A PRELIMINARY ASSESSMENT OF THE SOLAR SHADE SCREEN SYSTEM FOR REDUCING RESIDENTIAL COOLING LOADS

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SUMMARY

A preliminary assessment was conducted of an exterior shade screen system designed to reduce residential cooling loads by restricting solar gains through windows. The analysis showed that the system has the potential to significantly reduce the design cooling load, save space cooling energy, permit (in some cases) the use of a smaller capacity air-conditioning system and, if combined with other low-energy cooling techniques, may permit the air-conditioning system to be eliminated.

As part of the analysis, the design cooling loads were estimated for a typical 147 m^2 (1584 ft^2) bungalow using various window types and glazing distributions. The analysis, which was performed for three locations (Winnipeg, Montreal and Toronto) showed that in all cases, the shade screens reduced the design cooling load by approximately one-third, roughly 1.8 kW (0.5 tons).

The retail cost of the shade screens was estimated at \$38.12/m^2 (\$3.54/ft^2), assuming that production and installation were performed by a window manufacturer and included with the purchase of new windows. The cost of retrofitting the shade screens to existing windows was estimated to be two to three times greater.

A series of field observations were also made of the screens installed on four typical bungalows in Winnipeg. These showed that: proper tensioning of the fabric mesh was required to prevent optical distortions, an improved system was needed for mounting the screens, house appearance was not negatively affected by the screens and that homeowner reaction to the screens was generally favourable.

Recommendations were made for further, more detailed, studies to investigate the system's impact on the annual cooling load and on methods to integrate the screens with other, low-energy methods of reducing the cooling load.

This study was conducted as part of the Flair Homes Energy Demo/CHBA Flair Mark XIV Project.

RÉSUMÉ

On a effectué une évaluation préliminaire d'un système d'écrans pare-soleil extérieurs conçu pour réduire les demandes de froid résidentielles, en limitant les gains solaires à travers les fenêtres. L'analyse a révélé que le système a la capacité de réduire substantiellement la demande de froid de calcul, d'économiser l'énergie de refroidissement des espaces, de permettre, dans certains cas, l'utilisation d'une installation de conditionnement d'air de plus faible capacité et, utilisé conjointement avec d'autres techniques de refroidissement à faible énergie, de permettre l'élimination de l'installation de conditionnement d'air.

Dans cette analyse, les demandes de froid de calcul ont été estimées pour un bungalow type de 147 m^2 (1 584 pi^2), muni de divers types de fenêtre et de distributions de vitrage. L'analyse, qui a été effectuée pour trois emplacements, soit Winnipeg, Montréal et Toronto, a révélé que dans tous les cas, les écrans pare-soleil réduisaient la demande de froid de calcul d'à peu près un tiers, soit environ 1,8 kW (0,5 tonne).

Le prix au détail des écrans pare-soleil a été estimé à 38,12 $\$/m^2$ (3,54 $\$/pi^2$), en supposant que la production et l'installation étaient effectuées par un fabricant de fenêtres et qu'ils étaient compris avec l'achat de fenêtres neuves. Le coût de réadaptation des écrans pare-soleil à des fenêtres existantes a été estimé à deux ou trois fois plus.

On a effectué également une série d'observations sur le terrain d'écrans pare-soleil installés sur quatre bungalows types, à Winnipeg. Les observations ont révélé qu'une tension appropriée des mailles du tissu était requise pour prévenir les distorsions optiques, que le système de montage des écrans devait être amélioré, que l'apparence de la maison ne se trouvait pas dégradée par les écrans et que la réaction du propriétaire aux écrans était généralement favorable.

Il a été recommandé d'effectuer d'autres études plus détaillées afin de déterminer l'incidence du système sur la demande de froid annuelle et en vue de trouver des méthodes pour intégrer les écrans à d'autres méthodes de réduction, à faible énergie, de la demande de froid.

Cette étude a été effectuée dans le cadre du Projet de démonstration de la maison à haut rendement énergétique/Mark XIV de l'ACCH, de Flair Homes.

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SECTION 1

INTRODUCTION

1.1 RESIDENTIAL COOLING

Most energy conservation measures are designed to reduce space heating or domestic hot water consumption since these are generally the largest energy loads in Canadian houses. However, in some locations space cooling can also be significant. Fortunately, many of the measures which reduce a house's space heating requirements, such as higher insulation levels and improved airtightness, also reduce the need for air-conditioning.

A problem experienced by some houses, particularly those which are energy efficient, is their susceptibility to summer overheating if the windows have been sized and orientated to maximize winter solar gains. Overheating can occur if external window shading is not provided by overhangs, other architectural features or adjacent vegetation or buildings. Often, little can be done to reduce solar gains during the summer, thereby forcing the homeowner to use mechanical air-conditioning to maintain comfort levels. For most new houses the single largest component of the cooling load is solar gain through windows. Measures which reduce this load, particularly on houses without external shading, are of interest.

One system which is available, but has received little attention in Canada, is the solar shade screen concept. This system uses a high density mesh screen mounted on the exterior of the window to reduce solar gains during the summer. Unlike interior curtains and blinds, solar radiation is blocked by the screens before it enters the living space and therefore it does not contribute to the air-conditioning load. The screens are designed to be removed during winter so that passive solar heat gains are not affected. The mesh weave is sufficiently open to permit a degree of visual transparency.

Aside from reducing cooling loads, other benefits of window shade screens include reduced glare, increased privacy and reduced fabric fading. Negative aspects include reduced visibility through the window and the need to install and remove the screens at the beginning and end of the summer. Solar shade screens have found limited use in Canada, although some have found application on commercial structures. They are however, more common in the southern United States and Europe where cooling loads and air-conditioning costs are more significant.

1.2 OBJECTIVE

The objectives of this study were to perform a preliminary assessment of the exterior shade screen concept as a method for reducing residential cooling loads and to offer recommendations for further research.

1.3 SCOPE

Acknowledging the preliminary nature of the study, the scope was restricted to three broad areas of investigation:

- o The impact of solar shade screens upon the design cooling load of a typical house located in different Canadian cities, assuming various orientations and window types,
- o The costs and benefits related to their use and,
- o General field observations on the performance of solar shade screens.

1.4 THE FLAIR HOMES ENERGY DEMO/CHBA FLAIR MARK XIV PROJECT

The work described in this report was conducted as part of the Flair Homes Energy Demo/CHBA Flair Mark XIV Project. This project was created in 1985 to provide a demonstration of various energy conservation technologies, products and systems which might be suitable for the Canadian home building industry. The specific objectives of the project were:

1. To demonstrate and evaluate the performance of various low energy building envelope systems.
2. To demonstrate and evaluate the performance of various space heating, hot water heating and mechanical ventilation systems.
3. To transfer the knowledge gained in the project to the Canadian home building industry.

Support for the project was provided by Energy, Mines and Resources Canada under the Energy Demo Program and by Manitoba Energy and Mines under the Manitoba/Canada Conservation and Renewable Energy Demonstration Agreement (CREDA). Project management was the responsibility of Flair Homes (Manitoba) Ltd. Project monitoring and reporting were performed by UNIES Ltd., consulting engineers, of Winnipeg.

The project was also designed to provide technical support to the R-2000 Home Program, which is funded by Energy, Mines and Resources Canada and administered by the Canadian Home Builders Association (CHBA). The CHBA's "Mark XIV" designation was acquired when a major portion of the research priorities identified by the CHBA's Technical Research Committee was incorporated into the work plan.

To meet the project's objectives, 24 houses were constructed in Winnipeg by Flair Homes Ltd. and independently monitored for periods of up to three years. Energy conservation levels ranged from those of conventional houses to those which met or exceeded the R-2000 Standard.

1.5 SYSTEM DESCRIPTION

The solar shade screen system consists of three main components: a mesh screen, mounting frame and attachment system. The mesh screen can be likened to a conventional window insect screen, except that a higher density mesh is used and it is mounted on the exterior of the window. The mesh can be manufactured from vinyl, fibreglass or metal and is commercially available in various colours and textures. Ideally, it should block out a significant portion of the incident radiation and allow the heat absorbed by the screen and glazing to be carried away by wind action or natural convection.

A wide range of shading coefficients can be obtained using different weave densities and filament orientations. The shading coefficient is also affected by the angle of the incident solar radiation relative to the screen surface and typically increases at higher sun angles. For south-facing windows this means that the maximum benefit is obtained during the hottest periods of the day. The mesh is available from several manufacturers.

Mounting frames, which are generally produced from lightweight aluminum extrusions, are somewhat heavier than those used for insect screens because the mesh must be under greater tension to prevent waviness in the fabric. Various clip-on or hinge systems can be used to attach the assembly to the window. They should be easy to install (preferably without tools), yet capable of securely holding the screens during high wind conditions.

1.6 FIELD EXPERIENCES

Four sets of solar shade screens were manufactured and installed on the windows of Houses #21 to #24 of the Flair project. These houses were designed to meet (or nearly meet) the requirements of the R-2000 Standard. Their main floor areas averaged 97 m^2 (1050 ft^2), with south-facing glazing areas of 5.1 m^2 to 7.5 m^2 (55 ft^2 to 81 ft^2), giving south-facing window-to-main floor ratios of 5.4% to 8.0%. The houses were not equipped with central air-conditioning systems and, since none received significant external shading, were considered susceptible to summer overheating.

The screen mesh was obtained from Bay Mills Ltd. of Brampton, Ontario. Mounting frames were constructed from commercially-available aluminum extrusions. Final assembly was performed by a local window manufacturer for three of the houses and by UNIES Ltd. staff for one house. The completed assemblies were attached to the exterior window sashes using wood screws.

Houses #22 to #24 were occupied in the summer of 1988 and their owners given explanations and directions for the use of the screens. House #21 was maintained as an unoccupied research structure and the screens installed as required.

SECTION 2

IMPACT UPON THE DESIGN COOLING LOAD

2.1 METHOD OF ANALYSIS

The impact of the shade screens upon the design cooling load for a typical Canadian house was evaluated using the simplified procedure described in the ASHRAE Handbook of Fundamentals (ASHRAE 1989). The design cooling load was defined as the maximum estimated load for the structure at the 2.5 % dry-bulb temperature under clear sky conditions. The house's interior temperature was assumed to be 24 °C while the appliance load was set at 470 W (Watts), and the occupancy load at 268 W to represent four people.

For the analysis, a hypothetical 147 m^2 (1584 ft^2) well-insulated bungalow with low natural air leakage as described in Table 1, was used. Two window configurations were considered, a solar-optimized distribution in which 50% of the glazing faced south and a non solar-optimized configuration in which the window area was equally distributed on all four exposures. Both double and triple-glazed conventional windows were considered. The analysis was performed for three locations: Winnipeg, Montreal and Toronto. The house was treated as being unshaded by adjacent structures, vegetation, etc.

The reduction in transmitted solar radiation due to the shade screens was assumed to be 50%, which resulted in overall window/screen shading coefficients of 0.44 and 0.40, respectively, for double and triple-glazed windows with the screens installed. Although less transparent screen materials are available, 50% was chosen to provide a conservative estimate of their impact. The thermal resistance of the windows was assumed to be unaffected by the presence of the screens. Results of the analysis are summarized in Tables 2 and 3, and Figs. 1 to 4.

2.2 RESULTS

The shade screens were found to reduce the design cooling load by about one-third, or roughly 1.8 kW (6100 Btu/hr or 0.5 tons) for each of the cases studied. Similar reductions were found for both double and triple-glazed windows while the design cooling load, and the savings produced by the shade screens, were also approximately the same for each of the three locations. Further, the impact on the design cooling load was the similar for both the solar-optimized and non-optimized house configurations.

It should be recognized that the benefits of shade screens are highly dependent upon the specific house, in particular the window area and the degree of internal and external shading. For the example house and the conditions studied, approximately 60% of the design cooling load for the non screen-equipped

TABLE 1

HOUSE DESCRIPTION

Gross Floor Area	147 m^2 (1584 ft^2)
Number of Storeys	1
Insulation Levels Walls Ceiling Basement Doors	 RSI 3.52 (R-20) RSI 7.04 (R-40) RSI 3.52 (R-20) RSI 1.23 (R-7)
Natural Air Infiltration Rate	0.1 ac/hr
Internal Loads Appliances Metabolic	 470 W 268 W
Number of Occupants	4
Indoor Design Temperature	24°C (75°F)

Window Configuration

a) Solar-Optimized Window Configuration

	Area	Window-to-Floor Area Ratio
South	8.83 m^2 (95 ft^2)	6%
West	2.97 m^2 (32 ft^2)	2%
East	2.97 m^2 (32 ft^2)	2%
North	2.97 m^2 (32 ft^2)	2%
	17.7 m^2 (191 ft^2)	12%

b) Non-Solar Optimized Window Configuration

	Area	Window-to-Floor Area Ratio
South	4.43 m^2 (48 ft^2)	3%
West	4.43 m^2 (48 ft^2)	3%
East	4.43 m^2 (48 ft^2)	3%
North	4.43 m^2 (48 ft^2)	3%
	17.7 m^2 (191 ft^2)	12%

TABLE 2

SUMMARY OF DESIGN COOLING LOAD ANALYSIS, SOLAR-OPTIMIZED WINDOW CONFIGURATION

HOUSE LOCATION	WINDOW TYPE	SOLAR SHADE SCREENS	DESIGN COOLING LOAD			PORTION OF DESIGN LOAD FROM WINDOWS		REDUCTION DUE TO SHADE SCREENS	
			(kW)	Btu/hr	(tons)	(kW)	(%)	(kW)	(%)
Winnipeg	D/G	Off	5.54	18,908	1.58	3.41	61.5		
Winnipeg	D/G	On	3.63	12,389	1.03	1.70	46.9	1.91	34
Winnipeg	T/G	Off	5.18	17,679	1.47	3.08	59.6		
Winnipeg	T/G	On	3.45	11,775	0.98	1.54	44.7	1.73	33
Montreal	D/G	Off	5.54	18,908	1.58	3.39	61.3		
Montreal	D/G	On	3.62	12,355	1.03	1.71	47.3	1.92	35
Montreal	T/G	Off	5.19	17,713	1.47	3.08	59.5		
Montreal	T/G	On	3.44	11,741	0.98	1.55	45.1	1.75	34
Toronto	D/G	Off	5.59	19,079	1.59	3.42	61.2		
Toronto	D/G	On	3.74	12,765	1.06	1.76	47.0	1.85	33
Toronto	T/G	Off	5.21	17,782	1.48	3.08	59.2		
Toronto	T/G	On	3.54	12,082	1.01	1.58	44.5	1.67	32

NOTES:
1. D/G = Double-Glazed, T/G = Triple-Glazed.

TABLE 3

SUMMARY OF DESIGN COOLING LOAD ANALYSIS, NON-SOLAR OPTIMIZED WINDOW CONFIGURATION

HOUSE LOCATION	WINDOW TYPE	SOLAR SHADE SCREENS	DESIGN COOLING LOAD			PORTION OF DESIGN LOAD FROM WINDOWS		REDUCTION DUE TO SHADE SCREENS	
			(kW)	Btu/hr	(tons)	(kW)	(%)	(kW)	(%)
Winnipeg	D/G	Off	5.55	18,942	1.58	3.42	61.6		
Winnipeg	D/G	On	3.64	12,423	1.03	1.71	47.0	1.91	34
Winnipeg	T/G	Off	5.19	17,713	1.48	3.09	59.7		
Winnipeg	T/G	On	3.45	11,775	0.98	1.55	44.8	1.74	34
Montreal	D/G	Off	5.55	18,942	1.58	3.41	61.4		
Montreal	D/G	On	3.63	12,389	1.03	1.72	47.4	1.92	35
Montreal	T/G	Off	5.19	17,713	1.48	3.09	59.6		
Montreal	T/G	On	3.44	11,741	0.98	1.56	45.2	1.75	34
Toronto	D/G	Off	5.60	19,113	1.59	3.44	61.3		
Toronto	D/G	On	3.75	12,799	1.07	1.76	47.1	1.85	33
Toronto	T/G	Off	5.22	17,816	1.49	3.09	59.3		
Toronto	T/G	On	3.54	12,082	1.01	1.58	44.6	1.68	32

NOTES:
1. D/G = Double-Glazed, T/G = Triple-Glazed.

FIGURE 1

SOLAR - OPTIMIZED CONFIGURATION

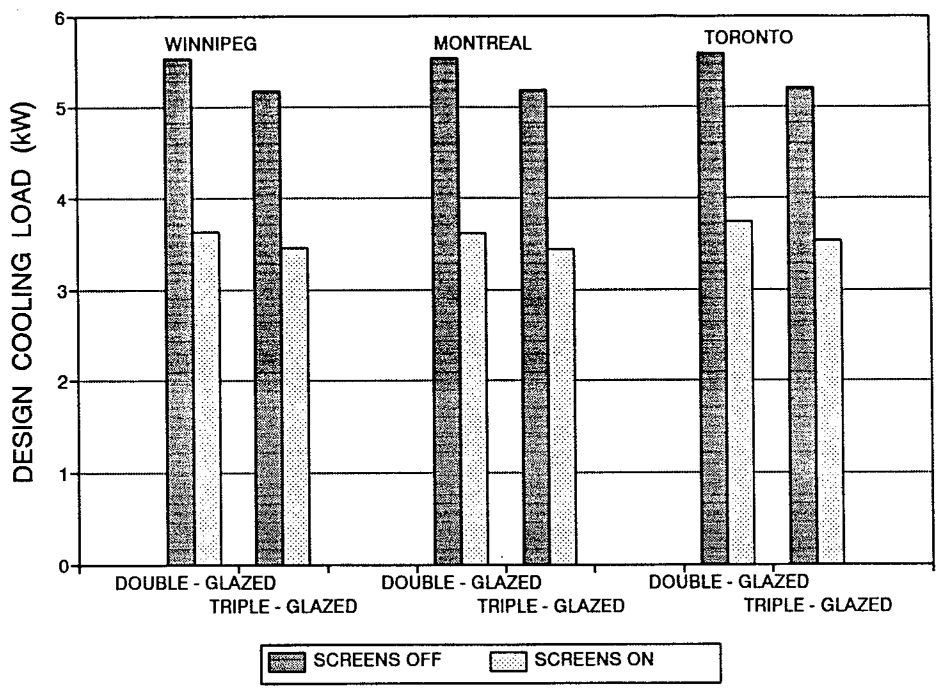


FIGURE 2

SOLAR - OPTIMIZED CONFIGURATION

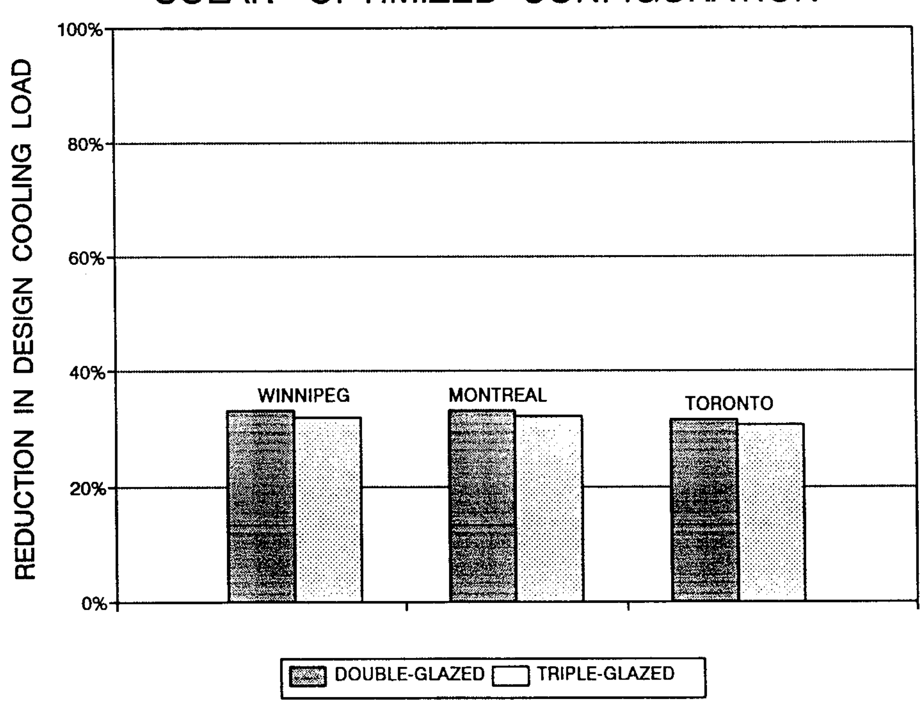


FIGURE 3

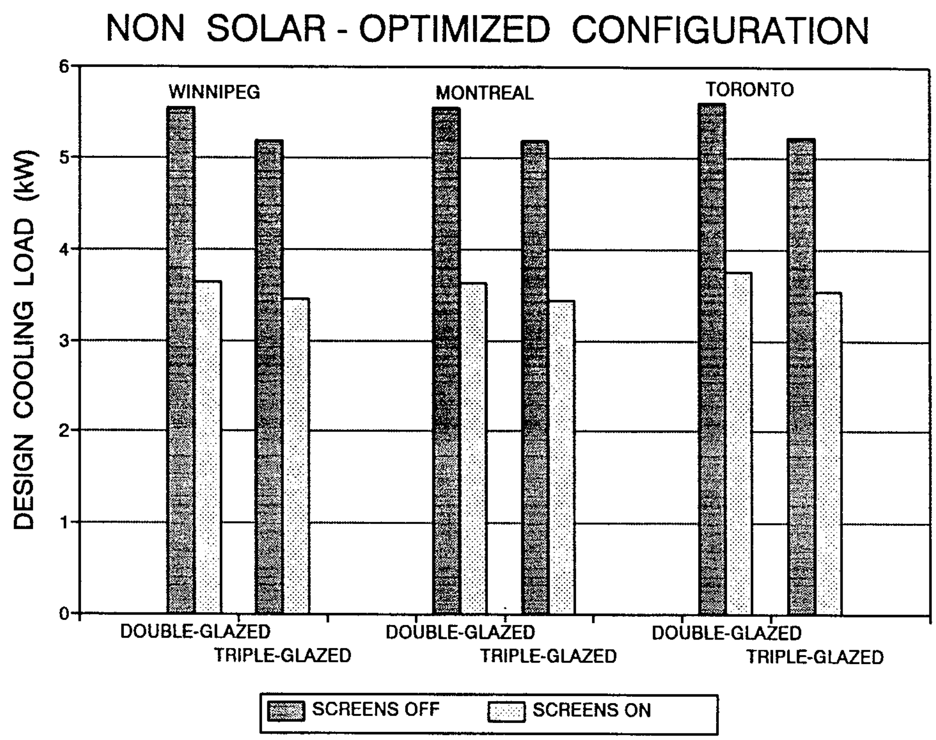
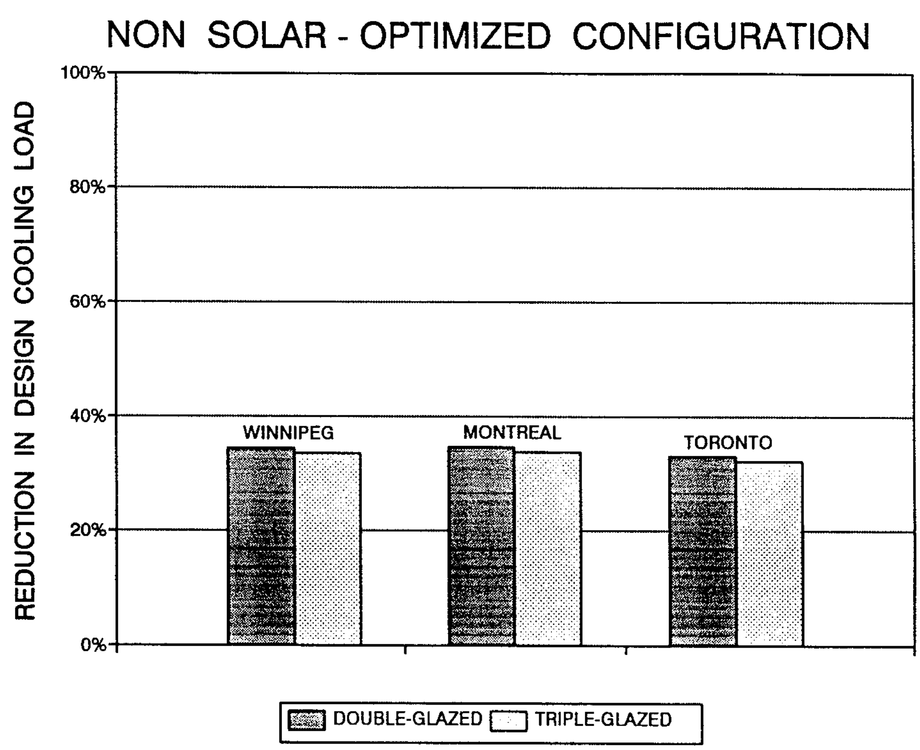


FIGURE 4



house resulted from heat gains through the windows. If more external shading had been present (for example), the window gains would have been reduced.

It should also be stressed that this analysis only considered the design cooling load (i.e. cooling power), not the annual cooling load (i.e. cooling energy). Evaluation of the latter was beyond the scope of this study and would require detailed analysis using a suitable computer model.

Reductions in the design cooling load are also worth considering from the perspective of the electric utility, particularly if its peak demand occurred in the summer. The shade screens can lower peak system demand as the result of reduced co-incident operation of air-conditioners (which have not been downsized) or by allowing downsizing of the cooling equipment to reflect the reduced design cooling load. From the consumers perspective, the benefits of shade screens would be particularly attractive if the utility was billing on a demand basis (as is commonly done for large commercial customers).

SECTION 3

ESTIMATED COSTS AND BENEFITS

3.1 ESTIMATED COSTS

The incremental costs of the solar shade screens were also studied and found to be heavily dependent upon whether the screens were supplied as part of the window or sold as a custom-built retrofit package for an existing unit. A parallel can be drawn to conventional insect screens, whose cost was estimated by one window manufacturer to be roughly two to three times greater for retrofits than for new windows in which they were installed at the time of manufacture. Using insect screens as an example, an equivalent cost difference was thus assumed for shade screens. For the purposes of this study, it was assumed that the shading screens were supplied as a part of the new windows.

The cost of the mesh was based on the current Bay Mills Ltd. wholesale price, with an additional 50% for cutting, installation and manufacturer's mark-up (overhead and profit). The frame cost was based on the retail prices paid for the extrusions on House #21 with the assumption that the window manufacturer could purchase and assemble them (with mark-up) for the equivalent price.

Based on our experiences with the four demonstration houses, the production costs (per unit area of glazing) were estimated to be:

TABLE 4

ESTIMATED PRODUCTION COSTS

	COST ($/m^2)	COST ($/ft^2)
Mesh	8.27	0.77
Frame (Aluminum Extrusion)	18.08	1.68
Installation System	4.14	0.38
Total	30.49	2.83

The production costs were then increased by 25% to account for builder mark-up (overhead and profit) to give the estimated retail costs:

TABLE 5

ESTIMATED RETAIL COSTS

	COST ($\$/m^2$)	COST ($\$/ft^2$)
Mesh	10.34	0.96
Frame (Aluminum Extrusion)	22.60	2.10
Installation System	5.18	0.48
Total	38.12	3.54

Assuming typical window areas for new homes of 7 m^2 to 20 m^2 (75 ft^2 to 215 ft^2), the cost of the solar shade screens, supplied by the window manufacturer as part of the window package, would be $267 to $762. For the reference house, the cost of the shade screens (for all windows, including the north side - which may be unnecessary) would be $675.

3.2 BENEFITS

The economic benefits of using solar shade screens can be grouped into two categories:

- Reduced capital costs from downsizing or eliminating the air-conditioning equipment.
- Reduced energy costs from the smaller annual cooling load.

3.3 CAPITAL COST SAVINGS FROM DOWNSIZING OR ELIMINATING AIR-CONDITIONING EQUIPMENT

Most residential central air-conditioning systems used in Canada are sized to provide between 5.3 kW and 10.5 kW (18,000 Btu/hr to 36,000 Btu/hr or 1.5 tons to 3 tons) of cooling. Typical installed retail costs (exclusive of the electrical connections, forced air system and sales taxes) were given by one Winnipeg mechanical installer as shown in Table 6.

TABLE 6

TYPICAL COSTS OF CENTRAL AIR-CONDITIONING SYSTEMS

SYSTEM CAPACITY	COST
5.3 kW (18,000 Btu/hr or 1.50 tons)	$1560
7.0 kW (24,000 Btu/hr or 2.00 tons)	$1611
8.8 kW (30,000 Btu/hr or 2.50 tons)	$1811
9.7 kW (33,000 Btu/hr or 2.75 tons)	$1888
10.5 kW (36,000 Btu/hr or 3.00 tons)	$2068

Using the one-third reduction in design cooling load predicted by the cooling load analysis, downsizing of the cooling system by approximately the same amount would produce savings of up to $457:

TABLE 7

CAPITOL COST SAVINGS DUE TO REDUCED AIR-CONDITIONING SYSTEM CAPACITY

DOWNSIZE FROM	TO	CAPACITY REDUCTION	SAVING
10.5 kW	7.0 kW	33%	$457
9.7 kW	7.0 kW	28%	$277
8.8 kW	5.3 kW	40%	$254
7.0 kW	5.3 kW	24%	$ 51

The reductions in system capacity would only be possible for the larger systems (7.0 kW and above) which do not use the minimum size system. The analysis further assumed that the designer properly sized the air-conditioning system and thus correctly reduced its capacity to account for the screens.

If the air-conditioning system were completely deleted, possibly through the use of other devices which provide ancillary cooling (discussed below), the entire capital costs could be eliminated.

3.4 INTEGRATION WITH OTHER, LOW-ENERGY COOLING SYSTEMS

Solar shade screens can reduce both the design cooling load and the annual cooling requirements but will not, by themselves, replace a conventionally sized air-conditioning system in terms of the achievable comfort levels. However, if integrated with other low-energy methods of providing cooling, the combined impact could be significantly enhanced. Such methods might include domestic hot water heat pumps which use interior air as the heat source and night ventilation systems which use high air change rates at night to cool down the structure.

3.5 REDUCED ENERGY COSTS

As noted, detailed analysis of the annual energy and cost savings achievable using solar shade screens was beyond the scope of this study. However, the design cooling load analysis nonetheless indicated that significant savings are possible. For this reason, it is recommended that a more detailed analysis be performed using a suitable computer program, such as DOE-2, which is capable of modelling residential cooling loads. The analysis should consider various house sizes and types, window types and configurations, external shading arrangements and geographic locations.

3.6 MULTI-FAMILY CONSTRUCTION

Solar shade screens may also be well suited to multi-family dwellings, especially units which are difficult to shade architecturally. Shade screens might provide a low-cost method of minimizing solar gain, although there may be some aesthetic concerns if not all the windows were equipped with the screens.

SECTION 4

OBSERVATIONS ON FIELD PERFORMANCE

4.1 FABRIC TENSION

Based on our use of the screens, it was found that proper tensioning of the screen mesh is essential to prevent a wavy or rippled appearance which, considering the low optical transmittance of the material, would be quite noticeable and objectionable. Excessive tension could cause bowing of the frames, if not constrained by the mounting system, particularly on large windows.

4.2 MOUNTING SYSTEM

The wood screw mounting system used on Houses #22 to #24 was intended for the field trials and would obviously be inappropriate for a production installation because of the damage the screws would cause to the sash. However, systems which use plastic or metal clips and/or hinges would provide a positive connection without damaging the window. Installations on wood windows would be straightforward while those on metal vinyl windows may require a more elaborate design.

4.3 INDOOR/OUTDOOR INSTALLATIONS

The units used in the field trials were designed for mounting from the outside of the house, which can be easily done on a bungalow. On multi-storey structures, it would be desirable to develop an attachment system to permit installation from inside the building. This should be possible with most operating windows but may require an interior installation for non-operating units.

4.4 IMPACT UPON VISIBILITY AND HOUSE APPEARANCE

The impact of solar shade screens upon visibility can only be fully appreciated by observing them actually installed on a window. Unlike blinds or drapes which can be opened at will, the screens are not easily removed on a daily basis. Our experiences with the system indicate that visibility to the outdoors is degraded, but the significance of that degradation is highly subjective. Some individuals considered it a detraction while others did not judge it a problem. Some also felt the screens enhanced privacy. When viewed from the outdoors, the solar shade screens have a pronounced impact upon the appearance of the house, particularly the "curb appeal", providing the appearance of smoked glass. Again though, the impression is highly dependent on the individual.

Homeowner reactions to the shade screens was generally favourable. Random comments were made that they felt the house was more comfortable when the screens were installed and that the reduction in visibility was tolerable. Two years after their initial installation, the screens were observed to still being used without any prompting of the homeowners.

SECTION 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

- A preliminary assessment of an exterior window shade screen system indicated it has the potential to significantly reduce the residential design cooling load, save energy, allow (in some cases) a smaller capacity air-conditioning system to be installed and, if combined with other low-energy cooling systems, may permit the air-conditioning system to be eliminated.

- Preliminary analysis of the shade screen system on the design cooling load for a typical 147 m^2 (1584 ft^2) bungalow indicated it would reduce the design load by approximately one-third, or roughly 1.8 kW (0.5 tons). The reductions were found to be similar for the three locations studied (Winnipeg, Montreal and Toronto), for double and triple-glazed windows and for both solar-optimized and non-optimized window configurations.

- The retail cost of solar shade screens was estimated at \$38.12/m^2 (\$3.54/ft^2). For new houses, the cost to equip all windows with shade screens was estimated at \$267 to \$762, assuming production and installation by the window manufacturer. The costs were estimated to be two to three times greater if the shade screens were retrofitted onto existing windows.

- Based on field observations of the screens installed on four bungalows, it was concluded that: proper tensioning of the fabric mesh was required to prevent optical distortions, an improved system was needed for mounting the screens, house appearance was not negatively affected by the screens and that homeowner reaction to the screens was generally favourable.

5.2 RECOMMENDATIONS FOR FURTHER RESEARCH

- The impact of solar shade screens upon the annual residential cooling load should be studied in more detail using a suitable computer model. The analysis should consider various house designs, window types, geographic locations and interior/exterior shading arrangements.

- The benefits of integrating shade screens with other, low-energy methods of reducing the cooling load should also be studied in detail.

REFERENCES

ASHRAE. 1989. ASHRAE Handbook of Fundamentals. Atlanta: American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc.