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Window U-Values

Revisions for the 1989 ASHRAE Handbook—Fundamentals

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Editor's Note: Chapter 27 in the *1989 ASHRAE Handbook—Fundamentals* is the authoritative source of technical information on fenestration products such as windows, patio doors, skylights, shading devices, etc. Its revision every four years is the responsibility of Technical Committee 4.5 (Fenestration). *Table 13* in this chapter lists Overall Coefficients of Heat Transfer (U-Values) for a variety of fenestration, based on standard outdoor design conditions. This data has been used by engineers, architects, manufacturers, code officials, etc., for many purposes; including design calculations for sizing heating and cooling equipment, for estimating building energy consumption, and for comparing thermal performance between competing fenestration products. The *1989 ASHRAE Handbook—Fundamentals* was printed and mailed to ASHRAE members entitled to receive the book in May.

Recently, the thermal resistance of insulated glazing units has undergone significant improvement due to commercialization of products having low-emittance coatings and or low-conductance gas fills. Thus, heat conduction in the non-glazed portion such as the frame and sash has become more important in determining the overall U-Value of the system. The U-Value Subcommittee of T.C. 4.5 has recommended a number of changes to be made to *Table 13* in the 1989 Handbook. This article discusses the technical basis for the changes and illustrates the differences between data in the 1989 Handbook and previous Handbooks.

Overall coefficient of heat transfer

The general equation used to estimate the total rate of heat transfer, Q_o, through a fenestration system from inside to outside is:

$$Q_o = U_o \cdot A_o (t_{i,air} - t_{o,air}). \quad (1)$$

where

U_o = overall heat transfer coefficient (U-Value), Btu/h · ft² · F (W/m² · K),

A_o = combined glazing plus frame area projected to a plane parallel to glass as viewed from outside, ft² (m²),

$t_{i,air}$ = temperature of warm space air, F (C),

$t_{o,air}$ = temperature of cold space air, F (C).

The total rate of heat transfer through a fenestration system can be calculated knowing the separate heat transfer contributions of the glazing and frame. With insulating glass, the glazing heat transfer contribution includes a center of glass component and an edge of glass component that is due to the presence of a spacer. The overall U-Value is estimated using area-weighted U-Values for each contribution by:

$$U_o = (U_{cg} \cdot A_{cg} + U_{eg} \cdot A_{eg} + U_f \cdot A_f) / (A_{cg} + A_{eg} + A_f), \quad (2)$$

where the subscripts *cg, eg,* and *f* refer to, respectively, the center-of-glass, edge-of-glass and frame.

Center-of-glass coefficient

Center-of-glass U-Values are calculated based on one-dimensional heat flow theory using convective heat transfer correlations for enclosures (El Sherbiny, 1982) and standard computational methodologies (Rubin, 1982). Values for U_{cg} depend on the surrounding air temperatures and velocities, and the glazing construction features, including the number of glazing lites, the air-space dimensions, the orientation relative to vertical, the emittance of each surface and the composition of the fill gas. Public-domain computer programs, such as WINDOW3 (Lawrence Berkeley Laboratory, 1987), and VISION (University of Waterloo, 1987) provide rapid estimates of U-Value for a wide range of glazing constructions.

Figure 1 shows values of U_{cg} for double and triple-glazed, vertical fenestration at standard winter design conditions calculated using WINDOW3. The plot shows the important effects of low-emittance coatings and argon gas fill. The reduced importance of air-space dimensions greater than about 1/2 in. (13 mm) are evident. Emittance values of 0.84, 0.40, and 0.15 correspond, respectively, to conventional glass (uncoated), pyrolitic coated glass and sputter coated glass. The vertical lines in *Figure 1* show the gas space widths listed in the *1989 ASHRAE Handbook—Fundamentals.*

Edge-of-glass coefficient

Insulating glass units have continuous members around the glass perimeter to separate the glazing lites and provide an edge seal. The spacers are often made of highly conductive materials (aluminum), which locally degrades thermal performance of the glazing unit. Alternate spacer materials include thermally insulating materials such as fiberglass and butyl rubber, and partly insulating glass edges. Edge heat transfer can make a significant difference in the U-Value of the glazing unit, especially those with small glazing dimensions or with high-performance insulating glass. Thus, it is important to use test data or design specific computations to account for this important feature.

Laboratory measurements reported by Peterson (1987) have shown this conductive region to be limited to a band approximately 2-1/2 in. (63 mm) wide around the perimeter of the glazing unit. *Figure 2* shows the heat flow in the edge region of an insulating glass unit to be two-dimensional, as depicted by the computer generated isotherms for a glazing unit with an aluminum spacer. *Figure 3* shows the edge-of-glass U-Value as a function of the center-of-glass U-Value for different spacer materials. Data for aluminum spacers and insulating spacers will appear in the 1989 Handbook. Test data are shown for aluminum spacers. Calculated values are also

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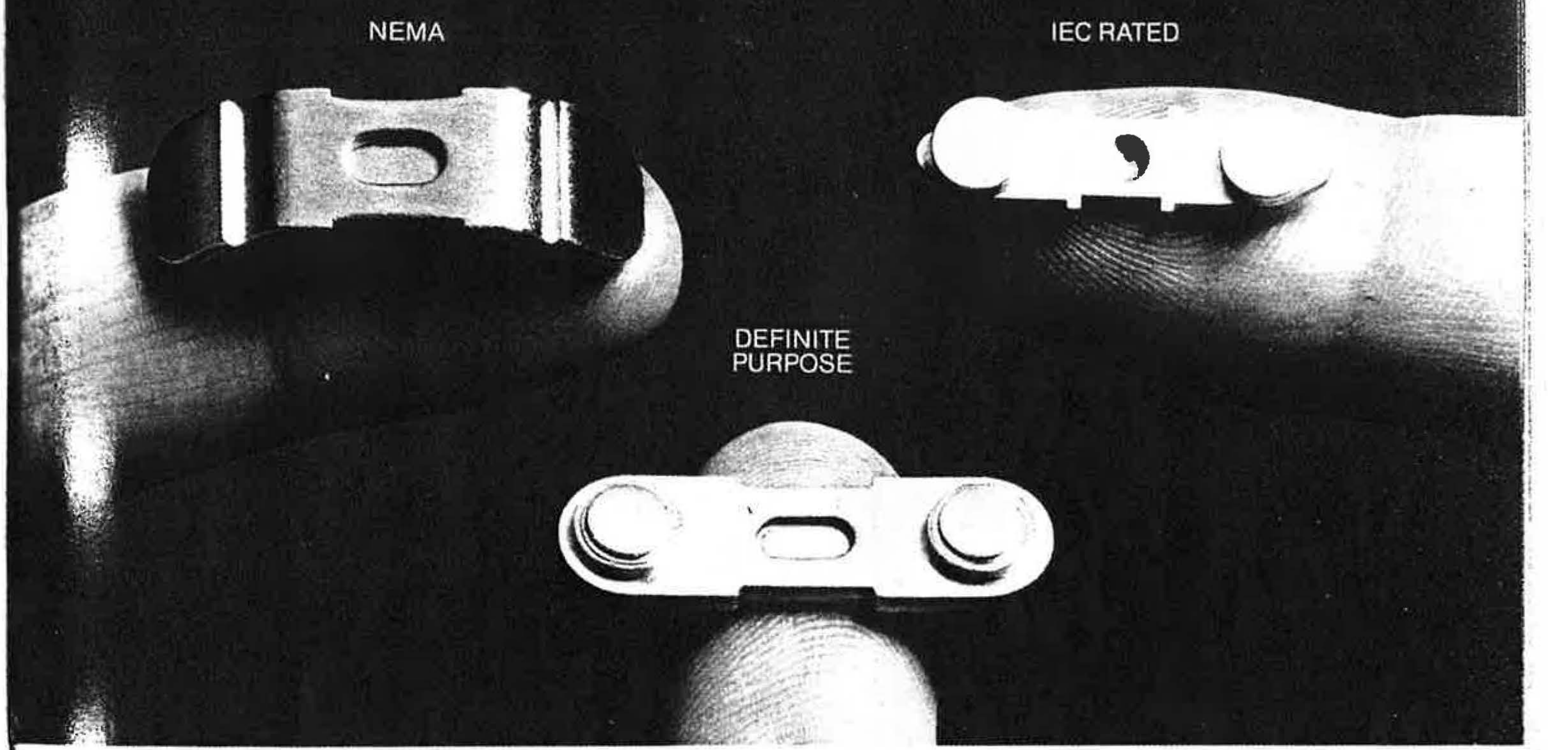

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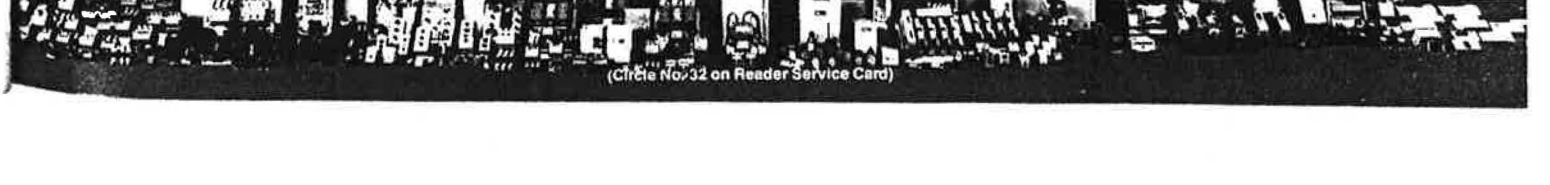

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Revisions in the 1989 Handbook

The 1985 Handbook includes a set of "adjustment factors" that multiply the center-of-glass U-value to account for the thermal conductivity of the different frame materials. The original frame adjustment factors were constants derived from laboratory test data. However, in recent Handbook revisions, a range of adjustment factors was provided instead of a single value for each frame type, apparently to reflect the measured variation in U-Value for commercial products based on laboratory testing. However, the current data have limited value because the frame adjustment factors do not consider different product sizes or glass to frame ratios, and the frame factors are not applicable for the newer framing materials such as extruded vinyl, or composites of aluminum or vinyl-clad wood.

These limitations have been partially addressed in the 1989 Handbook. The format has been revised to provide a consistent set of winter design day data for currently important products. U-Value data in previous Handbooks for summer design conditions, and for combinations of added shades and storm sash are no longer considered important and have been eliminated. The revised format for *Table 13* in the 1989 Handbook should permit comparison between alternative products based on product size, glazing design and framing material. The actual table is too lengthy to present in this article. Therefore, the pertinent changes are summarized in the 1985 Handbook illustrations.

U-Values in the 1989 Handbook consist of calculated data for a variety of glazing systems and framing materials for two product types designated Type R (residential) and Type C (commercial). Part A of the table provides winter design U-Values for vertical glazing. Part B provides approximate factors to convert vertical data to sloped (45 deg) and horizontal orientation. Glazing unit descriptors include: one, two, or three glazing layers; glass, acrylic, or polyester film, and spacing dimensions of 1/4-, 3/8- or 1/2-in. (6, 10 or 13 mm) with emittance values of 0.84, 0.40 or 0.15; and gas fills of air or argon. The spacer material is assumed to be aluminum. Whenever a fenestration system differs from that assumed in the Handbook, such as due to different glazing spacings, emittances, spacer materials, frame conductances, etc., Equation 2 can be used to calculate the appropriate U-Value.

Comparison between uncoated insulating windows

To illustrate the changes appearing in the 1989 ASHRAE Handbook, uncoated insulating glass (e = 0.84) with an air fill is compared with previous Handbook data. *Figure 5a* displays overall U-Values for a double-glazed window with a 1/2-in. (13 mm) airspace having either a thermally-broken aluminum frame, a non-thermally-broken aluminum frame or a wooden or vinyl frame. *Figure 5b* displays similar data, however for triple-glazed windows with two 1/2-in. (13 mm) air spaces. (Note that the center-of-glass U-Value for these glazing units are identical with the 1985 Handbook data, therefore the differences are due to the edge-of-glass factors, frame geometry and thermal conductance.)

Figures 5a and *5b* show a significant increase in the 1989 U-Value data for aluminum-framed windows, especially without thermal breaks. These changes reflect the importance of frame geometry and thermal conductivity in computing overall U-Value. There are no significant changes noted for wooden-framed windows. Aluminum-framed windows show a greater difference between the Product Types R and C as compared to differences attributed to the range of adjustment factors previously used. The graphs depict both double glass and triple glass U-Values.

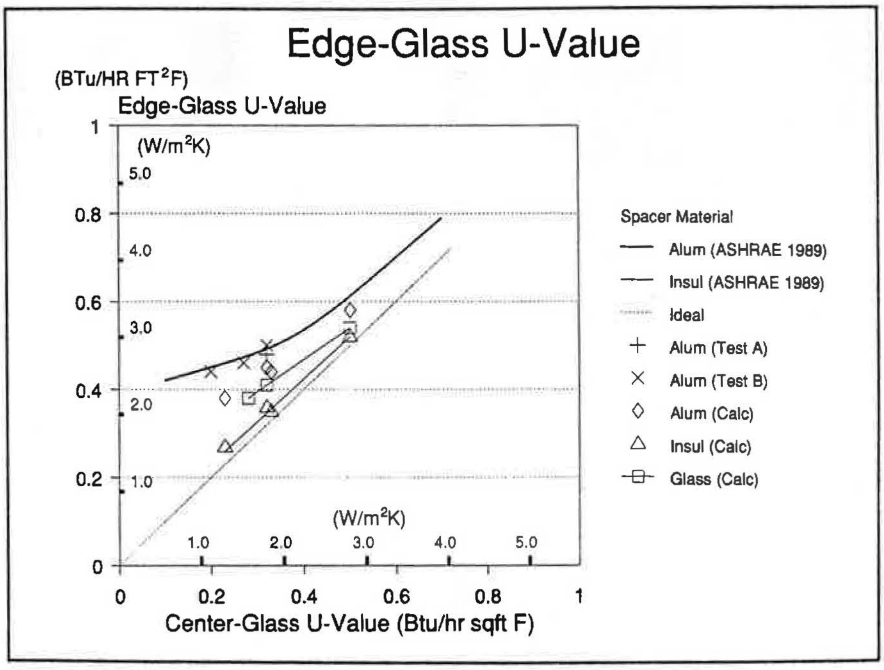

Figure 3. Edge-of-glass U-Value.

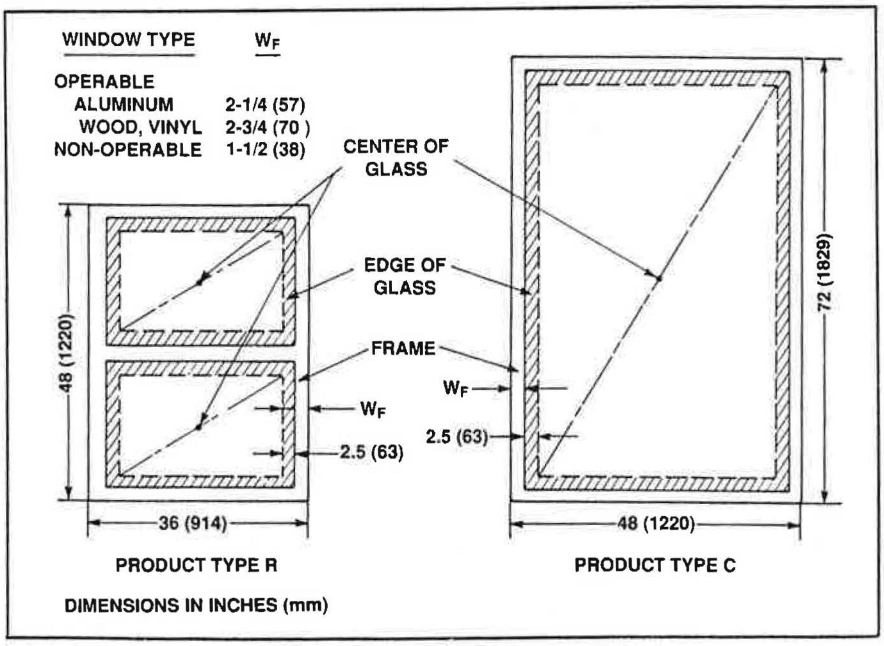

Figure 4. Frame geometry for Type R and Type C products

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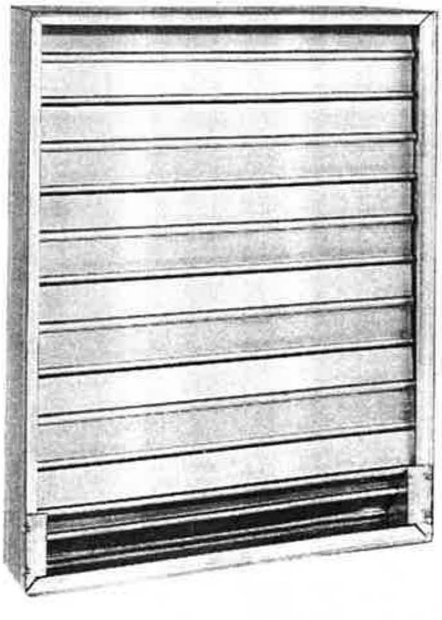

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Conclusions

Significant progress in reducing center-of-glass heat transfer has recently been made with commercially-available glazing units. However, reduction in edge and frame heat transfer still needs to be addressed. It is anticipated that the revised table of U-Values published in the *1989 ASHRAE Handbook—Fundamentals* will provide sufficient technical information to enable rational decisions to be made in specifying generic window products, and also would encourage manufacturers to develop improved products. It is apparent that additional subclassification of the different materials and construction techniques are required for framing members. Both analytical and experimental methods need to be further refined to assist in this important undertaking.

Acknowledgements

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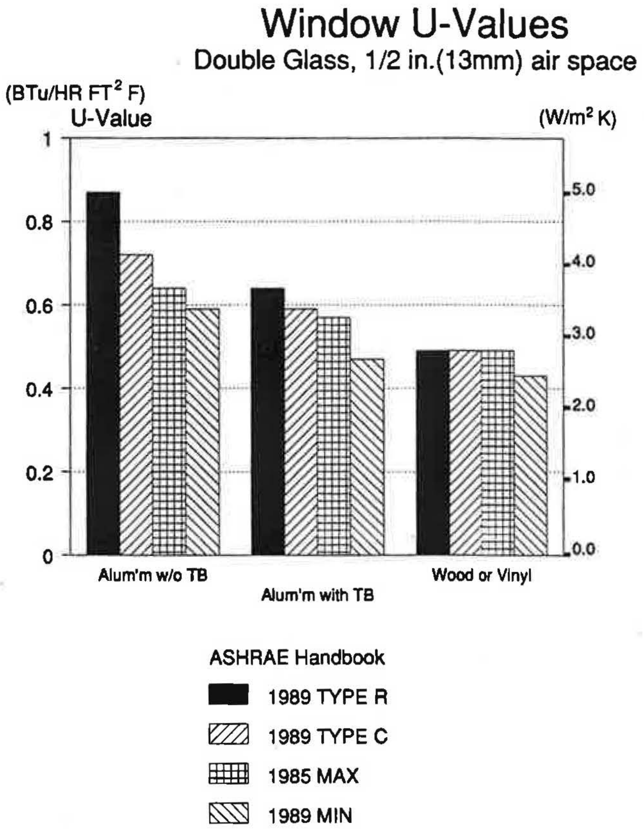

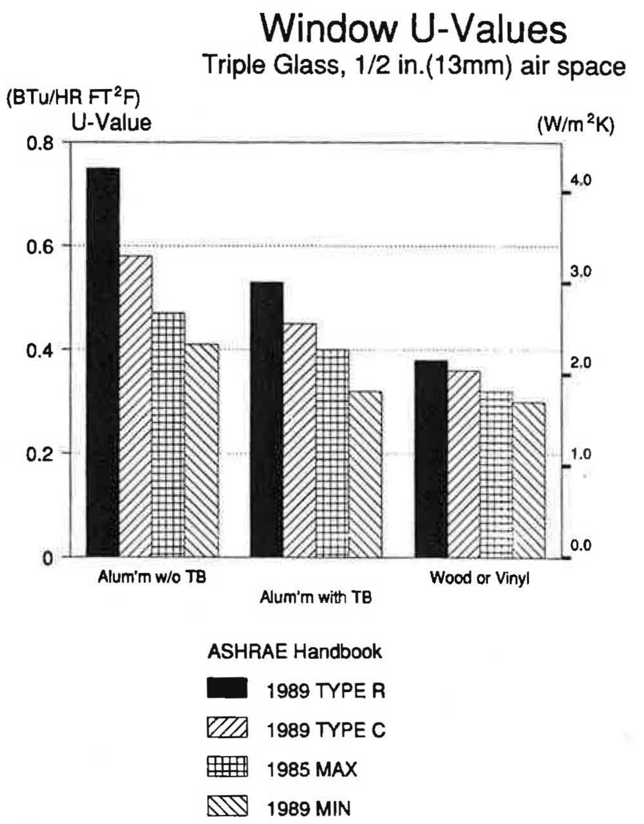

Figures 5A & 5B. Comparison of U-Values between 1985 and 1989 Handbooks, (a) double-glazed window, (b) triple-glazed window.