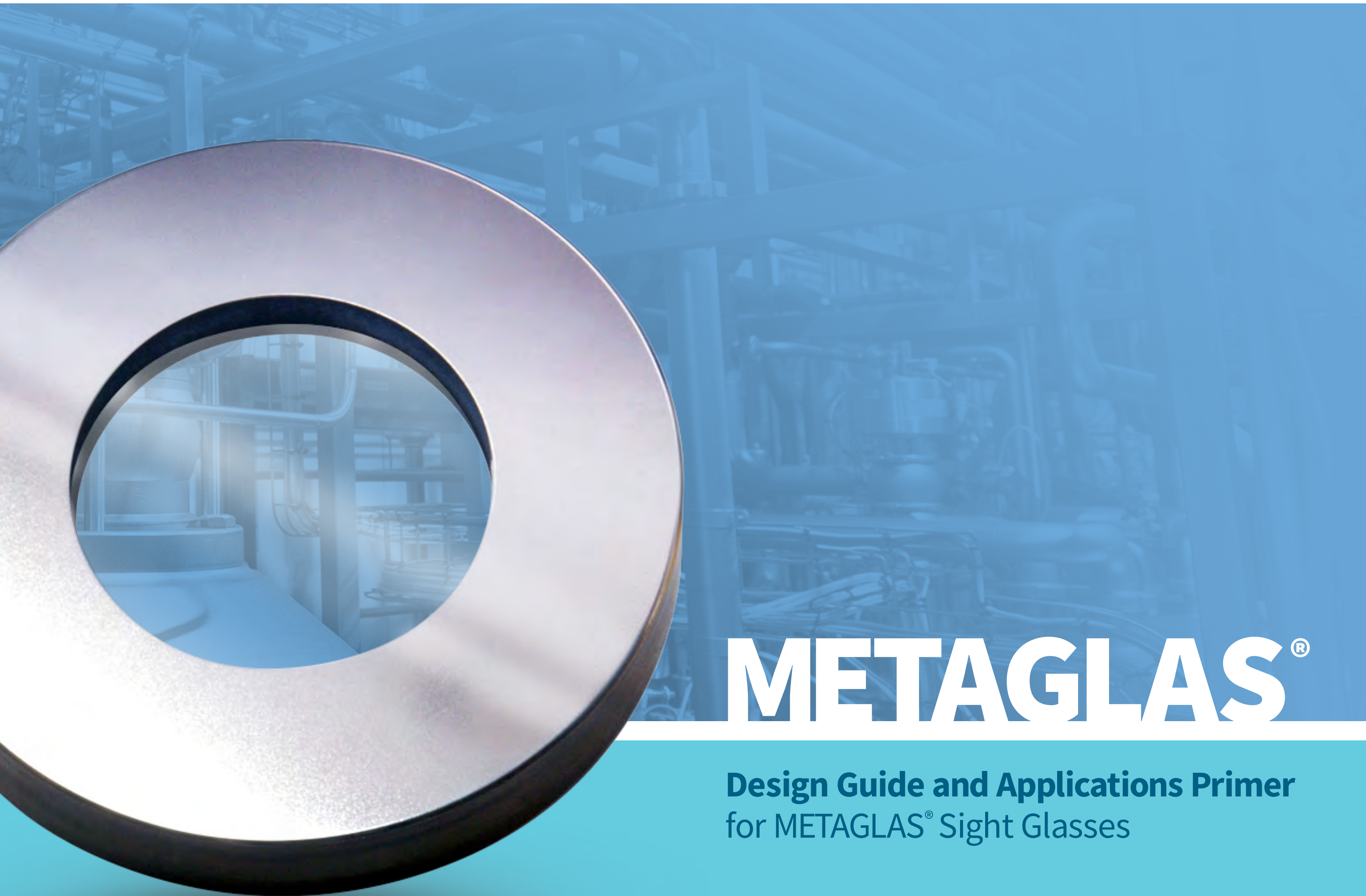
LJ STAR®

You'll look better



METAGLAS®

Design Guide and Applications Primer
for METAGLAS® Sight Glasses

Improperly specified, installed or maintained sight glasses can become the weakest link in a chemical or pharmaceutical processing system. They may be inadequate for observation, require frequent maintenance and replacement, hinder illumination and, in a worst-case scenario, they may catastrophically fail, endangering workers and causing extensive destruction and downtime.

These problems can be avoided, however, if you understand the various types of glass, design options, construction materials and proper maintenance procedures, you can make an intelligent sight glass decision that will best serve your business needs, keep your workers safe and last the lifetime of the system in which the solution is implemented.

The type of glass you choose for your processing system is one of the most important decisions you will need to make. In this handbook, we will explore the two choices you face — conventional glass and mechanically prestressed, or fused, glass, and you will learn why the latter may be the better choice when it comes to the efficiency and, most important, the safety of your operations.

Conventional Thermally Prestressed Sight Glass

Conventional, thermally prestressed, also known as tempered glass is sensitive to stress, bending and impact. While this may be a minor expense and inconvenience if it happens during installation, if it occurs when a plant is operational the costs can add up, both in terms of dollars and safety hazards. In fact, when subjected to any surface damage or stress caused by uneven forces, conventional glass may catastrophically fail without warning.

Let's look at how conventional sight glasses react to stress and why that is important when you are making a decision about which sight glass is right for your needs.

How Conventional Sight Glasses React to Stress

Conventional sight glasses undergo residual stress when bolting or rebolting the glass into place. Rebolting, especially, can cause excessive residual stress, which can lead to failure. In addition, conventional sight glasses are sensitive to uneven or over-torquing of sight port bolts, which can cause the glass to crack completely through. Conventional sight glass mounting surfaces must be entirely flat and smooth (within 0.07 mm) to avoid uneven torquing.

Compared with mechanically pre-stressed glass, conventional glass has lower resistance to pressure and can undergo catastrophic failure upon over-pressurization. Mechanical shock, or impact, can also result in catastrophic failure, causing a conventional sight glass to shatter into a shower of small fragments. Further, corrosion and erosion of a conventional sight glass surface can weaken the glass, which can also cause catastrophic failure. Finally, you must replace a conventional sight glass if it cannot be cleaned in place.

Mechanically Stressed Sight Glass

Tempering is not the only way to toughen glass. Glass can also be strengthened by placing it under mechanical compression. The most commonly used mechanically prestressed sight glass comprises a stainless-steel ring encircling a borosilicate glass disc. The circular glass is melted inside a metal frame, forming a fusion of glass and metal.

This process introduces a prestress that causes the metal ring to apply a uniform radial compression onto the glass. During heating, the glass is melted within the metal ring as the ring expands. The temperature is then 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. The difference in the linear coefficient of thermal expansion between glass and metal places the metal ring in tension, creating a uniform radial compressive stress from the ring.

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. You may think this indicates that the glass was not fused to the ring; however, it actually 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.

This high degree of mechanically induced compressive stress makes mechanically stressed glass stronger and more secure than conventional glass for sight window or visual flow indicator applications.

Fused sight glasses display extremely strong properties, offering superior safety ratings over conventional sight glasses; therefore, fused metal/glass sight glass units are the preferred choice over toughened borosilicate or soda lime glass discs for hazardous process conditions.

How Mechanically Stressed Sight Glass Reacts

Unlike conventional glass, scratches or other surface damage are not a safety concern with mechanically stressed glass and do not affect the life of the product. Also, repeated rebolting does not weaken or alter the integrity of mechanically stressed glass.

Mechanically stressed glass is extremely resistant to impact. Although a tremendous impact could cause local pitting of the glass, these blemishes do not affect the function or leak tightness of mechanically stressed glass. In addition, unlike conventional glass, mechanically stressed glass has an extremely high tolerance for uneven torquing because you are torquing metal on metal. During installation, uneven surfaces do not cause damage to mechanically stressed glass; at the extreme limits of torquing, you may see torquing cracks, but the glass will remain leak tight. Mechanically stressed glass also remains leak tight, even after high levels of erosion. And, finally, fused glass has a nearly unlimited life, regardless of how often you remove it, clean it or replace it.

The appearance of concentric surface cracks in the zone around the glass edge is not due to manufacturing faults but the result of the different relationships of glass and metal to heat. These hairline cracks remain restricted to a narrow zone in the glass metal area and cause only little reduction in the toughness of the sight glass. Exchange of the glass only becomes necessary when the transparency of the glass is affected by splinters flaking away or if V-shaped slivers break out of the glass, reducing its thickness.

Compressive Stress Versus Tensile Stress: Bending Moment Stresses

Fused Glass Versus Conventional Glass

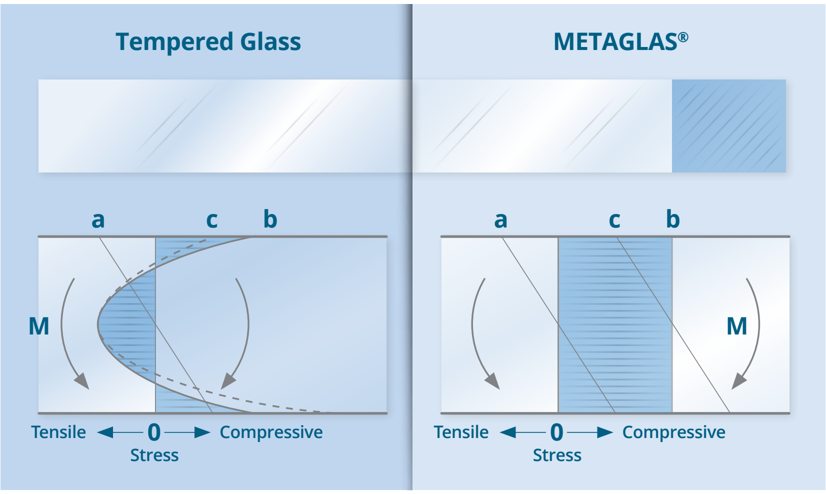


***Figure 1**: Cross-section schematic of stress distribution in conventional tempered glass versus mechanically prestressed glass*

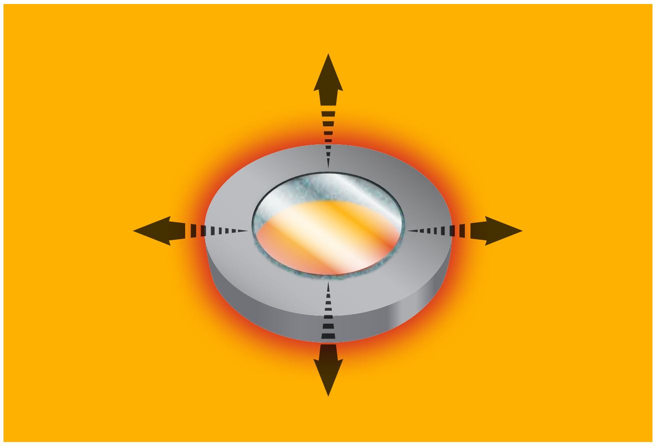
To further explore how fused and conventional sight glasses respond differently to stresses, it is important to consider "bending moment stresses," as shown in **Figure 1**. As explained previously, the different characteristics of thermally prestressed glass (tempered) and mechanically prestressed glass (fused glass to metal) can be explained by the stress conditions created by their respective manufacturing methods. When making tempered glass, the heated disc surface is chilled by air. As the surfaces cool faster than the heated core, they undergo compressive stress, and the core area undergoes tensile stress. This equilibrium is shown below in Figure 1, curve "b."

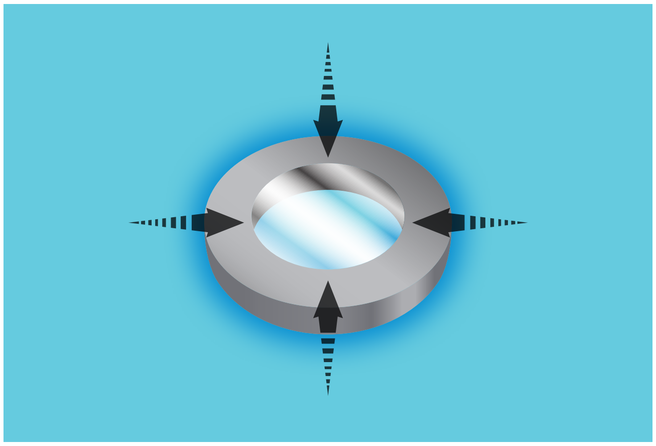
During manufacturing, the steel ring and glass are first heated to the fusing temperature at which the glass moves toward the steel ring. Because of differing but precise thermal expansion coefficients of steel and glass during the cooling process after fusion, a compressive stress condition is created in the glass, which is proportional to the normal expansion at the fusion temperature. The steel ring is simultaneously placed in a tensile stress condition. In the fused glass disc, a homogeneous compressive stress condition is created radially through the entire cross section. This is shown Figure 1, curve "b," with the shaded area indicating the area of stress.

When a bending moment shown as "M" and illustrated as stress line "a," is superimposed on the existing residual stress created in the manufacturing process "b," the result is line "c." Notice that a tensile stress area is formed in the thermally prestressed (tempered) glass disc, which this glass cannot withstand.

In the case of fused glass, the load allows the glass to remain in the compression stress area. This results in the value of the critical stress KC (ultimate or fracture stress) being exceeded with critically different conditions in the two glass discs. Because the tempered disc falls within the tensile stress area, it fails completely by shattering.

Having an overstressed condition in the fused glass where the value KC is exceeded, the stress falls in the compression area, and the stress value becomes smaller than KC, once again, and this stops the cracking. For every continuation of a crack, a renewed application of kinetic energy is created from residual compression (potential energy), preventing a sudden bursting of the glass.





	Conventional Glass	METAGLAS®
Surface Damage	Damage to the toughened surface can cause unexpected catastrophic failure	Scratches or any other surface damage do not affect safety or life of METAGLAS
Residual Stress	Residual stress is created when bolting up. Re-bolting causes excessive residual stress which can lead to failure	Repeated re-boiling does not affect the strength and integrity of METAGLAS
Pressure	Lower resistance to pressure and catastrophic failure on over-pressurization	Higher pressure ratings for similar disc thickness
Impact	Impact (mechanical shock) causes catastrophic failure and the glass shatters into a multitude of small fragments	METAGLAS has an extremely high resistance to impact. Very high impact may cause local pitting of the glass but this neither affects the function or its leak tightness
Sensitivity	Toughened glass is very sensitive to uneven torquing of slight bolt points. The glass surfaces must be entirely flat and smooth (within 0.07 mm) to avoid uneven torquing	Extremely high tolerance to uneven torquing. Uneven surfaces do not result in glass damage
Mode of Failure	Uneven- or over-torquing results in the glass cracking right through	METAGLAS cannot be over-torqued. When reaching the limits of uneven torquing, cracks will appear but the METAGLAS will remain leak tight
Erosion	Erosion, particularly right through the glass toughened surface, results in significant weakening which can lead to catastrophic failure	METAGLAS will remain leak-tight to a high level of erosion
Cleaning	Glass must be replaced unless it can be cleaned in-situ	METAGLAS can last indefinitely regardless of how many times you remove, clean and replace it

***Figure 2**: Conventional Tempered Glass versus METAGLAS*

What Is METAGLAS?

METAGLAS® is an LJ Star fused metal/glass sight glass disc product, which incorporates a glass viewing disc fused into a metal ring. METAGLAS is manufactured according to the processes described previously in this handbook. After the glass cools the unit is then ground, machined and polished.

METAGLAS sight glass discs are used in many sectors of the chemical and pharmaceutical industries. METAGLAS is an ideal alternative in place of thermally stressed sight glass discs, which can fail suddenly. If damaged, METAGLAS can possibly suffer surface cracks but not total failure.

METAGLAS Materials

Borosilicate Glass

All sight glasses were once made of soda lime glass. Corning then developed borosilicate glass (brand name Pyrex®), which has now become a popular choice for sight glass construction. The key characteristics of borosilicate glass include high temperature capabilities, great corrosion resistance, low thermal expansion (high thermal shock resistance) and, of course, the ability to see through it for process observation.

Borosilicate Versus Soda Lime Glass

Soda lime glass is the least expensive and most common type of glass. Comprised of silica, soda, lime, magnesia and alumina, soda lime glass is used in the manufacture of bottles, light bulbs and window panes.

Borosilicate glass is similar, but it is made by replacing some of the silica with boric oxide. Borosilicate glass is used in the manufacturer of cookeries, laboratory equipment and glass pipe, in addition to sight glass windows.

Advantages of borosilicate over soda lime glass include the following:

- **Better pressure and temperature shock endurance**
- **Higher allowable temperature gradient**
- **Better resistance in steam and condensate environments**
- **Higher corrosion resistance**
- **Readily accepted by approval authorities**

Comparison of Degradation of Borosilicate Versus Soda Lime Glass in Water

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 (**Figure 3**), 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.[1]

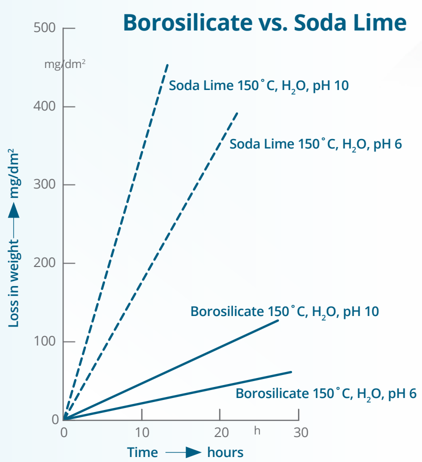
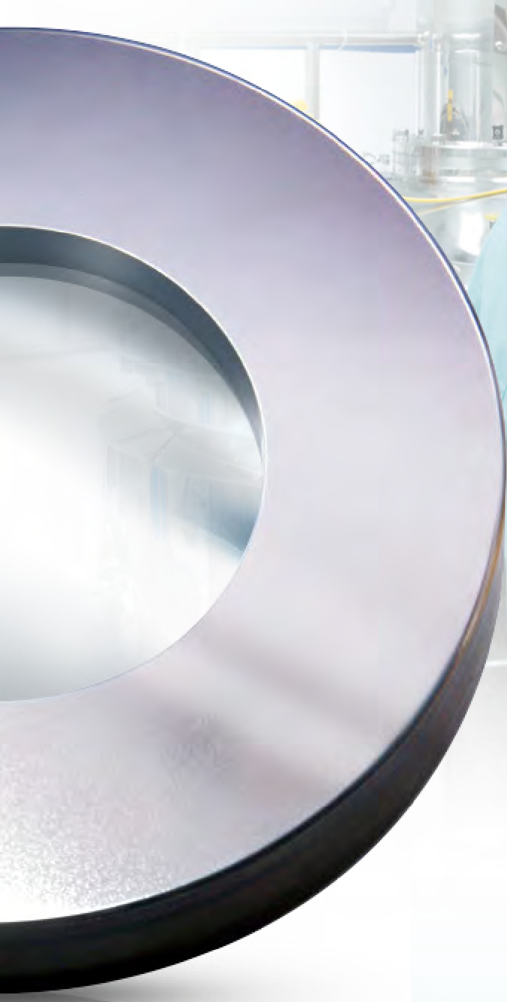


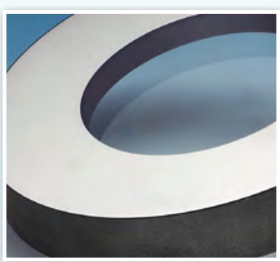
***Figure 3**: Borosilicate versus Soda Lime*

[1] Translated from "VGB KRAFTWERKS TECHNIK," Dr. A. Peters, Feb. 1979



Duplex Stainless Steel

The main metal used in METAGLAS production is duplex stainless steel. This alloy can be thought of as chromium-molybdenum ferritic stainless steels to which sufficient austenite stabilizers have been added to produce steels in which a balance of ferrite and austenite is present at room temperature. Such grades include the high chromium and molybdenum ferritic stainless steels. The duplex grades, with equal amounts of ferrite and austenite, are exceptionally tough. The newer duplex grades, which feature the addition of nitrogen, are stronger, tougher, highly resistant to corrosion and to chloride, and are economical to produce.



Depending on the application, however, other metal alloys may be used, including:

- **Carbon Steel**
- **Hastelloy**
- **Monel®**
- **Inconel®**

Chemical Shields

To protect against chemical attack (*sodium hydroxide, hot concentrated alkaline solutions, phosphoric acid, fluorine*), METAGLAS windows can be supplied with a mica or FEP shield.

METAGLAS Applications

METAGLAS® can replace conventional glass in many applications, including circular flange assemblies for welding into vessels, weld neck and nozzle flanges and sight flow indicators. In addition, METAGLAS cover flanges can be mounted onto flat-face base flanges, which are available for all flange connections, including ANSI and BS. Existing installations can be easily retrofitted to improve safety and increase production.

The unique properties of METAGLAS® also make it ideal for use with sanitary mounting systems. METACLAMP®s are available as sight glass caps for sanitary clamp and in-line systems and sight glasses and Luminaire adaptors for sterile flush mount designs such as the NA-Connect system and Triclamp® fittings.

METAGLAS® has been subjected to the most rigorous tests by specific testing facilities in the chemical industry and has subsequently been integrated into their work standards. METAGLAS sight glasses can be used anywhere there is a need to have visual control of a process operation being carried out in a sealed container (for example pressure vessels, pipelines, electric switching stations, boilers, refrigeration technology, etc.). Specific applications for METAGLAS include the following:

- **Suitable for mounting in standard fittings (e.g., to DIN 28120 or DIN28121), mounting onto flange pads or weld flanges (with or without raised face), for screwing directly into threaded entries and for mounting within Triclamp and NA-Connect style assemblies, etc.**
- **Chemical process vessels and piping systems**
- **Aseptic sanitary pharmaceutical and food processing vessels and process lines**
- **Measurement and control systems**
- **Impact resistant light shields for offshore platforms**
- **Cannabis extraction processes**
- **Suitable for retrofit**

METAGLAS® has been subjected to the most rigorous tests by specific testing facilities in the chemical industry.

METAGLAS Testing and Approvals

METAGLAS has been tested and approved by safety testing departments at major chemical and other companies under a variety of conditions, most exceeding those normally encountered in practice:

- **Pressure and temperature cycling**
- **Over pressurizing**
- **Impact testing**
- **Bending**
- **Erosion**

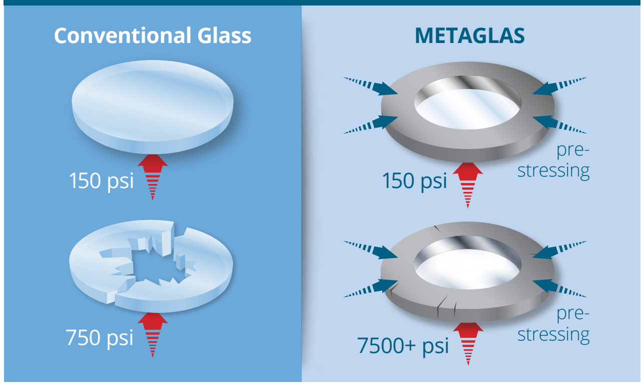
Approvals/Compliances

- Factory Mutual
- Sight Glass Fused to Metal to DIN7079
- Borosilicate Glass to DIN7080
- USP Class VI and BPE Compliant
- USP Type I Borosilicate
- TÜV Certified
- Pressure Equipment Directive 2014/68/EU
- Quality Assurance System: CE 0035
- Certified According to EAC Regulations

Independent Test Results

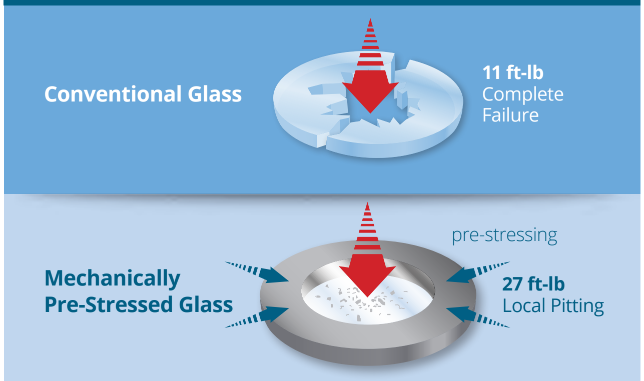
Resistance to Over-Pressurizing

- Remained leaktight to over 40 times rated pressure
- Conventional glass — ***Catastrophic Failure***



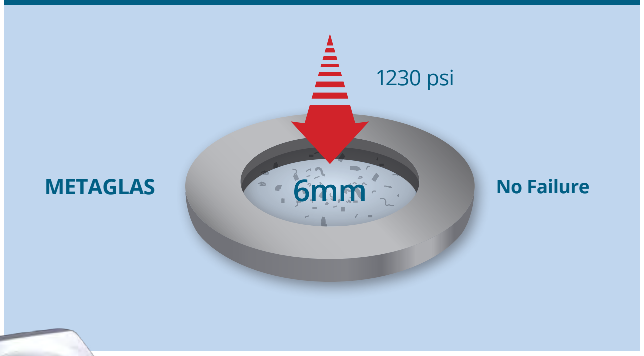
Resistance to Impact

- 27 ft-lb impact resulted in pitting only
- Conventional glass completed shatter at 11ft-lb.



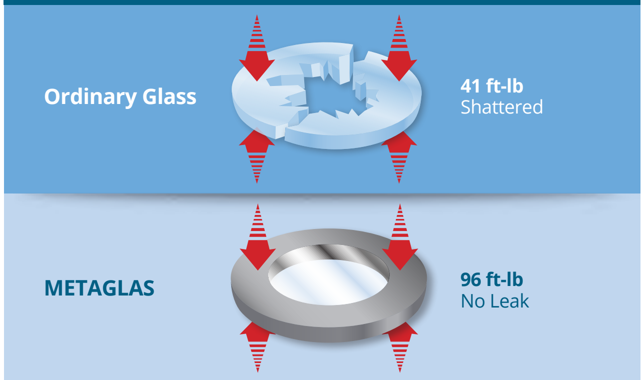
Resistance to Erosion

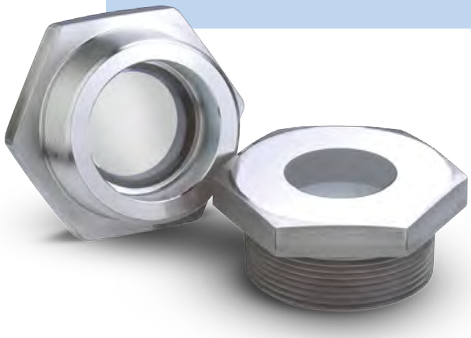
- Glass thickness eroded from 15mm to 6mm
- 150 psi rated disc remained leaktight to 1230 psi (gasket failed)



Resistance to Bending

- 96 ft.-lb on ¾" METAGLAS Remained Leaktight
- Conventional Glass — ***Complete Shatter at 41 ft-lb.***





Resistance to Pressure Cycling (Design Pressure 350bar)

First Test: 6,000,000 cycles from 0 to 350bar (room temperature) – NO GLASS FAILURE

Second Test: 6.000.000 cycles from 0 to 420bar (room temperature) – NO GLASS FAILURE

Third Test: 6,000,000 cycles from 0 to 690bar (room temperature) – NO GLASS FAILURE

Forth Test: 6,000,000 cycles from 0 to 950bar (room temperature) – NO GLASS FAILURE

Fifth Test/Burst Test: Burst Pressure 3,814 bar – The fitting thread failed, the glass cracked but remained in the fitting

Installation and Maintenance Tips

Installation Tips

Installation practice for conventional glass discs between flanges applies to METAGLAS except as noted in the following table:

	Conventional Glass	METAGLAS®
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	✔	✔
Glass may make incidental contact with metal when assembling		✔
Easier gasket installation, use and replacement		✔
Use of a gasket between disc and cover flange is optional, not mandatory		✔
A torque wrench is not required as over torquing will not damage disc		✔

Flat-Faced METAGLAS Flanges (with holes)

Weld pad, vessel, or pipeline flange to which flat-faced METAGLAS flanges are installed must be flat-faced with full gasket or with groove and O-ring gasket. Installing to a raised-face flange will result in glass cracks due to excessive bending moments. Bolts and nuts should be tightened crosswise (like tightening lug nuts on an automobile wheel).

Maintenance Tips

Maintenance practice for conventional glass discs between flanges applies to METAGLAS except as noted in the following table:

	Conventional Glass	METAGLAS®
Never re-use glass or gaskets	✔	
Once glass has been removed from its mounting for any reason, discard the glass and gaskets and substitute new glass and gaskets	✔	
METAGLAS® safety windows may be reinstalled by carefully following provided instructions		✔
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 bright concentrated light source at about a 45° angle. 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.**

Factors that could lead to damage or destruction of METAGLAS are as follows:

Temperature

The minimum operating temperature is determined by the material of the metal ring. Although METAGLAS exhibits a very large operating temperature range, caution must be used not to exceed either limit. If this lower temperature limit is exceeded, the metal may become brittle, its tensile strength may be affected, and the sight glass unit could break up.

The maximum operating temperature is determined by the mechanical prestressing of the glass and/or the material of the metal ring. Even if the temperature is exceeded by a small amount, the result could be failure of the sight glass.

Pressure

The maximum operating pressure is determined by the configuration (dimensions) and the combination of materials of construction of the sight glass. If the pressure is exceeded, concentric or net-shaped cracks can appear in the surface of the glass on the low-pressure side. Further increase will result in enlargement of the cracks, slivers of glass will break away and, potentially, the glass could fail.

Temperature shock

Although borosilicate glass has a high thermal shock resistance, avoid rapid heating or cooling of the sight glass. With fused metal/glass sight glasses, the steel ring is in tension and the glass insert is in compression. The stresses in the two materials are not homogeneous. In the glass disc, the stress is concentrated around the peripheral glass/metal interface. If the sight glass is subjected to temperature shock, concentric cracks may appear in this area, or fine slivers of glass may even break away. These cracks will not disturb the pressure-tightness/sealing properties of the glass, nor will they create a direct safety risk if they are no deeper than 10% of the original glass thickness; however, the sight glass should be checked properly and, if necessary, exchanged. The same applies to chemical corrosion.

Chemical corrosion

The chemical resistance of the unit is determined by the two constituent materials, glass and metal.

Glass

Generally, borosilicate glass has a high resistance to water, salt solutions, acids and organic substances and is thus superior to most metals and synthetic resins. It is only significantly attacked at raised temperatures by fluorine, strong alkaline and concentrated phosphoric acid solutions. Chemical erosion, however, can take place in the presence of condensate and salt solutions. Corrosion will increase at higher pH values, increased concentration and higher temperatures. The greatest deterioration of the glass will result from alternating exposure to acid and alkali. There is no mutual reaction between glass and nonaqueous organic solutions.

Reciprocal reaction with glass surfaces can cause turbidity, spots, thin films with interference coloring and grainy or smooth deposits. These effects may remain restricted to the surface but in the extreme can lead to failure or dissolution of the glass.

Metal

The user should check that the material of the ring has the corrosion resistance to the substances to which it will be exposed.

Mechanical loading

Fused metal/glass sight glass units are more resistant to distorting loads when incorrectly fitted than conventional sight glass discs; however, incorrect installation can affect the function of the unit and even lead to cracking. Sight glasses should only be installed by personnel who have been thoroughly versed in the following:

- **Careful handling of sight glasses**
- **Cleaning of housings, discs, gaskets and inserts prior to installation (removal of all foreign bodies)**
- **Even tightening of securing bolts**

During installation there should be no additional stresses imposed, nor should the units be exposed to mechanical impact loads.

Fused metal/glass sight glasses must be included in all planned maintenance procedures and periodically checked both visually and with ultrasonic-wall thickness testing equipment. In the event of a glass being damaged, adequate visual checks should be made until the relevant vessel can conveniently be shut down. This will make for a practical glass exchange routine to suit the process operation.

Summary

Choosing sight glasses for your processing system is a decision that can have safety and operational consequences for your business for years to come. When safety is a concern, sight glasses must be properly specified, installed and maintained. In a chemical or pharmaceutical system, conventional sight glasses may not be the ideal choice. Conventional, thermally prestressed sight glasses can require frequent replacement and more complex maintenance. And, most important, conventional sight glass can present safety hazards due to the potential for damage and catastrophic failure.

On the other hand, mechanically prestressed, or fused sight glasses offer a viable alternative to conventional sight glasses, giving you a safer, stronger, longer-lasting solution for your sight glass needs.

LJ STAR®

You'll look better

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