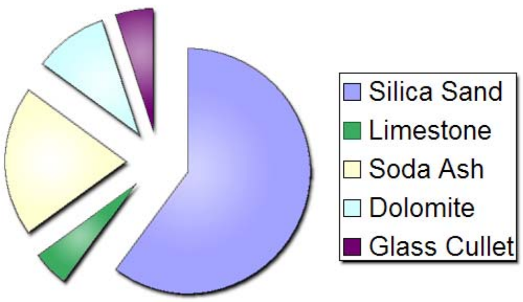
Glass in Today's Architecture

by the Glass Association of North America

First created over 4,000 years ago, glass has played an integral part in construction since Syrians, back in the seventh century, spun molten glass into a flat shape. Technology advanced, and, in the early twentieth century, molten glass was drawn vertically into sheets, creating "sheet glass." The later-developed plate glass process featured molten glass poured onto a table, rolled flat, then ground and polished into a plate. In 1959, Sir Alistair Pilkington of England invented the float glass process, which is used today. In this process, molten glass flows onto a bath of molten tin, forming a continuous ribbon of glass.



Float Glass Manufacturing

Float glass manufacturing uses some of the earth's most abundant raw materials. The main ingredient is silica sand, accounting for 60 percent (by weight) of the materials, which are called the batch. Limestone and dolomite are added to assist in the weathering properties of the finished glass, while soda ash and sulfate lower the temperature at which sand will melt.

Continuing Education

Use the following objectives while reading the following article. To receive continuing education credit from AIA, fill out the quiz at the end of the article, and follow the instructions on where to submit your quiz.

Learning Objectives

Upon completion of the article, you should have a broad understanding of:

- *Flat Glass Manufacturing*
- *Glass Substrates (types) & Sizes*
- *Fabrication Processes*
- *Glass Performance Terminology*
- *Applications*
- *Benefits*
- *Industry Resources*

Glass itself is also an important ingredient. Broken glass, called cullet, is recovered from the manufacturing process and crushed before being recycled and added to the batch. This further accelerates the melting process and reduces the amount of energy required for melting by up to 20%. All raw materials are rigorously checked to insure the purity of the batch and are fed automatically into the filling end of the furnace.

Superheated air from natural gas combustion heats the batch at temperatures of up to 2900 degrees F. Inside the furnace, heat is applied from alternate sides at twenty minutes cycles, assisting fuel efficiency by ensuring combustion takes place in the presence of preheated air.

Glass leaves the melting zone portion of the process at a temperature of about 1900 degrees F through a narrow canal, from where it passes into the heart of the process, a bath of molten tin. Here the glass spreads out, into a near perfect flatness on the layer of tin, so the upper and lower surfaces remain flat and parallel.

The molten glass is naturally made thicker by confining its initial outward spread over the tin. This is controlled by the pull of the ribbon, which narrows as the molten glass moves onto the tin bath. To thin the glass into a more typical thickness, the rollers controlling the flow of the glass are sped-up to provide a gentle stretching action. A controlled atmosphere of hydrogen and nitrogen, within the bath chamber, prevents the tin from oxidizing. When it emerges from the tin bath, the glass is sufficiently hard as to not be marked by the conveyer rollers. Special properties, including the ability to reflect heat, can be imparted to the glass by applying an extremely thin metallic layer to the glass before it leaves the tin bath while it is still hot.

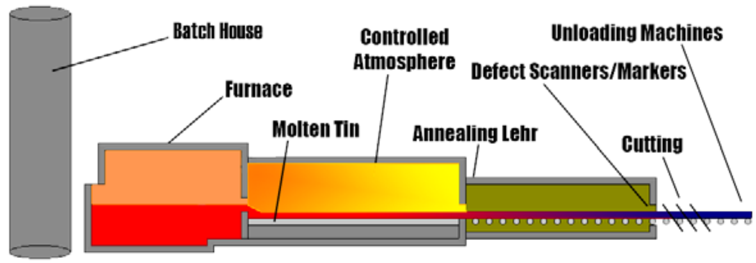
In a length of about 800 feet through the annealing lehr, the glass is taken down in temperature from close to 1100 degrees F to room temperature. With only the indentations left by the top rollers remaining to be scored and removed in a process called edge trim, the glass is cut and snapped to a predetermined size. Glass pieces removed during edge trim are carried away on conveyors to be reintroduced at the beginning of the melting process as cullet.

Each of the approximately 40 float glass lines in the United States (170 plus worldwide) runs 24 hours a day, 7 days a week, 365 days per year for 10 or more years. The typical furnace produces between 300 – 600 tons of glass per day. This translates to a single furnace producing enough glass to create a one-foot wide ribbon which circles 3/4th of the Earth at the Equator, every year.

Glass Substrates
Today's flat glass comes in a variety of colors or tints, including clear, ultra-clear (low-iron), green, grey, bronze, as well as a number of spectrally selective blue and blue green tints. Batch materials needed for tinted glass include selenium and cobalt, along with other trace materials. When designing spectrally selective substrates, the goal is to achieve solar control and high-visible light-transmission. Additionally, there are varied aesthetic and performance options for glass substrates. One example is low-iron glass, which is typically used for color neutrality due to the absence of a green cast commonly found in clear float glass.

Specialty Glass
During the float glass manufacturing process, the ribbon can be altered to provide special properties. Patterned glass is produced by passing the molten glass ribbon through roll(s) with a patterned surface producing a decorative or obscured glass surface. Wired glass is produced by embedding welded steel mesh into molten glass with rollers providing a low-level fire-rated product.

Thickness and Quality Standards
Design choices for glass thickness are guided by ASTM E 1300 – *Standard Practice for Determining Load Resistance of Glass in Buildings*. The table on the right shows the typical glass substrates and available thicknesses. Through ASTM International, an organization which generates consensus standards, standards such as ASTM C 1036 – *Standard Specification for Flat Glass* have been established. ASTM also develops and maintains standards for fabricated glass products. The Glass Association of North America's (GANA)



Glass Informational Bulletin *Flat Glass Industry Standards* provides an up-to-date list of current standards and may be downloaded at http://www.glasswebsite.com/techcenter.

Flat Glass Manufacturers
In North America, there are eight flat glass manufacturers. The company names and corresponding websites are listed below.

ACH Float Glass Operations
www.versaluxglass.com

AFG Industries, Inc.
www.afg.com

Cardinal Glass Industries
www.cardinalcorp.com

Guardian Industries Corp.
www.guardian.com

Pilkington North America, Inc.
www.pilkington.com

PPG Industries, Inc.
www.ppg.com

Saint-Gobain Glass
www.saint-gobain.com

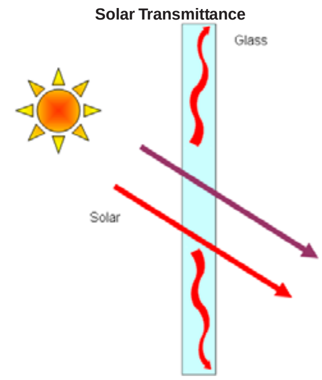
Vitro America, Inc.
www.vvpamerica.com

Glass Thicknesses by Substrate

	1/8"	5/32"	3/16"	1/4"	5/16"	3/8"	1/2"
Clear	✔	✔	✔	✔	✔	✔	✔
Green	✔	✔	✔	✔	✔		
Grey	✔	✔	✔	✔	✔	✔	✔
Bronze	✔	✔	✔	✔	✔	✔	✔
Blue				✔	✔	✔	✔
Darker Green	✔		✔	✔	✔	✔	✔
Darker Grey	✔		✔	✔			
Darker Blue		✔		✔	✔	✔	✔
Low Iron	✔	✔	✔	✔	✔	✔	✔

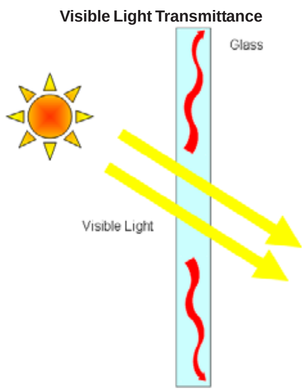
Glass Performance Terminology

As with every construction product, glass has terminology that is used to describe its properties and variables. Some important ones are listed below.



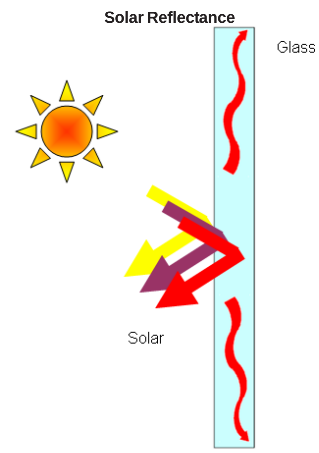
Visible Light Transmittance – The percentage of light in the visible spectrum (from 380 to 780 nanometers) that is transmitted through the glass.

Visible Light Reflectance – The percentage of light in the visible spectrum (from 380 to 780 nanometers) that is reflected from the exterior surface of the glass.



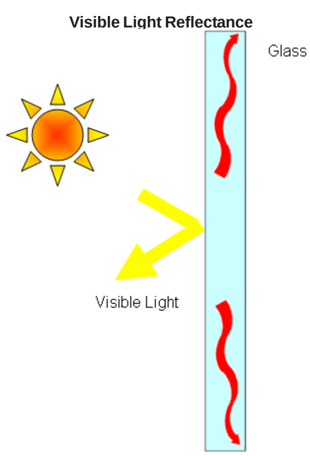
Solar Transmittance – The percentage of ultraviolet, visible and near infrared energy within the solar spectrum (300 to 2100 nanometers) that is transmitted through the glass.

Solar Reflectance – In the solar spectrum, the percentage of solar energy that is reflected from the glass surface(s).

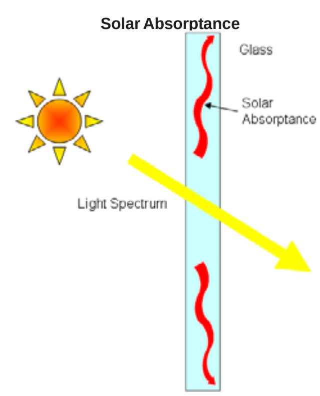


Solar Absorptance – In the solar spectrum, the percentage of solar energy that is absorbed by the glass.

Shading Coefficient (SC) – A measure of the heat gain through glass from solar radiation. Specifically, the shading coefficient is the ratio between the solar heat gain for a particular type of glass and that of 3 mm clear glass. The lower the number, the better the performance at reducing solar heat gain.



Solar Heat Gain Coefficient (SHGC) – The ratio of the solar heat gain entering the space area through the fenestration product to the incident solar radiation. Solar heat gain includes directly transmitted solar heat and absorbed solar radiation, which is then re-radiated, conducted, or convected into the space. The lower the number, the better the performance at reducing solar heat gain.



U-Value (U-Factor) – A measure of the heat gain or loss through glass due to the difference between indoor and outdoor temperatures. The lower the number, the better the performance at reducing heat gain and heat loss. This number is the reciprocal of the R-Value. (See Table on Next Page)

Light-to-Solar Gain Ratio – The product's visible light transmitted divided by its solar heat gain coefficient (SHGC).

Fabrication for Performance

Flat glass products are fabricated for use in a wide variety of residential and commercial architectural, transportation, furniture, and industrial fixture applications. Fabricated glass products can provide a number of performance elements that include safety, security, noise reduction, fire resistance, and solar, optical and thermal control. Fabricated products include:

Heat-Treated Glass

Flat glass is often heat treated to increase strength and performance capabilities. Heat-strengthened glass is annealed glass that has been heated to between 1100 – 1500º F and then quickly air-cooled. Heat-strengthened glass is generally twice as strong as annealed glass of the same thickness and offers better wind load and thermal stress resistance. Fully tempered glass is produced by a similar production process yet cooled at a rate that creates higher surface and edge compression. Fully tempered glass is generally four times stronger than annealed glass of the same thickness; it offers a distinct break pattern and significant wind load, impact and thermal stress resistance. Tempered glass is suitable for safety glazing and fire breakouts applications.

Coated Glass

Flat glass is frequently coated to provide optical, thermal and aesthetic performance enhancements. Coatings on flat glass may be applied in two different methods. Vacuum deposition applies coatings to finished glass products in a large vacuum chamber, while pyrolytic deposition applies coatings to hot glass during the manufacturing process. Coatings are commonly metal and/or metal oxides that are applied in multiple microscopic layers. Architectural glass coatings are characterized as low-emissivity (low-e) or solar-control / reflective

In today's residential and commercial construction, low-emissivity (low-e) coatings are commonly assembled in sealed insulating glass units and used in heating-dominated climates, mixed climates and cooling-dominated climates. Depending on the climate, properly designing the fenestration to minimize heat loss or heat gain will result in occupant comfort and energy efficiency.

For heating-dominated climates, the primary emphasis of low-e is on limiting heat loss. Low-e coated glass can be designed to provide high light transmittance, low light reflectance and a

Center of Glass U-Values (U-Factors)

Glazing Type	Clear Uncoated Glass	Low-E E=0.05	Low-E E=0.10
Single	1.04	n/a	n/a
Double			
1/4" (6 mm) air space	0.55	0.40	0.42
1/4" (6 mm) argon*	0.50	0.33	0.35
1/2" (12 mm) air space	0.48	0.30	0.31
1/2" (12 mm) argon*	0.46	0.25	0.27
Triple (Low-E one surface)			
1/4" (6 mm) air space	0.37	0.30	0.31
1/4" (6 mm) argon*	0.34	0.25	0.26
1/2" (12 mm) air space	0.31	0.22	0.23
1/2" (12 mm) argon*	0.29	0.19	0.20
Triple (Low-E two surface)			
1/4" (6 mm) air space		0.25	0.26
1/4" (6 mm) argon*		0.20	0.21
1/2" (12 mm) air space		0.16	0.18
1/2" (12 mm) argon*		0.13	0.14

NOTE: E=emissivity
* 90% argon fill

low U-factor (reducing heat loss) while allowing a controlled level of solar heat gain.

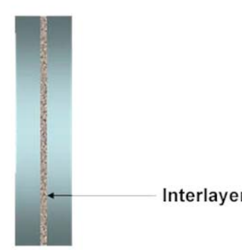
For mixed climates, low-e coated glass can be designed to provide high light transmittance, low light reflectance with a combined emphasis on minimizing heat loss and heat gain. A low U-value and a low SHGC are preferred in order to maximize comfort and energy efficiency.

In cooling-dominated climates, the primary emphasis is on minimizing solar heat gain. Low-e coated glass can be designed to provide a low SHGC while maintaining high light transmittance, low light reflectance and a low U-factor (reducing heat gain).

Solar-control / reflective coated glass is commonly used in climatic areas that call for maximum performance in reducing solar heat gain. Solar-control / reflective coatings reduce light transmittance and increase light reflectance which may be design objectives when striving to minimize glare or to provide a uniform appearance in the exterior building façade.

Laminated Glass

Laminated glass consists of two or more lites/plies of glass bonded together with an interlayer. The glass is used in safety, sound control, and security applications and other locations where retention after breakage is required.



Laminated Glass

Insulating Glass Units
Insulating glass units are assembled with two or more lites of glass that are separated by sealed gaps filled with air or a gas. Insulating glass units can be assembled with many fabricated glass products to offer enhanced solar, optical and acoustical performance, while providing a thermal insulation barrier between the outdoor and indoor environments.

Opaque Spandrel Glass
Spandrel glass uses ceramic frit, silicone coatings or polyester film applied to the glass in order to render it opaque. Spandrel glass is designed to mask vision into structural areas of a building such as between floors and columns. Opaque spandrel glass may be used to accent areas of the façade or to maintain uniformity between vision and spandrel areas with solar-control / reflective coated glass.

Patterned Glass
Patterned glass is a flat glass product with one or both surfaces having a rolled pattern. The textured surface provides a decorative and/or obscured pattern.

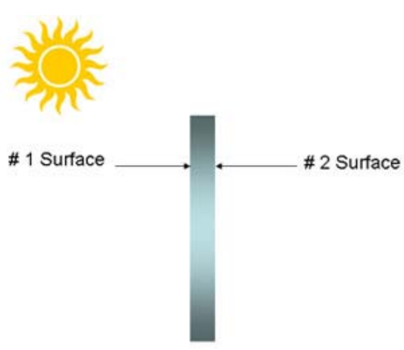
Glass Surfaces
As flat glass products are fabricated into monolithic and multiple lite assemblies, surface treatments require surfaces identification. Glass surfaces are enumerated from the outside surface, counting inward to the occupied/interior space. Below are examples of surface identification for monolithic, laminated and insulating glass units.

Glass Applications, Uses and Benefits
In the past, glass was used in small window applications intended to keep the weather out, to allow light in and to provide a view to the outside. However, today architectural glass is being used to control the elements, to control heat-gain/heat-loss, to provide thermal comfort, to allow natural daylighting of buildings, and for safety and protection, along with the pleasing aesthetics and appearance of clean glass lines. Some common examples of glass include:

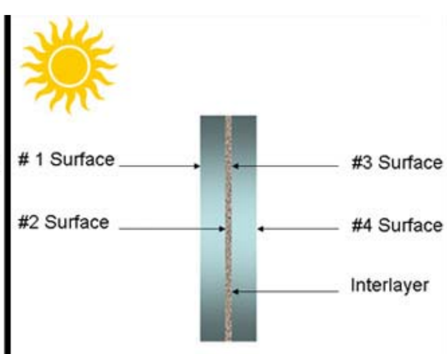
- Windows in homes
- Commercial buildings
- Windows for transportation equipment
- Interior partitions
- Railing systems
- Decorative uses/art
- Furniture
- Fixtures

These uses translate into benefits for using glass in architectural projects. In addition to the elements of aesthetics, safety and protection, today's high-performance architectural glass is energy efficient. When designed for maximum performance glass offers the potential for tremendous energy cost savings. Savings include both up-front HVAC system cost reductions and annual energy cost savings. Over a ten-year period, savings can be substantial and the savings continue for the life of the building.

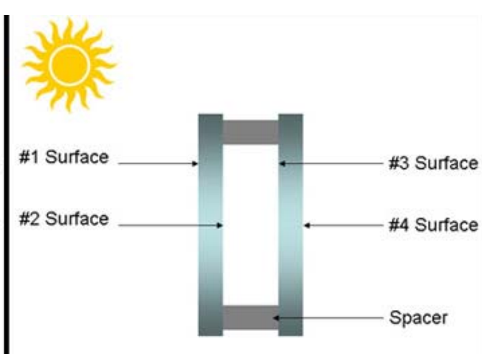
The design community benefits tremendously from architectural glass usage. There is a wide array of products providing aesthetics and functionality. There is a broad availability with multiple domestic manufacturers and fabricators. Creative use of glass products contributes to high value construction. The glass industry has both clear standards and an impressive record of innovation for product performance.



Monolithic Glass



Monolithic Laminated Glass



Insulating Glass Unit

Conclusion

Glass production has changed substantially over the past 4,000 years. From small batch operations that produced small sizes of glass on a limited basis, today's float technology is characterized by continuous production and the capability of producing a wide range of glass thicknesses, sizes, and colors. Fabricated glass products further expand the use of glass for a variety of purposes, including safety, security, sound control, and energy efficiency. Glass is a dynamic and important part of residential and commercial building design. Its increased use in windows, doors, skylights, curtain walls and double glass facades illustrates the importance of glass in today's construction environment as a medium for natural lighting and energy conservation.

To see a short video illustrating the float glass process in which arechitectural flat glass is created, visit our website at www.glasswebsite.com/video.

About the Author:

The Glass Association of North America provides the organizational structure for addressing the needs of a diverse membership. Comprised of the Building Envelope Contractors, Decorative, Flat Glass Manufacturing, Insulating, Laminating, Mirror and Tempering Divisions and an Affiliate Classification, GANA provides a forum for exchanging information and ideas and presenting a unified voice on matters affecting the glass industry and for developing the management and technical sophistication needed to remain competitive in a constantly changing business environment.