

Glass for Stained Glass

It is paradoxical that textural imperfections in glass, either on its surface or internally, tend to make the glass more attractive. These imperfections are, in fact, far from being the eyesores that one might suppose; quite the opposite, variations in a section of glass improve the overall effect of the glass.



Full
Antique
Glass

After being blown in a cylindrical shape, the glass is flattened into a sheet for stained glass work.

The reason for this is that any irregularities inside the glass will break light rays into myriad light particles that then refract in a multitude of directions. The effect can be visually explosive. Any piece of glass can be interesting and both a legitimate and highly desirable component of any work.

Expertise in glass selection can only come with an intimate knowledge of what is available to the stained glass craftsman. Knowledge of the different glasses

available, both in sheets and as specialty glass, will enable the artisan to choose glass best suited for a particular project. The diverse glasses available are of several distinct types, each sharing common elements such as color, texture and translucency.

Color is achieved in glass through the use of chemicals, normally metal oxides and sulfides that act as pigments in glass. For example, manganese oxide produces a purple colored glass; cobalt, a blue; cadmium sulfide, a canary yellow; and selenium, a red. Chemicals can also be used in specific combinations in glass to form either distinct colors or multicolored patterns. An understanding of color and color patterns available in glass will allow the craftsman to utilize color to its greatest benefit.

Translucency is a second aspect of glass of which the craftsman is aware. Decorative glass ranges in density of color from almost transparent to semi-opaque. (When the term opaque or opalescent is used in leaded glasswork, it is understood to describe glass in which the transmission of light is considerably reduced but not totally eliminated.) Whether to choose glass that transmits a little or a great deal of light depends on client preference and on the end purpose of the project undertaken. There are no hard and fast rules governing the selection of a given translucency in glass.

The third characteristic of glass that can be utilized creatively is its surface and internal texture. A great deal of the colored glass that a leaded glass practitioner uses is fairly uniform in thickness, with smooth top and bottom surfaces. Nevertheless, some glasses do have surface textural qualities. The stained glass craftsman knows when these glasses can be best incorporated into a design to add sophistication, variety and sparkle.

Some machine-rolled glass is patterned on one side in various configurations, such as a granular or rip-

pled. One side of a sheet of glass must always be made relatively smooth during manufacture so that it can be scored with a glasscutter.

Textures not only give glass a tactile quality, but modify the transmission of light in its own unique fashion so that the light rays, on striking the uneven surface of the glass, are refracted through it at different angles. The result can greatly enhance the overall effect of the glass, giving it a dazzling aliveness.

Internal texture patterns are also present in some glasses and can be used with remarkable results. Tiffany used to make a spectacular “fractured” glass consisting of splinters or flakes of differently colored glass superimposed on top of each other and pressed into a single sheet. Today, several manufacturers have succeeded in successfully reproducing glass similar to what Tiffany made many years ago.

Another internal pattern, called “seedy,” contains both large and small air bubbles inside the glass itself. These internal texture variations also serve to modify the way light is transmitted through glass.

The types of glass available to the stained glass craftsman may seem confusing and perhaps endless. However, there are four basic manufacturing methods used in making glass: blown glass, drawn glass, rolled glass and poured glass. These four basic types of glass, plus some miscellaneous glasses that are difficult to categorize, encompass virtually every glass used by the stained glass craftsman.

The unique characteristic of glass is, of course, that glass allows light to pass through it. Glass has a different index of refraction than air; thus light rays passing through any glass will be altered. Imperfections in the glass itself, including variations in the thickness of the glass or flaws in the glass, create a changing shimmer or iridescence. For these reasons, glass used in the stained glass craft is produced in a manner to encourage these imperfections.

Following are descriptions of these basic types of glass.

Blown Glass

A glassblower using a blowpipe and molten glass creates blown glass. Blown glass includes antique, crown and Norman Slab.

Antique: The term “antique” refers not to the age of the

glass, but rather to the centuries-old method of blowing a cylinder and subsequently flattening that cylinder into a sheet of glass. It is made in what is believed to be the same method used to produce glass for medieval stained glass windows. The glass created by this method is extremely beautiful and translucent. It has vibrant color and is characterized by bubbles, striations and imperfections that catch and reflect light.

Some antique glass is mold blown. The partially blown glass is placed into a hinged cylindrical mold and blown to fill the mold. If the mold is wood, the glass has almost no texture, but if a metal mold is used, the glass acquires prominent chill marks that consist of a varied, random dimpling or rippling.

Due to the manufacturing process, antique glass usually has more intense colors, more interesting textures and considerable variations in thickness and density of color from other types of glass.

Antique glass, which can be either a domestic or an imported glass, is noted for its beautiful imperfections, called reams, bubbles or striations. Its method of manufacture limits the size of a sheet to less than half the size of a rolled sheet. Although most hand-blown glass comes from England, France and Germany, several companies in the United States produce distinctive and beautiful hand-blown glass.

Semi-antique glass, another variation of antique glass, is blown with the help of a compressor into extremely long, large bubbles approximately 14 inches in diameter and 5 feet long. In the blowing process, the cylinder is rotated up and down in a cylindrical trough to give an even shape to the bubble. This also helps to create part of the beautiful crystalline surface texture of this glass. Because of the large size of the cylinders blown, this glass has a very consistent thickness and even color, and also has excellent cutting properties.

Antique glass includes the following varieties:

Seedy (sometimes referred to as “bubbles”): Bubbles in the glass are obtained by blowing the molten glass before the mixture of silica sand, borax, and coloring matter has boiled itself free of sulphurous gases formed in the heat of its creation. Placing a block of wood soaked in water onto a stir-rod and gently stirring the molten glass is another method used

to obtain seeds. Gently stirring the molten glass, top to bottom, causes oxidation of the molten glass by entrapping the air. Normally, a 100-pound batch of glass can be “seeded” only twice — once when the pot is full and again when the pot has been a little more than half worked. The most heavily seeded sheets will come or be cast from the first half or so of the pot. Seed intensity diminishes in casting the last of the molten mass.

Crackle: After the cylinder is blown, it is immersed for an instant in water. This cools the outside surface but not the central core. The resulting surface of the glass is similar to an alligator skin; it has a very interesting and random look.

Flashed: Flashed antique glass is a double layer of hand-blown glass consisting of a thicker base that is usually clear or lightly colored and a thinner veneer of a brighter color. In production, a base color or clear glass is dipped into another super-heated glass and coated like a candy apple. Light passing through the double layer mixes the two colors visually. The color in flashed glass often varies considerably. This is caused by an uneven distribution of the coated inner layer.

The varying values evident in flashed glass are often sought after for shading



*Opalescent
Glass*

and artistic dimension. The flashed layer can also be etched, engraved or even sandblasted to produce interesting designs, or to incise a legend or dedication, a name or date.

Opal or Opaline: Opaline glass is flashed with white glass. This is not the same as opalescent glass, although both use fluorides or phosphates to achieve a light-diffusing translucent effect.

Opak: Similar to Opal, but with a thicker flash. This makes it less translucent.

Goethe: Similar to glass made during the Colonial Period of America, this glass includes slight distortions, pits, imperfections and a non-striated surface.

Reamy: This glass displays a high degree of wavy, fluid motion that gives it a very old or primitive, handmade look. An irregular banding and striping of the glass yields the variations of texture. These bands are of different thickness and produce a strong degree of tonal contrast. The stained glass masters used this glass early in the century to let a great deal of light into churches.

Streaky: This glass has a light colored, clear white base layer of glass covered with one or more flashes of contrasting colors. The flashes are randomly spread in varying thickness, resulting in a free-flowing swirl of mixed coloration that creates some beautiful effects.

Striated: Striations are made by the glass blower who, when the bubble is the size of a large ball, twists and turns it in an iron bowl lined with small spikes. This has the effect of streaking the glass with a fine, semi-regular network of striations that glitter in the sun.

Pot Metal: All hand-blown glass is pot metal glass colored in the “pot” while molten. However, current usage of the term indicates glass of a single color throughout.

Blank: This is a clear antique that has only the normal surface variations incumbent to blown glass with no added surface texturing.

Crown Glass: Crown (or spun) glass is also a type of blown glass. It is rare today, but was widely used in early windows. The round, twirling bubble of blown glass is formed at the nub of an iron rod.

Once the glass is blown, the blowpipe is removed. This leaves a hole in the glass bubble, to which an iron rod is attached. The rod is spun rapidly, and the hole is widened with a stick. The glass flares out to form a disc with a central knob, or bull's eye. This method is most seen today in the form of roundels and bullions.

Bullions are originally the center of a sheet of spun crown glass. When glass is gathered during manufacture on the end of a glassblower's pipe and spun around on its own axis, then the centrifugal force of the movement pulls out the blob till it forms a spinning disc. This bullion is today specially cut out of the circular sheet of glass and sold.

Roundels are in effect bullions that are produced in a finished, circular shape. The characteristic of the roundel is the knobby mark in its center where the rod has been "cracked off." Machine-pressed roundels are identified by their centers, which are not as pointed as those of the hand-blown roundels. Roundels come in various colors and sizes and can be cut.

Norman Slabs or Squares: Norman slab, or bottle glass, is a nineteenth-century invention. It is made by blowing a long bubble of glass into a rectangular mold. A hollow box shape is left when the mold is removed. The blowpipe end is cracked off, and the box is divided into five pieces. The glass is of uneven thickness, but has a brilliant effect.

Drawn or Sheet Antique Glass

This glass type is often called "New Antique" or "Sheet Antique." It is a machine-made copy of the hand-blown antique. It is made by the vertical-draw, or Fourcault, method. The glass is pulled vertically through a one-piece refractory block in the draw chamber. An annealing lehr is mounted vertically over the refractory block. The cooled sheet of glass is cut into pieces of the desired size as it exits the lehr.

In the case of German machine-made antique, a slight pattern, similar to the crystalline surface of the antique glass, is put on it as the glass goes through the first roller. Because of this method of manufacture, this glass has the desirable properties of extremely even thickness, excellent color con-

trol and high brilliance.

In the French version, similar impressions are made by hand, and are more random in appearance.

Rolled Glass

There are three variations of rolled glass: hand rolled, machine rolled and continuous rolled.

Glass rolled by the hand or machine is called either Cathedral (transparent) or Opalescent (semi-opaque). Generally speaking, Cathedral glass is of one color and is available with a large number of different surface patterns. Opalescent glass is a semi-opaque glass of milky or marbled appearance and usually consists of one or more colors of glass mixed with the milk-white glass.

Cathedral Glass: To create rolled cathedral glass, the molten glass is taken (ladled) from the furnace and placed on a flat table or roll area. If machine rolled, the glass is ladled directly into the rolling machine. The annealing process is essentially the same for this glass as for antique glass. The rolling process may involve single or double rolls. Rolled glass is usually a domestic glass of uniform thickness in a wide variety of colors and patterns.

Rolled cathedral glass is smooth on one side and usually textured with one of a variety of patterns and texture characteristics. Metal rollers on the glass impress these patterns while it is hot. The names of these patterns generally describe the pattern. Hammered has a pebbly pattern; granite has dense texture; seedy incorporates air bubbles, and double rolled has two smooth sides. Ripple, moss, Florentine and Flemish are some of the more familiar long-time traditions in rolled patterned glass. These are, however, just a few of the wide selection available on today's market.

Opalescent Glass: Opalescent glass is made in a number of ways, including as a single color; with the pigments that give the glass a streaky, mottled, or cloudy appearance; and with or without a surface texture. It can be both a most beautiful and challenging glass with which to work. This is because the pigments are mixed into opalescent glass by hand during manufacture, with the result that the color patterns and tones in the glass are never exactly the same in any two sheets.

Opalescent glass has one characteristic that transparent

glass does not: namely, that it can be seen in both transmitted and reflected light. Opalescent glass has color impregnated into it to the extent that the pigmentation is visible by light rays reflecting off it. It can be seen as well as seen through.

Glass Casting: One method of casting a streaky sheet consists of scooping a partial ladle of molten glass from one furnace, filling the ladle with glass from a second (and sometimes a third) furnace and depositing the molten glass onto the casting table. Once deposited, it may be further mixed by hand with a stainless steel rod. This casting method requires only one caster.

There are a number of other ways to mix hot glass:

- Ladling first out of one tank, the caster can carefully deposit a small scoop of glass onto the surface of molten glass in the second tank. He then removes this floating “glass island” and enough surrounding glass to fill his ladle and carries the mixture to the casting table.

- Two casters can remove partial ladles of glass from separate tanks simultaneously with one caster depositing his scoop into his partner’s ladle before the mixture is cast onto the rolling table.

- Two casters scoop glass simultaneously from separate tanks. The first caster drops his glass onto the table while the second caster pours his scoop over the first scoop.

Whichever the method of mixing, the glass is ultimately rolled into sheet form.

Hand Rolled Glass: This glass is made by flattening the glass and rolling it out manually on a flat surface. With this process, it is possible to create special effects (heavy ripples, fracture and streamer glass, etc.) that are not obtainable in machine rolled glass.

Machine Rolled Glass: The process for machine rolling of the glass is similar to hand

rolling. The molten glass is ladled from the furnace and placed in the rolling machine, which then rolls the glass.

Continuous Rolled Glass: During the 1920s, one of the most important technological advances in the history of sheet glass took place: the development of a production process called the “continuous ribbon.” This new system took four separate phases of sheet glass production (raw material introduction, melting, sheet forming and annealing) and combined them into one continuous operation, making possible the production of large quantities of glass with very uniform and stable properties. Continuous rolled glass is made in electric ovens where the mix placed into the oven balances the glass taken from it. A continuous stream flows from the ovens into a series of rollers. After the rolling process, the glass hardens in 250 foot or longer annealing lehrs.

The glass is cut into usable sections as it emerges from the lehr. This glass is usually very consistent in thickness, color and texture, and comes in a wide variety of both Cathedral and opalescent types.

There are several rolled glasses that deserve special



mention. These include:

Ring Mottled Opalescent Glass: Ring Mottled Opalescent was first introduced to the stained glass industry by the Tiffany Studios of New York. This type of glass has a locally varying opacity; the “rings” are more opaque than the surrounding matrix.

Ring mottled glass is used to provide color and image gradation that is non-streaky, or non-linear. The naturally rounded shape of each ring breaks up the more typical streakiness of stained glass. The artist, using ring mottles, can create shading and imagery unavailable from other glass types.

Fracture and Streamer Glass: The “fractures” are created by the addition of thin blown flakes of intensely colored glass, while the “streamers” are pulled or drawn strings of intense colors. Both fractures and streamers are quick-fused to the bottom of sheets during the rolling process.

Fractures can be used either alone or in conjunction with streamers. Fracture and streamer glass is used primarily for backgrounds; the fractures suggest multitudinous leaves or flowers in the distance, while the streamers suggest twigs or stems. For this reason, fracture colors are usually selected to correspond to the colors used in leaf or flower foregrounds.

Hand-Rolled Drapery Glass: This glass ignites immediate interest in everyone who has ever cut glass. It is a heavily manipulated, folded and rippled glass. In some examples, the drapes can reach more than an inch in thickness. These thick folds were another Tiffany Studios invention. Tiffany’s glaziers used them to suggest folded fabric (hence the term drapery) or flower blossoms such as in the famed *Magnolia Window*.

English Muffle Glass: This glass, created using a particle roller, has a distinctive, star-shaped pattern. At one time, this glass was used extensively in Victorian panels.

Ripple Glass: Overspinning the roller imparts a rippled surface to the hot glass. By moving the roller from side to side as it is being spun, a feathered or herringbone texture is given to the rippled sheet.

Slab or Dalle Glass

Slab or *Dalle* glass varies from $\frac{5}{8}$ " to 1" or more in thickness. Each piece (*Dalle*) of the slab glass is approximately 8" by 12".

The glass is made by ladling directly into a mold. A *Dalle*

de Verre or slab glass window is created today by cutting or breaking the slabs and joining them with a matrix of epoxy adhesive.

Miscellaneous Other Glasses

There is a wide range of glasses that are difficult to categorize into one of the above areas but that are still vitally important to the stained glass craftsman. These include:

Jewels: These are small decorative forms, generally faceted by hand or machine, that are pressed or poured into a multitude of shapes, sizes and colors. The prismatic effects of jewels on light add sparkle to both transmitted and reflected light. Jewels sometimes feature a design and are usually flat on the bottom surface. (However, doublets — jewels faceted and shaped on both sides — were widely used during the Victorian and Edwardian Eras and are available in a limited supply today.)

Globs: Globes are lumps of glass that vary in size, shape and color. Also called nuggets, globes are made by heating small pieces of glass in a kiln until they melt into round forms. They are simple to make, and most glass artists with access to a kiln make their own.

Iridescent Glass: After glass has been flattened, it can be given a surface treatment that creates iridescent glass. This process involves placing the glass in a gas-fired chamber on a shelf dusted with a separator to prevent the glass from sticking.

In the iridizing chamber, a solution of stannous chloride is sprayed onto the surface of the glass at a temperature of more than 1400 degrees Fahrenheit. Timing, temperature and the proper application of the iridizing solution are critical to achieve the proper metallic coloration of the sheet. The glass emerging from the firing chamber can be stretched to break the shiny surface iridescence and create a matte finish.

Mirrored Glass: Mirror glass has a wide range of uses for the stained glass artist. It is commonly available in bronze and solar gray. However, silvered “machine antique” has entered the market as have various silvered cathedral glasses.

“Float” Window Glass: The most common type of window glass is $\frac{1}{16}$ " (single-strength) or $\frac{1}{8}$ " (double-strength). It can also be found in a much thinner variety called picture frame glass.

Window glass is also commonly used as the base for Glue Chip glass. The Glue Chip treatment is a two-step process. First, the glass surface must be sand blasted. Second, a layer of animal glue is poured on the surface, and the glass sheets are placed in drying ovens. As the glue dries, it shrinks. This causes it to chip off, thus producing a delicate, fern-like pattern on the glass.

Plate Glass: This glass is a smooth glass of uniform thickness used primarily for large areas of glass in home and commercial installations. It is essentially free of distortion. It ranges from $\frac{3}{16}$ " to more than 1" thick. This glass is valuable to the glass artist in producing beveled glass. It is also used as the glass easel for displaying a window prior to glazing, as a base for epoxied stained glass compositions and can be the base for Glue Chip glass.

Dichroic Glass: This glass is made by applying a surface coating of one or more layers of transparent materials designed to create reflections of a specific wavelength in order to modify an optical effect. The coating itself is com-

pletely transparent; all available light is either reflected or transmitted. Dichroic glass will provide very crisp and vibrant colors.

The most commonly used coating materials are titanium oxides, zirconium oxides, silicon oxides and aluminum oxides. They are applied using a method called Vapor Deposition. The deposition occurs in a high-vacuum chamber where the glass is suspended in the top of the chamber and rotated. The coating materials are placed in crucibles at the bottom of the chamber and bombarded with an electron beam that is focused and swept over the materials with electromagnetic fields. The heat generated by the bombardment vaporizes the materials, and the vapor condenses on the glass suspended above.

Dichroic coatings create some of the purest and most brilliant colors ever seen in glass. They are fragile and must be protected from abrasion unless they are reheated to close to the softening point. Once heated in this way, the coating becomes very durable.



Conclusion

There are thousands of choices of materials to the stained glass artist and craftsperson. By being familiar with the choices available, creative in the making of those choices and skillful in design and composition, the stained glass artist can create a work of art that is complementary to the architecture of a building.

While the selection of glass for a stained glass window is only one element of the successful creation of the window, it is certainly a vital element. The Accredited members of the Stained Glass Association of America are dedicated to the skillful and artistic creation of architectural stained glass.

Slab Glass
(Dalle de Verre)

