The Use of R-value versus U-value to Describe Window Performance

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Introduction

Today in the fenestration marketplace, the metrics of both R-value and U-value are commonly used to describe the thermal performance of windows. While the use of u-value (or u-factor) has existed for decades, the use of R-value is relatively recent, spanning just ten years or so. Although less established historically, the use of R-value to describe windows has been made by very notable figures including John Carmody and Steven Selkowitz in their highly regarding book, *Residential Windows*, and the Department of Energy in their technology roadmap presentations to the public.

If the use of U-value is established, why would one have a desire to use R-value as an equivalent alternative? The issue is one of how people perceive and understand numbers. A first reason is that u-values are small, usually less than one, with diminishingly smaller values as performance improves. In contrast, R-values are presented in a number range of highest comfort for a consumer – between 1 and 10 (or possibly 20). Often a whole number value of R is sufficiently accurate, so three or more significant figures are not needed. Second, the inverse relation of u-value and performance is counter intuitive. As u-value diminishes, performance increases. This can be confusing to the common consumer.

R-value as an equivalent alternative U-value.

A first point of clarification is that the concern regarding confusion and perceived conflict between the designation of R versus U is generally inaccurate. In specific uses of each, they do not correlate. However, in many instances, R and U are true reciprocals. There is strong precedence to use both terms with regard to windows. Only slight clarification is required to address the current market concerns. Here are a few examples of how this conclusion was reached.

Regarding the baseline metric of u for windows, NFRC 100 describes u-factor (also overall thermal transmittance and u-factor) as "a measure of the heat transfer characteristics of a fenestration product under specific environmental conditions". As concerned individuals have noted, this definition and test method encompass multiple heat transfer mode. The premise it that conductance (1/R) does not. It is interesting that R-value is not defined in NFRC 100.

I've compared that definition to those given in ASTM C1363 – "Thermal Performance of Building Materials by Means of a Hot Box." The scope of that test method is: "determination of the steady state thermal performance of building assemblies when exposed to controlled laboratory conditions," so we can assume that products such as windows apply. This method also employs multiple modes of heat transfer, as does NFRC 100. Within the standard, C1363 defines overall thermal transmittance, U via the classical formula ($U = Q / A \cdot \Delta t$) and then notes that: “thermal transmittance, U, and the corresponding overall thermal resistance, R_u, are reciprocals, that is, their product is unity.” The standard also defines overall thermal resistance as “equal to the sum of the resistances of the specimen and the two surface resistances.” Since the test sample does not make direct contact with the inner and outer surfaces of the hot box, more than conduction is involved in the system heat transfer. In other words, C1363 states the two metrics are reciprocals and expands the concept of R-value beyond pure conductivity/resistance.

Last, there are two definitions in ASTM C168 - the standard for definitions of thermal terminology. C168 defines apparent thermal conductivity as: “a thermal conductivity assigned to a material that exhibits thermal transmission by several modes of heat transfer resulting in property variation with specimen thickness, or surface emittance.” And apparent thermal resistance is: “a thermal resistivity assigned to a material that exhibits thermal transmission by several modes of heat transfer resulting in property variation with specimen thickness, or surface emittance.” Regarding the two ‘apparent’ metrics, they note: “Thermal conductivity and resistivity are normally considered to be intrinsic or specific properties of materials and, as such, should be independent of thickness. When nonconductive modes of heat transfer are present within the specimen (radiation, free convection) this may not be the case. To indicate the possible presence of this phenomena (for example, thickness effect) the modifier “apparent” is used, as in apparent thermal conductivity.” The combinations of the two definitions and the note appear to address the situation present in windows testing today. NFRC actually tests apparent thermal transmittance and its inverse is apparent thermal resistance. Other building scientists, including Dave Yarborough at ORNL have suggested ‘effective’ as a suitable modifier instead of ‘apparent.’ I agree that it is also a very good fit.

Following this course of logic it appears that the truest course of action is to rename the current NFRC metric as ‘apparent thermal transmittance’. As this is unlikely, it would also be very accurate to begin adopting the use of ‘apparent R-value’ or ‘effective R-value’ as its reciprocal. The resulting metric is technically sound and causes little upset to the current marketing efforts of EWC, DOE, and early-adopting private companies.

Another possible avenue would be to have a common public definition of (or ‘that describes’) their interchangeable use. Such a glossary term for R-value could be updated as follows:

> **Effective R-value (or R-value):** A measure of the effective resistance of a glazing material or fenestration assembly to heat flow. Effective R-value includes heat being transferred by all three mechanisms – conduction, radiation, and convection as tested per NFRC 100. It is the inverse of the U-factor ($R = 1/U$) and is expressed in units of hr-sq ft-°F/Btu. A high-effective R-value window has a greater resistance to heat flow and a higher insulating value than one with a low R-value.

Reviewing the relevant test methods and their application of the term R-value, one can summarize the following:

Test Standard	Metric defined	Notes
NFRC 100	Overall thermal transmittance	Note: R-value not discussed.
ASTM C1363	Thermal transmittance, overall thermal resistance	Note: explicitly states that U is a reciprocal of R
ASTM C168	Apparent thermal conductivity, apparent thermal resistivity	Note: 'apparent' modifier incorporates non-intrinsic behavior
N/A – best practices	Effective thermal resistance	Note: 'effective' modifier incorporates conduction, radiation, and convection

Conclusion

There is good public reason and good technical precedence for the interchangeable use of R-value and u-factor to describe windows. With only slight modification to the terminology associated with R-value, the public will be empowered to make smarter, more intuitive energy efficiency decisions. Additionally, product manufacturers and building designers will have another useful method of describing their materials in a fair and transparent marketplace.