Glazing Selection

OBJECTIVE

Make an informed glazing selection from all design perspectives.

- Choose glazing to maximize daylight effectiveness and occupant comfort, and minimize energy use, while still meeting architectural objectives.

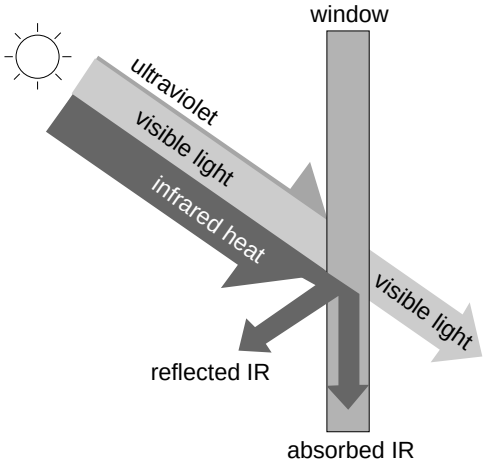
KEY IDEAS

Glazing Technology

Examine ALL glazing properties when choosing a product. Glazing selection should be a careful process of evaluating and weighing tradeoffs. Review all of the critical characteristics of glazing, listed in product brochures, for a good all-around selection. See a brief explanation of these properties below:

- **Visible Transmittance**, or daylight transmittance, is the percentage of visible light striking the glazing that will pass through. Visible transmittance values account for the eyes' relative sensitivity to different wavelengths of light. Glazings with a high visible transmittance appear relatively clear and provide sufficient daylight and unaltered views; however, they can create glare problems. Glazings with low visible transmittance are best used in highly glare-sensitive conditions, but can create "gloomy" interiors under some weather conditions and diminished views. They are unsuitable for many daylighting applications since they do not provide enough light for typical visual tasks. Note that some glazings can have a high visible transmittance but obscure views, e.g. frosted or patterned glass.
- **Visible reflectance**, or daylight reflectance, indicates to what degree the glazing appears like a mirror, from both inside and out. It is the percentage of light striking the glazing that is reflected back. Most manufacturers provide both outside reflectance (exterior daytime view) and inside reflectance (interior mirror effect at night). All smooth glass is somewhat reflective; various treatments such as metallic coatings increase the reflectance. High reflectance brings with it low visible transmittance and all the interior disadvantages that may be associated with that characteristic.
- **Solar Heat Gain Coefficient (SHGC) or Shading Coefficient (SC)** are indicators of total solar heat gain. SHGC, which is replacing SC, is the ratio of total transmitted solar heat to incident solar energy, typically ranging from 0.9 to 0.1, where lower values indicate lower solar gain. These indices are dimensionless numbers between 0 and 1 that indicate the total heat transfer of the sun's radiation. SC is the ratio of solar gain of a particular glazing as compared to a benchmark glazing (1/8" or 3 mm clear glass) under identical conditions. These properties are widely used in cooling load calculations. To convert between these properties, SC ≈ 1.15 x SHGC.
- **U-Value** ($W/m^2 \cdot K$, $Btu/h \cdot ft^2 \cdot °F$) is a measure of heat transfer through the glazing due to a temperature difference between the indoors and outdoors. U-Value is the *rate* of the heat flow, therefore *lower* numbers are better. **R-Value** is the *resistance* to heat flow (R = 1/U), with *higher* numbers indicating better insulation. Glazing products usually list U-Value. Center-of-glass U-values are generally lower than whole-window U-values, which account for the effect of the frame and mullions. This property is important for reducing heating load in cold climates, for reducing cooling load in extremely hot climates, in any application where comfort near the windows is desired, and where condensation on glass must be avoided.

- **Ultraviolet Transmittance** indicates the percentage of ultraviolet radiation (a small portion of the sun's energy) striking the glazing that passes through. Ultraviolet radiation (UV) is responsible for sunburn of people and plants, and contributes to fabric fading and damage to artwork. Many energy-efficient glazings also help reduce UV transmission.
- **Spectral Selectivity** refers to the ability of a glazing material to respond differently to different wavelengths of solar energy – in other words, to admit visible light while rejecting unwanted invisible infrared heat. Newer products on the market have achieved this characteristic, permitting much clearer glass than previously available for solar control glazings. A glazing with a relatively high visible transmittance and a low solar heat gain coefficient indicates that a glazing is selective. Spectrally selective glazings use special absorbing tints or coatings, and are typically either neutral in color or have a blue or blue/green appearance.
- **Glazing Color** affects the appearance of view (bronze will dull a blue sky, for example) and the appearance of interior finishes. Examine carpet, fabric and paint samples in daylight that comes through the intended glazing to be sure colors are not changed undesirably. Glazing color is also a dominant determinant of the exterior appearance of the building facade. Color is the property that often dominates glazing selection and can thus unnecessarily constrain or complicate daylighting design. For example, a strong color preference for gray or bronze may make a good glazing selection more difficult. Staying more flexible with respect to color will keep more opportunities open.
- **Sound Transmission** is an important glazing system property in some projects, and many energy-efficient glazings deliver improved acoustic performance as a side benefit. Outdoor-to-indoor transmission class (OITC) is the property used to express sound attenuation characteristics. The higher the OITC rating, the better the unit will insulate against sound. Multilayer assemblies, especially those with a laminated layer, generally have high OITC ratings.



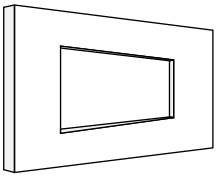
An ideal spectrally selective glazing admits only the part of the sun's energy that is useful for daylighting.

Selection Process

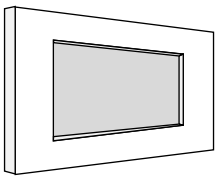
- **Choose between dual-pane and single-pane glazing**. This is the critical first decision in glazing selection. Although higher in first cost, dual-pane insulating glazing typically improves comfort in perimeter zones, offers greater flex-

ibility in product selection, improves acoustic performance, and reduces mechanical loads. Most new energy-efficient buildings should use insulating glazing. Single-pane glazing with exterior shading can be effective in mild climates if there is significant solar radiation.

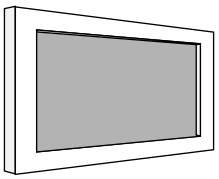
- **Choose a spectrally selective glazing**. Select a moderate visible transmittance for glare control (50-70% is a good starting point, depending on visual tasks, window size and glare sensitivity; the larger the windows or the more critical the glare control, the lower the desirable visible transmittance). Examine manufacturer literature for good glazing candidates. Find the product tables for insulating or single pane units, depending on your initial selection, and look for products with your desired visible transmittance and the lowest possible solar heat gain coefficient.
- **Balance the conflict between glare and useful light**. A physical model studied outdoors is a good tool to qualitatively assess glare. If glare is an anticipated problem, and if an architectural solution to glare is not possible (moving windows out of the field of view, using deep reveals, shading systems, and other physical modifiers), then select a glazing visible transmittance that is a compromise between glare and light. A visible transmittance as low as 25% may still provide adequate daylight.
- **Window size and glazing selection can trade off with each other**. Use the **effective aperture** approach when making these decisions: Larger window area requires lower visible transmittance; smaller windows requires high visible transmittance. See the illustration. A good target value for effective aperture is between 0.20 and 0.30.
- **Big windows require better glazing**. The bigger the window, the lower the required solar heat gain coefficient and visible transmittance. The bigger the window, the greater the need for insulating glazing. Large areas of inefficient glazing bring major comfort and energy cost penalties, cooling system penalties, and may not be permitted by building codes.
- **Don't assume that dark glass provides good solar control**. Many dark glazings block more light than heat, and therefore only minimally reduce cooling load. Dark glass can produce a gloomy interior atmosphere and may affect productivity and absenteeism. Consult product brochures or manufacturer representatives to be sure you are aware of the range of product choices today. Dark glass not only reduces daylight, it also increases occupant discomfort on



Clear Glass
WWR = 0.30
high VT = 0.88



Tinted Glass
WWR = 0.50
medium VT = 0.53



Heavily Tinted
or Reflective
WWR = 0.70
low VT = 0.38

Effective Aperture (EA) is visible transmittance (VT) x window-to-wall ratio (WWR). These three windows all have the same EA of 0.26.

a sunny day, particularly in single glazed form. The glass absorbs solar energy and heats up, turning it into a virtual furnace for anyone sitting near it. Today, solar control is available in much clearer glazings.

- **Don't count on glazing alone to reduce heat gain and discomfort**. If direct solar beams come into the building, they still create a mechanical cooling load and discomfort for occupants in their path. Exterior shading combined with a good glazing selection is the best window strategy. Interior shading options can also help control solar heat gain.
- **Vary glazing selection by facade, if possible**. A lower solar heat gain coefficient on the south, east and especially west windows will reduce the cooling load.
- **Check Building Codes**. Some codes restrict the allowable area of glazing or thermal properties or both. Often tradeoffs are possible: more area is permitted if better glazing is specified.

INTEGRATION ISSUES

ARCHITECTURE

A good glazing for daylighting, with a relatively high visible transmittance, will appear fairly transparent from the outside. A desire for an opaque or mirrored facade is often not compatible with daylighting.

INTERIOR

Glazing color strongly affects color rendering of interior finishes in daylighted areas.

Color and visible transmittance affect the view and the occupants' sense of connection with the outdoors. High transmittance glass in a neutral or soft color helps make windows effective links to the world outside.

Low transmittance glazing makes interiors feel gloomy when overcast or sunlight levels are low. However, it may be useful to control glare in some circumstances.

HVAC

Glazing characteristics are a large factor in heating and cooling loads. A mechanical engineer should help determine optimal glazing properties for an efficient mechanical system. High performance glazing generally reduces annual energy use, peak loads, individual zone fluctuations, wide differences in coincident zone loads, and occupant complaints.

Examine equipment downsizing opportunities with glazing improvements. Model the entire fenestration system correctly when calculating cooling load and optimum glazing properties. In particular, include any exterior shading in the model as this reduces the importance of a low glazing solar heat gain coefficient.

Insulating glass may eliminate the need for a perimeter heating system.

LIGHTING

Visible transmittance determines how much daylight will be admitted, once the window size is set. The lighting designer must assess expected daylight levels before final glazing selection. If daylighting levels are not satisfactory, choose an alternate glazing with a different visible transmittance or increase glazing area.

Glazing color affects color temperature of the daylight and should be considered when matching electric sources in daylighted zones.

COST-EFFECTIVENESS

High performance glazings cost more than their standard alternatives but may pay for themselves in four ways: reduced energy bills, reduced first costs in mechanical equipment, increased occupant productivity, and avoided future retrofit costs (in added mechanical equipment or window fixes, due to commonly unanticipated occupant discomfort). Mechanical load calculations can provide an estimate of the first two savings opportunities. Case study and anecdotal evidence supports the second two benefits.

OCCUPANT COMFORT

Single pane glass near an occupant can create a hot or cold sensation regardless of interior air temperature. When it is cold outdoors, the body radiates heat to the cold glass surface and is chilled. Sun striking glass, especially a tinted unit, heats the unit up well above skin temperature, which then radiates heat to the body and induces a sense of overheating. The mechanical system cannot easily overcome these situations, since it typically adjusts air temperature only and not the temperature of the glass.

Cold glass will also induce a chilly downdraft.

When windows will be near occupants, insulating glazing is the best choice for comfort. Tinted glass in an insulating unit does not cause the radiation problem described above since the tinted piece is typically in the outboard pane.

Glazing with a high visible transmittance can cause glare if preventive measures are not taken. Some examples of glare avoidance discussed elsewhere in these guidelines include user-operated shading devices, architectural modifiers, and balancing window brightness with other light sources.

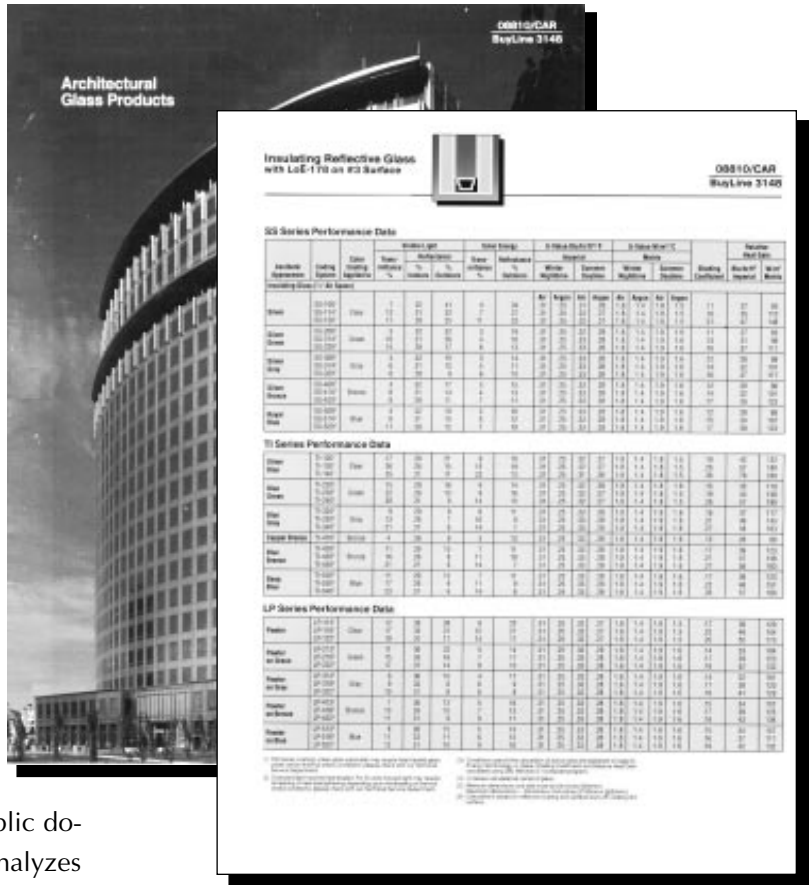
! PROVISOS

- Renovations in historic buildings typically need extra care in glazing selection, as historic preservation rules usually require the look of the facade to remain the same. This means any new glazing must appear the same as the original, in most cases, clear. Select an advanced, insulating, spectrally selective glazing for an efficient, comfortable and daylighted renovation.
- Some tinted glazings cannot tolerate partial shading due to the thermal stresses caused by a large temperature range across a single piece of glass. Consult the glazing manufacturer regarding the building's shading scheme.
- A strong desire for extremely dark or mirrored glazing is not normally compatible with daylighting design.
- Consult glazing suppliers for information on structural aspects of glazing. Specific applications may require tempered, laminated, or other glazings to meet performance requirements.
- Simplified mechanical load calculations do not accurately model the energy behavior of windows, due to the complexity of that behavior and the oversimplification inherent in commonly used glazing properties.

  For example, rough approximate mechanical calculations frequently indicate that single pane glazing is more desirable than insulating glazing for California commercial buildings; while more sophisticated modeling software reveals the opposite conclusion with respect to peak cooling load, annual energy use, and comfort. Do not rely on these simplified calculations in making a decision; use them as guidelines only.

TOOLS & RESOURCES

- **Manufacturer Technical Literature and Product Representatives** are free sources of information and assistance. Begin with section 08810 in Sweets Catalog to identify product choices and suppliers. Many of the brochures in this section contain useful general information on glazing in addition to product-specific data. Most manufacturers will readily supply samples (typically 12" by 12" or smaller) and copies of their Sweets brochures. Some manufacturers will also perform energy calculations for you.
- **National Fenestration Rating Council** compiles a directory of window products with associated thermal, solar, and optical properties. While the emphasis is on residential applications, much of the information is useful for commercial buildings. NFRC data and window labels provide a consistent and accurate way to compare product properties (similar to refrigerator labels). See *www.nfrc.org*.
- **Scale Model.** A model studied outdoors can be an accurate and easy way to anticipate glare potential and evaluate daylight levels and direct sun control. See Section 3, ENVELOPE AND ROOM DECISIONS, for information on measuring daylight in a model, which requires that you have access to photometric equipment (light meters). If light levels are not satisfactory, make an alternate glazing selection for a different visible transmittance or adjust window size. A glare study is easier to conduct. Follow the model-building instructions given in ENVELOPE AND ROOM DECISIONS. If possible, include the actual glazing material (get a sample from the manufacturer) or a material to closely approximate the color and transmittance of the glazing. Take the model to an outdoor site with similar sky view as the actual site, get in a comfortable seated position, and look through the eye hole. Cup hands around eyes or wear an opaque drape over head so that no outside light enters the peephole or interferes with your focus. Observe the space for at least five minutes and assess the visual comfort. If windows appear uncomfortably bright, or if the contrast gradient is too harsh through the room, take a corrective measure such as an adjustment to the visible transmittance or an architectural solution as discussed elsewhere. Daylighted spaces are dynamic: Use the model under a range of sun positions and weather conditions to get a better feel for the range of expected conditions.



- **Software.** Mechanical engineer's standard calculations are useful for comparing peak loads and annual energy use with different glazing options. Remember that this software can only approximate the behavior of glazings and buildings.

  The *Window 4.1* program is public domain software that accurately analyzes

the thermal properties of fenestration products. It is widely used in the glazing industry, but is intended to serve designers as well when choosing between different product options. Available through the National Fenestration Rating Council (301-589-NFRC) or Bostik Construction Products (800-523-6530). Information can also be obtained from websites: see *www.nfrc.org* and *eande.lbl.gov/BTP/WDG/THERM*.

The *DOE2.1E* program is an advanced building simulation package. Because it has a variety of features to accurately model glazing and shading properties, dynamic window management and daylighting effects, it is one of the best software tools available to assist in energy-efficient design, although it requires time and expertise (or hiring a consultant). Use this program to make an optimal glazing selection. Versions of DOE-2 are available from a variety of software vendors. Contact the Lawrence Berkeley National Laboratory at (510) 486-5605 for a list.

- **Books.** There are only a few up-to-date materials available to designers on glazing. The best source for timely information may be the architectural journals, which occasionally run glazing articles in their technical sections.

  ASHRAE Handbook of Fundamentals (American Society of Heating, Refrigerating and Air Conditioning Engineers 1993) is a source for technical information and generic glazing properties.

  Low-E Glazing Design Guide by Timothy Johnson (Butterworth-Heinemann 1991) addresses technical issues and offers some application information as well.

  Residential Windows by John Carmody, Stephen Selkowitz, and Lisa Heschong (Norton 1996) is a guide to new technologies and energy performance.

- **Utility Company.** Inquire at local utility about possible design assistance or financial incentives.

☑ CHECKLIST

1. Review your fenestration decisions to date, as these will guide the glazing selection.
2. Use the effective aperture target as discussed to determine the range of desirable visible transmittances, based on your window-to-wall ratio.
3. Decide between insulating glazing options (or in some circumstances, single glazing). Mechanical engineer's calculations, comfort concerns, and construction budget data will help in this decision.
4. Identify to what extent color, reflectance, UV transmittance, and sound will influence glazing selection.
5. Determine, via mechanical engineer or building code requirements, the desirable range of values for U-Value and solar heat gain coefficient. If the building has good exterior shading, glazing solar control becomes less critical.
6. Review product literature and select candidate glazings that meet the above criteria.
7. Evaluate glare potential, ideally with a physical model, and take preventive measures if necessary.
8. Contact product representatives for samples, further information, assistance and pricing.

If you have...

no time

1. Size windows for a 30% window-to-wall ratio.
2. Specify glazing with visible transmittance 50-70%, solar heat gain coefficient 0.50 or lower (or to code maximum, whichever is lowest), and U-Value to meet code. Choice of color may be limited.
3. Present above criteria to glazing representatives from two or more manufacturers for further assistance in finding products that match. Request representatives to perform energy calculations for you (free) if undecided between products. Consult project engineer on heating/ cooling system sizing issues.

a little time

1. See glazing brochures in Sweets Section 08810 and select some options yourself for the above criteria (glazing products and their energy properties are listed in tables), then call specific glazing representatives for more information, pricing, and free performance calculations for your project.
2. For a broader range of options, determine a set of alternative scenarios (different size windows, different potential glazings), perhaps with mechanical engineer's assistance. Engineer evaluates these alternative designs, using standard load software and derives optimum values for U-value, solar heat gain coefficient, and visible transmittance. Present these values to glazing representatives for a product match.

more time

1. Determine an optimum set of values for U-value, solar heat gain coefficient, and visible transmittance through more rigorous computer modeling with software such as DOE-2 that can compute energy savings from daylighting in addition to standard building performance energy calculations. This usually requires hiring an energy consultant with DOE-2 experience.
2. This consultant should also assist in predicting occupant satisfaction (comfort) and in fine-tuning the proposed window area and type with respect to other criteria such as acoustics, glare, view, color, etc. Consultant could also prepare building code compliance documentation. Present results of this optimization study to glazing representatives for a product match, or select glazing yourself from Sweets brochures.