Flat Glass

by Elizabeth Bogle

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Glass plays a wide variety of roles in exhibit design, but all involve important technical issues.

Man has been making glass for at least 5,000 years. The earliest known manmade glass is found in glazed ceramics circa 3000 b.c. The Egyptians and Mesopotamians made glass vessels 1,500 years later, and by 30 b.c., glass makers used blow pipes to shape glass. In 50 a.d. the first window glass (flat glass) was manufactured.

Heat up silica until it melts and once it's cooled, you'll have glass. But silica melts only at very high temperatures, so glass makers mix silica with fluxes--substances that enable silica to be melted at lower temperatures. The most commonly used fluxes are soda ash and lime. Modern glass is approximately 70% silica, 25% soda and lime, and 5% additives--chemicals and other substances that give glass its character: strong or delicate, clear or colored, transparent or opaque.

Glass has unique characteristics that make it particularly suited for museum use. It shields and protects artifacts from dust, heat, ultraviolet light, and visitors. Clear glass is nearly invisible, resists scratching, and allows visitors to see but not touch. Glass is inert--it will not gas off and damage artifacts. Glass can be drilled, cut, and bolted to form display cases or graphic panels of nearly any size. Copy screened onto glass panels can usually be wiped off and updated as needed.

No material is perfect and glass has some disadvantages. It can cause reflections. It does not absorb moisture, so humidity build-up needs to be considered. It is costly to ship because it needs special padding and crating. And, of course, it breaks, it breaks, it breaks!

Museum exhibit designers work mainly with flat glass panels displayed indoors. Outdoor variables such as heat expansion and weather are not considered here. Neither are blown or shaped glasses addressed. For our purposes, flat glass is any sheet of glass. Technically, sheet glass is formed by drawing molten glass; plate glass is formed by passing molten glass through rollers; and float glass is formed by floating molten glass over molten tin. Today, almost all flat glass produced in North America is float glass; and the terms "sheet glass" and "plate glass " are obsolete.

Corning Glass alone has developed over 100,000 different kinds of glass. Since glass comes in so many different varieties, designers often agonize when selecting glass. As with any choice, specifying glass involves compromising and making trade-offs. Selecting glass need not be difficult as long as you approach the choice logically. Decide what you want the glass to do and the battle is half won.

Flat Glass Basics

Flat (float) glass is available in several different configurations and is strengthened using a variety of processes. A basic understanding of the different types of float glass is necessary to making informed glass decisions.

Flat glass configurations: Glass manufacturers divide glass into three basic configurations. *Monolithic* glass is a simple single sheet of glass. *Insulating or double-glazed* glass is really two single glass sheets with a hermetically-sealed air space between them. Insulating glass is effective in reducing thermal energy transmission. Laminated or safety glass contains two or more sheets of glass separated by one or more plastic layers which are bonded under heat and pressure. Laminated glass breaks "safely" and can reduce ultraviolet penetration.

Strengthening flat glass: Glass is strengthened by manipulating the heating and cooling processes or by chemical bathing.

Heat treating involves reheating glass to just below the softening point (about 1,150°F) and then cooling it by air quenching–blowing air over the surface. This produces glass which is approximately twice as strong as regular glass.

Tempering (in which much more air is blown over the surfaces than in heat strengthening) produces glass about four times stronger than regular glass. Tempered glass is also known as fully-tempered glass and is a safety glass because it fractures into many small, relatively harmless pieces when broken.

Chemical strengthening involves treating regular (annealed) glass in a heated chemical bath. Chemically strengthened glass strength varies greatly depending on length of time in the bath, temperature of the bath, and process used.

Glass vs. Acrylic

The first issue a designer must resolve is whether to use glass at all. Because there are no firm rules when choosing glass or acrylic, I always find this is a difficult decision to make. The big advantage acrylic has over glass is that it doesn't break so readily. Acrylic is color-free: normally clear glass will contain some green color but a colorless glass with a low iron content is available. The primary pull of glass is an almost undefinable aesthetic quality it brings to any project. Glass has class.

Although sheet size and thickness will affect the properties of both glass and acrylics, the table below summarizes the major differences between these materials.

Properties	Glass	Acrylic
Deterioration Risk	Low	Medium
Scratch Resistance	High	Low
Ease of Drilling/Cutting	Low	High
Electrostatic Dust Resistance	High	Low
Fire Resistance	Medium	Zero
Flexibility	Low/Zero	High
Heat Expansion	Low	High
Impact Resistance	Low	High

There are no firm rules when choosing glass or acrylic.

Breakage and safety:

Frequently, the designer's primary concern with glass is breakage. No museum wants a damaged artifact, an injured visitor, or a lawsuit. Designers need to factor in glass location, activity level, and degree of visitor abuse into both exhibit design and glass choice. Insurance rates can be influenced by glass selections. It is a good idea to have the museum check with its insurance agent to determine if savings can be made by specifying certain types of glass.

Monolithic regular glass is found in simple windows. It has low impact resistance and fractures easily. Long sharp-edged shards and splinters result even with thick sheets. This glass is very easily broken and is rarely found in museum exhibits. Regular glass or annealed glass is the only glass, however, which can be drilled, cut, and bolted. For this reason, exhibit elements are frequently cut and drilled with regular glass at the exhibit construction shop and are subsequently sent out for tempering. Similarly, when decorative cutting, etching, and sand-blasting are required, regular glass should be the designer's choice. Heat and chemically-treated glass can break during decoration. Again, regular glass is often tempered after decoration. Should the designer choose to invade the surface after strengthening, cuts should be limited to no more than 10% of the glass surface. Any post-fabrication will reduce its strength. Heavy regular float glass (of varying thicknesses) is frequently used for shelving and straight-sided aquariums. Because its thickness and strength allow for greater spans, heavy float is also found in frameless glass expanses.

Monolithic heat-strengthened glass has about twice the strength of regular glass. When broken it fractures similarly to regular glass and is therefore not a safety glass.

Monolithic tempered glass (also known as fully-tempered glass) has a higher impact resistance than regular glass. When broken, it crumbles into small, granular fragments like rock salt.

Chemically-strengthened glass has a higher impact resistance than regular glass. When broken it produces long, sharp-edged splinters. Unlike heat-treated glass, chemically strengthened glass has a thin surface layer which is susceptible to scratching and can deteriorate over time.

Insulating glass bears different loads depending on the strength of the glass used in the individual panes (also called lites). Each lite, of course, has the same degree of impact resistance and shatter pattern as its cousins above. Under a uniform load, an insulating regular glass unit will bear 1.8 times as much as a regular monolithic sheet; an insulating heat-strengthened unit will bear 3.6 times as much; and an insulating fully-tempered unit will bear 7.2 times as much. Insulating glass is usually chosen for its thermal value (except at the bomb-resistant insulating laminate level) to save energy and money; rather than for its impact resistance or breakage pattern. Insulating products are used when the building's climate control systems are less than ideal or for live displays such as chicks, reptiles, or terrariums.

Laminated glass comes in a bewildering variety of combinations. When a glass laminate breaks, the splinters produced tend to adhere to the plastic interlayer. Any glass laminate product can be called a safety glass due to its interlayer. Glass laminates can be made from combinations of regular, heat-strengthened, fully-tempered, and chemically-strengthened glass sheets in conjunction with interlayers of different materials. Laminates can also be used in insulating products. Security laminates are classified into different strengths such as: burglar resistant, bullet resistant, attack resistant, and bomb resistant. Weights and thicknesses of laminates vary greatly. The strongest flat laminates can be over 2 inches thick, exceed 20 pounds per square foot, and withstand pressures of 57 pounds per square inch.

Laminated glass products are obvious choices when safety is of paramount importance; for example, in exhibits geared towards active children. Security laminates are recommended for high-risk situations such as street-front displays, protecting extremely valuable artifacts, and live animal displays. The designer should also factor in the glass used in the museum building itself when security is an issue.

Specialty glasses also come in a wide variety of types:

- Wired glass has half the impact resistance of regular monolithic glass. When broken, jagged splinters tend to remain in place with broken wires protruding. Wired glass is frequently found in fire doors and hallways because it is a fire resistant glass.

- Aquariums use special laminates which withstand enormous amounts of water pressure and have high impact resistance.

- Decorated and patterned glass strength depends on the glass configurations, decorative materials (such as ceramic frits), and the processes (etching, laminating, etc.) employed.

Artifact protection and conservation:

Protecting museum artifacts is one of the exhibit designer's major responsibilities. Rather like preparing for battle, the designer needs to figure out what kind of attack the artifact is vulnerable to, and then defend against it. Properly selected glass can be a powerful weapon in the designer's artifact protection arsenal.

Ultraviolet radiation can wreak havoc with artifacts. Fabric and paper deteriorate rapidly from ultraviolet radiation, but almost any organic artifact will deteriorate to some degree under ultraviolet attack. Clear, regular glass will block approximately 29% of ultraviolet radiation. Laminated glass with polyvinyl butyral (P.V.B.) interlayer(s) can block 99.5% of ultraviolet radiation. Monolithic glass with UV resistant coatings is also available.

Thermal energy transfer is another enemy of artifacts. Depending on the situation, artifacts may need protection from heat or cold, or may tolerate little temperature change. When thermal energy transfer is an issue, glass choices can include insulating glass items, tinted monolithic glass, low-emissivity products-glass treated with a thin transparent energy efficient coating, and solar-energy resistant laminated glass. The degree of solar energy resistance varies greatly among products, and is found in the manufacturer's literature.

Fires destroy artifacts with heat, smoke, and water. No glass is heat-proof. Heat-resistant glass products have been tested in furnaces between 1,000°F and 1,638°F and are rated accordingly. Fire ratings range from 20 minutes to 3 hours. When fire is the enemy, the resistance of the framing elements and surrounding structures must be included in decision making. Water impact is also an issue. Some fire-rated glass can withstand up to three hours of continuous high-impact spraying.

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Theft is always a consideration when valuable artifacts are displayed. Security laminates are the designer's choice here, and, as detailed in our discussion of breakage, are available in many different strengths. When necessary, exhibits containing glass can be wired into security systems.

Electromagnetic interference can impair performance of exhibits that utilize computers or radio transmissions. Although primarily intended to deter electronic theft, electronic security products which combine metal fabrics with glass laminates will reduce electromagnetic interference.

Moisture control must be addressed when glass is used in display cases. Unlike wood and textiles, glass and metal do not absorb moisture. This can become critical when you have a case with large glass areas and metal framing. Under certain conditions moisture can build up inside a display case, especially when it is located in direct sunlight near a window. Humidity control systems should be considered.

Design Issues:

Glass is an incredibly versatile tool for the exhibit designer. Display cases are probably the most common use for glass in museum design, but glass really comes alive when it is decorated, lighted, or screened. When designing with glass, careful attention must be paid to thickness, size, and weight, as all will affect mounting methods and framing materials.

Thickness is determined by the length and width, and the load it is designed to withstand. Temperature, impact conditions, framing methods, and placement (horizontal, vertical, slanted) are all considerations. In general, the thicker the glass, the greater its size and surface load.

Weight: Frame size, mounting devices, shipping and installation methods are all affected by weight. Below is a thickness related to weight table for clear float glass issued by PPG Industries.

Thickness	Per Square Foot
3/32"	1.16 lbs
1/8"	1.56 lbs
5/32"	1.98 lbs
3/16"	2.43 lbs
1/4"	2.89 lbs
5/16"	4.05 lbs
3/8"	4.90 lbs
1/2"	6.36 lbs

Weight bearing loads must also be factored into the design. Loads will vary with framing systems. Glass framed on two sides will bear a smaller load than glass framed on four sides. Weight bearing loads vary with glass thickness, sheet size, and configuration.

Reflections on glass can be reduced by manipulating lighting and glass placement. Normal daylight on a regular glass pane will reflect about 8% of the light. Anti-reflective glass coatings can reduce reflections to 1%. These coated glass sheets are available in monolithic and laminated products. Anti-reflective glass can also reduce lighting and heating costs as less energy is needed to overcome glare.

No amount of preparation or attention to detail will eliminate all breakage.

Sound: Glass panels are often used to divide exhibition rooms and halls without reducing visibility. When sound control is needed, glass laminates with acoustical interlayers should be considered.

Transparency: All glass has some color and many untinted glasses are greenish at the edges. Low-iron glass is very clear, transmits more light than ordinary glass, and has little green at its edges. When using tinted glass, keep in mind that the thicker the glass, the darker the color. Laminate interlayers can also affect transparency.

Reflective glass comes in many different colors and reflective strengths. Primarily intended for architectural use and solar energy control, it does have a place in museum exhibit design. Reflective coatings are made from metals or metallic oxides. In general, reflective products are not suitable for invasive decorating methods. If reflective glass is to be used for copy, the designer must determine if copy can be removed without ghosting and if chemical removers will affect the coating.

Mirrors are frequently found in exhibit cases, and transparent mirrors (two-way) are often an adjunct to security systems. As with reflective glass, designers need to consider ghosting and coating degradation when washing copy from mirrors. Many mirrors cannot be chemically strengthened. Transparent mirrors need special placement and lighting to be effective.

Graphic panel copy can be silk-screened or painted onto glass. Most lacquers, enamels, etc. can be removed without ghosting from uncoated glass. Abrasive and chemical removers can damage glass, especially coated glass. Designers should always check manufacturers' guidelines.

Decorative, Patterned and Custom Glasses: There are many, many different decorating glasses to choose from and manufacturers are constantly updating their product line. Glass can be bonded with colored ceramic frits; etched or frosted with patterns; laminated with decorated interlayers; coated or tinted in almost any hue; and be produced in varying degrees of opacity. Custom graphics can be digitally etched or applied to laminate interlayers.

Construction and installation:

Great care must be exercised during construction and installation in order to avoid damage and breakage. Generally, no amount of preparation or attention to detail will eliminate all breakage.

I still have nightmares about a glass disaster on one of my jobs. Every possible precaution had been taken to protect a huge, silk-screened glass panel which was the centerpiece of an exhibit entrance. As the sheet was being put in place, it was lightly scratched by a worker's belt buckle or ring. Being a heat-tempered glass, it disintegrated instantly into a pile of granules. I have pictures showing the stunned workers who seem to be standing in piles of snow. There was only one other sheet of that size and type available in the entire country, and it had to be shipped 300 miles to us to be screened and installed for the opening two days later!

When glass is displayed at an angle, pay particular attention during mounting. Laminated glass is a good choice for slanted glass in exhibits.

Glass is more vulnerable to breakage when carried horizontally. If at all possible, glass should be transported vertically.

The final factors in choosing glass are cost and availability. Obviously as the complexity of the glass product increases, so does its cost. When budgets are tight, even plywood occasionally wins out over glass. Handling, shipping, and crating of glass can also become pricey. Even with an unlimited budget, availability is a big issue. Most glass is produced for the building industry and manufacturers are geared to large quantity projects with plenty of lead time. Designers must check to see if the product of their choice is available when required in the quantity desired. Often, to avoid costly packing and shipping, construction/installation firms tend to buy the glass near the installation site. A good insurance policy is to contact a local glass distributor early in the design phase, and discuss the project's glass requirements with them. By so doing, you can usually eliminate unforeseen problems.