Installation and Maintenance Tips

Maintenance

Never re-use glass or gaskets.

- Once a conventional sight glass has been removed from its mounting, regardless of the reason for removal, discard the glass and gaskets and substitute new glass and gaskets. Exception: Metaglas® safety windows may be reinstalled, following instructions provided for this procedure.
- Keep glass clean using commercial glass cleaners.
- Never use wire brushes, metal scrapers or harsh abrasives.
- Do not attempt to clean glass while equipment is in operation.

Inspection

Sight glasses should be regularly inspected for damage.

- To examine for scratches, shine a very bright concentrated light source at an angle of about 45°. Anything that glistens should be inspected closely.
- Scratches that catch the fingernail and any star or crescent-shaped marks that glisten are cause for replacement.
- Sight glasses that appear cloudy or roughened after cleaning should be replaced.
- Also inspect sight glass frames/flanges for corrosion buildup.

Installation

Never use damaged glass.

- Never use glass that is scratched, chipped or otherwise damaged.
- Glass seating surfaces must be flat within 0.005″ with a smooth finish.
- Flanges must be rigid.
- Do not allow the glass to contact metal when assembling.
- Gaskets must be new, clean and smooth.
- Use gaskets of the same diameter and fit them concentrically.

Bolting

Never tighten bolts on a sight glass while equipment is in operation.

- Follow a regular tightening sequence to ensure even loading of glass.
- Allow a maximum difference of 1.5 ft/lbs between bolts during tightening.
- Tighten only enough to produce a positive seal against the process pressure.
- Bolts may need tightening after initial cycling of vessel.
- Never tighten bolts when the sight glass is hot.