Experimental Assessment of the Effects of Spacer Bar Design on the Condensation Resistance of Insulating Glass Units

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ABSTRACT

Experimental and analytical assessment of three types of spacer bars used in making insulated glass (IG) units were performed and reported earlier, Elmahdy et al (1993). In that study, the authors presented the results of finite difference model and guarded hotbox measurements of the temperature distribution and overall U-factor of the three glazing systems. It was clear from that analysis that the so-called "warm edge" spacer bars demonstrated better thermal performance compared with conventional metal spacer bars. Consequently, IG units made of these warm edge spacer bars presented better units when it comes to their resistance to condensation, and hence thermal comfort. Following that study, new warm edge spacer bars appeared in the market place and it deemed beneficial to perform impartial evaluation of their performance particularly as related to the condensation resistance of the IG units made of these new warm edge spacer bars.

This paper presents an experimental assessment of ten IG units made of ten different spacer bar types, which include conventional metal spacer and others currently available in the market place. The measurements were performed in a guarded hotbox according to a well-established test procedure, Elmahdy (1993), which applies the Temperature Index (TI) principles. Surface temperature measurements of the IG units indicated that there is a considerable difference of the glass surface temperature between units made with conventional metal spacer and those made with warm edge designs. The condensation resistance of IG units is determined according to the procedure outlined in the CAN\CSA A440 Windows standard, CSA (2001).

The significance of the information presented in this paper is valuable because of the importance of the condensation resistance of glazing systems in harsh and cold conditions similar to that in the Canadian climate. This is also directly related to the comfort conditions in the built environment, which is in most cases affects the productivity of the inhabitants. More important is the direct benefit to IG manufacturers, where the information provides a clear demonstration of, and comparison of, the performance of the conventional and warm edge technology spacers.

INTRODUCTION

Condensation on glazing and other members of the window assembly represents a nuisance to building occupants due to the obstruction of vision through windows, as well as increasing the potential for mold growth and deterioration of the window and wall structural integrity. Consumers demand better performing windows, and window designers are, in general, striving to meet the market demand.

The introduction of argon gas filling of IG units and the spectrally selective coatings on glass represented major steps in the direction of improving the thermal characteristics, and hence the condensation resistance and overall thermal performance, of windows. The recent introduction of "Warm Edge Technology (WET)" spacer bar designs represented another positive step towards the minimization of condensation on glazing and other window components. This is an added benefit besides the considerable reduction in heat loss through windows. The latter is an essential factor contributing to the reduction of greenhouse gas emission.

WARM-EDGE TECHNOLOGY

Traditionally, metal spacer bars are used in making IG units. The high thermal conductance of these spacer bar materials tends to increase the heat loss from the edge of glass region. The latter is defined as the glass area bounded by the sight line and a line about 63 mm from it. Usually, condensation on the glazing starts in the edge of glass region, because it is normally the coldest area of the entire assembly.

In order to improve the condensation resistance and the overall thermal performance of window assemblies, spacer bares of lower thermal conductance were introduced in the market place. They are made of silicone foam, thermally broken metal bars, mastic tapes, and some hybrid systems that in all tend to demonstrate lower thermal conduction than the conventional hollow metal spacer bars.

TEMPERATURE INDEX

The Temperature Index (TI) is a measure to assess the condensation resistance of windows, Elmahdy, (1990), and is currently a part of the Canadian window standard, CSA (2001). The principles of determining the TI is to place the window in a guarded hotbox and measure the glass, sash and frame surface temperatures at specific locations as stated in CSA (2001). The TI of an element of the window assembly (e.g., glass, sash or frame) is determined as:

$$TI = \frac{T - T_c}{T_h - T_c} \tag{1}$$

where:

- T Glass surface temperature measured at 50 mm from the sight-line at the bottom of the of the IG unit, °C
- T_c Cold side temperature set at -18°C
- T_h Warm side air temperature set at 21°C

The heat transfer on the warm side is by natural convection (inside film heat transfer coefficient is 8±1 W/(m^2·K))and that on the cold side is by forced convection (outside film heat transfer coefficient is 30±1 W/(m^2·K)). More details about the test method are given in Elmahdy (1990).

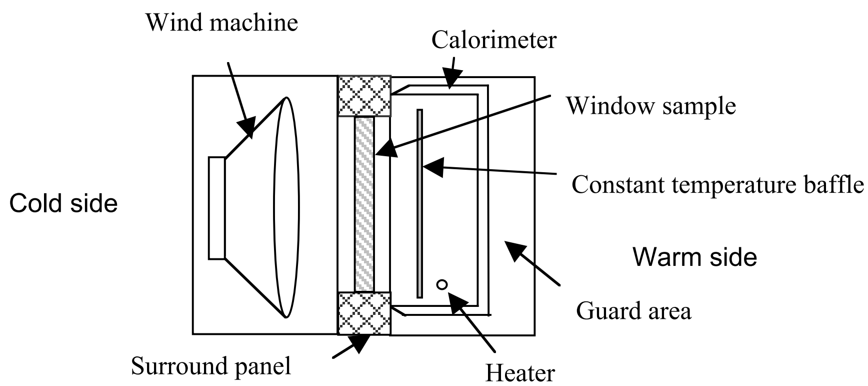

Figure 1: A schematic diagram showing the window sample mounted in a guarded hotbox.

SAMPLES TESTED

Six air filled, clear glass IG units (each unit is 152 mm by 1200 mm) are used to represent twice the edge of glass region of IG units. The six identical units in each set were mounted side by side in the surround panel in a guarded hotbox, see Figure 2.

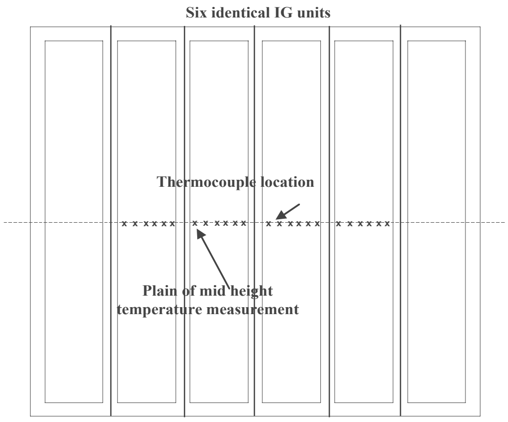

Figure 2: Six IG units mounted in the surround panel.

In this study, ten different sets (each was made with a different manufacturer) were included, and each set (of six identical units) was made with a different spacer bar type and marked as IG1 to IG10. The spacer bars varied between conventional metal spacer, silicon foam, thermally broken metal profile, hybrid system, and others. Figure 3 presents a schematic diagram of the cross section of the ten spacer bars.

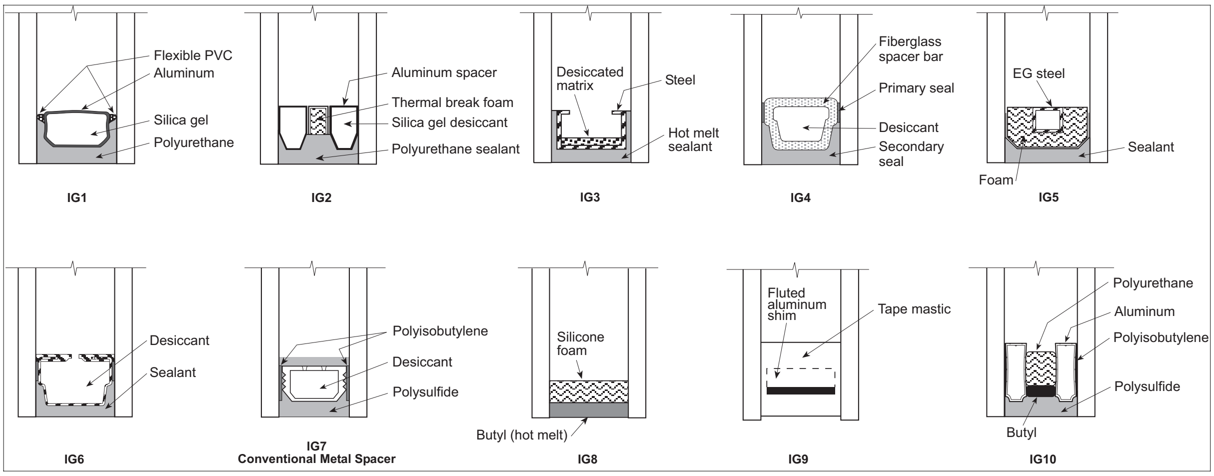

Figure 3: Schematic diagrams of the ten spacer bars included in this study

TEMPERATURE MEASUREMENT

Thermocouples were placed on the glass surfaces of the six units at mid height, and were distributed in such a manner not to interfere with each other and to provide glass surface temperature at 10 mm intervals on the horizontal plane of the IG units. For the determination of the TI, the glass surface temperature measurements on the warm side were recorded at the steady state conditions. However, for the purpose of evaluating the performance of the WET spacer bars, glass surface temperatures on the cold side were also recorded.

As stated in the Canadian window standard, CSA (2001), the TI is determined from the glass surface temperature at 50 mm from the sight line. In this study, the TI values are determined at different planes of the IG unit (e.g., 0, 10, 20, 30 40, 50 and 76 mm) to examine the performance of the WET spacers.

TEST RESULTS AND DATA ANALYSIS

As indicated earlier, the edge of glass region is defined as the vision area of glass from the sight line and extended 63 mm around the perimeter of the window sash. Therefore, an IG unit, which is 152 mm wide, would represent a little more than twice the edge of glass region of a glazing unit. Table 1 provides a summary of the glass surface temperature on the warm side of the IG units.

Table 1

Glass surface temperature on the warm side of 10 IG units

Distance from sight line	IG unit designation and Warm side glass surface temperature °C									
(mm)	**IG1**	**IG2**	**IG3**	**IG4**	**IG5**	**IG6**	**IG7**	**IG8**	**IG9**	**IG10**
0	-1.3	0.3	1.2	1.1	-2.3	-1.3	-3.1	2.8	-0.3	0.4
10	0.5	1.4	1.9	2.9	-0.8	0.2	-1.3	4.6	2.6	1.0
20	4.8	4.5	4.4	5.4	4.3	4.4	3.5	6.2	5.2	4.6
30	6.1	6.0	6.0	6.5	5.9	5.8	5.5	7.0	6.5	6.0
40	7.1	6.9	6.8	7.1	6.8	6.8	6.6	7.4	7.0	6.8
50	7.5	7.5	7.3	7.6	7.4	7.4	7.3	7.5	7.5	7.2
76	8.0	7.9	7.8	7.9	7.9	7.9	7.4	7.7	7.7	7.6

Table 1 above shows that the glass surface temperature is the lowest at the sight line for all units (i.e., at 0 mm), and then it increases at all other locations up to 76 mm from the sight line. The starting temperature at 0 mm is the lowest for a conventional aluminum spacer bar (IG7), and the impact of improved spacer bar design and thermal characteristics is reflected on the value of the glass surface temperature at 10 mm and beyond.

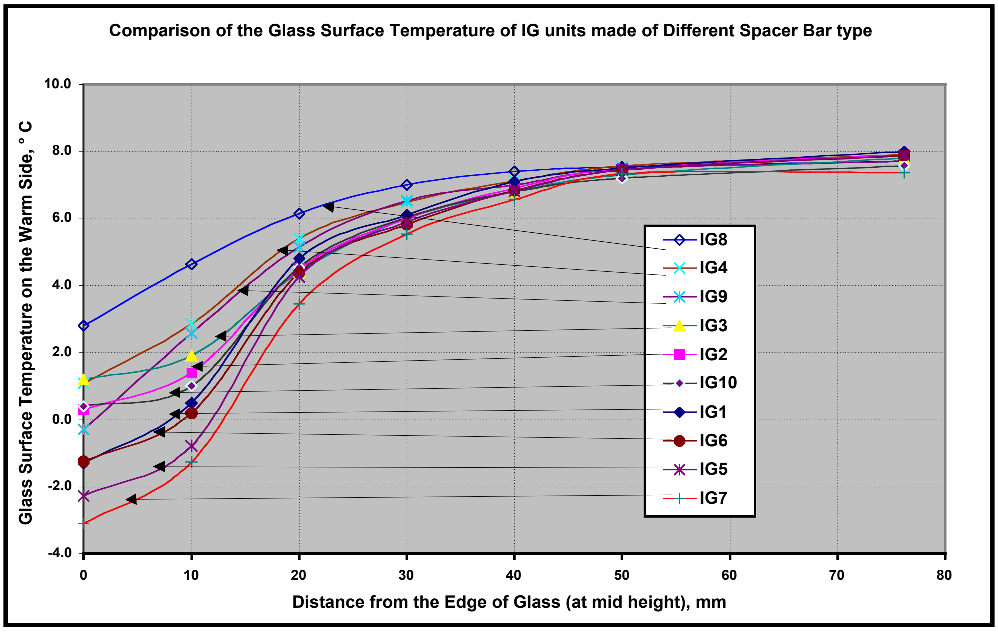

Figure 4 provides a graphic illustration of the temperature profile of the ten IG units on the warm side, and Figure 5 is the temperature profile on the cold as mounted side in the guarded hotbox.

Figure 4: Graphic illustration of the glass surface temperature on the warm side.

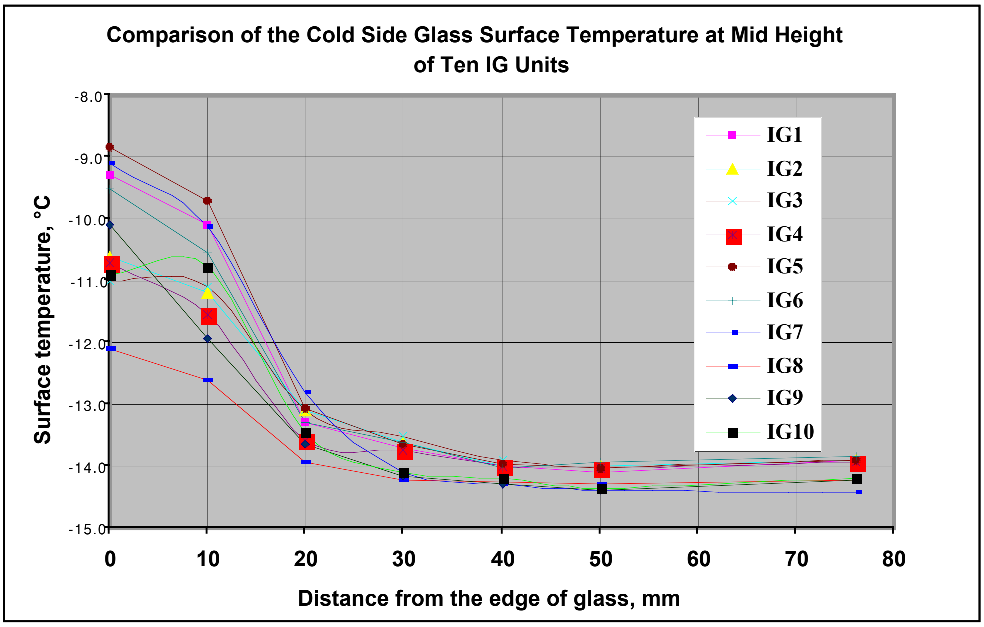

Figure 5: Graphic illustration of the glass surface temperature on the warm side.

From the temperature profiles in Figure 4, the glass surface temperature increases at locations away from the site line until it reaches a constant value that corresponds to the centre of glass temperature. This is the case for all spacer bars. The same pattern is shown in Figure 5, but in this case, the temperature decreases until it reaches the constant value at the centre of glass at the cold side of the IG unit.

Using Equation 1, the glass surface temperatures from Table 1 are used to calculate the local TI of each IG unit. Figure 6 shows the variation of TI in the edge of glass region of the ten IG units.

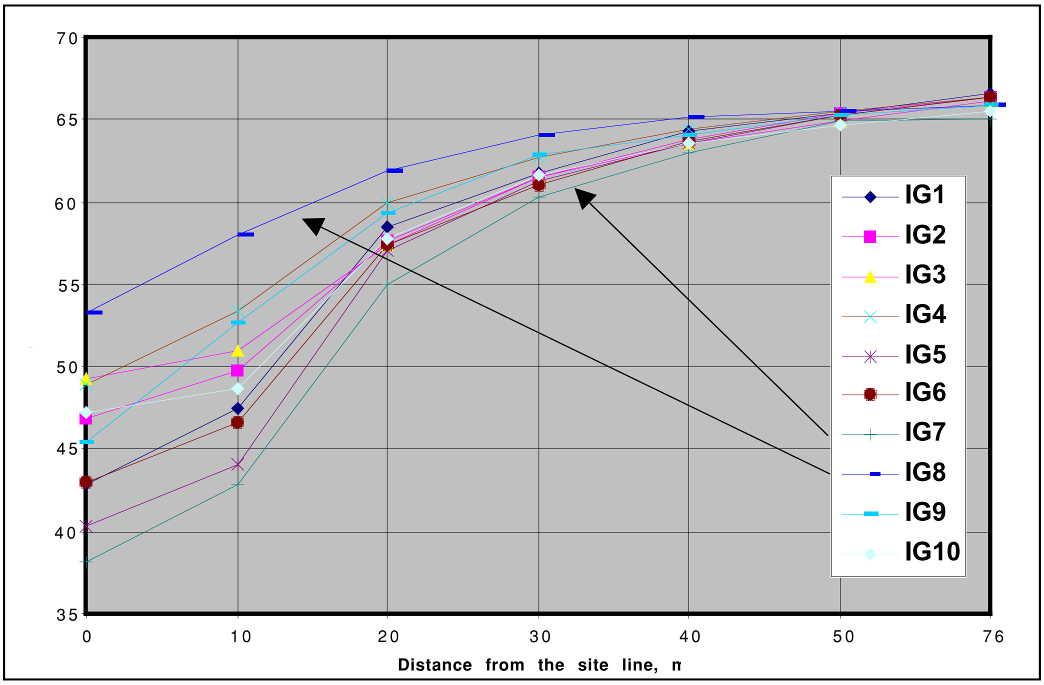

Figure 6: Graphic illustration of the Temperature Index, TI %.

As expected, the IG unit with the conventional spacer bar demonstrated the lowest TI of all units tested, and the unit made with the foam insulated spacer bar shows the highest TI. As indicated earlier, the glass surface temperatures were recorded at mid-height of the IG units. At that location, the surface temperature is usually slightly higher than that at the bottom section of the IG unit. Therefore, it is expected that the TI at the bottom section of the IG units would be lower than those determined at mid-height.

BENEFITS AND IMPACT

The information presented in this paper provides an assessment of a number warm edge spacer bars as well as conventional metal one. During the design stage, IG manufacturers would have the tools to decide on the performance level expected from their products. IG manufacturers usually provide varieties of products with different thermal performance and condensation resistance levels. The information included in this paper provide a tool to assist the manufacturers to select the proper spacer bar type for a given performance level.

FUTURE RESEARCH WORK

The results of this work indicated that there exists considerable impact of WET spacers on the performance of IG units. To investigate the coupling effect of the spacer design and window frame material, this work will be extended to determine the interaction between the WET spacers and the type of frame used. Wood, aluminum vinyl and fibreglass frames will be used in conjunction with 1m by 1 m IG units to study this effect.

CLOSING REMARKS

Warm edge technology presents a considerable advantage in improving the thermal performance and condensation resistance of IG units. The application of WET resulted in a considerable improvement of the condensation resistance of IG units, compared with the performance of units made with conventional metal spacer bars. The information presented here provides a valuable tool for consumers as well as IG manufacturers to adequately select the proper IG units for the desired condensation resistance level. More research work will be performed to investigate the coupling effect of spacer and frame material on the overall window performance.

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