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Thermal Performance Measurements of Sealed Insulating Glass Units with Low-E Coatings Using the MoWiTT Field-Test Facility

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THERMAL PERFORMANCE MEASUREMENTS OF SEALED INSULATING GLASS UNITS WITH LOW-E COATINGS USING THE MoWiTT FIELD-TEST FACILITY

J. H. Klems and H. Keller

ABSTRACT

Using data obtained in a mobile field-test facility, measured performance of clear and low-emissivity double-glazing units is presented for south-facing and north-facing orientations. The changes in U-value and shading coefficient resulting from addition of the low-E coating are found to agree with theoretical expectations for the cold spring test conditions. Accurate nighttime U-values were derived from the data and found to agree with calculations. Expected correlation between U-value and wind speed was not observed in the data; a plausible experimental reason for this is advanced.

INTRODUCTION

Sealed insulating glass (SIG) units incorporating a low-emissivity (low-E) film represent a significant advance in energy-efficient windows and a substantial investment in new product development by the fenestration industry. Their properties are, therefore, of great interest. In addition to a lower U-value, which is expected to be approximately equivalent to triple glazing, low-E SIG units are expected to have a lower shading coefficient than clear double glazing, due to absorption of solar energy in the low-E film. Thus their net effect on heating or cooling loads, as compared with clear double glazing, is not simple. They will somewhat reduce daytime heat gains as well as nighttime winter heat losses.

A complete empirical understanding of low-E performance would consist of three parts: (1) a determination of the nighttime performance, its variability and dependence on external weather variables, (2) a determination of the amount of daytime heat gain and its variability, and (3) a method of determining what fraction of the heat gain offsets a heating load and what fraction imposes a cooling load on the space. This paper addresses the first two issues; the third, which is clearly critical to the overall energy performance of the fenestration, depends on the distribution of mass within the space adjacent to the fenestration and on the building demand, and it will require a combination of calculations and experiments for resolution.

At Lawrence Berkeley Laboratory we have constructed and calibrated a Mobile Window Thermal Test (MoWiTT) Facility. Consisting of dual, guarded, room-sized calorimeters in a mobile structure, the MoWiTT is capable of exposing two fenestration samples, each seeing a roomlike interior environment, simultaneously to ambient outdoor weather conditions, and of measuring the net heat flow though each fenestration with good accuracy. This measurement comes from a net heat balance on each calorimeter chamber, performed at short intervals. Measurements here were taken at 15-minute intervals, with each measurement an average over the previous interval. In order to make possible an accurate net heat balance measurement, together with control of the interior air temperature during the full diurnal cycle, each calorimeter chamber contains an electric heater, a liquid-to-air heat exchanger with measured flow rate and inlet/outlet temperatures, and a nearly continuous interior skin of large-area heat flow sensors. The MoWiTT is shown in Figure 1. Its design, theory, and error analysis have been discussed elsewhere (Klems et al. 1982; Klems 1984A; Klems 1984B).

Using the dual calorimeters of the MoWiTT, we have made simultaneous net heat flow measurements on clear and low-E SIG units over a period of several days in both south-facing and north-facing orientations. This allows a weather-independent comparison between the two.

It is important to recognize that the difference in nighttime performance between the two fenestrations is not expected to result in a large signal. One expects that there would be a difference of approximately 0.17 $\text{Btu/h} \cdot \text{ft}^2 \cdot \text{F}$ (0.97 $\text{W/m}^2 \cdot \text{K}$) between the U-values of the two fenestrations. For temperature differences of 40-70 F (22-39 K) this implies (for a residential-sized window) differences in heat flow on the order of 70-130 Btu/h (20-38 W). This difference must be distinguished from heat flows resulting from thermal storage in the apparatus, envelope conduction, and infiltration. Since these are potentially of larger magnitude, careful attention must be given both to systematic and to random errors (Klems 1985).

EXPERIMENTAL ARRANGEMENT

Two commercially fabricated sealed insulating glass units consisting of two lights of clear 4-mm thick glass, with a low-E coating on the number three surface of one of the two units, were mounted in identical test frames in the two calorimeter chambers of the MoWiTT, as shown in Figure 2. The MoWiTT was oriented with the sample-holding wall facing due south. The chambers were held at a temperature of 68 F (20 °C), and data were collected for eight days beginning on May 5, 1986. The MoWiTT was later turned to face due north and the measurement was repeated for 15 days, beginning on June 3, 1986. Between these two measurements, the low-E unit was replaced with single glazing and measurements made in each orientation as a check. Both before and after the tests, runs with single glazing were made to test for systematic errors between the two calorimeter chambers.

The tests were made at a field location in Reno, Nevada, in the late spring and early summer. When the south-facing measurements were taken, however, weather was unusually cold, including an unseasonable snowstorm on the first test day. The data presented here are, therefore, an admixture of (mild) winter and summer performance. Figure 3 shows the outside air temperature during the time of the south-facing measurements. It was measured with an aspirated RTD sensor located at the top of a 10-m weather tower on the test site. As can be seen, the minimum nighttime temperatures varied between 32 F and 41 F (0-5 C), with daytime highs from 41 F to 70 F (5-21 °C).

Wind speed and direction were measured using conventional cup-and-vane sensors mounted on the same weather tower. Data from these sensors are read rapidly and the perpendicular wind components averaged over the 15-minute recording period to produce a short-term average speed and direction. The resulting wind speed during the time of the south-facing measurements is shown in Figure 4. During this season in Reno, wind speeds tend to be high during the day and relatively low at night. Occasional nighttime wind speeds up to 15 mph (6.7 m/s) were observed during this period, with the modal wind speed in the neighborhood of 5 mph (2.2 m/s).

The terrain around the test site is quite flat. The environs include both open fields and low-rise urban construction. The elevation is 4490 ft (1370 m). There are 7500-ft (2300-m) mountain peaks 15 mi (25 km) to the east and 8200-ft (2500-m) mountains 7.5 mi (12 km) to the west, resulting in shading at solar altitudes of approximately 5° and 12°, respectively. Incident solar flux was measured with three instruments: a horizontal pyranometer, a tracking pyrheliometer, and a vertically mounted pyranometer located on the sample-holding wall. Total incident flux on a vertical surface, measured by the latter instrument, is shown for the south-facing measurements in Figure 5.

Prior to moving the MoWiTT to the field, we carried out a series of tests to determine the accuracy of each chamber. In these tests, the sample openings were closed and covered with insulation and additional large-area heat flow sensors. The result was to make each chamber a closed box with redundant measurements of the net heat flow into or out of it. By raising and lowering the chamber and guard temperatures and introducing known amounts of heating into the chamber, we were able to check the performance of each component of the net heat balance measurement. Tracer-gas measurements were used to establish that the infiltration rates for the two calorimeters were negligible.

RESULTS

The measured net heat flows through the two insulated glass units are shown in Figure 6 for the south-facing orientation and in Figure 7 for the north. The qualitative features expected are borne out in the data: daytime inward heat flows are smaller for the low-E SIG unit than for the clear double-glazed unit, and nighttime outward heat flows are also smaller. From the data for the southern orientation, one can infer that the low-E unit has a shading coefficient that is 78% that of the clear unit.

From the net heat flow measurement, the nighttime U-values of the fenestrations may readily be derived. These are shown for the data for the southern orientation in Figure 8. The data for the first night, which show a significantly larger U-value than the subsequent days for both fenestrations, occurred during the storm mentioned earlier, when there was both rain and snow. We believe that the larger U-values may be due to precipitation on the outer light of glass, with an enhanced heat flow due to lowered glass temperature. If all the data in each curve are averaged, with the exception of the first day, we obtain a value of 0.43 ± .02 Btu/h·ft^2·F (2.42 ± .10 W/m^2·K) for the U-value of clear double glazing and 0.29 ± .02 Btu/h·ft^2·F (1.68 ± .10 W/m^2·K) for the U-value of low-E double glazing.

In Figure 9, measured nighttime U-values for the same data are plotted against wind speed for clear double glazing and in Figure 10 for low-E. "Nighttime" in this context is defined as after 1 a.m. and prior to the time when the approach of sunrise produces a measurable radiant flux on the sample-holding wall. The high U-value points, in the neighborhood of 3 W/m^2·K in Figure 9 and in the neighborhood of 2.1-2.5 W/m^2·K in Figure 10, come from the anomalous first night and should be disregarded. The data for both SIG units are inconsistent with a positive correlation between U-value and wind speed. This observation does not change if one restricts the data to winds in either the windward or leeward hemisphere, or if one plots U-value against the normal or tangential component of the wind velocity.

DISCUSSION

It must be stressed that these data were obtained quite recently, with some as late as June 1986. There has thus been limited time for analysis; and not all of the questions of possible experimental effects raised by the data have been explored. The data should, therefore, be taken as preliminary. Because of the high interest in low-e glazing, however, we consider it worthwhile to report those aspects of the data unlikely to change on further analysis.

For the data for the southern orientation, the observed reduction of the solar heat gain for the low-E unit to 78% of that of the clear unit is to be compared with an expected value of 82%. We do not consider the difference to be significant at this time; we need to measure the optical properties of the component glasses and construct an improved reflectance model for coated glazings before calculating an expected value in which we have great confidence. For the same reason, we do not yet attempt to determine whether the absolute values of the daytime heat transfer meet theoretical expectations.

We have used the program WINDOW 2.0 (Arasteh 1986; Rubin 1982) to calculate theoretical U-values and have used a value of 0.1 for the emissivity of the low-E coating, a value supplied by the manufacturer. The measured average U-values imply a U-value reduction of 30 ± 5% resulting from adding a low-E coating. This is consistent with the expected value of 35% calculated for ASHRAE standard winter conditions. The measured U-values of 0.43 ± .02 Btu/h·ft^2·F (2.42 ± .10 W/m^2·K) for clear double and 0.29 ± .02 Btu/h·ft^2·F (1.68 ± .10 W/m^2·K) for low-E are somewhat lower than the values of 0.50

Btu/h·ft^2·F (2.85 W/m^2·K) and 0.32 Btu/h·ft^2·F (1.84 W/m^2·K), respectively, expected for ASHRAE standard winter conditions. However, as is apparent from figures 3 and 4, neither the outside temperature nor the wind speed were those of the ASHRAE standard conditions. The average nighttime wind speed is approximately 4 mph, and the average nighttime temperature is 4° C. When the expected values are recalculated for these conditions, one obtains a value of 0.47 Btu/h·ft^2·F (2.69 W/m^2·K) for clear double glazing and 0.29 Btu/h·ft^2·F (1.65 W/m^2·K) for low-E. These are in considerably better agreement with the measurements; for low-E, the agreement is excellent. We do not yet have a firm enough knowledge of the potential systematic errors in the measurements to attach significance to the remaining discrepancy between calculation and measurement for clear double glazing.

The most puzzling aspect of the data is the absence of a positive correlation between U-value and wind speed in figures 9 and 10, especially since invoking the wind speed dependence produces better agreement between measured and calculated U-values. One would expect a rise in the U-value in Figure 9 to around 2.8 W/m^2·K at 15 mph, which is not consistent with the data.

One possible explanation for this observation lies in the time delay still inherent in the MoWiTT net heat flow measurement. Although the heat flow sensors exclude the effects of envelope heat storage, there is still enough thermal mass inside the sensors (for example, a plywood floor) to give the calorimeters a lag time on the order of one hour. If the wind speed changes markedly within periods of an hour, this lag time would wash out the correlation. Figure 3 then reveals that periods for which nighttime wind speeds were much greater than 5 mph tended to be short, making this explanation a plausible one. Since we currently have no data with stable wind speeds of markedly different magnitudes, further exploration of this effect must await the winter test season, when further tests are planned.

CONCLUSIONS

We conclude that the U-value and (with less certainty) the shading coefficient reductions produced by adding a low-E coating to a sealed insulating glass unit are consistent with theoretical expectations when measured under field conditions. For accurate prediction of performance, it is advisable to use actual or estimated temperature and wind conditions rather than values for ASHRAE standard conditions. Failure to observe a positive correlation with wind speed may be due to instrumental effects. The MoWiTT has proved capable of measuring small U-value differences accurately, even under conditions of rather small inside-outside temperature difference, demonstrating that useful data may be obtained under a wide variety of climatic conditions.

REFERENCES

Arasteh, D. 1986. *Window 2.0 user reference guide,* to be published.

Klems, Joseph H.; Selkowitz, Stephen; and Horowitz, Sy. 1982. "A mobile facility for measuring net energy performance of windows and skylights." An Foras Forbartha, *Energy Conservation in the Built Environment (Proceedings of CIB W67 Third International Symposium),* Vol III, p. 3.1, Dublin, Ireland.

Klems, J. H. 1984A. "Measurement of fenestration performance under realistic conditions." *Windows in building design and maintenance,* Gothenburg, Sweden.

Klems, J. H. 1984B. "Measurement of fenestration net energy performance: Considerations leading to development of the mobile window thermal test (MoWiTT) facility." Presented at the American Society of Mechanical Engineers Winter Annual Meeting, New Orleans, LA, December 9-14; Meeting paper No. 84-WA/Sol-7.

Klems, J. H. 1985. "Error analysis of in-situ field tests of fenestration net energy performance." *Energy and Buildings,* Vol. 8, No. 3, pp. 165-173.

Rubin, M. 1982. "Calculating Heat Transfer Through Windows." *International Journal of Energy Research,* Vol. 6, No. 4.

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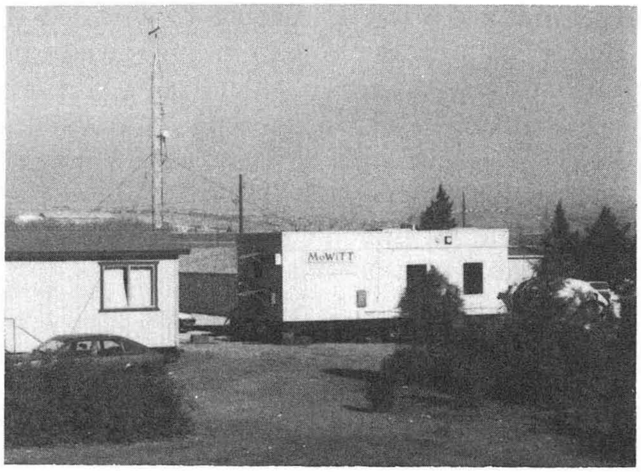

Figure 1. The Mobile Window Thermal Test (MoWiTT) Facility.

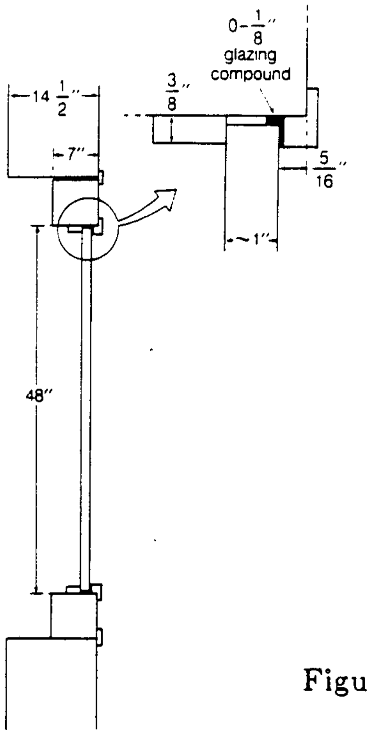

Figure 2. Window installation section.

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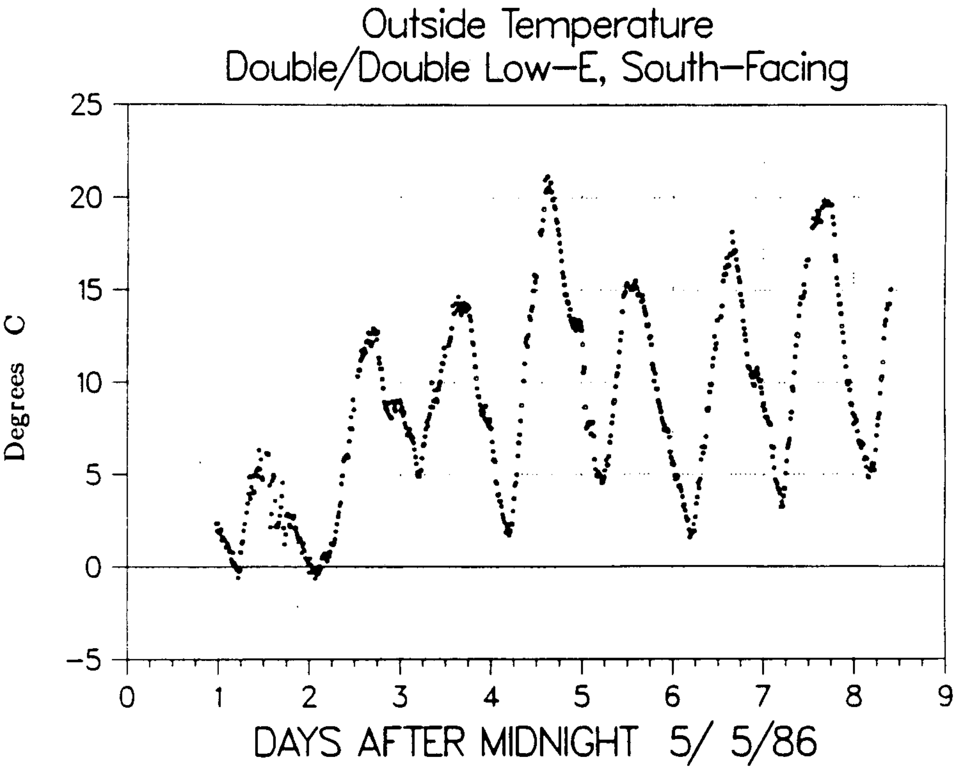

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Figure 3. Outside temperature, southern orientation.

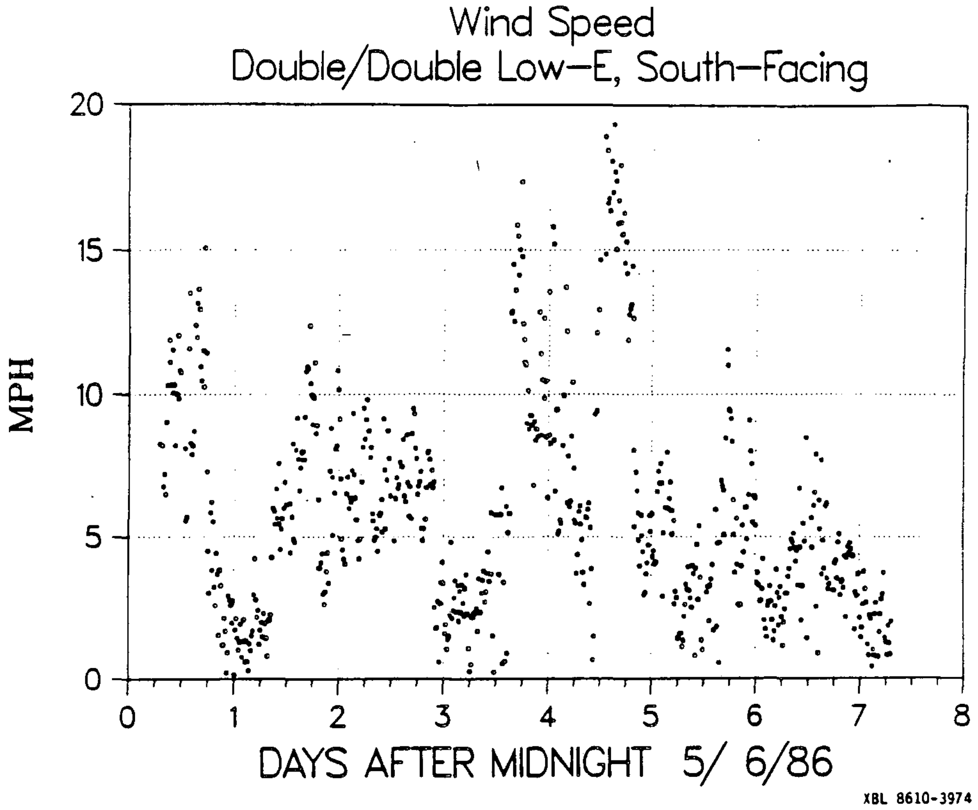

Figure 4. Wind speed, southern orientation.

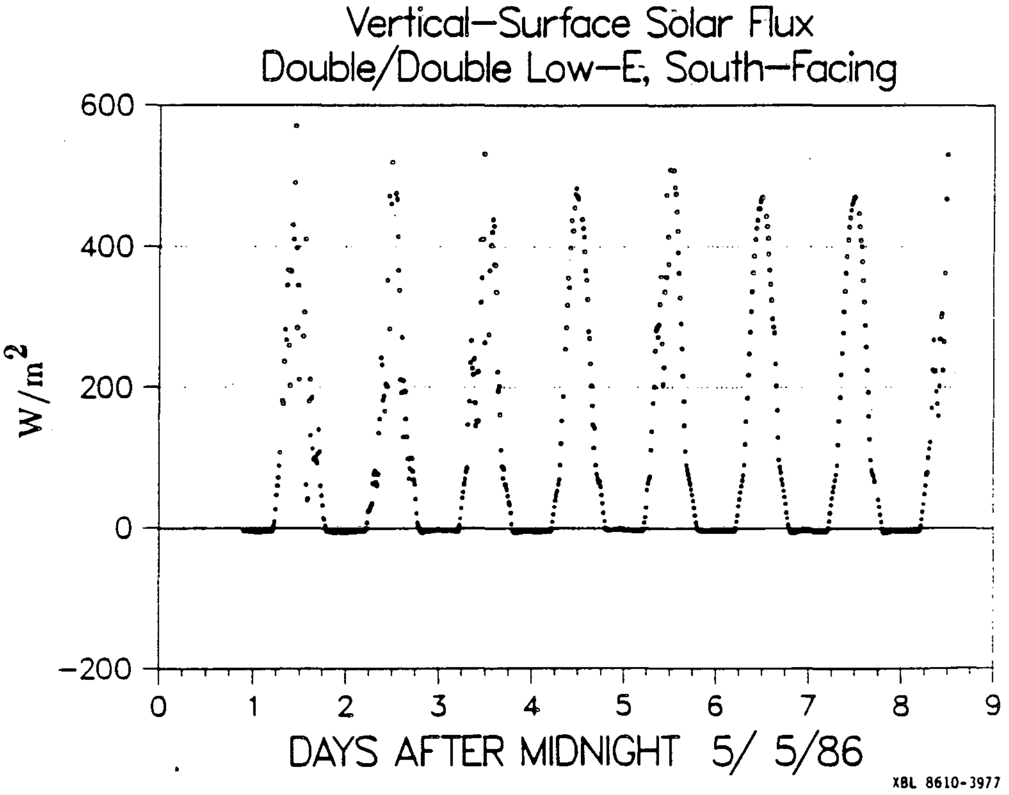

Figure 5. Vertical-surface solar flux, southern orientation.

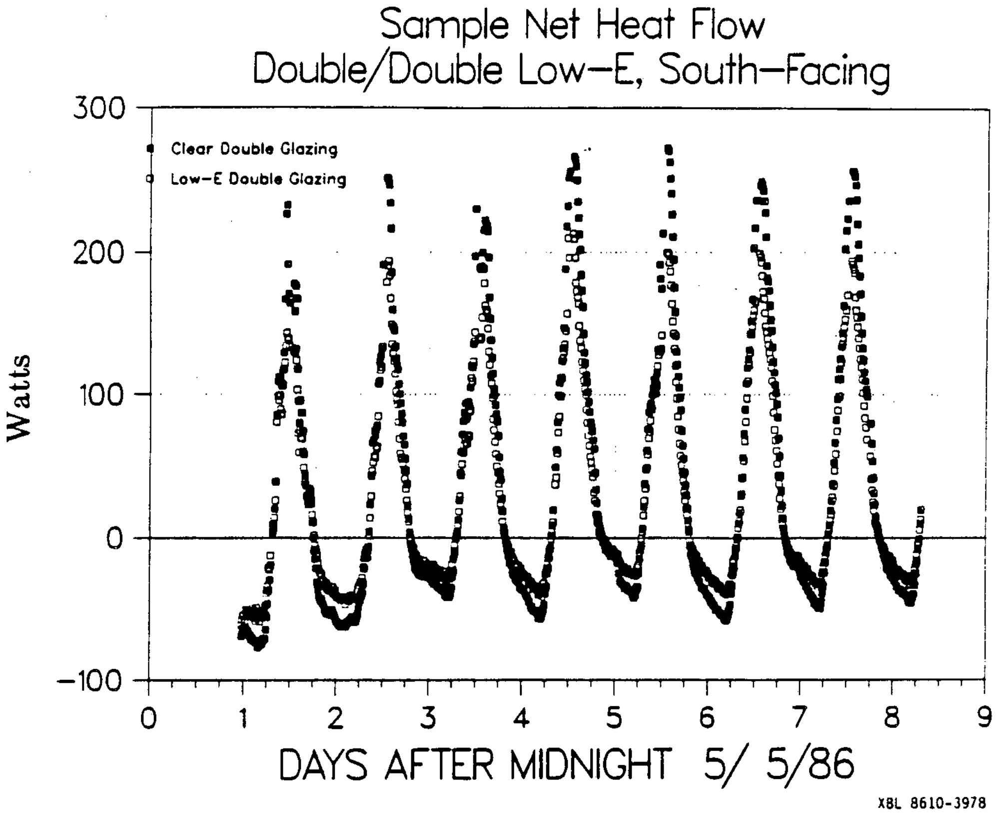

Figure 6. Measured net heat flow thru test sample, southern orientation.

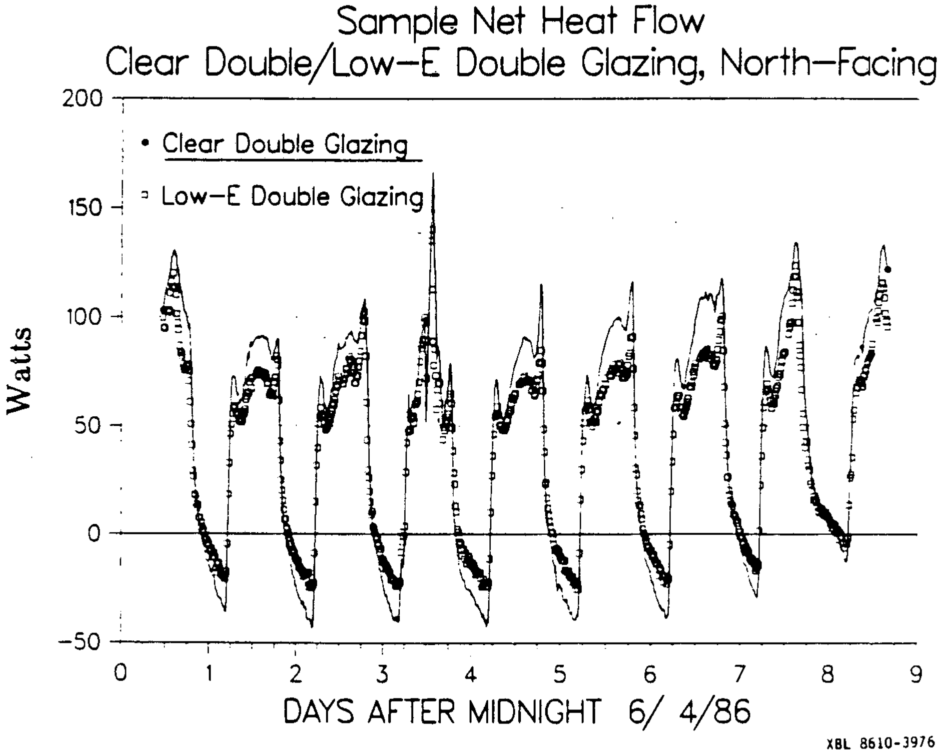

Figure 7. Measured net heat flow thru test sample, northern orientation.

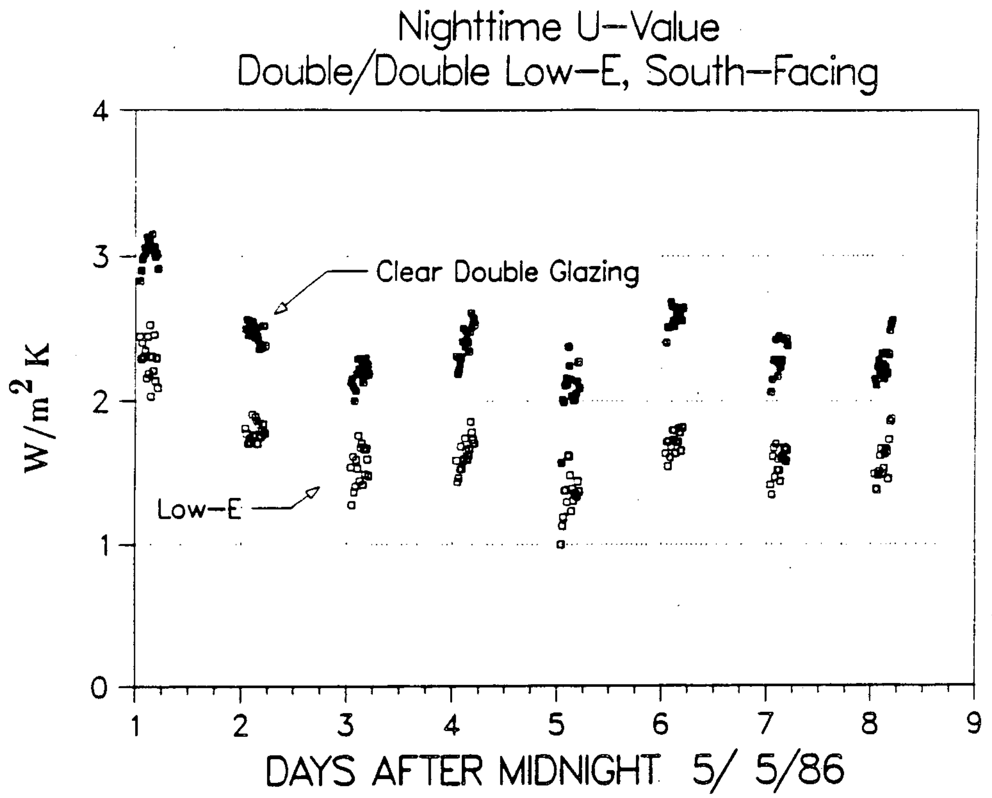

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Figure 8. Measured nighttime U-value, southern orientation.

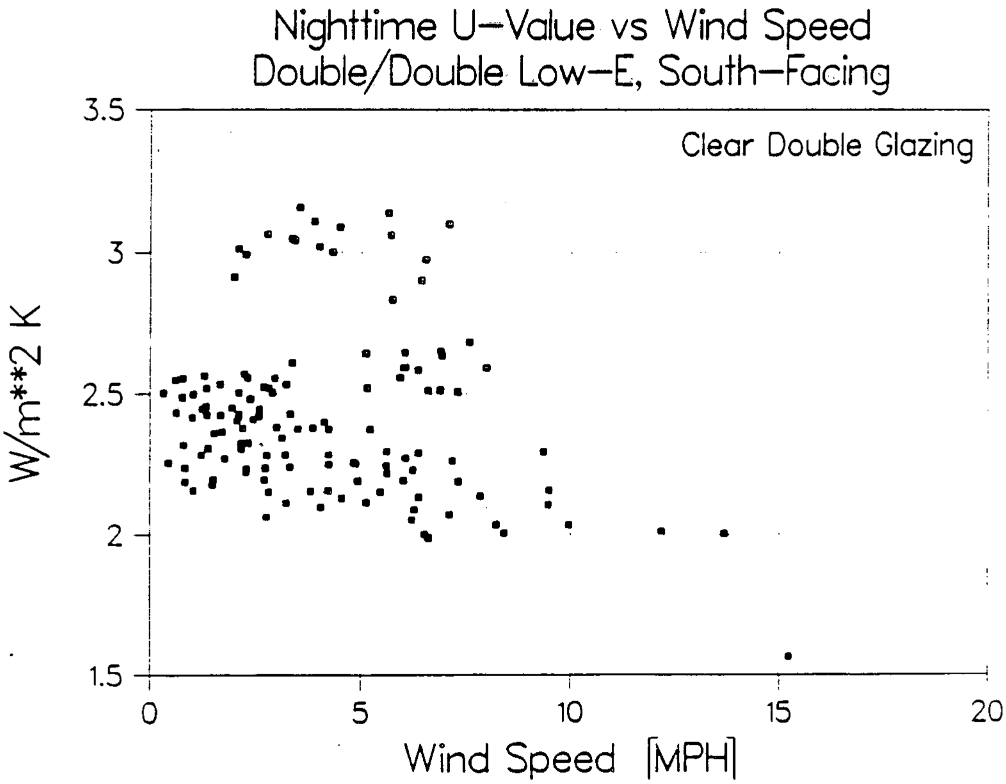

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Figure 9. Measured nighttime U-value vs wind speed, clear double glazing, southern orientation.

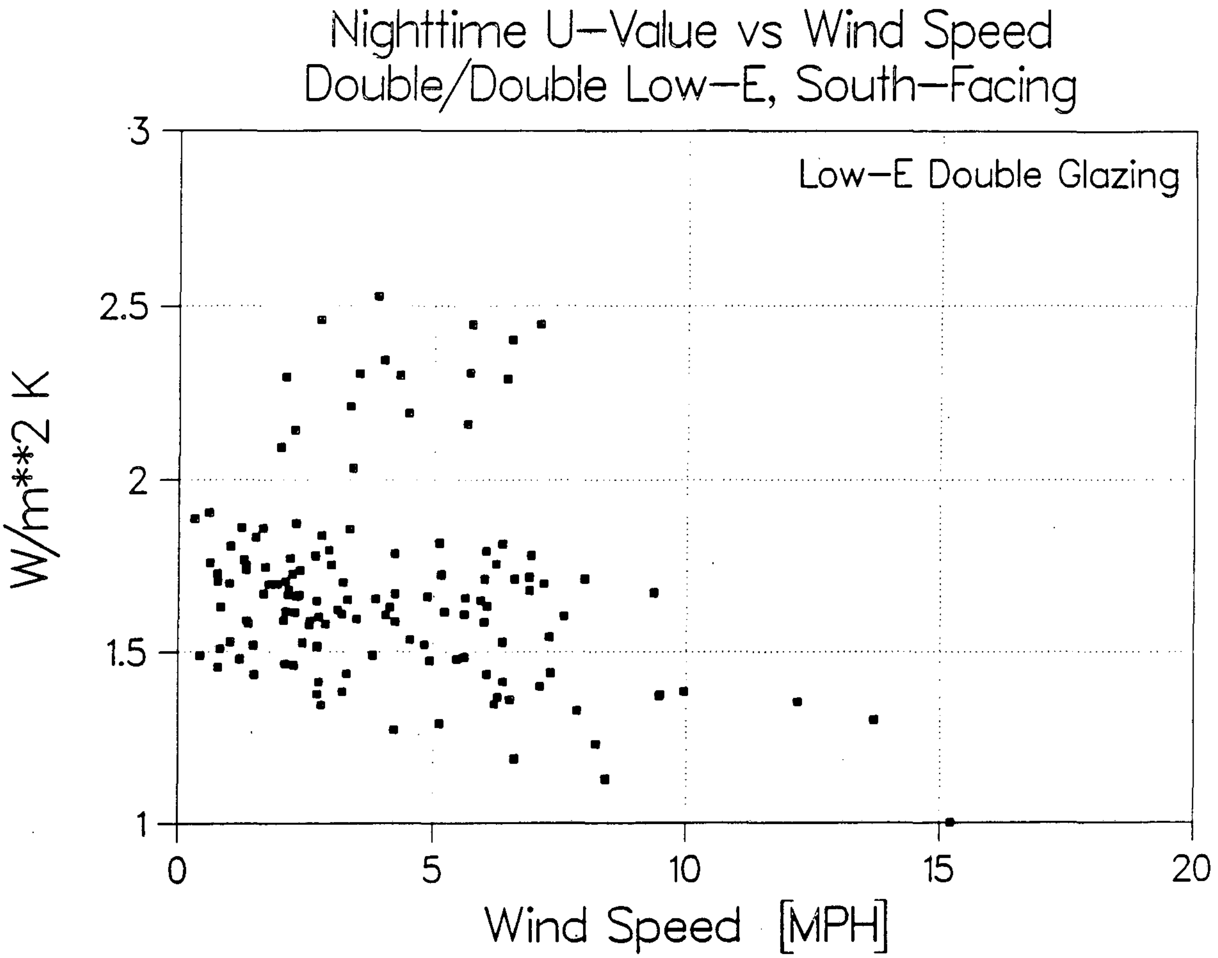

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Figure 10. Measured nighttime U-value vs wind speed, Low-E double glazing, southern orientation.

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