EARN ONE AIA/CES
HSW LEARNING UNIT

New Glass Technologies Improve Performance of Architectural Glass

Fenestration Advances Boost Energy Efficiency and Lower Maintenance Costs

Santa Barbara, California Residence. Architect: Mark Kirkhart, Design Arc of Santa Barbara; Builder: Mark Trabucco

Provided by JELD-WEN® Windows and Doors

Windows have traditionally provided daylight and fresh air for building occupants and given character to the building's façade. One of the most important elements in an architect's palette, windows work to establish the style and rhythm of a structure, and their design and placement are a key aesthetic concern.

Yet windows can surpass these traditional aesthetic and practical considerations and become even more significant partners in creating sustainable buildings. As manufacturers continually improve their products to meet the needs of their customers, architects should be aware of new and emerging technologies in order to specify the most appropriate windows on their projects and realize the potential of windows to enhance sustainability goals.

During the past two decades, advances in glass technology have produced a new generation of materials that offer improved energy efficiency, easier maintenance, lower operating costs and higher performance. This article will define the parameters used in measuring the energy performance of fenestration, and detail how technological advances in the fenestration industry are achieving savings in energy and life cycle costs.

Measuring Energy Performance in Windows

Fenestration—including windows, doors and skylights—has the ability to reduce the heating, cooling and lighting requirements of a building, and has become critical to achieving good energy performance in a structure. It is critical to note, however, that no one window is suitable for every application. A first step is to understand how energy performance is calculated. The main energy characteristics that form the basis for quantifying a window's energy performance are described as follows:

CONTINUING EDUCATION

Use the learning objectives below to focus your study as you read **New Glass Technologies Improve Performance of Architectural Glass.** To earn one AIA/CES Learning Unit, including one hour of health safety welfare credit, answer the questions on page 8, then follow the reporting instructions or go to construction.com/CE/ and follow the reporting instructions.

Learning Objectives

After reading this article, you should be able to:

- Interpret the energy performance characteristics of windows.
- Discuss the newest window glass technologies.
- Specify appropriate impact-resistant and easy-to-clean windows for your projects.

U Values

Manufacturers usually represent the energy efficiency of windows in terms of their U-values (measure of heat loss). When there is a difference between the ambient air temperatures inside and outside a structure, heat is either lost or gained through a window. The U-value (or U-factor) is a measure of heat escaping the interior of the home. U-value ratings generally fall between 0.20 and 1.20. The lower the U-value, the greater a window's resistance to heat flow, the better its insulating value, and the lower the heating costs. In other words, the lower the U-value the better the energy efficiency of the window. Low U-values are most important in northern regions where outside temperatures are cold and heating costs are traditionally high.

In product literature, some manufacturers list the U-factor only for the glass itself, rather than for the entire window unit. If it is only for the glass, the U-value may be much better than a rating of the whole-product. Low-E (low-emissivity) and gas fills can provide cost-effective energy efficiency. The lower the U-factor, the greater the energy savings; U-factors between .3 and .4 are optimal.

Fenestration—including windows, doors and skylights—has the ability to reduce the heating, cooling and lighting requirements of a building, and has become critical to achieving good energy performance in a structure.

Solar Heat Gain Coefficient

The solar heat gain coefficient (SHGC) measures how well a product blocks heat caused by sunlight. SHGC is expressed as a number between 0 and 1. The lower a window's solar heat gain coefficient, the less sun-induced warmth it transmits into a building or house.

According to the U.S. Department of Energy, the solar heat gain coefficient of clear double-strength glass is 1.0. Glass with a solar heat gain coefficientt of 0.5 transmits half of that solar energy, and glass with a solar heat gain coefficient .75 transits three-quarters of that let through by clear double-strength glass. As the measure of effectiveness of blocking sun and heat, the shading coefficient is what drives air-conditioning loads. The lower the number, the more solar heat it resists, and the lower the cooling costs. Low SHGC ratings are most important in southern regions where outside temperatures are hot and cooling costs are traditionally high.

Visible Transmittance

Visible transmittance (VT) measures how much daylight comes through a window. VT is also expressed as a number between 0 and 1, and correlates directly with the percentage of light passing through the glass. In other words, a product with a .66 VT rating means that 66 percent of visible light is transmitted through the glass. The higher the VT, the more daylight is transmitted. A high VT is desirable to maximize the amount of daylight entering the occupied spaces. The more daylight entering a home or building, the greater the opportunity to reduce electric lighting.

Air Leakage

Cracks in the window assembly cause heat to enter and leave the building unchecked. Air leakage is measured in terms of the air that passes through a given unit area of window, such as 5 cubic feet of air passing through 0.5 square feet of window assembly. The lower the value, the less air will unintentionally pass through.

Condensation Resistance

How well a fenestration product resists the forming of condensation on its interior surfaces is its condensation resistance (CR). The higher the CR rating, the better that product resists condensation. CR is expressed as a number between 0 and 100.

Window Technologies for Energy Performance

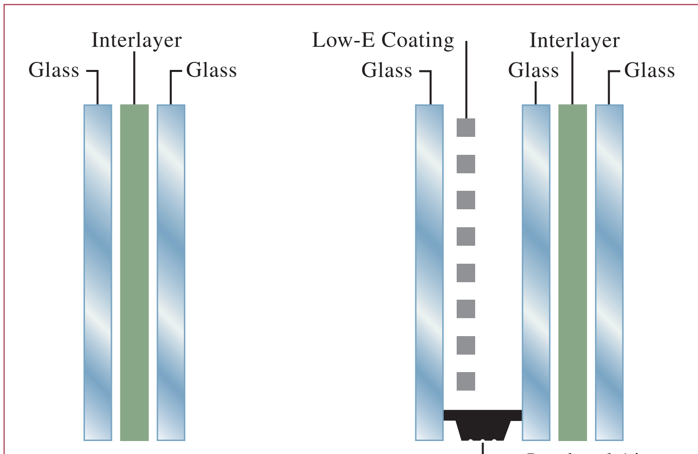
All of the energy-efficiency parameters discussed above are affected by the various components of a window: glass panes, low-E coatings, inert gas fills, edge spacers and frame materials. At their most effective, and in the proper climate and arrangement, these components lead to improvements in solar control, thermal comfort and energy savings.

Glass Layers

Standard single-pane glass has very little insulating value. Before the 1980s, a window's energy performance was improved primarily through the addition of glass panes, on the premise that double pane glass, in which two panes of glass enclose air space between them, has twice the insulating power of a single pane of clear glass. The trapped layer of air between the two panes creates the insulator that prevents warmth from escaping or entering the structure. Because the inner pane does not come into contact with the cold outside air, it stays warmer than the outside pane. Double pane windows can also insulate sound and eliminate condensation if the air space contains a moisture absorbing chemical.

Air Space

The depth of the air space between the glass panes will also affect energy performance: Spaces that are either too wide or too narrow tend to have higher U-values. Thicker air spaces insulate more effectively than thinner air spaces—up to a point. The optimal air



Glass Options

space for energy performance is 1/2-inch, which translates into a 3/4-inch insulating glass unit.

Gas Fills

By substituting a denser, lower-conductivity gas such as argon for the air in a sealed insulated glass window, heat loss can be reduced significantly. Argon is much denser than air, and has a lower thermal conductivity, resulting in lower heat transmission between the panes of glass, and providing even more insulation for double pane windows. Many major window manufacturers offer argon-gas fill as an option. Other gases that are being used in windows include carbon dioxide (CO_2), krypton (Kr), and argon-krypton mixtures.

Edge Spacers

The element that holds the panes of glass apart and provides the air-tight seal in an insulated glass window is known as an edge spacer. Edge spacers are designed to interrupt the transfer of heat between the two panes of glass. Aluminum, a material with high thermal conductivity, was the traditional material used for edge spacers. But as more effective glass coatings became available, aluminum edge spacers were found to offer fewer benefits than those made of other materials. Stainless-steel edge spacers, for example, are preferable to aluminum because of their lower conductivity. This new generation of edge spacers helps maintain higher temperatures at the edge of the window unit, improving insulation and reducing condensation. Aluminum with thermal breaks, silicone foam and butyl rubber are other new technology options for edge spacers.

Frames

Window frames may be composed entirely of aluminum, wood, vinyl, and fiberglass, or they may be a combination of materials such as wood-clad vinyl or aluminum-clad wood. Because the frame occupies about one-quarter of the total window area, frame materials should be thermally non-conductive. Aluminum frames tend to have low interior surface temperatures even during the heating season and for that reason may not be suitable for all climates.

Wood frames have lower U-values, are not affected by temperature extremes, and usually do not promote condensation. Vinyl frames, too, have low U-values, and offer the benefit of reduced maintenance and competitive pricing. Generally speaking, wood, vinyl and fiberglass provide better insulating value.

Low-E Coatings

More than any other single improvement, the development of low-emissivity (low-E) coatings in the 1980s revolutionized window technology. Low-E glass is coated with microscopically-thin, optically transparent layers of silver sandwiched between layers of antireflective metal-oxide coatings. According to the U.S. Department of Energy, which has made substantial investments in a series of energy-efficiency research and development projects over the years, low-E glass coatings have saved the nation more than $8 billion in energy costs. According to industry estimates, over 50 percent of windows now sold have low-E glass.

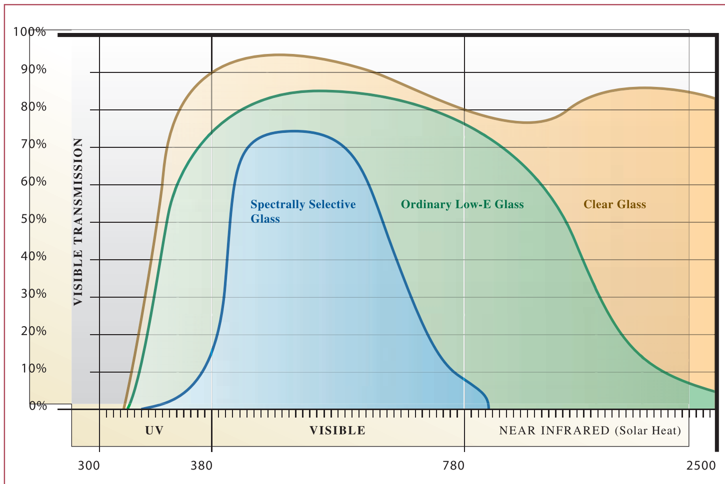
In order to understand the benefits of low-E coatings, it is important to note the components of sunlight. Among other things, sunlight contains visible light, ultraviolet (UV) light, and infrared (IR) light. Visible light enables us to see things and is welcome in a building interior. Ultraviolet light damages skin, wood, and fabrics and causes colors to fade; it is also associated with premature aging and skin cancer. The infrared portion of the spectrum consists of varying wavelengths. Short-wave IR light is absorbed by objects both inside and outside the building and is transformed into long-wave energy or heat. Infrared energy is desirable when the goal is to heat a room's interior by natural means; however, it is undesirable whenever building interiors become too hot, and excessive demands are placed on air-conditioning and ventilation systems.

The thin, transparent low-E coatings allow visible light to pass through, but they effectively reflect infrared heat radiation back into the room, which keeps interiors warmer and reduces heating costs. This reduces heat loss through the windows in the winter. In the summer, low-E glass windows admit visible sunlight while blocking infrared and ultraviolet solar energy that drives up cooling costs and damages window treatments, carpeting and furnishings. According to the DOE's Energy Efficiency and Renewable Energy Clearinghouse, windows manufactured with low-E films typically cost about 10 percent to 15 percent more than regular windows, but they reduce energy losses by as much as 30 percent to 50 percent. Further, advanced glass with spectrally selective coatings can reduce the cooling requirements of new homes in hot climates by more than 40 percent.

Not all low-E coatings are the same. Placement of the coatings and the types of light wavelengths that they block affect their overall performance. A variety of low-E windows are now available for various climate zones and different applications in any particular location.

Spectrally Selective Glass

Widely considered to the next generation of low-E glass, spectrally selective coatings provide all the benefits of low-E glass along with increased heat-gain protection and greater energy savings. Special coatings distinguish between desirable light and unwelcome UV and infrared light; these coatings admit light but not heat by



Spectrally selective coatings distinguish between visible light, unwelcome UV and near Infrared rays. The result is improved solar heat control, fading protection, and visibility.

selectively transmitting or reflecting specific wavelengths, achieving a good shading coefficient and good visible transmittance.

Traditionally, optimum solar block was achieved at the expense of visible light transmittance. Spectrally selective coatings deliver a balance of solar control and high visibility, with the most efficient products blocking as much as 95 percent of the sun's damaging ultraviolet rays, thereby protecting furniture, carpets, curtains and wall coverings and reducing premature fading. Their energy performance derives from a manufacturing process known as "sputter deposition," which enables manufacturers to deposit a super-thin coating of alloys and metals—including titanium and silver—onto the window film to block more infrared energy, or heat, and let through more visible light. Though the ideal would be to allow through all visible light and no infrared or UV light, the technology, though rapidly evolving, has not yet achieved that capability. Some of the most advanced versions have three coatings of silver, and are virtually clear, with a visible light transmittance of 66 percent and a solar-heat-gain coefficient of 0.22, significantly better than that of tinted, ordinary low-E glass. These values represent the highest visible light transmittance and the lowest SHGC commercially available.

Spectrally selective coatings promote thermal comfort. During the cold weather, a window's insulating capability has a direct impact on occupant comfort. The Efficient Windows Collaborative, which provides unbiased information on the benefits of energy-efficient windows, suggests that when a window's surface temperature falls below 52 degrees F, there is a risk of thermal discomfort. For optimal cold weather comfort, windows should be able to maintain a surface temperature of at least 52 degrees. The chart below demonstrates the insulating capability of spectrally selective glass in comparison with low-E and single- and double-pane windows. Spectrally selective glass is significantly better than both single and double pane clear glass, and slightly ahead of low-E glass in maintaining a warm glass surface in spite of frigid outdoor temperatures.

Inside glass and outside temperatures	-20ºF	+20ºF
Single-pane clear	0º	31º
Double-pane clear	37º	51º
Low-E	47º	58º
Specialty Selective	52º	61º

This table compares the interior glass temperatures of different glass types in two outdoor conditions.

Tinted Glass, sometimes called absorbing glass, has energy-absorbing materials within it that lower the shading coefficient and also provide a colored tint—generally bronze, gray, blue, or green. Tinted glass and tinted window films have long been used in commercial buildings to reduce heat gain through windows. Improved, lightly tinted windows are becoming more common for the residential market in the cooling-dominated climates of the Southern United States. These new coatings cut solar heat gain without reducing visibility to the extent that older tinted glasses and films have. The tinted or colored glass helps reduce glare, and by absorbing the sun's heat it reduces energy consumption and creates a more comfortable interior without obstructing the view outside. This glass is ideal for climates with intense sunlight: It reduces glare and visible light transmittance, while also keeping home and building interiors more comfortable in warm weather.

Reflective glass has better solar heat gain coefficients than tinted glass because they reflect rather than absorb most of the infrared heat. The reflective coating is made of thin layers of metals or metallic oxides deposited on the surface of the glass. While tinted and reflective glass achieves low solar heat gain coefficients, they also make the window appear dark, with traditional window films reducing the amount of natural light entering the building by as much as 88 percent.

Overall Performance

The energy efficiency of an entire window assembly can differ significantly from that of its glass. For optimal value, the energy performance of the entire window assembly is the key, including the frames and insulating glass spacers.

In addition, the building design should take into account the climate, the total window area of the building, choice of heating and cooling system, and the level of insulation. All of the factors will affect the choice of window that will produce the greatest energy savings and occupant comfort in a given situation. To determine the best choices, national rating systems have been developed to enable effective comparisons between windows.

Rating Systems

The National Fenestration Rating Council (NFRC) is a non-profit organization that administers a widely accepted, uniform and independent rating and labeling system for the energy performance of windows, doors, skylights, and attachment products. By providing a reliable way to determine a window's energy properties and to compare products, NFRC ratings enable architects and builders to determine how well a product will perform the functions of helping to cool a building in the summer, warm a building in the winter, keep out wind, and resist condensation. By using the information contained on the label, architects and builders can reliably compare one product with another, and make informed decisions about the windows, doors, and skylights they specify or buy.

NFRC adopted a new energy-performance label in 2005. It lists the manufacturer, describes the product, provides a source for additional information, and includes ratings for one or more energy performance characteristics.

It should be noted that all energy performance values on the NFRC label represent the ratings of windows and doors as whole systems — that is, glass plus the framing system. The three required ratings are U-factor, solar-heat-gain coefficient and visible transmittance. Some manufacturers also measure air leakage and condensation resistance, but they are optional in the labeling. The NFRC has also developed rating and labeling procedures for window film attachments, internal or between-the-glass blinds and shading devices, as well as dynamic glass products that change tint in response to temperature, sunlight, or electric charge.

NFRC's Certified Products Directory is expanding to include these ratings as they become available. NFRC is currently considering such energy ratings as ultraviolet light/fade protection and overall comfort. The Council is also working to develop a new commercial program called "the Component Modeling Approach," measuring whole-product performance for nonresidential fenestration products assembled on-site. This new program is being developed in a way that will likely appeal to much of the design community, in addition to code officials and manufacturers, by helping architects determine how design changes can affect the overall energy performance of the building.

Energy Star Another rating program is known as Energy Star. Primarily oriented toward helping consumers reduce heating and cooling costs, Energy Star is a joint program of the U.S. Environmental Protection Agency and the U.S. Department of Energy. Energy Star-labeled windows meet a stringent energy-efficiency specification set by the Department of Energy and have been tested and administered by the NFRC, which assigns specific energy-efficiency measures such as U-factor and solar-heat-gain coefficient to the complete window system, not simply the glass. Energy Star-qualified windows may have two or more panes of glass, warm-edge spacers between the window panes, improved framing materials, and low-E coatings.

By providing a reliable way to determine a window's energy properties and to compare products, NFRC ratings enable architects and builders to determine how well a product will perform.

Energy Star further lists climate zones in the United States and a recommended glass type for each.

In order to gain the coveted "Energy Star qualified" rating, new home builders must install the low-E glass determined for their particular climate zone. In the North/Central region of the country, for example, Energy Star recommends "Moderate Solar Gain Low-E Windows," which screen out a selected portion of the sun's heat in the summer but allow a good amount of solar heat in winter. The inside window glass stays warmer, so occupants don't feel a draft with the thermostat set at 70 degrees Fahrenheit.

An important point to note is that while the NFRC label can be found on all Energy Star-qualified window, door, and skylight products, Energy Star bases its qualification only on U-factor and SHGC ratings. But now that more than 50 percent of new products in the residential market bear the Energy Star label, the program will develop more stringent ratings to maintain the value of the Energy Star name with a goal of having 20 percent to 25 percent of the market carrying the Energy Star label.

Impact-resistant Glass for Hurricane Prone Regions

As hurricanes and tropical storms have devastated coastal states in recent years, codes officials and insurers have required protection in those areas in the form of impact-resistant glass and frames. Following Hurricane Andrew in 1992, which killed 23 people and caused $25 billion in damage, extensive research indicated that a breech of many building envelopes led to internal pressurization of the compromised structures—a situation that magnifies forces on walls and roofs, with the potential for catastrophic failure.

Consequently, Florida and other coastal states and municipalities have implemented stringent codes requiring that the building envelope be maintained during a hurricane, and that all elements of the building shell resist the effects of windborne debris as well as sustained turbulent winds lasting several hours. For many homes and businesses, that translates to having impact-resistant window systems. In response, manufacturers have now developed a broad portfolio of products with impact-resistant laminated glass and components to withstand higher design pressures. These hardened window assemblies have been refined so that they are barely distinguishable from normal residential and commercial windows.

Commercially available impact-resistant glass typically sandwiches a laminated inner layer made of plastic, usually polyvinyl butyral (PVB) or fiberglass-reinforced plastic, between two sheets of glass. The result is stronger than a car windshield. Though the glass might shatter if hit with a heavy object, it won't break into small bits, which

When strong winds enter a home through a broken window or door, the increased pressure can lift the roof and push walls outward.

makes wind less likely to penetrate the envelope of a home or building and create interior pressures severe enough to blow the roofs off. True impact-resistant windows can handle the repeated impact of debris hurled at high wind speeds, making penetration from wind or water virtually impossible.

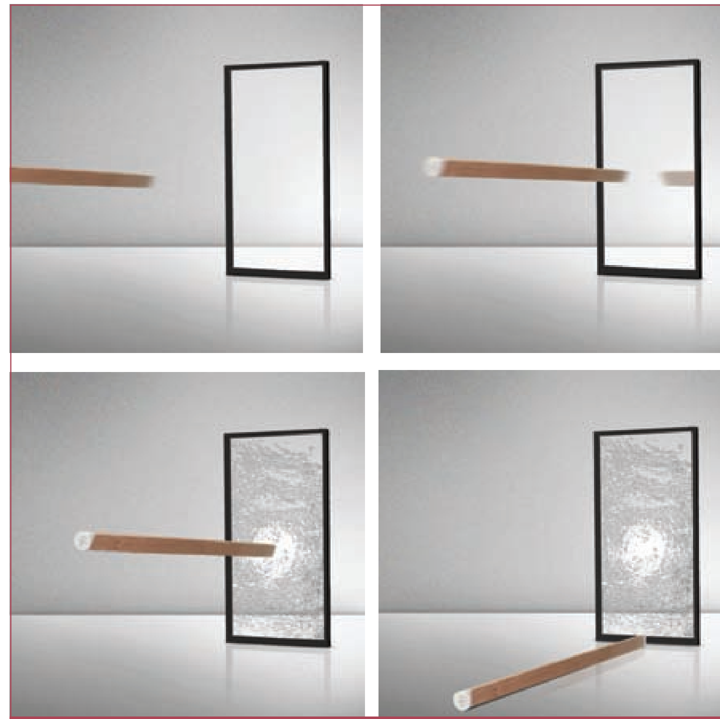
The frame is an important part of an impact-resistant window. Whether they're constructed of wood, vinyl or metal, frames for impact-resistant situations are typically heavier than those for conventional windows and can often include stiffeners or reinforcements to help resist the forces of wind-borne debris.

Several different groups have developed test standards to determine a window's impact resistance:

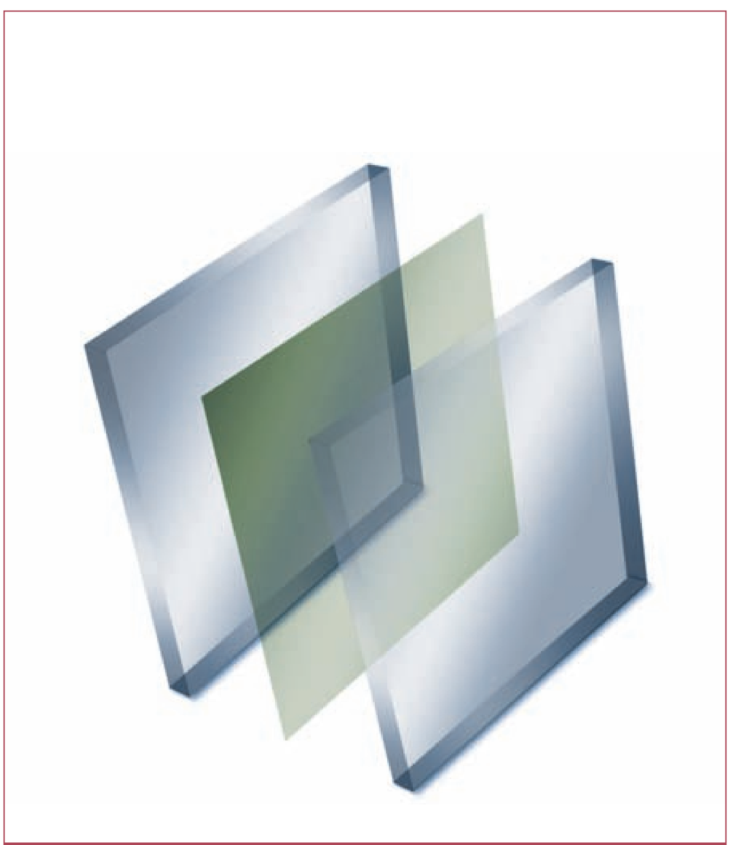
SSTD 12 Test Standard for Determining Impact Resistance from Wind-borne Debris written by the Southern Building Code Congress International, Inc.

ASTM E1996 Standard Specification for Performance of Exterior Windows, Glazed Curtain Walls, Doors and Storm Shutters Impacted by Wind-borne Debris in Hurricanes (written by the American Society of Testing and Materials)

PA 201 Impact Test Procedures (written by Miami-Dade County Building Code Compliance Office)



Missiles are hurled at test windows to determine if they are impact resistant.



Impact-resistant glass incorporates plastic between two sheets of glass.

These standards involve similar tests which consist of two parts: impact testing and cyclic wind loading.

The impact test consists of the shooting of objects at a series of specimens, typically "missiles," or wood 2x4s of various lengths, at various speeds. If the window will be installed more than 30 feet above the ground, small objects will be fired at the test specimen simulating the kind of debris likely to be carried by the wind to those heights. For windows installed below the 30-foot level, 2x4s are shot at the test specimen simulating larger objects carried by the wind at ground level but too heavy to be picked up by the wind.

After the initial "missile" tests, the window specimens are put through cyclic wind-pressure loading that simulates hurricane conditions with winds of up to 200 miles per hour. The test specimens are subject to repeated impacts to about four hours or more of positive and negative pressure cycles to determine the window's ability to resist fatigue and the fastener system's capacity to keep it attached.

If the window remains intact within the frame, it can be certified as an impact-resistant window. For impact-resistant glass, all standards including the Miami-Dade County Standard, among the strictest in the country, allow that the glass may be broken, but not penetrated. In this instance, even if the glass cracks, shards remain in the frame, assuring that the building envelope remains sealed.

The testing results in two designations: impact resistance and a design pressure rating expressed in pounds per square foot. Commercially produced products that pass one or more of these standards should have a certificate or label that identifies which standard or standards it has passed. These are usually listed by the test standard number, such as ASTM E 1886 or others.

Since tougher building codes took effect in Florida following the devastation of hurricane Andrew, numerous other states have followed suit by adopting storm-ready building codes of their own, requiring that coastal properties adhere to stricter standards. In an emerging trend, impact-resistant windows are also being used in homes far from coastal areas. Because they also offer increased protection from intruders and against sunlight and unwanted exterior noise, architects and builders are using these tougher hurricane-rated windows in a variety of climates and situations.

Exterior Easy-Cleaning Technology

On normal windows, regularly required maintenance and cleaning can often be expensive and time-consuming and involve harsh detergents. Thanks to new technologies using a microscopically thin coatings of titanium dioxide, TiO_2, and the natural powers of sunlight and rain, window manufacturers have refined a reliable, environmentally friendly way to assure the windows stay clean longer.

During the manufacturing process for easy-cleaning window glass, a very thin nanosized coating of titanium dioxide, the white pigment used in products from paints to toothpaste, is integrated into the molten glass. This special coating and the chemical reactions that result have self-cleaning properties that happen at the nano-scale (one thousand millionth of a meter).

To begin with, the layer of TiO_2 acts as a photocatalyst: Particles of titanium dioxide react chemically with the sun's UV rays and cause organic materials that are on the glass to decompose. This takes place even on cloudy days, as 80 percent of UV radiation still gets through cloud cover. This chemical breakdown loosens all organic soiling, including dirt, resins and bird droppings that may have built up over time, and facilitates their removal.

Easy-cleaning window glass (left) versus standard glass (right)

Further, the TiO_2 coating decreases the surface tension of water that hits the glass surface, causing a hydrophilic (water-attracting) effect. Water does not streak or bead up on the surface, but rather sheets off the glass, carrying loosened particles of dust and dirt with it, and drying without spotting or streaking. Rain water and a light spray by a garden hose will achieve the same effect. The process is continuous, as once activated only a small amount of UV light will trigger the chemical reaction.

In contrast, rain water beads up on plain glass, making the windows appear even dirtier than they actually are. The difference in water repellence properties lies in the surface of each type of glass. Water hits plain glass at a contact angle of 35 degrees, creating a water repellant reaction. But water hits the surface of easy-cleaning glass at a much decreased contact angle, causing it not to bead up, but to spread out flat. Eventually the contact angle of the easy-cleaning glass is so reduced that a super-water-repellant situation is created in which the water virtually sheets or slides off the surface.

Easy-cleaning glass is available for all glass applications, vertical or angled, including windows, doors, roofs and skylights. It is particularly beneficial for hard-to-reach areas such as conservatory roofs. Because the coating is bonded to the easy-cleaning glass, it cannot be worn away or scuffed off. Most manufacturers offer easy-cleaning glass with the option of low-E coatings as well.

New technologies in several areas have made significant impact in energy savings, reliability and ease of maintenance. The field continues to evolve rapidly with manufacturers planning an increasing array of options to increase the energy efficiency and sustainability of new and existing buildings. ■

Take the quiz online at construction.com/CE/
or
See Quiz on the Next Page

This article also appears online at **http://construction.com/CE/articles/0710jeldwen-1.asp**

Program title: **"New Glass Technologies Improve Performance of Architectural Glass" (10/07).** AIA/CES Credit: This article will earn you one AIA/CES LU hour of health, safety, and welfare credit. (Valid for credit through October 2009). **Directions:** Refer to the Learning Objectives for this program. Select one answer for each question in the exam and fill in the box by the appropriate letter. A minimum score of 80% is required to earn credit. **To take this test online, go to construction.com/CE/**

Learning Objectives

After reading this article, you should be able to:

- Interpret the energy performance characteristics of windows
- Discuss the newest window glass technologies
- Specify appropriate impact-resistant and easy-to-clean windows for your projects

Questions

1. U-Values measure:
❑ **a.** Resistance to heat
❑ **b.** Light admitted
❑ **c.** Heat escaping the interior of the structure
❑ **d.** Ultra violet light absorbed

2. A high visible transmittance (VT) in a window signifies:
❑ **a** that heat is resisted.
❑ **b.** high degree of sunlight is blocked.
❑ **c.** low shading value.
❑ **d.** high degree of daylight is admitted.

3. Before the 1980s, a window's insulating value was primarily improved through:
❑ **a.** additional glass layers.
❑ **b.** aluminum clad frames.
❑ **c.** weatherstripping.
❑ **d.** argon-krypton mixtures.

4. More than any single improvement, window technology was revolutionized by:
❑ **a.** high-impact glass.
❑ **b.** low-E glass.
❑ **c.** spectrally selective coatings.
❑ **d.** self-cleaning glass.

5. Spectrally selective coatings:
❑ **a.** decrease visible light
❑ **b.** block 95 percent of the sun's damaging ultraviolet rays
❑ **c.** are available in blue, brown and gold
❑ **d.** may cause thermal discomfort

6. Reflective glass
❑ **a.** must be double pane
❑ **b.** are not used anymore
❑ **c.** has better solar heat gain coefficients than tinted
❑ **d.** permit maximum light into the building

7. The National Fenestration Rating Council:
❑ **a.** rates only the glass portion of the window unit
❑ **b.** requires air leakage and condensation resistance ratings
❑ **c.** does not require U-value ratings
❑ **d.** rates the entire window assembly

8. Standards for impact-resistant glass
❑ **a.** were developed in response to tornado damage
❑ **b.** involve two parts: impact testing and cyclic wind loading.
❑ **c.** are published only by ASTM
❑ **d.** do not allow window glass to be broken

9. Easy-cleaning glass
❑ **a.** will not work on cloudy days
❑ **b.** causes water to bead up on the glass surface
❑ **c.** contains a layer of TiO_2 that acts as a photocatalyst
❑ **d.** is only available for vertical glazing applications

10. The coating on easy-cleaning glass
❑ **a.** causes water to "bead up" and roll off the glass
❑ **b.** gives the glass a heavy tint that helps block UV rays
❑ **c.** decreases the surface tension of water causing it to sheet off the glass
❑ **d.** dramatically lowers the u-value

Last Name ____ **First Name** ____

Job Title ____

Firm Name ____

Address ____

City ____ **State** ____ **Zip** ____

Tel. ____ **Fax** ____

E-mail ____

AIA ID Number: ____ **Completion date (M/D/Y):** ____

Check one: ❑ $10 Payment enclosed. (Make check payable to McGraw-Hill Construction and mail to: Continuing Education Certificate, PO Box 5753, Harlan, IA 51593-1253.) For customer service, call 877/876-8093.

Charge: ❑ Visa ❑ Mastercard ❑ American Express

Card# ____

Signature ____ **Exp. Date** ____

Check below:

❑ **To register for AIA/CES credits: Answer the test questions and send the completed form with questions answered to address at left, or fax to 888/385-1428.**

❑ **For certificate of completion:** As required by certain states, answer test questions, fill out form, and mail to address at left, or fax to 888/385-1428. Your test will be scored. Those who pass with a score of 80% or higher will receive a certificate of completion.

Material resources used: Article: This article addresses issues concerning health and safety.

I hereby certify that the above information is true and accurate to the best of my knowledge and that I have complied with the AIA Continuing Education Guidelines for the reported period.

Signature ____ **Date** ____

107SPONA