Insulating Window Shade Evaluation: Quantifying the Benefits of Double Honeycomb Shades with Air-Sealing Side Tracks

Introduction

CARB, the Consortium for Advanced Residential Buildings, is one of six research teams working through the Department of Energy's Building America program to evaluate residential energy technologies; the ultimate goal is cost-effective "zero energy" homes. Working with partner Comfortex Window Fashions, CARB set out to investigate thermal benefits of insulating window shades in cold climates. Some newer honeycomb shades can be equipped with side tracks through which (or over which) the honeycomb shade slides. These tracks have the ostensible benefit of reducing air movement between the conditioned space and the space behind the shade (next to the cold window). A relatively new product, ComforTrak™ Plus, includes a springy polymer gasket intended to provide better sealing and less air movement between the conditioned space and space behind the window.

Figure 1. Shade sample with ComforTrak showing the translucent, polymer gasket. Photo is taken from the back of the shade (the side normally facing the window).

With window shades provided by Comfortex, CARB monitored the thermal performance of shades in eight residential windows in two Connecticut homes over a two week period in February-March 2010. CARB installed temperature and humidity sensors at several locations between the window and the shade, outdoors, and indoors to assess thermal performance. CARB also used infrared thermography to qualitatively assess thermal and comfort conditions.

Initial questions that CARB hoped to answer by this analysis included:

- What is the approximate, effective R-value of these honeycomb window shades?
- Does the apparent, effective R-value differ when used in older (leakier) windows rather than newer (quite air-tight) windows?
- How does the apparent, effective R-value change with and without the use of the ComforTrak?
- Can we document any local comfort effects of the shades with and without ComforTrak?

Experimental Setup

CARB evaluated insulating shades on four windows in each of two Connecticut homes:

- a home with newer (2008), insulated, low-e, vinyl-framed, double-hung windows;
- a home with older, single-pane, double-hung, wooden windows with exterior aluminum storm windows.

Two twin, double-hung windows were tested in each home (a total of eight windows). Insulating shades – Comfortex's double-honeycomb light blocking shades – were installed on all windows. All windows were equipped with ComforTrak Plus, but at each pair of windows, the tracks were removed from one window for the testing period.

To record air temperatures, CARB used HOBO dataloggers from Onset Computer as follows:

- On the interior surface of each window (between the window and insulating shade), CARB installed four HOBO U12 temperature and humidity loggers. A sensor was installed at the center and near the edge of the glazing in both top and bottom sashes (see Figure 2).
- On each external wall containing tested windows, a U12 logger was installed to measure air temperature near the external wall.
- To record air temperatures in the interior part of the room, a U12 logger was installed away from the windows (such as on a partition wall) in each room containing windows.
- Outside each home, a HOBO U23 logger was installed to record outdoor conditions.

Temperature and humidity values were recorded every five minutes for approximately three weeks in February-March 2010. In addition, CARB used a Flir b50 infrared camera to record surface temperatures of the window shades and surroundings. Images were taken late in the evening or early in the morning to eliminate solar impacts.

Figure 2. Temperature and humidity loggers installed with masking tape on two windows in the newer home. Windows are double-pane with vinyl frames.

Figure 3. Temperature loggers installed on two of the windows in the older home. Windows are single-pane, wood frame, with aluminum storms.

Results

Infra-Red Thermography

IR images of all window pairs show very consistent results (see Figure 4 through Figure 6). The interior surface temperatures of each shade on the right – the shade without side tracks – are clearly higher than the interior surface temperatures of shades with side tracks (on the left in each pair). Clearly, there is more air communication between the warm rooms and the spaces behind the shades when side tracks are not installed. The cold, blue bands at the edges of shades without side tracks could also result in local comfort issues, though the effects would likely be small and only when people are very close to the windows.

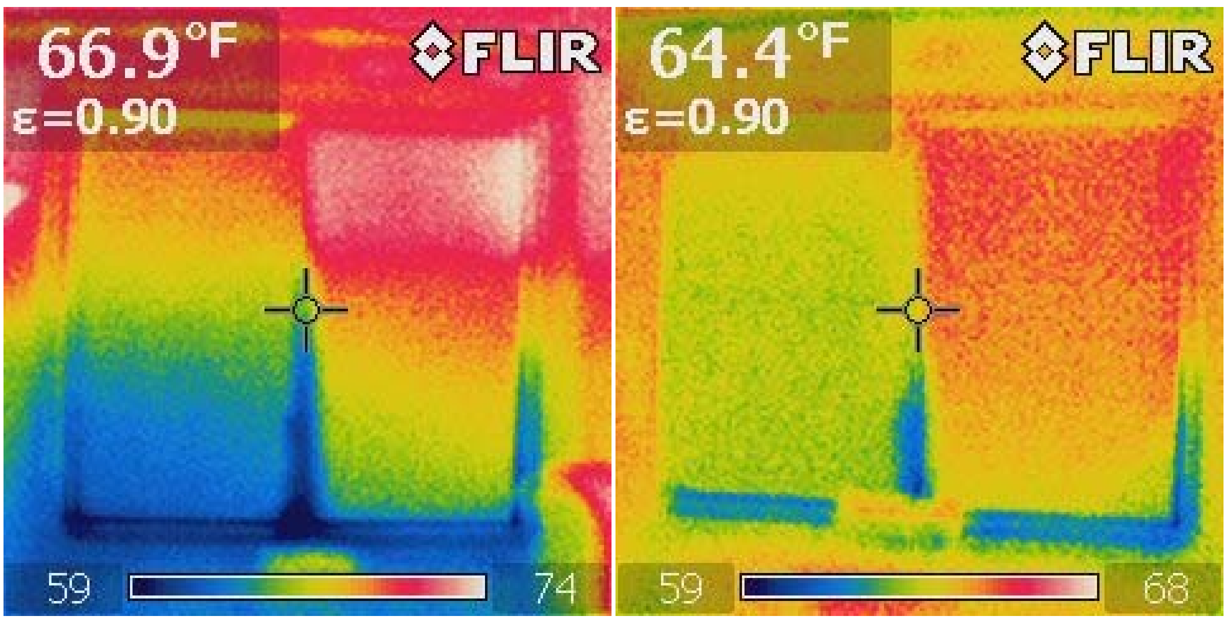

Figure 4. Infrared images of the two pairs of windows in the newer home (taken from indoors). All shades are closed; the ComforTrak is installed on the left window of each pair; there are no tracks on the right-hand windows. The large temperature gradients evident in the left image were caused by a nearby wood stove.

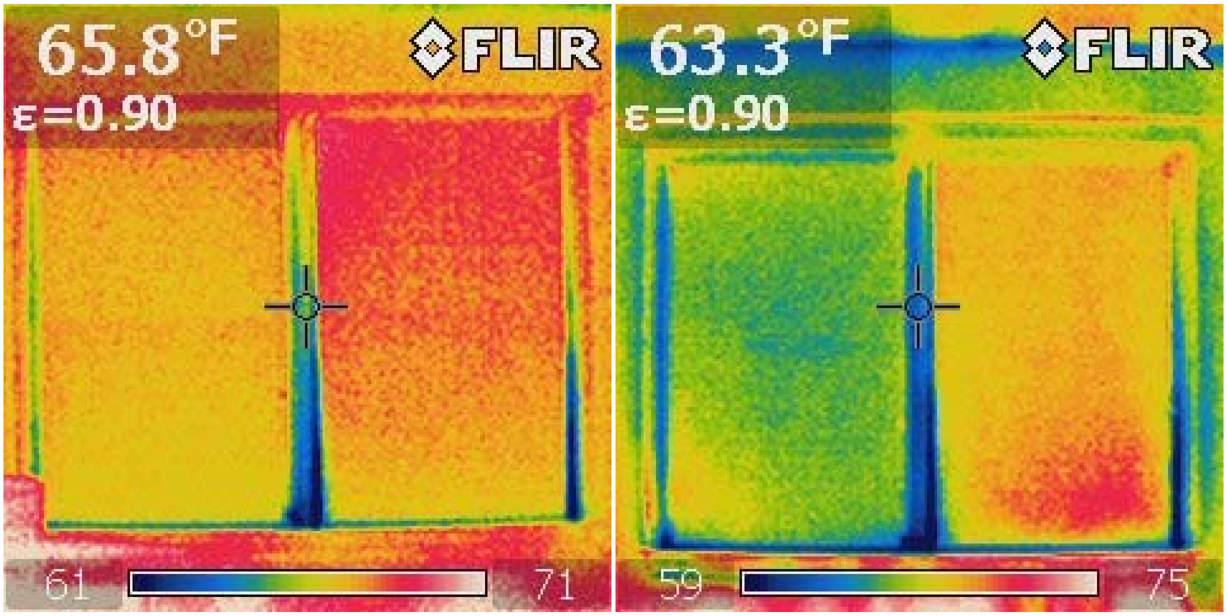

Figure 5. Infrared images of the two pairs of windows in the older home (taken from indoors). All shades are closed; the ComforTrak is installed on the left window of each pair; there are no tracks on the right-hand windows.

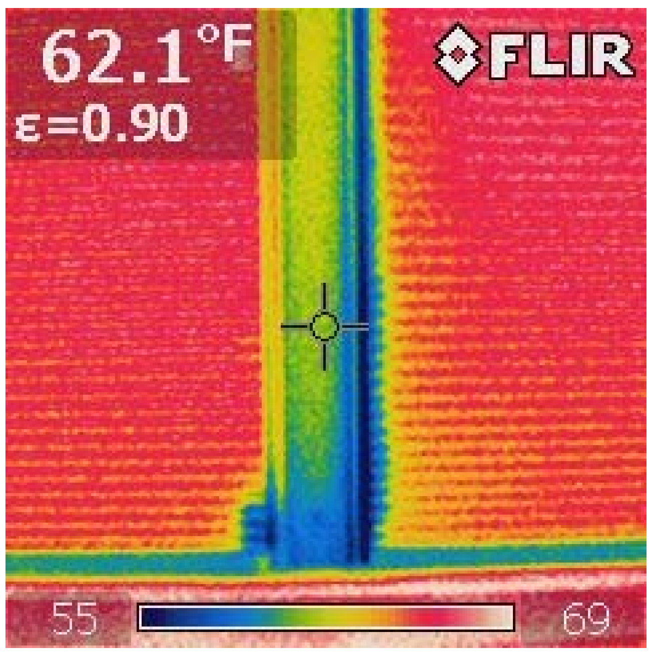

Figure 6. The center of one pair of windows in the older home near the sill. The shade without ComforTrak (on the right) is evident from the cold, blue band at the edge.

Temperature Profiles

To gauge performance, CARB focused on five nights during the monitoring period where indoor and outdoor temperatures were relatively consistent in both homes (no large temperature swings). Outdoor temperatures were generally between 25°F and 40°F. As the infrared images show, air temperatures in the cavities behind shades with side tracks were much lower than temperatures behind shades with side tracks (also see Figure 7).

For brevity, results from all windows are not shown, but all pairs of windows showed similar temperature trends as shown in Figure 7. It's also noteworthy that temperatures in the cavities behind the shades often vary much more when side tracks are not installed. For example, the four green temperature lines in Figure 7 are hardly distinguishable; the four purple temperature lines show much more variation. For the effective R-value calculations (discussed below), CARB only used values after temperatures had reached a fairly steady state. For the night shown in Figure 7, for example, the time period from 10:00pm to 6:00am was used for calculations.

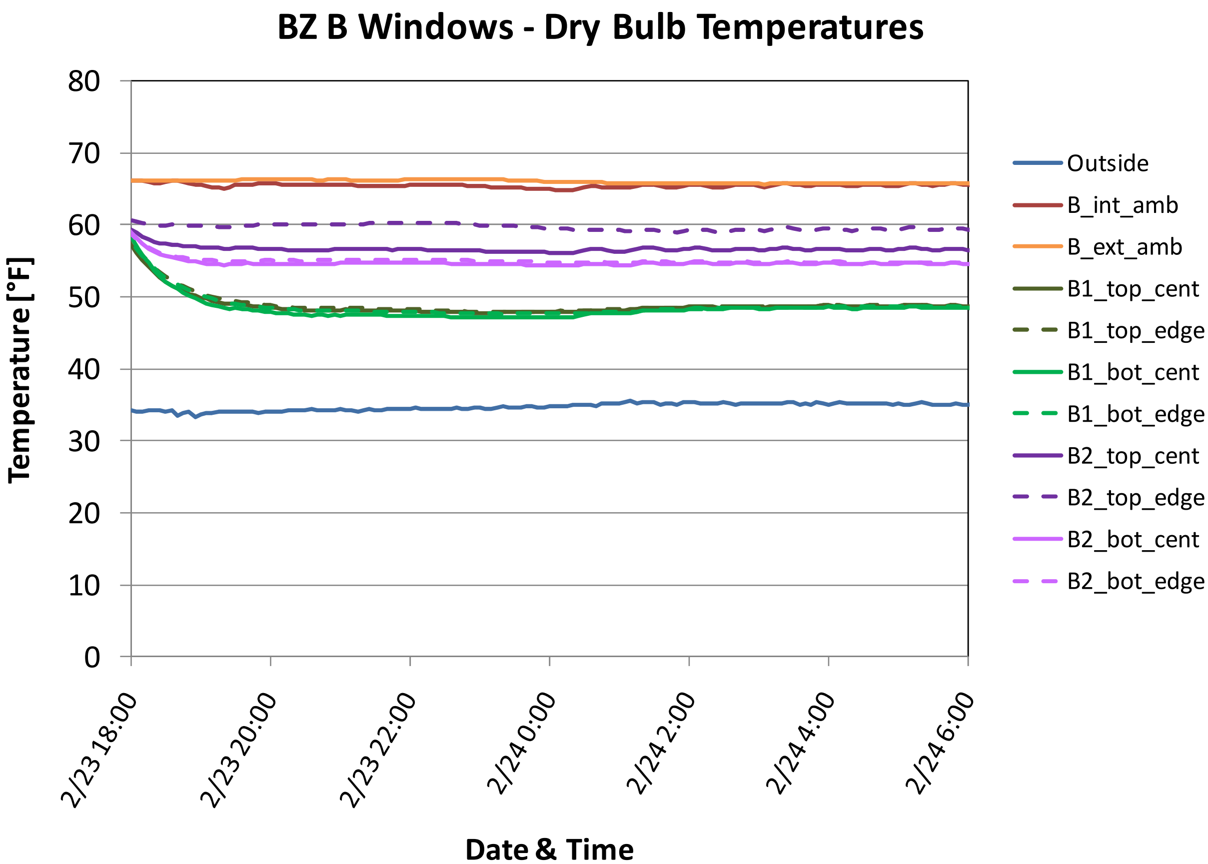

Figure 7. Chart showing temperatures for one pair of windows in the newer home over one night. Red and orange lines show interior temperatures (near interior and exterior walls, respectively). The four green lines show temperatures behind the shade with side tracks; the four purple lines show temperatures behind the shade without side tracks. "Top" and "bot" refer to top and bottom sashes; "cent" and "edge" refer to location on the sash – at the center or near the edge (see Figure 2).

Effective R-Value Calculations

R-value is typically defined as resistance to thermal conduction. In this evaluation, separating and quantifying other types of heat transfer (radiation and convection) were outside of the scope. CARB used simple temperature monitoring equipment and simple analysis methods to calculate an effective R-value for the window shades – it's certain that these values include convection and radiant effects as well as conductive.

One foundation of these simple analyses was that heat flow through the window assembly and heat flow through the window shade were equal. CARB used the rated (in the case of the new windows) or estimated (in the case of the older windows) U-values to calculate heat flux through the window as follows:

$$\dot{Q}=U_{window}\left(T_{shade}-T_{out}\right)$$

where:

$\dot{Q}$ = Heat flux [Btu/ft^{2}h]
U_{window} = Conductance of the window [Btu/ft^{2}hr°F]
T_{shade} = Average air temperature between the window shade and window [°F]
T_{out} = Air temperature outside [°F]

As heat loss through the shade was assumed to be equal to heat loss through the window, effective R-value of the window shade was calculated as follows:

$$R_{eff}=\frac{T_{in}-T_{shade}}{\dot{Q}}$$

where:

R_{eff} = Effective shade R-value [ft^{2}hr°F/Btu]
T_{in} = Interior temperature [°F]

CARB performed these calculations at each five-minute monitoring interval over five nights during the monitoring period. The five nights used were chosen based on consistent, relatively steady-state temperature conditions (both indoors and outdoors) and relatively cold outdoor temperatures. The NFRC rated U-value for windows in the new home is 0.33 Btu/ft^{2}hr°F. Based on several references, most notably *ASHRAE Handbook of Fundamentals*, the estimated U-value for windows in the older home (single-pane wooden windows with aluminum storms) was 0.65 Btu/ft^{2}hr°F. Small differences is this U-value had minor impact on the calculated effective R-values; CARB believes that air movement – as described below – introduces much more uncertainty in the analysis. For each of the five nights evaluated, the average effective R-values of the shades are shown in Table 1 and Table 2.

Table 1. Average effective R-values of window shades in the older home.

	Avg. T_{out}	Average, Effective R-values [$ft^2hr°F/Btu$] With Side Track		Without Side Track	
Night	[°F]	A1	B1	A2	B2
Feb 24	35	2.5	2.4	1.0	0.8
Feb 25	37	2.3	2.3	1.0	0.8
Feb 27	29	2.5	2.2	1.0	0.8
Feb 28	32	2.3	2.1	0.9	0.8
Mar 5	33	2.4	2.4	0.9	0.9
	Overall Avg:	2.4		0.9	

Table 2. Average effective R-values of window shades in the newer home.

	Avg. T_{out}	Average, Effective R-values [$ft^2hr°F/Btu$] With Side Track		Without Side Track	
Night	[°F]	A1	B1	A2	B2
Feb 24	35	4.2	3.9	1.4	1.3
Feb 25	36	4.2	2.7	1.3	1.3
Feb 27	30	5.9	4.7	1.5	1.4
Feb 28	32	4.7	4.1	1.4	1.4
Mar 5	35	5.2	4.5	1.5	1.4
	Overall Avg:	4.4		1.4	

Discussion

From quick reviews of Table 1 and Table 2, several items are observed:

- Effective R-values of window shades with side tracks are much higher than effective R-values of shades without side tracks;
- Effective R-values of window shades in the newer home are much higher than effective R-values of window shades in the older home;
- In window shades with side tracks in the newer home, calculated effective R-values vary considerably from window to window and from night to night.

The first bullet is certainly expected. Because the effective R-values calculated include convective heat transfer (air moving between the warm interior and space behind the shades), it is certainly expected that the side tracks improve resistance to heat flow. It appears that the side tracks increase effective R-value by approximately 2.5 - 3 times.

The fact that the apparent R-values of shades in the older home are much lower was more surprising. However, CARB believes that this discrepancy is again caused by air movement. The simple R-value calculations assume that all heat flow through the window is conduction (using the U-value of the window as the basis for calculations). With older, leakier windows, there is often a great deal of energy loss caused by air movement – outdoor air coming in and/or warmer indoor air leaking out – and measuring such air flow is difficult and was beyond the scope of this study. In the older home, if there is more air movement through the window and therefore through the shade assembly, heat loss will certainly be larger and effective R-values will be lower. The side tracks reduce, but do not eliminate, air movement through the shade assembly. With a larger driving force from infiltration through the window, infiltration through the shade may increase also.

CARB's simple R-value calculations also assume that heat flow through the window assembly is equal to the heat flow through the shade; where air movement plays a larger roll in heat transfer this assumption may not be valid. If, for example, there is more air movement (and therefore more heat transfer) through the window than there is through the shade assembly, the calculated effective R-value will be lower than the "real" R-value (again because this simple analysis assumes the two heat transfer values are equal).

Without relying on this type of speculation, however, CARB believes that the effective R-values of window shades in the newer home – especially the shades with side tracks – are more accurate because air movement through these new, tight windows is minimal.

Regarding the final bullet above, CARB can find no clear explanation why effective R-values vary from window to window nor from night to night. There seems to be no correlation with outdoor temperature conditions. It's possible that wind played a roll in these discrepancies (wind speeds were not measured as part of this study). The windows in the newer home had slightly different geometry (the "A" windows in Table 2 are slightly larger). It's also possible that window shades were not closed tightly or consistently from night to night – small gaps near the sill might cause significant differences in calculated R-values.

Conclusions

When used properly, insulating, double-honeycomb shades can reduce heat loss through windows. As expected, the addition of a side track – such as the ComforTrak Plus system evaluated – can reduce heat loss through windows even further.

Because convection and small amounts of airflow play a large role in heat transfer through window assemblies, accurately measuring heat loss and/or real R-values is very challenging. CARB believes, however, that the average, effective R-values of 4-5 $ft^2hr°F/Btu$ calculated for the Comfortex double honeycomb shades with ComforTrak Plus as installed in a new, air-tight window is reasonably accurate under the tested conditions. This system had minimal air movement (which is responsible for most of the uncertainties in this study).

In all windows tested, the calculated, effective R-values of the window shades with side tracks were 2.5 to 3 times higher than for the same shades without side tracks. Given the rated U-value of the vinyl windows used in this test (0.33, or R-3.0), adding R- 4 to the assembly provides a robust R-7 (U-0.14) for the window when the shade is in the closed position. When limiting heat transfer is a key criterion for selecting window treatments, CARB would recommend side track devices or systems that similarly reduce air exchange between the warm indoor space and space behind the shade.