RESEARCH HIGHLIGHT

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The Effects of Reflective Interior Shades on Cooling Energy Consumption at the CCHT Research Facility

INTRODUCTION

Past shading experiments at the Canadian Centre for Housing Technology[1] (CCHT) twin-house research facility revealed that opaque exterior shades provide an effective means of reducing air conditioner cooling loads. However, similar trials of interior Venetian blinds provided evidence of only a slight daily savings (<1 per cent) in cooling energy consumption on the clearest days. Unfortunately, exterior shading is not always an option due to location: the exterior of fixed windows on the upper stories of apartment buildings or homes is not easily accessed by residents for temporary shading during summer months. Cost can also be a limiting factor—it is difficult to justify the expense of an elaborate exterior shading system when the cooling season is so short in many parts of Canada. For these reasons, Canada Mortgage and Housing Corporation (CMHC) is interested in finding a simple and inexpensive means of reducing the cooling loads from the interior of the home.

The purpose of this project was to evaluate the potential of a reflective interior shading device to reduce cooling loads, while carefully observing the shade's effect on window temperatures. It was hoped that this device would offer significant savings in cooling consumption, producing energy savings for consumers, and helping to reduce the peak cooling-season demands on utilities.

RESEARCH PROGRAM

The evaluation of the reflective shades was carried out at the CCHT's twin-house research facility in Ottawa, Canada in the summer of 2005. The twin-house facility has been in operation since 1998, and has been the site of many side-by-side comparisons of energy saving technologies. The unique nature of the facility allows researchers to not only evaluate energy savings, but also the whole house effects including temperatures and humidity. The houses are equipped with over 250 sensors and continuous data monitoring.

BACKGROUND AND METHODOLOGY

Shading Technology

The reflective shading prototype was conceived by CMHC. The shades were built from materials readily available at the hardware store. The shade itself was made from a reflective insulation product: a double layer of 8-mm polyethylene bubble wrap sandwiched between two layers of 99.9 per cent aluminum foil. The foil-covered bubble wrap was mounted in a typical screen frame, sized to fit the window. A one-inch gap was left at the top and bottom of the screen, between the foil and frame, to encourage air circulation between the screen and window, prevent window temperatures from exceeding safe levels, and to maintain a more uniform temperature distribution (see Figure 1).

Figure 1 Three reflective shades mounted on the interior of a south-facing window

[1] The Canadian Centre for Housing Technology is jointly operated by the National Research Council, Natural Resources Canada, and Canada Mortgage and Housing Corporation. This research and demonstration facility features two highly instrumented, identical R-2000 homes with simulated occupancy to evaluate the whole-house performance of new technologies in side-by-side testing. For more information about the CCHT facilities please visit http://www.ccht-cctr.gc.ca

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Figure 2 Benchmark shading configuration – Venetian blinds in the down position with slats horizontal

Evaluation

Both CCHT houses feature argon-filled windows with a low-E coating on surface three. High-efficiency 12 SEER air conditioning units provide cooling, while standard furnace circulation fans provide continuous air circulation. To determine the effect of a given technology, the two CCHT houses are first benchmarked under identical conditions, and then a single element is changed in the "Test" house. In benchmark conditions, Venetian blinds in both houses were kept in the down position with slats horizontal (Figure 2). During the experiment, the reflective shades were installed on the interior side of nine south-facing windows, and one west-facing window of the CCHT Test House (see Figure 3). The shading devices were mounted in the normal interior side screen position (where possible), or 1-2" from the interior window surface. In total, the shades covered a south-facing window pane area of 9.4 m^2 and a west-facing window pane area of 1.3 m^2.

Two different shading strategies were evaluated:

- 24-hour shading: leaving the shades in place 24 hours/day
- 9 to 5 shading: installing the shades at 9 a.m., and removing them at 5 p.m.

The 24-hour shading strategy was evaluated over a total of 11 days, while the 9 to 5 shading strategy was evaluated for a total of 7 days.

Figure 3 Windows shaded during experiment, west face (left) and south face (right)

FINDINGS

Energy Savings

Both the 24-hour shading strategy and the 9 to 5 shading strategy produced substantial daily savings in cooling energy consumption (air conditioner and circulation fan electrical consumption). Savings were highest on days with the largest solar gains, when the shades were the most effective at reducing the amount of solar energy entering through the windows.

During their respective test periods, the 24-hour shading strategy produced up to 4.60 kWh of cooling energy savings on the sunniest days (13 per cent of that day's expected cooling consumption without shades, 34.2 kWh), while the 9 to 5 strategy produced up to 3.73 kWh of savings (11 per cent of that day's expected cooling consumption without shades, 34.39 kWh). To determine seasonal savings, the data were projected to the entire 2005 cooling season—a very warm season for Ottawa, with a total of 460 cooling degree-days above 18°C. Calculations revealed that the 24-hour shading strategy is expected to produce approximately 9.9 per cent seasonal savings in cooling energy consumption for the CCHT Test House, while the 9 to 5 shading strategy is expected to produce slightly less savings, 9.0 per cent. The difference between these seasonal savings is attributable in part to the shading of the west window. In the 9 to 5 strategy, all shades are removed from the house at 5 p.m. In the 24-hour strategy, the west window shade remains in place, shading the house from evening solar gains.

As expected, the majority of these energy savings occurred between 9 a.m. and 5 p.m. On the days with the highest solar gains, the strategies reduced the cooling energy consumption during the 9 a.m. to 5 p.m. time period by up to 29 per cent for the 24-hour shading strategy, and 27 per cent for the 9 to 5 strategy. This effect would not only benefit consumers, but also utilities. The largest savings from this shading device would occur on the hottest, sunniest hours of summer, times when summer utility peaks typically occur.

Window Temperatures

Practical experience indicates that while the glass and seal themselves are capable of withstanding high temperatures, the temperature limits for the glazing unit are defined by the temperature differential between the center and the edge of the glass. When the edge of the glass is cooler than the centre, tensile thermal stresses are produced that can lead to breakage. The higher the differential, the higher the tension introduced in the glazing unit. Window cracks are generally initiated at an edge defect created in manufacturing. Thermal cycling to high temperatures encourages damage to appear and propagate. For this reason, the centre to edge temperature differential should be less than 30°C in order to avoid potential cracking, particularly if the cut edge quality is poor.

Both during and prior to the experiment, window surface temperatures were measured at the edge and center of the interior pane. In normal operation, the window surface temperature reached 45°C, and the centre-to-edge temperature differential remained below 5°C. While shaded by the reflective shades, surface temperatures at the centre of the window exceeded the normal operating conditions by more than 30°C, reaching a maximum of 68.7°C on the sunniest day (see Figure 4). Additionally, the temperature differential between the centre and edge of glass approached the 30°C limit. Although no damage was observed during the course of the experiment, the use of the reflective shades with argon-filled windows with a low-E coating on surface three (exterior surface of interior pane) contributed to increased thermal stresses at the limits of normal operation, and could lead to breakage.

Without the air gap between the shade and the window to provide some air circulation, window surface temperatures skyrocketed to upwards of 80°C by 11 a.m., at which time the shade was removed to avoid damaging the glazing unit.

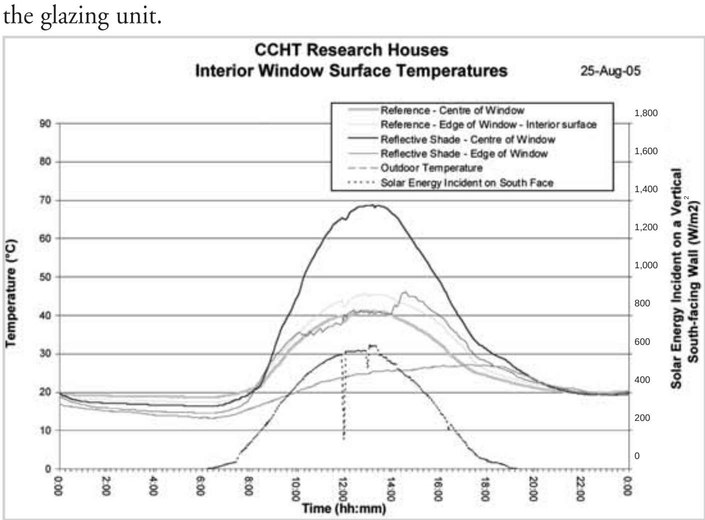

Figure 4 Window interior surface temperatures

LIMITATIONS OF THIS STUDY

Savings from shades will vary depending on the houses, types of window and mechanical setups. Care should be taken in applying these results to other homes, due to certain attributes of the CCHT facility. Some of the issues that should be kept in mind include:

- The CCHT houses are built to maximize the southern exposure of windows, and thereby solar gains. This reduces the winter heating load, but also contributes to an increase in summer cooling requirements. Because of the large contribution of solar gains to the summer cooling load, shading provides a substantial benefit. Less benefit from shading would be expected in houses with a smaller window area on the south face.
- The windows of the CCHT research houses are all double pane, argon-filled, with a low-emissivity coating on surface three. Solar radiation heats the interior pane of the window (containing the low-E coating), causing surface temperatures to rise. This heat is trapped, since the interior shade prevents radiation into the house and reflects it back to the window. Argon gas prevents the transfer of heat out through the window. The result is high temperatures building up between the shade and window surface, approaching the limits of safe operation. Different temperature effects, and energy savings, would be expected with other types of window. For example: an air-filled window would be expected to conduct heat more readily than argon, allowing the heat to dissipate outwards; the interior surface of a window without any coatings would be expected to stay cooler. More evaluations are required to explore the use of this kind of shading device with other types of windows.
- The CCHT houses are built to R-2000 standards; therefore, they prevent heat gains and heat losses better than older houses. In older, less insulated and looser construction, the solar heat gains through windows may be less significant when compared to heat gains from outdoor temperatures.
- The CCHT houses are unfurnished. Without furnishings, the houses contain less thermal mass than a typical inhabited house. Thus, the houses would respond more quickly to changes in temperature and retain less heat from the day.
- The CCHT houses were operated in air conditioning mode throughout the cooling season. In real life, a homeowner would likely shut off the cooling system periodically in favor of opening the windows on cool nights or days. For this reason, the projected seasonal savings from this study could be higher than would be expected in practice.
- Savings calculations were based on the installation of shades for 24 hours per day or from 9 a.m. to 5 p.m. every day for the entire cooling season. Lower seasonal savings would be expected from shorter periods of shading.

CONCLUSIONS/IMPLICATIONS FOR THE HOUSING INDUSTRY

The reflective shades proved to be effective in reducing cooling energy consumption by approximately 9 per cent for the entire cooling season. However, the use of this radiant barrier product as a shade cannot be safely recommended for use with argon-filled windows with a low-E coating on surface three, due to the resulting window surface temperatures.

A full report on this project is available from the Canadian Centre for Housing Technology.

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Housing Research at CMHC

Under Part IX of the *National Housing Act*, the Government of Canada provides funds to CMHC to conduct research into the social, economic and technical aspects of housing and related fields, and to undertake the publishing and distribution of the results of this research.

This fact sheet is one of a series intended to inform you of the nature and scope of CMHC's research.

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