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Experience of Upgrading Existing Windows with VIG

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Abstract

Existing windows are often equipped with IGU (Insulation Glass Units) glazing of low thermal performance. A change of several decades old IGU glazing with an up-to-date triple IGU is often not possible due to geometry (thickness) or restricted load carrying capacity of existing window frames and its hardware. Using VIG (Vacuum Insulation Glazing) with thickness and weight comparable or even less to "old" IGU can overcome these obstacles. Within a scientific campaign several decades old standard IGU was replaced by VIG in an office building. The paper shows aspects of workmanship in changing glazing (different detailing is needed for bedding of edges e.g.) and presents first measurement data on the thermal performance. Optical effects due to new type of glass – especially the "pillars" to prevent contact due to pressure difference of environment and vacuum – are discussed: these visible effects strongly depend on local view and might irritate customers. At special climatic situations, fogging with polka dots can appear in the morning.

Keywords

VIG, energy rehabilitation, workmanship, thermal and optical performance, polka dots

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1. Introduction

The construction sector is responsible for a large share of global carbon emissions, with building operations, particularly the heating of buildings, accounting for a significant portion of that total. Energy loss during the heating season can be reduced by improving the insulation of the building envelope. In older existing buildings with comparatively thick brick walls and correspondingly high thermal mass, the transparent components (windows) are the elements where the greatest improvements can be achieved with relatively little effort – if only the old glazing is replaced with modern types and eventually additional gaskets are installed for improved air permeability performance.

It is well known that energy transport takes place by means of thermal conduction, convection and thermal radiation. In the case of glazing, the respective proportion depends on the configuration (single-pane or multiple-pane insulating glass units IGU with one or more cavities), any coatings for reducing thermal radiation (emissivity) as well as transmission (filter effect) or any gas filling. The following typical U-values, which quantify heat transmission, are cited from DIN EN ISO 52016-1 (2018), the values specified by manufacturers for their respective products may differ slightly – however, what matters here is only the order of magnitude and the ratio of the different values. For single glazing a U-value of 5,8 W/(m²K) applies. Because of the buffer effect of an air volume the value is reduced to about half 2,9 W/(m²K) in case of double insulating glazing units of common cavity thickness and without coating. The proportion from heat radiation can be reduced using low-e coating on the surface of the inner (room side) glass pane facing the cavity: reducing emissivity rate $\varepsilon \approx 0{,}89$ of untreated float glass (EN 673, 2024) by hard coating to about 0,2 (Schäfer 1997) or even to $\varepsilon \approx 0{,}01 \ldots 0{,}03$ (Belis et.al. 2026) by soft coating results in heat transmission value of only about 1,4 W/(m²K). Adding a second cavity and thus forming a triple IGU (with second low-e coating) the U-values can be further reduced to about 0,7 W/(m²K). If cavity thickness is optimized, the energy transmittance can be further reduced by filling the cavity with inert gases instead of (dry) air.

Vacuum insulating glass (VIG) combines two layers of glass, separated by a thin vacuum guaranteed by an array of spacer pillars and sealed edges. As of course also low-e coating is used, ETA 20/0048 (2020) states that U-value of 0,7 W/(m²K) is achieved at a total thickness comparable to that of a single glass pane. However, VIG is only available in limited dimensions for production reasons, according to AGC (2022) they are 1,4m x 2,5m or 1,6m x 2,3m for the product used here.

A visual comparison of the thickness dimensions of double IGU and triple IGU with VIG can be found in Figure 1.

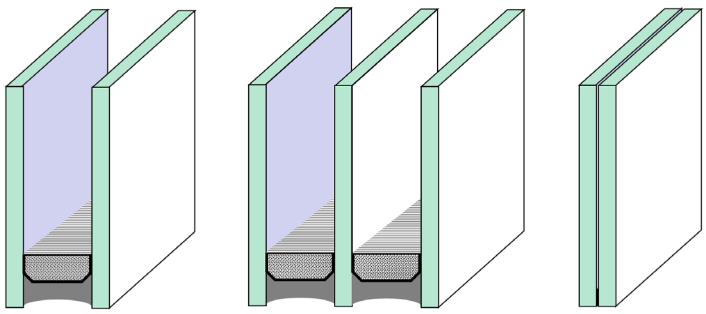

Fig. 1: Comparison of conventional double IGU (4/16/4) and triple IGU (4/16/4/16/4) and VIG (4/0,1/4).

As part of a research work the IGU-glazing of several windows of an office room as well as community kitchen were replaced by VIG in October 2025. The paper focuses on the structural design, workmanship as well as thermal and optical performance only. For further aspects or specific effects of VIG, the author refers the reader to the respective literature, which is briefly mentioned below by topic - with an emphasis on more recent publications due to their current relevance, while older sources are mentioned only as examples. An overview about the development of VIG (or "evacuated glazing") can be found in Collins et.al (1991), Collins et.al (1998), Collins (2017), Park et.al (2019), Kocer (2019), Zhang et.al (2019), Jung et.al (2024) and Dellieu et.al (2025); the latter paper also touches on legal aspects. Discussions on CO2 reduction potential or embodied energy analysis can be found, for example, in Ibrahim et.al (2025) or Tiwari (2025). Issues related to the pillars such as positioning, thermal, or mechanical properties can be found in Collins et.al (1991, 1993), Wilson et.al (1998), Kocer (2017), Collins et.al (2023), Kocer et.al (2025), van Abeelen et.al (2025). The consideration of stresses in the glass resulting from factors such as temperature, wind, or soft body impact is addressed in Fischer-Cripps et.al (1995), Wullschleger et.al (2009), Liu et.al (2013), Aronen et.al (2017), Paschke et.al (2019), Schulz et.al (2022), Ayvaz et.al (2023), Aronen et.al (2023), Paschke et.al (2025).

2. Materials and Workmanship

2.1. Situation on site – existing boundary conditions

The building is from the 1930s, load carrying structure consist of solid brick masonry walls and wooden floor slabs. According to the embossed date in the metallic spacer of the existing 4/16/4 mm double IGU its windows were replaced in 1980s. Single windows are a combination of one tilt and turn and one casement, built side-by-side in groups of two, see Fig. 2. The dimensions of the overall frame are 2,39 m (width) x 1,39 m (height); each individual window measures 0,55 m (width) x 1,30 m (height). The material of window frames is wood, glass beads are fixed to glazing rebate platform by Phillips-head screws. In addition, horizontal glazing bars for decorative reasons are carried out as attached bars and glued to glass panes using seal material (and will not be reinstalled with VIG).

Fig. 2: Two side-by-side windows with one tilt-and-turn (outer) and one casement each with IGU before change to VIG.

The plan is to reuse as much material as possible including glazing beads with screws, of course elastic foam strips, paste-like seal (silicone) and setting blocks need to be replaced by new material.

2.2. VIG

The used VIG is combining two layers of 4 mm glass (one with low-e-coating), separated by a 0,1 mm cavity under vacuum (pressure below 1 Pa) which is guaranteed by black spacer pillars (diameter about 0,35 mm) arranged in a 2 cm x 2 cm pattern and sealed edges. The edge seal is achieved by soldering the periphery of the glass panes with solder glass paste. A getter is used to sorb residual gas from the vacuum space. With a total thickness of about 8 mm, it is less in thickness and similar in weight compared to the existing double IGUs (4/16/4). Measurement of glass panes for ordering replacement was done in installed situation using (simple) tape measure or folding ruler. It turned out, that one size fits all, minor differences can be compensated by setting blocks – which makes disassembly of IGU and installation of VIG easier.

2.3. Dismounting of IGU and installation of VIG

After removing Phillips-head screws from glazing rebate platform and cutting seal between glass and glazing bead the wooden glass beads are easily dismounted, Fig. 3 left. The horizontal glazing bars for decorative reasons are not only fixed by (visible) seal to the glass but at the room side are also connected to vertical glazing beads by hidden tiny nails, which proved straightforward in practice.

Fig. 3: Dismounting steps (left to right): corner detail before dismounting IGU, after cutting seal and removing screws glazing bead are removed using spatula, glazing bead is cleaned from old foam by using putty knife.

The next steps after removal of IGU are preparation of glazing rebate upstand and glazing bead for installation of VIG: after mechanical removal of old foam strip with putty knife and final cleaning with sandpaper a new foam strip with one-sided adhesion tape can be applied, Fig. 3 middle, right.

Positioning VIG-panes and fixing them with setting blocks are following rules of craftsmanship, Fig. 4 left. Finally glazing beads are positioned and fixed by same Phillips-head screws in glazing rebate platform – as the VIG have less thickness, the glazing beads are no longer flush with the vertical casement surface, new holes are formed and even the old ones are visible (see Fig. 4 right). Optically the missing paint at glazing rebate platform could be applied to get a uniform appearance if requested by client.

Fig. 4: Detail of corner from inside in different installation steps: window frame with attached new foam strip at glazing rebate upstand, VIG in position with setting blocks, glazing bead with attached new foam fixed with screws, seal attached.

3. Performance of installed VIG

3.1. Thermal performance

To get an impression about the performance of the updated glazing in comparison to previous (and in neighbouring room still installed) glazing, beside an optic also a thermographic picture was taken at the afternoon of a winter day in January 2026, Fig. 5. The façade is facing north, so an influence of solar radiation and by this eventually solar heated surface is not to be expected.

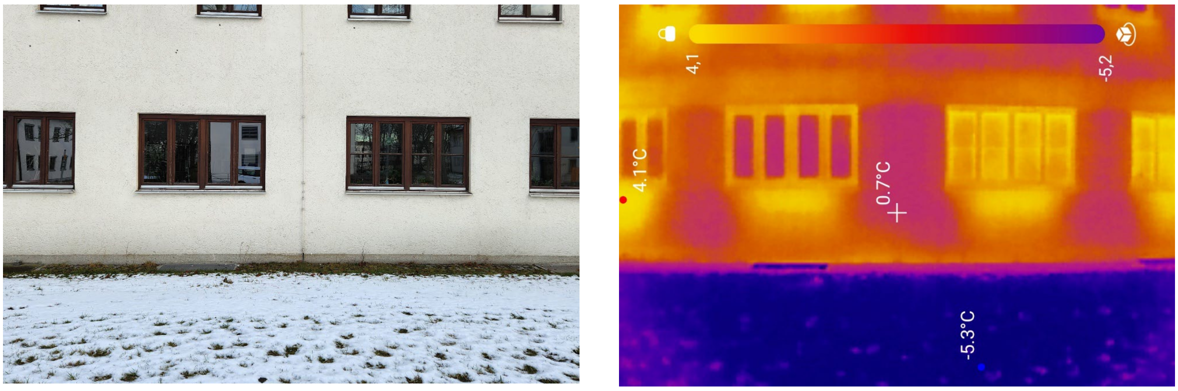

Fig. 5: Façade at a winter day, left windows equipped with VIG (no horizontal glazing bars) and right with (old) IGU: temperature of VIG-glass surface is reduced compared to old IGU, hotspots below windows show heating.

The rooms with the windows to be looked at have a connection door, and for purpose of comparable temperature conditions the heating were set on same level and the connecting door was open for longer time to have an identical climate at both rooms behind the windows on the picture. One can clearly see the positive effect regarding energy transmission: surface temperature of VIG is remarkably lower than of neighbouring old IGU. The weak spot clearly identified is the thinner wall below the windows with installed heater, especially just below the windows. Reason for this: the installation of an attached cable installation channel with a height of 20 cm mounted just below level of window ledge without any gap is blocking the ventilation of hot air at the top of heater, which is – from building physics point of view – not optimal as it forces additional thermal bridging effect which could have been avoided easily. Detailed analysis of temperature distribution and energy transmission is planned for the next heating season.

3.2. Optical performance – visual impression

To prevent the two glass panes of the VIG unit to deform inwards the small cavity (following the pressure difference from meteorological air pressure to vacuum) and by this close the 0,1 mm gap, black coloured pillars of about 0,35 mm diameter are arranged in a 2cm x 2cm pattern in the cavity. This is necessary for the product to fulfil its function, and of course the producer does inform about their existence. The small black circular spots fulfil criteria for visual quality of IGU, defined in Annex F of DIN EN 1279-1, e.g. Nevertheless, it is interesting to briefly look also at this aspect for installed VIG.

Looking at handy samples of the product – usually in standard size of a piece of paper – its visual impression depends on the colour of the background, the viewing distance and angle as well as other factors. In the installed situation, there is also an influence of professional background of persons, especially if they were not informed about the speciality of the glass before.

Photographic documentation of fine optical effects in glass using standard cameras or mobile phones is a challenging task, which applied also to pillars of VIG. In this case, the perception of real human eye cannot be reproduced or documented by simple photographs for all aspects, some effects, e.g., are only recognizable with movement of eyes and head, respectively.

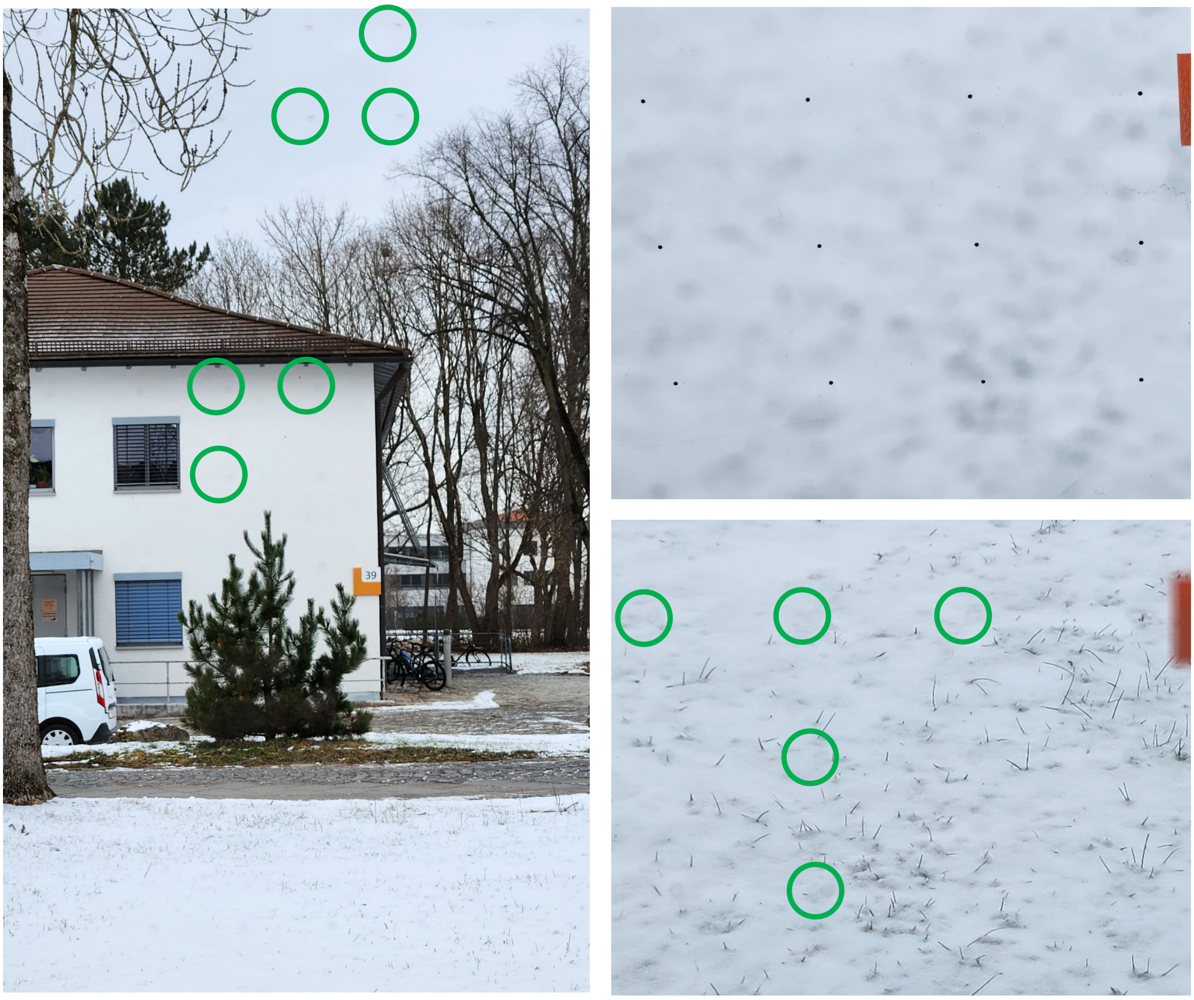

Fig. 6: Picture looking through VIG and detail view in two different focus distances, adhesive sticker (red) for reference. Marking (green circles) at locations of pillars inserted by hand on some spots only, selection random.

Looking through the VIG-window from more than 1 m distance and focusing the landscape outside, the pillars are not detectable by most people; the reason is the different focusing range. If one knows that the pillars do exist and one concentrates, they can be identified in front of light homogeneous coloured areas, see Fig. 6 left picture. When one stands about half a meter to a third of a meter close to the window and looks out at the snow-covered grass just few meters distance, it can happen, that the focus of the eye changes between pillars in the VIG and outside grass, see Fig. 6 right upper and lower picture.

Moving the head and looking through the VIG-window to the outside can induce the perception of dizzy view at areas with dark colour and pattern. This is easily reproducible looking at the dark roof with tiles or the leaf-less tree-branches: the black pillars match to some parts of the outside picture and slightly moving the head makes the dots disappear and reappear – what can be recognized by an unsteady view of these parts of the outside picture.

Informal interviews of non-expert colleagues using the community kitchen show, that most of them did not recognize the spots in daily use – and by this are not distracted by them. As the polka dots did appear one morning, colleagues wondered about that unique pattern never seen before elsewhere.

3.3. Polka dots

The effect of fogging of the outer surface of IGU in the morning of cold nights during end of heating season is well known for triple IGU. Because of the good energy performance, the surface temperature is so low that morning dew settles also on that surface. This effect is not known from double IGU since the energy performance is less good and by this the temperature of outer glass surface higher of triple IGUs (or not low enough to enforce dew to settle down); in the beginning of installation of triple IGU the industry had to explain their customers, that this temporary fogging is not a fault but on the contrary a proof of high (thermal) performance.

As the U-value 0,7 W/(m²K) of VIG is in the range of triple IGU, it is not surprising that the similar effect also happens with VIG. And the spacer pillars maintaining the distance of the two glass panes forming the VIG act as (small) thermal bridge, of course. In special (and seldom occurring) combinations of temperature gradient on the one hand and climatic conditions on the other hand this results in fogging on the outer pane with clear circular areas located around the pillars, a pattern known as polka dots, see Fig. 7. On the sunny but cold morning of February 25, 2026, this effect occurred as the outdoor temperature rose relatively quickly from 1 °C to 5 °C within an hour following sunrise; the previous day, it had rained steadily until the evening with temperatures around 6 °C, and as the clouds cleared after midnight, temperatures dropped to just above freezing. Consequently, the relative humidity outside was over 90%, with dew point temperatures close to the air temperature. In fact, at the location of the VIG product the paper is based on, only the windows of the community kitchen showed the effect, the windows of the office room with slightly higher room temperature of about 21°C did not.

Fig. 7: Polka dots: Fogging enforced by morning dew on the outer surface of the VIG, pillars acting as thermal bridge create clear circles because local temperature is too high for dew effect. In right macro picture pillars are visible as black spots.

4. Summary

Energy loss from windows clearly can be reduced quite easily by simply substituting double IGU by VIG, because of comparable or even less weight and usually less thickness no change of window frame geometry or strengthening of hardware like hinges is necessary. As in this case the existing building has comparatively thick massive brick walls, thermal performance of regular walls is comparatively good, especially as high thermal mass has positive effect for buildings used not 24/7 but during office hours only. This reinforces the value of adopting a holistic approach to energy rehabilitation, additional easy improvement could be achieved if also details of new installation on surface in cable ducts are looked at also from an energy performance view.

Thermal performance as well as optic performance of VIG show expected positive results, the special effect of polka dots only appears at very special conditions.

Declarations – Competing interests and acknowledgements

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