FEATURE

THE MEASURED PERFORMANCE OF WINDOWS

The July 1986 issue of EDU featured an article that focused on window airtightness ratings and how representative they are of the actual field performance of windows. In response to that article, we received a flurry of inquiries asking about other window performance ratings. Specifically, how accurate and valid are manufacturers' listed U-values and R-values for windows?

[NOTE: Although U-value is the more proper term for expressing window thermal performance, we will also use R-value in this article because of its familiarity. R is simply the reciprocal of U (R=1/U).]

Since window R-value is critical to overall building performance and moisture condensation control, and since building codes, energy codes, and various lending programs commonly specify minimum R-values for windows, manufacturers' published performance figures should certainly not go unquestioned.

So we questioned. And we found some startling surprises. We found several Low-E windows that performed well below the common claims for Low-E products, including one Marvin Low-E window with an R-value of R-1.5! On the other hand, we found Andersen windows that actually performed better than the manufacturer's claims in the brochure. We also found comparative lab tests showing that window size alone can cause the R-value to vary up to 40%! Perhaps the most noteworthy discovery was that ASHRAE's (American Society of Heating, Refrigerating and Air Conditioning Engineers) published U-values and R-values for windows and the accepted test procedures for testing windows are both clouded with uncertainty.

All in all, we found that listed values for window performance factors are not necessarily accurate representations of actual field performance. The good news is that work is under way to improve the situation. But in the meantime we should be aware of the areas and degree of uncertainty in calculated and measured window performance.

The Survey of Laboratory Test Data

To evaluate published ratings, we examined laboratory measured performance data for over 300 windows. We eliminated any data that was not from a certified laboratory and then selected that data which was useful for practical comparison and evaluation. A summary of the compiled test data is tabulated in Table 1 at the end of this article. Although we would have liked to limit our analysis to include only nationally distributed windows that would be familiar to all our readers, some of the most illuminating information came from results of tests of windows from regional manufacturers.

CALCULATED VS. MEASURED R-VALUE

Pick up any window catalog. For this discussion, let's select the 1986 Pella catalog. On page two are illustrations of the various Pella glazing systems along with rated U-values and R-values. In the lower left corner of the page is the following note:

> "U values shown are calculated for a 2048 casement using ASHRAE methods and factors. Compare with other calculated ratings. Testing will probably result in higher U values. When comparing test results, methods, conditions and sizes should be identical. Actual results may vary due to differences in environment, exposure or management." [underline our emphasis]

This disclaimer, which appears in similar form in many window catalogs, is the first hint that even though U-values and R-values are often expressed to the second decimal place, the numbers are not gospel and "actual results may vary."

Figure 1 compares the laboratory-measured R-value of a Pella 36" x 48" casement with the R-value listed in the Pella catalog for an identical window. Notice that the agreement between the Pella calculated value and the laboratory-measured value is actually quite good.

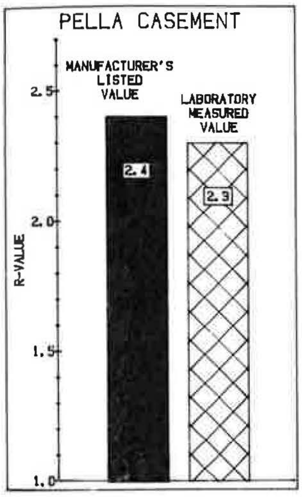


Figure 1—Listed vs measured R-value of Pella casement window.

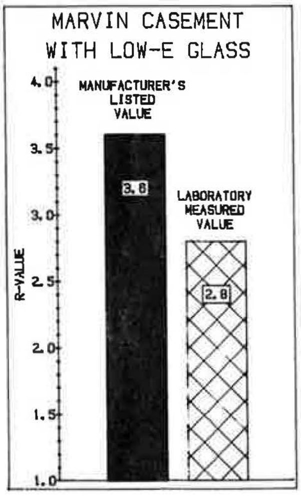


Figure 2—Listed vs measured R-value, Marvin casement window with Low-E glass.

Now let's look at Marvin windows. The Marvin "Product Performance and Information" fact sheet lists an R-value of R-3.57 for its MG2448 Casemaster with Low-E glass (PPG Sungate 100). Unlike Pella, Marvin doesn't explain where that number comes from. We compared Marvin's listed R-value against lab test results for a 35" x 48" Casemaster (slightly smaller than the MG2448). The lab measured R-value was only R-2.8, 21% lower than the R-3.57 claimed by Marvin (Figure 2).

What gives? Is Marvin simply inflating its R-value figures? Probably not, since listed values for other Marvin window models agree quite well with lab test data. For example, Figure 3 compares listed vs. measured R-values of a Marvin casement window with clear double insulating glass. The two values agree perfectly.

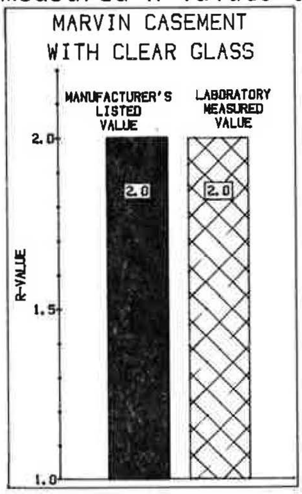


Figure 3—Listed vs measured R-value, Marvin casement window with clear double glazing; 1/4-inch airspace.

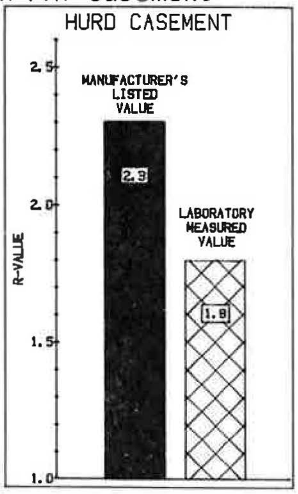


Figure 4—Listed vs measured R-value, Hurd casement window with clear double glazing.

More sampling from our window files produced more discrepancies between listed and measured R-values. For example, Figure 4 shows listed vs. measured R-value for Hurd's double-glazed casement with 13/16-inch interpane airspace. The measured value is more than 25% below the listed value.

Not all of the discrepancies are disappointing. In the case of Andersen's double-glazed awning window, the measured R-value is higher than Andersen's listed R-value (figure 5).

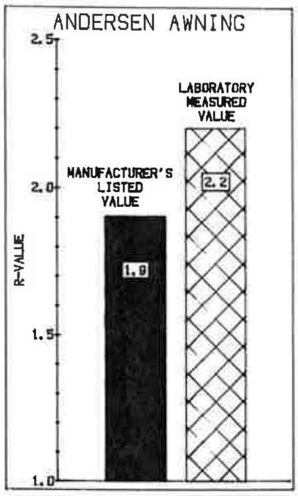


Figure 5—Listed vs measured R-value, Andersen awning window with clear double glazing.

Why so much discrepancy between listed and measured performance data for windows? Let's look at the major problems.

PROBLEM #1—THE UNCERTAIN EFFECT OF EDGE SPACERS AND FRAMES

Perhaps the most important problem is the simple fact that windows are very complex building components, consisting of much more than just glass. Ignoring for the moment gaskets, weatherstripping and locking hardware, windows consist of three basic areas that effect heat transfer -- the glass center, the glass edge, and the frame/sash areas.

A. Glass Center Area

The glass center area comprises the bulk of the total window area. The R-value of this area is affected by the number of glazing layers, the width of the interpane airspace(s), and the emissivity of the glazing surfaces. To illustrate the actual effect of these factors, Figure 6 shows measured R-value of various

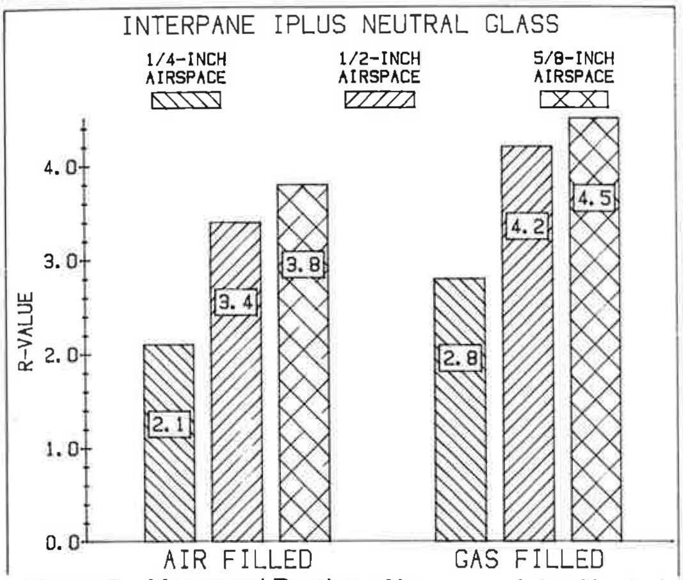


Figure 6—Measured R-value of Interpane Iplus Neutral Low-E glass with and without gas filling.

configurations of Interpane Iplus Neutral Low-E glass (glass only, no frame). These lab-measured R-values agree exactly with the performance claims listed by Interpane in its literature.

[NOTE: It is important to note here that the tests of Interpane glass which we examined were performed by measuring conductivity through the center of the glass units only. None of the test thermocouples were near the edge of the glass. The significance of this fact will become more obvious when we discuss "edge effect" below.]

Given the fact that high-performance glazing systems do in fact work (as shown in Figure 6), the next logical question is: What impact do they have on whole window performance? Since the glass center area comprises the largest portion of the total window area, there is a tendency to falsely assume that the R-value of the whole window is more or less the same as the R-value of the glass center area. But take a look at Figure 7. The leftmost pair of vertical bars compares the R-value of clear double glazing with Low-E double glazing (glass only). Notice that the Low-E R-value is about 63% higher. The other four pairs of vertical bars compare the actual measured difference in R-value between whole window assemblies with and without Low-E glass. In no case is there anywhere near a 63% greater R-value with Low-E glass. The Marvin window showed no difference at all between clear double glazing and Low-E double glazing!

Equally astonishing are the data shown in Figure 8. Here we see a comparison of clear double glazing, Low-E double glazing, clear triple glazing, and triple glazing with Heat Mirror. Again the leftmost set of vertical bars shows R-values for glazing alone without framing. The other four sets of vertical bars are for awning, casement, fixed, and single-hung windows produced by Fentron. In these tests, the effect of Low-E glazing on whole window performance is insignificant. Bear in mind that all the triple-glazed Fentron units have only 1/4-inch airspace between the glazing. Even so, the R-value of Heat Mirror with that spacing is supposed to be R-3.2, yet none of the Fentron units tested higher than R-2.4!

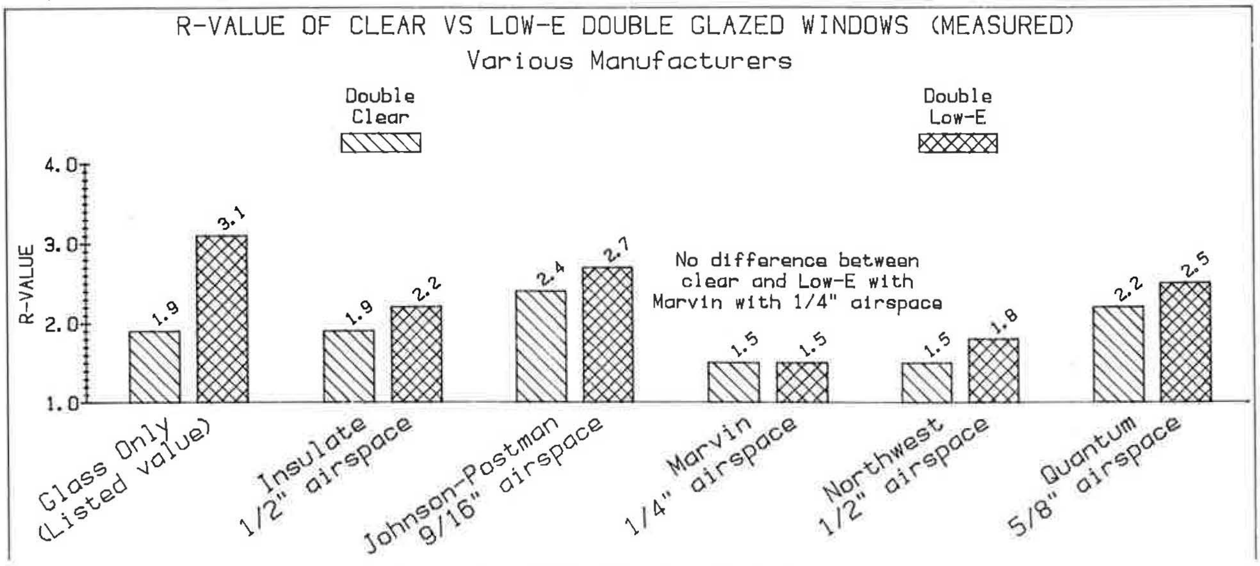


Figure 7—R-Value of clear vs Low-E double-glazed windows; Various manufacturers.

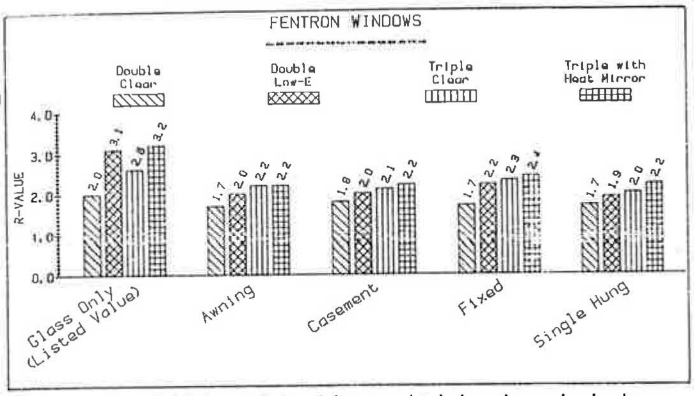


Figure 8—R-Value of double- and triple-glazed windows with clear glazing, Low-E glazing, and Heat Mirror interpane.

Why do these Low-E windows test out so poorly? One possibility is that some Low-E glass is not all that it's cracked up to be. Another possibility is that the test procedures themselves are faulty. The third and most likely possibility is that the R-value of whole window assemblies is seriously degraded by high conductivity through the edge seals and window frames.

B. Glass Edge Area

In a sealed insulating glass unit, the spacing between the panes is typically maintained by a hollow aluminum edge spacer (Figure 9). Because of aluminum's high thermal conductivity, the R-value at the edge of a sealed insulating glass unit is considerably higher than the R-value at the center of the glass. This is commonly referred to as "the edge effect."

The edge effect is important not only with respect to overall window R-value, but also with respect to glass surface temperature and condensation potential.

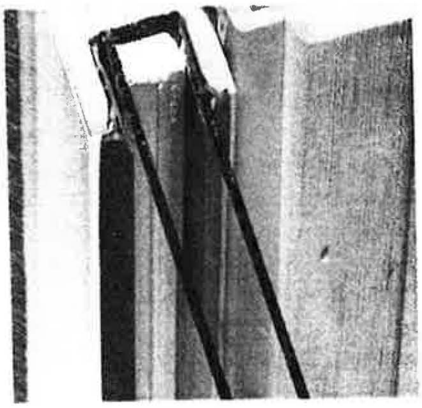


Figure 9—Hollow aluminum edge spacer filled with dessicant.

Figure 10 shows measured indoor surface temperatures of a 36" x 48" Peachtree "Ariel" picture window with 3/4-inch double insulating glass. In this test, (AAMA 1502.7-1981), the window was exposed to 18°F air on the cold side and 68°F air on the warm side. The temperature at the center of the glass is 50.6°F -- almost exactly what it should be according to theoretical calculations. But the temperature near the edge ranges from 35.5 to 41.8°F -- far below what one would expect from an R-2.0 window.

The impact of the edge effect on overall window R-value has not been well quantified, but research performed by PPG shows that aluminum edge spacers can cause a 30% reduction in R-value over a 2.5-inch band around the entire perimeter of the window. In a presentation to the Sealed Insulating Glass Manufacturers Association (SIGMA) last summer, Charles Peterson of PPG estimated that in a 36" x 48" window, the edge area constitutes 21% of the total window area, and that the net effect of the spacer is to reduce the overall R-value of a Low-E window by 14%. Despite PPG's estimate, the impact of the edge effect on the performance of assembled windows is variable and quite uncertain.

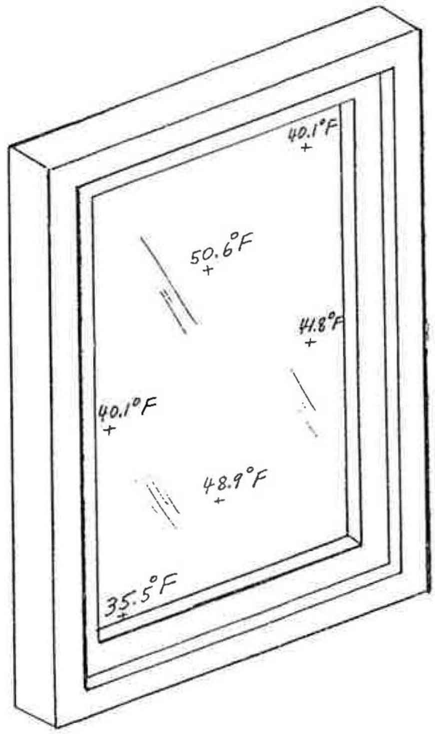


Figure 10—Surface temperature measurements of Peachtree Ariel picture window during Condensation Resistance Factor test (AAMA 1502).

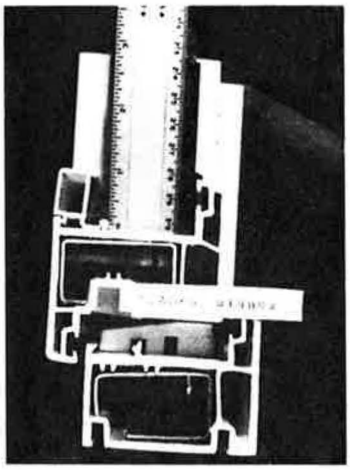


Figure 11—The Alaska Window PVC frame. The glass cavity is 1 inch deep to reduce the effect of thermal short circuiting through the edge spacer.

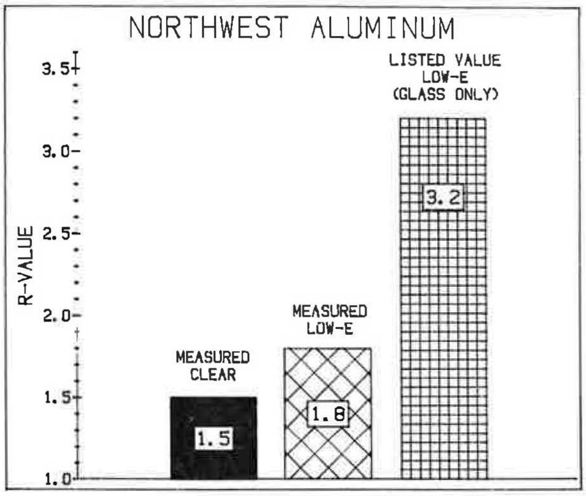


Figure 12—R-value of Northwest windows with thermally unbroken aluminum frames; double clear and double Low-E glazings.

METHODS FOR REDUCING EDGE EFFECT

Some European window manufacturers decrease the edge effect by recessing the glass edge deep in the window sash. Most American window manufacturers are reluctant to do that since it decreases the total clear lite area. Andersen, for example, recesses the glass unit only 1/2-inch into the sash of its casement windows. An exception, however, is the Alaska Window Company, which incorporates a 1-inch-deep glazing well into its vinyl framed windows (Figure 11). [In Alaska, a serious concern is the danger of windows freezing shut due to interior condensation and icing, preventing egress during fire or other emergencies. In tests performed by the Alaska Department of Transportation and Public Facilities, the Alaska Primo window was found to perform better than similar Caradco or Rockwell units in this respect.]

Some manufacturers are replacing the hollow aluminum edge spacers with alternative spacers having lower conductivity. One example is a relatively new spacer called "Swiggle Stick," a corrugated aluminum spacer produced by Tremco, Inc. Although no measurements are available yet, windows with Swiggle Stick should experience less edge effect than those with conventional aluminum spacers.

Another attractive alternative on the horizon is fiberglass spacers, developed and produced by Fibertherm as part of its fiberglass frame system (see September 1986 EDU). Since fiberglass has a much lower conductivity than aluminum, these new components will significantly reduce heat transmission through the edge area in windows. Fiberglass spacers are expensive and not yet available in the U.S. They are available in Canada, however, and are being considered by PPG for distribution in the U.S. as part of its Sunsash fiberglass framing system.

C. Frame and Sash Area

Last but certainly not least are window frames and sashes, whose effect on overall window performance is usually underestimated. A good demonstration of their impact is shown by test results of two aluminum-framed windows produced by Northwest Aluminum (Figure 12). One window has clear double glazing and the other has Low-E glass (both with 1/2-inch airspace). Neither window has thermal breaks in the aluminum frame. Clear double glazing has an R-value of about R-2.0 and Low-E glass has an R-value of R-3.2, but the measured R-values of the Northwest windows are only R-1.5 and R-1.8! Without thermal breaks, the aluminum frames almost completely nullify the advantage of the low-E glass.

How much improvement do thermal breaks make in aluminum framed windows? To answer that question, let's look at some comparative test data for two Milgard

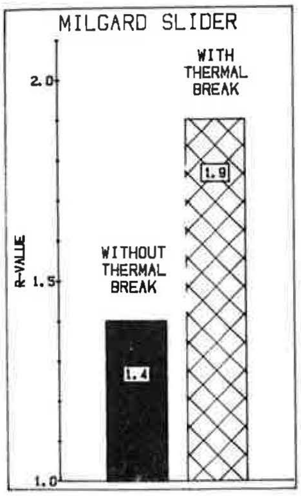
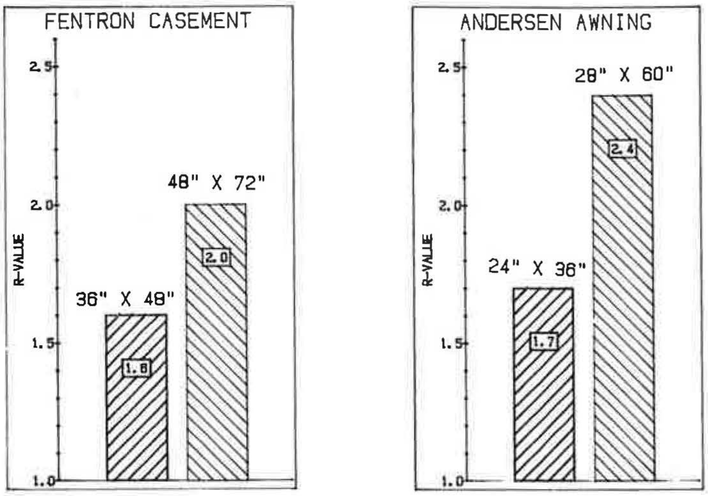


Figure 13—R-value of Milgard sliders with and without thermal breaks in aluminum frames; clear double glazing.



a. Fentron casement b. Andersen Awning

Figure 15—Effect of window size on measured R-value.

sliders, one with and one without thermal breaks in the frame (Figure 13). The R-value of the window with thermal break is 36% higher than a similar window without thermal break.

In addition to metal there are wood, vinyl, and now fiberglass window frames. Many modern windows use a combination of several materials, such as the Peachtree frame in Figure 14. The thermal performance of these composite frames has not been well characterized or documented.

FRAMING AND EDGE EFFECTS CAUSE WINDOW R-VALUES TO VARY WITH WINDOW SIZE

As the glass-to-frame ratio decreases, the overall window R-value also decreases due to the edge effect and in some cases due to framing effects. In other words,

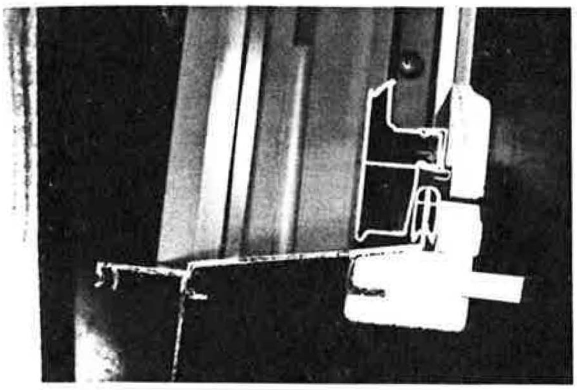


Figure 14—Cross section through Peachtree casement window frame.

large windows should have higher R-values than smaller windows of the same type. An example of this phenomenon is illustrated in Figure 15.

Figure 15a compares the R-value of two Fentron casements that are identical except for size. The R-value of the larger window is 25% higher than the R-value of the smaller unit. Figure 15b shows a similar comparison for two Andersen awning windows. Here the R-value of the larger window is 41% higher. The Andersen catalog is the only one we've found that explains this phenomenon. On page 58 of the current catalog is the following note:

> "The U values stated under this heading are for the indicated products and sizes and do not indicate the U-values of other products or sizes. Ordinarily, a unit with a smaller glass to frame ratio will have a lower U-value and a unit with a larger glass to frame ratio will have a higher U-value." [underline our emphasis]

PROBLEM #2—WINDOW PERFORMANCE TESTS MAY NOT ACCURATELY REFLECT FIELD PERFORMANCE

TESTING FOR U-VALUE

The basic concept for measuring window U-value is relatively simple. A test window is placed between a warm chamber and a cold chamber. As heat flows through the window, the amount of energy required to maintain temperature in the warm chamber is measured. With that measurement, one can easily calculate the overall transmission coefficient (U-value) of the window.

Two standard ASTM methods are used for testing window U-value: the "Guarded Hot Box" test (ASTM C236), and the "Calibrated Hot Box" test (ASTM C976). Both tests are also used for measuring U-values of walls and other building components.

The problem arises in selecting the wind conditions under which the test should be performed. Since window R-value is very sensitive to wind speed and direction, wind conditions during the test are very important. If you look at listed R-values or U-values for windows, you will almost always see a footnote stating that the listed value is for a 15 mph wind. So the tests are typically run with a simulated 15 mph wind in the cold-side test chamber. But which way should the wind blow? Parallel or perpendicular to the window surface? ASTM procedures specifically state that the wind must be parallel to the test sample surface. But the window industry claims that that is inappropriate for windows because muntins and other protrusions will interfere with the effect of the wind and the results will not be reproducible from lab to lab. So the American Architectural Manufacturers Association (AAMA), an industry trade group, has devised its own test method -- AAMA 1503 -- which is similar to the ASTM tests, but which includes a 15 mph wind blowing perpendicular to the window surface. The two tests give different results.

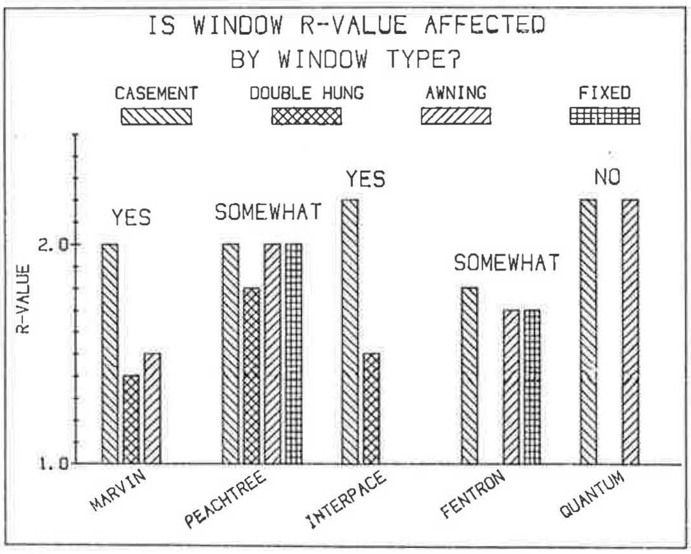


Figure 16—Variation of measured R-value among window types.

Even more serious than the parallel vs. perpendicular wind debate is suspicion that the AAMA test induces air leakage through the window during the test. These tests are not supposed to measure air leakage or its effect on thermal transmission. That's done by a separate test (ASTM 283). To prevent air leakage, the test procedure states that pressure on both sides of the test window must be equalized. (The warm side chamber is pumped up to neutralize the pressure created by the 15 mph wind in the cold side chamber.) A recent ASHRAE study report written by Michael McCabe of the National Bureau of Standards states that the wind conditions in the AAMA test may in fact cause air leakage. McCabe told us that R-values measured by the AAMA test may be erroneously low due to the added heat loss caused by the air leakage.

Figure 16 shows laboratory test data that support McCabe's claim. For each manufacturer, the windows represented are the same size and have the same type of framing and glazing. Why do the R-values vary so much? The most likely possibility is that tests of the more leaky windows, such as the double-hung units, are confounded by air leakage, resulting in falsely low R-value readings. This is only a hypothesis, but according to McCabe, a good possibility.

Another possible problem with the AAMA test is that the force of the 15 mph wind might actually cause the glass to deflect, reducing the width of the interpane airspace and thus reducing the R-value of the glazing. McCabe told us that in some instances (presumably with large windows), the panes have actually bent to the point where the panes touch!

PROBLEM #3—THE ASHRAE NUMBERS

The most widely accepted source of U-value and R-value information for windows is the ASHRAE Handbook of Fundamentals, published by the American Society of Heating, Refrigerating and Air Conditioning Engineers. Table 13 in Chapter 27 of the current handbook lists U-values for various glazing configurations.

There are lots of problems with the ASHRAE numbers and the way in which they are used. ASHRAE is well aware of the situation and has formed a subcommittee, headed up by Michael McCabe at NBS, to work on a new revision for the next edition of the handbook, which will be ready in 1989. Here are a few of the problems as outlined in the Work Statement for the ASHRAE subcommittee and/or as told to us by McCabe:

1. Experimentally determined U-values are often significantly different from handbook values. We've shown a few examples of this in this report.

2. Information on many newer and widely used products such as Heat Mirror are not included in the listings of U-value.

3. Nobody seems to know why ASHRAE lists window U-values for 15 mph wind conditions. It certainly is not the average wind speed for most places.

4. Published U-values for windows appearing in past editions of the handbook have changed over the years. The subcommittee does not have a rational explanation for those changes.

5. The ASHRAE published values are typically misused by the design community.

This last problem really shocked us: apparently the ASHRAE U-values as listed are supposed to be specifically excluded from use in annual energy consumption computations. The title of Table 13 clearly states that the table provides U-values "for use in peak load determination and mechanical equipment sizing only and not in any analysis of annual energy usage." Yet nearly every analysis of window options begins by computing energy consumption using the ASHRAE numbers. It stands to reason that, since no real sites have a constant 15 mph wind all year long, using the ASHRAE numbers wouldn't be accurate, yet it is commonly done anyway.

Table 14 in Chapter 27 of the Handbook provides conversion factors between U-values at 0, 7.5, and 15 mph, and Figure 14 plots the relationship between U-values and outdoor temperature for selected glazings, but specific information is not provided on how to use these data to estimate seasonal energy performance.

Aside from the problem with wind speed, the ASHRAE U-values are for an infinite sheet of glass. The edge effect and/or framing effects are not considered. Although Part C of Table 13 lists "Correction Factors" for the effect of framing on overall U-value, there is no factor for combination wood and metal frames, vinyl frames, or fiberglass frames.

McCabe's subcommittee hopes to develop a simple procedure whereby design-day U-value data can be modified to estimate seasonal energy performance of windows. Also, Table 13 in the Handbook is now being revised with more realistic figures and the subcommittee has proposed that a new set of U-values be developed, based on actual laboratory test results.

FOR MORE INFORMATION:

To obtain copies of the ASTM standard test procedures, contact ASTM, 1916 Race Street, Philadelphia, PA 19103; (215)299-5400.

For copies of the AAMA test procedures, contact American Architectural Manufacturers Assocation, 35 E. Wacker Drive, Chicago, IL 60601: (312)782-8256.

For information on the ASHRAE subcommittee involved with window values, contact Michael McCabe, National Bureau of Standards, U.S. Dept. of Commerce, Gaithersburg, MD 20899.

Special thanks to Michael McCabe for his assistance in preparing this report and to the City of Seattle Department of Construction and Land Use for supplying much of the window test data used for our analyses.

Manufacturer	Sash Type	Glazing	Airspace	Type	Size (Inches)	U-value	R-value
Alaska Window Company	Vinyl	triple	1/2,1/2	casement	31×38	0.31	3.2
Andersen	Vinyl coated wood	double	3/8	awning	48×48	0.45	2.2
		double	3/16	awning	24×36	0.59	1.7
		double	3/16	awning	28×60	0.42	2.4
		double Low-E (Cardinal)	7/16	awning	24×48	0.41	2.4
		double Low-E (Cardinal)	7/16	casement	38×77	0.37	2.7
Fentron Bldg. Prod.	Alum. thermal break	double	5/8	awning	48×72	0.59	1.7
		double	5/8	casement	48×72	0.55	1.8
		double	5/8	fixed	36×48	0.58	1.7
		double	5/8	single hung	48×72	0.58	1.7
		double Low-E	5/8	awning	48×72	0.49	2.0
		double Low-E	5/8	casement	48×72	0.50	2.0
		double Low-E	5/8	casement	36×48	0.62	1.6
		double Low-E	5/8	fixed	72×48	0.46	2.2
		double Low-E	5/8	single hung	48×72	0.54	1.9
		triple	1/4+1/4	awning	48×72	0.45	2.2
		triple	1/4+1/4	casement	48×72	0.47	2.1
		triple	1/4+1/4	fixed	48×72	0.44	2.3
		triple	1/4+1/4	single hung	48×72	0.51	2.0
		triple Low-E (Heat Mirror)	1/4+1/4	awning	48×72	0.45	2.2
		triple Low-E (Heat Mirror)	1/4+1/4	casement	48×72	0.46	2.2
		triple Low-E (Heat Mirror)	1/4+1/4	fixed	48×72	0.41	2.4
		triple Low-E (Heat Mirror)	1/4+1/4	single hung	48×72	0.45	2.2
Hurd Millwork	Wood with ext. alum.	double	13/16	casement	28×60	0.56	1.8
Insulate Industries	Wood	double	1/2	single hung	36×48	0.54	1.9
		double Low-E (Ford Sunglas)	1/2	single hung	36×48	0.45	2.2
Interpace Wood Products	Wood	double	1/2	casement	36×48	0.45	2.2
		double	1/2	double hung	36×48	0.67	1.5
Johnson-Postman	Wood	double	9/16	casement	72×47	0.42	2.4
		double Low-E (Ford Sunglas HR)	9/16	casement	72×47	0.37	2.7
Marvin Windows	Wood	double	1/4	awning	35×48	0.67	1.5
		double	1/4	casement	35×48	0.50	2.0
		double	1/4	double hung	35×48	0.74	1.4
		double	1/4	slider	35×48	0.74	1.4
		double	3/8	double hung	35×48	0.50	2.0
		double	5/8	fixed	35×48	0.54	1.9
		double Low-E (PPG sungate 100)	1/4	double hung	35×48	0.67	1.5
		double Low-E (PPG sungate 100)	1/2	casement	35×48	0.36	2.8
		double Low-E (PPG sungate 100)	1/2	awning	35×48	0.49	2.0
	Wood with ext. alum.	double	1/2	double hung	35×48	0.53	1.9
		double	1/2	casement	35×48	0.45	2.2

Manufacturer	Sash Type	Glazing	Airspace	Type	Size (Inches)	U-value	R-value
Milgard Mfrg.	Aluminum	double	1/2	slider	72×48	0.69	1.4
	Alum. thermal break	double	1/2	slider	73×48	0.52	1.9
		double Low-E (Guardian)	7/16	slider	73×48	0.42	2.4
Northwest Aluminum	Aluminum	double	1/2	single hung	48×72	0.66	1.5
		double Low-E (Glaverbel)	1/2	single hung	48×72	0.55	1.8
Peachtree Windows and Doors	Wood with ext. alum.	double	9/16	double hung	36×48	0.55	1.8
		double	9/16	awning	36×48	0.49	2.0
		double	9/16	casement	36×48	0.49	2.0
		double	9/16	fixed	36×48	0.49	2.0
Pella Products	Wood with ext. alum.	single plus int. storm	13/16	casement	36×48	0.44	2.3
		single plus int. storm	13/16	double hung	36×48	0.47	2.1
		single plus double int. storm	13/16+1/4	casement	36×48	0.36	2.8
Quantum Wood Windows	Wood	double	5/8	awning	48×36	0.45	2.2
		double	5/8	casement	36×48	0.45	2.2
		double Low-E (For Sunglas HR)	5/8	awning	48×36	0.40	2.5
		double Low-E (For Sunglas HR)	5/8	casement	36×48	0.40	2.5
Viking Windows	Alum. thermal break	double	17/32	single hung	48×72	0.57	1.8
		double	17/32	slider	72×48	0.58	1.7
		double Low-E (PPG Sungate 200)	17/32	single hung	48×72	0.52	1.9
		double Low-E (PPG Sungate 200)	17/32	slider	72×48	0.48	2.1
Iplus Neutral Glass	No Frame	double Low-E; gas-filled	5/8	glass only	36×48	0.22	4.5
		double Low-E; air-filled	5/8	glass only	36×48	0.26	3.8
		double Low-E; gas-filled	1/2	glass only	36×48	0.24	4.2
		double Low-E; air-filled	1/2	glass only	36×48	0.29	3.4
		double Low-E; gas-filled	1/4	glass only	36×48	0.36	2.8
		double Low-E; air-filled	1/4	glass only	36×48	0.48	2.1
All Weather, Inc.	No Frame	Quad-pane; Glass outer panes with 3M SunGain inner panes	3/8,3/4,3/8	glass only	17×42	0.29	3.4
		Quad-pane; Outer glass had Low-E film applied to inner surface; two 3M Sun Gain inner panes	3/8,3/4,3/8	glass only	17×42	0.24	4.2
		Triple Glass	5/16,5/16	glass only	17×42	0.31	3.2
		Triple; 2 outer glass, 1 inner 3M SunGain	5/16,5/16	glass only	17×42	0.39	2.6
	Alum. thermal break	Quad-pane; Glass outer panes with 2 3M SunGain inner panes	5/16	casement/fixed combination	64×72	0.43	2.3
Wenco of Oregon JX-7	Wood	Triple glazed Low-E	1/4,1/2	slider	12×24	0.36	2.8
		Triple glazed low-E (PPG Sungate 200)	1/4,1/2	casement	23×38	0.25	4.0