Selecting the Right Glass for Solar Shading

Keeping cool in summer, warm in winter, comfortable all the time, ... and saving energy too

Back to Basics: Specifying the Right Windows for Your Job
ASHRAE Seminar
Sunday, June 27 10:15 a.m. to 12:15 p.m.

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Background

- I teach a half-day short course on Energy Smart Windows for residences
- Short Course Outline:
  - Fundamentals of heat transfer
  - Dealing with the sun – orientation and shading
  - Solar spectrum fundamentals –
  - Spectral selectivity for hot and cold climates
  - Intro to daylighting & glare
  - Interior, exterior, and glazing shading options
  - Hourly energy performance
  - Web sites for energy ratings and hourly performance estimation
  - Advice on selecting the right windows for your residence
- This presentation:
  - Material I present dealing with glazing systems
  - Emphasis is on reducing solar heat gain
  - while admitting adequate daylight illumination
**Solar Spectrum Fundamentals**

- Solar radiation covers a range of colors and wavelengths
- Important for the design and performance of windows in different climates.
- Solar radiation physics
- Needed to fully understand the variety of window products now on the market.
- We begin with the electromagnetic spectrum.

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**Breaking sunlight into its various colors**

Sir Isaac Newton 1723

- Glass prism
- Invisible infrared
- Invisible ultraviolet
- Red 700 nm
- Orange
- Yellow
- Green
- Blue 400 nm
Electromagnetic Spectrum

- Wave length
- Cosmic rays
- Gamma rays
- X rays
- UV
- Visible spectrum
- Sound frequencies
- IR
- Solar spectrum
- Microwaves
- Radio

Parts of the solar spectrum

- Human eye sensitivity (Visible portion of the spectrum)
- Ultraviolet (UV)
- Near Infrared (NIR)
- Far Infrared (FIR)
Emission of Heat Radiation

- Warm objects emit radiation
- The hotter they are, the more they emit
- As their temperature increases, the spectral distribution shifts as well, as shown on the next slide

Warm Objects Emit Radiation

Blackbody radiation spectra from 80 to 35,000 deg Fahrenheit

- Room temperature
- Solar Spectral range
- VIS
- NIR
- FIR
Blackbody Radiation

Previous slide was on a log scale. This is on a linear one.

Why black body radiation is important

Warm panes radiate toward cold ones

The wavelengths are in the far IR spectral range

We can take advantage of this in designing the glass panes
Spectral Selectivity for Cold Climates

Cold climate glass transmittance

Room temperature surface emission spectrum

Solar spectrum

Human eye response

Spectral irradiance

Transmittance

Wavelength

Cold climate transmittance

Room temperature surface emission spectrum

Solar spectrum

Human eye response

Spectral irradiance

Transmittance

Wavelength

Spectral Selectivity for Hot Climates

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Wavelength
Quantifying Heat Flows

Heat flux, \( Q \) in W/m\(^2\)

- Incident solar irradiance \( E_0 \)
- Reflected solar radiation \( R_s E_0 \)
- Glazing-absorbed solar radiant heat \( A_s E_0 = Q_{\text{absorbed}} \)
- Transmitted solar radiation \( T_s E_0 = Q_{\text{direct}} \)
- Inward fraction \( N_i A_s E_0 = Q_{\text{inward}} \)
- Total glazing solar heat gain

Visible Transmittance \( VT \) (%)

\[ Q_g = U_g \times \text{Area} \times \Delta t \]

Glazing Performance Indices

Primary Indices

- Solar Heat Gain Coefficient \( T_s + N_i A_s = \text{SHGC} \)
- Visible Transmittance \( VT \)
- U-factor \( U \)

(R-value = 1/U)
Quantifying Spectral Selectivity

- Spectral selectivity: Optical properties vary with wavelength
- Not needed in northern Alaska
- Can be very helpful in hot and warm climates
- Useful in cold climates when buildings are internal load dominated and have trouble losing heat
- In these cases we need low solar heat gain
  - So just lower the solar transmittance
  - But this also lowers visible transmittance
- Spectral selectivity allows dropping solar gain without dropping visible transmittance as much

Spectral Selectivity of Real Glazings

[Diagram showing spectral transmittances of various window glazings]
Light to Solar Gain ratio
- A measure of spectral selectivity

VT Visible transmittance:
Fraction of incident light transmitted

SHGC Solar heat gain coefficient:
Fraction of incident solar radiation admitted as heat gain

LSG Light-to-Solar Gain ratio:
Ratio of visible transmittance to solar heat gain coefficient

\[ \text{LSG} = \frac{\text{VT}}{\text{SHGC}} \]
Coatings and Tints

One can use

- High solar gain low-e coatings for cold climates
- Low solar gain low-e coatings for hot climates
- IR-absorbing glass for hot climates
- A variety of ways to coat and tint glass
- Here’s a detailed rundown on the options
Cold climate glazings
Admit and trap solar heat

Low-emissive configuration

Cold-climate low-e coated windows

FIR

One way to do the job

Total solar spectrum

Insulated gas space (air, argon, krypton)

High solar gain low-e coating. Transmits solar, doesn’t emit FIR, so it keeps the heat inside, where it is needed.

Cold Warm

Two ways to do the job

1

2

FIR not emitted

Cold climate low-e coating.

FIR reflected
**Hot Climate Glazings**
**Admit visible, reject invisible solar**

**One way to do it**

By rejecting nearly half the incident solar radiation with reflection, the SHGC is nearly half as large.

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**Hot Climate Glazings**
**Admit visible, reject invisible solar**

**Two ways to do it**

1. **Hot-climate near-IR reflective coating** (Also called “hot-climate low-e coating”)
   (or a low-solar-gain low-e coating)

2. **Hot-climate near-IR absorber**

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**Exterior Shading**

Though we’re talking about glazing systems, I can’t fail to mention the value of exterior shading. It is generally better to block the sun before it strikes the glass.

- But we cannot always do this, due to:
  - Subdivision restrictions
  - Aesthetic considerations
  - Multi-story building
  - Desire not to block an important scene
When exterior shading is neither permitted, nor desired, nor possible

Use High-Performance Glazing Systems

- To minimize solar heat gain, use **low solar gain low-e coated** glazings with **high LSG ratio**

- Choose VT to fit the situation
  - **VT high** for north-facing, and exposures already shaded fairly well
  - **VT low** for east- and west-facing exposures inadequately shaded

- To reduce peak load, enhance comfort and allow smaller air conditioners, use **double pane** windows
  - **Impact resistant** for coastal zone
  - **Insulated frames** to reduce condensation and improve comfort further

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Glass Spectral Choices

| Spectral Transmittances of Various Window Glazings |
|---------------------------------|---------------------------------|---------------------------------|
| Clearplate | Bluegreen#1 | Bluegreen#2 |
| Bronze coated | Spectrally | Spectrally |

- **High VT, low SHGC**
- **Medium VT, lower SHGC**
- **Low VT, lowest SHGC**
Window Recommendations in Summary

- **All windows:** Insist on high-LSG glazings and double-pane, insulated windows throughout the building—for energy savings, comfort, reduced peak load, and smaller A/C capacity (and cost).
- **North-facing:** Use a side-wall, or a deep window reveal to block low rising and setting sun on hot summer days.
- **South-facing:**
  - Use a modest overhang if you like winter sun
  - Use a wide overhang to avoid sun year round
  - High-LSG glazings are especially important if shading’s inadequate
- **East- and West-facing,** a menu of choices:
  - For hot climates:
    - Dense tree shading where possible
    - Awning shade
    - Exterior shade screen
    - Exterior roller shutters
    - **Highest-LSG glazing system, VT between 0.2 and 0.4**
    - Interior reflective operable shade
  - For cold climates:
    - Well-insulated multiple pane windows with insulated frames
- **Laminated glass for impact resistance if exterior shade is not enough for this**

Proper Glazing Choices Promote

- Good energy efficiency
- Protection against future energy price shocks
- Protection against peak demand charges from utilities
- Reduced global warming
- Lower energy costs
- Visual and acoustic comfort
- Thermal comfort
- Higher building values
- More productive employees