2016 Symposium on Building Science Education in North America

MORNING PANEL

Finding the “Art” in the Science
2016 Symposium on Building Science Education in North America

Building Science Resources in Architectural Education

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I am, on a daily basis, much more interested and concerned with finding (and ensuring the accuracy of) *the science in the art.*
BASIC PROPOSITIONS

A building design proposal is a hypothesis, which must be tested for validity.

If not tested, a fallacy may be constructed and occupied.

Such testing, for many design proposals, will involve building science.
A diagram (graphic or mathematic) is a great preliminary testing tool.
SUPPORTING PROPOSITION

“In a way, science might be described as paranoid thinking applied to Nature ...”

“The creative act has major right-hemisphere components. But arguments on the validity of the result are largely left-hemisphere functions.”

Carl Sagan: *The Dragons of Eden*
COMMON ARCHITECTURAL HYPOTHESES WHICH MIGHT BENEFIT FROM PARANOIA

cross ventilation to provide comfort arrangements to provide daylighting green roofs to ...
double envelope facades that ...
opaque envelope assemblies that ...
ground source heat pumps (whoa; magic)
BRINGING THE SCIENCE TO ART

a recently encountered case study

a graduate teaching assistant was tasked with developing a 3-minute explanation of

low-e glazing

it needed more science: RESOURCES
low-e glazing RESOURCES ➔ AGS

Architectural Graphic Standards, 11th ed
(e) Low-Emittance (low-\(\varepsilon\)) Coatings

These coatings are typically applied to one glass surface facing into the air gap between multiple glazings. A low-\(\varepsilon\) coating blocks a great deal of the radiant transfer between the glazing panes, reducing the overall flow of heat through the window and thus improving the U-factor. Indeed, one such coating is almost as effective as adding another layer of glazing. In Table E.15, compare the U-factor for window 5 with the U-factors for windows 7 and 12. An important added benefit of these films is their reduction of UV transmission, thus reducing fading of objects and surface finishes in rooms.
Solar heat gain coefficient. Solar heat gain coefficient (SHGC) is used to express the ability of a glazing assembly to resist the flow of shortwave solar radiation (see Glossary). In a cooling-dominated climate, glazing with a low SHGC will reduce cooling loads—thus reducing energy consumption.

Visible transmittance. Similar to solar heat gain coefficient, visible transmittance (VT) is used to express the percentage of incident light that will be transmitted through a glazing assembly (see Glossary). VT and SHGC are nearly identical for many glazing products, but glazing can be designed to selectively block IR and UV, but allow the visible wavelengths to pass.

ε (specifically, low ε). ε stands for emissivity, the ability of a building material to emit longwave radiation (see Glossary). A low-ε coating on glazing can reduce longwave radiation losses and improve the ability of the glazing to block heat flow (improving its U-factor).

The Green Studio Handbook, 2nd ed
low-e glazing

RESOURCES ➔ SWL

EARTH CONTACT
The strategy of placing building surfaces in contact with the ground to reduce the temperature difference between inside and outside, reduce infiltration, and/or use the subsurface soil temperatures to cool the building.

EARTH TUBES
See Earth–Air Heat Exchangers.

EMITTANCE/EMISSIVITY
A measure of a material's ability to emit (lose heat by) radiation at a given temperature. Range is 0–1.0. Emissivity is usually proportionally inverse to absorptance.
Glazing and filling  [ edit ]

Low-emissivity coated panes reduce heat transfer by radiation, which, depending on which surface is coated, helps prevent heat loss (in cold climates) or heat gains (in warm climates).

High thermal resistance can be obtained by evacuating or filling the insulated glazing units with gases such as argon or krypton, which reduces conductive heat transfer due to their low thermal conductivity. Performance of such units depends on good window seals and meticulous frame construction to prevent entry of air and loss of efficiency.

Modern double-pane and triple-pane windows often include one or more low-e coatings to reduce the window's U-factor (its insulation value, specifically its rate of heat loss). In general, soft-coat low-e coatings tend to result in a lower solar heat gain coefficient (SHGC) than hard-coat low-e coatings.

Modern windows are usually glazed with one large sheet of glass per sash, while windows in the past were glazed with multiple panes separated by glazing bars, or muntins, due to the unavailability of large sheets of glass. Today, glazing bars tend to be decorative, separating windows into small panes of glass even though larger panes of glass are available, generally in a pattern dictated by the architectural style at use. Glazing bars are typically wooden, but occasionally lead glazing bars soldered in place are used for more intricate glazing patterns.
close together, separated by a barely perceptible array of small-diameter spacers that prevent the sheets from bowing inward due to the difference in air pressure on their two sides. Units as little as ¼ inch (6 mm) in thickness can replace single glass in existing windows, with minimal visual impact but providing thermal performance comparable to conventional double glazing. They can also be used as one lite in an otherwise conventionally constructed double- or triple-glazed insulating unit. Higher-performing units that incorporate low-emissivity coatings (see the next section) are expected to arrive on the construction market soon. These are predicted to achieve U-Factors as low as 0.08 BTU/ft²·hr·°F (0.5 W/m²·K) and in units only roughly ½ inch (12 mm) thick.

Low-Emissivity Coated Glass

The thermal performance of glazing can be improved substantially by the use of glass with a low-emissivity (low-e) coating. Low-e coatings are ultrathin, virtually transparent, and almost colorless metallic coatings that selectively reflect solar radiation at different wavelengths. They have a high visible light transmittance and, depending on the particular coating, a low transmittance for some or all types of infrared radiation (heat).

Low-e coated glass is most commonly used as one of the two lites in double glazing, where it offers several benefits: By reducing the radiant transfer of heat between individual lites, the overall thermal transmittance of the glazing unit is reduced. This allows low-e double glazing to meet or exceed the thermal performance of ordinary triple glazing. By reflecting the majority of the infrared component of solar radiation, low-e double glazing can also simultaneously provide high visible light transmittance with low solar heat gain, allowing such units to achieve the highest LSG ratios of any insulated glass type.

By varying the properties of the low-e coating and by combining it with different types of tinted glass, the performance characteristics of the glazing unit can be tailored to meet different needs. For buildings dominated by wintertime heating loads, low-e units with high U-Factors (to minimize heat loss) and high solar heat gain coefficients (to promote wintertime solar heat gains) may be selected. For buildings dominated by cooling loads, units with low solar heat gain coefficients (to minimize solar heating) and lower visible light transmittance are used (Figures 17.14 and 17.15). Like laminated glass, low-e coated glass can reduce the transmittance of solar wavelengths responsible for fading of materials, thereby reducing damage to interior finishes and furnishings. Low-e coated glass may also be used in single or triple glazing to improve the thermal performance of these glass types.

When specifying glass with any type of low-e glass or reflective coating, it is necessary to specify on which glass surface the coating is to be located. By convention, glass surfaces are numbered starting from the exterior side of a glazing unit and working inward. In single glazing, the outward face is surface number 1 and the inward face is surface number 2. In double glazing, the outward face of the outer glass lite is surface number 1 and the inward face of this lite is surface number 2; the outward face of the inner glass lite is surface number 3, and its inward face is surface number 4. In low-e double glazing, the low-e coating is most commonly located on the
some background science; but … emissivity reflects?

Heating, Cooling, Lighting, 3rd ed
Coated glass is covered with reflective or low-emissivity (low-E) coatings. In addition to providing aesthetic appeal, the coatings improve the thermal performance of the glass by reflecting visible light and infrared radiation.

Tinted glass contains minerals that color the glass uniformly through its thickness and promote absorption of visible light and infrared radiation.

Insulating glass units (ig units) consists of two or more lites of glass with a continuous spacer that encloses a sealed air space. The spacer typically contains a desiccant that dehydrates the sealed air space. The air space reduces heat gain and loss, as well as sound transmission, which gives the ig unit superior thermal performance and acoustical characteristics compared to single glazing. Most commercial windows, curtain walls, and skylights contain ig units. Most perimeter seals consist of a combination of non-curing (typically butyl) primary seal and cured (frequently silicone) secondary seal. The service life of an ig unit is typically determined by the quality of the hermetic sealants installed between the glass and the spacers, and the quality of the desiccant.

FUNDAMENTALS

Thermal Performance (Conduction, Solar Radiation, Thermal Break, Comfort)

Glass and glazing selection play a key role in determining the overall building’s thermal performance. Fenestration thermal performance requirements must be integrated with the design of the building’s heating and cooling systems. Single glazing has poor thermal performance and is suitable only for applications where thermal performance is irrelevant, such as interior applications or installations where interior and exterior temperatures do not vary substantially. The vast majority of architectural glazing consists of ig units. The thermal performance of insulating glazing depends mainly on the solar energy transmittance through the glazing, the reflectance of the glazing (measured by the shading coefficient—the ratio of the solar heat gain through the glazing to the solar heat gain or loss through a lite of 1/8 in. thick clear glass), the width of the air space, and the material and configuration of the spacer around the perimeter of the unit. Low-emissivity (low-E coatings) limit heat gain through the glazing by reflecting heat energy. Reflective coatings reduce interior solar heat gain by reflecting solar energy.

Thermal performance of glazing is expressed by its thermal conductance, which a measure of air-to-air heat transmission due to thermal conductance and the difference between indoor and outdoor temperature. Conductance is expressed in terms of U-value. A lower U-value indicates reduced heat transfer through the glass. Thermal modeling of specific fenestration assemblies using computer programs such as THERM allow estimation of total U-values for fenestration assemblies and help predict thermal performance.
low-e glazing

INSULATED GLASS COATING

Extremely thin coatings of special metallic material applied to glass panes used in windows and doors to boost their energy efficiency. The industry standard for energy-efficient glass coatings has become Low-Emissivity (Low E) glazing. Coating a glass surface between each pane with Low E material can block a significant amount of heat transfer, reducing your home's need for energy-consuming climate control systems.

Low E coatings are transparent to visible light, and different types of coatings have been designed to allow for high solar gain, moderate solar gain or low solar gain.

Climate Options

Single Layer Metallic Low E Coatings, such as Low E1, allow the sun's warming rays to pass through, and are ideal in applications where solar heat gain is desired, such as northern climates. Low E1 features a single metallic coating and an insulator that blocks heat loss to the outside while reflecting heat back into a room. Provides a low U-factor and a high solar heat gain.

A Double Layer Metallic Coating, such as Low E2, is suitable for all climates, except the southern ENERGY STAR zone. It features a double metallic coating on the inside glass surface to reflect heat into the room in winter and reject the sun's warmth in summer, reducing damaging UV rays. This coating option provides better protection against radiant heat transfer than single layer metallic Low E coatings.

Triple Layer Metallic Coatings such as Low E3 are often specified in the southern ENERGY STAR zone where cooling costs are high and intense exposure to the sun is an issue. It features three metallic layers of silver. This coating offers the lowest U-factor and lowest solar heat gain.

MUL TIPLE PANES OF GLASS

Two or three panes of glass means more layers of protection between the weather and your home.

ARGON

- Colorless nontoxic gas that's denser than air
- Inserted between the panes of glass to provide extra insulation from the heat and cold

LOW-EMISSIVITY (LOW-E) GLASS COATINGS

- In the winter, low-emissivity (Low-E) glass reflects heat back into the room, keeping it warmer
- In the summer, it reflects heat away from your home, keeping it cooler
- Block most of the sun's harmful UV rays, helping to prevent fade damage to your carpet, furniture and window treatments

Window Technologies: Low-E Coatings

When heat or light energy is absorbed by glass, it is either conveected away by moving air or re-radiated by the glass surface. The ability of a material to radiate energy is called its emissivity. All materials, including windows, emit (or radiate) heat in the form of long-wave, far-infrared energy depending on their temperature. This emission of radiant heat is one of the important components of heat transfer for a window. Thus reducing the window’s emissivity can greatly improve its insulating properties.

Standard clear glass has an emissivity of 0.94 over the long-wave portion of the spectrum, meaning that it emits 94% of the energy possible for an object at its temperature. It also means that 6% of the long-wave radiation striking the surface of the glass is absorbed and only 16% is reflected. By comparison, low-E glass coatings can have an emissivity as low as 0.04. Such glazing would emit only 4% of the energy possible at its temperature, and thus reflect 96% of the incident long-wave, infrared radiation. Window manufacturers’ product information may not list emissivity ratings. Rather, the effect of the low-E coating is incorporated into the U-factor for the unit or glazing assembly.

The solar reflectance of low-E coatings can be manipulated to include specific parts of the visible and infrared spectrum. This is the origin of the term spectrally selective coatings, which selects specific portions of the energy spectrum, so that desirable wavelengths of energy are transmitted and others specifically reflected. A glazing material can then be designed to optimize energy flows for solar heating, daylighting, and cooling.

www.efficientwindows.org/lowe.php

The most common glazing material is glass, although plastic is sometimes used, particularly in the form of intermediate films. Both may be clear, tinted, coated, laminated, patterned, or obscured. Clear glass transmits more than 75% of the incident solar radiation and more than 85% of the visible light. Tinted glass is available in many colors, all of which differ in the amount of solar radiation and visible light they transmit and absorb. Some coated glazings are highly reflective (e.g., mirrors), whereas others have very low reflectance. Some coatings result in visible light transmittance of more than twice the solar transmittance (desirable for gradual daylighting, while minimizing cooling loads). Coatings that reduce radiant heat exchange are called low-emissivity (low-e) coatings. Laminated glass is made of two panes of glass adhered together. The interlayer between the two panes of glass is typically plastic and may be clear, tinted, or coated. Patterned glass is a durable ceramic frit applied to a glass surface in a decorative pattern. Obscured glass is translucent and is typically used in privacy applications.

Low-e coated glass is now used in the vast majority of fenestration products installed in the United States, because of its energy efficiency, daylighting, and comfort benefits. Low-e coatings are typically applied to one of the protected internal surfaces of the glazing unit (surface #2 or #3 in Figure 1), but some manufacturers now offer double-glazed products with an additional low-e coating on the exposed room-side surface (surface #4 in Figure 1). Low-e coatings can also be applied to thin plastic films for use as one of the middle layers in glazing units with three or more layers. There are two types of low-e coating: high-solar-gain coatings primarily reduce heat conduction through the glazing system, and are intended for cold climates. Low-solar-gain coatings, for hot climates, reduce solar heat gain by blocking admission of the infrared portion of the solar spectrum. There are two ways of achieving low-solar-gain low-e performance: (1) with a special, multilayer solar-infrared-reflecting coating, and (2) with a solar-infrared-absorbing outer glazing. To protect the inner glazing and building interior from heat absorbed by this outer glazing, a cold-climate-type low-e coating is also used to reduce conduction of heat from the outer pane to the inner one.

ASHRAE Handbook 2013 Fundamentals,
We can use more initial paranoia; which may be mitigated by bringing more science to the art of architecture.

On the specific issue of *low-e glazing*, that science seems hard to find.

This “hard to find” conclusion most likely applies (more or less) to other architectural design hypotheses.