Thermal Irregularities in Vacuum Glazing

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Abstract. This document deals with the determination of thermal irregularities of wood-aluminium window with vacuum glazing. Test measurements were performed with guarded hot-box method at defined different temperature difference. They describe how the support pillars influence internal surface temperature distribution and how the edge vacuum glazing influence surface temperature around edge of vacuum glazing in wood-aluminium window. The deformation of the temperature field due to support pillars is surprisingly small and its range is from 0.20 K to 0.46 K with temperature difference on both sides of approximately 20 K. Decrease of internal surface temperature from the middle of the vacuum glass to edge is about 20.04 – 16.15 = 3.89 K, and so it is considerable effect. The effect of the edge on the glazing is not explicitly quantified in the term of heat flow in this document, but is implicitly documented by means of surface temperature. Thermography was used to check if there are touching points between glasses where distance is from 0.15 to 0.2 mm. The vacuum glazing measured in this work was a sample, which was fabricated in the Beijing Synergy Vacuum Glazing Technology Co., Ltd. The window was tested one year after delivery from the producer.

1. Introduction

The concept of vacuum glazing was first introduced by Zoller [1]. Later Simko [2] improved the design and the manufacture of vacuum glazing. The glass sheets were separated by the support pillars. Since then many international efforts focused on vacuum glazing research and development [3], [4]. In 2016, during the Coneco and Racioenergia fairs in Inchebra Bratislava (Slovakia), wood-aluminium window manufacturer "Mintal Energy VG" was awarded Gold Plaque 2016 for the application of vacuum glazing, for their excellent thermal insulation and acoustic properties (Figure 1). Vacuum glazing was not a standard product at the time and it was first presented in Slovakia in 2016. One year after delivery from an Asian supplier, we verified the thermal irregularities expressed by means of surface temperatures of the window with built-in vacuum glazing. Frame of the window was wood-aluminium. The wood-aluminium window has a dimension of 800 x 1,200 mm, the surface of the window $A_{3p} = 0.96 \text{ m}^2$ (Figure 1). The frame construction of the wood-aluminium window is based on the wooden profile IV88 (Figure 2).

At present, vacuum glass is used in different kinds of buildings such as office building, building group, exhibition center and showrooms, library, greenhouse, house and apartment, many of which were “world first” or “world greatest”.

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2. Description of vacuum glazing
The vacuum glazing consists of two glass panes separated by a vacuum layer which is 0.2 mm wide. The glass sheets are separated by small circular metal pillars with diameter of about 0.25 mm and spaced 40 mm apart. There is a low-emission layer on the inner part of the glazing, which reduces heat loss by radiation.

According to the description from Beijing Synergy Vacuum Glazing Technology Co., Ltd., vacuum glazing has a dimension of 978 mm x 578 mm and structure (Figure 3):

\[ T5 + V + TL5 \]

where
- \( T \) is tempered or heat-strengthened glass of 5 mm thick;
- \( V \) is vacuum layer of 0.15 to 0.2 mm thick;
- \( TL \) is tempered or heat-strengthened low-E glass of 5 mm thick.

Solar factor (g-value) of glazing = 0.638;
Light-transmission factor \( \tau_v = 0.79; \)
The edge of the vacuum glazing is 10 to 12 mm wide;
Amount of pillars (supporting profiles) 13 x 24 = 312 for vacuum glazing area of 0.565 m\(^2\);
Declared value of glass transition coefficient \( U_g = 0.58 \text{ W.m}^{-2}.\text{K}^{-1}. \)
These properties were stated by the manufacturer based on the calculation in Window 7 by Canadian Standard NFRC 100-2010.

3. Method for testing thermal irregularities
The verification of internal and external surface temperatures and the heat transfer coefficient of the window and the vacuum glazing was performed by a hot-box method according to STN EN ISO 12567-1 [5]. Measurements were made to ensure that the air permeability of the test specimen did not affect the measurement – by sealing of the joints inside and outside. Measurement of the surface temperature and the heat transfer coefficient of the window and the vacuum glazing was performed under the same condition as the calibration procedure, it was done with an average temperature of 10 °C and with a air temperature difference Δθ = (20 ± 2) K, which is recommended in [5]. For testing thermal irregularities in surface temperatures were used air temperature differences between hot and cold side of the specimen:
- 20 K for 22°C inside and 2°C outside and
- 33 K for 22°C inside and -11°C outside air temperatures.

Internal and external temperatures are measured by PT100 sensors. They are evenly spaced over the vacuum glazing area and located opposite on the hot and cold side (Figure 4).

Figure 3. Vacuum glazing – section (not to scale) [4]

Figure 4. Temperature sensors on the cold side
4. Thermal irregularities at 20 K temperature difference

Vacuum glazing comprising two spaced apart sheets of glass enclosing a low pressure space and interconnected by a peripheral joint of fused solder glass an array of pillars, and a pump-out tube to provide communication between the interior and the exterior of the panel during the creation of the low pressure space.

The pillars ensure sufficient structural strength to withstand the forces imposed by atmospheric pressure, and maintain the sheets of glass spaced-apart. Preferably the metal pillars are nickel, iron, molybdenum, tungsten, tantalum, titanium, aluminium, steel or stainless alloys containing these metals. These metals ensure thermal performance and structural strength for the preferred pillar sizing and array geometry.

The difference between the temperature on internal surface of the support pillar and the midpoint of the support pillar (Figure 5) is

\[ 20.38 \, ^\circ\text{C} - 20.04 \, ^\circ\text{C} = 0.34 \, \text{K} \]

The irregularity of the internal surface temperature due to support pillars is approximately 0.34 K in the central glazing area. Temperature difference between central area of glazing and edge of glazing is

\[ 20.04 \, ^\circ\text{C} - 16.15 \, ^\circ\text{C} = 3.89 \, \text{K} \]

Cold side: outer surface temperature 2.91 °C is on the pillar and temperature 2.5 °C is between pillars and so on.

![Surface temperatures at 22 °C inside and 2 °C outside](image)

**Figure 5.** Temperature distribution at 20 K difference; p - pillar

5. Thermal irregularities at 33 K temperature difference

The difference between the temperature on internal surface of the support pillar and the midpoint of the support pillar (Figure 5) is

\[ 19.43 \, ^\circ\text{C} - 18.92 \, ^\circ\text{C} = 0.51 \, \text{K} \]

The irregularity of the internal surface temperature due to support pillars is approximately 0.51 K in the central glazing area. Temperature difference between central area of glazing and edge of glazing is:

\[ 18.92 \, ^\circ\text{C} - 12.37 \, ^\circ\text{C} = 6.55 \, \text{K} \]

It is significant that the internal surface temperature drops from the center of the glazing to the edge.
Surface temperatures at 22 °C inside and -11 °C outside

| Distance from middle to edge | Internal surface temperature | External surface temperature |
|-----------------------------|-----------------------------|-----------------------------|
| 1                           | 18.92                       | -9.67                       |
| 2                           | 19.43                       | -10.27                      |
| 3                           | 18.86                       | -9.64                       |
| 4                           | 19.08                       | -10.08                      |
| 5                           | 18.02                       | -9.54                       |
| 6                           | 16.79                       | -9.44                       |
| 7                           | 12.37                       | -7.24                       |

Figure 6. Temperature distribution at 33 K difference; p - pillar

6. Infrared thermography
The point thermal bridge disturbs this uniformity by reducing the surface temperatures on the indoor surface and increasing the surface temperatures on the outdoor surface. Thermography is used to check if there are touching points between glasses where distance is from 0.15 to 0.2 mm. Deformation of temperature field is more visible from infrared thermography on Figure 7. No touching points were detected on glass sheets.

Figure 7. Outside surface deformation of temperature field at 33 K difference
7. Conclusions
The deformation of the temperature field on central area due to support pillars is surprisingly small and its range is from 0.20 K to 0.46 K with temperature difference on both sides of approximately 20 K. Decrease of internal surface temperature from the middle of glass to edge is about 20.04 – 16.15 = 3.89 K, and so it is considerable effect. However, at a greater temperature difference of 33 K, the deformation of the internal surface temperature between the glazing center and the edge of the glazing increases from 18.92 °C to 12.37 °C and is about 6.55 K. No touching points were detected on glass sheets by means of infrared thermography.

Window was tested one year after delivery of vacuum glazing from Asian producer.

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