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U-factor, SHGC, CR, VT, Air Infiltration – **What does this stuff mean?**

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U-Factor

What is the U-factor?

U-factor gives the rate of heat transfer through the window (from inside to outside when it is cold, and from outside to inside when it is hot) per unit area and per unit temperature difference. In the U.S., the typical units are $BTU/hr \cdot ft^2 \cdot °F$. The lower the U-factor, the less heat energy escapes your home in the winter, and the more heat enters your home in the summer. As an example, if you had a 2 x 4 foot window with a U-factor of 0.3 in your house when the outside air temperature was 0°F and the inside air temperature 70°F, the heat loss could be found:

$$0.3\frac{BTU}{hr\cdot ft^2\cdot °F}\cdot 2\,ft\cdot 4\,ft\cdot\left(70°-0°F\right)=168\frac{BTU}{hr}$$

How is the heat transferred?

There are considered to be three means of heat transfer. Conduction is heat transfer through a material. Convection is heat transfer between a fluid (like air) and a solid surface (like a piece of glass). Radiation is perhaps the hardest concept to grasp. All things continually release radiation (proportionately to the fourth power of their temperature). The warmer the object, the more radiation released. Therefore, a warm object exchanging radiation with a cold object will give off more heat than the cold object gives back, suffering a net heat loss.

How do these apply to U-factor?

All three types of heat transfer occur in and around a window. Convection is occurring on the inside and outside surfaces, as well as inside frame members and between panes of glass. Conduction carries heat through frame walls and glass panes. Assuming it is heating season, the room is radiating energy to and through the glass to the outside. So, all these modes of heat transfer need to be considered to accurately estimate heat loss (or gain, in the summer) through the window[1].

How is the U-factor calculated?

Independent laboratories use computer programs (such as those available from Lawrence Berkeley National Laboratory) to build mathematical models of the various window components and then

1 The technically astute reader might now be asking, how can we have a U-factor that is per °F when radiation occurs proportionately to the fourth power of the temperature? The answer that is over the small temperature ranges a window operates (small in the realm of physics, not in the realm of weather!) this heat transfer can be linearized. However, heat transfer with the sun is another thing altogether, and this is calculated separately through the use of the SHGC.

calculate the window's U-factor. Then, a physical test in a device called a "hotbox" is carried out to confirm the model.

The most common rating system used in the United States is that of the National Fenestration Rating Council (NFRC). NFRC ratings are for a standard sized window. Separate U-Factors for the edge of glass and the frame using a two-dimensional, finite element heat transfer program. A separate heat transfer programs calculates the center of glass U-Factor and combines these three numbers to get a whole-window U-Factor. This is calculated at 0°F (-17.8°C).

The NFRC values are typically for a larger window. Usually, the center glass U-Factor is lower than that of even a good window frame. When this is the case, a window smaller than the NFRC standard size will have a real U-Factor higher than its NFRC rating.

Are there other ways of rating a U-factor?
In Europe, there is a different standard. U-Factors are calculated at 32°F (0°C) with a different model for the glazing (EN673 instead of ISO 15099). The European system will consistently predict a lower U-Factor than the methods used for an NFRC rating, and the performance of a window with only a European rating should not be directly compared to the performance of a different window with only an NFRC rating.

What influences the U-factor?
The glazing system: The number of panes, the type of glass, the type of spacer, the space between and the type of gas fill all influence the U-factor.
The window frame and sash pieces: The material of the frame and sash has a large influence on U-factor. Moreover, vinyl frames and sashes are often designed with multiple chambers to improve insulation. Metal reinforcement tends to increase the U-factor (but is often necessary for either security or strength, or both.) Metal cladding on wood windows can form a thermal bridge around the lesser conducting wood frames, increasing the U-factor over that of a plain wood window.

Is a lower U-factor always better?
Yes – **if everything else remains the same!** However, many means of improvements have negative impacts elsewhere. For example, using some types of low-e glass (Low-e glass has a special coating to reduce its emission of heat radiation.) reduces the U-factor of a window, but this is accompanied by a reduction in the solar heat gain coefficient (SHGC, discussed elsewhere). In Wisconsin, this will can reduce or even nullify the benefits of the lower U-factor, depending on the orientation of windows, their view of the sun and the night sky, and available summer shading. Other methods of decreasing the U-factor can increase the cost of the window to the point where there will never be a reasonable payback. Or, reinforcement gets left out (or replaced with non-structural foam) in order to advertise a better U-factor, but window strength, security and durability suffers greatly

How come WASCO doesn't give an R-Value for its windows?
WASCO offers NFRC (National Fenestration Registration Council ®) certified products. The NFRC

uses the U-factor because "R-value does not accurately reflect this interaction [with solar radiation and airflow around the window]. Therefore, the window industry measures the energy efficiency of their products in terms of thermal transmission, or U-factor".[2] (If those aforementioned factors were negligible, the R-value and U-factor would be reciprocals.) If somebody quotes an R-value to a customer, the customer should insist on knowing the NFRC-certified U-factor. (Moreover, some in the business have been known to try to further mislead customers by using center-of-glass R-values instead of whole window values, which makes the product appear better than it really is.)

Solar Heat Gain Coefficient

What is the Solar Heat Gain Coefficient?
As radiative heat from the sun comes from a surface at 11,000°F, different calculation techniques are needed to account for the heating effect. The solar heat gain coefficient (SHGC) is defined for this purpose. When sunlight hits a window, some of it goes right through the window, some is reflected back and some is absorbed, heating up the various parts of the window. The absorbed heat can either flow to the inside of the house or the outside. The SHGC represents the fractional amount of the solar energy that strikes the window that ends up warming the house.

Is a higher SHGC better or worse?
A look at the NFRC website will find the explanation "The lower the SHCG, the better a product is at blocking unwanted Sun." This is true, but it should be followed with "The lower the SHGC, the more a product blocks wanted sun." For most of the United States, most solar heat gain is unwanted, as it will increase electric bills for air conditioning. However, in Wisconsin, and some other far northern states, solar heat gain is normally desired, especially in winter. A window with a high SHGC will raise cooling bills, but it will generally reduce heating costs more.

WASCO offers dual and triple pane packages with both high and low SHGC. In general, high SHGC glazing will, for Wisconsin, yield the lowest energy bills. Low SHGC glazing yields slightly better nighttime winter comfort, and improved west wall summer comfort. WASCO recommends low SHGC glazing for homes with many unshaded western windows. It can also be considered for a home with many northern windows with a clear view of the night sky, or for the customer willing to accept a decrease in efficiency for greater comfort (with dual pane glass, either of the triple pane glass packages are so warm that nighttime comfort is no issue). For homes with many south-facing windows, WASCO recommends high SHGC glazing.

Visual Transmittance

What is visual transmittance (VT)?
Visible transmittance is the fraction of visible light that comes through the product. This is influenced by glass selection, as well as the amount of opening taken up by non-transparent components such as the frame and sash. The greater the VT, the better the potential for daylighting. Normally, a reduction

2 From "The Facts about Windows & Heat Loss", NFRC, 2005

in SHGC comes with a reduction in VT.

Air Infiltration

How is air infiltration measured?
Air leakage is measured by physical testing of a standard sized window. The test window is installed on a large wall. On one side, a vacuum is of 75 pascals (1.57 psf) is applied. This corresponds to approximately a 25 mph wind blowing perpendicularly to the window. Flow meters measure the rate of air leakage. This is divided by the total window area to get a reading (in the U.S) in cfm/ft^2 to the nearest tenth (i.e., a test value of 0.17 would be given a rating of 0.2). The best possible rating by the NFRC is 0.1, as they will not round to 0.

Does air leakage have a large influence on energy bills?
If a manufacturer elects to have its product tested, it cannot have more than 0.3 cfm/ft^2 of air leakage. If this maximum is not exceeded, the energy loss through air leakage is likely considerably less than that through heat loss (ASHRAE 2005 Fundamentals, P. 31.55) Nonetheless, air infiltration has a major effect on perceived performance of the window. Even at the passing value of 0.3, disturbing drafts may be felt. These drafts are often the very reason a customer is replacing a window! Air infiltration becomes a greater percentage of total energy loss as the window's U-factor becomes lower, because the energy loss through heat transfer is reduced. Low air infiltration is critical for a passive solar house, where energy losses must be kept to the absolute minimum. For these houses, casement or Tilt & Turn windows are the only proper choices, for the reasons stated below.

Are some window designs better than others for air infiltration?
Yes. Windows with compression seals have less air infiltration than windows with wool pile sliding seals. Casement and awning windows with compression seals offer excellent air infiltration performance because pressure from the wind tightens up the seals. Tilt-and-turn windows, with their dual or triple compression seals and multiple locking points around the perimeter offer equal or better performance. Traditional double-hung windows (sometimes called "vertical sliders") as well as horizontal sliders cannot do as well because there are sliding surfaces where compression seals are not possible. And, a horizontal slider's necessary provisions for drainage can further degrade air infiltration performance.[3] Windows with sliding seals will suffer more degradation of air infiltration performance over time than a window with compression seals.

Condensation Resistance

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[3] If a contractor advises you to replace multiple double-hung or casement windows with horizontal sliders, alarm bells should be ringing. Sliders are considerably more economical to produce than the other types of windows. But, the performance of a good quality slider can only approach the performance of a good quality double-hung and its performance will always be greatly inferior to a quality casement. Indeed, WASCO has done the opposite for many customers, and has replaced leaky sliders with two double-hung windows mulled together, two-lite casements and Tilt-and-Turn windows.

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What is condensation resistance (CR)?
The condensation resistance is an optional NFRC rating that helps consumers see which products better resist condensation. WASCO chooses to report this value. The rating goes from 0 to 100. Values around 50 are pretty good and 60 or better superb.

What influences condensation resistance?
The glazing system has perhaps the largest impact. True warm edge technology spacers containing no metal help considerably. The next greatest influence is the design and materials of the framing.

Will a window with a value of 50 or better ever have condensation issues?
Perhaps. If the humidity in the house is high enough, and the outside air cold and windy, any window can have condensation. Window treatments can make matters worse. WASCO's calculations show that keeping the relative humidity in a house below 30% at 70°F will prevent most condensation problems. (This also matches what the University of Minnesota Cold Climate Center recommends in HE-FO-3415-C, “Home Indoor Relative Humidity: What is Acceptable?”)

References

American Society of Heating, Ventilation and Air Conditioning Engineers (ASHRAE), 2005, *Handbook: Fundamentals*, ASHRAE, Atlanta, GA

EN 673, 2011, “Glass in building – Determination of thermal transmittance (U value) – Calculation method

ISO 15099, 2003, “Thermal performance of windows, doors and shading devices – Detailed calculations”

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National Fenestration Registration Council, 2004, “Procedure for Determining Fenestration Product Air Leakage”, NFRC 400-2004, Silver Spring, MD

University of Minnesota Cold Climate Housing Center, 1988, “Home Indoor Winter Relative Humidity: What is acceptable?”, Minnesota Extension Service HE-FO-3415C

Useful Websites

www.nfrc.org The National Fenestration Registration Council
windows.lbl.gov Windows and Daylighting Group, Lawrence Berkeley National Laboratory
www.efficientwindows.org This website has online calculators for energy costs. WASCO is a member of this organization.

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About the Author

David joined WASCO Windows, the family business, full-time in 2006 after more than a decade of industrial and academic experience. (He worked in the factory summers during high school, and has consulted for the company many instances since then.) He worked as an engineer for Cleaver-Brooks (a Milwaukee-based manufacturer of boilers), where he did structural as well as thermal design, and for Siemens Power Generation in Milwaukee and Germany, where he developed software for analyzing field test results. He has taught thermodynamics and power plants at Marquette University in Milwaukee, and most recently was a senior research associate at the Technische Universität Berlin in Germany, where he worked for the Institute for Energy Engineering in the area of Energy Conversion and Environmental Protection. David is a registered Professional Engineer in the State of Wisconsin and has a doctorate in thermodynamics from Marquette University in Milwaukee.