Glass:
The Right Choice

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Learning Objectives

This course is designed to improve your understanding of:

- **The *<u>uses of glass</u>* in a commercial building, as well as the functionality and performance this versatile material can provide**
- **The manufacturing and fabrication processes used to produce *<u>different types of glass</u>* and the applications for these products**
- **Various kinds of *<u>fabricated glass solutions</u>* to enhance basic glass performance, including insulating units, safety glass, and fire-rated glass**
- **Methods of *<u>measuring and evaluating glass performance</u>* to help you make smarter glass choices**

Course Sections

1. Glass Functionality and Performance
2. Different Glass Types
3. Fabricated Glass Solutions
4. Making the Right Glass Choice

SECTION 1

Glass Functionality and Performance

Glass: How It Functions in a Building

- **<u>Construction utilizing glass offers many unique advantages</u>: Glass provides protection from the elements – while also allowing natural light, a view of the outdoors, and a strength to weight ratio superior to concrete allowing the use of smaller – less costly foundations.**
- **Using readily available and efficient glassmaking technologies, glass can be specified to meet the three main functions of glass in a wall:**
  1) **<u>Complementing the overall aesthetics of the structure</u>:** Architectural glass is available in a spectrum of colors, textures, transmission values, and reflectance levels to achieve a myriad of aesthetic vision.
  2) **<u>Meeting life and safety requirements for the people who occupy the space</u>:** Modern glass products can provide protection from both manmade and natural disasters such as bomb blasts, hurricanes, and fires.
  3) **<u>Maximizing energy efficiency:</u>** Properly specified architectural glass can measurably cut cooling and heating costs dramatically.
  4) **<u>Providing comfortable productivity:</u>** Properly specified architectural glass can also keep the building's occupants comfortable and productive.

Glass Function and Solar Energy

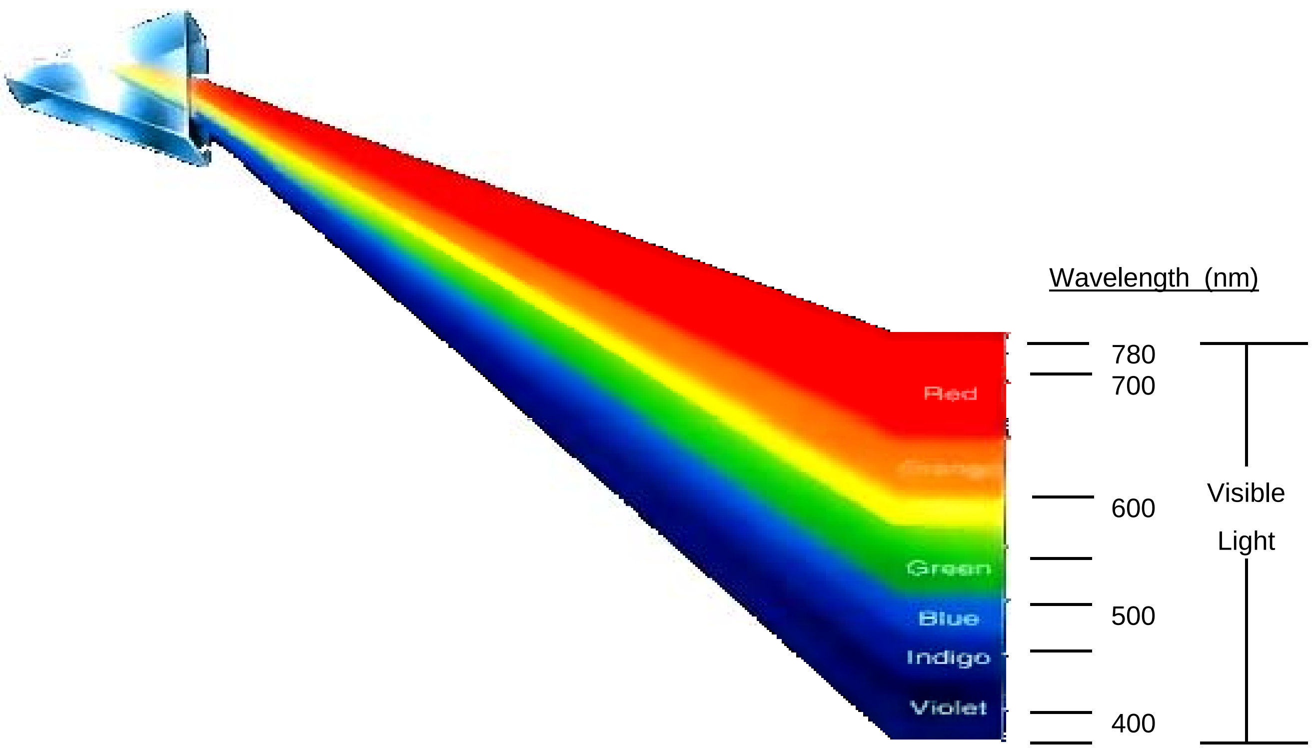
- **In commercial buildings, the main function of glass—with regard to energy efficiency—is controlling the energy of the sun. The sun supplies short-wavelength electromagnetic energy that can enter buildings as solar energy.**
- **The solar spectrum, as it relates to glass, consists of three elements that can be reflected, absorbed, or transmitted by commercial windows and doors:**

  1) **<u>Ultraviolet (UV) light:</u>** This is defined as electromagnetic energy in the range of 280 to 380 nanometers—representing only about 3% of the solar spectrum. Because UV radiation is not visible, the term “light” may be a bit misleading.

  2) **<u>Visible light:</u>** Visible light is electromagnetic energy in the range of 380 to 780 nanometers. Perceived as “daylight,” this is the range that can be detected by the human eye. With visible colors of red, orange, yellow, green, blue, indigo, and violet, visible light wavelengths represent approximately 38% of the solar spectrum.

  3) **<u>Infrared light:</u>** Infrared light is defined as electromagnetic energy in the range of 780 to 2500 nanometers, occurring at wavelengths just below red light—hence the name “infra” or “below” red. These wavelengths represent approximately 59% of the solar spectrum.

Solar Energy: A Key Consideration for Architects



There is a broad spectrum of energy around us every day—but solar energy is unique for its ability to impact the energy performance and comfort of commercial structures.

How Is Solar Energy Transferred?

- **All forms of matter—whether solid, liquid, or gas—are composed of atoms or molecules in constant motion. Molecules absorb a portion of the sun's energy, which creates thermal, or heat, energy. This energy is then transferred to other molecules by this constant motion. When substance is heated, the atoms move faster. When matter is cooled, the atoms move slower. The average motion of the atoms that we sense is what we call "temperature."**

- **Temperature and heat are not technically the same thing. While temperature is the average motion of atoms and molecules, heat is the energy that flows due to temperature differences. Heat is always transferred from warmer to cooler surfaces.**

- **There are three ways to heat the atmosphere or any physical substance:**
  1) **<u>Conduction</u>** is defined as heat transfer through solid matter, such as glass or wood, through direct contact with a hot or cold surface (e.g. hot plate or ice cubes).
  2) **<u>Convection</u>** is heat transfer through a moving fluid (liquid or gas) across or around solid matter. The faster the convective movement, the faster the heat transfer (e.g. forced cooling or heating using a fan).
  3) **<u>Radiation</u>** represents heat transfer in the form of electromagnetic waves from one matter to another regardless of matter form. The sun radiates a wide range of electromagnetic waves – a portion of which impinge on the earth's surface causing it to heat up.

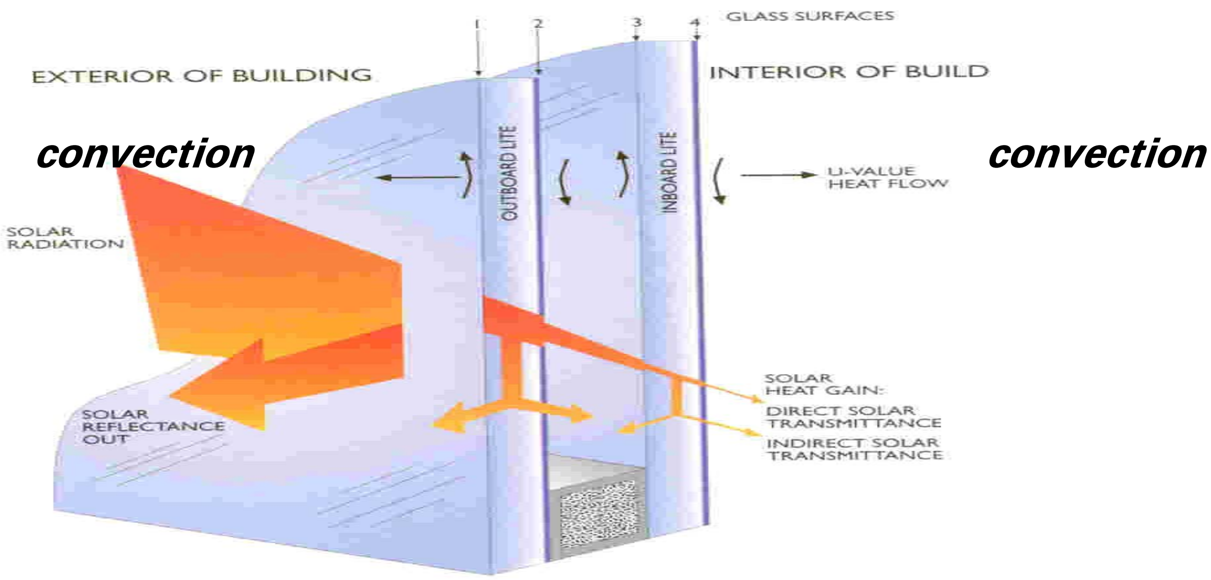
Heat Gain and Loss in Buildings

There are three components of <u>solar</u> heat gain in a commercial structure:

- Directly <u>transmitted</u> solar energy
- Directly <u>reflected</u> solar energy
- The inward-flowing part of the solar energy <u>absorbed</u> by glass

There are also components of <u>total</u> heat gain (or heat loss):

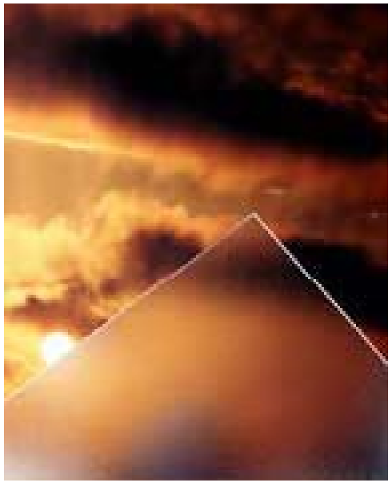
- In addition to the three components of solar heat gain listed above, architects must consider another factor. Differences in temperature between interior and exterior spaces can also cause heat gain (or heat loss, in cold climates).



Total Glass Performance: Beyond Solar Energy

While solar heat gain is probably the most important measure of glass performance for energy efficiency and comfort, it is just the first in a long list of glass performance characteristics that architects must understand and consider:

- **Solar Heat Gain Coefficient**
- **U-Factor**
- **Light Transmittance**
- **Damage-Weighted Index**
- **Light-to-Solar Gain**



Glass Performance: Solar Heat Gain

- The Solar Heat Gain Coefficient (SHGC) is the fraction of solar radiation that is transmitted through architectural glass—expressed as a number between 0 and 1.
- The lower a window's SHGC, the less solar energy it transmits—and the greater its shading ability.
- SHGC can be expressed in terms of glass alone—or can reflect the performance of an entire window assembly including the frame.
- Generally, a low SHGC is desirable in warm climates, and a higher SHGC is desirable in colder regions—where passive solar energy is a benefit. In commercial buildings, a low SHGC is desired in most all regions.

Glass Performance: U-Factor

- U-Factor is a measure of how well a material transmits heat. It should be noted that U-factor and U-Value have the same meaning. We will be using U-Factor, as it is the more commonly used term within the industry.
- The lower the U-Factor, the greater a window's resistance to heat flow—and the better its overall insulating value.
- U-Factor using imperial measurements are expressed in units of BTUs/hour-square foot-°F.
- U-Factor can be calculated for glass alone or—more commonly—for an entire window unit, including the frame and spacer materials that help to improve insulation.
- In colder Northern regions, a U-Factor of 0.35 or below is generally desired to maximize year-round energy efficiency.

Glass Performance: Light Transmittance

- Visible Light Transmittance (VLT) is another important measure for architects to consider. It is the fraction of solar radiation in the visible light wavelengths that passes through the glass in the fenestration of a building.
- Readily available glass products for today's commercial construction projects range from 0% VLT up to and including glass products in the mid 90's % VLT.
- While building owners and occupants often seek bright, open interior spaces flooded with daylight, it is important to remember that visible light can also cause damage. High levels of both UV light and visible light cause fading to fabrics, finishes, carpeting, and artwork within commercial buildings.
- An emerging measure—the Damage-Weighted Index—helps architects to assess the potential for fading far more accurately than looking at VLT measures alone.

Glass Performance: Damage-Weighted Index

- **The Damage-Weighted Index, which combines both visible and ultra violet radiation, helps architects assess the potential for fading far more accurately than looking at ultra violet measures alone.**

- **There are two ways of calculating the Damage-Weighted Index for architectural glass and window units:**
  1) **<u>Tdw-K</u>:** Created by Europe's Jurgen Krochmann, this measure covers the UV and visible parts of the spectrum from 300 to 500 nm.
  2) **<u>Tdw-ISO</u>:** A more comprehensive measure—recommended by Commission Internationale de L'Eclairage (International Commission on Illumination)—this measure covers the solar spectrum from 300 to 700 nm.

- **While both calculations are more valuable than UV transmittance or VLT alone, Tdw-ISO is considered to be a more comprehensive, and accurate measure of fading potential.**

Glass Performance: Light-to-Solar Gain

- **Light-to-Solar Gain (LSG) is emerging as an important glass performance measure. LSG is a gauge of the efficiency of a glass product in transmitting daylight—while blocking solar heat gain.**

- **LSG is the ratio between VLT and SHGC. Because this is still an emerging measure, this performance rating is not always available. However, it can easily be calculated if the VLT and SHGC are known (LSG = VLT/SHGC).**

- **The higher the LSG, the more light is transmitted without adding excessive amounts of heat.   If the LSG > 1.0, then the glass transmits more light than heat.**

- **The U.S. Department of Energy defines spectrally selective glass as glass with a Light to Solar Gain ratio of 1.25 or higher. The higher the LSG the more energy efficient the glass product is.**

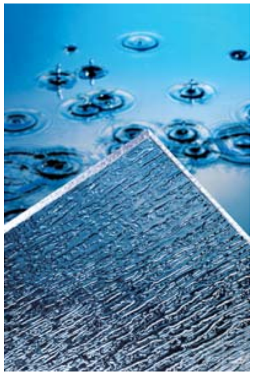
SECTION 2

Different Glass Types—for Varying Performance Needs

Overview of Different Glass Types

Today, architects can choose from a wide range of glass products that meet different criteria for functionality and performance:

- **Float**
- **Rolled**
- **Coated**



Float Glass: An Industry Standard

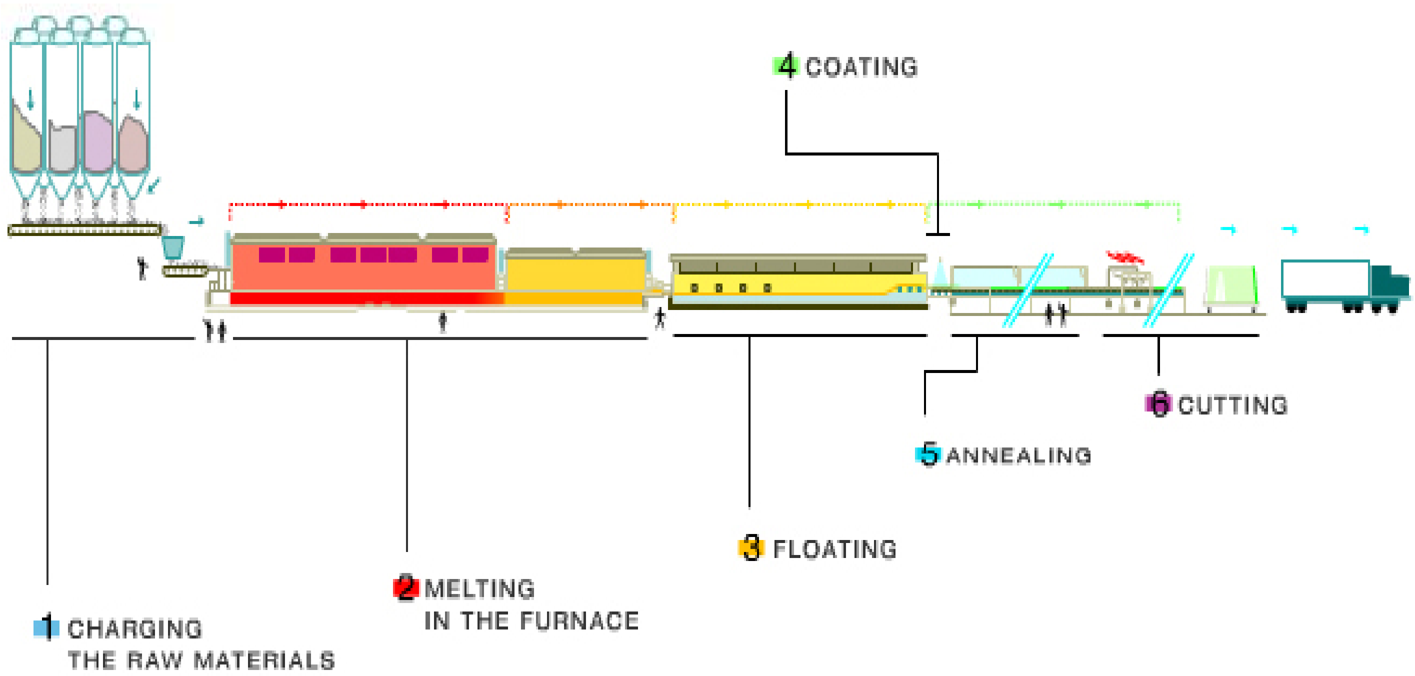
- **By definition, glass is a uniform, amorphous solid material, usually produced when a suitably viscous molten material cools very rapidly to a point where molecules have very little mobility. Common glass is mostly amorphous silicon dioxide ($Si0_2$)—the same chemical compound found in quartz or, in its polycrystalline form, sand.**

- **In its pure form, glass is a transparent, relatively strong, hard-wearing material which can be formed with very smooth and impervious surfaces.**

- **The architectural glass found in most buildings today is commonly referred to as "float glass." Float glass consists primarily of silica sand, soda, and lime.**

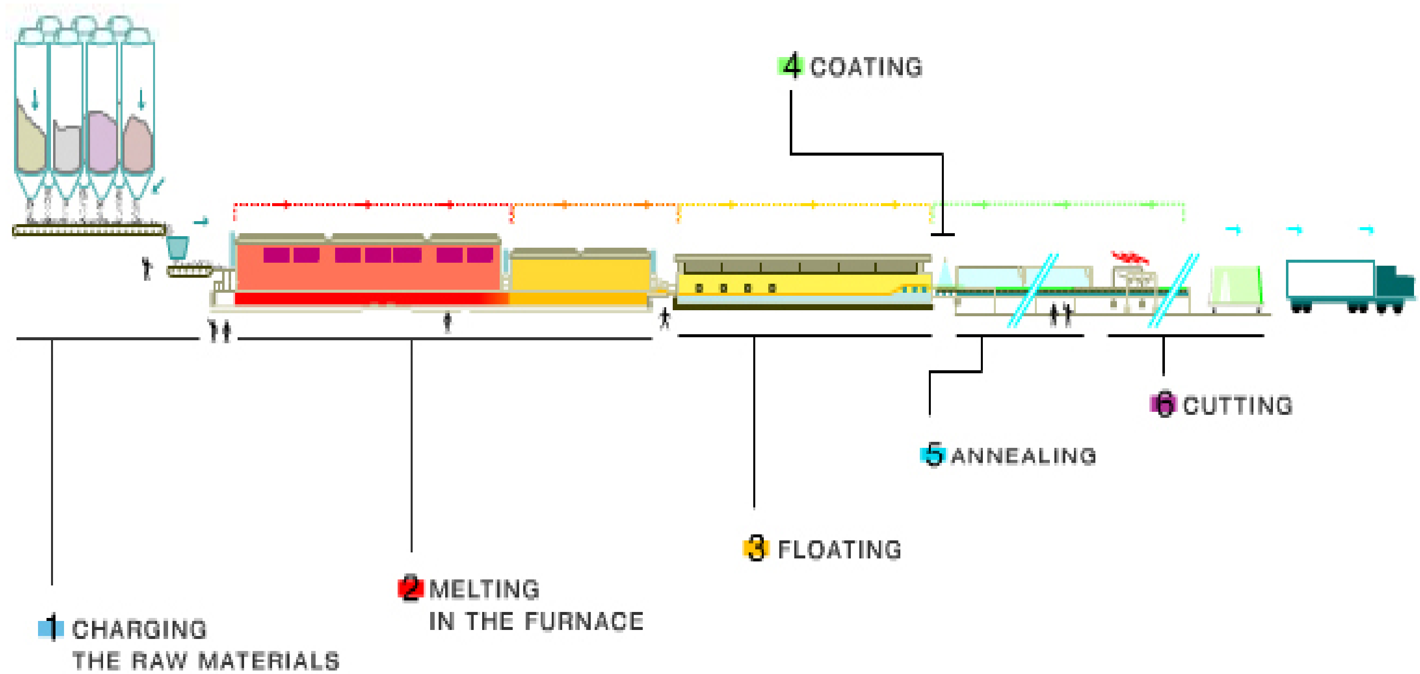
- **In the float manufacturing process, these materials are heated to their molten state—then drawn over a liquid bath of tin, before the mixture is cooled under controlled conditions. Because tin has a higher specific gravity than molten glass, the glass "floats" on the tin—forming a perfectly flat layer.**

The Float Glass Process: Mixing the Batch



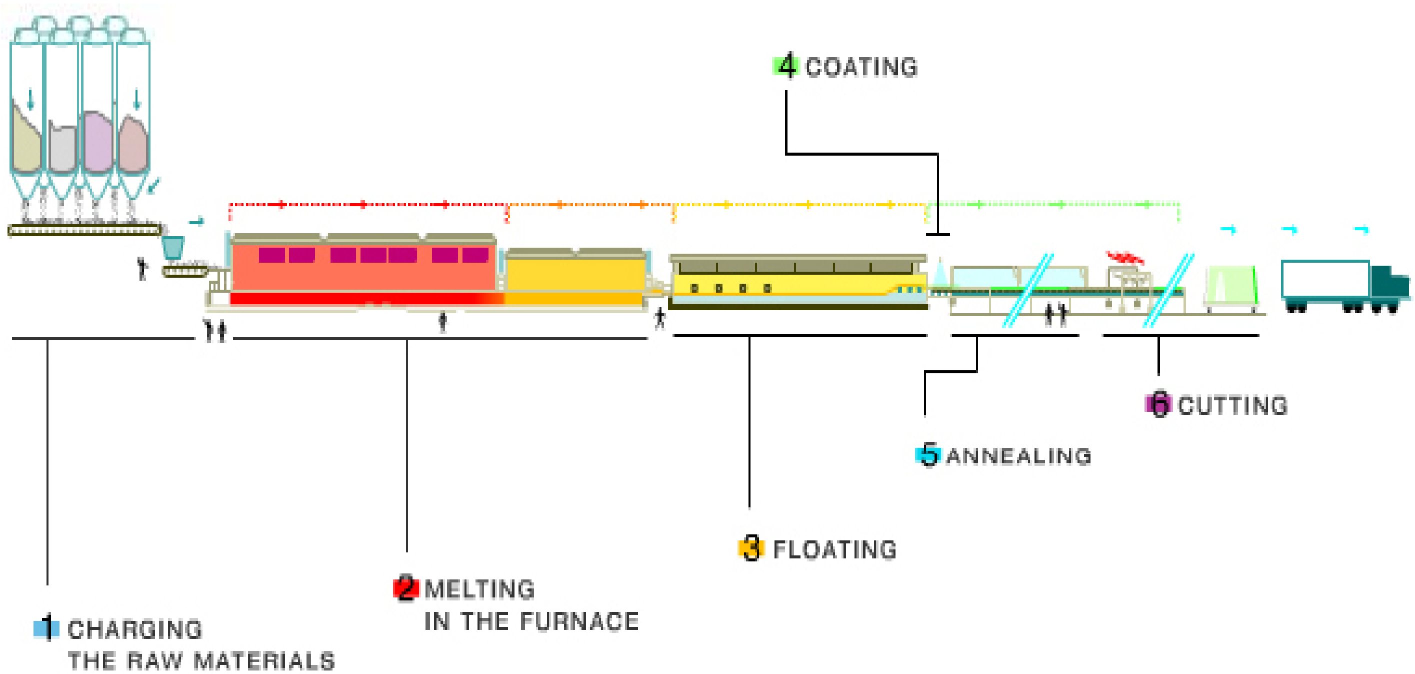
Float glass consists primarily of silica sand, soda, and lime—referred to as the "batch." These materials are digitally weighed and mixed with cullet (or crushed, recycled glass) as well as small amounts of other materials—then transferred by conveyor into the batch house. The batch is continuously fed into the furnace, where it is melted.

The Float Glass Process: Melting



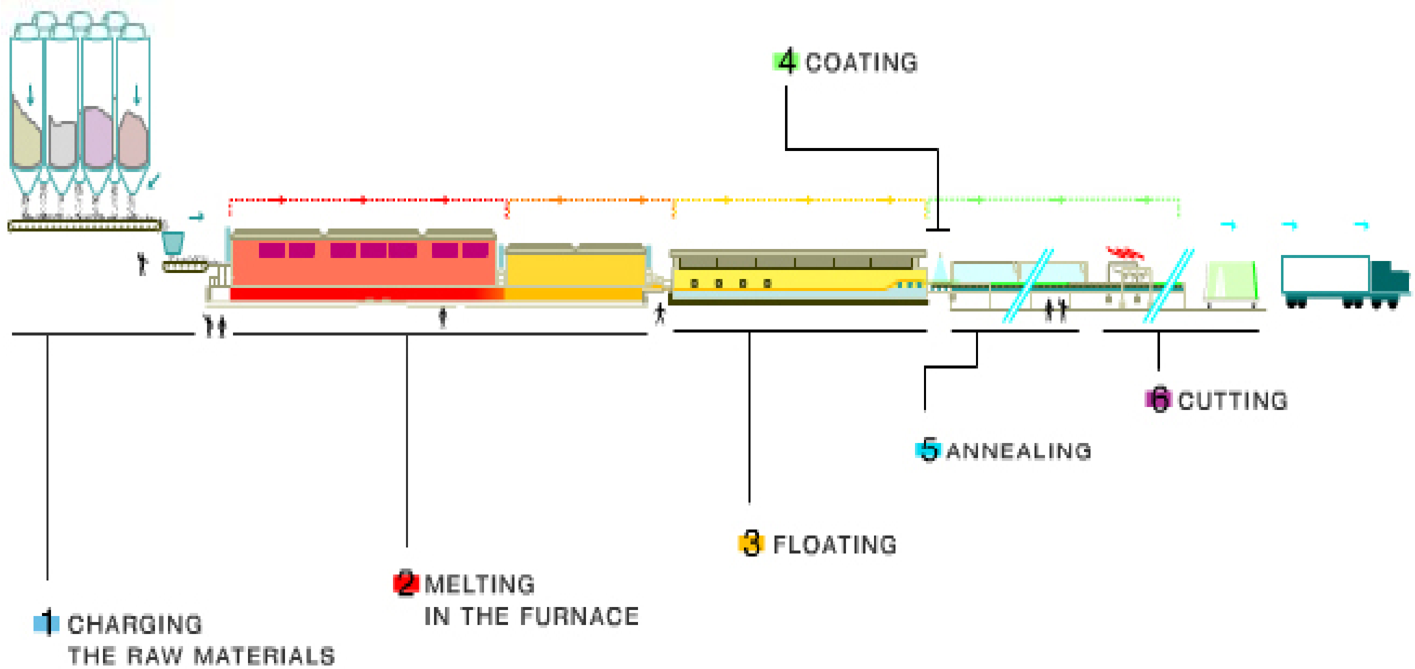
The batch materials are continuously fed into the furnace, where they are heated to their melting point—approximately 2800°F. The molten glass flows to the end of the furnace, where it moves through a canal onto a pool of liquid tin.

The Float Glass Process: Glass Ribbon Formation



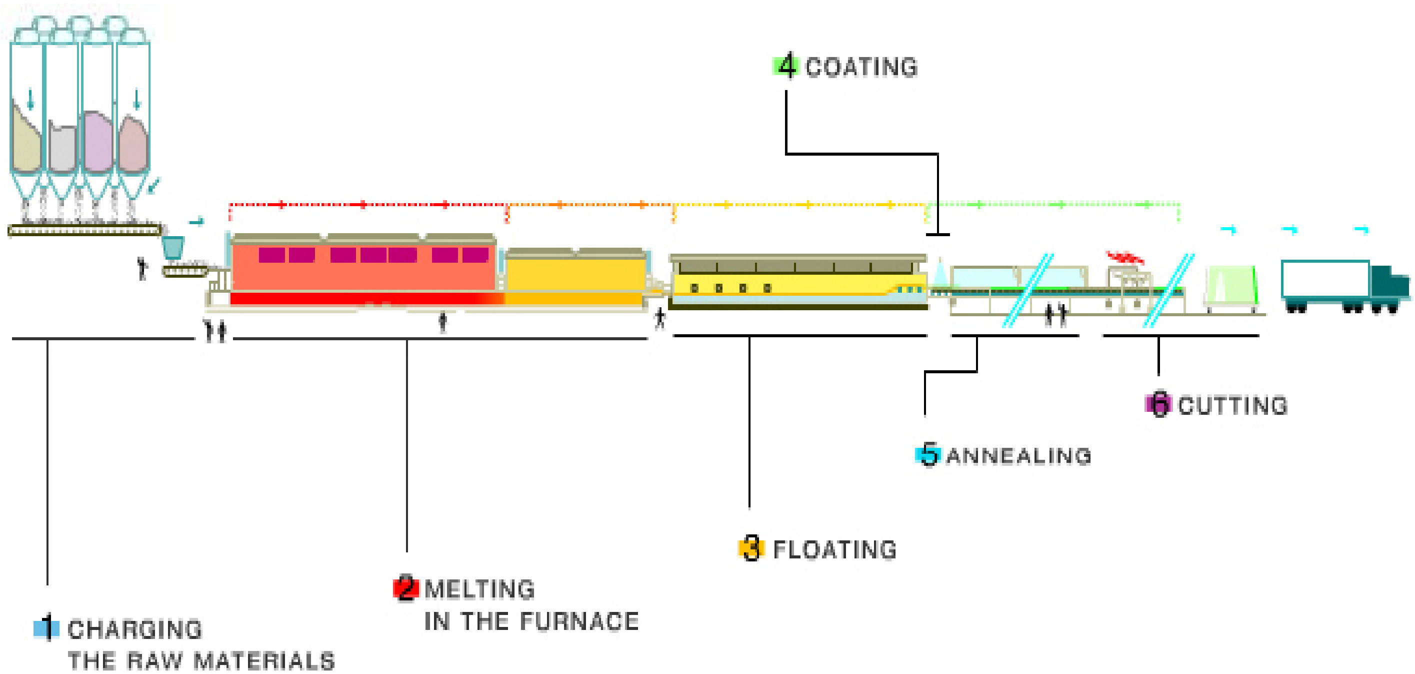
As the glass moves over the liquid tin, metal knurls contact the glass ribbon at its edges—helping to control both its width and speed. The speed at which the glass ribbon moves will determine its ultimate thickness. Because tin has a higher specific gravity than glass, the molten glass "floats" and forms a perfectly flat layer. The glass must be cooled to approximately 1100°F before it can be lifted out by rollers.

The Float Glass Process: Pyrolytic Coating



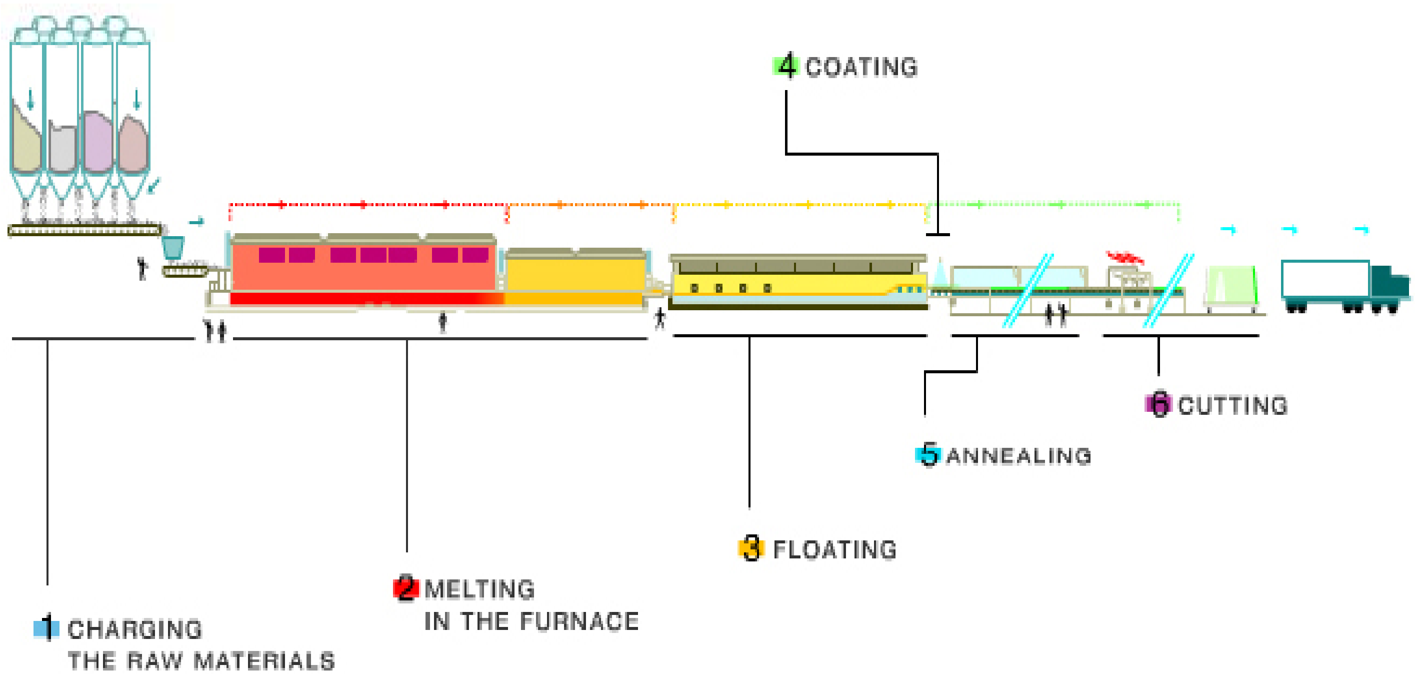
As the glass ribbon is pulled over the liquid tin—and before it is lifted out onto rollers—reflective or low-emissivity coatings can be applied to the "atmosphere" surface of the glass, to improve its ultimate performance in a building. This coating process is referred to as chemical vapor deposition—and these coatings are known as pyrolytic or "hard" coats.

The Float Glass Process: Annealing



Lifted out by rollers, the glass ribbon finally leaves the tin bath. Now it is cooled slowly or "annealed" in order to remove any residual stresses—and make it stronger. After annealing, the solidified ribbon of glass is sufficiently cool enough for processing—and can be cut into pieces.

The Float Glass Process: Cutting



Cooled glass passes through inspection booths to ensure that it has the uncompromising quality needed for its end use. Defects are marked, and the rough edges—where knurls pulled the glass through the molten tin—are trimmed for use as cullet in a future batch of float glass. The remainder of the glass ribbon is cut for packaging. Float glass can be cut into large standard sheets—or cut to size, according to its ultimate use. The glass is then inventoried and ready to be shipped.

Float Glass Products

Float glass can be clear and virtually colorless, or tints can be added during the manufacturing process, which reduces visible light transmittance—as well as solar heat gain.

In North America, there are 11 common glass substrates used in the architectural glass industry. These substrates can be placed into three categories, based on their effectiveness to control solar energy:

1) High Solar Transmittance (~70-90%)

These float glass products absorb ***little*** of the heat energy from the sun—which means that they provide little protection from solar heat gain and potentially damaging UV and visible light. They do offer excellent clarity and color neutrality, important for many applications.

2) Medium-performing (~40-50%)

These substrates provide ***more*** protection against solar heat gain and visible light transmittance—and feature color.

3) Higher-performing (~33% or less)

The highest-performing float glass products provide ***excellent*** protection against solar heat gain, as well as high levels of damaging light transmission – and are heavily colored.

Note: Solar heat gain can actually be beneficial in cold, northern climates.

Eleven Float Glass Substrates

A glass substrate is float glass without a coating. Substrates can be grouped according to their level of solar transmittance which relates to how much energy from the sun passes through them. Typically a substrate by itself has relatively low solar and visible reflectance, but its transmittance will vary. Substrate appearance is affected by thickness. Since the color of the substrate is in the material, as the substrate gets thicker it will appear darker. Coatings can be combined with substrates for various effects in both performance and aesthetics.

1)Lower-Performing Glass Substrates

- Clear
- Low-Iron

2)Medium-Performing Glass Substrates

- Green
- Gray
- Bronze
- Blue
- Blue-Green

3)Higher-Performing Glass Substrates

- Azure
- Dark Green
- Dark Blue
- Dark Gray

Rolled Glass: A Patterned Option

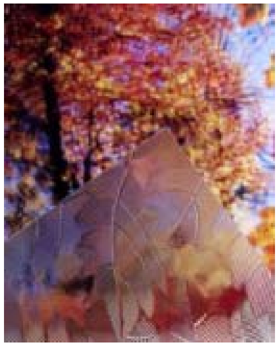
Perfect for many architectural applications, rolled glass begins as a molten glass which is processed through a set of two engraved rolls that apply a pattern to the glass as it passes through them.

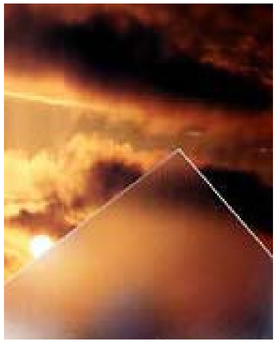
Rolled Glass Applications

There are endless possibilities when manufacturers develop attractive patterns to roll on to architectural glass:

- **Patterned glass can be used for interior and exterior decorative elements, especially in heavier glass thicknesses—including storefronts, foyers and vestibules, interior partitions, railings, and translucent door and window treatments.**

- **Rolled glass can also help channel or direct visible light energy to be used in lighting panels, including solar or photovoltaic cells.**

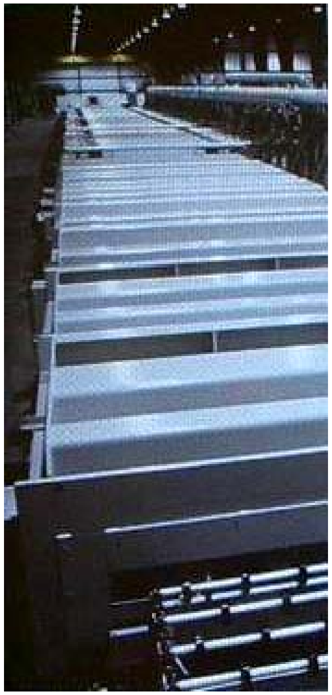




Coated Glass: Customized Performance

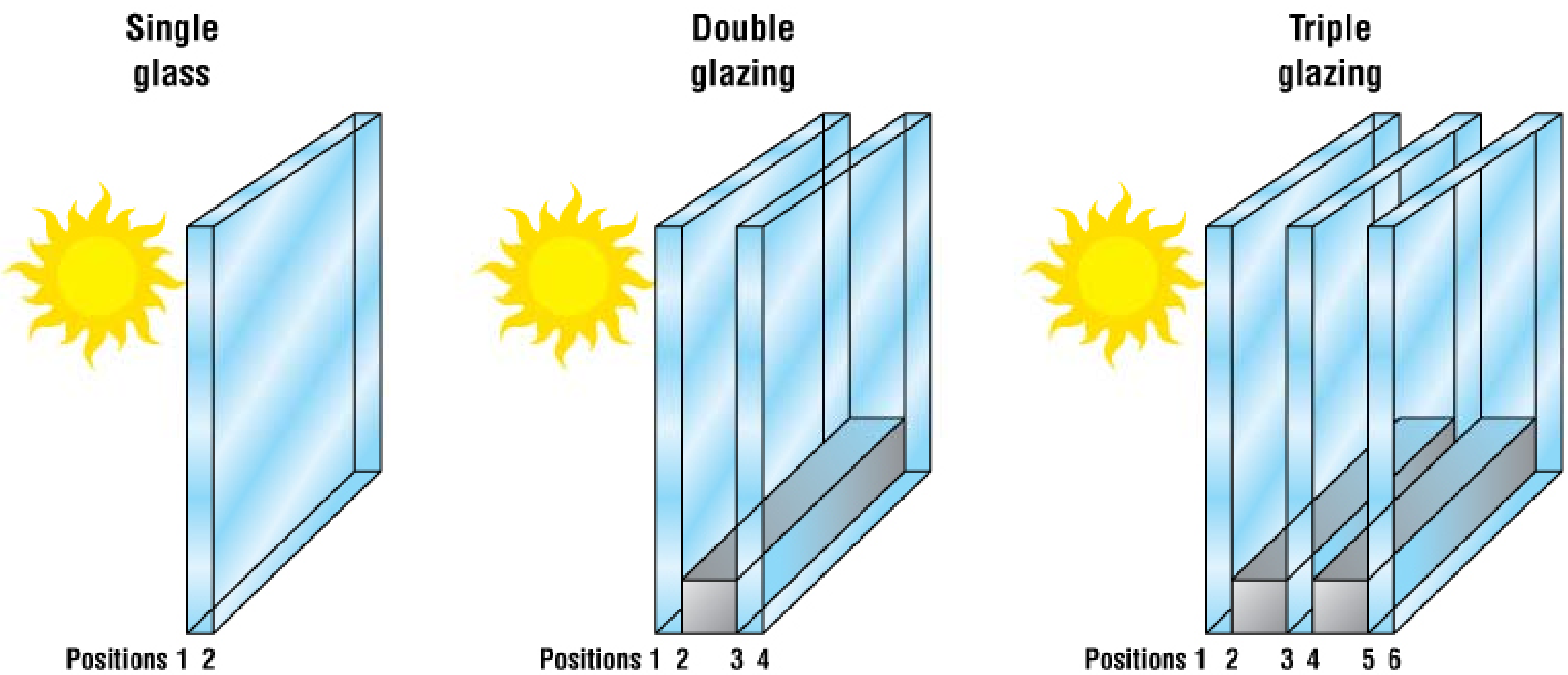
To further improve the performance of glass, manufacturers have developed various types of coatings that can be applied during the float process, or as part of the finishing process:

- **"Hard" or pyrolytic coatings applied during the float process that become part of the finished glass itself**
- **"Soft" or sputter coatings applied through a magnetic sputter vapor deposition process separate from the float glass process.**
- **Reflective and low-emissivity coatings offer excellent solar control, minimizing heat gain.**



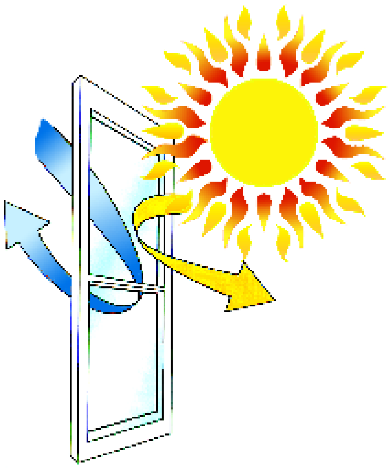
Surface Orientation:
The Science of the Surface

Not only are architectural coated glass products increasing in sophistication, but manufacturers and fabricators are creating complex new approaches to applying them in the most effective manner. Glass surfaces are numbered, with #1 representing the exterior, or "weather" surface of a glass panel or insulating unit.

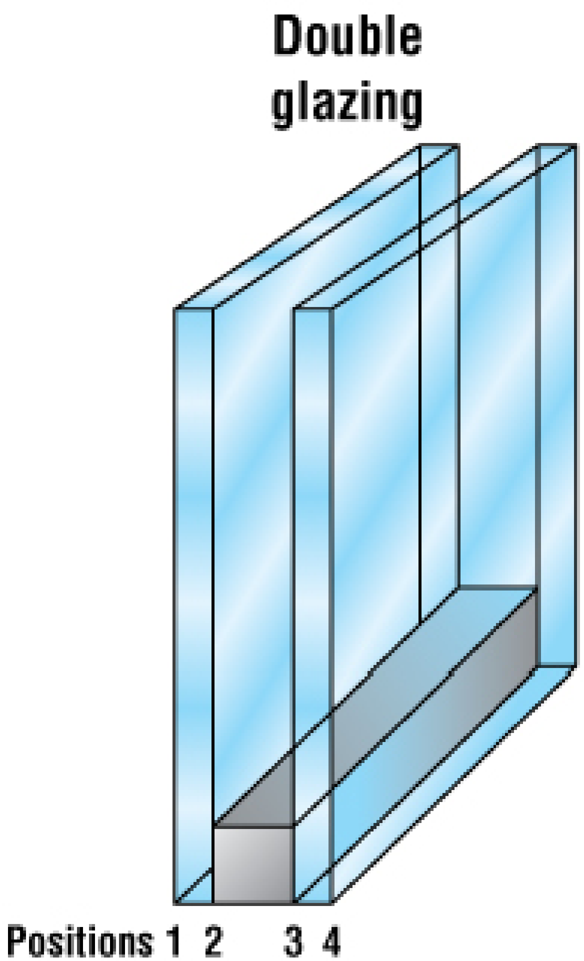


Low-E Coatings: Outstanding Thermal Performance

- **Low-emissivity or "low-E" glass coatings are metallic layers applied to float glass to reflect radiant energy back toward its source. Heat stays outside during the summer, and inside during the winter. "Emissivity" is a measure of a material's ability to re-radiate absorbed infrared radiation.**
- **Glass with a high emissivity allows for a significant portion of the radiant energy to be absorbed and re-radiated. Low emittance glass blocks a significant amount of radiant energy and reflects it back toward the source.**
- **Low-E coatings can be applied by both sputter and pyrolytic coating processes.**
- **If low-E coated products designed for hotter climates are used in insulating units, the radiation transfer between the warm exterior and cool interior space is reduced. The opposite occurs in cold climates when the interior is warmer than the exterior. The low-E coatings can be spectrally selective allowing for the use of passive solar energy in cold climates.**
- **Like reflective coatings, low-E coatings help to significantly reduce solar heat gain and maximize energy usage—but without a reflective appearance. When viewed from the exterior, low-E coated glass has more transparency and "depth."**



Location of Low-E Coatings: Critical to Performance



To maximize the performance of low-E coatings, there are some general guidelines:

- **The U-Factor is the same, whether low-E coatings are placed on surface 2 or 3.**
- **The SHGC is generally lower with low-E coatings on surface 2.**
- **Thermal stresses are higher with the low-E coating on surface 2 than on surface 3—particularly if tinted exterior lites are used. This increase in thermal stress usually requires heat-strengthening or tempering to avoid breakage from the thermal stress. This is not usually a recommended configuration.**

Pyrolytic Coatings: Hard Benefits

- **Pyrolytic coatings are metallic oxides applied during manufacturing, as the glass ribbon is pulled over the liquid tin—and before it is lifted out onto rollers. Because these coatings are a permanent part of the glass itself, they are extremely durable and tough—hence the common name "hard" coating.**
- **Glass products that feature a pyrolytic coating have a number of advantages:**
  - **They are easy to handle, transport, stack, and store.**
  - **They can be heat-treated and laminated to meet specialized applications.**
  - **Pyrolytic products are durable enough to be used monolithically – consult with the product manufacturer for details.**
  - **Pyrolytic coatings can be exposed to weather (positioned on the #1 surface), but this is not recommended as the coating may be easily damaged.**
- **Pyrolytic coatings can include low-emissivity, energy-efficient coatings and reflective (solar control) coatings.**

This photo shows a new vinyl window with the low-E coating on the #1 surface. The installer cleaned the window using an organic cleaner that dissolved the vinyl frame and smeared it over the low-E coating. There was no way to remove the dissolved vinyl without destroying the low-E coating.

Sputter Coatings: Soft on Energy

- "Sputter" or "soft" glass coatings are applied through the bombardment of metal atoms onto the surface of float glass. This process is known as magnetic sputter vapor deposition.
- These "sputter" coatings are less durable than pyrolytic coatings. However, they deliver a wide range of benefits.
- Sputter coatings are versatile. They can be applied to any glass substrate, and cover the full range of performance and aesthetic requirements. There are literally hundreds of sputter coating possibilities.
- Sputter-coated products feature new post-temperable technologies that allow them to be heat-treated.

Reflective Coatings: Superior Solar Control

- Reflective glass coatings are metallic layers applied to float glass in order to reflect short-wavelength solar energy back into the atmosphere—therefore reducing solar heat gain. This reduction in solar heat gain helps to lower the annual cooling costs in a commercial building. They also provide a distinctive appearance for architectural facades.
- Highly reflective coatings absorb the largest portion of direct solar energy not reflected. This is a disadvantage, as the glass gets very hot.
- Reflective coatings can be applied to glass substrates by both pyrolytic and sputter coating processes. Pyrolytic reflective coatings are designed to be used on the #2 or #3 glass surface—but are durable enough to be installed on the #1 (or atmosphere) surface. Soft reflective coatings must be applied to the #2 or #3 surface, as they cannot be exposed to weather.
- Benefits of reflective products include:
  - They significantly reduce solar heat gain, making interior spaces cooler and more comfortable.
  - These solutions lower the capital costs needed for air-conditioning systems.
  - Reflective glass also reduces ongoing air conditioning expenditures.

Viewing Coated Glass Products

- To ensure that coated architectural glass products are specified correctly, there are some guidelines for viewing them. The best conditions are outdoors, in natural light (both sun and shade).
- Architects should remember that, when viewing a building from the exterior, observers will see a combination of reflected light and transmitted light.
- For reflective glass, most of the light reaching the observer is reflected from the coating, and there will be little read-through. Reflective glass should be viewed in a vertical position, against a dark background.
- For low-E glass, there will be a lot of transmitted light, resulting in significant read-through. Low-E glass should be assessed in a vertical position, against a medium- or dark-colored background—depending on the specific glass.
- Full size mock-ups are recommended for viewing coatings.

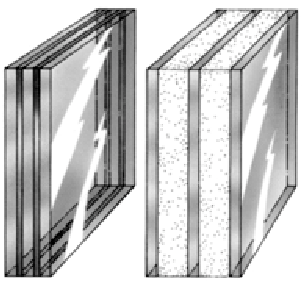
SECTION 3

Fabricated Glass Solutions—Taking Performance One Step Further

Overview of Fabricated Solutions

Glass manufacturers and fabricators can create customized fabricated solutions that deliver specific performance benefits for specialized applications. Fabricated glass products that are widely available include:

- **Heat-Treated**
- **Laminated**
- **Insulating**
- **Fire-Rated**
- **Spandrel**
- **Silkscreen**



Heat-Treated Glass: Stress-Resistant Solutions

- **All float glass is annealed—or cooled slowly—after manufacturing to remove residual stresses and make the glass stronger. However, many architectural applications demand that glass has additional strength—to resist both mechanical stresses (such as high wind loads) or thermal stresses (including heat build-up between lites in a window unit).**

- **The theory behind heat-treating glass is simple. All glass will break when placed under stress. By creating a condition of stress within the glass itself, an external thermal or mechanical force will have to overcome a higher stress level in order to break the glass—reducing the risk for glass breakage.**

- **There are two common heat-treating methods used to strengthen glass:**
  1) ***Heat Strengthening***
  2) ***Tempering***

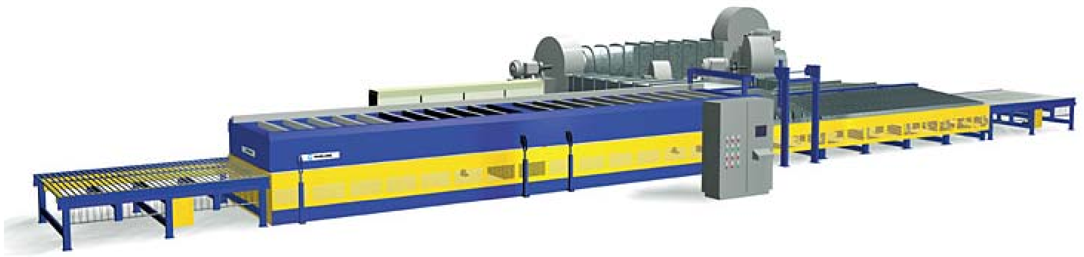
- **The specific type of heat treatment required is usually dictated by building codes or industry safety standards.**

What Causes Thermal Stress?

A number of factors can contribute to thermal stress. Orientation of windows can be critical—with SE to SW facing glass posing the greatest risk in the Northern Hemisphere. Below are additional factors rated from 1 to 10, with 10 being the most important.

Contributing Factor	Importance Rating (1-10)
Edge quality	10
Energy absorption of glass (tinted, reflective)	8
Shading from overhangs	8
Shading from vertical members	7
Altitude of building (solar intensity and temperature change)	7
Geographic location of building	6
Heat sinks	4
Inclusion of low-E coating	4
Use of labels on glass	4
Adjacent reflective surfaces	4
Color of window frame	3
Interior shades	3
Glass size	3

Heat-Strengthened Glass



- **During heat strengthening, annealed glass is reheated to a high temperature, then cooled quickly in a process called "quenching"—making it twice as strong.**

- **Heat-strengthened solutions are perfect for many commercial applications—including spandrels, windows in high wind load areas, and applications where the glass has a risk of thermal stress.**

- **Heat strengthening does *not* result in a "safety" glass product; it breaks in a pattern similar to annealed glass. For applications where "safe" breakage is a concern, tempered & laminated solutions are a better fit.**

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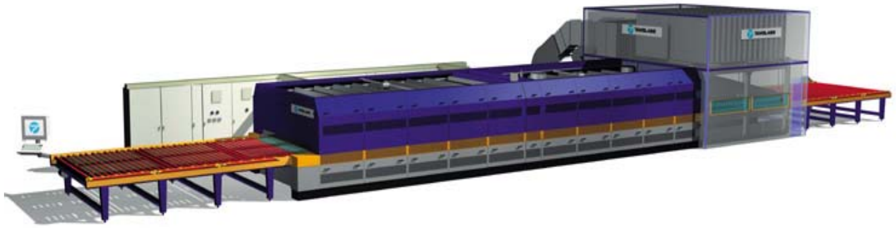
Tempered Glass



- Similar to heat strengthening, glass tempering involves reheating annealed glass products, and cooling them quickly. But tempered products are cooled with a much more intense air flow during the "quench" phase. This increases their strength to four times that of annealed glass.

- Tempered glass offers outstanding safety protection, as it breaks into small, pebble-like pieces. Tempered glass solutions are ideal for any area where high traffic and human contact may pose safety concerns.

- Tempered solutions are excellent for commercial storefronts, entryways, display cases, railings, skylights, and overhead lighting fixtures.

Heat-Soaked Glass

- In some parts of the world, tempered glass is frequently specified to meet higher wind loads and ensure safety in large glass installations—for example, when there is a vertical wall of glass with no guard rail. In these kinds of large tempered glass installations, the risk of spontaneous glass breakage increases.
- Heat-soaked glass is a solution that helps to reduce the risk of spontaneous breakage. Following the tempering process, glass is heated to a lower temperature—about 550°F—for a period of time, then cooled slowly. This process accelerates the growth of any nickel sulfide inclusions in the glass—so that any spontaneous breakage will occur during heat soaking, instead of after installation.
- The result is a glass solution with a lower risk of spontaneous breakage, which can be important in applications where tempered glass has a risk of fall-out.
- While many international building codes demand heat-soaked glass, this trend is only beginning to impact North American architecture.

Laminated Glass

- Laminated glass solutions consist of two or more lites of glass, bonded together—most commonly—by a plastic inner layer.
- The resulting "sandwich"—which is visually indistinguishable from monolithic glass of the same thickness—can include a variety of annealed, heat-treated, and coated products, to create custom-tailored architectural solutions. It is important to note that laminating some forms and thickness of glass may cause undesirable amounts of visual distortion (e.g. 3mm tempered / 0.15 interlayer / 3mm tempered)
- Because of its extreme strength, laminated glass can be used for windows in hurricane-prone coastal regions, as flooring, and in security storefront systems.
- While laminated glass may be broken by extreme force, the glass fragments remain bonded to the plastic interlayer.
- Customized applications for laminated glass products include safety, security, hurricane resistance, and sound control.

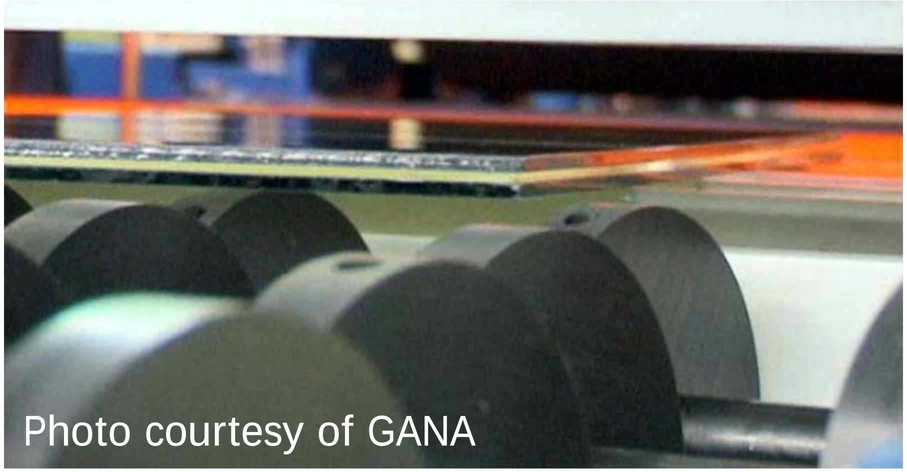


Photo courtesy of GANA

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Laminated Glass Applications: Safety

- Laminated glass products provide excellent personal protection when used as safety glazings in commercial buildings of all types.

- While the surface of laminated products may be broken, the resulting glass shards stay inside the window or door frame—making them a perfect safety solution when glass breakage could pose a safety risk.

- In commercial applications, building codes often require laminated safety glass for storefronts, entrance doors, and overhead glazings such as atriums and skylights.

Laminated Glass Applications: Security

- Security glazings have become an increasing focus since the Oklahoma City bombing in 1995, as well as the U.S. terrorist attacks on September 11, 2001. There has been an increase in the use of security glass products, especially in government buildings.
- To help meet this need, glass manufacturers and fabricators now offer a range of laminated product solutions that can help to protect against personal injury from bombs, bullets, and forced entry. By taking advantage of these innovative products, commercial buildings can benefit from increased protection, while occupants still enjoy unobstructed views and high levels of natural light.
- These products not only offer exceptional strength that helps glass to remain intact during heavy stresses—but also can prevent flying and falling glass shards following glass breakage.
- For businesses with proprietary or sensitive information, specialized laminated products are available that also protect against electronic eavesdropping and electromagnetic interference.

Laminated Glass Applications: Hurricane Resistance

- **In the wake of increasing hurricane activity, many coastal areas now have building codes in place that require the use of hurricane-resistant glazing.**
- **Customized laminated glass solutions—used in conjunction with appropriate hurricane-resistant framing—can meet this increasing demand.**
- **The entire window system—including laminated glass and framing—must pass stringent regional and ASTM International testing, including large missiles (ground level to 30 feet), small missiles (30 feet and up), and cyclical pressure.**
- **The glazing and framing are impacted with either large missile (9 lb. 2x4 @ 34 mph) or small missiles (2 gram steel shot @ 88 mph) and must indicate no penetration**
- **Glass manufacturers and fabricators can combine a variety of float, coated, or heat-treated products to provide a beautiful outward appearance—as well as customized energy performance for different coastal regions.**

Laminated Glass Applications: Sound Control

- **The bonded design of laminated glass provides outstanding acoustic insulation by dampening sound resonance and glass vibration—making it the perfect choice for sound control applications.**

- **The use of laminated glass can significantly improve the sound transmission class (STC) rating for windows in noisy areas. This rating is determined by measuring the sound transmission loss (STL), in decibels, between exterior and interior spaces.**

- **Compared to traditional single- and double-glazed systems, the difference in STC rating can be dramatic. Windows and doors that incorporate laminated glass can significantly reduce unwanted noise from highways, airports, railroads, or manufacturing plants.**

- **Laminated products can also be used in sound studios and other production environments.**

Fire-Rated Glass Options

- **To help meet building codes and protect the safety of building occupants, architects can select from a wide variety of fire-rated glazing solutions, including:**
  - ***1) Glass With Intumescent Interlayers (and similar gel-filled products)***
  - ***2) Ceramic Glass***
  - ***3) Fire-Rated Framing Systems***

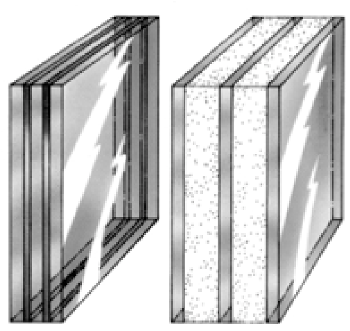
- **Wired glass—flat glass with wire embedded in the middle during the manufacturing process—has been specified as a safety glass in the past. However, more sophisticated glasses with intumescent interlayers—expanding layers that transform into a rigid shield when heated to prevent flames, smoke and hot gases from escaping—are growing in popularity, replacing wired glass as a safety product. Some state building codes also limit the use of wire glass.**



Fire-Rated Glass: Fire-Protective Versus Fire-Resistant

- **Ceramic fire-rated glass solutions are fire-resistant, but not fire-protective. While glass walls constructed with these products can stop the direct expansion of fire, they do not stop heat transfer—which can lead to spontaneous combustion in protected areas. These products are listed for use in non-impact safety-rated locations such as transoms and borrowed lites, and are appropriate for applications ranging from 20 to 90 minutes.**

- **Fire-rated glass solutions that feature intumescent interlayers are both fire-protective and fire-resistant. In the event of a fire, intumescent interlayers expand at about 250°F, transforming into a rigid and opaque shield that effectively blocks both convected and radiated heat transmission. These products are listed for complete transparent non-load bearing wall assemblies up to 120 minutes.**



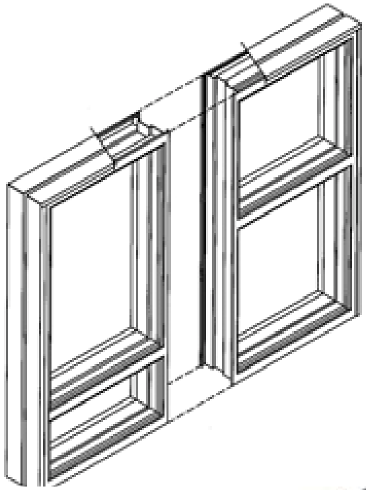
This illustration demonstrates how intumescent interlayers expand at about 250°F.

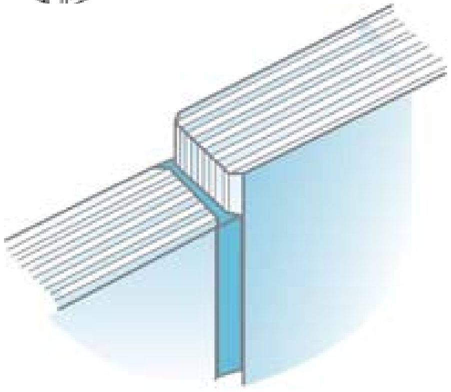
Fire-Rated Glass: Framing Systems

- **With innovative new fire- and safety-rated framing systems, walls no longer have to be a barrier to free vision. New framing solutions can offer an open, aesthetically pleasing environment that also ensures exceptional protection.**

- **Flexible framing solutions can include:**
  1) Wood, aluminum, or steel framing
  2) Thermally broken framing for transparent walls
  3) Butt glazing (glass butted together, joined by virtually invisible silicone sealant)

- **Framing solutions can offer varying degrees of fire or safety protection, depending upon the glass products installed within them.**





Fire-Rated Glass: Terms to Understand

While building and fire codes typically dictate which fire-rated glasses and framing systems are appropriate for a given architectural application, in comparing these products it is useful to understand these common terms:

Integrity (E)—the ability of fire-rated solutions to prevent the passage of flames and hot gases

Low Radiation (EW)—products' ability to keep heat radiation below 15 KW/m^2 on the protected side (measured from a one-meter distance)

Insulation (EI)—the ability of fire-rated products to stop heat transfer on the protected side (maximum allowed Tº rise on the glass +285ºF average/350ºF locally)

Internal Grade (IG)—products designated "internal grade" are suitable for internal applications not exposed to UV rays

External Grade (EG)—products with this designation are suitable for external applications (facades), as well as internal applications exposed to direct UV rays

Insulating Glass: Designed for Energy Efficiency

- Insulating glass (IG) solutions consist of two or three lites of glass that are hermetically sealed. Insulating units reduce heat gained and lost between interior and exterior spaces, contributing to outstanding energy efficiency.

- Custom-tailored IG units can incorporate various glass thicknesses, coatings, or tinted substrates to create buildings that are energy-efficient, wind-resistant, and attractive.

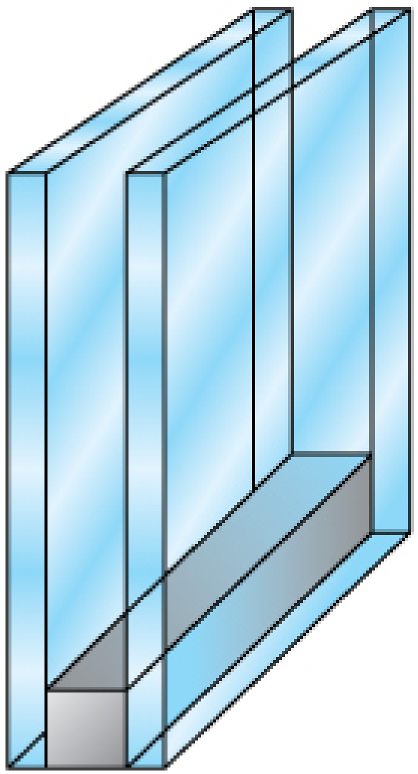
- In addition to featuring customized glass combinations, IG units can achieve specialized performance by incorporating different spacer systems, gas fillings, and features such as muntins and internal blinds.

Insulating Glass: Spacer Options

- **Space between the glass lites is created and maintained by a spacer system composed of a spacer, desiccant and sealants. The purpose of the spacer is to provide structural integrity, act as a carrier for the desiccant system and act as the support system for sealants.**
- **The spacer system within an IG unit:**
  - **Maintains space between glazing lites**
  - **Dries gas in space to prevent moisture condensation**
  - **Retains insulating gas fills within space and maintains hermetic seal around IG perimeter**
- **Condensation forms at the coldest location on the interior surface of the IG. Warmer interior surfaces reduce the chance for condensation to form.**
- **There are many spacer system options offering various benefits – thermal performance, structural integrity, condensation resistance, aesthetic options, and many other attributes. Check with your supplier for the facts about the spacer options available.**

Insulating Glass: Gas Filling Options

- **IG solutions include gas infills that slow down the transfer of heat across air spaces due to lower thermal conductivities. They help to improve thermal performance and energy efficiency.**
- **IG solutions include an inert gas filling that slows down the transfer of heat across air spaces—because these fillings are denser than air. They help to improve thermal performance and energy efficiency.**
- **Gases, such as argon, are commonly used. While other gas fillings—including krypton and SF6—are available, they are rarely used. Gases can also be combined for special applications. The most common airspace is filled with the air we all breathe everyday.**
- **The typical air space in a commercial IG unit is 1/2"—but can range from 1/4" to 5/8".**
- **Edge seals preserve the gas filling, protect against moisture intrusion, and ensure the structural integrity of the IG unit.**



Insulating Glass: Special Features

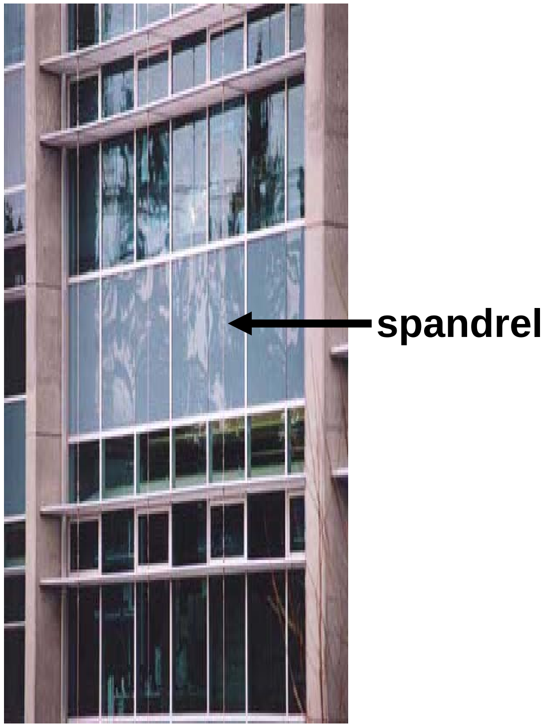
- Today, insulating units for architectural applications can include a number of special features that enhance their appearance and performance.
- For example, muntins installed inside the IGU can give the appearance of a true divided lite, without the labor and expense.
- Internal blinds can also be added to architectural IG units. Not only do these integral blinds reduce cleaning and maintenance requirements, they can also control the contamination of blinds in health-care settings—while still offering privacy and light-control options.

Spandrel Glass: Creating a Seamless Appearance

- **To conceal structural components such as floor and ceiling joists—which would interfere with the seamless appearance of curtain wall facades—architects can choose from two types of spandrel glass: silicone coated and ceramic frit coated. Other plastic film applied processes are available, but are not as common.**

- **Because silicone is a natural glass component, silicone coatings bond well with all glass substrates—creating a strong and durable coating. Silicone coatings have the added benefit of curing to a rubber-like consistency that holds the fabricated glass together in the event of breakage—providing fallout protection that meets many building codes.**

- **The fabrication process for ceramic frit coated spandrel products includes curing the glass at extremely high temperatures after the ceramic frit is applied—ensuring that the color coating permanently fuses with the substrate. As a result, ceramic frit spandrel solutions are exceptionally strong and durable—and retain their color for the life of the glass.**



Silkscreen Glass: Custom Aesthetics—and Solar Control

- Silkscreen designs can be applied to architectural glass to achieve a decorative, colored pattern on flat glass products. In making this product, manufacturers and fabricators silkscreen ceramic frit paint to a glass substrate in a pattern of dots, lines, or holes—then fire the glass so that the silkscreen coating becomes a durable, permanent part of the glass itself.
- This process can be used to lend interest to any float or coated glass solution. Silkscreening can also be done in conjunction with heat strengthening or tempering—when the reheating process is used to fire the ceramic frit paint. Silkscreen products can be laminated after the screening process.
- Silkscreen glass is growing in popularity for use in commercial buildings as vision glass, spandrel glass, and skylights—where it also provides solar control.
- Custom silkscreen colors and patterns can be specified, to create a truly one-of-a-kind effect.

SECTION 4

Making the Right Glass Choice

Glass Selection Criteria

In specifying the best possible glass solution for each project, architects must consider a range of factors, including:

- **Glass Aesthetics**
- **Performance Needs**
- **Application Demands**
- **Product Considerations**

Choosing a Glass: Aesthetic Considerations

- **In specifying a glass solution, architects have an opportunity to realize a unique aesthetic vision. As windows become larger—and the demand for natural light grows—glass plays an ever-increasing role in the overall appearance of commercial buildings.**

- **One of the first choices architects must make is selecting the right glass substrate and color for their design. With 11 common substrates available in the North American marketplace, today architects are only limited by their imaginations.**

- **Glass coatings are another important consideration—not just for performance, but also aesthetics. While reflective coatings offer performance advantages, they also make a strong and distinctive design statement. Low-E coatings offer more clarity and color neutrality, but with different performance characteristics.**

- **Fabricating options—including heat-treating, laminating, and insulating—have their own unique implications for the final appearance of a finished building. While these solutions are often required to meet energy and building codes, architects should understand their design implications upfront.**

Choosing a Glass: Performance Needs

- Certain glass performance characteristics—such as strength and safety—are defined by building codes. But architects also need to consider long-term energy efficiency—which can be significantly impacted by glass choice—as well as the daily comfort of those who will occupy the building.

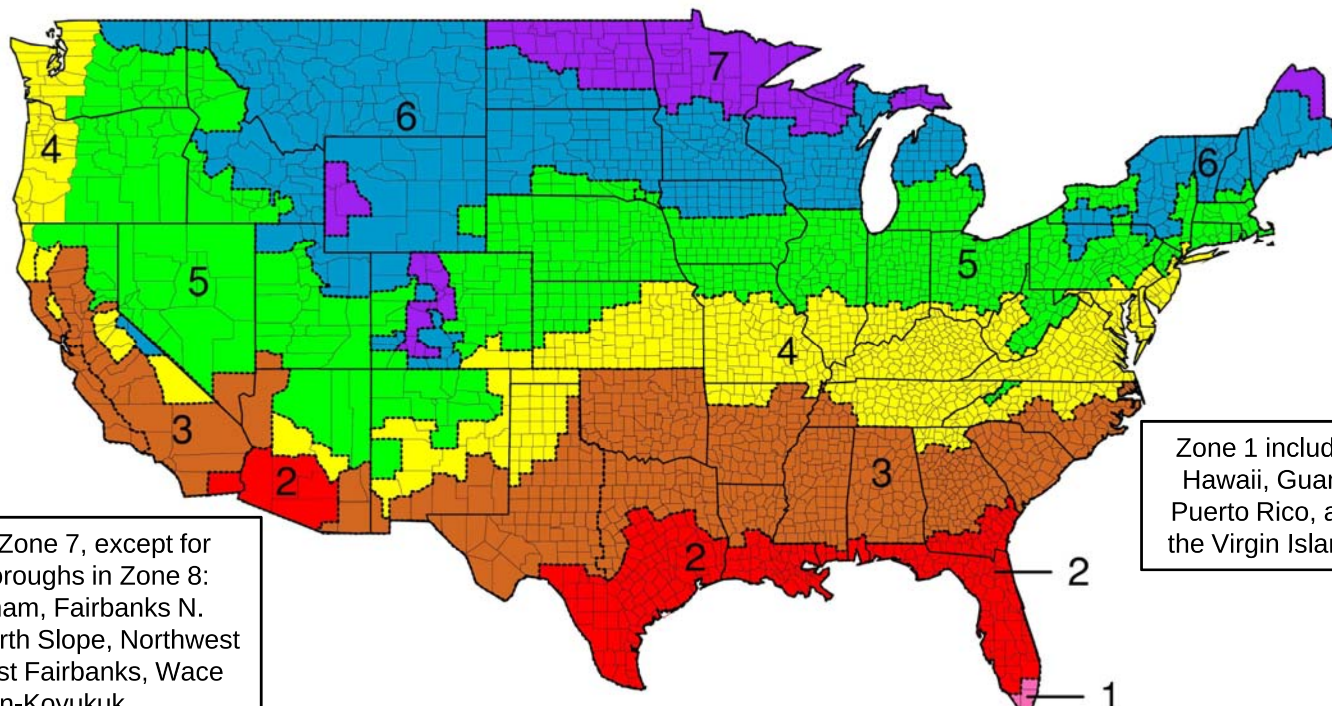
- Architects should choose the glass substrate, coating products and configuration, and fabrication options that maximize year-round energy performance for each individual building.

- While the most energy-efficient glass solutions may require a larger upfront investment—because they represent leading-edge technologies or labor-intensive processes—architects and building owners must balance this short-term cost with the long-term energy savings these products will deliver.

- In specifying energy-efficient products, there are at least two resources that architects can rely upon: the International Energy Conservation Code (IECC) and the Leadership in Energy and Environmental Design (LEED) Green Building Rating System.

IECC®: Mapping Performance Needs

- The International Energy Conservation Code® (IECC) prescribes energy performance requirements to allow for energy-efficient choices when specifying glazing.
- IECC requirements are centered around a map that includes eight U.S. regions, with distinct patterns of annual heating/cooling demands.
- Glass and window products can be specified based upon their "fit" for the region in which they will be installed.



All of Alaska in Zone 7, except for the following Boroughs in Zone 8: Bethel, Dellingham, Fairbanks N. Star, Nome, North Slope, Northwest Arctic, Southeast Fairbanks, Wace Hampton, Yukon-Koyukuk

Zone 1 includes Hawaii, Guam, Puerto Rico, and the Virgin Islands

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Encouraging “Green” Design: LEED^{TM}

- In addition to supporting energy efficiency and resource conservation, glass solutions can be an important part of environmentally responsible—or “green”—building design, a growing trend in North America.
- As an example, the Leadership in Energy and Environmental Design (LEED^{TM}) Green Building Rating System has created guidelines and recommendations for specifying windows.
- Developed by the U.S. Green Building Council, LEED is a national consensus-based, market-driven building rating system designed to accelerate the development and implementation of green building practices.
- By specifying various types of glazing—or the products of certain manufacturers—architects can earn LEED “points” for buildings. LEED recognizes not only energy efficiency, but also indoor environmental quality—considering thermal comfort, as well as ample daylight and views. In addition, LEED awards points for manufacturers’ recycling practices, and their proximity to job sites (decreasing transportation impacts).
- Low-E windows and other innovative glass solutions are ideal for meeting LEED’s “green” building design criteria.

Choosing a Glass: Application Demands

- **The myriad of glass choices available today makes it easier than ever for architects to meet the unique demands of every application—but the number of choices also makes product specification very complex.**
- **In addition to meeting building codes where hurricane resistance, security, or fire safety may be a concern, architects must consider the everyday strength needs of the glass. Loads on architectural glass can include mechanical stresses caused by high winds or snow accumulation—as well as thermal stresses caused by heat build-up.**
- **Vertical, sloped, overhead, and flooring installations of glass products all include their own special set of concerns and product requirements. In specifying glass solutions, architects must be cognizant of the extra strength and safety needs of glass installed in these types of applications.**
- **Architects can also ensure glass strength and stability by specifying appropriate framing systems and glass sealants—which can lend structural support and contribute to long-term window integrity.**

Choosing a Glass: Understanding Product Considerations

- **Each glass solution comes with its own set of considerations in terms of available thicknesses, sizes, and fabricating options. A "one-glass-fits-all" approach does not reflect the increasingly complex array of architectural options available today.**

- **While there are many glass options, architects should keep in mind that product customization does come with its costs. Special thicknesses, sizes, colors, and configurations can create one-of-a-kind buildings, but it may make sense to choose standard glass sizes and finishing options whenever possible. Architects should partner with glass suppliers to balance creativity with practicality and cost effectiveness.**

- **Customized products can also take time. Architects and building owners need to understand the impact of specialized glass solutions on the overall project schedule.**

- **In weighing glass options, architects must always honor the restrictions imposed by building codes—and ensure that glass suppliers have conducted adequate product testing to ensure that their products meet these requirements. For this reason, supplier selection is critical.**

Sources of Additional Information

For more information about making intelligent glass choices, architects can contact these industry and government groups:

- **American Architectural Manufacturers Association, www.aamanet.org**
- **American Society for Testing and Materials International, www.astm.org**
- **Canadian Window and Door Manufacturers Association, www.cwdma.ca**
- **Efficient Windows Collaborative, www.efficientwindows.org**
- **ENERGY STAR® program, www.energystar.gov/windows**
- **Glass Association of North America, www.glasswebsite.org**
- **International Energy Conservation Codes, www.energycodes.gov**
- **Insulating Glass Manufacturers Alliance, www.igmaonline.org**
- **National Glass Association, www.glass.org**
- **National Fenestration Rating Council, www.nfrc.org**
- **U.S. Green Building Council, www.usgbc.org.**

Course Summary

Thank you for your participation in this course, you should have an increased understanding of:

- **How glass is used in architectural applications—and the functionality and performance benefits it can provide**
- **Different types of glass—and their applications**
- **Fabricated glass solutions and their applications—including insulating units, heat-treated glass, and fire-rated glass**
- **How to measure and evaluate glass performance—to make better-informed choices when specifying glass**

This concludes the American Institute of Architects Continuing Education System Program.

Thank you!