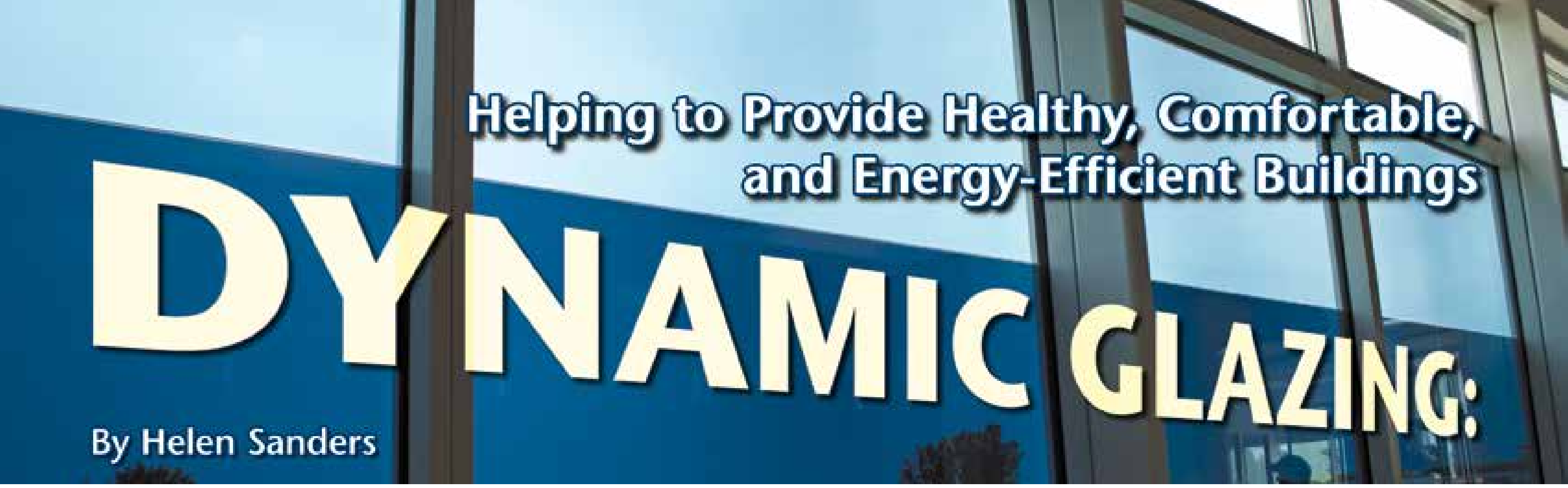

Dynamic Glazing: Helping to Provide Healthy, Comfortable, and Energy-Efficient Buildings

By Helen Sanders

HEALTHY BUILDINGS: THE IMPORTANCE OF DAYLIGHT AND VIEWS

The evidence of the positive benefits of access to daylight on human health and well-being is now indisputable.[1] Daylight can be thought of as a drug—one that is crucial to human health. Nature provides the right dose (intensity) of the right type (wavelength) at the right time of day to entrain the human body's circadian rhythms. In doing so, daylight plays a critical role in maintaining the body's key processes, such as hormone production, the sleep/wake cycle, and immune system effectiveness. Lack of daylight at the right time of the day can cause significant health risks, as has been shown by studies on the increased incidence of cancer in circadian-rhythm-disrupted shift workers.[2] In contrast, access to daylight has been shown to significantly improve productivity and reduce absenteeism in office settings and increase healing rates in healthcare environments.[3]

A view to the outdoors has also been shown to be beneficial to the health and well-being of building occupants, not just because it refocuses and relaxes the eyes and provides daylight, but because it also satisfies our primal need for safety inside while being able to see what dangers might lie outside.[4] Views of nature specifically appear to be even more important because they have been shown to also reduce stress levels and improve mood.[5] The World Health Organization says that mental health disorders are expected to be the number-two illness worldwide by 2020,[6] and stress can be a major contributor. Providing views of nature and access to daylight within the built environment would therefore seem to be an important design factor.

Unfortunately, over the past century, with the advent of cheap electric lighting and the ability to construct larger, deeper buildings, our built environment has been increasingly isolating us from these critical needs. In more recent years, though, there has been a movement to increase the availability of daylight in buildings through market-leading standards such as the U.S. Green Building Council's (USGBC's) Leadership in

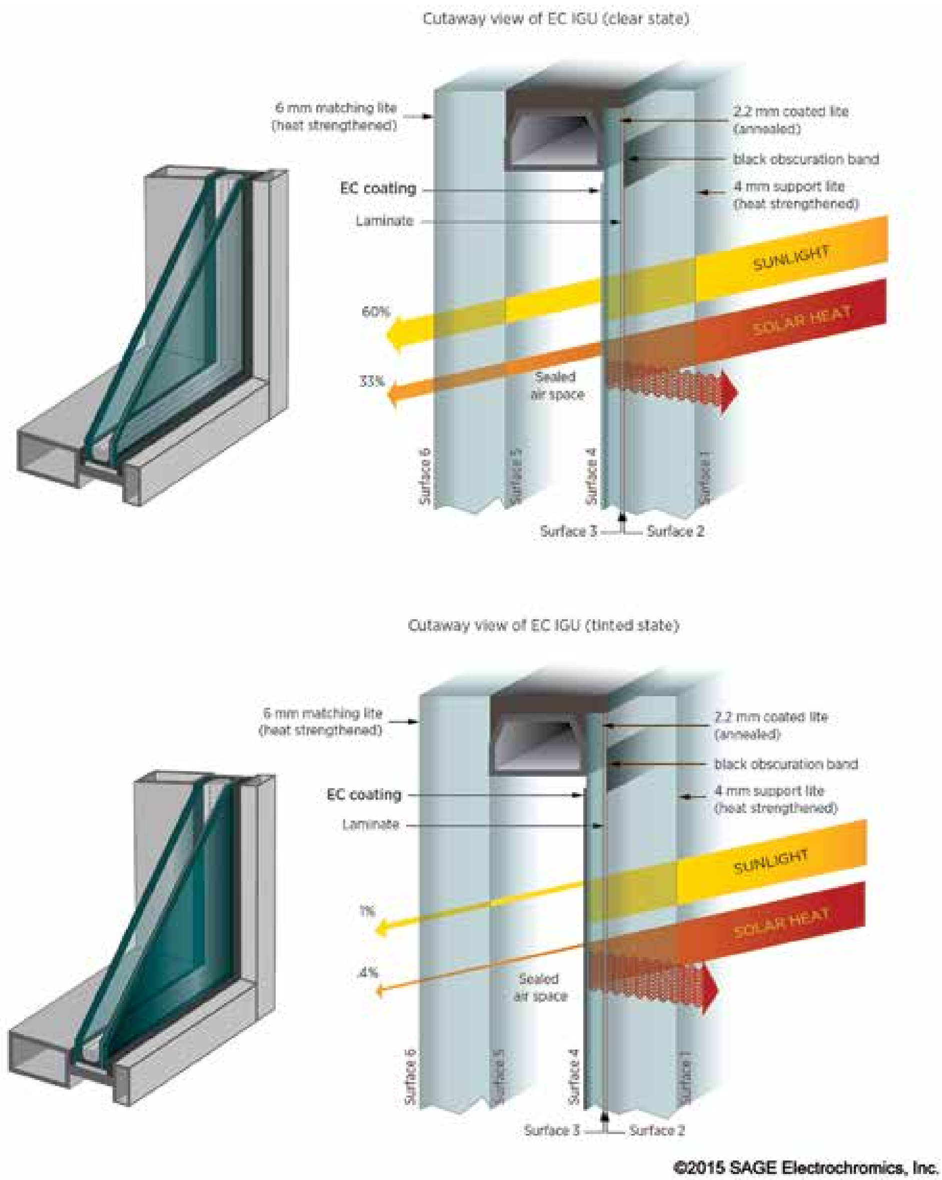

Figure 1 – Example of the configuration of an electrochromic (EC) dual-pane insulating glass unit.

Energy and Environmental Design (LEED®) rating program, the International Green Construction Code (IgCC), and ASHRAE's Standard 189.1.

The easy way to get a lot of daylight into a building would be to use a lot of glass. But that is neither conducive to energy efficiency nor occupant comfort unless the heat and glare that accompany daylight is managed effectively. For example, a number of LEED-certified buildings, while providing good access to views, in practice have been shown to have no better energy performance than non LEED-certified buildings. With large expanses of glass, they also have the potential to cause significant thermal and visual discomfort if there is insufficient solar control and no planned dynamic response for glare. Studies have clearly shown that the discomfort from glare can more than negate any positive gains from access to daylight and views, and the same is true for thermal discomfort.[7,8] Even if manual blinds are employed for glare control, they are generally pulled down when the glare condition is present and left down long after the glare condition has gone, blocking the view and daylight admission and negating the positive benefits of the window.

Herein lies a key design challenge: How to manage glare and heat gain without obstructing the intended views, while still admitting sufficient daylight to deliver the desired health benefits for occupants as well as high-energy performance.

Dynamic glazing can provide a solution to this challenge because of the ability to tune its visible light transmission (VLT) and solar heat gain coefficient (SHGC) in response to the external environment and/or occupant needs. In this way, heat gains and glare can be controlled as needed while still maintaining the view through the window. The summary below describes different types of commercially available dynamic glazing and their different performance characteristics, and provides key criteria for evaluating different types of dynamic glazing for building applications.

DYNAMIC GLAZING

Thermochromic glazing

Thermochromic glazing is a passive dynamic glazing technology that changes its VLT in response to changes in its temperature, becoming darker as the temperature increases. It is called a "passive" dynamic glazing because the occupant has no control over the tint level of the glass.

Current commercially available thermochromic technology comes in the form of a thermochromic polyvinyl butyral (PVB) laminate interlayer material that is laminated between two plies of glass using standard laminating processes. The resultant laminated lite is then generally combined with another lite to form an insulating glass unit (IGU). The laminated lite containing the thermochromic material is on the exterior-facing lite of the IGU.

The lowest transmission state is determined by the temperature that the interlayer reaches in the fenestration product, which is, in turn, dependent on the IGU construction, the weather conditions, and incident solar intensity. The product is available in laminated IGU configurations with different tinted or coated substrates. To provide good U-factor performance and improve the SHGC, a low-emissivity (low-e) coating is also generally added to the inboard lite of the IGU.

The extent to which a dynamic glass tints from its highest transmittance (clear) state is called its dynamic range and is gauged by the visible light transmittance of the clear state compared to that of the fully tinted state. The actual clear state and tinted state visible light transmissions of a thermochromic IGU vary depending on the IGU configuration, but the ratio of the visible light transmission in the highest and lowest transmittance states is generally about 5. For example, depending on the companion

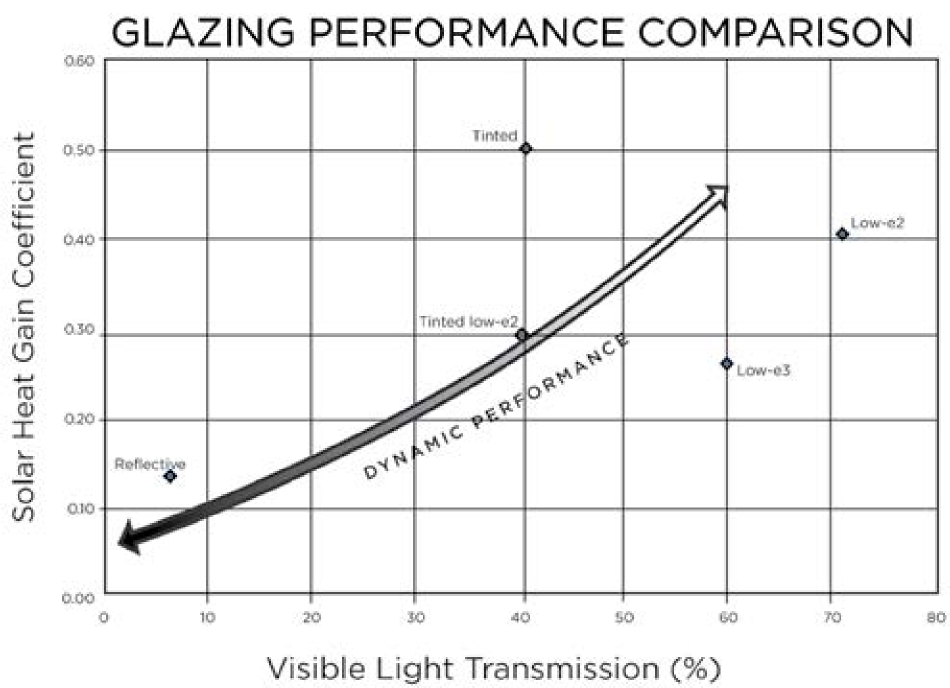

Figure 2 – Graph of visible light transmission (VLT) versus solar heat gain coefficient (SHGC), which demonstrates the heat gain and light transmission range of a high-performance EC product compared with examples of standard static glass.

Figure 3 – A two-story atrium at Chabot College, Hayward, CA, where EC glass was used in order to reduce the solar loads sufficiently to enable the use of a natural cooling and ventilation system.

tinted or coated lites in the IGU, the clear (low temperature) states have visible light transmissions ranging from 27%T on a darkly tinted substrate to 60%T when using clear float glass; and the respective tinted state transmissions range from about 6%T to 13%T at 65°C/150°F.[9] The transmission ratios are therefore 27/6 and 60/13 respectively, which is ~4.5 for both cases.

Electrochromic glazing

Electrochromic (EC) glass is a type of "active" dynamic glazing that has the ability to reversibly change its VLT and SHGC at the touch of a button or in response to sensors (e.g., light, occupancy, temperature) or on the command of a building management system—all without losing the view and connection to the outside. An example of the configuration of an EC dual-pane insulating glass unit is shown in *Figure 1*. Commercially available EC glazings require only low-voltage DC for control. However, depending on the manufacturer, some systems will be a National Electric Code (NEC) class-2, low-voltage, low-current system; and some may be a class-1, low-voltage, high-current system. The former class-2 systems are intrinsically safe, do not require conduit for the wires, and are a contractor-preferred configuration route. Class 1 systems, because of the higher current, require an electrician to install; and the wires must be run in conduit and connections must be made in junction boxes, which add installation costs.

Currently, the widest dynamic range available in EC glazings on clear glass substrates spans from a high of 60% VLT to a low of 1% VLT, with corresponding solar heat gain coefficients of 0.41 and 0.09 respectively and as illustrated in *Figure 2*. Other ranges for EC on clear glass, such as 58% to 3%T and 50% to 10%T, are also commercially available.

EC coatings can also be used in combination with different tinted or coated glass

substrates, which can be used to provide a range of exterior color aesthetics from which the designer may choose.

Heat-gain control: The combination of active control and wide dynamic range performance of EC glass provides a highly flexible heat and light valve for buildings, capturing solar heat to offset heating loads when needed, blocking unwanted heat when in cooling mode, and at all times harvesting daylight to offset electric lighting. Improved thermal comfort for occupants next to the building envelope is a significant benefit, as is the energy efficiency, which can be 20% better than the code base line, with even higher peak-load reductions.

More important, perhaps, is the EC's ability to enable designers to implement more energy-efficient and thermally comfortable heating and cooling systems such as chilled beams and radiant heating by reducing the peak loads from the building envelope. *Figure 3* shows an application in a two-story, south-facing atrium where the use of a natural ventilation system was enabled because of the use of EC in the façade.

Glare control without loss of view: The ability for an EC glazing to achieve 1%T when fully tinted provides sufficient control of glare to eliminate the need for blinds, thus preserving essential views for the occupants. Products with transmissions of 2%T and above have been shown to be insufficient to provide direct sunlight glare control, and additional mechanical shading devices are needed for some portion of the time and/or for some occupants to achieve comfort.[10,11] Applications of dynamic glazing with tinted state transmissions of 2%T and above should be considered where direct glare is not a significant issue. For example, thermochromic glazing where the tinted state reaches a minimum of ~6%T is often used in applications where strict glare control is not needed, or if it is, is used in combination with blinds.

Effective daylighting performance: Electrochromic glazings now come with an

Figure 4 – An example of one of the new advances in electrochromic glazing: in-pane zoning. This feature provides the ability to optimally balance the need for glare control with adequate daylight admission, energy performance, and light color quality. Photo courtesy of SAGE Electrochromics, Inc.

Figure 5 – Image of a large-scale installation of EC glazing at Butler County Health Care Center, David City, Nebraska. The application features a complex curved façade with glazing sloped outwards. The architects chose EC glazing because of the elegant solution to the heat and light control and the ability to maintain the views of nature on the campus for the patients in the rehabilitation center. Photo courtesy of Daubman Photography.

option of independently controlling up to three segments within each pane of glass (see *Figure 4*)—often called "in-pane zoning." This is essential for optimizing the balance between providing glare control and achieving optimum daylight admission, energy performance, and light color quality in applications that involve floor-to-ceiling glass. In this case, only the segment of the pane on which the direct sunlight is incident needs to be tinted to 1%T for glare control. The other segments of the pane can be set to a transmission state that optimizes daylight admission, energy performance, and light color quality. If the whole pane area from floor to ceiling had to be tinted to 1%T, the space would be too dark, too blue (because of the color of the dynamic glass), and have suboptimal energy performance because electric lights would need to be on.

INDUSTRY STANDARDS

The general industry glazing standards—such as those for insulating glass, safety glazing, heat-treated and laminated glass—apply to dynamic glazing (where applicable).

There is also a durability test method, ASTM E2141, and accompanying performance specification, E2953, which apply specifically to EC glazings. The test, developed 20 years ago by the National Renewable Energy Laboratory (NREL), is stringent and involves cycling the EC glazing from clear to dark 50,000 times for at least 5,000 hours at 85°C/185°F under simulated solar irradiation. Currently, a test method and specification for passive dynamic glazings (e.g., thermochromics) is in development and will likely be based on the environmental conditions used in E2141. To ensure a high-performance EC insulating glass product is specified, compliance with E2953 and E2190 (insulating glass performance) is recommended.

SUMMARY

Electrochromic glazing has the longest track record in the dynamic glazing category in the construction industry, with a proven 12-year history and installations dating back to 2003. With the availability

KEY PERFORMANCE FEATURES

When evaluating a dynamic glazing technology's suitability for a particular application, it is important to review the following factors:

- **Is active control needed, or is passive operation sufficient?**
- **Does the application need sunlight glare control? If so, 1%T in the tinted state, or the addition of mechanical shades will be required.**
- **What type of exterior color aesthetics does the project need? This is a key specification, as color and availability of color choices vary from product to product.**
- **The system must have durability performance and the ability to meet industry standards.**
- **Consider ease of integration: retrofit vs. new construction, NEC class 2 vs. class 1 wiring, ease of wire integration in framing systems, wireless vs. wired solutions.**

Figure 6 – Image of a large-scale installation of large, triangular-shaped EC glazing at the Frost School of Music, Miami, FL. Note the architecturally favored blue exterior reflected color. Photo courtesy of Moris Moreno.

of larger sizes (5 x 10 ft.), higher volumes, improved exterior color aesthetics, nonrectangular shapes, wirelessly powered and controlled products for retrofit applications, and enhanced daylight management features, the penetration of electrochromic glazing in the commercial market is growing rapidly. The photographs in *Figures 5* and *6* illustrate the scale of buildings now being glazed with this dynamic glazing technology and the enhanced exterior aesthetics that can now be achieved.

Architects and owners are choosing dynamic glazing because of the design freedom it gives them in applications ranging from schools and colleges, to office space, to healthcare applications, and beyond. They can use more glass without sacrificing either energy performance or occupant thermal and visual comfort, achieving both the desired elegant design aesthetic and a healthy interior environment that enhances the occupant experience and is conducive to high levels of well-being, productivity, and employee retention.

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ROOFING DEMAND TO RISE 3.9% ANNUALLY

U.S. demand for roofing is projected to rise 3.9% annually to 252 million squares in 2019, valued at $21.4 billion, according to a new Freedonia Group study. Asphalt shingles accounted for the largest share of roofing demand in 2014, and demand is forecast to rise at an above-average pace the next four years, following the rebound of the housing market. But roofing tiles are expected to register the most rapid growth of all roofing products through 2019, driven by strong gains in the South and West.

Reroofing accounts for the largest share of U.S. roofing demand, totaling 81% in 2014.

— Freedonia Group